NATIONAL SCIENCE, TECHNOLOGY, AND INNOVATION COUNCIL (NSTIC)

Project Theme:

Promotion of Innovative Energy Solutions

Project Title

Development of a Biogas Plant for Conversion of Solid Waste to Gas for Cooking and Heating in Kenema

-A Demonstration Project-

Submitted by:

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Executive Summary

Solid waste generation is a major source of concern for nations around the world due to their ever-increasing volumes and their impact on the environment including climate change. Global solid waste generation is expected to reach a volume of 2.59 billion tons by 2030 with a waste management business landscape worth $2.5 trillion. Some typical wastes are household waste, industrial waste and agricultural wastes including rice straws and husks, cassava and other vegetable peel wastes, waste chicken egg shells, palm kernel shells, etc. The increasing volumes of solid waste generation is due to the world population explosion, urbanization, industrialization, and ever-increasing agricultural activities. Although governments, environmentalists and other stakeholders have expressed grave concerns over the increasing volumes of solid wastes generation, no effective management or disposal solution has been proposed.

Management of solid wastes has been practiced only in the form of waste generation control techniques by industries, collection, storage, and disposal methods implemented by municipalities and in some cases processing into other by-products and/or reuse. These are seen as both too expensive and unsustainable for most developing countries where the most common disposal methods are discarding or burning in heaps which have severe impact on climate change. Control, conversion to other products, recycling and reuse is seldom practiced due to lack of technical capacity, financial means, and stakeholder support. Thus, this project proposes the development of a biogas plant for the conversion of municipal, industrial, and agricultural solid wastes to methane gas that can be proposed for cooking in a well-designed gas cooking stove. The Team will build and demonstrate this system in the eastern city of Kenema and the system will comprise of a biogas generation plant and a new model cooking stove that uses the generated gas also to be proposed as an effective alternative to other methods of cooking and heating used in the country presently such as cooking fires and coal burning stoves. This biogas plant will be solely powered by solar power system designed and installed by the team; thus, the entire innovation is renewable energy based and its benefits on climate change mitigation in Sierra Leone.

The proposed Kenema Biogas plant is a sustainable initiative aimed at converting organic waste into biogas, which can be used for cooking, heating, and lighting. The process involves the decomposition of organic waste in an anaerobic digester, which produces methane gas as a by-product. The generated methane gas will then be directed to a newly designed cooking stove that operates on biogas rather than biomass. The project aims to automate the biogas production process using sensors and control systems that monitor and regulate the temperature, pH, and gas production rate in the digester and the gas cooker.

Automation of the proposed Kenema Biogas plant will increase the efficiency and reliability of the biogas production process and reduce human intervention. The automated system will enable real-time monitoring

and control of critical parameters, ensuring optimal conditions for biogas production and use in the gas cooking stove. This will result in increased gas yield, reduced production time, and improved sustainability. Furthermore, automation will improve the safety of the process by reducing the risk of accidents and exposure to toxic fumes. The proposed Kenema Biogas plant will stimulate economic activity, create jobs, streamline the production process, reduce cost, reduce environmental pollution, mitigate overall impact on climate change and improve process efficiency, making it a more sustainable solution for organic waste management and energy production in Sierra Leone.

The implementing team will visit all refuse dumping sites around Kenema city to assess the scale of the waste generation and disposal problem in the city. The team will collaborate with government agencies, industry partners, local NGOs, and community leaders to garner support and ensure a holistic approach to the project implementation. A robust monitoring and evaluation framework will be established to assess the impact of the biogas plant and gas cooking stove on society, environmental impact, climate change mitigation, economic outcomes, and overall community well-being. Going forward the team will propose strategies for a wider implementation of the project nationwide and patenting of the knowledge and technology generated from the project.

In June 2022 the University of Sierra Leone (USL) signed a research and teaching collaboration agreement with the University of Johannesburg (UJ) in South Africa. As part of this agreement the USL can access the state of the arts research facilities of the UJ with potential for exchange of knowledge, teaching staff travels and student exchanges. This project will be undertaken under this collaboration with UJ as an international partner to provide consulting expertise to the Sierra Leone based team.

Keywords: Sierra Leone; Agricultural, Industrials and Household waste; Technology; Innovation; Solid Waste Management Mechanism; Municipality; Environmental Impact; Climate Change Mitigation Strategies.

1 Background and Rationale

Kenema, like many urban areas in Sierra Leone, grapples with the escalating challenges of municipal solid waste management, a predicament characteristic of many developing regions of the world. The lack of effective waste disposal mechanisms not only poses significant threats to public health and the environment but also exacerbates socio-economic vulnerabilities. The proposal to develop a biogas plant in Kenema emerges as a strategic response to this multifaceted issue. By harnessing cutting-edge technology to convert municipal solid waste into clean and sustainable gas and developing a gas cooking stove in parallel powered by solar system, the project aims not only to mitigate the environmental impact but also to catalyze economic opportunities, promote renewable energy use and foster community resilience. The conversion of municipal solid waste to biogas aligns with Sierra Leone's commitment to sustainable development that nonetheless meets environmental conservation requirements. Biogas is a clean and renewable energy source that can mitigate the environmental impact of waste while providing a reliable energy supply. This project aims to improve waste management practices, reduce the reliance on non-renewable energy sources, boost environmental preservation via reduction of reliance of forest wood and charcoal for cooking, boost innovation and industrialization, create jobs and stimulate economic activities in the community.

Sierra Leone's commitment to sustainable development and environmental conservation finds resonance in the rationale behind this project. The conversion of municipal solid waste into biogas represents a paradigm shift towards circular economy principles. Biogas, as a renewable energy source, not only alleviates the strain on traditional energy resources but also contributes to a significant reduction in greenhouse gas emissions. Moreover, by introducing an innovative waste-to-energy solution, the project aligns with Sierra Leone's broader vision for environmental stewardship and socio-economic empowerment. The anticipated benefits extend beyond waste management, offering a transformative pathway towards a greener, healthier, and more economically vibrant Kenema city and beyond.

The project envisions a holistic approach to sustainable development, recognizing the nuanced intersections of gender, ethics, and long-term viability. Inclusivity and gender equality are integral considerations, with specific initiatives to empower women through training and involvement in decision-making processes.

2 Project Goal and Specific Objectives

The primary goal is to establish a state-of-the-art facility industry with advanced waste-to-energy technology, ensuring optimal gas production and manufacturing of gas stoves while adhering to environmental and safety standards. This infrastructure will serve as a model for sustainable waste management and energy generation, contributing to the overall resilience and environmental health of the communities.

- Establish a functional biogas plant for the conversion of municipal solid waste to methane gas.

- Manufacture gas stoves that utilize the generated methane gas for cooking and heating.

Specific Objectives:

- Conduct a comprehensive waste assessment in Kenema to identify suitable feedstock for the biogas plant.
- Design and construct a biogas plant capable of processing the identified municipal solid waste.
- Design and construct a gas cooking stove that utilizes the generated gas from the biogas plant.
- Demonstrate the developed system in Kenema city for wider implementation.
- Implement community engagement programs to raise awareness and educate residents about waste management and the benefits of biogas.
- Monitor and evaluate the environmental and socio-economic impact of the biogas plant on the community.
- Disseminate the knowledge base created from the project via accredited journal papers, peer reviewed conference proceedings, book chapters and books.
- All activities will be implemented as a team.

Project Activities:

- Waste characterization and feasibility study.
- Design and construction of the biogas plant.
- Design and construction of gas cooking stove.
- Community engagement programs including workshops and awareness campaigns.
- Ongoing monitoring and evaluation of the biogas plant's performance.

3 Project Methodology and Approach

Collecting municipal wastes from consumers and depositing them in dump sites has been a thorny issue for past and the present government as there has been no reliable methods of transforming these wastes to useful products. Studies have shown that municipal wastes can be converted to biogas that can be used for cooking, heating, and lighting. The aim of this study is to design and produce a plant that will convert municipal wastes into biogas and a gas cooking stove that will utilize the generated biogas for cooking and heating. Implementation and completion of this project will contribute not only to a cleaner and healthier Kenema city and its environs, but will also reduce pollutants resulting from burning wastes, and improve wellbeing of individuals in these communities. Additionally, lots of jobs will be created with their favorable outcomes on national development. In this regard, participation of all stakeholders is important to achieve eventual success of this project. Therefore, an effective stakeholders' engagement to achieve effective participation will be carried out to achieve the aim of this study. The research and development phases of the project are outlined hereafter.

3.1 Research design and fabrication of plant and cooking stove

The objective to be achieved is design and construction of a biogas producing plant using municipal wastes and a gas cooking stove to utilize the generated gas. Activities involved to achieve this objective include.

3.1.1 Literature review

Undertake a review of existing literature on both waste management and engineering waste management; producing gas from municipal wastes; identification of waste conversion techniques that are appropriate for this project and design of gas cooking stoves. The review aims to assess existing techniques that are innovative and creative as part of specific objectives needed to achieve the general objective of this project. Identify challenges encountered and successes achieved by previous researchers in similar studies. Investigate issues emanating from inappropriate handling of municipal wastes – from producers and collectors of wastes for final deposits at dumpsites. Develop a mathematical and business model with specific variables to explain the functioning of the plant and to make predictions of the gas to be produced based on these variables.

3.1.2 Collaboration with experts

Consult and collaborate with Academics and practitioners in the field of waste management and engineering wastes conversion - from disposal to conversion of these wastes to biogas and their use in gas cooking stoves. Creation of a strong relationship with experts and research institutions to exchange vital knowledge and skills that are essential to achieve the objectives of the project.

3.1.3 Feasibility studies

I. Establish good relationship with primary and secondary stakeholders in the project site, Kenema
II. Preliminary visits and discussions with some producers of wastes and employees involved in wastes handling and disposal.
III. Inspection of wastes to assess suitability of producing required energy.
IV. Laboratory assessment of gas produced to ascertain suitability of purpose (in South Africa).
V. Use feasibility results to develop a model reflecting the actual product to be achieved and determine out its effectiveness, reliability, and efficiency.

3.2 Project implementation

Activities involved in implementation are presented herein.

3.2.1 Site selection

Main objective of selecting the site of the biogas plant is its suitability for purpose and closeness to dump site including accessibility by both human and vehicular traffic.

3.2.2 Construction and installation procedures

I. The design and production methods will be flexible and can be easily adapted to the local community and other communities in the country.

II. Th Team will make use of local expertise and knowledge throughout the process, but can collaborate and consult with international experts as and when the need arises.

3.2.3 Monitoring and improvement

I. Data collection from operators and users of biogas produced and gas cooking stove with the aim of improving efficiency.

II. Pollution emission monitoring of the system to assess suitability of produced gas on health of users and the environment.

III. Monitor collection and sorting of wastes and operations of the plant to protect operatives and other relevant workers of the system.

3.3 Training and capacity building

The objective of this section is to: offer training to wastes handling workers, and students in technical colleges and universities.

3.3.1 Workshops and training sessions

I. Conduct practical training sessions for operatives involved so that repairs and maintenance can be carried out when required.

II. Conduct workshops for non-technical employees of the plants to highlight importance of wastes and its effects on health and the environment if disposed inappropriately.

III. Provide internship for students with the aim of increasing skills and knowledge base of the community.

3.3.2 Community engagement

Continuous engagement with the community to provide relevant information regarding skills and knowledge needed to convert wastes into essential products that can be used to generate income

3.4 Participation of potential customers/consumers

The objective is to assess the relevance of engaging with potential customers/consumers as primary stakeholders of the project. The activities involved are presented hereafter.

3.4.1 Community meetings

Update stakeholders regarding progress of the project through regular community meetings

Collect information from customers on performance of the product in order to make improvements where needed.

3.4.2 Objective: involve the private sector in the project

Involve private sector businesses to discuss business opportunities and encourage contributions to improve efficiency and effectiveness of the plant.

3.4.3 Technological transfer and collaborative decision-making

I. Establish consultative decision-making process to foster better design and improvement in output.
II. Foster better understanding of the concept and performance of the plant and stove to enable easier replication in other areas of the country for commercial purposes.

3.5 Data collection and analysis

Objective: monitor and analyze performance of the plant and gas cooking stove. Activities involved are as outlined hereunder.

3.5.1 4.5.1. Data collection instruments

Use sensitive weighing machine to record accurate weights of wastes brought to the site, and install metering devices to monitor and collect data on energy produced.

3.5.2 Data analysis tools

I. Use data analyses software such as Microsoft, ANSYS fluent, TRANSYS, HOMER, Statistical Package for Social Sciences to analyse collected data and to make predictions, using the model, for future production and usage.
II. Both qualitative and quantitative data collection and analyses to determine outcomes of plant and gas cooking stove produced.

3.5.3 Data archiving, access and sharing

I. Adhere to regulations provided by both local and national authorities regarding privacy and compliance on how to share collected data.
II. Provide access to authorized employees and relevant stakeholders to collected and stored data.
III. Guarantee ethical standards on policies regarding data retentions and compliance.

3.6 Conceptual and theoretical framework

Outlining different variables and their respective hypotheses that are required in developing a mathematical and business model of the project.

3.6.1 Sustainable development goals (SDGs):

Association of project outcomes with UN 2030 SDGs pertaining to clean energy and human capital development.

3.6.2 Technological framework

Outcome of project based on scientific and engineering principles and skills on conversion of municipal wastes to biogas for domestic use in gas cooking stoves.

3.6.3 Social framework

Ensure long-term running and sustainability of the project through participation of leaders from traditional and formal institutions together with social inclusion strategies and female participation.

3.7 Ethical considerations

The objective of this section is to ensure confidentiality of participants and adhere to laboratory and workshop procedures and protocols.

I. Apply measures leading to strict confidentiality of all personal data collected during the project.
II. Clearly outlining use of data collected from participants and to obtain consent for their participation.
III. Adhere to relevant ethical standards regarding laboratory and workshop protocols and procedures to ensure methods employed in the design and production are transparent and can be reproduced using stated procedures.

4 Anticipated Outputs and Outcomes

Employing better management skills and engineering procedures to collect and dump municipal wastes at provided sites have been shown to produce better outcomes as regards the environment, climate and health of people living in the community. Therefore, participation of residents is paramount for success of such a project. However, there are ethical issues connected with such a project regarding data collection and analyses and how to protect privacy and confidentiality of participants. Consequently, informed consent will be sought from participants with the aim of achieving genuine participation from all stakeholders. The anticipated outcomes of the projects are listed hereunder:

I. Appreciation of concepts on wastes management and its expected results.

II. Employing engineering and scientific knowledge on wastes to produce biogas.
III. Involve the private sector in the entire process with the aim of rolling out the technology through an effective business model.
IV. Establish partnership with local businesses that are related to waste management.
V. Procedures involved design, fabrication, running and maintenance of the plant are outlined for better comprehension by those involved.
VI. Encourage and provide a conducive environment for female participation, including the physically challenged.
VII. Provide comprehensive operational and repair manuals including guidelines on how the plant can be replicated in other area of the country.
VIII. Providing appropriate sensitization on the harmful effects of incorrect handling of wastes by both employees and community dwellers.
IX. Effective communication through local media such as TVs, radio and newspaper and social media on using municipal wastes to produce energy for cooking and heating.
X. Consistent and regular meetings with community dwellers and stakeholders to enhance participation and provide insight into consequences of better management of municipal wastes.
XI. Regular and effective communication with relevant government ministries, departments, and agencies.
XII. Providing internships to undergraduates and training for postgraduate students from tertiary institutions, colleges, and universities in the district.
XIII. Disseminating the outcomes of the projects through peer-reviewed journals, books, and research conferences.
XIV. Final project that is workable will be patented to prevent unlawful replication.

5 Knowledge Utilization and Dissemination

The target audience includes the academic community, researchers, industries, community members, government officials, policymakers, think tanks, private sector entities, the public, businesses, distributors, online community, and media outlets. The dissemination plan for the project employs a multifaceted approach to share and apply project insights. Scientific publications will target academic communities, contributing to the research domain, while technical reports and guidelines will be crafted for agricultural services and engineers. User-friendly training materials will empower local communities, with public awareness campaigns ensuring broader community understanding. Private sector collaboration will be emphasized through workshops, aiming to facilitate technology transfer. Policy influence is pursued through workshops and briefs targeted at policymakers and community-led advocacy. Media engagement strategies will include press releases and social media campaigns for wider public outreach. Open Access compliance aligns with principles of inclusivity, and making research findings readily

accessible. This approach ensures a comprehensive and targeted dissemination strategy to maximize the impact of the solar-powered bioreactor for methane gas generation from solid waste in Sierra Leone.

Table 1: Awareness/Dissemination Plan for Year 1

Dates	Activity	Description of the activity
November 2023-January 2024	Building a stakeholder forum	The Team will meet with NSTIC and other Government stakeholders to present this intervention and its benefits to Sierra Leone. The forum will meet every 3 months thereafter for continuous reporting of implementation progress.
February-March 2024	Meeting the local leadership of the implementation region	The Team will meet with Paramount chiefs, locals in villages and Kenema District Councillors of the demonstration region. These meetings and presentations will be held to build support from the local leadership.
April 2024	Community sensitization events	Events to be attended by community members, local leadership. The Team, NSTIC, affected Ministries and other governmental and non-governmental agencies.
May –June 2024	Preparation and presentation of mid-year report on the biogas plant and gas cooking stove development	By the Team.
July-December 2024	Social events around Kenema District	Visit to schools, hospitals, and religious houses of warship, traditional leaders, youth and women's organizations and other NGOs operating in the region on sensitization activities. By the team.
July-December 2024	Science awareness	Drafting and publishing of high impact journal papers, conference papers, book chapters and books by the Team.
December 2024	Preparation and presentation of yearend report on the biogas plant and gas cooking stove development	By the Team.

Table 2: Awareness/Dissemination Plan for Year 2

Dates	Activity	Description of the activity
January-February 2025	Stakeholder forum meeting on the biogas plant and gas cooking stove development	Consolidation of year 1 implementation activities and review of project work plans for year 2.
March 2025	Demonstration event at the chosen project implementation site – biogas plant	Event to be attended by community members, local leadership, and Sierra Leone Government.

Dates	Activity	Description of the activity
April 2025	Demonstration event at the chosen project implementation site – gas cooking stove	Event to be attended by community members, local leadership, and Sierra Leone Government.
May –June 2025	Preparation and presentation of mid-year report on the biogas plant and gas cooking stove development	By the Team.
July-September 2025	Social events	Visit to schools, hospitals, and religious houses of warship, traditional leaders, youth and women's organizations and other NGOs operating in the region on sensitization activities.
July- September 2025	Science awareness on the biogas plant and gas cooking stove development	Drafting and publishing of journal papers, conference papers, book chapters and books by the Team.
September 2025	Preparation and presentation of project closing report	By the Team.

6 Project Governance

The management of the University of Sierra Leone and the Njala University will play a supportive role, ensuring resource allocation and facilitating collaboration between academia, industry, and community stakeholders. The project team (see attached CV document) which demonstrates that the project will be led by the current Dean of Engineering and Architecture, Fourah Bay College, University of Sierra Leone. The team comprises of experts in their respective fields ranging from engineering to economics to agriculture and environmental science with a combined total of more than 150 years of experience in Academic and research work. The selected industry partners are seasoned in their respective industrial applications with GEM Water Management Solutions having branches in South Africa, Ghana, and the USA. The governance structure is pivotal to the project's success, ensuring a holistic approach that combines academic rigor with practical applicability and stakeholder engagement. The project governance structure is designed for effective oversight and collaboration. The project will establish a governance committee comprising key stakeholders, including academic researchers, energy and agricultural experts, traditional leadership, and representatives from the private sector. This committee will provide strategic direction, ensure alignment with project objectives, and oversee decision-making. Advisory roles will be filled by experts in renewable energy, agriculture, and climate science, contributing valuable insights and overall project guidance. The research team is composed of highly qualified individuals with expertise in engineering, agronomy, earth science, and environmental science, each assigned specific roles in system development, testing, and community engagement. The project aims to foster collaboration with between universities, research institutes and industry partners to leverage diverse perspectives and resources. The

involvement of the private sector will be integral, with agribusinesses and distributors actively participating in workshops and decision-making sessions.

7 Suitability of the Host Institutions

Collaboration between the University of Sierra Leone (USL) and Njala University (NU) and the consultancy of the University of Johannesburg (UJ) presents an exceptionally suitable host for the proposed project. The participating Departments of these universities offer a unique blend of expertise in engineering, agronomy, soil science and environmental science, aligning perfectly with the interdisciplinary nature of the project. UJ boast a robust technical infrastructure while both USL and NU have a pool of highly qualified researchers with a proven track record in renewable energy and agricultural research. Leveraging these resources, the universities have previously spearheaded impactful initiatives in many areas of academic endeavour, showcasing a commitment to community outreach and development. These universities have, in the past, maintained strong connections with the private sector, ensuring active collaboration in project workshops and decision-making processes. This project harmonizes seamlessly with the overarching research strategy of both universities, which prioritizes innovative solutions to address local challenges, thereby reinforcing their status as ideal joint host institutions with the capacity to drive meaningful impact in Sierra Leone's agricultural landscape.

8 Capacity Building

The proposed project places a strong emphasis on capacity building at both individual and organizational levels. Final-year Undergraduate and Post-graduate students, including MSc. and PhD candidates, will be actively involved, offering them opportunities for hands-on research experience, data analysis, and technology development skills. Specialized training activities are envisaged for students to enhance their skills in renewable energy, agricultural engineering, and sustainable practices. Additionally, training workshops and knowledge-sharing sessions will be conducted for local communities, promoting the adoption of the solar-powered biogas plant and gas cooking stove. The project also plans to enhance the capacity of project partners, particularly in the private sector, through collaborative workshops and technology transfer sessions. This holistic approach to capacity building ensures that knowledge and skills are disseminated across various stakeholders, fostering sustainable impact beyond the project's duration in the form of small and medium enterprises (SMEs) in energy, city plant and environmental science.

9 Monitoring and Evaluation Strategy

The monitoring and evaluation strategy for the proposed project adopts a comprehensive approach to ensure effective progress tracking and impact assessment. Regular monitoring will involve the installation of data collection devices to capture real-time information on energy consumption, bio-digestion efficiency, and gas cooking stove performance. The research Team will conduct frequent site visits to assess the physical

implementation of the biogas plant and its integration with home cooking infrastructure. Continuous optimization will be informed by the collected data, ensuring the system's efficiency, and addressing any emerging challenges. Evaluation activities will include a robust data analysis process, utilizing statistical methods and modeling techniques to measure the correlation between biogas plant performance and cooking stove use. Feedback mechanisms will be established to engage stakeholders in reporting issues and observations, providing valuable insights for ongoing improvements. This strategy ensures that the project's objectives are met and that its impact on energy use in Sierra Leone is understood and continuously optimized.

Table 3: Monitoring and Evaluation Strategy

Indicator	Description of the indicator	How the indicator will be tracked over the duration of the project to show impact
Scheduling	Timelines for implementation, dissemination, and reporting	• Targets for each phase of the implementation and demonstration met and reported on timeously.
Awareness	Understanding of the value and benefit of the biogas plant and cooking stove by the locals in the implementation region	• Number of sensitization events held. • Number of varied locations for events. • Number of community members participating in each event.
Solid waste collection	Improvement in environmental sanitation from effective collection of solid waste in the implementation region	• Reduction in harmful effect of decaying solid waste in the demonstration region. • Cleanliness of the street drainages of the city of Kenema. • Reduction in air pollution from burning solid waste.
Biogas generation	Collection and storage of biogas from the plant	• Quantity of biogas collected and stored in large tanks, as reported by the installed gas flow meters. • Regularity of maintenance and servicing of the gas plant. • Review of tank capacity informed by quantity of gas generated by the plant.
Gas cooking stove	Generated gas used in the gas stove for cooking and heating	• Number of households replacing cooking mechanism with gas cooking stove. • Level of reduction in deforestation in Kenema district over 5 years from date of introduction of gas cooking stove.
Environmental impact assessment	Air, land and water pollution from solid waste	• Regular report of solid waste collection volume. • Air quality from reduction in burning

Indicator	Description of the indicator	How the indicator will be tracked over the duration of the project to show impact
		of solid waste. • Land and water free of decaying solid waste.

10 Gender, Ethics and Sustainability

10.1 Gender:

This project is firmly committed to fostering gender inclusivity and equality throughout its lifecycle. Recognizing the pivotal role that women play in community development, the Team, which involves two prominent female Academics, will actively engage, and empower women in decision-making processes. Specialized training programs will be implemented to ensure women's meaningful participation in various aspects of the project, from waste management workshops to technical roles within the biogas plant. By promoting gender diversity, the project aims to create a more inclusive and equitable environment, fostering the development of skills, ensure equal access to the benefits generated by the biogas plant, gas cooking stove manufacturing and opportunities for all members of the community.

10.2 Ethics

Ethical considerations are at the core of this project, guiding every facet of the development and operation of the biogas plant. All activities will strictly adhere to local and international environmental regulations, ensuring that waste conversion processes are conducted responsibly and with minimal ecological impact. Transparent communication channels will be established with the community/stakeholders, fostering an ethical relationship built on trust and accountability. The project Team will actively seek input from stakeholders, ensuring that their concerns and perspectives are considered in decision-making processes. Furthermore, community representatives will be engaged in regular consultations to maintain an ongoing dialogue, promoting ethical practices and a collaborative approach to sustainable waste management and energy utilization.

10.3 Sustainability

Sustainability is not just an aspiration, but a fundamental principle embedded in the design and execution of this project. The biogas plant and gas cooking stove will be engineered with longevity in mind, employing state-of-the-art technology for efficient waste conversion and energy production. In addition to the environmental sustainability of converting waste to clean energy, a comprehensive sustainability plan will be developed to ensure the long-term economic viability of the project. Community involvement is key to sustainability, and residents

will be actively engaged in the maintenance and management of the biogas plant. Moreover, the project will explore innovative economic models to secure sustained funding beyond the initial phase, ensuring continued benefits for the community and fostering a self-sustaining ecosystem for waste-to-energy initiatives in Kenema, Sierra Leone.

Table 4: Risks and Mitigations

Risks	Description	Mitigation
Lack of electricity during installation work	Blackouts, power outages can affect the installation work	Power banks and/or generators will be used by the industry implementation partners. This will also reduce power bills on home dwellers at the installation sites
Theft and vandalism	There is a risk of some community members stealing installed components	Local industry partners will install burglar bars, cages with good protection mechanisms. Community sensitization activities will be held to develop a sense of community ownership of the installations.
Dust and smoke pollution	Due to dusty roads traversed by vehicular traffic and the burning of grass and domestic waste in the villages	The biogas plant and gas cooking stove will be inbuilt with dust proofs, while all filters and flow meters have protective covers. Half yearly maintenance will be undertaken at the installation site.
Religious and traditional practices	Arising from belief systems and cultural practices, some communities may not be open to some developmental activities	The Team has been carefully selected to have members from all regions around the country where installations will take place. They will advise on the belief systems of their communities. The Team will then hold meetings with community leaders, local and traditional leadership, and religious leadership to discuss the benefits of this project to their localities

11 Proposed Budget and Timeline

See attached budget

12 Appendix A: Preliminary design model schematic view

PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	Surface
2	1	Waste Tank
3	1	Gas Waste Tank
4	2	Elbow
5	1	Pipe
6	1	Stand
7	1	Waste storage
8	1	Pipe 1
9	2	Valve