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Preface

Introduction

The rapid increase in energy costs due to the double effect of inflation and currency depreciation means that smart choices driven by research, development, demonstration, and sustainability should lead the way, especially as they affect the growth of developing countries.

African countries, therefore, have the opportunity to leverage the current global economic situation for sustainable technology enhancement and growth, and also transition towards green and sustainable pathways while securing energy needs and ensuring modern energy fuels from alternative and non-conventional sources. These energy sources, therefore, can easily be made available to the population at affordable and competitive prices.

This conference focuses on Africa and seeks to bring together various stakeholders such as academia and research scientists, industrialists, small and medium-scale enterprises, technocrats and political actors, NGOs, etc. to exchange knowledge on the following:

1. Establishing facilities.

2. Producing and marketing different green fuels and renewable energy options.

3. Creating an alternative sustainable future for Africa.

4. Advocating and considering the energy and fuel needs of rural, peri-urban, and urban communities.

5. Shaping the inclusive green pathways within the continent.

The conference will create an opportunity for thematic interactions between various stakeholders and carve out a unique growth pathway for the African continent and its partners.

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Background

In most of the African countries, access to electricity and modern energy fuels is still a big concern for the population. More than half of the population in Sub-Saharan Africa (SSA) representing about 570 million people, still lack access to electricity, while only about 18% of the population have access to modern fuels for cooking. What is more worrying is the fact that many of the countries with even high access to electricity are overly dependent on fossil fuels as a primary energy source. For instance, Ghana's electric generation capacity is heavily dependent on light crude oil and natural gas, meaning price fluctuations on the international market have a direct effect on consumers. Similarly, fossil fuels account for about 86% of South Africa's primary energy demand. These conditions as examples are alarming as many countries in Africa are facing major challenges due to massive debts, lack of maintenance, and system failures raising the need for new investment in the transition of the sector.

The need for diversification of energy and fuel sources, investment in technologies, and a new paradigm shift in energy and fuel access is more urgent than ever before. In addition, even though Africa is not a heavy emitter of greenhouse gases, the current situation of overdependence on fossil fuel coupled with the growing demand for energy and fuel as the economy expands and a strong positive population growth rate means the business-as-usual case will not persist for long. Rather sharp increases in greenhouse gas emissions are expected over the near to long-term future.

Even though the use of biomass as an energy source is predominant in Sub-Sahara Africa, it is mostly used in its raw state thus posing health hazards as a result of incomplete combustion. On the other hand, the amount of waste produced is also increasing due to various factors such as urbanisation, increased economic activities, rise in living standards, etc. Based on which waste management is also becoming one of the most pressing challenges faced by most of the countries on the continent. Although the per capita waste generation of Africa is lower compared to other, more developed continents, the lack of treatment technologies, finance, and legal and regulatory mechanisms makes the management of waste a very challenging aspect.

The lack of treatment has resulted in many calamities in several African countries including flooding, cholera outbreaks, pollution of surface water bodies and the ocean, and the pollution of the marine environment. Lastly, the generation of agricultural residues as a result of agriculture and agro-processing activities across the continent presents a great opportunity for energy transition. The diverse and large quantities of agricultural residues generation, amounts of energetic valuable wastes, and utilisation of non-conventional fuels mean various energy carriers can be developed and generated using these residues to meet or supplement Africa's energy and fuel demand. The current situation offers a window of opportunity for Africa to transition from a more dependent fossil-based economy to a more sustainable green economy pathway through technology, knowledge, and skills leveraging to support rapid transition and economic growth.

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Objectives

The main objective of the conference is to encourage a discussion on Africa's green transition to modern sustainable fuels to setup an action plan in each of the countries in Africa. Thus, the conference will offer the opportunity to the following objectives.

Interact & share

Researchers, academia, industry policymakers, and other stakeholders to interact and share ideas.

Create a platform for continuous exchange

Pathway to green energy Development of a strategy and action plans with specific focuses of individual countries on the transition towards green and sustainable energy and fuel economy.

Transfer technology

Enhance the transfer of technology and skills in the area of green energy generation.

Africa to the world - connect

Build on research collaboration between researchers from Africa and the rest of the world.

Promote new technology

Promote knowledge and experience sharing on various sustainable energies and fuel technologies.

Observation of regulations

Creation of country-based protocols as suggestions for implementation within the continent.

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Table of Contents

Preface **2**

A - Biomass and Waste as a Sustainable Resource ***13***

(A-1) Valorization of Sugarcane Molasses for Sustainable Aviation Fuel Production via Alcohol-to-Jet Pathway: Techno-Economic and Environmental Assessment 13

(A-2) Bioconversion of Agricultural Residues into Second-Generation Liquid and Gaseous Biofuels: Implications for Transport Energy in Cameroon 14

(A-3) Production of Biodiesel Using a Solid Acid Catalyst Derived from Biomass Waste and Waste Cooking Oil 15

(A-4) Catalytic Hydroprocessing of Brassica carinata Oil over AlPO4-18 Supported β-Mo_2C, Ni_3C, and WC Nanoparticles for SAF Production 16

(A-5) Modeling and Optimization of Bioethanol Production Yield from Agricultural Wastes by Co-culture of Thermo-tolerant Wild Yeasts using response surface methodology 17

(A-6) Estimation of Biogas and Biofertilizer Potential from Abattoir Waste in Dapaong as a Sustainable Waste Management Option 18

(A-7) Dual-Function Biorefinery: Simultaneous Organic Waste Treatment and Biogas Quality Improvement via Tailored Clay Adsorption 19

(A-8) Waste-to-Energy pathway for municipal organic waste in African cities: Technical and environmental assessment of biomethane production from source-separated food waste; A case study of Eldoret city, Kenya 20

(A-9) Optimization of Biogas Production from Wheat Straw and Cow Dung through Anaerobic Co-Digestion Using Response Surface Methodology. 21

(A-10) Prioritising Barriers to Anaerobic Digestion Adoption 22

(A-11) Techno-Economic and Environmental Feasibility of Biogas Upgrading to Bio-CNG for Heavy-Duty Vehicle Fuel in Ethiopia 23

(A-12) From waste to bioenergy: hydrothermal carbonization of coffee husks 24

(A-13) Evaluating The Quality of Briquettes from Coffee By-Products and Municipal Solid Wastes; Implication for Sustainable Waste Utilization and Energy Production 25

(A-14) Synergistic Blending and Characterization of Residual Biomass Feedstocks for Sustainable Pelletization 26

(A-15) Performance Evaluation of Rice Husk Biomass Briquettes as an Alternative Fuel for Industrial Boiler Applications 27

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(A-16) Conceptual Design and Performance Assessment of Waste-to-Energy Technologies Using the WROSE Model for an Integrated Energy Complex in South Africa 28

(A-17) Integrated biochar and vermicompost application for circular and sustainable maize production in Ethiopia 29

(A-18) Food and faecal waste as a biochar soil conditioner 30

(A-19) A Circular Economy Approach to Water Reuse: Converting Olive Mill Solid Waste into Biochar for Efficient Olive Mill Wastewater Treatment 31

(A-20) Optimizing the Utilization of Vermicompost in Nile tilapia (O. niloticus) culture in open cemented pond system 32

(A-21) Sustainable Biomass Sourcing, Aggregation and Storage Strategies for Efficient Energy Production: A Mini-Review 33

(A-22) Mapping Biomass Hotspots and Community Energy Vulnerability for Sustainable Biogas Development in Nigeria 34

(A-23) Drying kinetic models, thermodynamics, physicochemical qualities, and bioactive compounds of avocado (Persea americana Mill. Hass variety) seeds dried using various drying methods 35

(A-24) Hydrogen-Rich Syngas Production from Coffee Husk and Bagasse in a Throated Updraft Gasifier for Sustainable Energy Applications 36

(A-25) Design of an IoT-enabled portable biodigester for decentralized organic waste management in Togo 37

(A-26) Multi-Objective Deep Reinforcement Learning for Joint EV Charging and Renewable Energy Dispatch in Hybrid Energy Systems: A Case Study of Ethiopia 38

(A-27) Development and Performance Testing of low-emission injera baking gasifier stove 39

(A-28) SASSCAL's roles in the Production of Renewable Ammonia for Global Markets in Africa: Fueling Europe's Decarbonization Ambitions through the PRAGMA -E Project 40

(A-29) GreenQUEST – A Holistic Study of Green LFG as a Drop-in Cooking Fuel Replacement 41

(A-30) Green Ammonia Production Scenarios and Cost Analysis for Nigeria's Fertiliser Sector 43

(A-31) Food Waste Valorization into Biofertilizer: A Circular Approach for Smallholder Farmers 44

(A-32) Material Flow Analysis for Institutional Bio-waste Assessment as a Basis for

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With funding from the:
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Decentralized Waste-to-Energy Planning 45

B- Green hydrogen production, utilization, policy, regulatory framework, industrial requirements and transition **47**

(B-1) Ethiopia's Renewable Energy and Water Resources Potential for Green Hydrogen Production: A Roadmap to Sustainable Development 47

(B-2) Green Hydrogen for Agricultural Decarbonisation in Nigeria: A Demand Anchoring and Project Development Framework 48

(B-3) SASSCAL'S Progress on Green Hydrogen Pilot Projects, Research and Capacity Development 49

(B-4) Integrating Wastewater Resource Recovery, Renewable Energy Generation and Green Hydrogen Production: A Circular Economy Framework for Sustainable Urban Development in Africa 51

(B-5) Assessment of the Green Hydrogen Production Potential from Agricultural Residues in Burkina Faso 53

(B-6) Mathematical Modelling of a 590 MW Wind Power for Green Hydrogen Production: A Case Study of the Daures Green Hydrogen Village in Namibia 54

(B-7) Predictive Modelling of Green Hydrogen Production from a Rainwater-Harvesting Solar–PV Integrated System in a University Campus in the Global South. 55

(B-8) Valorisation of Phytoremediation Biomass for Hydrogen Production in Integrated Agroforestry and Agri-PV Systems: A Simulation-Based Assessment 56

(B-9) Prospects for Solar Systems Manufacturing and Assembly in Southern Africa Amid Renewable Energy Advancements: A Focus on Namibia's Green Hydrogen Initiatives 57

(B-10) Decentralized Green Hydrogen Production in West Africa: A Machine Learning-Based Optimization of Solar-Biohydrogen Systems using University Campus Wastewater 58

(B-11) Modeling the Role of Biomass-Derived Hydrogen in Ethiopia's Pathway to a Fully Decarbonized Energy System by 2050: An OSeMOSYS-Based Integrated Energy System Analysis 60

(B-12) Synthesis and Characterization of high entropy alloys for hydrogen storage applications 62

(B-13) Environmental and Economic Implications of Transitioning from Diesel to Hydrogen-Powered Construction Machinery: A Life Cycle Perspective 63

(B-14) Artificial Neural Network based Predictions of Hydrogen Storage in Metal-Organic Frameworks 65

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JIMMA UNIVERSITY
We are in the Community
With funding from the:
Federal Ministry of Research, Technology and Space

(B-15) Physicochemical Characterization of Fecal Sludge and Water Hyacinth as Potential Feedstocks for Biohydrogen Production through Dark Fermentation 67

(B-16) Balancing Societal and Ecological Resilience: A Critical Analysis of Biodiversity Conservation and Green Hydrogen interface in the Erongo and //Kharas regions of Namibia 68

(B-17) Assessing Circular Water Resource Management for Green Hydrogen and Ammonia Production from Rainwater Harvesting Systems in a University in the Global South 70

(B-18) Feasibility Study of a Grid-Hybrid Solar–Wind–Battery–Hydrogen System for a Housing Estate in Otjomuise, Windhoek, Namibia 71

(B-19) Curtailment-to-Hydrogen at Jebba Hydro Station: Exploiting Nigeria's Grid Fragility for Fully Renewable, Low-Cost Hydrogen 73

(B-20) Forecasting Rainfall and Bridge Deck Runoff for Decentralized Micro-Hydropower and Green Hydrogen Production: A Case Study of Canaanland, Ota, Nigeria 74

(B-21) Dynamic Techno-Economic Optimization of a Renewable-Powered Alkaline Electrolyzer: Insights from Five Moroccan Locations 75

C- Health, environmental, and Cultural Aspects of harnessing green energy in the African context ***76***

(C-1) From Invisible Labor to Green Agency: Care, Commons, and Women's Environmental Expertise in the OMVS Basin 76

(C-2) Gendered Informality and Energy Justice in Angola 77

(C-3) Informal waste management and inequality dynamics in Sub-Saharan Africa: a multidimensional analysis of economic and social disparity reproduction mechanisms in the Circular Economy 79

(C-4) Advancing Gender Equality in Renewable Heating and Cooling Sector: Lessons From SOLTRAIN+ WP5 Online Series 81

(C-5) Women's access to clean energy as a pathway for energy justice in Burkina Faso 82

(C-6) Ecological agency in practice: senegalese women's digital narratives of green entrepreneurship, environmental expertise and climate advocacy 83

(C-7) Unlocking the Potential of Waste Biomass to Renewable Energy in Ethiopia: Pathway to Green Transition 85

(C-8) Strengthening Sustainable Pathways for Africa's Development through Renewable and Green Energy Technologies 87

(C-9) Climate Adaptation Financing for Renewable Energy Transitions in the SADC Region:

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JIMMA UNIVERSITY
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With funding from the:
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Challenges, Opportunities and Pathways for Climate-Resilient Development 89

(C-10) Illuminating the informal city: Securing land tenure for a modern energy transition in Namibia 91

(C-11) The Effectiveness of Science Journalism in Communicating Renewable EnergyTechnology Diffusion to Accelerate 2030 SDGs in Africa 92

(C-12) Beyond Beneficiaries: Community Inclusion in National Fresh Produce Market (NFPM) Waste-to-Energy Transitions in South Africa 94

(C-13) Linguistic Justice in Green Energy Communication: Rethinking Public Inclusion in Namibia's Green Hydrogen Programme 95

(C-14) Economic feasibility and political risk of an e-methanol trade route between Côte d'Ivoire and Germany 97

(C-15) The Influence of Social Norms on Resistance to the Adoption of Domestic Gas in Northern Benin. 98

D– Recycling of valuables ***99***

(D-1) Defining Starting Points for the Circular Economy Transition in Angola's Construction Sector 99

(D-2) Circular Economy Adoption in Disaster-Related Demolition Waste Management in Africa: A Systematic Review 100

(D-3) Utilisation of incinerated sanitary sludge ash (SSA) with partial replacement for cement and lime in stabilised earth blocks: A case study of Dar es Salaam, Tanzania 101

(D-4) Decentralised granule production; cost-effective sustainable approach to plastics waste management 102

(D-5) Up-cycling PET Bottles into Vertical Gardens: Evaluating Container Size and Growing Media for Swiss Chard (Beta vulgaris L.) Growth Performance under Adigrat Conditions .. 103

(D-6) An Integrated Statistical, Economic, and Environmental Modeling Approach to E-Waste Management in Ethiopia: A Circular Economy Framework for Obsolete CRT Televisions .. 104

(D-7) Battery waste generation and management in west Africa: Systematic review 105

(D-8) Soil Contamination by Heavy Metals at E-Waste Sites in Dakar (Senegal): An Integrated Environmental and Health Assessment 106

(D-9) Fabric Waste Management and Recycling for Pollution Prevention, Environmental Sustainability, and Circular Economy 107

(D-10) Waste to Resource Approach: Sawdust Derived biochar Co-Doped with N/Fe for

With funding from the:
Federal Ministry of Research, Technology and Space

Simultaneous Removal of Multi-Heavy Metal from Wastewater 108

(D-11) Desktop Optimization of Donnan Dialysis for Coagulant Recovery from Potable Water Treatment residue using Response Surface Methodology, Particle Swarm Algorithm, and Artificial Neural Networks. 109

(D-12) Quantifying CO_2 emission from soils of agricultural managed land in north-western highlands of Ethiopia 110

(D-13) Upcycling Mine Tailings and Industrial Waste into Construction Products Through Geopolymerisation in Africa: A Review 112

(D-14) Development of Zinc nitrate Hexahydrate Salt (ZNH) based Deep eutectic Electrolytes for Rechargeable Zinc Air Batteries 114

(D-15) Green Computing: Advancing Energy-Efficient Materials and Systems for a Sustainable Digital Future 115

(D-16) Sustainable Engineering of ε-MnO2 Nanostructures for High Performance Supercapacitors: A Response Surface Methodology Approach 116

E - Development of strategies and implementation ***117***

(E-1) Can Urine-Based Circular Fertilisers Enter Smallholder Markets? Evidence from Ethiopia on Farmer Preferences and Willingness to Pay 117

(E-2) Knowledge Transfer as a Catalyst for Africa's Green Transition: A Multi-Stakeholder Framework for Sustainable Energy Innovation and Circular Economy Development 118

(E-3) Livelihood Diversification for Resilient Rural Economies: Evidence from Smallholder Farmers in North Wollo Zone, Ethiopia 119

(E-4) Examining Students' Preparedness to Utilize Artificial Intelligence for Facilitating the Adoption of Green Energy for Green Building Development in Nigeria, West Africa 120

(E-5) Integrating Workplace Safety and Circular Economy Practices in Ethiopian Manufacturing Industries: Opportunities and Challenges for Sustainable Industrial Development 121

(E-6) Resource Rich, Energy Poor: Politics, Policy Continuity, the Quest for Energy Security, and Strategic Transformation in Namibia 122

(E-7) The Grand Ethiopian Renaissance Dam: Energy Diplomacy, Regional Development, and Transboundary Water Governance in the Nile Basin 123

(E-8) TArtificial Intelligence, Circular Economy, and Green Energy: Emerging Research Frontiers in Africa 124

(E-9) Closing the Policy-to-Implementation Gap: A Systems Thinking Analysis of Solar PV for

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JIMMA UNIVERSITY
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With funding from the:
Federal Ministry of Research, Technology and Space

Productive Use in Rural Tanzania.....125

(E-10) Policy Drivers Promoting Innovation Technologies for Renewable Energy Resources Development and Utilization in Ethiopia.....126

(E-11) Machine learning-based weekly electricity consumption modelling under meteorological variability and population growth: Evidence from a West African city.....128

(E-12) Integrating Climate Data and Remote Sensing to Support Renewable Energy Planning in Angola.....130

(E-13) Leveraging Circular Economy for Sustainable E-Waste Business Models: Integrating Informal Entrepreneurs in Ghana's Formal Sector.....132

***F- Renewable Energy*.....133**

(F-1) Thermal Performance Augmentation of a PCM-Integrated Triple-Pass Indirect Solar Dryer: A CFD Investigation for Sustainable Agricultural Drying.....133

(F-2) Exergy and Thermoeconomic Analyses of Serpentine Tube Flat-Plate Solar Collector Working with Al_2O_3-CuO/water Hybrid Nanofluids.....135

(F-3) Scaling up solar water disinfection using solar thermal collectors in large-volume storage systems.....136

(F-4) Effect of absorber tube rotation combined with silica nanofluids application on parabolic trough solar collector efficacy improvement.....137

(F-5) Solar-Powered IOT Centralized Monitoring For Clustered Biogas In Rural Ethiopia.....138

(F-6) Optimizing Renewable Energy Systems For Sustainable Urbanization: A Multi-Criteria Assessment of Solar-Wind Hybrids in Ethiopia.....140

(F-7) Integrating Solar PV into Existing Distribution Networks Through Simultaneous Reconfiguration and Distributed Generation Planning.....142

(F-8) Assessment of the Impact of West African Interconnected Grid Fluctuations on Large-Scale Solar PV Plants: A Case Study of the 33.7 MWp Zagtouli Solar PV Plant in Burkina Faso.143

(F-9) Bridging the Reliability Gap between Machine Learning and Physical Models for Solar Irradiance Estimation across Ethiopia's Heterogeneous Climatic Regimes.....144

(F-10) Magnetic Properties of Metamaterial Selective Emitters for Renewable Energy Conversion.....145

(F-11) Long-Term Wind Resource Assessment in Ethiopia: A Hybrid Machine Learning Framework and Grid Complementarity Analysis.....146

(F-12) Factors Linking Climate Change and Energy demand in Guinea-Bissau: Renewable

Universität Rostock

JIMMA UNIVERSITY
We are in the Community

With funding from the:
Federal Ministry of Research, Technology and Space

energy impact 147

(F-13) Sustainable Energy Infrastructure In Sierra Leone; A case study - Bumbuna Hydro Power Plants 148

(F-14) Evaluation of Climate Change Potential Impact on the Optimal Operation of Hydropower Reservoir in Omo Basin, Ethiopia 150

(F-15) Assessment of a Hybrid Energy System for Reliable and Sustainable Power Supply to Boru Meda Hospital in Ethiopia 151

(F-16) Multi-Objective Deep Reinforcement Learning for Joint EV Charging and Renewable Energy Dispatch in Hybrid Energy Systems: A Case Study of Ethiopia 152

Joint Scientific and Organizing Committee ***153***

List of Authors and Affiliations Table ***154***

With funding from the:
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A - Biomass and Waste as a Sustainable Resource

(A-1) Valorization of Sugarcane Molasses for Sustainable Aviation Fuel Production via Alcohol-to-Jet Pathway: Techno-Economic and Environmental Assessment

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Abstract

The aviation sector remains one of the most difficult industries to decarbonize, yet its environmental burden continues to grow. In Africa, where agro-industrial biomass is abundant and energy transitions are urgently needed, Sustainable Aviation Fuel (SAF) produced via the Alcohol-to-Jet (ATJ) pathway represents a compelling intersection of circular economy principles and renewable energy innovation. This study presents an integrated techno-economic analysis (TEA) and life cycle assessment (LCA) of ATJ-based SAF production from sugarcane molasses — an abundant, low-value agro-industrial byproduct widely available in Ethiopia and across sub-Saharan Africa. The ATJ conversion process — encompassing fermentation, ethanol purification, dehydration, oligomerization, hydrogenation, and product fractionation — was simulated using Aspen Plus to evaluate mass and energy balances, fuel yield, and process efficiency. The TEA quantifies capital expenditure (CAPEX), operating expenditure (OPEX), utility demand, and the Minimum Jet Fuel Selling Price (MJSP), with sensitivity analyses identifying key economic drivers including feedstock cost and plant capacity. The LCA adopts a cradle-to-grave system boundary following the ISO 14040/14044 framework, evaluating greenhouse gas (GHG) emissions, fossil energy consumption, and additional environmental impact categories relative to conventional fossil jet fuel. Preliminary simulation results, based on an ethanol feed rate of 5,908 kg/hr with approximately 98% ethanol recovery efficiency after fermentation and distillation, indicate a total hydrocarbon (C4–C20) mass yield of approximately 58% following oligomerization. Of this total oligomer product, the jet-range fraction (C8–C16) constitutes approximately 35%, corresponding to an overall ethanol-to-SAF mass yield of approximately 21%, with the remaining light (C4–C6) and heavy (C18–C20) fractions representing valorizable co-products such as naphtha and diesel-range hydrocarbons. These findings confirm the technical feasibility of molasses-derived ethanol as a viable feedstock for SAF synthesis. Techno-economic and life cycle assessments are currently underway to quantify the Minimum Jet Fuel Selling Price and GHG emission reduction potential relative to the fossil jet fuel baseline, with preliminary indications suggesting economic feasibility under African feedstock and market conditions, further enhanced by potential policy support mechanisms. By converting a low-value agro-industrial residue into a high-value aviation fuel, this work directly supports circular economy goals, waste valorization, and Africa's long-term decarbonization agenda, thereby contributing to sustainable energy transition and circular economy development across the African continent.

Keywords: Sustainable Aviation Fuel; Alcohol-to-Jet; Sugarcane Molasses; Techno-Economic Analysis; Life Cycle Assessment; Circular Economy; Renewable Energy.

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(A-2) Bioconversion of Agricultural Residues into Second-Generation Liquid and Gaseous Biofuels: Implications for Transport Energy in Cameroon

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Abstract

In the context of rising global oil prices, energy security concerns, and environmental issues related to greenhouse gas emissions, biofuels derived from biomass have attracted increasing interest. This study evaluates the bioconversion potential of selected Cameroonian agricultural residues into second-generation biofuels, with the aim of assessing their suitability as feedstocks for renewable energy production.

Avocado, cocoa, and groundnut residues were converted at laboratory scale into gaseous (biogas) and liquid (ethanol) biofuels. Mechanical, thermochemical, and microwave pretreatments were applied prior to enzymatic hydrolysis using cellulolytic enzymes to enhance biomass accessibility to microorganisms. Biomethane yields varied depending on the residue type and pretreatment method, reaching up to 177.8 mL/g of biomass for avocado residues. Maximum biomethane yields of 126.5 mL/g and 72.4 mL/g were obtained for cocoa pods and groundnut shells, respectively. Regarding liquid biofuels, the highest ethanol yield was recorded for avocado seeds (178 mL/kg of biomass), followed by cocoa pods (61 mL/kg) and groundnut shells (49 mL/kg).

A comparative analysis of the energy content of the produced biofuels and the calorific value of the residual biomasses indicated that anaerobic digestion provided a higher energy conversion efficiency than the lignocellulosic ethanol pathway. The national potential for biogas production through anaerobic digestion in Cameroon is estimated at over 330,000 m³, corresponding to approximately 28% of petroleum consumption or 5.39% of electricity consumption. The national potential for lignocellulosic ethanol production is estimated at 200,000 kg, representing 17% of petroleum consumption in the transport sector and 3.19% of electricity consumption.

These findings demonstrate the technical feasibility of converting agricultural residues into gaseous and liquid biofuels and highlight the significant potential of organic residues as sustainable feedstocks for renewable energy production in Cameroon.

Keywords: Biomass valorization; Agricultural residues; Second-generation biofuels; Anaerobic digestion; Lignocellulosic ethanol; Renewable energy; Cameroon.

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(A-3) Production of Biodiesel Using a Solid Acid Catalyst Derived from Biomass Waste and Waste Cooking Oil

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Abstract

The simultaneous valorization of agro-industrial residues and waste cooking oil represents a sustainable approach to biodiesel production, addressing current environmental challenges. In this study, a solid acid catalyst was synthesized by carbonization of deoiled cashew nut shells followed by sulfonation with concentrated sulfuric acid. The resulting catalyst was characterized using X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FTIR), Brunauer-Emmett-Teller (BET) surface area analysis, and scanning electron microscopy (SEM) to investigate its chemical structure and morphological properties. The characterization results confirmed the successful grafting of sulfonic acid ($-SO_3H$) functional groups onto the catalyst surface. The catalyst exhibited an acid site density of 1.88 mmol/g and a specific surface area of 172.219 m^2/g. Its catalytic performance was evaluated through the transesterification of waste cooking oil. Under the optimized reaction conditions, a biodiesel yield of 90.7% was achieved. The catalyst reusability was further assessed over four consecutive reaction cycles. These findings demonstrate the feasibility of a circular biofuel production pathway based on the valorization of waste-derived resources.

Keywords: Biochar; Acid Catalyst; Waste Cooking Oil; Transesterification; Surface Acidity

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(A-4) Catalytic Hydroprocessing of Brassica carinata Oil over AlPO4-18 Supported β-Mo_2C, Ni_3C, and WC Nanoparticles for SAF Production

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Abstract

The transition from conventional petroleum-derived jet fuels to sustainable aviation fuels (SAFs) represents a critical pathway toward decarbonizing the aviation sector and mitigating global CO2 emissions. In this study, a catalytic hydroprocessing upgrading route was investigated for the conversion of Yellow Dodolla oil—a prominent non-food Brassica carinata feedstock indigenous to Ethiopia—into high-quality bio-jet fuel. The feedstock was upgraded to jet fuel via catalytic hydroprocessing under an elevated hydrogen pressure of 21 bar and temperatures of 300 and 500 °C. The process employed supported, carbon-coated mesoporous and crystalline nanocatalysts (β-Mo2C/AlPO4-18, Ni3C/AlPO4-18, and WC/AlPO4-18) evaluated within a bench-scale, continuous three-phase fixed-bed reactor system. Additional process parameters, including the oil feedstock and hydrogen volumetric flow rates, hydrogen-to-oil ratio, catalyst-to-oil ratio, space velocities (LHSV and WHSV), and residence time, were kept constant throughout the experimental runs. Following a comprehensive evaluation of key catalytic performance parameters (conversion, selectivity, yield, and deoxygenation rate), the resulting liquid-phase products were thoroughly characterized to determine their fundamental physicochemical properties. Catalytic hydroconversion of the feedstock yielded conversion levels ranging from 71.57 to 79.76 wt.%, with the peak conversion of 79.76 wt.% achieved over the Ni3C/AlPO4-18 catalyst at the highest evaluated temperature (500 °C). Furthermore, the degree of deoxygenation ranged between 8.08 and 11.67 wt.% at 300 °C, with the nickel-based catalyst exhibiting the highest efficiency. Elevating the temperature to 500 °C induced a sharp increase in performance, with the molybdenum-based catalyst achieving a superior deoxygenation range of 57.31 96.67 wt.%. Comparatively, bio-jet fuel (C8–C16) exhibited notably higher yields (23.34–27.31 wt.%) and selectivities (37–45 wt.%) than bio-gasoline (2.63–8.72 wt.%) and biodiesel (1.18–4.58 wt.%) at the maximum evaluated temperature (500 °C). Under these conditions, a favorable hydrocarbon product distribution concentrated in the C9–C16 range was achieved, with the WC/AlPO4-18 catalyst delivering the peak jet-fuel yield and selectivity. Characterization of the hydrocracked liquid products revealed that their physicochemical properties and chemical compositions closely resembled those of conventional jet fuels. Specifically, the products exhibited H/C atomic ratios of 1.90–1.92, O/C atomic ratios of 0.002–0.030, and gravimetric energy densities (higher heating values) of 41.35–42.89 MJ kg−1. The conclusions of the study demonstrated that the non-food Yellow Dodolla oil was successfully hydrocracked into sustainable aviation fuel using AlPO4-18 supported metal carbide catalyst nanoparticles under the right reaction conditions and reactor system, potentially supporting the significant efforts of the aviation industry to lower its carbon footprint.

Keywords: Brassica carinata; Vegetable Oil; Supported Catalyst; Fixed-Bed Reactor; Catalytic Hydrodeoxygenation; Catalytic Hydrocracking; Selectivity; Yield; Product Distribution; Sustainable Aviation Fuel.

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(A-5) Modeling and Optimization of Bioethanol Production Yield from Agricultural Wastes by Co-culture of Thermo-tolerant Wild Yeasts using response surface methodology

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Abstract

In developing nations like Ethiopia, population development and industrialization have resulted in higher energy consumption and serious waste disposal issues. The goal of this work is to increase ethanol production from hydrolysates of banana and pineapple peels by using co-cultures of thermotolerant wild yeast species, Saccharomyces cerevisiae and Scheffersomyces stipitis. The process included fermenting the peels after hydrolyzing them with acid and autoclave steam. Response Surface Methodology (RSM) was used to optimize fermentation conditions, and a digital refractometer and a UV-vis spectrophotometer were used to quantify the amounts of reducing sugar and ethanol, respectively. Under optimized conditions co-culture of S. cerevisiae 9Li2 and S. stipitis 39L1 enhanced the ethanol production by 18.7% (34 g/L to 41.8 g/L) and 17.1% (26 g/L to 31.35 g/L), respectively from sugar concentrations extracted from BP and PAP hydrolysates. With BP hydrolysates, the ethanol yield, productivity, and yield efficiency were 0.5 g/g, 1.16 g/L/h, and 98%, compared to PAP hydrolysates' 0.39 g/g, 0.87 g/L, and 76.47%, respectively. It is possible to efficiently transform fruit peel waste into bio-ethanol, reducing organic waste in the environment and offering a substitute energy source.

Keywords: Bioethanol, Wild yeasts, Lignocellulosic substrates, Co-cultures

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(A-6) Estimation of Biogas and Biofertilizer Potential from Abattoir Waste in Dapaong as a Sustainable Waste Management Option

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Abstract

The rapid growth in meat consumption has led to increased slaughterhouse waste generation, creating environmental and public health concerns, particularly in developing countries where waste management infrastructure remains inadequate. This study quantifies the biodegradable fraction of abattoir waste generated at the Dapaong City Abattoir (DCA) in northern Togo and assesses its potential for biogas and biofertilizer production through anaerobic digestion (AD). A total of 12 wastewater samples were collected over three months during morning and peak slaughter hours, and field measurements of blood and intestinal content were conducted on 30 animals (10 cattle, 10 goats, 10 sheep). Slaughter records from 2021–2023 supported waste generation analysis. Physicochemical analyses of wastewater (pH, EC, temperature, DO, BOD_5, COD, phosphate, nitrate, ammonia) were performed and compared to WHO/USEPA standards to evaluate pollution levels. Biogas yield was estimated using Temesgen's model, while digestate-based biofertilizer yield was computed using a digestate conversion approach reported in the literature [1] Results show that cattle, goats, and sheep generate an average of 58.86 kg, 2.91 kg, and 6.89 kg of biodegradable waste per head, amounting to a total of 3,349 kg/day. Although pH, temperature, and EC fall within permissible limits, BOD_5, COD, nitrate, and phosphate levels exceed WHO/USEPA thresholds. The theoretical biogas potential was estimated at 178 m^3/day (≈69% CH_4), while biofertilizer yield reached 246 kg/day. The findings demonstrate that combining field measurements and modelling provides a robust assessment of the valorisation potential of abattoir waste. AD presents a viable pathway for sustainable waste management at DCA by producing renewable energy and nutrient-rich fertilizer, contributing to improved environmental health and energy access (SDG 7) in northern Togo.

Keywords: abattoir waste; anaerobic digestion; biogas; biofertilizer; waste valorisation; Dapaong; SDG 7

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(A-7) Dual-Function Biorefinery: Simultaneous Organic Waste Treatment and Biogas Quality Improvement via Tailored Clay Adsorption

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Abstract

The contaminants in biogas erode and corrode metallic components, reduce the energy value of methane, and release carbon dioxide into the environment. The goal of this work is to remove biogas contaminants by adsorption on the surface of modified bentonite clay using carbide slag for H_2S removal and monoethanolamine (MEA) integration for CO_2 removal after anaerobic co-digestion. The highest co-digestion result of anaerobic digestion of cow dung with a banana peel at ambient air, with the composition of 71.23% (CH_4), 27.89% (CO_2), and 1470ppm (H_2S) at the ratio of 60%CD: 40%BP. The results suggested that Response Surface Methodology (RSM) to increase the concentration of CH_4 by parameter optimization involves the adsorption of H_2S and CO_2 on the surface of modified bentonite clay. The data from the optimization experiment on upgrading was analyzed and modeled using Design-Expert version 13 Box-Behnken Design (BBD) with three numeric factors: clay particle size (0.1-2 mm), Gas flow rate (0.1-2 l/min), and bed height (10-50cm) for the response of CH_4, CO_2, and H_2S. Significance was then accepted at a 0.05 level of probability ($P<0.05$). Analyzing the experimental trial data yielded highly statistically significant regression model equations with $R^2 = 99.99\%$, $R^2 = 99.99\%$, and $R^2 = 99.80\%$ for CH_4, CO_2, and H_2S, respectively. Consequently, the highest result has recorded CH_4 content of 96.22% from 71.23%, CO_2 3.65% from 27.89%, H_2S 71ppm from 1470ppm at the combination of actual parameters clay particle size at 0.10 mm, bed height at 30 cm, and gas flow rate at 0.10 l/min resulted with the methane's calorific (energy) value of 34.6392 MJ/m^3. Investigating biogas upgrading via modified bentonite clay provides a locally generated, cost-effective, and sustainable way to enhance the quality of biogas, increasing the accessibility of renewable energy.

Keywords: : Adsorption, Anaerobic Digestion, Bentonite Clay, Biomethane, RSM

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(A-8) Waste-to-Energy pathway for municipal organic waste in African cities: Technical and environmental assessment of biomethane production from source-separated food waste; A case study of Eldoret city, Kenya

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Abstract

Rapid urbanization across Africa is increasing the volume of municipal organic waste, while many cities continue to face unreliable energy access, rising waste-management costs and growing greenhouse gas emissions from uncontrolled disposal. Food waste, which forms a substantial fraction of municipal solid waste in many African cities, is often underutilized despite its high biogas potential. This study investigates a circular waste-to-energy pathway for source-separated food waste through anaerobic digestion and biomethane upgrading, with a focus on technical feasibility, environmental performance and implementation relevance for African urban contexts.

The research combines waste characterization, process simulation and life cycle thinking to evaluate biomethane recovery from mixed household and market food waste streams. A scenario-based assessment is developed for a representative African city, comparing the proposed system with current disposal practices such as open dumping and landfill. Key performance indicators include methane yield, energy recovery potential, avoided emissions, digestate valorization and overall system efficiency. The study also examines practical constraints including waste segregation behavior, collection logistics, contamination levels and the need for decentralized pre-treatment infrastructure.

Preliminary findings indicate that source-separated food waste can provide a reliable feedstock for decentralized biomethane production, with the potential to offset a meaningful share of cooking or thermal energy demand in institutions, markets and small industries. In addition to energy recovery, the digestate can support soil amendment applications where safe nutrient recycling pathways exist, contributing to broader circular economy goals. The analysis shows that the environmental benefits increase significantly when collection efficiency improves and contamination is reduced at source. The proposed model is designed to be replicable across rapidly growing African cities that face similar waste composition, energy demand and infrastructure constraints.

This work addresses a clear research gap by linking waste management, renewable energy and resource recovery in a context-specific framework grounded in African urban realities. It offers a scalable and sustainable pathway for municipalities, waste operators and energy stakeholders seeking integrated solutions for organic waste valorization. The approach supports the transition toward cleaner cities, reduced emissions and improved local energy resilience.

Keywords: Circular economy, food waste, anaerobic digestion, biomethane, waste-to-energy, African cities

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(A-9) Optimization of Biogas Production from Wheat Straw and Cow Dung through Anaerobic Co-Digestion Using Response Surface Methodology.

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Abstract

The rising in energy demand, continued dependence on fossil fuels, and challenges in agricultural waste management have increased interest in utilizing agricultural and animal wastes for biogas production via anaerobic digestion. This research focuses on investigating the production and optimization of biogas from wheat straw (WS) and cow dung (CD) using batch scale reactor. The effects of substrate mixing ratio, pH, and temperature on biogas production were investigated using response surface methodology based on a three-factor, three-level Box–Behnken design. Including replications 17 experiments were performed in 35 days of digestion. The optimal conditions leading to maximum biogas generation were a mixture of 75% wheat straw and 25% cow dung, pH of 7.0, and temperature of 37.5°C. Under these conditions, the maximum cumulative amount of biogas(197 Ml) and the highest concentration of methane (62.5%) were obtained. The results obtained from this study clearly indicates co-digesting wheat straw with cow dung at optimal operating conditions is effective in producing biogas with increased methane content, and therefore, it can be considered a viable method for renewable energy production from agricultural wastes

Keywords: Biogas, Anaerobic Digestion, Co-digestion, Wheat Straw, Cow Dung, Methane Production, Renewable Energy, Response Surface Methodology, Box–Behnken Design

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(A-10) Prioritising Barriers to Anaerobic Digestion Adoption

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Abstract

In Burkina Faso, many households still depend on firewood and charcoal for cooking, which creates health problems, damages the environment, and increases pressure on forests. The National Biodigester Programme has installed more than 17,000 biodigesters, but adoption remains low, showing that strong barriers prevent rural families from switching to clean energy. Previous studies have identified barriers such as high upfront costs, lack of water, limited technical skills, and poor after-sales service, but these studies looked at barriers separately and did not provide a clear way to measure which ones are most important. Without such a framework, engineers and policymakers cannot design biodigesters that respond to the most urgent needs of rural communities. This study addresses that gap by carrying out a systematic review of research published between 2000 and 2025, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. The review includes peer-reviewed articles and grey literature from Web of Science, Scopus, PubMed, Google Scholar, the Food and Agriculture Organization, the International Energy Agency, the Netherlands Development Organisation, and the National Biodigester Programme of Burkina Faso. Studies were screened by two reviewers using a standard form, and their quality was checked with the Mixed Methods Appraisal Tool and the checklist for Authority, Accuracy, Coverage, Objectivity, Date and Significance. The main result is a Weighted Barrier Priority Index, which combines how often barriers are reported, how severe they are, and how strong the evidence is. Barriers are then ranked into high, medium, and low priority groups using statistical methods. Where enough data are available, a random-effects meta-analysis is used to combine results and explore differences across regions and study types. The ranking is then turned into Design Constraint Parameters, which guide the design of biodigesters adapted to semi-arid climates. It is expected that financial barriers and water scarcity will be the most important obstacles, consistent with evidence from rural Burkina Faso. This study will provide a framework that links barriers directly to design choices for small-scale anaerobic digestion in sub-Saharan Africa, supporting better policies, technology transfer, and rural energy programmes.

Keywords: Anaerobic, Digestion, Barriers

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(A-11) Techno-Economic and Environmental Feasibility of Biogas Upgrading to Bio-CNG for Heavy-Duty Vehicle Fuel in Ethiopia

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Abstract

In Ethiopia, the transportation sector is undergoing rapid transformation, initiated by a national strategy to deploy up to one million compressed natural gas (CNG) vehicles by 2027. This strategy currently relies almost entirely on extracting fossil natural gas from the Ogaden Basin, offering short-term energy security and foreign-exchange benefits but risking long-term carbon lock-in. Meanwhile, Ethiopia's substantial organic waste streams— cattle manure, agro-industrial residues, and municipal organic waste — remain largely mismanaged, contributing to uncontrolled methane emissions and unrealized energy potential. Biogas upgrading to bio-compressed natural gas (Bio-CNG) would provide Ethiopia with a renewable fuel that can be used by the same vehicles and refueling stations. Yet, no integrated, site-specific feasibility assessment of commercial-scale Bio-CNG exists for Ethiopian conditions.

This research fills that gap through a case-study framework evaluating a representative Bio-CNG plant (300 Nm^3/h raw biogas capacity) fed with a mix of 30% cattle manure / 70% municipal organic waste, and it examines the problem from three angles. (a) technical feasibility, comparing multiple commercial biogas upgrading technologies via process simulation (Aspen HYSYS)and Multi-Criteria Decision Analysis(MCDA) to identify the optimal upgrading route under Ethiopian infrastructural and resource constraints; (b) economic viability, using a discounted cash flow model to estimate Net Present Value, Internal Rate of Return, payback period, and the Levelized Cost of Bio-CNG under baseline, subsidy, and carbon-credit policy scenarios; and (c) environmental feasibility, applying a cradle-to-wheel Life Cycle Assessment (ISO 14040/44, OpenLCA) benchmarked against two baselines — fossil CNG and current (unmanaged) waste handling practices.

The study's novelty lies in grounding all Technical, economic, and environmental feasibilities in Ethiopia-specific realities rather than extrapolating from assumptions of industrialized economies. Ethiopia's electricity grid is overwhelmingly hydropower-based, giving Bio-CNG upgrading a substantially lower carbon footprint than studies based on fossil-heavy grids — an advantage that has not yet been quantified for Ethiopian conditions. The analysis further captures the avoided-methane credit from changing manure and organic waste away from open dumping, a co-benefit largely not included in the existing literature, which has focused on household-scale digesters rather than commercial Bio-CNG production. By positioning Bio-CNG as a strategic complement to Ethiopia's fossil-CNG transition — rather than treating the two as separate tracks — this work directly engages with national policy debate at the intersection of energy security, waste management, and decarbonization.

The feasibility results and decision-support framework are designed for replication across other Sub-Saharan African economies that share Ethiopia's combination of renewable-dominated grids, large informal organic waste streams, and emerging gas-based transport policy, offering a transferable model for circular economy and green mobility planning across the region.

Keywords: Biogas upgrading, Bio-CNG, techno-economic analysis, life cycle assessment, circular economy, Ethiopia, sustainable transport fuel

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(A-12) From waste to bioenergy: hydrothermal carbonization of coffee husks

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Abstract

Ethiopia has a population exceeding one hundred thirty million, with the majority residing in rural areas. As a result, there is a high demand for energy among this densely populated rural community. Most energy needs are met through traditional biomass use, which leads to deforestation, contributes to global warming, and increases greenhouse gas emissions. In contrast, Africa in general, and Ethiopia in particular, possess abundant agricultural biomass resources like coffee husks that offer significant potential for renewable energy production. Globally, around 10 million tons of coffee husks are generated annually, with Ethiopia ranked fifth among the major producers of this by product. If not properly managed, coffee husk waste can contribute to greenhouse gas emissions and water pollution, highlighting the need for sustainable waste management and valorization strategies. Therefore, the valorization of coffee husks into value-added products offers a sustainable pathway for waste management while enhancing resource efficiency and reducing environmental effect.

Hydrothermal carbonization (HTC) is a promising thermal valorization technology that operates under mild conditions and does not require drying of the feedstock. In this study, coffee husks were converted into hydrochar by HTC at temperatures ranging from 210 to 230 °C with a fixed residence time of 120 minutes. The influence of thermal intensity on hydrochar production was assessed, showing that the highest hydrochar yield (57.14%) was achieved at 210 °C, while increasing temperature led to enhanced devolatilization and a corresponding decline in solid yield. The carbon content of hydrochar increased from 54.79 to 56.83 wt.% (d.b.) with increasing reaction temperature. This was due to the reduction of oxygen-containing functional groups, which enhanced the degree of carbonization. Furthermore, the thermal stability of the hydrochar was enhanced, as indicated by an increase in the fuel ratio from 0.23 for raw coffee husks to 0.36 after hydrothermal carbonization. In conclusion, the research demonstrates that coffee husks can be effectively converted into a solid biofuel, supporting sustainable energy production and improved biomass waste management.

Keywords: Waste to energy, Coffee husks, Hydrothermal carbonization, Waste management, Hydrochar

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(A-13) Evaluating The Quality of Briquettes from Coffee By-Products and Municipal Solid Wastes; Implication for Sustainable Waste Utilization and Energy Production

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Abstract

Converting biomass waste into high-density briquettes is a promising approach to overcome limitations of using biomass in its raw form. This study evaluates the quality of briquettes produced from coffee by-products (pulp and husk) and municipal solid waste (MSW) like sugarcane bagasse and khat waste. Briquette quality was assessed based on moisture content, volatile matter, fixed carbon, ash, sulfur, bulk density, and calorific value using ASTM D-standards at geochemical laboratory of Geological Institute of Ethiopia. Results showed that briquettes with a higher percentage of coffee pulp (T1 & T2) had a higher calorific value. Briquettes made entirely from coffee husk (T4) exhibited the lowest moisture content and the least volatile matter, ash, and sulfur content. However, T1 had the highest density. For MSW briquettes, those with a higher sugarcane bagasse content (T6 & T10) had a better calorific value. While T6 had the highest moisture content, it also had the lowest ash and sulfur content. The mix of khat and sugarcane waste (T9) had the lowest volatile matter, fixed carbon, and bulk density. Overall, briquettes made primarily from coffee pulp (with some husk) or sugarcane bagasse (with some khat waste) demonstrated the most favorable fuel properties. These findings suggest that coffee by-products and certain MSW components can be viable options for creating high-quality briquettes for sustainable fuel use.

Keywords: Biomass; Briquettes; Coffee by-product; Coffee husk; Municipal solid wastes

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(A-14) Synergistic Blending and Characterization of Residual Biomass Feedstocks for Sustainable Pelletization

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Abstract

Biomass feedstocks vary in structure, composition, morphology, energy density, and handling characteristics. This variation often influences pellet quality, combustion behavior, storage stability, and conversion efficiency. Thus, an optimized feedstock selection and blending strategy remains essential for sustainable biomass pellet production. Blending multiple biomasses has emerged as a practical route for enhancing pellet durability, calorific value, combustion performance, and material uniformity. This study adopts a synergistic blending approach to evaluate suitable combinations of selected residual biomass feedstocks for sustainable pelletization. Ten agricultural residues were selected based on their availability, utilization potential, projected sustainability, and relevance within biomass-based energy systems. Selected feedstocks include sugarcane bagasse, rice straw, rice husk, corn stover, groundnut haulms, sorghum stalk, sorghum straw, cowpea straw, cowpea husk, and wheat straw. Individual feedstocks were first characterized before blended combinations were examined to identify blends with the best physical and thermal properties. Physical properties such as moisture content, density, and particle size distribution are determined. Ultimate compositions including carbon, nitrogen, oxygen, hydrogen, and sulphur were also assessed. Proximate compositions, such as volatile matter, ash content, fixed carbon, and energy content, were evaluated. The obtained results are compared with established pellet quality standards to identify efficient blend ratios suitable for co-pelletization. Findings from the study are expected to strengthen feedstock handling, lower storage degradation, moderate logistics constraints, support waste valorisation, and broaden sustainable bioenergy access.

Keywords: Residual biomass feedstock, biomass blending, feedstock characterization, sustainable pelletization, bioenergy systems

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(A-15) Performance Evaluation of Rice Husk Biomass Briquettes as an Alternative Fuel for Industrial Boiler Applications

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Abstract

With the rising demand for sustainable and affordable energy, renewable biomass fuels are being explored as alternative to conventional fossil fuels. This study aims at investigating the performance evaluation of the rice husk biomass briquettes as an alternative fuel for industrial boiler application with focus on Kwara State Polytechnic, Ilorin, Nigeria. The rice husk was collected from the institution farm, processed into briquettes and tested for physicochemical and combustion performance properties. The study was experimental in nature, which included biomass characterization, briquette manufacturing, and testing of the combustion of the briquettes in a boiler under controlled conditions. The raw rice husk was analyzed for moisture, ash, volatile matter and calorific value. The initial moisture content, ash content and calorific value were found as 18.6%, 16.8% and 13.2 MJ/kg respectively. The moisture content was reduced to 8.1% after briquetting and the calorific value was raised to 15.8 MJ/kg, showing that the briquettes are more energy-dense and combustive. The briquettes were tested in a small scale boiler system with 3.0 kg of water and the performance indicators like temperature rise, burn rate, thermal efficiency, combustion efficiency and ash production were evaluated. The experimental results indicated a rise in temperature from 28°C to 92°C and the heat output produced was 804.29 kJ which was useful. The calculated thermal efficiency was 5.98% and combustion efficiency was estimated as 62.7%. The result of the burn rate was calculated as 0.0304 kg/min and ash content after combustion was calculated as 14.94%. The findings suggest that rice husk briquettes are a potential source of energy for rice husk fired CHP systems, as they offer low heat loss and moderate energy output under experimental conditions, but are also hindered by their low efficiency. It was concluded that rice husk briquettes are a renewable energy source for low to medium scale boiler application especially in the institutional and rural industrial application. Their use helps to reduce environmental pollution, waste-to-energy conversion and encourage circular economy within the agricultural community. It is recommended to further optimize the production of briquette and design of boiler to enhance thermal efficiency and scalability.

Keywords: Rice Husk, Biomass Briquettes, Renewable Energy

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(A-16) Conceptual Design and Performance Assessment of Waste-to-Energy Technologies Using the WROSE Model for an Integrated Energy Complex in South Africa

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Abstract

Waste-to-energy (WtE) technologies offer a dual contribution to sustainable waste management and renewable energy generation, particularly in rapidly urbanising developing countries where population growth simultaneously escalates waste generation and energy demand. In South Africa, landfilling has remained the prevailing municipal solid waste (MSW) management practice for several decades and is expected to continue in the near future, despite many landfill sites approaching the end of their operational lifespan. In response, the National Waste Management Strategy establishes a progressive solid waste diversion target of up to 60% by 2050, while national resource planning frameworks identify biomass as a potential pathway for energy generation. This work forms part of an integrated energy complex feasibility study funded by UK PACT and undertaken by multiple private consulting firms and Stellenbosch University for one of South Africa's metropolitan municipalities. This paper focuses on the work package led by Stellenbosch University and Anaergia Africa Pty Ltd, which assesses the conceptual design options for waste-to-energy technologies for MSW using the Waste Resource Optimisation and Scenario Evaluation (WROSE) model framework. Four conceptual design options were assessed for eThekwini Municipality using mixed municipal solid waste. The options included different configurations of anaerobic digestion, incineration, and pyrolysis. Performance was evaluated using key indicators, including energy production and consumption, greenhouse gas emission reduction, waste diversion, and landfill space-saving potential, relative to current waste management practices. The key results indicate that significant electricity generation could be achieved through anaerobic digestion (AD). Alternatively, upgraded biomethane production could replace diesel consumption in the municipal truck fleet. Additional benefits were observed when AD was integrated with pyrolysis, as this option demonstrated the highest overall fuel production potential among all the assessed scenarios. The AD-biomethane and incineration option combined fuel recovery with thermal treatment and generated the highest electricity potential. Overall, these results demonstrate that integrated waste treatment pathways substantially outperform single-stream options in maximising both electricity generation and fuel recovery from urban solid waste streams.

Keywords: Waste-to-energy, Municipal solid waste, Anaerobic digestion, Greenhouse gas emissions, Energy recovery, Pyrolysis, Incineration

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(A-17) Integrated biochar and vermicompost application for circular and sustainable maize production in Ethiopia

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Abstract

This study evaluated the combined effects of maize cob biochar (BC), vermicompost (VC), and reduced rates of inorganic NPSB–Urea fertilizers on soil chemical properties and maize yield in acidic Nitisols of Burie district, Northwest Ethiopia. A two-year field experiment was conducted using a randomized complete block design with a 3×3×3 factorial arrangement: N/P_2O_5 (0/0, 120/69, 240/138 kg ha^{-1}), BC (0, 4, 8 t ha^{-1}), and VC (0, 5, 10 t ha^{-1}). Grain yield was measured annually, and soil samples were collected before and after the experiment to assess treatment effects. Soil chemical parameters were analyzed using ANOVA and Pearson correlation, with normality and variance homogeneity verified in SPSS v27 and treatment effects analyzed in SAS 9.4 (PROC GLM). Partial budget analysis assessed economic feasibility. Integrated applications significantly improved soil chemical properties, increasing soil pH (from 4.87 to 5.82), soil organic carbon (SOC), total nitrogen (TN), and available phosphorus (avP), while reducing exchangeable acidity (Exc. Ac), hydrogen (Exc. H), and aluminum (Exc. Al). These chemical improvements were associated with higher maize grain yields. The highest mean yield (12.13 t ha^{-1}) was recorded under 120/69 kg N/P_2O_5 + 8 t BC + 10 t VC ha^{-1}, representing a 174.78% increase over the control (4.40 t ha^{-1}). The moderate treatment (120/69 kg N/P_2O_5 + 4 t BC + 5 t VC ha^{-1}, T14) consistently produced high yields (12.09 t ha^{-1}) and the highest net benefit (1861 USD ha^{-1} / 289,124 ETB ha^{-1}) with a marginal rate of return of 149.1%. Pearson correlation confirmed strong positive relationships between maize yield and improved soil chemical properties (SOC, TN, avP, pH). These results demonstrate that integrating BC and VC with reduced NPSB–Urea fertilizers effectively improves soil chemical conditions and maize yield in acidic Nitisols, providing a viable strategy for enhancing productivity while targeting soil chemistry.

Keywords: Maize cob biochar, maize yield, Nitisols, partial budget analysis, reduced inorganic fertilizer, soil acidity, vermicompost

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(A-18) Food and faecal waste as a biochar soil conditioner

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Abstract

Biochar is a carbon rich highly porous substance obtained after pyrolysis of organic biomass typically from feedstock of forest and agriculture residues, such as straw, nut shells, rice hulls, wood chips/pellets(Narzari et al, 2015). Production of biochar is a sustainable option for waste and disease management especially in the advent of growing waste streams such as food and faecal waste in urban areas. Hence this study explored the efficiacy of the prolysis of food waste(from orange peels, cassava and plantain/banana peels), faecal sludge and sewage sludge was to produce biochars.

Nine biochars were derived from three different precursors at three different temperatures (300°C, 450°C and 600°C) and were labelled as SSB, FWB and SDB. These were obtained from the Kwame Nkrumah University of Science and Technology (KNUST) campus in Kumasi city. Samples for the biochar production were picked around and in Food centres and the from the KNUST Sewage Treatment Plant. The biochar production was carried out at the Department of Materials Engineering, KNUST. Prepared samples were taken to the Soil Science Laboratory, KNUST and the Environmental Quality Engineering Lab KNUST where the quality of the biochar was analysed.

Proximate analysis was conducted on the charred samples and it showed that the highest moisture content 7.45% was recorded in FWB 60°C. The elemental analysis showed that carbon content decreased with increasing temperature across all samples from 58.97 to 81.28%. Also, physiochemical parameters such as Total Nitrogen (TN), Total Potassium (TK), Total Phosphorous (TP), Calcium (Ca), Magnesium (Mg), Organic Carbon (OC), Organic Matter (OM), Cadmium (Cd), Arsenic (As), Ash content, pH, Electrical Conductivity (EC), Moisture content, Porosity and Bulk Density, Bacteriological Analysis as well as the Germination test were performed on the various feedstock and biochar. Results obtained were subjected to the one-way ANOVA statistical analysis. The raw feedstock characteristics as well as pyrolysis temperatures had effects on the resultant biochars obtained. It was observed that the variability of samples from chemical composition affecting the stability of samples, providing increased concentrations of specific nutrients. For instance, biochar nturient results containing increased quantities of plantain/banana had the highest potassium levels, affirming literature. The advantage of biochar in these ratio provides reuse and income to local production with strict sanitary standards.

All biochar samples obtained a pass for germination, indicated by germination index (GI%) within 55%-80%. A control consisting of distilled water produced a GI of 50%. The highest GI of 80% was recorded by both SDB 450 ºC and SDB 600 ºC respectively, suggesting potential of samples to improve germination of crops rapidly compared to alternative options.

Keywords: Biochar, food waste, faecal waste

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(A-19) A Circular Economy Approach to Water Reuse: Converting Olive Mill Solid Waste into Biochar for Efficient Olive Mill Wastewater Treatment

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Abstract

Morocco is facing increasing water scarcity driven by recurrent droughts, climate change, and the uneven distribution of water resources. Renewable water availability has declined dramatically from approximately 2,500 m³ per capita per year in the 1960s to less than 600 m³ per capita per year today, far below the international water stress threshold of 1,700 m³ per capita per year. In this context, the reuse of unconventional water resources has become a strategic priority for ensuring sustainable water management. Olive mill wastewater (OMWW), represents both an environmental challenge and an untapped water resource. Its high concentrations of organic matter, suspended solids, and phenolic compounds make uncontrolled disposal particularly from small-scale olive mills a significant source of soil degradation and surface and groundwater pollution. This study presents an integrated circular-economy approach that converts olive mill solid waste (OMSW) into high-performance biochar for the treatment, detoxification, and potential reuse of OMWW. Biochar production was optimized using Response Surface Methodology based on a Doehlert experimental design, considering residence time, pyrolysis temperature, and heating rate. Multi-criteria optimization with the desirability function produced biochar with a yield of 27.7%. To evaluate continuous treatment under practical operating conditions, a fixed-bed column filtration system was developed using OMSW-derived biochar and raw olive stone (OS) as low-cost adsorbents. Biochar produced by pyrolysis at 585 °C exhibited a high BET surface area of 258.72 $m^2\ g^{-1}$, including 115.58 $m^2\ g^{-1}$ of microporous surface and 143.14 $m^2\ g^{-1}$ of external surface area. Under identical flow conditions (1 mL min^{-1}), biochar significantly outperformed raw olive stone. Following two successive filtrations, biochar achieved removal efficiencies of 91.6% for total suspended solids (TSS), 68.5% for mineral matter (MM), 73.5% for total phenolic compounds (TPC), and 76.4% for chemical oxygen demand (COD). Overall, this work demonstrates that OMSW-derived biochar is an effective, low-cost, and sustainable adsorbent for OMWW treatment, simultaneously promoting agricultural waste valorization and wastewater remediation. By substantially reducing the organic and phenolic pollutant load, the proposed process facilitates the recovery of valuable polyphenols and opens new opportunities for the safe reuse of treated OMWW in agricultural irrigation and other non-potable applications, thereby contributing to water resource conservation and sustainable olive oil production in water-scarce regions such as Morocco.

Keywords: Biochar, olive Mill wastewater, water reuse, polyphenols, sustainable management, Circular Economy

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(A-20) Optimizing the Utilization of Vermicompost in Nile tilapia (*O. niloticus*) culture in open cemented pond system

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Abstract

The increasing global demand for protein-rich animal feeds necessitates the exploration of sustainable alternatives to traditional fertilizers in aquaculture. This study investigates the application of vermicompost as an organic fertilizer in O. niloticus culture, aiming to assess its impact on growth performance, production efficiency, and economic viability. Conducted at Sidama Agricultural Research Institute, the experiment utilized four treatment groups with varying vermicompost application rates (0, 5000, 10000, and 15000 kg/ha/year) over a 12-week period. Results indicated that O. niloticus in the highest vermicompost treatment (15,000kg/ha/yr) achieved significantly higher final weights (115.29 g for males and 72.88 g for females) followed by 5,000kg/ha/yr and average daily gains (1.12 g/day for males and 0.70 g/day for females) compared to the control. The economic analysis revealed that 15,000kg/ha/yr vermicompost application generated the highest net revenue (471,534 ETB) and a favorable benefit-cost ratio (3.89) followed by 10,000kg/ha/yr, demonstrating the financial benefits of integrating vermicompost in O. niloticus farming. Overall, the findings underscore vermicompost as a viable, environmentally friendly alternative to inorganic fertilizers, promoting sustainable aquaculture practices while enhancing growth and production outcomes in O. niloticus. Future research should explore the nutritional benefits of vermicompost to further optimize aquaculture systems.

Keywords: Aquaculture, Circular economy, Economic viability, Growth performance, Nile tilapia, O. niloticus

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(A-21) Sustainable Biomass Sourcing, Aggregation and Storage Strategies for Efficient Energy Production: A Mini-Review

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Abstract

Biomass sourcing is among the most essential phases of bioenergy production. It serves as a pivotal sustainability indicator in setting up a biorefinery, as it determines feedstock availability, process efficiency, and environmental performance. This paper explores innovative measures in sustainable feedstock sourcing, aggregation, and storage with emphasis on climate resilience, ecological safety, and energy sustainability. Relevant literature published within the last five years was critically synthesized to evaluate current developments in biomass supply systems for efficient energy production. The review reports major biomass feedstock categories, sustainability indicators, feedstock availability, and environmentally responsible harvesting approaches. Particular attention was given to the utilization of residual biomass resources, climate-resilient energy crops, and waste-to-energy pathways as practical options for strengthening sustainable bioenergy production. Collection systems, aggregation models, transportation logistics, pretreatment techniques, and storage strategies were also examined because they influenced feedstock quality, supply chain efficiency, and overall conversion performance. The paper also reports policy and socio-economic aspects governing biomass production and harvesting to enhance energy production, adoption, and use. Persistent challenges associated with feedstock variability, logistics cost, storage degradation, land-use pressure, and infrastructure limitations were identified as major barriers affecting sustainable biomass deployment. Future perspectives on smart biomass logistics, circular bioeconomy integration, and climate-smart sourcing systems were equally discussed. Overall, the study shows that efficient and sustainable biomass sourcing, aggregation, and storage are fundamental for improving renewable energy production and environmental safety, and for advancing sustainable bioenergy systems.

Keywords: Sustainable biomass sourcing, climate resilient feedstocks, biomass supply chain, bioenergy systems

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(A-22) Mapping Biomass Hotspots and Community Energy Vulnerability for Sustainable Biogas Development in Nigeria

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Abstract

Persistent energy poverty and poor management of agricultural residues continue to constrain sustainable energy development in Nigeria despite the country's substantial biomass resources. This study mapped biomass hotspots and community energy vulnerability to identify priority locations for sustainable biogas development. Coconut husk, desert-date residue, and doum palm shell were evaluated using published agricultural statistics, government reports, measured occupancy factors, residue-to-product ratios, recoverability factors, and calorific values. State-level biomass distribution was derived through a scenario-based spatial allocation framework because comprehensive subnational production statistics were unavailable. Biomass hotspot indices were developed from recoverable biomass, biomass density, energy potential, biogas equivalent, and biogas density, whereas community energy vulnerability was assessed using indicators of electricity access and rural energy dependence. Sensitivity analysis was performed using recoverability factors to evaluate uncertainty in biomass recovery.

The analysis estimated 121,510 metric tons yr^{-1} of recoverable coconut husk biomass, with Lagos contributing 85,057 metric tons yr^{-1} (70% of national production), corresponding to an energy potential of 2.19×10^9 MJ yr^{-1}, a biogas equivalent of 1.02×10^8 m^3 yr^{-1}, and a biogas density of 2,826 m^3 ha^{-1}. Desert date generated 73.95 metric tons yr^{-1} of recoverable biomass, equivalent to 1.36×10^6 MJ yr^{-1} and approximately 6.31×10^4 m^3 yr^{-1} of biogas, with biogas density reaching 18.45 m^3 ha^{-1} across the Sahelian production belt. Doum palm exhibited the greatest biomass resource, with recoverable shell biomass ranging from 5.69 to 7.12 million metric tons yr^{-1} under recoverability factors of 0.80–1.00, producing 112.36–140.46 PJ yr^{-1} of energy and an equivalent biogas potential of 5.23–6.53 billion m^3 yr^{-1}, corresponding to biogas densities of 1,408–1,760 m^3 ha^{-1}.

The spatial convergence analysis identified Lagos as the principal coconut biomass hotspot and northern Nigeria as the dominant desert-date and doum palm hotspot, with several high- vulnerability communities located within those biomass-rich zones. Integrating biomass availability with community energy vulnerability provides a stronger basis for prioritizing decentralized biogas investments than resource assessment alone and offers a practical decision-support framework for state-level renewable energy planning and rural energy policy in Nigeria.

Keywords: Biomass hotspots, Sustainable energy, Waste-to-energy, Biogas development, Biogas in Nigeria, Biomass resources

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(A-23) Drying kinetic models, thermodynamics, physicochemical qualities, and bioactive compounds of avocado (Persea americana Mill. Hass variety) seeds dried using various drying methods

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Abstract

Avocados are among the most well-known nutrient-rich fruits worldwide. However, there is a high production of by-product waste, mainly avocado seeds. Avocado seeds can be used in many functional food and non-food applications, due to their nutritional and health-promoting properties. However, preservation technologies such as drying are essential to increase shelf life and preserve bioactive compounds. It has been anticipated that pre-drying techniques could improve the quality of dried products. This study investigates the drying kinetics of avocado seed slices that have been subjected to different pre-treatments (ascorbic acid, blanching, roasting) and drying methods (fluidized bed dryer, hot air dryer, and solar dryer) using freeze-dried samples as a control. In addition, the interaction effect of pretreatment and drying methods on the thermodynamic properties, physicochemical quality, and bioactive compounds of dried avocado seeds were also evaluated. Results indicate that the logarithmic model provides the best fit for the experimental data on drying kinetics. Thermal profile coefficients for avocado seeds activation energy and effective moisture diffusivity were predicted to range from 80.91 to 97.02 kJmol-1, and 4.8 to 5.8 x 10-10 m2s-1, respectively. Moreover, the study showed that the sample treated with roasting and dried using hot air drying (HAD) achieved the maximum desirability value of 0.9256 for thermal profile coefficients. In terms of nutritional and bioactive compound retention, samples treated with ascorbic acid and dried using a fluidized bed dryer (FBD) exhibited maximum values of phenols (106.6 mg GAE/100 g) and vitamin C (77%), along with a total colour difference recovery of 86%. In summary, dried avocado seeds are a valuable source of macronutrients and bioactive compounds, highlighting their potential as functional ingredients in the food industry. Furthermore, the implications of this research finding is to produce stable products with better quality from plant by-products using the proper drying methods and promoting a circular economy.

Keywords: avocado seed, bioactive, drying methods, plant by-product, physicochemical, thermal profiles

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(A-24) Hydrogen-Rich Syngas Production from Coffee Husk and Bagasse in a Throated Updraft Gasifier for Sustainable Energy Applications

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Abstract

The growing demand for clean energy systems has intensified interest in hydrogen-rich syngas derived from biomass gasification. Agricultural residues such as coffee husk and sugarcane bagasse offer significant potential for sustainable hydrogen production. Hence, in this paper, hydrogen-rich syngas production in a throated updraft gasifier is investigated using both thermodynamic equilibrium modeling (TEM) and experimental analysis by utilizing coffee husk and bagasse biomass feedstocks. Syngas composition, lower heating value (LHV), gas yield, and cold gas efficiency (CGE) are determined. The influence of moisture content (MC) and equivalence ratio (ER) on hydrogen yield is systematically analyzed. Results indicate that increasing ER leads to a decrease in H2, LHV, and CGE, while gas yield increase. Whereas, increasing MC enhances H2, and gas yield but reduces LHV, and CGE. At optimal operating conditions of 0.3 ER and 12% MC, coffee husk produces syngas containing 24.5% H2, while bagasse yields 23.54% H2. The corresponding hydrogen quality indicators show H2 to CO ratios of 0.9 and 0.86, and H2 to CO2 ratios of 2.73 and 2.23 for coffee husk and bagasse, respectively. Overall, coffee husk demonstrates slightly superior H2 production potential than bagasse. Moreover, compared to conventional updraft gasification, the incorporation of a throat increases H2 to CO2 ratio by 9% and 6% for coffee husk, and bagasse, respectively. These results indicate that the throated configuration promotes favorable reaction pathways and reduces tar formation, leading to enhanced H2-rich syngas production.

Keywords: Biomass gasification; Hydrogen-rich syngas; Sustainable energy; Throated updraft gasifier.

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(A-25) Design of an IoT-enabled portable biodigester for decentralized organic waste management in Togo

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Abstract

Energy insecurity and environmental pollution remain significant barriers to sustainable development in West Africa, with Togo exemplifying these challenges through rapid urbanization and heavy dependence on imported resources. Traditional agricultural practices, particularly cassava farming and processing, generate vast amounts of underutilized biomass and highly acidic wastewater. When left untreated, these processing residues are often discarded or burned, worsening local land and water pollution while contributing to greenhouse gas emissions. Building upon previous laboratory research that demonstrated a high volatile solids content (91.03%) and a maximum methane yield of 469.5 mL CH_4/g VS from cassava peels, this study shifts its focus to the practical engineering and implementation challenges of decentralized anaerobic digestion.

While centralized large-scale biogas plants face immense geographical and logistical barriers in sub-Saharan rural contexts, small-scale portable units offer a flexible and dynamic solution for local processing cooperatives. This paper aims to detail the complete design, structural construction, and intelligent monitoring framework of a compact, interconnected mobile biodigester prototype. The core methodology centers on practical engineering utilizing a durable high-density polyethylene (HDPE) vessel, specifically selected for its structural integrity and chemical resistance against highly acidic organic substrates and process effluents, such as cassava peelings and processing wastewater.

To overcome the common operational failures and lack of quality tracking in domestic bioenergy units, a specialized Internet of Things (IoT) hardware layer was integrated into the construction, focusing primarily on gas presence and concentration monitoring . A raccordement assembly utilizing a silicone tube and a PG9 gland reinforced with silicone sealant ensures gas-tight extraction from the HDPE vessel. For optimized gas composition tracking and safety, an MQ-4 methane sensor is deployed within a dedicated, external ventilated IP54 housing. This configuration isolates the delicate electronic components from the highly humid anaerobic environment (Marycz et al., 2025) while allowing continuous measurement of methane levels (ppm) to evaluate biogas quality and ensure early leak detection during usage (Asminar et al., 2025).

Centralized data processing is achieved using an ESP32 microcontroller, selected for its superior power efficiency, low cost, and built-in wireless connectivity required for remote operations (Ma et al., 2026).

The primary objective of this phase is to establish a reliable, real-time interface and a local control display for tracking methane concentration and gas availability, verifying the fuel's readiness for cooking applications. By successfully bridging digital instrumentation with affordable bioenergy technology, this work demonstrates a scalable, standalone approach to waste valorization and circular economy practices, contributing directly to Togo's climate adaptation and clean energy strategies.

Keywords: Cassava residues, smart biodigester, IoT engineering, ESP32 microcontroller, mobile waste-to-energy, methane monitoring.

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(A-26) Multi-Objective Deep Reinforcement Learning for Joint EV Charging and Renewable Energy Dispatch in Hybrid Energy Systems: A Case Study of Ethiopia

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Abstract

Ethiopia is undergoing one of the most rapid electric vehicle (EV) transitions in the world, having become the first country to ban the importation of internal combustion engine vehicles in January 2024. The national EV fleet has since grown to over 115,000 vehicles, with EVs accounting for more than 60% of new car registrations in 2024, yet the country has fewer than 100 public charging stations against a government target of 2030. This rapid fleet growth collides with a deeply heterogeneous power system in which grid-connected urban centers coexist with renewable-dependent off-grid rural communities, where less than 5% of the rural population has electricity access. Coordinating EV charging across this hybrid landscape requires the simultaneous optimization of competing objectives charging cost, renewable energy utilization, grid stability, battery longevity, and equitable service access a multi-dimensional challenge that existing single-objective and grid centric optimization methods cannot adequately resolve.

This study proposes a Multi-Objective Deep Reinforcement Learning (MODRL) framework for the joint coordination of EV charging and renewable energy dispatch across Ethiopia's grid-connected and off-grid hybrid renewable energy systems. The research formally models the problem as a Partially Observable Markov Decision Process with a five-dimensional reward structure, and designs, implements, and compares three MODRL architectures weighted scalarisation, Pareto-based Envelope Q-Learning, and decomposition-based MOEA/D-RL each integrated with a Vehicle-to-Grid (V2G) coordination module enabling EV batteries to function as flexible distributed storage assets. The framework will be trained and evaluated using an Ethiopia-calibrated simulation environment incorporating empirical solar, wind, and grid data, benchmarked against uncontrolled charging, rule-based scheduling, single objective reinforcement learning, and offline multi-objective optimisation baselines.

The research is expected to produce the first MODRL framework validated for hybrid grid/offgrid EV charging coordination in a developing-country context, generating Pareto-optimal charging policies, an open-source simulation environment, and evidence-based guidance for Ethiopia's e-mobility and renewable energy policy. Findings are anticipated to be transferable to other rapidly electrifying sub-Saharan African economies pursuing similar renewable-led EV transitions.

Keywords: Multi-Objective Reinforcement Learning; Electric Vehicle Charging; Hybrid Renewable Energy Systems; Vehicle-to-Grid; Pareto Optimisation; Ethiopia

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(A-27) Development and Performance Testing of low-emission injera baking gasifier stove

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Abstract

Renewable energy has now been recognized as the only solution to the problem of sustainable development. The fourth-largest source of energy in the world, biomass fuels account for 13% of all energy consumption. In developing countries, biomass energy is widely used for cooking foods like injera, but traditional stoves are inefficient and smoky. Improved gasifier stoves burn cleaner and use less fuel, making it essential to understand fuel properties and stove performance for better efficiency. Biomass combustion meets the basic energy needs for cooking, heating rural homes, and supporting traditional industries in developing countries like Ethiopia, accounting for 92% of the nation's primary energy. The traditional cooking and baking practices in Ethiopia have significant negative effects, including 16 million households using biomass stoves, 5% of deaths linked to respiratory illnesses from indoor air pollution, 24 million hours spent on firewood collection, and 86 million tons of wood consumed for fuel. Additionally, 20% of greenhouse gas emissions from deforestation are attributed to tree cutting for fuel wood. The development of gasifier cooking stoves is important due to their efficiency, smoke-free combustion, stable flame, easy flame control, and long-term operational capabilities. The objective of the present study was to design a biomass gasifier stove for injera baking purposes and evaluate its performance. Furthermore, the effect of the physical and thermal properties of the Eucalyptus Globulus wood fuel on the performance of the gasifier was experimentally investigated. Performance was influenced by the wood fuel's properties such as particle size, biochar yield, burning rate, syngas composition, and tar content. The gasifier stove was designed with a height of 50 cm and a diameter of 40 cm, operating at a temperature range of 657 to 840°C at full grate opening. Its performance was evaluated using Standard Control Cooking Test procedures, and regression analysis was conducted with IDM SPSS software. The largest increase in biochar yield (12% to 19.8%) was obtained by varying biomass particle size from 8 to 30 mm; however, larger particles also triggered tar generation, which peaked at 93g/m^3 syngas at 30-mm biomass particles; in contrast, the hydrogen content and CO composition in syngas was at its lowest at this condition, 2.89% and 11.82%, respectively. The amount of tar present in the syngas was negatively correlated with the combustion temperature. Using 8mm-sized particles, a maximum combustion temperature of 840°C was attained. The burning time in the reactor using 6kg of fuel was 26 minutes. Results showed that heated air is more fuel-efficient for gasification and effective for reducing baking time. The Control Cooking Test indicated that the new gasifier reduces baking time and fuel usage by 32% and 50%, respectively, when compared to a three stone stove.

Keywords: air flow rate, fuel saving, gasifier stove, injera, moisture content, particle size

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(A-28) SASSCAL's roles in the Production of Renewable Ammonia for Global Markets in Africa: Fueling Europe's Decarbonization Ambitions through the PRAGMA -E Project

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Abstract

Ammonia plays a vital role in global food production, yet most of its current output depends on fossil fuels, contributing significantly to greenhouse gas emissions. Many African countries rely heavily on imported fertilisers, which are often expensive and vulnerable to global market disruptions. At the same time, Africa possesses abundant renewable energy resources that could enable the production of green ammonia for both domestic consumption and export. This creates a strategic opportunity, particularly as Europe pursues climate neutrality and increasingly depends on imported green hydrogen derivatives, including green ammonia, due to limited domestic renewable capacity. Despite this clear complementarity between African supply potential and European demand, Africa's green ammonia value chain remains underdeveloped and insufficiently supported by robust evidence and hence the research objective of PRAGMA-E Project is addressing and finding solutions to the these shortcomings . This weak evidence base these hampers effective policymaking, limits investor confidence, and slows the development of integrated markets, ultimately constraining Africa's ability to capture economic, environmental, and food security benefits from green ammonia production.

SASSCAL methodology for the PRAGMA-E exercise is through combining quantitative technical assessments with qualitative analyses, as this ensures findings that are practical, evidence-based and directly applicable. Furthermore, these interdisciplinary methodology integrates engineering, economics, agricultural policy, social sciences, and environmental assessment into a coherent framework, ensuring a robust, interdisciplinary approach that addresses both technical feasibility and socio-economic inclusivity.

The findings for SASSCAL PRAGMA-E includes the development of the geospatial datasets and cost maps of green hydrogen and green ammonia potential in selected African countries focusing on Namibia, Morocco and Senegal; domestic fertilizer demand forecasts and agricultural demand identified addressing implications for food security ensuring intra-African utilization and identifying commercial pathways that align with real-world market conditions. Furthermore, the findings will also include appropriate regulations and formulated trade frameworks that would boost agricultural productivity, food security and decarbonization in Africa and Europe.

PRAGMA-E advances several Sustainable Development Goals (SDGs), notably SDG 2 (Zero hunger), 7 (Affordable and clean energy), 9 (Industry, innovation, and infrastructure), 13 (Climate action) and 17 (Partnership for the goals). Furthermore, Africa's underpinning frameworks such as regional power pools, offer the foundation for an interregional approach to green hydrogen and green ammonia. This not only supports export strategies but also fosters domestic industrial development, helping countries meet their Nationally Determined Contribution (NDCs), decarbonize regional and global value chains, and move toward long-term green energy and green fertilizer self-sufficiency.

Keywords: Green Ammonia; Green Hydrogen; Value Chain Development; Market Analysis;

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(A-29) GreenQUEST – A Holistic Study of Green LFG as a Drop-in Cooking Fuel Replacement

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Abstract

Over 2 billion people across the world lack access to modern, clean and affordable fuels and technologies to carry out daily household activities, such as cooking, heating and lighting, with this situation being exacerbated in sub-Saharan Africa. As a result, many households rely on traditional fuels such as biomass (wood, agricultural residues, and animal dung), coal, and kerosene, which are inefficient and harmful to human health. Women and children are disproportionately affected, bearing the burden of fuel collection and experiencing greater exposure to household air pollution (HAP), particularly during cooking. According to the World Health Organization, HAP was responsible for approximately 6.7 million deaths in 2019 [1].

Liquefied petroleum gas (LPG) has been classified as a priority transition fuel in Sub-Saharan Africa to address this energy inequality [2]; however, it remains a fossil fuel. Project GreenQUEST seeks to produce a green, sustainable alternative to LPG – called green Liquefied Fuel Gas (LFG) – made from captured CO_2 and green-H_2, as a drop-in replacement for LPG (Figure 1).

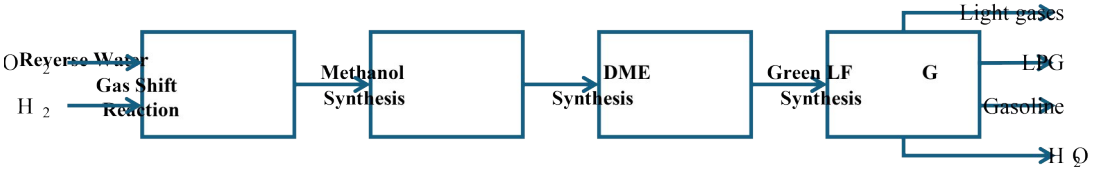


Figure 1: Synthesis of green LFG from captured CO_2 and green-H_2

This project represents a successful collaboration between South African institutions (University of Cape Town, Nelson Mandela University, CSIR, and HYENA) and German partners (Helmholtz Zentrum Berlin and Forschungszentrum Jülich GmbH), running from 2022 to 2026.

A key challenge for achieving commercial viability of such a process (Figure 1) lies in the final synthesis step; the catalytic conversion of dimethyl ether (DME), a key intermediate, into green LFG - which has been successfully demonstrated in this work (Figure 2), maintaining high green LFG selectivity (C_3 + C_4 hydrocarbons) and stable DME conversion over extended time-on-stream [3].

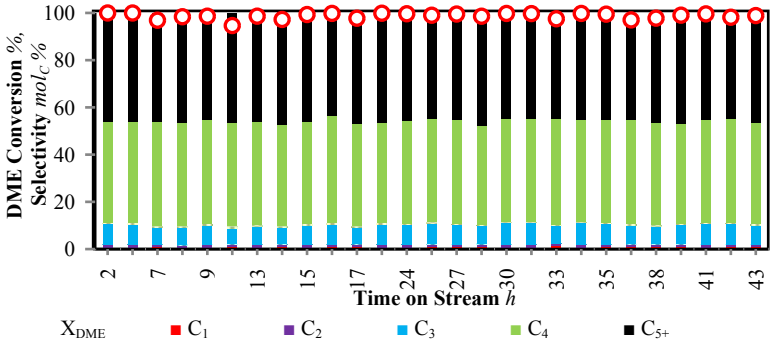


Figure 2: DME conversion (X_{DME}) and hydrocarbon selectivity (■) evaluated over a Pd/Beta catalyst under high conversion conditions.

Beyond the catalytic focus of the project, this paper synthesizes findings across four interconnected pillars of the LPG value chain to present a holistic, systems-level perspective on green LFG – an approach that is rarely captured within a single study and which highlights the necessity of interdisciplinary collaboration for successful real-world implementation.

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- Technical: a technoeconomic assessment of the process for green LFG synthesis in Figure 1, catalytic upscaling green LFG synthesis, and validation of green LFG in cooking trials and electricity generation [4].
- Social: user acceptance of a green cooking fuel in low-income communities, assessment of the current LPG distribution network (from imports to end-consumer use), and job creation potential within a renewable fuel economy.
- Environmental: identification of CO_2 sources within South Africa, and circularity and life cycle assessments (from cradle to gate, and cradle to grave) of green LFG.
- Economic: policy analysis surrounding LPG and the inclusion of a renewable alternative, as well as identifying economic hubs and regions within South Africa for affordable green LFG synthesis.

Together, these findings demonstrate the feasibility of green LFG as a scalable, sustainable drop-in solution to advance clean cooking access while supporting a low-carbon energy transition in Africa.

Keywords: Renewable LPG, green-H_2, Power-to-X, clean cooking, carbon capture and utilisation, energy systems integration

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(A-30) Green Ammonia Production Scenarios and Cost Analysis for Nigeria's Fertiliser Sector

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Abstract

In 2022, Nigeria's fertiliser consumption was estimated at 1.8 million metric tonnes, against demand exceeding 2.5 million metric tonnes. The three largest urea plants (Dangote, Indorama Eleme, and Notore) have a combined design capacity of 6.5 million metric tons per year but produced only 3.65 million MT in 2023, largely due to chronic natural gas shortages. The NIGERIA4H project examined whether green hydrogen could fill that gap, and what it would cost. Using three scenarios developed through 2060 (Local NPK, Best Guess, and H2 Diplo), the study modelled investment requirements and green ammonia production trajectories based on a 20 MW electrolyser reference model, using both alkaline water electrolysis (AWE) and proton exchange membrane (PEM) technologies. Electricity inputs were assessed across solar PV (1,200–1,830 full load hours/year), onshore wind (450–1,100 full load hours/year), and hydropower (3,600–4,600 full load hours/year). The levelized cost of hydrogen under the optimistic progression reaches approximately 1.5 €/kg by 2050. At that price point, green ammonia produced via hydropower-AWE approaches cost competitiveness with grey ammonia, whose production in Nigeria currently depends on fossil-derived hydrogen. The H2 Diplo scenario is the most ambitious, projecting Nigeria as a regional green ammonia exporter. The Best Guess scenario targets domestic fertiliser self-sufficiency. Even under the most conservative Local NPK scenario, integrating green hydrogen into existing ammonia plants remains a viable near-term option, especially for Dangote Fertiliser, which operated at only 50% capacity in 2023 due to gas supply constraints. The limitation is that Nigeria's fertiliser policy has been inconsistent across government transitions, and both the Agricultural Transformation Agenda and the Agricultural Promotion Policy struggled to maintain continuity of implementation. In addition, investment decisions will need stable offtake frameworks that current policy doesn't yet guarantee.

Keywords: Green ammonia, green hydrogen, fertiliser, Nigeria, scenario analysis, food security

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(A-31) Food Waste Valorization into Biofertilizer: A Circular Approach for Smallholder Farmers

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Abstract

Food waste is one of the most rapidly growing waste streams globally, representing approximately one third of all food produced for human consumption and having significant environmental, economic and social consequences. Africa generates large quantities of biodegradable food waste from households, municipal markets, and agro-processing industries that goes to landfills adding to greenhouse gas emissions with valuable nutrients under-utilised. At the same time, declining soil fertility, increasing fertiliser prices and decreased agricultural productivity for smallholder farmers.

The study investigated the valorization of food waste to biofertilizer with the Black Soldier Fly (BSF) (Hermetia illucens) larvae as a circular bioeconomy. The effect of various combinations of food waste as larval feed substrates on waste conversion efficiency and physicochemical properties of the produced frass were studied. The feedstocks were characterized and the produced frass was analyzed in the laboratory for nutrient composition, organic matter content, pH, moisture content and fertilizer quality. The study also assessed the suitability and potential of BSF frass as an organic fertilizer for sustainable crop production.

The results indicate that Black Soldier Fly (BSF) larvae efficiently bioconvert mixed food waste (including vegetables, fruits, and poultry manure) into nutrient-rich frass with better soil amendment potential than single-stream waste, producing frass with total nitrogen ranging from 0.82% to 1.99%, phosphorus from 0.16 to 0.52, and potassium from 0.19% to 2.82%. The composition of the feedstock strongly influenced larval growth performance, waste reduction efficiency and macro- and micronutrient concentrations in the resulting biofertilizer. The results are consistent with the circular economy principle of closing the loop between urban food waste and agricultural production systems. The approach directly supports the achievement of SDG 2 (Zero Hunger), 12 (Responsible consumption and production) and 13 (Climate action).

This work shows that the Black Soldier Fly technology offers a scalable and sustainable pathway for waste valorization with the potential to transform food waste from an environmental burden into a valuable agricultural resource. The findings offer concrete proof for policy makers, municipalities, waste management practitioners, and agricultural stakeholders to advance circular bioeconomy strategies that enhance resource recovery and build resilience in smallholder farming systems across Africa.

Keywords: Food waste; valorization; Black Soldier Fly; Organic waste recycling; Sustainable agriculture

With funding from the:
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(A-32) Material Flow Analysis for Institutional Bio-waste Assessment as a Basis for Decentralized Waste-to-Energy Planning

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Abstract

Effective implementation of circular economy (CE) practices requires having access to context-specific information on waste generation rates and material flow distribution patterns, yet such data are still sparse in resource-poor institutional entities in developing countries, especially in the context of residential institutions with significantly high organic waste generation rates, such as universities with on-campus residential hostels. This study aims to make use of Material Flow Analysis (MFA) to analyze the generation and flow of biowaste in the Federal University of Education, Zaria, Nigeria as part of the planning of circular resource recovery. The study will identify and measure organic waste flows from generation to disposal and use mass balance techniques to balance inputs and outputs throughout the processing nodes to identify where material is lost from the system. Data will be gathered via on-site waste sampling, segregation and weighing of biodegradable streams, observation of waste handling practices, and the tracking of waste movement from waste production point to the disposal point within the institution. The resulting mass balance should highlight the main pathways of waste, the highest losses of material, and the amount of organic waste that may reasonably be recovered. The approach is transdisciplinary by combining technical waste characterization and institutional management practices and can be easily replicated in similar institutions in Nigeria and in other countries in the developing world to enable locally appropriate circular economy planning beyond this case. The study adds to the current discussion about the practical implementation of CE at institutions where waste management systems are weak and underdeveloped and the resulting baseline data can be used for future waste-to-energy projects at the institutional level, specifically for decentralized biogas recovery.

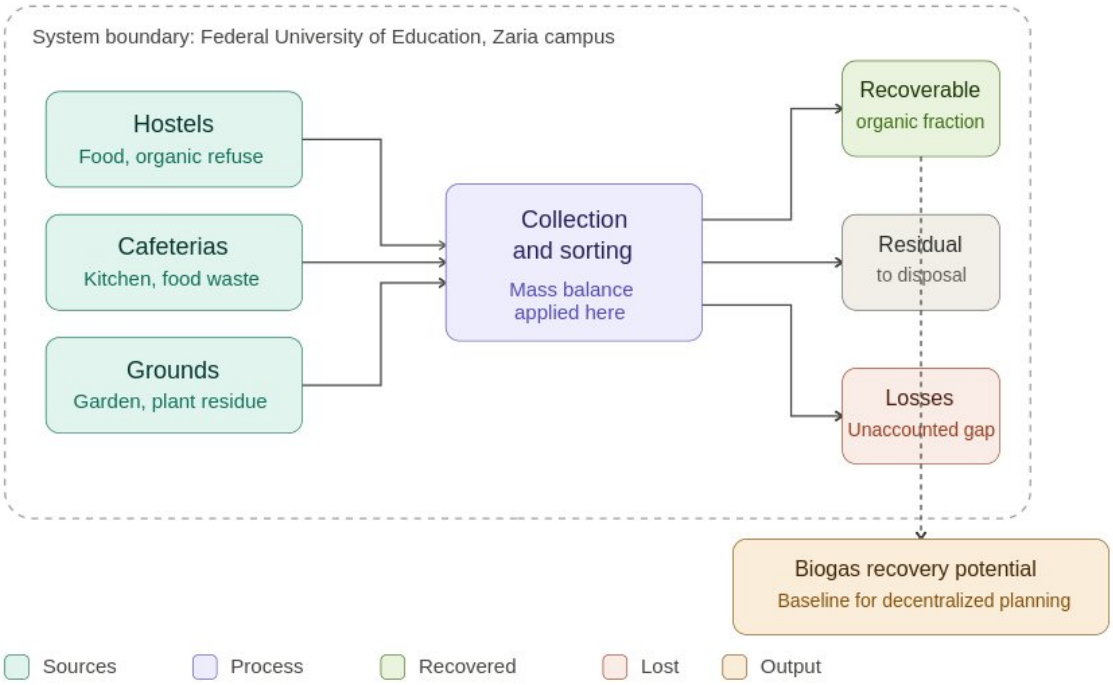
Keywords: Circular economy; Material Flow Analysis; Institutional biowaste; Resource recovery; Waste-to-energy; Sub-Saharan Africa

Figure 1: Material Flow Analysis (MFA) framework for institutional bio-waste assessment, showing the pathway from data collection to waste-to-energy planning.

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B- Green hydrogen production, utilization, policy, regulatory framework, industrial requirements and transition

(B-1) Ethiopia's Renewable Energy and Water Resources Potential for Green Hydrogen Production: A Roadmap to Sustainable Development

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Abstract

The global transition toward low-carbon energy systems has increased interest in green hydrogen as a sustainable pathway for decarbonization, defossilization, energy security, and green industrial development. Ethiopia possesses abundant renewable energy and freshwater resources that provide favorable conditions for green hydrogen production through water electrolysis. This review assesses Ethiopia's renewable energy and freshwater resource potential and evaluates their prospects for supporting a future green hydrogen economy. Peer-reviewed literature related to freshwater availability, renewable energy resources, and green hydrogen development was critically reviewed to identify opportunities, challenges, and future development pathways. The findings indicate that Ethiopia has substantial freshwater resources, including approximately 124.4 billion m³ of annual river runoff, 70 billion m³ of lake water, and nearly 30 billion m³ of renewable groundwater reserves. The country also has significant renewable energy potential, including about 45 GW of hydropower, 10 GW of wind energy, and solar irradiation ranging from 4.5 to 7.5 kWh m^{-2} day^{-1}. Ethiopia's installed electricity generation capacity is currently dominated by hydropower, which could potentially be allocated for green hydrogen production after meeting domestic electricity demand. The relatively low cost of renewable electricity, particularly from hydropower, provides favorable conditions for competitive green hydrogen production. However, challenges related to grid infrastructure, transmission capacity, financing, policy frameworks, and technological readiness remain major barriers to large-scale implementation. Overall, the strategic integration of Ethiopia's renewable energy and freshwater resources could accelerate green hydrogen development and contribute to climate change mitigation, industrial decarbonization, sustainable development, energy security, and regional energy integration.

Keywords: Green hydrogen; Renewable energy; Freshwater resources; Decarbonization; Defossilization; Electrolysis; Energy transition; Sustainable development; Power-to-X; Ethiopia

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(B-2) Green Hydrogen for Agricultural Decarbonisation in Nigeria: A Demand Anchoring and Project Development Framework

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Abstract

Green hydrogen is increasingly recognised as a strategic pathway for decarbonising energy-intensive sectors while supporting sustainable industrial growth. In Nigeria, the agricultural sector presents a major opportunity for green hydrogen deployment due to rising fertiliser demand, expanding agro-industrial activities, and national priorities for food security and climate resilience. However, green hydrogen development in Nigeria remains limited by low project maturity, uncertain offtake structures, and insufficient integration between sectoral demand and investment planning.

This study explores the potential of green hydrogen for agricultural decarbonisation in Nigeria through a demand-anchoring and project-development framework adapted to the country's agricultural and industrial context. The analysis focuses on agriculture-related value chains, particularly green ammonia for fertiliser production and hydrogen-supported agro-industrial energy systems. A qualitative case study methodology was used, combining desk research, agricultural market analysis, policy review, and comparative assessment of green hydrogen and green ammonia initiatives in African contexts.

The findings identify Nigeria's fertiliser sector as the most credible near-term demand anchor for green hydrogen because of existing industrial infrastructure, sustained domestic fertiliser demand, and dependence on hydrogen-intensive ammonia production. The study also finds that Nigeria has strong renewable energy potential, particularly solar resources, capable of supporting electrolytic hydrogen production. At the same time, infrastructure limitations, financing constraints, and the absence of dedicated hydrogen regulation remain important barriers.

The research further demonstrates that investment readiness depends on a structured project development pathway integrating demand assessment, technical feasibility, offtake agreements, stakeholder coordination, and financial de-risking measures. The proposed framework indicates that integrating green hydrogen into Nigeria's agricultural transformation strategy can reduce emissions linked to fertiliser production while strengthening agricultural productivity and supporting food security.

The study concludes that agriculture can provide a practical entry point for green hydrogen development in Nigeria and offers a scalable framework for agricultural decarbonisation and green industrial transition across Sub-Saharan Africa.

Keywords: Green hydrogen, agricultural decarbonisation, green ammonia, fertiliser production, project development, food security.

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(B-3) SASSCAL'S Progress on Green Hydrogen Pilot Projects, Research and Capacity Development

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Directorate of Science and Technology/Capacity Development, SASSCAL, Namibia

Abstract

The Joint Communique of Intent (JCOI) is a partnership between the governments of Germany and Namibia, focused on piloting green hydrogen projects and developing local capacity through research and education. The program, initiated in 2021, was extended in 2025 for another four years, now running until 2029. SASSCAL has a significant role in monitoring progress and coordinating the implementation of pilot projects in line with their respective plans and timelines.

This abstract presents the progress up to date on the current pilot projects, research and capacity development. The projects currently under implementation are the are the on-going Daures Green Hydrogen Village (DGHV) plus the newly contracted EXTENSION to the Cleanergy Green Hydrogen Plant and Refuelling Station Project and UNAM RealTest Project.

DGHV's purpose is production of green hydrogen and ammonia from renewable sources, job creation, and demonstration of green hydrogen applications in housing and agriculture, and it has completed most infrastructure work packages (boreholes, solar park, housing, greenhouses, training center, eco-lodge) all being fully operational. The hydrogen electrolyser and ammonia generation assets reached 90% completion by end of 2025 as it faced various delays in procuring appropriate equipment and consequent installation with the original equipment manufacturer (OEM).

Research collaboration on ammonia fertilizers production potential, mineral extraction, and electrode materials for water splitting by the University of Namibia (UNAM) and University of Stuttgart at DGHV, has been completed to about 80% of intended scope of research and research showed promising results for agricultural and industrial applications. There were challenges in equipment procurement and project commissioning which have impacted research timelines.

The Cleanergy Green Hydrogen Plant and Refueling Station's purpose was to demonstrate and integrate green hydrogen production and refueling technologies into Namibia's green economy and has progressed with major systems (electrolyser, compressors, solar-park, hydrogen-storage, dispenser) fully functional. The plant was commissioned and inaugurated in September 2025. The H2 Academy was tailor-made to provide a wide range of training on Green Hydrogen and related topics to learners and industry practitioners on site. It has already started providing safety and operational training for local stakeholders and staff.

Cleanergy EXTENSION Project is a new project that was contracted during September 2025 with purpose to expand local hydrogen applications, upskilling, capacity building, and research. It has progressed with procurement of Mobile refueller, hydrogen bus and dual-fuel trucks that are all operational.

The UNAM RealTest Project is a new project that was contracted in August 2025 and its purpose is safety and reliability testing, and sustainability research on green hydrogen technologies. It has secured equipment and progressed site preparations. The project will mainly focus on material compatibility, large-scale testing, and welding skills development.

Y4H2 scholarships programme's purpose is to build capacity among Namibian youth through academic and non-academic courses. The objective of the Y4H2 Scholarship programme is to equip the youth with unique and relevant skills in line with the envisaged Green Hydrogen Industry future. A total of

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235 scholarship beneficiaries consisting of 130 males and 105 females from all three cohorts spread from 2023, 2024 and 2025 participated in the programme, from Masters and Technical Vocational Education Training (TVET).

SASSCAL's progress in the green hydrogen sector marked significant milestones for Namibia's green hydrogen sector, including the first production of green hydrogen, successful scholarship graduations, and the operationalization of key pilot projects. Strategic efforts were in capacity development, research, and stakeholder engagement that have laid a strong foundation for future growth and innovation in the sector

Keywords: Green Hydrogen; Pilot Projects; Research; Capacity Development;

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(B-4) Integrating Wastewater Resource Recovery, Renewable Energy Generation and Green Hydrogen Production: A Circular Economy Framework for Sustainable Urban Development in Africa

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Abstract

Africa is experiencing rapid urbanisation, increasing energy demand, water scarcity, and mounting environmental pressures associated with waste generation and greenhouse gas emissions. Conventional wastewater treatment systems across many African cities remain energy-intensive, financially constrained, and focused primarily on pollution control rather than resource recovery. At the same time, many countries are investing heavily in renewable energy and green hydrogen initiatives to support sustainable development and climate resilience. Despite these efforts, limited research has explored how wastewater treatment infrastructure can be transformed into integrated resource recovery hubs that simultaneously support circular economy objectives, renewable energy generation, and green hydrogen production within African contexts.

This study proposes a transdisciplinary circular economy framework that integrates wastewater treatment, biogas recovery, renewable electricity generation, and green hydrogen production into a unified urban infrastructure system. The framework reimagines wastewater not as a waste stream but as a valuable resource containing water, nutrients, organic matter, and energy potential. The proposed approach combines anaerobic digestion of sewage sludge for biogas generation, solar photovoltaic energy systems for renewable electricity production, and electrolysis technologies powered by renewable energy to produce green hydrogen. Reclaimed wastewater serves as an alternative water source for electrolysis, reducing pressure on freshwater resources while enhancing resource efficiency.

The novelty of this research lies in the integration of three traditionally separate sectors which are mainly water management, renewable energy systems, and hydrogen production within a single circular economy model tailored for African cities. Existing studies often focus on individual technologies in isolation, with limited consideration of how these systems can be interconnected to maximize environmental, economic, and social benefits. Furthermore, many green hydrogen initiatives in Africa emphasize large-scale export-oriented projects, while comparatively little attention has been given to decentralized municipal applications capable of addressing local development needs. This research addresses this gap by proposing a scalable framework suitable for municipalities of varying sizes and levels of technological development.

The study adopts a systems-thinking and transdisciplinary methodology that combines engineering design principles, resource flow analysis, environmental sustainability assessment, and socio economic evaluation. Material and energy flows within wastewater treatment facilities are analysed to identify opportunities for resource recovery and energy optimisation. The framework also considers stakeholder participation, governance mechanisms, policy alignment, and community benefits to ensure practical implementation and long-term sustainability. Particular attention is given to the applicability of the framework within African urban centres where infrastructure limitations, financing constraints, and institutional challenges often hinder the adoption of advanced technologies.

Expected outcomes indicate that integrated wastewater resource recovery systems could significantly reduce operational energy requirements of treatment facilities while generating renewable energy and green hydrogen for municipal applications such as public transport, industrial processes, and backup power systems. The framework also contributes to reductions in greenhouse gas emissions, improved wastewater management, enhanced water security, and increased circularity of urban resource flows. Additional benefits include the creation of green jobs, promotion of local innovation, and support for sustainable industrial development.

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The proposed framework aligns strongly with the African Union's Agenda 2063, the United Nations Sustainable Development Goals (SDGs 6, 7, 9, 11, 12, and 13), and emerging national green hydrogen strategies across the continent. Its modular design enables replication in diverse African settings, from rapidly growing metropolitan regions to secondary cities seeking sustainable infrastructure solutions. By integrating wastewater resource recovery with renewable energy and green hydrogen production, the study contributes a practical pathway for advancing circular economy principles while addressing interconnected water, energy, and climate challenges facing Africa.

Keywords: Circular Economy, Wastewater Resource Recovery, Renewable Energy, Green Hydrogen, Sustainable Urban Development, Africa, Energy Transition, Resource Efficiency.

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(B-5) Assessment of the Green Hydrogen Production Potential from Agricultural Residues in Burkina Faso

[1]Bagaya, Noufou[1], Bulgo, Julien[1], Semekonawo, Kokou Prosper[1], Koffi, Kouakou Valentin[1,2], Korgo, Bruno[1,3], Narra, Satyanarayana[4], Sam Firmin[1], Ouedraogo, Dayagnewende Victorien[1]

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Abstract

The comprehensive analysis of agricultural residues in Burkina Faso reveals a substantial biomass resource of 21,505,629.4 metric tons per year, consisting of millet, sorghum, and cotton stalks, maize cobs, rice husks, and peanut and cashew shells. After accounting for competing uses, i.e., soil amendments, livestock, craftsmanship, and energy, the net mobilizable potential stands at 2,312,561 tons per year. Its geographical distribution enables a decentralized deployment of green hydrogen production. From a technological standpoint, gasification is the most suitable conversion pathway for dry lignocellulosic residues. Anaerobic digestion coupled with reforming is preferred for wet residues, with dark fermentation serving as a third option. Optimizing thermal processes and scaling up industrial operations (particularly for rice husks and cashew shells) help offset the high initial capital costs of small-scale installations, thereby achieving a competitive levelized cost of hydrogen.

The annual technical production potential reaches 4,342.88 tons of green hydrogen via dark fermentation and 85,806.57 tons via gasification. Furthermore, steam methane reforming of biogas generates a co-product of 85,806.57 tons of fertilizer per year. The study recommends maximizing the sector's efficiency through regional development hubs. In the Cascades region, integrating gasification into the sugar industry would add value to sugarcane bagasse. In cereal and cotton-producing zones, structuring collection chains for stalks and shells will support local energy autonomy and meet rural and industrial needs.

Keywords: Agricultural Biomass, Conversion Technologies, Green Hydrogen, Energy potential, Burkina Faso.

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(B-6) Mathematical Modelling of a 590 MW Wind Power for Green Hydrogen Production: A Case Study of the Daures Green Hydrogen Village in Namibia

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Abstract

Namibia has positioned green hydrogen as a strategic asset for long-term economic diversification and decarbonisation of its energy system. This study presents a mathematical modelling framework for assessing the technical and economic feasibility of a 590 MW wind-powered green hydrogen production system at the Daures Green Hydrogen Village (DGHV) in Namibia. DGHV is one of Namibia's flagship hydrogen pilot projects. The study evaluates the suitability of local wind resources to supply electrical energy to a Proton Exchange Membrane (PEM) electrolyser for large-scale hydrogen production. Site-specific wind data were analysed using the Weibull probability distribution to characterise wind speed variability at hub heights of 50 m, 100 m, and 120 m. Wind energy output was estimated using turbine power curve modelling, while hydrogen production was quantified assuming an electrolyser efficiency of 60%.

The findings indicate that an average wind speed of approximately 5 m/s at 120 m hub height yields a wind farm capacity factor of 32.5%. To achieve the targeted installed capacity of 590 MW, a total of 330 wind turbines rated at 5.5 MW each are required. Under these conditions, the system is expected to produce up to 20 kt of green hydrogen annually. Overall, the results confirm the technical feasibility of continuous wind-powered hydrogen production at the DGHV site. However, the economic analysis reveals a levelised cost of hydrogen (LCOH) of USD 5.02/kg and a payback period exceeding 20 years. The findings suggest that, under current cost assumptions, the project faces economic constraints that can threaten its viability. The presented mathematical modelling framework provides a tool to support decisions for energy system planning and hydrogen market development in Namibia.

Keywords: Green hydrogen, mathematical modelling, PEM electrolysis, techno-economic modelling, wind power.

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(B-7) Predictive Modelling of Green Hydrogen Production from a Rainwater-Harvesting Solar–PV Integrated System in a University Campus in the Global South.

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Abstract

Nigeria's persistent energy shortage and reliance on fossil-fuel-based energy generation in tertiary institutions demand urgent clean energy alternatives. This study develops and validates a predictive machine learning model to explore the potential for green hydrogen production at Covenant University (CU), Ota, by combining rooftop rainwater harvesting with a roof-mounted solar PV system over a 20-year (2026–2045) forecast period. A Random Forest (RF) model, trained on 25 years (2000–2025) of NASA POWER weather data, forecasts yearly rainfall and daily solar irradiance. Water volume collected from a 44,624 m^2 rooftop catchment (runoff coefficient = 0.85) was calculated, while annual PV electricity generation from a 9,468 m^2 array includes temperature-related efficiency reductions. Green hydrogen production was evaluated for three electrolyzer types: Alkaline (AWE, 63% efficiency), PEM (68% efficiency), and SOEC (74% efficiency), using a hydrogen lower heating value of 33.33 kWh/kg. CO_2 savings were compared to Steam Methane Reforming at 10.0 kg CO_2 per kg H_2. Rainfall is projected to stabilize between 1,320 mm and 1,850 mm annually, ensuring a reliable water supply. The PV system produces roughly 2,380 MWh per year, with PEM electrolysis generating the most hydrogen of about 36.4 tonnes annually, more than AWE (32.4 tonnes) and SOEC (29.1 tonnes). Although SOEC has higher efficiency, its stringent thermal management requirements necessitate reducing its net output without waste-heat recovery. PEM requires only about 325 m^3 of process water per year, which is minor compared to the catchment capacity. Using PEM avoids around 364 tonnes of CO_2 emissions annually, totaling over 7,200 tonnes over 20 years. Findings identify PEM electrolysis as the best option for campus-scale green hydrogen in tropical Nigeria. This integrated random forest-PV-electrolysis model offers a clear, data-driven plan for green energy adoption in higher education institutions across West Africa, supporting the achievement of SDGs 6, 7, 9, and 13, as well as Nigeria's 2060 Net-Zero Energy Transition Plan (NETP).

Keywords: Green hydrogen; Rainwater harvesting; Solar PV; Random Forest; PEM electrolysis; Decarbonisation; Nigeria

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(B-8) Valorisation of Phytoremediation Biomass for Hydrogen Production in Integrated Agroforestry and Agri-PV Systems: A Simulation-Based Assessment

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Abstract

The remediation of heavy-metal-contaminated soils in post-mining landscapes remains a major environmental challenge, particularly due to the limited utilisation of biomass generated through phytoremediation activities. Although phytoremediation is recognised as a sustainable remediation approach, it produces substantial quantities of non-edible biomass that are often inadequately managed, representing a missed opportunity for renewable energy recovery and resource valorisation. This study evaluates the potential for hydrogen production from harvested remediation biomass obtained from integrated agroforestry and agrivoltaics (Agri-PV) systems in post-mining areas. While previous studies have investigated phytoremediation and hydrogen production separately, limited research has explored the integrated application of phytoremediation, biomass valorisation, and renewable hydrogen production within a unified post-mining land restoration framework.

A simulation-based framework was developed using Aspen Plus to assess both biohydrogen and green hydrogen production pathways. Fast-growing and metal-tolerant species, including sunflower (*Helianthus annuus*), Moso bamboo (*Phyllostachys edulis*), and Indian mustard (*Brassica juncea*), were considered as phytoremediation feedstocks. Biohydrogen production was simulated through downdraft biomass gasification using the harvested plant material as feedstock, while green hydrogen production was modelled using alkaline water electrolysis powered by electricity from the Agri-PV system.

The simulation results indicate that the system could produce approximately 7,923 kg of green hydrogen annually through photovoltaic-powered electrolysis and 284 kg of biohydrogen through biomass gasification, resulting in a total hydrogen production of nearly 8.2 tonnes per year. These findings demonstrate the potential of converting contaminated plant-derived biomass into a valuable renewable energy resource in post-mining landscapes. The proposed approach also contributes to sustainable land management and circular economy objectives by integrating environmental remediation, renewable hydrogen generation, and resource recovery within a single framework. However, further experimental validation is required to evaluate the practical feasibility and long-term sustainability of the proposed system, particularly regarding tar formation, heavy-metal partitioning during gasification, and the limited experimental data available for the selected plant species as gasification feedstocks.

Keywords: Phytoremediation Biomass, Agrivoltaics, Biohydrogen, Green Hydrogen, Circular Economy

With funding from the:

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(B-9) Prospects for Solar Systems Manufacturing and Assembly in Southern Africa Amid Renewable Energy Advancements: A Focus on Namibia's Green Hydrogen Initiatives

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Abstract

Southern Africa continues to face challenges related to energy insecurity, technological dependence, and limited industrialisation in the renewable energy sector. Namibia, despite its abundant solar resources, remains reliant on imported energy technologies and electricity. The emergence of large-scale green hydrogen projects presents a strategic opportunity to stimulate domestic manufacturing and assembly of solar energy systems. This study examines the prospects of establishing solar systems manufacturing and assembly industries in Southern Africa, with particular emphasis on Namibia's green hydrogen developments and their potential contribution to regional energy security, industrialisation, and economic transformation.

The study adopted a qualitative research approach based on documentary analysis and literature review. Secondary data were collected from government policy documents, renewable energy reports, academic literature, industry publications, and regional trade frameworks, including the African Continental Free Trade Area (AfCFTA). The analysis focused on Namibia's renewable energy landscape, solar thermal deployment initiatives, green hydrogen projects, and regional industrial development opportunities.

The findings indicate that Namibia possesses significant comparative advantages for solar manufacturing and assembly, including high solar irradiation levels, supportive renewable energy policies, and growing investments in green hydrogen infrastructure. The study found that increasing deployment of solar thermal technologies in public institutions demonstrates the viability of local renewable energy solutions. Furthermore, green hydrogen developments are expected to increase demand for solar technologies, creating opportunities for downstream manufacturing industries. The AfCFTA framework provides an enabling environment for regional value chains, market access, and cross border trade in renewable energy technologies. However, challenges remain, including limited technical capacity, inadequate industrial infrastructure, financing constraints, and continued dependence on imported components.

The study concludes that Namibia is strategically positioned to become a regional hub for solar systems manufacturing and assembly. Green hydrogen investments provide a unique catalyst for industrial development, job creation, technology transfer, and enhanced energy security. Realising this potential will require coordinated policy interventions, investment in skills development, infrastructure expansion, and stronger regional cooperation. Successful implementation could contribute significantly to Namibia's industrialisation agenda while advancing sustainable energy transitions across Southern Africa.

Keywords: Solar Systems, manufacturing, assembly, Namibia, green hydrogen, southern Africa, renewable, energy

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(B-10) Decentralized Green Hydrogen Production in West Africa: A Machine Learning-Based Optimization of Solar-Biohydrogen Systems using University Campus Wastewater

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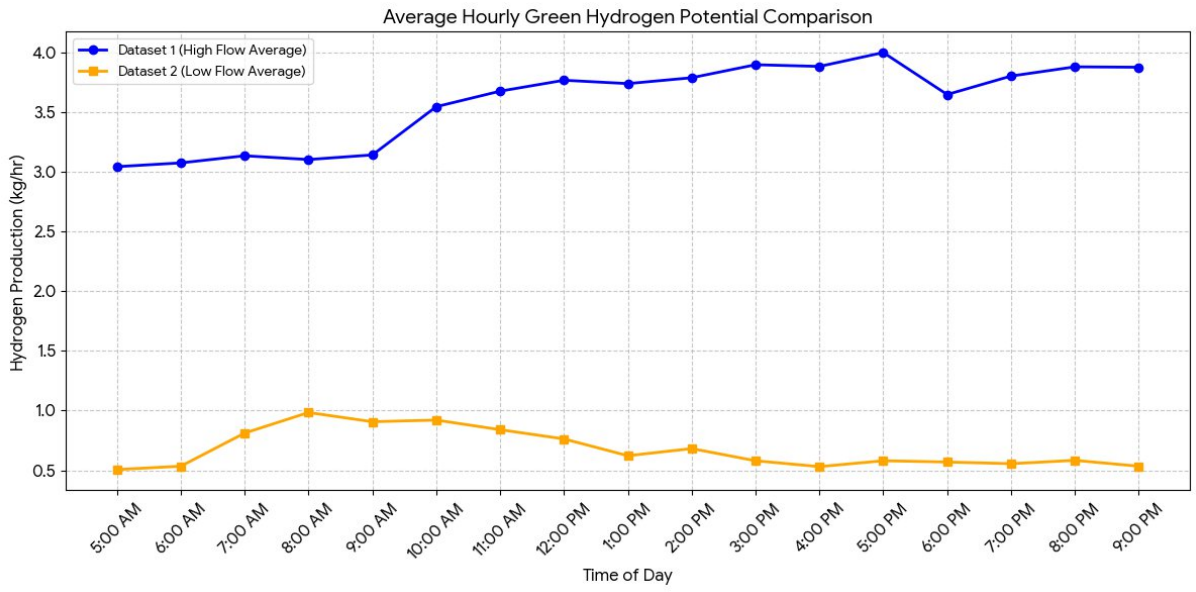
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Abstract

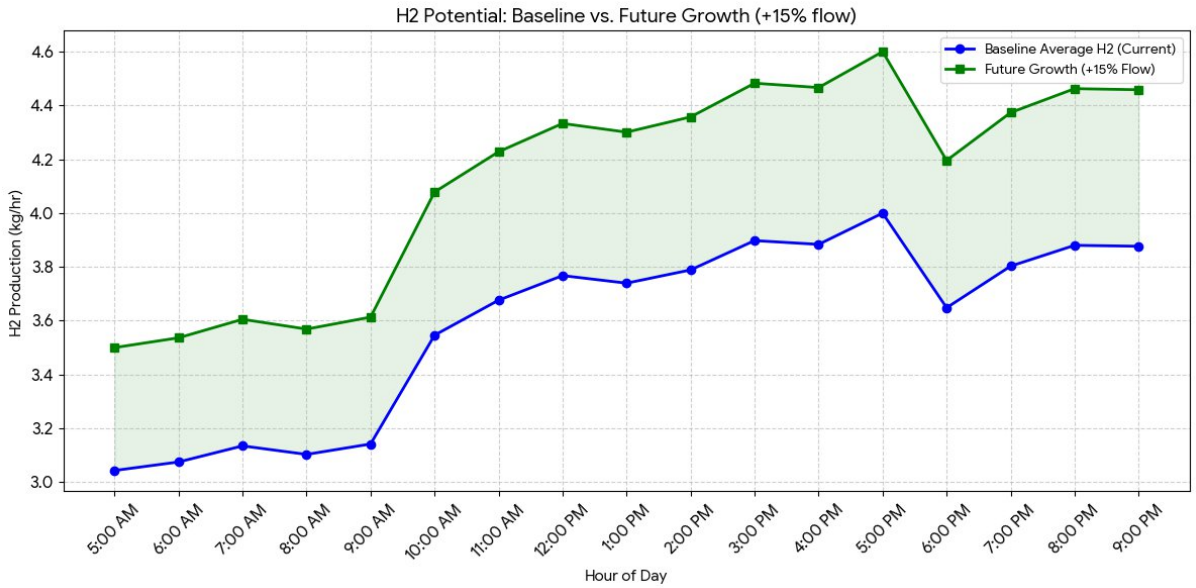
Sub-Saharan Africa faces a significant dual challenge: inadequate urban wastewater management and persistent energy poverty. This study introduces a circular Energy-Water Nexus framework that leverages institutional wastewater from the campus community to produce green hydrogen (H2) via solar-driven photofermentation. Using high-resolution hourly data from a Nigerian university, a decentralized system was modeled to synchronize variable hydraulic loads with solar photovoltaic (PV) availability. A comparative machine learning (ML) approach was employed to benchmark a Random Forest Regressor (RFR) against a Long Short-Term Memory (LSTM) neural network for predicting hydrogen potential. The models were trained on a continuous 168-hour cycle to account for daily peaks and hydraulic lag. The system's baseline weekly bio-hydrogen output was estimated at 427.04 kg, corresponding to an electricity generation capacity of 7,110.25 kWh via stationary fuel cells. Results showed the LSTM outperformed RFR, attaining an R-squared (R^2) of 0.803 and reducing RMSE by 14.7%. This better performance stems from LSTM's capacity to capture the temporal dynamics of wastewater discharge. Scenario analysis with a 15% increase in flow suggests a potential yield of 491.10 kg/week. This research provides a scalable, AI-driven model for decentralized energy hubs in West African campus communities with high wastewater generation. By converting waste water into a valuable energy carrier with 80% predictive accuracy, it offers a practical approach to low-carbon development and climate-resilient infrastructure in sub-Saharan Africa.

Keywords: Green Hydrogen, Decentralized Energy, Machine Learning, LSTM, Wastewater-to-Energy, West Africa

Relevant Figures



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(B-11) Modeling the Role of Biomass-Derived Hydrogen in Ethiopia's Pathway to a Fully Decarbonized Energy System by 2050: An OSeMOSYS-Based Integrated Energy System Analysis

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Abstract

A large amount of sustainable biomass residue produced in Ethiopia provides an opportunity to produce green hydrogen. The research presented in this paper represents the first GIS-supported assessment of the biomass-to-hydrogen production chain in Ethiopia. The results show that Ethiopia has an overall potential for biomass-to-hydrogen production, 24.1 million ton/year from sustainable biomass derived from seven major crop residues; however, only 15.65 million ton/year of technically recoverable biomass can be utilized (after the impacts of sustainability constraints and competing uses have been taken into consideration). In terms of energy production, an estimated total of 436 PJ can be recovered from sustainable crop residue sources, while an estimated 283 PJ can be obtained from mobilized crop residue sources; when steam gasification is applied to these sources, it is expected that annual hydrogen production can reach 2.05 million tons from the total sustainable crop residue potential or 1.33 million tons from the mobilized crop residue potential. According to a techno-economic analysis, the estimated levelized cost of hydrogen (LCOH) will range from $4.18 per kg for steam gasification and to $5.5 per kg for fast pyrolysis using an expected plant size of 500 tons biomass per day. Based on the same sensitivity analyses, the results agree with previous international studies that hydrogen yield and capital cost are key drivers of LCOH for both pathways. OSeMOSYS modeling of the energy system of Ethiopia was done with the intention of integrating hydrogen produced from biomass with focus on production, fuel cell use, methanol and ammonia synthesis, by 2050. The model results show that hydrogen produced from biomass will be a flexible means of energy and provide support for the integration of renewables into the energy system, as well as assist in the decarbonization of the hard-to-abate sectors. These findings support the development of policies by providing an opportunity to identify optimal technology pathways, facilitating the establishment of hydrogen hubs, and outlining strategic means of accessing Ethiopia's bio-hydrogen potential that are in line with the Climate Resilient Green Economy (CRGE) and updated Nationally Determined Contributions (NDCs) policies.

Keywords: Biomass residues, Green Hydrogen, Steam Gasification, Fast Pyrolysis, Techno Economic Analysis, LCOH, OSeMOSYS, Energy System Modeling, Ethiopia

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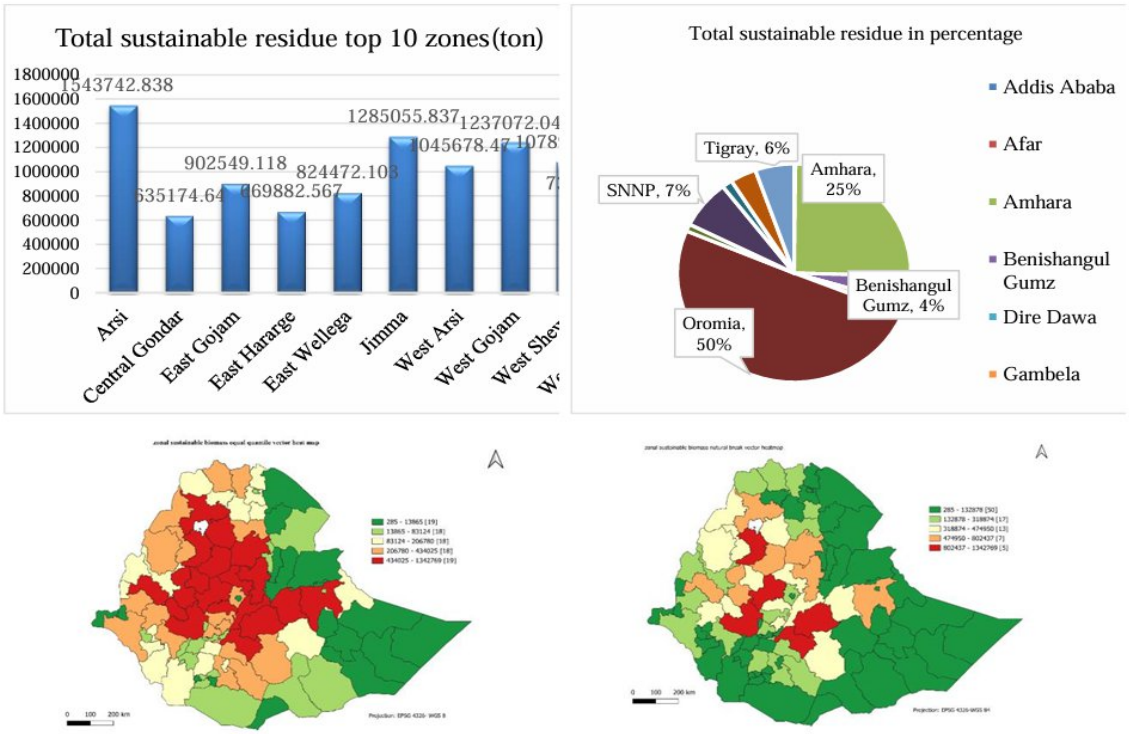


Figure 1: Zonal distribution of total sustainable biomass residues using equal quantile and natural breaks (Jenks) classification methods.

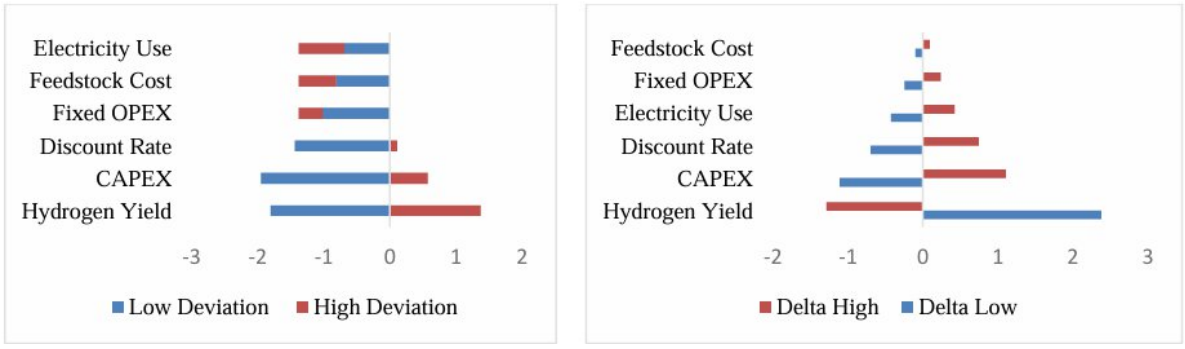


Figure 2: Tornado sensitivity analysis of the levelized cost of hydrogen (LCOH) for the steam gasification and Fast Pyrolysis pathway showing the effect of ±30% variation in key techno-economic parameters.

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(B-12) Synthesis and Characterization of high entropy alloys for hydrogen storage applications

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Abstract

Hydrogen is a promising clean energy carrier, but its widespread application is limited by the lack of safe, efficient, and compact storage materials. High-entropy alloys (HEAs) have emerged as potential solid-state hydrogen storage materials; however, many BCC-structured HEAs undergo hydrogen induced phase transitions that cause significant volume expansion and compromise structural integrity. This study investigates the effects of interstitial alloying on the structural stability and hydrogen storage properties of nitrogen-, carbon-, and boron-modified Ti–V–Zr–Nb-based HEAs. Ti–V–Zr–Nb–M (M = N, C, B) alloys were synthesized by planetary ball milling and characterized using X-ray diffraction, scanning electron microscopy, and energy-dispersive spectroscopy. Hydrogen absorption and desorption properties were evaluated using pressure–composition isotherms and thermogravimetric analysis coupled with differential scanning calorimetry. The synthesized alloys exhibited rapid hydrogen absorption kinetics at 20 °C, with maximum hydrogen storage capacities ranging from 0.9 to 1.8 wt%. Pressure–composition isotherms revealed a single plateau below 1 bar, indicating stable hydride formation. The nitrogen- and carbon-containing alloys exhibited enhanced FCC phase stability with no measurable phase transition or volume expansion during hydrogen cycling, while the boron-containing alloy retained a BCC structure with a reduced volume expansion of approximately 13.8%, compared to 30.8% for the base alloy. The alloys retained 80–95% of their initial hydrogen storage capacity after repeated hydrogenation–dehydrogenation cycles and exhibited lower hydrogen desorption onset temperatures than the base alloy. These results demonstrate that interstitial alloying is an effective strategy for stabilizing HEA crystal structures and mitigating hydrogen-induced volume expansion, providing insights into the design of structurally stable materials for solid-state hydrogen storage applications.

Keywords: High entropy alloys, Hydrogen, Interstitial atoms, Storage, Phase transition, Ball milling, Volume expansion

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(B-13) Environmental and Economic Implications of Transitioning from Diesel to Hydrogen-Powered Construction Machinery: A Life Cycle Perspective

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Abstract

In this era of sustainability, driven by the growing demand for clean energy systems, environmental protection, and economic development, this study aims to provide decision-makers in the construction industry with insights into environmentally safe and cost-efficient technology options between Internal Combustion Engine (ICE) and Fuel Cell (FC) systems in construction machinery over their life cycle. It also highlights the potential role of green hydrogen in supporting the energy transition, enhancing environmental safety, and achieving cost savings in construction machinery applications.

As industries look for cleaner alternatives to fossil fuels, many studies have highlighted the significant benefits of gas-powered machinery, electric systems, diesel-electric hybrids, and hydrogen fuel machinery. Hydrogen, in particular, is emerging as a promising clean energy source for heavy-duty machinery, especially during the usage stage, since it mainly emits water. This stands in stark contrast to diesel-powered machinery, which emits CO_2, nitrogen oxides, and particulate matter throughout its operational life. To better understand the performance of ICE and FC construction machinery, it is important to look beyond GHG emissions and include other environmental and cost indicators. While prior studies have examined individual aspects of alternative powertrains, no comprehensive life cycle study combining both LCA and LCC for diesel versus hydrogen-powered construction machinery has been conducted, representing a clear research gap this work addresses. This would inform decision makers in ensuring a sustainable shift toward cleaner construction and industrial practices, as regards environmental and economic decoupling.

The appropriate methodology for this study is the Life Cycle Assessment (LCA) and Life Cycle Costing (LCC), following the LCA framework, related to the environmental and cost assessment of diesel and hydrogen excavators throughout their life cycle. The LCA framework, based on ISO 14040:2006, offers a comprehensive method for evaluating the environmental impacts and costs of diesel and hydrogen-powered construction machinery throughout their entire life cycle, from production to end of life (EoL). It encompasses four key phases: Goal and Scope Definition, Life Cycle Inventory (LCI), Life Cycle Impact Assessment (LCIA), and Interpretation.

This study emphasizes data transparency, environmental relevance, and cost-effectiveness. This study uses SimaPro for the environmental LCA and a basic Excel model to calculate the cost performance of each excavator.

As for the results of this study, green hydrogen fuel cell (FC) excavators significantly reduce environmental impacts compared to diesel, cutting climate change emissions by 75%, ozone-forming gases by 95%, and particulate pollution by 84%, while also lowering water and marine toxicity by around 94%. However, the FC systems require 52% more mineral resources and consume over five times more water. The ICE systems are more cost-efficient at the acquisition stage. In contrast, FC systems benefit from lower operational costs due to reduced fuel consumption, making the FC system, under the optimal configuration, the most cost-effective choice in the long term.

Thus, this study reveals the environmental and cost benefits of the ICE and FC powertrains in excavators, highlighting hydrogen's long-term cost benefits and cleaner emissions despite higher studies, and a comprehensive LCC model that includes EoL treatment to improve decision-making accuracy. Also, hydrogen FC powertrains are expected to become cost-competitive with ICE systems as the cost of FC components decreases.

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Keywords: Life Cycle Assessment, Life Cycle Costing, Internal combustion engine, Fuel cell, ISO 14040:2006.

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(B-14) Artificial Neural Network based Predictions of Hydrogen Storage in Metal-Organic Frameworks

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Abstract

Metal-organic frameworks are a category of materials that are highly crystalline and porous. They are made up of metal ions or clusters that are linked together by organic linkers. They can be adjusted make them suitable for hydrogen storage. Hydrogen is widely regarded as one of the most promising clean energy carriers for the purpose of developing carbon-neutral energy systems. Despite this, the storage of hydrogen in a manner that is both efficient and secure continues to be a significant obstacle. Metal–organic frameworks, often known as MOFs, have emerged as leading possibilities for hydrogen storage applications due to their extraordinarily high surface area, pore architectures that can be tuned, and chemical functionalities that may be adjusted. Because there are so many different framework structures that may be used, determining which MOFs have the best performance in terms of hydrogen adsorption is a time-consuming and computationally expensive process. This is despite the fact that substantial experimental and computational advancements have been made. The purpose of this research is to investigate the use of artificial neural networks (ANNs) of Levenberg Marquardt algorithm, and Scaled Conjugate Gradient of as a predictive tool for the purpose of analyze and optimize the performance of hydrogen storage in metal-organic frameworks (MOFs). A dataset that contains important structural and physicochemical parameters is utilized in the process of training and validating the artificial neural network (ANN) model. This dataset includes particular surface area, pore volume, pore size, density, metal center, and operating temperature and pressure. In addition to precisely predicting hydrogen adsorption capacity, the model that was built also identifies the material factors that have the most significant impact on storage performance. The results of the ANN-LM reveal a significant predictive capability, which reduces the requirement for extensive experimental testing and molecular simulations while simultaneously accelerating the discovery and design of high-performance MOFs. When ANN is combined with sophisticated porous materials, a powerful framework is created that allows for the rapid screening of materials, optimization of materials, and the development of hydrogen storage systems of the next generation. A pathway that is both cost-effective and efficient towards the commercialization of sustainable hydrogen energy solutions is provided by this approach, which also contributes to the development of data-driven materials engineering. LM model shows the best results with R^2 = 0.9987 and Root Mean Square Error of 0.074. Sensitivity analysis demonstrates that surface area, pore volume, pressure, and temperature have almost the same contribution on hydrogen storage.

Keywords: Hydrogen storage, Metal-organic frameworks, Aritifical neural network, Prediction

Model development

Predictions of hydrogen storage are made in the current work by making use of four essential characteristics as input: the BET surface area, the pore volume, the pressure, and the temperature. An additional point to consider is that the single output is regarded to be gravimetric hydrogen storage. It is the surface area that is responsible for the hydrogen storage in MOFs. Physisorption with weak van der Waals bonds results in poor storage capacities, unless the substance in question has a large surface area, which allows it to provide a greater number of active sites for adsorption. The value of this parameter can be obtained using a variety of approaches. The Langmuir and BET procedures are the ones that are used the most frequently. When calculating the Langmuir isotherm, only mono-layer adsorption on the

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surface of the adsorbent is taken into consideration. Consequently, this theory does not consider the phenomenon of multi-layer adsorption. Due to the fact that the BET approach considers multi-layer adsorption, the surface area of the BET method is often lower than the surface area of the Langmuir method.

Data collection

An experimental dataset consisting of 294 data points is acquired for the purpose of determining the hydrogen storage capacity of MOFs in the current work. The BET surface area, pore volume, pressure, and temperature are the proposed input properties. This was described earlier. Despite the fact that the majority of the data related to the output feature have been provided based on excess adsorption, there have been some studies that have reported the total hydrogen storage values. An increase in the BET surface area and pore volume of MOFs leads to an increase in the amount of hydrogen that can be stored, as was indicated earlier. This pattern is readily apparent within the dataset, in particular within the data points of a single study within the dataset. Because of the influence that these parameters have on weak van der Waals bonds, it is hypothesized that a rise in pressure would result in an improvement in hydrogen storage, but an increase in temperature would result in a loss in hydrogen storage. This pattern is also discernible in the dataset that was acquired for the purpose of this investigation, which is evidence of the reliability of the dataset. Fig. 1, and Fig. 2 indicates the schematic diagram of Levenberg-Marquardt algorithm.

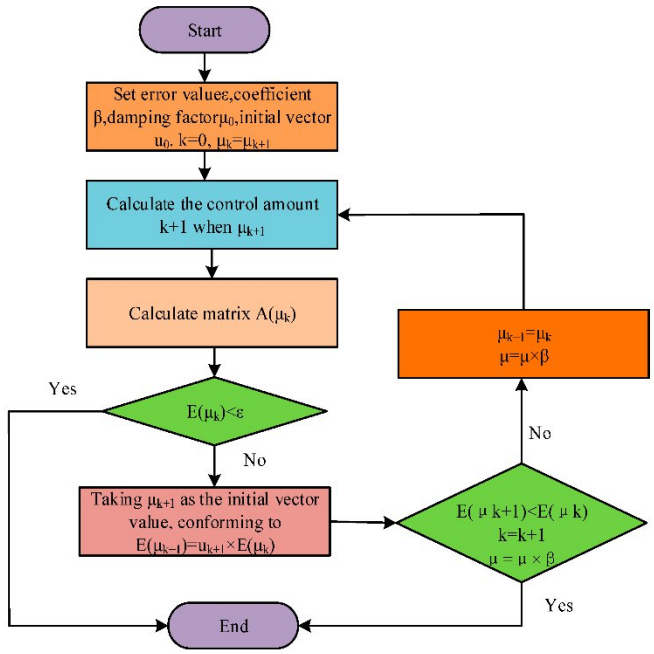


Fig. 1: Schematic diagram of Levenberg Marquardt algorithm

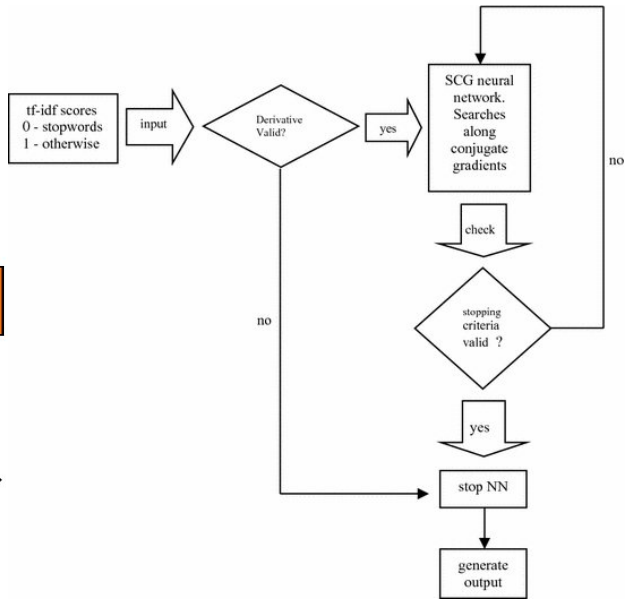


Fig. 2: Schematic diagram of scaled conjugate gradient algorithm.

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(B-15) Physicochemical Characterization of Fecal Sludge and Water Hyacinth as Potential Feedstocks for Biohydrogen Production through Dark Fermentation

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Abstract

Biological hydrogen production through dark fermentation has emerged as a promising converting organic residues into renewable energy. The efficiency of this process is strongly influenced by the physicochemical and biochemical characteristics of the feedstock employed. Fecal sludge generated from onsite sanitation systems and water hyacinth harvested from aquatic environments, constitute abundant biomass resources with considerable potential for biohydrogen production. However, limited information is available regarding their suitability as co-substrates for dark fermentation, particularly in the context of West African urban environments.

This study evaluates the characteristics of fecal sludge and water hyacinth as potential feedstocks for sustainable biohydrogen production through dark fermentation. Water hyacinth samples were collected from the Lagoon of Bè in Lomé, while fecal was obtained from local sanitation management facilities. A comprehensive characterization of both substrates was conducted to assess their biodegradability, nutrient available and energy recovery potential. The analyses included pH, electrical conductivity, total solids, volatile solids, ash content, chemical oxygen demand, total organic carbon, total nitrogen, carbon-to-nitrogen ratio and heating value. In addition, structural carbohydrate fractions, including cellulose, hemicellulose, and lignin, were quantified to evaluate the accessibility of fermentable organic matter. Thermogravimetric analyses were performed using a LECO TGA 701 analyzer, and the heating value was determined according to DIN EN ISO 21654 (2021-12) standards, for fecal sludge, the methods for fecal Sludge Analysis, 2021, were used.

The study is based on the premise that the complementary characteristics of fecal sludge and water hyacinth may provide a balanced substrate matrix for dark fermentative hydrogen production. The generated dataset is expected to provide insights into the c organic composition, biodegradability, and energy potential of the feedstocks and to support the identification of suitable substrate combinations for future co-digestion experiments. Particular attention is given to the relationship between carbon availability, nutrient balance, and the potential performance of dark fermentation processes.

The findings of this research will contribute to the scientific understanding of locally available waste-derived feedstocks for renewable hydrogen production. Furthermore, the study supports the development of integrated waste valorization strategies by promoting the conversion of sanitation residues and invasive aquatic biomass into valuable bioenergy resources within a circular bioeconomy framework.

Keywords: Biohydrogen; Dark fermentation; Fecal sludge; Water hyacinth; Feedstock characterization; Co-digestion; Renewable energy; Circular bioeconomy.

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(B-16) Balancing Societal and Ecological Resilience: A Critical Analysis of Biodiversity Conservation and Green Hydrogen interface in the Erongo and //Kharas regions of Namibia.

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[1]*University of Namibia*

Abstract

Most countries have been making investments in clean energy as a response to the problems brought on by climate change, and as a means of ensuring energy security to raise the standard of living of their citizens. Green hydrogen is a form of hydrogen that is produced using renewable energy sources, such as solar or wind power, through a process called electrolysis (Nnachi, et al.,2024).

It is considered a clean and sustainable energy source because it does not produce carbon emissions when used as fuel (Nnachi, et al., 2024). Green hydrogen produced from renewable power and water is considered as one of the pivotal solutions to achieve net-zero emissions by 2050 worldwide (IRENA 2022).

The Government of Namibia is pursuing the long-term goal of climate neutrality and to become a global net exporter and hub to produce Green Hydrogen and its derivatives. Green Hydrogen is sustainable in the long term, and the Namibian Government is to develop Green Hydrogen production capacities, promote a rapid market ramp-up and establish the corresponding value chains – both nationally and internationally. This will support local markets and local decarbonisation efforts, while generating employment for the Namibian people.

As such, developing a Green Hydrogen industry will result in long-term pathways for economic recovery. One of the key Namibian Green Hydrogen Projects is the first large-scale green hydrogen project in the Tsau //Khaeb National Park, undertaken by Hyphen Hydrogen Energy (Hyphen). Mapaure (2022) reported that one of the major challenges and threats that humanity has ever faced is Climate change. Climate change poses major threats to biodiversity. The Chairs of the seven Expert Commissions at the International Union for Conservation of Nature (IUCN, 2021) emphasized the need for countries to unite efforts to fight climate change and biodiversity loss. At the same time, Namibia is rapidly positioning itself as a global leader in GH development, particularly within the Erongo and //Kharas regions. These areas that are also home to ecologically sensitive landscapes and of high biodiversity conservation priorities. While GH projects promise significant economic transformation, they also raise complex governance challenges, especially regarding environmental protection and community inclusion (Ruppel & Katoole (2023).

Objectives of the study: the overall objective is to critically examine the interface between large-scale green hydrogen development and biodiversity conservation in the Erongo and //Kharas regions of Namibia, with the aim of identifying strategies that enhance both societal and ecological resilience within the country's green energy transition. Firstly, assess existing and proposed management strategies for biodiversity conservation associated with green hydrogen infrastructure development in protected and adjacent areas of the Erongo and //Kharas regions.

Secondary, analyse stakeholder perceptions and institutional dynamics, including knowledge, attitudes, opportunities, and concerns related to green hydrogen projects in the selected regions. Thirdly, evaluate the effectiveness of socio-economic integration strategies and governance approaches in promoting inclusive participation, local livelihood opportunities, and socio-economic resilience in green hydrogen project areas. Existing and proposed management strategies associated with large-scale green hydrogen infrastructure development do not have a significant effect on biodiversity conservation outcomes in protected and adjacent areas of the Erongo and //Kharas regions. Stakeholder perceptions and institutional dynamics, including knowledge, attitudes, opportunities, and concerns related to green hydrogen projects, do not have a significant effect on the implementation and sustainability of green hydrogen development in the selected regions. Socio-economic integration strategies and governance

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approaches do not have a significant effect on inclusive participation, local livelihood opportunities, and socio-economic resilience in green hydrogen project areas.

Keywords: Green Hydrogen, Biodiversity, Socio-economic, Erongo, //Kharas.

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(B-17) Assessing Circular Water Resource Management for Green Hydrogen and Ammonia Production from Rainwater Harvesting Systems in a University in the Global South

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Abstract

The rising demand for sustainable energy and efficient water management has increased interest in integrated systems that promote circular economy principles. This study presents a conceptual framework for circular water resource management and green hydrogen and ammonia production from harvested rainwater, using Covenant University as a case study. The framework features a three- layer architecture: a physical layer with rainfall inputs, rooftop catchments, storage, a micro-hydropower unit, and an electrolyzer; a virtual layer with mathematical models and Python simulations to replicate system behavior; and a data and intelligence layer that uses long- term rainfall data and operational parameters for decision-making. It illustrates a complete resource conversion pathway-from rainwater harvesting on rooftops, through hydroelectric power generation, to producing green hydrogen and ammonia via the Haber- Bosch process. Rainwater collected from 10 residential hostels supplies energy to the micro-hydropower system, which powers water electrolysis and green ammonia synthesis. Mathematical models of rainfall runoff, storage, and chemical production are embedded in the virtual environment to realistically simulate different climatic conditions. A 25-year simulation from 2001 to 2026, using the CHIRPS rainfall dataset, showed an average annual rainfall of 1,1463.59.59 mm, a total harvested volume of 1,437,051.30 m^3, and energy generation of 3333.2857 MWh. This energy supported the production of 462. 97 kg of green hydrogen and 1,837.54 kg of green ammonia. Results indicate that although rainfall is generally sufficient, rooftop systems' low hydraulic head limits energy output. The framework provides a solid method for evaluating the technical and sustainability aspects of decentralized rainwater-to- hydrogen systems using digital twin technology. A key challenge identified is the high energy demand of electrolysis, which requires 55 kWh per kg of H_2, constrained by the limited gravitational energy available. To scale up, the study suggests integrating rainwater harvesting with additional renewable energy sources, such as solar PV. Overall, this research lays the groundwork for developing smart, data- driven green hydrogen infrastructure and promotes circular water management strategies.

Keywords: Rainwater Harvesting, Circular Water Economy, Renewable Energy, Green Hydrogen, Ammonia Production, Micro-Hydropower, Sustainable Resource Management.

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(B-18) Feasibility Study of a Grid-Hybrid Solar–Wind–Battery–Hydrogen System for a Housing Estate in Otjomuise, Windhoek, Namibia

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Abstract

Namibia possesses significant renewable energy resources, particularly solar and wind energy, positioning the country favourably for the development of sustainable electricity generation systems (International Energy Agency [IEA], 2024). However, despite this resource abundance, Namibia remains heavily dependent on imported electricity, with more than 60% of its electricity demand being supplied by neighbouring countries such as South Africa and Zambia (International Energy Agency, 2024). This dependence exposes the country to regional supply disruptions, price volatility, and energy security risks (International Energy Agency, 2023).

Furthermore, access to reliable and affordable electricity remains a major challenge in peri urban and informal settlements, including Otjomuise in Windhoek, where limited grid infrastructure and uneven electrification rates contribute to persistent energy poverty (World Bank, 2021; African Development Bank, 2023). The lack of reliable electricity negatively affects household welfare, economic productivity, safety, and overall quality of life (The Namibian, 2022; Trotter et al., 2017). Consequently, there is a growing need for innovative and sustainable energy solutions that can improve energy access while supporting Namibia's energy transition objectives.

Grid-connected Hybrid Renewable Energy Systems (HRES), which integrate multiple renewable energy technologies with storage and backup systems, have emerged as a promising approach for enhancing energy reliability and reducing dependence on conventional fossil-fuel based electricity generation (Khan et al., 2020). In particular, the integration of solar photovoltaic (PV) systems, wind turbines, battery storage, and hydrogen technologies offers considerable potential for improving system flexibility, reliability, and long-term sustainability.

Solar and wind resources exhibit complementary generation characteristics, thereby reducing intermittency and enhancing system performance (Rehman et al., 2021). Lithium-ion batteries provide efficient short-term energy storage and rapid response capabilities for balancing fluctuations in electricity supply and demand (DiOrio et al., 2020), while green hydrogen technologies offer long-duration and seasonal energy storage through the conversion of surplus renewable electricity into hydrogen for later use in fuel cells (International Energy Agency, 2022; Zhang et al., 2022). Despite these advantages, the technical feasibility, economic viability, and environmental sustainability of grid-connected solar–wind–battery–hydrogen systems for residential applications in Namibia's semi-arid environment remain insufficiently investigated.

This study therefore aims to design, model, and evaluate a grid-connected hybrid solar–wind battery–hydrogen energy system for a typical housing estate in Otjomuise, Windhoek. The study seeks to determine the optimal configuration and sizing of system components capable of ensuring reliable and sustainable electricity supply while minimising costs and environmental impacts. Specifically, the research will assess system performance in terms of energy generation, storage behaviour, reliability, and load matching; determine economic indicators such as the Levelised Cost of Energy (LCOE), Net Present Cost (NPC), operating costs, and payback period; evaluate the role of grid interconnection as a backup and economic optimisation mechanism; and examine environmental sustainability indicators, including greenhouse gas emissions, water use, and resource requirements.

A techno-economic modelling approach will be adopted using HOMER software to simulate and optimise alternative system configurations based on local solar and wind resource data obtained from NASA databases and representative residential load profiles for an Otjomuise housing estate (HOMER Energy, 2025). Sensitivity analyses will be conducted to evaluate the influence of variations in

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component costs, electricity tariffs, resource availability, and technology efficiencies on system feasibility.

The findings are expected to contribute to improved understanding of hybrid renewable energy systems in peri-urban communities and provide valuable insights for policymakers, researchers, and energy planners seeking to enhance energy security, reduce electricity imports, and support Namibia's transition towards a sustainable, low-carbon energy future in line with the National Development Plan 6, the National Renewable Energy Policy, and the Sustainable Development Goals (Government of Namibia, 2025; United Nations, 2015).

Keywords: Hybrid Renewable Energy System (HRES), Green Hydrogen, On-grid, HOMER Pro, Load Profiling, Otjomuise, Namibia.'

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(B-19) Curtailment-to-Hydrogen at Jebba Hydro Station: Exploiting Nigeria's Grid Fragility for Fully Renewable, Low-Cost Hydrogen

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Abstract

Nigeria's power transmission network is one of the weakest in the world, experiencing more than 100 grid disturbances annually. In the wet season, these disturbances are often due to the excess renewable hydropower the weak transmission system cannot evacuate, leading to hydro spillage and generation curtailment. Paradoxically abundant during grid failure, this spill is a significant and wasted clean energy resource. In contrast, the dry season offers abundant solar irradiation but the grid remains unreliable. This paper proposes and models an opportunistic electrolysis system at Nigeria's Jebba transmission hub in Niger State, which is activated during grid disturbances. In the wet season, it takes in this curtailed hydro surplus; during the dry season, it runs off a 60-MWp solar array dedicated for this purpose. As importantly, being sited on the Niger River ensures free and plentiful conflict-free water for electrolysis, thus addressing water energy food tensions inherent to semi-arid solar-hydrogen projects. Using hourly solar resource data (NASA POWER), a grid disturbance time series synthesized from Nigerian Electricity Regulatory Commission (NERC) reports and Transmission Company of Nigeria (TCN) logs and an IRENA/IEA defined PEM electrolyzer, we built a techno-economic dispatch model that uses a clear and stringent operational constraint: the electrolyzer draws from the grid only when a wet season disturbance occurs, meaning it is processing verifiably stranded hydro and 100% renewable energy. This system can produce some 400-450 tonnes of green hydrogen annually at a levelized cost of hydrogen below 3.5 USD/kg, which is competitive even against subsidized diesel backup. Sensitivity analyses surprisingly show that, even more disturbances per year (50 to 150 per year) help to decrease the LCOH up to 22% as it allows greater utilization of curtailed hydro. The estimated carbon footprint is extremely low: below 10g CO_2 eq/kWh, compared to around 800g CO_2 eq/kWh for diesel backup. This research concludes that far from being a limitation, Nigeria's weak transmission network can indeed be leveraged to create a renewable fuel, address transmission congestion, and serve as a viable template for similar hydropower- rich but transmission-challenged nations throughout Sub-Saharan Africa.

Keywords: Green hydrogen, grid curtailment, hydropower, solar-hydro complementarity, Nigeria, PEM electrolysis, waste-to-fuel, energy access.

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(B-20) Forecasting Rainfall and Bridge Deck Runoff for Decentralized Micro-Hydropower and Green Hydrogen Production: A Case Study of Canaanland, Ota, Nigeria

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Abstract

Nigeria faces a persistent energy shortfall worth around $29 billion annually, leading both public and private institutions to rely on diesel generators, which emit high levels of carbon. Meanwhile, urban bridge infrastructure often releases stormwater runoff as waste. This study introduces a Python-based machine learning system that repurposes bridge deck runoff into a dual-purpose resource: micro-hydropower for campus electricity generation and green hydrogen (GH2) for seasonal energy storage. Satellite rainfall data from CHIRPS were analyzed using a Random Forest (RF) model to predict rainfall through 2026-2035. Runoff from the 880 m² Canaanland Bridge was measured using the Volumetric Method, with a runoff coefficient of 0.34 due to the mix of permeable and vegetated surfaces. This runoff is channeled through a closed penstock into an 8.56 m³ tank to drive a Pelton Wheel turbine utilizing a 30 m head (efficiency $\eta = 0.85$). The generated electricity is sent directly to the campus grid or used to power a PEM electrolyzer for hydrogen production. Five scenarios, from 0/100 to 100/0 power-to-hydrogen splits, were tested against the 10-year energy forecast. The RF model achieved an R^2 of 0.56–0. 60, effectively capturing seasonal changes without fitting noise. Over the decade (2026–2035), the system collects 4,940.59m^3 of runoff, producing an estimated 343.31 kWh of electrical energy. The 70/30 power split yields 240.32 kWh for grid supply and 2.06 kg of green hydrogen for dry-season storage. Full hydrogen focus (0/100) can produce up to 6.87 kg of GH2 over ten years. Scaling this across the 64 km regional highway at a 0. 6 utilization rate suggests a regional potential of 224. 46 MWh per decade. These results show that bridge decks can serve as zero-fuel hydraulic catchments, providing both immediate power and hydrogen storage. The Pelton turbine's high- head operation and the PEM electrolyzer's flexibility make this setup ideal for tropical urban areas. Additionally, the closed penstock minimizes downstream erosion and filters vehicular pollutants, protecting the nearby Iju River ecosystem. This integrated approach offers a scalable model for transforming civil infrastructure into active clean energy sources across West Africa, contributing to both the achievement of the SDGs and Nigeria's clean energy transition plan

Keywords: Green hydrogen; Bridge deck runoff; Micro-hydropower; Green hydrogen; Random Forest; PEM electrolysis; Decentralised energy; Nigeria

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(B-21) Dynamic Techno-Economic Optimization of a Renewable-Powered Alkaline Electrolyzer: Insights from Five Moroccan Locations

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The economic performance of renewable hydrogen systems depends not only on renewable resource availability but also on how realistically the electrolyzer is represented under variable operating conditions. This study develops an integrated techno-economic framework for a 20 kW alkaline water electrolysis micro-pilot, based on the McPhy Piel-M (M5.1) unit installed at the Green Energy Park in Benguerir, Morocco.

The electrolyzer is represented through a NaOH-specific semi-empirical electrochemical model accounting for polarization behavior, Faradaic efficiency, and progressive voltage degradation. This model is embedded in an hourly simulation of hybrid solar-wind generation and coupled with a Particle Swarm Optimization (PSO) algorithm that minimizes the Levelized Cost of Hydrogen (LCOH) over a 25-year project horizon. The methodology is applied to five Moroccan locations — Benguerir, El Jadida, Laâyoune, Tan-Tan, and Dakhla — characterized by different solar and wind resource profiles.

The results identify Dakhla as the most favorable location, reaching a minimum LCOH of 3.18 $/kg$H_2$ at an optimal electrolyzer capacity factor of 50.85%, supported by the complementarity of solar and wind resources. The analysis also reveals a strong trade-off between operational continuity and production cost: reducing the targeted capacity factor from 100% to 70% lowers LCOH by 39.6–69.5%, while total hydrogen production decreases by 29.13%. Sensitivity analysis further shows that battery and photovoltaic CAPEX are the main cost drivers, whereas electrolyzer CAPEX represents less than 3% of total LCOH under continuous operation.

These findings highlight the importance of renewable-resource complementarity and operational flexibility in the design of decentralized green hydrogen systems and reinforce the potential of Morocco's southern Atlantic corridor for pilot-scale renewable hydrogen production.

Keywords: Green hydrogen; Alkaline water electrolysis; Techno-economic optimization; LCOH; Hybrid renewable energy systems; Particle Swarm Optimization; Morocco.

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C- Health, environmental, and Cultural Aspects of harnessing green energy in the African context

(C-1) From Invisible Labor to Green Agency: Care, Commons, and Women's Environmental Expertise in the OMVS Basin

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Session: Energy Justice and Women's Agency in Africa's Green Transition
ICERA 2026

Abstract

Africa's green transition is frequently narrated as a story of technology, investment, and policy reform. Yet the everyday actors who sustain ecological systems, manage shared resources, and transmit environmental knowledge at the community level remain largely absent from dominant governance frameworks. This paper argues that women's contributions to environmental governance in the OMVS transboundary basin are not marginal — they are structurally central, yet systematically rendered invisible by the very categories through which green transitions are planned, evaluated, and legitimised.

Drawing on fieldwork conducted across the OMVS basin in Senegal, Mauritania, Mali, and Guinea — through field diagnostics, participatory workshops, and semi-structured interviews conducted within the Integrated Water Resources Management Programme (PGIRE, 2014–2021) — the paper examines the specific forms of environmental expertise, collective stewardship, and invisible labour that women enact within Water Users' Associations and community-based resource management systems. Beyond formal water governance, it also traces how women operating in agro-residue economies and informal circular resource practices function as knowledge producers and agents of change within local energy and waste valorisation systems — roles that existing CSR, governance, and responsible innovation frameworks consistently fail to recognise.

Mobilising care ethics, situated knowledge, and feminist epistemology, the paper proposes the concept of *infrastructural care* to describe the continuous, collective, and technically sophisticated attention women bring to the maintenance of shared water and energy systems under conditions of ecological stress and institutional precarity. It interrogates the misrecognition of this labour not as an oversight but as a structural effect of frameworks that render embodied, community-embedded, and care-based knowledge illegible as governance — raising fundamental questions of epistemic justice and representation in climate and energy debates.

The paper concludes that achieving energy justice in Africa's green transition requires not only inclusive policies, but a fundamental reorientation of institutional frameworks toward the ecological agency already operating at ground level. It calls for gender-responsive governance mechanisms that recognise women not merely as beneficiaries of renewable energy transitions, but as the institutional actors and knowledge holders whose community agency must be placed at the centre of just and inclusive green futures in Africa.

Keywords: energy justice; infrastructural care; invisible labour; circular economy; OMVS basin; women's agency; epistemic justice; inclusive governance

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(C-2) Gendered Informality and Energy Justice in Angola

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Abstract

Angola is classified as a lower-middle-income country with an informal economy estimated at around 41 per cent of gross domestic product, characterised by a gender centred business ecosystem in which women-led micro and own-account firms predominate. Despite their centrality to household livelihoods and local economic activity, women informal entrepreneurs face compounding structural barriers that constrain productivity and impede transitions to formality. The presentation exames how energy access shapes the productive capacity of women-led informal businesses in Angola and explores the gaps in current policy frameworks in fostering an inclusive energy transition. Drawing on a national survey of 6,607 economic operators across 23 informal markets in 16 provinces, a gender assessment of microcredit applications in Luanda's two largest informal markets, and 17 semi-structured interviews across 11 African countries, the research reveals that energy poverty is both a driver and a consequence of low productivity among women-led informal enterprises. Political Rights, Economic and Social Rights, and Family Security, our findings demonstrate that energy access is not merely a welfare input but an enabling condition for business growth, household well being, and women's participation in emerging renewable energy sectors. However, Angola's formalisation strategy and energy sector policies currently operate in institutional silos, failing to address the gendered dimensions of energy poverty and informality. The presentation concludes by advocating for the inclusion of the energy sector in the governance model of Angola's national formalisation programme, and for gender-responsive, demand-driven policies that place women's priorities at the centre of an inclusive transition to formality.

The informal economy is part of Africa's development trajectory, shaping labour markets, enterprise structures, and the continent's prospects for structural transformation. A recent study estimated that approximately 83 per cent of Africans and 85 per cent of those in sub-Saharan Africa are employed in informal economic activities (UNDP, 2022). One of the constraints basic infrastructure faces in the context of Informality is limited access to energy (Okwoche, 2024), which strains productive capacity and disproportionately affects women entrepreneurs (Clancy et al., 2003). Recent evidence from the World Bank's1 Informal Enterprise Surveys (IES2) shows that women-led informal enterprises face larger productivity gaps. Limited access to reliable and affordable electricity emerged as a critical constraint on women's inclusion in the formal economy, due to firms' low productivity, higher operational costs, restricted market access, and diminished competitive capacity, thereby impacting their livelihood systems. Most studies on the gender gap in productivity in the context of informal micro, small, and medium-sized enterprises (MSMEs) are scarce, with the usual focus being on formal enterprises (Islam, Amin, 2023). Some emerging evidence links poor energy performance to the expansion of the informal economy as a structural determinant, whereas improvements in energy efficiency contribute to its reduction (Okwoche, 2024). In Angola, as in most African countries, there is no national index to measure MSME informality and productivity, and the lack of disaggregated data (especially by gender and energy access) further hinders a better understanding and the formulation of effective policy responses (ILO 2023).

To contextualise the conditions under which MSMEs emerge, operate, and transition into formality, we propose an analytical linkage between the Informality Patterns (IP) developed by the International Labour Organisation (ILO 2025) and the World Bank's country income classification3, (GDI4). The analysis indicates that the average firm's size in 85 per cent of African countries is micro, with a larger portion of the population in subsistence farming, slowly scaling to commercial agriculture and services (urban). The different stages of economic diversification among the three country groups impact the

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size of informality, the main informal economic sectors and poverty. This suggests that informality is both a cause and a consequence of low productivity (Cilliers & Chipanda, 2025; AfDB, 2025). This dynamic reinforces the need for integrated, inclusive policies that address the gender gap, enterprise constraints, labour market vulnerabilities, and structural transformation in a transversal manner.

Evidence challenges to give the demand side a relevant, participatory role to support the swift transition from low-productivity firms to gradually more productive ones, if the desired priorities are to be at the centre of policy dialogue concerning formalisation. It means that the energy sector must be included in the governance model of the Angolan formalisation strategy. As an enabling condition, access to energy enhances productivity, reduces monetary and multidimensional poverty, and enables businesses to expand and participate in emerging sectors such as renewable energy. At the same time, the benefits extend beyond business performance, strengthening household livelihoods and reinforcing gender inclusion as a central component of the transition to formality.

Energy justice is associated with production and consumption framed by a fair distribution of benefits (Miller, 2012), fair prices, and equitable access, including the right to choose the energy system (Clark et al., 2013). Adopting energy systems in a productive environment reshapes social practices, values, relationships, opens opportunity for new business models, forms of work and living. If consumers are not at the centre of the energy system choice and distribution (O'Rourke and Connolly, 2003), it can contribute to inequality (Clark et al., 2013). Informed by an original Gender-Centred Business Ecosystem framework articulated across three interdependent dimensions: Political Rights, Economic and Social Rights, and Family Security, our findings demonstrate that energy access is not merely a welfare input but an enabling condition for business growth, household well-being, and women's participation in emerging renewable energy sectors. However, Angola's formalisation strategy and energy sector policies currently operate in institutional silos, failing to address the gendered dimensions of energy poverty and informality. The article concludes by advocating for the inclusion of the energy sector in the governance model of Angola's national formalisation programme, and for gender responsive, demand-driven policies that place women's priorities at the centre of an inclusive transition to formality.

Keywords: Informal Markets; Energy Poverty, Just Transition; Gender Justice, MSMEs, Sub-Saharan Africa

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(C-3) Informal waste management and inequality dynamics in Sub-Saharan Africa: a multidimensional analysis of economic and social disparity reproduction mechanisms in the Circular Economy

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Abstract

The informal waste management sector (encompassing waste pickers, itinerant collectors, informal sorters, and small-scale recyclers) handles an estimated 50% to 80% of solid waste collection and recovery in sub-Saharan African cities, and provides livelihoods to a workforce largely excluded from formal social protection (AFRISTAT/WIEGO, 2025). While this sector constitutes the de facto backbone of urban circular economy value chains, recovering valuable materials that would otherwise be lost, it appears to simultaneously perpetuate and amplify economic and social inequalities among those who depend on it. This research proposes a multi-dimensional analysis of the mechanisms through which informal waste management contributes to the reproduction of disparities in Africa, while highlighting its untapped potential as a lever for inclusive circular economy transitions.

Our methodological approach combines quantitative and qualitative analyses. Quantitatively, we use a panel of 15-20 sub-Saharan African countries (2010-2024), mobilizing 1-2-3 surveys of the informal sector (AFRISTAT/DIAL), WIEGO data on waste pickers and informal recyclers, World Bank solid waste management (What a Waste) databases, and WIDER inequality indicators. We deploy several advanced econometric techniques: simultaneous equations with instrumental variables to address the bidirectional endogeneity between informal waste sector expansion and inequality, Shapley-Owen decompositions to identify factorial contributions, quantile regressions to analyze differentiated effects across the income distribution of waste-chain actors, and mediation analyses to quantify transmission channels. Qualitatively, in-depth case studies of waste picker communities and recycling cooperatives in 3-4 countries identify causal mechanisms.

Findings reveal six major insights: (1) a non-linear inverted U-shaped relationship between the share of waste informally managed and inequality, with a turning point around 40-45% of total waste stream volume; (2) considerable intra-sectoral heterogeneity, with a Gini coefficient among informal waste workers (0.45-0.55) higher than in the formal waste management sector (0.35-0.45); (3) intergenerational inequality traps, where children of waste pickers face a 40-60% higher probability of remaining in informal waste work; (4) amplified gender disparities, with a 30-45% pay gap between men and women along the waste value chain, women being concentrated in the lowest-value sorting activities; (5) a crucial mediating role of municipal solid waste governance and cooperative organization; (6) four main transmission channels: human capital and technical/sorting skills (35-40%), access to finance and equipment (25-30%), social protection (20-25%), and technology/productivity in material recovery (15-20%).

Policy implications advocate differentiated strategies aligned with circular economy objectives: integration of waste pickers into formal municipal recycling systems through recognition and cooperative formalization, capacity building and equipment access for artisanal recyclers, and targeted social protection for subsistence-level collectors. Investment in human capital and technical training emerges as a priority to break intergenerational traps, while extension of social protection and inclusive financing constitute essential complementary levers to convert informal waste management from a source of inequality reproduction into an engine of equitable circular economy growth.

This research contributes to the literature by moving beyond the binary informality-inequality debate to analyze bidirectional causal mechanisms specific to the waste and resource recovery value chain, adopting a multidimensional approach, and anchoring the analysis in African specificities identified by Ouédraogo (1996) and Benjamin & Mbaye (2012).

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Keywords: Informal waste sector, Waste pickers, Circular economy, Economic inequality, Sub-Saharan Africa.

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(C-4) ADVANCING GENDER EQUALITY IN RENEWABLE HEATING AND COOLING SECTOR: LESSONS FROM SOLTRAIN+ WP5 ONLINE SERIES

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Abstract

Achieving a just and inclusive energy transition requires tackling barriers that limit women and youth participation in the renewable heating and cooling (RHC) sector. To address barriers such as limited access to finance, underrepresentation in technical careers, and lack of mentorship, SOLTRAIN+ gender and diversity launched an online meet-up series in 2024, coordinated by national gender managers. Between July 2024 and July 2025, ten sessions engaged over 200 participants, followed by an Action-Point Dialogue to consolidate outcomes. Key priorities identified included; mentorship programmes, gender-sensitive training, targeted financing schemes, inclusive workplace practices, and stronger peer-to-peer platforms. The series demonstrates that sustained dialogue, mentorship, and organisational support are essential to advancing inclusivity in the RHC sector, offering lessons that will inform the final phase of SOLTRAIN+and contribute to broader efforts for a just and inclusive energy transition.

Keywords: Gender Equality; Renewable Heating and Cooling (RHC); Gender Mainstreaming; Women's Empowerment; Mentorship; Just Energy Transition.

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(C-5) Women's access to clean energy as a pathway for energy justice in Burkina Faso

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West African Service Center for Adaptable Land use and Climate change (WASCAL), Burkina Institute of Technology (BIT)

Abstract

Access to clean and modern energy services remains a major development challenge across Sub-Saharan Africa, particularly for women living in rural and underserved communities. In Burkina Faso, limited rural electrification and continued dependence on traditional biomass fuels such as firewood and charcoal continue to reinforce gender inequalities and energy poverty. Women are primarily responsible for household cooking, fuel collection, water-related domestic activities, and household energy management, placing them at the center of the social, economic, and health impacts associated with inadequate access to clean energy

In West Africa, women play a critical role not only in household energy systems but also in local economic activities and community resilience. Despite their central contributions, women continue to experience disproportionate burdens related to energy poverty, including long hours spent collecting firewood, exposure to indoor air pollution, respiratory illnesses, physical exhaustion, and limited access to electricity for education, healthcare, and income-generating activities. Women remain indispensable actors within grassroots energy systems, yet they are often excluded from energy policy, financing mechanisms, and access to renewable energy technologies.

This study examines how women's access to clean energy can contribute to energy justice in Burkina Faso. The research adopts a qualitative case study approach based on literature review, policy analysis, and institutional reports related to renewable energy, clean cooking, rural electrification, and gender inclusion. Particular attention is given to renewable energy initiatives such as improved cookstove programs, decentralized solar systems, and rural electrification interventions aimed at reducing household energy poverty and improving women's living conditions.

The findings indicate that improving women's access to clean and affordable energy can significantly reduce household energy burdens, decrease exposure to indoor air pollution, improve health outcomes, strengthen women's economic participation, and support local resilience. Access to clean energy technologies also contributes to reduced fuel consumption, reduced time spent on fuel collection, improved household productivity, and enhanced opportunities for education and entrepreneurship. However, persistent structural barriers, including poverty, affordability constraints, weak rural energy infrastructure, limited financing opportunities, and insufficient implementation of gender-sensitive energy policies, continue to constrain equitable access to modern energy services in rural communities. The study argues that women should not be considered solely as passive beneficiaries of energy interventions, but also as active agents capable of accelerating renewable energy adoption, supporting sustainable development, and contributing to more inclusive energy transitions. Expanding women's access to affordable and sustainable clean energy technologies is therefore essential for promoting energy justice, gender equality, and equitable development in Burkina Faso.

The paper concludes that strengthening gender-sensitive renewable energy policies, improving rural electrification, expanding clean cooking initiatives, and supporting women-led clean energy entrepreneurship are necessary to promote inclusive and sustainable energy transitions aligned with broader sustainable development objectives.

Keywords: Energy justice, clean energy, renewable energy transition, energy access, gender equality.

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(C-6) Ecological agency in practice: senegalese women's digital narratives of green entrepreneurship, environmental expertise and climate advocacy

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Abstract

Africa's green transition is commonly approached through renewable energy, circular economy models, sustainable agriculture and public policy. These dimensions are essential, yet they do not fully explain how ecological change is interpreted, narrated and made socially meaningful by those who act on the ground. Women, in particular, are still frequently represented as vulnerable groups or beneficiaries of sustainability programmes. This perspective remains relevant, but incomplete. In Senegal, women also create green businesses, develop technical solutions, work with rural communities, produce environmental knowledge and bring climate concerns into public debate.

This study examines how Senegalese women occupying different positions within the environmental field construct their identities, circulate ecological knowledge and claim recognition through public digital narratives. It asks: how do women situated across green entrepreneurship, environmental expertise and climate advocacy use podcasts and online interviews to define their roles, articulate gendered obstacles and position themselves as actors in Senegal's green transition?

The study addresses a twofold gap. Research on Africa's green transition largely emphasises technologies, infrastructure, institutions and access to resources, while studies on women often focus on vulnerability, empowerment or participation in development programmes. Less is known about how women in heterogeneous professional and civic positions narrate their ecological agency, or how digital media connect entrepreneurial action, technical expertise, community engagement and climate advocacy within a shared public space.

Methodologically, the research adopts an exploratory qualitative multiple-case design. It draws on a purposive corpus of podcast interviews and online media narratives concerning five Senegalese women: an environmental restoration expert involved in the pan-African Great Green Wall initiative; an organic agriculture and agri-food entrepreneur; a diaspora entrepreneur developing local sunflower production and processing; a civil engineer-innovator working on sustainable construction and recycled materials; and a media entrepreneur and climate advocate mobilising women around environmental issues. The material is examined through thematic and narrative analysis (Braun & Clarke, 2006; Riessman, 2008).

The theoretical framework combines visibility labour, situated knowledge and recognition-based environmental justice. Visibility labour helps examine how mediated exposure may support credibility and legitimacy (Abidin, 2016). Situated knowledge foregrounds practical expertise rooted in lived and professional experience (Haraway, 1988). Environmental justice extends the analysis beyond distribution to participation, voice and recognition (Schlosberg, 2004).

Four dimensions guide the comparison: professional and entrepreneurial self presentation; the transmission of ecological and technical knowledge; representations of women's roles and gendered constraints; and claims to social, economic or environmental impact. The cases highlight multiple forms of ecological agency. Some women act through agroecological production and local value creation, others through technical innovation or institutional expertise, and others through media work and climate advocacy. Ecological engagement, therefore, does not begin only with formal activism.

The study contributes by treating women not as a single beneficiary category, but as differentiated actors who produce solutions, knowledge and public meaning. It also shows how digital narratives can transform individual experience into shared knowledge and claims for recognition. Senegal's green transition is shaped not only by technologies and policies, but by the women who act, explain and make ecological change visible.

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Keywords: green entrepreneurship; environmental expertise; climate advocacy; women's ecological agency; digital narratives; situated knowledge; Senegal.

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(C-7) Unlocking the Potential of Waste Biomass to Renewable Energy in Ethiopia: Pathway to Green Transition

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Abstract

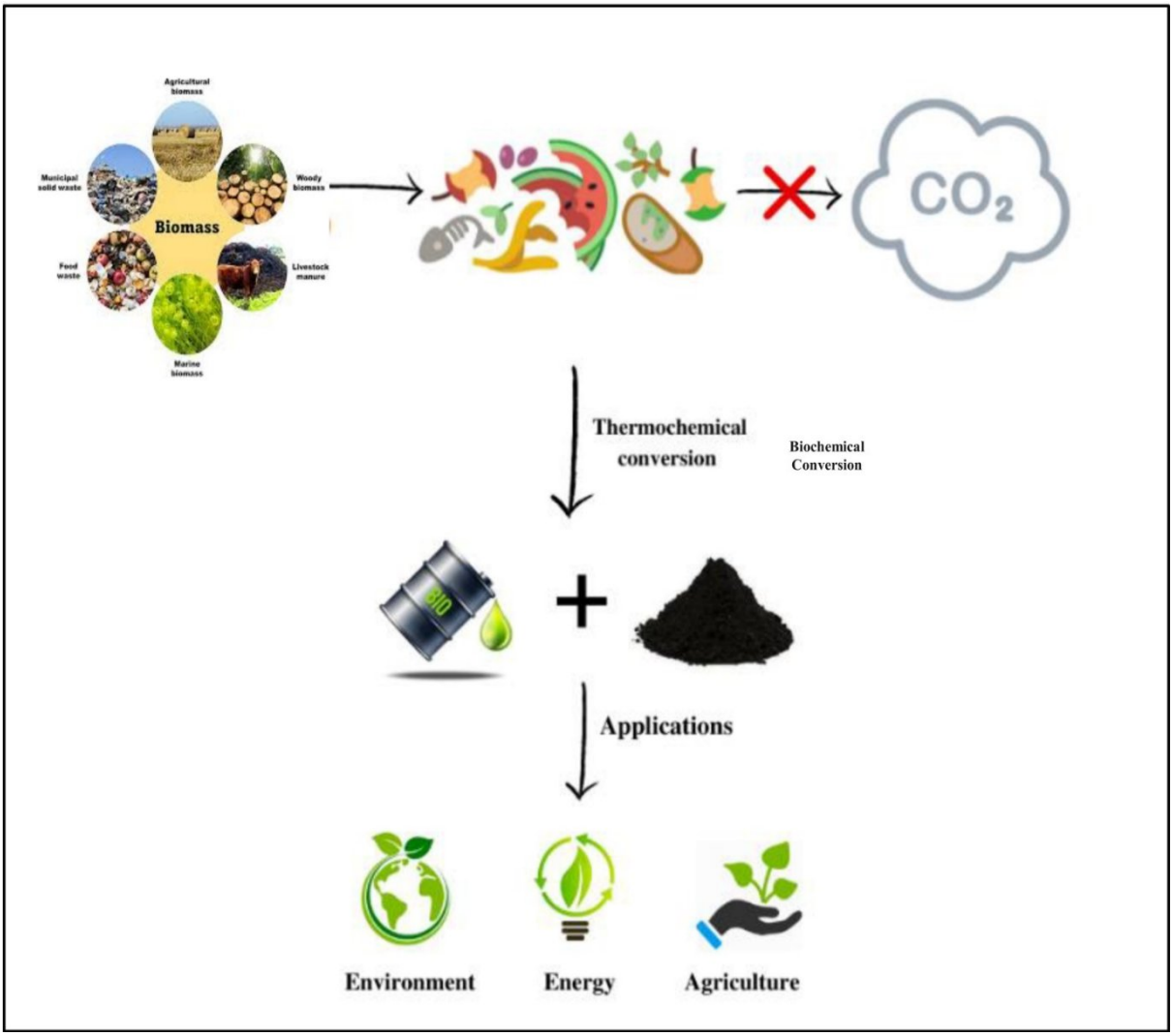
Waste biomass is the major energy source in Ethiopia contributing to about 89% of Ethiopia's primary energy supply in villages. However, current utilization patterns are highly inefficient, driving severe environmental degradation and missing critical opportunities for modernized energy harvesting. This study aims to quantify Ethiopia's untapped waste biomass resources and evaluate viability of the conversion technologies to accelerate the country's transition to a sustainable, self-dependent green economy. Moreover, the study aims to determine the waste biomass resources and its valorization, value prospective, waste biomass to energy conversion methods and green transition policy in the country. The most recent data was gathered from published papers and various types of literature. Methodologically, the research employs a systematic meta-analysis and data-synthesis approach, aggregating a decade of national agricultural inventories, municipal solid waste records, and energy sector reports to quantify total annual bioenergy yield. The potential of the broad areas agricultural crop residues, forest product residues, urban wastes and animal wastes was explored in detail. The study on the availability of various waste biomass resources together with a brief description of the conversion processes of these resources into renewable energy and value-added chemicals were inspected. This study provides a detailed evaluation of Ethiopia's waste biomass energy potential, challenges, and future prospects. These renewable energy sources have great prospects but some challenges make it difficult to utilize these properly at large scale. Mainly, the results identify critical technical and economic barriers hindering conversion technology deployment, specifically high capital costs, fragmented feedstock supply chains, and a deficit in localized technical expertise. Utilizing these sources that will help to reserve the non-renewable energy for the future and hence the country will be self-dependent for longer period of time. The study recommends making considerable use of nation's biomass energy potential as alternative energy technology with minimal impact on both the environment and the socioeconomic system. The study not only revealed the country's waste biomass energy potential, but also the challenges and potential solutions to the issue of expanding this energy option. Although this study primarily provides information about Ethiopia's waste biomass energy, it could also be helpful to other countries within the East African region.

Keywords: Biomass, Bioenergy, Circular economy, Renewable energy, Waste valorization

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Graphical abstract

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(C-8) Strengthening Sustainable Pathways for Africa's Development through Renewable and Green Energy Technologies

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Abstract

Africa is experiencing accelerating urbanization, increasing environmental vulnerability, rising energy demand, and rapid population growth. Regardless of possessing abundant renewable energy resources, including hydro power, wind, solar, geothermal, biomass, and green hydrogen potential, Africa continues to struggle with persistent unsustainable resource utilization, limited industrialization, energy poverty, and climate-related challenges. The majority of the population in sub-Saharan Africa still lacks consistent access to electricity, while dependence on fossil fuels and traditional biomass continues to weaken public health, environmental sustainability, and socio-economic transformation. Similarly, the increasing global transition toward low-carbon development grants Africa with a transformative opportunity to establish itself within the emerging green economy through renewable and green energy technologies incorporated with circular economy principles. Even though many studies have studied renewable energy development in Africa, there remains a significant research gap regarding how renewable energy technologies, green hydrogen initiatives, and circular economy approaches can be holistically embedded within a unified sustainable development pathway tailored to African realities. Existing studies largely concentrate on isolated technologies or country-specific cases without critically synthesizing the broader institutional, environmental, socio-economic, and governance dimensions necessary for long-term sustainability and scalability.

This study used a critical systematic review aimed at critically synthesizing existing scholarly literature, institutional publications, policy reports, and international development frameworks related to green hydrogen, renewable energy technologies, and circular economy transitions in Africa. The review adhered to a transparent and structured approach grounded in Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol to ensure reliability, rigor, and replicability. Relevant literature published between 2010 and 2026 was retrieved from major academic databases, including Web of Science, Scopus, Google Scholar, SpringerLink, ScienceDirect, and institutional repositories of international organizations such as the United Nations Development Programme (UNDP), International Renewable Energy Agency (IRENA), African Union (AU), African Development Bank (AfDB), and International Energy Agency (IEA). A total of 327 documents were at first identified, of which 38 peer-reviewed articles, policy documents, and technical reports met the inclusion criteria after quality assessment and screening. The literature reviewed comprised various African regions and thematic areas, including hydropower, solar energy, geothermal energy, wind energy, biomass, green hydrogen production, circular industrial models, waste-to-energy systems, energy financing, governance systems, sustainable urban development, and socio-economic transformation.

The review shown that Africa owns huge renewable energy potential capable of supporting green industrial transformation and sustainable development. Solar energy emerged as the most viable renewable energy source due to the continent's high solar radiation levels, particularly in the East Africa, Sahel, and Southern Africa. Geothermal, hydropower, wind, and biomass resources also revealed substantial opportunities for rural development, decentralized electrification, agricultural modernization, and green manufacturing. The findings also highlighted that green hydrogen technologies have considerable potential to position Africa as a future global supplier of clean energy, particularly in countries with plentiful renewable energy resources such as Ethiopia, Kenya, Morocco, Namibia, Egypt, South Africa, and Mauritania. Green hydrogen production was determined to facilitate opportunities for green exports, industrial decarbonization, fertilizer production, sustainable transportation, and regional energy integration. Nevertheless, the review identified extensive infrastructural, technological, and financial barriers hindering large-scale implementation.

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The analysis also revealed that integrating renewable energy systems with circular economy principles can meaningfully increase environmental sustainability, waste valorization, resource efficiency, and socio-economic resilience. Circular industrial production, waste-to-energy technologies, sustainable urban infrastructure, recycling systems, and bioenergy innovations were identified as critical pathways for reducing environmental degradation while promoting inclusive economic growth and green employment. In spite of these opportunities, the review shown persistent governance and institutional challenges restricting effective implementation. Inconsistent regulatory frameworks, limited technical expertise, inadequate research, weak policy coordination, dependence on foreign technologies, and insufficient public-private partnerships continue to challenge sustainable energy transitions in many African countries. Moreover, unequal access to financing, energy injustice, political instability, and limited community participation were recognized as major bottlenecks to equitable and long-term sustainability.

The study concludes that green hydrogen initiatives and renewable energy technologies offer transformative opportunities for strengthening sustainable development pathways in Africa when strategically combined with circular economy principles. The review further concludes that locally adaptive and trans-disciplinary approaches are indispensable for ensuring the long-term sustainability and scalability of renewable and green energy transitions across the continent. Strengthening collaborations among governments, industries, academic institutions, regional organizations, local communities, and international development partners will be vital for fostering inclusive and resilient green economies. On the basis of the findings, the study recommends that African governments prioritize circular economy policies and integrated renewable energy within the climate action frameworks and national development strategies. Investment in research, technical education, innovation, and local manufacturing capacities should be strengthened to reduce technological dependency and promote indigenous green technologies. Regional collaboration through continental frameworks such as the African Continental Free Trade Area (AfCFTA) should also be encouraged to facilitate technology transfer, green energy trade, and infrastructure development.

Keywords: Renewable energy, Green Energy Technologies, Socio-economic Transformation, Circular Economy, Africa's sustainable future

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(C-9) Climate Adaptation Financing for Renewable Energy Transitions in the SADC Region: Challenges, Opportunities and Pathways for Climate-Resilient Development

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Abstract

Southern Africa is among the world's most climate-vulnerable regions, experiencing increasingly frequent droughts, floods, cyclones, heatwaves and ecosystem degradation that threaten food security, water resources, livelihoods and energy systems. Building climate resilience therefore requires not only adaptation measures but also accelerated deployment of renewable energy technologies capable of reducing vulnerability while supporting sustainable socio-economic development. However, inadequate access to climate adaptation finance continues to constrain investments in renewable energy infrastructure, climate-resilient energy systems and other green transition initiatives across the Southern African Development Community (SADC).

This study examines how climate adaptation financing can accelerate renewable energy deployment and support Africa's green transition. It analyses adaptation finance flows, institutional readiness, governance frameworks and financing mechanisms that facilitate investments in decentralized solar energy, wind power, mini-grids, climate-smart irrigation powered by renewable energy, biomass and waste-to-energy technologies, green hydrogen, ecosystem restoration and other climate-resilient infrastructure. The study also evaluates policy and institutional barriers limiting access to international climate finance for renewable energy adaptation projects.

A transdisciplinary mixed-methods approach was adopted, integrating policy analysis, comparative regional assessment, desk review and secondary data obtained from international climate finance databases, multilateral climate funds, national energy and climate policies, and regional development frameworks. The analysis combines perspectives from climate science, renewable energy, economics, governance and sustainable development to evaluate financing effectiveness and opportunities for scaling green investments across SADC.

Results indicate that although climate finance to SADC countries has increased during the past decade, investments supporting climate-resilient renewable energy systems remain substantially below regional needs. Major constraints include limited institutional capacity to develop bankable renewable energy projects, complex accreditation procedures for international climate funds, inadequate domestic financing mechanisms, weak private-sector participation, fragmented governance arrangements and insufficient regional coordination. These barriers continue to slow investments in renewable energy infrastructure that could simultaneously strengthen climate adaptation, energy access and economic resilience.

The study identifies significant opportunities to mobilize adaptation finance through blended finance mechanisms, green and sustainability bonds, climate-resilient infrastructure funds, public-private partnerships, carbon finance and regional climate investment facilities. Strengthening climate finance readiness can accelerate deployment of solar, wind, biomass, waste-to-energy and emerging green hydrogen technologies while enhancing water security, climate-smart agriculture, sustainable livelihoods and ecosystem resilience. Such integrated investments generate multiple environmental, economic and social co-benefits, contributing to both climate adaptation and low-carbon development.

The paper proposes a scalable framework for integrating climate adaptation finance with renewable energy investment strategies across Africa. It recommends strengthening institutional capacity, improving policy coherence, expanding innovative financing instruments and enhancing regional cooperation to unlock greater investment in renewable energy and climate-resilient infrastructure. By demonstrating how adaptation finance can drive renewable energy deployment and support Africa's

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green transition, the study contributes directly to ongoing discussions on sustainable energy systems, green growth and resilient development pathways in the region

Keywords: Climate adaptation finance, climate resilience, sustainable development, blended finance, renewable energy, climate governance, SADC, Africa.

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(C-10) Illuminating the informal city: Securing land tenure for a modern energy transition in Namibia

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Abstract

The absence of sustainable access to modern energy services serves as a significant barrier to escape poverty. Informal settlement residents are worst affected by energy poverty, inequality and tenure insecurity. Hence, there is a dual need to achieve Sustainable Development Goal 7 and 11- ensuring modern energy access to all and creating cities that are inclusive, safe, resilient and sustainable. Traditional approaches for providing electricity to the urban poor fail due to the socioeconomic conditions, governing structures and the question of legal tenure. The purpose of the paper is therefore to assess land tenure security as a variable to enable the use of modern energy in urban informal settlements. It closes an energy research gap by linking land tenure as key determinant. A qualitative research method is employed to determine the role of land tenure security to access energy and to identify opportunities for the use of modern energy sources to alleviate energy poverty. Findings indicate the Namibian government has articulated a commitment to renewables for energy security and is positioning itself as a leader in the Green Hydrogen space, forging energy partnerships to respond to the energy need. A key finding outlines sociospatial aspects of land, being land management, ownership, and the geographic aspects, hinders the access and availability of energy. Additional outcomes indicates that there are institutional barriers to electrification as secure land rights remain a prerequisite for infrastructure installations and connections; there is a lack of household investment in long-term modern energy technologies due to fear of evictions and there is a further need for spatial regularisation through sustainable energy planning and upscaling informal settlement upgrading approaches. Households generally use a combination of energy sources that can be categorised as traditional (such as dung,agricultural residues, fuel and wood,candles, paraffin); intermediate (such as charcoal and kerosene) and on small scale, modern (such as solar, biogas and electricity). The use of modern energy helps to achieve urban climate mitigation goals which is a vital climate change mitigation strategy. Technical innovations, specifically in the realm of modern energies and energy efficient technologies influences sustainable urban settlements. The relevance of this paper is therefore maintained in explicitly linking three core variables, the problem (energy poverty), the mechanism (land tenure) and the objective (modern energy). This transdisciplinary research grounded in African realities covers the context in Namibia's informal settlements, a research gap in land tenure security and a global relevance in energy transition.

Keywords: Energy poverty, Informal settlements, Land tenure security, Modern energy, Namibia

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(C-11) The Effectiveness of Science Journalism in Communicating Renewable EnergyTechnology Diffusion to Accelerate 2030 SDGs in Africa

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Abstract

Africa faces significant energy access challenges despite being endowed with enormous renewable energy resources. It is estimated that over 600 million Africans (almost 43%) still lack access to electricity (making it the darkest continent in the world), while more than 900 million people depend on traditional biomass fuels for cooking and heating. Women and girls are disproportionately affected by energy poverty due to increased domestic workloads, health risks from indoor air pollution, and limited access to clean energy technologies. Renewable energy technologies such as solar mini-grids, clean cook stoves, wind power, and bioenergy systems are increasingly recognized as strategic pathways toward achieving Sustainable Development Goal (SDG) 7 on affordable and clean energy by 2030. Science journalism plays a critical role in communicating evidence-based information, promoting public awareness, influencing policy dialogue, and accelerating technology diffusion across communities.

Key Policy Question: How effective is science journalism in communicating gender-responsive renewable energy technology diffusion to accelerate universal clean energy transition in Africa by 2030?

Problem Statement: Despite the increasing growth of investments in renewable energy policies, programmes, and projects across Africa, many communities still experience limited awareness, misinformation, weak public engagement, youth empowerment, and inadequate access to scientific information regarding renewable energy technologies. It has emerged that below 35% of rural households in Sub-Saharan Africa receive regular science and environmental information through mainstream media channels. Besides, women account for nearly 70% of populations affected by household energy insecurity, yet they are underrepresented in energy policy communication, technology design, and decision-making processes. Weak science communication systems, limited digital infrastructure, low science journalism capacity, and inadequate gender-responsive reporting continue to slow renewable energy adoption and public participation.

Objectives were to: (1) Assess the effectiveness of science journalism in promoting renewable energy technology diffusion in Africa. (2)Examine gender-responsive communication approaches in renewable energy reporting. (3)Identify best practices and lessons learned in science communication for clean energy transition. (1) Strengthen evidence-based policy recommendations aligned with SDG 5, SDG 7, SDG 13, and Agenda 2063.

Methods: We applied a systematic literature review, policy and document analysis, comparative regional assessment, and stakeholder engagement involving journalists, policymakers, researchers, women groups, and renewable energy practitioners from selected African countries. Communication theories guiding the analysis included Agenda-Setting Theory, Diffusion of Innovation Theory, Development Communication Theory, and Participatory Communication Theory. Multiple policy documents, journal articles, energy reports, media, and recent publications published were reviewed and analyzed.

Results (1): Science journalism signify cantly influences renewable energy awareness and adoption. Countries with active science media programs recorded up to 40% higher public awareness of solar technologies compared to regions with weak science reporting systems. Community radio stations contributed to approximately 55% of renewable energy awareness campaigns in rural areas, while digital media platforms increased youth engagement by nearly 48%. Evidence further showed that science journalism improved public trust in renewable energy innovations and increased community participation in local clean energy initiatives. (2): Gender-responsive science journalism improved women's participation in renewable energy programs by nearly 30% in selected projects. Media

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programs highlighting women-led solar enterprises, clean cooking technologies, and female renewable energy innovators enhanced inclusivity and policy visibility. However, only about 25% of energy-related media content in Africa currently incorporates gender perspectives, indicating persistent communication gaps and unequal representation. (3): Best practices identified included the use of multilingual community radio broadcasts, mobile-based energy awareness campaigns, science documentaries, digital storytelling, climate and energy journalism fellowships, and partnerships between universities, media houses, and renewable energy agencies. Lessons learned demonstrated that participatory communication approaches, local language reporting, and indigenous knowledge integration significantly improved technology acceptance and sustainability outcomes. Countries investing in science journalism training recorded stronger public engagement and policy accountability mechanisms. (4): Science journalism contributds to policy advocacy, public accountability, environmental education, and investment mobilization for clean energy transition. Media engagement supported the expansion of off-grid solar systems, especially in rural communities where electrification rates remain below 30%. Evidence also indicated that inclusive communication strengthened partnerships among governments, civil society organizations, private sector actors, and development partners.

Conclusions: Science journalism remains a strategic instrument for accelerating gender-responsive renewable energy technology diffusion and universal clean energy transition in Africa. Effective science communication enhances public awareness, strengthens policy dialogue, promotes behavioral change, and increases community participation in renewable energy programs. Gender-inclusive communication approaches further improve women's empowerment, social inclusion, and sustainable development outcomes. However, inadequate science journalism capacity, limited financing, weak digital infrastructure, and low gender integration continue to hinder progress toward universal clean energy access by 2030. Contributions: to emerging knowledge on the intersection between science journalism, gender-responsive communication, renewable energy technology diffusion, and sustainable development in Africa. It garnered evidence-based insights for policymakers, media practitioners, researchers, universities, and development organizations working toward clean energy transition and climate resilience. Recommendations: increase investment in science journalism training, expand of rural digital communication infrastructure, promote of women-centered renewable energy reporting, integrate indigenous knowledge systems into science communication, and strengthen partnerships among governments, universities, media institutions, and renewable energy partners. African governments should allocate more funding toward public science communication programs and establish national frameworks supporting gender-responsive energy journalism. Strengthen community media platforms, local land anguage broadcasting.

Keywords: Gender-Responsive, Renwable Energy, Science Journalism, SDG 7, Africa

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(C-12) Beyond Beneficiaries: Community Inclusion in National Fresh Produce Market (NFPM) Waste-to-Energy Transitions in South Africa

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Abstract

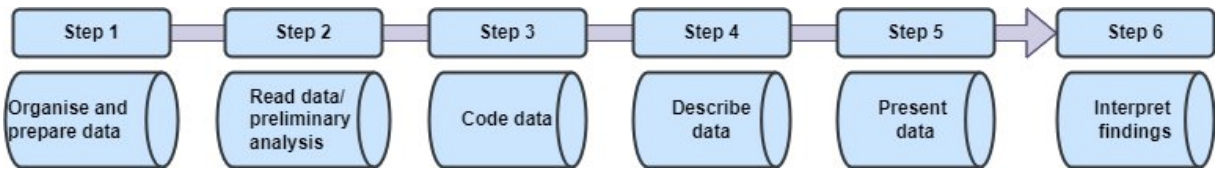
Fresh Produce Markets are one of the main contributors to agricultural waste, whereby over 1.3 billion tons of fresh produce is wasted globally each year. In response to this challenge, South Africa's shift towards greener and sustainable energy has sparked the interest for using circular economy approaches such as waste-to-energy initiatives, which are linked to municipal agricultural waste streams. While this shift is usually associated with environmental and economic benefits, less attention has been given to the socio-economic justice implications of such transformations. This leaves a gap on who participates in, benefits from, and shape these emerging energy systems at municipal level. Ultimately, local communities are often regarded as passive beneficiaries rather than active stakeholders within sustainability processes.

This research explores community inclusion within NFPMs waste-to-energy transitions in South Africa. Insights are drawn using a qualitative policy and governance analysis of waste-to-energy initiatives, policies, and reports on NFPMs. In addition, this research outlines how municipal governance structures, local participation initiatives, and institutional capabilities influence procedural outcomes in circular energy initiatives.

This research contends that the process of transitioning to greener energy systems, particularly in NFPMs' initiatives, does not automatically guarantee inclusion for all stakeholders. It emphasises that, in the absence of genuine community engagement, local ownership, and explicit institutional acknowledgement of community roles, these transitions may inadvertently perpetuate the very socio-economic disparities they aim to address. Without concerted efforts to involve communities as active participants and decision-makers, waste-to-energy projects risk maintaining existing inequalities and failing to deliver on the promise of just and equitable sustainability outcomes.

The research contributes to emerging debates on energy justice in South Africa's green transition by positioning NFPMs governed by municipalities, together with local communities as central actors in shaping inclusive sustainability pathways. It further highlights the need for governance approaches that move beyond technical and infrastructure-centred transitions toward more participatory and socially just models of renewable energy development.

A six-step process of qualitative data analysis is used:



This research uses Atlas.ti for coding, constant comparison and content analysis to analyse the documents and construct findings.

Keywords: Waste-to-Energy, Agrofood Waste Management, Sustainable Development

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(C-13) Linguistic Justice in Green Energy Communication: Rethinking Public Inclusion in Namibia's Green Hydrogen Programme

[1]Liicka Andima

Abstract

Namibia's transition toward green energy development through the Namibia Green Hydrogen Programme represents a significant milestone in Africa's sustainable development agenda. Positioned as one of the continent's emerging green hydrogen hubs, the programme seeks to advance renewable energy innovation, industrial transformation, economic growth, and environmental sustainability. Central to these ambitions is the use of digital communication platforms; including websites, policy documents, social media, audiovisual materials, and online public engagement campaigns to disseminate information and mobilise public participation. However, despite Namibia's highly multilingual sociolinguistic landscape, the programme's communication remains overwhelmingly English-dominant. This monolingual orientation raises critical concerns regarding linguistic justice, equitable participation, and the inclusion of indigenous communities within Namibia's green transition.

Namibia is home to more than twenty indigenous languages, such as Oshiwambo, Khoekhoegowab, Otjiherero, Rukwangali, Silozi, and Thimbukushu. Although English was adopted as the sole official language after independence in 1990 to foster national unity and international engagement, Namibia's language policy also recognizes the cultural and educational significance of indigenous languages. Nevertheless, English continues to dominate governance, education, policy communication, and digital spaces, often marginalizing non-English-speaking populations from meaningful participation in national development initiatives. Within the context of green energy communication, this linguistic imbalance risks excluding rural and indigenous-language-speaking communities from accessing information, participating in decision-making processes, and contributing local perspectives to sustainability discourse.

This paper explores linguistic justice in green energy communication by critically examining public inclusion within Namibia's Green Hydrogen Programme. Drawing on Sociolinguistics, Linguistic Citizenship, indigenous knowledge systems, and energy justice frameworks, the study argues that language is not merely a communicative medium, but also a carrier of cultural identity, ecological knowledge, and community participation. Indigenous languages embody generations of environmental knowledge, including local understandings of land stewardship, water conservation, climate adaptation, biodiversity, and sustainable coexistence with nature. The marginalization of these languages within green energy communication therefore risks silencing valuable indigenous ecological knowledge that could contribute meaningfully to sustainable development and environmentally responsive policy implementation in Africa.

Using a qualitative approach, the study conducts a digital content analysis of selected communication materials produced by the Namibia Green Hydrogen Programme, including official websites, public statements, online campaigns, and social media content. The analysis focuses on language use, accessibility, representation of indigenous languages, and patterns of inclusion and exclusion in digital sustainability communication. The paper further engages literature on multilingualism, development communication, decoloniality, and indigenous knowledge systems to situate Namibia's green transition within broader African debates on linguistic equity and inclusive development.

The study argues that English-only green energy communication may unintentionally reproduce existing socio-linguistic inequalities by limiting meaningful public engagement among indigenous-language-speaking communities, particularly in rural areas where local languages remain central to knowledge-sharing and everyday communication. Moreover, excluding indigenous languages from sustainability discourse risks undermining local ownership of green initiatives and neglecting community-based ecological knowledge that has historically supported environmental resilience and sustainable living practices. The paper therefore advocates for multilingual and culturally inclusive communication

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strategies that integrate indigenous languages into green energy discourse through translation, multilingual digital platforms, community radio, subtitles, local engagement forums, and participatory communication models.

By positioning linguistic justice and indigenous knowledge as central dimensions of energy justice, this paper contributes to emerging interdisciplinary scholarship at the intersection of language, sustainability, and Africa's green transition. The study contends that equitable green development cannot be achieved through technological innovation alone but must also involve inclusive communication frameworks that recognize linguistic diversity, indigenous knowledge systems, and community participation as fundamental components of sustainable futures. Ultimately, the paper calls for a reimagining of green energy communication in Namibia and across Africa to ensure that no linguistic or knowledge community is excluded from the continent's transition toward renewable energy and environmental sustainability.

Table 1: Major Indigenous Languages Commonly Spoken in Namibia

Language	Speaker Distribution	Regions Commonly Spoken
Oshiwambo	Largest language group	Northern Namibia
Khoekhoegowab	Widely spoken	Central and Southern Namibia
Otjiherero	Significant population	Central and Eastern Namibia
Rukwangali	Regional language	Kavango East and West
Silozi	Regional language	Zambezi Region
Thimbukushu	Minority language	Kavango East Region
Setswana	Minority language	Omaheke Region

Keywords: Linguistic justice; Green energy; Indigenous knowledge systems; Multilingualism; Namibia Green Hydrogen Programme; Energy justice; Ecological knowledge; Sustainable development; Sociolinguistics; Public participation.

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(C-14) Economic feasibility and political risk of an e-methanol trade route between Côte d'Ivoire and Germany

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Abstract

The transportation sector is the largest contributor to overall carbon dioxide emissions in the European Union, particularly in Germany. The German Federal Environment Agency has proposed carbon-neutral e-fuels as a viable solution for the part of the transportation sector that cannot be completely electrified. However, producing e-fuels requires large amounts of water and electricity from renewable sources, such as solar energy. Those regions of the world with high solar energy potential often face water constraints and higher levels of political risk. To address these problems, this study offers an economic assessment of a novel technological approach, combining off-grid solar, direct air capture, and water electrolysis for sustainable water-conscious e-methanol production in arid regions. An extensive levelized cost analysis integrating political risk factors was conducted for a sample production site in Côte d'Ivoire. The results indicate that carbon neutral methanol is not cost yet cost-competitive with fossil-based methanol (EUR 1.15/kg) but may become economically feasible by 2030 (EUR 0.74/kg) and 2050 (EUR 0.47/kg). However, the political risk may increase production costs by up to 17%, and thus could deteriorate the economic feasibility, calling for an effective risk management. Hence, various tailored mitigation strategies are proposed for enhancing the economic viability of the production and export of e-methanol. For the methanol industry this implies that West Africa may become a potential destination region for future investments, and for policymakers it implies that improvements in the institutional framework conditions are necessary to promote such investments.

Keywords: Solid oxide electrolysis cell, Direct air capture, Green hydrogen, E-methanol, Political risk, Risk management

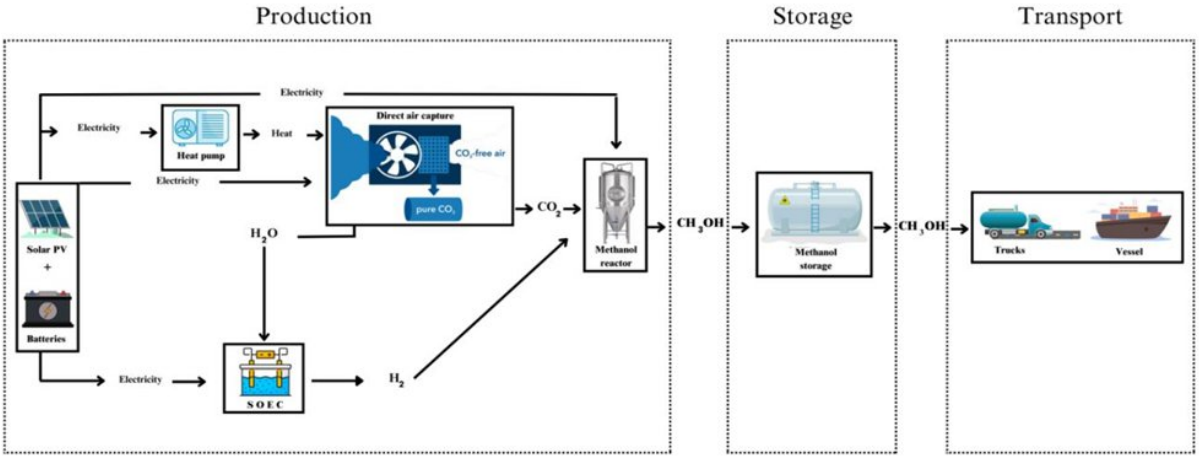


Figure 1: Overview of the novel technological solution - Material and electricity flowchart (own illustration)

With funding from the:
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(C-15) THE INFLUENCE OF SOCIAL NORMS ON RESISTANCE TO THE ADOPTION OF DOMESTIC GAS IN NORTHERN BENIN.

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Abstract

The transition to clean cooking energy is a major challenge for sustainable development in sub-Saharan Africa. In Benin, despite government efforts to promote domestic gas as an alternative to firewood and charcoal, its uptake remains limited, particularly in the northern regions. Existing research mainly attributes this situation to economic and infrastructural factors, paying less attention to the social mechanisms that may hinder the adoption of this energy innovation. This study aims to analyse the influence of social norms on resistance to the adoption of domestic gas in northern Benin. It draws on the theory of resistance to innovation developed by Ram (1989) as well as Ajzen's (1991) theory of planned behaviour. A sequential mixed-methods approach will be employed. An exploratory qualitative phase, based on semi-structured interviews with households, will identify the salient social norms. The findings will be used to develop a questionnaire to be administered to a larger sample (400) in order to empirically test the relationships between social norms and resistance to adoption. This research aims to contribute to the literature on energy consumption behaviour in African economies and to provide public decision-makers with policy levers tailored to local socio-cultural realities. The expected results should show that the success of energy transition policies depends not only on the affordability of domestic gas, but also on a shift in the social norms governing household cooking practices

Keywords: Social norms; Resistance to innovation; Domestic gas; Energy transition

With funding from the:
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D– Recycling of valuables

(D-1) Defining Starting Points for the Circular Economy Transition in Angola's Construction Sector

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Abstract

The Circular Economy aims to generate economic, social, and environmental value by promoting more efficient use of resources, extending product life cycles, and reducing waste and pollution. Its implementation represents a complex transition involving changes in business models, technologies, and public policies. These challenges are particularly pronounced in the construction sector, which is characterized by fragmented value chains, multiple stakeholders, and high material and energy intensity.

In Angola, the construction sector plays a strategic role in economic growth and infrastructure development. However, it remains largely dominated by linear production models, resulting in inefficient resource use and increasing volumes of construction and demolition waste. Despite the growing international relevance of circular economy approaches, their application within the Angolan construction sector remains limited and has received little scientific attention.

Against this background, this study addresses the following research question: where should the transition from a linear economy to a circular economy begin in Angola's construction sector?

To answer this question, a mixed methodological approach based on decision-support techniques was adopted. In a first stage, the Fuzzy Delphi method was applied to a panel of 11 sector specialists to identify and validate the 25 most relevant strategies, selected from an initial list of more than 62, taking into account Angola's social, cultural, and economic context. In a second stage, six experts assessed the interdependencies among the selected strategies using the Interpretive Structural Modelling method, resulting in the analysis of 300 relationships. Finally, a MICMAC analysis was conducted to classify and rank the strategies according to their driving power and dependence.

The results provide a structured identification of strategic starting points for the circular economy transition in Angola's construction sector. This research offers practical insights for policymakers, industry professionals, and researchers, supporting informed decision-making and contributing to the development of context-specific circular economy strategies adapted to national realities.

Keywords: Circular Economy, Construction Sector, Angola, Fuzzy Delphi, Interpretive Structural Modelling, MICMAC Analysis

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(D-2) Circular Economy Adoption in Disaster-Related Demolition Waste Management in Africa: A Systematic Review

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Abstract

With barely four years left to achieve the 2030 United Nations Sustainable Development Goals (SDGs), governments worldwide, through policymakers, academia, and industry practitioners, are urging actors in the construction industry to improve waste management practices. This sector alone has been identified as a significant contributor to global solid waste, accounting for approximately 40%. The rising frequency and severity of disasters across Africa in recent years have also contributed to already substantial waste streams in the construction and demolition industry, posing critical environmental, economic, and public health challenges in post-disaster contexts. Despite the growing global emphasis on circular economy principles as pathways to sustainable resource use, post-disaster demolition waste in many African countries is still managed through traditional practices, including open dumping, landfilling, and uncontrolled burning. While the scholarly community has made strides in construction and demolition waste management, much of the research has focused on developed countries, with an emphasis on the preconstruction and construction phases. Relatively few studies have examined waste management during the post-construction phase, particularly in the aftermath of disasters in Africa. This study examines the adoption of circular economy principles to manage disaster-related demolition waste in the construction industry. The study employs a systematic literature review guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol to retrieve peer-reviewed papers. Scopus and Web of Science databases were used as the primary sources to retrieve 79 publications following the initial search. Further screening yielded 18 publications, and snowballing added 12, for a total of 30. Findings indicate that circular economy approaches, such as reuse, material recovery, recycling, and adaptive reconstruction, can improve post-disaster resilience and make construction materials more affordable in Africa. Yet implementation remains constrained by weak national circular economy frameworks, insufficient waste segregation systems, limited technical capacity, poor regulatory enforcement, and inadequate investment in recycling infrastructure. The findings also indicate a lack of integrated policy mechanisms that link disaster risk reduction, sustainable construction, and circular resource management in many African countries. This study contributes to existing knowledge by synthesizing dispersed evidence on circular economy adoption in post-disaster African contexts and by proposing a conceptual linkage among demolition waste valorization, sustainable construction, and disaster resilience. The findings provide policymakers, urban planners, disaster management organizations, and construction stakeholders with useful insights for transitioning from linear waste management systems to regenerative, efficient reconstruction models. Importantly, the study advances the discussion of sustainable post-disaster recovery by aligning circular demolition waste management with the 2030 United Nations SDGs, particularly SDG 11 (sustainable cities and communities) and SDG 12 (responsible consumption and production).

Keywords: Circular Economy, Construction Industry, Demolition, Post-Disaster, Sustainable Development Goals, Waste Management, Africa.

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(D-3) Utilisation of incinerated sanitary sludge ash (SSA) with partial replacement for cement and lime in stabilised earth blocks: A case study of Dar es Salaam, Tanzania

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Abstract

The rapid growth of urban populations and the increasing generation of sanitation waste present significant environmental and housing challenges in developing countries such as Tanzania. Dar es Salaam generates large quantities of sanitary sludge, much of which is inadequately treated or illegally disposed of, posing serious environmental and public health risks. At the same time, the high cost and environmental impact of conventional construction materials, particularly Ordinary Portland Cement (OPC), limit access to affordable housing. This study investigates the utilisation of incinerated sanitary sludge ash (SSA) as a partial replacement for cement and hydrated lime in the production of stabilised earth blocks using laterite soil from Kigamboni, Dar es Salaam.

An experimental research design was adopted involving the preparation, characterisation, and evaluation of SSA-stabilised earth blocks. Sanitary sludge collected from faecal sludge treatment facilities was sun-dried, carbonised at 400°C, and incinerated at 600°C to produce SSA. Material characterisation included particle size distribution, Atterberg limits, Standard Proctor compaction, X-ray fluorescence (XRF), and X-ray diffraction (XRD) analyses. Different mix proportions incorporating SSA, cement, and hydrated lime were developed and tested for compressive strength and gross density at 7 and 28 days.

The results indicate that the laterite soil satisfied the requirements of WD-ARS 1333:2018 for stabilised earth block production, with a liquid limit of 29.3%, plasticity index of 15.9%, and maximum dry density of 1.765 Mg/m³. XRF analysis showed that SSA contained significant pozzolanic oxides, with SiO_2 + Al_2O_3 + Fe_2O_3 equal to 50.21%, satisfying ASTM C618-19 requirements for Class C pozzolana. XRD analysis confirmed the presence of reactive silica and alumina phases that can contribute to secondary cementitious reactions. Furthermore, experimental results from lime-stabilised and cement-stabilised mixes incorporating sanitary sludge ash demonstrated that the resulting blocks achieved sufficient compressive strength for stabilised earth block applications, indicating the potential suitability of combined SSA–cement–lime binder systems for sustainable construction materials.

The study demonstrates the potential of SSA as a sustainable supplementary binder material for stabilised earth blocks, contributing to waste valorisation, reduced cement consumption, and affordable housing development. The findings support the integration of SSA into sustainable construction practices and provide an evidence base for future policy and standard development in Tanzania.

Keywords: Sanitary sludge ash, Stabilised earth blocks, Pozzolanic materials, Waste valorisation, Affordable housing, Sustainable construction materials**.**

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(D-4) Decentralised granule production; cost-effective sustainable approach to plastics waste management

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Abstract

Plastic waste has become one of the most pressing environmental challenges worldwide, particularly in developing countries where waste collection collection and recycling system remain limited by lack of updated best practices/innovations. Traditional centralized recycling systems often face high high transportation cost, inefficient collection mechanisms and limited participation from local communities. In the context of the TAKIWAMA project, various initiatives have been set up to protect the waters of Lakes Tanganyika and Kivu. Under the 'circular economy' component, solid waste management strategies are currently being implemented. The decentralisation of plastic waste shredding is an innovation that involves bringing shredding units closer to waste collection and production areas, rather than concentrating the activity in a single central plant. This approach is particularly relevant in cities where transport costs are high, such as Kigoma in Tanzania. Transporting uncrushed plastic waste to a single centre poses significant problems due to the high volume of plastics, high fuel and transport costs, material losses during transport, low profitability for collectors and rapid landfill saturation. Innovation related to decentralised shredding is a strategy for improving the profitability of recycling, developing green SMEs, supporting circular economy policies, reducing transport-related emissions and strengthening sustainable waste management. Decentralized granules production offers an innovative, cost-effective and sustainable solution for improving plastic waste management.

Keywords: Granules, pre traitmenrt, cost effective

With funding from the:
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(D-5) Up-cycling PET Bottles into Vertical Gardens: Evaluating Container Size and Growing Media for Swiss Chard (Beta vulgaris L.) Growth Performance under Adigrat Conditions

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Abstract

Addressing the urban challenge of plastic waste accumulation, this study investigates the feasibility of up-cycling discarded polyethylene terephthalate (PET) bottles into vertical gardening systems. Conducted at Adigrat University's main campus within the vertical garden during the 2018 cropping season (March–June) under typical Adigrat climatic conditions, this experiment aligns directly with the Plastic Waste Management track by testing a low-cost, replicable model for urban food production. The objective was to determine the optimal plastic bottle size and growing media combination for maximizing Swiss chard (Beta vulgaris L.) growth performance within a vertical garden system under Adigrat conditions. Three bottle sizes (2 L, 1 L, and 0.5 L) were factorially combined with five growing media variants: 100% topsoil; 50% sand + 50% manure; 50% topsoil + 50% sand; 50% topsoil + 50% manure and 33.33% each of topsoil, manure, and sand. The 15 treatment combinations were arranged in a Completely Randomized Design (CRD) with three replications. Morphological and biomass data were subjected to analysis of variance (ANOVA) using SAS (v9.1). Mean separation was performed using Least Significant Difference (LSD) at $P < 0.05\%$. Results revealed that both bottle size and growing media had significant ($P < 0.05$) effects on all growth parameters, although their interaction was non-significant ($P > 0.05$). The 2 L bottle significantly outperformed the 1 L and 0.5 L variants, demonstrating that larger container volume provides an adequate root zone for optimal yield.

Among media, the mixture of 33.33% topsoil, 33.33% manure, and 33.33% sand produced the most vigorous growth, validating a circular nutrient loop by utilizing organic manure rather than synthetic fertilizers. The non-significant interaction effect simplifies adoption, as urban households can independently scale either the bottle size or the media mix without complex trade-offs. This system is highly replicable across Ethiopian cities due to the universal availability of discarded PET bottles and locally produced compost. By extending the lifespan of single-use plastics and converting urban waste into a productive food asset, this research provides a scalable, grassroots model for Africa's circular economy transition.

Keywords: Vertical Garden, PET Up-cycling, Urban Agriculture, Semi-Arid Climate, Plastic Waste Valorization, Container Gardening



Fuger 1 Vertical garden

With funding from the:

Federal Ministry of Research, Technology and Space

(D-6) An Integrated Statistical, Economic, and Environmental Modeling Approach to E-Waste Management in Ethiopia: A Circular Economy Framework for Obsolete CRT Televisions

Abstract

The rapid accumulation of electronic waste (e-waste) presents a significant challenge to sustainable urban development in East Africa. Among legacy waste streams, obsolete Cathode Ray Tube (CRT) televisions represent a dense, material-rich fraction that remains largely unmanaged or relegated to the informal sector in Ethiopia. This study proposes an integrated, data-driven framework for e-waste resource recovery by combining statistical generation forecasting, Technical Cost Modeling (TCM), and Life Cycle Assessment (LCA). First, a Weibull distribution function is applied to historical import data and product lifespans to quantify and forecast the annual volume of obsolete CRT TVs entering the Ethiopian waste stream. Second, these volume projections are utilized as capacity inputs for a TCM configured with localized economic parameters, including industrial utility tariffs, local labor wages, and equipment amortization schedules. Concurrently, a localized LCA inventory is deployed to quantify the environmental impacts, global warming potential, and net material displacement credits associated with the recovery of valuable secondary materials. The system boundaries encompass collection logistics, manual dismantling, and fraction segregation (valuable metals, plastics, and hazardous leaded glass). The integrated model demonstrates that while high initial capital expenditures are required for hazardous waste handling, a structured recovery framework yields a positive Net Present Value (NPV) and significant carbon emission reductions under optimized collection scenarios. By bridging the gap between waste volume estimation, financial viability, and environmental benefits, this research provides a practical blueprint for operationalizing circular economy principles and designing sustainable e-waste infrastructure tailored to Africa's development.

Keywords: Circular Economy, E-Waste Management, Technical Cost Modeling, Life Cycle Assessment (LCA), Weibull Distribution, CRT Recycling, Ethiopia.

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(D-7) Battery waste generation and management in west Africa: Systematic review

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Abstract

Technological advancements, coupled with the massive influx of second-hand electrical and electronic equipment (EEE) have significantly increased the generation of waste electrical and electronic equipment (WEEE) or electronic waste (e-waste) across parts of Africa. At the same time, the transportation, energy, telecommunications, and other sectors are contributing to the increasing generation of waste batteries, further exacerbating the e-waste challenge in the region. The end-of-life management of these waste batteries from various waste streams poses severe ecological and public health threats. In this context, this study analyses the current state of battery waste management in West Africa by synthesizing regional data on waste generation, recycling practices, environmental risks and the effectiveness of existing policy frameworks. To achieve this objective, the review follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology to identify and evaluate peer-reviewed research and institutional reports published between 2010 and 2026, focusing on Sub-Saharan Africa. The synthesis reveals that West Africa leads the continent in e-waste generation, with Nigeria (~500,000 tonnes/year), Ghana (~72,000 tonnes/year), and Côte d'Ivoire (~42,000 tonnes/year) serving as major regional hubs. This generation is driven by a combination of domestic consumption and the continued illegal importation of non-functional used electronics. Moreover, waste management is overwhelmingly dominated by the informal sector, where workers including children and women employ rudimentary techniques such as manual dismantling, open-air burning, and acid leaching to recover valuable metals such as lead, copper, and cobalt from waste batteries. As a result, these practices have caused severe environmental contamination, with soil lead concentrations near recycling sites such as Agbogbloshie reaching up to 14,000 mg/kg, far exceeding international safety thresholds. Consequently, surrounding populations face significant health risks, including neurodevelopmental delays in children, respiratory illnesses, and carcinogenic exposure. Although the region has made progress through the ratification of the Basel and Bamako Conventions and the introduction of Extended Producer Responsibility (EPR) frameworks in Nigeria and Ghana, implementation remains constrained by weak enforcement, fragmented institutional capacity and the lack of formal recycling infrastructure

Keywords: Waste batteries, waste electrical and electronic equipment (WEEE), recycling, circular economy

With funding from the:

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(D-8) Soil Contamination by Heavy Metals at E-Waste Sites in Dakar (Senegal): An Integrated Environmental and Health Assessment

Tchimboungou L[1], Foko R.F.[1], Ndong A.[2], Bah F.[1], Diop C.[1], Mbemba Peleka J.C.[1], MAHOUEKPO M.O[1], Fall M.[1], Toure A.[1], Cabral M.[1]

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Abstract

The exponential growth of electrical and electronic equipment (EEE) consumption worldwide has generated an unprecedented wave of waste electrical and electronic equipment (WEEE or e-waste), which now constitutes one of the fastest-growing solid waste streams globally. In 2021, approximately 57.4 million tonnes of e-waste were generated worldwide, of which less than 20% reached formal recycling facilities. The remainder was diverted to informal circuits, often in low- and middle-income countries in Africa, Asia, and Latin America.

In Dakar, Senegal, the management of end-of-life electronic equipment is predominantly informal, conducted in open air by collectors, dismantlers, and recyclers with minimal protective measures. These activities involve practices such as open burning of cables for copper recovery, acid stripping of circuit boards for precious metals, and uncontrolled landfilling, which directly release toxic heavy metals, including lead (Pb), cadmium (Cd), copper (Cu), mercury (Hg), chromium (Cr), arsenic (As), and zinc (Zn), into surrounding soils. The local workers and nearby populations, including children, are chronically exposed to these contaminants through ingestion, inhalation, and dermal pathways, yet their living and working conditions remain poorly documented and largely unregulated.

Keywords:

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(D-9) Fabric Waste Management and Recycling for Pollution Prevention, Environmental Sustainability, and Circular Economy

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Abstract

Recycling of fabric waste represents one of the ways to control environmental pollution and encourage sustainable use of resources. This research focuses on the fabrication and characterizing the eco-friendly composite materials from the fabric waste and polyester resin for possible usage as building materials as well as furniture in Ethiopia. In the current study, fabric wastes generated from the garment industry have been used as reinforcing agent and placed in sandwich, chopped, and laminate forms. Specimens of the composites have been fabricated using hand lay-up technique with reinforcement to matrix weight ratio from 10/90 to 60/40.

The characterization of the materials has been performed via mechanical, thermal, microstructural, water absorption tests and painting of the surfaces. It has been found out that mechanical properties enhanced with increase in reinforcement content until reaching optimum ratio of 40/60. Among different forms of reinforcement, chopped fiber-based composites showed best performance owing to uniform distribution of fiber and stronger interface between fiber and matrix. Thermal analysis revealed sufficient thermal resistance. Moreover, microstructure evaluation showed strong bonding between fibers and matrix resin. Besides, it was noted that these composite materials showed low water absorption and acceptable surface painting ability.

The results indicate that the composite material made from recycled polyester fabric reinforcement can be employed for use in non-load-bearing structures such as partitions, wall coverings, shelving units, cabinets, and other interior decorations. This paper has brought to light the application of fabric recycling in ensuring environmental sustainability, pollution control, and recycling economy through the production of composite material.

Keywords: Recycled fabric waste; Composite materials; Environmental sustainability; Pollution prevention; Structural applications; Household furniture; Circular economy.

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(D-10) Waste to Resource Approach: Sawdust Derived biochar Co-Doped with N/Fe for Simultaneous Removal of Multi-Heavy Metal from Wastewater

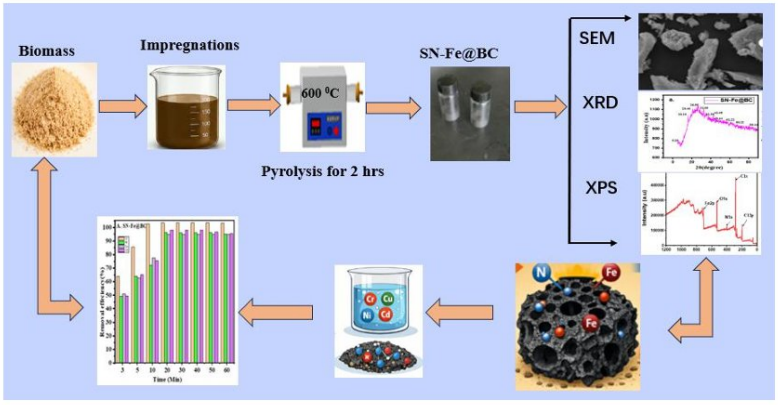
Ababo Workineh Tadesse ab

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Abstract

Wood-processing residues represent an abundant biomass resource with significant potential for sustainable environmental applications within a circular economy framework. Among these, sawdust has emerged as eco-friendly and cost-effective, promising precursors for heavy metal remediation in wastewater; however, the understanding of how adsorption performance and mechanisms in multi-metal systems remains limited. In this study, a sawdust-derived nitrogen/iron co-doped biochar (SN-Fe@BC) was successfully synthesized through a one-step pyrolysis approach using sawdust as the carbon precursor, urea as the nitrogen source, and $FeCl3{\cdot}H_2O$ as the iron source. The synthesized biochar was evaluated for the simultaneous removal of Cr, Ni, Cu, and Cd ions from aqueous solutions. Comprehensive characterization using SEM, BET, FTIR, XRD, and XPS analyses confirmed the successful incorporation of nitrogen and iron functionalities into the porous carbon matrix. The prepared SN-Fe@BC exhibited a rough porous structure with a high specific surface area of 340.77 m^2/g, providing abundant active adsorption sites. Adsorption equilibrium was achieved within 30–40 min and followed pseudo-second-order kinetics, indicating chemisorption-dominated interactions. Langmuir isotherm analysis revealed monolayer adsorption behavior with maximum adsorption capacities of 22.93 mg/g for Cr, 28.09 mg/g for Ni, 25.56 mg/g for Cu, and 30.82 mg/g for Cd. Regeneration studies demonstrated good reusability over multiple adsorption–desorption cycles. Mechanistic investigations indicated that the removal process involved synergistic interactions including surface complexation, electrostatic attraction, ion exchange, cation–π interaction, and Fe–N active-site coordination. The study demonstrates a sustainable waste-to-resource strategy for converting biomass residues into high-performance adsorbents for wastewater remediation, contributing to circular economy practices and sustainable environmental management pathways relevant to Africa's development.

Keywords: Biochar, Sawdust, Heavy metals, Sustainable material, Adsorption



Graphical Abstract

With funding from the:
Federal Ministry of Research, Technology and Space

(D-11) Desktop Optimization 0f Donnan Dialysis for Coagulant Recovery from Potable Water Treatment Residue using Response Surface Methodology, Particle Swarm Algorithm, and Artificial Neural Networks.

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Abstract

Purpose: This study examines the environmental and health issues related to sludge from wastewater and drinking water treatment plants, especially its disposal in landfills. It investigates recovering valuable aluminum-based coagulants from potable water treatment residue (PWTR) through Donnan Dialysis, aiming to support sustainable waste management and resource recovery.

Methodology: The study utilized Response Surface Methodology (RSM) with Box-Behnken Design (BBD), Artificial Neural Networks (ANN), and Particle Swarm Optimization (PSO) to evaluate and optimize coagulant recovery. A 16-run Box-Behnken experimental setup was designed to investigate how feed flow rate (50–99%), feed concentration (200–900 mg/L), and sweep concentration (0.25–0.75 M) influence aluminum recovery. The optimization process employed Design-Expert software along with MATLAB-based PSO techniques.

Findings: RSM-BBD determined the best conditions at a feed flowrate of 58.53%, feed concentration of 329.33 mg/L, and sweep concentration of 0.1 M, resulting in a predicted aluminum recovery of 89.40%. This was supported by a highly significant quadratic model ($p < 0.001$). Particle Swarm Optimization further enhanced the results, reaching a recovery of 91.15%, showcasing its superior optimization ability compared to RSM alone.

Practical Implication: The findings show that Donnan Dialysis can efficiently reclaim aluminium-based coagulants from treatment sludge, lowering disposal challenges and promoting sustainable water management.

Social Value: This process supports environmental protection by reducing sludge-disposal risks and encouraging circular-economy principles through resource recovery and reuse in water treatment systems.

Originality: This study combines Donnan Dialysis with RSM, ANN, and PSO for the first time to optimize coagulant recovery from PWTR, showing improved prediction and optimization compared to traditional statistical methods

Keywords: Coagulant Recovery, Optimisation, Donnan Dialysis, Waste Management, Water Treatment Plant Sludge.

With funding from the:
Federal Ministry of Research, Technology and Space

(D-12) Quantifying CO_2 emission from soils of agricultural managed land in north-western highlands of Ethiopia

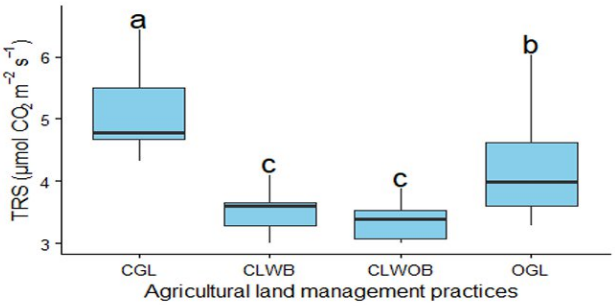
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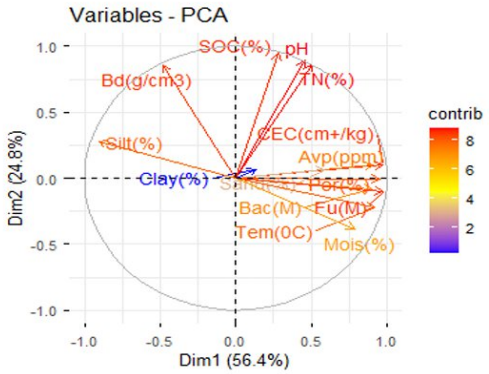
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Abstract

Exchange of CO_2 between soil and the atmosphere is the major component of global carbon dynamics; however, the impact agricultural land management and the mechanism controlling soil respiration was poorly understood in Ethiopian highlands. The purpose of this research was to evaluate the impact environmental drivers, grazing land enclosure and soil bund on soil respiration and its components. Soil respiration, temperature, and moisture content data were collected over a 24-month period from June 2023 to May 2025 using the LI-8100A automated soil CO_2 flux system, soil temperature and moisture sensors. In terms of the key soil nutrients, there was a significant difference ($P < 0.05$) among cultivated land, grazing land and their respective control plots. Consequently, RS was highest in closed grazing land (5.38 µmol CO_2 m^{-2} s^{-1}) followed by open grazing land (4.79 µmol CO2 m^{-2} s^{-1}, lower in cultivated land treated with bund (3.8 µmol CO2 m^{-2} s^{-1}) and lowest in cultivated land without bund (3.2 µmol CO2 m^2s^{-1}.



Despite no significant depth effect, soil respiration was highest at 0–5 cm and decreased with depth. Belowground heterotrophic respiration exceeded autotrophic respiration across land management practices. The principal component analysis results highlighted that soil organic carbon, soil pH, total nitrogen, and cation exchange capacity constitute the primary drivers of soil respiration variability.



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Overall, these findings indicated the potential contribution of land management practices to regulate soil carbon fluxes, contributing to climate change mitigation and enhanced soil carbon storage.

Keywords: Climate factors; CO_2 emission; land management; soil respiration components; soil properties.

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(D-13) Upcycling Mine Tailings and Industrial Waste into Construction Products Through Geopolymerisation in Africa: A Review

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Abstract

Mine tailings and industrial waste represent a significant environmental crisis across Africa, contributing to groundwater contamination, public health risks, and extensive land pollution. With the global transition toward clean energy, Africa's mineral reserves have become increasingly important. The continent possesses a substantial proportion of the world's critical minerals, including graphite in Mozambique and Madagascar, cobalt and copper in the Democratic Republic of the Congo and Zambia, manganese in Côte d'Ivoire, Gabon, Ghana, and South Africa, as well as extensive gold and iron ore deposits. These resources are essential for clean energy technologies such as solar panels, electric vehicles, green hydrogen systems, geothermal energy, and battery storage. To satisfy rising global demand, mining and mineral extraction activities in Africa are expected to expand significantly in the coming decades, resulting in increased generation of both mine tailings and industrial processing waste.

Transforming these twin waste streams into geopolymers offers a powerful solution, directly reducing the massive CO^2 emissions tied to traditional cement production. To map out this potential, this paper presents a systematic review of 80 existing studies. Crucially, the current literature treats these materials in isolation: past studies have upcycled mine tailings alone into pavements, road bases, and roof tiles, or processed industrial waste alone into those same products. Rather than focusing on a single source, this review comprehensively examines the wide variety of different mine tailings and diverse industrial wastes generated across various mineral processing industries. We analyze the distinct mix designs reported across these separate studies, evaluate how these materials affect the mechanical and durability performance of the final construction products, while critically assessing both their technical limitations and real-world commercial viability.

Ultimately, this analysis exposes a major gap: no study has yet examined a fully integrated approach that encapsulates mine tailings within industrial waste-derived geopolymer binders to fabricate these construction products within the African context. While raw material inconsistency and a lack of standardized design guidelines remain significant hurdles, the data show that geopolymerization is a highly viable pathway to address both waste streams simultaneously. Moving forward, future research should focus directly on this combined encapsulation strategy to build sustainable, low-carbon road pavements, roof tiles, and road bases across the continent.

Keywords: Geopolymers, mine tailings, industrial waste, slag, upcycling, road pavements, roof tiles, product design, Africa, sustainable construction

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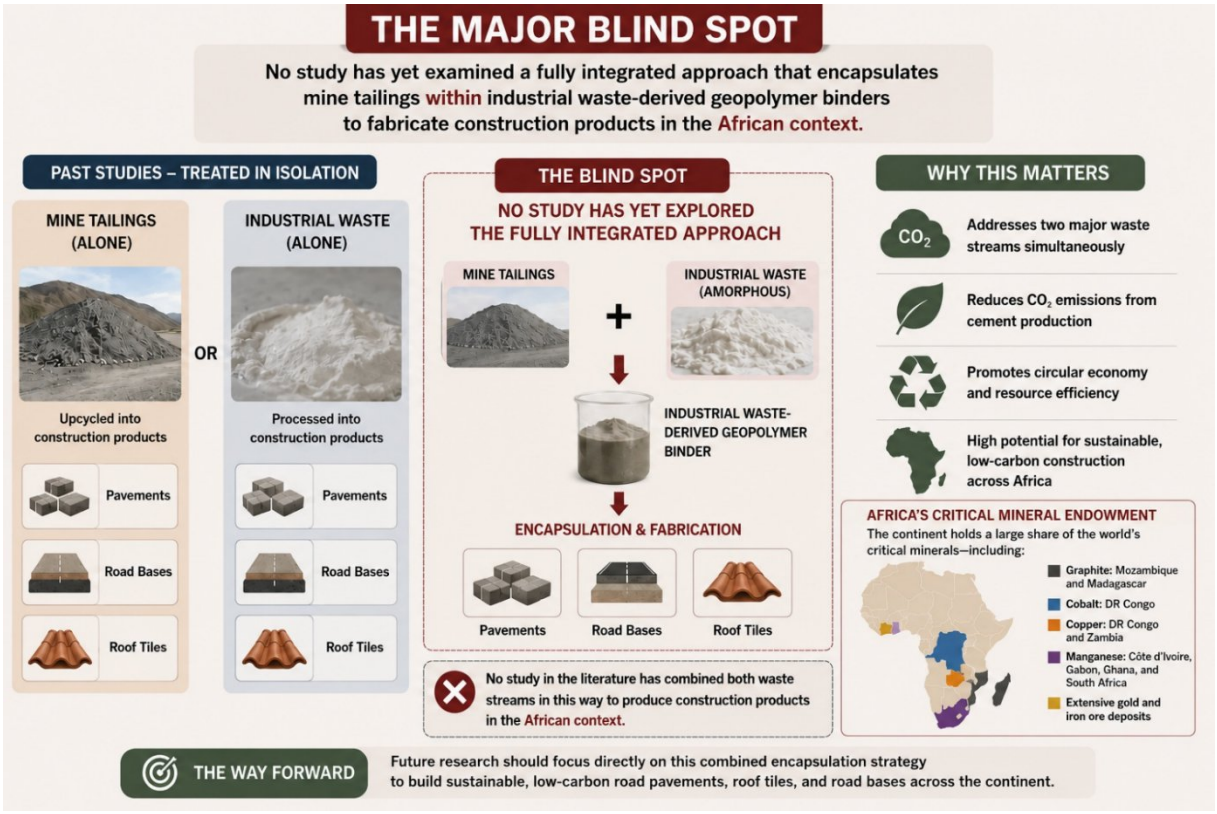


Fig. 1: Graphical Abstract: Conceptual diagram illustrating the integrated pathway of encapsulating diverse African mine tailings within industrial waste-derived geopolymer binders to fabricate low-carbon road bases, pavements, and roof tiles. (Image conceptualized by the author and rendered with the assistance of AI tools)

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(D-14) Development of Zinc nitrate Hexahydrate Salt (ZNH) based Deep eutectic Electrolytes for Rechargeable Zinc Air Batteries

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Abstract

In this study, four deep eutectic solvents (DESs) were synthesized from ZNH (zinc nitrate hexahydrate) (and various HBD (hydrogen bond donor) atoms namely ethylene glycol (EG), glycerol (Gly), urea (U), and a mixture of urea and ethylene glycol (U/E) using the heating approach for reversible zinc (Zn) anode reactions. Here in, the reversibility of the zinc anode for as-prepared DESs was examined through electrochemical and morphological analyses using CV (cyclic voltammetry), EIS (electrochemical impedance spectroscopy), Tafel extrapolation measurements, and scanning electron microscopy (SEM). The CV results showed a broad Zn reduction and oxidation peaks for ZNH/EG DES compared to ZNH/Gly, ZNH/U, and ZNH/UE DESs. Electrochemical impedance spectroscopy (EIS) is employed to investigate the electrochemical properties of zinc anode in zinc air battery. The EIS resulted indicated that Zn electrodes in the ZNH/EG DES possessed a higher reaction kinetics and Rct (lower charge-transfer resistance) 7.2369 Ω at the electrode-electrolyte interface. Additionally, the lower negative corrosion potential of the Zn anode obtained from ZNH/EG DES (-0.804 V) could enhance charge efficiency in Zn-based batteries. Unlike the other DESs, the ZNH/EG DES yielded a highly uniform surface with densely packed and smaller zinc flakes compared to the bare Zn anode. The zinc anodes in ZNH/EG DES exhibit a notably lower charging plateau voltage (**0.4 V**) and higher discharging plateau voltage **(1.9 V**) at a current of 1 mA/cm². In general, these findings highlighted that the ZNH/EG DES effectively suppressed Zn dendrite growth and reduced side reactions, thereby improving the reversibility of the Zn anode.

Keywords: Zinc-Air Batteries; Deep Eutectic Solvents, Zinc Anode, Electrochemical Performance, Rechargeable.

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(D-15) Green Computing: Advancing Energy-Efficient Materials and Systems for a Sustainable Digital Future

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Abstract

Green computing offers a vital pathway to decarbonize the digital economy through sustainable IT strategies including energy-efficient hardware, AI-driven data centers, and circular e-waste systems. Yet challenges in scalability, equitable access, and implementation evidence call for integrated approaches. The ICT sector currently consumes 4% of global electricity and is projected to contribute 14% of carbon emissions by 2040. In Ethiopia, rapid digital transformation is increasing energy demand and e-waste generation, yet energy access remains constrained and waste management systems are nascent. Therefore, this study aims to explore how green computing can advance energy-efficient materials and systems for a sustainable digital future in Ethiopia, examining materials innovations, system architectures, and policy frameworks that reduce environmental footprint. A mixed-methods approach combined quantitative data from 50 global data centers, qualitative insights from 120 stakeholders, industry case studies, and a systematic review of 45 studies (2015–2025). Metrics included PUE, CUE, WUE, material recovery rates, and carbon intensity. Findings reveal that green computing technologies deliver significant environmental and economic benefits. AI-optimized cooling systems reduced energy use by 40% (95% CI [37–43%]), and low-power processors achieved 40–60% reductions (95% CI [36–64%]). Integration of renewable energy decreased carbon intensity by 80–90% (95% CI [78–93%]), while circular economy programs recovered 90–98% of critical metals from e-waste and extended product lifespan by 40–50%. Despite these gains, a 15–25% rebound effect showed that rising computational demand offsets some efficiency improvements. Economic analysis indicated a 20–40% upfront cost premium but 30–40% energy savings, with 3–5 year payback periods and 15–25% lower total ownership costs over 5–7 years. Server utilization improvements from 15–20% to 60–80% and carbon intensity variations from 0.01–0.05 to 0.3–0.7 kg CO_2/kWh highlight location-based disparities in impact. We conclude that green computing represents a viable and impactful pathway to sustainable digital transformation, supported by an implementation framework integrating technology, policy, financing, and capacity building to enable equitable and scalable adoption.

Keywords: Digital transformation, e-waste management, energy-efficient materials, green computing, sustainable ICT

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(D-16) Sustainable Engineering of ε-MnO2 Nanostructures for High Performance Supercapacitors: A Response Surface Methodology Approach

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Abstract

Sustainable energy development across Africa depends on the availability of affordable, scalable, and environmentally responsible energy storage materials. Manganese dioxide (MnO_2), an earth-abundant and low-cost transition metal oxide, has emerged as a promising electrode material for supercapacitors; however, systematic optimization of synthesis parameters and the electrochemical potential of the ε-MnO_2 (akhtenskite) polymorph remain insufficiently explored. In this study, ε-MnO_2 nanostructures were synthesized through a simple co-precipitation route using $MnCl_2{\cdot}4H_2O$ and $KMnO_4$ precursors, followed by statistical optimization using Response Surface Methodology (RSM) based on a Box-Behnken design (BBD). The effects of precursor concentration, calcination temperature, and reaction time on electrochemical performance were investigated, with analysis of variance identifying calcination temperature and reaction time as the most influential factors. Structural characterization confirmed the formation of phase-pure ε-MnO_2 (akhtenskite), while BET analysis revealed a high specific surface area of 156.82 m_2 g^{-1} for the optimized sample. Electrochemical evaluation demonstrated a specific capacitance of 113.996 F g^{-1} at 10 mV s^{-1} and an areal capacitance of 317.84 mF cm^{-2} at 0.5 A g^{-1}. The electrode delivered an energy density of 2.4 Wh kg^{-1} and retained 78.3% of its initial capacitance after 200 charge-discharge cycles, with a coulombic efficiency of 112%. These findings demonstrate that statistically guided synthesis can enhance the performance of ε-MnO_2 nanostructures while employing accessible materials and straightforward processing methods. The approach offers a reproducible pathway toward sustainable energy storage technologies suitable for supporting renewable energy integration and long-term energy resilience in Africa.

Keywords: RSM, Specific capacitance, Box-Behnken design, ε-MnO_2, EIS

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E - Development of strategies and implementation

(E-1) Can Urine-Based Circular Fertilisers Enter Smallholder Markets? Evidence from Ethiopia on Farmer Preferences and Willingness to Pay

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Abstract

The market entry of circular fertilisers produced through resource-oriented sanitation systems hinges on whether farmers perceive recycled nutrients as legitimate and economically viable inputs. This study examines how smallholder farmers in Ethiopia evaluate human urine–based fertiliser (UBF) when confronted with realistic trade-offs in product form, nutrient content, price, and mode of delivery, with the aim of identifying conditions under which circular nutrient recovery technologies can be integrated into sustainable fertiliser management systems. We conducted a discrete choice experiment with 449 farm households and estimated farmers preferences using a Generalized Multinomial Logit model in willingness-to-pay space. The results show that farmers strongly prefer granular urine-based fertiliser over liquid formulations, value products with organic-carbon content equivalent to cattle dung, and favourcooperative-based distribution over private input dealers. Estimated willingness to pay is highest for granular formulation, at ETB 3,703 per 100 kg, followed by cattle-dung-equivalent organic-carbon content, at ETB 3,089 per 100 kg. These values are close to the prevailing market price of mineral fertilisers during the survey period, suggesting that urine-based fertilisers are not necessarily discounted when they are formulated and delivered in ways that match farmers' expectations. In contrast, private-dealer distribution reduces willingness to pay, indicating the importance of trusted supply channels for novel recycled inputs. The findings suggest that urine-based fertilizers can successfully enter smallholder markets if designed and delivered in ways that align with farmers' expectations and existing fertilizer use practices, emphasizing the importance of trusted supply channels. The study contributes evidence on circular nutrient management and market-oriented design of sanitation-derived fertilizers in low-income agricultural systems, emphasizing the importance of aligning product design, safety assurance, and distribution methods with farmers' expectations.

Keywords: Urine-based fertilizer, Circular economy, Discrete choice experiment, behavioral economics

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(E-2) Knowledge Transfer as a Catalyst for Africa's Green Transition: A Multi-Stakeholder Framework for Sustainable Energy Innovation and Circular Economy Development

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Abstract

Africa possesses abundant renewable energy resources, including an estimated 1,000 GW of exploitable solar energy potential. Hitherto, approximately 600 million people across the continent continue to lack reliable access to electricity. This highlights a critical challenge that extends beyond technological and infrastructural deficits to include persistent gaps in information exchange, knowledge transfer, institutional coordination and innovation capacity. Despite commitments to sustainable development and climate action from frameworks like the United Nations Sustainable Development Goals (SDGs), the United Nations Framework Convention on Climate Change (UNFCCC), and the African Union's Agenda 2063, knowledge transfer initiatives across Africa remain fragmented, externally driven and often insufficiently aligned with local contexts. Against this backdrop, the study aims to examine how effective exchange, co-creation and utilisation of knowledge among governments, research institutions, industry actors, civil society organisations, and local communities can accelerate sustainable energy innovation and circular economy development across the continent. The study will adopt a qualitative research design. It will draw on a systematic review of scholarly literature published between 2010 and 2025, sourced from Scopus, Web of Science and African Journals Online (AJOL). This will be complemented by a comparative case analysis of selected African countries, namely Ghana, Kenya, Morocco and South Africa. The proposed framework is informed by Triple Helix Theory, Social Learning Theory, and the African Union's Science, Technology and Innovation Strategy for Africa (STISA-2024). The study is expected to attempt to address the paucity of local frameworks for knowledge transfer in the context of sustainable energy. It will aim at advancing a shift in perspective from viewing African stakeholders as passive recipients of external expertise to recognising them as active co-creators and producers of knowledge.

Keywords: Africa, circular economy, green transition, knowledge transfer, open science.

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(E-3) Livelihood Diversification for Resilient Rural Economies: Evidence from Smallholder Farmers in North Wollo Zone, Ethiopia

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Abstract

This study examines the determinants and constraints of livelihood diversification intensity among smallholder farmers in the drought-prone North Wollo Zone of Ethiopia. Using multistage sampling, primary data were collected from 384 rural households across Habru, Gubalafto, and Meket districts. A fractional probit model was applied to analyze the intensity of livelihood diversification measured by the Simpson Diversity Index (SDI), complemented by descriptive statistics and a constraint ranking approach. The findings indicate that although 65.89% of households engage in some form of diversification and the overall intensity remains low, with a mean SDI of 0.28. On-farm income remains the dominant source, with limited participation in non-farm (48.7%) and off-farm (45.6%) activities.

Econometric findings show that mobile phone ownership, credit access and male-headed households has the strongest positive effect on diversification.Conversely, older age, larger landholdings, and irrigation use negatively influence diversification intensity. Financial constraints, poor infrastructure and market access, and human capital gaps (education and skills) were identified as the major barriers. Livelihood diversification in the study area is largely a survival-led strategy pursued by resource-poor, younger, and digitally connected households to mitigate risks. The study recommends expanding mobile phone access and digital literacy, strengthening rural financial services, investing in infrastructure, and implementing targeted support for youth, women, and asset-poor households to foster more resilient and diversified rural livelihoods.

Keywords: Livelihood, Diversification, Simpson Diversity Index, Smallholder Farmers, Ethiopia

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(E-4) Examining Students‘ Preparedness to Utilize Artificial Intelligence for Facilitating the Adoption of Green Energy for Green Building Development in Nigeria, West Africa

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Abstract

The global transition to renewable energy and circular economies depends on technological innovation and the development of human capital skilled in digital technologies. Artificial Intelligence (AI) is vital in sectors such as energy system optimization, smart grids, green building design, and life-cycle assessment, making graduate-level AI expertise essential to Africa's green energy shift. In Nigeria, with its energy poverty, urbanization, and a growing construction sector, the built environment is crucial for implementing green energy aligned with national renewable energy targets. However, little is known about how ready students in Estate Management, Architecture, Building Technology, and Civil Engineering are to use AI for sustainable building and green energy. This research assesses the preparedness of students at a Nigerian tertiary institution to adopt and utilize AI for green energy for green building development, using a survey based on the Technology Acceptance Model and Self-Efficacy Theory. A respondent sample of 400 was determined from the total student population. Survey questionnaires were distributed to students from four programs at the higher institution using an online Google form to measure AI awareness, green energy knowledge, self-efficacy, curriculum readiness, perceived usefulness, barriers, and skills. Results show moderate awareness of AI and renewable energy (scores of 3.05 out of 5), but there were low practical AI skills, such as energy modeling and site analysis. Main barriers include poor digital infrastructure, limited AI content in curricula, lack of AI-green building standards, and shortages of qualified staff. Civil Engineering students had slightly better computational skills, while Estate Management students were more aware of the impact of green certification on property values. The study highlights the need for curriculum reform, more investment in AI-enabled learning, and government programs tailored to Africa. Recommendations include integrating AI literacy into built-environment programs, fostering industry-academia partnerships, and updating accreditation standards to include digital green skills.

Keywords: Artificial Intelligence; Green Energy; Green Building; Students' Preparedness; Nigeria; Circular Economy; Renewable Energy; Built Environment Education; West Africa

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(E-5) Integrating Workplace Safety and Circular Economy Practices in Ethiopian Manufacturing Industries: Opportunities and Challenges for Sustainable Industrial Development

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Abstract

African industries are increasingly facing challenges related to environmental sustainability, industrial waste management, occupational safety, and resource efficiency. In Ethiopia, manufacturing industries are under growing pressure to adopt sustainable production systems that align with global circular economy principles and renewable industrial transformation. However, limited integration between workplace safety systems and circular economy practices continues to affect industrial sustainability and worker well-being.

This study examines the opportunities and challenges of integrating workplace safety awareness and circular economy practices within Ethiopian manufacturing industries. The research particularly focuses on industrial environments where waste reduction, recycling practices, occupational health, and environmental compliance are becoming essential for sustainable development. The study aims to explore how industries can improve resource efficiency while simultaneously strengthening worker safety and compliance systems.

The research applies a qualitative and descriptive approach using workplace observations, compliance reviews, and analysis of industrial safety and environmental management practices. Experiences from manufacturing industries in Ethiopia are used to identify major barriers affecting sustainable industrial implementation. Key issues include limited awareness of circular economy concepts, inadequate safety training, weak environmental compliance systems, financial limitations, and insufficient integration between occupational safety and sustainability planning.

The study further highlights potential opportunities for African industries, including green manufacturing transitions, industrial waste reuse systems, energy-efficient production processes, and improved workplace safety management. Integrating occupational safety with circular economy strategies can contribute to reduced industrial accidents, improved environmental protection, enhanced employee productivity, and long-term industrial resilience.

The findings are expected to support policymakers, industries, researchers, and development organizations working toward sustainable industrial transformation in Africa. The study also contributes to ongoing discussions regarding renewable energy transition, green industrialization, and sustainable economic development within the African context.

Keywords: Livelihood, Diversification, Simpson Diversity Index, Smallholder Farmers, Ethiopia Circular Economy, Workplace Safety, Sustainable Manufacturing, Green Industrialization, Occupational Safety, Ethiopia, Renewable Energy, Industrial Sustainability.

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(E-6) Resource Rich, Energy Poor: Politics, Policy Continuity, the Quest for Energy Security, and Strategic Transformation in Namibia

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Abstract

Despite possessing abundant renewable and non-renewable energy resources, Namibia has remained largely energy dependent since attaining independence in 1990. Successive administrations have pursued various energy initiatives aimed at improving energy security and reducing reliance on imported electricity; however, implementation challenges and policy inconsistencies have limited progress. The emergence of Green Hydrogen under the administration of President Hage Geingob repositioned Namibia as a potential renewable energy hub for Africa, creating new opportunities for energy transformation, industrialization, and strategic influence. Concurrently, the discovery of significant offshore oil and gas reserves introduced competing development pathways and policy priorities. This paper examines the role of politics, leadership transitions, and policy continuity in shaping Namibia's energy landscape and strategic transformation. Particular attention is given to evolving state priorities regarding green hydrogen, hydrocarbons, and emerging discussions around nuclear energy under successive administrations. Employing a qualitative case study and policy analysis approach, the study analyses national energy policies, legislative frameworks, presidential policy pronouncements, Green Hydrogen Programme documents, and Namibia's National Development Plans (NDP1–NDP6) to assess the relationship between political decision making and energy outcomes. The paper argues that while Namibia possesses the resources necessary for energy independence, governance structures, institutional arrangements, and political priorities remain decisive determinants of energy security. It contributes to broader debates on energy governance, resource management, and strategic transformation in resource-rich developing states.

Keywords: Energy Security, Strategic Transformation, Green Hydrogen, Hydrocarbons, Namibia.

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(E-7) The Grand Ethiopian Renaissance Dam: Energy Diplomacy, Regional Development, and Transboundary Water Governance in the Nile Basin

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Abstract

Shared river basins play a critical role in global development, environmental sustainability, and regional security, with the Nile River representing one of the most complex transboundary water systems in the world. This study presents a systematic review of the Grand Ethiopian Renaissance Dam (GERD) and its implications for transboundary water governance, regional cooperation, and sustainable development in the Nile Basin. Using a systematic literature review guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, 404 records were identified from major scientific databases and institutional repositories, of which 30 studies were selected for qualitative synthesis. The analysis integrates hydrological, socio-economic, political, institutional, and environmental dimensions to provide a comprehensive understanding of GERD as a socio-technical and governance system. Findings indicate that the GERD represents both a transformative development opportunity and a significant hydro-political challenge. Hydrologically, the dam enhances flow regulation, reduces downstream flood risks, and supports renewable energy generation, while simultaneously introducing challenges related to sedimentation, evaporation losses, and seasonal variability. Socio-economically, the project strengthens Ethiopia's energy capacity and regional electricity trade potential, although downstream countries express concerns regarding water security during reservoir filling phases. Politically, historical water allocation agreements, institutional fragmentation, and mistrust among riparian states remain major barriers to effective hydro-diplomacy. Environmental uncertainties associated with climate variability further complicate long-term basin management. Despite these challenges, the review highlights substantial prospects for cooperation through benefit-sharing frameworks, regional energy integration, joint monitoring systems, and adaptive governance mechanisms. Lessons derived from GERD demonstrate that successful transboundary water management requires transparent data exchange, institutional trust, and climate-resilient planning. The study concludes that the GERD has the potential to function as a cornerstone for regional stability and cooperative development, offering a replicable model for integrated water-energy governance in transboundary river basins worldwide.

Keywords: Transboundary water; GERD (Grand Ethiopian Renaissance Dam); Governance; Sustainable development; Hydrology; Socio-economic impacts; Regional cooperation

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(E-8) TArtificial Intelligence, Circular Economy, and Green Energy: Emerging Research Frontiers in Africa

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Abstract

Africa faces interconnected challenges of rapid urbanization, energy poverty, environmental degradation, climate change, and unsustainable resource utilization. Emerging technologies such as Artificial Intelligence (AI), circular economy (CE) models, and green energy systems offer transformative pathways toward sustainable development across the continent. This manuscript critically examines the convergence of AI, circular economy principles, and renewable energy transitions in Africa, highlighting emerging research frontiers, opportunities, barriers, and policy implications. The paper synthesizes recent literature on AI-driven resource optimization, waste valorization, smart energy systems, green hydrogen, sustainable industrialization, and digital innovation ecosystems. Furthermore, it explores how AI can enhance renewable energy forecasting, circular supply chains, smart agriculture, healthcare sustainability, and climate resilience. The study identifies persistent barriers including digital infrastructure gaps, limited technical expertise, policy fragmentation, inadequate funding, and ethical concerns surrounding AI deployment. The manuscript concludes by proposing strategic frameworks for African governments, universities, industries, and development partners to foster inclusive and sustainable green transitions. The integration of AI, circular economy systems, and green energy technologies represents a major opportunity for Africa to leapfrog traditional industrial models and achieve sustainable economic transformation.

Keywords: Artificial Intelligence, Circular Economy, Green Energy, Renewable Energy, Sustainability, Africa, Green Hydrogen, Digital Transformation, Sustainable Development.

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(E-9) Closing the Policy-to-Implementation Gap: A Systems Thinking Analysis of Solar PV for Productive Use in Rural Tanzania

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Abstract

This paper examines the extent to which Tanzania's national policy, planning, and implementation frameworks are aligned with solar photovoltaic (PV) deployment for productive use in rural areas. Applying systems thinking, it diagnoses the structural conditions that prevent strategic endorsement of solar PV from translating into operational practice at the sector and local government levels. Using a qualitative desk-based document analysis, the study purposely reviews key policy and strategic planning documents, selected against four explicit criteria covering policy hierarchy, sectoral breadth, operational status, and institutional authority. The analysed documents include: the Tanzania Development Vision 2050 (NDV 2050), the National Renewable Energy Strategy 2024-2034 (NRES), the National Energy Compact (Mission 300), the Third National Five-Year Development Plan 2021/22-2025/26 (FYDP III), the Second National Five-Year Development Plan 2016/17-2020/21 (FYDP II), the Tanzania Rural Energy Master Plan 2022/23-2029/30 (REMP), the National Irrigation Policy, the National Livestock Policy, the National Water Policy, Water Sector Development Programme III, the PMO-RALG Planning and Budget Guidelines, together with related sector budget documents. The analysis of each document examined whether it establishes operational requirements, cross-sector connectors, feedback mechanisms, and a budget for rural solarisation.

The findings reveal that Tanzania's national strategy and energy policy frameworks consistently endorse solar PV for productive use in rural areas, however, the endorsement has not been translated into sector-specific design standards, budget lines, local government planning templates, or basin water governance frameworks that govern the delivery of rural infrastructures. Three structural gaps explain this disconnect; the first is the absence of cross-sectoral solar design standards since the responsibility for solar PV systems design sits outside any single ministry's mandate, meaning that productive use projects are designed and funded without a solar appraisal requirement. Second, the absence of solar PV budget tagging. Solar PV for productive use carries no budget sub-code across the agriculture, water, and livestock sector votes, remaining invisible to Treasury and LGA planners, reflecting that the Rural Energy Fund has financed rural electrification rather than productive use activities. Third, the absence of LGA planning tools and basin water governance frameworks for solar-powered abstraction. The Annual Development Plans contain no solar appraisal requirement, and Basin Water Boards regulate abstraction without a simplified permit track for small-scale solar-powered systems.

This paper argues that the challenge is not the absence of a policy framework, but the structural disconnection between national strategic intent and the planning, budgeting, and implementation of solar PV systems through which rural infrastructure is designed and financed. Applying the systems thinking lens, the paper identifies a self-continuing planning and implementation gap in which each project cycle without solar specification makes the next one less likely to include it, a gap which is sustained by the absence of institutional requirement to include solar PV systems. The paper concludes that four specific harmonisation measures are required: cross-sectoral solar PV design standards for productive use in rural, technology quality assurance, solar-sensitive budget tagging across sector votes and integration of solar PV appraisal into local government planning and basin water permitting.

Keywords: solar PV, productive use, rural development, policy alignment, systems thinking

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(E-10) Policy Drivers Promoting Innovation Technologies for Renewable Energy Resources Development and Utilization in Ethiopia

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Abstract

Ethiopia is one of the fastest-growing economies in the world despite immense challenges towards access to sustainable energy supplies and modern energy technologies. The country is undertaking great effort towards the development of renewable energy technologies and green legacy. However, the largest share of energy consumption (≈87%) in Ethiopia is dominated by traditional fuels (charcoal, fuel wood, dung cakes, and agricultural residues) which pose various health and environmental risks. The country has an enormous amount of renewable energy potentials (e.g., solar, hydro, wind and geothermal), but only 5% of its full hydropower potential is exploited and others are not fully harvested or not well developed to date.

Ethiopia possesses vast, untapped renewable energy resources—including the largest hydro-power potential in Africa, significant geothermal, solar, and wind capacity—yet it faces immense challenges in transforming these into accessible energy for its population. Mixed study design was implemented to conduct this study. Methodologies and techniques used to undertake this research include GIS mapping and statistical modeling to evaluate resource potential (solar, wind, hydro, etc.), alongside Multi-Criteria Decision Analysis (MCDA) (AHP, TOPSIS) for site selection, and financial modeling (NPV, ROI) for viability, integrating technical, economic, social, and environmental factors to guide policy and investment decisions for sustainable energy systems.

Ethiopia generates most of its electricity from renewable energy, mainly hydropower. The country is strategically expanding its energy sector, aiming for a more diverse and resilient mix. Currently, Ethiopia's energy production is heavily reliant on hydropower, which constitutes about 90% of its generated electricity but is vulnerable to climate-induced droughts (Kruger, 2018). To address this, the government is implementing key hydropower, geothermal, wind, and solar projects. While the country is a leader in renewable energy generation—producing over 90% of its electricity from renewables—only about 5% of this potential has been exploited. As of 2026, the sector is experiencing significant expansion, with total installed capacity reaching approximately 9.7 GW, driven by the Grand Ethiopian Renaissance Dam (GERD) and new wind projects.

Key approaches used involve resource mapping, energy audits, policy impact and integrated assessment models for strategic planning taking Reppie Waste Recycling Energy Hub and Asho Goda Wind Energy design and implementation. Ashegoda near Mekelle in the Tigray region is a 120 MW wind farm supplieselectricity to more than 3, 000,000 Ethiopians. The findings show there is critical lack of infrastructure, limited financial resources, and high upfront costs for technologies like waste recycling, geothermal and wind hinder development. Ethiopia has Massive Untapped Potential of renewable energy with an estimated 60 GW of combined renewable potential, with only 5% of its 45,000 MW hydropower potential exploited. Diversification into wind and solar is “a risk management strategy of the country that will determine the resilience of the entire regional grid. The 120-megawatt Aysha II Wind Project near the Djibouti border marks a key step. In the first half of 2025/26, electricity exports contributed to more than 5.1 billion dollars in export earnings.

Ethiopia's Reppie (or Koshe) Waste-to-Energy Plant in Addis Ababa is Africa's first such facility, converting 1,400 tons of daily waste into ~25MW of electricity, turning a former landfill into a renewable energy source and addressing pollution as part of Ethiopia's green growth strategy. While a significant step for recycling and renewable energy, the project faces challenges like ash disposal, potential negative impacts on informal waste pickers, and ensuring strong regulatory oversight, with calls for more transparent monitoring and community engagement. Ethiopia's engineering and technology for renewable energy (solar, wind, bio), smart agriculture (AI weed control), and resilient urban planning, but faces challenges like funding gaps, technology access, institutional barriers, skill

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deficits, and bridging research-to-application divides, requiring strong collaboration for inclusive, sustainable solutions.

Harnessing innovation and engineering technologies is critical to shifting from heavy reliance on traditional biomass (approx. 87% of consumption) to a modern, diversified energy system. For instance, Ethiopia has to switch to renewable energy innovations like utilizing urban waste, such as the Reppie waste-to-energy plant, to manage urban waste while generating power. Strengthening regulatory frameworks to support long-term investment, such as the National Sustainable Energy Development Strategy 2024-2030. Engineering Local Capacity and Manufacturing can enhance its renewable energy development and utilization opportunities shifting from importing capital hardware to developing a local industrial base for assembling solar components and wind turbines.

Strengthening Public-Private Partnerships PPPs for mobilizing blended green financing and engaging the private sector through independent power producer (IPP) tenders for large-scale solar and geothermal projects. Ethiopia need to maximize its renewable potential, driving both economic growth and improved living standards creating innovative, accessible financing improving efficiency of energy engineering innovations, particularly for rural households and businesses to adopt decentralized wind, geothermal and solar home systems and productive use technologies.

Keywords: Livelihood, Diversification, Simpson Diversity Index, Smallholder Farmers, Ethiopia

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(E-11) Machine learning-based weekly electricity consumption modelling under meteorological variability and population growth: Evidence from a West African city

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Abstract

Electricity demand forecasting is becoming increasingly important for African cities facing rapid urbanisation, climate stress, rising energy costs, and the need to transition toward more sustainable energy systems. In many developing urban power systems, planning decisions are constrained by limited reserve margins, dependence on imported electricity, data quality issues, and uncertainty about future demand growth. These challenges are particularly relevant for Lomé, the capital and main economic hub of Togo, where high urban electricity access, concentrated economic activity, tropical coastal climatic conditions, and substantial dependence on external electricity supply make accurate demand estimation essential for procurement, infrastructure planning, service reliability, and future renewable energy integration. While electricity forecasting studies often focus either on short-term operational prediction or long-term annual projections, fewer studies provide interpretable, intermediate-scale frameworks that connect meteorological variability, demographic growth, seasonal demand patterns, and forward-looking scenario analysis in African urban contexts.

Objective:
This study addresses that gap by developing and evaluating an interpretable machine-learning framework capable of forecasting weekly electricity demand under changing demographic and climatic conditions. The study further aims to identify the main drivers of demand, quantify the contribution of heat-related stress and population growth, and assess how future scenarios may affect average consumption, seasonal peaks, and extreme weekly loads. The work provides a replicable decision-support approach for climate-sensitive and data-constrained urban energy systems in Africa.

Method
The analysis uses daily electricity consumption, meteorological, and population data for Lomé from 2010 to 2017, aggregated to weekly resolution to reduce short-term disruptions associated with holidays, outages, reporting inconsistencies, maintenance operations, and temporary supply constraints, while preserving seasonal and climate driven patterns. Weekly mean electricity demand is modeled using climate-sensitive features, including averages, variability indicators, cooling degree days, seasonal cycles, and dynamic population data. Fourteen regression algorithms were benchmarked under chronological validation, with hyperparameters optimized via particle swarm optimization (PSO) and 2017 reserved for out-of-sample testing. The best-performing model was then examined using four complementary interpretability and diagnostic tools: Shapley Additive Explanations (SHAP) values, permutation importance, partial dependence plots, and scenario-based experiments for the period 2018-2030.

Results
Benchmark results indicate that nonlinear ensemble models outperform simpler baselines, with the PSO-optimized LightGBM achieving the highest accuracy (R2 = 0.80) on the 2017 test set. Interpretability analysis shows that electricity demand in Lomé is driven by two key forces: long-term growth shaped by population expansion and short term variability driven by climate conditions,

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particularly cooling degree days. These findings are consistently supported by SHAP values, permutation importance, and partial dependence plots, confirming that the model captures meaningful physical relationships, rather than relying only on statistical correlations. Scenario analysis for 2018-2030 reveals that demographic changes dominate long-term demand trends, while heat-related factors significantly intensify seasonal peaks and extreme loads, especially under hot and humid conditions.

Contribution and relevance to ICERA 2026

This study advances the ICERA 2026 agenda by presenting a transparent and transferable framework for sustainable energy planning in climate-sensitive, data constrained African cities. By integrating forecast accuracy, interpretability, and scenario based stress testing, it supports improved decisions on renewable integration, infrastructure investment, and urban energy resilience. Applied to Lomé, the framework provides policy-relevant insights into electricity demand dynamics driven by population growth and heat exposure, while promoting energy efficiency and savings. It offers practical value for policymakers in Togo and across West Africa, supporting energy transition strategies and circular economy objectives.

Keywords: Electricity demand forecasting, Machine Learning, LightGBM, Cooling degree days, Scenario analysis, Urban energy systems

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(E-12) Integrating Climate Data and Remote Sensing to Support Renewable Energy Planning in Angola

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Abstract

The global transition towards renewable energy has become one of the most important strategies for mitigating climate change, improving energy security and promoting sustainable economic development. Angola possesses considerable renewable energy resources, including solar radiation, wind, biomass and hydropower, yet access to reliable electricity remains uneven, particularly in rural areas. Although national policies increasingly recognise the importance of renewable energy, planning processes often rely on fragmented datasets and limited spatial analyses. This study proposes an integrated framework combining climate data, Earth Observation and Geographic Information Systems (GIS) to support evidence-based renewable energy planning in Angola. The research aims to identify spatially suitable areas for renewable energy development while considering environmental constraints, climatic variability, land-use characteristics, infrastructure accessibility and long-term sustainability. The study integrates freely available datasets including Sentinel-2 imagery, ESA WorldCover, the Shuttle Radar Topography Mission Digital Elevation Model, Climate Hazards Group InfraRed Precipitation with Station Data (CHIRPS), ERA5 climate reanalysis, the Global Solar Atlas, OpenStreetMap, and meteorological observations from the SASSCAL WeatherNet network and INAMET, where available. Sentinel-2 imagery will be processed to characterise land cover and vegetation dynamics, whereas SRTM data will derive terrain variables such as elevation and slope. Climate datasets will provide long-term rainfall, temperature and solar radiation information to assess climatic suitability and resilience. A GIS-based Multi-Criteria Decision Analysis using the Analytical Hierarchy Process will integrate annual solar irradiation, climatic stability, land cover, slope, elevation, proximity to roads, settlements, transmission infrastructure and environmentally sensitive areas into a Renewable Energy Suitability Index. Each criterion will be standardised and weighted according to expert knowledge and published literature before being combined using weighted overlay techniques. Suitability classes ranging from very low to very high will identify priority investment zones. Particular attention will be given to avoiding protected areas, wetlands, dense forests and other ecologically sensitive environments, ensuring that renewable energy expansion remains compatible with biodiversity conservation and sustainable land management. The methodology also incorporates climate resilience by recognising that future changes in rainfall and temperature may affect energy production and infrastructure performance. Expected outputs include national and provincial suitability maps, spatial statistics of suitable land, priority investment corridors, and a geospatial database supporting government agencies, utilities and private investors. Provinces such as Huambo, Benguela, Huíla and Bié are expected to exhibit high suitability because of favourable climatic conditions, terrain characteristics and infrastructure accessibility. The study is expected to demonstrate that integrating climate services with remote sensing provides a more comprehensive basis for renewable energy planning than conventional resource assessments. Scientifically, the research contributes a transparent and reproducible workflow based entirely on open-access datasets and modern geospatial techniques. From a policy perspective, the proposed framework supports Angola's commitments under the Paris Agreement and the Sustainable Development Goals, particularly SDG 7 and SDG 13, by promoting low carbon development, improved energy access and climate resilience. Furthermore, integrating observations from SASSCAL WeatherNet, INAMET and satellite-derived information illustrates how environmental monitoring systems can strengthen decision making and reduce uncertainty in infrastructure planning. The framework is scalable and can be adapted for national, provincial and municipal planning, supporting strategic investments in renewable energy while minimising environmental conflicts and enhancing socio-economic development. Ultimately, this research demonstrates the value of combining climate information, remote sensing and GIS to guide sustainable renewable energy planning across Angola, providing practical tools for policymakers, researchers and development partners seeking to accelerate the country's transition towards a diversified, resilient and environmentally responsible energy future. The proposed framework also strengthens collaboration

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among government institutions, research organisations, universities and the private sector, facilitating evidence-based policy formulation, improving investment prioritisation and supporting the long-term implementation of resilient and sustainable renewable energy systems across Angola and the wider Southern African region.

Keywords: Renewable energy; Climate data; Remote sensing; GIS; MCDA; Angola; Earth Observation; Sustainable planning.

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(E-13) Leveraging Circular Economy for Sustainable E-Waste Business Models: Integrating Informal Entrepreneurs in Ghana's Formal Sector

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Abstract

This study addresses the critical gap in the literature on sustainable business models, sustainable transistions and circular economy, by asking how the principles of circular economy can be leveraged to co-create sustainable business models that effectively integrate informal e-waste entrepreneurs into Ghana's formal sector,a sustainability transition. The importance of this inquiry cannot be overstated. While informal e-waste workers have long practiced resource recovery and reuse—generating between US$105-268 million annually and supporting over 200,000 livelihoods—they remain largely excluded from formal circular economy frameworks (Akon-Yamga et al., 2021; Oteng-Ababio et al., 2016; Forti et al., 2009). The theoretical framework developed in this study offers a novel approach to this challenge. By integrating sustainable business model theory (Lüdeke-Freund et al., 2018, 2020, 2024), stakeholder value theory (Neesham et al., 2023), and circular economy (Geissdoerfer et al,2025, Kirchherr et al, 2023, Kirchherr et al,2017).

Using Gioia methodlogy, I investigate through interviews with stakeholders their value perceptions. Instead of treating "value" as a black box or assuming that formalization is inherently beneficial, this framework makes explicit the multiple, sometimes conflicting, value perceptions of different stakeholders. It recognizes that sustainable business model design is not merely a technical exercise but a normative one, involving choices about what is valued, for whom, and under what conditions. The theoretical contributions of this study are threefold. First, it operationalizes stakeholder-specific value in an informal economy context, extending Neesham et al.'s (2023) methodological framework to a setting where value conflicts are particularly pronounced. Second, it extends Lüdeke-Freund et al.'s (2020) sustainable business model framework to circular-informal contexts, demonstrating how the four normative questions of sustainable value creation can be adapted to design business models that integrate informal entrepreneurs. Third, it theorizes sustainable transistions as a bridge to circular economy, challenging deficit-based narratives and positioning informal entrepreneurs' existing practices as foundational assets for circular transitions.

The practical implications of this study are significant. By mapping stakeholder value perceptions and identifying opportunities for value co-creation, this research will provide actionable insights for policymakers, development practitioners, and business actors seeking to design inclusive circular economy interventions in informal economy contexts. In a context where formalization efforts have often been fragmented and disruptive—as evidenced by the Agbogbloshie demolition and its aftermath—this study offers an alternative approach that centres the perspectives and assets of informal entrepreneurs.

Ultimately, this study aims to contribute to a broader imperative: reimagining sustainability transitions not as top-down formalization processes that displace informal actors, but as collaborative efforts that leverage existing circular innovations to build more just and inclusive economies. By centering the voices and values of informal e-waste entrepreneurs, this research seeks to inform a future where formalization is not a threat to livelihoods but a pathway to their enhancement—a future where the circular economy is not only sustainable but also equitable

Keywords: Sustainable transistions, Sustainable Business Models, Circular Economy, e-waste, informal economy, value

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F- Renewable Energy

(F-1) Thermal Performance Augmentation of a PCM-Integrated Triple-Pass Indirect Solar Dryer: A CFD Investigation for Sustainable Agricultural Drying

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Abstract

Drying of agricultural products is one of the most energy-intensive post-harvest processes in developing countries, where losses are significant due to inadequate preservation technology and the use of traditional drying methods relying on fossil fuels. In most African countries, open sun drying is widely used despite its inefficiency, risk of contamination, inconsistency in drying process, and lack of maintaining product quality in varying climatic conditions. The currently available indirect solar dryers face challenges such as the intermittency and fluctuation of solar radiation, low thermal efficiency, and poor airflow distribution within the dryer. Furthermore, most previous studies on indirect solar drying systems are based on conventional single-pass or double-pass airflow arrangements with limited thermal storage capability. To address these challenges, the present research introduces a novel combination of triple pass airflow configuration, corrugated absorber geometry, and Phase Change Material (PCM) integrated indirect solar dryer for sustainable agricultural drying applications using Computational Fluid Dynamics (CFD).

The proposed solar dryer encompasses a double-glazed triple pass solar air heater (SAH) with a corrugated absorber plate, a PCM-based thermal energy storage (TES) unit, and an insulated drying chamber in a staggered tray arrangement. Thermo-hydraulic performance analysis of the designed solar dryer was numerically investigated for the climatic conditions of Jimma, Ethiopia. The 3-D CFD simulations were carried out using ANSYS Fluent 2021 to examine the thermal and thermo-hydraulic performance analysis in terms of airflow, temperature distribution, heat transfer augmentation, and pressure drop of the triple pass SAH. Charging and discharging processes of the PCM were additionally modeled using COMSOL Multiphysics to determine the transient thermal energy storage characteristics, development of the liquid fraction, and heat energy storage performance. The proposed numerical model incorporated the Realizable k-ε turbulence model with enhanced wall function treatment to predict the performance of turbulent flow and heat transfer rate. The numerical results were validated using previously published experimental and numerical studies available in the literature, and a good agreement was obtained between the present model and reference data.

The design of the solar air heater incorporated with a sinusoidal-shaped absorber plate promotes turbulence intensity, airflow mixing, and convective heat transfer between the absorber plate and the flowing air. The thermo-hydraulic performance was investigated for different mass flow rates, starting from 0.01 kg/s up to 0.07 kg/s. It was observed that the triple pass design performed better than the conventional single pass and double pass SAHs, due to increased heat transfer surface area and increased residence time of air. The maximum outlet air temperature attained at the minimum mass flow rate was about 346 K.

It was also found that the corrugated absorber configuration has superior thermal performance as compared to the conventional flat absorber plate. The Nusselt number increased with the increase of Reynolds number, which indicated that the corrugated absorber plate configuration had high convective heat transfer ability due to the creation of flow separation and reattachment. There was a marked improvement in thermal efficiency for the corrugated absorber with an increase from 39% to 68%, whereas the thermal efficiency of the flat absorber was relatively poor. Even though there was a significant increase in the pressure drop due to the generation of turbulence and rough surface in the

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corrugated absorber, the value of the Thermo-Hydraulic Performance Enhancement Parameter (THPP) ratio was always above one. The results indicated that the PCM thermal energy storage unit was capable of demonstrating considerable promise in terms of maintaining thermal stability during the intermittent and fluctuating solar radiation. The results from numerical simulations indicated that the PCM charging process took place within a time period of about 9,900 seconds, whereas the discharging process was completed in about 11,700 seconds. The total thermal energy stored in the PCM system during charging was approximately 4.4 MJ. The use of multiple fins embedded in airflow tubes increased the heat transfer rates in the PCM storage tank and helped in reducing charging times.

The combined effect of triple-pass air flow, corrugated absorber design, PCM thermal energy storage system, and staggered drying chamber configuration improved the thermal efficiency and stability of the solar drying system. Therefore, the developed PCM-integrated triple pass indirect solar dryer is a promising and sustainable solution for minimizing post-harvest loss and improving food preservation in agriculture-based communities. In addition, the proposed system has great potential for large-scale application in the agricultural drying process in rural Africa, where there are rich solar energy sources.

Keywords: Triple-pass solar dryer; Phase Change Material (PCM); CFD Simulation; Thermo-hydraulic performance; Sustainable agricultural drying; Renewable energy

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(F-2) Exergy and Thermoeconomic Analyses of Serpentine Tube Flat-Plate Solar Collector Working with Al_2O_3-CuO/water Hybrid Nanofluids

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Abstract

The performance of flat-plate solar collectors can be significantly enhanced through the use of advanced heat transfer fluids and comprehensive thermodynamic evaluation. This study presents an exergy and thermoeconomic analysis of a serpentine tube flat-plate solar collector operating with Al_2O_3-CuO/water hybrid nanofluids. The hybrid nanofluids, prepared by dispersing two different nanoparticles in a conventional base fluid, are employed to improve the thermal conductivity and heat transfer characteristics of the collector. A detailed thermodynamic model is developed to evaluate the energy and exergy performance under varying solar irradiance, mass flow rate, ambient temperature, and nanoparticle concentration. The exergy analysis quantifies the irreversibilities within the collector and determines the second-law efficiency, while the thermoeconomic assessment integrates exergy destruction with economic considerations to estimate the cost effectiveness of the system. Experiments were conducted from 09:00 to 16:30 hr, with volume loadings of 0.048%, 0.096%, 0.144%, 0.192% and 0.24%, respectively. Entire region is divided into time zone-1 (09:00 hr to 13:00 hr), and time zone-2 (13:00 hr to 16:30 hr). The results indicate that the use of hybrid nanofluids enhances heat transfer, increases thermal and exergy efficiencies, and reduces exergy destruction compared with conventional working fluids. Furthermore, the thermoeconomic analysis demonstrates that the improved thermodynamic performance can offset the additional cost associated with nanoparticle preparation under optimized operating conditions. The findings provide valuable insights into the design and optimization of high-performance solar thermal systems and demonstrate the potential of hybrid nanofluids as an effective working medium for sustainable solar energy applications.

Keywords: Flat plate solar collector, Exergy analysis, Thermal efficiency, Economical analysis, Enhancement.

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(F-3) Scaling up solar water disinfection using solar thermal collectors in large-volume storage systems

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ABSTRACT

Solar disinfection of drinking water (SODIS) is a well-established low-cost method typically applied to small volumes (≈1.5–2.0 L), which limits its applicability in household and community water storage systems. In Luanda (Angola), high levels of microbial and bacterial contamination have been reported in domestic water stored in tanks, highlighting the need for scalable and sustainable treatment solutions. Our preliminary findings from field investigations conducted in Luanda indicate that replacing conventional metallic tank covers with transparent glass can delay bacterial contamination in water storage systems of approximately 1 m³ or larger. These findings suggest that solar radiation exposure may contribute to improved microbial water quality and reveal an opportunity to extend the SODIS concept beyond small containers, addressing a critical gap in solar-based treatment solutions for large-volume domestic water storage systems commonly used across African cities. Based on these findings, this study proposes a scalable solar water treatment approach based on the adaptation of solar thermal collectors capable of enhancing the conversion of solar radiation into thermal energy, enabling microbial inactivation in large-volume reservoirs. Given the spatial variability of solar irradiance across Angola, system design must account for regional differences in solar availability to optimize heat generation and treatment efficiency. The proposed approach bridges household-level SODIS and decentralized large-scale water storage systems, offering a sustainable pathway based on green energy for improving drinking water safety in tropical regions.

Keywords: SODIS; water tanks; bacterial contamination; solar radiation; solar thermal collectors; green energy

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(F-4) Effect of absorber tube rotation combined with silica nanofluids application on parabolic trough solar collector efficacy improvement

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ABSTRACT

The study aims to maximize the solar energy absorption capacity of the parabolic trough collector to ameliorate its thermal performance. PTCs are mature technology and have the capability of delivering medium- and high-temperature heat for power generation and industrial processes. Non-uniform solar heat flux distribution occurs in common parabolic trough solar collectors due to solar radiation is not evenly concentrated on surface of heat collection elements. The bottom part of PTCs suitable to have more heat flux than the upper body of the collector, which causes non-uniform heat flow in the collector system. Consecutively, heat-collecting elements have experienced high and peak temperature, which causes thermal load, tube deformation and reduction of thermal efficiency. Therefore, to mitigate the problems hybridizing absorber tube rotation and silica nanoparticle with water as base fluid are suggested to minimize the surface temperature of the tube and increase the absorption of solar energy with the working fluid. The impact of varying flow rates and tube rotating speeds at 0.3 percent volume concentrations of silica nanoparticles on collector performance has been widely examined. The study was conducted with numerical simulation using steady state model to investigate the effect of absorber tube rotation and nanofluids on collector efficiency. The finding indicates that at a 0.034 kg/s mass flow rate and 1 rad/s rotational speed, silica nanofluids enhanced thermal efficiency by 7% and 24% compared to the base fluid with and without tube rotation, respectively. Moreover, use of a rotating absorber tube and nanofluids achieves a reduction of 37 K in the circumferential temperature difference of the tube.

Keywords: Non-uniform, heat flux, numerical, PTC, efficiency, rotation, absorber tube

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(F-5) Solar-Powered IOT Centralized Monitoring For Clustered Biogas In Rural Ethiopia.

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Abstract

Biogas technology is important for renewable energy utilization, organic wastes management and rural sustainable development in Ethiopia. However, although there is a growing number of household and community scale systems based on biogas digesters, there have been many examples of failures and declining performance of these systems, primarily because of lack of proper monitoring, delayed maintenance and lack of current performance data. The manual monitoring techniques are generally inefficient, and the local environmental conditions mentioned above also render them impractical in rural African areas, where access to energy or communication services is generally poor and the ability to support technical activities is limited. Hence, these constraints in conventional monitoring methods of biogas systems usually do not provide sustainable and scalable solutions.

The objective of this research project is to develop a solar powered IoT based centralized clustered biogas digester monitoring system for the dispersed rural settings. The proposed system integrates the low power sensor technology, long-range wireless communications technology, renewable energy supply systems and cloud-based data collection and processing services to develop an economically viable and reliable dispersed biogas digesters operating system. A biogas production plant will be equipped with temperature, pressure, pH and methane (CH 4) sensors to monitor the key operating parameters. The data obtained from the monitoring will be collected and accessed by data acquisition and transmission devices such as a Heltec ESP32-S3 LoRa node with SX1262 (868 MHz) which is designed to offer low-energy consumption and long-range communication capabilities, and thus, can function efficiently in dispersed rural locations.

All monitoring nodes are off grid autonomous. The network nodes are equipped with solar PV systems coupled with batteries to deliver continuous renewable energy and implement power management using duty cycles to alternate between active sensing/transmitting and low power sleep modes to reduce the overall energy demand while keeping the monitoring operations reliable. The proposed overall architecture is a cluster-based architecture, where many biogas plants communicate with a central LoRa gateway. The gateway aggregates the data in a centralized location, and then sends it to a cloud server using MQTT protocol for real time monitoring, data visualization and alerting using web-based platforms such as ThingsBoard. This enables greater scalability at a lower infrastructure cost and lower ongoing operational costs than traditional stand-alone monitoring solutions.

One important contribution of this research is an energy-aware clustered monitoring architecture that makes optimal tradeoffs between the communication efficiency, scalability, power consumption and deployment cost. The clustering method also bridges the gap between the underutilization of smaller scale systems and the overcomplexity of larger scale implementations and is an excellent option for dissemination within the rural communities. We use energy modeling and analysis of the communication architecture to evaluate the system and its ability to operate as a stand-alone solar-powered system in low-resource settings over the long term. The results show that it is possible to operate continuously with very small amounts of solar energy from small distributed sources, thus the possibility exists to use this system for low-cost and reliable deployment in rural areas without access to an energy grid.

The framework facilitates the integration of a solar-powered IoT (internet of things) infrastructure with decentralized biogas technologies, which in turn promote circular economy and renewable energy systems. This offers a scalable, low-cost and environmentally friendly way to make biogas production facilities more reliable, enabling proactive maintenance and helping to drive evidence-based decisions on biogas production enhancement. This system has high potential for being duplicated for rural citizens across Ethiopia, and elsewhere in Africa to provide resources for a sustainable energy future and the development of digital transformation through decentralized renewable energy systems.

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Keywords: Clustered Biogas, Internet of things (IOT),LoRa communication, Centralized monitoring system, Solar PV, Ethiopia.

Flow diagram of monitoring system

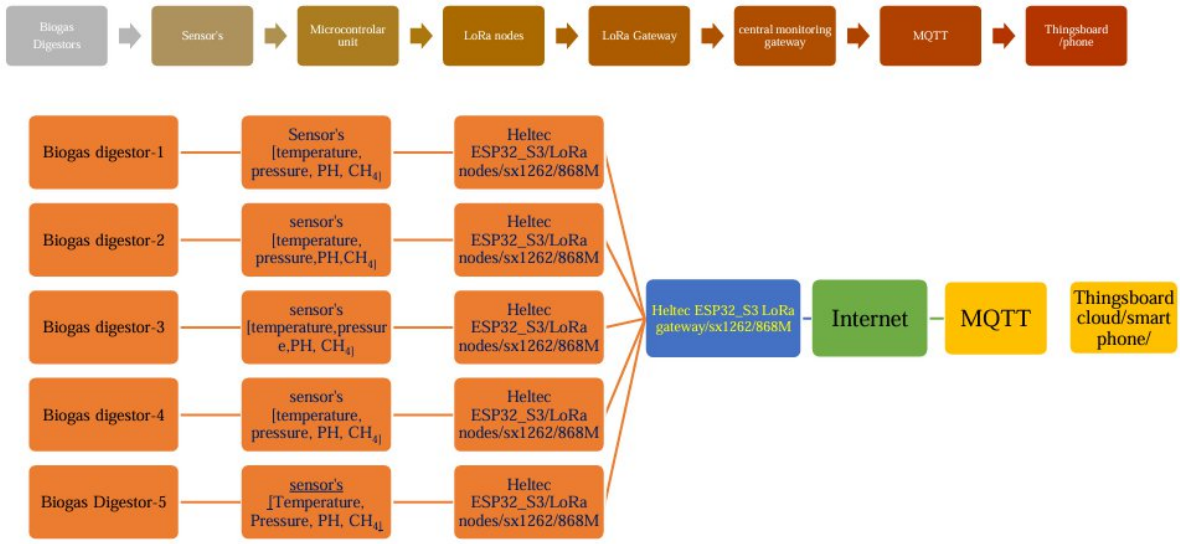


Figure 1 conceptual architecture for IoT monitoring system for 5-biogas clusters

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(F-6) Optimizing Renewable Energy Systems For Sustainable Urbanization: A Multi-Criteria Assessment of Solar-Wind Hybrids in Ethiopia

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Abstract

Background

Rapid urbanization and increasing energy demand in Ethiopia have intensified pressure on conventional energy systems, resulting in energy shortages, environmental degradation, and rising greenhouse gas emissions. Renewable energy technologies, particularly hybrid solar–wind systems, offer sustainable alternatives capable of supporting low-carbon urban development and climate resilience. Integrating multiple renewable energy sources improves energy reliability, efficiency, and sustainability while contributing to circular economy objectives.

Objective

This study assessed the technical, economic, and environmental performance of solar–wind hybrid energy systems for sustainable urbanization in selected Ethiopian cities using a multi-criteria decision analysis framework.

Methods

A mixed-methods and model-based research design was employed. Primary and secondary data on solar irradiance, wind speed, electricity demand and energy infrastructure were collected from Addis Ababa, Adama, and Hawassa. The Hybrid Optimization of Multiple Energy Resources (HOMER Pro) software and Analytic Hierarchy Process (AHP) were applied to evaluate system feasibility and optimize energy configurations. Assessment criteria included cost efficiency, energy reliability, carbon emission reduction, land-use suitability, and scalability.

Results

The findings revealed that hybrid solar–wind systems significantly outperformed standalone renewable energy systems in terms of reliability and cost-effectiveness.

Table 1. Comparative Performance of Hybrid Renewable Energy Systems in Selected Ethiopian Cities

City	Renewable Energy Fraction (%)	CO2 Emission Reduction (%)	LCOE (USD/kWh)	Feasibility Score
Addis Ababa	92.4	68.7	0.082	0.84
Adama	88.1	63.5	0.089	0.79
Hawassa	84.6	59.8	0.094	0.74

The optimized hybrid configuration achieved a renewable energy fraction of 92.4% and reduced annual carbon dioxide emissions by approximately 68.7% compared to diesel-based systems. Addis Ababa demonstrated the highest hybrid system feasibility score (0.84), followed by Adama (0.79) and Hawassa (0.74). The levelized cost of electricity (LCOE) for the optimized hybrid system was estimated at USD 0.082/kWh, lower than diesel-generated electricity costs in urban fringe areas. Furthermore, sensitivity analysis indicated that integrating battery storage increased energy reliability by 34% during peak demand periods.

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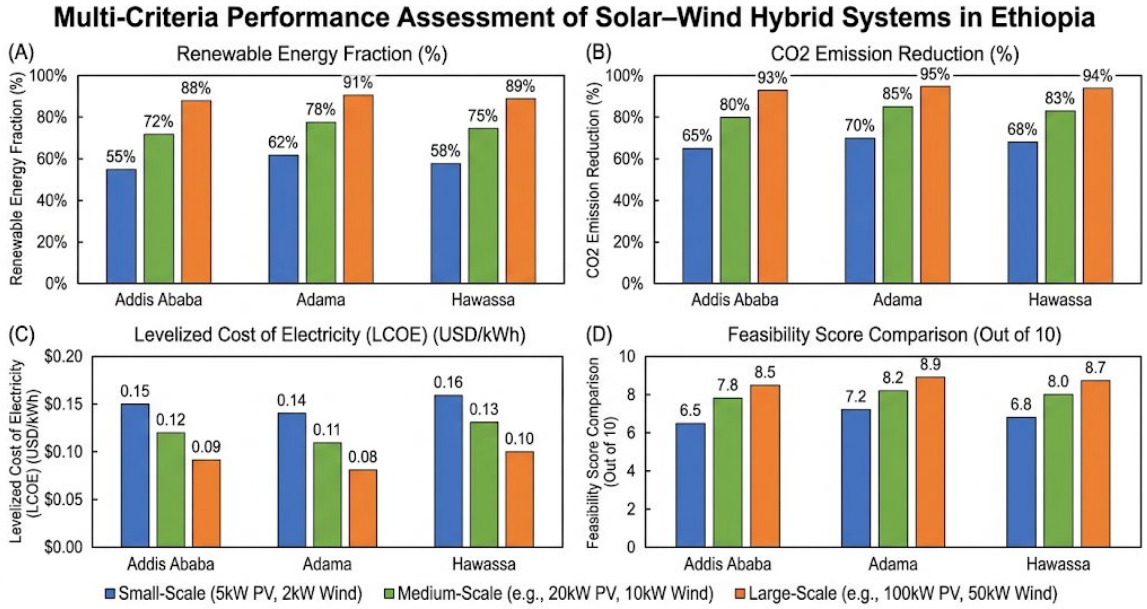


Figure 1: Performance comparison of optimized solar–wind hybrid renewable energy systems in Addis Ababa, Adama, and Hawassa.

Conclusion

Solar–wind hybrid systems provide viable pathways for sustainable urbanization and low-carbon energy transitions in Ethiopia. Expanding investments in hybrid renewable infrastructure, urban energy planning, and decentralized smart-grid systems can accelerate sustainable development while supporting Africa's renewable energy transformation agenda.

Keywords: Renewable energy; Solar–wind hybrid systems; Sustainable urbanization; Multi-criteria assessment; Ethiopia; Energy transition

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(F-7) Integrating Solar PV into Existing Distribution Networks Through Simultaneous Reconfiguration and Distributed Generation Planning

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Abstract

Integrating distributed renewable energy into existing electricity networks has become a critical challenge for utilities seeking to improve sustainability while maintaining reliable and efficient power delivery. In many developing regions, distribution systems experience high technical losses, poor voltage regulation, and limited operational flexibility, constraining the effective integration of Solar Photovoltaic (PV) generation. Although feeder reconfiguration and distributed generation planning have been widely investigated as independent strategies for improving network performance, their coordinated application under uncertain operating conditions remains insufficiently explored.

This study investigates the simultaneous optimization of feeder reconfiguration and Solar PV distributed generation planning as a coordinated approach for improving the technical performance and renewable energy integration capability of existing distribution networks. A Particle Swarm Optimization (PSO) algorithm is employed to determine the optimal feeder configuration together with the location and capacity of Solar PV units while satisfying network operational constraints. The proposed approach is evaluated using a real 15 kV radial distribution network in northern Ethiopia operating under peak loading conditions.

The optimization results demonstrate that coordinated network reconfiguration and PV planning can significantly outperform conventional reconfiguration-based interventions. Active power losses are reduced from 940.84 kW to 423.50 kW, corresponding to a 54.9% reduction, compared with the 35.7% reduction achieved through feeder reconfiguration alone. In addition, the minimum bus voltage improves from 0.8309 p.u. to 0.954 p.u., indicating substantial enhancement in voltage regulation and overall network performance. The optimized solution is achieved through strategic feeder reconfiguration combined with the integration of 1,450 kW of Solar PV generation at selected network locations. Beyond improving technical performance, the results demonstrate how existing distribution infrastructure can accommodate greater renewable energy penetration through operational optimization, reducing reliance on costly network upgrades.

Recognizing the inherent uncertainty associated with electricity demand and solar resource availability, a Monte Carlo simulation framework was employed to assess the robustness of the optimized solution under stochastic operating conditions. The probabilistic analysis yielded an expected mean power loss of 438 ± 15 kW and indicated a 98% probability of maintaining bus voltages above the 0.90 p.u. threshold. These results demonstrate that the proposed strategy maintains stable performance despite variations in load demand and solar irradiance, providing additional confidence in its practical applicability.

The findings show that simultaneous feeder reconfiguration and Solar PV planning offer an effective and scalable means of improving network efficiency, enhancing voltage performance, and facilitating renewable energy integration within existing distribution systems. The proposed approach provides a replicable planning strategy for utilities seeking to maximize the value of existing network assets while supporting long-term renewable energy deployment and sustainable power system development.

Keywords: Renewable Energy Integration; Solar Photovoltaic; Distribution Networks; Feeder Reconfiguration; Distributed Generation Planning; Sustainable Energy Systems.

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(F-8) Assessment of the Impact of West African Interconnected Grid Fluctuations on Large-Scale Solar PV Plants: A Case Study of the 33.7 MWp Zagtouli Solar PV Plant in Burkina Faso

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Abstract

Despite significant progress in electrification efforts, access to electricity remains a major challenge in West Africa, where more than 43% of the population lacked access to electricity in 2022. To improve energy security and expand access to electricity across the region, countries in West Africa have strengthened regional power exchanges through the West African Power Pool (WAPP) interconnected grid while simultaneously accelerating the deployment of large-scale solar photovoltaic (PV) power plants. However, the interconnected West African grid continues to experience recurrent disturbances, including outages, voltage variations, and frequency fluctuations, which can adversely affect the performance and reliability of grid-connected solar PV systems. As one of the largest utility-scale solar power plants in Burkina Faso, the 33.7 MWp Zagtouli Solar PV Plant is connected through the Zagtouli HV/MV substation to the interconnected transmission network linking Burkina Faso with Ghana and Côte d'Ivoire, making its operation directly influenced by both national and regional grid conditions.

This study assesses the impact of West African interconnected grid fluctuations on the operation and energy production of the Zagtouli Solar PV Plant and provides an in-depth understanding of how regional grid disturbances affect the performance of large-scale solar PV installations. The analysis is based on SCADA data continuously recorded at 5 minute intervals between January 1, 2020, and December 31, 2025. The dataset includes PV power generation, grid electrical parameters, and solar irradiation measurements. An Energy Loss Estimation Methodology was applied to the collected data to quantify the energy losses associated with grid outages, voltage fluctuations, and frequency deviations and to evaluate their impact on the overall performance of the plant.

The results indicate that grid instability caused an estimated cumulative energy loss of 23.7 GWh during the study period. Grid outages represented the largest share of losses, accounting for approximately 65% of the total energy loss, followed by voltage fluctuations with 33%, while frequency deviations contributed about 2%. These disturbances resulted in inverter tripping events, temporary production interruptions, and reduced plant availability, highlighting the vulnerability of large-scale solar PV installations to the operational conditions of the interconnected electricity network.

The findings provide valuable insights for utilities, transmission system operators, policymakers, and renewable energy developers seeking to enhance the resilience and reliability of solar PV deployment within the West African interconnected electricity system.

Keywords: West Africa interconnected grid, grid instability impact, Zagtouli solar PV plant, Burkina Faso.

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(F-9) Bridging the Reliability Gap between Machine Learning and Physical Models for Solar Irradiance Estimation across Ethiopia's Heterogeneous Climatic Regimes

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Abstract

Establishing a dependable solar grid across Ethiopia's diverse climate isn't just a technical goal anymore; it's the backbone of the country's energy security. In this study, we have conducted a high-stakes comparison between a custom-tuned CatBoost machine learning (ML) model and the standard McClear physical approach across twelve unique geographical zones. By benchmarking National Solar Radiation Database (NSRDB) inputs against high-fidelity, ground-based pyranometer data, we uncovered a significant divergence in predictive reliability. Our analysis reveals that while the McClear model holds some value in steady, arid regions, its underlying logic essentially hits a wall when faced with the rough terrain of the Ethiopian Highlands or the unpredictable moisture of the tropical monsoon belts. In these high-complexity zones, the physical model suffered from massive systematic errors, with Mean Bias Errors (MBE) climbing past 400 W/m² and correlation coefficients (R2) bottoming out at a negligible 0.203. Conversely, the localized CatBoost framework proved it could decode the region's chaotic, non-linear atmospheric shifts, preserving a high-precision baseline with R2 values consistently staying between 0.903 and 0.960. Most importantly, this ML approach effectively neutralized the seasonal spikes in bias typical of the Kiremt (summer) rains, keeping variance ($\sigma < 25$ W/m2) remarkably tight across nearly every tested location. These findings suggest that a transition from generalized global physical models to site-specific, adaptive ML estimators provides the granular accuracy required to de-risk solar investments and stabilize energy grid planning throughout sub-Saharan Africa.

Keywords: Solar Energy; Machine Learning; Physical Model; Ethiopia; Solar Resource Assessment; Kiremt Season

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(F-10) Magnetic Properties of Metamaterial Selective Emitters for Renewable Energy Conversion

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Abstract

Thermophotovoltaic (TPV) systems have emerged as a promising renewable energy technology capable of converting thermal radiation directly into electrical energy with high efficiency. The performance of TPV systems strongly depends on the spectral characteristics of selective emitters. In this study, a broadband, wide-angle, and polarization-independent metal–dielectric–metal (MDM) grating metamaterial selective emitter is designed and investigated for high-efficiency TPV applications. The electronic properties of the constituent materials were analyzed using Density Functional Theory (DFT), while the optical response and electromagnetic behavior of the metamaterial structure were evaluated using the Finite Element Method (FEM). The selective emitter was optimized with a cutoff wavelength of 2.7 μm to match the spectral response of InGaAsSb photovoltaic cells, thereby maximizing radiative energy conversion efficiency. Furthermore, the influence of the magnetic properties of the constituent material on the emission characteristics was systematically investigated. The results reveal that magnetic effects significantly enhance broadband emissivity through the excitation of magnetic resonances and improve spectral selectivity. The optimized structure exhibits an average emissivity of approximately 94% over the wavelength range of 0.3–2.7 μm. In addition, a spectral efficiency of 76% is achieved at an operating temperature of 800 K for an InGaAsSb cell with a bandgap energy of 0.46 eV, outperforming previously reported selective emitters.

The enhanced optical performance is attributed to the synergistic excitation of surface plasmon polaritons (SPPs), magnetic polaritons (MPs), and the intrinsic optical response of InMnAs, resulting in strong and selective absorption near the designed cutoff wavelength. The proposed metamaterial emitter combines high average emissivity, excellent spectral selectivity, polarization insensitivity, wide-angle performance, structural simplicity, and cost-effective fabrication, making it a promising candidate for next-generation high-efficiency thermophotovoltaic energy conversion systems.

Keywords: Thermophotovoltaics; Selective Emitter; Metamaterials; Magnetic Polaritons; Renewable Energy.

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(F-11) Long-Term Wind Resource Assessment in Ethiopia: A Hybrid Machine Learning Framework and Grid Complementarity Analysis

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Abstract

This study provides a comprehensive spatiotemporal assessment and predictive modeling of Ethiopia's wind energy potential to address the climate vulnerability of its hydropower dominated grid. Using NASA POWER and ERA5 datasets (2000–2024), a high-resolution hybrid framework combining physical aerodynamic modeling with XGBoost was developed. The hybrid model significantly outperformed standalone approaches, achieving strong predictive accuracy (R^2 = 0.962; MAE = 42.8 W/m²) and reducing errors by 64.4% and 14.9% relative to physical and ML models, respectively, while overcoming spatial resolution limitations. The analysis indicates a national mean annual Wind Power Density (WPD) of 304.03 ± 20.65 W/m², with the Southern Lowlands and Afar Triangle identified as high-potential Class 7 wind energy zones. A strong wind hydropower complementarity is observed, with negative correlation ($r < 0$) across 92.71% of the country. Annual SCI values are predominantly within the optimal 0.0–0.25 range (57.13%), indicating substantial potential for grid stabilization. This complementarity is most pronounced during the dry season (Winter > Spring), where peak wind availability (~385 W/m²) coincides with hydrological minima. Overall, the findings demonstrate that integrating wind resources can enhance grid reliability and support Ethiopia's CRGE objectives through improved energy balancing and regional power system stability.

Keywords: Hybrid Model, Wind Energy Assessment, Wind Power Density, East Africa Rift Vally, and Climate Resilient Green Economy

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(F-12) Factors Linking Climate Change and Energy demand in Guinea-Bissau: Renewable energy impact

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Ministry of Energy (Guinea-Bissau)

Abstract

The relationship between climate change and energy demand in Guinea-Bissau, with a particular focus on the role of renewable energy in improving energy security, resilience, and sustainable development, was analyzed in this study. The research addresses an existing gap in country-specific studies by analyzing how climate-related factors influence energy consumption patterns, infrastructure performance, and access to electricity. A mixed-methods approach was adopted, combining institutional consultations, stakeholder discussions, and a review of national policy documents, technical reports, and adaptation planning frameworks. Data were collected through engagement with government institutions and development partners involved in the National Adaptation Plan process, supported by the United Nations Development Programme. The findings reveal that the energy sector in Guinea-Bissau remains constrained by limited infrastructure, high technical losses, unequal electricity access, and low private investment. Before hydropower expansion, the national electrification rate was approximately 35.8%, with strong disparities between urban and rural areas. Despite renewable energy contributing more than 87% of the current energy mix, over 80% of households still depend on wood and charcoal for domestic energy use. Hydropower dominates the energy supply with 80%, while diesel and solar contribute 13% and 7%, reflecting progress toward renewable energy use alongside opportunities to expand solar power and reduce dependence on a single energy source. Climate-related risks such as rising temperatures, floods, storms, hydrological variability, and environmental degradation are increasing energy demand while threatening infrastructure reliability and system stability.

The study discuss decentralization of energy systems, including solar mini-grids, hybrid technologies, bioenergy, and hydropower, as effective solutions for improving energy access and strengthening climate resilience, particularly in remote and island regions. Priorities identified include modernization of energy infrastructure, diversification of energy sources, improved institutional coordination, evidence-based planning, and stronger integration of climate adaptation into energy policies. The research concludes that renewable energy development can play a critical role in supporting sustainable socio-economic growth and enhancing adaptive capacity in Guinea-Bissau

Keywords: Climate change, Energy demand, renewable energy, energy resilience, Guinea Bissau

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(F-13) Sustainable Energy Infrastructure In Sierra Leone; A case study - Bumbuna Hydro Power Plants

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Abstract

The growing demand for sustainable energy in developing countries has placed emphasis on the development of renewable energy infrastructure. In many developing countries, energy infrastructure remains underdeveloped, unreliable, and inadequate to meet growing demand. Sierra Leone has faced chronic energy shortages due to insufficient infrastructure, limited financial resources, political instability, and technical delays due to prolonged project's timeline, with the first phase becoming operational only in 2009.

This paper explores the role of sustainable energy infrastructure, addressing energy deficits, promoting socio-economic development, and mitigating environmental concerns. The research examines historical development, operational challenges, and prospects of the Bumbuna project. It assesses the historical development and current status. Identify the technical, financial, and socio-political challenges affecting the project's performance and evaluate the environmental and socio-economic impacts on local communities.

This study contributes to academic, policy, and practical discourses on sustainable energy. It provides insights into the challenges and opportunities, offering a model for other developing countries. Policymakers, engineers, and development agencies can leverage the findings to optimize energy infrastructure.

This study employs a mixed-method approach, to provide a comprehensive analysis of the Bumbuna Hydroelectric Power Project. Purposive sampling used to select participants with relevant expertise or direct involvement in the Bumbuna project. A stratified sampling was adopted to ensure representation from diverse stakeholder groups, Semi-structured interviews conducted with key stakeholders, including policymakers, engineers, and local community members. Site visits to the Hydro Power Plants facilitated assessment of operational conditions, infrastructure status, and environmental impacts.

Reports from Sierra Leone Ministry of Energy, AfDB, and international organizations were analyzed for technical and financial data. Peer-reviewed articles, books, and policy papers provided insights into global and regional perspectives on hydropower. Data from interviews and field observations were analysed thematically using Nvivo software. Quantitative data on electricity generation, operational costs, and environmental impacts were analyzed using statistical methods.

The Key findings confirmed that the Bumbuna hydro power plants was a long-term characterized by delays and interruptions largely attributed to political instability and insufficient funding, Conteh (2016, Energy Policy Journal). The prolonged timeline increased costs and reliance on international donor.

Additionally, delayed implementation hindered early realization of socio-economic benefits, particularly during the civil war (1991–2002). The study further highlighted seasonal variability and maintenance challenges which significantly impact electricity generation during dry season, reducing the plant's output. Maintenance challenges were also prominent, with inadequate infrastructure upgrades and lack of skilled personnel. The findings showed that initial cost overruns and reliance on external loans created long-term financial burdens. Socio-political challenges, including governance and community resistance, were significant barriers to project's success.

The project contributed to economic growth providing electricity to urban areas, supporting industries, and reducing reliance on costly diesel generators. Furthermore, findings revealed significant disparities in electricity access between urban and rural areas, with rural electrification remaining limited. Resettlement programs failed to fully restore affected communities' socio-economic conditions, consistent with observations by Conteh (2016).

In conclusion, while the BHEP has achieved notable milestones, including increased electricity access and economic benefits, it faces significant technical, financial, and socio-political challenges. The socio-

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economic impacts, though positive in some areas, have been unevenly distributed, and displaced residents bearing disproportionate burdens. These findings reinforce for holistic approach to energy infrastructure development that addresses technical inefficiencies, ensure financial sustainability, and prioritizes social and environmental equity.

Keywords: Energy infrastructure, Sustainability, political instability, Local community resistance

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(F-14) Evaluation of Climate Change Potential Impact on the Optimal Operation of Hydropower Reservoir in Omo Basin, Ethiopia

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Abstract

In every aspect of life, the need for water resources has grown dramatically. However, managing basin water resources and reservoir operations is becoming more difficult due to climate change and increasing water demand. Examining the relationship between hydropower reservoir operations and climatic fluctuation is crucial for efficient resource management and power generating optimisation. This study's goal was to study the best reservoir operation systems for the Omo River Basin under the Coupled Model Intercomparison Project phase 6 (CMIP6) climate circumstances. In this study, the Soil and Water Assessment Tool (SWAT) model simulation and performance evaluation were performed in order to use the simulated streamflow as input into the optimization of the Omo Gibe cascade hydropower reservoirs under current and future climatic scenarios. The Hydrologic Engineering Centre's Prescriptive Reservoir Model (HEC-ResPRM) was used for computation of optimal operation of Gilgel Gibe I reservoir under the two Shared Socioeconomic Pathways (SSP245 and SSP585) climate change scenarios. The result indicates that compared to the baseline period, the average monthly reservoir inflow will decrease by 0.07 % under the SSP245_2050 scenario, however it increases by 49.08,18.85, and 50.60 % under the SSP245_2080, SSP585_2050 and SSP585_2080 scenarios respectively. Similarly, the average monthly optimized power generation will increase by 28.98,19.81 and 34.01 % in the SSP245_2080, SSP585_2050 and SSP585_2080 respectively scenarios except decline by 2.5 % in the SSP245_2050 scenario. The future optimized release is expected to decline by 3.40 % under the SSP245_2050 climate change scenario, however, it increases by 53.73,22.32 and 55.31 % in the climate change scenarios of SSP245_2080, SSP585_2050 and SSP585_2080 respectively. The SSP245_2080 and SSP585_2080 scenarios exhibit quicker recovery from failures and less vulnerability than other scenarios, despite difficulties in maintaining water supply for power generation to fulfil demand. Besides, the findings of inflow, outflow, storage, elevation, and power production variance in the June, July, August, and September (JJAS) and March, April, and May (MAM) seasons confirm to the probable impact of climate change on the basin's future reservoir operation strategies. The study finding is very essential for sustainable development of water resources, policy makers, spatial-temporal optimal water allocation, adjustment of reservoir operation rule curve, and climate change mitigation.

Keywords: Climate change, HEC-ResPRM, Omo Basin, Optimization, Power, Reservoir operation, SWAT model

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(F-15) Assessment of a Hybrid Energy System for Reliable and Sustainable Power Supply to Boru Meda Hospital in Ethiopia

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Abstract

Reliable and sustainable energy sources remain serious problems for health services in low income counties, where regular power outages risk patient safety. This study aims to identify an optimal hybrid energy system (HES) for Boru Meda Hospital, Ethiopia, employing HOMER Pro 3.11.2 to assess multiple Grid-integrated and off-Grid configurations from locally available resources. In this study a strict zero capacity shortage and unmet load reliability procedure to certify continuous service operations were implemented in addition to a techno-economical analysis. The results confirm that BG/PV/DG/batt/conv outperform other systems to meet a daily energy demand of 11,214.66 kWh with an net present cost (NPC) of $15.3M and a cost of energy (COE) of $0.289/kWh. It achieves a renewable fraction (RF) of 90.40% and effectively reduces diesel usage and emissions, with over 91% of the yearly energy supplied by photovoltaic (PV) and bio-energy sources. These reveal offer a confirmed framework for attaining 100% stable electrification of healthcare, linking the gap between unbalanced national Grids and a critical energy need of modern healthcare delivery system. Compared with Grid connected power systems, renewable dominant hybrid systems prove better environmental performance and the capability to produce extra electricity. These findings ensure that optimized hybrid designs can improve the strength of the power supply, minimize operational costs, and advance car- bon reduction targets. The proposed framework offers a solution with verifiability and scalability for the electrification of healthcare facilities in Ethiopia and other developing areas.

Keywords: Cost of energy, energy demand, emission, environment friendly, HOMER simulation, net present cost, techno-economic, power shortage

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(F-16) Multi-Objective Deep Reinforcement Learning for Joint EV Charging and Renewable Energy Dispatch in Hybrid Energy Systems: A Case Study of Ethiopia

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Abstract

Ethiopia is undergoing one of the most rapid electric vehicle (EV) transitions in the world, having become the first country to ban the importation of internal combustion engine vehicles in January 2024. The national EV fleet has since grown to over 115,000 vehicles, with EVs accounting for more than 60% of new car registrations in 2024, yet the country has fewer than 100 public charging stations against a government target of 2030. This rapid fleet growth collides with a deeply heterogeneous power system in which grid-connected urban centers coexist with renewable-dependent off-grid rural communities, where less than 5% of the rural population has electricity access. Coordinating EV charging across this hybrid landscape requires the simultaneous optimization of competing objectives charging cost, renewable energy utilization, grid stability, battery longevity, and equitable service access a multi-dimensional challenge that existing single-objective and grid centric optimization methods cannot adequately resolve.

This study proposes a Multi-Objective Deep Reinforcement Learning (MODRL) framework for the joint coordination of EV charging and renewable energy dispatch across Ethiopia's grid-connected and off-grid hybrid renewable energy systems. The research formally models the problem as a Partially Observable Markov Decision Process with a five-dimensional reward structure, and designs, implements, and compares three MODRL architectures weighted scalarisation, Pareto-based Envelope Q-Learning, and decomposition-based MOEA/D-RL each integrated with aVehicle-to-Grid (V2G) coordination module enabling EV batteries to function as flexible distributed storage assets. The framework will be trained and evaluated using an Ethiopia-calibrated simulation environment incorporating empirical solar, wind, and grid data, benchmarked against uncontrolled charging, rule-based scheduling, single objective reinforcement learning, and offline multi-objective optimisation baselines.

The research is expected to produce the first MODRL framework validated for hybrid grid/offgrid EV charging coordination in a developing-country context, generating Pareto-optimal charging policies, an open-source simulation environment, and evidence-based guidance for Ethiopia's e-mobility and renewable energy policy. Findings are anticipated to be transferable to other rapidly electrifying sub-Saharan African economies pursuing similar renewable-led EV transitions.

Keywords: Multi-Objective Reinforcement Learning; Electric Vehicle Charging; Hybrid Renewable Energy Systems; Vehicle-to-Grid; Pareto Optimisation; Ethiopia

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