INITIATIVE FOR CLIMATE ACTION TRANSPARENCY (ICAT)

PHASE II

FIJI

The Greenhouse Gas Mitigation Potential of the Biogas Projects for Fiji

Deliverable I

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1.0 INTRODUCTION

Pacific Island nations face a dual challenge: addressing rising greenhouse gas (GHG) emissions while ensuring energy security and sustainable development for their growing populations.[1] Fiji has made an ambitious commitment to reducing GHG emissions in its 2020 updated Nationally Determined Contribution (NDC), reiterating reducing greenhouse gas (GHG) emissions by 30% of its energy sector emissions by 2030 against the baseline year 2013. This commitment translates to a reduction of 750 gigagrams of carbon dioxide equivalent by 2030. Of the 30% reduction of Business As Usual (BAU) baseline CO2 emissions, 10% will be achieved "unconditionally" using available resources in the country, and 20% will be achieved "conditionally"[2]. The NDC Implementation Roadmap 2017-2030 outlines the renewable energy, transportation and demand-side energy improvement interventions to achieve the NDC target[3].

Fiji further enacted its Climate Change Act in 2021, where it legally pledged to achieve economy-wide net-zero emissions by 2050. The journey to obtaining this net-zero goal has been outlined in the Very High Ambition Scenario in Fiji's Low Emission Development Strategy (LEDS)[4]. According to the LEDS, biogas plants have significant potential to contribute to achieving the net-zero target, presenting the opportunity to scale up from household-level use to feeding back into the grid. Thus, among the various renewable energy solutions being explored, biogas technology presents a promising pathway for reducing GHG emissions while addressing multiple sustainable development objectives, including the Fiji Government's vision *'A resilient, resource-efficient, cost-effective, accessible, reliable, and environmentally sustainable energy sector'*[5] which aligns to Sustainable Development Goal 7 (SDG 7) on Affordable and Clean Energy as well as SDG 13 on Climate Action. Fiji's key focus areas for SDG 7 and SDG 13 has been summarized in Table 1 below. Progress on these goals are available through Fiji's Voluntary National Reports[6] submitted to the United Nations.

Table 1: SDG target reported by Fiji[6]

SDG	Target	Target in words
7	7.1	By 2030, ensure universal access to affordable, reliable and modern energy services.
	7.2	By 2030, increase substantially the share of renewable energy in the global energy mix.
	7.3	By 2030, double the global rate of improvement in energy efficiency.
13	13.1	Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries.
	13.2	Integrate climate change measures into national policies, strategies and planning.

[1] World Bank (2023). *Pacific Islands Climate Change Policy Assessment*. World Bank Group, Washington, DC
[2] Government of Fiji (2021). *Fiji's Updated Nationally Determined Contribution*. Ministry of Economy, Suva, Fiji.
[3] Government of Fiji (2017). *Fiji NDC Implementation Raodmap 2017-2030*. Ministry of Economy, Suva, Fiji.
[4] Government of Fiji (2018). *Fiji Low Emission Development Strategy*. Ministry of Economy, Suva, Fiji.
[5] Governemnt of Republic of Fiji (2024). *Republic of Fiji National Energy Policy 2023-2030*. Ministry of Public Works, Meteorological Services, and Transpor, Suva. Fiji ; Govermnent of Republic of Fiji (2024). *Fiji National Development Plan 2025-209 and Vision-2050*. Ministry of Finance, Strategic Planning, National Development and Statistics Suva, Fiji
[6] Government of Fiji (2023). *Voluntary National Review*. Republic of Fiji, Suva.

SDG	Target	Target in words
	13.3	Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning.
	13b	Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and Small Island Developing States, including focusing on women, youth and local and marginalised communities & Fiji'sd National Biodiversity Strategy and Action Plan (NBSP).

Biogas projects typically involve converting Organic Waste[7] (OW) materials into renewable energy through anaerobic digestion, producing CH_4-rich biogas that can be used for cooking, electricity generation, or as a renewable fuel source. The multiple-purposed biogas technology offers a unique opportunity to simultaneously address waste management, energy security, and climate change mitigation in Fiji/Pacific[8]. By capturing methane (CH_4) emissions from OW and converting them into renewable energy, biogas projects can significantly reduce GHG emissions through two primary mechanisms: avoiding CH_4 emissions from waste decomposition and displacing fossil fuel-based energy sources. For Fiji, where organic materials constitute approximately 60% of the waste stream[9], the potential for biogas development is substantial. Additionally, these multifaceted benefits of biogas could enhance resilience and food security, particularly for households using biogas digesters for cooking.

The initial desktop review revealed that large-scale biogas facilities are not currently operational in Fiji, several small-scale household digesters exist, and new projects are in various planning stages. The ICAT Phase II project aimed to evaluate the GHG mitigation potential of biogas facilities in Fiji, a recommendation received during the lessons learned workshop for the ICAT Phase I project.

This report can significantly contribute towards Fiji's next NDC update in 2025, which seeks to include the agriculture sector under the mitigation target. It explores the theoretical potential for implementing biogas projects across multiple sectors in Fiji and their role in reducing the country's GHG emissions. The analysis encompasses various OW streams, including municipal solid waste (MSW), livestock manure, sugarcane biomass, and food waste from the tourism industry. Additionally, the report examines existing household-level biogas initiatives and proposed future projects, providing a comprehensive assessment of both current activities and future opportunities for biogas in Fiji .

[7] Organic waste - any material that is biodegradable and comes from either a plant or an animal
[8] Pacific Community (2022). *Sustainable Energy for All: Pacific Regional Energy Assessment*. SPC, Noumea.
[9] Source

2.0 FIJI'S CONTEXT

Fiji contributes 0.004 % to the global GHG emissions according to the National Inventory Report 2023[10], the total emissions for Fiji in the year 2019 was 2657.64 Gg CO2-eq from the Energy, Waste, IPPU and Agriculture sectors, whereas the total removals were 854.68 Gg CO2-eq from the Forestry and other land use sectors. Emissions from the energy sector (52.74 %) make the largest contribution to the national GHG inventory, followed by forestry and other land use as a sink (21.18 %) and agriculture (13.14 %). The waste sector (9.70 %) and industrial processes (3.24 %) make minor contributions.

The ambitious LEDS sets forth a comprehensive approach to decarbonisation across key economic sectors, particularly emphasising the transformation of waste management and energy systems through innovative solutions like biogas technology. Fiji's efforts to improve its national and sectoral Monitoring, Reporting and Verification Systems is very commendable as it will build the foundation for evidence-based policymaking in the future. The implementation of biogas projects can contribute towards the waste and agriculture sectors in the following ways:

(a) **Waste Sector**:
- Reduce GHG emissions by capturing CH_4 from OW that would otherwise be released into the atmosphere;
- Converting waste into renewable energy, displacing fossil fuel use; and
- Reducing the volume of waste sent to landfills.

(b) **Agricultural Sector**:
- Process agricultural waste into renewable energy and organic fertiliser;
- Reduce CH_4 emissions from livestock manure; and
- Support sustainable farming practices aligned with Fiji's LEDS.[11]

The evolution of biogas technology in Fiji presents a unique case study in renewable energy development. While introduced in 1975[12], the technology has followed a distinctly different deployment pathway compared to industrialised nations. Unlike developed countries where biogas production predominantly occurs in centralised, industrial-scale facilities[13], Fiji's biogas sector has evolved through a distributed, community-based approach. This decentralised model, characterised by household and small-scale community digesters, aligns with Fiji's rural development priorities and geographical constraints as an archipelagic nation. According to the National Energy Policy for Fiji 2023-2030, there is significant potential to scale up the use of biogas systems to produce cooking fuel, manage waste, create sustainable fertiliser for small-scale agriculture, create health benefits, and minimise environmental harm.[14] On the contrary, the opportunity remains to set up centralised systems in managed and semi-managed landfills.

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[10] Government of Fiji (2023). *National Inventory Report of Fiji*. Office of the Prime Minister, Suva, Fiji.
[11] Government of Fiji (2018). Fiji Low Emission Development Strategy 2018-2050. Ministry of Economy, Suva, Fiji.
[12] Andrew Tukana (2005), A study of biogas digesters as an animal waste management tool on livestock farming systems in Fiji. USP, Suva
[13] UNFCCC (2023) Technical Review Of National Inventory Reports Of Anthropogenic Emissions By Sources And Removals By Sinks Of Ghg Sub Course B6: Waste Sector.
[14] Government of Fiji (2024). Republic of Fiji National Energy Policy 2023-2030. Minister of Public Works, Meteorological Services, and Transport, Suva, Fiji.

3.0 BIOGAS

Biogas is a renewable fuel that is produced through anaerobic digestion, a biological process where microorganisms such as acidogenic bacteria break down organic matter in oxygen-free conditions[15]. The Figure 1 below represents the anaerobic digestion process of biogas generation. The system converts the OW (input) into valuable outputs in an oxygen-free environment, such as an anaerobic digester. The two primary outputs of the anaerobic digestion process are biogas and digestate. The digestate is a wet mixture that is usually separated into solid and liquid portions and is used as a fertiliser.[16] Biogas is also referred to as landfill gas in the IPCC guidelines on Waste, Vol. 5, Chapter 3.

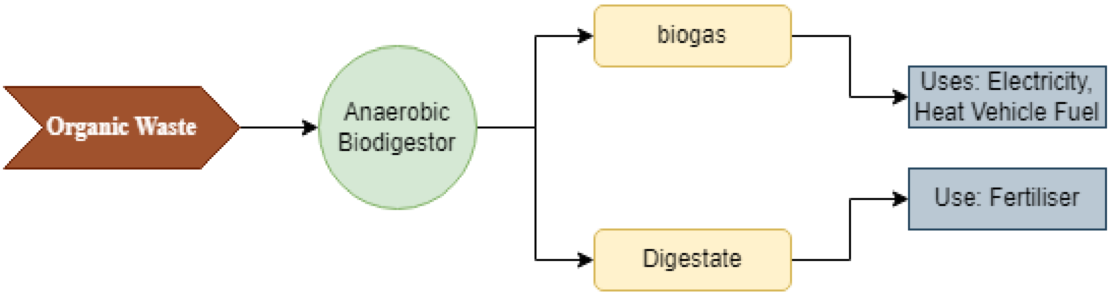


Figure 1: Anaerobic process of biogas production

The generation of biogas through anaerobic digestion can utilise diverse organic feedstocks such as animal manure, solid waste and landfill breakdown, plant material breakdown, food waste, sewage, and wastewater.

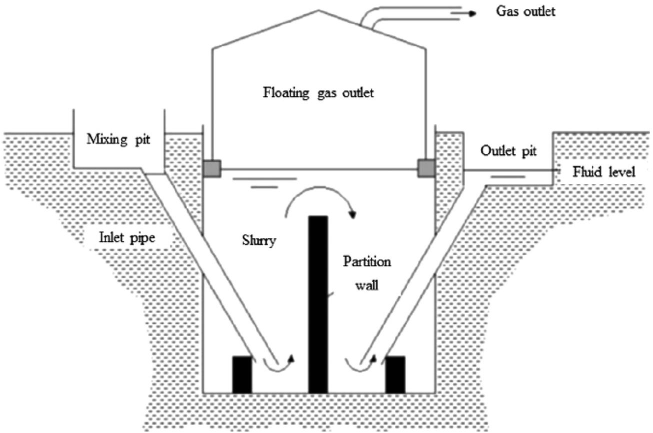
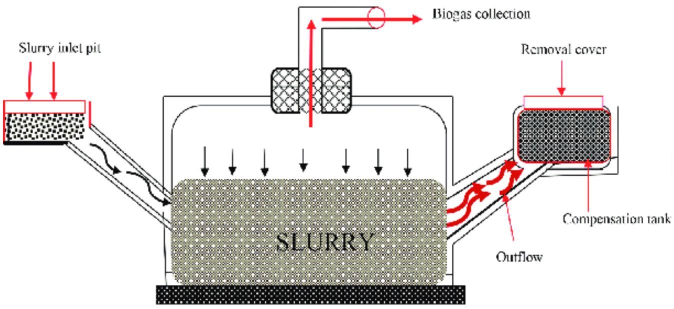
In Fiji, the primary sources of OW for biogas production are livestock, food waste and wastewater.[17]

3.1 Biogas Technology in Fiji

Various biogas technologies have been introduced in Fiji. These technologies are presented in *Table 2* below.

Table 2: Type of Biogas digester technology in Fiji

[15] This naturally occurring process generates a CH_4-rich gas mixture that can be harnessed for various energy applications, from electricity generation to thermal uses and transportation fuel
[16] Digestate
[17] Report on Feasibility of Resources and Sites For Waste-to-Energy Power Generation in Fiji

	Biogas Technology Description	Pictures
a.	*Old irregular dome (OID)* The Figure 2: OID- type digester The OID-type biodigester below was introduced in Fiji in the mid-1970s. However, OID was not considered a success due to its poor design (no hydrostatics) (A. Tukana, 2005).	*Figure 2: OID- type digester*[18] 
b.	*Indian Floating Chamber (IFC)* The Figure 3 outlines the IFC-type digester. This was introduced in Fiji from the late 1970s to the early 1980s. This setup was found to be too expensive to maintain (A.Tukana, 2005)	*Figure 3: IFD-type digester*[19] 
c.	*Chinese Modified Dome (CMD).* *Figure 4* shows the CMD-type biodigester. This type of digester was first constructed in 1976 and was invested in after 1997. This design was unsuccessful because of its poor construction (no hydrostatics) (A.Tukana, 2005).	*Figure 4: CMD-type digester* [20] 

[18] Picture Source: https://octopus-training.solidarites.org/topics/fixed-dome-digester/
[19] Source: Picture Source: https://www.researchgate.net/figure/Floating-cover-Indian-type-digester-adopted-from-Gunnerson-and-Stuckey-66_fig3_274028972
[20] Picture Source: https://www.researchgate.net/figure/Chinese-fixed-dome-digester-adapted-with-permission-from-9_fig1_312965292

	Biogas Technology Description	Pictures
d.	*Home system portable digesters* This was introduced recently in Fiji. The Home system comes in sizes/models 2.0 (manages up to 4L kitchen waste), 4.0 (manages up to 8L kitchen waste), and 7.0 (18L)[21]. More than 300 pieces of the system have been installed around Fiji.	*Figure 5: Portable biodigester*[22] 
e.	*LFC-300 Digester* This is a fully enclosed automatic biodigester that safely disposes of 100–900 kg (220–2000 lb) of food waste every 24 hours with no noise or odour.[23]. Vomo Island Resort currently uses this biodigester. 4400kg of food waste is fed to the digester monthly, thus offsetting 18.4 tonnes of carbon dioxide (CO_2)eq[24] monthly	*Figure 6:LFC 300 biodigester*[25] 

[21] HBG 7.0 Household Biogas System
[22] Picture source: https://www.facebook.com/photo/?fbid=10160995102197058&set=g.549205625266234
[23] https://powerknot.com/product-details/lfc-300/
[24] Source: https://vomofiji.com/the-very-hungry-bio-composter/
[25] Picture source: https://powerknot.com/product-details/lfc-300/

3.2 Benefits of Biogas Systems

- **Reduction of CH_4 Emissions:** Biogas systems effectively capture CH_4 emissions from OW, preventing their release into the atmosphere. Methane is a potent GHG with a global warming potential 28 times greater than CO_2 over 100 years.

- **Substitution of Fossil Fuels:** Biogas can be used in place of fossil fuels, reducing energy costs, reliance on energy imports, and GHG emissions from their use.

- **Improvement in Waste Management:** Biogas initiatives enhance waste management practices by decreasing the amount of waste sent to landfills and mitigating the GHG emissions resulting from waste decomposition. It prevents wastes from entering the waterways and from ending up in the Ocean, disturbing the marine ecosystems.

- **Uplift communities:** Support rural and economic development through income generation, soil improvement from digestate and energy access in rural areas.

3.3 Biogas Projects in Fiji

The table below shows the type and number of biogas digesters installed in Fiji since 1975. The current status of these projects are unclear. These can be potentially explored in future projects.

Table 3: Type and number of biogas digesters in Fiji

Year Installed	Type	Total Number Installed	In Operation
1975[26]	Old irregular dome (OID)	8	1
1975-1985[27]	Indian Floating Chamber (IFC)	9	0
1997-2003[28]	Chinese modified dome (CMD)	9	5
2009-2012[29]	The study did not specify the type	14	10
2023	LFC-300	1	1
2020-2024[30]	Portable Digesters	300+	300

Some of the planned projects for biogas digester installation since 2003 are reflected in the *Table 4* below. The table portrays Fiji's long-term engagement with renewable energy and biogas initiatives. In 2006, a commitment was made to install 10,000 biogas digesters, compared to the rest of the years it was quite significant. Other future commitments from the Fiji government and

[26] The information is from the study conducted in 2005. Current information not available
[27] The information is from the study conducted in 2005. Current information not available
[28] The information is from the study conducted in 2005. Current information not available
[29] The information is from the study conducted in 2005. Current information not available
[30] The exact number of portable biodigesters installed are not known. The information was requested from companies that were installing it but till to date the information was not made available.

the Water Authority of Fiji do not specify the numbers or the types of biogas digesters planned for installation.

Table 4: Number of planned biogas digester projects from 2003 to 2050.

Reports Referenced	**Year of Publication of the Report**	**2003**	**2005 - 2007**	**2006**	**2007 - 2012**	**<2050**
Pacific Islands Renewable SPREP Energy Project PIREP- Department of Energy (PWD then) - Kinoya Sewage Plant	**2004**	1				
Pacific Islands Renewable SPREP Energy Project PIREP-Department of Energy (PWD then) - ADB loan	**2004**	1				
Pacific Islands Renewable SPREP Energy Project PIREP- DoE's Departmental Strategic Development Plan for 2005 - 2007	**2004**		3			
A study of biogas digesters as animal waste management tool on livestock farming systems in Fiji	**2005**		5			
Strengthening the biogas program: A study for Department of Energy, Government of Fiji, 2006	**2006**				10000	
Water strategy 2024	**2024**					number not mentioned
Ministry of Agriculture (depending on the budget allocation[31])	**2024** (year of consultaion)					number not mentioned

3.4 Potential of Biogas in Fiji

Fiji's solid waste management presents significant opportunities for GHG mitigation through biogas projects. This analysis examines the potential impact of biogas capture and utilisation systems at solid waste disposal (SWD) sites across Fiji. However, currently no biogas capture facility exists for SWD sites in Fiji. The Water Authority of Fiji used to have a CH_4-capturing and flaring program at its Kinoya Sewerage Treatment Plant, but it is currently on hold.[32]

Several studies have been undertaken to determine the biogas generation potential for the Naboro and Vunuto landfills. The research was conductedon the Vunato disposal[33] site, which caters to MSW collected by the Lautoka City Council, Nadi Town Council, and hotels in both the Nadi and Lautoka areas. The researcher used the three scenarios to calculate the generation potential: *Scenario 1: Power generation from Biogas produced from the organic fraction of the municipal solid waste (OFMSW), Scenario 2: Power generation from Incineration of OFMSW and*

[31] This information was obtained via consultation.
[32] Source: during the waste sector meeting on 16 October 2024
[33] Chapter 6, waste to Energy from Municipal Solid Waste for Power Generation, Malvin Kushal Nadan, pages 129

Scenario 3: Power generation from AD and Incineration of OFMSW. The scenario 1 estimated that 944,500 m^3 of biogas could be produced annually. This is equivalent to 2587 m^3/day.

A separate study was conducted on the Naboro landfill in Suva,[34] which has been operating since 2005 and caters for MSW collected by Korovau Town Council, Nausori Town Council, Nasinu Town Council, Suva City Council, Lami Town Council and Navua Town Council. The landfill receives about 70,000 tonnes of waste annually and has no CH_4 recovery or biogas utilisation systems. In 2016, the landfill generated approximately 47,000 tons of CO_2 equivalent per year, thus 800 m^3/hectare (h) of CH_4 and is expected to reach 1600 m^3/h by the end of stage 4 of the landfill development.

According to the study, the estimated investment cost for setting up the system (vertical well, horizontal well, landfill gas station, piping, and 600kW gas engine) is FJD 2.4 million. The annual revenue potential from the electricity supply is FJD 1.3 million. The expected return on investment is less than 4 years.

Another assessment was conducted for the Department of Energy, Ministry Public Works, Transport, and Meterological Services on Waste to Energy Resource Assessment in Fiji in September 2014[32]. The study indicated that while Fiji has significant theoretical potential for waste-to-energy projects, practical implementation faces various logistical and economic challenges. The most promising opportunities appear in biomass waste (particularly from sugar mills) and (MSW) from significant landfills. Represented in the Table 5 is the theoretical potential for biogas/ electricity generation. The assessment report estimated the biogas potential for most of the potential sources of biogas production.

Table 5: Theoretical potential of the biogas production[35]

Potential Sources	**Estimate Biogas Potential (m^3/year) 80% of the capacity**
Major Sewage Treatment Plants	2,162,560
Livestock Waste (cows, pigs and chickens)	20,111,680
Fiji Meat Industry Board (FMIB)	1,138,222
South Pacific Distillery (SPD) and Paradise Beverage	262,118
Agriculture Crop Residue	117,789,623
Landfill and Dumps	13,950,537

3.4.1 Potential Biogas estimation from the recent data

This section details the findings after the evaluation of the GHG mitigation potential of biogas facilities in Fiji. The results indicate that OW's from three sources (agriculture, SWD, and food waste from the tourism industry) lead to biogas generation in the country. The current GHG emission from solid waste disposal alone was 241.32 Gg of CO_2 equivalent, as per the Fiji's NIR. However, the total CH_4 generation calculated from the three sources using the indicated data as per Table 6 below resulted in approximately 39.8 million m^3/year of CH_4. This is approximately 800 Gg of CO_2 equivalent. The agriculture sector, which consists only of livestock (cattle, pigs,

[34] Pre-feasibility study for methane recovery at Naboro Landfill, Suva, Fiji Islands
[35] Waste to energy resource assessment in Fiji (2014). Government of Fiji, Suva.

and poultry) and sugarcane bagasse, is the most significant contributor to the biogas potential, followed by municipal solid waste and food waste from the tourism industry.

Agriculture sector

The agriculture sector in Fiji generates substantial OW, mainly from sugar cane processing, which produces approximately 2.1 million tonnes of bagasse annually.[36] Secondly, the livestock sector, comprising approximately 119,691 cattle, 27314 pigs, and 1.41 million poultry[3] represents another significant source of OW suitable for biogas production.

Biogas digesters installed for livestock manure and sugarcane bagasse could prevent 160 and 582 of CO2 equivalent emissions respectively from the atmosphere by converting methane into an energy source for communities and industries.

Solid Waste Disposal

For the municipal solid waste, all the landfills and dumps operating in Fiji were considered with the waste disposal from the urban population. This was because the municipal councils collect waste from the town boundary and dispose of it at its allocated disposal sites. Hence, there is a potential to harvest methane from the sites with proper infrastructure in the future. Noting that the Naboro landfill is a managed site, it can be one of the feasible sites to commence the biogas facility. The total waste disposed at Naboro Landfill in 2023 was approximately 93820 tons/year, generating approximately 90.4 Gg of CO_2 equivalent/ year, assuming 100% of the generated CH_4 is captured and the biogas facility operates at 80% capacity. However, as per the 2016 study[31], the technology recommended for capturing the methane generated will capture 45% of the total methane generated, bringing the biogas potential to 40 Gg of CO2 equivalent/ year, with the biogas facility operating at 80% capacity.

Tourism Industry

Fiji's tourism industry, which accounts for about 38% of GDP in pre-pandemic levels[1], generates considerable volumes of food waste from hotels and resorts, presenting opportunities for decentralised biogas systems that could simultaneously address waste management and energy needs. Generally, all waste from hotels end up at the landfill in Fiji, however, while conducting the literature review, it was discovered that Vomo Island Resort have opted for the biodigester with the potential to offset 18.4 tonnes of carbon dioxide (CO2)eq[37] monthly. With subtaintial number of island based resorts, there is an opportunity to replicate this technology on other offgrid island but also on mainland resorts. However, further study on other hotels and resorts regarding the total amount of food waste generated must be done to comprehend the feasibity and sustainability of the technology.

The tourism industry is also considered as one of the data providers for solid waste. To understand how the Tourism industry could contribute towards Fiji's GHG mitigation efforts, the calculations in this report for the tourism industry assumes that all the food waste generated on the premises is not diverted to the disposal site but to the biogas digester.

[36] Ministry of Agriculture Fiji (2023). *Agricultural Census Report 2023*. Government of Fiji, Suva.
[37] Source: https://vomofiji.com/the-very-hungry-bio-composter/

Table 6: Theoretical potential of the biogas production using 2023 data

Potential Sources	Estimate Biogas Potential (m^3/year)	Estimated CH_4 yield (m^3/year) 80% of the capacity
Municipal Solid Waste [a]	5517136	2,648,225
Agricultural Sector - Sugarcane bagasse	65,940,000	29,013,600
Agricultural Sector - Livestock	16,609,256	7,972,443
Tourism Industry (Food Waste)	537,600	258,048

Based on the Table 5 and Table 6 it is noted that the agriculture sector (consisting of livestock and sugarcane baggase) dominates biogas production. However, it is also worth noting that the scope of materials included for biogas calculation was not exact. Hence, the tables cannot be comparatively analysed.

3.5 Calculations

3.5.1 General Methodology Overview

A mass-balance approach was used to calculate the CH4 emission and conversion factors to estimate biogas and methane potential from various organic waste streams. The calculation follows the following steps:

- Calculate the base organic matter available
- Apply collection/recovery factors
- Convert to volatile solids (VS) where applicable
- Apply biogas conversion factors
- Calculate methane content

In order to calculate the biogas potential and estimate CH_4 yield, the following steps and equations were used.

(i) *Solid waste*

The key parameters include population base, waste generation and organic fraction.

Key parameters	Significance[38]	Key Assumptions
Population base	Urban population focus suggests a concentrated waste stream	Uniform waste generation across the population
Waste generation	Uses median values from ranges to account for uncertainty	IPCC default biogas yield (100 m^3/tonne) applies to local conditions
Organic fraction	A high organic fraction indicates good biogas potential	Consistent organic content throughout the year

[38] Significance refers to the importance, relevance, and implications of specific parameters and data points in the calculations

Step 1: Calculate the Annual organic MSW.

Annual organic MSW = Population × Daily waste × Organic fraction × 365 days (kg/year)

Step 2: Calculate biogas potential

Annual biogas potential from MSW = Annual OW (Tonnes/year) × Biogas yield (m^3 biogas/year)

Step 3: Estimate methane yield.

Estimated CH_4 yield= (Annual Biogas potential*60% CH_4 content) *80% yield capacity

The CH_4 content is estimated to be 60%. The result is multiplied by 80%, assuming that any biogas facility operates at 80% capacity.

(ii) Sugarcane Biomass

Key parameters	**Significanc**	**Key Assumptions**
Annual bagasse	Largest potential source by volume	Uniform bagasse quality
Moisture content		Constant moisture content
Volatile solids (VS content)	High VS content indicates good conversion potential	All bagasse is potentially available for biogas

Step 1: Dry mass calculation

Dry matter = Total bagasse × (1 - moisture content) (tonnes dry matter)

Step 2: Annual biogas potential from bagasse

Annual biogas potential from bagasse = VS [Annual biogas potential from bagasse = VS × Biogas yield (m^3 biogas/year)] × Biogas yield (m^3 biogas/year)

Step 3: Estimated CH_4 yield

Estimated CH_4 yield= (Annual Biogas potential*55% CH_4content)*80% yield capacity

The CH_4 content is estimated to be 55%. The result is multiplied by 80%, assuming that any biogas facility operates at 80% capacity.

(iii) Livestock Manure

Key parameters	Significance	Key Assumptions
Species-specific manure production rates	Multiple waste streams with different characteristics	Year-round animal populations
Variable VS content (16-25%)	Collection efficiency varies by farm type	Standard manure production rates apply
Collection efficiency: 70%	Different biogas yields for each manure type	Collection efficiency is achievable

Step 1: Calculate the total manure production.

Annual manure= Total animal count*Manure production kg/day* 365*collection efficiency (kg/year)

The total manure production[39] for different livestock are as follows:

- Cattle: 11-13 kg/day. Therefore, the average will be 12kg/day. VS content[40] =16%
- Pigs: 1.8-2.4 kg/day. Therefore, the average will be 2kg/day. VS content =20%
- Poultry: 0.08-0.12 kg/day. Therefore, the average will be 0.1kg/day. VS content =25%

Step 2: Calculate the annual biogas potential

Annual Biogas potential= VS available [Annual manure x VS Content]/1000*biogas potential

Step 3: Estimate CH_4 yield

Estimated CH_4 yield= (Annual Biogas potential*60% CH_4 content)*80%

The CH_4 content is estimated to be 60%. The result is multiplied by 80%, assuming that any biogas facility operates at 80% capacity.

(iv) Tourism Industry (food waste)

Key parameters	Significance	Key Assumptions
Tourist numbers	Concentrated waste stream in tourist areas	Uniform tourist stays (7 days)
Food waste	High collection efficiency is possible due to centralised locations	Consistent food waste generation
Collection efficiency: 80%	High-quality substrate for biogas production	High collection efficiency is achievable

[39] IPCC Guideline, Volume 4, Chapter 10
[40] IPCC, 2019

Step 1: Calculate the annual food waste

Annual Food Waste= Tourists arrival*Average stay*waste generated*collection efficiency (kg/year)

Step 2: Calculate Biogas potential.

Annual Biogas potential = Annual food waste * biogas potential for food waste

The biogas potential for food waste used is 120m^3/tonne.

Step 3:

CH_4 Content= (Biogas potential/ year *60%)*80%

The CH_4 content is estimated to be 60%. The result is multiplied by 80%, assuming that any biogas facility operates at its 80% capacity.

3.6 Limitations and Uncertainties

The calculation of biogas potential across different sectors in Fiji faces several significant limitations and uncertainties that need careful consideration. Temporal variations represent a major challenge, as the calculations assume constant rates throughout the year, which may not reflect reality. Tourist numbers fluctuate seasonally, affecting food waste generation in the tourism industry, while agricultural processing cycles, particularly in sugarcane bagasse production, create inconsistent feedstock availability. The livestock sector also experiences variations in manure production due to seasonal changes in feeding patterns and animal management practices.

Technical constraints pose another substantial limitation to the accuracy of these calculations. The collection efficiency assumptions, particularly the 70% rate for livestock waste and 80% for tourism industry waste may be optimistic given the practical challenges of waste collection and transportation in Fiji. The biogas yields used in the calculations are based on international standards (IPCC, IRENA), which may not perfectly align with local conditions. Factors like temperature, humidity, and local waste characteristics could significantly affect biogas production rates. The calculations also do not account for potential waste composition and quality variations, which can significantly impact biogas yield.

Practical considerations introduce additional uncertainties to the estimations. The calculations do not factor in waste collection's logistics and transportation requirements, which could affect the feasibility of achieving the assumed collection rates. The potential effects of co-digestion - mixing different types of waste to optimise biogas production - are not considered in the current calculations. This could lead to either underestimation or overestimation of the total biogas potential. Furthermore, the economic feasibility aspects, including the costs of collection, transportation, and processing infrastructure, are not integrated into these technical calculations, which could significantly impact the practical implementation of biogas projects.

Environmental and operational factors add another layer of uncertainty. Local climate conditions, operational expertise, and maintenance practices can affect the efficiency of the biological processes involved in biogas production. The calculations assume optimal conditions for biogas production, which may not be consistently achievable in real-world operations. Additionally, the potential impact of contaminants in the waste streams, particularly in MSW and tourism industry waste, could affect the actual biogas yield and quality.

System stability and reliability considerations are also not fully captured in these calculations. The steady supply of feedstock materials, crucial for continuous biogas production, can be affected by various external factors such as changes in agricultural practices, tourism patterns, or waste management policies. The calculations also do not account for potential system downtime for maintenance or technical issues, which could affect the annual biogas production potential.

Table 7: Summary of limitations and uncertainties

Temporal Variations	Technical Constraints	Practical Considerations
Agricultural processing cycles	Collection efficiency assumptions may be optimistic	Transport and logistics are not factored in
Livestock production variations	Biogas yields based on international standards	Co-digestion effects not considered
Seasonal tourist fluctuations	Local conditions may affect conversion rates	Economic feasibility not assessed

3.7 Recommendations for Improved Estimation

Several key recommendations should be implemented across different aspects of the assessment process to enhance the accuracy and reliability of biogas potential estimations in Fiji. Regarding data quality, it is essential to conduct comprehensive local biogas yield studies that reflect Fiji's specific conditions rather than relying solely on international standards. These studies should regularly monitor actual biogas production rates from different waste streams and systematically verify collection efficiencies across various sectors. Additionally, implementing a robust system for monitoring seasonal variations in waste generation and composition would provide more accurate baseline data for calculations.

The improvement of technical parameters represents another crucial area for enhancement. Developing locally-specific conversion factors through pilot-scale testing and experimental studies would significantly increase the accuracy of biogas potential estimations. This should include a detailed assessment of the co-digestion potential of different waste streams, as mixing various organic materials could optimise biogas production. Regular evaluation of volatile solids content in different waste streams, particularly in agricultural and livestock waste, would provide more precise input data for calculations. Furthermore, establishing a standardised methodology for measuring and monitoring biogas quality and methane content under local conditions would improve the reliability of production estimates.

Implementation considerations require a systematic approach to validation and monitoring. Conducting pilot studies at different scales and across various sectors would help validate the theoretical calculations and identify practical challenges that affect biogas production. Regular monitoring programs that track actual versus projected biogas production rates should complement these pilot studies. Building local technical capacity through training programs and knowledge transfer initiatives is crucial for ensuring accurate data collection and monitoring. This should include training in modern monitoring techniques and technologies for measuring biogas production and quality.

To improve the overall estimation framework, developing a comprehensive database management system would be beneficial for tracking and analysing waste generation patterns, collection efficiencies, and biogas production rates. This system should incorporate real-time data collection where possible and include regular data validation and quality control mechanisms. Additionally, establishing partnerships with academic institutions and research organisations could facilitate ongoing research and development in biogas production optimisation and monitoring methodologies. This collaborative approach would help continuously refine and update the estimation methods based on empirical evidence.

The final aspect of improving estimations involves integrating economic and practical feasibility assessments into the technical calculations. This should include developing models that account for transportation costs, infrastructure requirements, and operational expenses in different contexts. Regular feasibility studies considering technical and economic aspects would provide a more realistic assessment of achievable biogas production levels. Furthermore, establishing a feedback mechanism from existing biogas projects would help continuously refine and update estimation methodologies based on real-world operational experience.

Table 8: Summary of recommendation for improvement

Data Quality	**Technical Parameters**	**Implementation Consideration**
Conduct local biogas yield studies.	Develop local conversion factors	Pilot studies for validation
Verify collection efficiencies	Assess co-digestion potential	Regular monitoring and adjustment
Monitor seasonal variations	Evaluate actual VS content regularly	Local capacity building

4.0 INSTITUTIONAL ARRANGEMENTS AND DATA FLOWS

If biogas projects are implemented as part of the NDC, Fiji needs to track emissions and progress and needs to have access to data/ parameters as alluded to in section 3.5.1 General Methodology. The arrangement for collecting, compiling, and estimating biogas potential can be acquired through the Fiji Climate Change Act 2021 under emission reduction and mitigation as follows:

No	Fiji Climate Change Act Section	Relevance to Biogas
1.	Section 43(1) and (2): "Minister has the power to introduce and implement regulations, measures and actions" Specifically: 43(2)(c): "introduce and implement fiscal incentives and national levies with the purpose of— (iii) encouraging public and private investment in renewable energy and efficient cogeneration technologies, energy-efficient infrastructure and zero-waste infrastructure and processes"	Biogas digesters can be classified as renewable energy technology and waste management infrastructure, making them eligible for potential fiscal incentives for communities to have energy security. The NEP[41] has identified that biogas systems can be significantly scaled-up to produce cooking fuel, manage waste, create sustainable fertiliser for small scale agriculture, create health benefits, and minimise environmental harm.
2.	Section 88(1): "Incentives for the promotion of climate change initiatives" "The Minister responsible for finance may, in accordance with the Financial Management Act 2004, grant to persons that— (a) encourage and put in place measures for the mitigation of climate change including reduction of greenhouse emissions, use of renewable energy and energy efficiency"	Biogas digesters directly contribute to: • Reducing greenhouse gas emissions (by capturing methane) • Generating renewable energy (biogas) • Improving energy efficiency (through combined heat and power potential)
3.	Section 30: "Sector-based collection of data and information needed to estimate emissions and emissions reduction data" Particularly relevant under subsection (1)(d) .	In the waste sector, biogas digesters can be considered waste management technology.
4.	Section 32: "Voluntary facility-level reporting on emissions and emissions reduction data"	Facilities using biogas digesters could report their emissions reductions under this voluntary scheme.

The arrangement proposed below can be used to monitor, report and verify the biogas data.

[41] Government of Fiji (2024). Republic of Fiji National Energy Policy 2023-2030. Minister of Public Works, Meteorological Services, and Transport, Suva, Fiji.

(a) The *Ministry of Agriculture* can collect biogas activity data from Fiji's livestock sector. Currently, the Ministry's data collection efforts encompass livestock population statistics, manure management system monitoring, and tracking of Ministry-funded biogas digesters among farmers. Despite these existing measures, significant data gaps need to be addressed. The Ministry requires more comprehensive information, including annual livestock census data, detailed documentation of manure management system types and their distribution, monthly measurements of biogas production volumes, precise mapping of biodigester locations, CH_4 recovery rate tracking, and quarterly assessments of biodigester operating conditions. While it is noted that the Livestock Survey Developed under the ICAT Phase II will be used to collect livestock data from June 2025, it is essential to acknowledge that implementing these recommended data collection improvements for Biogras project monitoring may prove challenging due to Fiji's unique geographical constraints and the Ministry's limited available resources.

(b) The *Hotels and Tourism Association,* in collaboration with the Ministry of Tourism and Civil Aviation, can facilitate data collection in the tourism industry. Some of the data requirements are OW Generation and energy consumption patterns to assess potential biogas replacement capacity. The constraints in obtaining this type of data will be the geographical location of the hotels, seasonal variation of tourists that will affect the consistency in waste generation, and limited local expertise for data collection and recording, especially when most hotels lack standardised waste segregation and measurement systems.

(c) The *Department of Environment*, Ministry of Environment and Climate Change can facilitate data collection related to the waste sector. The data collection requirement includes CH_4 generation parameters such as daily CH_4 production rates and waste characterisation. Currently, the department collects data on waste generation. However, this can be further improved by adding the recommended parameters. However, obtaining the above data can prove difficult due to the lack of proper weighbridges in most town councils.

The data flow for the sectors mentioned above is illustrated in Figure 7 below. For the agriculture sector, a mechanism for data collection, such as the agriculture census or the livestock survey, already exists (top section blue-green box). Therefore, there will not be a need to create a new mechanism. However, Figure 7 below outlines the potential pathway for data collection if the Climate Change Division decides to coordinate data collection from waste disposal sites and hotels/ resorts.

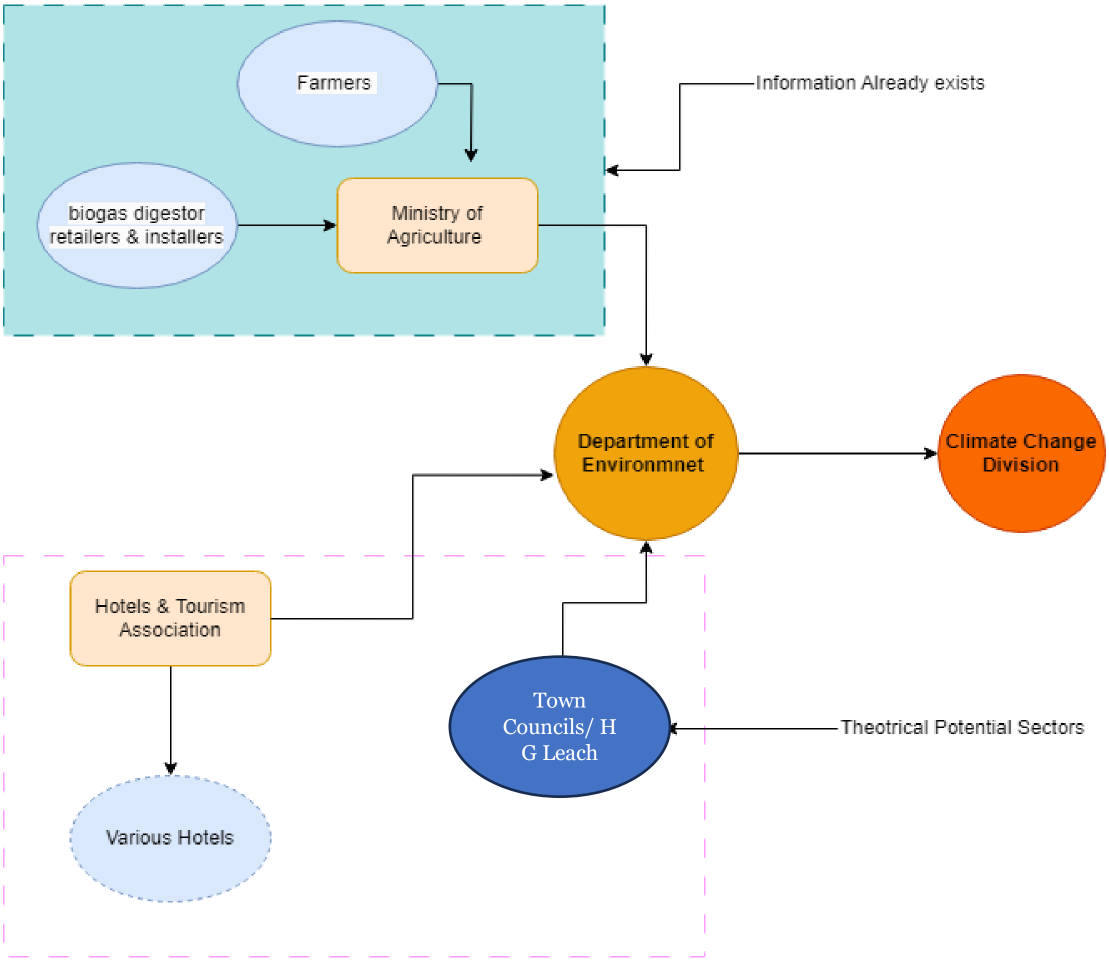


Figure 7: Data flow diagram for biogas activity data

5.0 CHALLENGES OF BIOGAS IMPLEMENTATION IN FIJI

There are a number of challenges identified for the successful implementation of biogas projects, especially at farm/ household level.[42]

Challenges	Explanation
Technical and Operational Challenges	• Temperature fluctuations significantly affect biogas production • Formation of scum layers (10-15cm thick) that interfere with digestion process • Need for proper mixing and agitation of digesters • Requirement for proper insulation to maintain constant temperature • High total solids content in poultry manure affects biogas yield • Ammonia inhibition due to high nitrogen content in poultry manure

Environmental Challenges	• Extreme weather conditions affect operation:
	    ○ Severe tropical cyclones (like TC Yasa and TC Ana)
	    ○ Variable temperatures impact bacterial activity
	    ○ Heavy rains and storms can damage equipment
	    ○ Weather patterns can cause temperature shocks even of 1°C that affect production

Economic Challenges	• High initial capital costs:
	    ○ FJD 488,750 for digester and storage tank for 2 units as per the study conducted[43].
	    ○ FJD 34,650 for CHP biogas engine
	    ○ Additional costs for maintenance and operation
	• Long payback period (17 years without fertiliser sales)
	• Need for trained operators (FJD 20,000 estimated annual cost)
	• Maintenance costs (FJD 5,000 estimated annual cost)

Infrastructure Challenges	• Need for proper storage facilities • Requirement for biogas collection and distribution systems • Need for proper effluent handling and storage • Requirements for monitoring and control systems
Knowledge and Expertise Gaps	• Lack of established studies or applications in Fiji • Limited experience with anaerobic digestion technology • Need for trained personnel to operate and maintain systems • Limited understanding of optimal operating conditions for the local context.

[42] Anaerobic digestion of poultry manure to power a poultry farm in Ba: Pilot and techno-economic study, Geeta M. Naidu, Atul Raturi, & Francis S. Mani.

[43] Anaerobic digestion of poultry manure to power a poultry farm in Ba: Pilot and techno-economic study, Geeta M. Naidu, Atul Raturi, & Francis S. Mani

These challenges need to be addressed for the successful implementation of biogas systems in Fiji. However, the study shows that despite these challenges, biogas implementation can be technically and economically feasible with proper planning and management.

6.0 RECOMMENDATION

The following recommendations are made for improving the biogas-related data management and monitoring:

- Noting that Fiji does not have a specific policy and legislation regarding biogas development, this provides us with a window of opportunity to be proactive and develop one, considering experience from other countries. This includes developing clear guidelines for biogas plant operations, establishing emission standards specific to biogas facilities, and creating incentives for adopting emission reduction technologies.
- Strengthen data collection and standardised monitoring systems by establishing a national biogas database to collect and track biogas production and waste input sources and offset fossil fuel usage.
- Support research and development in the biogas area.
- Upskill the workforce and create community awareness programs.
- Promote public-private partnership.
- Adopt CH_4 capture and utilisation at the Naboro landfill, which can later on be included in the carbon market development and trading.

~END~