

CONFERENCE PROCEEDINGS REPORT



Science Week on Hybrid Renewable Energy Systems and Electricity Access in Uganda (11 -12 February, 2026)



MAKERERE UNIVERSITY



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1. Background

Science Week was convened at Makerere University as a major dissemination and reflection platform under the Promotion of Hybrid Renewable Energy Systems (PHRE) project. The event brought together university leadership, representatives from the Austrian Embassy, faculty members, researchers, postgraduate students, development partners, and energy sector stakeholders to review progress, share research findings, and strengthen collaboration on renewable energy solutions for Uganda.

The PHRE project is a three-year academic partnership between Makerere University and BOKU University, supported by Austria's APPEAR programme. The initiative seeks to strengthen renewable energy education, enhance institutional capacity, and promote hybrid renewable energy systems as viable solutions to Uganda's electricity access challenges.

The event was organised against the background of Uganda's persistent energy access gap, particularly in rural and off-grid communities where electricity remains limited, unreliable, or unaffordable. Hybrid renewable energy systems, integrating solar, biomass, and other resources, were highlighted as practical and decentralised alternatives capable of improving livelihoods and supporting economic transformation.

2. Opening Ceremony

The Science Week was officially opened by Professor Barnabus Nawangwe, the Vice Chancellor of Makerere University, who highlighted the strategic importance of energy in national development. He noted that limited electricity access continues to constrain industrial growth, entrepreneurship, and job creation. He emphasised the university's responsibility to drive innovation and equip graduates with practical skills that enable them to create enterprises and contribute meaningfully to economic stability. He commended the partnership with BOKU University and the Austrian Government, recognising the project as a significant step toward strengthening science, technology, and innovation at Makerere University.

Dr. Katja Kerschbaumer Head, Coordination Office for International Cooperation Austrian Embassy, Kampala, noted Austria's long-standing partnership with Uganda and reaffirmed support for higher education, research cooperation, and sustainable development through programmes such as APPEAR. She emphasised that hybrid renewable energy systems offer decentralised, affordable, and environmentally sustainable solutions to communities that remain underserved by the national grid.

The APPEAR programme was highlighted as a key instrument for promoting long-term academic partnerships and institutional capacity building.

In her address on behalf of BOKU University, Prof. i.R. Mag.Mag.Dr.iur. LL.M. Eva Schulev-Steindl, Rector of BOKU University, Vienna, Austria, underscored the critical role of international collaboration in advancing hybrid renewable energy systems and sustainable energy access. She highlighted the integration of technical, social, and economic dimensions in projects such as the Promotion of Hydrogen Renewable Energy Systems for Electricity Access in Uganda (PHRE), noting that participatory approaches, gender inclusion, and stakeholder engagement are essential for long-term impact.

Prof. Schulev-Steindl also emphasised the importance of linking research, education, and practical application, citing BOKU University's longstanding international strategy and alignment with the United Nations Sustainable Development Goals. She expressed optimism that the Science Week would generate innovative ideas, policy recommendations, and strengthen partnerships that contribute to sustainable energy solutions and capacity building in Uganda.

Prof. Moses Musinguzi, Principal of CEDAT, highlighted the significance of the APPEAR-supported project in enhancing laboratory infrastructure, developing human capital, and strengthening research through the East African Centre of Excellence for Renewable Energy and Energy Efficiency (EACREE).

He noted ongoing infrastructure investments and the College's strategic focus on developing skilled staff to fully leverage these resources, and thanked partners for their collaboration in consolidating and expanding research and innovation gains.



Left to the right, Prof. Moses Musinguzi, Principal of CEDAT, Professor Barnabas Nawangwe, Vice Chancellor of Makerere University, Dr. Katja Kerschbaumer, Head of the Coordination Office, ADA, and Prof. i.R. Mag.Mag.Dr.iur. LL.M. Eva Schulev-Steindl, - Rector of BOKU University, Vienna, Austria



Dr. Hillary Kasedde

3. Project Overview and Objectives

A comprehensive overview of the PHRE project was presented by Dr Hillary Kasedde, outlining its goals, achievements, and strategic direction. The overall objective of the partnership project is to promote hybrid renewable energy systems to enhance electricity access in Uganda. The overall goal is to strengthen scientific cooperation between the partners and build their capacities in renewable energy studies, address future challenges, enhance engineering students' practical skills in renewable energy sources within Uganda, and establish networks between the academic partners.

The project addresses social, technical, and economic barriers to HRES deployment by offering tailored training programs in system design, sizing, optimisation, and maintenance. Special focus is placed on gender diversity and inclusion through targeted engagements with women, youth, and persons with disabilities across Uganda. Additionally, the partnership promotes knowledge exchange and sustained collaboration between the participating institutions.

4. Curriculum Development and Academic Strengthening

A major milestone under the project is the successful development and integration of new academic courses into the Master of Science programmes. Two key courses, Hybrid Renewable Energy Systems (HRES) and Gender and Energy, were introduced following extensive consultations with industry stakeholders, academic staff, and sector experts.

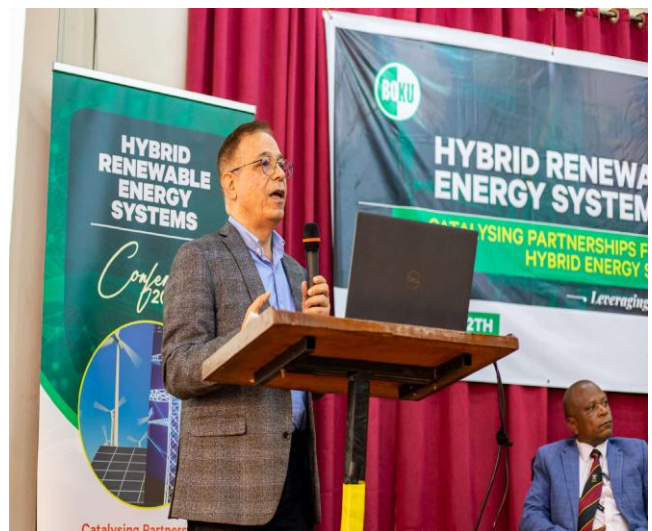
The curriculum development process involved conducting needs assessments, drafting course content aligned with emerging technologies, reviewing and refining modules, and securing academic approvals. The inclusion of Gender and Energy ensures that renewable energy interventions are inclusive and socially responsive.

This reform strengthens the university's ability to produce graduates equipped with both theoretical knowledge and practical competencies in renewable energy system design and implementation.

5. Establishment of the Makerspace

The establishment of a makerspace at CEDAT represents one of the most significant tangible achievements of the project. The makerspace functions as an instructional laboratory dedicated to hands-on teaching, research, and prototyping in hybrid renewable energy systems. The facility provides students and staff with opportunities to design, assemble, test, and optimise renewable energy technologies. By bridging theory and practice, the makerspace enhances experiential learning and promotes innovation.

To ensure effective utilisation of the facility, training-of-trainers workshops were conducted between 2024 and 2026. These trainings facilitated knowledge transfer from BOKU University experts to Makerere University staff, strengthening local technical capacity.



Assoc. Prof. Dr. Rafat Al Afif, coordinator from BOKU university Presentating on the PHRE project's objectives and its significance in improving electricity access in Uganda

6. Keynote and Technical Presentations

6.1 Keynote Speech



Univ. Prof. Dipl. Christoph Pfeifer
Head of the Institute of Chemical and Energy
Engineering at BOKU University, Austria

The discussion highlighted the dual role of biochar in addressing two major global challenges: improving soil quality and contributing to long-term carbon sequestration. The central argument was that biochar should not be viewed solely as a carbon capture tool, but equally as a soil enhancement strategy that supports agricultural sustainability.

Biochar is produced through thermochemical biomass conversion processes, particularly pyrolysis. Biomass naturally stores solar energy and carbon during plant growth. Through pyrolysis, biomass is heated under limited oxygen conditions, releasing volatile compounds while retaining a stable carbon-rich structure known as biochar. Typically, about one-third of the biomass carbon remains in the biochar, while the remainder is converted into gases and bio-oils that can be used for energy. The resulting material is highly porous, carbon-dense, and chemically stable.

Technologies for producing biochar range from traditional low-tech methods, such as soil-covered pyrolysis pits still used in many countries, to modern industrial systems such as screw reactors. A major advantage of biochar production lies in its flexibility in feedstock. Agricultural residues, nutshells, wood waste, olive residues, organic household waste, and slaughterhouse waste can all be utilised, making biochar production adaptable across different regions and resource conditions. From an environmental perspective, biochar contributes to climate change mitigation by enabling long-term carbon storage. When incorporated into soil, biochar remains stable for centuries, effectively locking carbon away.

This positions it as a negative emissions technology, which is particularly important given that reducing fossil fuel use alone may not be sufficient to meet global climate targets. While technologies such as direct air carbon capture exist, they are energy-intensive and costly. Biochar, by contrast, is relatively low-tech, cost-effective, and energy-efficient, making it especially suitable for rural and agricultural contexts.

However, carbon storage should not be the sole objective. Biochar significantly enhances soil quality. Its porous structure improves water retention, supports seasonal water storage, and creates habitats for beneficial microorganisms. It reduces nitrogen leaching, lowers nitrous oxide emissions, increases soil pH in acidic soils, and can immobilise heavy metals. Research and historical evidence, including studies of ancient "terra preta" soils in Latin America and long-term trials in Brazil, demonstrate that biochar can improve soil fertility for hundreds of years.

Biochar application also reduces groundwater contamination by retaining nitrates and nutrients within the soil matrix. Multiple meta-analyses confirm its positive effects on crop yield, land productivity, water-use efficiency, and environmental protection indicators.

From an economic perspective, carbon markets are increasingly recognising biochar's sequestration potential, enabling farmers to generate revenue through carbon credits. Nonetheless, caution was raised that biochar should not be treated merely as a carbon dumping strategy; its soil improvement function must remain central.

The overall message stressed urgency. Climate mitigation requires immediate action using practical and energy-efficient technologies. Biochar is recognised by the IPCC as a viable climate mitigation tool because it is scalable, low-cost, and accessible. Farmers can produce it locally using improved kiln technologies, gradually enhancing soil fertility over time. Global climate action requires collective responsibility. Every country, community, and individual must implement available solutions without delay. Biochar stands out as a practical, scientifically validated tool that simultaneously improves soil health and contributes to long-term carbon sequestration, making it a valuable component of sustainable agricultural and climate strategies.

6.2 Hybrid Renewable Energy Systems: Opportunities and Challenges

The discussion examined the opportunities and challenges associated with Hybrid Renewable Energy Systems (HRES), beginning with an introduction to system configuration, energy storage systems, and energy flow management strategies in order to clarify the technical and operational considerations involved. Renewable energy resources such as solar, wind, hydropower, geothermal, and biomass provide significant opportunities for affordable and clean energy access, particularly in remote and hard-to-reach areas. These technologies also contribute to broader development outcomes, including improved health, gender equality through reduced time burdens on women and girls, decent work and economic growth through employment in design, installation, and maintenance, and the development of sustainable cities through green buildings, e-mobility, and reduced emissions that address climate change. However, the stochastic and intermittent nature of renewable energy resources presents challenges related to cost, stability, and reliability. Hybrid systems mitigate these challenges by integrating multiple energy sources through AC and DC bus configurations, converters, inverters, storage units, and control systems to enhance resilience, efficiency, and energy availability. Energy storage options discussed included mechanical systems such as pumped hydro, flywheels, and compressed air; thermal storage using molten salts and other materials; chemical storage such as hydrogen and batteries including lead-acid, lithium-ion, and flow batteries; and electrical storage using supercapacitors and superconductors. Each of these technologies differs in capacity range, lifespan, capital investment requirements, maintenance needs, and environmental considerations.

Effective operation of hybrid systems depends on maintaining energy balance, whereby generation, storage charging and discharging, demand, system losses, grid import or export, and excess energy are managed through optimisation and control strategies. This ensures reliability in both standalone and grid-connected modes. The opportunities presented by hybrid systems include enhanced system resilience; decarbonisation of industries, mining operations, farms, data centers, telecommunications sites, and transport; expansion of rural electrification without costly grid extension; integration into buildings and microgrids with modular scalability; and the application of emerging technologies such as artificial intelligence, blockchain, digital twins, and advanced forecasting tools for improved planning and management.



Assoc. Prof. Dr. Samuel Baker Kucel - Renewable Energy Consultant

Increasing global renewable energy financing from governments, multilateral institutions, bilateral partners, private investors, and community initiatives further supports scaling efforts. Hybrid systems also create significant opportunities for education, training, and research.

Despite these prospects, several constraints remain, including high initial capital costs, system optimisation complexity, storage limitations, grid integration and power quality challenges, regulatory and policy barriers, and the need for inclusive support mechanisms. Panel discussions highlighted private sector opportunities in decentralised energy solutions, solar blending technologies, reduced transmission costs, solar-powered irrigation and water supply systems as alternatives to diesel, carbon compliance incentives, and practical training linkages, with strong emphasis on cross-sector collaboration. Support for women and youth requires improved access to finance through tailored credit and grant schemes, inclusive policies, capacity-building programmes, mentorship, digital inclusion, community engagement, and the involvement of men to address structural and social barriers. Academia's role includes offering short courses, supporting business incubation, facilitating technology transfer, extending outreach beyond classrooms and laboratories, and translating technical knowledge into accessible language to ensure broader societal participation in hybrid renewable energy development.

Hybrid renewable energy systems offer substantial technical, economic, and social benefits. Their successful deployment requires integrated system design, supportive policy environments, inclusive financing mechanisms, and coordinated collaboration among academia, industry, government, and communities.

6.3 Scaling Inclusive Access to Energy-Efficient Productive Use Solutions



Jacob Etunganan, Certified Energy Auditor, Energy Manager and Measurement and Verification Professional

Scaling inclusive access to energy-efficient productive use solutions is a critical enabler for sustained energy access. This report draws lessons from the Inclusive Markets for Energy Efficiency in Uganda (IMEU) project to demonstrate how energy efficiency can drive improved energy access outcomes through structured collaboration between industry, academia, and government. The IMEU project positions energy efficiency not merely as a technical intervention, but as a systems-level solution that expands access, strengthens markets, and ensures long-term sustainability.

IMEU: Industry, Research, Government Collaboration

The IMEU model is founded on coordinated collaboration among three key actors:

- Industry contributes innovation, product development, and service delivery.
- Academia generates evidence through applied research, supports skills development, and informs policy with credible data.
- The government provides the regulatory and institutional environment necessary to strengthen markets and attract investment.

This triangular collaboration ensures that policies are evidence-based, technologies are appropriate, and financing is informed by data and real market needs.

The Energy Access Challenge in Uganda

Despite progress in grid expansion and off-grid deployment, Uganda's energy access remains below optimal levels, particularly in rural and underserved communities. Many households face affordability constraints and limited productive use, leading to disconnections and inconsistent access. Achieving sustainable energy access therefore requires moving beyond connection to focus on energy security, energy efficiency, and productive use.

Addressing this challenge requires interventions across multiple dimensions: demand activation, market development, de-risking financing, evidence generation, and institutional strengthening. These components collectively contribute to climate change mitigation, resilience, equity, job creation, and enterprise development. Within this framework, energy efficiency serves as the key enabler that links renewable energy, productive use, and inclusive economic growth. Energy Efficiency as an Enabler for Scaled Access Energy efficiency is central to scaling energy access because it directly impacts affordability and sustainability. While consumers cannot control electricity tariffs, they can control how energy is used. Optimising consumption enables households, small and medium enterprises (SMEs), and institutions to reduce costs and increase productivity. Energy-efficient solutions reduce the size and cost of renewable systems, improve return on investment, and enhance economic viability. When energy use generates income, access becomes self-sustaining, supporting inclusion of youth and women, job creation, and resilience to climate and economic shocks.

Pathways for Impact and Scale

Scaling energy-efficient solutions requires a systems approach, implemented through four interconnected pathways:

- 1. Demand Activation** – Sustained behaviour change initiatives that move beyond awareness to practical action and adoption.
- 2. Supply Strengthening** – Ensuring availability of quality, appropriately sized technologies, skilled technicians, and diversified supply chains, including support for local enterprises.
- 3. Policy and Regulatory Environment** – Establishing standards, labelling systems, and minimum energy performance standards to protect consumers and stimulate market growth.
- 4. Applied Research and Institutional Coordination** – Generating reliable data to guide investment, regulatory reform, and market expansion.

Addressing these pathways concurrently enables systemic and scalable impact, rather than isolated pilot interventions.

Inclusion of Youth and Women

Inclusion is treated as a core design principle. IMEU supports Energy Efficiency Ambassadors and student chapters to drive behaviour change in communities. Youth and women are engaged as co-creators rather than passive beneficiaries. Tailored consumer financing mechanisms, such as Village Savings and Loan Associations (VSLAs) and Savings and Credit Cooperatives (SACCOs), enhance affordability and adoption. Employment mapping across the energy value chain ensures meaningful participation in enterprise development. Inclusion strengthens both market growth and long-term sustainability.

Enablers for Scaling.

Sustained adoption of energy-efficient solutions requires:

- Continuous investment in behaviour change initiatives.
- Reliable, data-driven evidence to guide policy and market decisions.
- Strong regulatory frameworks to create investor confidence.
- Inclusive and sustainable financing mechanisms.
- Skills development and technical capacity building.
- Collaborative learning platforms to align stakeholders around common objectives.

Energy Service Company (ESCO) models are highlighted as an effective mechanism to separate financing from technical delivery, improving affordability while maintaining quality.

Lessons Learned

Key lessons from the IMEU experience include:

- Scaling is an ongoing process, requiring continuous reinforcement of behaviour change.
- Co-design and co-implementation with industry and communities yield contextualised and sustainable solutions.
- Strong regulations underpin market growth, while inclusive financing increases adoption.
- Transitioning to an energy-efficient, renewable energy future requires patience, coordination, and sustained investment.

The path forward depends on strengthened collaboration among research institutions, private sector actors, policymakers, and communities. Evidence-based decision-making, inclusive financing, and coordinated action are essential to achieving universal, sustainable energy access. Inclusive energy efficiency solutions are scalable when systems are aligned, stakeholders coordinated, and inclusion embedded at all stages of design and implementation.



7. Research Presentations and Case Studies

Science Week featured detailed research presentations by postgraduate students and faculty members focusing on biomass, solar, and wind energy potential assessments for hybrid renewable energy systems.

7.1 Biomass Resource Assessment

Researchers collected agricultural crop residue data across selected sub-counties to determine biomass availability and quantify the magnitude of harvestable resources.

Laboratory characterisation of biomass included assessments of higher heating value (HHV), lower heating value (LHV), ash content, ash fusion temperatures, and ultimate carbon content.

Findings confirmed that the biomass resources met operational temperature requirements for gasification technologies and would not cause significant operational challenges such as slagging or fouling. Carbon content levels exceeded the 40 percent benchmark typically required for sustainable combustion processes, indicating technical suitability for energy conversion.

7.2 Solar Energy Potential Assessment

Solar energy potential was assessed using ArcGIS and NASA datasets to generate spatial distribution maps of solar radiation across the study area .

Results showed that solar radiation levels exceeded the 1600 kWh/m² threshold necessary for sustainable hybrid systems. The study area recorded approximately 2474 kWh/m² of global solar radiation, confirming strong viability for photovoltaic integration.

These findings reinforce the central role of solar energy within the proposed hybrid renewable energy system design.

7.3 Wind Energy Assessment

Wind speed data were collected at heights of 10 meters and 50 meters. The findings revealed wind speeds ranging between 1.49–1.95 m/s at 10 meters and 2.25–2.5 m/s at 50 meters.

These values fall below the approximately 3.5 m/s cut-in speed required for viable wind power generation.

Consequently, wind energy was deemed unsuitable for significant contribution within the assessed sites and was not prioritised in the hybrid system design.

7.4 Refugee Settlement Energy Study

A PhD study examined renewable energy potential in a refugee settlement in Northern Uganda. The settlement, not connected to the national grid, relies heavily on biomass fuels for cooking and lighting. The research assessed biomass, solar, and wind potential and analysed social acceptance factors affecting renewable energy adoption. The findings emphasized the importance of community sensitisation, behaviour change strategies, and inclusive planning to ensure successful deployment of hybrid renewable energy systems.

8. Case Studies

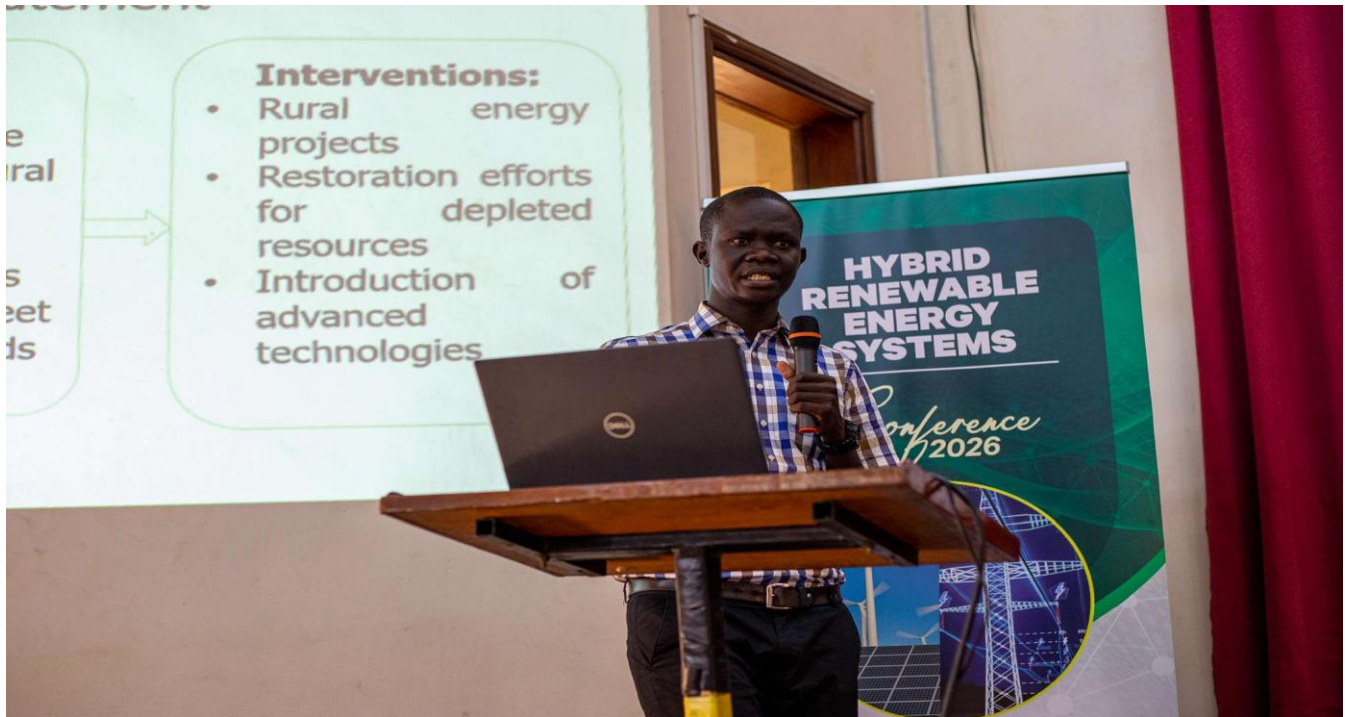
Renewable Energy Resource Potential for a Sustainable Hybrid Energy System: A Case Study of the Bidibidi Refugee Settlement, Uganda



Aidah Namagembe, a PHD Student, presenting her PHD research paper

My name is Aidah Namagembe, a Ph.D. student at Boku University. I presented my study on assessing renewable energy resource potential for Bidibidi refugee settlement in northern Uganda bordering South Sudan, a remote area not connected to the national grid and facing severe energy poverty. The settlement, which hosts about 40,000 refugees, relies heavily on agriculture, with 99% of refugees and 97% of the host community depending on firewood for cooking, leading to deforestation, environmental degradation, harmful indoor air pollution, and gender-based risks as women and children travel long distances to collect firewood. Basic facilities such as schools and hospitals depend on diesel generators and stand-alone solar systems, which face challenges of high fuel costs and intermittency. The study aimed to identify sustainable green energy sources and appropriate technologies by mapping the settlement using GIS and geospatial data, applying a stepwise methodology to independently assess biomass, solar, and wind resources before aggregating the overall renewable energy potential. Using statistical, geospatial, and meteorological data from sources including NASA and UNHCR, as well as laboratory analysis of biomass residues, we evaluated moisture content, heating values, elemental composition, and ash fusion behaviour to determine energy suitability. Results showed significant biomass availability of about 45,000 tonnes per year from crop residues and organic waste, with most feedstocks having low moisture content, suitable heating values, and compatibility with thermal conversion technologies such as gasification and pyrolysis, generating an estimated biomass energy potential of approximately 131 GWh per year. Solar assessment indicated an average radiation of about 1,630 kWh per square metre per year, yielding roughly 15 GWh annually, while wind speeds were too low for viable power generation. Overall, the total renewable energy potential was estimated at about 135 GWh per year, with biomass contributing 89% and solar 11%, demonstrating that an integrated biomass and solar system could provide a sustainable, off-grid energy solution for the settlement. The study recommends further research on optimising biomass conversion technologies and assessing the economic viability of integrated renewable systems, and notes that the methodology can be replicated in other remote, off-grid refugee or rural settlements.

Design and simulation of a hybrid renewable energy system for vulnerable communities in Uganda



Kumakech Kassim, a PHD Student, presenting his PHD research paper

My study on the design and simulation of a hybrid renewable energy system for vulnerable communities in Uganda, focuses particularly on refugee-hosting rural areas such as Yumbe District, which hosts one of the largest settlements. Drawing from national statistics showing that about 16.1% of Ugandans are considered vulnerable, most of them in rural areas, and considering Uganda's open refugee policy where most refugees live in integrated rural settlements, I noticed that these communities face immense pressure on limited resources, especially energy. Because most households rely on firewood and charcoal for cooking, this has led to deforestation, environmental degradation, and continued energy poverty. I therefore set out to develop a scientifically grounded solution using system design and simulation before implementation. I began by characterising one zone of the settlement, Zone II, selected because it hosts key social infrastructure such as schools and health facilities. I assessed renewable energy potential (solar, wind, and bioenergy), analysed current energy use patterns, studied household demographics, income levels, and conducted load profiling based on questionnaires administered to about half of the 8,400 households. The data showed that most energy demand is for cooking, with peak electricity demand occurring in the evening at about 410 kW, and an annual demand of roughly 3,610 MWh. Using Aspire for bioenergy estimation and MATLAB for optimisation modelling, I applied a minimisation technique to determine the most cost-effective hybrid configuration that could always meet demand while minimising annual system cost, net present value, payback period, and levelled cost of energy, and also estimating CO₂ savings. Although wind potential was found to be too low for viable generation, solar irradiation was strong and bioenergy potential significant, especially from animal waste and organic residues rather than woody biomass to avoid worsening deforestation. The optimised system consisted mainly of a biogas generator supported by solar PV and battery storage, as relying solely on biogas would increase energy costs beyond feasibility. Economic analysis showed the hybrid system could achieve financial viability with a reasonable payback period and positive net present value under adjusted tariff assumptions. However, beyond technical and economic feasibility, I found that social acceptance remains a critical challenge, as some community members are hesitant to adopt technologies such as biogas derived from faecal waste and often expect free services within humanitarian settings. Therefore, I concluded that while a hybrid solar-biogas system is technically and economically viable for vulnerable rural settlements, successful implementation requires strong community sensitisation, behavioural change efforts, and alignment of technological solutions with social realities.

Assessment of renewable energy resources' potential for hybrid electrification: A case study of Kasenyi fish landing site, Kasese District, Uganda



Asasio Sunday, a PHD Student, presenting his PHD research paper

My study, funded by the ADA Scholarship Office and conducted under a project promoting hybrid renewable energy systems for education in Uganda, focuses on the development and design of a biomass and solar PV hybrid system, beginning with an assessment of renewable energy resource potential in a rural area of Kasese District near a fishing landing site close to a national park. I started from the reality that Uganda faces a significant energy deficit, especially in rural areas where electricity access is low and about 87% of the population depends on biomass for cooking, leading to deforestation, environmental degradation, and serious health impacts for women and children exposed to smoke. Through field surveys and data collection, I established that while modern energy access is limited and settlements are scattered, the area has strong solar radiation and meaningful biomass residues from two growing seasons annually, though wind potential is weak. To quantify the resource base, I collected crop production statistics from district offices to estimate biomass availability, then carried out proximate, ultimate, heating value, and ash fusion analyses to determine whether residues such as coffee husks, cotton stalks, bean husks, and other crop wastes are technically suitable for energy conversion. The results showed adequate carbon content above 40%, acceptable ash behaviour for gasification above 800°C, and generally favourable higher heating values, meaning the biomass can be reliably converted without major operational issues like slagging or fouling. Using GIS tools such as ArcGIS, I mapped solar radiation distribution, slope, aspect, proximity to roads, water sources, and settlements to identify optimal installation sites, and found that global solar radiation averages around 2,474 kWh/m² per year, well above the 1,600 kWh/m² threshold required for viable hybrid systems, confirming strong solar potential. Wind mapping at 10 and 50 meters showed speeds below the 3.5 m/s cut-in requirement, so I excluded wind from the final system design. Spatial analysis also confirmed that sufficient biomass could be collected within a 10 km radius from multiple sub counties, despite lower availability in areas covered by the national park. Overall, I concluded that the study area has adequate crop residue potential capable of generating significant energy and strong solar resources, while wind is not viable; therefore, the most rational hybrid configuration for future system design should combine biomass and solar PV, with subsequent work focusing on optimal system sizing and integration.

Hybridisation of Renewable Energy Systems: Enhancing Reliability, Efficiency, and Resilience in Energy Applications



Masendi Patrick, a PHD Student, presenting his PHD research paper

My name is Masendi Patrick, and in my presentation I focused on the hybridisation of renewable energy systems to improve reliability, efficiency, and resilience in rural energy applications, particularly in response to the rural energy crisis where reliance on single renewable sources often leads to system failure, loss of trust, and continued dependence on traditional biomass. I argued that single-source systems are fragile and that combining multiple renewable sources enhances continuity, efficiency, and the ability to withstand climatic shocks. To demonstrate this, I presented a case study on the techno-economic analysis of a hybrid solar-thermal and biogas-powered dryer for pineapple processing, aimed at reducing post-harvest losses, which range between 30–50% for many farmers who depend on inconsistent open sun drying. I designed, simulated, constructed, and tested a hybrid drying system integrating solar and biogas heat supplied to a controlled drying chamber, using CFD modelling in SolidWorks to analyse airflow and heat transfer, refine chamber design, and improve temperature uniformity by modifying inlet pipe configurations. I then optimised key parameters such as temperature, airflow, slice thickness, and moisture content using response surface methodology to determine ideal drying conditions. Experimental validation showed that the hybrid dryer removed 78.3% moisture in 10.5 hours with a drying rate of 0.55 g/min, about three times faster and far more consistent than open sun drying, which achieved only 22.3% moisture removal under the same conditions. The system achieved a 78% uniformity index in heat distribution, operated at 60°C, and produced better quality dried products with lower emissions due to exclusive use of renewable sources. Economically, the prototype cost about USD 472 to build, had a net present value of USD 321, and a payback period of 1.47 years, significantly better than open sun drying at 3.75 years, showing strong viability for SMEs and rural agro-processors. I concluded that hybrid renewable systems not only enhance technical performance but also offer economic feasibility and resilience, and recommended scaling up through field piloting, exploring flexible business models, conducting life cycle and environmental assessments, integrating AI and IoT for monitoring, and replicating the model across different crops and regions to strengthen rural agro-processing and energy sustainability.

9. Institutional Capacity Strengthening

CEDAT highlighted its expanding role in renewable energy research and innovation. The College hosts the East African Centre of Excellence for Renewable Energy and Energy Efficiency and continues to strengthen research infrastructure and postgraduate training.

Ongoing infrastructure developments, including new engineering buildings and laboratories, were noted as critical investments that will sustain long-term academic excellence and innovation. They also partner with organisations like SNV that have projects focusing on renewable energy.

10. Panel Discussions

Scaling Sustainable Hybrid Renewable Energy Systems in Uganda: Policy, Skills Development, Inclusion, Financing, and Regional Competitiveness.



Representatives from the Women in Renewable Energy Association of Uganda (WREAU), the National Renewable Energy Platform (NREP), Gulu University, and Nexus Green participated in the panel discussion on scaling sustainable hybrid renewable energy systems in Uganda.

Key Messages:

Regional Positioning and Competitive-

ness: Panelists reflected on Uganda's position within East Africa and globally in the advancement of renewable and hybrid energy technologies. While Uganda has made notable progress, particularly in hydropower infrastructure and emerging renewable technologies, the region still faces challenges in scaling and competitiveness. Compared to countries like Kenya, which have advanced faster in certain renewable segments, Uganda must strengthen policy implementation, market development, and energy consumption capacity.

2. Policy Frameworks and Implementa-

tion: The discussion emphasised that Uganda has strong and well-developed renewable energy policies. However, the main challenge lies not in the absence of policy, but in effective implementation, dissemination, and public awareness.

Ms. Maria Kisa, Head of Project Finance and Corporate Affairs at the National Renewable Energy Platform under the Ministry of Energy, highlighted that:

- The Energy Policy for Uganda serves as the cornerstone guiding renewable energy development.
- Mini-grid frameworks are in place to support decentralised energy access, especially for marginalised and off-grid communities.
- Clean cooking transition initiatives, including behaviour change campaigns and targeted incentives, demonstrate how policies are translated into action.
- Incentives such as subsidies, result-based financing, flexible financing models, and public-private partnerships are critical in accelerating scale-up.

She stressed the importance of embedding environmental and social safeguards, gender inclusion, and productive use components within renewable energy policies.

3. Incentives for Innovation and Investment:

Panelists noted that scaling hybrid systems requires a combination of:

- Grant financing
- Debt financing
- Corporate social responsibility (CSR) contributions
- Co-financing models
- Public-private partnerships

Demonstration centres and training facilities

There was strong emphasis on aligning technical proposals with business cases. Investors are more responsive to clear return-on-investment frameworks than purely technical descriptions. Therefore, renewable energy projects must integrate economic analysis, life-cycle costing, and financial modelling to attract sustainable investment.

4. Role of Academia in Shaping Policy and Investment:

Academia was recognised as central to bridging skills gaps and informing policy. Universities contribute through:

- Master's programs in Renewable Energy and Energy Access.
- Courses in Energy Policy, Energy Modelling, and Hybrid Optimisation Systems.
- Training in economic evaluation tools such as Net Present Value (NPV) and cost-benefit analysis.
- Life-cycle assessment methodologies to assess environmental impacts.

Through research and industrial collaboration, universities help generate evidence that informs policy decisions and investment strategies. Panelists emphasised that academic research should be practical, locally relevant, and aligned with national priorities.

5. Youth and Women Inclusion in the Renewable Energy Value Chain:

Ms. Harriet Achieng emphasised that Uganda has a youthful population, with a significant percentage under 35 years and over half being women. However, youth and women remain underrepresented in energy access and decision-making spaces.

Key opportunities identified include:

- Entrepreneurship and renewable energy startups
- Technical and vocational training in renewable technologies
- Smart grid and clean cooking solutions
- Access and control over renewable energy technologies
- Research and innovation opportunities for women and youth
- Community-level skilling for informal and semi-literate populations

The panel stressed that inclusion must go beyond policy statements and translate into targeted awareness campaigns, practical skilling, financing access, and leadership representation.

6. Energy Efficiency and Conservation:

Energy efficiency and conservation were identified as critical and often underestimated components of the clean energy transition. Panelists noted that:

- Behavioural change can reduce energy demand significantly through implementing energy conservation measures such as switching off lights.
- Energy conservation practices in households, businesses and social institutions yield high returns at low cost.
- Demonstration projects and awareness campaigns are effective in influencing adoption.
- Clean cooking technologies, such as electric pressure cookers, can significantly reduce household energy expenditure when properly communicated.

7. Financing and Market Dynamics:

Financing mechanisms must be accessible and flexible. Models discussed included:

- Pay-as-you-go systems
- Partial subsidy schemes
- Blended financing
- Productive-use financing (e.g., solar irrigation systems)
- Climate-smart agriculture financing.

It was emphasised that renewable energy technologies are increasingly affordable, particularly as solar generation costs continue to decline. However, storage costs remain relatively high and require innovative financing mechanisms.

Q&A / Interactions:

The session was highly interactive, with participants engaging panelists on several issues:

- Uganda's ranking in renewable energy advancement relative to East Africa.
- Whether policy gaps or implementation gaps are the greater barrier.
- The effectiveness of mini-grid frameworks in supporting marginalised communities.
- Practical pathways for youth employment within hybrid energy value chains.
- The role of universities in influencing national policy decisions.
- How to balance large-scale infrastructure investments (such as dams) with decentralised renewable systems.
- Incentives the government can deploy to accelerate innovation and private-sector participation.
- Strategies for ensuring that women and rural communities are aware of existing policies and opportunities.

Participants also challenged the panel on the need for better policy dissemination, improved coordination between academia and government, and stronger communication strategies to translate research findings into actionable investments.

The discussion concluded with consensus that collaboration across government, academia, private sector, development partners, and communities is essential for scaling sustainable hybrid renewable energy systems in Uganda.

10. Special Activities / Demonstrations

- Presentation of renewable energy training initiatives under the Renewable Energy Training Centre.
- Showcasing of research findings from Master's and PhD students.
- Demonstration discussions on clean cooking technologies and electric pressure cookers as cost-saving innovations.
- Highlighting of the Renewable Energy Conference platform as an annual demonstration and stakeholder engagement space.

11. Key Outcomes

Presentation of renewable energy training initiatives under the Renewable Energy Training Centre.
Showcasing of research findings from Master's and PhD students.

Demonstration discussions on clean cooking technologies and electric pressure cookers as cost-saving innovations.

Highlighting of the Renewable Energy Conference platform as an annual demonstration and stakeholder engagement space.

13. Way forward

Strengthen collaboration: Encourage continued partnerships among universities, government, industry, and development partners to scale hybrid renewable energy solutions.

Invest in research and skills development: Expand research, training programmes, and practical learning platforms to build technical capacity in renewable energy systems.

Improve policy implementation: Enhance awareness and effective implementation of existing renewable energy policies to accelerate adoption.

Promote inclusion and financing: Support women, youth, and vulnerable groups through targeted training, entrepreneurship opportunities, and accessible financing mechanisms.

Scale decentralised renewable energy solutions: Prioritise solar and biomass hybrid systems for rural and off-grid communities while promoting energy efficiency and productive use of energy.

14. Conclusion

Science Week provided a comprehensive platform for reviewing progress under the PHRE project and reinforcing the importance of hybrid renewable energy systems in addressing Uganda's electricity access challenges. Through curriculum reform, establishment of a makerspace, rigorous technical research, and strengthened international collaboration, the project has significantly enhanced Makerere University's capacity in renewable energy education and innovation.

The findings presented confirm that biomass and solar energy offer viable pathways for hybrid system deployment, while wind energy potential remains limited in the assessed areas. The event concluded with a renewed commitment from all partners to continue collaboration, deepen research excellence, and translate scientific findings into practical, scalable solutions that contribute to sustainable development in Uganda.

Awarding Ceremony

Awarding of certificates to the participants in the first, second and third trainers' training in the Makerspace during the years 2024, 2025 and 2026, under the APPEAR Project Promotion of Hybrid Renewable Energy Systems Towards Electricity Access in Uganda (PHRE #288) at Makerere University



Participants pose with their certificates after the awarding ceremony

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