20th International Conference on Sustainable Energy Technologies

15 – 17 August 2023

Nottingham, UK

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#2: A disruptive approach to improving energy efficiency of air conditioning chillers

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In 1902, Willie H. Carrier invented the first electrically driven chillers. From then, assorted figures of merits (FOMs) were used for efficiency evaluation, assuming parity between all types of derived energy consumed. Such practices of interpreting FOM expressions are deemed thermodynamically incomplete, as the units of energy conveyed merely the quantitative aspects, ignoring its embedded qualitative aspects subtly. The quality exclusion in derived energy has plagued the chiller industry since its inception with a numerical oddity, propagated erroneously, i.e., the useful output (kWh_cooling) of chillers is found greater than the input (kWh_electricity or thermal). Pedagogically, the incongruity defies the Laws of Thermodynamics of any cooling cycle. As all real chillers incurred much dissipation, and rationally, the energy efficiency must always be less than unity unless there exists a fundamental abnormality. In this presentation, a standard primary energy (QSPE) platform is proposed for all FOM expressions of chillers. Invoking the classical heat engines and the same Carnot work associated with the derived energy, its equivalent QSPE at a common primary energy platform can be correlated. By ascribing the QSPE to the input and output terms of chiller FOM, an accurate universal efficiency is formulated, resolving the said thermodynamic misconception and ensuring the laws of conservation within a cycle are observed. Henceforth, the chillers' efficacy expression returns to its normalcy which is always less than unity. In addition, the causal energy efficiency improvement enables designers and users to intuitively improve the design and optimal rating regimes of chillers and heat pumps. Consequently, the thermodynamic methodology ensures a better understanding of the energy efficacy of chillers that yield lower energy needs of AC cooling for a sustainable future.

Keywords: disruptive cooling; advanced cooling processes; common primary energy platform; universal efficiency

#3: Zero carbon emission dehumidification via microwaves

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A recent change in the development direction of science, technology, and industry towards zero carbon emission and sustainability has not excluded dehumidification. Commonly, dehumidification is provided by mechanical vapour compression systems, where the air is cooled to dewpoint to get low moisture content. However, the refrigerant used in this system is usually not a zero-carbon emission fluid. However, emerging microwave dehumidification can lower moisture amounts due to the adsorption of water vapour on desiccant material and its desorption with microwaves, and no refrigerants are used. The critical aspect is direct energy transporting to adsorbed water molecules by microwaves, which lowers energy consumption for desorption; moreover, desorption can occur at relatively low temperatures. This paper analyses the microwave-assisted dehumidification method and the interaction theory of microwaves with adsorbed and free water molecules. Microwave dehumidification could be one of the zero carbon emission systems with clean, renewable energy-based electricity generation. Moreover, energy efficiency could be archived due to the selective effect of microwaves.

Keywords: adsorption; dehumidification; microwaves; desorption; energy efficiency

#4: Integrated IEC+MVC air conditioning system for future sustainability

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The global air conditioning (AC) demand have increased significantly, from a mere 800 TWh/yr in 2002 to 2200 TWh/yr in 2022, growing annually at a CAGR of 4.8%. Over this period, the increase in global warming effect is marked by a 16% increase in cooling-degree days (CDD) and almost 96 % increase in the European Union countries. The unusually high ambient temperatures recorded in many countries have affected the regional climatic weather patterns where severe draughts, stronger heatwaves and cyclones or hurricanes are increasingly occurring. In a business-as-usual (BAU) report on global cooling demand, it predicted by 2050 the AC electricity consumption could reach a massive 6300 TWh/yr or about 19% of global electricity production. Without major breakthrough in technology innovation and adequate green-house gases (GHG) emission guidelines from AC, the World Economic Forum predicted that the cooling industry alone could worsen the ambient temperatures rise by as much as 0.5-degree Celsius. In addition to the global warming effects from AC electricity, the continued usage and production of refrigerants for compressors, such as the hydro-chloro-fluorocarbon (HCFC) and hydrofluorocarbons (HFC), have damaging effects on weather patterns from their high specific GWP potentials, typically 1500 times than CO2. However, the International Energy Agency (IEA) predicted a likely reduction of refrigerants use in AC and this reduction may lessen global warming gradually till then. The adoption of Montreal Protocol (1987) by all countries was an excellent example in limiting the production, consumption, and trade of HCFCs and CFCs refrigerants. Similar concern in the continued production of HFC-32 and HFC-125 refrigerants for AC had similar bad effects to the environment, but the policy to curtail their production could reduce emissions to the ambient by 50% and 100%, respectively. Despite the zero-ozone potential of HFCs, their usage as alternative to HCFCs could still harm the environment due to their high GWPs. The high energy consumption and GWP effect from AC refrigerants could be attributed partially to the low performance conventional chillers. We proposed innovative hybrid cooling system for future sustainability. In proposed system, indirect evaporative cooler (IEC) is hybridized with mechanical vapour compression (MVC) chiller to improve overall performance, effective temperature and humidity control and reduced water consumption. Hybrid IEC+MVC system is designed, fabricated, and tested as assorted outdoor air conditions. In schematic, partial air from room return is utilized as a working air in IEC and accordingly outdoor air is introduced to makeup the cooling requirement. The IEC handles 33-45 of the total cooling load, and the energy consumption can be reduced by 20-40% as compared to conventional MVC. Moreover, the condensate collected from the evaporator can compensate for >75% of water consumption in IEC, making the system applicable in arid regions. We also proposed a simplified empirical model for hybrid system performance evaluation based on experimental results.

Keywords: air-conditioning; hybrid cooling system; indirect evaporative cooler; sustainable cooling

#5: Sensitivity analysis of optimising retrofit strategy for a Beijing urban residential neighbourhood

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Due to the high energy consumption in the building sector and the ever-increasing urbanisation rate, the demand for retrofitting old buildings in the urban areas is increasing in China. However, it is a challenge to determine the strategies that make the retrofit projects cost-effective. Considering this, the study establishes an approach that analyses the sensitivity of building energy consumption on parameters defining the materials used on the building envelope, as well as the solar shading and airtightness of the building. This research builds EnergyPlus models using geometric data captured from the map, building fabric data from local design standards, and a set of varying activity schedules, and carries out simulations to calculate the building energy consumption of a case study residential neighbourhood with 32 buildings in Beijing, China. The energy consumption data is then used for a sensitivity analysis using Morris Method on 14 parameters in total. For different building shapes, the sensitivity analysis results highlight that the energy is most sensitive to infiltration, followed by window U-value and window SHGC. The solar absorptances and U-values of external walls and roofs are also found to have a moderate influence on the total energy consumption. By using predicted weather files, this research further discusses the changing influences of these parameters considering climate change over the next few decades. The approach of this research can support the analysis of different building types at different locations, and the result can be an important reference for building management teams and policymakers to determine suitable retrofit strategies.

Keywords: building retrofitting; energy simulation; sensitivity analysis; Morris Method; EnergyPlus

#6: Experimental and numerical investigation on thermal heterogeneity of a novel zoning air conditioning system

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Thermal heterogeneity in indoor environment is not only critical for the thermal comfort with high indoor environment quality, but also contributes to the complexities of ZEB energy saving solutions. There is a growing consensus that variability in indoor conditions can be acceptable to occupants, reduce the energy consumption of buildings without compromising on the thermal comfort perception in occupied spaces. The contribution of this study is to create a novel zoning air conditioning system and to reveal its thermal performance in an open-plan office in terms of temperature non-uniformities in the zoning thermal environment. The novel zoning air conditioning system is consisted of four supply air openings mounted on zone border separately and one central return air opening. Recycle the indoor air by pulling air out through the central return air opening and replacing it with conditioning air through the supply air openings. Hence in each zone, circulating airflow form from border to the centre, which reduce the air convection between neighbouring zones and improve the thermal efficiency. In this study, the impact of various control strategies on zoning thermal environment are investigated by using computational fluid dynamics (CFD) numerical analysis which are validated through the full-scale field experiments. The CFD simulation result is highly comparable to the experimental findings with an average temperature difference of approximately 0.4K. Cases studies under different operating schedules are successful in providing the acceptable temperature difference between neighbouring zones though the CFD numerical analysis. The temperature non-uniformity is evaluated with temperature utilization coefficient to evaluate thermal performance of the novel zoning air conditioning system. The mechanisms of zoning thermal heterogeneity for circulating airflow application are evaluated, the finding shows that the maximum temperature difference between the neighbouring zone can reach up to 2.8K.

Keywords: zoning air conditioning system; CFD; field measurement; thermal heterogeneity; temperature non-uniformity

#7: A study of the negative impact of urban heat islands: case study Aswan city, Egypt

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The constant change in temperature and the continuous rise in global temperature, especially in urban areas has led to the urban heat island effect. Currently, there is an increase in population which lead to the need for more urbanism. With this increase, the Urban Heat Island effect appeared. Urban heat island is considered to be one of the most prominent contributors in urban areas. Given that Aswan is a relatively hot city with rapidly expanding urban areas, it may pose a great challenge to the city in the need for energy for cooling to compensate for the temperature difference in recent years, which represents an economic burden on the city. This paper cites Aswan as an example of the temperature rise caused by increasing urbanization. An analysis has been done on the city's energy needs in recent years to illustrate the gap caused by the temperature rise. The study recommends reducing heat islands through rational urban planning. By simulation using ArcGIS temperature differentiation according to land cover ratio. The highest temperature appeared in high-density areas like the city centre. Where the temperature represented in the largest area of the city exceeded 35 degrees Celsius.

Keywords: urban heat island; land surface temperature; green spaces; ArcGIS; landcover

#8: Experimental investigation of the effect of frost formation on heat transfer in cylindrical pipe

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Frosting is a condition encountered in many engineering applications and often negatively affects heat transfer. Controlling frost in such applications greatly affects both the system performance and the operating life of the system. In this thesis, the effects of frost and freezing around a cylindrical pipe on heat transfer were experimentally investigated. The tube with an inner diameter of 10 mm and an outer diameter of 14 mm is made of aluminium. The cylindrical pipe is placed in the air flow channel made of transparent plexiglass material with a width of 150 mm, a height of 140 mm and a length of 2500 mm. Experiments were carried out for 300, 506, 875, 1124 and 1426 Reynolds numbers, 30%, 45%, 55% of air relative humidity and 15°C, 30°C and 45°C values of air inlet temperature. In the experiments, antifreeze coolant fluid was used in the cylinder pipeline. The cylinder pipe inlet was kept constant at a flow rate of 0.126 kg/s and a temperature of -30°C. As the frost thickness on the cylindrical pipe increased, the thermal convection coefficient decreased with time. Here, depending on the layer formed on the surface with the effect of snow, the thermal resistance increased, and the heat transfer decreased. From the experimental data, it was determined that the most effective parameter on heat transfer and snow thickness was the Reynolds number. The Reynolds number is followed by air inlet temperature and relative humidity.

Keywords: freezing; snow; condensation

#9: Solar cooking experiments with a finned heat storage cooking pot

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Solar storage cooking pots can use stored heat for cooking during non-sunshine periods to enhance their usefulness during non-sunshine hours. A finned type solar cooking storage pot is designed and evaluated experimentally. The storage cooking pot is designed with a finned storage cavity to store heat during sunshine cooking periods. Sunflower oil is used as the storage medium inside the cavity with a capacity of 5 litres. The solar cooking pot is heated up during solar cooking periods with a 1.8m parabolic dish concentrator. During storage cooking periods, the pot is placed in a wonderbag insulating cooker to investigate the storage performance. Sunflower oil and water are used as the cooking loads. For both solar and storage cooking periods, 1kg of water/sunflower oil is used as the load. The solar and storage cooking periods are both 3 hours. 1kg of water is boiled in around 30 minutes, and all the water in the pot is fully evaporated after around 2.5 hours. The maximum temperature achieved by sunflower oil in the storage cavity is about 134°C during the solar cooking period using water has as the load. For sunflower oil as the load during the solar cooking period, the maximum temperatures achieved in the pot and storage cavity are around 188°C and 190°C, respectively, at the end of 3 hours. For the storage cooking period, fresh water poured in the pot achieves a maximum temperature of around 84°C in about 30 minutes. The load temperature is around 70°C at the end of the storage cooking period. For the oil heating test, fresh sunflower oil in the pot achieves a maximum temperature of 150°C in about 20 minutes. The cooking temperature drops to around 120°C at the end of the storage cooking period. Higher temperatures are achieved with sunflower oil as the load compared to water. The pot is also tested with chicken, and it can fry chicken during both solar and storage cooking periods.

Keywords: experimental thermal performance; finned storage cooking pot; solar and storage cooking

#10: Integrated energy system design and techno-economic analysis for electric vehicle charging station

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Fossil fuel utilization has increased considerably over the last few decades, which has increased global warming. Developing nations face multiple challenges, and it becomes necessary to grow their economy by satisfying sustainable development goals by establishing a green energy sector. Integrated Renewable Energy Systems (IRES) is a promising solution for conventional electricity generation. Introducing electric vehicles makes developing an environmentally friendly, alternative transport sector. Infrastructure development requires significant investment and the latest technologies, a major obstacle to adopting electric vehicles. This paper proposes a standalone Integrated renewable energy system-based charging station development for electric vehicles (EV). To design, optimize and techno-economic analysis of multiple combinations of standalone integrated renewable energy systems considered. The HOMER software performs the simulations of considered systems. The optimized, integrated scheme is obtained according to economic, technical and environmental parameters for EV charging stations. The present analysis demonstrates that the optimized, integrated system provides low-cost and reliable power to fulfil the charging capacity of estimated Electric Vehicles' energy demand with the proper renewable fractions. The optimal integrated system is obtained as the combination of Solar PV, Wind Energy system, Battery Energy Storage and Diesel Generator Units for Najran City's considered location in the Kingdom of Saudi Arabia. The optimal integrated energy system for electric vehicle charging stations positively achieves sustainable electricity generation in this study, which may be a suitable future model for electric vehicle charging projects.

Keywords: electric vehicle; Integrated Systems; renewable energy; charging stations; Najran City

#11: Reconnecting indoor confined individuals (ICIs) with nature through virtual reality: exploring the potential of biophilic architecture for enhancing mental health

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Exposure to nature has been demonstrated to boost mental health, with research indicating that access to green areas can improve mood, reduce stress, and promote general well-being. However, access to natural settings is not always possible when people desire it. Various factors such as pandemic lockdowns (e.g COVID-19 pandemic), being hospitalized, imprisoned, having a disability or even working long hours in institutional buildings can confine people in indoor environments. Indoor Confined Individuals (ICIs) are people who are forced to stay inside for a lengthy amount of time owing to situations such as quarantine, lockdown, or jail. Indoor Confined Individuals (ICIs) can experience stress and negative effects on their mental health due to confinement. Enhancing the mental health of these individuals is the ultimate objective of the current research. ICIS needs to have access to mental health resources and assistance to preserve their mental health, however, they might not have access to traditional healthcare systems such as consultancy with psychologists. Recently Virtual reality (VR) has been utilized to help with therapy and treatment of mental health issues like anxiety, phobias, and post-traumatic stress disorder (PTSD). VR provides an immersive experience, allowing individuals to feel as though they are in a natural environment, promoting relaxation and stress reduction. VR also offers a non-invasive alternative to traditional mental health therapy, making it accessible to a wider range of individuals. The current study attempts to reconnect Indoor Confined Individuals (ICIs) through reconnection with nature using VR. The study attempts to provide the users with the experience of biophilic architecture through VR that mimics the sensory experiences of nature and allows them to interact with this environment in a way that can positively impact their mental well-being. Turning around the idea of biophilic architecture the research attempts to provide this target population with the experience of walking and interacting with a series of biophilic buildings that integrated nature and the built environment reducing their stress, depression, and anxiety improving their mood and consequently mental health. By monitoring the brain signals of individuals through BCI, the research can provide a more accurate and valuable measure of their mental health progress.

Keywords: biophilic architecture; mental health; sustainable architecture

#12: Retrofitting strategies for sustainable offices and the well-being of the occupants

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The quality of the indoor environment has an undeniable effect on the occupants' well-being and the buildings' energy consumption. The harsh climatic conditions along with the lack of knowledge or interest can result in poor internal conditions that inversely affect the health and productivity of the users and unnecessarily increases the energy consumption of the building. The reported study aims to evaluate the performance of an office building and proposes a list of recommendations to improve its sustainability and the well-being of its occupants. The investigated office building is located in Muscat, the capital city of Oman, which is characterised by its hot extended climate based on the Koppen-Geiger climate classification, where the air temperature can easily reach 40°C. The building consists of three floors and an extended wing in the adjacent factory. Objective and subjective measurements were performed including an indoor environmental quality survey and energy audit. The results revealed the need to improve the working environment as satisfaction rates were 65% of below for the thermal, acoustical, indoor air velocity, and indoor air quality conditions. The lighting conditions were satisfactory for around 83% of the participants. Potential energy conservation measures were identified and the estimated annual energy savings ranged between 3068 kWh and 68766 kWh. Besides, the estimated CO_2 reductions ranged from 3.3 tons to 74.2 tons.

Keywords: retrofitting strategies; Indoor environmental quality; energy audit; sustainable office; occupants' well-being

#13: A multi-directional flap fin louver windcatcher: experiment, numerical and field test investigations

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Windcatchers, as natural ventilation apparatuses, are integrated into architectural designs to facilitate fresh air circulation, minimize energy expenditure, and occasionally, enhance indoor thermal comfort. However, their operational efficacy is often compromised by adverse meteorological conditions. To circumvent this limitation, researchers have been exploring the amalgamation of passive and low-energy heating, cooling, and dehumidification technologies. Despite these advancements, the majority of existing studies have not adequately addressed the impact of fluctuating wind conditions, which can potentially render windcatchers ineffective. In response to this gap, we propose an innovative windcatcher design equipped with flap fins at the inlet openings. This design ensures a consistent supply of fresh air, irrespective of wind direction, and facilitates the integration of passive and low-energy technologies. Drawing inspiration from the check valve mechanism, the flap fin design permits unidirectional wind flow into the windcatcher's supply channel, thereby ensuring that changes in wind direction do not affect the ventilation rate or the positioning of the supply and return channels. This, in turn, allows for the effective application of passive technologies. The flap fin, which operates via gravity and leverages wind pressure around the openings to regulate airflow, is lightweight. We developed an open wind tunnel and test room to experimentally assess the ventilation performance of the proposed windcatcher prototype. Additionally, a validated Computational Fluid Dynamics (CFD) model was constructed. Preliminary findings indicate that the ventilation performance of the flap fin louver windcatcher is independent of wind direction, as observed in both field tests and wind tunnel experiments. Furthermore, the use of lighter and longer fins appears to enhance the ventilation rate.

Keywords: building; energy; machine learning; HVAC

#14: Deep learning-based vision for real-time building occupancy and window status detection: enhancing energy efficiency and indoor comfort

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This study introduces a vision-based deep learning approach aimed at enhancing the control of Heating, Ventilation, and Air-Conditioning (HVAC) systems by detecting and recognizing occupant activities and window opening behaviour in real-time. Traditional HVAC control methods often fall short in responding to the dynamic behaviours of occupants, leading to energy inefficiencies and compromised indoor air quality. The motivation behind this research arises from the pressing need for energy-efficient buildings and sustainable practices. Leveraging deep learning and computer vision techniques, the proposed methodology involves the development and training of a specialized convolutional neural network (CNN) model using diverse video data capturing occupant actions and window operations. Rigorous experimental evaluations conducted within a case study building demonstrate impressive detection accuracies of 92.72% for occupant activities and 87.74% for window operations, validating the model's ability to accurately identify a wide range of occupant behaviours, including subtle window-opening actions. By utilizing real-time detection, Deep Learning Influenced Profiles (DLIP) are generated, allowing for building energy simulations to assess the approach's impact on energy demand and indoor air quality. The implications of this vision-based deep learning approach are far-reaching, as it holds promise in predicting indoor air quality, enhancing thermal comfort, and optimizing HVAC and natural ventilation systems based on real-time occupant behaviour, thereby contributing to energy conservation and fostering a more sustainable and comfortable indoor environment.

Keywords: building; CFD; energy; field testing; ventilation

#15: Continual learning-based adaptive data-driven model for building energy prediction

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Data-driven models have been increasingly employed in smart building energy management due to their superior performance. To avoid performance degradation, the data-driven models should be continuously updated to adapt to the changes of building operation characteristics. During the continual model update process, the knowledge of previous learned task(s) can be lost as information relevant to the current task is incorporated (i.e., catastrophic forgetting issue). Conventional model update methods cannot address concept drift and catastrophic forgetting issues in an efficient and effective way. Continual learning focuses on learning a model from a continuous data stream which can originate from changing input domains or be associated with different tasks. This paper reports on a comparison study conducted on the performance of two advanced continual learning methods (i.e., Elastic weight consolidation, Gradient episodic memory) and three conventional update methods (i.e., accumulative learning, incremental learning, and ensemble learning) for adaptive building energy prediction. The case study on a large open-source dataset demonstrated that, the CV-RMSE of Elastic weight consolidation and Gradient episodic memory decreased by around 14% and 8% on average compared with static model and accumulative learning. The research insights could facilitate the wide deployment of advanced machine learning techniques in the building energy sector.

Keywords: building energy prediction; model update; continual learning; accumulative learning; incremental learning

#16: Smart cities: advantages and challenges

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Enormous urbanization is menacing the sustainability of cities and the standard of living in cities. Massive growth of population and cities can cause social insecurity and sap the ability of cities to be sustainable. Thus, great incentives, through a new sustainability model, to protect the environment, by reducing the consumption of energy and water and lessening the pollution, and improving the life quality of citizens, are required. The current paper presents a review on the future cities, their features, and the exciting and developed innovations inaugurated in cities. In addition, the different challenges faced by the future cities are highlighted in the current paper.

Keywords: smart cities; sustainability; urbanization; advanced technologies

#17: Optimizing solar energy harvesting with self-cleaning surfaces: examining the role of wetting state in dust removal

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The optical properties of protective surfaces used for photovoltaic (PV) panels are crucial for efficient energy harvesting. These surfaces must have high transmittance and low absorption to achieve maximum performance. However, environmental factors such as temperature, humidity, and dust settlement can cause irreversible damage to these surfaces and lower system efficiency for solar thermal and solar PV systems. When the dust settles on protective covers, it scatters and diffuses incident solar radiation, negatively impacting solar receiver performance. Despite efforts to mitigate the effects of dust particles on protective covers and reflective surfaces, the cost-effective removal or self-cleaning of these surfaces remains challenging. Dust particles in humid air collect water vapour and produce mud on solid surfaces, creating a chemically active fluid layer through condensation. This layer can dissolve alkaline (K, Na) and alkaline earth metal (Ca) compounds, causing selective surfaces to lose optical transparency. To prevent this, dust must be removed before chemically active layer development. Hydrophobic surfaces can help with dust removal. Creating a hydrophobic state on a surface is one method for facilitating the removal of dust particles. Nano/micro pillars can trap air and reduce surface dust particle interaction. Therefore, the wetting state of a surface plays a significant role in the self-cleaning application of surfaces, with water droplet rolling/sliding being the preferred method for dust particle removal. Experimental evaluations have been conducted on the optical properties of self-cleaning surfaces and the influence of dust on water droplets. The droplet fluid cloaking of dust particles during its transition on a hydrophobic surface is one of the key processes for dust removal by rolling liquid droplets.

Keywords: photovoltaic panels; energy harvesting; self-cleaning; dust removal

#18: Remote monitoring unit for solar home systems: a field trial

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Solar home systems (SHS) can be utilised for electrification of areas for the 770 million people worldwide who do not have connection to a national electricity grid. SHS, comprising of a solar photovoltaic panel, charge controller, battery, and appliances, provide small amounts of power for household items such as charging phones, LED lights, radios, and televisions. The practical implementation of SHS in, typically, remote rural locations make asset monitoring and operation and maintenance of these systems difficult. For example, in one programme over 30% of SHS implemented had some form of fault reported within the first 12 months of operation. This impacts the economics and reputation of the SHS supplier and is highly inconvenient to the user. However, the faults were difficult to analyse, as their symptoms were reported verbally in varying levels of detail. The ability to remotely monitor these systems in real time could help to improve their long-term performance and allow pre-emptive maintenance to be performed. Knowledge of the actual solar power generation and load provision on these systems helps a SHS supplier manage their assets and could help with the future development of lower cost and more efficient SHS. This paper introduces the design of a low-cost low-power data-logging device for remote monitoring of SHS. The logging unit monitors voltage, current, power and temperature sensors, stores this data locally and sends it to a cloud-based store, either using Wi-Fi or General Packet Radio Service (GPRS). The system can be installed in any area with GPRS reception or Wi-Fi and monitored from anywhere with an internet connection. The data is presented in interactive graphs and maps via an IoT web dashboard. Data from field trials of the remote monitoring unit on solar power systems in Zambia, Malawi and the UK is presented. This shows key issues such as low battery state of charge that can be used to inform customers when to reduce their loads and charge the battery.

Keywords: monitoring; remote data-logging; solar home systems; solar photovoltaics

#19: Classification of climate zone using degree-day method: a case study of Saudi Arabia

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Understanding of the local climate specification is vital for designing and operating low-carbon buildings. This is particularly important in countries with a hot and arid climate, such as the Kingdom of Saudi Arabia (KSA), where meteorological data may be available only in specific locations. However, there is a lack of literature on the impact of the local climate on the behaviour of buildings with little local classification or zoning. The literature assessment of the building performance under the Saudi climate is based mainly on a general climate zone based on the hot, cold, and moderate classifications. This paper utilises the degree-day method to address the gap in Saudi Arabia's hot and arid climate classification, currently adopted by the Saudi building codes and specifications. The cooling degree days (CDD) and heating degree days (HDD) for 21 cities in Saudi Arabia were calculated using recent meteorological data from Saudi weather stations over five years (2017-2021) and included cities from all the 13 Saudi regions. The study used DegreeDays.net software to compute the CDD and HDD for these cities, using an integrated approach. Multiple base temperatures were used to calculate the cooling and heating degree days, and then the results were categorised accordingly. The analysis of Saudi Arabia's climate classification using this approach has produced a climatic zoning map which is more specific and accurate than for previous hot and arid based categories. This will enable better building design and thermal comfort improvement for particular parts of the Kingdom. In addition, the proposed classification will support energy and building research that can be applied to all Saudi buildings. In particular, this research provides valuable insights into sustainable building design and construction in KSA, with implications for policy and practice.

Keywords: Saudi Arabia; cooling degree days; heating degree days; climate classification

#20: Energy performance of solar PV/T system integrated with nano-enhanced PCM

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The hybrid solar photovoltaic-thermal (PV/T) technology is the main strategy for harvesting solar energy due to its stability, non-polluting, security and good visibility features, which is regarded as the main battlefield to achieve the green energy and low-carbon transformation. The utilization of the multispectral solar energy is an effective solution to enhance the solar energy system efficiency. The aim of the project is to develop a novel solid and liquid MXene nano-enhanced phase change material (PCM) applied in the solar PV/T system. Specifically, 0.6 cm thickness of optical filtration channel filled with the liquid MXene-enhanced PCM is directly attached to the front surface of PV panel for enhancement of optical performance in the hybrid solar PV/T system, meanwhile, solid MXene-enhanced PCM is filled between the PV module and copper absorber pipe for storage heat and cooling purposes. Furthermore, the MXene-enhanced PCM as novel heat transfer fluid is injected into the copper absorber pipe to enhance the heat transfer rate resulting the system thermal and electrical efficiency enhancements. This study demonstrates that thermal and electrical efficiencies of the PV/T system using the MXene-enhanced PCM could be boosted by approximately 16-20% and 7-14%, respectively, and the surface temperature of the PV cell could be decreased by 35-40%, compared to that with traditional PV/T system.

Keywords: solar PV/T; optical filtration channel; thermal efficiency; electrical efficiency

#21: Using system intrinsic thermal storage to enhance chiller plant efficiency: control strategy development and on-site validation

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Previous studies have proofed that the use of thermal energy storage can significantly improve the energy efficiency of a chiller plant via proper control. However, thermal energy storage systems are not commonly available in building cooling system. This study proposes an optimal control strategy to enhance chiller plant efficiency by utilizing the intrinsic thermal energy storage effect of the chilled water delivery system in a building. The fundamental idea of the proposed strategy is to maintain a high Part Load Ratio (PLR) of operating chillers so that they can produce cooling with high efficiency. The strategy also keeps the supply chilled water temperature within the allowed range, so that the building thermal comfort is not compromised. The proposed control strategy consists of two modes applicable for two different scenarios. Mode A is applicable during the end of office hours. It can bring forward the shutdown of chillers at the end of office hours and utilize the stored cooling energy to cool the building for a short period of time. Mode B is applicable for extreme low cooling load conditions (e.g. night mode operation), particularly when the actual cooling load is much lower than the rated capacity of a single chiller. The concept of the optimal control strategy has been validated on-site in a high-rise commercial building served by a large and complex cooling system whose chilled water delivery system has a thermal capacitance of around 3,312,600 kJ/K. On-site validation of Control Mode A shown the efficiency of chiller plant was improved by14% during the tested period, and the electricity consumption was reduced by 998 kWh. On-site validation of Control Mode B shown that the chiller efficiency could be improved by 43.3% during the tested hours and the electricity consumption was reduced by 2508 kWh.

Keywords: optimal control; chiller efficiency; thermal energy storage; air-conditioning; building energy

#22: A spectrally selective metal mesh coating for photovoltaic/thermal applications

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In this paper, a nano-scale metal (silver) grid coating was proposed for the photovoltaic/thermal applications (PV/T), it has high transmittance in the solar radiation band (0.3-2.5 μm), and high reflectivity in the infrared band (2.5-25 μm). When combined with PV/T absorber that was high absorption/emission in the full band (0.3-25 μm), it can guarantee the spectral selection characteristics of high absorptivity in solar band and low emissivity in infrared band, which can significantly reduce the radiation heat loss of PV/T. Based on the finite-difference time domain method, the effects of grid period, width and height on the spectral characteristics of metal grid coatings were simulated and analysed. The results show that when the period of the nano-metal grid is 500nm, the height is 50 nm, and the width is 30 nm, the transmittance in the solar band reaches 0.90, and the mid-infrared reflectance reaches 0.88. Compared with the existing ITO coating, the solar radiation transmittance of the metal mesh coating is increased by 20%, the infrared reflectance is increased by 24%, and the sheet resistance (5.3 Ω Sq-1) is reduced by 47%.

Keywords: solar energy; Nanometals; thermal energy; photovoltaic/thermal applications; low emissivity coating

#23: Solar control devices on glazed facades: optimizing the shape of an outer slat array as function of latitude, climate and solar control strategy

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The arrays of external movable louvers are one of the most effective solar control devices on transparent building envelope elements. Furthermore, they significantly affect the image of the building. For a south-facing glazed façade it is normally assumed that slats with the major axis horizontal are convenient, while for the east and west orientations it is better to arrange their major axis vertically. Therefore, intermediate slope/inclinations should be appropriate for intermediate orientations of the façade. The optimal shape of a slats array depends on a number of factors such as:
- visible solar paths, defined by Latitude and façade orientation;
- local climate, in particular: temperatures, intensity of solar radiation;
- building's energy balance, which determines the relative weight of energy demand for heating, cooling and artificial lighting.
If the slats are equipped with PV cells, the energy balance of the building must also take into account their electricity production. If the slats are movable and/or combined with other devices, such as internal curtains, any solar control strategy reduces the incoming luminous flux, and this increases the period of use of the lamps, with the necessary consequences on energy demand and comfort. Therefore, it becomes important what part of the sky the façade sees through the slats, and this depends on the inclination of their longitudinal axis. In reference to a typical office room with an entirely glazed exterior wall, in a northern Italian climate, this work proposes a method for finding the optimal slope of the longitudinal axis of the slats as a function of local climate, façade orientation and various solar control strategies. The analysis was performed only by means of computer simulations, the results of which are reported.

Keywords: building energy; solar control; comfort

#24: A BIM-based framework for the integrated assessment of building circularity and sustainability

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The construction industry consumes raw materials and produces tons of waste and pollution. Traditional building design strategies are based on an unsustainable linear model. The transition to the circular economy, a new sustainability paradigm, aims to reduce the consumption of natural resources and raw materials and minimize the waste and harmful environmental impact and greenhouse gas emissions that cause global warming and climate change. This research aims to propose a novel framework to leverage building information modelling (BIM) in the implementation of the sustainable circular economy concept in the built environment by integrating the building circularity assessment and sustainability aspects, such as environmental and economic. The implementation of the framework is presented in a prototype in form of a BIM-Based tool that will be developed within Autodesk Revit. The validation of the proposed framework and the tool will be in a case study of a typical building design. The tool will help designers in the decision-making of building design and material selection for achieving a sustainable circular-built environment.

Keywords: building circularity assessment; sustainability; building information modelling; life cycle assessment; embodied carbon

#25: Numerical study of PCM integrated two-evaporator variable speed compressor domestic refrigerator for applications in remote areas

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This paper presents a physical model for studying the enhancement of cold storage capacity in non-freezer domestic refrigerators through the integration of phase change material (PCM). Literature has proven that adding PCM to fridges improves their performance and cold thermal storage capacity. It increases the compressor's off-time, helping to maintain a cold temperature in the cabinet for longer periods. Furthermore, the use of PV-powered variable speed compressors in refrigeration systems promotes solar utilization by shifting the compressor load to daytime when the abundant cooling load can be stored in the PCM. However, limitations in the application need to be considered and addressed. For instance, the solidification of PCM during compressor on-time is challenging because the cabinet air temperature cannot effectively charge the PCM when the PCM packs have no contact with the evaporator. Therefore, PCM needs to be attached to the evaporator, as the compressor operating time is shorter than the off-time period, and the evaporator temperature should be much lower than normal operating conditions. This colder evaporation results in local air temperature drops, which may cause food spoilage. To overcome this problem, a two-evaporator fridge is adopted. The high-temperature evaporator operates to maintain a normal temperature range for fresh foods, while the low-temperature evaporator is immersed in the PCM pack to ensure that it is charged during compressor on-time periods. A dynamic CFD analysis is conducted to determine the effective PCM volume, heat transfer rates, the temperature gradient in the fridge, and PCM liquid fraction variations during compressor on and off times. The results show that by using two evaporators, the air temperature in the cabinet can be maintained in a safe range for the foods, and the PCM can be successfully charged using only PV output.

Keywords: domestic refrigerator; PCM; heat exchanger; CFD analysis

#26: Thermal performance of a multistorey residential building with five passive cooling technologies in different climates of China

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It is a global trend to reduce the energy consumption of the building. This paper proposed five passive cooling strategies and integrated them into a multi-storey residential building in three typical climates of China. The Energy Plus software was used to investigate the thermal performance of the multi-storey residential building combined with five passive cooling technologies individually. The best combination of these technologies was also proposed in this paper. The results showed that, for individual strategy, shading devices could help the multi-storey residential building reduce more energy consumption, and it could reduce up to 20.81%-29.91% energy usage in Beijing, Shanghai and Hong Kong. For the combinations of different technologies, the combination of PCM, green roof, changing the thermal mass of the building envelope, changing the window-to-wall ratio of the building envelope and shading could reduce energy consumption dramatically, reducing up to 31.53%-35.03% energy consumption in Beijing, Shanghai and Hong Kong. This paper will give an insight to architects in China to design low energy consumption buildings and retrofit the old buildings to save energy. It is recommended that other researchers in this field test more passive cooling technologies and evaluate their performance in more areas of China.

Keywords: passive cooling; energy plus; residential building

#27: Toward Zero-carbon HVAC for temperate regions: cooling using thermoelectric heat exchanger: an experimental study

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As buildings contribute up to 40% of greenhouse gas emissions, exploring eco-friendly and sustainable HVAC and heat recovery solutions is vital. This experimental study presents a novel integration for passive wind towers that use thermoelectric heat exchangers to cool or heat fresh air as it enters a room. The proposed method utilises thermoelectric modules (TEM) also known as Peltier devices or thermoelectric coolers (TECs) to regulate the surface temperature of heat pipes within a wind tower. The TECs are capable of cooling as well as heating based on the current polarity. This paper focuses on investigating the cooling potential of this system through a range of experimental and CFD analyses. The primary experimental setup consisted of heat pipe(s), TEC module, heatsink and fans for heat dissipation. Water-filled aluminium heat pipes allow effective and consistent temperature distribution across their length (1m). Preliminary results show a reduction of pipe surface temperatures by up to 11.8ºC using 40.8W of power at natural convection (indoor). Despite the rated voltage of 12V, experimental results showed 7.5V of input voltage delivers an optimal temperature drop (10.1ºC) to power consumption (13.5W) ratio. Convection tests showed reduced temperature drop with higher wind velocities, however, an addition of a volume control damper (at 30° opening) before the heat pipes was proposed as a solution to restore optimum cooling. The CFD model of a wind tower mounted on top of a closed room having two rows of heat pipes was used for simulations. A total of 35 heat pipes were modelled to reflect steady state temperatures from the experimental data, which showed temperature reductions below the pipes of 0.9ºC with no damper and 3.5ºC with damper at 1m/s supply wind velocity and of 3.7ºC with no damper and 6.6ºC with damper at 0.5m/s supply wind velocity. The preliminary results showed a viable opportunity for a solar-powered thermoelectric heat exchanger system on passive wind towers. The proposed TEC-based cooling offers a low-maintenance, sustainable and environmentally friendly solution to meet the heating and cooling demands of buildings in temperate regions. Further design optimisation and improvements are recommended to maximise the cooling performance whilst ensuring ventilation requirements.

Keywords: thermoelectric cooling; zero-carbon HVAC; passive wind towers; heat pipes

#28: A dynamic simulation of controllable crystallisation supercooled PCM for space heating via using Simulink\Simscape software

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Energy-efficient and low-carbon heating has led to the development of solar-assisted heat pumps (SAHPs) with latent heat storage (LHS) and load-shifting capabilities. In latent heat storage applications, the concept of releasing stored heat whenever needed is a promising topic as the current trend considers the importance of demand-based systems and more renewable energy utilization. In short to long-term heat storage applications, heat loss from the latent storage units is still a big problem, however, controllable supercooled PCMs offer a solution to this problem by releasing the latent heat when the supercooled PCM is triggered to induce crystallization. The advantage of using these PCMs in the heating systems has been presented with simulations using demand profiles, however, a comprehensive dynamical model including a building model, solar-assisted heat pump unit and PCM storage model will provide real dynamic thermal behaviour of the system for heating the houses. This paper presents a comprehensive dynamic modelling framework by using Simulink/Simscape for SAHP-LHS systems that account for various design parameters, operation modes, and control strategies considering different weather conditions and heating loads. The model incorporates the load-shifting mechanism by optimizing the operation of the system to minimize the peak electricity demand and maximize solar energy utilization. The analysis shows that the load-shifting strategy can significantly reduce the peak electricity demand. Finally, this study provides a valuable tool for designing and optimizing SAHP-LHS systems with load-shifting capabilities, which can contribute to achieving energy efficiency and sustainability goals in the building sector.

Keywords: controllable crystallization; Simulink\Simscape; solar-assisted heat pump

#29: Nanocomposite TiO_2/MgO photocatalyst for CO_2 reduction to solar fuels

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Generation of renewable solar fuels by photocatalysis of carbon dioxide utilising suitable semiconductor materials is a promising strategy for environmental remediation. In this regard, titanium dioxide has emerged as a benchmark photocatalyst owing to its low cost, low toxicity, relative abundance and facile synthesis. However pristine titanium dioxide is a wide bandgap semiconductor (3.2 eV) having low carbon dioxide photoreduction selectivity and fast recombination of charge carriers. These limitations can be overcome through design of titanium dioxide nanostructures, surface and morphology modification and development of co-catalysts. This study reports an easy and scalable synthesis of ordered one-dimensional rutile titanium dioxide nanostructures through a facile single step hydrothermal route. Morphology of the as prepared nanostructure investigated using electron microscopy confirms highly uniform growth of nanostructures. The synthesised titanium dioxide nanostructures revealed relatively high photoreduction activity because of its larger specific surface area. A further improvement in photoreduction activity was achieved after the development of a nanocomposite photocatalyst by the integration of magnesium oxide over the one-dimensional titanium dioxide nanostructures.

Keywords: CO_2 photoreduction; photocatalyst; TiO_2 nanostructures; MgO; solar fuel

#30: A field study on occupants' thermal sensation vote in a test room equipped with trombe wall

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Trombe walls have emerged as energy-efficient and sustainable solutions for providing thermal comfort. They make use of solar energy to passively deliver heat, reducing the need for traditional heating systems that rely on non-renewable energy sources, and contributing to the mitigation of carbon emissions. During the day, a Trombe wall absorbs solar radiation and heats the air that lies between the glass cover and the wall. Heated air rises and circulates through the vents positioned at the top and bottom of the wall supplying predominantly convective heat to the occupied space. In contrast, during the night, the vents are closed to prevent heat loss, enabling the wall to gradually release the stored energy into the occupied space, thereby providing mostly radiant heat. In addition to sustainability and energy efficiency, Trombe walls may offer better thermal comfort than traditional heating systems, thanks to low air speeds and radiant heat. To evaluate their performance in terms of thermal comfort, it is essential to assess the Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD) indices, which quantitatively measure human thermal comfort by taking into account several factors, including air temperature, radiant temperature, air velocity, humidity, and clothing insulation. Although PMV and PPD are widely used for assessing comfort, real occupant votes would obviously be more reliable. This study aims to evaluate a Trombe wall-installed test room's thermal comfort performance located in Cyprus through real occupant votes during daytime use. Indoor and outdoor environmental conditions were monitored to determine the correlation between comfort levels reported by the occupants and the recorded conditions. Participants completed a survey on their thermal sensation, which was converted into a 7-point scale using the Fanger model for quantitative and qualitative analysis. Although the mean value of the occupants' votes did not entirely fall within the acceptable PMV and PPD range suggested by the standards, the deviation was not significantly high. The thermal sensation votes indicated that the conditions were slightly warm.

Keywords: trombe wall; solar energy; thermal comfort; thermal sensation vote; radiant heating

#31: Minimising the performance gap using calibrated Dynamic Building Performance Simulation (DBPS) models

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Urbanization, population growth and climate change are the main reasons for the increase in energy consumption worldwide. The developing countries face several additional challenges that impact their energy consumption like inadequate infrastructure and fuel poverty coupled with the absence of sustainable energy consumption measures. These challenges are more urgent in areas with political instability. In this paper, the heating load in an apartment in Hebron, Palestine, was modelled for internal gain. Then the model was calibrated using internal environment measurements (internal temperature) that were taken through two monitoring phases for an apartment in Hebron, Palestine. Dynamic Building Performance Simulation (DBPS) modelling is a useful tool to estimate the energy saving in new buildings and when retrofitting existing buildings as well. Despite the significant applications of DBPS, the performance gap is defined as the discrepancy between the calculated and actual energy savings which is a concern for the building industry. To overcome the performance gap, calibrating the DBPS models is a prerequisite before using the model to estimate energy savings through certain measures. The calibration method that is commonly used is a statistical method that depends on indices related to energy bills to perform the calibration. As energy crises are getting worse, users are shifting towards cheaper energy sources and using a combination of energy sources to fulfil their needs. Hence, these statistical indices that depend on energy bills are not easily applied in many cases, especially where a combination of fuels is used for heating, cooking, and heating water. In this paper a validation method for an apartment is presented using the internal temperature depending on the monitoring phases. The results show that the model was calibrated and can be used for optimization.

Keywords: Dynamic Building Performance Simulation (DBPS) models; calibration performance gap; statistical indices; case study

#32: Arsenic contamination of groundwater and mitigation strategies

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High quality drinking water is one of the major challenges in today's world; over 2 billion people in the world rely on groundwater source. Arsenic has contaminated many ground water sources, hence listed as a dangerous toxic element by the World Health Organization (WHO) and the U.S. Environmental Protection Agency (USEPA). The sources of arsenic can be natural or anthropogenic. Over 100 countries across the world have arsenic contamination higher than the maximum permissible limit of 10μgL−1 set by the WHO. Proximity to sedimentary rocks and a tropical climate has been associated with vulnerability to arsenic contamination. Prolonged or short-term expose of arsenic to human body poses severe health challenges. Traditional methods employed in removing arsenic from groundwater are characterized by reduced efficiency and high energy demand. Membrane technology has taken care of these disadvantages coupled with reduced waste production and can be easily integrated to the traditional methods.

Keywords: arsenic; removal technologies; groundwater

#33: The intermittency and flexibility of heating systems with different terminal types in buildings

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The electrification of building heating is an effective way to meet the global carbon target. As a clean and sustainable electrified heating technology, air-source heat pumps (ASHPs) are widely used in areas lacking central heating. As a major component of space heating, heating terminals have great effect on both intermittency and flexibility of the system. In this study, an integrated dynamic model is developed by considering the interaction of thermal processes among building envelopes, terminals, and heat pumps. The radiation heat transfer ratio of the heating terminal, which was introduced in the dynamic thermal balance equations, is a key parameter to describe the characteristic of heat transfer between the terminal and the building. Field tests demonstrated that the simulated results were closer to the tested values when considering the proposed ratio. An intermittent heating control strategy as well as demand response operation were applied to heat pump heating systems respectively. The effect of different terminals on room temperature response speed, energy saving rate, load shifting rate and electric cost was analysed. The results indicated that heat pumps under intermittent heating were more efficient in buildings with convective heating systems. Specifically, fan-coil heating systems could use 16.48% less energy, while radiant floor heating systems consumed more energy under intermittent heating. For office buildings with convective terminals (such as fan coils), the warm-up time was 0.17h to 0.5h, and for those with convective-radiative terminals (such as radiators), the warm-up time is 0.83h to 4h under daily intermittent heating, while there was nearly no need to preheat in buildings with radiative terminals (such as radiant floors). On the other hand, the buildings with radiative heating terminals had better flexibility. Under the model predictive control strategy, the load shifting ratio of radiator heating system was about 2.9 times that of fan coil heating system. Finally, an idea of a novel radiation-adjustable heating terminal was proposed in order to achieve both intermittency and flexibility.

Keywords: heating terminal; radiation heat transfer ratio; thermal inertia; intermittent heating; load shifting

#34: Investigation on heat transfer and flow organization characteristics in porous media based on entransy analysis model

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For the paper, a new entransy analysis model of heat transfer process in porous media was built and a new utilization efficiency of entransy proposed, meanwhile the field function characteristics of entransy were found. Based on this model, according to the cooling curve, the surface temperature of frozen products in the porous media quick-freezing zone and the convective heat transfer coefficient along the quick-freezing device were predicted for the first time. It was found that the convective heat transfer coefficient of the upper part of the corn surface and the lower part of the corn in the porous medium region for the top corns were significantly different. It was confirmed that the radiation heat transfer could inhibit convective heat transfer under certain conditions, and the entransy dissipation mechanism in the surface heat transfer process was analysed, meanwhile the effect of radiation on convective was quantitatively evaluated. The surface heat transfer coefficient of the surface modified by radiation was used to predict the cooling trend of the central temperature of the top corns in quick-freeze and the cooling cure matched well with the measured values. The cooling curve of convex, concave and approximate straight line can be simulated by using the convective heat transfer coefficient along the way with high precision for different types of cooling process. The air flow organization efficiency of the porous medium in quick-freeze was proposed, and the enhanced heat transfer characteristics of porous medium were found, which provided inspiration for the optimization design and performance evaluation in porous media.

Keywords: entransy; entransy efficiency; field coordination; surface temperature; along heat transfer coefficient; air flow organization efficiency

#35: A novel hybrid multi-layer CdTe-based PV ventilated window system integrated with phase change material: concept, construction and experimental investigation

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The aim of this study was to expand the functions of traditional building envelope windows and improve its thermal performance, so a novel hybrid multi-layer CdTe based PV ventilated window system integrated with phase change material (abbreviated as CdTe-PCMVW) was proposed, constructed and experimentally investigated in this current work. Detailed fabrication process of the key component, the hybrid PV glass module integrated PCM (abbreviated as PCMG) was provided. Functions of electrical power generation, indoor passive space heating, heat preservation and ventilation cooling are integrated for this novel system, which can be realized by switching the operating modes. Different operating modes were established according to the ambient conditions and indoor thermal demands. Experiment platform was constructed and the PCMVW system was installed on it for experimental test. Two groups of continuous full-day experiments were conducted under the heating and non-heating season days. Main conclusions of the current study are: (1) Daily total electricity generation and average electrical efficiency were respectively 0.419 kWh, 0.423 kWh and 7.42 %, 7.40 % for the heating season days and 0.156 kWh, 0.159 kWh and 6.20 %, 6.33 % for the non-heating season days. (2) Utilization of PCM has realized thermal management of the PV glass, with the decrease and delay of peak temperature of PV glass. Thermal comfort rates (TCR) of the experimental room and reference room were respectively 25.51 %, 6.25 % and 37.45 %, 17.74 % for the two groups of experiment. (3) Effective lighting rates (ELR) of the novel system during the working time under the two groups of experiment were respectively 99.91 % and 98.52 %. The indoor daylighting performance of the PCMVW system was able to meet the demands of indoor daily work and life activities under the sunny days of both heating and non-heating season.

Keywords: solar energy; BIPV/T; ventilated window; phase change material; experimental test; performance analysis

#36: Treatment of water polluted by oil spill by ferromagnetic particles

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Water constitutes 71% of the Earth's surface, and up to 60% of the human body. The amount of water that humans consume, and need depends on the age, gender and the location. According to many studies, oil spills are considered to be one of the most common environmental disasters resulting in the destruction of ecosystems and significant losses for the economies of the countries that suffer from leaked oil, not only because of the price of the leaked oil but also because of the extinction of many marine organisms that live in these environments. The Kingdom of Saudi Arabia exports a huge amount of crude oil, varying between 6.935 and 7.737 million barrels per day, leading to a rise of oil pollution that may harm the vital marine environment. The current paper aims to examine the effects of micro and nano-ferromagnetic in the treatment of water polluted by oil spill. The method was based on mixing the oil with ferromagnetic particles and using the neodymium magnets to separate the particles from the oil. The experiment was repeated by changing the concentration of ferromagnetic particles that were able to purify water from oil at rates ranging from 154 for microparticles to 185 for nanoparticles. The properties of seawater treated with ferromagnetic particles were identified in both parts by measuring the acidity value and identifying the compounds present in the samples, followed by mechanical experimentation. Results showed that the efficacy of purifying seawater from oil leakage using ferromagnetic nanoparticles as well as the extent to which ferromagnetic materials can be separated from oil by examining the components of the water after purification. Also, this method is safe, highly efficient, and cheap for purifying sea water from oil pollution. In addition, the acidity of the water was not affected using ferromagnetic particles, as it ranged around 8.5 for all samples.

Keywords: oil spill; water treatment; ferromagnetic nano-particles; magnets; water acidity

#37: Navigating the energy transition: a review for investment decision-making in energy communities

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This paper focuses on the urgent need for energy transition to combat global environmental issues, with a particular focus on the energy inefficiency of European residential buildings. Residential households are responsible for a significant portion of final energy consumption in the EU, making investments in building innovation and energy transition for resident collectives crucial to reduce energy consumption and CO_2 emissions. Energy communities have the potential to drive energy transition at grassroot level by fostering a culture of energy efficiency and renewable energy use. However, research regarding people's decision-making in energy communities are not sufficient. Current research on energy communities is mostly focused on separate aspects, with the technical perspective overlooking social acceptance, and the social perspective lacking validation. There is a research gap in how to build a socio-technical model that can simulate decision-making in energy communities. This paper aims to address this gap by reviewing the characteristics of energy communities to identify barriers in energy transition and develop strategies to overcome them. Additionally, some modelling methods are explored to potentially simulate the residents' decision-making process in the energy community to better understand people's willingness to change their energy consumption behaviour. The paper highlights the importance of taking a holistic approach that considers both technical and social factors in achieving energy transition goals, emphasizing the need to establish a bridge between them. The proposed research is expected to provide valuable insights into the decision-making processes of energy communities and their role in achieving energy transition goals.

Keywords: energy transition; energy community; socio-technical system; investment decision

#38: ‘Patriotic Seed’ economic growth in generating electricity from a database of bacteria collected from wastewater factories in the Kingdom of Saudi Arabia

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Energy recovery and electricity generation from abattoir waste play an important role in combating the energy crisis and developing a new source of energy by using wastewater as well as minimizing water pollution. This paper explores the potential of using microorganisms found in wastewater produced by petrochemical factories in Saudi Arabia to generate electrical energy. By analysing the physical and chemical characteristics of the bacteria, the study aims to identify the best type of bacteria that can contribute to the production of electricity, which can be a valuable source of energy in a country with limited renewable groundwater and low recharge rates. The significance of this research lies in reducing environmental pollution, utilizing wastewater as a source of energy, and disposing of wastewater in an inexpensive and environmentally friendly manner. Additionally, the study investigated the use of waste from abattoirs as a source of energy, which could combat the energy crisis and environmental pollution problems. The research concludes that waste-to-wealth technology, if appropriately explored, is a viable solution to energy crises in Saudi Arabia, as it provides a way to convert waste into a valuable source of energy and reduce the country's reliance on fossil fuels. The results of this research could potentially lead to new ways of utilizing wastewater and reducing environmental pollution while providing a sustainable source of energy.

Keywords: abattoir waste; energy recovery; wastewater treatment; microorganisms

#39: Design analysis of closed hydronic loop system for PV cooling in the hot and arid region

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Photovoltaic (PV) cooling systems have the potential to generate both electricity and thermal energy from solar radiation. However, the performance of PV panels can be limited by high operating temperatures, leading to reduced power output and decreased efficiency. In this regard, using closed-loop cooling system have been proposed to improve the performance of PV systems. The system consisted of a PV collector mounted on a heat sink or connected with closed loop channels, which were cooled by water. The system also included a thermal heat storage tank, which stored the thermal energy generated by the system and was used for the circulation of the working fluid or for later use. This study aimed to analyse the design of the hydronic loop system, including the heat transfer fluid and tubing as well as evaluate the system by investigating the effects of different parameters on its design and performance. The study proposed to analyse various parameters that affected the design and performance of the PV cooling system, such as the cooling fluid, flow rate, cover type and some other factors. The effects of these parameters were evaluated using 3D CFD simulation to determine the optimal design and operation of the system. The results of this study will provide insights into the design and performance of PV cooling systems and the optimal selection of parameters to improve their efficiency. The proposed PV cooling system offered a sustainable and cost-effective solution to improve the performance of PV modules, particularly in hot and dry climate regions. The results of this research have important implications for the development of sustainable energy technologies and efficient energy production.

Keywords: solar energy; photovoltaic PV; radiative cooling; dual mode; cooling power

#40: Experimental and numerical analysis of concentrating parabolic trough collectors integrated with semiconductor thermoelectric generators

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Solar thermal utilization plays an indispensable role in the solar energy field and in realizing the goal of carbon neutrality. Concentrating solar thermal system is the main means to obtain high-level thermal energy. As a typical representative, the parabolic trough collector (PTC) is widely used in different areas, such as concentrating solar power (CSP) and solar-powered seawater desalination. Currently, the operating temperature of the PTC system is as high as 400~550°C. However, due to the special concentrating structure of the PTC system, there is obvious irradiance inhomogeneity in the circumferential direction of the parabolic trough receiver (PTR). In a previous study, a phenomenon of the negative thermal-flux region (NTR) in the PTR, incurred by inhomogeneous high temperature and solar concentration distribution around the PTR, was demonstrated. The existence of the NTR caused a large amount of hidden heat loss and decreased solar-thermal conversion efficiency. In this study, a novel system integrating PTC with semiconductor thermoelectric generators was proposed. On the one hand, the use of semiconductor thermoelectric generators can effectively block the external radiant heat loss in the NTR of the PTR and thus improve the efficiency of the PTC system. On the other hand, semiconductor thermoelectric generators can also cooperatively utilize the radiated heat and recover the electricity to improve further the thermal energy utilization efficiency of the PTC system. A testing platform in Hong Kong Polytechnic University and a numerical model were established to demonstrate that the proposed method can greatly improve the solar-thermal efficiency of the PTC and achieve high-efficiency step utilization of thermal energy from both experimental and numerical views. The experimental and simulation results showed that the radiant heat loss of the novel PTC system could be effectively reduced by 18%, the generation efficiency of the semiconductor thermoelectric generators exceeded 5.0%, and the comprehensive thermal efficiency could be improved by over 10%, which was one of the best-reported results.

Keywords: parabolic trough collector; concentrating solar power; thermoelectric generator; heat loss; thermal efficiency

#41: Comparison of the behaviour of rock wool and EPS in hot climate conditions in Greece, in search of the optimal technique for the energy upgrade of existing buildings

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There are far more buildings that were built from 1950 to 1980 than there are to be built in the next 50 years. Buildings without thermal insulation are a big energy blow to existing cities, much more so in European ones. There are many cases where energy upgrading works in buildings built before 1980 and the widespread use of thermal insulation materials are economically unprofitable or not allowed by the current urban planning regulations, forcing the owners to permanent energy waste. Furthermore, the need for cooling tends to exceed the need for heating in importance and difficulty due to global warming. It is important to combine the selection of the appropriate material with the corresponding technical application. To confirm and search for the behaviour of the most suitable material for hot climates, a detailed measurement of the temperature variation was made in two experimental cubes made of different materials, rockwool and EPS. The recording was made in the city of Athens where the indoor temperature and the ambient temperature were recorded from sunrise to sunset on a particularly hot summer day and with a southeast orientation. The conclusions of the recording highlight the positive and negative characteristics of the above materials from their use in a warm climate like that of Greece.

Keywords: blown-in insulation; retrofit; rockwool; EPS; sustainability; warm climate

#42: Influence of EGR and injection timing on combustion and emissions of a diethyl ether-diesel blend fuelled compression ignition engine

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As vehicle emission regulations have become stricter, improving engine performance using suitable alternative fuel has become important to reduce engine-out emissions and dependency on fossil fuel. The present research work emphasizes the utilization of diethyl ether for the partial replacement of diesel. Diethyl ether (DEE) has evolved as a potential alternative fuel for partial diesel replacement in compression ignition (CI) engines. DEE has favourable properties for application in diesel engines, such as higher cetane number (>125), moderate energy density, higher O_2 content in its structure, lower auto-ignition temperature, prolonged flammability, and improved miscibility with diesel. The present study investigates a light-duty diesel engine under conventional diesel combustion mode at a constant engine speed of 2200 rpm for various engine loads. Two different blends of diesel-DEE (20 and 40% DEE in the diesel, v/v) were tested and compared with baseline diesel. Different operating parameters such as exhaust gas recirculation (EGR) and the start of injection (SoI) were swept to find their influence on the engine performance and emission for diesel-DEE blends. An open ECU was installed for developing fuel injection maps. Main injection timings varied from 6 to 14ºbTDC at a constant FIP of 1200 bar, whereas the EGR rate varied to 15 and 30% at various engine loads. Overall, this study showed that engine combustion and emissions can be improved by selecting a suitable combination of fuel injection timing and EGR with the partial replacement of conventional diesel.

Keywords: diethyl ether; alternative fuel; compression-ignition engine; injection timing; sustainability

#43: Concept of net-zero-ready residential buildings in hot-humid region: lessons learned from the Arabian Gulf vernacular architecture

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This paper investigates the technical and economic viability of the Net-Zero-Ready House in the eastern Arabian Gulf peninsula considering the local vernacular architecture and passive cooling techniques, regional hot and humid climate conditions, and architectural context. The Net-Zero-Ready stage is when it's reasonable to start installing the solar panels, and usually, the building consumes around 50% less than the regional EUI. This study can help enhance our residential building energy consumption by producing a new housing trend that consumes low energy and emits less carbon footprint. Even though the Gulf residential buildings' electricity consumption is almost double that of their international counterparts, most of the NZEH in hot-humid climates have reached the zero-energy stage through active and passive measures. Usually, after applying the passive measures, the building achieved a low energy consumption level at this stage, averaging 70 kWh/m2 /year for all investigated case studies. In this paper, by using energy simulation programs (IES), two main steps to reach the Net-Zero-Ready stage were performed in the base case: introducing passive cooling techniques and applying hot-humid climate energy-efficient measures. The result showed that by utilizing our ancestor way of building their home by applying passive cooling techniques, including natural ventilation strategies, through a wind catcher, wind scope and a courtyard, the total energy consumption could be reduced by around 11%. In fact, the lessons given by Arabian Gulf's traditional and vernacular architecture in the harsh condition of deserts' hot-arid-humid zones make us respect our ancestors' imagination and creativity. On the other hand, applying energy efficiency measures helped reduce energy consumption by 30%, which made the home perform at a low energy consumption level and reach the Net-Zero-Ready stage. The most effective measures were enhancing the envelope specification quality and increasing the HVAC efficiency with an energy reduction of 8% & 24% consecutively.

Keywords: Net-Zero-Energy; passive cooling techniques; vernacular architecture; low energy consumption

#44: Exploring vernacular courtyard strategies to improve thermal performance of modern housing in Dhaka

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The present Dhaka, a rapidly growing unban centre of Bangladesh, is experiencing a major shift in the last three decades, exhibiting a mixed and complex set of characteristics. This study aimed to investigate the thermal effect of the age-old courtyard strategy of Bengal architecture by integrating them with the modern housing. Through an extensive literature study, three vernacular case studies were selected to represent different building styles. Generic models for the modern housing styles were also generated for studies. The thermal performance of courtyard in the vernacular buildings was analysed followed by a comparative study between the modern conventional and courtyard buildings. Each study was comprehensively analysed to observe the efficiency of the courtyard throughout the year. The final outcomes of this research were based on experiments conducted through building performance simulations software (IES-VE). The investigation revealed that the courtyard helped the vernacular buildings to increase the thermal performance maximum up to 10%. The incorporation of the courtyard in the modern housing resulted in 3% lesser indoor temperature than the conventional houses. The analysis also reviewed that the courtyards support to provide additional solar radiation to increase the comfortable indoor temperature by 10.5% in the winter season.

Keywords: vernacular; courtyard; thermal comfort; energy efficiency

#45: Application of a biogas system for cost-effective municipal waste management in African cities: a case study in Nkolmbong, Yaounde, Cameroon

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In most African cities, as time goes on the population is increasing and a consequence the amount of waste generated increases. However, the available space to do a landfill is reducing with the scarcity of lands, and the waste are deposited everywhere leading to pollution and spread of diseases. In the Central Africa region including Cameroon about 80-90% of the population has limited access to modern forms of energy such as electricity and relies on traditional biomass for cooking and heating. There is an urgent need to investigate in waste management to produce clean energy that have very minimal or no impact on the environment and households. Field works in Nkolmbong showed that the area possesses only one big bin of 8 m3 for all the community and the waste generated are rarely collected due to bad access to the road. People have begun to create many wild dumps behind their houses or along the road to get rid of their waste, without taking into account the present environmental risk. Ten households have been chosen, sensitized on problems around waste management and the importance of source segregation to constitute a pilot test for the collection of their waste and then the anaerobic digestion of that waste. The analysis of the composition of the waste leaded toward 5 systems of anaerobic digestion of more frequent waste which were banana peels, plantain peels, cocoyam peels, potato peels and the mixture of all the 4 previous stated. All the waste passed through mechanical pre-treatment to facilitate the digestion. During the 30 days of incubation in psychrophilic condition, among the 5 systems, the system with the mixture presented a good result with a production of 0.5L of biogas in only 10 days of incubation, meanwhile inhibition occurred in the other systems mainly because of high accumulation in volatile fatty acid suggesting the need to multistage or increase the inoculum. Those results and the economical evaluation allowed us to see a good potential in doing anaerobic digestion of waste mixed. In fact, with an investment of 105,560 FCFA, one person can produce his own energy for cooking and avoid polluting the environment by creating wild dump or cutting down trees for firewood; for a sustainable development.

Keywords: organic fraction of solid waste; waste management system; clean energy; anaerobic digestion biogas

#46: Storytelling of the flat-panel ground heat exchanger: pros and cons of an intuitive shape

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In HVAC systems, the ground is considered to be a more profitable thermal source/sink to carry out heat exchange having a less fluctuating temperature through seasons than air. Water and groundwater would also be more interesting than ground, but because of the main intended uses, the authorisation for energy goals is often bounded in many regions and saved for human use. Thus, several technical solutions have been designed and made available to maximise performance and to minimise costs according to the boundary conditions. Given the very low thermal diffusivity of ground, the heat transfer enhancement is mainly linked to higher temperature differences (deep boreholes, vertical) and/or wider surfaces (shallow laying, horizontal). The last strategy makes the shaping design free (baskets, radiators, slinky coils, …), and among them, the intuitive idea for a flat surface supported the design of the so-called flat-panel ground heat exchanger, as patented by the University of Ferrara in 2012. The flat shape maximises the ground involved in heat transfer and minimises interference among piping, therefore optimising the ground as a thermal source/sink. Because of its shallow and horizontal placing into very narrow trenches, installation costs are minimised, and maintenance is easily implemented. However, as all that glitters is not gold, ten years of evolution, lab tests, trials in real cases, advances in coupling with phase change materials and with multi-source heat pumps for underground thermal energy storage are shared here to highlight pros and cons of an intuitive technology toward novel functionalities.

Keywords: ground heat exchangers; flat-panel; storytelling of advances; pros and cons

#47: Machine learning applications in data centre cooling performance optimisation and forecasting: a review

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The demand for data centres (DCs) is surging due to the explosive growth of cloud services and social media. In 2022, DCs accounted for 1% of global electricity consumption, while in the United Kingdom, this figure further increased to 2.5%. Even though the IT system attributes primarily (around 56%) to a DC's total power consumption, depending on different cooling techniques (air, liquid, and free cooling), the cooling system alone can make up to 30% to 40% of the energy demand. As a subset of free cooling, dew-point evaporative cooling (DPC) can achieve a Coefficient of Performance (COP) of up to 52.5, compared to the COP of 2 to 3 of most wildly applied traditional mechanical vapour compression cooling. Therefore, applying DPC to DC can achieve significate energy saving and carbon reduction. To meet the cooling demand of DCs without sacrificing thermal safety, preliminary modelling is required during the designing stage. While due to the dynamics natural of DCs cooling system, it often results in inadequate optimisation and inaccurate forecasting of cooling performance which require hand-tuning for specific devices. In this case, machine learning (ML) techniques fundamentally outperform conventional modelling as it only learns and derives from the massive data collected from the desired system. Combining ML techniques with DCs cooling can achieve energy saving for up to 26.6%, 15%, and 72% of air, liquid and dew-point cooling respectively under diverse climate conditions, which makes integrating ML into DPC a promising research area. This review paper focuses on the development of ML techniques in DCs control strategy optimisation and long-term performance forecasting from 2000 to 2022. Existing literature is categorized based on five elements, while five ML-based optimisation strategies and four forecasting methods are initially introduced, followed by three jointly optimizing approaches with IT system. Based on above analysis, existing research gaps in DC cooling optimisation and forecasting are identified, and associated recommendations are offered from the standpoint of the authors. The findings of this review can act as a steppingstone for scholars, researchers, and policy makers in related fields, thereby contributing to the advancement of the SET agenda.

Keywords: data centre cooling; machine learning; control optimisation; performance forecasting; energy saving

#48: Rapid evaluation of a building's thermal performance using infrared thermography and artificial neural network

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Domestic energy consumption forms a significant share of the UK's overall energy usage. Space and water heating are responsible for most of the household energy consumption and any price hike, such as the current energy price situation, would seriously affect many households living in poorly insulated buildings. Improving insulation by deep retrofitting existing buildings is a good solution for reducing the domestic heating energy demands for those households. However, the level of insulation is a key issue, as retrofitting with excess insulation will incur higher cost and results in longer payback periods, especially in moderate climatic countries such as the UK. Therefore, it is necessary to estimate the thermal performance of existing building stock at the planning stages of retrofitting. Such evaluation of thermal performance requires prolonged monitoring of buildings using sensors installed within the buildings. Building on previous research by the authors (Al-Habaibeh, Sen, and Chilton 2021) of using infrared images and artificial neural network (ANN) for rapid evaluation and prediction of a building's thermal performance, this paper presents a case study of evaluating energy consumption of a three-bedroom flat using temperature and humidity sensors for two months during winter and the energy meter readings for monthly energy usage. The results prove that the use of infrared technology and ANN can provide rapid evaluation of building insulation and energy performance.

Keywords: infrared thermography; artificial neural network; insulation; energy consumption; retrofitting; buildings

#49: An investigation into the challenges, benefits, and drivers for integrating renewable energy technologies into Nigerian electricity grid

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Electricity is central to making life easier and more comfortable for humans and is even more so in its role in driving sustainable development in most countries. Global demand for electricity has been on the rise and is predicted to grow at an accelerated rate in the future with most countries seeking to meet this demand. In Nigeria, electricity demand currently outweighs supply with the national grid infrastructure failing to transmit enough electricity to meet the demand of over 200 million Nigerians. At present, 85 million Nigerians do not have access to electricity. With a per capita electricity consumption of 151 kWh, Nigeria is the most energy access deficit country in the world. Currently, the installed grid-based electricity generation capacity in Nigeria is estimated to be 13,435 MW and relies mainly on fossil fuel and hydropower plants. To address the supply gap challenges, Nigeria is seeking to integrate renewable energy sources into the country's national grid. The country aims to encourage transition towards renewables, reduce dependence on conventional energy resources and diversify the country's energy mix. However, the integration of renewable energy sources into the national grid has been met with setbacks and proceeds at a slow pace. This paper presents a holistic review of electrification in Nigeria with a focus on the challenges, drivers, and benefits of integrating distributed renewable energy sources into the Nigerian national grid. The paper analyses the current electricity situation in Nigeria and proposes recommendations with the view to encourage energy diversification, sustainability, renewable energy technological growth and energy policy advancement. The paper concludes that Nigeria's evenly distributed renewable energy resources serve as huge potential to bridge the electricity supply gap. Suggesting that adopting innovative power generation technologies that increases the transmission capacity of the country's national grid with no visible changes to existing grid infrastructure would be beneficial in increasing electricity access and reduce energy waste. Furthermore, power generation technologies such as smart grid systems, dynamic line rating, high temperature low sag conductors (HTLS), flexible alternating current systems (FACTS) could increase the penetration of renewable energy sources into Nigeria's energy mix.

Keywords: Nigeria; energy; grid; renewables; sustainability; net zero

#50: Air conditioning improvement in a residence and a bakery workplace using the oven released heat

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In the industrial field of bread production, the bakery's oven releases high heat to the surrounding environment. On the one hand, this heat is harmful to the personnel workplace, requiring continuous evacuation of the excess heat toward the enclosure outside. On the other hand, heat recovery presents a free energy source for the air conditioning of a neighbouring residence. The system contributes to the rationalization of energy consumption and the improvement of thermal comfort in the workplace. The recovered heat can be used directly for heating during the winter. Also, it can be used for cooling during the summer via an absorption refrigeration machine. The collection of released heat from the bakery during the winter period was investigated. The hot air evacuation canals and an air-air heat exchanger were integrated, and the numerical simulation performed using ANSYS code. The results showed a significant improvement in thermal comfort in the residence and the workplace. The temperature of 22°C was reached at 1.7m in the concerned areas using slightly forced air convection.

Keywords: bakery; oven; heat recovery; air conditioning

#51: Electricity distribution networks for multi-technology residential communities: a sufficiency assessment

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Climate change is becoming an increasing concern all around the world. The fossil-based sources of electricity generation are one of the primary factors of climate change. In many countries, the transition to low-carbon technology has already begun toward achieving zero-carbon targets. Electric vehicles (EVs) and heat pumps (HPs) are promising technologies to help tackle the source of carbon emissions. However, the uncontrolled application of these technologies could potentially result in unintended outcomes and damage the distribution networks. This research paper examines the hourly based electrical demand in a residential community using advanced multistage stochastic modelling methods. Moreover, this study investigates the sufficiency of the existing distribution networks in the UK for full EV and HP adaptations. The study also discusses the requirements for future grid systems to provide uninterrupted and safe electricity to end users.

Keywords: electric vehicle; vehicle-to-grid; renewable energy source; heat pump; energy storage

#52: Modelling analysis of a novel thermochemical energy storage reactor coupled with a finned microchannel tube heat exchanger for water heating

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Thermochemical Energy Storage (TCES) offers higher energy storage density compared to other energy storage technologies. It is a promising solution for addressing the mismatch between solar heat production and heating demands, contributing to decarbonization in buildings. Salt hydrate-based open TCES systems have garnered considerable attention due to their advantages in terms of high volumetric energy storage density. However, existing research on open TCES systems has primarily focused on air-based TCES systems (TCES-only), which are incompatible with the existing heating systems in buildings and require extensive pipeline modifications. Additionally, TCES-only systems lack a straightforward method to control the system supply temperature, leading to potential overheating issues. To address these challenges, a novel TCES system coupled with an air-to-water finned microchannel tube heat exchanger and an air-to-air heat recovery unit (TCES-FHEX-HRU system) is proposed in this study. A COMSOL model is developed to evaluate the discharging performance of the TCES-FHEX-HRU system. Results suggest that with the incorporation of fins and the HRU unit, the TCES-FHEX-HRU system achieves an outlet water temperature and overall thermal efficiency of 32.70°C and 94.07%, respectively, which are higher than those of the TCES system with a finless bare microchannel tube heat exchanger unit (TCES-HEX) by 4.57 ℃ and 82.87 percentage points. For a given depth of packed vermiculite-CaCl2, increasing the FHEX height could result in an enhancement of the water supply temperature and overall thermal efficiency of the TCES-FHEX-HRU system. However, as the FHEX height increases, the incremental improvements in the outlet water temperature and overall thermal efficiency diminish. When the FHEX height is increased from 0.05m to 0.06 m, the outlet water temperature and overall thermal efficiency of the system increase by only 0.1 °C and 0.33%, respectively

Keywords: thermochemical energy storage; finned microchannel tube heat exchanger; heat recovery; COMSOL

#53: A novel modelling approach for performance analysis of a concentrated radiative cooling system using the compound parabolic concentrator

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Radiative sky cooling (RC), a passive cooling strategy, can emit the waste heat from the earth into outer space to cool itself or practical objects. Despite it has great potential for energy saving and environmental protection, the low energy density of RC technology and its dependence on atmospheric conditions have limited its practical application. To enhance the cooling capacity of the RC system, concentrated RC systems have been developed. In this study, a compound parabolic concentrator (CPC) is put forward as the concentrator for the concentrated RC system, and a modelling approach to investigate its cooling performance is developed. Previous outdoor experiments have demonstrated the CPC can block a portion of daylight and undesirable external radiation, while effectively concentrating the thermal radiation emitted by the emitter, thereby enhancing the RC performance. Building upon these findings, the amount of light emitted from the RC emitter reaching different annular intervals is simulated using the optical software Photopia. The equivalent sky emissivity can be calculated by the simulated light ratio, and the net cooling power of various models is further deduced. Through the investigation of relevant parameters in the mathematical model, the key factors influencing the cooling power of the RC systems are analysed and determined, providing further evidence of the cooling advantages offered by the CPC-RC system.

Keywords: concentrated radiative cooling system; equivalent sky emissivity; net cooling power; Photopia

#54: Simulation of thermal performance of horizontal slinky-loop ground source heat exchangers

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The thermal performance of a horizontal slinky ground heat exchanger has been investigated using a validated transient 3D model for different trench separations, initial soil temperature profiles and soil properties. The effect of trench separation on the thermal interference was analysed for a range of centre-to-centre distances between parallel trenches from 1.5m to 11m. The initial soil temperature was found to have a significant effect on the predicted thermal performance. The predicted heat extraction using a varying and more realistic initial soil temperature for a heating season would decrease with the increasing depth of installation whereas using a uniform initial temperature would lead to increasing heat extraction with installation depth. It has also been found that soil with a high thermal conductivity would exacerbate the thermal interference between trenches with a small separation as a results of heat depletion in the ground.

Keywords: ground source heat pump horizontal; slinky-loop heat exchanger; thermal interference; trench separation

#55: A novel PCM cooling system for building applications

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In Malaysia, addressing heat stress-related issues and providing sustainable long-term affordable energy is crucial. Malaysia has great potential for solar energy as it is located near the equator, with the estimated potential for solar generation reaching up to 6500 MW. To utilize abundant solar energy resources and to alleviate living issues in Malaysia, a novel solar PV power cooling system has been proposed. The system combined a radiant cooling ceiling with a PV-driven vapour-compression system and stores phase change material (PCM) in a water tank. The experimental setup consisted of mini-DC refrigeration, a water tank containing PCM material, a circulation pump connected to the chiller unit, and a second pump connected to the radiant ceiling. The system effectively cooled the PCM water tank, supplying cold water to the radiant ceiling. This significant temperature difference highlighted the potential for energy savings in relation to the ambient temperature. The field measurements were conducted in Malaysia and the findings carry significant implications for the citizens of Malaysia as it could allow for the investigation of the cooling performance of this system in a tropical climate setting, where the need for cooling is particularly acute.

Keywords: Malaysia; phase change materials; PV-vapour compressor system; radiant cooling; thermal energy storage

#56: Performance of CO_2 air-to-water heat pumps for small domestic buildings in the UK

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The current study presents the performance analysis of a domestic high-temperature CO2 air-to-water heat pump (AWHP) coupled with a thermal energy storage system for a 2-bedroom house in the UK. TRNSYS simulation model incorporating the heat pump with the house and storage tank was developed to investigate their interactions. Data collected from experiments carried out on a commercially available 4.5 kW transcritical CO2 AWHP was used to build the heat pump model. Single storage tank of varying capacity under the same operating conditions were implemented on the model to assess their impact on the performance of the heat pump. Simulation results indicated that a tank size of 300 L was the most suitable one for a 2-bedroom house in the UK with heat load of around 7797 kWh. Environmental effect and cost analysis were undertaken by calculating the carbon emissions and annual fuel expenses for both the heat pump and natural gas boiler, simulated under the same working boundaries. While the utilisation of heat pump showed a reduction of CO2 emission by 44% compared to gas boiler, and the operating cost at present tariffs was higher for heat pumps by 38%.

Keywords: CO_2 air-to-water heat pump; CO_2 emission; domestic hot water; hot water storage tank; space heating

#57: Design, production and thermodynamic analysis of solar energy supported, nanofluid integrated thermoelectric vaccine cabinet

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Thermoelectric coolers (TECs) are becoming the focus of attention for researchers on a global scale due to their various advantages such as quiet and vibration-free operation and the absence of moving parts, as well as being energy efficient and compact. They are frequently preferred especially for portable cooler applications. This study was about the design, fabrication, and thermodynamic analysis of a solar-assisted nanofluid integrated thermoelectric vaccine cabinet. The aim was to investigate the effects of using nanofluids as refrigerants in portable thermoelectric vaccine cabinet applications on basic performance parameters. For this purpose, a cooling cabinet with an internal volume of 40L was planned, designed and manufactured. Then, the Peltier assembly, with a water-cooled block integrated on its hot surface, was placed from the back of the cooling cabinet, and a water-to-air heat exchanger used to transfer the heat taken from the hot surface of the Peltier to the environment with the help of the refrigerant. Al_2O_3-Water, TiO_2-Water and SiO_2-Water were used as refrigerants in the system. PV panels were placed on the upper surface of the cooling cabinet in order to benefit from solar energy. In order to store the electrical power obtained from the PV panel, a battery was located at the bottom of the cabinet. Cooled cabin temperatures was observed with experimental studies, and the results compared with the situation where no nanofluid was used as the reference situation.

Keywords: thermoelectric cooling; nanofluids; cooling of vaccines; electrical efficiency

#58: Design, production, and performance analysis of a pyramid-type solar desalination system; an experimental study

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With the rapid increase in the world population and the rapid decrease in clean water resources, access to clean water is rapidly progressing to become a worldwide problem. Moreover, global warming, especially caused by fossil fuel-based energy production, triggers the rapid depletion of water resources. In addition to being a basic nutrient, water is a basic need in almost every sector. The increase in the rate of industrialization and population density also stand out as important factors in the rapid depletion of clean water resources. According to international research, by 2030, almost half of the world's population will have problems in accessing clean water. For this reason, obtaining clean water, especially by using renewable energy sources, is of global importance. In this context, solar desalination systems come to the fore. Solar-assisted desalination systems attract attention as an environmentally friendly technology as well as being economical and sustainable. Especially in rural areas where access to traditional energy sources such as electricity grids, batteries or fossil fuel energy sources is limited, solar-assisted desalination systems can meet the average freshwater requirement of a family. Although solar-assisted desalination systems are economically feasible, the water production cost is around 0.03 $/L and still needs improvement compared to large-scale production systems. For this reason, even minor improvements in the efficiency of these systems are important. In this study, the design, production, and performance analysis of a pyramid-type solar desalination system were made. With the tests performed at different radiation values, the daily production amounts of the produced system were observed.

Keywords: solar desalination; solar still; water productivity; fresh water

#59: Wells for NetZero

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With the growing energy demand and increasing efforts for transitioning towards a carbon-neutral society, the world is switching to cleaner energy generation and storage concepts, such as geothermal energy (GE), underground hydrogen storage (UHS), and carbon capture and storage (CCS). Well construction can amount to roughly 50% or more of the total capital expenditure for the three concepts. As such, one way to make GE, UHS, and CCS more commercially viable would be to drive the well construction cost down while ensuring the adopted well designs provide desired longevity and benefit. Millions of underperforming oil and gas wells are at the cusp of being abandoned. Abandoning these wells incurs a sunk cost; as such, utilizing these wells after assessment for GE, UGS, and CCS could be a game-changer as it would drive the capital expenditure down exponentially compared to standalone projects. Here we discuss the locked-in potential of re-purposing these wells, highlighting the valuable insight into economics built upon the recent studies and pilot projects. For the US, re-purposing underperforming wells instead of abandoning them shows routing approximately 350 billion USD toward CCS, UHS, or GE projects. Furthermore, our hypothetical scenario of utilizing the existing, proven reserves of the 42 countries using re-purposed wells showcases a cost reduction of approximately 2500 billion USD for carbon capture from 2021-50. Similarly, utilizing re-purposed wells in these proven reserves for storing a working volume of 252 billion tonnes of hydrogen showed roughly 104,000 billion USD in savings.

Keywords: wells; NetZero; geothermal; carbon capture and storage; underground hydrogen storage; clean and sustainable energy

#60: The net zero energy building with carbon credits for sustainable future: a case study in Chandigarh

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The increasing population and elevated energy consumption has resulted in climatic change and the concept of zero-energy building developed to overcome this problem is gaining popularity towards an eco-sustainable future. The main objective of the present study was to analyse and overview the configuration technology, analytical parameters and feasibility of net zero energy building. The present paper deals with energy retrofitting to improve energy efficiency and recycling of solid waste to achieve decarbonization targets and improve building resilience, all of which will contribute to a positive and sustainable zero-waste future. The study highlights the adept schemes for successful co-composting of food, fruit and green waste, with a mechanism to mitigate carbon leakage in developing countries. The present study deals with implementing the green building concept to improve energy efficiency through the adaptation and integration of technologies to achieve decarbonisation targets to limit the global temperature rise to 1.5ºC to avoid catastrophic impacts of climate.

Keywords: net zero energy building; green building; energy efficiency; climatic change; carbon credits

#61: Highly oriented thermally conductive stearic acid/expanded graphite-graphene films phase change material for efficient photothermal energy storage

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Phase change materials (PCMs) have emerged as a promising solution for photothermal energy storage due to their high energy density. However, the low thermal conductivity of PCMs leads to delayed heat storage from the photothermal conversion surface, resulting in substantial heat loss, while the low thermal conductivity also limits the rate of heat extraction. In addition, the risk of PCM leakage poses a significant challenge to the long-term reliability of these systems. To address these issues, we proposed a new approach that utilizes PCM (stearic acid) encapsulated by expanded graphite alternatively stacked with graphene films and assembled into a laminar composite structure under pressure induction. The encapsulation of stearic acid by expanded graphite serves to mitigate the risk of leakage, while the highly thermally conductive graphene films substantially enhance the oriented heat conduction of the phase change material. The resulting PCM exhibited high stability and excellent oriented thermal conductivity. In addition, we designed a photothermal storage experiment and developed a numerical model to explore the impact of the improved phase change material properties on the performance of the all-weather photothermal storage system and the rate of heat energy release. The results indicated that the use of the prepared PCM can rapidly store heat from the photothermal conversion surface, reduce the heat loss from the photothermal conversion surface, and improve the photothermal storage efficiency, while the high thermal conductivity can significantly increase the speed of heat release. Overall, this study provided a promising approach to solve the problem of leakage and low thermal conductivity of PCM, contributing to the development of photothermal energy storage systems.

Keywords: stearic acid; expanded graphite; graphene film; oriented thermal conduction; photothermal energy storage

#62: Experimental research on the operation modes for a water source heat pump system to expand heating operation range

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Recently, since water heat energy was included in renewable energy in Korea, interest in water source heat pumps for space cooling and heating has increased. Since the temperature of the water is lower than the ambient temperature in summer and higher in winter, a water source heat pump has an advantage in COP over an air source system. However, when the water temperature drops in winter, the operation of a water source heat pump becomes limited due to the risk of freezing in heat exchangers. In this study, we analysed the heating operation characteristics according to the change in the temperature of the water and proposed operation modes to overcome the drawbacks in heating operation. A test loop of 20 kWth was constructed. Operation modes for utilizing low-temperature water sources, reverse cycle operation, heat storage tank-associated operation, and heat source compensation operation were derived. Test results and operation characteristics analysis for reverse cycle operation and heat source compensation operation are presented. These results tested in the laboratory can be used to design the optimal operation modes for water source heat pumps when applied to actual buildings in the future.

Keywords: water source; heat pump; heating

#63: Sustainable cooling solutions for rural communities: solar PV-driven DC vapour compression with PCM storage

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This paper presents a solar photovoltaic (PV)-driven DC vapour compression system with low-cost phase change material (PCM) storage for cooling, with the aim of providing an affordable and sustainable cooling solution for low-income B40 community areas in Malaysia. The system is operated by using the PV panel to power the compressor during the day, providing cooling to the space, and storing the excess electricity in the form of cooling energy for later use. The key performance index of the system was evaluated in three modes of operation: grid, off-grid, and hybrid mode, for a 1.5 hp system. The results showed that the off-grid mode had the highest energy-saving performance. The system's performance was also found to be consistent across the different days of testing indicating its reliability in providing cooling even in areas with inconsistent electricity supply. Furthermore, the low-cost PCM storage unit contributed to reducing the system's overall cost, making it more affordable for low-income communities. The system's potential for use in stop centres located in low-income areas was significant as it could provide much-needed cooling to individuals during the day and serve as a source of coolth at night. In conclusion, the solar PV-driven DC vapour compression system with low-cost PCM storage offers an affordable and sustainable cooling solution for low-income community areas. The results of this study could provide valuable insights for the design and implementation of similar systems in other low-income communities, contributing to the sustainable development of such areas.

Keywords: PV cooling; PCM storage; off-grid

#64: Technology originally developed for Formula 1 now used to increase efficiency on construction sites

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PUNCH Power 200 was designed as a power-assist hybrid system for dynamically operated generators. Developed to seamlessly connect to any power grid, PUNCH Power 200 is able to rapidly inject and absorb electrical power to maintain a stable grid frequency and voltage while simultaneously reducing the required generator size, hence realising significant fuel and emissions savings. PUNCH Flybrid's flywheel technology was originally developed as a kinetic energy recovery system for Formula 1. The aim here was to recover energy that would normally be wasted by the vehicle's braking system and deploy it to achieve similar vehicle performance with a smaller and more efficient internal combustion engine. The same principle is applied with PUNCH Power 200 when coupled to a generator powering construction equipment. In the case of tower cranes, the required generator size is typically double that of the mains connection. By storing energy in the flywheel during periods of lower power demand and deploying this energy during periods of peak power, the generator can be 'rightsized' for the average load. The downsized power unit has lower friction and operates at a higher base load and therefore at greater efficiency: typically, the generator rating can be reduced by 50% or more, with similar reductions in fuel consumption and carbon dioxide (CO_2). This submission describes the major components used in the creation of the PUNCH Power 200 unit and the key technology features that make it such an effective hybridisation option for the construction industry. Chief amongst these is the flywheel module itself; constructed from materials and techniques widely adopted in the automotive industry, it is efficient to produce, ultra-reliable and also gives the flywheel a low embedded CO_2 figure allowing even greater CO_2 savings. Coupling this to an advanced control system results in a highly modular unit capable of operating in conjunction with a variety of power systems, while extensive use of telematics and data analytics ensure savings are maximised and accurately quantified.

Keywords: construction; plant; generator; decarbonisation; fuel reduction

#65: Implementation of demand side response in supermarkets: a feasibility study

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Demand Side Response (DSR) is one of the key strategies adopted by the National Grid ESO in order to decarbonise the power system in the UK. Flexibility in both supply and demand sides will be paramount to achieve the net zero goal for buildings by 2050. The aim of DSR is to stabilise load by modifying demand rather than increasing power generation, thereby reducing CO_2 emissions. There are various programs available to consumers to participate in the DSR market and in recent years flexible asset size has been reduced from 10MW to 1MW in order to encourage wider participation. Commercial buildings consume almost 40% of the world's primary energy with consumption in the form of lighting, heating, cooling and ventilation etc. Supermarkets are commercial buildings which have a sizeable thermostatic load in the form of power demand by the refrigeration systems which account for around 50% of the total power consumption in addition to all the other building loads. Some UK supermarkets are participants of DSR market by using onsite generators, lighting and HVAC system. So far, DSR implementation using refrigeration systems has not been reported beyond the laboratory. Supermarkets are unable to shift demand by switching off refrigeration systems without affecting the temperature and quality of products displayed in cabinets. To add to the challenge of maintaining product quality, the compressors of refrigeration systems draw a significant amount of current during start-up which affects the supply voltage and reduces system efficiency. This paper will present current developments in DSR and challenges and opportunities for its application in supermarkets.

Keywords: demand side response; commercial refrigeration systems; supermarket; demand side flexibility

#66: Economic viability of integrating heat pumps with thermochemical heat storage for residential space heating in the UK

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Nowadays, the thermal energy systems which assist in dealing with the mismatch between the renewable electricity production and the peak demand hours are of particular interest. Using thermal storage technologies to provide heat during the peak demand hours, alleviating the need for electricity usage, is also becoming attractive for customers and utilities. Due to its high energy storage density and long-term storage capability, thermochemical heat storage (THS) compromises the opportunity of reducing space heating costs of buildings. Although, there are extensive ongoing studies on THS systems for building applications, economic feasibility of this technology is rarely investigated in the literature. In order to fill this gap, economic viability of integrating a THS unit with an existing heat pump (HP) system for space heating was investigated in this study. With this purpose, initially, the heating load of a living room of a hypothetical building under UK climate conditions was simulated by employing Design Builder software. Later, sizing of THS unit was completed by considering the obtained energy storage density in a previous experimental work. In the study, vermiculite-calcium chloride (V-$CaCl_2$) was selected as the THS material due to its proven performance data available in the literature. Accordingly, annual energy and cost savings potential of an integrated THS-HP system compared to stand-alone use of a HP or gas boiler system was analysed. Based on the obtained results, economic feasibility of THS-HP system was evaluated by using net present value (NPV) and payback period method. Potential strategies and approaches for improving economic viability of THS-HP systems are also discussed.

Keywords: thermochemical heat storage; economic feasibility analysis; design-builder simulation; heat pump; heat storage density

#67: Graph neural network-based spatio-temporal methodology for hydraulic modelling of district cooling systems

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Hydraulic modelling plays a crucial role in effective management of district cooling systems, enabling fault detection and diagnosis and pump speed control to achieve energy savings. The development of traditional detailed physical hydraulic models is time-consuming and labour intensive, and the models developed need to be calibrated several times during the operational stage. Data-driven modelling has made significant strides in capturing temporal relationships using advanced machine learning algorithms. However, existing data-driven modelling methods often make simplistic assumptions about water distribution and generally overlook structural relationships, such as the topology of cooling water pipes and pumps. To address this issue, this study presents a novel spatio-temporal data-driven methodology for representing district cooling systems as graphs and modelling the hydraulic system. A case study of a district cooling system based on real cooling load simulation was carried out to evaluate the efficacy of the proposed methodology. Graph neural network-based models consisting of a graph layer and a recurrent layer were developed to capture the structural and temporal relationships separately. The graph layer utilized graph convolutional network (GCN) and graph attention network (GAT) to learn the structural relationships from the input graphs. The recurrent layer utilized Long Short-Term Memory (LSTM) to learn the temporal relationships from massive historical operational data. The developed models generated better prediction performance than conventional deep learning models. This methodology provided a new approach for analysing hydraulic systems that could facilitate effective management of district cooling systems. By incorporating both the structural and temporal relationships in the data-driven modelling process, the methodology offered a more comprehensive understanding of the hydraulic system and could provide valuable insights for optimizing the system's energy efficiency and fault detection. It has the potential to be widely applied in the field of district cooling systems and other related hydraulic systems.

Keywords: hydraulic model; graph; district cooling system; spatio-temporal modelling

#68: Rotary desiccant wheel systems: a review

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Rotary desiccant wheel systems work according to the principle of dehumidification. These systems use salt such as silica gel for dehumidifying the process air. Desiccant cooling is adopted as an alternative option against traditional cooling systems owing to its outstanding advantages. Regeneration is of vital importance in the overall performance assessment of rotary desiccant wheel systems. In terms of regeneration technique, these systems can be split into two types which are natural and electrical regeneration. Natural regeneration systems usually have solar air collectors. On the other hand, electrical regeneration systems use typical fossil fuel-powered heaters. There are many design-oriented factors that affect the performance of rotary desiccant wheel systems. At the same time, operating conditions have a notable influence on system performance. This article aims to provide information about recent studies on rotary desiccant wheel systems, and cost-effective and eco-friendly strategies to enhance system performance characteristics. COP, cost, payback period, dehumidification effectiveness, and moisture reduction rates are taken into consideration in the comparative performance assessment analyses.

Keywords: rotary desiccant wheel; dehumidification; dehumidifiers

#69: Thermal insulation performance assessment of UK dwellings through co-heating test methodology: a critical review

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Several studies show that the designed performance value of buildings may differ from the actual energy performance value. A large part of this performance criterion is due to the thermal resistance of the elements in the building envelope. The most commonly used method for calculating the thermal performance of a real building is the co-heating test. Co-heating is an experimental method used to determine the heat loss coefficient (HLC) of an 'as-built' building. This result emerges by determining and plotting the daily heat input against the indoor and outdoor temperature difference of the building. Also, it is a quasi-steady state method that can be calculated correctly for the whole dwelling HLC. This article covers the evaluation of the thermal insulation performance of residential buildings in the UK by using the co-heating test method. The aim of this study was to describe improvements in U-values of building envelopes at pre- and post-retrofit cases in the UK dwellings. The assessments were done over a wide range of building types with different structural and constructional features.

Keywords: co-heating test; energy performance; envelope performance; performance gap; heat loss

#70: A model for energy assessment of opaque adaptive façades with variable thermal resistance

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Climate adaptive building shells could make a significant contribution towards reducing the energy consumption of buildings and their environmental impacts. There is extensive research on glazed adaptive façades mainly due to available technology of glass materials. Technological development of opaque adaptive façades has been focused on variable thermal resistance envelopes, and simulation of this type of façades is a challenging task that has not been fully studied. The aim of this study was to configure and validate a simplified office model that can be used for simulating an adaptive façade with variable thermal resistance via adaptive insulation thickness in its opaque portion. Software-to-software model comparison based on the results of an EnergyPlus BesTest 900 validated model was used. Cooling and heating annual energy demand (kWh), peak cooling and heating (kW) and maximum, minimum, and average annual hourly zone temperature variables were compared for both the adaptive and non-adaptive validated model. An adaptive EnergyPlus model based on the BesTest 900 model that used the EnergyPlus SurfaceControl:MovableInsulation class list was successfully validated, and could be used for studying office buildings with a variable thermal resistance adaptive façade wall configuration, equivalent to a heavyweight mass wall construction with an external insulation finishing system (EIFS). A software framework was also presented, where the simulation of the Adaptive model was coded in EnergyPlus and executed by a Python program that communicated with EnergyPlus via an EnergyPlus API that was available for calling EnergyPlus as a function from Python. To illustrate the usage of the model, the results of four different case examples of optimal insulation thickness for total energy demand (annual heating + annual cooling) minimization are presented. The four cases were: balanced insulation of the adaptive model, and repeating them every day of the 365 days of the simulation period; unbalanced insulation where each wall repeated the same insulation adopted every day; optimal balanced insulation thickness that could change every day (adapt) during a 365 days simulation period for minimizing total energy demand; and same as previous case but with electrochromic glazing added on both windows of the adaptive model.

Keywords: adaptive opaque façade; building performance simulation; Climate Adaptive Building Shell (CABS); EnergyPlus model validation; Nearly Zero Energy Building (nZEB); variable thermal resistance

#71: How can green renovation solve the problem of energy poverty in South Korea?

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There exists a paradoxical spatial inequality wherein vulnerable households living in inadequate housing conditions are more severely affected by the climate crisis despite their relatively low energy use and impact on the environment. To mitigate this inequality and improve the energy efficiency of low-income households, it is necessary to address both non-monetary support methods, such as energy vouchers, and physical inefficiencies in household energy through housing improvement projects and heating system upgrades. Thus, the purpose of this study was to propose policy improvements that facilitate GHG reduction in the building sector through efficient energy use while ensuring the full quality of life for households living in energy poverty via support for green renovation. The study employed various research methods, including a comprehensive literature review analysing the current state of buildings occupied by households living in energy poverty, their energy usage, and current government support policies in South Korea. Additionally, we conducted interviews with 16 experts to collect data on the challenges and improvement measures of the energy poverty policy. We also conducted in-depth interviews with approximately 25 residents living in vulnerable villages where the government conducted renovation projects, and public rental housing where the government carried out renovation projects with a green focus. Finally, we conducted a survey of 1,000 citizens based on their income levels to determine the current status of their homes, energy usage, and intentions for green renovation projects. The findings of this study indicated the need for a specific green renovation policy for households living in energy poverty, including energy-related requirements to be added to the minimum housing standard. Additionally, we suggest that detailed guidelines for green renovation-related matters be provided for renovation projects in vulnerable villages. Furthermore, securing multiple funding sources for green renovation projects for households living in energy poverty is essential. In conclusion, this study provided valuable insights into how policy improvements can address energy poverty and reduce GHG emissions in the building sector. By improving energy efficiency through efficient energy use in residential buildings, it is possible to prevent future conflicts related to rising energy costs due to global paradigm changes.

Keywords: energy poverty; fuel poverty; green renovation; retrofit; household energy

#72: Field trial and numerical study of a wind tower and run-around heat exchanger

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This study proposes the integration of a run around heat exchanger within a passive ventilation wind tower to provide heating, cooling, and thermal energy recovery on a seasonal basis. A field trial of the system was conducted at a test site in Sheffield, UK, with the results recorded through experimental testing used to validate a numerical model. The numerical model was developed through the commercial computational fluid dynamics program ANSYS and was used to investigate the performance of the proposed system under a range of boundary conditions. The minimum volumetric flow rate through the wind tower was 0.09 m3/s at an inlet velocity of 1m/s for a heat exchanger model featuring three rows of pipes. Fresh air temperature was increased by 4.14°C and reduced by 4.36°C when the temperature difference between the fresh air and water flowing through the heat exchanger was 27°C. The difference in water temperature between the inlet and outlet of the heat exchanger was 6.15°C for both heating and cooling simulations at the same temperature difference, equivalent to 7.92 kW of thermal energy recovery.

Keywords: passive ventilation; heat recovery; seasonal thermal energy storage; computational fluid dynamics

#73: Rural energy accessibility profiling to enable effective energy decarbonisation research

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Accessing energy is a key challenge for rural dwellers. The forms of energy available to rural energy users is much more varied than the traditional electricity and grid gas, for example oil, LPG gas, coal and wood. This splintering of the forms of energy used creates inefficiencies and therefore increases cost, resulting in high rates of domestic fuel poverty, and health and safety implications from greater exposure and risk from more toxic and greater polluting fuels. This rural situation varies from urban energy systems where typically only gas and electricity from the grid are used in relatively high, safe and clean energy-efficient devices and buildings. With the broader societal goal to decarbonise the energy we consume in all walks and aspects of life, understanding on a local level the current conditions, the archetypes of typical rural energy users compared to urban energy users, are key to best develop decarbonised energy systems in these places. This work begins to develop archetypes of the rural energy user, informed by surveys carried out of rural residents and broader collating of figures. It is fundamental to do this as rural dwellings are much more varied in age, quality, technology, and climate compared to urban dwellings which increases the difficulty of developing an archetypal representative rural dwelling. Developing archetypal dwellings is important in developing a base common model of a dwelling to enable more effective research in rural energy decarbonisation with technologies and measures such as hydrogen, heat pumps and insulation, particularly with rural off-grid homes, which can be difficult to characterise and develop effective research or policy.

Keywords: rural; energy; decarbonisation; issues; hydrogen; heat pump; off grid; low carbon; fossil fuel; buildings; domestic; agriculture

#74: A BIM-based framework to assess embodied carbon of a structural model

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Understanding the integration of BIM as an enabling factor in embodied carbon (EC) analysis is becoming vital as the global climate crisis accelerates. In this paper, we present a BIM-based framework and a prototype tool to quantify the EC of a building, enabling informed design decisions early in a project's development. A comprehensive review of existing literature on EC assessment techniques was conducted to identify current gaps. Based on this review and the background theory, we proposed a conceptual framework for EC assessment within a BIM environment. A prototype tool was developed to implement and assess the proposed framework. The tool takes BIM data and a carbon factor repository to calculate the EC of each element in the model, which can then be visualised using a dynamic colour coded system, highlighting the most efficient and onerous elements by category. Moreover, the tool rates the overall design based on several existing EC rating schemes to support the decision-making process.

Keywords: embodied carbon; building information modelling; sustainable design

#75: Forecasting PV generation for a community energy scheme

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In 2021, the domestic sector accounted for 38% of UK electricity demand at 109 TWh, exhibiting a larger percentage share of electricity demand than the industrial sector. With the push towards net-zero goals, grid stress is only going to be exacerbated by the electrification of heat and EVs. Community energy schemes aim to directly address growing concerns surrounding peak grid demand stress by maximising the usage of on-site micro-generation and simultaneously decarbonising the community. In the case of utilising community PV alongside energy storage technologies, understanding site-specific future PV generation is a key challenge in implementing an energy management strategy. This work outlines a linear regression model that relates the measured on-site global solar irradiance and community PV array generation. The model is used to generate a 3-day PV generation forecast using forecast solar irradiance data via a weather API whilst using observational data to continually retrain the model to improve specificity and accuracy. This data will then be used to optimise a community energy management system in determining the available on-site generation and how this interacts with community electricity demand loads, storage and grid imports/exports. The model has demonstrated an average forecasting accuracy of approximately 80%, thus providing an effective forecast tool for on-site PV generation. Over time, the linear regression fit has changed by over 20% when compared with the initial training set fit, demonstrating a clear improvement in model performance over a 5-month period. This flexibility is an important characteristic in making the model specific to the community site and resilient to change. Further work will involve improving forecast resolution and implementing this as part of a wider community energy management system.

Keywords: community energy system; energy storage; PV self-consumption; demand; forecast

#76: Literature review: CO_2 transformation with calcium looping

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As one of the most effective methods of mitigating greenhouse gas (GHG) emissions, carbon capture, usage, and storage (CCUS) has gained widespread attention as a carbon-negative technology. Despite the barriers facing CCUS, such as inefficient transportation of stored carbon and the high energy demands of applying carbon, it represents significant potential, particularly in the field of chemical engineering. Considerable efforts have been directed towards calcium looping, a technology that utilizes the redox reaction between CaO and $CaCO_3$ to absorb and re-emit CO_2. Calcium looping offers an ideal solution for bridging waste CO_2 emissions from industries such as cement and steel manufacturing and chemical product manufacturing, such as methane and methanol. However, the current challenge lies in the high energy consumption required when converting collected CO_2 to chemical products, as high temperatures are needed. To address this issue and reduce energy usage, a high-temperature CO_2 storage method could offer benefits not only to the required equipment but also to costs. This could be achieved by capturing both CO_2 and heat during the decomposition of $CaCO_3$ in the reduction reaction of calcium looping. This paper reviews and discusses the possibilities and insights of applying high-temperature CO_2 from calcium looping, and it is believed that this approach could significantly reduce manufacturing costs, making it a promising energy storage technology.

Keywords: carbon capture; calcium looping; carbon transformation

#77: An energy storage optimization system for residential solar installations in unstable electric grid conditions: a Nigerian case study

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Nigeria's electric grid is characterized by frequent power outages, poor phase sequencing, and significant voltage variations among phases, creating substantial challenges for the country's energy infrastructure. Solar energy has emerged as the most popular renewable energy source in Nigeria, primarily due to the country's abundant solar resources. However, solar energy's intermittency necessitates implementing energy storage solutions to maintain a reliable power supply. In Nigeria, the electric grid does not support on-grid systems that enable solar energy to be fed back into the grid, primarily due to the grid's inherent instability. Consequently, the grid can only be a backup for charging storage batteries in residential solar installations. This study presents an innovative energy storage optimization system, designed to leverage the random availability of grid power to minimize the size of batteries required for home solar systems. Batteries are the most expensive component of residential solar installations, and minimizing their size without compromising system performance is crucial for cost reduction and improved affordability. The proposed system aimed to maximize the use of grid power for battery charging, considering the unpredictable nature of power outages, while avoiding the oversizing of the energy storage optimization system. This paper will provide an in-depth analysis on the challenges posed by Nigeria's unstable electric grid and the need for energy storage solutions to support solar energy systems. The paper will elaborate on the reasons behind the lack of on-grid systems and discuss the importance of developing innovative approaches to adapt to the existing grid infrastructure in Nigeria. Furthermore, details of the proposed energy storage optimization system will be presented, including its design and development considerations, and its potential benefits in enhancing the affordability and efficiency of residential solar installations. Finally, the study will also explore the applicability of the proposed storage optimization system in other regions facing similar grid instability issues and discuss on the broader implications of the findings for the global renewable energy landscape.

Keywords: power outage; solar energy; storage systems; optimization; efficiency; affordability

#78: Mathematical methods for pipeline monitoring: review and applications

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This study reviews the mathematical methods used in pipeline monitoring and their practical applications. A comprehensive literature review was conducted to identify the models used for pipeline monitoring and their strengths and limitations. The review revealed that mathematical models are widely used for monitoring, and that they can effectively detect and locate pipeline defects. The study also highlighted the practical applications of mathematical models in pipeline monitoring, including leak detection, corrosion monitoring, and pipeline integrity assessment. The findings suggest that mathematical models are a valuable tool for pipeline monitoring, and they can improve the safety and reliability of pipeline systems. However, the study also identified several gaps in the existing literature, including the need for more research on the integration of different mathematical models for pipeline monitoring and the development of real-time monitoring systems. These gaps provide opportunities for future research to advance the field of pipeline monitoring and improve the effectiveness of mathematical models in detecting and preventing pipeline failures. Overall, this study provided a comprehensive overview of mathematical methods for pipeline monitoring and their practical applications, highlighting the importance of continued research in this field.

Keywords: pipeline; failure; modelling; energy

#79: Numerical analysis of crack propagation in API X52 pipeline steel under internal pressure caused by sour gas

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Defects in hydrocarbon transmission pipelines are common in the form of scratches, dents, and cracks on the inner wall surfaces. In this paper, the propagation of a 2mm long crack present in API X-52 pipeline steel in contact with sour gas (containing H_2S) was investigated. Fluid-Structure Interactions (FSI) play an important role in generating hydrogen which in turn diffuses into crystallographic traps such as dislocations, vacancy clusters, micro-cracks, and similar defects. ANSYS ® finite element in combination with finite volume methods were used to study this FSI problem. The crack of 2mm length was assumed to be present on the internal surface of the steel pipe wall. The crack growth was triggered by hydrogen pressure emanating from hydrogen built-up on the vicinity of the crack tip and was studied while maintaining a constant internal pressure of 5.34 x 104 Pa caused by fluid flow. The length of the crack was increased to 4.83mm when crack tip blunting, due to material plastic deformation, took place. The first mode of stress intensity factor played an important role in its propagation. The allowable operating pressure for the sour gas was 12.7 bar.

Keywords: hydrogen embrittlement; oil and gas; FEA

#80: CO_2 capture and biomass production from an industrial scale lime kiln flue gas using microalgae

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Microalgae presents a promising feedstock due to high solar energy efficiencies, large lipid fractions, and utilization of various waste streams including industrial flue gas. This study evaluated the feasibility of microalgae cultivation using lime kiln flue gas at an industrial scale. The lime industry is one of the most carbon intensive sectors in South Africa. Fuel combustion efficiency and/or change of fuel can help reduce the carbon emissions but are not significant enough for the lime industry; therefore, end of pipe techniques should be employed if lime kilns are to achieve carbon neutrality. This study will therefore provide an option for the lime industry to reduce CO_2 emissions whilst producing biomass without compromising the availability of arable land. This study will address four main gaps in literature. First, microalgae cultivation using lime kiln flue gas has not been studied before, therefore this study will close that gap. Second, there is inadequate information on microalgae species interplay with other species in an open reactor hence this study will explore integration of more than one microalgal species in the system to create diverse microalgae communities that are resilient and decrease its vulnerability to external environment. Third, native microalgae species on outdoor cultivation systems have not been studied extensively therefore this study will use native microalgae species sampled from freshwater bodies around the kiln. Lastly, the study will also exploit the potentially favourable environmental conditions for microalgae cultivation (abundant sunlight, warm temperatures) in South African Northern Cape region.
Successful microalgae cultivation is dependent on selection of the suitable photobioreactors and microalgae species. Thus, photobioreactors selection and design in this study considered important factors for optimum microalgae cultivation, surface to volume ratio, mixing effectiveness, degree of shear stress on the microalgae culture among others. On the other hand, it was envisaged that biomass productivity is enhanced by using native microalgae species because they are already acclimatised to the lime kiln exhaust gases. Therefore, microalgae used for this study was sampled from water bodies around the lime plant.

Keywords: carbon dioxide; microalgae; photobioreactors; biomass; flue gas; lime kiln

#81: Lignin-phytic acid nano-particle synthesis and their potential application as flame-retardant additives

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The usage of biobased polymers has grown dramatically over the past ten years, but their high flammability restricts their use in applications where fire resistance is a priority. Numerous scientific investigations have demonstrated the feasibility of developing polymers from renewable resources as potential substitutes for polymers derived from fossil fuels. To improve the fire behaviour of polymer materials, the incorporation of bio-based additives and fillers, which include modified or unmodified polysaccharides, such as starch, chitosan proteins, and phenolic biomass have been explored. Because of its availability and capacity to create char, lignin is one of the phenolic biomasses that has received the most attention for its potential to lessen the flammability of polymers. The biomolecules from the wood sector and other renewable sources are the raw materials that appear to be suitable for sustainable development of biodegradable flame retardants. These include cellulose, vanillin, lignosulfonate, starch, and lignin, all of which have excellent potential as flame retardants. At the same time, nanotechnologies have made it possible to improve the fire-retardancy of polymers. Very little research has linked bio and nanotechnologies to the development of flame retardants. This method has been shown to be useful with phosphorylated cellulose nanocrystals. Since lignin nanoparticles (LNPs) are simple to functionalize, lignin may be a suitable material in this approach. However, lignin nanoparticles have never been applied extensively to polymers as flame retardants. Synthesis of LNPs functionalized with phytic acid is the main objective of this paper.

Keywords: lignin nano-particle; flame-retardant; functionalization; biobased polymers; green additives

#82: Comprehensive evaluation on CPV/T-daylighting of a window with solar louvers

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This work presents a solar-concentrating photovoltaic-thermal (CPV-T) module for building louvers which was designed to provide electricity and heat for buildings by capturing solar radiation in vertical building spaces. The solar louver was a concentrating blade combined with a PV-T module. It enabled incident sunlight to converge into a solar cell, thus obtaining electricity. The heat generated in the solar cell was taken away and collected by thermal fluid, thus overcoming the deficiency of integrated photovoltaic when extra cooling that exists in traditional building is demanded in summer. The solar louver was designed to work under the solar incident angle of 0-90°, and its high-efficiency photovoltaic-thermal working range was 20°-70°. Optical simulations were conducted to illustrate the characteristics of the solar louver. Remarkably, the maximum geometrical concentration ratio was 2.96 at the incident angle of 20°. Over a wide range of incident angles between 12.5° and 52.5°, the geometric concentration ratio maintained was above 2. A window was made by utilizing the solar louvers and then the comprehensive evaluation on CPV/T-daylighting performance was tested and evaluated. The results illustrated that its overall efficiency could reach above 55% for nearly 5 hours without tracking during the all-day experiment. It could significantly reduce the heat load of a room, and still provide a good daylighting condition in the morning and afternoon.

Keywords: CPV/T-daylighting; solar louver; geometrical concentration ratio; lighting; regulation; solar energy

#83: Feasibility study of machine learning in solar energy storage systems optimisation

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Currently, the use of renewable energy sources such as solar and wind power has been growing rapidly to meet the growing global demand for clean and sustainable power generation. However, the intermittence and volatility of renewable energy sources pose challenges to the operation and stability of energy systems. Furthermore, efficient storage of surplus energy during peak generation periods and release of surplus energy during peak demand periods are crucial to ensure a stable and reliable energy supply. Traditional renewable energy system forecasting and optimization methods have limitations in dealing with the inherent complexity and uncertainty in the process of renewable energy generation and utilization. Machine learning techniques offer the potential to address these challenges by enabling accurate predictive models and optimization strategies based on patterns and trends identified from large volumes of historical data. The application of machine learning to solar and renewable energy system optimization aims to enhance power generation, increase grid stability, and facilitate seamless integration with conventional power sources. In this study, recent relevant research utilizing learning-based methods in the field of renewable energy problems is reviewed, with a special focus on deep learning and machine learning algorithms. A feasibility study was conducted focusing on evaluating the effectiveness of applied machine learning techniques in addressing challenges related to solar and renewable energy system optimization and energy storage. The results of this study suggest that hybrid learning techniques that combine machine learning and deep learning with other optimization methods hold promise to further enhance the construction and optimization of these techniques. It is suggested that utilizing blended learning techniques in future energy production problem solving can take advantage of multiple approaches, contributing to more accurate predictions and more efficient energy utilization.

Keywords: energy storage; grid connection; smart control; artificial intelligence; deep learning

#84: Sustainability through innovative materials and government intervention in residential housing

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The World Health organisation (WHO) stated that one of the biggest threats to global health is that of climate change (WHO, 2022). Climate change is defined as shifts to the weather and temperature patterns which may occur naturally but more often than not, it occurs due to human activity through the use of fossil fuels which creates CO_2 emissions (UN, 2022). Alarmingly, the built environment produces approximately one third of all global emissions and therefore is a huge contributor to climate change (IEA, 2019). With such an alarming statistic, the built environment should be looking at how buildings can be greener and subsequently, more sustainable. The UK government is determined to meet a net zero emissions target by 2050, which was set out in the Planning for the future consultation which set out a plan of goals that would need to be met in order to achieve this (Climate Change Committee, 2021). One way of working towards this target is by making houses more sustainable. When considering the reduction of emissions and striving for more sustainable housing, it is important to breakdown specific elements that form the building both externally and internally. Looking at innovative and sustainable ways that houses can work towards net zero is paramount: the assessment of heating systems, insulation, the way the property is built and other factors are all assessed and considered. The author highlights some key innovative materials and systems that are being trialled or are available but not currently being used.

Keywords: sustainability; innovation; net zero; government intervention; housing

#86: Enhancing energy efficiency in hospital buildings: a comprehensive diagnosis strategy for chiller plant fault detection

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Due to the lack of process and easy-to-learn system-level diagnosis methods for a chiller plant. The authors of this article presented an energy-saving diagnosis strategy for chiller plants to detect faults early and achieve sustainable built environments. This strategy analyses common weaknesses in building chilled water systems from maintenance, design, and operation perspectives. It comprises four steps: macroscopic energy efficiency index judgment, system troubleshooting, design diagnosis, and operation diagnosis. The authors applied the strategy to a typical hospital building in a hot and cold region of China. They found that partial-load conditions were a significant problem, reducing cooling efficiency and excess cooling in unoccupied rooms. The overall yearly energy efficiency (COP_plant) was 3.27, and the useless energy consumption caused by this operation in 2021 is as high as 510327 kWh. A specific solution was proposed, including replacing the check valve, cleaning the condenser, and avoiding multiple water pumps with a small number of hosts. The authors also recommended developing a frequency conversion control strategy for the water pump under partial load and creating a chiller opening strategy at different load intervals of the building.

Keywords: energy-saving; fault detection; chiller plant; sustainability; building efficiency

#87: Fouling resistance improvement with a new superhydrophobic electrospun PVDF membrane for seawater desalination

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With excellent water repellence, superhydrophobic membranes are good candidates for membrane distillation (MD). In this study, a new superhydrophobic electrospun poly (vinylidene difluoride) (PVDF) membrane was prepared and applied to the MD type desalination. The casting solution compositions were optimized to produce a rough surface with porous microspheres. The membranes exhibited an acceptable permeability with a contact angle of 152.4°, which was ideal for MD desalination application. After desalinating real seawater for 120 hours, the proposed membrane displayed more stable permeate flux than the conventional PVDF membrane. The desalinated water with the newly developed membrane had a lower conductivity owing to the fouling resistance of the membrane caused by the air gap formed between the feed solution and the membrane. The developed membrane provided a possible strategy for improving the long-term efficiency of MD-type seawater desalination.

Keywords: direct contact membrane distillation; pollution control; superhydrophobic; electrospinning

#88: Development of wake model and yaw control simulation models validated by experiments for optimized wind power generation

Hongxing YANG*, Ruiyang HE – Keynote Presentation

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Wind power generation is the most rapidly developing renewable energy application nowadays in the world. However, wake effects, exposing downstream wind turbines (WTs) within a wind farm characterized by lower power and higher turbulence, would undermine the merits of high capacity and cost-effectiveness, posing significant challenges to their efficient and economic operation. Yaw control is one of the most widely adopted and effective active wake control methods. This study proposed a multi-objective yaw-based coordinated control strategy for wind turbines in wind farms to integrate the power enhancement and fatigue effects caused by yaw control, which in turn can increase the total power output of wind turbines. A three-dimensional elliptical Gaussian (3DEG) wake model and a yaw wake model with wake deflection caused by yawed rotors was proposed, which was validated by experiments (field tests and wind tunnel experiments). The proposed models adopted anisotropic wake expansion rates in the horizontal and vertical direction instead of uniform ones. A method that can accurately predict the fatigue loads and power output of WTs under yaw misalignments with little computational cost was developed, i.e., the multi-objective yaw-based coordinated control strategy was proposed for the wake effects alleviation and maximization of the farm-level wind power generation, which is expected to lay the foundation for efficient use of wind energy.

Keywords: wind power; wind farm; wake model; yaw control; fatigue effects

#89: Thermal energy storage system integration in solar process heat applications for reliability improvement

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The implementation of solar thermal technologies for process heat applications through thermal energy storage system is very important for improvement of system reliability. Design and development of solar energy systems with thermal energy storage for various residential, industrial and agricultural process heat applications have carried in this article. The process heat applications considered in this study include desalination for potable water production and residential wastewater treatment, ceramic industrial process heat and jiggery production. Solar integrated combined organic ranking cycle and multi-stage desalination with packed bed thermal energy storage is proposed for thermo-economic-environmental analysis in residential sector. The designed system has produced power and potable water of 118.51 kWe and 74.03 kg/day without energy storage. The energetic and exergetic efficiency of the storage adopted combined system was found as 79.38% and 34.82%, nearly 23.91% and 6.96% higher than without an energy storage system. The adoption of energy storage increased power output to 222.3 kWe, and potable water production to 202.51 kg/day, which is nearly 1.5 and 2.73 times more than the conventional system. Furthermore, the energy storage has drastically reduced the payback period from 4.61 years to 2.31 years at the cost of power, and potable water is Rs.6.54/kWe and Rs.4/litre. Thermo-economic-environmental analyses were performed for solar-aided ceramic tile dryer with packed bed thermal energy storage under Indian climatic conditions. The ceramic industry's solar aided cogeneration plant consists of a gas turbine power cycle coupled with ground and wall tile manufacturing units and a thermal energy storage system. The solar field concentrates the solar radiation on the designed phase change molten salt receiver. The thermal energy from the molten salt receiver has effectively transferred to the molten salt heat exchanger. In this work, 59.5% LiCl-49.5% KCl eutectic molten salt has been used as a heat transfer fluid due to inherent properties among that boiling point (1400°C) and melting temperature (354°C) is a crucial one. The atmospheric air is compressed to high pressure and temperature in a compressor, and it reaches the turbine through a molten salt-air heat exchanger.

Keywords: solar process heat applications; thermal energy storage; water desalination; ceramic industry; thermo-economic-enviro analysis

#90: Microplastics and nanoplastics pollution: challenges and the way forward

Ashok PANDEY – Keynote Presentation

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Many countries around the world are suffering with the ubiquitous influence of plastics. From polar regions to deep oceans, aquatic ecosystems and terrestrial areas, plastic proliferation is everywhere. It remains in the environment for a very long time and their surfaces become weathered resulting in numerous micro- and nanosized plastics. Due to their small size, these microplastics and nanoplastics have the potential to be ingested by the biota, thus entering into food webs and causing adverse biological effects. In addition, they can travel globally and have the potential to accumulate and interact with toxic pollutants existing in the environment. The pollution and health hazards caused by microplastics (MPs) and nanoplastics (NPs) in the environment (freshwater, marine water and terrestrial ecosystems) have become serious concerns globally. Microplastics have been detected around the globe and have had a serious impact on biota and humans. In order to understand the possible risks, provide recommendations for future studies and to develop technologies to eliminate the micro/nanoplastics, it is important to understand their sources, distribution and occurrence, interactions with other contaminants, interactions with biota and their sampling and detection methods. The term ‘microplastic’ was introduced in 2000 and while initial studies focused on marine sources, the focus during 2010-2015 shifted to the estimation of MPs in freshwater and soil, impacts on environment, adsorption of co-pollutants, bioplastics as potential alternate, whilst during 2015-2020, the focus shifted to the estimation of MPs from air, snow, ecotoxicity, impacts on health, fate and migration, policy development. The current trend is on atmospheric transport and impacts on air, micro-nano-plastics (MNPs), economy and feasible solutions. This lecture will discuss the recent advancements and research in the field of micro-/nano-sized plastics and future research perspectives to tackle the plastic pollution.

Keywords: microplastics; nanoplastics; environmental pollution; health hazards; policy

#91: Daylight performance of vertical green wall on building in a hot arid region

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Natural lighting plays a crucial role in reducing energy consumption and enhancing occupants' comfort in built environments. However, using glazed facades and shading systems to control daylight intensity often results in increased reliance on artificial lighting, leading to higher energy consumption. In this context, vertical greening systems (VGS) have emerged as a potential solution to manage the amount of sunlight entering building interiors while maintaining occupants' visual connection with the outdoor environment. The current research highlights the potential of vertical greening systems as a sustainable strategy for enhancing daylighting performance and energy efficiency in buildings. By reducing the intensity of sunlight penetrating glazed facades, VGS offer a viable solution to mitigate visual discomfort and optimize energy consumption. The findings contribute to the growing body of knowledge on passive technologies for building facades, emphasizing the importance of building energy efficiency in addressing global climate change challenges. For this research, a green wall model was constructed to investigate the effectiveness of its shading effect in reducing overexposed glare in a passive daylighting study environment. The study was conducted in a student housing unit located on a university campus in Irbid, Jordan. It involved the application of simulations and field experiments.

Keywords: vertical greening systems; green wall; shading effect; daylight; DesignBuilder; field experiment

#92: Approaching industrialization of housing construction in Jordan

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The current paper focuses on the production line process in the buildings industry, particularly in residential buildings in Jordan. It aims to address whether there is a buildings industry in Jordan and identify the gaps and challenges faced by this industry. The research methodology involves comparing the international construction methods used in buildings industrial with the approaches employed by housing companies in Jordan. The researchers conducted a survey of 20 randomly selected housing companies in Jordan to gather data. The findings of the paper suggest that there are initial signs of buildings industrial in Jordan. However, the situation remains unclear due to several challenges. The most significant challenges identified in the study are the availability of ready-made materials, establishing long-term collaboration between project participants, and incorporating technical construction components. Furthermore, the strategies adopted by housing companies in Jordan are still ambiguous and require further development. Overall, the paper sheds light on the current state of the buildings industry in Jordan, highlighting both the progress made and the challenges that need to be addressed. It provides valuable insights for researchers, policymakers, and industry professionals interested in understanding and improving the buildings industrial sector in Jordan.

Keywords: buildings industrial; construction; housing industrialization

#93: Splitting the exergy destruction into avoidable and unavoidable parts for integrated biomethane liquefaction process and liquid air energy storage system

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In terms of bioenergy alternatives, biomethane (BM) is extremely competitive and has the potential to reduce the world's reliance on fossil fuels. Liquefied biomethane (LBM) is the form of BM that is most appropriate for both storage and transport to remote parts of the planet. It is, however, an expensive and energy-intensive process since the compressors used in the BM liquefaction process (like natural gas) consume a lot of electricity. Aside from that, unlike conventional natural gas, biomethane is generated at atmospheric pressure, hence liquefaction consumes more energy because the pressure at which BM is produced is significantly lower than the equivalent critical pressure. As a result, a cost-effective and energy-efficient system has been proposed that combines a biomethane liquefaction process and a liquid air energy storage (LAES) system discharging end. The thermal exergy of a compressed mixed refrigerant (MR), on the other hand, enhances the expansion stage of liquid air, giving it an additional advantage. In this study, the effects of novel integration of LBM and LAES were computed on the basis of conventional and advanced exergy analysis. Conventional exergy analysis determines that compressors and heat exchangers are the primary sources of irreversibility, contributing 16.5% and 39.6% respectively. Due to integration of two energy systems, results revealed that the exergy efficiency of the process increased to 53%, in comparison with conventional SMR process having exergy efficiency of 35.5%. Advanced exergy analysis showed that 50% of the overall destruction of exergy in the modified process could be avoided. Compressors and turbines had the most potential for improvement and could avoid 54% and 94% of exergy destruction respectively. However, cryogenic heat exchangers and coolers had the highest percentage of unavoidable exergy destruction, 62% and 83% respectively.

Keywords: liquid biogas; integrated energy systems; liquid air energy system; advanced exergy analysis; improvement potential

#95: Molecule dynamic simulation on the effect of lubricant on R32 during condensation

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Ozone layer depletion and greenhouse effect are two major global environmental issues, and R32 is an alternative refrigerant currently widely used in developing countries. The compressor of the refrigeration system requires a lubricant to cool it down and reduce the energy consumption of the system. However, lubricant is inevitably carried away and participates in the flow and heat transfer of other components of the system. The physical properties of refrigerant-lubricant mixture in the condenser are different from pure refrigerant, and the lubricant has an impact on the condensation process. It has been confirmed by macroscopic experiments that lubricating oil can improve the flow performance of the heat transfer surface and also has an adverse effect on the condensation heat transfer capacity of the refrigerant. To investigate the influence of lubricating oil molecules on refrigerant condensation process, the authors studied the effect of adding different mass fractions (0 wt%, 4.58 wt%, 8.77 wt%, 12.61 wt%) of lubricating oil PEC4 molecules to the condensation process of refrigerant R32 from a microscopic point of view using molecular dynamics simulation. The results showed that the addition of lubricating oil could inhibit the condensation process of refrigerant, and the inhibitory ability became more obvious with the increase of its mass fraction. In addition, all lubricating oil molecules were adsorbed on the copper plate to form an oil film, thereby increasing the heat transfer resistance at the fluid-solid interface. When the mass fraction of lubricating oil was 0 wt%, 4.58 wt%, 8.77 wt%, 12.61 wt%, the time required for the temperature of the fluid area to drop to the condensation temperature was 100ps, 152ps, 205ps and 220ps, respectively.

Keywords: lubricating oil; R32; molecular dynamics; condensation; mass fraction

#96: A comparison of photovoltaic sun-tracking methods

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Solar energy is one of the most sustainable sources of energy that many countries are investing in. Photovoltaic technologies are becoming increasingly popular due to their renewable energy perspective and low environmental impact. However, the efficiency of commercial fixed photovoltaic panels is under 27% as a reduced amount of solar radiation can be captured during the day. Solar tracking systems are gaining ground as they propose to optimize the angle of incidence of the sun's rays on photovoltaic panels to address the low efficiency issue of fixed PV panels. This study compares the different methods of solar tracking systems with single-axis movable PV panels to quantify the increase in energy production versus fixed PV panels. A simple sun tracking method based on the sun-path diagram is compared with more advanced approaches using the incident angle of the sun ray, measured by a sun position sensor. The electric output power produced by the photovoltaic system is also used to track the sun's position with a high degree of accuracy. Additionally, other hybrid strategies combining different sun tracking algorithms are proposed to improve the low PV efficiency during cloudy days. The performance of the solar tracking system is evaluated by measuring the power output of the PV panels in both static and dynamic positions. A test bench of several single-axis movable PV panels is used to compare the performance of the different sun trackers simultaneously, under the same weather conditions. Key parameters such as solar radiation, sun position in the sky and generated output voltage and current are considered to evaluate the effectiveness of the various sun tracking methods. The experimental results demonstrate significant benefits of sun tracking control strategies by improving the efficiency of PV panel systems up to 16%.

Keywords: photovoltaic technology; sun tracking system; sun sensor; single-axis movable PV panel

#97: Study on the effect of intercellular gaps on the thermal profile of solar PV systems

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Solar photovoltaics (PV) are a leading means of renewable power generation. One of the biggest challenges that PV systems face is the increase in cell temperature in the real field which leads to a reduction in its efficiency and lifespan. To propose a viable cooling method, it is imperative to study the thermal behaviour of PV systems using CFD modelling. Most researchers have modelled a PV module as a single or multi-layered cuboidal body, ignoring its internal geometrical complexities. This study, however, developed a novel geometric model of a PV module that assumed PV cells as different individual domains with encapsulant-filled intercellular gaps and investigated its effect in the obtained temperature profile vis-à-vis the conventional geometrical model. Conjugate heat transfer analysis was performed using CFD under a variety of irradiation and wind conditions. K-ω SST and S2S were used as turbulence and radiation models, respectively. The results revealed that the novel model consistently predicted higher cell temperature than the conventional model. For a PV module of 90% packing density, the maximum difference was as high as 4°C or 7.7% at a wind speed of 1.5m/s, and 3.1°C or 6.9% at a wind speed of 2.7m/s. A greater difference of 7.7% was obtained in the prediction of the temperature of hotter cells compared to only 3.5% in the case of colder cells. This proved that the encapsulant-filled poorly conducting intercellular gaps had a considerable effect on the temperature profile of a PV system and hence, should be incorporated in the geometry for a more accurate CFD analysis.

Keywords: solar PV; heat transfer; temperature; CFD analysis; packing density

#98: Exploring the relationship between investor profiles and sustainable investment drivers: a systematic review

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The purpose of this study is first, to systematically review articles on sustainable investments (SI); second, to identify and classify investors in SI; third, to map out linkages between investor classifications and drivers of SI; and fourth, to provide future research directions in the underlying domain. For this investigation, the PRISMA methodology was used to choose 81 publications that were published between 2014 and 2022 from the Web of Science database. These articles were then analysed using VOSviewer software. A thematic analysis was conducted to assess the state of research in the field of sustainable investments (SI). Furthermore, the authors conducted a mapping exercise to determine the linkages between types of investors and SI drivers. This exercise can help identify opportunities for collaboration between investors, policymakers, and NGOs to achieve common sustainability goals. The study revealed that the number of published research articles on sustainable investments has exponentially grown in the last 8 years. A total of three clusters emerged from the network analysis that was conducted on the selected set of research papers. The study identified seven drivers and eight types of investors for sustainable investments. Policymakers can draw inferences from this study and investigate the different barriers, ways to get around them, and opportunities that come with successfully implementing sustainability practices. Future researchers and scholars can conduct a comparative study of developed and developing economies regarding the integration of sustainability practices like ESG in investor decisions in order to get a comprehensive outlook.

Keywords: sustainable investments; environment social governance (ESG); VOSviewer; thematic mapping

#99: The impact of ambient conditions on the performance of the bifacial photovoltaic-thermoelectric generator (PV-TEG) system

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Synergistic power generation utilizing solar photovoltaic (PV) systems and thermoelectric generators (TEG) is a promising approach to enhance the adaptability of current solar systems. The coupling of TEG with PV systems can improve the overall efficiency of the hybrid system, resulting in higher electrical production. Effective thermal management of PV systems is critical to enhance their conversion efficiency and ensure long-term stable operation. The flat heat pipe (FHP) is a highly efficient passive cooling device with a long-distance efficient heat transfer coefficient and no parasitic energy consumption. In this study, the coupled bifacial PV-TEG system is established by numerical methods to investigate the impact of the structure and different parameters on the comprehensive performance of the system. The effects of varying solar concentration ratios, wind speeds, and ambient temperatures on the coupled system's power generation efficiency and output power are analysed. The findings demonstrate that solar irradiance positively impacts the performance of the bifacial PV-TEG system, with the overall output power of the coupled system increasing with an increase in solar irradiance. However, higher ambient temperatures have a negative effect on the overall system gain but are beneficial to the TEG unit.

Keywords: photovoltaic; thermoelectric; flat heat pipe; thermal management

#100: An empirical study on condensation process and heat transfer enhancement under corona discharge: a visualization-based investigation

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The gas-liquid phase change process plays an important role in fields such as building heat and humidity regulation and low-carbon urban construction. Efficiently controlling the heat and mass transfer on the surface of a heat exchanger is essential for sustainable energy development. While many studies have focused on passive or active methods to enhance condensation heat transfer, this paper proposes using corona discharge to enhance dropwise condensation heat transfer on hydrophobic surfaces. The study analyses the effect of surface properties, electric charge, and electrostatic fields on the condensation process. High-definition camera observation and adaptive threshold binarization algorithms were used to analyse droplet behaviour on hydrophilic, hydrophobic, and superhydrophilic surfaces under different negative corona discharge conditions. Negative corona discharge was found to increase nucleation density and shedding speed of droplets on hydrophobic surfaces. The study also analysed the parametric analysis of corona discharge-enhanced condensation heat transfer systems and found that corona discharge promoted condensation heat transfer on surfaces with different wettability. The energy efficiency analysis of the corona discharge enhanced condensation heat transfer system found that it had an extremely low power consumption cost, with power consumption ranging from 0.1W to 1.4W. Combining theoretical and experimental results, this study provides a research basis for the design and application of hydrophobic surface heat exchangers.

Keywords: corona discharge; phase transition condensation; surface wetting properties; heterogeneous nucleation; heat transfer enhancement

#102: Experimental assessment of spray characteristics of hydrogen and CNG using schlieren imaging

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Hydrogen and compressed natural gas (CNG) are considered to be one of the most promising and cleanest alternative fuels for spark-ignited (SI) engines. Their high-octane number allows for increased compression ratio engine operation leading to improved thermal efficiency and fewer emissions. However, CNG-fuelled engines suffer lower flame speeds when running separately, and hydrogen-fuelled engines suffer from knocking and surface ignition. Hydrogen-enriched CNG mixture, also known as Hythane, is considered to be encouraging to overcome these issues. This study uses the schlieren imaging technique to analyse the macroscopic spray characteristics of CNG and hydrogen under different ambient conditions. A comparative analysis of the tests is presented for high-flow rate gaseous injectors for Hydrogen and CNG. A different injection pressure of about 2 to 6 bar was considered under constant ambient temperature. With gaseous fuel, volumetric efficiency was reduced. Ambient pressure of 80 kPa, 90 kPa, 100 kPa and 200 kPa was taken considering the normal and boost engine operation. The jet penetration and spray width increased with the increase in injection pressure. However, with the increase in ambient pressure, the trend was the opposite. Image analysis revealed that H_2 spray spread faster than pure CNG and exhibited a larger cone angle. This could be due to hydrogen's lower density and high diffusivity relative to CNG. The study concluded that ambient conditions considerably impact hydrogen and CNG spray.

Keywords: hydrogen; compressed natural gas; spray; image analysis

#103: The energy transition will require a strong systems view

Peter LUND – Keynote Presentation
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The Paris Climate Agreement strived to limit the increase of the global temperature to 1.5°C, which will require reaching a net-zero emission level around the middle of this century. To keep the pace of the Paris goals, emissions would need to drop by around 40% by 2030. The required future emission cuts require massive measures that will concern all members of society. Therefore, the energy transition will be a socio-technical transition with a range of systemic questions, covering technical, economic, social, and political issues at the same time. A key prerequisite for a successful transition to carbon-neutrality will be a socially-just energy transition with a strong systems view. In parallel to the climate crises, the energy crisis trigged by the Russian invasion of Ukraine needs attention, which is likely to accelerate the clean energy transition in Europe. The energy sector will play a central role in the transition due to its high share of emissions. In particular, the rapid development of new renewable technologies helps to cut emissions not only in the power sector but also in other sectors such as heating, mobility, and fuels through strong electrification. However, this does not come without challenges such as increased balancing needs of power, huge material demand, co-evolving of the new and old energy systems, etc., which call for advanced solutions such as artificial intelligence, material and energy efficiency, smart materials, behavioural changes, etc. For example, complex systems control with AI could help to build resilient energy systems, end-use energy efficiency could halve the energy production investments, novel battery chemistries could avoid critical material bottlenecks, etc. The complexity of the energy transition calls for viewing the different elements required as a whole, i.e., as a system, which will enable the development of optimal solutions for the deep decarbonization pathways required.

Keywords: energy transition; energy systems; energy efficiency; energy crisis; complex systems; renewable energy; digitalization; climate change

#104: Conversion of waste to energy and resource

Chi-Hwa WANG – Keynote Presentation

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Across the globe, sustainable waste management has become a burning issue in view of global warming, food and water insecurity, and the landfill crisis. Supported by Singapore National Research Foundation under the E2S2-CREATE program (Energy & Environmental Sustainability Solutions for Megacities), our research focused on the waste-energy-resource-environment nexus in a long-term effort to favour resource, energy, and environmental sustainability via Eco-Solutions. In this talk, I will review recent developments in the subjects of conversion of waste to energy and resource, and eco-energy systems towards environmental sustainability.

Keywords: waste to energy; waste to resource; environmental sustainability

#105: The impact of indoor climate and occupancy rates on electricity use in campus buildings

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Energy efficiency in buildings can be achieved by many approaches including high-performance HVAC systems, passive design strategies, and accurate energy consumption predictions. Energy evaluation is crucial in existing buildings to improve system control by detecting any unusual patterns of consumption as well as identifying the most influential variables in energy usage for a better target in retrofit projects. This study aimed to identify the significant contributors to energy consumption in both heating and non-heating periods of campus buildings situated in the south of France. The linear regression model was adopted to investigate the relationship between the dependent variable (response) and independent variables (predictors). During the heating period, the analysis focused on five potential variables, namely, time index (daytime/night-time), day index (weekday/weekend), building size, indoor and outdoor climate, and their confounding. When electric heaters (reversible air-conditioners) were likely to be involved, results have shown that the model with the interactive effect variables achieved the coefficient of determination of 68%. That model consisted of CO_2, time index, day index, building size, indoor humidity, and indoor temperature. During non-heating period, the occupancy rate was the main target for the impact level on electricity use. The regression model found that the occupancy rate and day index alone could explain 50% of the consumption variation. Together, this study points out the importance of the occupant's precision to better the predictive model in future studies. This includes a better assumption on occupied space and schedule and a better understanding of the scale of the occupant.

Keywords: electricity consumption; campus buildings; linear regression model; occupancy rate; indoor climate

#106: Paraffin/GO emulsion as a composite phase change material for efficient enhancement of thermoelectric performance of solar PV/T system

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In order to improve the energy utilization efficiency of PV/T systems, phase change material emulsions (PCME) have emerged as ideal functional fluids for latent heat storage in PV/T systems. While most existing research has been limited to simulation studies, little is known about the practical application of PCMEs in real PV/T systems. This paper presents the findings of an experimental study that was conducted to examine the thermoelectric performance of PCMEs in flat-plate heat pipe solar PV/T systems and compares their performance against conventional water-based heat transfer systems. The study involved two main parts: (i) preparation of paraffin/graphene oxide (GO) emulsions and analysis of their characteristics, including latent heat, thermal conductivity, and fluidity, and (ii) building two identical flat-plate heat pipe solar PV/T systems, one using paraffin/GO emulsion as the heat transfer medium and the other using water, to compare their thermoelectric performance based on thermal and electrical efficiency. The results showed that the 30 wt% paraffin emulsion with 0.02 wt% GO had the best overall performance, with a phase change temperature of 35°C, latent heat of 42.93 J/g, thermal conductivity of 0.505 W/(m·k), and viscosity coefficient of 0.91, and could be effectively used in PV/T systems. The use of paraffin/GO emulsion resulted in a significant improvement in the thermal efficiency of the system by 92.28%, the electrical efficiency by 8.87%, and the comprehensive efficiency by 45.75%, whilst also increasing the tank heat collection by 15.8% relative to the water-based system. This study provided valuable insights for the practical application of nano composite phase change material emulsions in solar energy storage.

Keywords: PCME; nanoparticles; paraffin/GO emulsion; PV/T; thermoelectric properties

#107: Performance assessment of a photovoltaic-thermal system with nanofluid for energy cogeneration in a building

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Thermal photovoltaic collectors are being developed to generate electricity and recover the waste heat that prevents the negative effect on the efficiency and life cycle of photovoltaic panels. Also, the use of water-based nanofluids as heat transfer fluids in thermal photovoltaic collectors can improve the heat transfer rate. This study aimed to investigate a thermal photovoltaic system with a copper flat plate collector in which different working fluids i.e. pure water, alumina/water nanofluid, graphene/water nanoplatelets nanofluid, and SiC/water nanofluid were compared. Additionally, the application of fins on the thermal absorber to increase the heat excretion rate of the photovoltaic panel was analysed. A three-dimensional simulation of thermal photovoltaic collectors was performed using ANSYS Fluent software and the effect of different parameters such as fin thickness, fin number, different concentrations of nanofluids, different mass flow rates, and solar radiation on thermal photovoltaic system performance were investigated. The results showed that the fin thickness had no significant effect on the performance of the system and the number of fins was the determinant factor in how much they affected the system. Investigation of different nanofluids revealed that in different mass flow rates, different concentrations led to the best performance. The best electrical efficiency was achieved by using graphene nanoplatelets. Moreover, graphene nanoplatelet with a concentration of 0.5 wt% and mass flow rates of 0.1 kg/s in an absorber with 400 fins were found to be more effective. In this case, the electrical efficiency obtained with incident solar radiation of 1000 W/m^2 and input temperature of 298 K to a photovoltaic panel with 15% reference efficiency, reached 14.51%, which was close to nominal panel efficiency.

Keywords: PV/T system; electricity and heat co-generation; nanofluid; performance analysis; finned surfaces; building energy demand

#108: Towards sustainable development: a comprehensive review of the interconnections between circular economy and the sustainable development goals

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This study assessed the importance of circular economy (CE) practices in the achievement of the Sustainable Development Goals (SDGs). A three-step methodology, consisting of the PRISMA protocol, bibliometric analysis and network analysis was adopted for the purpose of conducting the systematic review of 166 articles (2016-2023). The following clusters were found as a result of the network analysis: Cluster 1 - Red: Impact of CE on Climate Change & Renewable Energy (SDGs 7 & 13); Cluster 2 - Green: Impact of CE on SDGs (Overall SDGs); Cluster 3 - Blue: Role of Innovation in CE (SDGs 8, 9, 12); Cluster 4 - Yellow: Impact of CE on Supply Chain Management (SDG 9); and Cluster 5 - Purple: Role of Governance in achieving SDGs and CE (SDGs 11 & 12). In this study, the authors concluded through a mapping exercise that CE plays a very important role in the achievement of SDGs, especially SDGs 6, 7, 8, 12 and 15. This study also investigated the "Barriers, Mitigation Strategies, and Emerging Opportunities" that are related with the successful implementation of CE for the SDGs. The authors also found that CE initiatives were prevalent mostly in developed economies and developing economies can draw inferences from this study and assess barriers regarding the adoption of CE practices. This study also presented directions for future research based on developing themes in the field of CE and SDGs, which were outlined in this study. The findings of this paper are relevant for managers, researchers and policymakers.

Keywords: circular economy; systematic literature review; sustainable development goals; network analysis; mapping exercise

#109: Advances in hybrid-electric propulsion for aircraft: trends, obstacles, and prospects

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In response to rising environmental concerns and the need to reduce carbon emissions, the aviation industry is exploring alternative energy sources to power aircraft. Current reliance on fossil fuels has significant environmental consequences; therefore, it is necessary to discover cleaner, more sustainable alternatives. In this context, a variety of new and innovative sustainable energy technologies, such as electric and hybrid-electric propulsion systems, hydrogen fuel cells, and biofuels, are being developed. These technologies have the potential to reduce emissions significantly and increase the sustainability of air travel. This study examined the current state of hybrid electric propulsion technology that can be used in aircraft. This paper discusses the benefits, challenges, and potential for widespread adoption. An effective control scheme will be proposed to minimize the block fuel burn during the flight. Simulation studies were carried out in MATLAB to demonstrate the impact of hybrid propulsion systems on fuel consumption.

Keywords: hybrid electric propulsion; more electric aircraft; optimal control

#110: Tackling marine plastic pollution and energy shortages in Pakistan: a synergistic approach

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Pakistan faces a severe environmental crisis with the impacts of global warming, as well as the issue of plastic waste management and marine plastic pollution, which is one of the most pressing problems. However, plastic waste can be converted into a valuable resource by using modern technologies, such as waste-to-energy conversion. This approach offers a synergistic approach to tackle multiple environmental challenges in the country. Plastic waste-to-energy conversion technologies convert plastic waste into electricity through thermal or chemical processes, mitigating energy shortages and reducing the country's contribution to marine plastic pollution. This approach can also help address climate change by reducing greenhouse gas emissions, as plastic waste is often burned in open dumps or landfills, releasing potent greenhouse gases. Pakistan has a significant potential for plastic waste-to-energy conversion, given the abundance of plastic waste generated and the increasing energy demand. World Bank's Biomass Resource Atlas survey has acknowledged this potential. This study examined the prospect of a circular approach to tackle marine plastic pollution, energy shortages, and climate change in Pakistan by applying plastic waste-to-energy conversion technologies. The benefits of this approach are discussed in this paper from a socioeconomic perspective. Various challenges and ways to implement this approach, such as technical and economic feasibility, are also examined. Our findings indicated that a synergistic approach to tackling marine plastic pollution, energy shortages, and climate change through plastic waste-to-energy conversion could provide a sustainable solution to these pressing challenges in Pakistan.

Keywords: environmental crisis; marine plastic pollution; modern technologies; plastic waste-to-energy; climate change; synergistic approach

#111: An AHP-BOCR analysis of different biomass resources for clean electricity generation in Pakistan

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The world is moving towards a global sustainability crisis. The post COVID-19 economic crisis is something that we are not familiar with. Climate, energy, food, and water are a growing concern, and the knot of these four key development areas could be the cause of the next unsustainability pandemic or an effective solution to all our problems. The economic and environmental need for clean and renewable energy is indispensable. Agriculture is one of the key economic sectors of Pakistan, contributing 19% to GDP and 43.5% to employment. The biowaste produced by the livestock population of 213 million can be significantly valuable for biogas production. Despite diverse indigenous biomass resource availability, only bagasse has been used as a biomass resource for power generation in the country. The critical barriers to biomass deployment to an optimal level in Pakistan involve a lack of indigenous experience and expertise to identify proper resource vs. technology combination and a lack of in-depth cost-benefit case studies. Based on a benefit, opportunity, cost, and risk (BOCR) analysis, this study aimed to identify the cost-effective biomass resource for clean electricity generation in Pakistan using the Analytical Hierarchy Process of multi-criteria decision-making science. This method incorporates different yet conflicting aspects, viz., technical, economic, environmental, and socio-political, in the long-term energy planning, balancing the qualitative and quantitative approaches, dealing with trade-offs, and supporting the decision frameworks.

Keywords: AHP; bagasse; biomass; plastic waste; BOCR; clean power; MCDM; multi-criteria decision-making

#112: Assessment of retrofitting old residential buildings in urban districts

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This study contributes to the very limited literature on energy efficiency retrofitting of old buildings in an urban area. The considered case study was the capital city of Jordan, Amman, with the aim of investigating possibilities and economics of selected retrofitting energy efficiency measures in old residential buildings. The analysis presented the thermal performance of different types of dwellings and energy demand based on real data obtained from official surveys and statistical reports. The developed simulation model examined the impact of each of the studied energy efficiency measures on different types and sizes of housing units under the same operating conditions and comparing results with the base case. The adopted retrofitting technique of existing envelopes, i.e. external walls and final roofs, depended on boosting thermal resistance, thus the overall heat transmission coefficient would be reduced. In the case of windows, new double-glazed windows should decrease heat losses as well as the solar heat gain coefficient under different conditions. The maximum savings could be generated in small housing units, in a multi-family building, which represented the major fraction of dwellings in Amman. This group was the most attractive and challenging due to poor performance of existing envelopes and being occupied by low-income families. The simulated results suggested that such a group of houses had remarkable potential for energy savings of about 22%, resulting from insulating external walls and replacing old inefficient windows. Unfortunately, final roof insulation and replacement of basic appliances, i.e. washing machine and the fridge, would have relatively long payback periods, which made such options unattractive from the economic point of view.

Keywords: energy efficiency; retrofitting; old buildings; residential sector

#114: Performance analysis of waste heat recovery in hydrogen storage compression process based on TEG

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By establishing a mathematical model, the combination of hydrogen compression and storage with a thermoelectric power generation model was studied, and the heat generated during the compression of hydrogen was recovered and utilized by thermoelectric generation. The effects of hydrogen mass flow rate, cold-side mass flow rate, and compression ratio on the performance of the thermoelectric power generation device were studied. The results showed that two operating parameters, hydrogen inlet temperature and hydrogen mass flow rate, had a significant impact on the maximum output power, conversion efficiency, and energy recovery rate. Specifically, with the increase of hydrogen mass flow rate, the maximum output power and optimal component length increased significantly. When the hydrogen mass flow rate was fixed, the higher the hydrogen inlet temperature and the lower the cold-side inlet temperature, the higher the output power, and the optimal module length did not change. This indicated that for a fixed length thermoelectric power generation device, there existed an optimal hydrogen mass flow rate value that could achieve the highest energy recovery rate. When L=1m, the energy recovery rate reached the maximum value at a mass flow rate of 20g/s.

Keywords: hydrogen storage; TEG; waste heat recovery

#115: Study on the multi-functional application of BIPV/T system

Jie JI – Keynote Presentation

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Prof Jie Ji will introduce the latest research in Building Integrated Photovoltaic/Thermal system. Some new concepts and research works including the newly developed PV/T systems, solar thermal catalytic oxidation of formaldehyde, solar thermal sterilization and disinfection, the new configuration of multi-functional BIPV/T system like curved PV-roof, PV-window and PV-wall, solar PV driven heat pump and air conditioning system will be presented.

Keywords: multi-functional utilization of solar energy; building integrated photovoltaic/ thermal; solar thermal sterilization/ disinfection; building energy conservation; PV heat pump

#116: The impact of street orientation and aspect ratio on cooling demand in buildings: a case study of the "Sakan Misr" Housing Project in Egypt

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In Egypt, households are the largest consumers of electricity, accounting for 41% of total electricity consumption in the country, according to a report by the Egyptian Holding Company for Electricity and Renewable Energy in 2021. Furthermore, the majority of residential energy consumption is dedicated to space cooling and heating, with a percentage of 46%, as reported by the Ministry of Electricity and Renewable Energy in the same year. With a rapidly growing population and increasing urbanization, the government has implemented policies to establish new urban communities, many of which are located in hot arid climates. Therefore, these developments must be designed to minimize energy consumption from building space cooling to mitigate its impact on global warming. This study investigated the influence of street orientation and aspect ratio on cooling demand in buildings for newly established housing projects in Egypt. The "Sakan Misr" housing project in Cairo was selected as the case study, and a parametric simulation was carried out using Design Builder software to compare cooling energy consumption through different building orientations and street aspect ratios. The study found that as the aspect ratio of a street decreased, cooling consumption increased. North-south streets buildings had the highest average cooling demand, while buildings on east-west streets had the lowest values for cooling demand, with the lowest values observed in buildings with north and south-facing orientations. In contrast, buildings with west-facing orientation had the highest required cooling load. Incorporating these findings into building codes could potentially lead to a reduction of carbon emissions from buildings caused by space cooling by approximately 20% which could lead to more energy-efficient housing projects in Egypt, particularly crucial given the expected increase in temperatures due to global warming.

Keywords: residential energy consumption; residential projects in Egypt; street orientation; street aspect ratio; cooling demand in buildings; energy-efficient housing projects; reduction of carbon emissions; building orientations

#117: Revitalizing Bangkok's skywalks: a sustainable design approach to enhance 'Green Mile' walkway

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Urban areas face challenges in providing safe, accessible public spaces for pedestrians. Bangkok, a densely populated city, is addressing this issue through the development of elevated walkways. The Green Mile Walkway, a crucial pedestrian infrastructure, currently faces limitations, such as inadequate facilities, poor maintenance, and a lack of green spaces. This project aims to redesign the Green Mile Walkway using a sustainable urban design approach that meets the needs of all stakeholders. Double Diamond design framework was employed to empathize with stakeholders, define the challenge statement, ideate potential solutions, prototype designs, and test them with feedback. Site analysis, interviews with stakeholders, collaboration with local businesses, and secondary research on sustainable urban design principles and successful skywalk designs informed the project's design process. The challenge statement was formulated to create a pedestrian infrastructure that connects various areas, promotes local sustainable businesses, and fosters pro-environmental practices while providing a comfortable, safe, and inclusive space. The skywalk design prioritized connection, function, green spaces, adequate space, and enjoyment. Connection ensured linkage between commercial and residential areas and public transportation hubs. Function addressed the needs of pedestrians, local businesses, and government agencies, while green spaces enhanced aesthetics and environmental sustainability. Adequate space ensured comfortable walking without overcrowding, and enjoyment was emphasized through amenities and educational signage. The redesigned Green Mile Walkway addressed existing limitations and incorporated sustainable urban design principles, meeting the needs of all stakeholders. This project showcases the potential for revitalizing urban spaces using a human-centered approach, promoting sustainable urban development, and fostering environmentally responsible practices. Future research could explore scalability and adaptability to different urban contexts.

Keywords: eco-design innovation; Green Walkway; sustainable development; community research; pedestrian Infrastructure

#118: Comprehensive study of energy, comfort, and economic performance of the smart all-in-one window with integration of PV vacuum glazing and window frame heat recovery ventilation system

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Poor glazing insulation and natural window ventilation represent an average of 15% and 35% primary energy consumption in most residential and commercial buildings, which is crucial in energy conservation for net zero energy target in 2050. Besides, occupants spend about 90% of their time on indoor activities, where sick building syndrome (e.g., pruritus, dry cough, ocular pruritus, and headache) are attributed to poor indoor air quality, as well as diseases like extrinsic allergic alveolitis and asthma. This study proposed a smart all-in-one window by integrating PV vacuum glazing, a heat pipe-based window heat recovery ventilation unit and battery storage for space heating, cooling, insulation, ventilation, heat recovery and renewable electricity generation and storage. The PV vacuum glazing generates electricity which is stored in the battery to supply the window heat recovery ventilation when required. The glazing insulation achieves U-value of 0.45 W/m^{2}K with glazing solar to electricity conversion efficiency of 5.5%-8.9% varied according to the transparency between 70% to 50%. In addition, the window heat recovery unit using the heat pipe as high thermal conducting method with heat recovery efficiency between 78%-92% with variation of ventilation rate between 20-60m3/h. A 1940s' British masonry house was selected as a case study to evaluate the comprehensive energy, comfort, and economic performance by utilizing the all-in-one smart window. Results indicated that the total building energy usage was reduced by 47% annually with quick payback periods of 6.5 years. Moreover, the average indoor temperature fluctuation was reduced by 78% from 3.6°C (pre-retrofit) to 0.8°C (post-retrofit). It was also noted that the average indoor CO_2 content during sleep time was reduced from 1800PPM to 750PPM as 100% warm and fresh air inlet from the window heat recovery unit, which indicated a significant improvement of indoor thermal comfort. Thus, the proposed smart all-in-one window could play a significant role in the future low-carbon building design in both retrofit and newly constructed buildings.

Keywords: smart window; all-in-one window; window heat recovery; PV vacuum glazing; heat recovery ventilation

#119: Design, preliminary testing and construction of a novel water collection system using PCM for water scarce regions in Africa

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A safe water supply is a crucial and growing concern in many African regions, with desalination and water transportation being costly and energy intensive. The project this paper is based on aimed to provide a sustainable solution for water scarcity in Ethiopia, Sudan, and other sub-Saharan African countries with similar climates. This paper presents the methodology and results of a series of experiments conducted on a novel water collection system that combined phase change materials (PCMs) and adsorbent technologies. The system, which is patent protected, uses PCM for passive cooling of atmospheric air during the day, taking advantage of the adsorbent material's capability to capture and release water vapour from ambient air. The experiments focused on evaluating the system's condensing side performance under various operating conditions. The first experiment investigated the heat transfer efficiency (U value) of the system under different incoming air temperatures. The second experiment examined the impact of varying air velocities on the heat transfer efficiency. The third experiment assessed the system's water recovery efficiency under different levels of relative humidity. Preliminary Computational Fluid Dynamics (CFD) analysis supported the experimental findings. Through these experiments, the study aimed to identify the optimal operating conditions for the water collection system and develop a comprehensive understanding of its performance characteristics. The water collection system has potential applications as a stand-alone unit or in groups, providing clean water for daily use and additional benefits. This paper discusses the challenges and innovative features of the system, offering a promising solution for water scarcity in remote African communities.

Keywords: phase change materials; water harvesting; latent heat storage; sustainable water supply; experimental methodology

#120: The impact of prefabricated wall insulation (PWI) panels on building energy performance: Numerical simulation and experimental validation

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External wall insulation to reduce the heat loss of building envelope is evident to energy conservation and energy costs. However, traditional insulation methods require long installation time and high labour cost which significantly increase the initial investment of the retrofit work and the thermal quality is usually affected by the in-situ weather conditions when it is installed. Besides, most of the conventional insulation materials have high embodied energy consumption and carbon emissions. This paper advances the current knowledge on the use of prefabricated wall insulation (PWI) panels in building renovation by analysing the heating and cooling energy performance of five PWI panels in a 1940s detached masonry house. Five PWI panels are proposed and designed in the framework of the ongoing SureFit H2020 project, using the core materials of vacuum insulation materials, starch-aerogel insulation materials, silica-aerogel insulation materials and breathing insulation membrane, and incorporated with extruded polystyrene insulation layers. The thermal resistances of the five composite PWI panels are numerical simulated with R-value varied between 3.0 and 5.5 m2K/W. Meanwhile, a hot-box environmental chamber method is applied to experimentally test their U-values and the temperature distribution between layers under the ISO-9869 standard of 30℃ temperature differences (C-5/H25). Comparing with the experimental results, the numerical calculation results are validated with maximum difference of 6.39%. The dynamic energy simulations reveal that the proposed solutions allow reducing the energy need for space heating by 55% - 58%. However, the space cooling demand increases by 70% - 77%, which is still minor due to the baseline space cooling demand of only 1.63 MWh in the UK climate. Moreover, the future work suggests that the increased air-conditioning electricity could be compensated with the sufficient PV power generation in summer.

Keywords: prefabricated wall insulation; starch aerogel; silicon aerogel; hot-box; building retrofit

#121: A dual-purpose innovative cooling cycle for future sustainability

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A surge in cooling demand has been observed in the last few decades because of rising temperatures, a growing population, high urbanization, and improved living standards. As a result, the global demand for air conditioning is increasing continuously with the highest rise in developing countries. Therefore, air conditioning-related energy demand and emissions are also increasing exponentially. Conventional vapour compression systems are energy intensive and result in harmful emissions so there is a need to develop unconventional water-based cooling systems with lower energy consumption and benign emissions. In this regard, a dual-purpose innovative indirect evaporative cooling system was proposed and tested. The system aimed to address the major limitations in existing systems like water consumption, complex wall, low heat transfer rate, and intensive maintenance requirements. The experimental investigation revealed that the proposed system achieved a temperature drop of as high as 19°C, a cooling capacity of 118 W, and a coefficient of performance of 29 (only for cooling) at a higher outdoor air temperature of 46°C. Moreover, the system produced the supply air temperature at 21±0.5°C for different outdoor air temperatures varying between 30 to 46°C. Furthermore, the proposed IEC system could be used as a cooling tower to cool the intake water while simultaneously providing cool air. The experiments showed that water in a humidifier achieved wet bulb temperature irrespective of water intake temperature. For experimentation, the water intake varied from 15 to 45°C. Therefore, developing this advanced system is potentially a remarkable step toward the commercial-scale realization of indirect evaporative cooling technology.

Keywords: dual purpose IEC; innovative cooling system; sustainable development

#122: Performance investigation of a novel double-skin ventilated purified window integrated with solar photo-thermal conversion/synergistic-catalytic blinds

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In this paper, a novel double-skin ventilated purified window integrated with solar photo-thermal conversion/synergistic-catalytic blinds that realized the functions of space heating, air purification and shading was proposed. Firstly, experimental tests on the hybrid system with solar photo-thermal conversion/synergistic-catalytic blinds were conducted under different blind turning angles. Secondly, the heat and mass transfer model of proposed system was developed and verified experimentally. Thirdly, the thermal and formaldehyde degradation performance applied in five cities under various blind turning angles were investigated to acquire the annual optimal operation strategy on blind angle. Main results were: (1) The photo-thermal composite catalyst behaved better formaldehyde removal performance compared with single thermal catalytic material. (2) The RSMD values of air outlet temperature, air thermal efficiency, formaldehyde outlet concentration, and CADR calculated by the established model were 1.8%, 7.1%, 2.1% and 8.5%, respectively. (3) Applying the annual optimal operation strategy on blind angle in Beijing, Nanjing, Hefei, Guangzhou and Xining, the annual total reduced heating load was 375.12, 276.42, 202.22, 124.49 and 947.61 MJ/m2. The annual total reduced cooling load was 257.78, 193.10, 355.87, 345.11 and 0 MJ/m2. The annual total generated clean air was 11393.11, 9868.48, 8367.68, 7151.36 and 18135.83 m3/m2.

Keywords: double-skin ventilated window; solar photo-thermal purification; blinds; space heating; formaldehyde degradation

#123: Thermodynamic evaluation and comparison of electric heating paths

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The vast majority (>90%) of energy conversion and utilization entails thermal energy over a wide range of temperatures. The phasing out of fossil fuels is accompanied by the emergence of numerous alternative and renewable energy sources in the form of chemical, electrical, solar, and geothermal energy, etc., resulting in more flexible and diverse energy conversion. In this paper, we elucidate the characteristics and applicability of different thermodynamic evaluation methods for energy conversion centring on thermal energy, involving energy conversion efficiency, exergy efficiency, and entransy efficiency. Moreover, for the prevalent conversion of electrical energy to thermal energy, comparisons and thermodynamic evaluations are conducted based on three electric heating alternatives, including electric heaters coupled with user-end thermal energy storage, heat pumps coupled with user-end thermal energy storage, and two-stage compression heat pumps coupled with intermediate thermal energy storage. Three paths are compared under three conditions, with ideal scenarios (both heat pumps and thermal energy storage devices are ideal), partially ideal scenarios (considering energy and temperature loss of thermal energy storage), and actual scenarios (taking winter heating conditions in Shanghai as an example). Based on the prudent application of three thermodynamic evaluation methods, the results of the comparison of three electric heating paths indicate that two-stage compression heat pumps coupled with intermediate thermal energy storage are more favorable, with higher energy conversion efficiency, higher exergy efficiency, and lower entransy dissipation in both theoretical and case-based comparisons. Considering the time-sharing tariff, the electric bill is the lowest in Shanghai when the output temperature of the thermal energy storage device is around 15°C. Thermal energy storage with the intermediate storage temperature enables effective load regulation for both winter heating and summer cooling. Based on the thermodynamic comparison, two-stage compression heat pumps coupled with intermediate thermal energy storage can further reduce electricity costs by 520 yuan per year compared to direct electric heating for the entire heating season in Shanghai. By 2060, its carbon reduction will be 28.t CO_2eq compared to the coal-based heating path, 4.25t CO_2eq compared to the NG-based heating, and 25.7t CO_2eq compared to the direct electric heating path.

Keywords: energy conversion efficiency; exergy efficiency; entransy; electric heating; heat pump; thermal energy storage

#124: Zero-energy modularized atmospheric water harvester with advanced thermal management

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Recently, water scarcity has seriously affected human survival and social development, especially in remote underdeveloped inland regions. To alleviate the crisis, sorption-based atmospheric water harvesting (SAWH) technology emerges to extract water from air without the limitation of geography. It relies on sorbent capturing and releasing moisture to enrich the water vapor, which is subsequently condensed into liquid water. But at present, the lack of knowledge of heat and mass transfer design from sorbent material to SAWH system level has restricted practical water production at SAWH field. Herein, a zero-energy modularized atmospheric water harvester (ZMH) has been designed through advanced heat and mass transfer management. Specifically, the hollow cylindrical sorption bed enables the fast transport of water vapor during sorbent's adsorption-desorption process, out of which the solar vacuum tube is employed to both concentrate the solar energy and reduce the heat loss during the desorption. The ingenious parallel layout via cascading the solar vacuum tube with the condenser can shield the heat radiation between desorption area and condensation area automatically, semi-decoupling the desorption temperature and condensation temperature to enhance the desorption-condensation performance. It also gets rid of setting solar absorber above the condenser in all previous passive SAWH devices, contributing to heat moisture's migration toward the condensation area with the help of natural thermal buoyancy. Through practical outdoor experiments, our ZMH prototype is demonstrated to achieve a remarkable water production of 3.72 kg/(m2*day) without any input of active energy and any auxiliary power equipment even for various sorbents. It's the first purely passive scalable SAWH device reported so far, as well as its water productivity is the highest among those of all reported solar-driven SAWH devices for a single cycle. This new design strategy holds the significant promise of promoting SAWH into marketization, further realizing safe water supply for global humans indeed.

Keywords: atmospheric water harvesting; sorption kinetics; thermal management; zero energy; mass transfer

#125: Flow and heat transfer in a double-pipe heat exchanger using microencapsulated phase change material (MPCM) slurry

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As the energy demand of many industrial processes increases day by day, it is essential to consider enhancing the performance of the device for efficient energy utilization and conservation. An improved heat transfer fluid (HTF) is one of the mechanisms to be implemented to enhance the heat transfer performance of thermal-fluid devices such as heat exchangers. And the other prevalent heat transfer enhancement technique is employing heat transfer augmentation in the heat transfer tubes. Microencapsulated phase change material (MPCM) slurry has been adopted as an HTF and energy storage medium due to its high heat capacity and heat transfer performance. The present work investigates an MPCM slurry as an HTF in comparison to plain water in a double-pipe heat exchanger. In addition, a groove-cut tube has been proposed as a passive heat transfer enhancement mechanism to improve heat transfer performance. A numerical model based on the Eulerian-Eulerian multiphase flow model has been adopted for the investigation, and the accuracy of the model has been validated with experimental work. It has been found that the model well predicts the flow behaviour and heat transfer characteristics of the slurry. The heat transfer and energy transport performance of the HTFs has been analysed with respect to various flow parameters. The result showed that the performance of the heat exchanger improved for MPCM slurry as it transports more heat than the corresponding plain water. However, the heat transfer performance of the HTFs was highly dependent on the Reynolds number of the flow. The performance index analysis indicated that the performance of the double pipe heat exchanger enhanced with a groove cut tube compared to a plain tube. The MPCM slurry exhibits a higher pressure drop than the improved heat transfer at high Reynolds numbers.

Keywords: MPCM slurry; double-pipe heat exchanger; eulerian-eulerian multiphase flow model; performance index

#126: Analysis of ignition at different fuel injection timings in gasoline direct injection engine

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The fuel injection technology largely determines the fuel-air mixture quality and emissions formation during engine combustion. With gasoline direct injection technology, spark-ignition engines have shown enhanced power output and fuel economy. However, the influence of fuel injection parameters needs to be understood properly so that it can be optimized for improved performance. Further, the ignition timing should be tuned depending on the fuel-air mixture formed via different fuel injection timings. This study evaluated the effect of ignition timing for three different fuel injection timings, corresponding to early, mid and late intake stroke. The analysis was done by examining the combustion, performance, and regulated emissions characteristics. The test conditions were operated at fixed engine speed of 1500 rpm and torque of 20 Nm with a stoichiometric mixture. The results showed that late fuel injection resulted in early pressure rise while mid-intake injection retarded the combustion. However, the early injection led to faster combustion with the highest combustion efficiency. The brake thermal efficiency of the engine was higher for early injection and increased with ignition advance. Carbon mono-oxide and hydrocarbon emissions were lowest for early injection; however, it resulted in increased NO emissions.

Keywords: gasoline direct injection; fuel injection timings; spark advance; combustion; emissions

#127: A preliminary investigation comparing the use of biochar powder coatings to standard materials for heat and mass transfer surfaces in evaporative coolers

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Recently, evaporative cooling systems have gained importance thanks to the study and development of the Maisotsenko cycle, which adopt an innovative indirect evaporative cooling strategy. This technology allows lowering the theoretical outlet temperature limit to the dew point temperature of the inlet air, thus increasing its wet bulb effectiveness, giving a second chance to the diffusion of indirect evaporative coolers (IEC) often penalized by poor performance in relation to their higher complexity and cost. The Maisotsenko cycle improves the performance of the IECs by pre-cooling the working flow. This is achieved by diverting a portion of air from the primary channel at its outlet and reintroducing it, cooler, into the wet secondary channel. To obtain the best performance the Maisotsenko cycle requires special attention to the wet channel where water evaporation occurs. Many studies have tested different materials and coatings to absorb and distribute water as evenly as possible over the entire heat and mass exchange surface. The most common choices are waterproof aluminium walls and coatings made of organic fibres or fabrics. However, this study aims to investigate a coating made of biochar powder glued onto an aluminium sheet by means of a layer of epoxy resin. Biochar is a high carbon content material and is produced through thermochemical process of biomass. It is characterized by high stability, porosity, and a large specific surface area. Although traditionally used as a soil amendment in agriculture, it is now being investigated for various other applications. In this work, the promising results of initial tests to assess the feasibility of using biochar in evaporative cooling are presented.

Keywords: Maisotsenko cycle; evaporative cooling; coating; biochar

#128: Multi-level simulation of cooking processes in a domestic oven

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Household appliances are responsible for more than 50% of household electricity consumption in the UE. In particular, the electricity used for cooking is 12.15% of the total. Therefore, they have a relevant impact on energy consumption in the residential sector. Electric ovens, compared to surface or microwave cooking, consume more energy for the same cooking processes. The average cooking efficiency on stoves is about 40%, microwaves nearly 55%, and electric ovens are less than 14%, so there is a great deal of potential for their improvement. There is a wide-range of numerical models implemented in the literature to analyse the thermal behaviour of the oven. Many numerical models aim to predict the results of the test regulated by the EN60350 standard, which evaluates the energy class of the oven in the UE at a rate between A+++ and D. In this project, a multi-level approach that provides a dynamic analysis of the energy and mass exchange processes within a cooking cavity is presented. The model is based on lumped parameter models coupled with finite volume simulations. The lumped parameter models, written in a Matlab-Simulink environment yield the dynamic evolution of temperature and velocity field within the oven cavity, together with the interaction with the outdoor environment. The variables used as input in the model are integrated with the results obtained by steady-state numerical simulation giving the velocity and temperature distribution within the cavity under certain boundary conditions, typical of the cooking processes. The numerical approach has been validated through the comparison with experimental results. By this methodology, an innovative cavity design tool that integrates the results in steady state conditions obtained from detailed simulations with dynamic results is deployed. It is shown that this approach can be implemented also during the control of the parameters in order to achieve higher performances and lower energy consumption.

Keywords: multi-level simulation; electric oven; CFD

#129: Air conditioning system optimization for historical building thermal comfort: a CFD analysis

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This study presents a novel approach for the optimization of thermal comfort distribution in offices within historical buildings. The approach is aimed first to show the optimal comfort locations for the workers in the office when no modifications on the installed HVAC system are proposed. In a second step, some modifications in the air distribution and other devices are combined in order to improve the comfort by reducing the energy consumption of the HVAC system. These changes need to be integrated and harmonized with the laws that regulate the artistic heritage. A number of novel solutions which can be adopted in a frame where an efficient engineering approach should also achieve the beauty are presented. These ideas are applied to an office room located in one of the historical buildings of the Alma Mater Studiorum, University of Bologna. In a previous study, thermal comfort indexes distribution within the office were analysed both in summer-cooling and winter-heating conditions. The analysis is carried out thought detailed CFD simulation in the Starccm+ environment where the HVAC parameters are varied to obtain the optimal thermal comfort level within the workstations. The goal is to develop a customized and dedicated conditioning approach for each workstation in the office, while minimizing energy consumption, providing a personalized thermal environment for each occupant. In this context, possible solutions to optimize thermal comfort are evaluated. The optimization strategy involves the identification of the optimal position of the fan coil unit to best address potential hotspots and cold spots. Low mass flow rate diffusers are also evaluated due to their capacity to improve the global thermal comfort minimizing possible local discomfort due to air drought rate. The study also wants to demonstrate the effectiveness of shading devices in reducing the solar heat gain with consequent improvement in the indoor thermal environment and energy demand reduction. Overall, the study highlights the effectiveness of using CFD analysis to optimize thermal comfort in a building, especially when, due to the heritage value of historical buildings, only non-invasive strategies can be adopted for the indoor environment improvement. The findings provide valuable insights for HVAC system design and operation in similar buildings and can help improve the energy efficiency and comfort of indoor spaces.

Keywords: thermal comfort; CFD; historical building; HVAC system

#130: CFD analysis of the effect of rectangular groove structure on heat transfer in parabolic fins

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With the technological developments, the increasing use of electronic devices has reached an incredible point. The constant use of these devices, which we do not keep with us in our daily life, causes a decrease in performance due to heating and heating in electronic devices. To eliminate this situation, the use of refrigeration equipment is inevitable. In small-scale electronic devices, forced convection is predominant because cooling cannot be provided with sufficient surface area. However, the reduction in device dimensions makes it difficult to integrate forced transport equipment. Therefore, this problem is tried to be solved by using enlarged surfaces. In this study, the effect of the rectangular groove structure on the heat transfer for the non-traditional parabolic fin, which is one of the fin structures used in electronic devices, is evaluated with the CFD model. The effect of the increase in the number of rectangular grooves on the heat dissipation is examined and the optimum situation is tried to be obtained. For a convection coefficient of 10 W/m2K at 400 K fin bottom temperature and 300 K ambient temperature, the heat dissipation is 0.267 W/cm3 in the non-grooved parabolic fin in the reference case, while this value increases by 90% to 0.507 W/cm3 in the 5-groove parabolic fin. It is also seen that increasing the convection coefficient increases the heat dissipation but decreases the efficiency in any case. It is concluded that the number of grooves should be increased, and the convection coefficient should be high in order to obtain surfaces at lower temperatures.

Keywords: rectangular fins; heat transfer; electronic cooling

#131: Numerical analysis of the effect of material type on heat dissipation in rectangular ducts in parabolic fin application

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Heating is a common problem in electronic devices due to continuous operation. Especially the shrinking of the size of the devices produced with new possibilities makes this situation even more complicated. Although it is possible to use mainly forced convection for cooling in medium and large sized devices, this is not possible as the device sizes get smaller. In this case, the use of expanded surfaces is common. With the application called fin, the surface area for heat dissipation is expanded and more heat is removed from the device. In this study, the effect of the use of aluminium, brass and iron on parabolic blade performance in an unconventional parabolic blade application is discussed with a 3D CFD model. For 400 K wing base temperature and 300 K ambient temperature, analyses are made with convection boundary condition. With the mesh-independent solution and numerically verified model, the heat output per unit volume for aluminium material is 0.267 W/cm3. This value is 0.263 W/cm3 for brass and 0.259 W/cm3 for iron. Then, the wing performance is evaluated according to the number of perforations by adding a rectangular groove. In the best case, with 5 perforations and 40 W/m2K convection coefficient, 1.732 W/cm3 heat dissipation is obtained for the aluminium fin. This value is 1.515 W/cm3 for brass fin and 1.392 W/cm3 for iron fin. It is seen that the fin efficiency decreases with increasing perforation and convection coefficient. The minimum temperature value for the blade decreases with increasing perforation. The same is true for the transport coefficient. The minimum fin temperature, which is 10 W/m2K convection coefficient for aluminium and 395.46 K without perforation, drops to 361.35 K with 5 perforations and 40 W/m2K convection coefficient.

Keywords: heat transfer; electronic cooling; heat dissipation in fins

#132: The development potential of renewable energy in the process of mine restoration

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Mining has made outstanding contributions to the development and progress of the economy, society, and human society through the supply of energy and resources. However, with the continuous resolution of excess production capacity in the coal industry, a large number of coal mines have been closed and withdrawn, and a large amount of mining land resources have been idle. This abundant abandoned land has great potential for the development of renewable energy. Revitalizing land resources in the process of mine restoration is of great significance for energy strategy. This article takes the Xishan Coal Mine Restoration Area in Shanxi Province as the research object, demonstrating the potential for renewable energy development in the ecological restoration process of mines. The expected research results have the following three aspects of significance:

(1) The results of this study will help to accurately identify the main ecological problems at present, and establish a long-term mechanism for mining ecological restoration research and renewable energy connection;

(2) The research results contribute to the establishment of scientific ecological restoration models;

(3) The research results will help to realize the carbon sink capacity estimation and carbon sink goal oriented development planning research of Xishan mine.

The research results can be used as a pilot demonstration for pollution control and ecological restoration in the Yellow River basin mining areas. Through the implementation of green mine standards and evaluation system, the transformation and upgrading of mines have been accelerated. In the future, all new mines will meet the requirements of green mines. “Double carbon (the carbon peaking and the carbon neutrality)” goal will be achieved.

Keywords: renewable energy; mine restoration; Xishan coal mine; carbon sink

#133: Study, qualitative-quantitative analysis and sizing of the environmental impact of the photovoltaic panel recycling process

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This article delves into the crucial topic of photovoltaic panel recycling and its environmental impact. The study is based on two case studies conducted in Peru, where the effectiveness of the recycling process is evaluated through both qualitative and quantitative analyses. The primary objective is to examine the efficiency of the recycling processes and their impact on the environment. The first case study focuses on a group of five rural houses, where solar panels were installed to meet the energy demands of the households. The second case study analyzes the Rubi solar plant, which has capacities of 2kW and 179.5kW, respectively. Both case studies were analyzed qualitatively by describing the sub-processes of the solar panel recycling, which includes the dismantling, delamination, recuperation, sorting and leaching of the panels. Moreover, a quantitative analysis was conducted to determine the energy payback time (EPBT) factor of the recycling process. The EPBT factor refers to the time required for a photovoltaic panel to generate the same amount of energy that was consumed during its production and disposal. This calculation enables a more comprehensive understanding of the effectiveness of the recycling process, which is crucial in ensuring the sustainability of the solar industry. Finally, the environmental impact of the recycling process was determined by calculating the total carbon footprint of the recycling process. The carbon footprint measurement allows a better understanding of the impact that the recycling process has on the environment, including the emission of greenhouse gases. In conclusion, the study provides valuable insights into the photovoltaic panel recycling process's efficiency and environmental impact. The qualitative and quantitative analyses reveal the critical factors that influence the effectiveness of the recycling process and identify areas where improvements can be made to ensure the sustainability of the solar industry.

Keywords: PV recycling; photovoltaic panels; energy payback time (EPBT); carbon footprint; greenhouse gas emissions; energy

#135: The smart kitchen scanner for Gen-X wellness: design approach of 'Mealition'

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This paper focuses on the wellness of Gen X in retirement through their cooking habits and preferences, which prioritize health-consciousness. Most members of Gen X are interested in eating a balanced and nutritious diet to support their overall health and prevent disease. The paper aims to create smart residential for wellbeing. The methodology of this paper is based on the Double Diamond framework. This paper uses a survey from the GG form to categorize and uses in-depth interviews, empathy maps, and user journeys to understand the target group. Data-driven design is used to inform and guide the design process by capturing and analysing data to make informed decisions. Along with technology integration, ingenuity is used to create more creativity to make the project unique and possible to develop. The value proposition is used to create the uniqueness of the project. The project found that Gen X consumers tend to spend more time in the kitchen cooking and are interested in eating a balanced and nutritious diet to support their overall health, which is concerned with sustainability. The project proposes a sustainable product called Mealition, which is a smart projector that can scan, recognize, and calculate the safe amount of nutrition from the user's medical report and suggest the appropriate amount of ingredients. The project also considers the business model and benefits for the customer, investors, and partners. Overall, the project highlights the importance of developing sustainable products to meet the evolving needs and preferences of Gen X, who are becoming more aware and concerned about food nutrition.

Keywords: Gen X wellness; wellness in retirement; smart kitchen; nutrition; sustainable design products

#136: Energy, exergy, and techno-economic analysis of a 10-kW biogas fuelled solid oxide fuel cell

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Biogas is a renewable and promising alternative energy source produced by anaerobic digestion (AD) of organic wastes like animal, vegetable, kitchen, municipal solid, wastewater, and agriculture residue. At small and medium scales, biogas energy is frequently used to generate heat and electricity using power turbines and internal combustion engines; however, the efficiency of these systems is very low when compared to solid oxide fuel cell (SOFC) systems. The high-temperature operation and direct internal reforming of SOFC make it possible to use biogas to generate electricity through the most efficient electrochemical pathway. This study developed a thermodynamic model of a 10-kW Biogas-SOFC system for decentralized combined heat and power applications. For this system modelling, the direct internal reforming SOFC with anode off-gas recirculation has been chosen. All aspects of the proposed system's energy, exergy, and techno-economic viability are evaluated. The SOFC performance is also examined using sensitivity analysis to account for variations in the steam/carbon ratio, fuel utilization, and recirculation ratio. The biogas-fuelled SOFC system yields an electrical efficiency of 61.47% and combined heat and power (CHP) efficiency of 89.37% for energy analysis. In exergy analysis, the system delivers an electrical efficiency of 58.66% and a CHP efficiency of 65.29%. The energy and exergy analysis reveal that the system has maximum efficiency with 85% fuel utilization and 60% anode off-gas recirculation. The techno-economic study of the biogas-SOFC system shows the levelized cost of electricity (LCOE) as $0.08/kWh, which is far better than conventional energy systems. The energy, exergy and LCOE for the 10-kW biogas-SOFC system prove that this system is a feasible energy solution for decentralized power applications.

Keywords: biogas; SOFC; internal reforming; energy; exergy; LCOE

#137: Experimental study of desiccant regeneration driven by solar interfacial evaporation

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Liquid desiccant air conditioning systems (LDAC) have attracted increasing interest for the high efficiency of temperature and humidity control. Improving the regeneration performance with low-grade energy could make LDAC systems more competitive. In this work, we studied the regeneration performance by solar interfacial evaporation method. The lignocellulose sponge was prepared into the evaporator by combining the Chinese ink to enhance the sunlight absorption. This work investigated and compared the influence of solution type and concentration on the regeneration rate and efficiency. Experimental results demonstrate a regeneration rate of 0.39 kg/m2h for LiCl desiccant solution with a concentration of 40 wt.% at 25°C and a regeneration rate of 0.37 kg/m2h for KCOOH desiccant solution with a concentration of 80 wt.% at 25°C under 1-sun irradiation can be achieved. The similar regeneration rate of LiCl and KCOOH desiccant solution shows that the vapor pressure determines the regeneration performance. Optimizing the transport properties of the solution by adding surfactants can slightly improve its regeneration performance. Importantly, the solar interfacial regeneration method exhibits a significantly higher regeneration rate when compared to traditional membrane regeneration and thermal regeneration in packed towers, thereby establishing it as a promising and efficient approach for solution regeneration.

Keywords: liquid desiccant air conditioning systems; solar interfacial evaporation; desiccant regeneration; surfactant

#138: Enhancing infant wellness: a collaborative approach to ideate crying behaviour monitor

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This paper outlines a collaborative effort between Thammasat Design School and SCG WEDO to alleviate the challenges faced by parents in tracking their child's development and wellness during the first year of life. The purpose of this study is to develop a solution that supports parents in understanding and monitoring their infant's crying behaviour to enhance the wellness of both parents and children. Research has indicated that excessive crying can have negative impacts on a child's physical and cognitive development, highlighting the importance of monitoring and understanding this behaviour. To develop the solution, the researchers employed the double diamond methodology, which consists of four stages: Discover, Define, Develop, and Deliver. This methodology was supported by various methods, including surveys, in-depth interviews, competitor analysis, user journey mapping, persona creation, and a risk register table. The proposed solution is a Monitoring device and Cry Journaling Application, which integrates product and service elements to create a cohesive and customized system. The solution criteria were established based on research findings, which included distinguishability, safety, user-friendliness, customizability, portability, privacy, and compatibility. With the device's advanced technology and the application's machine-learning algorithms, parents can identify potential issues early on and take appropriate action, reducing the stress and anxiety associated with caring for a newborn. Overall, this study provides an innovative solution that can help parents monitor their child's wellness and development, ultimately enhancing their well-being. The proposed solution exemplifies the potential of design thinking and collaboration between academia and industry to address real-world challenges and improve people's lives.

Keywords: infant wellness; design thinking; crying behaviour; monitoring device; parental stress

#139: Sustainability and vernacular architecture in the Maldives: a study of local knowledge and building practices for sustainable urban development

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The Maldives, situated in the Indian Ocean, consists of 1,192 small, low-lying islands that are clustered into 26 atolls, spanning over 820 km, and covering an area of more than 90,000 square km. However, the country's total land area is less than 300km2, making it the smallest country in Asia in terms of both land area and population. The Maldives is facing various environmental challenges due to its location and geography, including rising sea levels, coastal erosion, and coral reef degradation, which are exacerbated by climate change. These issues can have a significant impact on the country's economy, environment, and society. By adopting sustainable practices and policies, the Maldives can work towards mitigating the negative impacts of these environmental challenges. Sustainable urban planning and architecture can help reduce the vulnerability of the Maldives to natural hazards such as flooding and storms, by designing buildings and infrastructure that are more resilient to these challenges. Overall, adopting sustainable practices can help the Maldives address the environmental challenges it faces while promoting economic and social development. Vernacular architecture refers to the traditional building practices of a specific region or culture, often using locally sourced materials and techniques that are adapted to the local climate and environment. The Maldives, being an island nation, has a rich history of vernacular architecture that has evolved over centuries, in response to the unique challenges and opportunities presented by the local environment. This research topic aims to investigate the potential of vernacular architecture as a means of achieving sustainable urban development in the Maldives. By studying the local knowledge and building practices of the Maldivian people, the research can identify ways in which traditional techniques and materials can be adapted and integrated into modern urban design and planning strategies. Overall, this research has the potential to contribute to a better understanding of the relationship between culture, tradition, and sustainability in urban development, and to inform the development of more sustainable and resilient cities in the Maldives and beyond.

Keywords: Maldives; vernacular; sustainability; resilient; urban development

#140: Analysis of thermal comfort in a university building during the hot/dry season in Kebbi State, Nigeria

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This study examines overheating and thermal comfort in an Architectural studio complex at Federal University Birnin Kebbi, Nigeria. Thermal comfort parameters (temperature, relative humidity, carbon dioxide, and noise levels) were analysed through instrumentation, an objective building assessment methodology using a NETATMO smart weather data logger. Data collected during the hottest month (April) in the summer aimed to understand occupants' experiences during the intense solar radiation of the hot/dry season. The assessment focused on maintaining indoor environmental quality (IEQ) for students and staff. The findings established a lower and upper of 27ºC and 32°C, respectively, as standard effective temperature (SET) necessary for attaining thermal comfort for the studio complex, as against 26ºC recommended for educational facilities. This highlights the need for sustainability measures in the indoor built environment to ensure occupants' comfort and well-being.

Keywords: thermal comfort; indoor environments quality; instrumentation; assessment; architectural design studios

#141: Exploration of simulation methodology for thermal comfort assessment of educational buildings in Nigeria

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The utilisation of computer software for building assessment has been widely accepted by professionals of the built environment globally in recent years and used as an alternative method for improving building performance and energy efficiency. This paper presents a methodology for whole building parametric simulation of a university building in Nigeria's hot/dry climatic zone, using the IESVE software suite for building performance, thermal comfort provisions and energy-saving methods. The various applications of the IESVE simulation software suite, such as Mode IT, Sun-Cast, and MacroFlo, were explored to generate the building model, solar insulation and ventilation modes, and the Apache app served as the central simulation engine that provides data navigation, input interphase and visualisation. IESVE software provides comprehensive building energy modelling, design, and compliance features. This study contributes to passive cooling techniques through simulation to minimise indoor overheating and energy consumption reduction of education buildings in pursuit of desirable interior thermal comfort conditions.

Keywords: hot/dry climate; passive cooling; IESVE software; parametric methodology

#142: Investigating thermal comfort in traditional adobe buildings in warm-humid climates: a case study of Ilorin heritage buildings in Nigeria

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As global temperatures continue to rise, the need for sustainable and energy-efficient building design is more pressing than ever. Traditional adobe buildings have been used for centuries in warm-humid climates due to their ability to regulate indoor temperatures and provide thermal comfort. The Ilorin heritage buildings in Nigeria are a testament to the sustainable building practices of traditional communities in warm-humid climates. Consequently, understanding human thermal discomfort is a significant issue in providing residents of buildings with solutions to heat stress through various cooling options. This study employs a subjective evaluation approach of the thermal comfort of traditional residential buildings in a warm, humid climate, focusing on Ilorin adobe heritage buildings as a case study. A mixed-method approach was employed to collect data on environmental and human parameters, including an objective aspect that was utilized to discuss the thermal comfort set point only and a field survey of the users' perception of thermal comfort, indoor environmental measurements, and post-occupancy evaluation through the administration of questionnaires. The questionnaire was carefully designed to understand the impact of factors that affect thermal comfort such as the indoor temperature, humidity, and subjective thermal sensation and thermal preference experienced by the occupants of the Ilorin traditional adobe residential buildings thus, this study is based on the compilation of responses from the conducted survey. The study further identifies the factors contributing to thermal discomfort in the construction of traditional buildings, including the wrong application of building materials, passive design strategies, and cultural practices. The qualitative data reveals that cultural background and social norms influence the occupants' perception of comfort. The results show the potential of traditional Adobe buildings in terms of indoor comfort provision to users, despite the prevailing warm and humid climatic conditions.

Keywords: adobe; traditional buildings; warm/humid climate; thermal sensations; thermal preference; thermal comfort

#143: Thermal insulation and flame-retardant properties of konjac glucomannan/sodium alginate aerogel for building application

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This study presents the preparation and property characterization of polysaccharide aerogel as a kind of thermal insulation and flame-retardant biomass material. For safe and sustainable thermal insulation applications in buildings, a polysaccharide aerogel with both low flammability and thermal conductivity is of great importance. Therefore, the konjac glucomannan (KGM) /sodium alginate (SA) aerogel prepared by sol-gel process and as freeze-drying method were investigated in this study. KGM was used as the skeleton material of aerogel and SA was selected due to its inherent flame-retardant properties, which easily formed a dense carbon layer barrier to prevent the fire. Results showed that the higher addition of sodium alginate resulted in a denser pore wall structure with the thickness increased and thus changed thermal conductivity. The mechanical properties were significantly enhanced by the formation of hydrogen bonding interactions between KGM and SA. Finally, the KGM/SA aerogel with the optimized formula had a minimum heat release of 30.66 W/g, mechanical properties of 313.40±1.10 kPa, density of 0.052 g/cm^3, porosity of 91.97±0.11%, and thermal conductivity of 0.0465 W/(mK). These results prove that the KGM/SA aerogel had excellent flame-retardant properties as well as high mechanical properties and good thermal insulation properties, which showed potential applications in building fire protection and thermal insulation.

Keywords: biomass aerogel; thermal insulation; flame retardancy; building application; sustainable development

#144: Technology readiness level assessment on digital technologies for energy efficiency

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Digitalization offers the potential to increase through new/developed technologies that can gather and analyse datasets then use it to improve or change the physical behaviour of indoor or outdoor environments either automatically or through human intervention. Technologies are evaluated and compared based on the nine parameters on the TRL. The Technology Readiness Level (TRL) assessment is based on the type and size of the entity developing the technologies. This study presented an approach to measuring TRL on digital technologies related to building energy efficiency. An expert survey assessed the technology readiness level in buildings energy efficiency digital technologies. This paper contributes to the widening and systematizing of knowledge on the maturity and understanding digital technologies related to energy efficiency. This study aims to inform researcher, user, and industry to support energy efficiency technology development focusing on digital technologies.

Keywords: technology readiness level; energy efficiency; digital technologies; sustainable buildings

#145: Increasing the energy efficiency with an intelligent light-management photovoltaic greenhouse

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Greenhouses are crucial facilities for agricultural production. The efficiency of solar energy utilization can be enhanced by integrating photovoltaic panels (PV panels) into greenhouses as a type of agricultural photovoltaic (APV) system. An Intelligent Light-Management Photovoltaic Greenhouse (LMPG) system is proposed to overcome the shortcoming with low solar energy utilization and uneven solar irradiation distribution. This system consists of flexible PV panels, even-sunlight plates (ES plates) and light-emitting diodes (LED) luminaires. The core principle of the LMPG is “wavelength conversion and time transfer”, which can improve the lighting condition for crops in a whole day. In an actual planting experiment of lettuce and pepper, the average fresh weight of the lettuce under PV panels with supplemental lighting was 98.1% of that under normal plastic film, and the average fresh weight of the pepper under PV panels with supplemental lighting was 30.2% higher than that under normal plastic film.

Keywords: greenhouse; photovoltaic; even-sunlight plate; photosynthesis; LED

#146: Assessment of indoor thermal comfort with respect to building materials in low-income housing typology: a case of Trivandrum, Kerala

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Demand for housing and rapid urbanisation has led to higher energy consumption in the building sector and a larger percentage is contributed by the housing sector, the population using affordable housing is higher compared to other developed countries (MOUHA, 2013). The occupants tend to achieve the desired level of thermal comfort by personal adjustments and mechanical means. Using energy intensive methods for comfort is not feasible for a country, like India, with a low energy economy. This study analyses the indoor thermal comfort in low-income housing with respect to the building materials and construction technology used. Two typologies of housing were identified - a row housing constructed using conventional materials, with wall thickness of 15cm and a vertical stacking multi dwelling constructed using Laurie Baker's sustainable construction Technology, with wall thickness of 23cm. The first section of the study explores the current scenario of housing based on a thermal comfort field study to understand the current scenario by questionnaire survey and onsite measurements (following ASHRAE class II protocol) and a detailed analysis of the results from the computed data. The second part of the study is software simulation of the existing case of row house and then with changing the material used to that of vertical stacking house and analysing the results to understand the improvement in indoor thermal comfort. To evaluate the impact of choice of building materials used from field monitoring, an adaptive comfort model of thermal comfort is generated, and neutral temperature is calculated from PMV and PPD obtained. The adaptive comfort ranges obtained for both housing were too warm than the acceptable ranges and the PMV values in row housing are hot, while that in vertical stacking is slightly warm to warm. Compared with the IMAC model, the neutral temperature obtained in vertical stacking housing (28°C) is within the acceptable range, whereas in row housing (28.8°C) is greater than the upper limit range of neutral temperature under the IMAC model. From the results, it can be concluded that building material with higher thermal mass can cause a significant reduction in indoor temperatures and PMV thus improving indoor thermal comfort. This concludes that one of the major causes of the difference in results in the two typologies is the building materials and construction technology used, and the design approach. Thus indoor thermal comfort in low-income housing can be improved with respect to building materials and construction technology used, without breaking the concern of cost-effectiveness in affordability, and also contribute to energy efficiency.

Keywords: thermal comfort; EWS housing; sustainable building materials; neutral temperature; adaptive comfort

#147: Thermal insulation and flame retardancy properties of polysaccharide-based composite aerogels

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This study introduces the preparation and performance characterization of polysaccharide-based composite aerogels as sustainable thermal insulation and flame retardancy materials. Two polysaccharides, konjac glucomannan and starch, combined with inorganic silica microspheres, were chosen as raw materials, to prepare polysaccharide-based composite aerogels with excellent thermal insulation and flame retardancy properties by sol-gel and freeze-drying methods. The study showed that the interaction between konjac glucomannan and starch forms the network skeleton structure of aerogels, and the addition of starch can effectively reduce the number of open pores on the aerogels pore wall; Meanwhile, the silica microspheres can attach to the pore wall of aerogels, causing the pore wall to be thicker and the pore diameter to be decreased, increasing the closed pore structure and preventing heat transfer, thus reducing the thermal conductivity of aerogels. Silica as a non-combustible inorganic material, starch will adhere to the aerogels surface after the initial combustion to prevent oxygen, thus realizing the effect of flame retardant. The experimental data demonstrated that the optimal polysaccharide-based composite aerogels density was 0.21 g/cm3, with the thermal conductivity of 0.038 W/m K and the limiting oxygen index of 27.2%. Compared with the conventional petroleum-based materials PU and EPS, the thermal conductivity was reduced by 20.8% and 26.5%, and the limiting oxygen index were improved by 32.6% and 60%, respectively. These data indicate that the polysaccharide-based composite aerogel already has good thermal insulation and flame retardancy properties.

Keywords: aerogels; polysaccharide; thermal insulation; flame retardant

#148: Performance simulation research of the novel PVT-PCM-GSHP system in different climate zones

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The utilization of renewable energy in buildings has become an important means to solve the problem of building energy consumption. By coupling the photovoltaic/thermal (PV/T) system with ground source heat pump (GSHP) system, energy complementarity can be realized and system performance can be improved. However, most investigated PV/T-GSHP systems before were designed for large commercial buildings thus leading to high investment. In this study, phase change material (PCM) was coupled into the composite system to improve the heat storage capacity and reduce the operating temperature of solar cells. The composite system was designed for a typical two-storey residential building and meet the design requirements of the local climate. Moreover, the model of this novel PVT-PCM-GSHP system was built in TRNSYS software to analyze its operating performance under eight climate conditions. The PCM tank model in TRNSYS was macro-encapsulated as a component. At the same time, six operation modes were designed to reduce its operational energy consumption. In Rome, for example, the system increased the average COP of heat pump to 5.6 and the renewable power fraction (RPF) to 100% as well as in Berlin. In the hot areas like Singapore, Bangkok or Doha, the average soil temperature decreased by about 1 to 2 degrees Celsius throughout the year. Compared with the traditional PVT-GSHP, the system improves the operating performance of the equipment, enhances the efficiency of solar cells, and realizes the triple supply of heating, cooling and electricity generation. This study provides a new solution to the building efficiency which can be a reference in the future.

Keywords: renewable energy; PVT-PCM-GSHP system; performance simulation; climate zones; building efficiency

#149: Theoretical and experimental investigation of a novel PCM heat exchange/storage unit for a micro-channel heat pipe PV/T system

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One effective way to reduce energy consumption is to store surplus or waste energy which cannot be used timely. In response to this approach for "carbon peaking and carbon neutrality goals", a novel PCM heat storage unit is combining into a PV/T system to improve heat utilization efficiency. This paper presents the dedicated numerical and experimental investigation of a novel heat storage/exchange unit. This unit comprises of numerous tiny phase change material (PCM) rods which makes smaller heat transfer distances within the PCM block, thus creating larger contact area between the passing water and PCM particles than the traditional PCM-wall-based and PCM-full-filled heat exchangers, leading to the faster melting and freezing of the PCM blocks and increased heat transfer capacity. A numerical model was developed to simulate the temperature distribution, melting/freezing conditions and heat flux across the water flow and PCM blocks, thus enabling the optimization of the geometrical size of the unit and assessment of its thermal performance. A prototype PCM heat exchange/storage unit was constructed and tested in the laboratory to examine the reliability of the numerical mode and validate its accuracy. It was found that simulated and experimental results are in good agreement, with an average discrepancy of around 5.5%. This close agreement provides confidence in our simulation to inform the future design and optimization of appropriate heat exchanger/storage units and assess their performance for solar and other thermal applications. It is shown that the PCM tank used here can store up to 8.6 kWh and provide continuous hot water for 2 hours.

Keywords: solar energy; PCM tank; PCM tube; energy storage; energy release; latent heat

#150: Performance evaluation test for ground source heat pump system (GSHP) equipping hybrid pile foundations

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Hybrid pile foundation can exchange heat with ground formations for a ground source heat pump (GSHP) system by composing its main reinforcements with steel pipes, which have annular space for circulating the working fluid. This study experimentally evaluated the practical applicability of hybrid pile foundations, which were connected to the GSHP system for commercial office. Four hybrid pile foundations were installed, which can be classified into large and small diameter cast-in-place piles. A series of thermal performance tests (TPTs) was conducted in cooling operation to calculate heat exchange capacities of installed hybrid pile foundations. Then, a 3 RT GSHP system was designed and installed in the commercial office, considering the results of TPTs. Finally, coefficient of performance and entering water temperature of the GSHP system were monitored in various operation conditions for seven days. As a result, the 3 RT GSHP system was stably operated regardless of indoor temperature when all the hybrid pile foundations in the site were connected to the GSHP system.

Keywords: hybrid pile foundation; ground source heat pump system; steel pipe; thermal performance test; coefficient of performance

#151: A multi-criteria decision analysis (MCDA) for sustainable energy supplies in Sub-Saharan Africa

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Energy is crucial for reducing poverty, according to the United Nations Declaration on the Right to Development, which established the right to development as a universal and inalienable right. Energy security has been deemed essential for social, cultural, and economic development in complex societies. Globally, there has been a drive toward renewable energy sources due to the increasing demand for energy and the detrimental impacts of fossil fuels on the environment and human health. Millions of people in Sub-Saharan Africa lack access to electricity due to the cost of generating and transmission of electricity to rural and remote areas, making it difficult for the region to meet its power demands. A substantial amount of renewable energy potential exists in the area and utilizing it could aid in sustainable growth and the eradication of poverty. In this study, a Multi-Criteria Decision Analysis (MCDA) of energy sources in Sub-Saharan Africa with emphases on Ghana and Nigeria was carried out. Various criteria, such as use of technology, Socio-economic factors, Climate change/environmental factors, economics factor, strategic significance, and policy factors were identified and weighed, to evaluate and compare renewable energy sources with Fossil fuel and nuclear energy. Data on the performance of each energy source with respect to the set criterion was collected from various sources such as literature reviews, field surveys, and expert consultations. The data collected was used to score each energy source on each criterion, and sensitivity analysis was conducted to test the robustness of the results. The study found that among the energy sources, renewable energy was the most promising energy source in Sub-Saharan Africa. The result of this study provides decision-makers with access to useful information that will help them make decisions that will encourage sustainable development and lessen the reliance on fossil fuels in the area.

Keywords: renewable energy; multi-criteria decision analysis; sustainable energy; Sub-Saharan Africa; fossil fuel; nuclear energy

#152: Solar PV power output estimation through numerical weather prediction and neighbouring area meteorological data assessment

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Solar photovoltaic (PV) energy sources have shown promising impacts on fulfilling the energy demand as well as keeping the environment clean. One of the major challenges of integration of Solar PV energy sources on the power grid is the intermittency. Accurate prediction of PV power output from solar PV stations helps greatly in the optimization of overall power generation of the grid from the generation point of view, which will eventually minimize the use of fossil fuel. There are several machine learning techniques that can estimate solar PV power output using meteorological data and past power output data, among which Long Short-Term Memory (LSTM) provides excellent results. Meteorological data can be obtained from numerical weather prediction (NWP) models as well as local measurements. NWP models are expected to incur some more errors than local measurements in the estimation of PV power output. Moreover, the weather conditions of neighbouring areas are related, and this information can be utilized in the estimation. In this paper, the prediction of solar PV power output along with the error propagation from NWP to the estimation has been investigated using LSTM. Furthermore, the effect of meteorological data from the neighbouring areas on the estimation of solar PV power output has been explored with the help of LSTM. The results show that there is a considerable improvement in Mean Absolute Error when predicted with local meteorological measurements, although NWP data can predict the output well. However, the effect of meteorological data from the neighbouring areas did not affect the results much, which can be further investigated with higher distances of the solar PV stations.

Keywords: solar PV power prediction; machine learning; LSTM; numerical weather prediction; locally measured weather data; neighbouring area weather

#153: Storage and distribution warehouses: a neglected building type in natural ventilation design

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Covid-19 and Brexit accelerated the move to an e-commerce economy in the UK. The issue with this is that for every 1 billion pounds spent online, a further 750,000 square feet of warehouse space is required. Just one average-sized warehouse today consumes as much electricity as 400 British households. The energy consumption of the fast-growing warehouse sector poses a mammoth problem, made worse by outdated building regulation, and a lack of understanding of how these buildings perform. It is widely understood amongst building engineers that the primary solution to reducing energy consumption of any building is to incorporate a level of natural ventilation, meaning little to no use of fans and therefore eradicating the associated electricity consumption. Warehouses represent a neglected building type in ventilation design guidance and regulation as using benchmarks for required fresh air per person does not serve such a space with a large volume compared to number of occupants. This paper looks at one of the primary driving forces of ventilation, wind, and how a typical storage and distribution warehouse performs under different wind speeds and wind angles. Using lab-scale wind tunnel data to verify a computational fluid dynamics model of a case study warehouse, the results close the gap in understanding of whether cross-ventilation is a viable strategy for large shed buildings. The results indicate that positioning inlet and outlet ventilation openings on opposite facades across the length of a standard-shaped warehouse can provide a consistent level of ventilation not just for fresh air purposes, but also to tackle the key issues of stratification in tall spaces and pressure-balancing with the frequently open large rolling bay doors. The future of the built environment is ever-changing as society evolves, and the research in this paper can help inform new and improved building regulation for these unique, large spaces to highlight that ventilation design guidance in national and international standards is incomplete.

Keywords: warehouses; cross-ventilation; ventilation; wind tunnel; computational fluid dynamics; stratification; energy consumption

#154: Quantification of environmental benefits of crop residues pyrolysis for carbon sequestration in Northern India

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Biochar has been considered a competent tool for climate change mitigation due to its immense potential for carbon sequestration in soil. Biochar application in the agricultural fields has also boosted agro-production and improved soil health. The current study quantifies the environmental benefits of rice straw (RS) and wheat straw (WS) derived biochar applications in agricultural fields in Northern India. It was estimated that Punjab & Haryana produces 52.2 MT RS & WS annually, of which 22.3 MT is burned in-situ. RS holds a 41% share in the gross residues and a 71% share of the in-situ burnt residues. In-situ burning of RS & WS has been considered a harmful residue management practice as it releases approximately 29 MT of pollutants, inducing a 41 MT CO_2e environmental footprint. In-situ burned RS & WS can produce around 8.8 MT of biochar. Biochar production would consume 5.8 TWh of electricity, whereas pyrolysis volatiles has 12.8 TWh electricity generation potential. Biochar production from coal-based electricity and pyrolysis volatile (pyrolysis gas & bio-oil) combustion would produce 13.9±0.4 MT CO_2e emission, whereas 12.5±0.8 MT CO_2e carbon credit could be earned from coal replacement. Transportation, material handling, biochar spreading, and others would impart a 1.9±0.2 MT CO_2e environmental footprint. Biochar application in agricultural fields has the potential to sequester 11.6±0.3 MT CO_2e carbon in the soil. 31.2±0.8 MT CO_2e carbon could also be sequestrated due to enhanced rice & wheat yield and reduced soil organic carbon mineralization. Additionally, biochar in the agricultural fields can reduce the NPK fertilizer consumption by 24,516±2,042 T, N_2O emissions by 4,488±1,541 T and CH_4 emissions by 0.32±0.06 MT, whereas CO_2 emissions increase by 0.2±0.1 MT. The overall environmental footprint of the agricultural system in Northern India might be reduced by 69.3±7.7 MT CO_2e by the biochar conversion of RS & WS and its use in soil for carbon sequestration. The current study's findings will contribute to creating a sustainable and environment-friendly RS & WS management system in the nation.

Keywords: biochar; residue valorisation; pyrolysis; carbon sequestration; renewable energy

#155: Assessment of horticulture waste derived biochar for electricity generation: a case study of New Delhi

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Safe disposal of horticulture waste in metropolitan areas is a significant challenge in India. Biochar conversion of horticulture waste biomass and its application for electricity generation could be a sustainable approach toward the safe disposal and clean energy supply, reducing dependence on fossil fuels. The present research aimed at biochar conversion of horticulture waste biomass through slow pyrolysis at 300, 400, 500 & 600ºC and study its suitability for cofiring. It was observed that biochar yield decreased from 65.0% to 35.6% on increasing pyrolysis temperature from 300ºC to 600 oC, while pyrolysis gas & bio-oil yield increased from 13.4% to 24.2%, & 21.6% to 40.2%, respectively. Biochar ultimate analysis showed that C, H, & N content varied between 52.2 - 69.3%, 2.9 - 5.5%, & 2.2 - 3.4%, respectively. Biochar proximate analysis showed that volatile matter decreased from 42.7% to 14.6% on increasing temperature from 300ºC to 600ºC, while ash content increased from 10.3% to 21.5%. Fuel characteristics calorific value and fuel ratio increased from 21.7 to 28.3 MJ/kg and 1.10 to 4.35 in the same temperature zone. Principal component analysis was applied to study biochar suitability for cofiring. It was determined that biochar produced at 500ºC from horticulture waste was most suitable for cofiring. About 36,500 tons of horticulture waste is annually produced in Delhi, having 14,600 tons of biochar potential. Electrical equivalence of volatile matters obtained from horticulture waste pyrolysis was considered for process heating to decrease energy load for biochar conversion. It was estimated that about 35,107.8 tons of coal could be replaced by horticulture waste-derived biochar. The proposed pathway of horticulture waste-derived biochar cofiring would significantly reduce 308.9 tons of PM (PM2.5 & PM10), 149.2 tons of SO2, 201.9 tons of NOx, 114.1 tons of CO, 7.3 tons of VOC and 0.08 MT of CO_2 emissions during electricity generation. The results of the present study find its twin significance in horticulture waste management and reducing dependency on fossil fuels for electricity generation.

Keywords: municipal solid waste biomass; pyrolysis; biochar; energy potential; waste valorisation

#156: Unlocking the potential of floating solar farms: a study of comparison of potential in the UK and Malaysia

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Floating solar is a type of solar photovoltaic (PV) system that is installed on water bodies such as lakes, reservoirs, and oceans. The potential for floating solar depends on a variety of factors, including the availability of water bodies, the intensity of sunlight, and the regulatory environment. In the UK, floating solar projects can be built on a large number of water bodies, including reservoirs, lakes, and other inland water bodies of UK and Malaysia. However, due to the UK's northern latitude, the region receives lower levels of solar irradiation compared to Malaysia is located closer to the equator and therefore, experiences higher levels of solar irradiation. The study aims to provide insights into the feasibility and viability of floating solar projects in these two locations, taking into account the unique characteristics and challenges of each country. By comparing and contrasting the potential for floating solar in the UK and Malaysia, the paper seeks to contribute to the development of sustainable and efficient renewable energy solutions that can help address the global energy and environmental challenges. The analysis is based on a comprehensive review of literature, satellite data, and case studies of existing floating solar installations in the two countries. The study gathers data on solar irradiation levels, water body characteristics (size, depth, temperature, etc.), wind speed, rainfall, water evaporation rate, regulatory framework and other relevant parameters using simulation tool. Based on the simulation results, of both locations, the relative potential of floating solar in the UK and Malaysia or compared. The findings of this study can provide useful information for policymakers, energy planners, and investors in determining the most suitable locations for floating solar projects.

Keywords: bodies; viability; solar irradiation; sustainability; policy framework

#157: Solar water pumping for agrivoltaics: a comparative study of performance in different climates

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Agrivoltaics is an innovative approach where agricultural crops are grown in the same area as solar panels also known as photovoltaic systems. The combination of solar water pumping and agrivoltaics has led to the development of a new generation of irrigation systems that are highly sustainable and efficient. In different climatic zones, solar water pumping can be used to irrigate crops, feed livestock, and provide drinking water for rural communities. This paper deals with identifying the best suitable location for solar water pumping systems across five climatic zones i.e. tropical climate, dry climate, temperate climate, continental climate and polar climate. The SISIFO tool has been used to simulate the solar water pumping performance for the various climatic conditions. The various parameter like site details, climate data, type of PV modules, converters are used as input data to evaluate the energy parameters (solar energy in DC and AC form), hydraulic parameters (volume of water pumped), loss parameters (capture and system losses) and efficiency parameters (build of system). The data inputs are obtained from five different climatic locations in different continent of the world. A comparative analysis is performed for the five climatic zone based on the obtained result. Based on the technical parameter results the sites are ranked and the best location for solar water pumping system for agrivoltaics application has been identified This can greatly assist policymakers in selecting the optimal solar pumping station for their region, taking into account their specific climatic conditions. In addition, the study also highlighted the importance of considering various factors when selecting a solar pumping station for agrivoltaics.

Keywords: solar water pumping system; SISIFO; agriculture; parameters

#158: Kinetic study on the reaction of ammonium carbamate for low-grade heat utilization

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The reversible decomposition of ammonium carbamate is accompanied by significant endothermic/ exothermic effects, which is promising when applied in the thermal management, storage and utilization of low-grade heat. The reaction kinetic characteristics are the basis for the technology development and application of ammonium carbamate. However, there are few kinetic studies on the reaction of ammonium carbamate. In this study, the kinetic characteristics of the thermal decomposition of ammonium carbamate were systematically investigated by thermogravimetric analysis method. The decomposition kinetic properties of ammonium carbamate under different temperature modes (isothermal and non-isothermal) were obtained. The results of isothermal model experiments indicated that the decomposition reaction of ammonium carbamate belongs to the decelerating reaction type, which can give guidance for the selection of reaction mechanism. The variation of activation energy with reaction progress was determined using is conversional method. The results showed that the decomposition of ammonium carbamate is a two-step reaction controlled by a single step, so the reaction process could be described by a single-step reaction kinetic equation. The reaction kinetic parameters (apparent activation energy and pre-exponential factor) and possible reaction mechanism models were determined. The kinetic equations for the decomposition reaction of ammonium carbamate were established, based on which a model that can describe the reaction process of ammonium carbamate in reactors was developed. The influence of the working parameters on the results of kinetic studies was analysed. The effects of key operating parameters (temperature and pressure) on the ammonium carbamate reaction process were discussed. The results of this study can provide a basis for the optimization of reactor structure design and system operation parameters determination for the low-grade heat management and utilization applications based on ammonium carbamate.

Keywords: ammonium carbamate; reversible reaction; kinetics study; thermogravimetric analysis; low-grade heat utilization

#161: Design of intelligent lighting system for plants with high uniformity

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As the world's population continues to increase and land resources dwindle, traditional agricultural farming models are no longer able to meet the growing demand for agricultural products. Plant factories have been developed to address this issue. However, most plant light sources in plant factories have problems such as poor light uniformity and a single mode of light supplementation. To address these problems, this paper presents an intelligent light supplementation system with high uniformity and capable of spectral adjustment at different plant growth stages. The system uses an isotropic LED light source array with higher lighting uniformity and an STM32 microcontroller as the core for overall system design. The system can monitor ambient temperature and light intensity, change PWM output according to system preset values, and control the brightness of red and white LEDs by changing the current of the LED to achieve spectral adjustment. The test results show that the light uniformity of the light source reached 91.67% and the light source system was able to make precise changes according to the set light formula. This intelligent light supplementation system can be well applied in the field of plant growth lighting.

Keywords: plant LED light source; light quantum flux density; light uniformity

#162: Effect of light stress on designed algae-bacteria model for amelioration of fuel worthy lipids

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Research on ecologically efficient technologies and sustainable products has highlighted the microalgae as the most promising resource. Microalgae can produce variety of natural products by simply modulating their metabolic pathway to enhance nutri-cosmeceutical properties along with biofuels. Environmental stresses such as high light intensities, high salinity, and nutrient depletion have been proved to be efficient strategies for enhanced lipid accumulation in microalgae. However, these strategies are not economically efficient when operated alone for large scale production due to the constraints in higher biomass production. Therefore, there is need to find an alternative strategy which can be applied in combination with one of the stresses so that high lipid content along with high biomass production and low cost can be achieved at the same time. Microalgae-bacteria consortia system represents one of the most ecologically efficient system which may produce higher biomass. The phycospheric interactions in designed consortium includes the exchange of essential nutrients like carbon, nitrogen, phosphorus, vitamin B12 etc., needed for growth and reproduction of microalgae. Phycosphere of microalgae is a pool of growth promoting as well as growth inhibiting bacteria. So, community designing became crucial parameter to develop synthetic ecology model. This study endeavoured the co-cultivation of axenic monoalgal culture with some of the isolated phycospheric bacteria to identify the growth promoting bacteria (PGPB) and development of synthetic ecology model for better biomass yield. In addition, different light intensities will be used simultaneously for enhanced lipid induction for biofuel production. Our research outcome suggests that with the addition of selected specific growth promoting bacteria of native phycosphere the biomass productivity increased by 1.7-fold when compared to control axenic monoalgal culture at 28.38μmol m−2 s−1 but no major increment was observed in lipid productivity. In high light intensity of about 100 μmol m−2 s−1 the biomass productivity improved along with enhanced lipid productivity of 2.4 folds when compared to the control conditions.

Keywords: biofuel; lipid; algae-bacteria; PGPB; biomass

#163: Deep learning-based model for a real-time generation of characteristic performance maps of concentrator photovoltaic for electrically and thermally driven applications

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Concentrator Photovoltaic Technology is encountered with intense incident solar radiation, holding potential for combined electrical power generation and thermal utilization through compact, cost-effective heat sinks. However, maximizing the concentration ratio is associated with intensive cooling, resulting in low-grade heat. On the other hand, to achieve the demanded temperature of thermally driven applications, several operational and design parameters need to be harmonized, such as concentration ratio and other heat sink characteristics, to successfully obtain the dissipated heat at an acceptable grade. This can be numerically achieved by common finite volume methods (FVM) through optimization techniques or intensive parametric studies to obtain thermal, energy, and exergy-related parameters as a function of wide-range concentration ratios under different cooling techniques. Either way, a prohibited computational cost is required. To overcome that challenge, the present work develops a deep learning-based model of concentrator photovoltaic as an alternative to FVM to instantly generate characteristic performance maps of concentrator photovoltaic under a wide range of concentration ratios and heat transfer coefficients for given metrological conditions. The deep neural networks are constructed with different structures and trained with large numerical simulation datasets generated by a thermal-fluid, FVM based model. Such a model is verified for mesh independency and validated with previous works in the literature. The optimal deep neural network (DNN) structure is chosen that attains a lower mean squared error between output and target values with a regression approaching one. Such DNN is further tested by subsequent validation with other simulated FVM-based datasets showing a satisfactory agreement. The proposed deep learning model of concentrator photovoltaic facilitates the selection and design of the concentrator photovoltaic integrated with diverse cooling techniques for electrically and thermally driven applications.

Keywords: deep learning; concentrator photovoltaic; characteristics maps; energy analysis; exergy analysis; thermal utilization

#164: A study of the sustainable integration of English language in the workplace in enhancing work effectiveness: a case study of Faculty of Architecture and Planning, Thammasat University

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English is a widespread lingua franca that people from all over the world use either as their first language, second language or as a foreign language. Knowing English can help people communicate across cultures and build interpersonal relationships, which is essential in social and workplace communication. Effective interpersonal communication skills are desirable qualities in employees, and they play a significant role in constructing professional identity, building solidarity, presenting views, and facilitating collaboration and problem-solving in the workplace. A basic understanding of English language skills is crucial for semi-international office communication as well as connecting with international students at the Faculty of Architecture and Planning, Thammasat University, also known as Thammasat Design School (TDS). Currently, there are 6.57% of non-Thai staff at TDS. With this in mind, the aim of this study is to explore how to integrate English language in the workplace for enhancing work effectiveness by taking an analytical look at the common English language skills and how to use them effectively at work, and to provide the solution for overcoming language barrier of non-native speaker staff at TDS especially communication skill which is one of the important soft skills that the workforce of the future needs. The findings of this study will address how to meaningfully integrate English Language into the workplace in order to enhance work effectiveness and provide sustainable solutions for overcoming the language barriers of non-native speaking staff. The result will be useful for TDS to develop itself at the international level and to excel in accordance with international academic standards. This research will collect the data from non-Thai instructors, and Thai Academic Support Staff who have been using English language at work or dealing with documents in English at TDS. There will be a total of 30 target participants.

Keywords: sustainable development; English language; international perspective; integration; workplace

#165: Analysis of energy efficient two evaporator refrigeration system using expander-compressor enhanced subcooling

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Refrigeration systems are highly used in many applications including household, transportation, and industry. Refrigerating two different zones using single system are also preferred when two different temperature is required. Subcooling the condenser exit refrigerant is a general method to increase performance of the refrigeration system. To increase performance of the two-evaporator refrigeration system an expander-compressor enhanced subcooling method is integrated. In this system, at the condenser outlet, the refrigerant is separated into two parts: one piece expands in the expansion device to attain the required subcooling temperature, while the other half flows directly into a different heat exchanger. Then the other refrigerant then flows into the opposite expansion valve, the evaporator, and an expander-compressor booster to raise the compressor's input pressure. Effect of condensing and evaporating temperature on the performance of the system are investigated in terms of dimensionless subcooling temperature using three different low global warming refrigerants. The dimensionless subcooling temperature covers the both the evaporating and subcooling temperatures. This system can be later adjusted to phase change material integrated two evaporator refrigeration systems and battery cooling systems to increase energy efficiency.

Keywords: refrigeration; subcooling; expander-compressor; energy efficiency

#166: Utilisation of digital twins for community heat decarbonisation

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Decarbonisation of the heating sector is critical in achieving the ambitious targets for net-zero carbon emissions that have been set by many countries around the world. While heat pumps offer a promising solution to reduce carbon emissions from heating, their large-scale deployment could strain the energy system by increasing electricity demand and challenging the maximum power capabilities of the low-voltage network. Therefore, it is crucial to explore innovative solutions to manage this challenge and support the rapid deployment of heat pumps. This paper explored the potential of digital twins to support the decarbonisation of heating at a community level. A digital model of the Trent Basin housing development in Nottingham, UK was used to simulate domestic heat demands. The modelled demands were validated using real data from the houses, and multiple scenarios for deploying heat pumps were simulated to determine the impact of full heat decarbonisation on the low-voltage substation that serves the community. The research demonstrated that an unmanaged, large-scale deployment of heat pumps would likely challenge the maximum power capabilities of low-voltage substations. An issue that would be further exacerbated by the growth of other demands for electricity such as electric vehicles. The paper highlights the potential of digital twins to help mitigate this issue by supporting decision-making and the development of control strategies to help manage the demand. Areas for further research to optimise the use of these technologies in the future are also identified.

Keywords: digital twins; decarbonization; heating sector; net-zero carbon emissions; heat pumps; energy storage; low voltage network

#167: Using digital twins to investigate the need for active cooling systems in Danish public buildings

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When it comes to energy consumption in buildings, Denmark is not an exception, where the building sector contributes to around 35% of the overall energy consumption in the country, with a comparable share in greenhouse gas emissions. Traditionally, most of the energy used in Danish public buildings is devoted to satisfying the demands for heating, hot water, ventilation, lighting, and equipment. On the other hand, such buildings are rarely equipped with cooling systems, even in newly built facilities, and rely mainly on passive techniques and mechanical ventilation systems to provide good indoor thermal comfort in the summer. However, the rise in average ambient air temperatures in recent years has opened the discussion wide on the need to equip public buildings in Denmark with active cooling systems to satisfy the cooling loads of the summer months. In this work, a case study of a public teaching building is considered a case study to investigate the impact of the rise in ambient air temperatures on the overall indoor thermal comfort levels in addition to assessing the need for active cooling systems in such facilities. The case study considered is relatively modern in terms of envelope design and energy supply systems. It has no active cooling systems and relies mainly on four mechanical ventilation systems to establish indoor comfort. A digital twin of the building is developed and calibrated using actual data collected from the building. The building twin is used to predict the impacts of installing an active cooling system in the facility and the corresponding effects on energy consumption and indoor thermal comfort. On this basis, key recommendations are drawn, and suggestions for future implementations in Danish public buildings are provided.

Keywords: buildings; energy consumption; active cooling systems; energy modelling; digital twins

#168: Bioprocessing of industrial wastewater for removal of heavy metal ion by ulva lactuca seaweed biomass

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Pollution from industrial effluents is a major concern because of their toxicity and threat to human life and the environment. The discharge of industrial effluents into water bodies has sparked widespread concern due to the potential health risks associated with toxic components entering human and animal food chains. A sustainable city and eco-friendly environment can only emerge if pollution control and waste management concept is incorporated. This study aims at the removal of selected heavy metal ions from industrial wastewater using ulva lactuca seaweed biomass. A batch reactor study was carried out using one-variable at-a-time (OVAT) for the removal of selected heavy metal ions from industrial wastewater. Atomic absorption spectroscopy and Fourier Transform Infrared Spectroscopy (FTIR) were used for quantifying the heavy metal ions and adsorbent characterization, respectively. The maximum removal efficiency for cadmium, chromium, and lead is 77.78% at pH 4, 60 mins contact time, temperature 60°C, 250 mg absorbent dosage, and agitating speed of 200 rpm. Absorption behaviour was described using Langmuir and Freundlich isotherm model. Langmuir isotherm model (R2≈1) was in good agreement with the experimental data and best described the studies. Kinetics data were best modelled by a Pseudo second-order equation. The data obtained from the study would be useful to industry stakeholders for proper waste management plans.

Keywords: bioprocess; heavy metals; industrial effluent; pollution; sustainable cities

#169: Artificial intelligence for waste management and classification

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Disposal of wastes is an incisive and widespread in many developed and developing countries. It has negative effects on environment, human health, land, air, and water. A new survey about recycling done on 2,000 Americans revealed that 62 percent did not know how to recycle their waste correctly. The study aims to use artificial intelligence and robotics to classify the types of waste in order to facilitate its recycle and management. Robots will be used to classify waste outside and inside the bins in the streets and prepare it to be recycled and managed correctly. The use of AI and robotics could improve the recycling process and make it more accurate by 97%. In addition, waste will be sorted fast and as soon as it's dumped on the ground or in bins, as well as a notification will be sent when the garbage is full to be treated.

Keywords: waste on land; robots; artificial intelligence; saves the environment; recycling

#170: Numerical study of phase change material nodal arrangements in multi-directional windcatcher

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Multi-directional windcatchers (MDW) are natural ventilation systems that are appropriate for buildings with low outdoor wind conditions. MDWs fall short of attaining temperature reduction when external air temperature surpasses 35°C. This is a key challenge to their widespread adoption in hot climates. Nonetheless, integrating phase change materials (PCM) directly into the air stream of MDWs has the potential to improve their cooling performance. But the impact of PCM nodal arrangement on the cooling performance of MDWs has not been thoroughly explored and thus remains unclear. This paper aims to fill this gap by assessing distinct PCM nodal arrangements in the air stream of an MDW, with the objective of establishing the PCM nodal arrangement that maximises MDW cooling performance in hot climate buildings. A validated PCM integrated MDW model based on the outdoor condition of a typical hot climate was developed using computational fluid dynamic (CFD) software. The air temperature variation was monitored for the two alternate nodal configurations of PCM profiles in the MDW's air stream. However, the airflow resistance caused by the PCM profiles being placed directly in the MDW air streams was minimised by incorporating a wall-mounted solar fan set at a constant pressure jump of 10Pa. After running the CFD simulation for 20,000 s flow time, results showed PCM liquid fractions was between 0.18 and 0.38 for both cases. This variance in PCM melting was subject to the PCM profile location in the MDW air stream. Even though the PCM had not fully discharged at 20,000 s flow time, an average temperature reduction of 1.06 - 1.21°C was observed. Most importantly, better cooling performance was demonstrated when PCM profiles were integrated into all four air stream quadrants of the MDW rather than just one. Overall, the results show that PCM distribution and positioning influence the cooling performance of a PCM integrated MDW system. This paper contributes to the body of knowledge for MDW cooling performance studies, establishing more widespread application of MDW in hot climate buildings.

Keywords: computational fluid dynamics; cooling performance; multi-directional windcatcher; nodal arrangement; phase change material

#171: Greener aviation-carbon footprint and proposed photovoltaic energy saving solution for Heathrow T5

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Carbon emissions associated with the UK's biggest and busiest airport, Heathrow, come from various activities, including aircraft emissions, which account for about 95% of all carbon emissions related to Heathrow during the cruise and LTO phases. Therefore, the UK Committee on Climate Change (CCC) recommends that the aviation industry can limit its emissions to 2005 levels by 2050 by adopting more fuel-efficient aircraft, efficient operations, and sustainable biofuels. This level of emissions reduction is considered a proportionate contribution from aviation to meeting the UK's long-term climate change goals. This abstract proposes a PV solution for a greener aviation carbon footprint for Heathrow Terminal 5 to control CO_2 emissions. The project aims to design and integrate a PV system using perovskite silicon-based tandem solar cells to deal with the Heathrow Terminal 5 electrical load and reduce its carbon footprint. As solar cells are perceived as one of the most prominent renewable energy sources suitable for large-scale adoption in a carbon-constrained world, they can help lower dependence on energy imports while optimizing energy supply security and reducing carbon emissions. Additionally, solar cells based on hybrid organic-inorganic perovskites have high-power conversion efficiencies and low-cost fabrication methods, which can potentially raise the relative efficiency of silicon solar cells by 1.1% while being cost-effective. Therefore, tandem applications are used due to their higher PV performance, which contributes to lower total energy costs and requires less surface area for solar power. Both elements will help accelerate the transition to large-scale renewable energy use, making it the perfect proposed solution for a sustainable zero-carbon airport.

Keywords: low carbon solution for Heathrow T5; sustainable zero-carbon airport; greener aviation-carbon footprint; photovoltaic energy; hybrid organic-inorganic perovskites

#172: Development of a campus sustainability assessment tool in Jordanian universities

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Several universities and Higher education institutions worldwide have developed and implement different tools to carry out the process of assessing the campus sustainability level. They faced many challenges while they implanted the tools. Jordanian universities faced difficulties while they use some of those tools in evaluating campus sustainability. The aim of this study is to develop and test an appropriate campus sustainability assessment tool for universities and higher education institutes in Jordan. Using document analysis and case studies, a 21 normative campus assessment tools were defined. The researchers analysed all indicators and reorganized them in a new proposed tool. The preliminary indicator matrix shared with experts to identify the indicators most related to the state of sustainability in Jordanian universities and to classify the indicators based on their importance. The result of this study is a campus sustainability assessment tool for Jordanian universities that covers all aspects of sustainability from the environmental, educational, economic, social, and other aspects. The tool was validated by experts' focus group and was used to assess a Jordanian university. An adequate campus sustainability assessment tool may assist in evaluating the success of sustainable campus management and design, comparing sustainability performance among various campuses, and ultimately guiding the full-scale green campus. It is expected that this tool could be used by researchers in future to assess campuses in different regions.

Keywords: sustainability; assessment tool; campus

#173: Comparative analysis of concentrated solar power and photovoltaic in Saudi Arabia

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This study focuses on the global trend towards solar energy as a viable alternative to fossil fuels, with particular emphasis on the Kingdom of Saudi Arabia (KSA), a country endowed with abundant land area and high solar potential. Concentrated solar power (CSP) and photovoltaic (PV) technologies have emerged as the most promising approaches for converting solar energy into electricity. This study aims to assess the techno-economic feasibility of both PV and CSP technologies across the Kingdom using SAM software. The research findings indicate that Saudi Arabia offers a favorable location for solar power generation, with a relatively low levelized cost of electricity (LCOE) compared to global costs. The LCOE analysis reveals that CSP projects in Saudi Arabia have an LCOE ranging from 6.6 to 10.6¢/kWh, which is lower than the global average. Similarly, PV technology exhibits an LCOE range of 3.77 to 4.5 ¢/kWh, highlighting its cost-effectiveness. The study identifies specific regions within Saudi Arabia, particularly in the northern and north-western parts, as being very suitable for the implementation of both CSP and PV power plants. Additionally, central parts of the KSA exhibit a moderate level of solar potential. However, regions along the south-western coastal area, such as Jazan and Al Baha, may not be as economically viable for solar energy projects due to reduced solar resource availability when compared to other parts of the country.

Keywords: concentrated solar power (CSP); levelized cost of energy (LCOE); photovoltaic (PV); renewable energy

#174: Assessing the energy performance and solar energy potential of low-rise residential buildings in the Kingdom of Saudi Arabia

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The Kingdom of Saudi Arabia has experienced a significant increase in energy demand, particularly in the residential sector, due to a growing population, rapid urbanization, and industrialization over the past few decades. This has made the country one of the largest energy consumers in the Middle East. Residential buildings are the largest consumers of electricity in Saudi Arabia, accounting for more than half of the country's total electricity consumption. The high demand for electricity in residential buildings is largely due to air conditioning, which is necessary to cope with the country's hot climate. Air conditioning loads account for approximately 70% of the total electricity consumption in residential buildings. The overall electricity demand continues to increase by approximately 5–8% annually, which will contribute to oil production and consumption becoming equal in 2035. The Kingdom of Saudi Arabia has taken significant policy steps to promote energy-efficient measures and improve the sustainability of the building sector. The adoption of the Saudi energy conservation code (SBC 602) will help minimize economic costs, as indicated in the country's Vision 2030. For this reason, in line with the global sustainable development goals and following the country's Vision 2030, this study aims to evaluate the impacts of various energy-efficient measures on the energy demand of an archetypical building model in Saudi Arabia. Using a validated archetypical building baseline model, the simulations will focus on maximizing the energy efficiency of the building envelope. The proposed approach involves using computer simulations with a well-suited tool, Integrated Environmental Simulation Virtual Environment (IES-VE), to assess the thermal performance of building envelope elements across three locations in KSA by applying selective passive design strategies, such as thermal insulation, shading devices, and glazing solutions. The simulations will also consider the potential benefits of incorporating roof photovoltaic (PV) systems. Further simulations were conducted to evaluate how operational factors such as systems could be adjusted to improve energy efficiency. The study also involved simulations to determine the best-performing parameters for energy efficiency and a cost-benefit analysis to determine the economic feasibility of the proposed solutions. The present findings show that applying and combining various energy-efficient measures are responsible for reducing energy consumption by 58.2%, 61.4%, and 59.5% for Riyadh, Jeddah, and Dhahran, respectively. Based on the simulation outcomes, it has been shown that the recommended optimal strategies hold the potential to reduce peak electricity demand by almost 60%. Additionally, the study has found that carbon emissions (Co2) can be reduced by 58.1%, 61.7%, and 58.4% in comparison to a base case study building for the respective cities. Overall, by identifying optimal solutions to reduce energy consumption in the building envelope, the study suggests that promoting sustainable development and reducing the environmental impact of residential buildings can be achieved in Saudi Arabia.

Keywords: retrofit approach; energy efficiency measures; building envelope; photovoltaic systems

#175: Simulations of the different U-tube heat exchanger designs for ground source heat pump systems

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Despite the promise of abundant renewable energy resources in the world, getting the reliable design of the Vertical U-tube ground source heat exchangers (GSHE) for the heat pump in buildings is not easy and straightforward. Evaluating the performance of ground heat exchangers and identifying their energy potential is essential for achieving optimal heat pump performance. Although simulation tools are available today, numerical investigations take long computational running times, especially ideal GSHE designs requiring strong expert knowledge. In the present paper, the GSHE tubes with different fin configurations to enhance heat transfer on the performance of vertical U-tube GSHEs have been investigated numerically with Ansys Fluent software. A comprehensive validation of this methodology for the GSHEs is presented, using the different number of fin designs. The results show that the fins have a high potential to increase the heat exchanger rate, between 5-9 %, in the thermal performance of GSHEs, depending on the design and the number of fins on the GSHEs. The system design limitations and the effect of Reynolds number and tube diameter are also discussed in the study, and the feasibility of the results are also verified with the data given in the literature.

Keywords: heat pump; GSHEs; heat exchange rate

#176: Optimization of building rooftops for solar photovoltaic panels

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Utilization of rooftop space has been a major issue in residential homes for mounting of solar photovoltaic (PV) panels in the Kingdom of Saudi Arabia due to the umpteen number of obstructions for buildings located in the Kingdom of Saudi Arabia. Residential building consumes about 75% of total energy in the kingdom and with the call to shift to about half of the consumed energy to renewable, space within the building has become as problem for PV system. Hence, the 1st phase of this study was conducted to identify the obstacles on the rooftop that affect the usable area and performance of the PV solar panels. These obstacles were categorized under various factors to obtain a percentage ratio for different building types. 4 alternatives solution were proposed namely, case A (base case), Case B (rearrangement with same parapet), Case C (rearrangement with lower parapet), and case D (fly roof), this is to maximize the usable area, surveys were conducted from consumer ends to see their preference on various criteria related to PV system. A typical residential building rooftop was modelled based on three alternatives (Case A, B and C) and was analysed using ArchiCAD and PVSOL respectively to study the impact of shading on the usable area, while Case D was left out because of the obvious 100% useable area. Also, various criteria based on the identified obstacles were considered to seek an expert opinion where Multi criteria decision making assessment (MCDA) using analytical hierarchy process (AHP) where experts from the Academia, Building and PV industry were targeted. A total of 35 responses were analysed using Spicelogic AHP software resulting in a group decision based on aggregated judgement in selecting the best among the proposed systems. Result for the Shading analysis shows that Case C has the most usable area among the 3 rooftop models with least effect of shading, while final results show that case B is the most feasible from the experts' end.

Keywords: solar; photovoltaics; rooftop

#177: Technology readiness level assessment of smart cities: the case of London

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The globe is confronting intricate difficulties due to population increase, urbanization, and technological advancements that negatively impact the environment and citizens' well-being. Many local governments worldwide aspire to transform into prosperous smart cities. The concept of the "Smart City" aims to tackle the aforementioned challenges by exploring innovative and intelligent approaches to handle the intricacy of urban life and resolve multifaceted issues. These include optimizing energy consumption, managing resources efficiently, conserving the environment, enhancing safety and security, improving the quality of life, and ensuring efficient urban operations and the accessibility of diverse services.

The concept of a Smart City is a manifestation of the Internet of Things (IoT) philosophy, driven by the need to find Creative approaches to urbanization challenges. London, the focus of this research, ranks second in the top ten Internet of Things (IoT) cities in the world, according to a report by IoT Analytics. It is a pioneer city in the advancement of smart cities, with a vision that is being actively pursued through concrete actions. It hosts the highest concentration of entrepreneurial ventures globally and has initiated the Smarter London Together project, which aims to transform the city into a global leader in smart technology and innovation. One factor that sets London apart is its openly accessible and extensively recorded Smart City Strategy. London has received recognition for its performance in various smart city rankings. These include the IESE Cities in Motion Index 2022, where it ranked as the top city, and the IMD Smart City Index 2023, where it ranked sixth. Additionally, London secured the first position in the Global Power City Index 2022. The Technology Readiness Level (TRL) is an effective tool for measuring the development of a technology, graded on a scale of 1 to 9, with 9 indicating the highest level of technological maturity. This paper will employ the TRL to assess the level of maturity of the case study based on the smart city indicators discussed.

Keywords: smart city; sustainable city; TRL assessment tool; energy and environmental impacts; climate change

#178: Technology readiness level assessment of smart homes

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The ideas of "smart homes" and "smart transformation" have been developing recently, and have grown in acceptance and application, and the two new transformations will gain attention in the future. This article aims to illustrate and provide examples of how technology and sustainability can be used in homes. The first half of the article discusses the definitions of smart, smart, and sustainable homes, and raises the question of whether technology or sustainability comes first and leads the other. This question was asked to the audience in a survey. We also understand the sustainability standards we have adopted from the LEED rating system, the technology that supports smart solutions, and the qualities and criteria that smart homes must meet to be referred to as such. This will be discussed in the first section, but more about it will be said in the second. The Smart Home Classification Scheme will present “smart home technologies” as devices that provide some level of digitally linked, automated or enhanced services to building occupants. Smart homes are frequently brought up in conversations about politics and modern technology. To collect ratings, ascertain the level of technology maturity in smart homes, and ascertain the level of technology in smart homes based on the TRL rating, a standard rating methodology was used: this tool was developed by NASA to evaluate technology and determine how well it can serve people. There are levels one through nine, and each level indicates that a certain set of conditions have been met. Finally, we got to the level of technology used in smart homes and evaluated the level of the smart home by creating a chart showing the progress of each home according to the gadgets and technology inside it. To learn about the components, tools and processes required to make homes smart and sustainable, we conducted a study. The purpose of this study, which was conducted in a house at King Abdullah University of Science and Technology (KAUST), was to determine how well the technology was performing in terms of user assistance and environmental friendliness.

Keywords: technology readiness level (TRL) assessment; technology adoption technology

#179: The impact of buildings' glazing on operational carbon emissions across multiple climates

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Decarbonizing the built environment to mitigate climate change and carbon emissions is a global target with various pathways and action plans in different countries. This study aims to develop an understanding of the real impact of glazing used in building envelopes on operational carbon emissions in different climates, mainly the cold, temperate, and hot arid, by answering the main research question, "What is the impact of different glazing systems as a form of building envelopes on the operational carbon emissions of a high-rise office building across multiple climates?" The high-rise office building is modelled with four alternatives of glazing systems of different thermal transmittance (U-factor) in Open Studio/ Energy Plus to simulate the annual operational energy used and calculate the operational carbon (OC) accordingly across multiple scenarios of window-to-wall ratio (WWR). As a result, the operational carbon (OC) is analysed in relation to the glazing systems type, WWR, and the U-factor of each system. The results emphasized that operational carbon relates directly to the U-factor and WWR for different glazing systems. As the WWR or the U-factor reduces, the possibility of operational carbon reduction is raised due to the decrease in the office building's Energy Use Intensity (EUI) in different climate zones (ASHRAE 2020). An average reduction of 31% to 50% in carbon emissions of the high-rise office building can be achieved if the WWR changes from 90% to 25%. The U-factor decreases from 0.47 W/m²K to 0.19 W/m²K, based on a natural gas heating system with a carbon emissions factor of (1.084) as per the IPCC Database on GHG emission factors and an electrical-powered cooling system with a carbon factor of (3.167). However, more cutbacks in operational carbon are expected if the electricity carbon factor gradually decreases in the next 30 years to zero afterward when the electricity is assumed to become clean in 30 years.

Keywords: decarbonization; climate change; carbon emissions; glazing systems; building envelopes; operational carbon (OC); operational energy; thermal transmittance (U-factor); window-to-wall ratio (WWR); energy use intensity (EUI); clean electricity

#181: Trans-critical rotating heat pump system

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The concept of a trans-critical cycle rotating heat pump is modelled. In this, the centripetal force of rotation creates the compression pressure of the working fluid, replacing the conventional positive displacement or dynamic compressor. The rotating heat pump was conceived over five decades ago and the first know realization is a reverse Brayton cycle heat pump proven in early commercialization. In this, both the low and high temperature heat exchangers rotate, meaning the entire fluid cycle is rotating. In this work, the rotating concept is applied to a trans-critical cycle with only the compressor tube, high temperature heat exchanger, and expander are rotating, with the evaporator external to rotation. This arrangement is modelled in EES, assessing rotor radius and rpm required for the trans-critical cycle for various fluids to include natural refrigerants and modern refrigerants meeting the latest F-Gas regulation. The model is assessed over various heat pump applications; domestic heat pump, freezer system, and high temperature industrial heat pump. The modelling shows the pressures that are relatively easy to achieve with this arrangement allow the high pressures required for trans-critical cycles of not only R744, but also R600, R290, R152, and significantly, R717 Ammonia. The new possible range of trans-critical cycles offer high COP and significantly greater volumetric and specific power compared to the commercial reverse Brayton cycle rotating system.

Keywords: heat pump; trans-critical; rotating; cooling; COP

#183: Phase change materials embedded in plasters: criticalities and limitations

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Phase change materials (PCMs) have proven to be a valid strategy in case of passive energy refurbishment of the existing building stock. Over the years, in fact, researchers have investigated the possibility of their integration within different components of the building envelope, such as walls, roofs, and floors, to increase the overall building thermal inertia and thus reduce the energy demand for heating and/or cooling. Many studies were focused, either experimentally or numerically, on the optimization of the PCM location and of its thermo-physical properties to maximise their effect and thus reduce the energy demand for cooling or heating. However, in case of existing building refurbishment the amount of PCM that can be integrated is usually rather limited and their location constrained in order to avoid any design alteration of the building, which is fundamental when dealing with historic buildings, whose aesthetical preservation is of outmost importance. Nevertheless, this inevitably leads to reduced thermal storage capacity that can be added to a building component and with special regard to the addition of PCM within plasters, suitable mass ratios do not usually exceed 20%. In some circumstances, therefore, the application of PCM might seem not convenient in achieving a reduction of the energy demand, either for cooling or heating. Based on the know-how gained over the past years through both experimental and numerical investigations on granular PCMs embedded in lime-based plasters applied on exterior walls, the main limits of such application were assessed. This was done differentiating the analysis according to the building envelope properties, hence the variety of their construction period, the thickness and thermo-physical properties of their materials and the outdoor weather conditions.

Keywords: Phase Change Materials (PCM); building envelope; historical buildings

#184: Heat pump retrofit for boiler heating systems

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The latest UK legislation stating that no gas-powered boilers are to be installed after 2025 in new build homes and therefore all new homes built after 2025 will have to have an alternative heating system, such as heat pumps. However, there are 23 million homes in the UK have a gas-powered boiler to supply their central heating and hot water. According to market statistics from the 'Heating and Hot Water Industry Council' (HHIC), sales of UK domestic boilers hit almost 675,000 for the first four months of 2021 – that is a staggering 41% increase from the same time in 2020 and this trend likely to continue until 2025 deadline. Considering 15~25 years life span of these boilers for the next few decades engineers have to find a simple and cost-effective retrofit options for these existing boiler installations. Currently, conventional heat pumps available on the market can only produce 55~60°C water supply, which is far too low for existing radiators selected for 70~90°C water supply by the boiler. Hence, any existing radiators would need to be replaced with radiators either twice the size to provide the same output, or convert the system to underfloor heating options, which makes heat pump installations costly and highly disruptive as a retrofit application. Furthermore, the current heat pumps on the market require electric boost by means of having an additional electric heating element whereby this additional heater to come on when it's cold outside to provide extra help, or if you have asked the system to provide extra legionella protection in your hot water cylinder as under building regulations in the UK, hot water cylinders are expected to reach temperatures of greater than 60°C on a 'regular' basis to protect against Legionella. This paper will be extended to provide examples and design guide for cost-effective retrofit options by means of newly developed high temperature heat pumps which can provide 75~850C water supply identical to any existing oil or gas boilers as well as the possible alternative / new design options to help practising engineers or consultants developing a simple energy saving heat pump installations for both new and retrofit applications.

Keywords: heat pump; heating; boiler retrofit

#185: Thermal energy storage for under floor heating systems

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A Thermal Energy Storage (TES) may be considered as a useful tool to reduce the cooling load requirement by means of spreading daytime loads over 24-hour period utilising the naturally occurring ambient temperature difference. Phase Change Material based Thermal Energy Storage “PCM-TES” systems between +27°C and +35°C can be incorporated as part of an underfloor heating system and utilise to store excess or free energy within the floor. Later the stored energy by the “PCM_TES” can be released back to the occupied space during peak periods in order to handle the heat losses and keep the space. This technique is generally called passive heating and it may enable the charging process to take place by means of utilizing using off-peak and/or free energy via solar thermal collectors without running any mechanical / electrical or fuel driven heating source. Even if one cannot achieve the total free heating via solar thermal energy for certain part of the world by simply storing any free heating energy minimise the use of fossil fuel or any other means of heating source energy demands. As a result, the proposed PCM_TES passive heating system offers a very economical and environmentally friendly system for a free and load shifting concept over an annual cycle. PCM based heating systems has no moving parts and it offers unmatched reliability and maintenance free operation. Furthermore, PCM-TES opens new opportunities to explore heat balance for the existing and new systems, which could offer significant overall system efficiency improvements. This paper will be extended to provide examples of the current Globally applied PCM based heating applications as well as the possible alternative / new options to help practising engineers or consultants developing a simple energy saving PCM based passive cooling systems for both new and retrofit applications.

Keywords: thermal energy storage; underfloor heating; heat pump

#186: Analysis of the use of photovoltaic systems within the AGRI-PV concept in the Portuguese context

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Currently, most of the agricultural activities are powered by fossil fuels, which increases greenhouse gas (GHG) emissions and, as a consequence, climate change. Agriculture accounts for around 10% of total European Union GHG emissions and requires an increasing amount of energy, land resources and water. In this context, it is possible to address both problems with the combination of photovoltaics and plant production, often referred to as agrivoltaics (agri-pv) or agrophotovoltaic (APV) systems, providing a suitable resource-efficient solution to the persistent problem of arable lands, reduced GHG emission and energy efficiency. The present study is carried out with the objective of introducing and evaluating the potential of implementing this concept in Portuguese territory. The purpose of the study is not only to address the compatibility of energy production with food growth but also to make the farm energetically self-sufficient and to make use of the excess energy through the respective commercialization with market agents. The work aims to study the techno-economic viability of implementing an agri-pv system within a kiwifruit farm located in the north of Portugal. Three sites belonging to the same production were selected and then divided into plots that constituted different types of photovoltaic applications. The study was based on three fundamental pillars: the study of the shadow projection by the PV panels on the existing plantations and how this affected the amount of incident sunlight; the sizing and analysis of the photovoltaic systems simulated with PVsyst software in the selected areas; and finally, an economic overview on all designed systems. The results showed that combining photovoltaics with agriculture can be highly beneficial from an energetic point of view.

Keywords: agri-PV; photovoltaic; PVsyst; farm

#187: Instability analysis of the thermocline thermal energy storage system during high flow rates for solar process heating

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The thermal energy storage system is essential for solar thermal plants to improve the reliability of process heating applications. In thermocline energy storage, the filler materials were arranged randomly, and the heat transfer fluid flowed from the top of the tank. During the charging process, the heat transfer fluid transfers the energy to the filler materials, and the temperature of the filler material is raised. The difference in the temperature is formed a thin layer in the system, which can move top to bottom/bottom to top during the charging - discharging process. The present study develops a comprehensive model based on the viscous and k-ε turbulent with adiabatic boundary conditions to study the thermocline instability for modern bidisperse concrete filler material-based thermal energy systems during high-speed flow (Re=189-3000). The instability analysis identifies axial temperatures based on the Local Thermal Non-Equilibrium (LTNE) model. It is found that Re=1 provides better-discharging efficiency for nearly 5.84hrs which is highly suitable for solar process heating applications. The discharging efficiency decreases while increasing the Reynolds number from 1-3000. Based on the stability scale, the effective length of packing and timing to achieve stability is identified for H/D =4. From that result, the top layer of the thermocline tank porosity is also found, which is less than 0.3 is more suitable for ε=0.3 packed TES system.

Keywords: thermal energy storage; thermocline; instability; Reynolds number; LTNE; solar process heating

#188: Glass powder stabilized adobe, mechanical and thermal behaviour for short-term durability and low environmental impact

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The present article aims to revalorize the adobe bricks of southern Algeria; it is concerned with the effect of glass powder on its compressive strength, thermal conductivity, specific heat, and capillary absorption, as well as on its production-phase environmental impact. The adobe was substituted with percentages of 0, 5, 10, 15, and 20 of the aforementioned additive resulting, mainly, from recycling post-consumer white glass, considering two samples; newly produced adobe and recycled adobe from the old Ksar of Laghouat. The results show that the glass powder improves the mechanical and thermal properties, and durability of mud brick. The best results, both technically and environmentally, were obtained with a 5% weight content of this mineral additive. The SimaPro-based environmental impact analysis reveals that, despite the high content of glass powder (20%), adobe remains more environmentally friendly than the commonly used clay brick. This research can contribute to the rehabilitation of the old Ksar of Laghouat, which a highly advanced state of decay, endangering the safety of its inhabitants. This degradation is primarily attributable to the vulnerability of adobe to water, which is reduced by the use of glass powder.

Keywords: Ksar of Laghouat; stabilized adobe; glass powder; compressive strength; capillary absorption; thermal behaviour; production-phase environmental impact.

#189: The optimum atrium configuration for the best inside thermal comfort in hot arid zone buildings

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The built environment is quite complex and involves many interactions, even if it was limited to environmental and comfort issues, the building design issues are generally very complicated and cannot be verified by a simple use of design rules or guidelines, However, the flexibility of computer modelling and simulation can deal with this complexity, so it is necessary that simulation tools have a reliable and accurate means of predicting and analysing in detail the thermal behaviour of buildings and subsequently offering recommendations for design strategies. The interior environment of an unconditioned atrium being numerous, heating, cooling, and air movement which vary widely depending on the atrium configurations. In addition, the building envelope plays an important role in the transmission of heat between spaces, through the process of conduction, convection and radiation. These subsystems interacting with each other, a numerical thermal simulation has become a required element to complement and fill some weak points that the in-situ investigation may have. The impact of the atrium configuration on the inside thermal environment, for summers and winter periods, was the aim of the present study. A series of simulations were carried out using the Edsl TAS software in order to study the Atrium geometric factors that have a considerable impact on the interior thermal comfort, the height / width ratio (SAR Index), the glazed atrium cover ratio and the cover angle and orientation.

Keywords: atrium configuration; thermal comfort; air renewal; air stratification; SAR index; glazed roof ratio; hot and arid climate

#190: A dynamic fuzzy analytic network process approach for assessing renewable energy technologies

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Renewable energy technologies play a pivotal role in achieving sustainable development. However, selecting the most suitable technology from various alternatives can be challenging and requires an evaluation of pertinent criteria. This study presents a dynamic fuzzy analytic network process (ANP) for assessing renewable energy technologies. The proposed approach incorporates a generalized trapezoidal fuzzy number, enabling a comprehensive evaluation of economic, environmental, and social criteria. To illustrate the applicability of the proposed approach, an application is conducted.

Keywords: renewable energy technology; fuzzy ANP; trapezoidal fuzzy numbers

#191: A super-performance dew point cooler: research and application

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This presentation addresses research and applications relating to a super-performance dew point air cooler. Innovations of the cooler include complex heat and mass exchanger structure, advanced fibre materials, superior thermal-assisted pressing approach for bonding of the fibre material with dry side material, as well as intelligent control of the pump and fan. The research process covered ideas, numerical simulations, lab testing and comparisons with the commercially available technologies. The application of the dew point cooler in a number of computer and data centres are detailed, and associated energy savings, bill savings, and carbon emission reduction are analysed.

Keywords: dew point cooler; data centre; energy saving; carbon emission reduction

#192: Innovative development of photovoltaic vacuum glazing for net zero energy buildings

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The innovative development of PVVG (Photovoltaic Vacuum Glazing) shows not only its high solar power generation but also high insulation capability both for cooling load and heating load. The SHGC and U value of this innovative PVVG is 0.18 and 0.447 respectively. With low SHGC and U value, it can save both cooling energy and heating energy due to high insulation for radiation heat and transmittance heat. The laminating process is shown in this research for the future manufacturing process. The solar power generation of this PVVG is 121 W under the size of 1.1 m x 1.4 m. The heating consumption of PVVG is only 60% of normal double glazing under a chamber test. Meanwhile, the cooling load of PVVG is only 10% of normal double glazing. With high solar power generation and high energy saving of PVVG, an energy efficiency assessment of a real house applied by PVVG both in UK and Taiwan for various climate is done in this research. It shows that the conservatory applied by PVVG in Nottingham only requires 8% of traditional power while compared with normal double-glazing conservatory. As well, the conservatory applied by PVVG in Taichong, Taiwan shows net zero energy capability under the Subtropical climate due to high solar power generation and high radiation insulation.

Keywords: photovoltaic; vacuum; glazing; net zero energy; buildings; innovative

#193: Computational analysis of heat transfer in a fluidised bed thermochemical energy storage reactor

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With the rise in necessity for eliminating fossil fuel use, the application of renewable energy technology has become essential. However, the primary concern with regards to renewable energy dependence is its intermittency and reliance on uncontrollable weather conditions; this introduces the international importance of energy storage technologies. An energy storage technology of interest is thermochemical energy storage (TCES) due to its unique capability to store energy with near-zero losses, making it potentially capable for inter-seasonal storage. The primary aim of this research is to observe the effects of various boundary conditions on a simulated fluidised bed TCES reactor, which will ultimately allow for the development of an experimental rig based on this model. The application of existing research findings and material characterisation techniques has allowed for the proposition of a design concept for a novel fluidised bed TCES system. The fluidised bed TCES reactor has been modelled using computational fluid dynamics software ANSYS Fluent, with the effects on model performance of inlet velocity, fluidised bed particle diameter and inlet temperature being evaluated. The model consists of a cylindrical reactor containing calcium oxide particles; these undertake an exothermic hydration reaction to form calcium hydroxide when steam-saturated air is used to fluidise the bed. A helical pipe is also inside the reactor and is used as a working heat exchanger, with liquid water being used as a heat transfer fluid. The simulation concluded that increasing fluidised bed particle diameter would not be beneficial for further development due to the prolonged calcium oxide depletion time this causes; increasing the inlet temperature of the steam-saturated air proved advantageous due to an increased rate of reaction. However, insufficient conclusion could not be drawn on the ideal heat transfer fluid inlet velocity and therefore requires further investigation.

Keywords: thermochemical energy storage; fluidised bed; computational fluid dynamics; ANSYS fluent; heat transfer

#194: Deep learning-based building energy optimization system: a cost-effective, robust and efficient approach to reduce energy consumption and carbon emissions

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Global annual mean CO_2 concentration has increased by 50% since the start of the Industrial Revolution, from 280 ppm to 420 ppm as of April 2021. The present concentration is the highest for 14 million years. The increase has been attributed to human activity, particularly deforestation and the burning of fossil fuels. Assuming that the increase in energy consumption continues at the same rate, this value is predicted to be 550 ppm in 2050. Buildings account for 40% of the total energy consumption. The increasing demand for energy-efficient buildings has led to the development of advanced optimization systems that can reduce energy consumption and greenhouse gas emissions. In this study, we propose a deep learning-based building energy optimization system that can predict the optimal set points of lighting, heating, ventilation, and air conditioning systems, thereby reducing energy consumption while maintaining comfort levels. The proposed system is built on a deep learning architecture that uses a multi-layer neural network to predict the optimal settings for each energy consuming objects in the buildings. The model takes inputs such as weather conditions, lux levels, occupancy, and thermal properties of the building, then outputs the optimal set points for the lighting and HVAC systems. The system is trained on historical building data and can adapt to changes in building occupancy, weather, and other factors. The proposed system uses a wireless sensor network (WSN) to monitor the indoor environment and collect data on natural/artificial lighting, temperature, humidity, and occupancy. The collected data is transmitted to an intelligent control module that uses a deep learning model to predict the optimal set points for the energy consuming objects. The system also uses a wireless actuator network (WAN) to control the building systems. To evaluate the performance of the proposed system, we conducted a series of experiments in a controlled laboratory environment. We compared the energy consumption of the building with and without the proposed system, and also compared it with other existing optimization systems. The results show that the proposed system achieved a significant reduction in energy consumption while maintaining occupant comfort levels. Furthermore, we conducted a sensitivity analysis to understand the impact of various inputs on the system's performance. The analysis revealed that weather conditions and occupancy are the most significant factors that affect the performance of the system. We also evaluated the system's robustness to changes in the building environment. We introduced various perturbations such as changes in occupancy levels, thermal properties, and weather conditions, and observed the system's response. The results showed that the system could adapt to changes in the building environment and continue to provide optimal set points for lighting and HVAC systems as well as home/office appliances. Finally, we compared the computational efficiency of the proposed system with other existing optimization systems. The initial tests results show that the proposed system is computationally efficient and can provide real-time optimization of energy consuming building systems. In conclusion, this study proposes a deep learning-based building energy optimization system that can significantly reduce energy consumption while maintaining occupant comfort levels. The system is robust and can adapt to changes in the building environment, and it is also computationally efficient, making it suitable for real-time optimization of HVAC systems. The proposed system has the potential to make a significant contribution towards achieving energy-efficient buildings and reducing greenhouse gas emissions.

Keywords: artificial intelligence; deep learning; energy optimization; wireless sensor networks; smart buildings

#195: Optimizing building orientation for energy-efficient residential buildings in various cities across Afghanistan

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Residential buildings play a substantial role in the overall energy consumption of the building and construction sector worldwide, with space heating and cooling systems making notable contributions to this consumption. Despite Afghanistan having one of the lowest energy usage rates globally and relying heavily on imported energy, residential buildings consume a significant amount of energy, leading to environmental issues and energy crises in major cities. In light of recent efforts to redevelop the built environment from the ground up, it is crucial to identify energy-efficient design parameters for buildings that can endure for decades, contributing to creating sustainable cities. Building orientation is a critical architectural design parameter that significantly influences energy consumption. Since the optimal orientation varies based on geographical location and climatic conditions, this study examines the effects of building orientation on the energy performance of buildings in nine diverse cities across Afghanistan. Energy simulations were conducted using the BEoptTM software for buildings in all nine cities, considering sixteen cardinal, intercardinal, and secondary intercardinal directions. The results indicate that in Kabul, Mazar-e-Sharif, Herat, Jalalabad, and Kandahar, a south orientation yields the best energy performance. In Bamiyan, Ghazni, and Chakhcharan, the optimal orientation is south-southeast, while in Farah, the north orientation proves to be the most energy efficient. The study's findings highlight that optimizing building orientation can result in energy savings ranging from 20% to 30.5%, depending on the specific location. These insights are valuable for architects and engineers involved in designing sustainable buildings in Afghanistan and contribute significantly to the development of sustainable urban areas within the country.

Keywords: building orientation; energy consumption; Kabul; passive house; sustainable building

#196: Investigation of the key barriers of energy efficiency retrofitting UK social houses

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The UK has committed to reaching net zero carbon emissions by 2050, however, it has the oldest housing stock in Europe, which contributes to about 45% of the country's carbon emissions. To achieve this target, energy efficiency retrofitting is necessary. This measure has to be particularly considered for social houses, as the tenants are not able to afford retrofitting themselves, and the landlords are not incentivised to invest in retrofitting. Social houses need a very different approach, compared to the rest of the UK's housing stock, because of the peculiarity of their tenants, their age and poor-quality materials they were built with. The study proposes several strategies to address the identified barriers, including the implementation of an effective funding scheme covering a minimum cost of £47,500 per house, with the government providing at least 70-80% of the total cost and the remaining 20-30% integrated by social landlords. Additionally, regulations should be in place to ensure funding accessibility and proper coordination of contractors. The study also emphasizes the importance of monitoring the performance of social houses before retrofitting and optimizing their energy management through education and smart meters. By implementing these strategies, social tenants can benefit from lower energy bills, improved thermal comfort, and reduced fuel poverty rates, while also contributing to the decarbonization of the housing sector towards the net-zero target.

Keywords: social houses; retrofitting; decarbonisation; barriers of retrofitting

#197: Flax fibre reinforced concrete for sustainable building material

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Industries are in high demand to produce materials from natural resources such as natural fibre in order to reduce the impact of climate change, promote economic growth and reduce energy consumption. This work was performed to examine the effect of incorporating flax fibre in concrete at different fibre content, in terms of compressive strength, split tensile strength and compressive modulus of elasticity. Flax fibre reinforced concretes with different percentages of fibres were casted in-house, followed by mechanical testing at 28 days of the age of the concrete. Flax fibre reinforced concrete manifested notable improvement in the compressive strength and modulus of elasticity up to 1% of fibre by weight of concrete. Flax fibre reinforced concrete with 1% fibre provided maximum mechanical performance in terms of compressive strength, split tensile strength and modulus of elasticity of 30.30 MPa, 2.67 MPa and 26.25 GPa, respectively compared to other fibre content tested. Incorporating flax fibre in concrete provides good mechanical performance that can be used as a sustainable construction material for buildings.

Keywords: flax fibre; natural fibre reinforced concrete; mechanical properties; natural fibre

#198: Evaluating the impact of locally sourced building materials on indoor comfort and building energy consumption: an experimental and numerical approach

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A sizeable component of the air conditioning load in buildings is caused by solar thermal gains. Solar thermal gain is heavily influenced by the building geometry, fenestration ratio and building materials. This study compares the solar thermal gain and air conditioning load of a proposed building design based on the locally sourced building materials with the current conventional building under the climatic conditions of Jos, Nigeria, using a combined experimental and computational method using TRNSYS software. According to the findings of this study, the proposed design building's annual average solar thermal gains are lower compared to, the reference building's average solar heat gains. The study case building's decreased solar heat gain is mostly attributable to the somewhat lower temperature of the building zones because of the lower thermal conductivity of the locally source building materials and lower fenestration ratio (ratio external opening area to the area of the external walls). This result shows that the proposed building design adjusts to the local climate better than the standard conventional construction in Jos to maintain a suitable temperature within the building. This finding means that the air-conditioning electrical energy consumption per volume of the proposed building design will be lower than that of a conventional building design.

Keywords: solar heat gain; building zone; cooling energy; air conditioning; zone temperature

#199: Performance of multiphase anaerobic hybrid reactor for the treatment of biopesticide wastewater

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The major industries in the world are facing challenge in eliminating or decreasing the carbon footprint. The pioneer technological bioreactor, multiphase anaerobic hybrid reactor is identified as one of the high-rate anaerobic reactors that treat the high strength wastewater and simultaneously generate green energy biogas. In this investigation, experimentations on the performance of the multiphase anaerobic hybrid reactor were conducted for the treatment of neem based biopesticide wastewater uninterruptedly for 115 days at mesophilic temperature (30 - 35˚C). The research was carried out in three different stages based on the acclimatization, variation in loading and hydraulic retention time. By operating the multiphase anaerobic hybrid reactor at different the organic loading (OL) such as 4.0, 5.0, 6.5 and 7.6 kg COD/m^3 at 24 h hydraulic retention time (HRT), it was found that 6.4 kg COD/m^3 as the most apt for conducting the further experiments for attaining better reactor performance with 96.0 % COD removal efficiency. Moreover, it was also observed that the biogas production rate increased with increase in organic loading. The generation rate of biogas ranged from 2810 mL/d to 7020 mL/d. Thereafter, the HRT was decreased from 24 h to 12 h and to 6 h by maintaining the organic loading constant at about 6.4 kg COD/m^3. Furthermore, an adaptive-network-based fuzzy inference system modelling was applied with the obtained experimental raw data and compared. It was found that there was one to one correlation between the modelling and the experimental results.

Keywords: biopesticide wastewater; ANFIS modelling; multiphase anaerobic hybrid reactor

#200: Experimental investigation on nucleating agent for low temperature binary eutectic salt hydrate phase change material

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Thermal energy storage using phase change materials (PCMs) in the form of latent heat, highly depends on the melting enthalpy and melting temperature. Among the available PCMs, inorganic salt hydrates exhibit higher latent heat and thermal conductivity compared to the organic PCM. Nevertheless, the issue of the degree of supercooling with salt hydrates restricts their application in energy storage units. In this research work, a low temperature inorganic-inorganic eutectic salt hydrate PCM with higher melting enthalpy and desired phase transition temperature is developed using sodium carbonate decahydrate (SCD) and sodium phosphate dibasic dodecahydrate (SPDD). The eutectic SCD/SPDD salt hydrate PCM eutectic point and the eutectic composition of salt hydrate PCMs to operate at low temperature range is numerically determined using Schrader equation. By numerical methods we obtain the 68 wt% of SCD with 32 wt% of SPDD to exhibit eutectic SCD/SPDD composite with eutectic melting temperature of 26.2°C and melting enthalpy of 210.6 J/g. The synthesized eutectic PCM are characterized to explore their chemical stability, latent heat, melting point and their shortcoming due to degree of supercooling. Dispersion of nucleating agent is an effective solution to overcome the issue of degree of supercooling. The developed eutectic PCM composition is experimentally analysed using Borax, Alumina and Sodium Sulphate Dodecahydrate as nucleating agents at 1-10% to evaluate the nature of degree of supercooling. However, for building cooling applications PCM with minimal degree of supercooling, with the ability to release low enthalpy during discharging is an advantage.

Keywords: phase change materials; degree of supercooling; latent heat; nucleating agent; eutectic salt hydrate

#201: Power generation prediction of a new tower type thermal/photovoltaic (T/PV) power generation system based on spectral beam splitting

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At present, photovoltaic power generation can only utilize a portion of the solar band, and the remaining bands entering the battery will not be used for power generation, but will instead increase the temperature of the battery, leading to a decrease in photoelectric conversion efficiency. Therefore, using frequency division to utilize some photons that do not respond to the battery for thermal utilization can effectively improve the energy conversion efficiency of solar energy. This article proposes a tower-type thermal/photovoltaic （T/PV) power generation system using spectral beam splitting technology, The spectroscopic glass is formed by plating a layer of spectral selective film on the surface of special glass, and then install the spectroscopic glass as a cover plate on the photovoltaic cell to replace the heliostat in the tower thermal power generation, so that specific wavebands enter the photovoltaic cell through the spectroscopic glass for photovoltaic power generation, and other wavebands are reflected onto the collector for thermal power generation. The mirror field arrangement was designed using the MUUEN algorithm, and the proposed system was analysed optically and thermodynamically at the AM1.5D solar spectrum as the incident irradiance flux density. Solar radiation data for a typical meteorological year were used to forecast and compare the full-year power generation of photovoltaic power, solar thermal power and this system. The results show that the combined power production of the tower-type sub-spectral thermal-photovoltaic composite system is higher than the other two systems under the selected climatic conditions.

Keywords: solar energy; power generation system; solar tower; beam splitting technology; thermodynamic analysis

#202: Designing ecological landscapes: a case study of Amata City's smart environment

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Rapid industrialisation and urbanisation offer economic opportunities but also lead to the degradation of ecosystem functioning and ecosystem services, which affect local food security and the preservation of local habitats. The concept of Eco-Industrial Parks, which demonstrate the symbiotic relationship between factories within the same industrial estate to promote circularity of energy and material flows, has been implemented since 1998 in Europe, the United States, and Canada. In 2000, this concept was also adopted in Thailand, though it has yet to be fully realised. Amata City is one of the largest industrial estates in the Eastern Economic Corridor of Thailand, covering 43 square kilometres or 4,330 hectares. It is a part of Industrial Estate authority of Thailand plans towards the eco-industrial park and smart city development. This article presents a literature review based on three components: i) academic papers related to the concept of eco-industrial parks, ii) an analysis of the Sustainability Report of Amata City, with a focus on the smart environment section, and iii) landscape design proposals by a group of Landscape Architecture students at Thammasat University. In order to interpret the review material, 60 peer-reviewed academic papers, 2014 to 2022 Sustainability Reports of Amata City, and 6 landscape design proposals were analysed. The results indicate that there are essential characteristics for understanding and implementing the concept of eco-industrial parks, such as the flow of material and energy. Moreover, for a successful sustainability approach, the community and environment should be at the centre, with emphasis placed on the community participatory process and improving environmental quality in the estate and its surroundings. By offering alternative futures for ecological approaches and restoring ecological balance, the design proposals provide insights into designing with ecological approaches and community involvement. Based on these findings, we suggested developing a guideline plan for improving and designing sustainable approaches and practices, which takes into account ecosystem services and maintains the ecosystem function of the industrial landscape.

Keywords: sustainable landscape; eco-industrial park; ecosystem functioning; smart environment; urban biodiversity

#203: Experimental investigation of concentrated triple junction solar cells under non-uniform illumination

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A concentrated multijunction solar cell offers good promise for high energy density. In a concentrated photovoltaic system, the solar cell's output power depends not only on the illumination energy but also on the spectral distribution and the uniformity of illumination. Under field operating conditions, non-uniformity is a major factor affecting the performance of concentrated solar cells at high energy density. The present work is intended to address non-uniform illumination created on concentrated commercial triple junction solar cells. The study considered non-uniformity (both spatial and spectral) based on two cases (varying focal length and masking cell area). Both methods create non-uniformity, which affects the performance of triple-junction solar cells and is addressed here with experimental evaluation considering the shadowing factor as a critical parameter. A Fresnel-based concentrating (commercial) photovoltaic system with InGaP/InGaAs/Ge triple-junction solar cells is employed for the purpose. The experimental results indicate that there is an 8% ± 3% reduction in overall efficiency with varying non-uniformity under 500-700 W/m^2. The main parameters that are affected significantly are maximum power point voltage and current. Also, the influence of series resistance under increased non-uniformity plays a vital role in performance reduction. The experimental results are fitted to a proposed simple lumped diode model.

Keywords: non-uniform illumination; concentrated solar cell; equivalent circuit model; outdoor experiments

#204: Optimum scheduling by creating feeder scale islands for continuity of supply of critical loads in emergency network conditions

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Because of the increase in distributed generation facilities based on renewable energy sources around the world, one-way energy flow in the electricity distribution network is replaced by multi-directional, multi-point to multi-point and changing according to the times of the day. The fact that most of the users in the electricity distribution network have sensitive loads makes it necessary for individual measures to be replaced by measures to be taken on the basis of the grid. This inevitability puts forward the concept of micro-grid with the approach of minimizing the impact of critical loads from interruptions and malfunctions in the interconnected grid. When analysed in the context of the main grid, the most important advantage of the microgrid is that it has the ability to operate in a controllable structure within the main grid and as a discrete energy source when necessary. From the user's point of view, the ability to meet individual energy needs by providing quality and uninterrupted energy and this situation to prevent possible damages stands out as the biggest advantage of the micro grid. In this study, the necessary technical criteria on the basis of distribution network level and distributed generation level, for the establishment of a distribution feeder-scale micro-grid (isolated island) over power plants connected to the distribution network and renewable energy sources, in order to improve supply continuity in emergency network conditions where the electricity distribution network is without energy, standards and regulatory needs were researched and criteria suitable for such a structure were developed. In this context, pilot feeders connected to a real electricity distribution network were determined on the DIgSILENT Power Factory program, and microgrid (isolated island) modelling was carried out at the scale of the distribution feeder with conventional and distributed generation plants on the feeder. With the study, it has been understood that microgrids to be operated in the distribution feeder scale island mode can be a rational and economical solution in improving the supply continuity indicators in emergencies that cause feeder interruption in medium voltage networks, as long as the necessary criteria are met.

Keywords: distributed generation; feeder; isolated island; microgrid

#205: 3-E analysis of plasma gasification combined cycle integrated molten carbonate fuel cell for power production based on refused derived fuel feedstock

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Solid waste management is serious yet often overlooked, possibly due to the challenges it possesses worldwide. It is also a major source of greenhouse gas emissions in the form of methane, contributing to nearly half of global warming. Therefore, enhanced technologies have to be adopted that utilize the waste efficiently and recover valuable resources to safely dispose of waste and reduce environmental impact. This work focuses on using plasma gasification for clean syngas production and employing it for power production through the application of combined cycle i.e., gas and steam turbine (IPGCC) and molten carbonate fuel cell (MCFC). Refused Derived Fuel (RDF) is chosen as the feedstock for simulation using a thermodynamic model developed in Aspen Plus software. Steam is used as plasma gas at 4,000°C and oxygen as additional gas for gasification. The splitting ratios of syngas (25:75, 50:50 and 75:25) to IPGCC and MCFC based on the 3-E analysis (energy, exergy and economic) are studied to evaluate the performance of the system. It was observed that the plasma gasification could convert the RDF fuel into simpler compounds of H_2 and CO of >90 % among the syngas composition. Further, the maximum energy efficiency of 42.78% and exergy efficiency of 40.65% with carbon capture were found to be for a 25:75 [IPGCC: MCFC] ratio. While the economic assessment resulted in levelized cost of electricity (LCOE) values between110-114 $/MWh considering all the cases. Therefore, the 3-E analysis reported that IPGCC systems integrated with MCFC unit using RDF has the potential for producing good calorific value syngas, high power generation and a safe ecosystem.

Keywords: plasma gasification; refused derived fuel; molten carbonate fuel cell; energy; economic

#206: The effect of velocity increment by blockage factor on Savonius hydrokinetic turbine performance

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Hydrokinetic turbines can be used to produce power in inaccessible villages located near rivers. The hydrokinetic turbine uses the kinetic energy of the water and may be put directly in the natural flow of water without dams. For off-grid power production, the Savonius type vertical axis turbine is the easiest to design and manufactured. This proposal uses three-dimensional computational fluid dynamics (CFD) simulations to measure the considerable interaction and complexity of turbine blades. Savonius hydrokinetic turbine (SHKT) performance is affected by blockage in the river, canals, and waterways. Putting a large object in a water channel causes water obstruction and raises local free stream velocity. Blockage correction factor or velocity increment measures the impact of velocity on the performance. SHKT performance is evaluated by comparing power coefficient (Cp) with tip-speed ratio (TSR) at various blockage ratios. The maximum Cp was obtained at TSR of 1.1 with blockage ratio of 45%, whereas TSR 0.8 yielded the highest Cp without blockage. The greatest Cp of 0.29 was obtained with a 45% blockage ratio compared to a Cp max of 0.18 without a blockage.

Keywords: Savonius hydrokinetic turbine; blockage ratio; vertical axis turbine; power coefficient

#207: Estimating energy savings in Singapore's building benchmarking policy for office buildings

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As ever more countries commit to net-zero greenhouse gas emissions in official policy documents and laws, a series of relevant building energy policies have emerged in different areas to enhance building energy usage efficiency. However, the quantification of their effectiveness is challenging due to substantial uncertainty. Much of relevant research employ linear regression models to analyse the correlation between time and energy consumption, aiming to ascertain the energy savings linked to a specific policy. Nonetheless, these approaches may deviate to some extent due to priori unknown or underestimated interventions. In this study, we develop econometric models to investigate the causal link between energy savings and building benchmarking policy in Singapore for office buildings. Using matching and regression techniques, we find that Singapore's 2019 benchmarking policy contribute to energy savings ranging from 15% to 19% across all office buildings in 2020. These savings are equivalent a reduction of 380 million dollars in electricity costs based on average electricity prices. However, we also find that the policy does not reduce energy consumption homogeneously in different buildings, exhibiting a more pronounced impact on buildings that are not certified as green buildings prior to 2019. These buildings have the potential to reduce their energy usage intensity (EUI) by 20% to 30% if they can get certified in 2019. Although uncertificated buildings tend to exhibit higher energy usage intensity, a small percentage of them are actually more energy efficient than certificated ones. These findings enable a better understanding of benchmarking policy impact and help policymakers further improve energy efficiency of buildings.

Keywords: building energy; building benchmarking policy; casual analysis; energy savings

#208: Optimization control study of indoor VOC pollution by demand-controlled ventilation coupling durability and energy saving in public buildings

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Long-term exposure to indoor volatile organic compounds (VOCs) can affect the personnel comfort, health and work efficiency. However, traditional ventilation dilution strategies have low energy efficiency or poor equipment durability due to their difficulties to achieve multi-parameter collaborative optimization objectives such as energy efficiency and air quality. In that context, a demand-controlled ventilation (DCV) optimization strategy was proposed to perform intermittent constant volume mechanical ventilation (CAVMV), which is controlled by the maximum and minimum levels of indoor total volatile organic compound (TVOC) concentration optimized by non-dominated sorting genetic algorithms (NSGA-Ⅱ). The experimental results indicated that, the DCV optimization strategy improves energy efficiency by up to 77% compared with continuous ventilation or unoptimized intermittent ventilation strategies. This study could be a reference to better improve the ventilation strategy against indoor VOC pollution in public buildings.

Keywords: indoor VOC pollution; energy efficiency; durability; demand-controlled ventilation; collaborative optimization

#209: Effect of diffuser proximity to buildings on wind energy potential

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Due to their promising augmentations of wind flows in a manner combating wind intermittency and turbulence, diffusers integration within the built environment is highly demanded. This paper investigated the effect of diffuser integration to a side of generic tall building. It examined diffuser's resulting velocities when varying diffuser's proximity to buildings. This proximity of diffusers provides one of the key factors affecting diffusers' performance within the Built environment. A generic diffuser is formed of an aerofoil profile following the NACA 1244 aerofoil. The diffuser is then subjected to an array of proximities to a generic tall building section ranging from 20cm-110cm. In addition to a range of velocities ranging from 1-16m/s. The paper concluded that optimum diffuser proximity to building is at 90cm from the building, which produced a resulting velocity of 29.8m/s with an increase of 86.6% over the resulting velocity in the same diffuser but as a stand-alone scenario. The study employed ANSYS FLUENT educational R1 CFD to model diffusers without incorporation of a turbine.

Keywords: diffuser positioning; wind energy augmentation; building integrated diffusers

#210: Integration of electric cooking and electric bike charging into East Africa mini grid projects: a policy review

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Access to clean, reliable and affordable energy services is crucial for sustainable development. Renewable energy stemming from solar photovoltaic (PV) systems to support mini grids have emerged as a potential solution to address energy poverty and expand electricity access in remote and rural areas beyond the reach of centralised grids in Africa. Delivering universal electricity access under the UN Sustainable Development Goal-7 (SDG 7) will require more that 217,000 new mini grids serving 490 million people by 2030. Poor load factor leading to high-end user tariffs and unattractive return on investment have been a key challenge for long term financial sustainability of mini grids. Introducing electric cooking (e-cooking) and electric bike charging (e-bike charging) can be a potential solution to the low per capita consumption and poor load factor issues of mini grids if these are integrated through careful considerations. However, such integration requires appropriate policy supports. This paper provides an overview of the current mini grid policy frameworks in selected East African countries (Kenya, Uganda, Rwanda, Tanzania, Nigeria and Ghana), focusing on the integration of e-cooking and e-bike charging. The conducted review examines the opportunities and challenges of such integration in terms of policy driven support mechanisms and business models, highlighting the implications for sustainable energy transitions in the region. Findings indicate that there is a paucity of clear policy guidelines for accommodating e-cooking and e-bike charging on mini grids. The review also highlights that there is also need for further strengthening of current policies in the areas of (i) fostering public-private partnerships, (ii) adding investment de-risking tools, (iii) provision of extended mid-project support for mini grid capacity increase, and (iv) introducing micro credit for consumers and local entrepreneurs. Learning from such policy review would benefit other countries across Africa in delivering strategic targets of renewable energy transitioning and universal energy access in the region.

Keywords: mini grid; electric cooking; electric bike charging; policy; sustainability; SDG 7

#211: Analysis of suitability of local sustainability recommendations for thermal comfort in post-disaster social housing in Yucatan, Mexico

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This study focused on users' thermal comfort in post-disaster houses in The Yucatan Peninsula in México. FONDEN was the national fund in Mexico until 2020 dedicated to reconstructing public infrastructure and social housing after disasters. An equivalent of eight hundred million American Dollars was invested yearly in reconstruction throughout Mexico. However, recent research has pointed out that these delivered poor thermal comfort, being one of the main causes of dissatisfaction in them and in some cases led occupants to abandon or repurpose their houses]. The relevance of this study is that this house model has been mass-produced to date in similar government-led housing programmes. This study aimed to analyse options to optimise thermal comfort in these houses and assess the effectiveness of local recommendations in naturally ventilated buildings such as these social housing. The method utilised was a computer-based simulation analysis using the Software IES- Virtual Environment (2019). The strategies tested evaluated the national recommendations for improving thermal comfort in the Mexican context. Results indicated that the common approaches for improvements including building insulation in naturally ventilated buildings might result in counterproductive effects while optimised ventilation combined with air movement produced by fans might be the best option for these buildings reducing discomfort by 61.2%. This study contributed to the scarce knowledge about thermal comfort in naturally ventilated buildings in Mexico. This study highlights how cost-efficient strategies based on orientation, shadow casting and optimised natural ventilation could lead to an improvement in thermal comfort. This is relevant, given that economically restricted societies cannot rely on air conditioning systems to achieve comfortable environmental levels in their houses.

Keywords: thermal comfort; optimisation; naturally ventilated buildings; environmental simulations

#212: Carrot pomace as a perspective raw material for obtaining a bunch of value-added bioproducts

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Poland is among the top producers of carrot pomace. In 2020 almost 690,000 metric tons of carrot were produced. That accounted for 14.7% of the total carrot production in the EU and ranked Poland as the 2nd largest carrot producer in Europe. A substantial amount of fresh product is further processed to juice, resulting in the generation of various types of waste, particularly carrot pomace. During the production of juice from 1 kg of raw carrot, approximately 0.45 to 0.65 kg of pomace is produced, depending on the production method used. Only a small percentage of carrot pomace can be used for the production of fodder or fertilizer, mainly due to its low protein content and potential soil acidification. Carrot pomace constitutes a source of precious compounds like various free and bound saccharides in the lignocellulose structure, carotenoids, mainly β- and α-carotene, and pectins, which could be useful for various sectors. Moreover, as the by-product of the juice industry, it can be recognized as a viable raw material to obtain advanced biofuels according to the Renewable energy directive II (RED II). This study aims to provide reliable, up-to-date information on carrot pomace valorisation toward sustainable production of a bunch of green products such as food ingredients, biocomponents, or biochemicals. Herein, we proposed a two-stage processing approach allowing for the sustainable valorisation of carrot pomace. The investigated route was based first on hot-water extraction of carrot pomace to isolate reducing sugars. Subsequently, hydrothermal liquefaction of the extraction residue at 350oC was carried out to convert residual organic matter to high-energy-density bioproducts. It allowed us to obtain advanced fuel biocomponents precursors in the form of isolated monosaccharides and other high-value compounds like biocrude and hydrochar. The advantages and disadvantages of this approach were identified and collated to provide easy-to-use guidelines for carrot pomace utilization.

Keywords: biomass; pomace; carrot; biorefinery; waste; HTL; bio-oil; extraction; monosaccharides; saccharides; carotenoids; lignocellulose; cellulose; hemicellulose; lignin; sustainability; pectin

#213: Composite filament winding technology for ultra-lightweight chassis in L7e class electric vehicles: enabling cost-effective zero emission urban mobility solutions

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The pursuit of cost-effective electric vehicles (EVs) tailored for zero emission urban mobility solutions have gained significant momentum in recent years. The L7e class of EVs, specifically designed for urban transportation, presents a unique opportunity to address the challenges of polluted and congested city environments. However, the high costs of these vehicles and lack of charging infrastructure remain significant barriers to their widespread adoption. This study explores the application of composite filament winding technology to develop an ultra-lightweight chassis for L7e class EVs, with the aim of achieving cost-effectiveness by reducing the weight, battery capacity and production costs of these advanced urban mobility solutions. Composite filament winding offers a promising manufacturing method for producing structurally efficient and lightweight components. By combining high-strength fibres, such as carbon or glass, with a polymer resin matrix, composite materials can be engineered to exhibit superior mechanical properties while significantly reducing weight. Leveraging this technology for the construction of ultra-light EV chassis in the L7e class vehicles can enhance energy efficiency, extend driving range, and contribute to cost reduction. In this research, we investigate the design and manufacturing aspects of a composite filament-wound ultra-light EV chassis for L7e class vehicles. Utilizing advanced computer-aided design and simulation tools, we optimize the composite layup configuration to meet stringent structural performance requirements while considering cost constraints. Extensive mechanical testing, including tensile, flexural, and impact evaluations, is performed to validate the performance and safety of the composite materials. Additionally, we examine the feasibility of integrating composite filament-wound ultra-light EV chassis into L7e class vehicles from a manufacturing standpoint. Scalability, assembly processes, and the potential for mass production are evaluated, taking into account cost-effectiveness and efficient integration within existing production lines. The environmental impact and cost analysis encompass various factors, such as raw material selection, energy consumption, and waste management, to ensure sustainability in the manufacturing process. The findings of this study demonstrate the potential of composite filament winding for developing ultra-light EV chassis in L7e class vehicles, paving the way for cost-effective and sustainable urban mobility solutions. The lightweight characteristics of composite materials contribute to increased energy efficiency, extended driving range, and reduced battery requirements. Furthermore, the manufacturing scalability and integration feasibility highlight the viability of this technology for large-scale production, facilitating the transition towards affordable and environmentally friendly urban transportation systems.

Keywords: composite filament winding; ultra-lightweight EV chassis; L7e class electric vehicle; Polymer Exchange Membrane (PEM) Fuel-Cell Technology; cost-effective urban mobility solutions

#214: Performance optimization and dynamic characterization of the dual cooling source cycle with adjustable heat and moisture ratio

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Air conditioning system deviates from design conditions due to the changing weather, and the common strategies such as variable air volume or inverter compressor leads to energy deficiency. The irreversible loss is eliminated due to the temperature match of the zeotropic mixture. A composition-adjustable chiller is proposed utilizing the characteristics of temperature glide and inequivalent condensation of the non-azeotropic mixture. Two flows of working fluid with individual composition and flow rate respectively afford the residual heat and moisture. Active composition requirement due to the heat source variation and passive concentration change due to the composition shift can be addressed by composition tuning. The predetermined thermodynamic characteristics can be achieved under off-design conditions by coupling the composition regulation module. In this paper, the thermodynamic performance of the composition-adjustable chiller can be optimized based on pinch point method. Various zeotropic mixture composed of different refrigerant are screened from the aspect of the environmental impact, heat transfer characteristic and cycle configuration. Liquid separation performance is researched to seek for the optimal vapor quality, ensuring that the corresponding heat and moisture load can be afforded by the separated streams. The dynamic characteristic of the active concentration regulation module is constructed to study the control mechanism of the cycle with adjustable heat and moisture ratio. Processible heat and humidity ratio based on double cooling source ranges from 8000 to 11000 kJ/kg. The energy performance (COP = 5.1) and dynamic characteristic of the cooling source cycle guarantee the potential for efficient operation and flexible control of indoor thermal environment.

Keywords: composition tuning; pinch point; performance optimization; dynamic characteristic; zeotropic mixtures

#215: Could locally generated PV power satisfy energy demand for a small city in Saudi Arabia?

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The Kingdom of Saudi Arabia is committed to replace its reliance on fossil fuel electricity supply through the expansion of renewable energy technologies deployment such as solar photovoltaic (PV) and wind. In relation to PV, the need to reduce greenhouse gas emissions has led the country to target 40 GW of PV power capacity by 2030. Such development needs to be augmented with analyses to overcome the challenges faced in the research and technical capability of the country and to understand how these can play a role in supporting the declared target. It is with this in mind that this work aims to investigate the deployment of PV systems at a city scale and understand to what level this can displace the current fossil fuel used. The methodology encompassed the development of a load profile of a modelled medium size city based on a 25 MW diesel generation grid coupled with approaches to install multi-MW solar photovoltaic systems in the city including options for building integrated and ground mounted systems. The modelling considered various scenarios including PV systems with and without battery storage as well as diesel generator, taking into account weather conditions using an optimised consumption profile. The analysis showed that the city central chillers were responsible for 35% of the modelled city electrical load. Evaluation of the load profile and peak consumption hours was undertaken under the different scenarios informed the various designs of the PV system's capacity and hence yield. The results showed that the optimum solution to supply the city was a combined PV and a diesel generation grid which over two decades decreased the total cost of electricity by a 20 to 30 percent whilst reducing the carbon emissions of the city by half.

Keywords: solar photovoltaic; renewable energy; PV penetration; climate change; Saudi Arabia vision2030

#216: Hydrogen and fuel studies at Lentatek

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Lentatek, a member of the Zorlu Group Companies, was established in 2003 and specializes in unmanned aerial vehicles (UAVs) and hydrogen and fuel cell technologies. It is the largest private group in this field in Turkey, employing around 15 engineers and technicians. Lentatek's primary focus is on hydrogen production from various raw fuels and the development of fuel cells, including PEM, solid oxide, and direct methanol fuel cells. They prefer steam reforming and PEM electrolysers for fuel preparation. Lentatek have developed a mobile steam reforming reactor that can use natural gas, kerosene, and diesel as raw fuels, catering to military-compliant solutions for logistical purposes. The company maintains strong relationships with universities, particularly Nigde Omerhalis University, with whom they have established a research laboratory. Lentatek benefits from the expertise of university academicians, who serve as consultants. Lentatek designs and produces bipolar plates to meet power requirements. Materials such as graphite, gold-plated stainless steel, and titanium (for weight considerations) are used for PEM fuel cells. Lentatek procure sub-components and conduct research on catalysts and their application on proton exchange membranes. Similar work is carried out for direct methanol fuel cells. For solid oxide fuel cells, Lentatek primarily uses Croyfer®, for bipolar. Lentatek have completed in-house development of electrolyte and anode-supported single cells, short stacks, and full stacks with a power output of approximately 1.2 kW. Lentatek's research strategy involves modelling, producing, verifying, and iteratively updating models. They scale the parameters and sizes based on specific requirements. Currently, Lentatek aims to develop PEM fuel cells ranging from 50 to 80 kW and electrolysers with a production rate of 100 kg H2 per day. They are also working on air independent propulsion (AIP) systems using PEM fuel cells for Turkish Navy submarines. Hydrogen is to be stored as metal hydrate cylinders outside the body. Trials are being conducted to install the reforming reactor and the metal hydrate cylinder in submarines, with a focus on addressing carbon dioxide discharge issues when submerged. Lentatek's overarching goal is to advance hydrogen and fuel cell technologies through university collaborations and targeted solutions for military and defence applications.

Keywords: fuel cell design; reformer design; hydrogen generation; catalyst preparation

#217: Multi-criteria optimization of an integrated energy system driven by power grid, photovoltaic and fuel cell

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Hydrogen fuel cell-based energy system is benefit for fossil energy saving and carbon emission reduction. However, the feasibility of its application in the building still needs further investigation. In this paper, a grid/photovoltaic/high-temperature proton exchange membrane fuel cell-driven integrated energy system (IES) is proposed. The operation strategy is designed for the real-time loads following. The availability analysis of the IES is carried out based on an office building considering energy, environmental and economic performances. The photovoltaic coverage ratio and the capacity of fuel cell are selected as the decision variables, and they are determined through a dynamic multi-criteria optimization to maximize the comprehensive performance. The optimized IES is compared with a conventional grid-driven system. The results show that the annual electricity productions from photovoltaic, fuel cell and grid account for 41%, 32% and 27%, respectively. The annual fossil energy saving ratio, carbon emission reduction ratio and annual cost saving ratio of the proposed IES are 53.8%, 57.6% and 1.3%, respectively, compared to the conventional system. The sensitivity analysis shows that the IES is economically viable when the hydrogen price is less than 5.15 $/kg.

Keywords: proton exchange membrane fuel cell; integrated energy system; energy management strategy; multi–criteria optimization

#218: Waste heat recovery and 4E analysis-based (energy, exergy, exergy-economic and exergy-environment) comparison of five cycles integrated annealing furnace considering PCMs energy storage

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Climate change poses one of the most significant challenges that humanity has encountered thus far. To address this pressing issue, the European Union has established ambitious objectives for the future. Alongside environmental concerns and escalating expenses due to increased energy consumption, forecasts indicate that fossil fuel depletion may occur by 2050. Consequently, the European Union has prioritized the critical objective of reducing greenhouse gas emissions by 80-90%. According to available statistics, the steel and iron industry in Europe is responsible for 3.7% of global greenhouse gas emissions. Thus, it is imperative for steel-producing nations to consider reducing these emissions. This can be achieved through strategies such as diminishing steel demand, augmenting the use of recycled steel, innovating steel production technologies, or enhancing the efficiency of steel processes. It is noteworthy that improving thermal efficiency can be accomplished by harnessing waste heat from various processes. Among these processes, the batch annealing furnace (BAF) plays a significant role in steel production and is responsible for substantial heat loss to the environment. These furnaces hold the potential for heat recovery in two key stages: the heating process, wherein exhaust gases are released, and the cooling process, during which a significant portion of heat transfers from the coils inside the furnace to the surrounding environment through cooling methods. Aligned with these objectives, a study was conducted on Mobarake Steel Company's cold rolling furnaces. The first step involved analysing the energy balance during the cooling and heating processes of the annealing furnace to determine the amount of wasted heat. Subsequently, combined heat and power (CHP) and combined cooling, heating, and power (CCHP) cycles equipped with latent thermal storage tanks were explored for energy extraction. Under optimal conditions, approximately 3.8% of energy and environmental impacts could be recovered.

Keywords: annealing furnaces; cold rolling unit; thermodynamic evaluation; exergy-economic analysis; exergy-environment analysis; 4E analysis; latent energy storage; waste heat recovery; PCM

#219: Metal doped $Ca(OH)_2$ for the improvement of heat transfer in thermochemical energy storage systems

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The main purpose of this work to study the metal doped $Ca(OH)_2$ have been synthesized and their thermal behaviour has been investigated. The prepared materials have been characterized by techniques such as XRD, SEM, XRF, FTIR, TGA and Advantageous Transient Plane Source (ATPS) Method. The doping concentration used (5%) has little effect on the crystal structure of $Ca(OH)_2$. SEM analysis showed that flaky structure of $Ca(OH)_2$ has become more like platelets and needles. It has been observed that the introduction of additives resulted in increased thermal conductivity of the doped materials and thermal conductivity was found to increase with increasing temperature for all the samples.

Keywords: thermal energy; thermal conductivity; calcium hydroxide

#220: A computational study into the charging of an agitated fluidised bed thermochemical energy storage system

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Waste heat of medium to high temperatures (150-500°C) is often dissipated directly to atmosphere or used in low temperature applications. However, much of this waste heat could be used in industrial, process and renewable energy applications. Sensible and phase change materials storage are generally, not suitable for these temperature ranges, but thermochemical energy storage (TCES) can store and release this heat at high temperatures, sufficient to drive industrial and process applications. TCES stores the energy in the form of chemical bonds, which are released with exothermal reactions. This enables heat to be stored without degradation until a reaction is activated and so can store the energy over long periods, allowing short term and long-term storage. An agitated fluidised bed thermochemical reactor is being developed to optimise the system and create an efficient and effective thermal store. To gain a better understanding of the interaction between the fluidised bed, agitation and thermochemical reaction, computational fluid dynamics (CFD) simulations were developed. The process was developed in stages, from an initial fluidisation study of a multiphase system, to a multiphase agitated, fluidised bed and finally, to a fully integrated agitated fluidised bed thermochemical reactor model. All simulations were found to compare well with published data. Key findings included successfully simulating water vapour dehydration, the change in volume fractions of the products and reactants as the simulations progressed and gaining insights into the hydrodynamics of agitation, chemical reaction and fluidisation.

Keywords: thermochemical energy; energy storage; energy efficiency; waste heat; agitated bed

#221: Implementing a university's sustainability strategic plan: the journey so far

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Many cities declared climate emergency with some universities signed up to such declaration. In response, the University of Southampton (UoS) has instigated a Sustainability Strategy in 2020 setting out ambitious goals addressing emission reduction and implementing sustainability in operations. The strategy aims to reduce Scope 1 and 2 emissions to net-zero by 2030; estimate, set reduction targets and start to implement reduction strategies for Scope 3 emissions (with an initial focus on business travel). In addition, the UoS is embedding sustainability in every education programme by 2025; make sustainability a cornerstone of its research and implement a sustainable/ ethical investment policy. Here, an overview is provided of the work of the University's Sustainability Implementation Group to underpin these goals. This includes analysing a range of options for decarbonisation alongside energy efficiency investments; embedded in a GHG Protocol-based approach to estimate the emissions footprint; setting Scope 3 reductions targets and 'developing internal dashboards to monitor energy use and goal progress. This work demonstrated the value of collaboration between research and professional services staff. Research staff are providing detailed modelling of potential heat decarbonisation pathways as input to the University's Estates' Scope 1 and Scope 2 emissions reduction roadmap, providing overviews of evidence-based approaches to nature-based solutions as well as conducting in-depth analysis of business travel behaviour using detailed data from the University's travel management system. The paper will conclude with an overview of current progress towards the UoS Sustainability Strategy Goals and outline the future challenges in meeting them.

Keywords: climate change; higher education; carbon footprint; sustainable development; decarbonisation

#222: Synthesis and characterization of doped magnesium hydroxide for medium heat storage application

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A vast amount of waste heat is generated annually from the industrial and power sectors, estimated at approximately 391 TWh, equivalent to about 35% more than the UK's total annual electricity demand. It is therefore imperative to utilize efficiently all possible waste heat sources which may be classified according to their temperatures as; low grade (ambient–250°C), medium grade (250–500°C), and high grade (> 500°C). With appropriate technologies, a large proportion of this waste energy could potentially be recovered for useful applications. In this context, thermal energy storage (TES) technologies provide the best opportunities to recover waste heat at various temperatures for long-term storage and application. The potential of thermochemical energy storage (TCES) materials such as magnesium hydroxide, $Mg(OH)_2$, has been established but it has a relatively high dehydration temperature thus limiting its potential for medium-temperature heat storage applications that account for a vast proportion of industrial waste heat. To this end, samples of doped $Mg(OH)_2$ with varying proportions of (5,10, 15, and 20 wt%) of potassium nitrate (KNO_3) have been developed and characterized for evaluation. The results showed that the doped $Mg(OH)_2$ sample with 5 wt% KNO_3 achieved the best outcome and was able lower the dehydration temperature by about 23°C with an increase of 6% in the energy storage capacity. The results also showed good surface topology and thermal stability in the non-isothermal test conducted on the sample. The composite $Mg(OH)_2/KNO_3$ material, therefore, appears to have the potential for medium heat storage applications ranging from 293°C to 400°C. Thermal conductivity enhancement of the sample is however encouraged to establish its full thermophysical potential.

Keywords: thermochemical; energy storage; characterization; magnesium hydroxide; composite material; dehydration temperature

#223: Fifth generation district heating and cooling network coupled with geothermal energy source for realising a sustainable community: a case study of Embassy of Sharing at Mälmo

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With growing urbanization and increase in energy demand for space heating and cooling in buildings, effective assurance and distribution of energy and its efficient end use is of utmost importance particularly when emissions from energy use and indoor thermal comfort of the end users is of question. Numerous solutions have been put forth in the field of effective distribution of thermal energy to meet the space heating and cooling requirements of buildings to assure indoor comfort of which fifth generation district heating and cooling (5GDHC) is regarded as a viable solution in terms of low emissions, low distribution losses and effective energy supply. The challenges however lie in connecting the buildings in the network in order to facilitate the energy sharing between the buildings such that otherwise waste heat from one of the buildings can be used by another building connected to the same network. This paper presents the concept and design of such advanced 5GDHC network which facilitates energy sharing between connected buildings comprising of office spaces, residential complex, shopping centres occupying approximately 55,000 square meters in Hyllie region of Malmö, Sweden. The system design consists of a unidirectional one pipe network with 113 decentralized borehole heat exchangers as the primary and only energy source for the network with heat pumps and dedicated heat exchangers to alter the temperature of district heating and cooling fluid going into the buildings. The system as such is self-sufficient and does not need any assistance from other energy source to meet the thermal demands of the connected buildings.

Keywords: 5GDHC; geothermal energy; energy sharing

#224: Maximizing solar power harvest: experimental analysis of vacuum insulated photovoltaic/thermal (PVT) power module in subtropical climates

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The utilization of solar energy as a clean and sustainable source of power has gained significant attention in recent years. Photovoltaic/thermal (PVT) systems have emerged as a promising technology, integrating both electrical energy generation and thermal energy collection in a single device. This paper presents an experimental analysis of a solar vacuum-insulated photovoltaic/thermal (VPVT) power module in a subtropical climate. The objective of this study is to assess the performance and energy efficiency of the VPVT system under realistic operating conditions and to evaluate its potential for solar energy harvesting in subtropical regions. The experimental setup consists of a side-by-side configuration of a conventional solar PVT as a control and a VPVT module integrated with a vacuum insulation chamber, enabling simultaneous electricity and thermal energy generation from solar radiation. The experiment was conducted in a subtropical climate zone in the coastal city of Durban in South Africa, over an extended period to capture the seasonal variations in climatic conditions. The study included the measurement and analysis of various parameters such as solar radiation, electrical power output, thermal energy output, and overall system efficiency. Additionally, the impact of various factors, including ambient temperature, wind speed, and humidity, is considered in the analysis. Preliminary results indicate that the solar vacuum-insulated PVT module exhibits favourable performance characteristics in subtropical climates. The electrical energy generation efficiency of the module remains high, even under high ambient temperatures. Moreover, the thermal energy collection efficiency is enhanced through vacuum insulation, allowing for the effective utilization of solar energy. The results indicate that the solar vacuum-insulated PVT module performs effectively in subtropical climates, exhibiting a 16.01%, increase in thermal efficiency, while electrical efficiency remained largely the same with a difference of 0.28 % even when the PV cell encapsulation was removed. Consequently, the overall efficiency was improved by 9.16 %. The overall exergy and primary energy-saving efficiencies also increased by 2.74 % and 4.25 % respectively. Furthermore, the study investigated the impact of various factors, such as ambient temperature, solar irradiance, and flow rate of the heat transfer fluid, on the performance of the PVT module. It was observed that higher solar irradiance levels and lower ambient temperatures positively influenced the electrical and thermal efficiencies of the system. The findings from this experimental analysis provide valuable insights into the feasibility and effectiveness of utilizing solar vacuum-insulated PVT modules in subtropical climates. The results demonstrate the potential of this technology for renewable energy generation, especially in regions with abundant solar resources and demands for electricity and thermal energy. The outcomes of this study can assist engineers, researchers, and policymakers in making informed decisions regarding the deployment and integration of solar PVT systems in subtropical regions. The findings contribute to the advancement of solar energy technologies, supporting the transition towards a sustainable and low-carbon future.

Keywords: solar energy; photovoltaic/thermal (PVT) system; vacuum insulation; subtropical climate

#225: Enhancing policy framework to support rooftop photovoltaic deployment in Saudi Arabia

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Rooftop solar photovoltaic (PV) power generation is likely to hold significant prospects for the Kingdom of Saudi Arabia (KSA) which will assist in the country's endeavour to diversify its energy mix, reducing fossil fuels dependency and the transition to Net Zero by 2060. This study analyses the policy frameworks and the potential driving forces that influence the adaptation and uptake of rooftop solar power generation in KSA. The research combined a comprehensive review of related publications, policy documents and regulations, and examined the key drivers and challenges. The outcomes were then tested through the 'Techno-economic Paradigm (TEP)' and the Multi-Level Perspective (MLP)' theories of socio-technical transitions. The findings reveal that despite the introduction of clear policy guidelines to promote the deployment of rooftop solar PV under the National Renewable Energy Programme (NREP), uptake of this micro generation technology has been negligible. The main reasons identified for such poor growth of rooftop solar PV in KSA have been related to the historical trend of fossil fuel subsidies, cheap electricity tariff (making unattractive return on investment), unclear net metering regime and absence of financial stimulus packages coupled with the lack of public awareness of the impact of the technology. The research suggests that effective energy price reform by the government in conjunction with introducing attractive financial packages as well as application of flexible import duties on PV and accessories for the sector can catalyse the uptake of this technology and will result in reducing the carbon footprint of the residential sector. Addressing these challenges will require planned and coordinated efforts from policymakers, industry stakeholders and the financial sector to develop targeted packages to support the deployment. This will need to be combined with campaigns to raise awareness, the development of local expertise, and streamlining administrative processes. This research will contribute to the reform of the current policy framework and the outcomes can be applied to other Gulf States to promote enhanced and sustained rooftop PV deployment programmes in the region.

Keywords: rooftop solar PV; policy framework; micro generation; Saudi Arabia

#226: The performance of residential rooftop PV arrays in a hot, arid climate: a case study in Jeddah, Saudi Arabia

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Despite abundant solar resource and high daytime electrical demand from air conditioning, residential PV installations are rare in Saudi Arabia, in part due to low electricity prices. In this work we take a case study approach to investigate whether the Saudi feed-in tariff scheme is likely to shift the economics in favour of installing PV on residential buildings. 15kWp PV arrays were installed on the flat rooftops of two villas in Jeddah, Saudi Arabia ("Villa 1" and "Villa 2"). The villas are of identical layout, each with total floor area 812 m^2 and roof area 227 m^2. The arrays were instrumented for plane-of array insolation, module and ambient temperature, power output (DC and AC side). The electrical energy imported from the network was also monitored at the utility meter connected to the PV array. The arrays were installed in December 2021 and the monitoring period was for one year, from May 2022-May 2023. The mean daily proportion of avoided electrical import was 36% (total 14.1 MWh) for Villa 1 and 32% (total 16.5 MWh) for Villa 2, resulting in cost savings of SAR2500 (USD680) and SAR3000 (USD800) respectively. Feed-in was not implemented in the monitoring period due to lack of support for metering from the electrical utility, but if it had been, a further 14.4 MWh would have been exported to the grid from Villa 1 and 12.0 MWh from Villa 2 (assuming average efficiency). Theoretically this export would result in feed-in tariff income of SAR1000 (USD270) and SAR840 (USD225). Summing the avoided import and the potential feed-in income, and taking industry average installed costs of USD1500 per kWp, it is clear that payback periods will be >15 years and therefore unlikely to be attractive as an investment, assuming that electricity prices do not increase substantially. In this study, there was no attempt to optimize the scheduling of the air conditioning in the villas. It is possible that approaches such as overcooling the buildings during daylight hours and using the thermal mass of the building to reduce night-time demand, could reduce electricity imports further. This is the focus of ongoing work.

Keywords: photovoltaics; Saudi Arabia; residential buildings; rooftop

#227: Performance potential exploration of four new HFC/DMETEG working pairs in absorption refrigeration system

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New DMETEG-based working pairs with HFC refrigerants showed its feasibility to be applied in absorption systems, so as to compensate for the drawbacks of traditional working pairs. To explore the performance potential of these new developed working pairs, the pinch technology was adopted in this work for maximal heat recovery. R134a/DMETEG has the COP about 0.476 at the basic setting conditions and can be further improved to 0.803 with enhanced heat recovery of absorption and condensation heat by reducing the temperature approaches. By comparisons, R152a exhibits more overall performances and wider operating ranges, and obtains the overall COP of SSARS from 0.100 to 0.599 and the overall COPmax from about 0.154 to 1.053. R134a showed the worst performances, which may be ascribed to it worst affinity of solution concluded. This work provides one technical method to estimate the applicability of new working pairs.

Keywords: performance potential; absorption refrigeration; low-GWP; HFC refrigerants

#228: Growth in electrical demand in a PV mini-grid: the first decade of operation at Kitonyoni, Kenya

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Mini-grid based electrification is an alternative to waiting for the grid to arrive in parts of the world lacking energy access – concentrated in rural sub-Saharan Africa – and has been championed by the World Bank. Accurate forecasting of electrical demand growth in PV-battery-inverter mini-grids is critical for project success: sluggish growth dents revenue projections whereas rapid growth can lead to early system failure, in turn resulting in customer frustration and reluctance of government agencies to pursue future projects. Long-term, real-world measured demand data from mini-grids is hard to come by, partly due to commercial sensitivity and partly because PV-based mini-grids are a recent phenomenon compared to micro-hydro and diesel-based schemes. This work focuses on Kitonyoni mini grid (Makueni County, Kenya), established in 2012 and in continuous operation since that time. In 2021, the mini grid was connected to the main distribution network (which was extended to the location prior to this) and simultaneously the kWh tariff was reduced by 70% to national levels. This work describes the growth in electrical demand and related challenges over the lifetime of the mini grid, with a focus on the period from early 2017 to the present (2012-2016 was covered in more detail in previous work), including the transition to interconnection with the utility network.

Keywords: mini grids; photovoltaics; Kenya; energy access

#229: An evaluation of energy saving potential from a 30kWp grid tied PV system in a student residence in the Eastern Cape: South Africa

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This study focuses on evaluating the energy savings potential from implementing a grid tied Solar PV for a student residence. Energy consumption profile for the residence measured using a Power Track Energy Analyzer and Verifier. The results showed that the student residence has an average of 27 kW during the peak sunshine hours of between 09:00 – 16:00 with a peak demand of 76 kW due to electric geysers. The residence has annual energy consumption of 236 818.58 kWh. A 30kWp grid tied system was proposed and its performance simulated for the facility to assist in energy reduction during the day. The grid tied system's annual energy production of 38 793.61kWh will be realized to offset the energy from the grid. The performance ratio of the PV system was found to be 0.75. The study also revealed that the avoided carbon dioxide emission of 41.12 Mt. Economic analysis of the PV system deduced an estimated payback period of 7.8 years.

Keywords: grid tied PV system; energy savings potential; student residence

#230: Efficiency Improvement of wide-bandgap DC-DC for PV System

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PV systems are standard in residential and industrial settings because of their low upfront costs and operating costs over their lifetimes. Buck or boost converters are used in photovoltaic systems, regardless of whether the system is autonomous or connected to the grid. These converters became less appealing because of their low efficiency, inadequate power density, and use of silicon for their power components. Traditional devices based on Si are getting close to reaching their theoretical performance limits, which makes it more challenging to improve the performance and efficiency of these devices. GaN and SiC are the two types of wide-bandgap (WBG) semiconductors with the most recent technological advancements and are available. Tolerance to high temperatures and switching frequencies can potentially reduce the size of both active and passive components. The utilization of high-efficiency DC-DC boost converters is the primary emphasis of this work. These converters are for photovoltaic systems that use wave energy.

Keywords: SiC component; wide-bandgap; PV system; MPPT; DC-DC converter; efficiency

#231: Enhancing maximum power point tracking for wind turbines based combined approach of adaptive sliding mode and fractional-order theory

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The purpose of this study is to investigate the integration of adaptive sliding mode and fractional-order theory to enhance the Maximum Power Point Tracking (MPPT) in a wind turbine model. The combined approach considers the nonlinearity of the system to analyse its response. To evaluate the performance of the system, disturbances were introduced to the output of the regulator, and the response of the wind turbine was assessed. The obtained results demonstrate the system's remarkable ability to track the reference signal with high accuracy, regardless of the presence of disturbances. The system remains unaffected by the disturbances, showcasing its stability and robustness. The combination of adaptive sliding mode and fractional-order theory proves to be effective in maintaining the desired tracking performance even in the presence of external disturbances. This indicates the system's capability to adapt and respond appropriately to changes in environmental conditions. Furthermore, the control scheme exhibits strong robustness in rejecting disturbances, further emphasizing its stability and reliability. The system remains resilient and continues to perform optimally even under challenging conditions. Overall, this study highlights the successful application of the integrated approach in enhancing MPPT in wind turbines. The results validate the system's ability to effectively track the reference signal and its robustness against disturbances. The findings contribute to the development of more efficient and reliable wind turbine control strategies, paving the way for improved performance and increased energy production in wind power systems.

Keywords: wind energy; maximum power point tracking; adaptive sliding mode; fractional-order theory.

#232: Field monitoring of indoor air temperature of 3D-printed house in the hot climate of Saudi Arabia: a case study of the 3D Studio 2030 in Riyadh

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The residential sector in Saudi Arabia accounts for about 50% of the total energy consumption in Saudi Arabia, 70% of which is attributed to cooling requirements to satisfy indoor thermal comfort. To achieve the objectives of the country's reform plan, known as Vision 2030, Saudi Arabia aims to increase house ownership rates from 47% to 70% within a short time frame (from 2018 to 2030). Statistics suggested that Saudi Arabia needs to build millions of new residential units, at a high rate, to satisfy the significantly growing housing demand. Thus, the country is being pushed to consider advanced construction technologies, robotic technologies and large-scale 3-dimensional printing techniques, to accelerate housing ownership rates and achieve the 70% target. The growing housing demand is expected to increase the already high energy consumption, mainly produced from fossil fuels, in the next few years. The work presented in this paper is a small part of a continuous study to assess thermal performance of existing residential buildings constructed using 3D-printing technology in Saudi Arabia. Data discussed here were gathered from field monitoring of indoor and outdoor temperatures for a house constructed using 3D-printing technology in Riyadh City during the overheated season. Methodology included recording of environmental variables inside different rooms, with different orientations, as well as measurements of external environmental variables, to compare thermal performance of individual rooms and the whole house in relation to the outdoor environment. The monitored data will later be used to validate a standard energy simulation software, which will be used to carry out further investigations to assess and improve overall thermal performance of 3D-printed houses.

Keywords: thermal performance; 3D printing; residential buildings; indoor air temperature

#233: Building retrofit: an active influence on the residential building's energy consumption by changing the size of the windows

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Heating buildings is a pressing issue in the UK given the UK's commitment to achieving net zero emissions targets. To solve this problem, a building strategy to effectively reduce energy consumption by simulating and modifying window size parameters is developed. This study mainly uses computer simulation experiments to evaluate the impact of optimizing window size on energy consumption during building renovation. For this purpose, a semi-detached building located in Nottingham, UK was chosen as a model. The results of the study show that the south side of the building has the most significant impact on energy consumption. Therefore, by increasing the size of the south-facing windows, the overall energy consumption of the building can be significantly reduced. The study showed that the ideal window size increase was 1.6 times the original size, resulting in a window-to-wall ratio of 7.86% compared to 4.91% of the original size. On the contrary, the study highlights that the presence of north-facing windows has a negative impact on the building's energy consumption. The findings have important implications for window reconstruction in British buildings. The research methodology and results can provide a valuable reference for architects and engineers seeking to optimize window design to minimize energy consumption in various types of residential buildings. By applying a similar window optimization approach, it is possible to determine optimal values for reducing energy consumption in different types of residential structures. The research demonstrates the potential to improve the energy efficiency of buildings and contribute to the UK's wider efforts to achieve net zero targets. Implementing these findings in building renovations could pave the way for a more sustainable future and promote energy awareness in the building industry.

Keywords: net zero target; building retrofit; window size; energy simulation; energy consumption

#234: Development of sustainable fracturing fluid utilizing various produced waters

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This study looks into ways to develop an environmentally friendly fracturing more by using produced water (PW) as a replacement for freshwater, which is becoming scarce and expensive. However, PW has high levels of total dissolved solids (TDS) that can affect the fluid's performance and damage the formation. The study explores the best combinations of eco-friendly CMHPG polymers, chelating agents, and crosslinkers to use in different types of PW. To thoroughly assess the impact of different additives, we utilized a cutting-edge industry rheometer in our research. We aimed to investigate the effects of various crosslinkers and chelating agents at different concentrations. It is noteworthy that the fracturing fluids were designed to be biodegradable and have minimal impact on the ecosystem. Each variation was subjected to a shear rate of 100 1/s, a pressure of 500 psi, and temperatures ranging from 25°C to 149°C at different rates of heating. The fluids were tested in de-ionized water (DI) as well as different types of PW with different salinities. The objective of this study was to evaluate the potential of using PW as a substitute for freshwater in hydraulic fracturing, under normal and harsh conditions where the fluid contains polymers, chelating agents, and crosslinkers. The performance of the fluid was assessed based on its highest viscosity. The tested PW samples had TDS concentrations of 100,000, 70,000, and 45,000 parts per million (ppm). It was found that the lower the salinity the better the fluid performance. The study concluded that produced water with a TDS of up to 70,000 ppm can effectively replace freshwater in hydraulic fracturing operations. The study also provided recommendations for the sequence of adding ingredients, optimal pH of the chelating agent, and the resulting fluid properties. The viscosity of the fluid was identified as the key controlling factor. Among the chelating agents tested, DTPA demonstrated better viscosity performance under harsh conditions. Some chelating agents were found to be incompatible with certain types of Zr crosslinkers. While there was little difference observed in scale formation when comparing scale inhibitors to chelating agents, the viscosity of the fluid was significantly affected. The temperature was varied using two different rates of ramping, 20°C per minute and 1°C per minute, depending on the specific application, and the results are detailed in the research paper. The research aims to replace the fresh water, utilizing different PW from worldwide reservoirs. The tested fracturing fluids from the selected PWs had the minimum impact on the environment. This is achieved by not only using PW, which is expensive to dispose, but also by incorporating the least amount of environmentally friendly additives.

Keywords: hydraulic fracturing fluid; treatment; produced water; freshwater consumption; rheology measurements; scale inhibitor; crosslinker; chelating agent; polymer; harsh condition; HPHT

#235: Evaluation of the impact of the aerofoil shape on the performance of an oscillating aerofoil energy harvester integrated into a building structure

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The increasing demand for sustainable building solutions has driven the exploration of renewable energy technologies integrated into buildings. One such approach involves harnessing wind energy around buildings through the integration of oscillating aerofoil-based energy harvesters. Whilst previous studies have investigated building-integrated wind energy devices, these technologies faced challenges such as low wind speeds, high turbulence levels, and cost concerns, hindering widespread adoption. To address these limitations, researchers have turned their attention to oscillating aerofoil energy harvesters. However, the integration of these devices onto building structures requires further investigation, as there exists a knowledge gap in this area. To fill this void, this study utilises computational fluid dynamics simulations and a one degrees of freedom solver in ANSYS Fluent to analyse the behaviour and performance of an oscillating aerofoil installed on a building's roof structure. The study's findings reveal promising results, demonstrating the prediction of the aerofoil's performance under varying conditions. In addition, the placement of oscillating aerofoils on pitched structure has shown to enhance the energy harvester's overall performance. This insight could drive future research to explore additional parameters to further optimise the energy extraction process. Through integrating oscillating aerofoil energy harvesters onto building structures, this study shows the method for the advancement of building-integrated wind energy technologies. This technology holds great promise in enhancing wind energy extraction from the built environment, contributing to more sustainable and eco-friendly energy solutions. As the demand for low-energy building design and renewable energy solutions continues to grow, this research aligns with the broader goal of promoting sustainable development and mitigating climate change. In conclusion, the integration of oscillating aerofoil energy harvesters onto building structures offers a promising approach to maximize wind energy extraction and foster the development of sustainable energy solutions in the built environment. As further research explores and refines this technology, it has the potential to revolutionize the way buildings generate and utilise clean energy, significantly reducing their environmental footprint.

Keywords: building energy; wind energy; computational fluid dynamics; oscillating aerofoil; six degrees of freedom

#236: A review on the state-of-the-art wind energy harvesting technologies and potential integration into building roof structure

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In this study, the focus was on exploring alternative wind energy harvesting technologies that can overcome the limitations of conventional wind turbines in rural communities located in the equatorial regions. The conventional wind turbines have shown low power output in areas with low wind velocities, and their heavy installation on lightweight building structures can compromise the integrity of the structure and lead to a shorter lifespan of the turbines. To address these challenges, the study investigated the power and harvesting performance of various wind energy harvesting systems, particularly those employing oscillating mechanisms like galloping, flutter, and vortex-induced vibration. The objective was to provide a clean energy solution for off-grid communities within the equatorial belt, and to capture energy from the accelerated air flow on building roofs. The review analysed the technical features of each wind-induced vibration technology, considering non-uniform wind flow and a wide range of wind speeds that the energy harvester might encounter on the roof. The findings indicated that small-scale wind energy harvester devices achieved a power output of 8.4 mW at 2.5 m/s. However, further improvements in power output were possible by integrating the energy harvester into roof building structures to create wind velocity acceleration, scaling up the harvester, and incorporating power management. The review revealed a lack of studies on the integration of small-scale energy harvesting devices with structures and buildings, indicating a crucial area for future research. Through exploring lightweight building integrated wind energy harvesting systems with longer lifespans, this study provides opportunity to sustainable energy solutions for off-grid communities, where conventional wind turbines may not be practical.

Keywords: wind energy; small-scale wind energy harvesting system; building-integrated wind energy harvesting system; buildings

#237: A review: practices and challenges of environmental management in the construction industry

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Construction activities, when uncontrolled, have detrimental effects on the environment and also pose risks to social and economic aspects. To address these concerns, environmental management practices are implemented to mitigate the environmental impacts associated with construction activities. However, despite its significance, environmental management faces several challenges and limitations. This study examines the practices and challenges related to environmental management in the construction industry. Employing a content analysis approach, the review draws upon existing literature, official reports, and guidelines. Environmental management practices are categorized based on key elements such as water pollution control and management, air pollution control and management, noise pollution control and management, and construction waste management. The identified challenges of environmental management are classified into factors including resources, human factors, knowledge, regulations, coordination, nature of construction, documentation, and technical aspects. The study findings highlight that knowledge, resources, and human factors emerge as the major challenges in effectively implementing environmental management within the construction industry. Recognizing the crucial role of environmental management in ensuring the sustainability of the construction sector, it is essential to strive for further improvements and adopt greener construction practices. Therefore, the study recommends exploring the potential of human resources and implementing training initiatives to develop green skills among construction team members. The findings underscore the importance of investing in human resources development and training programs to enhance the implementation of environmentally friendly practices in construction projects.

Keywords: environmental management; construction industry; practices; challenges; training; human resources

#238: Addressing incompatibility between crosslinkers and chelating agents in produced water-based fracturing fluids

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This research focuses on optimizing hydraulic fracturing by utilizing produced water (PW) as a substitute for freshwater, which is becoming scarce and costly. As produced water has elevated levels of total dissolved solids (TDS) that can impact the performance of the fluid, the study aims to address this challenge by utilizing chelating agents. However, it has been observed that these agents adversely affect the stability of crosslinked fracturing fluids. Therefore, the study aims to develop a high-viscosity fracturing fluid based on produced water that exhibits superior stability even in harsh environments while minimizing potential harm to equipment and formations. In our research, we employed the advanced Anton Paar-MCR 302 rheometer used in the industry to comprehensively examine the influence of various additives. We aimed to investigate the impact of different chelating agents on the stability of crosslinked CMHPG polymer when combined with zirconium and borate crosslinkers. Four distinct types of chelating agents were analyzed, a) low pH Diethylenetriamine pentaacetate (DTPA), b) low pH L-glutamic acid-N, and N-diabetic (GLDA),c) high pH GLDA, and d) high pH ethylenediaminetetraacetic acid (EDTA). Under the experimental conditions of a shear rate of 100 1/s, a pressure of 500 psi, and temperatures varying from 25°C to 120°C, we tested the fluids in de-ionized water (DI) and diverse PW. Our selection criteria for the optimal fluid included high viscosity, low conductivity, and scaling inhibition. This study aimed to explore the polymers, chelating agents, and crosslinkers behavior in produced water and their response to temperature. Our findings indicate that utilizing a low pH chelating agent leads to elevated viscosities compared to employing a high pH chelating agent. Furthermore, we found that introducing a chelating agent after polymer hydration resulted in increased viscosities. Comparatively, the DI-based system outperformed the PW-based system regarding stability and viscosity. Notably, the GLDA chelating agent demonstrated incompatibility with numerous Zr crosslinkers. However, in PW-based systems, GLDA was observed to enhance stability and viscosity by capturing ions that negatively affect rheology. Similarly, the EDTA chelating agent demonstrated effects on viscosity comparable to that of the GLDA chelating agent. Applying much lower concentrations of the DTPA chelating agent improved the viscosity and stability of high salinity crosslinked produced water fracturing fluid. The optimized fluid concentrations were tested with ICP_OS and DSL scale loop devices and demonstrated substantially better performance than the other chelating agents. Based on these results, we propose utilizing better variations in field operations. In response to growing environmental concerns and the high demand for freshwater, our study sought to develop a fracturing fluid that would effectively mitigate the negative impacts of PW. Our proposed solution involved the integration of a polymer, crosslinker, and chelating agent in a simple and effective fracturing fluid design.

Keywords: seawater; produced water; hydraulic fracturing; chelating agents; zirconium; crosslinker; rheology; viscosity; sustainable

#239: Automatic first arrival picking for seismic data using Kalman filter

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Seismic data processing is an essential part of the oil and gas exploration industry, as it helps to create accurate images of the subsurface geology. The first arrival time of seismic waves is a crucial parameter for seismic data analysis, which is used to determine the depth and location of subsurface structures. However, the estimation of first arrival time is often challenging due to the presence of noise and uncertainties in the data. In this study, we propose a novel approach that utilizes the Kalman filter with generalized likelihood ratio (GLR) to estimate the first arrival time in seismic data. First, a discrete time linear system with unknown amplitudes changes occurring at unknown time instants is used to reformulate the convolutional model. Then, to provide residual signals, we apply a Kalman filter based on the no change hypothesis to the linear system. Finally, a generalized likelihood ratio (GLR)-based change detection technique is utilized to estimate the first arrival time. Using the simulated data, we verified the performance of the proposed approach. Overall, this study presents a promising approach for improving the accuracy of first arrival picking.

Keywords: first arrival picking; seismic waves; Kalman filter

#240: Inter-unit transmission of pollutants inside a typical street canyon

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The recent pandemic has accentuated the importance of clean indoor air, as the spread of COVID-19 virus is primarily airborne. Amongst the various determinants of indoor air quality, the transmission of outdoor pollutants into indoor environment is a significant source. While conventional studies have helped to quantify personal exposure to pollutants and related health impacts, they have not paid attention to the transmission mechanism of pollutants between the two environments. Nevertheless, understanding this process is essential to determine the contribution of ambient pollutants in indoor air quality. Whereas multiple studies have assessed the outdoor pollution in a typical street canyon, very few have simulated the exchange of pollutants between the two domains. The following study aims to assess the transmission characteristics of pollutants between the indoor and outdoor domain in a street canyon using CFD. A validated model of a street canyon was developed, and two ventilation strategies were investigated representing extreme scenarios. Results indicate that in the case of single-sided ventilation, the circulation of air in the canyon forces pollutants from upper rooms on the downstream building to be transported to the lower floors. Similarly, lower rooms on the upstream building can deteriorate air quality on the upper floors. Contrastingly, cross-ventilation prevents inter-unit transmission as the air is always drawn from the side away from the street. Findings from the study assist in understanding the dynamics of indoor pollution dispersion in street canyons.

Keywords: CFD; natural ventilation; pollution; cross-transmission; street canyon; inter-unit

#241: Operational tool for selecting energy systems for small buildings based on useful energy needs

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The European Union is constantly improving the energy performance of buildings directive (EPBD), one of its main objectives being to offer a methodological framework that allows identifying the cost-optimal of energy conservation measures, now with a very strong focus on retrofitting. The share of new buildings is very low, from 1 to 2% of the built stock, and it has become clear that the low renewal rate can jeopardize the assumed goals of reducing energy consumption and, consequently, mitigating the climate changes. There are countless barriers to the energy retrofitting of buildings with an eco-efficiency approach, highlighting the lack of clarity in the strategy of policy makers at national level, complicated regulations of minimum requirements for intervention in the building envelope and renovation of energy systems, lack of information for building owners, corroborated by low quality energy performance certificates and need of simple decision-making support tools. The complexity of analysing scenarios of possible interventions comes from the fact that the economic and environmental impact of a specific measure is influenced by other measures of the same package, which affect the cost optimality. For this reason, the best intervention option may not be a simple combination of individual retrofitting measures. Faced with this complexity, building owners are limited to replacing energy systems at the end of their life cycle. This work proposes an operational tool for selecting energy systems for small buildings based on useful energy needs for domestic hot water preparation, space heating and cooling. Few input parameters are required: energy needs and costs, primary energy and greenhouse gas conversion factors, initial investment, efficiency and embodied impact of energy systems. The methodology applied in this article is aligned with an eco-efficiency approach for the pre-selection of energy systems, integrating cost optimality and life cycle assessment to support decision-making on energy conservation measures. In order to demonstrate its applicability also in the pre-study of the competitiveness of new technologies, an example of an innovative heat pump is presented, in comparison with conventional energy systems in the Portuguese market, to meet useful energy needs in the consumption range of dwellings.

Keywords: buildings; energy retrofit; cost optimality; life-cycle assessment; eco-efficiency

#242: Power quality impacts of grid-tied PV inverters on low voltage distribution networks

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As a renewable initiative, risen attention can be seen in solar photovoltaic (PV) installations in the world. Since tropical countries and even many other countries during summer experience higher irradiance levels, there is great potential for PV generation in solar panels. However, power quality can be impacted when the number of PV modules is increased in a network due to the emergence of harmonics, unbalanced voltages, voltage flicker, neutral voltage variations, etc. Therefore, it is essential to empirically analyse power quality parameters, i.e., total harmonic distortion (THD), voltage unbalance, etc., and find threshold margins of PV capacities in a network. Based on a case study conducted in Negombo, Sri Lanka, this work determines power quality impacts with reference to the number of PV interconnections in a distributed network. For the task, a low-voltage distribution network was chosen which was fed by a 250kVA, 11/0.4kV transformer with domestic loads and grid-tied PV inverters. A simulation model was developed in Open Distribution System Simulator (OpenDSS) with time-varying load patterns and PV generation. Consequently, a smart efficient method was introduced to model domestic loads with unique time-varying demand patterns. A determination criterion was established to derive snapshot load flow instants using time-varying load flow results to analyse voltage profiles along distribution feeders. Then, the model was enhanced to quantify the power quality parameters such as individual harmonic content, THD of voltage as well as current and neutral voltage variation. The results reveal that node voltage has improved with PV interception without violating the upper limit. The THD of voltage and current have slightly increased with the addition of PV inverters.

Keywords: solar PV; renewable energy; low voltage distribution; power quality; OpenDSS

#243: Incorporating monitoring, reporting and verification (MRV) with financial incentives in blockchain-enabled framework

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Global carbon market has been growing significantly over the past decade, in both demand and supply side. Yet, there are hindering effects on the adoption of long-term Carbon Abatement Technologies (CAT) under the existing Emission Trading System (ETS). Companies are lack of management tools and incentives for reducing their operational emissions, instead they choose to buy carbon offsets to meet their emissions compliance. Previous solutions focus on the ETS model, whilst none of them have considered the emission reduction on businesses' operational process integrated with the financial incentives when adopting the abatement tools. A novel design of a Blockchain-enabled Monitoring, Reporting, Verification and Financing (BMRVF) system is presented. The state-of-the-art model allows businesses to monitor, report and verify their emission data, while providing a financial platform to execute transaction and involve investment fundings, as an essential part of the low-carbon transition, under the framework of the Carbon Border Adjustment Mechanism (CBAM). The objective of the proposed system is to provide responsible, effective, and integrated data for verification, while robust, secure, and trustful transaction process. The case study demonstrates the proposed system to provide data integrity and security features using cross-chain blockchain. Business transaction cost and operational cost will also be examined in this paper. Multi-criteria analysis is used to evaluate the proposed scheme against conventional transaction model based on three key features: environmental performance, political acceptability, and feasibility of implementation. The proposed system is examined to be feasible as a design of novel emission management tool under the CBAM framework.

Keywords: blockchain application; MRV system; carbon border adjustment mechanism; cross-chain

#244: The potential of green engineering solutions toward sustainable residential buildings: a case study of Saudi Arabia

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The word “green” has become associated with sustainable products and environmental awareness, while the ‘green engineering’ term is used to describe building design that seeks to minimise pollution and promote human health, as well as promoting sustainability and nurturing the environment. Efficient green buildings can potentially boost economic growth, enhance social development, and promote the sustainability of the environment. Hence, buildings featuring minimal greenhouse gas (GHG) emissions and energy use while delivering thermal comfort are among the contemporary challenges of building design. Since the building sector is highly significant in Saudi Arabia because of its complex national economy and the fact that its development rests on the development of other economic sectors. Additionally, Saudi residential buildings consume almost half of the total national electricity consumption, so it will play a pivotal role in addressing energy and sustainability issues. One of the current mega projects of Saudi Arabian Vision 2030 is the Saudi Public Investment Fund’s (PIF) ROSHN housing project, which involves 150 million square metres across nine major cities. The first stage involves the Sedra district in Riyadh city which will eventually have over 30,000 residential buildings across a 20 million square metre area. Thus, ensuring the exploitation of the advantages of green engineering solutions to improve the energy consumption and thermal comfort performance of such mega projects without impacting their architectural values should be a national goal. However, less scholarly attention has been directed toward investigating how energy efficiency measures, renewable energy، and traditional passive architectural design can be combined in one model. Moreover, previous studies have used case studies focused either on old buildings or those that have been built without claims to the use of sustainable principles. Therefore, the author demonstrates in this poster the integration of applying energy efficiency measures, low carbon technology (renewable energy), and traditional passive architectural design in one model within the context of the sustainability concept by using one of the residential buildings from the project above as a case study.

Keywords: green buildings; sustainability; energy consumption; Saudi Arabia

#245: A renewable multigeneration energy system for a public school in Denmark

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Distributed energy resources are becoming increasingly popular in times of energy volatility caused by large price fluctuations in the energy markets. It is therefore pro-actively interesting and advantageous for energy-heavy consumers if they establish renewable multigeneration systems to partly cover their own energy demand. Multigeneration systems create both low-emission energy and have the potential to yield positive impacts in terms of the total energy price and the economic feasibility of the energy generation solutions for the consumer. By implementing linear programming, a well-documented optimization method, this paper sets out to construct an open-source framework that can be used to evaluate different distributed renewable energy resource combinations for different types of consumers. This framework will make it possible to evaluate known and thoroughly tested technologies in combination with alternative technologies to determine the potential of investment. To showcase this possibility, scenarios containing different energy supply technologies were examined to determine the optimal technology mix and production plan for a public school located in Southern Denmark. The findings highlighted that the socioeconomic benefits of utilizing photovoltaic-thermal technology are very promising and have a large potential. Nevertheless, the combination of photovoltaic technology and heat pumps was the best overall scenario because of its ability to generate relatively cheaper energy while also maintaining socioeconomic benefits. This is especially important because it fits into the Danish plan for district heating expansion and reimbursement. The paper illustrated how the framework can be applied in combination with different technologies to determine the most efficient scenarios. The proposed technology combination of heat pumps, district heating, and photovoltaic units would, after implementation, be able to save the public school around 6.7 MDKK in a period of 20 years, with a payback period of around 9 years. It was shown that, within the specific multigenerational system proposed, heat pumps would cover 92% of the heat demand but would not be sufficient in peak load hours; therefore, district heating will be needed as a support.

Keywords: linear optimization; production planning; multigeneration system; renewable energy; socioeconomic evaluation

#246: Implementing deep reinforcement learning for enhanced energy management in renewable energy microgrids

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In light of the rising global energy demands and heightened environmental considerations, the integration of renewable energy into microgrids has been identified as a vital progression towards sustainable energy solutions. However, the characteristic variability and unpredictability associated with renewable energy sources present formidable obstacles in achieving equilibrium between supply and demand within the microgrid. This feasibility study investigates the potential application of deep reinforcement learning to enhance energy management in renewable energy microgrids. A comprehensive evaluation of a sophisticated deep learning model, used for time series prediction, is conducted to determine its capability in providing accurate, real-time forecasting of power generation. The study also explores a ground-breaking strategy, rooted in deep reinforcement learning, to improve energy distribution and coordination within the microgrid. The practicability of this approach, which encourages continuous interaction between the agent and the microgrid environment to develop an optimised action policy, is evaluated. By potentially enabling the efficient orchestration of the "source-grid-load-storage" system, the strategy could significantly improve energy management in renewable-energy microgrids. The paper examines the viability of this approach as a holistic energy management solution for renewable energy microgrids, which could facilitate optimal control and ensure consistent energy supply. The study gauges the potential impact of such advanced energy management strategies, the practical implementation, and the contribution towards advancements in the renewable energy sector, potentially paving the way for a future of increased energy sustainability and efficiency.

Keywords: feasibility study; renewable energy microgrids; deep reinforcement learning; real-time power generation forecasting; energy sustainability and efficiency

#247: The impact of applying the new Saudi building code on residential buildings performance in Riyadh region

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The continual increase in energy consumption is a great concern of human life due to the environmental impact. The rapid population growth, fast urbanisation and high economic growth are the main factors for a considerable expansion in the building sector. The extensive construction activities in the building sector, especially with respect to domestic buildings are certainly a cause of the overall increase in energy consumption. Worldwide, over a third of the total global energy consumption occurs in the building sector. Domestic energy consumption in particular has experienced fast growth in many developing countries during the last few decades. For example, in the Kingdom of Saudi Arabia (KSA), the energy demand in the domestic building sector has increased approximately by 7% annually since 1990, mostly due to air conditioning load for cooling. One way to curb the building energy consumption is through building's energy efficiency measures and introduction of effective energy standards and codes, which have been adopted in over 30 countries and regions around the world. This paper assesses and analyses the energy consumption patterns in residential buildings in the Riyadh region, the largest region in the KSA in terms of population and housing density. The impact of applying the recently developed Saudi Building Code (SBC) on the building energy performance is presented. This study includes 21 typical residential buildings within the Riyadh region, involving villas and apartments, which are growing rapidly with the Saudi building sector. The analysis is based on actual electricity bills, user behaviour, and results of building simulation using DesignBuilder (DB) software. Results have shown that, application of the SBC and standards to the buildings' fabric could lead to an improvement in the energy consumption in villas and apartments by to 19% and up to 40%, respectively. The variation is due to the impact of the various retrofitting strategies. The building fabric elements in particular are found to have a significantly impact in the reduction of the building energy consumption.

Keywords: energy modelling; residential buildings; KSA; Saudi Building Code (SBC)

#248: Experimental study on film hole wall heat transfer by using transient liquid crystal technique

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Film cooling plays a crucial role in creating effective cooling systems for gas turbine blades, which are necessary to meet thermal protection standards to achieve high thermal efficiency. Whilst the downstream film effectiveness is well understood, the internal heat sink effect, caused by heat transfer coefficients within the entry length to the cylinder are often not well understood. This study was conducted to experimentally evaluate detailed heat transfer coefficients within a representative geometry, provide contours of internal surface Nusselt number, circumferentially averaged Nusselt number along the entry length of the channels, and provide discharge coefficient data. The Transient Liquid Crystal techniques has been implemented to study the heat transfer distributions over the wall of the film hole. The test section representing the film cooling hole was a cylindrical channel and it had a length of 5 jet diameters. The experimental tests have been conducted at wide range of Reynolds numbers (30,000–60,000), inclination angle (0^o-135^o) and rotation angle (0^o-135^o). Based on the results, Nusselt number distribution was independent of Reynolds number, but Nusselt number magnitude increases monotonically with Reynolds number. When inclination angle was introduced, it was discovered that there was a reduction of the reattachment heat transfer enhancement, but an overall increase in heat transfer could be achieved, with most enhancement shown for inclination angle of 45°. While varying the rotation angle illustrated that the most significant impact was within one diameter in length from the channel entry, with overall reductions in heat transfer when varied by more than 90°. The effect of channel entry configuration was also varied between sharp, filleted, and chamfered. Results showed that the sharpness of the nozzle was directly related to the magnitude of the entry length separation and reattachment heat transfer enhancement. When assessing the impact of geometry and flow variations on discharge coefficient, it was observed that discharge coefficient decreases with increasing entry sharpness, increasing inclination angle, and increasing rotation angle.

Keywords: film cooling; transient liquid crystal technique; heat transfer

#249: A BIM-based framework for designing sustainable structures through the reuse of precast concrete components

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The widespread use of concrete within the global construction sector is primarily attributed to its inherent qualities of resilience, versatility, longevity, and facilitation of economic growth. Nevertheless, it is noteworthy that this popular material is a significant contributor to the industry's greenhouse gas emissions, material depletion, and substantial waste production. Particularly in Europe, concrete constitutes the major component of demolition waste. Consequently, the practice of recycling and reemploying concrete components from pre-existing architectural structures harbours a considerable potential to attenuate the construction sector's ecological footprint substantially. This study presents a Building Information Modelling (BIM)-based reusability framework that aims to facilitate the reuse of precast concrete components in new sustainable structures, predicated on their performance and in line with specific matching criteria. This methodology involves utilising two distinct types of BIM models as input data. The first category, called 'Supply BIM', encapsulates data regarding existing components. In this category, the disassembly cost, the cost of each component, the disassembly durations, and the Life Cycle Analysis (LCA) of each component are calculated. Moreover, the load-bearing capacity of each component is analysed. The second category, termed 'Request' BIM, incorporates data necessary to reuse components during their subsequent lifecycle. The operational procedure relies on the BIM-based reusability model to aggregate matching concrete elements. Under the assumption that the Supply BIM possesses custom-built attributes equivalent to the Request BIM, the system will autonomously collect these components. This provides the foundation for a sustainable design for a new construction project. However, if the cost or LCA of the existing matching components exceeds that of the conventional new components, such components will be disregarded. This framework will underpin the development of a tool for designers that has the potential to reduce time and cost expenditures while minimising human error in sustainable design processes.

Keywords: reusability framework; BIM for reusability; circular economy; sustainable structure; precast concrete reuse

#250: Enhancement of indoor air quality: an experimental study on the MopFan-based photocatalytic air cleaning system

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This paper presents a comprehensive investigation into the development and application of an innovative MopFan-based photocatalytic air cleaning system designed to significantly improve indoor air quality. The primary focus of this research is the utilisation of Photocatalytic Oxidation (PCO) technology, a method previously employed to effectively remove organic contaminants and compounds from air streams. The MopFan system, a novel concept in air purification, incorporates a unique design featuring a Titanium Dioxide (TiO2) coated fibre mop system and UV lights. This design provides a large surface area for UV irradiation, thereby enhancing the efficiency of the air purification process. The paper details the process of developing the MopFan system, from the initial concept to the creation of functional prototypes. The prototypes demonstrate the operation of the PCO-based air purification principle, with the mop system providing a significantly larger surface area for UV irradiation compared to traditional air purification systems. The MopFan system uses four commercially accessible materials for the construction of the mop: Tampico, Brass, Coco, and Natural synthetic. Two types of UV lights were used: 365 nm (UVA) and 270 nm (UVC), to test the effectiveness of different UV light wavelengths in the air purification process. The study includes a series of rigorous tests conducted to prove the prototype's functionality and its efficiency in reducing volatile organic compounds (VOCs) and formaldehyde (HCHO). The results indicate that a MopFan with a rotary mop constructed with Coco fibres and utilising UVC light achieves the best VOC and HCHO purification performance. Within two hours, this combination lowered HCHO by 50% and VOCs by 23% approximately, demonstrating the potential of the MopFan system in real-world applications. The findings of this study have implications for the design and implementation of future air purification systems.

Keywords: photocatalytic oxidation; air purification; MopFan system; volatile organic; compounds; indoor air quality

#251: The role of the informal sector towards sustainable waste management practices in developing countries: case study in Jordan

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Waste management is a growing environmental concern worldwide due to its carbon footprint as well as the rising waste quantities coupled with the increasing global population. Waste management is challenging in developing countries in particular due to the insufficient sustainable practices in waste collection and disposal. This study aims to characterize and investigate the role of the informal recycling sector in Jordan from technical, economic, and social perspectives. Informal recycling plays a vital role in Jordan's waste management sector; however, recent strategies have discussed eliminating or regulating this sector under the government's umbrella. Several interviews were conducted with government officials and workers in the informal recycling sector in Jordan, and it was concluded that recycling in Jordan does not exceed 10%, which is mainly attributed to informal recycling. It was also inferred that informal scavengers typically belong to socially marginalized groups in Jordan, and they experience harsh socioeconomic conditions because of this profession. Informal recycling workers also expressed their concerns towards the governmental plans to regulate their profession as this may increase the financial burdens associated with taxing and social security.

Keywords: informal recycling; waste scavengers; sustainable waste management; waste recycling

#252: A comparative study on utilization of marine Ulva Lactuca seaweed and freshwater Azolla Filiculoides macroalgae as feedstocks for lipids extraction and biodiesel production

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Utilization of algal biomass for biodiesel production attracted the researchers' attention due to its availability as a feedstock that does not threaten human food sources. In this research, the productivity and characteristics of lipids and biodiesels were compared between two algal species: marine ulva lactuca seaweed and the freshwater azolla filiculoides macroalgae. Soxhlet apparatus was used to extract lipids from both species at conditions of 1:10 w/v solvent ratio, varying temperatures 60 – 75°C, and varying times 1 – 9 h. The maximum extracted lipids were 7.6±0.10% and 12.52±0.23% from ulva lactuca and azolla filiculoides, respectively, at solvent ratio 1:10 w/v, temperature 70°C, and time 8 h. Kinetics and thermodynamics analyses for lipids extraction of both species were conducted using the second-order kinetic model and Eyring equations. The estimations of activation energies were 53.93 kJ/mol and 85.79 kJ/mol for ulva lactuca and azolla filiculoides, respectively, indicating that the Soxhlet extraction was temperature-dependent process for both species. Furthermore, enthalpy (ΔH) and entropy (ΔS) values were -510.94 kJ/mol and -75.99 J/mol/K for ulva lactuca, and -33.67 kJ/mol and -214 J/mol/K for azolla filiculoides, respectively, revealing that the Soxhlet's lipid extraction from both species was an exothermal process. For Gibbs free energy of activation (ΔG), the analysis showed a spontaneous extraction process for ulva lactuca and non-unspontaneous process for azolla filiculoides. For biodiesel production, four independent variables were optimized using response surface methodology (RSM). The maximum biodiesel was 88.77% yielded from ulva lactuca lipids at synthetic conditions of 1:12 oil to methanol molar ratio, 1.5% NaOH ratio, 63°C temperature, and 1.7 h time. Conversely, azolla filiculoides lipids yielded 82.85% of biodiesel at optimal conditions of oil to methanol molar ratio 1:10, catalyst ratio 1%, temperature 60°C, and time 2 h. The characterized physicochemical properties of biodiesels synthesized from both species were found to comply closely with the ASTM D6751 and EN14214 standards. Finally, the findings of this study conclude that marine ulva lactuca seaweed and freshwater azolla filiculoides macroalgae are viable, cost-effective, and promising feedstocks for sustainable biodiesel production.

Keywords: biodiesel; biofuel; lipids extraction; seaweed; macroalgae; sustainability

#253: The impact of courtyards and window designs on thermal and visual comfort conditions in adobe traditional buildings of Nigeria

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Most traditional buildings are designed based on ventilation, thermal comfort, wind flow, etc. courtyards and windows are common features of vernacular architecture, and they play major roles in maintaining visual and thermal comfort in traditional building practices. The influence of courtyards and window designs on ventilation, daylighting, and thermal comfort is specific to a region shaped by local climate, culture, and available resources. This study analyses the comfort conditions (thermal and visual) of Ilorin adobe traditional buildings in the warm-humid region of Nigeria, West Africa. The research aims to understand and analyse how courtyards, window sizes, designs, and arrangements affect occupants' comfort and overall environmental performance by employing a combination of case studies, fieldwork, and computer simulations using Optivent 2.1 and Andrew Marsh simulation tools. The study will evaluate the efficacy of various environmental and window design options to optimize natural ventilation, maximise daylight penetration, and improve thermal conditions. The performance predictions and output of simulations will not only identify strategies to conserve energy consumption but will also provide a valuable understanding of sustainable design principles for adobe traditional buildings, offering guidance to designers, conservationists, and policymakers to preserve cultural heritage while maintaining comfort and healthy living conditions.

Keywords: adobe; traditional buildings; window design; courtyards; ventilation; daylighting; thermal comfort

#254: Advancing thermal comfort research: evaluating indices for naturally ventilated residential buildings in diverse climatic zones

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Thermal comfort research has taken a turn in the last decade with more focus on comfort models applicable to different climatic zones. Working home conditions due to pandemics added to it and started giving it a different direction altogether. Liveability and thermal comfort of houses of all income classes have hogged attention. There are several studies carried out in thermal comfort in naturally ventilated residential buildings specific to different regions and climatic conditions. Most of these thermal comfort studies are carried out in last two decades and used different thermal comfort indices to analyse the adaptiveness and other thermal comfort parameters of the occupants. This paper is an attempt towards that direction by reviewing the models or indices used for the evaluation of indoor thermal comfort specific to a climatic zone for naturally ventilated residential buildings and an evaluation of different indices are carried out based on the ASHRAE DB-RP884 specific to different climatic zone on the preview of the comfort indices used. The result of this study shows that the researchers preferred certain indices for each of the climatic zones. Based on the evaluation, a recommendation is made on the indices which gives the highest thermal comfort estimation of the occupants specific to the climatic zone. This result can guide future researchers on the selection of the indices specific to a climatic zone.

Keywords: thermal comfort indices; different climatic zones; adaptiveness; NV residential buildings; ASHRAE DB-RP884

#255: A hardware-in-the-loop simulation of a heat pump system for vehicle thermal management

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The need to reduce vehicle emissions imposed by governments has led manufacturers to focus on the development of battery electric vehicles. Although this is a promising solution for improving air quality and reducing CO2 emissions, there are still some limitations hindering the widespread adoption of electric vehicles. The primary obstacle is the limited driving range compared to traditional internal combustion engine vehicles. This is due to the significant difference in energy density between the two technologies' energy storage systems and the longer charging time required for batteries compared to refuelling a tank of fuel. To address the limited driving range without increasing battery size (which would raise vehicle cost and weight), enhancing the energy efficiency of auxiliary systems, particularly the thermal management system, becomes crucial. Installing heat pumps and integrating them into a system that manages the thermal needs of the cabin, battery, power electronics and electric motor (PEEM) in a single unit can be an effective option for improving vehicle energy efficiency. The solution explored in this study is referred to as a single-liquid coolant loop. It consists of a primary refrigerant loop (a heat pump) that exchanges heat with a secondary liquid coolant loop. Through an intelligent valve system, the secondary loop delivers cold or warm coolant to various vehicle subsystems that require thermal management and allows for the recovery of the waste heat from the electronic components. Implementing control logic and defining the system's working modes necessitate simulating it using a mathematical model due to the high cost of conducting experimental tests on a real vehicle. To overcome the computational time required for simulating a model with a high level of accuracy, particularly regarding the refrigerant circuit, this paper presents the design of a hardware-in-the-loop (HIL) simulation. The HIL simulation allows testing the various functionalities of a vehicle-integrated thermal management system in real-time. The simulation focuses on the coolant loop and the models of cabin, battery and PEEM, while a dedicated test bench replicates the thermal loads calculated in the simulation to evaluate the performance of the heat pump. The thermal loads are replicated by incorporating an electric heater into a coolant circuit connected to the evaporator and a radiator into a separate coolant circuit connected to the condenser. An important advantage of this HIL simulation is that we can verify the performance of the compressor's and electronic expansion valve's control systems on the real heat pump without assembling the entire vehicle thermal management system in the testing area. The results demonstrate the HIL system's ability to synchronize the test bench with the mathematical model by showcasing a battery electric bus driving in summer conditions. The only limitation of this HIL system is represented by the electric heater installed in the test bench, which should be more powerful to accurately reproduce the scenarios with the maximum thermal load on the evaporator.

Keywords: heat pump; hardware-in-the-loop; thermal management; battery electric vehicles

#256: The impact of PV, battery and Immersun on the Meadows community: data analysis of Project SENSIBLE

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High energy prices and the goal of net zero by 2050 are putting pressure on the lives of people in the UK. Project SENSIBLE is a programme that ended five years ago with the goal of saving energy costs and carbon emissions by installing renewable energy devices in houses within the Meadows community in order to achieve self-consumption of electricity. In this paper, the data records of the project are collated and the relationship between PV, battery, Immersun and energy trading is analysed separately from the perspective of electricity exchange. The impact on economic and carbon emission indicators from different operating strategies of renewable energy devices is finally summarised. Firstly, the typical daily load profile of a single house is summarised in a regular manner, and it was concluded that the peak energy use is almost entirely in periods of high rate. Secondly, the contribution of different control strategies to peak shaving is analysed, concluding that battery can reduce electricity sales by more than 60% and use this electricity for their own consumption, resulting in more efficient use of PV output. On this basis, by considering the change in electricity price during a day, it is concluded that the combination of PV and storage devices can reduce the amount of electricity bought during periods of high rate by more than 50%, with positive impact on the reduction of carbon emissions. Finally, a simulation of three houses with renewable energy equipment supporting one house with conventional energy sources is presented to show that the formation of a community energy network can further reduce the exported energy with very low income, improving the use of PV output and reducing energy cost. As there is still excess PV output, the use of heat pumps will be considered in the future to further improve energy efficiency.

Keywords: self-consumption; energy cost; carbon emission

#257: Data-driven optimisation-based machine learning for thermal comfort in building environment

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Achieving thermal comfort under minimum energy considerations has become a hot topic in the field of energy building management. The existing studies have suggested several methods to predict thermal comfort and accordingly adjust the temperature setpoints to reduce the energy. The two drawbacks of the existing studies involve the increased complexity in optimisations using multiple models and the lack of these methods on optimisations. Our novel work proposes a data-driven optimisation solution based on machine learning (ML) to maintain thermal comfort under energy efficiency considerations. We simply infer the input from a desired output using supervised learning models as an optimisation solution. We discuss the efficiency and cost-effectiveness of the proposed solution using a public UK-schools dataset from the ASHRAE database.

Keywords: machine learning; energy efficient building; thermal comfort

#258: Heat exchangers technology and applications in heat exchanger engineering

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Over the years, all parts of a commercial refrigerator, such as the compressor, heat exchangers, refrigerant, and packaging, have been improved considerably due to the extensive research and development efforts carried out by academia and industry. However, the achieved and anticipated improvement in conventional refrigeration technology is incremental since this technology is already nearing its fundamentals limit of energy efficiency is described is ‘magnetic refrigeration’ which is an evolving cooling technology. The word ‘green’ designates more than a colour. It is a way of life, one that is becoming more and more common throughout the world. An interesting topic on ‘sustainable technologies for a greener world’ details about what each technology is and how it achieves green goals. Recently, conventional chillers using absorption technology consume energy for hot water generator, but absorption chillers carry no energy saving. With the aim of providing a single point solution for this dual-purpose application, a product is launched but can provide simultaneous chilling and heating using its vapour absorption technology with 40% saving in heating energy. Using energy efficiency and managing customer energy use has become an integral and valuable exercise. The reason for this is green technology helps to sustain life on earth. This not only applies to humans but to plants, animals and the rest of the ecosystem. Energy prices and consumption will always be on an upward trajectory. In fact, energy costs have steadily risen over last decade and are expected to carry on doing so as consumption grows. Refrigerants such as hydrochloroflurocarbons (HCFCs) are present in the ground source heat pump (GSHP) systems and can pose a threat to the environment through being toxic, flammable or having a high global warming potential.

Keywords: absorption cycles; environment; heat pumps; refrigeration cycles; thermodynamic

#259: Analysis of the impact of evaporative cooling strategies on the aero-thermal comfort performance of courtyard buildings in hot-dry climates

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A courtyard is a central open-air area that can ventilate room spaces surrounding it via wind-driven and buoyancy (stack effect) forces. Evaporative cooling strategies such as well or water features are integrated with courtyard spaces to provide additional cooling. The role of different water bodies in providing evaporative cooling and increasing humidity in the courtyard has been the focus of several studies. However, the impact on the aero-thermal comfort conditions of the surrounding building or rooms adjoint to the courtyard is still not tackled. The present study investigates the effect of an evaporative cooling system on the wind and thermal conditions inside a courtyard and the indoor spaces ventilated using single-sided and cross-flow ventilation. A computational fluid dynamics (CFD) model has been developed and validated for assessing the aero-thermal comfort conditions of various evaporative cooling water spray configurations. The courtyard and hollow-cone nozzles were validated based on previous data from wind tunnel experiments. Indoor thermal comfort conditions under four scenarios were assessed. The results showed that the evaporative cooling water spray had positively impacted the indoor aero-thermal comfort conditions, with a maximum cooling effect of 1.62°C for the single-sided ventilation courtyard, while an increase in indoor wind speed of 14% was observed for the cross-ventilation courtyard. The cooling for the indoor space is limited especially in cross ventilation courtyard and is not economical, however, it could still provide cooling for the courtyard area, with more than 3°C cooling effects for the cross-ventilation courtyard and 1°C to 2°C temperature reduction for single-sided ventilation courtyard area, which can be used to prevent overheating during extreme conditions.

Keywords: aero-thermal comfort; CFD modelling; water sprayer; evaporative cooling strategy

#260: Converting flood risk areas to water resilient and productive dryland production systems: example of flood water spreading weirs in Ethiopia

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The drylands of Ethiopia are faced with recurrent droughts and an increasing frequency of flash floods that lead to severe food insecurity and malnutrition, resulting in humanitarian response actions. However, beyond humanitarian response, the strategies for drought and flood risk management, and particularly the investment and development opportunities of using floods for dryland farming, are poorly understood. Historical flood risk information and remote sensing tools were used to assess suitable areas for flood recession areas. The tested flood water spreading weir (WSW) practice assisted in converting flash floods that emerge from adjacent mountains to a productive use. WSWs established different farming zones based on the soil moisture regime and nutrient deposition distribution. The approach has enabled pastoralists to produce substantial amounts of biomass and grain during short and long rainy seasons, which would be stored and utilized during succeeding dry months. Highland-to-lowland geomorphological connectivity of landscape segments and characterizing their rainfall conditions can be useful frameworks for flood risk analysis and assessing floodplain farming. This case study suggests that flood risk can be managed through spreading weirs in the form of recession farming, negating the need for recurrent humanitarian response actions. Thus, addressing the knowledge and evidence gaps contributes to an informed decision towards unlocking the opportunities of flood farming to support livelihoods and economic development in drought-prone areas.

Keywords: flash floods; water spreading weirs; recession farming

#261: Carnot battery using a partial cascade organic-steam Rankine cycle

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Carnot battery is an emerging technology for low-cost, site-independent, environmentally friendly electricity storage and is also suitable for use in the heat sector. State-of-the-art Carnot battery uses subcritical steam Rankine cycles (SRC) for heat-to-power conversion because of the significant technical challenges of supercritical cycles, including increased leakage losses at high-pressure turbines and wetness at low-pressure turbines. The maximum operating temperature of about 565ºC for molten salts limits the live steam pressure, water evaporation temperature (310-340ºC) and power cycle efficiency. To increase the average temperature in the heating process and the cycle power efficiency, this paper proposes an innovative Carnot battery using a partial cascade organic-steam Rankine cycle integrated with molten salt storage. The organic fluid, a mixture of biphenyl and diphenyl oxide, absorbs heat from the molten salts and evaporates at a high temperature. It drives a turbine and then releases heat to generate steam for the bottom cycle. The steam is superheated and reheated by the molten salts. Fundamentals of the proposed system are illustrated, and mathematical models are built. Optimization is conducted. The results show the proposed Carnot battery has an efficiency of 8% higher than conventional ones.

Keywords: Carnot battery; organic Rankine cycle; steam Rankine cycle; molten salts; biphenyl/diphenyl oxide mixture

#262: Determinants of consumer purchase decision-making for building materials made from steel slags in Taiwan

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The phenomenon of globalization has significantly shifted the focus towards carbon neutrality, green design, and green consumption as the primary drivers of sustainable practices. Steel slags, which are by-products of steelmaking, hold potential for resource recycling and regeneration. This study aims to investigate the determinants that influence consumer purchase decision-making for functional building and textile materials made from steel slags, positioning them as eco-friendly products. Drawing upon industry analysis and ecological marketing theory, this research utilizes structural equation modelling (SEM) to verify the factors affecting consumers' green-oriented buying behaviours. A questionnaire was distributed to consumers in Taiwan, encompassing three independent variables (green consumption awareness, social value, and innovative product history) and one dependent variable (green perception value). A total of 338 valid responses were collected. The findings indicate that consumers' green consumption awareness and social value are the two most influential factors affecting purchase intention, whereas the impact of innovative products is relatively less pronounced. The study provides practical suggestions for corporations seeking to enter new green markets.

Keywords: circular economy; steel slag; consumer purchase decision-making; building material

#263: Simulation models with different electric vehicle charging strategies: a case study in East Midlands Airport

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The demand for electric vehicles (EVs) has witnessed a remarkable 40% global increase in registrations in 2020, signalling a significant transition from internal combustion engines (ICE). In the UK, the number of EVs on the road is projected to reach a staggering 10 million units by 2030, constituting 30% of the total vehicle population. However, this shift towards EVs poses challenges to the existing energy infrastructure if electricity demand is not effectively managed. Simultaneously, EV batteries' energy storage capacity opens new prospects in energy trading and grid arbitrage services. This study aims to assess the impact of EVs on the future energy landscape, considering three use cases (traditional, peak shaving, and grid arbitrage) for a large commercial parking facility during the period from 2022 to 2030. To achieve this goal, the artificial neural networks (ANN) algorithm was first used to estimate the building energy demand and tariff, within the context of East Midlands Airport from 2023 to 2030, followed by simulating impact of EV penetration. Results demonstrate that the traditional charging method leads to an exponential increase in energy demand of 44% until 2030, with a total cost of £3.2 million. Smart charging, on the other hand, offers cost benefits by optimizing charging during lower demand periods, resulting in a total cost of £1.4 million (56% savings compared to the traditional method). The most optimal solution, however, is the bidirectional charging facility with grid arbitrage, enabling EVs to charge during lower tariff periods and engage in energy trading during higher tariff periods. This mode offers a 90% reduction of the total cost as compared to the base case, with a total saving of £2.9 million. The findings underscore the importance of investment in infrastructure and technology today to prepare for future EV penetration, as a delayed deployment of necessary infrastructure will impose substantial strain on the energy grid.

Keywords: electric vehicles; use cases; traditional charging; peak shaving; grid arbitrage

#264: Study on the energy-saving benefits of intelligent lighting systems by using occupant-centric control

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Smart technology has long been considered the future standard for buildings; however, its implementation in the construction industry has not been as widespread as in industrial manufacturing and vehicles. Among the various smart building control technologies available, Occupant-Centric Control shows significant promise in terms of energy efficiency and carbon reduction. Thus, this study aims to integrate dynamic user behaviour as decision-making criteria into the existing sensor-based lighting technology, with the goal of establishing a fundamental model for occupant-centric control. The results of this study, conducted at National Cheng Kung University on a container testing house, highlight that the positioning, detection range, and activation time of occupancy sensors are the primary factors influencing the power consumption of lighting systems. To achieve the optimal configuration of the lighting system using occupant-centric control, careful consideration should be given to the positioning and detection range settings, similar to the configuration of fire sprinkler systems. Furthermore, the activation time setting of the intelligent lighting system should account for the intended purpose of the space and the duration of occupancy. Microwave sensors, known for their heightened sensitivity and ability to detect through walls, are well-suited for intelligent lighting in large areas such as underground parking lots. On the other hand, PIR infrared sensors are more suitable for smaller areas like restrooms, corridors, and pantries. Notably, when the PIR sensor is set with a detection range of 0.5m, the activation frequency is the least frequent. Compared to traditional lighting systems, it can achieve energy savings of up to 84%.

Keywords: smart building; occupant-centric control; lighting system; energy-saving

#265: Ambient humidity-driven power generator using ionic hydrogels

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Harvesting and converting energy from ambient humidity is an attractive topic of intense interest and could offer an alternative to satisfy the growing demand for electrical energy in an environmentally friendly manner. The abundant and widely distributed moisture in the atmosphere can also be considered as a renewable energy source. When both sides of a surface-charged nanomaterial are exposed to different ambient humidity, the spontaneous moisture diffusion through the specific material will drive charge movement and uneven distribution, thereby potentially converting the Gibbs free energy into electricity. The difficulty of this technological breakthrough lies in the development and assembly of power generation materials, which investigation is still in progress. Recently, we developed a poly (acrylamide-co-acrylic acid, AM/AA) hydrogel with oxygen-containing functional groups (-COOH) for humidity power generation. The hydrogel has good moisture permeability inside and has good hygroscopicity by doping 30-35 wt% hygroscopic salt (LiCl). This material can also be easily prepared by ultraviolet light irradiation. By further assembling multi-walled carbon nanotubes electrodes on both sides of the hydrogel and exposing them to ambient air, a stable output power was observed. The results show that the AM/AA generator (size: 1×1cm2) can achieve an open circuit voltage of 1.2V and a short circuit current of 20 μA/cm2 in air at 20°C and 60-90% RH, as shown in Fig.1. When connecting to an external resistor (RL = 500 kΩ), a continuous power density of 2.34 μW/cm2 was obtained. Furthermore, this power output remains steady after 210 hours with decaying <5%. It was found that the presence of lithium ions significantly can increase the moisture adsorption and ion transport capacity of the hydrogel, thereby enhancing the power generation. The positive potential of the bottom electrode repels ions under double-layer effect, driving the directed movement of ions and producing electrical energy output. This hydrogel humidity-generator demonstrates promising potential for the development of portable power sources and self-powered electronics.

Keywords: ambient humidity; humidity gradient; power generation; hydrogel; hygroscopic salts

#266: Non-Traditional Social Housing in the UK

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Homes account for 26% of total greenhouse gas emissions in the UK, primarily arising from energy consumption. The UK's housing stock is among the oldest and least energy-efficient in the world, relying heavily on heating, typically powered by gas. As a result, meeting the UK's net zero greenhouse gas emissions target by 2050 relies on housing retrofitting for energy efficiency. Housing retrofit provides several benefits, such as reduced energy demand and costs, thereby reducing fuel poverty; improved comfort and wellbeing for occupants; and lower maintenance and repair costs. The social rented sector accounts for 4 million (17%) of England's projected 24 million households. Despite having a larger proportion of energy-efficient housing within its stock than other tenures, social housing has a significant decarbonisation challenge. The housing shortage at the end of the Second World War sparked a local-authority-driven house-building initiative across the nation. To meet the demand, in addition to 'traditional' brick-built homes, an estimated 1.5 million 'non-traditional' homes were constructed between the 1940s and the 1970s. Half of the stock is still in the social rented sector, which also falls under the Energy Saving Trust's subcategory group of 'hard-to-treat' homes. Precast reinforced concrete, in-situ concrete, and steel-framed construction were the most prevalent types of non-traditional construction. In spite of the fact that non-traditional housing comprises a significant portion of the social housing stock and exhibits greater improvement potential, due to its innate architectural complexities, it tends to be overlooked in favour of other traditional archetypes when it comes to retrofitting with energy-efficiency measures. Additionally, it remains a challenge to understand and identify the key characteristics of these typologies. This is, therefore, the focus of this work. The authors have explored the potential impact of retrofitting 'hard-to-treat' homes on the UK's net zero ambitions. The authors have identified and collated the most prevalent non-traditional housing archetypes' stock profile, general characteristics, features, and construction conditions. This comprehensive evaluation covered construction systems such as Wimpey No-Fines, British Iron and Steel Federation Housing, Unity, and Easiform type. This will aid in understanding the existing thermal performance and serve as a basis for suggesting practical and cost-effective retrofit alternatives for future research.

Keywords: social housing; non-traditional construction; fuel poverty; hard-to-treat homes; retrofitting; stock profile; Unity construction; Wimpey No Fines; British Iron and Steel; Federation Housing; Easiform type

#267: Unlocking the potential of renewable energy: analysing energy storage deployment and policy in the EU

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The share of renewable energy utilized for power generation within the European countries will experience a substantial rise, ultimately attaining unprecedented levels in the forthcoming decades. The aforementioned trend can be attributed to the ambitious targets for renewable energy production and electrification set by the EU, which are stimulating investment and fostering innovation in the renewable energy sector. The incorporation of substantial amounts of renewable energy into the power grid poses various challenges, such as the intermittent and variable nature of renewable energy sources. To compensate for the volatile nature of renewable energy, energy storage and conversion (e.g. Power-to-X technologies) has been identified as a crucial factor in accelerating decarbonisation in the European Union. This study examines the current trends in energy storage deployment throughout the European countries and identifies the challenges and opportunities in energy storage policy. This study offers a comprehensive analysis of the installed capacities of energy storage facilities and investigates the energy storage policies that have been implemented in various European countries. The findings of this study provide valuable insights for policymakers in formulating energy policies that effectively promote the adoption and implementation of energy storage technologies.

Keywords: energy storage; renewable energy; energy policy; sustainability; energy transition

#268: Unlocking affordable and low-carbon retrofit solutions for residential buildings with homeowners' motivations using the Energy-Flow based Ensemble Calibration (EF-EC) model

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According to the EU Commission projection (2016/547/EU), the current average renovation rate is far below the expected rate of 3% to achieve carbon neutrality in building sectors by 2050. This is due to the fact that, during the building retrofit optimisation process, the decision-making criteria and objectives are generally optimised separately, and homeowners' motivations are often ignored or not carefully defined in most research. Besides, the decision-making criteria and objectives are generally optimised separately, and homeowners' motivations are often ignored or not carefully defined in most research. Limitations existed with a lack of in-depth and comprehensive understanding of the homeowners' motivations in undertaking building retrofit. However, few studies have addressed the issue of 'Rapid and accurate energy-economic performance prediction of deep energy retrofit and solution optimisation for residential buildings with varied homeowners' motivations' over the past decades. This paper proposes a novel Energy-Flow based Ensemble Calibration model to tackle this issue, with a maximum discrepancy of 6% compared to other building performance simulation results and 0.72 s computing time on a single combination. To address this, we propose an inclusive Energy-Flow based Ensemble Calibration (EF-EC) model, aiming to bring forward optimised decision-making for building renovation, accommodating different homeowners' retrofit motivations, objectives and criteria. The sensitivity analysis results are conducted in this research, indicating that the optimal retrofit measures and baseline energy consumption input are in good agreement, with a 10% discrepancy. Thus, the proposed inclusive EF-EC model can incorporate homeowners' engagement in the building retrofitting design process, serving as a decision-making supporting tool to accelerate building retrofit with maximised user acceptance and market penetration.

Keywords: building retrofit; deep energy retrofit; decision-making model; retrofit motivations; multi-objective optimisation

#269: A study on vermiculite-based salt mixture composite materials for low-grade thermochemical adsorption heat storage

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High-performance renewable energy technologies are desired to meet the enormous demand during the clean energy transition. Thermal energy storage can help balance the mismatch between renewable energy supplies and end-user's demands. Thermochemical adsorption heat storage (TAHS) has attracted widespread attention for its ability to efficiently utilise low-grade renewables and waste heat. Composite adsorbent materials have been gaining increased research interest, which combine hygroscopic salts and host matrix via impregnating salts in the matrix. This paper reviews recent progress in composite materials for TAHS and provides material characterisation analysis on different vermiculite-based composites. The composites use vermiculite as the host matrix with impregnation of different binary and ternary salt mixtures (i.e. $MgSO_4$-$CaCl_2$, $MgCl_2$-$LiNO_3$, $MgSO_4$-LiCl and $MgSO_4$-$LiNO_3$-$MgCl_2$). Vermiculite impregnated with a binary mixture of $MgSO_4$-$CaCl_2$ demonstrated a high energy storage density of 1213 kJ/kg, with fast desorption kinetics in the temperature range of low-grade heat. It shows good suitability for domestic TAHS applications, particularly for space heating, with stable cyclic performance over 20 charging-discharging cycles, maintaining approximately 91.3% of its initial energy storage density. The findings of this study contribute to the growing body of research on composite materials and demonstrate the potential of vermiculite-based composites impregnated with binary salt mixtures for low-grade TAHS.

Keywords: thermochemical heat storage; adsorption; composite material; vermiculite; binary/ternary salt mixture; characterisation

#270: Investigation into sustainable technologies for mitigation urban heat island effects in subtropical monsoon climate: thermal energy storage technologies contribution

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The urban heat island (UHI) is a concerning environmental phenomenon, and mitigation strategies have been proposed to reduce its adverse effects. This study was conducted to find that urban cooling technologies such as green roofs, cool roofs, and urban vegetation can comprehensively affect urban building energy use, carbon emissions and improve human comfort. Additionally, the study assessed the effectiveness of conventional and thermal energy storage-based UHI mitigation strategies through meteorological simulations using the software ENVI-met and a novel model called UHIMS-ECHE. The simulation results showed that conventional UHI mitigation scenarios can reduce UHI intensity, building cooling energy use, and carbon emissions, and improve human thermal comfort. Moreover, the integration of phase change materials (PCMs) and photovoltaic (PV) systems were analysed by the UHIMS-ECHE model, which demonstrated that the integration of PCM and PV technologies can significantly reduce UHI, improve energy efficiency, and enhance human thermal comfort in urban environments. Specifically, the PCM-Roof -A36H -10cm model reduced outdoor air temperatures by up to 7.09°C and total urban building cooling energy use cooling loads by up to 23.68% compared to the baseline case. These findings provide insights for policymakers, urban planners, and building designers to create sustainable urban environments. Further research is recommended to investigate the feasibility and cost-effectiveness of these technologies in different urban contexts and climatic conditions.

Keywords: urban heat island; thermal energy use; energy use; carbon emissions; human thermal comfort

#271: Maximizing solar power harvest: experimental analysis of vacuum insulated photovoltaic/thermal (PVT) power module in subtropical climates

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The utilization of solar energy as a clean and sustainable source of power has gained significant attention in recent years. Photovoltaic/thermal (PVT) systems have emerged as a promising technology, integrating both electrical energy generation and thermal energy collection in a single device. This paper presents an experimental analysis of a solar vacuum insulated photovoltaic/thermal (VPVT) power module in a subtropical climate. This study seeks to assess the performance and energy efficiency of the VPVT system under realistic operating conditions and to evaluate its potential for solar energy harvesting in subtropical regions. The study included the measurement and analysis of various parameters such as solar radiation, electrical power output, thermal energy output, and overall system efficiency. Additionally, the impact of various factors, including ambient temperature, wind speed, and humidity, is considered in the analysis. The results indicate that the solar VPVT module exhibits favourable performance characteristics in subtropical climates. The electrical energy generation efficiency of the module remains high, even under high ambient temperatures. Moreover, the thermal energy collection efficiency is enhanced through the vacuum insulation, allowing for effective utilization of solar energy. The outcomes show that the solar VPVT panel operates well in subtropical temperatures, with a 16.01% gain in thermal efficiency and a 0.28% reduction in electrical effectiveness even after the PV cell coating was eliminated. As a result, overall efficiency improved by 9.16%. Total exergy and primary energy reduction efficiency improved by 2.74% and 4.25%, correspondingly. Furthermore, the study investigated the impact of various factors, such as ambient temperature, solar irradiance, and flow rate of the heat transfer fluid, on the performance of the VPVT module. It was observed that higher solar irradiance levels and lower ambient temperatures positively influenced the electrical and thermal efficiencies of the system. The findings from this experimental analysis provide valuable insights into the feasibility and effectiveness of utilizing solar vacuum insulated VPVT modules in subtropical climates and further assists engineers, researchers, and policymakers in making informed decisions regarding the deployment and integration of solar VPVT systems in subtropical regions. The results demonstrate the potential of this technology for renewable energy generation, especially in regions with abundant solar resources and a demand for both electricity and thermal energy.

Keywords: solar energy; photovoltaic/thermal (PVT) system; vacuum insulation; subtropical climate

#272: Towards decarbonised transportation with L6e electric vehicle: exploring CERYAN

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Over the last decade, interest in sustainable transportation solutions related to electric vehicles (EVs) has grown globally. With this increase in global interest, researchers for sustainable transportation solutions have focused on L6e-type EVs. The EU defines the EV class of such vehicles as light-duty EVs. Also, L6e-type vehicles are categorised by their technical characteristics, such as weight and maximum speed. This EV type may both mitigate negative environmental impacts and enhance mobility with its compact dimensions and environmentally friendly structures. This study aims to provide a further understanding of the significant contribution of L6e-type EVs to decarbonised future transportation. This research will focus on the technical features and environmental benefits of the CERYAN L6e-type EV. CEYRAN is an L6e-type electric vehicle prototype that completed all road tests and is ready for mass production. In this context, all technical specifications of this eco-friendly car will be discussed and detailed using sustainable materials such as an electric motor and battery. This study also set out to identify the potential socio-economic contribution of CEYRAN to the field by highlighting the cost-economic advantages of the car. Additionally, this study contributes to understanding the possible environmental benefits CEYRAN provides. In the final step, the research clarifies the project vision by considering several aspects of future e-mobility. Overall, this article will offer a promising perspective for future sustainable transportation.

Keywords: electric L6e quadricycle; future of transportation; low carbon technologies; environmental benefits; electric vehicles

#273: Techno-economic assessment of solar/ground dual-source heat pump based electro-thermal energy storage (ETES) system with control and operation strategies for British housing stock

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Along with clean electricity supply, electrification of heating is considered to be one of the most effective and promising strategies to achieve zero carbon targets in the building sector. This paper investigates the techno-economic performance of a solar/soil-dual-source heat pump combined with photovoltaic power generation and thermal energy storage. Through the integrated PV-DSHP-TES system, an innovative concept of electrothermal energy storage (ETES) is proposed, which solves the problem of mismatch between supply and demand of renewable energy, and is an effective solution for energy economy. The structure of the dual-source heat pump is made of solar thermal power panels and ground soil pipes as evaporators, in which the solar-assisted heat pump works when the solar radiation is sufficient, and the ground-source heat pump operates when the solar energy is insufficient. Due to garden space constraints and roof space constraints in most UK homes, neither solar assisted heat pumps alone nor ground source heat pumps alone can provide the required heating needs in a cost-effective manner. This PV-DSHP-TES system could provide a replicable and affordable solution to facilitate the electrification of heating in UK building complexes. In addition, through the calculation of EnergyPro building simulation software, it is found that the energy, carbon emission and cost reduction rates of the renovated buildings reach 80%, 56% and 89% on average. At the same time, after adopting the integrated system, the seasonal heating efficiency increases to 4.96-5.51. In addition, different heat storage scales and system operation strategies are discussed, and an optimal design method is derived. Finally, under the sensitivity analysis of inflation rate, bank interest rate, natural gas and grid electricity price changes, it is found that the system still has good economic performance in the case of rising inflation rate and energy price.

Keywords: solar assisted heat pump; ground source heat pump; zero carbon building; dual source heat pump; electro-thermal energy storage; British housing stock

#274: An integrated liquid desiccant air-conditioning (ILDAC) system for multi-family terraced houses in subtropical and humid Mediterranean climate regions

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In the European Union (EU-28), while residential space cooling currently forms a minor share of sectoral final energy use (0.6% in 2015), it was the fastest-growing household end-use during 2000-2015, recording an average consumption growth rate of 6.3% per year. With a traditional air-conditioner, the sensible heat can be removed successfully with dew-point cooling coils, however, latent heat removal brings the challenge. In recent years, membrane-based liquid desiccant dehumidification has emerged as an efficient approach for air humidity control in the air conditioning process, where the internally cooled dehumidifier types are regarded as an energy-efficient approach to improve the dehumidification effectiveness and cooling performance. However, limited effort has been made to investigate the building energy performance in real buildings with liquid desiccant dehumidification systems under subtropical and humid Mediterranean climate conditions. This paper aims at investigating a heat pipe internally cooled liquid membrane-based desiccant dehumidification (HP-ICMLDD) system for multi-family terraced houses in subtropical and humid Mediterranean climate regions, which will be integrated with the air-water heat pump (AWHP), photovoltaics-thermal (PVT), and hot water storage systems as an integrated liquid desiccant air-conditioning (ILDAC) system. Moreover, the building energy simulation model using the ILDAC system has been established via the IES VE and EnergyPro software with the reference buildings (RBs) in Spain, Italy and Greece. By comparing the pre-retrofit net energy and post-retrofit net electricity consumption of the RBs, the energy reduction rate is calculated as 77.6%, 74.8% and 78.8% in Barcelona, Rome and Methoni. Moreover, the carbon reduction rate of the RBs is 88.8%, 84.3% and 76.9% in Barcelona, Rome and Methoni. The ILDAC system could achieve higher COP of 6.41, 8.14 and 7.52, which is significantly higher than both the complete LDD and AWHP systems. The discounted payback period varies between 5-7 years, with the annual return on investment ranging from 8.40% to 11.90% in Barcelona, Rome and Methoni.

Keywords: space cooling; dehumidification; liquid desiccant air-conditioning; building retrofit; energy efficient

#275: Performance study for selected HVAC systems

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This paper explores the effectiveness and energy consumption of three types of HVAC systems for summer cooling: fan cooling, split air conditioning (AC) system, and radiant system. The study focuses on evaluating the comfort level and energy efficiency of these systems using simulations. The simulations consider an office room with an occupant and analyse human body temperature distribution, air flow distribution, and energy consumption. Computational fluid dynamics (CFD) method is used for the simulations, considering various factors such as air conditioning equipment, room dimensions, and occupant characteristics. The findings provide valuable insights into the performance of different HVAC systems for achieving optimal comfort and energy efficiency in buildings.

Keywords: HVAC; summer cooling; comfort level; energy efficiency

#276: Pop-up farm (self-powered) profitable solution for climate migration

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The aim of the project is to develop a viable solution to address world-wide food security issues affected by climate. We offer all that is needed to make a profitable business in agricultural farming with a head start in the form of regular income from utility services and telecom. Just add city folk to, a out of the box climate proof sustainable business. The advantages of farming smarter are well understood, however there are challenges in providing these facilities in rural and semi-rural locations where the supply of reliable, always-on electricity and fast Internet communications are a must to progress better quality crops and soil, as well as provide data for a new, evolving, international, demand-led market.

Concept overview: All the technology proposed has already been successfully demonstrated. Based on existing data we know that a typical Sri Lankan farm can produce 96 small salad / root crops items per square metre of land. The natural growing environment also allows up to four cropping cycles per year, but that natural environment is at risk. The vertical growing system we have developed vastly increases the growing space per square metre of land and creates an optimum growing environment which can deliver ten crop cycles per year resulting in a potential 92-fold increase in productivity, regardless of any external changes. Prior to any mass installation of this facility, we need to demonstrate viability in different control installations in different climatic conditions around the world. Data from installations will then able the facility to be optimised for different environments.

Keywords: pop-up farm; vertical growing system; food security

#277: Challenges of climate change & resilient housing design solution

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The escalating challenges of climate change necessitate a novel approach to our built environments, especially housing, to foster adaptability and resilience. This investigation thoroughly scrutinizes academic literature to discern design strategies that bolster housing resilience amidst changing climate conditions. The analysis includes multiple case studies across Northern and Southern Pakistan, exploring the distinct challenges and environmental nuances in each area. This multidisciplinary literature exploration delves into housing design resilience from architectural, environmental, health, and socio-economic perspectives. It critically assesses both established techniques and pioneering trends, merging traditional knowledge with contemporary advancements. This comprehensive approach emphasizes the role of community-driven design solutions, public engagement, and policy formulation in nurturing resilience. The case studies from various Pakistani regions offer practical insights, revealing region-specific climate challenges and exploring housing design vulnerability in times of rain and flooding. Comparing these disparate climatic scenarios allows us to define tailored design and protection guidelines, promoting a resilient housing infrastructure capable of withstanding climate change. In summary, this research highlights the necessity of immediate and future-oriented housing design strategies to combat climate change. By integrating insights from both the literature review and case studies, we provide recommendations for architects, urban planners, and policymakers to advance resilient housing design not only in Pakistan, but globally.

Keywords: climate change and housing; climate resilient housing; housing design in Pakistan

#278: Cooling access among female home-based workers in a village in Selangor, Malaysia

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This study examines the accessibility of cooling facilities among female home-based workers in a small village in Selangor, Malaysia. With rising global temperatures and the increasing significance of heat stress, access to cooling has become a crucial aspect of ensuring the health, productivity, and well-being of individuals working from home. However, the accessibility of cooling infrastructures is often overlooked, especially in rural areas. The research employs a mixed-methods approach, combining qualitative interviews and quantitative surveys to assess the current cooling provisions available to female home-based workers in the selected village. The qualitative component delves into the experiences and challenges faced by the participants in obtaining cooling solutions, highlighting factors such as affordability, technological availability, and cultural norms. On the other hand, the quantitative survey investigates the prevalence of cooling technologies in households and assesses the overall thermal comfort experienced by the female home-based workers during work hours. Preliminary findings suggest that despite the village's relatively small size, disparities exist in cooling access, with a significant number of female home-based workers lacking sufficient cooling resources. Additionally, financial constraints and traditional gender roles emerge as prominent barriers to acquiring cooling technologies, exacerbating the adverse effects of heat stress on the workers' health and productivity. The results of this study shed light on the overlooked issue of cooling access in rural settings and emphasize the importance of addressing this disparity to promote gender equality, health, and sustainable development. Policy recommendations and potential interventions are discussed to improve cooling accessibility and empower female home-based workers in Selangor, Malaysia, and similar regions worldwide.

Keywords: gender; cooling access; village; Malaysia

#279: Rotation heat pump: a presentation of the integral rotor design

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The environmentally friendly working fluid based on noble gases such as Helium, Argon and Krypton is used in a Rotation Heat Pump (RHP) in the counter-clockwise Joule cycle. In combination with centrifugal compression, this leads to a very high coefficient of performance (COP) with simultaneously high sink outlet temperatures compared to conventional compression heat pumps. Since the realized Joule Cycle is based on an always gaseous working fluid, the heat transfer in the heat exchangers is sensible. Therefore, neither the issue of compressor lubrication nor the critical point of the working fluid limits the maximum sink temperature. So far, the RHP principle has been tested and validated in several plants. The underlying design and construction of the rotor have been presented and the structure explained in several publications. Due to further development, especially in the field of heat transfer and associated components, a completely new rotor design was conceived and elaborated for the structure and system of the Rotation Heat Pump. This is based on the system of a diffusion-welded integral rotor, which is manufactured by welding several thin individual layers into a solid block and withstands extreme boundary conditions. This process and system make it possible to manufacture the entire rotor, including all compression and expansion pipes and the heat exchangers, from a single piece. The resulting advantages are a very simple design with few components and sealing points that can withstand very high pressures and temperature levels. This not only increases the possible temperature range, but also the maximum possible temperature lift. In addition, heat can already be dissipated during compression by means of appropriate channel routing, thus enabling the process to be implemented with a minimum of exergy losses. The current development status and the concept of this integral rotor will be presented.

Keywords: rotation heat pump; Joule process; high temperature; integrated rotor design

#280: The role of digital twins in decarbonising the built environment

Don McLEAN – Keynote Presentation

IES, UK

The built environment has a crucial role to play as we work towards the goal of zero-carbon energy. Latest reports indicate that the buildings and construction sector accounts for a significant 37% of energy- and process-related CO2 emissions, and over 34% of energy demand globally. To limit the impacts of climate change, building industry leaders have stated that, by 2030, 100% of new buildings must be net-zero carbon in operation, embodied carbon must be reduced by at least 40%, and by 2050, all new and existing assets must be net-zero across the whole lifecycle. However, while many countries and organisations have made pledges to decarbonise, few understand how their buildings truly perform or have concrete plans in place to improve them at the scale required. Fortunately, advancements in digital technologies – and, more specifically, digital twins – is helping to address many of these challenges. By providing a highly accurate virtual replica which leverages physics-based simulations, data, machine learning and AI, a digital twin responds and behaves like its real-world counterpart to uncover detailed insights into our buildings' current and future performance. Helping to identify optimisation opportunities and simulate the impact of future changes and zero-carbon interventions, prior to implementation, to de-risk decarbonisation decisions. Digital twin expert, Don McLean, Founder & CEO at IES, has dedicated the last 40+ years to pioneering and developing performance simulation tools to improve the performance of buildings across their lifecycle. In this keynote presentation, Don will explain how IES' own digital twin technology is supporting built environments around the globe in their decarbonisation journeys, sharing lessons learned from real case study examples. This will include an overview of the Living Lab partnership which has been established between the University of Nottingham and IES, through which a campus wide digital twin encompassing 280 buildings has been developed. The presentation will also provide an overview of the building level Digital Twin created by IES for the University's Monica Partridge building, where the conference is being hosted.

Keywords: digital twins; decarbonisation; built environment

#281: Smart responsive shading for enhanced energy efficiency in hot climates

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Smart material technologies are employed to promote low-energy solutions and achieve sustainability in buildings. The responsive shading system operates based on a self-actuating Shape Memory Polymer (SMP) that dynamically switches and responds to varying thermal conditions. This study focuses on determining the optimal thermal activation stimulus for the opening and closing mechanisms of the system. For this, the study examined and analysed the impact of various activation parameters on building performance including energy efficiency, and thermal comfort. In addition, the IES-VE dynamic building energy simulation was employed to analyse and evaluate the adaptable shading performance. The results were validated using a multi-criteria approach to compare with the existing glass facade of a high-rise apartment in Jeddah, Saudi Arabia. Findings showed that the co-activation technique, combining solar radiation and air temperature triggers, proved to be the most efficient activation for improving the performance of responsive shading mechanisms. This system minimised solar heat gain, reduced glazed surface temperature, lowered indoor temperatures, reduced glare, and enhanced thermal comfort, resulting in notable energy savings and low-carbon emissions through reduced cooling consumption.

Keywords: responsive shading; smart material; energy efficiency; IES simulation

#282: Acceptability of heat pump energy deferral for mitigating peak electricity demands: findings from a UK field trial

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In the UK domestic heating accounts for around 14% of carbon emissions, therefore in order to meet the net zero objectives, residential heat demand will need to be decarbonised through a combination of electrification at the building level alongside that of the electricity supply and combined with energy efficiency measures. However, electrification of residential heat, in addition to decarbonation of mobility through electric vehicles (EV), could lead to a 200-300% increase in the UK's annual electricity demand, resulting in serious capacity issues for the electricity supply system. In order to maintain grid supply and stability, the future electrical heating appliances or EV charging loads will need to be remotely controlled and adjusted (knowns as Heat Flex) to better suit the capacity of electricity network infrastructure whilst maintaining substations and feeders within their regulatory and technical limits. In this work we present the learnings gained from online interviews and surveys (N=60) in a first of a kind UK field trial which tests third party remote control of domestic heat pumps (Heat Flex). The responses alongside the online survey from a sample of households (N=4,100) is combined with online focus group discussion (N=120) providing insights on whether households would approve of Heat Flex. Hence, this paper reports on what (i) level of heat deferral (e.g. temperature and time) would be considered acceptable, (ii) required incentivisation strategies and (iii) what factors, such as energy literacy and household composition, were found to influence acceptance of Heat Flex. Initial results indicate that appropriate pathways can be identified to support Heat Flex. The ongoing research, facilitated by the combine samples is also providing guiding principles to optimise the Heat Flex approaches through follow-up online focus group that will further examine the factors influencing household acceptance. Moreover, with demand flexibility is becoming an increasingly significant part of the energy landscape, such as the National Grid ESO’s demand flexibility services and the Cosy Octopus Tariff, our results are providing a pathfinder evidence to inform national energy reduction policies, as well as providing insights of influencing acceptability factors.

Keywords: energy; heat pumps; flexibility; heating; demand reduction; direct control

#283: Interpretable data-driven methods to automate energy model calibration: Southampton Highfield Campus case study

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In the journey towards zero emissions, the energy transition is a fundamental aspect of the transformation, and the construction industry is one of the largest contributors to carbon emissions. Due to the magnitude of investments required to meet decarbonisation objectives and in order to achieve them within given temporal constraints, we must engage in medium/long-term planning. Consequently, a more in-depth understanding of energy consumption is required to facilitate effective decision-making and reduce uncertainty, which could undermine the effectiveness and credibility of measures. The present project leverages interpretable data-driven methods applied to building energy analytics. The case study is the Highfield Campus of the University of Southampton where 48 buildings are present, which are served by a natural gas fuelled Combined Heat and Power (CHP) and District Heating (DH) system. As part of the research, individual energy signature models have been developed for the buildings monitored, as well as for the entire district energy system (CHP, DH). The monitored data cover the periods before, during and after COVID 19 pandemics, from 2017 to 2022. Two primary results have been achieved. First, by creating a novel formulation of energy signature regression it is possible to find the best fitting models and to determine the actual building balance points (for degree-days consumption normalization) efficiently. The second was a counterfactual analysis of energy consumption patterns before, during, and after COVID to detect potential changes. The focus of future research will be on developing digital twins of building models that can analyse data at varying temporal and spatial resolutions, to support the University decarbonisation strategy.

Keywords: data-driven methods; regression-based approaches; decarbonisation; energy efficiency; performance benchmarking; digital transformation

#284: Baseload smart regulation and carbon intensity reduction using innovative automation

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Power consumption in the UK and its strain on the national grid is a growing concern that needs to be addressed immediately. Although the technological advances has helped increase the power consumption efficiency of electronic appliances, subsequently, there has been a considerable increase in appliances used in a commercial property which balances out or even worse increases the electricity demand even more. It has been identified that one of the biggest wastages when it comes to any infrastructure is the baseload (or passive load). As a countermeasure address the baseload wastage, multiple smart metering solutions are introduced, which helps the consumers understand where the baseload wastages are and what measures can be taken to eliminate them. This has so far been proven successful but requires dedication and consistency from consumers to make sure these best practices are always followed. What if there was a way to eliminate human intervention which determines efficiency based on consistency? A pilot experiment was run in an office property with 2 scenarios. Scenario 1 is business as usual where baseload is monitored but the counter measure to reduce baseload is left to the occupants to decide. Scenario 2 is when all sockets are monitored and automated using innovative intelligent cloud connected systems with commands provided for hard switch off from socket side during non-working hours. In the end, the results were compared and the difference in value was quite dramatic. Scenario 1 obviously had higher readings when it came to average baseload consumption and power spikes. In addition to this detail, carbon intensity was also calculated which proved to be high as compared to scenario 2. Scenario 2 showed a more optimized output especially when it came to baseload regulation which in-turn reduced the overall power consumption of the office, a saving of 60% was recorded when it come to power consumption and carbon intensity reduction of 40% was recorded as compared to scenario 1 results. So, from the overall data collected, it is recommended to have smart monitoring with an automated control system that requires zero human intervention to make sure that are no unnecessary baseload wastage and power spikes.

Keywords: baseload reduction; phantom power; power consumption reduction in commercial spaces; carbon intensity reduction

#285: Mapping electric vehicle charging points for Hampshire County using the multi-criteria decision analysis optimisation

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Achieving net-zero carbon in the UK by 2050 will require the decarbonisation of the transportation system. However, there are challenges to this, especially for vehicles in cities where charging infrastructure is at a minimum. Overcoming these challenges will undoubtedly encourage electrical vehicle (EV) use, with commensurate reductions in emission coupled with better environmental conditions in cities, specifically air quality. Drivers, overall, are reluctant to invest in an EV if they cannot access a convenient charging point within their living area. This research provides a methodology to support the planning for optimum siting of EV charging infrastructure, so it is accessible to as many citizens as possible within a city. The work focuses on Hampshire County in the UK. The multi-criteria decision approach is based on the Analytical Hierarchy Process (AHP) linked to site spatial assessment using Geographical Information System (GIS). The assessment considered key criteria such as road type, road access, on-road parking availability, road slope, proximity to fuel stations, proximity to low voltage grid, current/planned charging points, car parks and population distributions. The process contained two suitability filters, namely, restricted road and suitability mask. In the first, all restricted roads were excluded from further analysis, which resulted in reducing the road segments from over 90 thousand to around 18 thousand. When applying the second filter an overall result of less than 500 suitable EV charging point locations was achieved. These locations were then validated using the Google Earth® imaging platform to check actual locations against those predicted by the analysis.

Keywords: electric vehicles; EV charging infrastructure; geographical information system; analytical hierarchy process

#286: An experimental investigation on adsorption and regeneration performance of composite desiccants for building applications

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Composite desiccants have attracted attention for dehumidification purposes in the last few years, these materials are formed by impregnating hygroscopic salt to the pores of a host material. They are characterized by their high absorption capacity and low regeneration temperature, making them suitable for building applications. This paper experimentally investigates composite desiccant materials suitable for moisture control in buildings. Novel composite materials using $CaCl_2$, $KHCO_2$, LiCl, and $MgSO_4$ - $CaCl_2$ salts mixtures were impregnated into raw vermiculite. The adsorption performance was tested using an environmental chamber and the regeneration performance was assessed using an oven. The experimental results demonstrate the superior performance of the composite materials in comparison to the raw material. The experimental results show the LiCl composite presents the highest adsorption performance. For the regeneration process, the LiCl presented the highest reduction in a short-term period. However, in the long term, the $CaCl_2$ composite posed superior performance.

Keywords: building humidity control; composite desiccants; solid desiccants; vermiculites

#288: Evaluating the thermal impact of built environment surfaces on urban trees for achieving maximum cooling performance in the school's car parking and walkways in the UK and Saudi Arabia

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During heatwaves, built-up, urban areas can easily overheat, which put people's health at risk or require expensive mechanical air conditioning. However, greener areas remain several degrees colder and powerful in reducing the heat island effect and provide thermal comfort to people. Built environment surfaces usually contribute to increasing local climate temperatures, particularly streets and parking areas, where urban heat island radiated. Those extents where impervious surfaces are increasing with urban expansion. Where it is affected and influenced by anthropogenic heat, urban design, canyon radiative geometry, and street materials physical properties. The purpose of this research is to examine the impact of built environment surfaces on urban tree cooling performance and the urban microclimate in the United Kingdom and Kingdom of Saudi Arabia hot climate, to improve urban canopy cover. This research intends to enrich the decision-making process, in improving the pavement surface materials used in schools and to tackle future climate change challenges in summer, particularly heat waves. This experimental research is based on field studies and measurement for empirical data collection. Data analysing will be by using infrared thermal imaging analysing software and statistical methodology (LMM).

Keywords: heatwaves; built environment surfaces; thermal imaging; urban trees cooling

#289: Investigation on a novel thermoelectric ventilator system for retrofit in heritage buildings

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In recent years, there has been a risen interest in retrofit in heritage buildings, especially energy and comfort retrofitting. Global governments pay much more attention on the preservation and reuse of heritage buildings. However, the retrofit might alter appearance of heritage building. In this paper, the investigation on a novel thermoelectric ventilator retrofit in heritage buildings has been undertaken. Firstly, an AHP methods-based survey has been conducted to identify appropriate component to apply the ventilator with minimum impact on the heritage features. Secondly, an overview of the prototype design, heat transfer model and experimental parameters would be presented. Finally, the MATLAB model along with Revit has been used to simulate the prototype's performance when installed in a sustainable house in the UK. According to the result, the prototype would supply 655 kWh heating energy for year-round operation and enhance the air change rate of the heritage buildings. This research would provide a new solution to reduce energy consumption during daily ventilation in heritage buildings.

Keywords: ventilator; thermoelectric module; heritage buildings

#290: Investigations on the retrofitting strategies coupling multiple targets on heritage dwellings located in Suzhou

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Suzhou city is one of the national historical and cultural cities in China. There is a huge stock of heritage buildings built about 200 years ago. They are necessary carriers of splendid Wu Culture. Most of them are still in function, especially heritage dwellings, but suffer from many serious problems, such as high energy consumption and low comfort. Thus, the energy retrofit is essential for heritage conservation. However, the energy retrofit on the heritage dwelling without impacting on their characteristics, especially appearance, presents a major challenge for architects and policymaker. This proposal aims to systematically put forward an applicable design method and an overall retrofit plan on heritage dwellings. The thermal properties and potential retrofit strategies will be collected and documented by in-situ testing. Then, the Analytic Hierarchy Process (AHP) model would be implemented to evaluate the adaptability of potential retrofit strategies and select the strategies that preserves the uniqueness of historic building. After that, the selected strategies could be fully combined to form various scenarios, and the energy simulation for various scenarios would be carried out. The combination with least energy consumption is obtained. Finally, the strategies that satisfy the research objectives will be promoted. The results of this research will highlight the limitation of current research and promote a more appropriate method to evaluate the retrofit strategies on heritage buildings.

Keywords: Suzhou; heritage dwellings; retrofit

#291: Comparative study on a low-carbon house and common houses with post occupancy evaluation in rural area of China

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Nowadays, due to the construction of new buildings, global warming becomes more serious than ever before. In order to investigate the actual performance of low-carbon houses, post-occupancy evaluations have been undertaken on a low-carbon house and two typical normal houses in the rural areas of China. The result of the low-carbon house is compared with normal houses in perspective of indoor environment quality, energy consumption and satisfaction questionnaire. The result indicates the Eco-house enjoys advantages over the conventional houses in all respects. This paper also identifies the underlying factors that cause the gaps between predicted and recorded energy performance of the Eco-house. Most of the factors are associated with parameters regarding occupancy behaviour and facilities management in simulation.

Keywords: low-carbon house; energy benchmarks; post-occupancy evaluation

#292: Advancing double pass PV/T solar collectors with asymmetric compound parabolic concentrators for building façade

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The use of symmetrical compound parabolic concentrator (CPC) for a stationary double pass photovoltaic thermal (PV/T) air solar collector has been widely employed as an approach to enhance the performance of the PV/T. However, for a CPC, the key to the high performance is that the incidence angle must be within the full acceptance angle of the collector without moving all or parts of the collector. As a result, it is a challenge to determine the CPC collector's optimum acceptance half-angle, which determine the yearly energy delivery. In this paper, the performance enhancement of a double pass photovoltaic/thermal air solar collector using asymmetric compound parabolic concentrator (PV/T-ACPC) suitable for building façade application is presented. For this purpose, the optimum configuration for the asymmetric compound parabolic concentrator (ACPC) was investigated when the collector was in a vertical configuration. Mathematical modelling based on energy balance equations were developed in MATLAB and validated against established experimental results. Using the validated mathematical model, the potential of double pass PV/T-ACPC for vertical façade application was evaluated for four different locations of different latitudes that represent low, mid, and high latitude weather conditions, namely Kuala Lumpur, Malaysia; Abu Dhabi, UAE; London, UK and Bergen, Norway. The analysis carried out shows that the double pass PV/T-ACPC outperforms the conventional symmetric compound parabolic concentrator (PV/T-CPC) and the conventional flat type of double pass PV/T solar air collector when employed as façade application. In comparison to the conventional flat type, the average percentage increase in the average daily total power yield for the PV/T-ACPC is as high as 14% for the low and mid- latitude countries and 50% for the high latitude countries. Meanwhile, for the PV/T CPC, the percentage increase in the average daily total power yield was slightly negative in value for low and mid-latitude countries, which indicates worse performance in comparison to the conventional flat type. The building heating load-demand analysis was performed in TRNSYS and MATLAB for high latitude countries. The results indicated that the application of the PV/T-ACPC double pass façade gives a solar fraction as high as 60%. The acceptable range of output temperature from the solar façade, was found to be suitable for space heating application at certain months of the year.

Keywords: BIPVT; building facades; asymmetric CPC

#293: Impact of various technologies on peak energy demand of residential buildings in the cold climate of the UK

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Residential buildings are the key contributors to the high electrical energy demand in the United Kingdom. Heat pumps mainly consume electricity to meet space heating and hot water demands. The Time-of-use tariffs have been introduced to enable consumers to time dependency of demand. However, peak energy demand, which occurs in a small percentage during a specific time of day, significantly impacts the overall power balance and stability of the utility grid. Investigation on integrating various demand side management technologies to reduce peak heating demand has been increasing. In the present study, the impact of various technologies, such as photovoltaic panels with battery energy storage system (PV-BESS) (case 1), PV-BESS with solar thermal system (case 2), and photovoltaic/thermal (PV/T) with BESS (case 3) system on peak energy demand have been analysed in cold climatic conditions. In the context of a residential building, a simulation model of David Wilson home was developed integrating various technologies, which was compared against the baseline model (case 0) integrated with an air source heat pump. The simulation was performed on DesignBuilder/EnergyPlus software for the entire month of January. The Simulation results show that without any integration of technologies, the heating demand of David Wilson home in the month of January was 1531.6 kWh in case 0, which was reduced to 1456.1 kWh in case 1, 1318 kWh in case 2 and 1132.47 in case 3. With the integration of the solar heating system, a maximum reduction in peak energy demand is observed with PV/T-BESS (case 3) system.

Keywords: building heating demand; peak energy demand; battery energy storage system; solar assisted heat pump; photovoltaic/thermal system

#294: Research and application of phase change energy storage technology

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To introduce research, development and application of phase change energy storage technology, involving in novel phase change material development, packaging, property testing, application, papers and patents etc.

Keywords: research; development; application; phase change; energy storage

#295: AI-based hourly electricity consumption prediction for households and residents

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This research aims to develop an LSTM-based predictive model for precise hourly electricity consumption forecasts in diverse household scenarios. Leveraging household-specific details and time-specific data from the IDEAL dataset encompassing over 200 UK households, the study explores accurate electricity usage forecasting. Data pre-processing ensures data reliability, and LSTM's capability to capture temporal dependencies makes it well-suited for time series forecasting. The trained LSTM model utilizes household-specific information and timestamps to predict electricity consumption accurately, empowering energy management decisions. By providing precise predictions based on household-specific information, the model encourages consumers to adopt energy-efficient practices, fostering a greener future. Additionally, energy experts can utilize this model to analyse residents' electricity usage, offering valuable insights for future energy production arrangements and further advancements in sustainable energy strategies.

Keywords: artificial intelligence; LSTM; sustainable energy strategies; electricity consumption

#296: Analytical investigation of an MPC control strategy of a seasonal thermochemical energy storage system of a district heating scheme

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Nottingham City Council operates a district heating system which is fed from an energy-from-waste incinerator and a steam power plant. At time of low demand for space heating in buildings, large quantities of energy are released to the environment. This project investigates potential thermochemical process of excess heat storage using computer simulation. This allows stored energy to be used at peak load, minimise heat energy waste and reduce carbon emission. The computer simulation considers a one-year time period of heat generation and demand during which the thermochemical energy store is used as a thermal buffer to store and release heat as required. The initial result show that the deployment of the thermochemical storage can smooth out the seasonal heat demand of the site. The proposed STES system could save approximately 50% more energy than the original district heating system without storage technology.

Keywords: seasonal thermal energy storage; demand response; model predictive control (MPC); district heating system

#297: An empirical critique of the low-income low energy efficiency approach to measuring fuel poverty

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Fuel poverty is a complex socio-environmental issue of increasing global significance. In England, fuel poverty is assessed via the Low Income Low Energy Efficiency (LILEE) indicator, yet concerns exist as to the efficacy of this metric given its omission of households based on Energy Performance Certificate (EPC) ratings, rather than the ability of occupants to afford energy. To assess the potential shortcomings of the LILEE metric, we perform quantitative analyses of fuel poverty in two English cities. A spatial analysis of Nottingham, UK, exposes discrepancies between deprivation and expected fuel poverty incidence, demonstrating that a significant proportion of households are currently classed as “not fuel poor” (7.5% of the city’s stock) but remain likely to be energy insecure. Subsequently, we analyse primary survey data (n=2886) collected in London, UK, using a Random Parameters Ordered Probit modelling framework. 28.2% of respondents were energy insecure, which is 145% higher than the LILEE estimate for London. Surprisingly, no significant variation in energy insecurity rates was found between the most and least efficient homes surveyed. Model estimation results reveal the key characteristics of respondents impacting energy security in the London; factors which could effectively underpin an amended approach to measuring fuel poverty in England.

Keywords: fuel poverty; energy security; energy policy; spatial analysis; statistical methods