

Monitoring & Evaluation (M&E) Plan and Impact Statement Form

Objective of the M&E Plan and Impact Statement:

- The M&E Plan and Impact Statement must be designed based on the Technical Assistance Response Plan and must enable the Implementer to complete the Closure Report at the end of the assistance.

Process for filling in the form:

- The Implementer must identify relevant quantitative and qualitative indicators as specified in the Closure Report. A sub-set of indicators to monitor and assess must be chosen among these.
 - The Implementer may also identify other specific, measurable, achievable, relevant, and time-bound indicators suitable to monitor Activities, Outputs and anticipated Outcomes from the technical assistance and add to the M&E Plan and Impact Statement.
 - During implementation of the TA or FTA, the Implementer must collect all relevant data as described in the Monitoring & Evaluation Plan. Aggregated data on selected indicators as well as an updated version of the Impact Statement will be presented in the Closure Report at the end of the assistance.
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Basic Information	
Title of response plan	Carbon Reduction and Health Improvement by Retrofitting Biogas Plant in Tanzania
Technical assistance reference number	2023000014
Country/ countries	Tanzania
NDE focal point and organisation	Tanzania Commission for Science and Technology Name: Dr. Gerald Majella Kafuku Position: Manager of Innovation and Technology Email: kafukugm@gmail.com, gerald.kafuku@costech.or.tz Address: P.O. Box 4302, Ali Hassan Mwinyi Road, Kijitonyama (Saynasi) COSTECH Building, Dar es Salaam, Tanzania

Sector(s) addressed	Bioenergy
Technologies supported	Biogas technology Household biogas Renewable energy
Implementation period and total duration	June 2024-March 2025
Total budget for implementation	141,225 (pro-bono)
Designer of the response plan	Prof. Dong-Hoon Kim (Lead Investigator)
Implementer of response plan	<p>Dong-Hoon Kim</p> <p>Professor</p> <p>Inha university</p> <p>South Korea</p> <p>Lead Investigator</p> <p>Si-Kyung Cho</p> <p>Professor</p> <p>Dongguk University</p> <p>South Korea</p> <p>Co-Team Investigator 1</p> <p>Chang-Kyu Lee</p> <p>CEO and Founder</p> <p>R.E.D. Corp. South Korea</p> <p>Co-Team Investigator 2</p> <p>Seongwon Im</p> <p>Assistant Professor</p> <p>Suchon University</p> <p>Om Prakash</p> <p>Post-Doc fellow</p>

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(A) Outputs and Activities as described in the Response Plan	(B) Indicator	(C) Expected results	(D) Method and frequency for data collection	(F) Comments
Output 1: Meeting to discuss the problems mentioned in the CTCN request form and highlight the causes behind the low CH ₄ efficiency of the biogas plant. Preparing a plan to visit Arusha, Tanzania and onsite biogas plant observations	There is total 7 meetings held. Out of that 5-meetings happened between the proponent and the technical assistance team.	Total no. of participants: 50, No. of Men: 46 No. of Women: 4	Overview of meeting participants in meeting report	No comments
Activity 1.1 Problem identification of biogas plant in Tanzania	Discussion about the problem identification regarding the low biogas performance was done.	It will help to summarize the list of problem to be identified.	N/A	No comments
Activity 1.2 Checking the possibilities of importing samples from Tanzania to South Korea for analysis	A discussion was made to import the samples from Tanzania to South Korea for analytical purpose.	An attempt to import feedstock samples from Tanzania to South Korea will be initiated.	N/A	An on-site analysis will be planned by providing and carrying the instrument required for the analysis.

Activity 1.3 Buying chemicals and sensors to export from South Korea to Tanzania		Buying chemicals and sensors to export from South Korea to Tanzania	N/A	No comments
Output 2 Plan to visit Tanzania: Onsite biogas plant inspection and giving lecture regarding biogas basics, biogas industry in South Korea, and carbon emissions to university student		Plan to visit Tanzania: Onsite biogas plant inspection and giving lecture regarding biogas basics, biogas industry in South Korea, and carbon emissions to university student	N/A	No comments
Activity 2.1 On-site biogas plant observation, real time monitoring performance and experimental condition check	1. Number of communication and outreach activities conducted by proponents and implementing partners to showcase CTCN support.	On-site biogas plant observation, real time monitoring performance and experimental condition check	N/A	No comments
Activity 2.2 Lecture at Nelson Mandela African Institution of Science and Technology (NM-AIST)	2. A total of 3 training sessions and capacity strengthening activities were done	Lecture at Nelson Mandela African Institution of Science and Technology (NM-AIST) No. of participants: 15, No. of Men: 12 No. of Women: 3	Overview of participants during in meeting report	No comments
Activity 2.3 Comparison of indoor dust concentration	3. Indoor dust quality monitoring after biogas and biomass.	Comparison of indoor dust concentration	PM ₁₀ concentrations were measured in the cooking areas within each kitchen. For particulate matter collection, cellulose thimble filters (30 × 80 mm) resistant to temperatures up to 200 °C were used. Prior to sampling, each thimble filter was dried at 105 °C for	No comments
Activity 2.4 Comparison of indoor dust concentration				No comments

			<p>2 hours and weighed to obtain the initial mass. PM₁₀ was collected by drawing air through the filter using a vacuum pump at a flow rate of 35 L/min. Filters were replaced every 15 minutes over a 1-hour sampling period, aligned with typical cooking durations. After sampling, the thimble filters were again dried at 105 °C and reweighed to determine the amount of PM₁₀ collected. The PM₁₀ mass was then calculated and analyzed.</p>	
<p>Output 3 Second visit to Tanzania: Retrofitting of digester tank, biogas leakage fix, optimization of feeding process, and teaching methane potential calculation to NM-AIST students</p>	<p>1. Cleaning of digester tank by removing the accumulated sediments were done, followed by repairing the gas leak and installation of gas flow meter.</p> <p>2. Number of other information materials strengthened, revised or created (For example training and workshop reports, Power Points, exercise docs etc.)</p>	<p>After retrofitting the biogas digester, the biogas production efficiency will be increased to the theoretical expectation which is up to 70% as mentioned in the summary reports.</p>	<p>Real time data monitoring of the biogas per day using the installed gas flow meter.</p>	<p>Sludge and feedstock analysis will be performed to characterize their properties.</p>
<p>Activity 3.1 Preparation for buying chemicals for physico-chemical analysis, biochemical methane potential (BMP) test of feedstock samples.</p>		<p>Preparation for buying chemicals for physico-chemical analysis, biochemical methane potential (BMP) test of feedstock samples</p>	N/A	
<p>Activity 3.2 Data accumulation</p>		<p>Data accumulation</p>	<p>The data were recorded by using gas flow meter installed near the biogas utilization stove. The recorded data were</p>	

			calculated to estimate the production of biogas generation per day.	
Activity 3.3 Complete retrofitting of digester tank		Complete retrofitting of digester tank	N/A	
Activity 3.4 Lecture to NM-AIST students		A total of 10 students were attended the lecture.	N/A	
Activity 3.5 Sample collection for COD, TN, and ammonia analysis		Sample collection for COD, TN, and ammonia analysis	Samples were collected from the digestate collector	No comments
Activity 3.6 Utilization of sludge waste for fertilizer		Utilization of sludge waste for fertilizer	Digestate sludge was used as fertilizer for plant growth and the it was measured on weekly basis.	No comments
Output 4 Continuous data collection for performance analysis of retrofitted biogas plant in terms of CH ₄ yield and carbon reduction calculation	<p>1. Anticipated metric tons of CO₂, equivalent emissions reduced or avoided as a result of the Technical Assistance.</p> <p>2. Anticipated increased economic, health, well-being, infrastructure and built environment, and ecosystems resilience to climate change impacts as a result of technical assistance.</p> <p>3. Anticipated number of direct and indirect beneficiaries as a result of the TA.</p>	Continuous data collection for performance analysis of retrofitted biogas plant in terms of CH ₄ yield and carbon reduction calculation	Continuous data on biogas production, CH ₄ content, and sludge characteristics was collected from the retrofitted biogas plant.	No comments
Activity 4.1 Continuous data collection from retrofitted biogas plants and BMP		The baseline emission was considered as the undigested cattle manure into the digester tank. For example, before retrofitting of the reactor the daily biogas production rate was 0.5 m ³ /day which improved to 2.5 m ³ /day after retrofitting.	Biogas utilization data was used to calculate carbon emission reductions, and the plant's efficiency was assessed by comparing theoretical and actual data.	No comments
Activity 4.2 Collaborative biogas experiment		Collaborative biogas experiment	N/A	No comments
Activity 4.3 Data		The estimated	The following two	No comments

analysis for further suggestions		CO ₂ reduction, from the retrofitted biogas plant. The biogas production before retrofitting and after retrofitting were taken into account and then compared the difference. For example, before retrofitting the biogas production was 0.5 m ³ /day, which increased by 400 % and become 2.5 m ³ /day. The improved quantity was converted into CO ₂ reduction since CH ₄ is 28 times higher potential than CO ₂ .	international methodologies can be used: a) AMS-III.D. Methane recovery in animal manure management systems, and b) AMS-I.D. Grid connected renewable electricity generation. Generally, AMS-III.D is applicable for slurry manure, which is commonly stored under anaerobic conditions.	
Activity 4.4 Business model establishment		Business model establishment	N/A	No comments
Output 5 Closure report: Concluding results and future suggestions		Closure report: Concluding results and future suggestions	N/A	No comments
Activity 5.1 Prepare a final report showing the conclusion, sustainability of the project and future suggestions based on current challenges		Prepare a final report showing the conclusion, sustainability of the project and future suggestions based on current challenges	N/A	No comments
Activity 5.2 Presentation at conference and research article writing (Domestic)		Presentation at conference and research article writing (Domestic)	N/A	No comments
Activity 5.3 Presentation at conference and research article		Presentation at conference and research article writing	N/A	No comments

writing (International)		(International)		
Activity 5.4 One scale-up project concept note with the package of supporting documents, as applicable.		The guidelines prepared this concept note are to be considered throughout all the activities listed above for better alignment of the deliverables with the requirements of the concept note.	N/A	No comments

Note: The Response Plan may contain information useful for the section below. The information in the table below will be used by the CTCN for public communication of the achieved and expected results of the Technical Assistance through the CTCN website www.ctc-n.org and other communication channels. See for example: https://www.ctc-n.org/sites/www.ctc-n.org/files/benin_a_ag_forestry.final_.pdf

Impact Statement	
Challenge	<i>Tanzania aims to meet 60% of its energy needs from renewable sources by 2026, but rural areas still rely heavily on biomass, causing pollution and health issues. Additionally, improper disposal of cattle waste contributes to soil pollution and greenhouse gas (GHG) emissions. To address this, a biogas plant was set up in Arusha, Tanzania having a capacity of 10 m³, using locally sourced cattle manure. However, the efficiency of the biogas plant is low due to sludge accumulation, temperature fluctuations (20-40oC), an unoptimized manure-water mixing ratio, and biogas leakage. During the technical assistance accumulated sludge cleaning with overall retrofitting of the digester tank, methane potential of feedstock, process optimization such as feed rate and interval of feeding will be designed.</i>
CTCN assistance	<ul style="list-style-type: none"> - Onsite inspection of the biogas plant and current status of biogas generation and utilization in Arusha, Tanzania - Cleaning of accumulated sludge in the digester tank - Biochemical CH₄ potential (BMP) test based on temperature variation and cattle manure-water mixing ratio - Change in feeding pattern to maximize digestion process during the daytime
Anticipated impact	<ul style="list-style-type: none"> - Clean and renewable energy production - Reduce GHG emissions - Improve the local and personal hygiene - Improve indoor air quality thus overall health improvement - Reduce the burden due to high fuel costs (firewood, charcoal, etc.) - Digested sludge as fertilizer will enhance sludge disposal and soil quality - GHG assessments

<p>Anticipated co-benefits from the TA</p>	<p><i>Women use biomass such as wood and charcoal for cooking in most of the rural Tanzania suffers lung problems due to toxic smoke and particulate matters comes out from biomass. It increases the burden of social health infrastructure and personal medical expenses which could have been used otherwise for social development or education purposes. Biogas does not produce smoke on burning and release CO₂ and water vapor both are harmless. Thus, save women from getting lung problems and reduce the medical expenses.</i></p>
<p>Gender aspects of the TA</p>	<p><i>Traditional cooking through firewood and charcoal leads to significant indoor air pollution causing respiratory diseases, eye related problems and other pollution related health complexities to women and children. This reduces an average life expectancy.</i></p> <p><i>The responsibility of fuel collection often falls on girls, reducing the time for school attendance and study. In areas without biogas plants, girls are more likely to be pulled out of school to assist with household energy needs, perpetuating gender disparities in education.</i></p> <p><i>Women and girls who travel long distances to collect firewood may face heightened risks of violence. This is particularly true in conflict zones or areas with insecure environments.</i></p> <p><i>A survey was taken among the local population with high number of womens involved. The survey was regarding the improvement in indoor air quality and got the positive response.</i></p>
<p>Anticipated contribution to NDC</p>	<p><i>Technical assistance related to biogas plant retrofitting and awareness will help to reach the NDCs to reduce the GHG emissions and adapt to climate change. As the goal of the Paris Agreement is to hold the increase in the global average temperature to well below 2°C above pre-industrial levels and pursue efforts to limit the increase to 1.5°C above pre-industrial levels.</i></p> <p><i>The current climate technologies will lay groundwork for implementation strategies to improve the biogas efficiency and regular data monitoring. After long term monitoring and evaluating the performance, new policies can be set to improve the biogas plant further and make aware about the climate technologies and its benefits among the people so that voluntary actions can be taken to reduce the GHG emissions. In this way other relevant priorities like Technology Needs Assessments (TNAs), Technology Action Plans (TAPs), National Adaptation Plans (NAPs), and Nationally Appropriate Mitigation Actions (NAMAs) can be met.</i></p>
<p>The narrative story</p>	<p>Context: <i>Biogas is a composition of CH₄, CO₂ with small amount of H₂S and water vapor produced by degradation of organic matter in an anaerobic environment. The CH₄ content in biogas generally varies from 55-70%, with most of the remainder being CO₂. It makes biogas a flammable gas with an energy content of 28MJ/m³. Biogas can be used as cooking gas, transportation fuel, electricity and heat generation.</i></p> <p>Problem: <i>Improper disposal of cattle waste contributes to soil pollution and greenhouse gas (GHG) emissions. In rural Tanzania almost 92% homes still use biomass and charcoal as fuels. And the use of biomass and charcoal is one of the main CO₂ and GHG emitters. Biomass and charcoal does not only responsible for GHG emission, but they are also responsible for smoke, toxic gases such as CO, NO_x, VOC, black carbon and PM_{2.5}. It deteriorates the woman health mostly, since they expose themselves for longer period of time affecting the respiratory system. According to Ahamad</i></p>

	<p><i>et al., (2021), Tanzania’s smoke exposure risk (SER) is 84.3% and it belongs to high SER countries. Therefore, usage of biogas that meets WHO’s standards can lower the SER to 14.6%.</i></p> <p>Technical Assistance: <i>To address this, a biogas plant was set up in Arusha, Tanzania having a capacity of 10 m³, using locally sourced cattle manure. However, the efficiency of the biogas plant is low due to sludge accumulation, leakage and improper maintenance. A technical assistance plan was proposed for retrofitting the biogas plant by cleaning the accumulated sludge inside the reactor, checking for the leakage source and by installing the gas flow meter to measure the biogas output. Use of digested sludge was tested for fertilizers.</i></p> <p>Expected Outcome: <i>After retrofitting, it was expected that the biogas production will enhance and will reach its theoretical outcome which was considered to be 70% of the digestion efficiency. Since biogas is a clean source of energy and can be used as cooking gas. Since it does not produce smoke, it will enhance the indoor air quality, ultimately improving the health condition of people. Further, use of digested sludge could be a good fertilizer for plant growth.</i></p>
Contribution to SDGs	<p><i>(3) Good health and wellbeing: By using biogas instead of biomass and charcoal will reduced the air pollution and improve the indoor air quality. Minimizing the chances to get respiratory problems.</i></p> <p><i>(7) Affordable clean energy: Biogas (clean energy) produced through biowaste which is easily available and can be used as feedstock otherwise could have created nuisance and water and air born disease.</i></p> <p><i>(8) Decent work and economic growth: Promoting and utilization of biogas not only improve the air pollution, and provide clean energy, it also improves the local economy by providing jobs of maintenance, attract the youth towards scientific way to produce clean energy. Improve the money flow since it works with minimum cost and does not bear a high production value.</i></p>
Reference to knowledge products	No TEC products were used