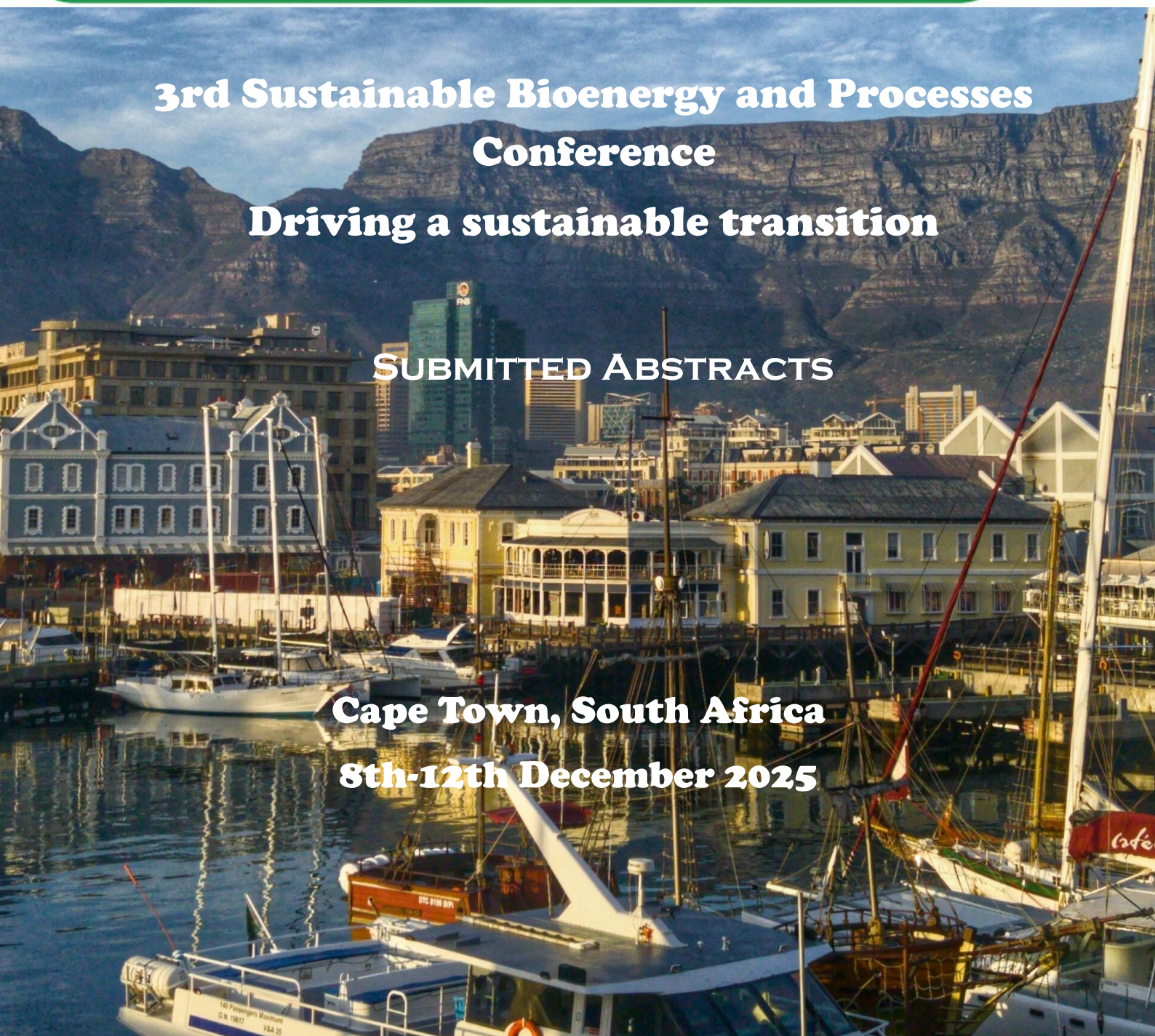
SUSTAINABLE BIOENERGY AND PROCESSES



3rd Sustainable Bioenergy and Processes Conference

Driving a sustainable transition

Submitted Abstracts

Cape Town, South Africa

8th-12th December 2025

Standardization And Methodological Challenges In Lca Of Beccs Systems: A Systematic Literature Review

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Life Cycle Assessment (LCA) applied to Bioenergy with Carbon Capture and Storage (BECCS) systems is a tool that enables the evaluation of the environmental feasibility of this technology, particularly in the face of the global challenge of decarbonization. This study conducted a systematic review of articles published between 2022 and 2025 in the Scopus and Web of Science databases, with the aim of critically analyzing recent methodological advances, focusing on aspects such as normalization, impact allocation, functional unit definition, and the treatment of uncertainties. The results show an increase in the number of publications in 2024 and 2025, reflecting the growing scientific interest in carbon dioxide removal technologies, aligned with the goals of the Paris Agreement and with the scenarios outlined by the IPCC to limit global warming to 1.5 °C. A diversity of methodological approaches was observed, particularly regarding the treatment of uncertainties and the application of allocation criteria, although gaps remain that hinder comparability among studies. In this context, it is important to emphasize the need for methodological standardization in the application of LCA to BECCS, so that more consistent and comparable analyses can be carried out. The harmonization of criteria, such as the definition of the functional unit, the selection of normalization methods, and transparency in the treatment of uncertainties, is a crucial step toward consolidating robust evidence and supporting decision-making in scientific, technological, and policy spheres.

State-Of-The-Art Study Of Bio-Based Flame Retardants From Phosphorylated Lignin For Polymer Composites Applications

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Polymer-based materials are widely used in engineering and daily life due to their unique physicochemical and mechanical properties. Traditionally derived from fossil resources such as petroleum, they raise concerns because of resource depletion and environmental pollution. To address these issues, bio-based polymers are gaining attention as sustainable alternatives. They offer biodegradability and green synthesis methods, and although initially used for short-term applications, they are now expanding into technological, construction, automotive, and electronic industries. A major limitation of polymers, however, is their high flammability, which restricts use in many fields. Flame retardants (FRs) are added to reduce combustion, flammability, and the release of toxic fumes during burning. While halogen-based FRs dominate the market, they persist in the environment due to poor biodegradability. Current research is thus shifting toward bio-based flame retardants with environmentally friendly profiles. Biomass derivatives such as carbohydrates, proteins, tannic acid, isosorbide, and phytic acid are being studied either as independent FRs or in combination with conventional systems. Among these, lignin—a highly aromatic, carbon-rich biopolymer—shows strong potential as a charring agent in intumescent FR systems. Lignin is particularly attractive because it produces significant char upon thermal degradation. However, its performance depends greatly on plant origin, delignification method, and its inherent structural variability and chemical complexity. This study explores technical lignins obtained from the five main delignification processes, highlighting recent advances in chemically modified lignins, especially those incorporating phosphorus. Their application in polymer composites, aerospace manufacturing, automobiles and textiles as flame-retardant additives is also discussed.

State-Of-The-Art Study Of Bio-Based Flame Retardants From Phosphorylated Lignin For Polymer Composites Applications

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Polymer-based materials are widely used in engineering and daily life due to their unique physicochemical and mechanical properties. Traditionally derived from fossil resources such as petroleum, they raise concerns because of resource depletion and environmental pollution. To address these issues, bio-based polymers are gaining attention as sustainable alternatives. They offer biodegradability and green synthesis methods, and although initially used for short-term applications, they are now expanding into technological, construction, automotive, and electronic industries. A major limitation of polymers, however, is their high flammability, which restricts use in many fields. Flame retardants (FRs) are added to reduce combustion, flammability, and the release of toxic fumes during burning. While halogen-based FRs dominate the market, they persist in the environment due to poor biodegradability. Current research is thus shifting toward bio-based flame retardants with environmentally friendly profiles. Biomass derivatives such as carbohydrates, proteins, tannic acid, isosorbide, and phytic acid are being studied either as independent FRs or in combination with conventional systems. Among these, lignin—a highly aromatic, carbon-rich biopolymer—shows strong potential as a charring agent in intumescent FR systems. Lignin is particularly attractive because it produces significant char upon thermal degradation. However, its performance depends greatly on plant origin, delignification method, and its inherent structural variability and chemical complexity. This study explores technical lignins obtained from the five main delignification processes, highlighting recent advances in chemically modified lignins, especially those incorporating phosphorus. Their application in polymer composites, aerospace manufacturing, automobiles and textiles as flame-retardant additives is also discussed.

Strategic Integration Of Biomass In Brazil'S Future Energy Mix: Implications For Electricity Generation And Sustainability

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Prolonged droughts and the need to expand generation capacity to mitigate the variability of solar and wind energy effects on system performance have significantly altered Brazil's electricity generation matrix, increasing dependence on environmentally detrimental alternatives. Although bioelectricity in Brazil is predominantly sourced from sugarcane, a substantial portion of the country's biomass potential remains underutilized. This study quantifies the theoretical, technical, and economic potentials of untapped biomass sources, including dedicated energy forests, crop residues, forest residues, vinasse, animal manure, municipal solid waste and excess electricity generation from the sugar industry, and assesses their integration into Brazil's future electricity mix from 2023 to 2050 using the Low Emission Analysis Platform (LEAP). Two energy scenarios were modelled, Business-As-Usual (BAU) and Available Potential Scenario (APS), which fully utilize the calculated economic potential. Results show that the economic potential of

bioenergy could increase from 599.86 PJ in 2023 to 1,455.27 PJ by 2050, supporting up to 70 GW of installed capacity. Under the APS, the renewable share in electricity generation increases from 87% (BAU) to 95% by 2050, with bioenergy contributing up to 26% of total electricity generation. This transition boosts energy availability by 42% compared to BAU and increases total installed capacity by 62% relative to the base year. Investment analysis showed that the additional installed bioenergy capacity does not create an additional investment burden, but rather reallocates capital toward cleaner energy alternatives. This research provides a practical strategy for Brazil to achieve its emissions reduction goals in electricity generation.

Structural Manipulation Of Perovskite Systems For Selective Biofuel Synthesis From Biomass-Derived Substrates

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To successfully advocate for adoption of green and sustainable fuels requires innovative approaches to design highly active heterogeneous catalysts. Currently, the challenges associated with ill-defined mechanistic pathways in the synthesis of biofuels lead to lack of targeted fuel components. Herein, structural manipulation of highly active metal oxides by partial substitution of active sites was employed to synthesize biofuels. Biomass-derived feedstocks such as methyl benzoate produced fuel components with high calorific value. Furthermore, the ratio of active cations in the LaNiCuOx dictates the yield of the reaction.

Normally, biofuels are obtained using high temperatures through pyrolysis of lignin to phenol derivatives that further undergo hydrodeoxygenation [1,2]. Herein, we proposed a low temperature (< 90 °C) and one-pot multistep mechanism to biofuels. Furthermore, the use of biomass-derived feedstocks and low-cost metals makes our proposed method economical.

References :

1. F. Cheng, C.E. Brewer; Renewable and Sustainable Energy Reviews 72 (2017) 673–722

2. J. Yan et al. Fuel Processing Technology 250 (2023) 107914

Sustainable Approaches In Composting And Biofertilizer Production From Organic Waste

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Biowaste represents a substantial available resource for organic fertilizer production. In this study, recent advances in composting technologies with a focus on their integration into circular economy frameworks were explored. Anaerobic digestion, windrow composting, in-vessel systems, and vermicomposting were reported for their effectiveness in transforming biowaste into nutrient-rich compost. Key composting parameters including optimal moisture (40–65%), pH (6.5–8.0), temperature (40–65 °C), and carbon-to-nitrogen ratio (25:1 to 30:1) were quantitatively analyzed for their roles in process efficiency and product quality. Life cycle assessments (LCA) revealed that composting can reduce greenhouse gas emissions by up to 60% compared to landfilling, with emission rates around 1.29 tons CO_2-eq per ton of waste. Advanced bioreactor designs achieve C/N ratios of 12–18 and seed germination indices exceeding 90%, indicating high compost maturity. Applications of artificial intelligence (AI) and Internet of Things (IoT) have led to predictive models with R^2 values up to 0.97 for parameters such as ammonia emissions and compost maturity. Comparative reactor studies showed compost outputs with total nitrogen ranging from 8.7 to 22.4 g/kg and total organic carbon between 207 and 408 g/kg. Despite the environmental benefits, challenges such as odor control, ammonia loss, and initial capital cost remain significant. Nevertheless, composting of food waste, when optimized, offers a sustainable path to reduce dependency on synthetic fertilizers, recover valuable nutrients, and mitigate environmental degradation.

Sustainable Co2 Capture And Biomass Production From An Industrial Scale Lime Kiln Flue Gas Using Microalgal Photobioreactor

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Microalgae offer a promising feedstock because of their high solar energy efficiency, significant lipid content, and ability to utilize waste streams such as industrial flue gas. This study evaluates the feasibility of cultivating microalgae using lime kiln flue gas at an industrial scale. The lime industry is one of the most carbon-intensive sectors in South Africa. While fuel efficiency improvements or fuel switching can reduce emissions, these measures alone are insufficient. End-of-pipe solutions are therefore necessary if lime kilns are to achieve carbon neutrality. This research provides an option for the lime industry to mitigate CO_2 emissions while producing biomass without competing for arable land.

The study addresses four major gaps in the literature. First, microalgae cultivation using lime kiln flue gas has not been previously studied. Second, the interaction of multiple microalgal species in open reactors is poorly understood; this work explores creating diverse, resilient microalgal communities. Third, native species in outdoor cultivation systems remain underexplored; this study employs microalgae sampled from local freshwater bodies near the kiln. Lastly, the research leverages favorable conditions in South Africa's Northern Cape, such as abundant sunlight and warm temperatures.

Successful cultivation depends on appropriate photobioreactor design, considering surface-to-volume ratios, mixing, and shear stress on cultures. Productivity is expected to improve by using native species already acclimatized to lime kiln exhaust gases. Thus, local water bodies around the lime plant serve as the source of microalgae for this study.

Sustainable Conversion Of Food Waste Through Animal Manure-Enriched Composting With Catalytic Support

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This study investigated the enhancement of food waste composting through the incorporation of camel manure at different ratios in the presence of catalytic additives. The study aimed to accelerate the composting process, improve nutrient quality, and promote sustainable waste management practices in arid regions where organic waste and animal manure are abundantly available. Food waste was mixed with camel manure in varying proportions (10–50%) and treated with selected catalysts such as biochar to enhance microbial activity and optimize physicochemical parameters. Throughout the composting period, temperature, moisture content, pH, and C/N ratio were monitored to evaluate the composting dynamics and maturity index. The addition of camel manure significantly improved the thermophilic phase duration and microbial degradation rate, while the catalysts enhanced oxygen diffusion and nutrient stabilization. The final compost demonstrated higher nitrogen, phosphorus, and potassium contents compared to the control samples, with a C/N ratio below 20, indicating high maturity and stability. The produced compost exhibited an improved germination index and lower heavy metal concentrations, meeting agricultural safety standards. The synergistic effects of camel manure and catalysts resulted in a shorter composting period, improved nutrient recovery, and superior fertilizer quality. The findings confirmed that integrating camel manure and catalytic additives into food waste composting provided an efficient, eco-friendly approach for organic waste valorization and sustainable fertilizer production,

contributing to circular economy goals and sustainable agriculture, particularly in desert and semi-arid environments.

Sustainable Utilisation Of Acid Mine Drainage Sludge In South Africa: Iron Recovery And Barium Hexaferrite Production

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South Africa's mining sector, particularly coal and gold operations in Gauteng Province, faces the ongoing challenge of acid mine drainage (AMD), which contaminates surface and groundwater while creating severe environmental and socio-economic risks. Conventional lime neutralisation remains the most widely applied treatment method, but it produces large volumes of iron-rich sludge that are costly to manage, accounting for 5–20% of treatment facility operating expenses. This underscores the need for innovative approaches that transform AMD sludge into valuable products while reducing disposal burdens.

This study developed a process to recover iron from AMD sludge and utilise it as a precursor for synthesising barium hexaferrite (BHF), a high-value magnetic material. Sludge samples from the Central Basin (CB) and Eastern Basin (EB) were characterised using ICP-OES, XRD, BET, and SEM-EDS, with CB sludge showing the highest Fe content (40.2 wt%). Sulphuric acid leaching under optimised conditions (75 °C, S/L ratio of 0.08 g/ml, 400 rpm, 1.5 M acid) achieved 87.2 ± 0.42% Fe recovery. Kinetic modelling based on the shrinking core model indicated diffusion-controlled leaching with an activation energy of 4.19 kJ/mol. The recovered iron was reacted with barium carbonate via solid-state synthesis to produce BHF.

Characterisation confirmed the formation of hexagonal BHF phases with ferromagnetic properties, including saturation magnetisation (49.96 Am^2/kg) and coercivity (189.71 kA/m). This approach provides a pathway for addressing AMD sludge disposal challenges, lowering treatment costs, and promoting circular economy practices in South Africa's mining sector.

Techno-Economic And Environmental Analysis Of The Use Of Green Hydrogen For Enhancing Methane Production In Biodigestion Systems

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This paper evaluates the synergies between green hydrogen and biomethane production through a techno-economic and life cycle assessment (LCA). Eight scenarios were considered, exploring different biogas upgrading approaches, including direct hydrogen injection, methanation technologies, and co-digestion processes. The assessed scenarios involved the use of low-carbon hydrogen produced via water electrolysis (Power-to-Gas technologies – P2G), coupled with technologies such as in-situ hydrogen injection and ex-situ methanation (biological, amine-based, and catalytic methods), resulting in a total of eight scenarios.The findings reveal that synergy options between low-carbon hydrogen and anaerobic digestion significantly reduce greenhouse gas emissions and enhance biogas-fueled electricity generation. The anaerobic digestion of pig manure, co-digested with energy crops such as elephant grass, not only mitigates methane (CH_4) and nitrous oxide (N_2O) emissions associated with manure disposal but

also increases methane content in biogas while offering a renewable alternative to synthetic mineral fertilizers. From an economic perspective, scenarios involving pig manure monodigestion demonstrated greater viability, with higher Net Present Value (NPV) and Internal Rate of Return (IRR), along with shorter payback periods. A sensitivity analysis was conducted to identify ways to improve the economic feasibility of all assessed scenarios. This paper highlights the environmental and economic benefits of various synergy pathways between low-carbon hydrogen and biogas production—both in mono- and co-digestion modes—suggesting a substantial contribution to sustainable energy practices and improved waste management. This represents its main novelty.

Techno-Economic And Environmental Assessment Of Co-Cultivated Scenedesmus-Lemna Sp In An Airlift Raceway Photobioreactor For Algal Biofuel Production Using Industrial Wastewater

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The integration of wastewater valorisation with renewable energy serves a dual solution to the global energy and environmental crises. This study presents a techno-economic assessment and life cycle analysis of the biorefinery process utilising Scenedesmus-Lemna sp. co-culture cultivated in a 240 L airlift raceway, using sewage wastewater for the recovery of lipids and hydrocarbons. This approach targets algal challenges of upscaling, harvesting and low-lipid recovery by incorporating double-sparging enhanced streams and co-cultivation as a natural attached technique with enhanced lipid recovery. Direct fatty acid methyl ester purification eliminated transesterification, reducing the dependency on solvent and the overall process cost. The integrated process achieved significantly lower capital and operational expenditure, compared to traditional biofuel pathways, with an approximate profit margin of 0,35 – 0,95 UDS/L, a payback period of 3 – 6 years and a strong internal rate of return of 15 – 25 %. Economic feasibility arises from the multiple revenue streams created being biofuels, treated effluent and residual biomass valorisation. Sensitivity analysis confirmed reliability and resilience against the energy price fluctuations and variations within the market, showing great potential for large-scale implementation. The LCA quantified the environmental performance across the process chain with reductions exceeding 90 % in nutrient pollutants and 98 % GHGs. This study demonstrated a positive energy return on investment (EROI > 1,5), substantial GHG mitigation and a minimal water footprint. The TEA and LCA validate the technical, economic and environmental feasibility for a scalable biorefinery future and a circular pathway to transforming municipal wastewater treatment facilities into revenue-generating renewable energy hubs.

The Effect Of Cao, Fe2O3 And Tio2 On Methane Production During The Anaerobic Digestion Of Cow Dung

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The anaerobic digestion of biodegradable organic material offers a sustainable solution for renewable energy generation and waste management. Cow dung, a readily available feedstock, can be converted into biogas through microbial processes, yet methane yield is often limited by suboptimal reaction kinetics and microbial efficiency. This ongoing study investigates the influence of calcium oxide (CaO), iron (II) oxide (Fe2O3), and titanium oxide (TiO2) on the methane production during the anaerobic digestion of cow dung. The objective of this study is to determine how varying concentrations of these additives affect the methane concentration by enhancing microbial activity and facilitating catalytic reactions. Batch anaerobic digestion experiments are being conducted under mesophilic conditions, maintaining a hydraulic retention time (HRT) of 28 days, with periodic monitoring of methane concentration to assess the effect of metal oxide additives. Preliminary observations suggest that the inclusion of moderate levels of metal oxides promotes methane generation, likely by stimulating enzymatic activity and improving electron transfer within the microbial consortium. Further analyses will include X-ray Diffraction (XRD), X-ray Fluorescence (XRF), and Scanning Electron Microscopy (SEM) to characterize both the additives and the digested residue. These findings are expected to contribute valuable insights toward optimizing biogas production systems and developing efficient, low-cost strategies for circular bioenergy processes.

The Influence Of Temperature And Pressure On Sugar Yields From Sweet Sorghum Via Subcritical Water Hydrolysis

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This study focuses on the use of sweet sorghum bagasse, an abundant agro-industrial by-product, as a feedstock for the subcritical water hydrolysis process, aiming to unveil its decomposition behavior at different pressures and temperatures. Batch experiments were performed under controlled temperature and pressure conditions (200-280 ºC and 14-100 bar) to evaluate the effects of these variables on biomass degradation efficiency. Each experiment used 3.0 g of biomass and 300 mL of water (1:100 ratio), stirred at 500 RPM for 2 hours. Conversion efficiency and product yields were calculated based on sugar concentrations in the hydrolysate. The results show that temperature significantly affects fermentable sugars release. At 200 ºC, moderate glucose and xylose production was observed, while at 240 ºC the rate increased significantly, reflecting greater efficiency in the degradation of cellulose and hemicellulose. However, at 280ºC sugar yields decreased due to thermal degradation and by-product formation, such as furfural

and levulinic acid. Pressure was more influential at 200°C, where its effect was verified on the kinetic profile of sugar formation, chemical platforms and inhibitors. High pressures were not necessary to ensure the decomposition of lignocellulosic biomass at 240 and 280 °C. Kinetic analysis showed different behaviors for cellulose and hemicellulose: hemicellulose hydrolyzes more easily at lower temperatures and pressures, whereas cellulose requires higher temperatures. This study advances the understanding of optimal subcritical water hydrolysis conditions, highlighting the lack of need to pressurize the system under certain conditions.

The Potential Of Bioenergy To Reduce Fossil Fuel Dependence In South Africa'S Energy Transition Toward Carbon Neutrality.

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In line with South Africa's demands to meet her Nationally Determined Contributions (NDC) by 2030 and her Low Emission Development Strategy (LEDS) which aims to achieve a Net-Zero carbon emission by 2050, South Africa's shift towards carbon-neutrality requires an urgent diversification of the energy infrastructure, and bioenergy offers a promising solution for reducing overdependence on fossil fuels. This paper examines the role of bioenergy in reducing the reliance on coal in the context of South Africa's energy transition. Even though there have been recent advances towards the use of renewable energy, bioenergy has not been utilized to its full potential, and there is a slow rate of development of bioenergy in the national grid. The study points out the benefits of Organic Solid Waste (OSW) and Invasive Alien Plants (IAP) conversion into biofuels as a tool for economic growth and ecosystem protection and preservation. It also discusses the contribution of Bioenergy with Carbon Capture and Storage (BECCS) to offsetting GHG emissions during biomass conversion processes, and the financial and infrastructure difficulties faced in scaling up these technologies for large scale productions. The study calls for increased investment, more regulatory support, and increased research focus in the innovation of more efficient and cost-effective biomass conversion methods to unlock bioenergy's full potential. Strengthening this sector will not only reduce fossil fuel reliance but also enhance waste management, public health, and rural development, which are all major pillars in South Africa's journey toward a low-carbon future.

The Preparation Of Alkali Treated Cornhusk/Polycaprolactone Composite For Industrial Packaging

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With the global shift towards sustainability, there is an increased demand for environmentally friendly alternatives, especially in packaging. Traditional plastic packaging, derived from fossil fuels, significantly contributes to environmental degradation. This research explores the use of cornhusk, an agricultural waste product, in creating a biodegradable polymer composite for packaging. The polymer matrix, polycaprolactone (PCL), was blended with cornhusk at 80°C for 3 minutes using a local hand mixer. The mixture was then cooled and fabricated using a thermal hot press. The composite's thermal and mechanical properties were examined using scanning electron microscopy (SEM), Fourier transform infrared spectroscopy (FTIR), and standard mechanical testing. Results indicated that alkali treatment significantly enhanced the composite's performance. Notably, tensile strength increased by 51%, with the optimal treatment at 10 ml, showing the highest flexural strength (17.55 MPa) and hardness (12.9 N/mm^2). Water absorption was lowest at 0.75% in the 10 ml treated sample. Thermal analysis showed improved degradation performance. The 10 ml alkali-treated CH-PCL composite demonstrated superior mechanical and interfacial properties, making it a promising alternative for sustainable industrial packaging.

Keywords: Sustainable Packaging, Biodegradable Polymer Composite, Alkali Treatment, Eco-Friendly Packaging

The Sustainability Of Global Industrial Off-Gases In The Ferrochrome And Petroleum Industries: A Systematic Literature Review

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The sustainability of industrial off-gas utilisation has become increasingly critical as global industries face mounting pressure to reduce greenhouse gas (GHG) emissions and adopt cleaner energy practices. Industrial off-gases have the potential to be sustainably utilised to assist energy-intensive industries in decreasing GHG emissions, while improving economic performance. This research examines off-gas management strategies currently employed in the ferrochrome and petroleum refining industries, which are among the most energy-intensive industries in South Africa.

The South African ferrochrome industry faces formidable challenges, primarily due to exorbitant electricity prices, which have led to the cessation of several smelter operations and negatively impacted the industry's economic relevance in the global market, thereby restricting investments in advanced off-gas utilisation technologies.

This research employed a systematic literature review (SLR) to analyse peer-reviewed articles from ten academic databases. This research adopted the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

A comparative analysis seeks to identify the strengths, challenges, and areas for potential improvement in off-gas management strategies between the two industries. It was found that cogeneration, SmeltDirect, deep conversion of associated petroleum gas (APG) and carbon capture and storage (CCS) represent the most promising technologies, which have the potential to resolve economic, environmental and technological challenges by increasing energy efficiency and decreasing emissions. The ferrochrome industry has a promising opportunity to advance with the introduction of cogeneration systems, which have the potential to enable power independence and reduce operational costs.

Thermo-Catalytic Biorefining Of Waste Cooking Oil To Gasoline-Like Fuel Using Hzsm-5

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The increasing demand for sustainable energy and the environmental challenges posed by waste disposal have driven interest in the valorisation of waste cooking oil (WCO) into alternative fuels. This research investigates the thermo-catalytic conversion of WCO into gasoline-range hydrocarbons using HZSM-5, a zeolitic catalyst known for its acidity, thermal stability, and shape selectivity. The study focuses on the synthesis and characterization of the HZSM-5 catalyst, the optimization of reaction conditions in a fixed-bed reactor, and the analysis of liquid fuel products. The XRD pattern of the HZSM-5 catalyst exhibited intense diffraction peaks in the regions of 7–9° and 22–25° (2θ), which are characteristic of the highly crystalline MFI-type structure of HZSM-5. Other catalyst characterization techniques, including FTIR, EDXRF, BET, and TGA/DTA, confirmed the MFI zeolite structure, composition, pore distribution, and thermal stability of HZSM-5, all of which are essential for effective catalytic cracking. Experimental results indicate that a reaction temperature of 500 °C, a reaction time of 45 minutes, and a catalyst loading of 10 g yield an optimal conversion of 89.35%, producing a liquid product rich in C_5–C_{12} hydrocarbons with significant paraffin, olefin, and aromatic content. FTIR and GC-MS analyses confirmed effective deoxygenation and the formation of fuel-grade hydrocarbons. The findings demonstrate the potential of HZSM-5 for transforming WCO into gasoline-like fuels, offering a promising approach to renewable energy production and waste minimization.

Toward Sustainable Transport Fuels: Biomass And Metal Oxide-Based Catalysts For Valorization Of Waste Feedstocks In Biodiesel Synthesis

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The global pursuit of sustainable energy alternatives has driven increased interest in biodiesel as a renewable alternative for fossil-derived diesel. This work presents the development and application of environmentally benign bifunctional catalysts derived from biomass waste and transition metal oxides for biodiesel synthesis from waste cooking oil (WCO). Emphasis is placed on integrating process intensification strategies, particularly microwave-assisted transesterification, to enhance reaction efficiency, reduce energy consumption, and improve product yield. Three catalyst systems were investigated: (i) carob pod-derived solid base catalyst, (ii) ferric sulfate-modified bifunctional catalyst for WCO and Delonix regia oil mixtures, and (iii) metal oxide-based catalyst system incorporating Zn and Fe oxides on calcined eggshell. These catalysts demonstrated high activity and reusability, achieving favourable conversion rates under optimized conditions. Characterization results (TGA, XRD, FTIR, BET, SEM/EDS, CO_2– and NH_3–TPD) confirmed the crystalline phase, functional group, surface morphology and area, and bifunctional nature of the catalysts, promoting both esterification and transesterification processes. The produced biodiesel met key physicochemical and fuel quality requirements specified by international biodiesel standards, affirming its suitability for engine applications. The low specific energy consumption and specific CO_2 emissions observed suggest effective utilization of microwave energy in driving the reaction and contributing to a reduced carbon footprint. The valorization of low-cost, abundant feedstocks and the utilization of green catalytic systems offer promising route for sustainable biodiesel production. This work contributes to the development of scalable and cleaner fuel technologies aligned with global goals for a circular economy and carbon neutrality in the transport sector.

Transforming Agro-Industrial Residues Into Biochar: A Pathway For Carbon Capture, Energy Transition, And Circular Bioeconomy

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The transition toward low-carbon energy systems requires strategies that integrate renewable resources, carbon capture, and circular economy approaches. This study investigates the thermochemical conversion of agro-industrial residues into biochar, emphasizing its multifunctional role as a carbon-negative material and sustainable energy vector. Carbonization was performed at different temperatures (300–700 °C) and heating rates (10 and 20 °C/min), followed by comprehensive physicochemical, kinetic, and morphological characterization. Results indicate that biochar produced at 400 °C exhibits favorable properties for application as a soil amendment and long-term CO_2 sequestration. Treatments at 400–500 °C with higher heating rates yielded biochars with enhanced energy density, suitable as renewable solid biofuels to partially substitute fossil sources. Lower temperature treatments (300–400 °C) revealed catalytic potential, enabling opportunities in green chemistry and environmental applications. By coupling agro-industrial waste valorization with carbon capture and renewable energy generation, this work demonstrates that biochar can serve as a versatile solution to accelerate the energy transition, mitigate greenhouse gas emissions, and foster a circular bioeconomy.

Treatment Of Pharmaceutical Wastewater Using Nanoparticle-Modified Banana Peels And Indian Siris Pods Composite

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The presence of antibiotic residues in pharmaceutical wastewater poses various harmful effects on human health and the environment due to their refractory nature, low biodegradability, and bioaccumulation toxicity. In this study, green-synthesized manganese oxide (MnO2) nanoparticles were loaded onto composite biochar (CBC) derived from banana peel (BP) and Indian siris pods to create a nanocomposite (BC-MnO2), which serves as an effective biosorbent for the removal of antibiotic ciprofloxacin (CIP) and tetracycline (TCY) from pharmaceutical wastewater. Both CBC and BC-MnO2 were characterized using SEM, XRD, BET, and DLS to confirm enhanced surface morphology and porosity. The modification process significantly increased the surface area from 282.9 m^2/g for CBC to 320.8 m^2/g for BC-MnO2. Batch adsorption experiments investigated the effects of initial concentration, contact time, dosage, pH, and temperature on the removal of CIP and TCY. The BC-MnO2 achieved removal efficiencies of up to 97.76% for CIP and 97.52% for TCY. The adsorption followed the Freundlich isotherm and pseudo-second-order kinetics, indicating multilayer chemisorption on heterogeneous surfaces. Thermodynamic analysis confirmed that the process was spontaneous and endothermic. This work highlights the importance of agricultural waste-based composites as sustainable materials for removing antibiotics from pharmaceutical wastewater, contributing to cleaner water systems and supporting SDGs 6, 11, and 12.

Tuning Adsorption In Mofs Via Linker Functionalization: A Simulation-Only Gcmc–Dft Study

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Metal–organic frameworks (MOFs) offer a unique handle to tailor gas uptake through chemical modification of the organic linker. We present a simulation-only framework to quantify how linker functional groups (e.g., $–NH_2$, $–NO_2$, –OH, –F/Cl, $–CH_3$, $–CF_3$, –CN, $–OCH_3$) modulate adsorption capacity and energetics across isoreticular MOFs. Our pipeline couples grand canonical Monte Carlo (GCMC) with DFT-informed parameters under strictly controlled modeling choices: rigid frameworks typed with UFF/DREIDING (or UFF4MOF), consistent fixed charges, explicit sorbate models (e.g., CO_2 TraPPE; H_2 with quadrupole and Feynman–Hibbs correction at cryogenic T), Ewald electrostatics, and vdW cutoffs ≥12.5–14 Å with long-range corrections. For each functionalized structure we compute Henry's constants, isotherms, and isosteric heats (Qst), and we generate 3D occupancy and energy maps to locate dominant binding sites (windows, cages, open-metal regions vs functional group pockets). We then relate performance to physicochemical descriptors—accessible pore volume, surface area, pore-limiting diameter, linker dipole/quadrupole, and Hammett σ parameters—to build interpretable structure–property trends that separate pore geometry effects from chemistry-driven polarization. Sensitivity analyses (charge scheme, mixing rules, supercell size, quantum correction for H_2) quantify numerical robustness, enabling reproducible benchmarking without experimental input. The study delivers a ranked map of functional groups by uptake and Qst at application-relevant conditions, design heuristics for selecting substituents that enhance specific gas/framework interactions, and a lightweight toolkit (ready-made sorbate files, parameter sheets, and scripts) to transfer this protocol to new MOF families and multicomponent separations.

Valorization Of Fly-Ash As A Source Of Heterogenous Catalyst For Biodiesel Production From Waste Cooking Oil

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Reaction conditions coupled with catalyst stability are some of the major drawbacks affecting the application of inorganic heterogeneous catalyst for simultaneous esterification and transesterification of WCO. The purpose of this study is to develop a biomass-derived bifunctional catalyst (BFAC) from functionalized fly-ash (FA) for simultaneous esterification and transesterification of waste cooking oil (WCO). Various characterization of the BFAC was performed including X-ray fluorescence (XRF), scanning electron microscope (SEM), X-ray diffraction (XRD), Brunauer–Emmett–Teller (BET), and Fourier-transform infrared spectroscopy (FTIR). The catalytic activity of the developed BFAC in simultaneous esterification and transesterification of WCO with high free fatty acid (FFA) of 4.15% was investigated. Response Surface Methodology (RSM) of Design Expert Software was used to design the experiment and during optimization of process parameters. Results showed that BFAC possess both basic and acidic physico-chemical properties, making it highly bifunctional. This observation was deduced by the presence of symmetric/asymmetric stretching vibrations of CO32- at peak 1455 cm1, strong asymmetric Si-O-Si/Al-O-Si stretching in the range of 1000-1150 cm-1, and Si-O-Si at 471 cm-1 At optimum conditions of reaction temperature, methanol to oil ratio (MTOR), catalyst weight, and reaction time of 67.92oC, 11.1:1, 1.54 wt%, and 61.4 minutes, the biodiesel yield of 97.4 wt% with acid value of 0.82 mg KOH/g was obtained. The recovery and/or reuse of the BFAC was also explored and results revealed that recovery catalyst from the process gave a biodiesel yield of 82.1% after four successive cycles.

Integrated Utilization Of Biogas And Sludge For Thermal Drying And Sustainable Hygienization Of Anaerobic Sludge

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Sustainable management of sludge remains one of the main challenges for wastewater treatment plants (WWTPs), due to the need to reduce the volume sent for final disposal and to promote the valorization of by-products. In this context, thermal processes stand out by combining pathogen inactivation, moisture reduction, and energy recovery, thereby supporting circular economy strategies. This study assessed the technical feasibility of integrating biogas from UASB reactors and dried sludge produced in a thermal dryer as complementary energy sources for the drying stage in a large-scale WWTP. Monitoring from 2022 to 2024 covered biogas production and composition, dried sludge characterization, and dryer performance. Biogas contained on average 75.6% CH_4, yielding an energy potential of 5.9×10^4 MJ/d. Dried sludge contained 88.8% total solids, a calorific value of 11.2 MJ/kg, and macronutrients and trace metals, with restrictions only for zinc, associated with the use of ferric chloride in the physicochemical polishing stage of the effluent. The energy potential of dried sludge was estimated at 2.96×10^5 MJ/d. Together, biogas and dried sludge supplied 97% of the process energy demand, with a specific consumption of 930 kcal/kg (3891 kJ/kg) of water removed, which falls within internationally reported ranges. The biosolid achieved Class A quality, with agricultural use conditioned by Zn control. The results demonstrate the feasibility of this integrated arrangement, which reduces fossil fuel dependency, enhances by-product valorization, and fosters practices aligned with the circular economy.

Investigation Of Biodiesel From Selected Biomass Materials Using Cao Extracted From Eggshell For Future Fuel Generations

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Biodiesel has become more attractive recently because of its environmental benefits and the fact that it is made from renewable resources. In this work, biodiesel (methyl ester) will be prepared from Ricinuscomunis, daturastramonium and Chrysophyllumalbidiumoil extracted from their seeds. The oil will be extracted using N-hexane with the Soxhlet apparatus at a temperature of 650 C for 4 hours. The oil will be characterized by its properties including an average oil yield, density, acid value of the extracted oil, saponification value of the extracted oil, Iodine value of the extracted oil. Methyl alcohol (methanol) with CaO derived from eggshell as a catalyst will be used for the trans-esterification process. GC/MS will indicate significant result for the conversion of the oil to biodiesel as it will be indicated by fatty acid methyl ester profile of the sample, inline to this other fuel properties of biodiesel produced will also be determine which include Cetane number, density, cloud point, pour point, flash point. Production of biodiesel from seed plant oil using heterogeneous catalyst (CaO) for diesel substitute is particularly important because of the decreasing trend of economical oil reserves, environmental problems caused due to fossil fuel use and the high price of petroleum products in the international market and our country Nigeria.

Investigation Of Sodium Magnesium Silicate (Na2Mgsio4) Supported On Hard Carbon As Anode Material For Enhanced Performance Sodium-Ion Batteries

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The growing demand for sustainable and affordable energy storage systems has accelerated research into sodium-ion batteries (SIBs) as potential alternatives to lithium-ion technologies. In this study, Sol-gel approach followed by pyrolysis was used to prepare Na_2MgSiO_4 supported on hard carbon for investigation as potential anode materials for high-performance SIBs. The structural and morphological characteristics were primarily evaluated using X-ray diffraction (XRD) and transmission electron microscopy (TEM). XRD analysis confirmed the successful formation of crystalline Na_2MgSiO_4 phases with well-defined diffraction peaks, while the broad background signal indicated the amorphous nature of the hard carbon support. The TEM images further revealed a uniform dispersion of nanostructured Na_2MgSiO_4 particles anchored within the porous carbon matrix, suggesting a close interfacial contact that could facilitate fast electron and Na^+ transport. These preliminary results demonstrate the successful preparation of the Na_2MgSiO_4/hard carbon composite. Ongoing studies, including SEM, EDS, XPS, FTIR, and Raman spectroscopy, will provide deeper understanding into the surface chemistry, elemental distribution, and bond arrangements, while upcoming electrochemical characterizations will investigate the Na-storage performance, rate capability, and long-term cycling stability. This work lays the foundation for optimizing Na2MgSiO4/hard carbon anodes and advancing the development of high-energy, long lasting sodium-ion batteries.

Investigation Of The Carbon Dioxide Adsorption Capacity Of Kikuyu Grass (C. Clandestinus) Biochar Produced Under Different Pyrolysis Conditions And The Use Thereof To Enhance The Growth Of Swiss Chard (B. Vulgaris).

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Urban communities generate large quantities of grass clippings that remain underutilized despite their potential as a renewable biomass resource. Converting this municipal organic waste into biochar through pyrolysis offers a pathway for carbon sequestration while producing a multifunctional carbon-rich material. This study produced biochar from Kikuyu grass (C. clandestinus) and evaluated the effect of two feedstock size classes (100–500 µm and 1000–2000 µm), and three peak temperatures (400°C, 500°C, and 600°C) on biochar characteristics. Higher pyrolysis temperatures increased biochar pH and graphitization and reduced biochar yields. Biochar specific surface area was maximized at 500°C using the larger feedstock size. Biochar specific surface area had a strong positive correlation on both water retention capacity and CO2 adsorption capacity. A greenhouse study on Swiss chard (B. vulgaris) was conducted to assess the functional performance of these biochars as a soil amendment. Biochar improved soil water retention and, under certain conditions, enhanced plant growth. These findings demonstrate the potential of grass-derived biochar as an environmentally sustainable tool for urban biomass valorization, carbon sequestration, and soil improvement.

Investigation Of The Physicochemical Properties Of Biochar Derived From Residual Seeds As A Potential Support For Bifunctional Magnetic Nanocatalyst In Biodiesel Production

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Biodiesel emerges as a promising alternative because of its cleanliness, renewability, and environmental friendliness, produced mainly by transesterification of vegetable oils or animal fats. However, current commercial biodiesel production faces challenges with homogeneous catalysts, such as the need for extensive water washing and limited reusability, causing a shift towards heterogeneous catalysts such as CaO. Despite its advantages, CaO's instability and leaching issues limit its effectiveness. This study will explore the use of biochar as a catalyst support to enhance CaO stability and reduce contamination. Biochar offers numerous benefits, including high porosity, biodegradability, and large surface area. This research will utilise biochar derived from sorghum waste to support bifunctional magnetic nanocatalysts in biodiesel production, with the aim of achieving a high yield of fatty acid methyl ester (FAME) and optimising the transesterification process with cosolvents. The composition, structure and texture of prepared catalysts will be examined by XRD, thermogravimetric analysis (TGA), Fourier transform infrared spectroscopy (FTIR), scanning electron microscope (SEM), energy dispersive spectrometer (EDS), and N2 adsorption/desorption. The catalytic performance of the resulting catalysts will be evaluated through the transesterification reaction using waste cooking oil. This innovative approach aims to improve biodiesel yield and reduce production costs, addressing the need for sustainable and efficient energy alternatives.

Keywords: Biochar, Sorghum seeds, Bifunctional magnetic nanocatalysts

Life Cycle Assessment Of Msw Management In Medium-Scale Cities: A Brazilian Case Study

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Municipal solid waste management in medium-scale cities is a difficult task in developing countries, because high moisture content of waste, the technical complexity of improved technologies, and outdated regulations that permit landfilling of MSW. Therefore, the objective of this study is to provide the assessment of environmental impacts from six scenarios, considering waste-to-energy alternative systems. The scope comprises MSW generated in CIMASAS, a consortium of 11 municipalities in southeast Brazil. An environmental assessment was accounted for via LCA using SimaPro® software, considering the CML IA method baseline. To complement the analysis, the IMPACT 2002+ methodology was applied. Additionally, four indicators were used to

evaluate the energy and environmental performance of the different systems: Specific power generation, Specific fossil Energy consumption, Fossil energy ratio, and Carbon footprint. Results indicate that there is a need to reduce waste disposal in landfills, which was the worst scenario for all impact categories. The results indicated improved environmental performance in integrated systems that benefit from electricity generation, recovery of materials from waste sorting/recycling, and production of biofertilizers. The analysis also demonstrated that the best environmental performance corresponds to an integrated system of gasification and anaerobic digestion along with waste sorting/recycling, the only alternative to provide a reduction in carbon footprint.

Low-Cost Biomass Conversion System For Power Production: A Case Study For South African Villages

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The increasing depletion of fossil fuels and the imperative of environmental sustainability have compelled the adoption of renewable energy sources (RES). Particularly, the utilization of renewable resources is crucial in African countries where challenges persist in accessing electricity and modern cooking fuels. Therefore, this study investigates the viability of alternative energy sources, focusing on the conversion of biomass into biogas through anaerobic digestion technology for a hybrid microgrid system. The study addresses the feasibility of using anaerobic digestion to convert household and poultry waste from rural areas in Limpopo and Western Cape province, South Africa, into biogas for cooking. To achieve the above aims, MATLAB and HOMER Pro software are employed. Research outcomes indicate that anaerobic digestion of kitchen and animal waste is a viable method for biogas production. Food waste amounting to 668 kg and 467.5 kg from Madombidzha village and Walladecene area produced a biogas volume of about 522.3 m3 and 365.2 m3, respectively. The estimated electric power production from a hybrid microgrid using a biogas generator in Madombidzha village and Wallacedene area amounts to about 109,508 kWh/year and 199,000 kWh/year, respectively. Conclusively, this investigation underscores the potential of anaerobic digestion as a sustainable energy solution, paving the way for the wider adoption of biogas technology in rural African communities.

Low-Cost Decorated Biochar Derived From Sweet Sorghum Stalks As A Support Material For Platinum Electrocatalyst In Pemfcs

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The growing demand for sustainable and cost-effective energy solutions has increased interest in developing different materials for proton-exchange membrane fuel cells (PEMFCs). This study aims to investigate low-cost, sorghum-derived biochar as a support material for platinum electrocatalysts, with a focus on enhancing catalytic performance and sustainability. Two catalyst techniques synthesized: Pt-Biochar@Silicon, utilizing silicon as a dopant, and Pt-Biochar without doping. These catalysts are synthesized using pyrolysis and characterized using Raman spectroscopy, atomic resolution microscopy (ARM), scanning electron microscopy (SEM), and X-ray diffraction (XRD). Electrochemical performance is assessed through cyclic voltammetry (CV) and electrochemical impedance spectroscopy (EIS). Additionally, electron beam deposition will be utilized to make silicon-platinum thin films for comparative study. The results show that silicon doping improve the dispersion and stability of platinum nanoparticles, resulting to increased electrocatalytic activity. The silicon-doped alternative is anticipated to mitigate Pt nanoparticle agglomeration, a common issue in carbon-supported catalysts. This research is results contribute to Sustainable Development Goals 7 and 13 by promoting the use of agricultural waste and increase clean energy technologies. Ultimately, the project aspires to demonstrate the possibility of waste-derived biochar from sorghum as a functional and eco-friendly catalyst support in PEMFC applications.

Measurement Of Biomass In Small-Scale Microalgal And Microalgal-Bacterial Systems Treating Complex Wastewaters

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It is important to obtain accurate measurements of microbial biomass when assessing the performance of microalgal and microalgal-bacterial (MAB) wastewater treatment systems. However, small-scale studies often face methodological challenges due to the heterogeneous nature of some wastewaters, especially in terms of the solids fraction, and the close association between algal and bacterial cells. This study adopts a two-fold approach: (i) a concise review of current biomass quantification methods for bench-scale systems, and (ii) an experimental evaluation of a gravimetric protocol developed for composite tannery wastewater (raw, settled, and filtered). The review systematizes commonly applied techniques, highlights their strengths and weaknesses, and identifies critical research gaps in data comparability and reproducibility.

Experimental investigations were conducted to evaluate the effect of key factors such as culture volume (250 ml to 1 L), and test aliquots (2.5ml to 10ml), biomass concentration (0.2 g/L to 2 g/L), and suspended solids that influence the accuracy of gravimetric biomass determination. The findings demonstrate that variations in these parameters can lead to significant discrepancies in biomass estimation, emphasizing the need for procedural standardization. Based on these results, a practical gravimetric protocol is proposed, optimized for small-scale studies dealing with high-strength complex wastewaters. The method enhances precision and representativeness in measuring total biomass in both axenic and consortium-based systems. This study provides an evidence-based roadmap for obtaining more reliable biomass measurements in small-scale microalgal and MAB system

Multimodal Pedagogy In Communication Engineering As A Catalyst For Waste Valorisation & Circular Sustainability

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My work examines how multimodal, communicative, and computational pedagogies within communication engineering education can contribute to waste valorization and circular economy initiatives. It is an attempt to bridge technical engineering with ecological responsibility through integrating guided annotation, jigsaw reading, stakeholder-informed artefacts (posters, podcasts, computational models), and plastic waste case studies. Drawing on Bakhtin's dialogic discourse and Gutiérrez's "third space," the pedagogical design empowers students to develop artefacts that both analyze waste flow patterns via computational modelling and propose reuse strategies (e.g., plastic lumber, recycled bricks), while engaging policy and community perspectives. The findings reveal that such pedagogies foster student agency, disciplinary literacy in modelling waste systems, and reframe engineering as a socially and ecologically embedded practice. Institutional constraints—such as large class sizes, accreditation demands, and disciplinary silos—posed challenges but also generated openings: collaborations between engineering, environmental science, and computer science departments led to co-developed modules and cross-disciplinary projects. More than a classroom innovation, this pedagogy offers a model for how engineering curricula might support circular materials systems and sustainability in practice. The study underscores that education can play a strategic role in shaping both technical and policy dimensions of waste valorization and circular transition in South African contexts.

Numerical Modeling Of Innovative Thermal Energy Storage Systems Employed For Energy Conservation During The Processing Of Biomass

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This study presents a comprehensive numerical modeling approach for innovative thermal energy storage (TES) systems designed to enhance energy conservation during biomass processing. Biomass conversion processes often require stable and efficient thermal management to optimize yield and reduce energy consumption. The proposed TES systems integrate advanced materials and novel configurations to store surplus thermal energy generated during biomass drying, pyrolysis, or gasification phases, enabling its reuse and reducing reliance on external energy inputs. Using computational fluid dynamics (CFD) coupled with heat transfer and phase-change models, the energy storage performance, charging-discharging cycles, and thermal efficiency of these systems are simulated under varying operational conditions. The model captures transient heat transfer phenomena, including conduction, convection, and phase-change mechanisms within the storage media, allowing assessment of different TES designs and materials such as phase change materials (PCMs), molten salts, and packed bed arrangements. Results demonstrate significant potential for reducing overall energy demand, smoothing temperature fluctuations, and improving process sustainability. Sensitivity analyses highlight the impact of material properties and system parameters on performance metrics. This work provides valuable insights into the design and optimization of TES systems tailored for biomass processing applications, supporting the broader goals of energy conservation and green technology development in renewable energy sectors.

Performance Assessment Of Undershot Hydrokinetic Turbines For Renewable Energy Generation

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This study undertook an in-depth numerical investigation and optimisation framework focused on hydrokinetic turbines designed specifically for micro-scale electricity generation within sustainable renewable energy contexts. Undershot hydrokinetic turbines, which extract kinetic energy from moving water, present a significant opportunity for distributed power generation with a low environmental footprint. The research integrates advanced computational fluid dynamics (CFD) modelling with an optimiser-led blade design methodology, allowing for detailed exploration and enhancement of critical turbine parameters such as blade geometry, chord distribution, and hydrofoil configuration.

An optimisation protocol that employs a multi-objective genetic algorithm, coupled with blade element momentum theory (BEMT), has enabled the efficient assessment of hydrodynamic performance across the variable flow conditions commonly encountered in riverine environments. The validity of the numerical models is established through comparisons with both BEMT and experimental data, ensuring confidence in the predictive capacity of the simulation results for micro-turbine applications. Key performance indicators, including power coefficient, tip speed ratio, and cavitation safety factor, are systematically analysed for various configurations, identifying optimal design parameters that maximise annual energy output while maintaining operational safety margins.

The findings demonstrate the potential and scalability of CFD-driven optimisation in advancing the effectiveness of hydrokinetic systems for innovative bioenergy solutions. This work provides a foundation for future integration into microgrid and rural electrification initiatives, emphasising the pivotal role of computational modelling and design optimisation in the evolution of sustainable energy technologies.

Persistent Oceanographic Device Power (Podpower): Harnessing Energy Of Marine Organic Matter Through Dark Fermentation

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The growth of marine-based industries has stimulated interest in developing biotechnological pathways to valorize marine organic matter. This project focuses on converting biomass to valuable intermediates through dark fermentation and subsequently into electricity. Research in the efficacy of dark fermentation of marine organic matter under saline conditions is limited. This project investigates the transition of a terrestrial dark fermentation processing food waste into a saline dark fermenter processing marine organic matter through mid-term (150 day) continuous trials. The highest volatile fatty acid (VFAs) yield (>12 g/L) was observed at 30 ppt salinity. Acetic acid was the most prominent VFAs, constituting over 70% of the VFAs observed. The microbial community was evaluated at different transition stages, highlighting the impact of salinity and feedstock on the microbial consortia observed, resulting in improved VFA yields. The impact of the hydraulic retention time (HRT) on saline dark fermentation was also investigated, which highlighted the stability of saline dark fermentation of marine organic matter. The specific hydrogen yield decreasing with reducing HRT. Saline dark fermentation can provide an intermediate processing phase for other biotechnologies that could further valorize marine organic matter, supporting further innovation in the blue economy.

Photocatalytic Degradation Of Methylene Blue Using Zno-Based Composites: Evaluating The Efficiency Of Zno, Zno-Tio_2, And Zno-Tio_2-Acfa/Biochar

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The persistence of synthetic dyes such as methylene blue (MB) in wastewater poses serious environmental threats due to their toxicity, resistance to biodegradation, and interference with aquatic photosynthesis. This study investigates the photocatalytic degradation of methylene blue using zinc oxide (ZnO)-based composites, with the aim of enhancing photocatalytic efficiency under simulated solar irradiation. Pure ZnO, ZnO–TiO_2, and ZnO–TiO_2/ biochar composites were synthesized through sol–gel and impregnation methods, followed by detailed characterization using XRD, FTIR, BET, and UV–Vis spectroscopy. Photocatalytic experiments were performed under varying operational parameters such as dye concentration, catalyst dosage, and irradiation time. The results revealed that ZnO–TiO_2–biochar composites exhibited superior degradation performance, 100% MB removal within 15 minutes. For ZnO-TiO2 there was complete degradation after 25 minutes and 45 minutes for ZnO. The enhancement was attributed to improved charge separation, extended light absorption range, and increased surface area provided by the carbonaceous support. Kinetic analysis followed a pseudo-first-order model, confirming the synergistic effect between the semiconductor oxides and biochar. The scavenger study was done to confirm the dominant radicals - hydroxyl radicals, superoxide anions, and photogenerated holes as the primary active species. The reusability was study over three cycle was done, the efficiency decreased to about 30% on cycle 3. This study demonstrates the potential of ZnO-based photocatalysts for sustainable wastewater treatment applications and contributes to circular economy strategies through the valorisation of industrial by-products such as fly ash and biochar.

Potentials Of Biomass Derived Coal As A Substitute For Fossil Coal

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The escalating climate crisis and finite fossil fuel reserves necessitate sustainable energy alternatives. This research investigates biomass-derived biocoal produced through slow pyrolysis as a substitute for fossil coal. Three biomass feedstocks (softwood, hardwood, and sugarcane bagasse) were pyrolysed at temperatures of 400°C, 500°C, and 600°C with varying particle sizes (100-300 µm, 300-500 µm, and 500-1000 µm). Strategic 50/50 feedstock blending was employed to optimise fuel properties.

Results demonstrated that pyrolysis temperature significantly influenced biochar quality, with 600°C producing biochar containing 75-85% fixed carbon and heating values of 27-29 MJ/kg, approaching bituminous coal. The sugarcane bagasse-hardwood blend showed promising characteristics for co-firing applications with low Base-to-Acid ratios (0.11-0.21) and minimal operational risks.

Thermogravimetric analysis revealed superior combustion characteristics compared to bituminous coal, with ignition temperatures of 296-375°C versus 420°C for coal, and combustion index values 2-4 times higher. Techno-economic analysis showed that energy-efficient biochar kilns reduced capital costs by 77% and operating costs by 67%. The optimised scenario processing 2 tons/hour achieved positive cash flow with a 2.4-year break-even period at R3,655 per ton selling price.

This research demonstrates that biomass-derived biocoal represents a technically feasible and economically viable alternative to fossil coal, offering sustainable energy production whilst addressing climate imperatives and agricultural waste valorisation.

Saccharification Of Plant Biomass Utilizing Nano-Coupled B-Glucosidase From Thermoanaerobacterium Thermosaccharolyticum For Low Cost Bioethanol Production

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Nowadays there is an increased demand of an alternative energy sources for transportations and industries. Thermostable cellulases are being used for the saccharification of cellulosic material for biofuel production. Our work is unique as novel thermophilic strain Thermoanaerobacterium thermosaccharolyticum is used for cloning of β-glucosidase gene to produce biofuel using PCR, pET-21a(+) vector and E. coli as expression vector. β-glucosidase enzyme obtained was purified using precipitation by ammonium sulphate and affinity chromatography using immobilized metal ion and analysed using agaose gel and SDS-PAGE, enzyme assays, scanning electron microscopy, saccharification and immobilization. A 2.74 fold purification of the enzyme with specific activity of 31.87 U mg-1, 29.42% recovery and 75 kDa molecular weight was obtained. The enzyme showed stability upto 80°C and between pH 4-9. Increased activity of the enzyme was noted in the manifestation of Ca+2,and Mg+2 and was activity was significantly affected by EDTA. Maximum saccharification percentage (18.4%) was observed with sugarcane baggase pre-treated and analysed by scanning electron microscopy, using 25 units of enzyme at 56°C after 72 h of incubation. Better saccharification and reusability was determined after enzyme immobilization with magnetic nanoparticles. Saccharification process was repeated 13 times with immobilized β-glucosidase to achieve atleast 50% enzymatic activity. A yeast strain, Wickerhamomyces anomalus, was used for maximum bioethanol production (3.18±0.05 g/L). The results suggest that recombinant β-glucosidase is the efficient candidate for the biofuel production. The repeated saccharification process using immobilized β-glucosidase can facilitate in significantly reduction of the cost of the biofuel production.

Simultaneous Removal Of Cu2+ And Pb2+ Ions By Unmodified Apple Pomace: Isotherms, Kinetics And Implications For Scale-Up

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Climate change has resulted in declining and erratic patterns of rainfall in recent years, while the widespread pollution of water by heavy metals has further exacerbated the global water crisis. Cu2+ and Pb2+ ions are among the heavy metals that pose a significant threat to aquatic organisms and human beings that drink contaminated water or consume aquatic organisms that have absorbed these heavy metals. This study focuses on the assessment of the simultaneous removal of Cu2+ and Pb2+ from wastewater using apple pomace. Apple pomace, a largely underutilised by-product of apple juice production, is often discarded through landfilling or incineration. Isotherm studies were conducted for the binary solute, with one metal fixed at 50mg/L and the other varying from 5 to 50mg/L to characterise equilibrium adsorption and determine adsorption mechanisms. The Langmuir isotherm model provided the best fit for all the scenarios, with R2 values of 0.9097 and 0.8607 for Cu2+ and Pb2+ respectively. Furthermore, the adsorption kinetics were performed under equimolar conditions (50 mg/L) and analysed using non-linear pseudo-first-order, pseudo-second-order, Elovich, and intra-particle diffusion kinetic models. Elovich model provided the best fit for both metal with R2 values of 0.96 and 0.8806 for Cu2+ and Pb2+ respectively. The Pb2+ ion demonstrated a greater selectivity over Cu2+, resulting in a 53% reduction in Cu2+ uptake

compared to a 34% reduction in Pb2+ uptake. The findings underscore apple pomace as a potential adsorbent for simultaneous removal of Cu2+ and Pb2+, with significant potential for scale-up in wastewater treatment applications.

Solar Driven Pyrolysis Of Biomass For Biofuel Production: An Experimental Investigation

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This study investigates the pyrolysis of biomass using solar energy as a renewable and sustainable approach for biofuel production. With the rapid increase in global energy demand and the progressive depletion of fossil fuel reserves, bioenergy has gained recognition as a viable short- to medium-term alternative, offering considerable potential to mitigate greenhouse gas (GHG) emissions. Among the available conversion pathways, thermochemical conversion is regarded as the most efficient route for the transformation of biomass into biofuels. In the present work, an experimental study was conducted

using a solar-powered pyrolysis reactor to thermochemically convert biomass under varying operating conditions. The process was carried out within a temperature range of 250–500 °C. Slow pyrolysis was employed to evaluate product distribution, and the effect of different catalysts on bio-oil yield and quality was systematically investigated. The pyrolysis process produced three primary products: bio-oil, biochar, and syngas. Under slow pyrolysis conditions, approximately 25% bio-oil and 45% biochar were obtained. The catalytic experiments demonstrated that the use of catalysts significantly improved both the yield and quality of the bio-oil. The optimum condition was identified at 500 °C, which yielded the maximum bio-oil output. The results highlight the potential of solar-driven biomass pyrolysis as a sustainable method for biofuel production. Integrating solar energy into pyrolysis not only enhances process efficiency but also contributes to reducing reliance on fossil fuels and mitigating GHG emissions.

Spatial Optimisation Of Sorghum Residue And Plastic Waste Supply Chains For Circular Biorefineries: A Case Study Of Zimbabwe

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The sustainable valorisation of agricultural residues and plastic waste presents a promising strategy for advancing circular bioeconomy transitions in Sub-Saharan Africa. This study investigates the spatial optimisation of multi-feedstock supply chains for integrated circular biorefineries in Sub-Saharan Africa, using Zimbabwe as a case study. Sorghum harvesting residues and plastic waste are analysed as representative feedstocks to demonstrate scalable approaches to resource integration and logistics planning. Zimbabwe produces approximately 5.5 million tonnes of sorghum residue annually, while generating an estimated 342,000 tonnes of plastic waste per year. These resources remain largely underutilised despite their high potential for conversion into value-added bioproducts. Using Geographic Information Systems (GIS), the study aims to map spatial variability in feedstock generation, identify optimal biorefinery siting zones, and evaluate transport distance, cost, and emission trade-offs under different aggregation scenarios. The modelling integrates spatial datasets on sorghum cultivation, road networks and waste generation rates to construct a multi-feedstock supply framework. The study aims to unravel region-specific feedstock clusters that minimise logistics costs while maximising year-round biorefinery utilisation. The findings will contribute to developing data-driven decision-support tools for sustainable biorefinery planning, highlighting how spatial integration of agricultural and plastic waste streams enhances resource circularity, reduces supply-chain vulnerabilities and supports the deployment of value-added product production systems in resource-constrained regions. Ultimately, this work could provide a replicable modelling framework for designing resilient, circular bioeconomy pathways across Sub-Saharan Africa.

Effect Of Microbial Activity On Jarosite Properties: A Sustainable Bioleaching Of Mineral Sulfide

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Low-grade sulfide minerals, such as chalcopyrite and pyrite, represent untapped resources for metal extraction amid depleting high-grade ores. Bioleaching, a sustainable microbial process, offers a relatively eco-friendly alternative to energy-intensive methods but generates tons of jarosite precipitates annually, which are often dumped in landfills. These precipitates occlude valuable metals during leaching, reducing recovery efficiency and posing environmental risks through potential seepage of occluded metals into soils and water systems. This study investigates the influence of microbial activity on the surface properties of jarosite precipitates that makes for metal sorption, a critical factor for optimizing maximum metal recovery and minimizing waste. Bio-and chemical leaching of pyrite was conducted at pH 1.9–2.4 under controlled redox conditions using mixed mesophilic cultures. Jarosite precipitates were characterized for phase, morphology, surface area, pore structure, functional groups, thermal stability, and point of zero charge (PZC). Biogenic jarosites exhibited K-jarosite dominance, smaller crystallites (22–27 nm), rose-flower aggregates with cauliflower-like particles, higher surface areas (mesoporous), and lower PZC compared to chemical Na-jarosite composed of cubic crystals. This microbial modification (likely via extracellular polymeric substances) increased reactivity and negative surface charge, which may be responsible metal entrapment during leaching. The findings from this study may provide a fundamental understanding of microbial contributions to the sorptive capacity, mechanisms of jarosite precipitates, and other underlying phenomena that govern metal occlusion. This knowledge could inform strategies to optimize bioleaching, minimize waste generation, and enhance the design and management of biohydrometallurgical processes. Ultimately, it supports sustainable bioprocesses for mining-waste valorization.

Energy Integration And Process Optimisation Of Hydrothermal Treatment-Anaerobic Digestion Systems For Sustainable Sludge Valorisation

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Hydrothermal treatment (HT) energy intensity is one of the primary obstacles to high-scale adoption in wastewater treatment plants , although it is known to have significant benefits in the improvement of sludge biodegradability and the recovery of nutrients. This study explores how heat recovery networks, process optimisation and mass-energy balancing can be incorporated into an HT-Anaerobic digestion systems that treat waste-activated sludge in a scaled-up operation. The system ran at an optimum temperature of 220°C and operation time of 20 minutes, where bench-scale experimental data were used to model the system to determine how the efficiency of the heat exchanger, reuse of the hydrochar, and hydrodynamics of the reactor affected the net energy output. Findings suggest that proper thermal contact between HT and AD could recover between 44-53 % of input heat, which compensates the operation cost and lowers the net specific energy demand by 0.8 kWh/kg-VS treated. Process simulation also indicated that the concentration of sludge feed and hydraulic retention time optimisation increase the yield of biomethane and decrease CO2-equivalent. Comparison of the scenario analysis of direct combustion of hydrochar and its re-utilisation as a co-substrate in AD showed that the latter yields a better circularity and lower carbon footprint. The paper highlights that both integrated energy management and thermal recovery design are critical to the commercial scalability of HT-AD systems. These results are a decision framework to

convert WWTPs into energy-producing biorefineries instead of energy-consuming biorefineries, in line with the UN SDGs on clean water, affordable clean energy.

Energy Recovery And Techno-Economic Analysis Of Hydrothermal Carbonization And Anaerobic Digestion Of Food

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The sustainable valorization of food waste is crucial for achieving the goals of circular bioeconomy and lowering the environmental costs associated with organic waste disposal. This study presents an integrated approach that combines hydrothermal carbonization (HTC) and anaerobic digestion (AD) of food waste to recover sustainable bioenergy and valuable resources. To assess the impact of feed moisture (60-85%) and HTC temperature (180-280 °C) on process performance, the combined process was simulated in Aspen Plus using thermochemical and biochemical reaction models. Results indicated that HTC-AD integration boosts overall energy recovery efficiency by 26-38% compared to standalone AD with a feed moisture content (85%), organic loading rate (4 kg^{-1} VSm3d), mesophilic and thermophilic temperatures of 35 and 55 °C, respectively. This gain is due to increased methane yield (0.42 m^3 CH_4 kg^{-1} VS) from HTC-derived liquor and energy-rich hydrochar (25–29 MJ kg^{-1}). A techno-economic analysis revealed a net energy ratio (NER) of 2.3, an internal rate of return (IRR) of 18.6%, and a payback period of 4.8 years, confirming the process's economic viability. Sensitivity analysis identified energy price and feedstock cost as key economic drivers, while the Monte Carlo simulation demonstrated the system's robustness under ± 10% uncertainty. HTC temperature (220 °C), moisture (65%), and solid loading (100 kg/h) also significantly influenced profitability and carbon efficiency. Overall, this integrated HTC-AD process offers a technically, economically, and environmentally sustainable pathway for converting food waste into renewable energy and biochar, advancing the circular bioeconomy and net-zero energy objectives.

Energy System Application Of A Constraint Hybridization Optimization Algorithm For Optimal Sizing Of A Hybrid Renewables Storage

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In this study, a novel constraint Particle Swarm Optimization-Grey wolf Optimization (PSO-GWO) algorithm was developed. The algorithm was applied to optimize the hybrid PV/wind/battery/diesel generating systematic powering for a residential house in a Yobe state Nigerian considering coordinate (12.1871o N, 11.7068o E). Load demand, PV and Profiles for Winds and the aforementioned location were used to develop the hybrid system, using Rule base Energy Management System (REMS) PSO/GWO algorithm. The simulation was carried out on PV/Wind/Battery/Diesel generator. The Levelized Cost of Energy (LCOE) and system capital cost obtained from REMS-PSO-GWO yields a better result as it offers the minimum objective function of $0.22326/kWh, followed by REMS-GOA with $0.3656/kWh, REMS-CSA with 0.3662 and REMS-PSO with $0.3674/kWh. Nevertheless, the REMS-PSO-GWO convergence period in the minimum condition is 10s and better than the REMS-GOA and REMS-CSA, which 17s and 25s. The REMS-PSO converges to the minimum condition at 7s because PSO is prone to premature convergences. In terms of percentage improvement, the hybrid PSO-GWO performed better than REMS-GOA, REMS-CSA and REMS-PSO by 63.76%, 64.024% and 63.35% on COE respectively. In the case of system capital cost, the PSO-GWO had similar performance with REMS-GOA, REMS-CSA and REMS-PSO by 4.45%, 17.87% and 22.87% respectively in terms of system capital cost. The result of REMS-PSO-GWO shows significant reduction in COE and system capital cost as compared to the REMS-GOA, REMS-CSA and REMS-PSO.

Enhanced Heavy Metal Adsorption Performance Of Corncob And Bagasse Derived Biochars

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Pollution caused by toxic heavy metals from various anthropogenic activities poses a serious threat to the environment due to their non-biodegradable nature and tendency to bioaccumulate in living organisms. Biochar derived from agricultural waste has emerged as a promising, eco-friendly adsorbent for removing heavy metals from wastewater. This review highlights the performance of biochar produced from corncob and sugarcane bagasse for the remediation of heavy metals, including lead, copper, cadmium, chromium, and zinc, from wastewater. The effects of different pyrolysis methods and operating conditions on biochar properties are discussed. Biochar produced from corncob and sugarcane bagasse through pyrolysis has surface areas of up to 520 m^2/g for corncob and 698 m^2/g for sugarcane bagasse at temperatures ranging from 350 to 600°C. The optimal adsorption efficiencies ranged from 74–97% for corncob and to a maximum of 81% for sugarcane bagasse under varying conditions. Adsorption performance further improves with chemical or physical modification of the biochar. This review also explores the underlying adsorption mechanisms, including ion exchange, electrostatic attraction, surface complexation, and pore filling, as well as the regeneration and reusability of biochar to evaluate its long-term applicability. Key knowledge gaps and future research directions are identified to enhance the absorption performance. Generally, biochar derived from corncob and sugarcane bagasse demonstrates considerable potential as a low-cost, sustainable, and efficient materials for heavy metal removal, contributing to the achievement of Sustainable Development Goals 6, 11, and 12.

Enhancing Biogas Production From Poultry Waste: Comparative Co-Digestion With Cow Rumen And Grass For Farm-Scale Energy Recovery

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The poultry industry in Nigeria generates substantial waste, posing environmental and health challenges if not managed sustainably. Anaerobic digestion (AD) offers a solution by converting this waste into biogas, a renewable energy source. However, poultry dung (PD) alone has a suboptimal carbon-to-nitrogen (C/N) ratio (~19.77), which can limit biogas yield due to potential ammonia inhibition. This study investigated the enhancement of biogas production through the co-digestion of PD with carbon-rich substrates: cow rumen (RM) and grass (GR). PD was co-digested with RM and GR at various ratios in batch digesters under mesophilic conditions over a 28-day hydraulic retention time. Results demonstrated that co-digestion significantly improved biogas production compared to mono-digestion. The PD:RM (3:1) blend yielded the highest cumulative biogas volume of approximately 16.5 L, attributed to an optimised C/N ratio and the introduction of robust microbial consortia from the rumen. In contrast, PD:GR mixtures produced lower volumes, with the 4:1 ratio being the least effective.

Temperature and pH remained within optimal ranges for methanogenesis throughout the process. A predictive model was developed, revealing a strong exponential relationship between temperature and biogas yield. This study concludes that co-digesting PD with RM at a 3:1 ratio is a highly effective strategy for maximising biogas production, offering a viable pathway for waste-to-energy conversion and enhancing circular economy practices on poultry farms.

Estimated Potential For Green Ammonia Production In The State Of Minas Gerais From Sugarcane Biomass And Floating Solar Plants

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Brazil is among the world's largest agricultural producers, with approximately 24% of its Gross Domestic Product (GDP) originating from the agribusiness sector. However, the country is dependent on imported fertilizers, which accounted for approximately 85% of domestic consumption in 2023.

In this context, the state of Minas Gerais, which occupies just over 6.5% of the national territory, has favorable conditions for the production of green ammonia — a fertilizer obtained through technologies that use renewable energy sources.

This study estimates the potential for green ammonia production in Minas Gerais based on two technological routes: (i) water electrolysis, using electricity generated by floating photovoltaic solar plants installed on hydroelectric reservoirs; and (ii) biomass gasification, focusing on sugarcane residues, which account for 80% of the agricultural waste generated in the state.

By using 10% of the available area of the reservoirs, it is estimated that 60.8 TWh/year of electricity could be generated, enabling the production of 2.9 million tons of ammonia. In parallel, Minas Gerais annually produces about 84 million tons of sugarcane-derived biomass, of which 12% is currently unused. If this portion were directed toward green ammonia production, it could yield up to 4.8 million tons of this input.

In 2023, Brazil's national ammonia consumption was 3.6 million tons, indicating that the integrated use of these two routes could not only meet domestic demand but also position the country as a potential exporter of this sustainable commodity.

Evaluating A Novel Helical Screw Torrifier: A Proppaga-Based Benchmarking Of Continuous Biomass Torrefaction Technologies

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The development of efficient biomass torrefaction technologies is essential to advancing the bioeconomy. In this study, the PrOPPAGA multicriteria decision-making method was applied to benchmark a novel continuous helical screw torrifier, developed at the Federal

University of Bahia (UFBA), against four established technologies: rotary drum, cyclonic reactor, multi-plate furnace, and vibrating furnace. The helical screw torrefier developed at UFBA features multiple heating configurations, enabling both direct and indirect modes of biomass heating. Among the available methods, PrOPPAGA was adopted because of two key advantages: its capacity for the simultaneous analysis of qualitative and quantitative criteria, and its ease of implementation. The latter facilitates the rapid execution of sensitivity analyses on the weights attributed to each criterion. The assessment considered six key operational criteria: product homogeneity, by-product utilization potential, flexibility, scalability, energy source, and energy consumption. Results indicated that the helical screw torrifier ranked fourth or fifth, depending on expert evaluations of flexibility and scalability. These findings provide a strategic diagnosis, highlighting these two criteria as priority areas for improvement to strengthen the technology's competitiveness in biomass pre-treatment applications.

Evaluating De-Ashing Indices For Acid Leaching Of Corncob Biomass

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Pretreatment of lignocellulosic biomass to remove ash-forming inorganics is a critical step for improving both yield and operational stability during thermochemical conversion. This study presents a systematic comparison of de-ashing performance metrics for corncob biomass pretreated via acid leaching. The metrics evaluated were: (1) alkali and alkaline earth metal (AAEM) elimination rate (%), (2) variation in alkali index (ΔAI), (3) change in Base-to-Acid ratio (ΔB/A), and (4) demineralization efficiency (% ash). Corncob feedstocks were subjected to controlled variations of acid concentration, liquid-to-solid ratio, and leaching contact time. Subsequent analyses included ash quantification, elemental profiling (XRF), and characterization of compositional changes in the pretreated material. Initial findings demonstrate that the demineralization efficiency correlates strongly with AAEM removal, with both ΔAI and ΔB/A serving as reliable secondary indicators. However, while these indices track well with AAEM reduction, their responsiveness diminishes under extreme leaching conditions, where they exhibit reduced sensitivity to incremental changes. This highlights the consistency of these indices in capturing reductions of ash-forming elements. This benchmark study provides one of the first comparative assessments of multiple de-ashing indices applied concurrently to corncob biomass. The findings provide a valuable reference point for optimizing biomass pretreatment strategies and offer methodological guidance for selecting performance metrics. Ultimately, this work contributes to advancing thermochemical conversion research by promoting higher efficiency, scalability, and feedstock flexibility in future bioenergy and biomass upgrading processes.

Evaluating Energy And Nutrient Recovery From Onion Waste: A Simulated Biorefinery System

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Onion waste, including peels, trimmings, and unsold bulbs, which are rich in protein, carbohydrates, moisture, and sulfur compounds, is unavoidable in the agricultural value chain (farm, transport, market, and consumption). This poses a significant threat to the environment through improper landfill disposal and contributes to greenhouse gas emissions, and requires a sustainable, resource-recovery approach. In this study, a biorefinery system configured with anaerobic digestion (AD) and hydrothermal liquefaction (HTL) was simulated in Aspen Plus® version 14.0 to convert onion waste into biomethane, biocrude, biochar, and biofertilizers. Results showed that a thermophilic (55°C) AD system produced a biogas yield of 550 L kg^{-1} VS with 65 % CH_4 and an energy content of 12.5 MJ kg^{-1} VS. The upgraded biomethane exceeded 95% purity, and the offgas from the combined heat and power (CHP) produced 80% of the process heat. HTL of the solid digestate (at 280 °C, 15 MPa, for 30 min) yielded biocrude (23 wt%, HHV 34.2 MJ kg^{-1}), biochar (18 wt%), and process water (54 wt%), combined with liquid digestate, was stabilized into a biofertilizer containing 4.1 % N, 1.8 % P, and 3.5 % K. The integrated system achieved 85% energy recovery and over 90% carbon utilization. This integrated onion waste biorefinery demonstrates a circular bioeconomy model, providing

an economically and environmentally sustainable pathway for renewable energy, biofuel production, and nutrient recovery from onion waste.

Evaluating The Bioconversion Potential Of Oxidation Products From Uv/H_2O_2 Pre-Treated Coal Fines For Biogenic Methane Production

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Coal fines (CF) waste poses an environmental problem and could be used as a feedstock to produce renewable bioenergy. Previous studies have focused on the clean technology of CF bioconversion to produce methane (CH4) gas. However, coal bioconversion is limited by low biodegradability due to its complex aromatic structure. As a result, pre-treatment of (CF) using oxidizing agents such as hydrogen peroxide (H2O2) under Ultraviolet light (UV/H2O2) increases the coal bioavailability by producing free radicals that interact with the CF moieties. There is a limited comprehension of the specific contributions of these oxidation products to biogenic CH4 production. Therefore, this study aims to investigate the bioavailability of the oxidation products derived from UV/H_2O_2 pre-treated CF for biogenic methane production. The oxidation products were characterized using FTIR, SEM, TGA and TOC analyses to determine their biodegradability and compositional changes post pre-treatment. Both oxidation products, were subjected to bioconversion to investigate their bioavailability. The results demonstrated that UV/H_2O_2 oxidation significantly solubilized organic matter and enhanced the presence of oxygenated functional groups, resulting in higher CH4 production relative to untreated CF. Both oxidation products were successfully converted into CH4. However, the solid fraction produced more CH4 compared to the aqueous fraction since the pre-treatment converted the large molecules from the CF into smaller fragments which were easily biodegradable in the solid fraction. Overall, the study demonstrates that oxidative pre-treatment effectively enhances the bioavailability and bioconversion efficiency of CF, presenting a feasible approach for waste-to-energy value through biogenic CH4 generation

Evaluating The Bioconversion Potential Of Oxidation Products From Uv/H_2O_2 Pre-Treated Coal Fines For Biogenic Methane Production

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Coal fines waste presents both an environmental challenge and a potential feedstock for renewable bioenergy generation. Previous studies have focused on the clean technology of coal fines waste bioconversion to produce methane gas. However, coal bioconversion is limited by low biodegradability due to its complex aromatic and aliphatic structure. As a result, pre-treatment of the coal fines (CF) using oxidizing agents such as hydrogen peroxide (H2O2) under Ultraviolet light (UV/H2O2) increases the coal availability by producing free radicals that interact with the CF moieties. However, there is a limited comprehension of the specific contributions of these oxidation products (filtrate and residue fractions) to biogenic methane production. Therefore, this study aims to investigate the bioavailability of the oxidation products derived from UV/H_2O_2 pre-treated coal fines for biogenic methane production. The oxidation products were characterized using FTIR, SEM, TGA and TOC analyses to determine their compositional changes post pre-treatment and biodegradability. Both oxidation products, the aqueous and the solid fraction were subjected to AD to investigate the bioavailability of the oxidation products.

Evaluation Of Anaerobic Co-Digestion Of Sewage Sludge With Waste Cooking Oil And Spent Coffee Grounds

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Renewable energy processes are now key alternatives to fossil fuel reliance. Anaerobic co-digestion entails the mixing of organic wastes such as sewage sludge with co-substrates to increase biogas yield, an eco-friendly pathway to waste management and energy recovery. In this work waste cooking oil (WCO) and spent coffee grounds (SCG) as co-digestants impacts on sludge digestion with periodic biochar addition for enhanced microbial activity and stability, at temperatures (ambient, 35°C) and loadings (0.5, 1.0, 1.5 g/L) relative to controls are evaluated. Chemical oxygen demand (COD), total suspended solids (TSS), and pH were also measured to assess digestion efficiency and stability. WCO produces up to 399 mL of biogas at 35°C (1.0 g/L loading, runs 1 and 6), the lower production yields of 305 mL at 1.5 g/L (Run 4) suspected to be due to lipid overloading with consequent microbial inhibition through the accumulation of long-chain fatty acids. In contrast, SCG produces more at 1.5 g/L (416 mL, run 4) than at 1.0 g/L (205 mL and 182 mL, Runs 1 and 6) as evidence of enhanced substrate utilization from lignocellulosic material without inhibition accumulation. 30°C. These results emphasize the central role of temperature in enzymatic activity and infer differential optima—1.0 g/L for WCO to prevent inhibition, 1.5 g/L for SCG for higher carbon availability—that catalyse active optimization of co-digestion operations in waste-to-energy technology.

Evaluation Of Biofuel Blends With Diethyl Ether As Additive For Compression Ignition Engines In The Context Of Brazilian Energy Transition

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In Brazil, biofuels face multiple challenges—economic, structural, and regulatory—despite on going efforts to promote their development as a means to reduce greenhouse gas emissions and meet environmental standards, particularly those established by the current PROCONVE L8 regulation. This study investigates the performance and emission characteristics of alternative biofuel blends enhanced with diethyl ether (DEE) for use in compression ignition engines. Experimental tests were conducted using an MWM 229-4 diesel engine coupled to an engine dynamometer under partial load conditions. The tested fuel blends included B15 (15% biodiesel), HVO (hydrotreated vegetable oil), and combinations with DEE, using ultra-low sulfur diesel (S10) as the baseline. Parameters analyzed include engine performance (torque and power), energy efficiency, specific fuel consumption, and exhaust gas emissions (O_2, CO_2, CO, and NOx). The results provide both quantitative and qualitative insights into the impact of DEE-enhanced biofuel blends on engine operation and emissions. Findings suggest that these blends have the potential to reduce pollutant emissions while maintaining satisfactory engine performance, offering a promising path for the sustainable development of biofuels in Brazil. This work contributes to the advancement of cleaner combustion strategies and supports the ongoing energy transition in the transportation sector, while informing future research and public policy design.

Experimental Gasification Of Glycerol-Impregnated Eucalyptus Biomass For Hydrogen-Rich Syngas

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This study presents an experimental analysis of the gasification procedure of eucalyptus biomass impregnated with residual glycerol, aiming at the generation of hydrogen-enriched synthesis gas. The research was motivated by the growing need for renewable energy sources and the urgency of using by-products from production chains, such as industrial organic solid waste, and residual glycerol from biodiesel. The biomass was configured with different glycerol proportions and subjected to gasification in a competing reactor, operating on a semi-industrial scale (45 kWth), under controlled atmosphere. Operational variables such as temperature and equivalence ratio of the gasifying agent were evaluated. The results showed that the addition of glycerol promoted an increase in the fraction of hydrogen present in the syngas. The physicochemical characterization of the biomass revealed that the increase in the proportion of glycerol in the eucalyptus/glycerol mixture considerably increased the calorific value of the sample, reaching up to 50% increase in relation to the "in natura" biomass. This increase favored the production of hydrogen during the gasification process, as verified by chromatography applied to the identification and quantification of the components of the syngas. The present research contributes to the development of biomass thermochemical conversion technologies, proposing a promising and sustainable alternative for the generation of hydrogen from industrial waste, in line with contemporary energy transition guidelines.

Extraction Of Mannose From Spent Coffee Grounds Using Three Different Ionic Liquids For Lactic Acid Production.

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With the world looking for alternative renewable energy sources that will minimising waste production, waste disposal, seek valuable components in waste and promoting sustainability. Coffee has gained tremendous popularity over the years, it one of the most traded commodities in the world and SCGs has various high value products like caffeine, oils, fermentable sugars which are used in pharmaceutical and biofuel production. In this study fermentable sugars particularly, mannose was extracted from SCGs to be used as feedstock for lactic acid fermentation. A parr reactor purged with nitrogen gas in the presence of 1-ally-3-methylimidazolium chloride, 1-ethyl-3-limidazoluim acetate and 1-butyl-3-limidazolium chloride were used to extract fermentable sugars from SCGs. With the use of 96% ethanol as an antisolvent, the hydrolysate underwent filtration for solid-liquid separation, vacuum distillation and dilution prior injection into the high performanceliquid chromactography (HPLC). In-order to improve solvent performance, extraction conditions were optimised using a statical method namely response surface methodology (RSM). The extraction conditions were optimised as follows; temperature 165.6°C, time 15 minutes and 15 mL solvent/g SCGs. Extraction of mannose within optimised conditions using AMIMCL (0,5759 cg/g SCG), BMIMCL (0,5402 g/g SCG) and EMIMOAc (0,1072 g/g SCG). 1-Ally-3-methylimidazcolium chloride was the most performing solvent, extracting the highest yield of mannose as compared to 1-butyl-3-methylimidazolium chloride and 1-ethyl-3-methylimidazolium acetate. The mannose monosaccharides extracted could be utilised in further studies as the carbon source for Lactobacillus cultivation in the production process of lactic acid.

Fe-Doped Mesoporous Zsm-5 For Upgrading Bioethanol Into High-Calorific Sustainable Aviation Fuel (Saf)

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The global reliance on fossil fuels continues to drive greenhouse gas emissions, prompting the urgent pursuit of sustainable energy alternatives. Among these, low molecular weight alcohols such as bioethanol have emerged as promising candidates for renewable fuel and chemical feedstock applications. However, bioethanol's limited compatibility with modern automotive engines necessitates its catalytic transformation into fuel-range hydrocarbons. This study investigates the performance and calorific efficiency of a hydrothermally synthesised, tunable mesoporous ZSM-5 zeolite catalyst doped with iron (Fe) at 0.5 and 5 wt.%. The catalytic upgrading of ethanol was conducted in a fixed-bed reactor at 400 °C under a weight hourly space velocity (WHSV) of 12 h^{-1}. Comprehensive physicochemical characterisation of the catalysts was performed using XRD, FT-IR, SEM, EDS, XRF, PSD, BET, and NH_3-TPD techniques. Hydrocarbon product profiles were analysed using gas chromatography, while the low heating values were determined via bomb calorimetry. Results demonstrated that Fe-doped HZSM-5 catalysts significantly enhanced ethanol conversion, achieving over 97% efficiency across all samples. Notably, the 0.5 wt.% Fe variant exhibited superior hydrocarbon selectivity, broader product distribution within the SAF hydrocarbon range, and a higher calorific value (43.2 MJ/kg) compared to the 5 wt.% Fe catalyst (41.5 MJ/kg). These findings underscore the viability of tailored zeolite-based catalysts for the efficient conversion of bioethanol into aviation-grade fuel, offering a scalable pathway toward decarbonized energy systems.

Forecasting The Demand For Sustainable Maritime Fuel At Key South African Ports.

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In its 2023 IMO GHG Strategy, the International Maritime Organisation adopted a net-zero target for international shipping by 2050, with a further goal of 5% to 10% of the energy used in international shipping to come from zero or near-zero (ZNZ) sources by 2030. ZNZ fuels include biofuels and green hydrogen-based e-fuels. Historical port call data at eight commercial South African ports was analysed, to assess the potential future demand for ZNZ fuels for the South African Department of Transport and potential ZNZ fuel suppliers.

Port call data was grouped according to vessel classes assumed most likely to detransition to ZNZ fuels. It was then assumed that during each port call, each vessel takes on board the fuel required for the voyage to the next port (listed in its port call data entry). This amount was quantified by determining the distance to the next port, and the fuel consumption per vessel. The latter was determined from the ship engine power, estimated using a correlation based on vessel size, type, geometry and speed.

Forecasting the fuel consumption for each vessel type at each port involved running the processed data through a Long-Short term model which determines a predictive scheme through learning the patterns from historical data; trend analysis demonstrated which vessel classes are most active at the ports and as such which are most fuel consumers. For the analysis, biofuels were used as the potential ZNZ fuel for transition.

From Waste To Sensing: Biodegradable Electrodes From Rice Starch With Green-Synthesized Cqd/Nio For Non-Invasive Glucose Detection

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Diabetes mellitus necessitates frequent glucose monitoring, but current methods are often invasive or generate non-biodegradable waste. This study reports the development of a novel, eco-friendly, non-enzymatic glucose sensor utilising a biodegradable electrode fabricated from waste-derived rice starch, chitosan, and PVA, functionalized with green-synthesized carbon quantum dot/nickel oxide (CQD/NiO) nanocomposite. The CQD/NiO was synthesized using Aloe arborescens extract as a reducing and capping agent, resulting in materials with enhanced electrocatalytic properties, as evidenced by a significantly reduced charge transfer resistance (Rct of ~33 Ω for CQD/NiO vs. ~3.67 kΩ for NiO on FTO). The biodegradable rice starch substrate exhibited favourable mechanical flexibility, controlled swelling, and excellent biodegradability. The integrated carbon quantum dot/nickel oxide biodegradable sensor (CQD/NiO/BS) demonstrated effective electrocatalytic activity towards glucose oxidation. Cyclic voltammetry for the biodegradable seonsor revealed a linear glucose detection range of 0 - 40 µM (0 -0.04 mM) with a sensitivity of 21 µA cm-2 mM-1 and a limit of detection (LOD) of 0.29 µM and good selectivity against common interferents, demonstrating a promising operational stability. Crucially, it showed excellent recovery, 99-105.2% for glucose detection in spiked artificial sweat samples. This work presents a sustainable "waste-to-sensing" approach, offering a promising pathway towards developing cost-effective, biodegradable, and non-invasive glucose monitoring systems.

Green And Facile Synthesis Of Santa Barbara Amorphous – 15 (Sba-15) From Biomass-Derived Silica For The Conversion Of Waste Oil To Biodiesel

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The reliance on fossil fuels continues to exacerbate environmental degradation, emphasising the urgent need for sustainable alternatives. This study explores a green route for the synthesis of Santa Barbara Amorphous-15 (SBA-15) mesoporous silica using sugarcane bagasse ash (SCBA) as a renewable silica source. The work introduces environmentally benign pretreatments employing hydrochloric acid (HCl), citric acid (CA), and L-cysteine hydrochloride monohydrate (L-cys) to replace conventional harsh reagents. A one-pot synthesis route using L-cys and tetrapropylammonium hydroxide (TPAH) was also developed to enhance structural integrity and sustainability. The catalysts (HCl-SBA-15, CA-SBA-15, L-cys-SBA-15, and OP-SBA-15) were characterised by FTIR, XRD, SEM, TEM, TGA, and BET, confirming the successful formation of ordered mesostructures with high surface areas. Catalytic performance was evaluated in the transesterification of waste sunflower oil (WSO) with methanol. Among the catalysts, L-cys-SBA-15 achieved the highest biodiesel yield (≈ 5.6 %), demonstrating the viability of biogenic silica for clean-fuel synthesis. This dual valorisation of agricultural and waste-oil feedstocks highlights a circular-economy approach, converting low-value residues into functional catalysts and renewable fuels. The study provides a foundation for scaling eco-friendly catalyst design and reinforces the potential of South African biomass in advancing sustainable bioenergy technologies.

Green Extraction Of Bioactive Compounds From Biomass Using Subcritical Water And Deep Eutectic Solvents: Towards Sustainable Industrial Valorisation

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Solvent extraction using organic solvents is a common recovery method for extraction of valuable compounds from natural products, industrial by-products, and waste. While they have high dissolving power, organic solvents have many disadvantages, including environmental hazards, health and safety risks, potential degradation of target compounds, and economic and operational inefficiencies. Deep eutectic solvents (DES) provide an alternative. They are made by combining Lewis or Brønsted-Lowry acids and bases that form eutectic mixtures. By carefully selecting the components, DES can be biodegradable, safe, and tailored for high selectivity. This work compared extracts of Leonotis leonurus obtained using traditional and greener solvents and methods. Extracts obtained using water, DES, and subcritical water in combination with supercritical CO2 at varying temperatures and pressures were compared with those obtained using hexane, methanol, ethanol, and ethyl acetate, via maceration and Soxhlet extraction. FTIR, HPLC and TPC, TFC and DPPH antioxidant activity assays revealed substantial differences in the profiles and yields. Principal component analysis revealed that the extracts obtained using DES showed high selectivity in favour of specific classes of compounds. The findings highlight opportunities for process innovation aimed at optimising industrial-scale extraction, based on these alternative process routes, and the quality of products obtainable. The product quality and conceptual process differences are discussed with respect to the synthesis of industrial-scale processes. Practical distinctions between subcritical water and DES extraction methods versus traditional techniques are also discussed. This study advances the understanding of applying DES, subcritical water, and supercritical solvent extraction for the valorisation of biomass.

Green H_2 Production From Water And Scrap Aluminium Alloys

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The global push for decarbonisation necessitates innovative and sustainable green hydrogen production methods. This study presents a circular economy solution by generating hydrogen from scrap aluminium via alkaline hydrolysis. Through systematic investigation, the relationship between particle size range (150–425µm), alkali type/concentration (NaOH/KOH, 1.0–3.0 M), and alloy grade (1050 vs 6082) was established. Results showed that the <150 µm particle size range resulted in the highest cumulative amount of hydrogen produced, with Alloy 6082 in 3.0 M NaOH achieving its peak of 6150 mL H_2 per gram Al. A critical finding is a definitive alloy-alkali synergy: Alloy 6082 performs best in NaOH, while Alloy 1050 excels in KOH, governed by the alkali's ability to disrupt specific passivation layers. Analysis via SEM and EDS confirmed that surface morphology and elemental composition, respectively, dictates reactivity, with the higher-purity Alloy 1050 delivering a more consistent performance. The hydrogen generated in this study is classified as green, validated by the partial use of on-site solar energy to power the experimental reactions. Techno-economic analysis confirms the viability of a scaled, continuous process, demonstrating competitive production costs. This work establishes a practical waste valorisation approach for decentralised hydrogen production, directly contributing to sustainable development goals for clean energy, responsible consumption, and climate action.

Green Synthesis Of Crystalline Silicon Nanoparticles (Sinps) Extracted From Sugarcane Bagasse Ash (Scba)

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Silicon nanoparticles (SiNPs) have gained attention in recent years due to their range of applications and specific properties, including high surface area, size control, and high functionality. However, producing high-purity SiNPs necessitates high energy production, in addition to addressing the significant pollutants and CO2 emissions generated throughout the process. The cost of SiNPs has delayed commercial utilization; thus, there has been an acceleration in research to find alternative sources. Additionally, there has been an increase in research on extracting SiNPs from various agricultural wastes as a cost-effective source. The sugarcane production process generates a huge amount of bagasse, an agricultural waste by-product from the sugar and bioethanol industries, which may constitute an environmental hazard if not properly managed. Due to sugarcane bagasse being a natural source of silica, this study produced SiNPs as an alternate purpose for this waste. This study investigates the extraction of SiNPs from sugarcane bagasse ash (SCBA). To study the extracted silicon, XRD, XRF, SEM/EDS, TEM, Raman and BET were used to identify its composition, morphology, crystalline phases, and porosity. Additionally, this study includes the use of a green-sustainable synthesis method to decrease energy usage and replace toxic counterparts utilized in current research while obtaining high-purity SiNPs. Silicon extracted from sugarcane bagasse are an excellent candidate for applications in a variety of new technological advancements, such as nanoelectronics, energy production, and storage devices, which contribute towards the UN's sustainable development goals, particularly SDG 7 (Affordable and clean energy) and SDG 13 (Climate Action).

Hydrogen Production Through Biomass Gasification In Bubbling Fluidized Beds: A Meta-Review Of Key Parameters And Performance Data

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Biomass gasification is a promising pathway for sustainable hydrogen production, but the vast and varied results in the report on hydrogen composition in syngas from the literature hinder process optimization. This study addresses this through a rigorous meta-review, applying a statistical framework to a dataset of 257 unique points from studies on bubbling fluidized bed gasifiers. The study quantitatively synthesizes the complex, multi-dimensional parameter space, moving beyond qualitative summaries. Using k-means clustering, heterogeneous feedstocks were classified into distinct biomass categories based on their elemental ratios. Analysis of Covariance (ANCOVA), Response Surface Methodology (RSM), and Random Forest algorithms were employed to model variable effects, identify optimal conditions, and rank their relative importance. Results show steam is the superior gasifying agent. Sensitivity analysis revealed that catalyst category is the most influential variable (importance score = 0.58), followed by temperature and

steam-to-biomass ratio. The models identified optimal conditions, predicting an average hydrogen concentration of 71% for a biomass category with H/C and O/C range of 1.23-1.52 and 0.52-0.75, respectively, using a metal catalyst with CaO. These findings highlight the pivotal role of catalyst selection, particularly in sorption-enhanced reforming systems, for maximizing hydrogen yield and advancing efficient biomass-to-hydrogen conversion.

Hydrogen-Rich Syngas Production From Biomass Steam Gasification By Biochar-Based Catalysts

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Thermochemical conversion technologies, such as pyrolysis and gasification, offer a promising route for producing hydrogen-rich syngas from biomass. However, the gasification process often faces challenges such as suboptimal product selectivity, excessive tar formation, and low hydrogen content in the syngas. This study aims to develop a two-stage biomass gasification process, that is, biomass gasified in the first stage for the maximum primary volatiles and then catalytic reformed in the second stage for the tar elimination and meanwhile for hydrogen-rich syngas. Pyrolyzed char was found to be a promising catalyst due to its abundant oxygen-containing functional groups and hierarchical porous structure. Besides, for industrial operation, hot char from the first stage could be directly converted to the second stage and served as the catalytic bed for volatiles steam reforming. Also, the spent char with low-reactivity could be continuously replaced via the nascent char and recovered via combustion for energy and the recycled catalytic metal oxides. A two-stage fixed-bed reactor was employed to evaluate the performance of various biochar-based catalysts. The physicochemical properties of biochar were systematically tailored by adjusting preparation parameters. Biochar prepared under an oxygen atmosphere at 800 ℃ resulted in a hydrogen concentration of 55.26 vol.% and a hydrogen yield of 24.03 mmol/gbiomass. Furthermore, loading biochar with 10 wt.% Ni and 2.5 wt.% K significantly enhanced hydrogen production, achieving a yield of 46.48 mmol/gbiomass. This work provides fundamental insights for the rational design of efficient biochar-based catalysts to improve hydrogen yield and reduce tar byproducts in biomass gasification.

Impact Of Alcohol-Based Biofuels On Diesel Engine Emissions Under Wltc Driving Conditions

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The transition to a cleaner energy matrix requires the assessment of renewable alternatives to fossil fuels, such as alcohol-based biofuels, which can be produced from different sustainable processes and raw materials, including agricultural and industrial waste. Each bioalcohol has distinct physical properties, such as cetane number, oxygen content, and enthalpy of vaporization, which impart unique characteristics to blends. In this study, different alcohols have been blended with diesel fuel and have been evaluated in a CI engine operating under the WLTC Cycle. The results showed that all blends

significantly reduced particle mass and carbon monoxide emissions compared to diesel fuel (D100), with drops of up to 58.7% in PM and 44.7% in CO. This positive effect is associated with the oxygen content of the alcohols, which favored a more complete combustion. However, the combination of a lower cetane number and oxygen contributed to increasing nitrogen oxide emissions by up to 25.6% for the blends. Unburned hydrocarbon emissions were more sensitive to vaporization behavior: short-chain alcohols with high enthalpy of vaporization caused a drop in the in-cylinder temperature and a significant increase in HC, reaching +211.8% in the case of blends between diesel fuel and 15% of ethanol. However, long-chain alcohols showed more moderate increases, such as +7.4% for D80OC20, thanks to the less significant cooling effect. It has been concluded that the use of alcohol-diesel blends in diesel engines has real potential for mitigating critical pollutants, but requires optimization of engine parameters to maximize environmental gains without compromising performance.

A State Of The Art Review On Catalytic Hydrotreating Of Biomass-Derived Oils: Pathways, Catalysts, And Commercialization Hurdles

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Hydrothermal liquefaction (HTL) is an emerging technology for transforming wet biomass into energy-dense biocrude, offering a sustainable pathway for advanced biofuels. Nevertheless, raw biocrude possesses high oxygen and nitrogen content, thermal instability, and elevated viscosity, precluding its immediate application in refineries. This review evaluates the current status and future prospects of catalytic hydrotreating as the foremost upgrading route to produce drop-in synthetic crude oil. An in-depth bibliometric analysis, utilizing specialized software, reveals research trends connecting biocrude production capacity to upgrading methods and their impact on process costs. Key process parameters—temperature (350–420 °C), hydrogen pressure (50–200 bar), and catalyst selection—are critically assessed, highlighting robust nickel-based catalysts as emerging alternatives to traditional CoMo and NiMo, which suffer rapid deactivation in oxygen-rich environments. This interconnected analysis underscores three principal challenges: fast catalyst deactivation caused by coking and poisoning, elevated hydrogen consumption affecting both economic and environmental sustainability, and severe operating conditions requiring considerable capital investment. Integrating these findings, the review emphasizes the necessity for innovative, resilient catalysts and process configurations. The discussion further explores the integration of hydrotreating within circular biorefinery models, focusing on the valorization of byproducts (such as the aqueous phase) to generate renewable hydrogen.

A Combined Cooling, Heating And Power System Based On Lng Cold Energy Utilization: Static Analysis And Dynamic Optimization

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This study aims to address the challenges of seasonal load fluctuations in distributed energy systems, including those utilizing biomass energy. an integrated combined cooling, heating, and power (CCHP) system is presented, which utilizing liquefied natural gas (LNG) cold energy and solid oxide fuel cell (SOFC) technology to achieve cascade-based efficient energy utilization. A static analysis framework was developed, incorporating energy balance, exergy analysis, and economic evaluation to assess system performance and economic viability under design conditions. Subsequently, dynamic operational optimization was conducted to address challenges arising from seasonal load fluctuations. By integrating regional electricity pricing mechanisms, a co-optimization model was formulated that simultaneously considers system configuration and operational strategy. The novel system achieved an overall energy efficiency of 96.43% and an exergy efficiency of 75.36%. Based on these performance metrics, a methodological framework was established that spans from static assessment to dynamic optimization while enabling the formulation of load-adaptive peak-shaving strategies. The research offers theoretical foundations for enhancing both economic performance and operational reliability in LNG cold energy utilization systems.

A Prospective Analysis Of Nigeria'S Energy System: Bridging Energy Poverty And Environmental Goals

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This study examines Nigeria's energy system transformation from 2025 to 2060 using the LEAP (Low Emissions Analysis Platform) model. Unlike many analyses that base projections solely on fixed capacity expansion targets, it integrates both a proposed expansion plan and demand-driven capacity growth to align electricity generation with multi-sector energy use, population growth, and economic development. Three scenarios were evaluated: a Business as Usual (BAU) trajectory, a Gas Transition Economy (GTE), and an Ambitious Green Transition (AGT). The BAU scenario has the highest total emissions by 2060, at 783.4 MtCO2e, followed by GTE at 766.1 MtCO2e. In contrast, the AGT scenario, driven by large-scale electrification and renewable energy, presents the most sustainable pathway, reducing total emissions to 493.5 MtCO2e. Notably, the AGT pathway also delivers the greatest developmental benefits. Despite having the lowest final energy demand (3991.4 PJ), it achieves the highest per capita electricity access, reaching 2.86 kWh/day by 2060. This is a direct result of strategic electrification and efficiency gains that decouple human development from raw energy consumption. A key conclusion of this study is that Nigeria's path to a low-carbon, inclusive future lies in prioritizing strategic electrification and aggressive renewable energy targets, which are proven to reduce emissions while simultaneously improving energy access for its citizens.

Activated Carbon Derived From Coconut Shell For The Adsorption Of Cu2+ And Pb2+ Using Central Composite Design

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The bioremediation of pollutants in wastewater is a widely investigated research focus area with the aim of preserving and sustaining the environment. Copper and lead are poisonous, non-biodegradable heavy metals that persist in the environment which can cause severe health challenges in the human body. This study investigates the effectiveness of coconut shell-activated carbon (CSAC) as an adsorbent for the removal of copper and lead ions from wastewater in a batch mode. The effects of varying operating parameters in the adsorption process namely, initial concentration (10 – 200 mg/L), pH (2 – 12), adsorbent dosage (1 – 5 g) and particle size (75 – 300 µm) using the Response Surface Methodology (RSM) was conducted. The central composite design (CCD) technique was used to obtain the experimental runs. The adsorbent was characterised prior to and after adsorption to determine the functional groups, morphological structure and the elemental composition with the aid of Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM) and Energy Dispersive Spectroscopy (EDS) analytical instruments respectively. The EDS analysis of post-adsorbent usage revealed the presence of copper and lead. The analysis of variance (ANOVA) indicated a strong coefficient of determination (R^2) for copper and lead, measuring 0.9761 and 0.9689, respectively. The regression model and the agreement between the experimental and projected results validated the efficacy of the second-order polynomial model for the bio-sorption of copper and lead utilizing coconut shell activated carbon. This research aids in the pursuit of environmentally sustainable methods for treating water contaminated with copper and lead metal.

Advanced Valorization Of Lignocellulosic Biomass Residues Into Functional Carbon Materials For Sustainable Energy Applications

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Transition to new energy systems is a process of efficient utilization of renewable sources of carbon to substitute fossil material. The prime objective of this research is to critically evaluate the valorisation routes of lignocellulosic biomass wastes to functional carbon materials for sustainable energy applications through systematic literature review (SLR) method. SLR search and extraction of 186 peer-reviewed articles (2010–2025) were synthesized in line with PRISMA 2020 guidelines from renowned science databases like Scopus, Web of Science, and ScienceDirect. Review focus on pre-treatment approach and feedstock availability, conversion processes including hydrothermal carbonization and chemical activation, structure–property performance of the resultant carbons. Also, applications in energy storage system including redox flow batteries and supercapacitors.

Results show that fractionated and optimally activated lignin-rich residues are able to yield hierarchically porous carbons of high surface area (>1500 $m^2 g^{-1}$), conductivity, and electrochemical stability competing with commercial carbons. Feedstock compositional adjustment, process non-uniformity, and scale-up data remain significant impediments to industrial realization. This is scarcity of life-cycle and techno-economic studies in published literature, which indicates a requirement for further integrated frameworks of sustainability.

Originality of this review is the full cross-comparison of performance parameters, sustainability parameters, and biomass processing path, and development of meaningful correlations between biomass structure, processing path, and electrochemical performance. The study offers a model of decision-making for biomass residues and valorisation pathway selection to optimize material performance and environmental value thereby driving green energy technologies and circular bioeconomy.

Advancing Circularity In Coal Processing: Renewable Energy Generation From Synthetic Colliery Wastewater Via Reverse Electrodialysis

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In pursuit of enhanced sustainability, particularly through carbon-footprint reduction and increased circularity in coal-processing operations, the potential of generating renewable electricity from industrial effluents has been explored. Reverse electrodialysis (RED) was investigated as a prospective technology for harvesting salinity-gradient energy from synthetic colliery wastewater. The effects of temperature (20–40 °C), high-salinity feed concentration (1.0–2.0 mol/L NaCl), and flow rate (896–1550 mL/min) were systematically examined. Power densities ranging from 2.31 to 10.75 W/m^2 and NaCl removal efficiencies of 3.94 to 16.13 wt.% were achieved. Process optimisation using Response Surface Methodology (RSM) identified optimal operating conditions of 40 °C, 1.93 mol/L NaCl, and 896 mL/min. Because real colliery wastewater contains additional ionic species, further tests were performed using synthetic wastewater incorporating Ca^{2+} and SO_4^{2-} to evaluate potential interference effects. It was concluded that RED is a promising technology for improving energy efficiency in coal-related industries. The renewable energy generated has the potential to partially offset internal energy demands in collieries and coal-fired power stations, contributing to broader decarbonisation and circular-economy goals.

Advancing South Africa'S Renewable Energy Infrastructure And Research Through Geospatial Education: A Global Review Of Best Practices And Policy Development Strategies

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South Africa's transition to renewable energy requires the integration of advanced geospatial technologies into both infrastructure planning and educational systems. Geographic Information Systems (GIS) and Remote Sensing (RS) have demonstrated global effectiveness in renewable energy site selection, resource optimisation, and climate resilience. Yet, their application in South Africa remains limited, constrained by fragmented policy, institutional inertia, and persistent skills shortages. This study employs a Systematic Literature Review (SLR), following PRISMA protocols, to examine 143 international publications on geospatial integration in renewable energy. The analysis identifies best practices from leading contexts, including Germany's policy-driven GIS adoption, India's solar mapping initiatives, and Brazil's RS-based environmental impact assessments, illustrating the importance of legislative foresight, open-data frameworks, and targeted capacity-building. Grounded in the Energy Justice Framework, findings reveal that advancing geospatial literacy within higher education and vocational training enhances data-driven decision-making, promotes equitable access to clean energy, and accelerates project deployment. For South Africa, alignment of geospatial education with the Integrated Resource Plan offers a strategic opportunity to address current gaps. The study proposes a multi-tier roadmap focused on capacity development, cross-sectoral collaboration, and research investment to institutionalise GIS and RS in renewable energy planning. This research underscores its pivotal role in advancing sustainable and equitable energy futures across Southern Africa by positioning geospatial education as both a technical enabler and a driver of energy justice.

Aloe Arborescens-Mediated Green Synthesis Of Cuo/Cqd Nanocomposites For Microplotted Electrochemical Glucose Sensor

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Biomass-derived precursors offer an approach to synthesising nanomaterials that align with sustainable processing principles. This work utilises Aloe arborescens extract as a biomass precursor for the green synthesis of copper oxide/carbon quantum dot (CuO/CQD) nanocomposites. The use of this biomass source and the application of microplotting for fabricating green-synthesised nanomaterial-based NEG sensor electrodes have not been previously explored, establishing the novelty of this work. Structural characterisation confirmed the formation of quasi-spherical CuO nanostructures decorated with CQDs. Electrochemical characterisation of CuO and CuO/CQD films drop-cast on fluorine-doped tin oxide (FTO) substrates revealed the superior performance of the CuO/CQD/FTO platform. A transition from drop-casting to microplotting was implemented to improve film uniformity. Comparative evaluation showed that microplotting produced CuO/CQD electrodes with more application-relevant electrochemical behaviour. Accordingly, CuO/CQD ink was microplotted onto screen-printed gold electrodes (SPGEs) and evaluated for glucose detection in 0.1 M NaOH. The resulting CuO/CQD/SPGE platform exhibited a linear range of 0.9–17.1 mM, a detection limit of 0.33 mM, and sensitivities of 0.131–0.0826 mA·mM-1·cm-2. The linear range covers hypoglycemic to hyperglycemic concentrations. The CuO/CQD sensor also demonstrated excellent repeatability, reproducibility, stability, and selectivity under the influence of common interferents, chelating agents, and physiologically relevant chloride concentrations. Proof-of-concept testing in serum showed <6% deviation from a commercial glucose meter, confirming the clinical relevance of the CuO/CQD/SPGE platform. These findings show how biomass-derived nanomaterials and precision microfabrication can enable sustainable glucose sensing platforms for clinical applications.

An Integrated Hydrothermal Processing Strategy For Sweet Sorghum Bagasse To Improve Fermentable Sugar Production

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Sweet sorghum bagasse is an agro-industrial residue generated from the sorghum harvest. This residue has a high content of cellulose and hemicellulose, as well as free sugars, making it a suitable raw material for obtaining fermentable sugars through appropriate hydrolysis. This study evaluated the increase in fermentable sugar production from sweet sorghum bagasse through pressurized water extraction, steam explosion pretreatment, and sequential subcritical water hydrolysis. All processes were performed in a single experimental run and unit, without the need to transport the raw material from one equipment to another. Steam explosion was evaluated with varying reaction times of 5 and 10 min and temperatures of 150 and 200°C and 5 MPa. Subcritical water hydrolysis (SWH) was evaluated under conditions 260°C with solvent to feed-ratio 32. SWH performed in integrated processing using the best pretreatment conditions. The results showed that the steam explosion produced a pretreated solid with 50,26% cellulose. For the sequential process, the highest sugar yield was 5,051g/L, a value 1.25 times higher than that obtained for the process with only SWH.

Application Of Water Hyacinth Derived Biochar In Heavy Metal Removal From Wastewater: Effects Of Pre-Treatment On Biochar'S Adsorption Capacity

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Industrial mining releases heavy metal-contaminated wastewater, with Acid Mine Drainage (AMD) producing extremely acidic, metal-rich effluents causing severe health and environmental damage. While conventional activated carbon treatment works effectively, its high cost limits application. This research addresses three challenges simultaneously: valorizing water hyacinth (an invasive species causing ecological problems), removing heavy metals from AMD using biochar, and optimizing adsorption through sustainable steam and CO_2 activation—creating a circular waste-to-resource solution. Water hyacinth biomass underwent pyrolysis at 400°C, 500°C, and 600°C (20°C/min heating rate, 60 minutes, nitrogen atmosphere). Samples were sieved into five particle size fractions (1000-2000 µm to <100 µm). Characterization included TGA, CHN elemental analysis, FTIR (functional groups), SEM-EDS (surface morphology), and BET analysis (surface area). Biochar yield decreased with temperature—40-50% at 400°C to 35-45% at 600°C—due to enhanced volatilization. FTIR revealed essential metal-binding functional groups (O-H, C-H, C=O, aromatic C=C). SEM imaging showed progressive pore development, with pore volume increasing from 0.0143 cm^3/g (400°C) to 0.0340 cm^3/g (600°C). BET surface area improved significantly; the finest fraction achieved 13.565 m^2/g at 600°C. Higher pyrolysis temperatures and smaller particle sizes enhanced surface area and porosity while maintaining functional groups necessary for metal adsorption. Future work will implement steam and CO_2 activation, followed by column experiments evaluating Pb(II), Cu(II), and Cr(VI) removal efficiency from synthetic AMD, advancing sustainable wastewater treatment solutions.

Are We Overlooking The Potential Of Marginal Lands For Biofuel Production?

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In 2024, we co-edited a book titled "The Marginal Soils of Africa: Rethinking Uses, Management, and Reclamation." This book explores how researchers can harness the potential of marginal lands for bioenergy production, such as biofuels, without compromising food security. This concept has the potential to help ensure sufficient food supply. According to the Bioenergy Atlas for South Africa, 69% of the land consists of pastures and meadows, while 10% is designated as arable land, with the remaining land used for other purposes. The pressing question is: Can we utilize marginal lands to grow energy crops? Marginal lands can be improved to support food production while also generating fuels. The South African Department of Agriculture has advocated for the cultivation of energy crops like sorghum, sugarcane, and soya. They emphasize the importance of crop rotation and reduced irrigation to address water challenges. Some of these crops, such as sorghum, are climate-resilient and can thrive on marginal soils. Our research focuses on utilizing sorghum stalks to produce biofuels. We have explored various types of biomass for their potential in producing biofuels such as bioethanol and biogas. Collaborating with small-holder farmers in rural communities who already cultivate sorghum for income and food supply, we utilize the sorghum stalks—referred to as "2nd generation biomass"—to evaluate their potential for bioethanol production. Additionally, we investigated anaerobic digestion methods for optimizing biogas production. The overarching goal of these detailed projects is to help farmers integrate technology into their practices for effective value stream production.

Assessing Source-Separated Organics For Double-Stage Anaerobic Digestion In A South African Metro Municipality

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South African landfills receive 76% of the national municipal solid waste (MSW) generation and are rapidly filling up. Moreover, organics constitute a substantial portion of landfilled MSW due to the lack of separation at the source, contributing to the rising carbon footprint of waste management in South Africa. Double-stage anaerobic digestion (2S-AD) has been identified as a potential alternative treatment that could provide, in addition to methane and digestate, a high-value product such as hydrogen, whose demand is expected to double by 2040.

This research examined the system architecture necessary for the potential full-scale implementation of 2S-AD, beginning with a source-separation scheme investigated through a case study of the eThekwini Municipality in Durban. After evaluating the volumes and characteristics of available feedstock, the environmental benefits of 2S-AD were compared with those of the current practice of landfilling with gas extraction and flaring, as well as with alternatives such as landfilling with gas extraction and electricity generation, composting, and anaerobic digestion. While the 2S-AD scenario shows positive results (-312% in carbon emissions), conventional AD achieves an even greater reduction (-328%) in greenhouse gas emissions compared to the current situation.

The techno-economic feasibility of a 2S-AD plant emphasised its financial viability, especially when factoring in the avoided costs of landfilling. However, this system would not be cost-competitive with conventional AD plants and would depend heavily on a consistent supply of high-quality feedstock, leading to the recommendation to set aside the idea of adopting 2S-AD in eThekwini until these key issues are resolved.

Biochar Enhanced Co-Digestion With Oily Food Waste For Bio-Methane Production

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Anaerobic digestion (AD) of oily food waste (OFW) is often inhibited by the accumulation of long-chain fatty acids (LCFAs), leading to acidification and process failure. This study investigates the efficacy of a low-dose biochar amendment to mitigate inhibition and enhance methane production from OFW. A simulated OFW mixture (30% potato flour, 20% raw minced chicken, 20% leafy vegetables, 5% vegetable oil) was co-digested with anaerobic inoculum at a 0.3 inoculum/substrate ratio. Biochemical methane potential (BMP) tests were conducted in a batch reactor under mesophilic conditions (35-40°C) for a 25-day hydraulic retention time. Two conditions were tested: a control (0% biochar) and a sample amended with 1% biochar (w/w). The results show a significant positive impact of biochar. The control (i.e., 0% biochar) produced no measurable methane throughout the 19-day period, while the methane production was initiated in the biochar-amended sample on the 12th day. The pH initially declined to 3.9 by day 18, followed by a recovery to 4.6 between days 19 and 25. This pH increase correlated with the highest daily

methane yield, suggesting biochar's positive role in improving buffering capacity/facilitating microbial acclimation to acidic conditions. The study concludes that even a low biochar addition is sufficient to improve LCFA inhibition, stabilise the AD process, and enable methane generation from challenging oily food waste substrates, where digestion would otherwise fail. Future work will focus on the effect of biochar particle size, wood type, and their pyrolysis temperatures on the co-digestion characteristics.

Bioeconomy Of An Integrated Anaerobic Digestion – Hydrothermal Carbonization Of Agricultural Waste To Energy

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The integration of anaerobic digestion (AD) and hydrothermal carbonization (HTC) provides a promising approach for simultaneous energy recovery and waste valorisation within the circular bioeconomy. In this study, an integrated AD-HTC system with a capacity of 1,142 kg hr^{-1}, operated at conditions of 230 °C, 60 min, 1:10 ratio, was explored for the valorisation of crop residues into biogas and hydrochar. The process produced 48.6% hydrochar with a high heating value (HHV) of 25.4 MJ kg^{-1} and 0.68 m^3 CH_4 kg^{-1} VS compared to HTC process only. The integrated AD-HTC process decreased net greenhouse gas emission by 31.5 % and increased total energy recovery by 37.8%. Economic evaluation showed strong profitability with a net present value (NPV) of USD 2.15 million, an internal rate of return (IRR) of 21.3% and a payback period of 4.5 years. The study demonstrates the synergistic potential of integrating AD-HTC for carbon sequestration from crop residues and sustainable energy production. The results provide quantitative evidence to support policy adoption of integrated thermochemical-biochemical systems as low-carbon bioenergy solutions in future agricultural waste management frameworks.

Bio-Recovery Of Base Metals (Zn, Ni, Cu, Mn, And Mg) From Acid Mine Drainage Using Magnetic-Bioadsorbents (Magnetite, Chitosan, And Magnetite-Chitosan).

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This study investigates the systematic recovery of valuable base metals (Zn, Ni, Cu, Mn, and Mg) from acid mine drainage (AMD) using novel magnetic-bioadsorbents. Three adsorbents were synthesized and evaluated: pristine magnetite nanoparticles (Fe_3O_4), chitosan biopolymer, and a magnetite-chitosan composite. The adsorption performance was rigorously analyzed by applying both linear and nonlinear regression methods to fit various adsorption isotherms and kinetic models, aiming to identify the most accurate description of the equilibrium and rate processes. The results demonstrated that the magnetite-chitosan composite exhibited superior performance, leveraging the high surface area and magnetic properties of magnetite with the excellent chelating functionality of chitosan. High recovery efficiencies were achieved for several metals: 95% for Fe, 92% for Cu, 91% for Mn, and 80% for Mg. However, the recovery of Ni was significantly lower at 6%, suggesting a need for further optimization for this specific metal. The study confirms that the magnetic-bioadsorbents, particularly the composite, are highly effective for the selective recovery of base metals from complex wastewater like AMD, presenting a promising, sustainable, and efficient treatment strategy for environmental remediation and resource recycling.

Catalytic Co-Pyrolysis Of Microalgae And Hardwood Over Cuo/Nio/Moo3/Hzsm-5 Hybrid Catalyst

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This study presents a dual-valorization approach that integrates the catalytic co-pyrolysis of Scenedesmus sp. microalgae and hardwood for enhanced bio-oil production, as well as the reuse of catalyst-laden biochar for wastewater remediation. A CuO/NiO/MoO_3/HZSM-5 hybrid catalyst was applied in in-situ and ex-situ modes to compare effects on yields and product quality. XRD confirmed retention of the HZSM-5 crystalline structure after metal oxide loading, and TGA indicated stability up to 700 °C. FESEM–EDS revealed uniform metal dispersion with altered surface morphology. At 500 °C, hardwood and microalgae yielded 33.0 wt% and 20.2 wt% bio-oil, respectively, while non-catalytic co-pyrolysis of a 1:1 blend produced 22.1 wt%, increasing to 23.9 wt% (in-situ) and 23.5 wt% (ex-situ) with catalysis. Catalytic upgrading enhanced carbon and hydrogen contents, reduced oxygen and nitrogen, and improved the higher heating value (up to 25.27 MJ/kg in-situ), with ex-situ favoring aromatics and phenols. In-situ catalyst-loaded biochar showed a zeta potential of –21.6 mV, achieved rapid methylene blue removal (96.6%; 144.9 mg/g) within 40 min, and maintained >92% removal over five regeneration cycles. This work demonstrates an integrated route to produce high-quality bio-oil and a functional adsorbent from a single process, advancing sustainable bioenergy production and wastewater treatment within a circular bioeconomy framework.

Catalytic Hydrothermal Valorisation Of Sewage Sludge: Effects Of Operating Conditions In A Water-Ethanol Co-Solvent System

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The rapid population growth, coupled with industrialisation and migration, is responsible for the increasing levels of municipal sewage sludge. Increased sewage sludge levels and its management are a global problem. Hydrothermal liquefaction, a high-pressure and moderate thermochemical process, is a promising technique for managing sewage sludge by adding value to the sludge to produce energy-dense bio-oils. The municipal sewage sludge was subjected to hydrothermal liquefaction under thermal conditions ranging from 240°C to 320°C. Water and ethanol, in a 3:1 v/v ratio, were used as the co-solvent for the system. To determine their impact on bio-oil production and quality, catalysts, including NaOH, KOH, FeS, and a novel catalyst in the hydrothermal liquefaction of sewage sludge, Cu-Zn-Al mixed oxide, were dosed at 5%. Residence times varied from 15 to 45 min. The highest bio-oil yields were associated with 300°C when alkali catalysts, particularly NaOH, were employed. liquefaction of municipal sewage sludge under hydrothermal conditions for 30 min yielded the highest bio-oil. Prolonged residence times, low temperatures, and the omission of a catalyst were correlated with low bio-oil yields. The involvement of catalysts, particularly NaOH, at an elevated temperature of 300°C and a moderate residence time of 30 min, was a suitable recipe for enhanced bio-oil recovery.

Clean Energy Recovery From Acid Mine Drainage Via Reverse Electrodialysis

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South Africa faces a dual challenge of persistent energy shortages and water pollution arising from mining activities. Acid mine drainage (AMD) is one of the country's most severe environmental problems, characterized by highly saline and acidic effluents that threaten surface and groundwater quality. The high ionic content of AMD, however, presents an opportunity for clean energy recovery through reverse electrodialysis (RED), a process that converts salinity gradients into electrical energy.

This study investigates the feasibility of generating sustainable energy from AMD using RED technology. Laboratory-scale experiments were conducted to evaluate the effects of key operating parameters, including concentration, flow rate, and temperature, on performance metrics such as open-circuit voltage (OCV) and power density. Results indicated that both OCV and power density increased with larger salinity gradients in AMD, while excessively low flow rates hindered ion transport. Optimal flow rates reduced concentration polarization and enhanced overall system performance. Temperature exerted a modest influence, slightly improving electrochemical efficiency without compromising membrane integrity.

The findings provide valuable insights into the conversion of AMD's ionic potential into usable clean energy, offering a dual benefit of wastewater treatment and renewable power generation. This research supports the integration of RED into AMD remediation frameworks, contributing to both environmental protection and energy security in mining-affected regions.

Keywords: acid mine drainage, reverse electrodialysis, energy recovery, wastewater valorization, clean energy.

Comparative Catalytic Pyrolysis Of Wheat Straw For Enhanced Bio-Oil Production

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The catalytic pyrolysis of lignocellulosic biomass is a promising thermochemical route for the sustainable production of renewable biofuels. Egypt possesses abundant sources of biomass, e.g. rice straws and wheat husks. Effective reuse of such residues presents a viable environmental solution for waste management. In this study, wheat straw was utilized as a representative agricultural residue to investigate the effect of two different catalysts—zinc oxide (ZnO) and cement kiln dust—on bio-oil yield and quality. An Egyptian Cement Company provided kiln dust. Experiments were conducted in a bench-scale fixed-bed reactor under an inert nitrogen atmosphere at temperatures ranging from 500 °C to 600 °C. Each catalyst was tested independently at different loadings (from 0 to 7 g per 500 g of biomass) to evaluate its influence on product yield and composition. The yields of bio-oil, biochar, and non-condensable gases were measured, and the produced bio-oils were analyzed using GC–MS to determine the chemical composition. Results showed that both catalysts improved the deoxygenation of pyrolysis vapors and enhanced the production of hydrocarbons and phenolic compounds compared to non-catalytic runs. ZnO exhibited higher catalytic activity at 500 °C, while cement kiln dust performed better at 600 °C, reflecting differences in their basicity and mineral composition. An average of 29% of bio-oil yield was obtained, and for the biochar, the

yield was estimated at 38%. At 500 °C and 3 g, ZnO resulted in 102 g bio-oil and 193 g biochar; kiln dust yielded 124 g bio-oil and 183 g biochar.

Co-Pyrolysis Of Sewage Sludge And Softwood Over Cuo/Coo/Ceo2/Hzsm-5 Hybrid Catalysts

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This study investigates the catalytic co-pyrolysis of sewage sludge (SS) and softwood (SW) using CuO/CoO/CeO2/HZSM-5 hybrid catalysts synthesized via co-impregnation (CI) and sequential impregnation (SI). X-ray diffraction confirmed the successful incorporation of metal oxides while preserving the parent MFI zeolite structure. Compared with CI, the SI catalyst exhibited superior metal dispersion, higher Cu (18.9 wt%) and Co (11.8 wt%) loadings, and a more uniform surface morphology. BET analysis revealed that SI possessed a larger surface area (205.78 m^2/g) and higher pore volume (0.06 cm^3/g) than CI (187.84 m^2/g, 0.03 cm^3/g), indicating better preservation of the zeolitic textural properties. Thermogravimetric analysis further showed greater thermal stability for the SI sample. In pyrolysis experiments, SI achieved the highest feedstock conversion (66%) and gas yield (42.6 wt%), alongside reduced biochar formation (34 wt%). Conversely, CI produced bio-oil with a higher aromatic content (34.31%), dominated by phenol (20.61%). Elemental analysis showed that the non-catalytic SS–SW system yielded bio-oil with the highest carbon content (68.97 wt%) and heating value (32.29 MJ/kg), while the CI catalyst offered an optimal trade-off between heating value (28.61 MJ/kg), oxygen reduction, and hydrocarbon enrichment. These findings demonstrate that the catalyst synthesis method strongly influences phase structure, metal dispersion, and pyrolysis product distribution, providing key insights for the rational design of catalysts for efficient waste-to-biofuel conversion.

Definition Of Operating Modes For A Gasifier Power Plant Within A Hybrid Energy System

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The gasification technology, which meets the modern state of technical development, must comply with the following criteria: a) automatic operation of the unit; b) stable operation of the gasifier with minimal fluctuations in gas composition and flow rate; c) the gasifier must produce minimal amounts of liquid and solid waste; d) the conversion process must be relatively insensitive to changes in the properties of the biomass fuel—moisture content and particle size.

The technology of staged gasification most fully meets modern technical requirements.

This work presents experimental studies of the multi-stage gasification technology for wood waste, for which new technological solutions were developed. These solutions enabled the creation of a 30 kW (fuel input) gasifier prototype. The gasifier consists of three reactors: a pyrolysis reactor, a combustion reactor for pyrolysis gas and tar, and a gasification reactor. This process design allows for the production of tar-free producer gas. This fact was confirmed during an experiment using the developed gasifier. Another result of this work is the study of the operating modes of a gasifier power station that combines several energy sources (solar, biomass energy, and storage). The research is comprehensive and combines a full-scale demonstration experiment.

Funding: The work was carried out within the framework of the project of the Ministry of Science and Higher Education of the Russian Federation No. 13.2251.21.0241 (el. budget No. 075-15-2024-659).

Determination Of Residual And Equilibrium Moisture In Sanitary Sludge Subjected To Low-Temperature Thermal Drying

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The thermal drying of solids is often associated with high energy consumption and costs. Thus, it is crucial to establish drying limits to prevent energy wastage, extended drying times, and degradation of product characteristics. Furthermore, most dried materials can rehydrate just by coming into contact with moisture in the air. Therefore, selecting the final moisture content of sanitary sludge subjected to low-temperature thermal drying is a crucial operational decision. Drying below the equilibrium moisture content (EM) without proper storage can lead to rehydration from ambient air moisture, and achieving the desired final moisture level can be challenging at low drying temperatures. Given this context, this study aims to determine the residual moisture (RM) of sanitary sludge with different total solids (TS) under low-temperature convective drying, as well as the EM of dried sludge stored in plastic bags and exposed to environmental conditions. The results show that drying at temperatures of 60 to 90 °C produces sludge with RM of 2.24±0.88% to 0.52±0.20%. Based on these findings, correlations were established between the TS contents of wet sludge and drying temperature and between TS and RM. The EM experiments resulted in moisture contents of 2.53±0.09% for bagged sludge and 7.52±0.16% for sludge exposed to ambient conditions. It was noted that low-temperature thermal drying results in low residual moisture, making the sludge suitable for subsequent processes requiring strict moisture control, such as gasification. Storing sludge in plastic bags can help retain moisture below the EM, enhancing its heating value.

Development Of Low-Cost Hierarchical Bio Char Derived From Agricultural Waste As A Support Material For The Pem Fuel Cell.

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In response to the increasing environmental challenges, renewable energy sources have emerged as a

sustainable solution. Among the green energy technologies being studied, Proton Exchange Membrane

Fuel Cells (PEMFCs) stand out because of their exceptional efficiency, high energy density, and eco-friendliness. These fuel cells have applications in various sectors, including transportation, portable

power, stationary power, aerospace, and underwater; however, their commercialization is hindered by

their high cost. Thus, the focus has now shifted to improving the performance and reducing the cost of

PEMFC components(Qasem, 2024) . Platinum serves as the preferred electrocatalytic material as it offers

high activity to both oxidation and reduction reactions, while support materials play a very significant role

in how well a catalyst performs, as they improve characteristics such as stability, electrochemical activity,

and durability (Visser et al., 2023). Biochar, a carbonaceous material produced from biomass, offers

several benefits as a support material for electrocatalysts in fuel cells. Its high surface area, hierarchical

porosity, and adaptable microstructures enhance electrocatalytic activity, while its low cost and sustainability are also making it a promising alternative to traditional carbon supports derived from fossil fuels(Shyam et al., 2025). This project will investigate the potential of hierarchical biochar as a support material in PEMFCs, focusing on its economic feasibility and advantages for both the agricultural and energy sectors.

Educating For Equity: Academic Engagement And Policy Reflections On Just Energy Transitions Across The Global North And South

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This study investigates how academic institutions and educational engagement influence awareness and policy discourse around Just Energy Transition (JET) across Africa, Europe, and South Asia. Drawing on survey and focus group data from universities and stakeholders in multiple countries across the globe, the research reveals that while environmental concerns are widely acknowledged, practical challenges, such as financial constraints and infrastructural gaps, often limit meaningful participation in JET initiatives. A recurring theme is the limited integration of JET concepts within academic curricula and institutional strategies, particularly in regions where energy transitions intersect with complex socio-economic realities. Discipline-specific analysis shows that awareness and engagement vary not only by geography but also by academic role and field: STEM academics tend to be more informed and proactive, while students, especially undergraduates in the Global South, often lack exposure to JET topics. Energy professionals, though directly affected by transition policies, are constrained by cost and infrastructure, yet show a strong willingness to adopt renewables if conditions improve. The findings suggest that universities can play a transformative role by embedding JET into interdisciplinary teaching and engaging with local communities to co-develop context-sensitive solutions. Strengthening links between academia and energy professionals, through collaborative curriculum design, joint research, and targeted outreach, can help bridge knowledge gaps and support the development of inclusive policy frameworks. Raising awareness through tailored educational interventions and

empowering youth as advocates are essential steps toward a more equitable energy future.