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REVIEW ARTICLE

Current Status of Biogas Technology Adoption in Uganda

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ABSTRACT

Biogas technology offers a sustainable and renewable energy solution to Uganda's challenges of energy poverty, environmental degradation, and inefficient agricultural waste management. Predominantly an agrarian nation with a high rural population dependent on traditional biomass fuels such as firewood and charcoal, Uganda stands to benefit significantly from adopting biogas. This review examines the current status of biogas technology adoption in Uganda by exploring its potential, national programs, adoption trends, barriers, recent innovations, gender and social considerations, and environmental and economic benefits of biogas use. The National Biogas Programme has played a pivotal role in promoting biogas through capacity-building and financing mechanisms; however, adoption remains limited by high installation costs, a lack of technical expertise, cultural perceptions, and policy gaps. Recent initiatives, including institutional biogas projects, private sector innovations, and gender-responsive approaches, demonstrate growing momentum and opportunities for scaling. The paper highlights the importance of integrating biogas into national energy, climate, and agricultural policies to foster inclusive and sustainable growth. Addressing financing constraints, enhancing technical capacity, and promoting gender and social inclusion are critical to unlocking the full benefits of biogas for Uganda's clean energy transition and rural development.

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1. INTRODUCTION

Biogas technology offers a promising and sustainable solution to some of Uganda's most pressing socio-economic and environmental challenges. As a country characterised by a predominantly agrarian economy, with between 70 - 80% of the population engaged in agriculture and the majority residing in rural areas (Ainebyona *et al.*, 2025; UBOS, 2020; Uzorka *et al.*, 2025a), Uganda faces significant issues related to energy access, environmental degradation, and poor waste management. More than 90% of Ugandan households rely on traditional biomass fuels, such as firewood, charcoal, and crop residues, for their daily energy needs, particularly for cooking (Aggarwal *et al.*, 2025; Nanteza *et al.*, 2025; Uzorka *et al.*, 2025b). This heavy dependence on unsustainable biomass has led to rapid deforestation, soil degradation, indoor air pollution, and health-related issues, disproportionately affecting women and children, who are often tasked with collecting fuel and preparing food (World Bank, 2023; IEA, 2023).

Against this backdrop, biogas technology emerges as a viable renewable energy option that simultaneously addresses energy needs and environmental concerns. Biogas is produced through the anaerobic digestion of organic waste materials, including animal dung, crop residues, food waste, and human excreta (Makumbi *et al.*, 2025a; Zhang *et al.*, 2025). This not only provides a clean source of energy for cooking, lighting, and heating but also produces nutrient-rich slurry that can be used as organic fertiliser, enhancing soil fertility and agricultural productivity.

Figure 1 illustrates how biogas is produced from organic waste. The process begins with the collection of organic waste materials such as livestock manure (cow dung, pig manure), food waste (vegetable peels, leftovers), agricultural residues (crop waste, husks), and sewage or human waste (in some advanced systems). Water is typically added to the waste to form a slurry, which helps it flow easily into the digester. The slurry is then fed into an anaerobic digester, a sealed, oxygen-free tank or dome where the microbial decomposition occurs. The biogas rises to the top of the digester and is stored or piped to cookstoves for household cooking, lamps for lighting, and engines for mechanical or electrical power. After digestion, the leftover material, called bio-slurry, is drained from an outlet pipe and used directly or dried and composted for use as organic fertiliser in agriculture.

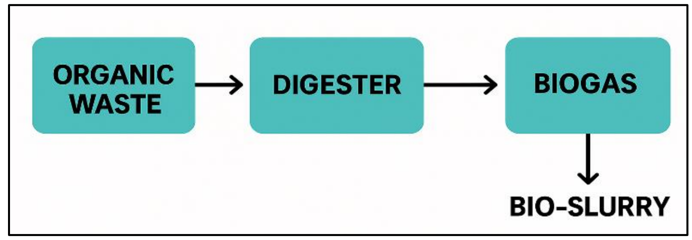

Fig. 1. Biogas production process flow

Biogas digesters come in various designs, each suited to different needs, environmental conditions, and budget levels. The most commonly used types in Uganda are the fixed dome digester, the floating drum digester, and the Plug-flow digester, shown in **Figure 2**. **Figure 3** is a Pictorial Representation of Biogas Digester Types in Uganda. A fixed dome digester is a permanent, underground structure made of brick, cement, or concrete. The gas is stored in a fixed, non-movable dome at the top of the digester. Gas pressure pushes the slurry into an outlet chamber when biogas is generated. The floating drum digester consists of an underground digester chamber with a movable steel drum or plastic container that floats on top of the slurry to collect biogas. As biogas is produced, the drum rises; as gas is used, it sinks. A plug-flow digester is a long, narrow, horizontal tank (usually above ground) where slurry flows in one direction—new material is added at one end, and digested slurry exits at the other. mostly tubular in design, often using plastic or rubber materials. A comparison summary of the bigas system types is presented in **Table 1.**

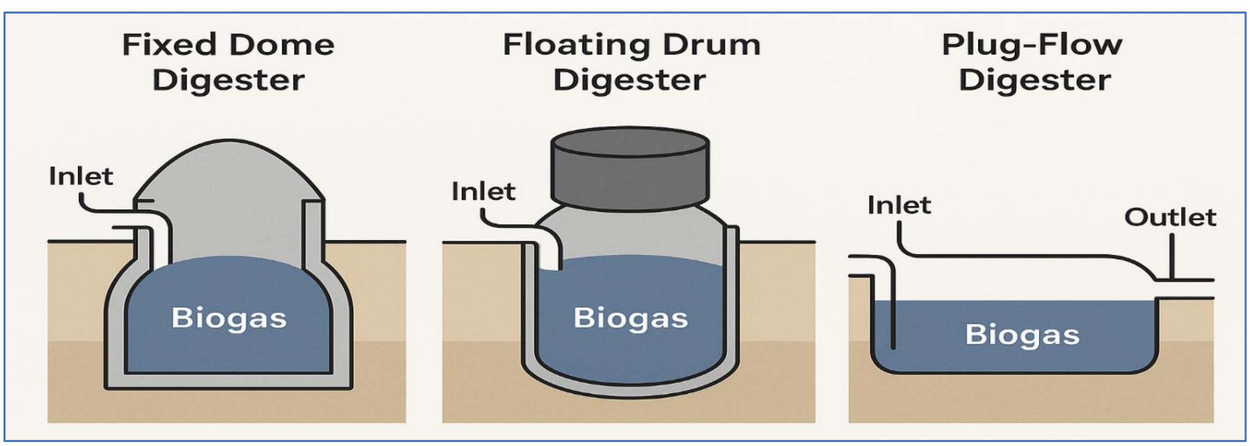

Fig. 2. Biogas system types

Fig. 3. Pictorial representation of biogas digester types in Uganda

Table 1: Biogas system types

System Type	Durability	Gas Pressure	Cost	Maintenance	Ideal For
Fixed Dome	High	Variable	High	Low	Rural households, institutions
Floating Drum	Medium	Stable	Moderate	Medium (drum rusts)	Urban/peri-urban homes
Plug-Flow Digester	Low–Medium	Variable	Low	Low	Small farms, pilot projects

Over the past two decades, Uganda has made modest progress in promoting and adopting biogas technology, facilitated by both government initiatives and support from development partners, NGOs, and private sector actors. Programs such as the Africa Biogas Partnership Programme (ABPP) have played a critical role in creating awareness, building capacity, and providing subsidies to low-income households for the installation of household-level biogas digesters (Jima, 2025; Roopnarain *et al.*, 2021). Moreover, the technology aligns with national and international goals, including Uganda's Vision 2040, the National Development Plan (NDP), and the Sustainable Development Goals (SDGs), particularly those related to affordable and clean energy (SDG 7), climate action (SDG 13), and sustainable agriculture (SDG 2).

Despite these opportunities, the adoption of biogas technology in Uganda remains limited compared to its potential. Several barriers, such as high initial investment costs, limited technical expertise, inadequate financing mechanisms, cultural perceptions, and weak policy enforcement, continue to hinder widespread uptake, especially among the rural poor who stand to benefit the most (Robinson *et al.*, 2025; Uzorka & Wonyanya, 2025). Nonetheless, with the right mix of policy support, public-private partnerships, financial incentives, and community engagement, biogas technology could significantly contribute to Uganda's sustainable development agenda.

This review, therefore, aims to provide an analysis of the current status of biogas technology adoption in Uganda. It examines the key drivers facilitating its growth, the challenges constraining its expansion, and the prospects for scaling up its implementation in both rural and urban settings.

2. BIOGAS POTENTIAL IN UGANDA

Uganda possesses significant untapped potential for biogas production, driven largely by its abundant agricultural resources, high population of livestock, and widespread availability of organic waste. As an agro-based economy with between 70 - 80% of the population engaged in farming (Ajer *et al.*, 2024; Kibirige *et al.*, 2024; Waiswa *et al.*, 2021), Uganda generates vast quantities of biodegradable waste materials ranging from animal dung and crop residues to food waste and human excreta, which are ideal feedstock for biogas production. These resources, if efficiently harnessed, could provide a decentralised, clean, and renewable energy source for millions of households, institutions, and small-scale enterprises across the country.

The livestock sector, in particular, offers a strong foundation for biogas development. According to the Uganda Bureau of Statistics (UBOS), the country has an estimated livestock population of over 14 million cattle, 16 million goats, 4 million sheep, and a rapidly growing number of pigs and poultry (Atuheire *et al.*, 2021; UBOS, 2024). Cattle dung, one of the most commonly used feedstocks for biogas digesters, is therefore widely available in rural households (Clemens *et al.,* 2018;

World Bank, 2019). A single cow can produce approximately 10–15 kg of dung per day, sufficient to generate enough biogas to meet the daily cooking needs of a small household when used in combination with other organic materials (Ananno *et al.*, 2021; David *et al.*, 2022).

In addition to livestock waste, Uganda's urban centres and institutions such as schools, prisons, and hospitals generate substantial volumes of food waste and sewage, which also hold promise for medium- to large-scale biogas installations (Uzorka & Wonyanya, 2025). Municipal organic waste and human waste from latrines and septic tanks are increasingly being explored as alternative sources for biogas production, particularly in peri-urban and slum areas where waste management remains a persistent challenge (Makumbi *et al.*, 2025 b; Nabaggala, 2023). Integrating biogas systems into such settings could not only produce energy but also contribute to improved sanitation and public health outcomes.

Furthermore, Uganda's favourable climatic conditions, characterised by relatively high and stable temperatures, enhance the efficiency of anaerobic digestion processes, making biogas production technically viable across most parts of the country. The country's equatorial climate helps maintain the optimal mesophilic temperature range (30–40°C) required for effective microbial activity within digesters (David *et al.*, 2022), especially in rural households where advanced heating technologies are often not available.

Several feasibility studies and technical assessments have indicated that Uganda has the potential to install hundreds of thousands of household biogas digesters and numerous institutional and commercial-scale plants. The Africa Biogas Partnership Programme (ABPP) estimated that over 1 million Ugandan households are technically suitable for biogas systems (Roopnarain *et al.*, 2021). This potential informed the Uganda National Domestic Biogas Programme's (UDBP) target of installing 12,000 plants by 2018. However, actual installations remain far below this potential, highlighting a significant gap between capacity and adoption.

Moreover, biogas presents an opportunity to diversify Uganda's energy mix, which is currently dominated by biomass (over 90%) and hydropower (Bongomin & Nziu, 2022). While hydropower accounts for the bulk of electricity generation, access to grid electricity remains low, especially in rural areas (Adolf & Uzorka, 2025). Biogas can help fill this gap by providing off-grid energy solutions that are affordable, sustainable, and adaptable to local conditions. In agricultural settings, biogas energy can also support small-scale agro-processing activities such as milk pasteurisation, grain milling, and fruit drying, thereby contributing to rural development and poverty alleviation.

3. NATIONAL BIOGAS PROGRAMME

The development and promotion of biogas technology in Uganda has been significantly influenced by the establishment of the Uganda National Domestic Biogas Programme (UDBP) and other government and development partner initiatives. Recognising the potential of biogas to contribute to energy access, environmental protection, and improved agricultural productivity, the Ugandan government, in collaboration with international organisations, has made strategic efforts to mainstream biogas within its national renewable energy agenda. The Uganda National Domestic Biogas Programme (UDBP), launched in 2009, was implemented under the broader Africa Biogas Partnership Programme (ABPP), a multi-country initiative designed to promote the construction and sustainable use of small-scale, fixed-dome biogas plants primarily in rural households (Roopnarain *et al.*, 2021). The program was a partnership between the Uganda Ministry of Energy and Mineral Development, the Hivos Foundation, and SNV Netherlands Development Organisation, with funding support from the Dutch government (Mukisa *et al.*, 2022).

The UDBP aimed to create a robust biogas sector in Uganda by building local technical capacity, increasing awareness, facilitating access to financing, and ensuring quality assurance of biogas systems. Its specific objectives included (Mukisa *et al.*, 2022): Construction of over 12,000 household biogas plants by 2018; Training of masons, technicians, and entrepreneurs to establish a sustainable biogas service sector; Promotion of integrated farming systems using bio-slurry as fertilizer to improve crop productivity; Development of financing mechanisms such as subsidies and credit facilities to make biogas systems more affordable for low-income households.

By the end of Phase I and II of the program (2009–2018), approximately 13,000 domestic biogas plants had been installed across the country, primarily in the cattle-keeping districts of Central, Western, and Eastern Uganda (Mukisa *et al.*, 2022). The program also trained hundreds of technicians, established regional construction teams, and developed quality standards and a monitoring framework to ensure proper functionality and sustainability of the biogas units.

While the UDBP focused on household-level adoption, other initiatives have targeted institutional and commercial-scale biogas systems. Schools, prisons, hospitals, and agricultural processing units have been encouraged to adopt larger biogas plants to manage organic waste and reduce fuel costs. Organisations such as the Uganda National Biogas Alliance (UNBA) and Biogas Solutions Uganda Ltd. (BSUL) have played key roles in scaling up these efforts, supported by donors like the European Union and GIZ (Kakembo & Kakembo, 2021).

The National Biogas Programme operates within the framework of Uganda's broader Renewable Energy Policy (2007) and Energy Policy for Uganda (2002), both of which emphasise the role of bioenergy in achieving energy access and sustainability (Mirembe *et al.*, 2024). The National Development Plan (NDP III) and Uganda Vision 2040 also identify biogas as a strategic technology for rural electrification, clean cooking, and climate change mitigation (Mwangu, 2024). Despite these policy commitments, the sector still faces challenges such as weak enforcement of quality standards, limited integration of biogas in national electrification strategies, and inadequate public funding (Mwangu, 2024). The absence of a specific, updated national biogas policy or legal framework has also been cited as a gap that hinders coordinated development and investment in the sector.

Some key achievements of the National Biogas Programme include (Mwangu, 2024): Improved energy access for thousands of rural households; Reduced deforestation and greenhouse gas emissions through the substitution of firewood and charcoal; Empowerment of women and youth, who have benefited from reduced cooking time, better indoor air quality, and training/employment opportunities; Enhanced agricultural productivity through the use of bio-slurry as an organic fertilizer.

4. ADOPTION TRENDS AND PATTERNS

Trends and patterns of biogas adoption in Uganda are summarised in Table 2. Uganda's biogas adoption has shown measurable progress but remains limited in scale. Uptake has followed classical diffusion curves, with early adopters concentrated in better-resourced households. Key strengths include cost-recovery within a year and multi-purpose benefits for cooking and farming. However, sustainability and expansion are hampered by quality concerns, lack of technical support, high initial costs, and low government subsidy influence. Strengthening maintenance networks, improving infrastructure and training, and broadening financial access will be essential to transition from early adopters toward a broader mainstream market.

Table 2: Trends & Patterns

Feature	Trend / Pattern
Regional comparison	Behind Kenya and Tanzania (Mukisa *et al.*, 2022)
Type of digester	Fixed-dome dominant (Ketuama *et al.*, 2022)
Feedstock	Primarily animal dung (Ogwang *et al.*, 2021)
Primary use	Cooking, lighting (Mukisa *et al.*, 2022)
Adoption demographics	Income, cattle ownership, male-headed, less remote locations (Jima, 2025)
Retention challenges	Dis-adoption in some early projects within 4 years often due to poor maintenance services, lack of spare parts, and lack of skilled technicians (Lwiza *et al.*, 2017)
Economic outlook	Payback ~1 year; long-term O&M critical

5. KEY BARRIERS TO ADOPTION

Despite the recognised potential and demonstrated benefits of biogas technology in Uganda, its widespread adoption remains limited. Several structural, economic, technical, and socio-cultural barriers have hindered the scale-up of biogas systems across both rural and urban settings. Understanding these challenges is critical to designing effective interventions that can accelerate uptake and ensure long-term sustainability.

Key barriers to the adoption of biogas technology in Uganda are summarised in Table 3. One of the most significant barriers to biogas adoption in Uganda is the high upfront cost of installing a digester. The cost of a standard fixed-dome system ranges between UGX 2.5–5 million, equivalent to approximately USD 700–1,400 at the time of publication of the cited work (Wasajja *et al.*, 2024), depending on size and location. For low-income rural households, who often operate on subsistence-level incomes, such costs are prohibitively high, even when subsidies or financing schemes are available. Moreover, the cost of associated materials (cement, bricks, piping, etc.) has risen due to inflation and supply chain issues, further deterring potential adopters. Although biogas is cost-effective in the long term, the lack of upfront capital remains a major bottleneck for most families.

Closely related to the issue of cost is the limited access to affordable credit for rural households. Financial institutions are often reluctant to lend for renewable energy technologies due to perceived risks, lack of collateral, or limited awareness (Mirembe *et al.*, 2024). While some microfinance institutions and donor-funded programs have attempted to bridge this gap, the scale and reach of such financing schemes remain inadequate. In addition, many rural communities are not fully integrated into formal financial systems (Holm-Nielsen *et al.*, 2022; Ukagwu *et al.*, 2022), making it difficult for them to participate in loan or repayment plans for biogas installations. Without targeted financial support mechanisms, adoption will continue to be skewed toward wealthier households.

Another key challenge is the lack of skilled technicians and quality assurance mechanisms. In many parts of Uganda, biogas systems have failed due to poor construction practices, substandard materials, or improper sizing (Robinson *et al.*, 2025). Inadequately trained masons and technicians can install digesters that leak gas, crack under pressure, or fail to produce sufficient output. Additionally, regular maintenance and repair services are often unavailable or too expensive for users, leading to system abandonment (Uzorka & Wonyanya, 2025). Many users are also not adequately trained in the day-to-day operation of digesters, resulting in improper use or neglect. These challenges reflect the retention problems already highlighted in

Table 2, where some projects experienced dis-adoption within 4 years. For a biogas system to function effectively, it requires a consistent supply of organic waste, particularly animal dung and water. In Uganda, however, not all households meet the minimum livestock ownership requirement, typically 3 to 5 cattle to sustain daily gas production (Uzorka & Wonyanya, 2025). In semi-arid areas or during dry seasons, water scarcity also becomes a constraint, making it difficult to maintain the proper slurry consistency required for optimal digestion (Uzorka & Wonyanya, 2025). As a result, many potential users are disqualified from adoption due to inadequate feedstock or poor year-round availability.

While awareness of renewable energy in general has increased in Uganda, knowledge of biogas technology remains limited, especially in remote rural communities (Makumbi *et al.*, 2022; Robinson *et al.*, 2025). Many people are unfamiliar with how biogas works, what it requires, and what benefits it can deliver. Misconceptions such as the belief that biogas is unsafe, difficult to use, or only suitable for the wealthy further discourage adoption. In some cases, cultural taboos associated with using human waste as feedstock for biogas also prevent the adoption of toilet-linked digesters (Somorin *et al.*, 2025). Overcoming such deeply rooted perceptions requires sustained, culturally sensitive awareness campaigns and community engagement.

While Uganda lacks a dedicated, comprehensive national biogas policy, biogas development operates within broader frameworks such as the Renewable Energy Policy 2007, the Energy Policy for Uganda 2002, and emerging initiatives like the Energy Efficiency and Conservation Bill 2024 (Bongomin & Nziu, 2022). As a result, coordination among stakeholders is fragmented, and implementation lacks consistency. Government programs are often short-term and donor-dependent, with limited follow-up or impact evaluation. Currently, Uganda lacks fully established national standards and certification for biogas construction, which has led to inconsistent system quality and reduced public trust in the technology. However, ongoing initiatives such as UBEP and the Energy Efficiency and Conservation Bill 2024 aim to address this gap through capacity building and standard-setting (Bongomin & Nziu, 2022; Muhamad *et al.*, 2022). Without stronger institutional commitment and a coordinated policy framework, biogas is unlikely to gain the mainstream traction needed for large-scale impact.

In many Ugandan households, especially in rural areas, women are the primary users and beneficiaries of improved cooking technologies. However, women often lack decision-making power or financial autonomy to invest in biogas systems (Somorin *et al.*, 2025). Furthermore, the daily tasks of collecting dung, feeding digesters, and maintaining the system add to women's labour burden, which can be a disincentive unless the benefits are immediate and substantial. Failure to incorporate gender-sensitive design and outreach strategies has led to underutilization and disinterest in many communities.

Table 3: Key Barriers

Barrier	Description
High installation costs	Prohibitively expensive for most rural households
Lack of financing	Limited access to loans and credit facilities
Technical quality issues	Poor construction, lack of skilled technicians
Feedstock and water scarcity	Insufficient dung or water to run digesters year-round
Low awareness and cultural resistance	Misconceptions and limited understanding of benefits
Policy and institutional gaps	No dedicated biogas policy, weak standards and coordination
Gender constraints	Women lack decision-making power; labor burden concerns

6. RECENT INNOVATIONS AND INITIATIVES

Recent innovations and initiatives in biogas technology in Uganda are summarised in Table 4. In May 2025, the African Development Bank approved US $8.79 million in funding for the Uganda Biogas and Electric Cooking Project (UBEP) (AEP, 2025). This national initiative targets clean cooking solutions through (AEP, 2025): Installation of 47 biogas plants in public institutions, schools, markets, and community facilities, designed to reduce charcoal and firewood use by up to 50%; Capacity building and development of standards, distribution networks, and technical support systems. UBEP aligns with Uganda's Vision 2040, Energy Transition Plan, and national climate pledges under the Paris Agreement, supporting broader goals like reduced indoor air pollution, deforestation, and gender empowerment (AEP, 2025).

Uganda Christian University (UCU) has emerged as a hub for biogas innovation and community outreach in Mukono. In September 2023, UCU launched a 12 m³ combined organic-waste biogas plant (powered by kitchen, faecal, and cow-dung inputs), demonstrating integrated waste-to-energy conversion (Edith, 2023). The plant supports hands-on research and training through the Bingo Project, enabling students, staff, and local farmers to engage with biogas technology—from construction to slurry usage. Over a dozen Mukono farmers have received practical training, and UCU researchers continue to explore efficient gas storage, packaging solutions, and digestate separation techniques.

National-level initiatives and policy momentum include: The National Renewable Energy Platform (NREP) February 2025 newsletter spotlighted biogas integration efforts, including clean

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cooking campaigns by the Buganda Kingdom, targeting urban districts like Masaka, Mbale, and Jinja (NREP, 2025); Jinja College partnered with the Ministry of Energy to pilot a biogas system fed from latrines, aiming to use waste to power cooking and lighting at the school, a notable leap in sanitation-linked energy use (NREP, 2025). The Energy Efficiency and Conservation Bill 2024, currently before Parliament, aims to set quality standards and regulations for clean cooking technologies, including biogas systems, to solidify policy support (Parliament, 2025).

Biogas adoption is increasingly intersecting with regenerative agriculture and innovative science: TechnoServe's HortiMAP project (2021–2024), implemented in eastern Uganda, linked biogas digesters from Sistema.bio with women's savings groups, leading to improved yields and financial resilience for farmers like Evelyn Cheroriot (Technoserve, 2025). Bio-slurry use boosted a 30% yield increase in onion harvests while reducing synthetic fertiliser dependency (Technoserve, 2025). While not exclusively biogas-focused, recent IoT-driven agri-tech projects at Makerere and national research institutes are laying the groundwork for better feedstock and operational efficiencies: The TORCH project at Makerere University, launched in June 2025, will create "living laboratories" for green technologies, including bioenergy, across Uganda's central, south-western, and eastern regions. These labs aim to integrate women-led innovation, technical skills training, and policy engagement (Mak, 2025). Complementary research on IoT-based climate-resilient smart agriculture enhances the potential for precision farming systems that could optimally supply and monitor biogas digesters in real time.

Table 4: Recent Innovations & Initiatives

Initiative / Innovation	Description
UBEP (ADB-funded)	~$8.8M national rollout of institutional biogas + eCooking units
UCU Bingo Project	Waste-to-biogas living lab and farmer training centre
Policy & Clean Cooking Campaigns	Buganda Kingdom, Jinja College pilot, new energy bill
Regenerative ag & bio-slurry adoption	TechnoServe-supported women farmers scaling biogas links
Advanced co-digestion R&D	Ferric oxide boosts yield by ~81% in waste co-digestion
Smart agriculture frameworks	IoT systems, Makerere living labs to support bioenergy-driven farming

7. GENDER AND SOCIAL CONSIDERATIONS

Biogas technology has the potential to bring transformative social benefits in Uganda, particularly concerning gender equity, household welfare, and community resilience. However, its implementation and impact are not gender-neutral. Understanding the gendered and social dynamics of biogas adoption is essential to designing inclusive and equitable energy solutions that meet the needs of all members of society, especially women and marginalised groups.

Key gender and social considerations are summarised in Table 5. In most Ugandan households, especially in rural areas, women and girls are the primary users and managers of household energy, mainly for cooking, water heating, and food processing (Kyayesimira & Muheirwe, 2021). This means they are disproportionately affected by the negative impacts of traditional biomass use, such as: Exposure to indoor air pollution, leading to respiratory illnesses; Time poverty, due to long hours spent collecting firewood; Physical burden and safety risks associated with fuelwood collection in remote areas. By reducing dependence on firewood and charcoal, biogas technology can significantly ease these burdens, making it a gender-responsive energy solution when implemented thoughtfully.

One of the most immediate benefits of biogas adoption for women is the drastic reduction in cooking time and fuel collection labour (Elasu *et al.*, 2025). With biogas, cooking becomes faster and cleaner, freeing up time for other productive activities such as: Engaging in income-generating ventures (e.g., agriculture, tailoring, small businesses); Participating in community or leadership roles; Caring for children and attending education or training sessions.

Biogas stoves produce no smoke or harmful emissions, unlike traditional open-fire cooking (Adhikari *et al.*, 2025). This leads to improved indoor air quality, which directly benefits women and children who are often the most exposed to household smoke. Key health-related impacts include: Lower incidence of eye infections, respiratory diseases, and burn injuries (McCord et al., 2017); Enhanced safety, especially for girls and women who no longer have to travel long distances in search of firewood, thereby reducing exposure to violence or sexual harassment. Biogas systems linked to sanitation facilities (e.g., toilet-fed digesters) can also improve hygiene and dignity, particularly for adolescent girls and the elderly.

Despite being primary beneficiaries, women often lack decision-making power when it comes to adopting or investing in biogas technology. In many Ugandan households, men control financial resources and determine major expenditures (Kyayesimira & Muheirwe, 2021). This can result in: Underrepresentation of women in biogas training sessions and technical roles; Exclusion from maintenance decisions, even though women use the technology daily; Lower adoption rates in female-headed households due to lack of capital and technical support. Efforts to mainstream gender into biogas programs must therefore go

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beyond targeting women as users; they must also promote women's involvement as decision-makers, technicians, entrepreneurs, and policy influencers.

Beyond gender, several other social factors affect biogas adoption: Low-income households are often unable to afford installation costs, even when subsidies are available (Tereka *et al.*, 2025); Youth and persons with disabilities (PWDs) are rarely targeted in outreach or training programs; Geographic isolation of some rural communities limits access to biogas services and support. Unless these groups are explicitly included in planning and implementation, biogas programs may inadvertently reinforce existing inequalities. Tailored financing models, inclusive training sessions, and localised support networks are essential to reach the most vulnerable.

Table 5: Key Gender and Social Considerations

Issue	Observation	Recommendation
Women as primary users	Bear the brunt of fuelwood-related burdens	Prioritize women in design, training, and outreach
Time and health savings	Significant reductions in labor and illness	Highlight co-benefits to boost adoption
Limited decision-making power	Men often control finances	Engage both men and women in household-level decisions
Financial barriers for women & marginalized groups	Access to credit is limited	Develop targeted microfinance and subsidy programs
Underrepresentation in technical roles	Few women as masons or technicians	Invest in gender-inclusive technical training
Empowerment potential	Women-led biogas enterprises growing	Scale up support for female entrepreneurs

8. ENVIRONMENTAL AND ECONOMIC BENEFITS OF BIOGAS USE IN UGANDA

Biogas technology provides not only a renewable source of energy but also significant environmental and economic benefits for Uganda. As the country faces rising energy demands (Elasu *et al.,* 2025; Fashina *et al.,* 2018; Murungi et al., 2025), deforestation (Naluzze & Ruppel, 2025), and rural poverty (Margret & Ann, 2025), biogas presents a sustainable alternative that aligns with both ecological preservation and economic development. The environmental and economic benefits of biogas are far-reaching, touching on climate resilience, forest preservation, household welfare, and local economic empowerment as summarised in Table 6.

Biogas helps mitigate climate change by capturing methane, a potent greenhouse gas, that would otherwise be released from decomposing organic waste (Makepa *et al.,* 2025; Nyang *et al.,* 2020). By converting this methane into usable energy, biogas systems reduce Uganda's overall carbon footprint. Additionally, substituting biogas for firewood and charcoal helps lower CO_2 emissions from the combustion of biomass fuels. Widespread use of firewood and charcoal is a leading driver of deforestation in Uganda (Byamukama et al., 2025; Elasu et al., 2025). Biogas offers a cleaner alternative, thereby reducing pressure on forests and promoting ecosystem conservation. The by-product of biogas digestion, bio-slurry, is a nutrient-rich organic fertiliser that improves soil fertility and moisture retention. It reduces dependence on chemical fertilisers, thereby minimising runoff and water contamination.

Biogas significantly reduces household expenditures on cooking fuels such as charcoal and firewood (Elasu et al., 2025). Over time, the investment in a biogas unit leads to substantial savings. The biogas sector creates employment opportunities through digester construction, maintenance, bio-slurry management, and equipment supply chains (Somorin et al., 2025). Training programs for masons, technicians, and entrepreneurs have opened new livelihood options, particularly for youth and women. By improving access to organic fertiliser, biogas supports higher agricultural productivity and cost-efficiency for smallholder farmers. This contributes to improved food security and farm profitability.

9. RECOMMENDATIONS

The future of biogas technology in Uganda holds considerable promise. Given the country's abundant organic waste resources, growing energy demands, and environmental challenges, biogas can play a transformative role in shaping a cleaner, more resilient, and inclusive energy future. However, achieving its full potential will require a deliberate and coordinated approach involving policy reform, investment, capacity building, and stakeholder engagement. To unlock the full potential of biogas in Uganda, the following strategic actions are recommended:

1. Develop a National Biogas Policy and Regulatory Framework: The absence of a dedicated biogas policy limits coordination, quality assurance, and investment. A comprehensive national biogas policy should be developed, aligned with Uganda's energy, agricultural, and climate policies. This policy should set clear standards, outline subsidies and incentives, promote

integration with sanitation and farming systems, and define institutional responsibilities.

2. Strengthen Financing Mechanisms: There is a critical need for accessible and flexible financing models for households and institutions. Government and development partners should: Expand subsidy schemes for low-income adopters; Support microcredit and savings group models tailored for women and farmers; Encourage results-based financing to ensure accountability and quality installations.

3. Build Technical and Human Capacity: Invest in the training of masons, technicians, extension workers, and entrepreneurs to ensure quality construction and long-term system performance. Incorporating biogas training in vocational schools and university curricula can institutionalise expertise and create sustainable career pathways.

4. Promote Gender and Social Inclusion: Biogas programs must be intentionally designed to empower women, youth, and marginalised groups. Gender-sensitive approaches should be embedded in all aspects of project design, including outreach, training, financing, and decision-making. Supporting women-led biogas enterprises can amplify impact and scale.

5. Increase Awareness and Behaviour Change Communication: To overcome misconceptions and cultural resistance, national and local governments should support awareness campaigns that emphasise the health, economic, and environmental benefits of biogas. Peer-to-peer learning, community demonstrations, and success stories can help shift perceptions and encourage uptake.

6. Foster Public-Private Partnerships and Innovation: Collaborations between government, NGOs, academia, and private sector actors are essential for technology innovation, cost reduction, and market development. Encouraging local manufacturing of digester components and stimulating research and development (R&D) in waste-to-energy technologies can further drive adoption.

7. Monitor, Evaluate, and Learn: Effective monitoring and impact assessment mechanisms should be embedded in all biogas programs to track functionality, user satisfaction, gender impact, and environmental benefits. This data should inform adaptive programming and evidence-based policy decisions. Policy recommendations are summarised in Table 7

Table 6: Environmental and Economic Impacts of Biogas in Uganda

Impact Area	Description
Greenhouse Gas Reduction	Biogas captures methane and reduces CO_2 emissions from biomass combustion
Deforestation Reduction	Replaces firewood and charcoal as cooking fuels
Soil Fertility Improvement	Bio-slurry used as organic fertilizer enhances soil health
Water Conservation	Reduces chemical fertilizer runoff, protecting water sources
Household Fuel Savings	Reduced spending on firewood and charcoal
Job Creation	Employment through biogas system construction, maintenance, and training
Agricultural Productivity	Boosted by availability of bio-slurry fertilizer

Table 7: Policy Recommendations

Thematic Area	Key Action Point	Responsible Actor(s)
Finance	Provide subsidies or low-interest loans for biogas digester installation	Government, Microfinance Institutions
	Develop public-private partnerships to attract investment in biogas infrastructure	Government, Private Sector
Gender Inclusion	Integrate gender-sensitive approaches in biogas programs	NGOs, Government Ministries (Gender, Energy)
	Support women-led biogas enterprises through training and financing	NGOs, Private Sector
Technical Capacity	Train local masons, technicians, and extension workers in biogas installation & maintenance	Government, NGOs, Vocational Institutes
	Establish regional biogas service centers for technical support	Government, Private Sector

Awareness & Education	Run national campaigns to raise awareness on benefits of biogas	NGOs, Government, Media
	Include biogas in school curricula and farmer extension services	Ministry of Education, NGOs
Policy & Regulation	Update and enforce biogas-related policies and standards	Ministry of Energy, NEMA
	Monitor and evaluate ongoing biogas projects to inform policy	Government, Development Partners

CONCLUSION

Biogas technology holds immense promise for Uganda as a multi-dimensional solution to energy poverty, environmental degradation, and agricultural waste management. With its ability to convert organic waste into clean energy and nutrient-rich fertiliser, biogas presents a unique opportunity to address several national development challenges simultaneously, ranging from health and gender inequality to climate change and food insecurity.

Over the past two decades, Uganda has made commendable strides in promoting biogas adoption through national programs, donor-funded initiatives, and innovative private-sector interventions. These efforts have led to the installation of thousands of digesters, increased awareness of clean cooking technologies, and demonstrated the viability of biogas in both domestic and institutional settings. Yet, the current scale of adoption remains far below the country's potential, constrained by persistent barriers such as high installation costs, limited financing, inadequate technical capacity, weak policy frameworks, and socio-cultural resistance.

Recent innovations, such as urban waste-to-energy models, slurry recycling systems, and gender-responsive programming, show that the biogas sector is evolving and adapting to local contexts. Moreover, the integration of biogas into broader national priorities, such as the Energy Transition Plan, Sustainable Development Goals, and Uganda Vision 2040, offers new momentum for scaling up.

To fully realise the potential of biogas in Uganda, a coordinated and inclusive approach is essential. This involves strengthening policy and regulatory frameworks, enhancing financing and capacity-building mechanisms, promoting social and gender equity, and investing in research, innovation, and community engagement. If these strategic measures are taken, biogas can emerge not just as an alternative energy source but as a catalyst for sustainable development, environmental stewardship, and social transformation across the country.

In conclusion, biogas is more than a technological solution; it is a pathway toward a cleaner, healthier, and more resilient Uganda.

CONFLICT OF INTEREST

The author declares no potential conflict of interest from the institutions, persons or any other entities.

DATA AVAILABILITY

The data used to support the findings of this study are available upon reasonable request from the corresponding author.

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