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Biogas systems in Tuvalu: Achieving a just energy transition through clean cooking

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Cover photo: Ioana (right), Letia (left) and their children next to their home biogas system in Funafuti.

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INTRODUCTION

This policy brief summarises the findings of a research project investigating the impact of home biogas systems on households in Tuvalu and the effectiveness of such systems in replacing traditional stove types in Tuvaluan households. Data were collected, from June to September 2024, from the main atoll, Funafuti. The research employed quantitative methods (a survey of 36 households, cooking tests, stove-use monitors) and qualitative methods (focus group discussions, key informant interviews, biogas diaries, observations) to assess the technology's impact on energy use and family wellbeing, and to provide recommendations for future biogas initiatives in Tuvalu and the Pacific region. A validation workshop was held on 27 November 2024 to present and validate key findings with key government and community stakeholders.

This policy brief is complemented by *Biogas systems in Tuvalu: Gender impact assessment*, which synthesises research findings, analysis, and policy recommendations on the gendered impact of biogas systems on Tuvaluan households on the main coral atoll of Funafuti. Funding and technical support for the research was provided by the Pacific Women Lead at the Pacific Community (PWL at SPC) programme, supported by the Government of Australia, and the Funding with Intent programme, supported by the Government of New Zealand. The Government of the United States provided initial financial support for the Pacific Community to procure and install 20 biogas systems across four islets in Tuvalu.

CONTEXT

Tuvalu, a small Pacific Island nation, faces unique challenges, including high energy costs, limited resources and vulnerability to climate change. A significant portion of household income is spent on energy, contributing to energy poverty. While the majority of households use LPG and electricity for cooking, there is a reliance on wood, charcoal, and kerosene, particularly in rural areas, which has negative health and environmental impacts.

KEY FINDINGS

- **Biogas adoption leads to reduced fuel expenditure**: Households with biogas systems reported significant reductions in fuel costs, with some eliminating LPG expenses.
- **Biogas stoves offer comparable cooking times and efficiency:** Biogas stoves perform similarly to LPG stoves in terms of cooking time and fuel efficiency, providing a viable alternative.
- **Biogas use influences time allocation:** While biogas can free up time for other activities, it also requires dedicated labour for operation and maintenance, affecting household routines.
- **Biogas systems offer potential health and safety benefits:** By reducing reliance on open-fire cooking, biogas systems can minimise health risks associated with smoke inhalation and burns.
- **Biogas supports income generation:** Households with cooking-related businesses reported increased earnings due to reduced fuel costs and improved cooking efficiency.
- **Biogas by-products enhance home gardens:** The liquid slurry from biogas systems is used as a fertiliser, improving soil quality and crop yields in home gardens.
- **Challenges to biogas adoption remain:** These include space constraints, labour-intensive operation and maintenance, limited local expertise, insufficient biogas production for some households, high initial costs, and socio-cultural factors.

POLICY RECOMMENDATIONS

- **Prioritise biogas in national energy policies:** Promote biogas systems as a key strategy for reducing energy poverty and transitioning to cleaner cooking fuels.
- **Promote agricultural initiatives:** Encourage the use of biogas slurry in home gardens and small-scale farming to enhance food security and sustainable agriculture.
- **Support biogas for small businesses:** Provide incentives for businesses to adopt biogas technology, particularly those reliant on cooking.
- **Fund research and development:** Fund research on biogas system optimisation, including saltwater tolerance, alternative feedstock for biogas systems and factors affecting biogas production in the Tuvaluan context.
- **Develop strategies for effective operation and maintenance (O&M):** Establish local expertise; provide training and support for users not just in O&M of biogas systems but also in managing livestock, water security and crop production; ensure availability and accessibility of tools and spare parts; and create communication channels for addressing operational issues.
- **Strengthen awareness programmes:** Conduct public awareness campaigns to highlight the benefits of biogas and promote its sustained use. Users must be made aware of the amount of work required for biogas systems to operate and the minimum number of adult pigs required to provide manure.
- **Maintain momentum for biogas adoption:** Provide ongoing monitoring and support to users.
- **Address infrastructure and logistical challenges:** Review piggery designs and incentivise manure collection.
- **Promote gender inclusive and equitable approaches, including training women in biogas operation and maintenance:** Also refer to *Biogas systems in Tuvalu: Gender impact assessment* for further recommendations on gender inclusive and equitable approaches.

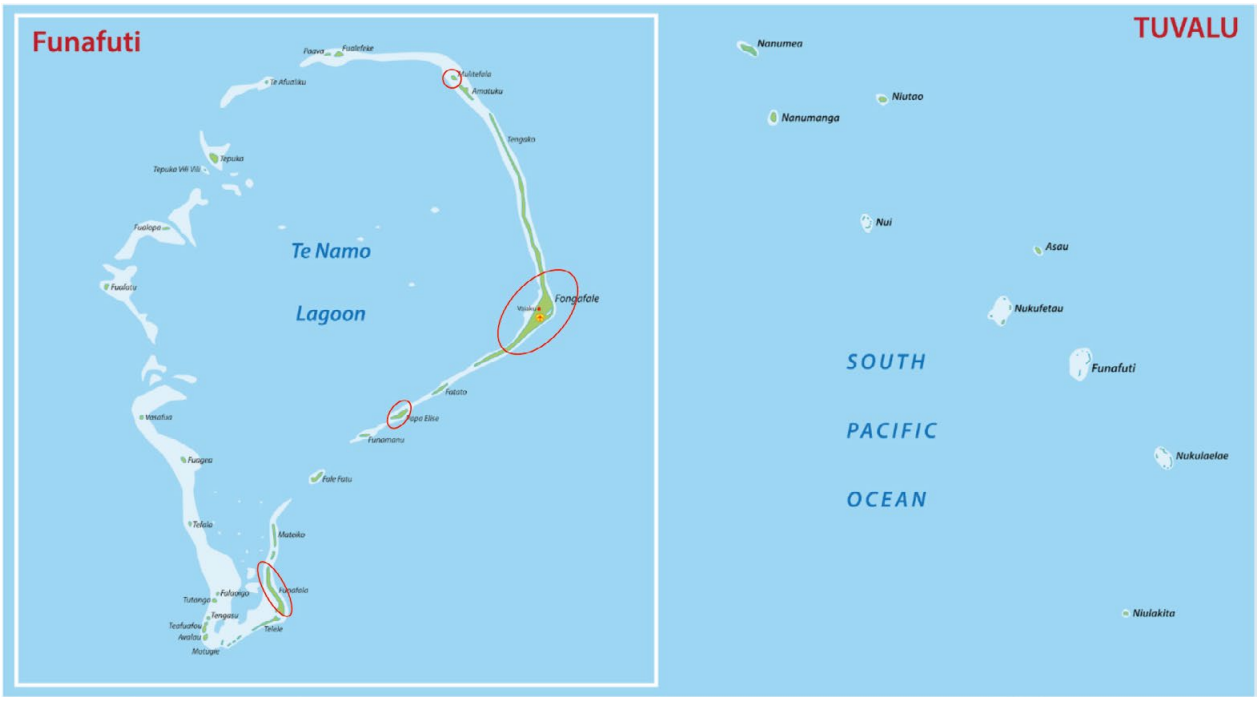
This research demonstrates the potential of biogas systems to address energy poverty, improve livelihoods, and promote sustainable practices in Tuvalu. By integrating these policy recommendations, Tuvalu can harness the benefits of biogas technology and pave the way for a cleaner, affordable and more resilient energy future.

1 Introduction

Tuvalu is a Polynesian island nation in the west-central Pacific Ocean with a total land area of around 26 km^2. This archipelago includes three reef islands (Nanumanga, Niutao and Niulakita), and six coral atolls (Funafuti, Nanumea, Nui, Nukulaelae, and Vaitupu) along with more than 100 small islets, all of which are scattered over a very large area (WorldAtlas 2024). The 2022 Tuvaluan census survey reports 1,799 households with a total population of 10,941 (Menaouer 2024). In 2023, Tuvalu's gross domestic product per capita was USD 4,111.5 (constant 2015 USD) (WBG 2024).

The Funafuti atoll is the capital and the most populous of the nine atolls. It has around 30 islets, as shown in Figure 1 and includes Vaiaku village on its Fongafale islet where most of the government's administrative offices are located (WorldAtlas 2024).

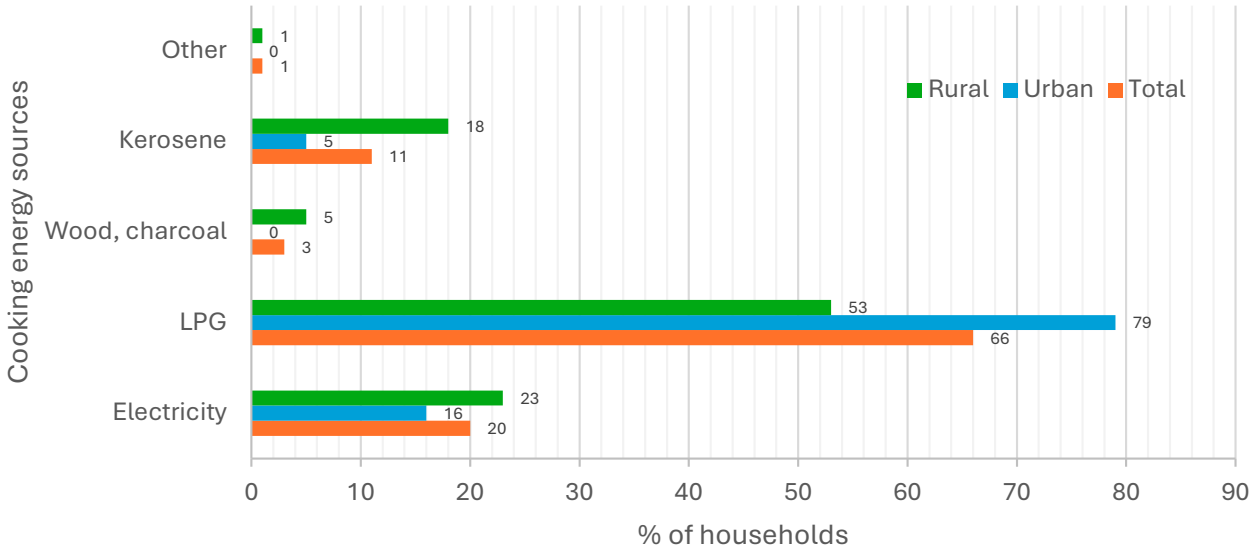
FIGURE 1: Map of Tuvalu with a focus on Funafuti Islet. Source: (WorldAtlas 2024)



As seen in Figure. 2, 86% of Tuvaluan households use LPG and electricity for cooking while the rest use wood, charcoal or kerosene. However, there is a disparity between urban and rural households, with 23% of rural households using kerosene and wood or charcoal for cooking, while only 5% of urban households use these polluting fuels. The Tuvaluan Household Income and Expenditure Survey (HIES) reports that the average household annual income is AUD 27,526 while the average household annual expenditure is AUD 29,383 (Menaouer, 2024). This indicates that there is zero to minimal savings for households to use in cases of emergency or being more resilient towards climate change.

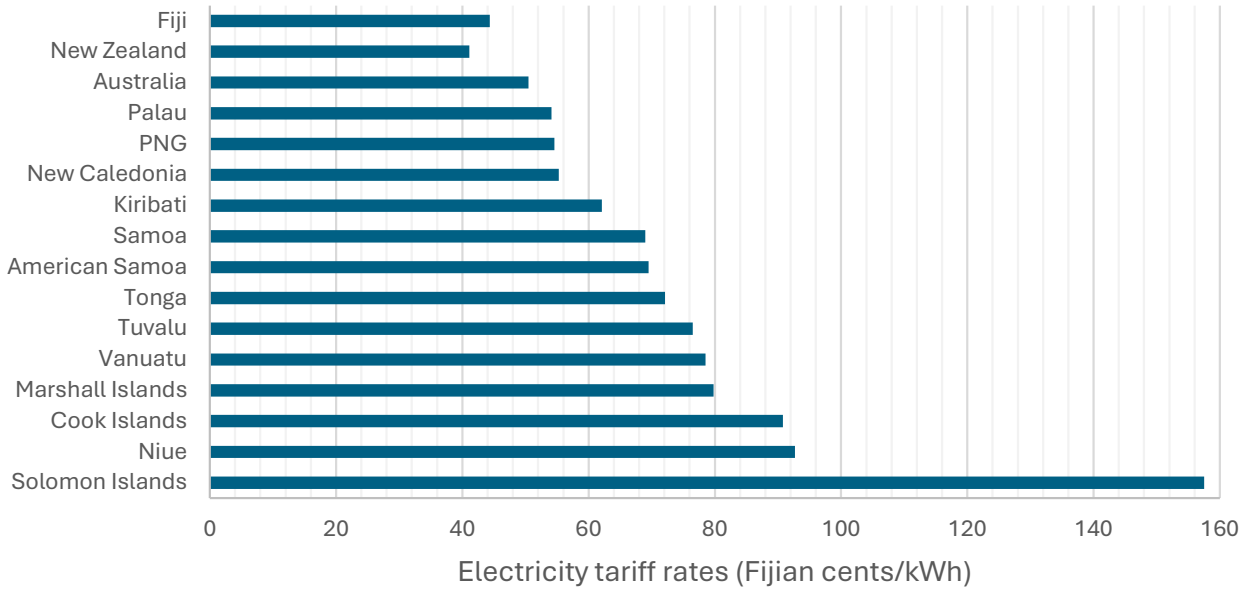
Housing and utilities expenditure account for 25.6% of total household expenditure in Tuvalu (Menaouer 2024). Of the total housing and utilities expenditure, gas expenditure accounts for 8%, while imputed rental is 66%, actual rental is 14% and electricity is 14%. In terms of the percentage of household income spent on gas and electricity, the 2022 HIES report found that average annual electricity, gas, liquid and solid fuels expenditure account for 6.7% of the average annual household income (with an average annual household income of AUD 5,345, gas expenses account for AUD 127, electricity expenses for AUD 220, liquid fuel for AUD 7, and solid fuel for AUD 4 on average). In developed countries, if the household is spending more than 10% of its household income on energy, it is considered to be in energy poverty (Al Kez et al. 2024).

FIGURE 2: Cooking energy sources in Tuvaluan households. Data source: (Menaouer 2024)



The electricity tariff in Tuvalu is relatively high compared to other Pacific Island countries, as seen in Figure 3. The same is true for LPG cylinder costs in Tuvalu. Because the main island is densely populated and there is a lack of trees on the island, Fongafale does not use firewood for cooking but uses mainly LPG, with some households using kerosene. The cost of a 13 kg cylinder for Tuvaluan households is AUD 85 on the main island while on outer islets the cost is around AUD 100 (ManaPacificConsultants 2024). This is around 2.5 to 3 times more than the costs in Fiji.

FIGURE 3: Electricity tariff rates for Pacific Island countries. Source: (EFL 2019)



Apart from the high cost of commodities in Tuvalu, there are various other challenges that Tuvalu is experiencing, including extreme vulnerability to climate change, natural disasters and adverse weather events. These challenges are intensified by its limited geographic size, small population, and remote location. Additional factors, such as low productive capacity, limited agriculture, the small private sector, and employment mostly offered by government departments, further exacerbate Tuvalu's vulnerabilities (GoT 2019).

THE RESEARCH INTERVENTION

Tuvalu has had previous biogas initiatives with some success rates but reports on these initiatives are not accessible to the public. In recent years, SPC, with financing from the US government, installed 20 home biogas systems (18 units of 4.0 cubic metres and two units of 7.0 cubic metres) on four islets (two on Funafala, two on Papa-E-Lise, one on Mutitefala and the remaining 15 on the main islet of Fongafale).

The research project aimed to understand the impact of the installation of biogas systems on Tuvaluan households, and their effectiveness in replacing traditional stove types. The purpose of this study was to use qualitative and quantitative research methods to understand if the biogas systems are having positive or negative effects on households' energy use and their wellbeing, and to develop recommendations for future projects in other communities in Tuvalu and the Pacific region.

TOOLS USED IN THE RESEARCH METHOD

Quantitative: A survey was conducted with 18 households (two Papaelise, two Funafala and 14 Fongafale) that had biogas systems (Intervention Group, IG) and 18 nearby households that did not have a biogas system (Control Group, CG). The survey questions aimed to compare the results of these groups. Additionally, an uncontrolled cooking test (UCT) and field water boiling test were performed to evaluate the thermal performance of biogas stoves versus LPG stoves. Indoor air quality was also measured, using a UHoo monitor during the UCT. Furthermore, stove use meters (SUMs) were installed in selected households to monitor usage from late May to late August 2024.

Qualitative: Focus group discussions, biogas diary entries by IG samples and general observations by researchers upon visiting homes to carry out SUM installation, UCT and SUM data downloading were conducted.

Suilelei cooking a meal on her stove fuelled by her family's home biogas system

2 Main findings

GENERAL

1. **Respondent information:** IG had two male respondents while CG had one male respondent in the survey. The survey questionnaire was intended for the main cook of the surveyed households. The main cooks were mostly female, but when there were no females in the house, the main cooks were male. The household survey employed the Washington Group short set of questions to identify the disability status of participants. One person (female) with disability participated in the household survey.

2. **Respondents' demographics (household size):** Comparing the number of women respondents in both groups, the mean household size for the CG was 5.41, while for the IG it was 7.94. An independent sample t-test revealed that there was no significant difference in the household size of the two groups. The household size is comparable to the 2022 HIES of Tuvalu, which reports an average household size of six, with rural areas averaging 5.1 and urban areas 6.9, indicating that urban homes have more residents (Menaouer 2024).

3. **Respondents' demographics (asset ownership):** House: 61% and 44% of IG and CG respondents respectively stated that their house is owned by the family, while the rest were either renting or living in a house free of charge. Agricultural land: All respondents, except one in the IG from Funafala, did not own any agricultural land.

4. **High visitor presence and extended stay could lead to greater cooking load:** The majority of female respondents in both the IG (75%) and the CG (65%) reported visitors staying in their homes, primarily from within Tuvalu. On average, CG households hosted 5.27 visitors annually, with a maximum stay duration of 9.27 weeks, while IG households hosted more, averaging 8.17 visitors, though with shorter stays averaging 6.92 weeks. This influx and duration of visitor stays may have implications for household resources, privacy, living conditions, cooking load and energy requirements.

TECHNICAL

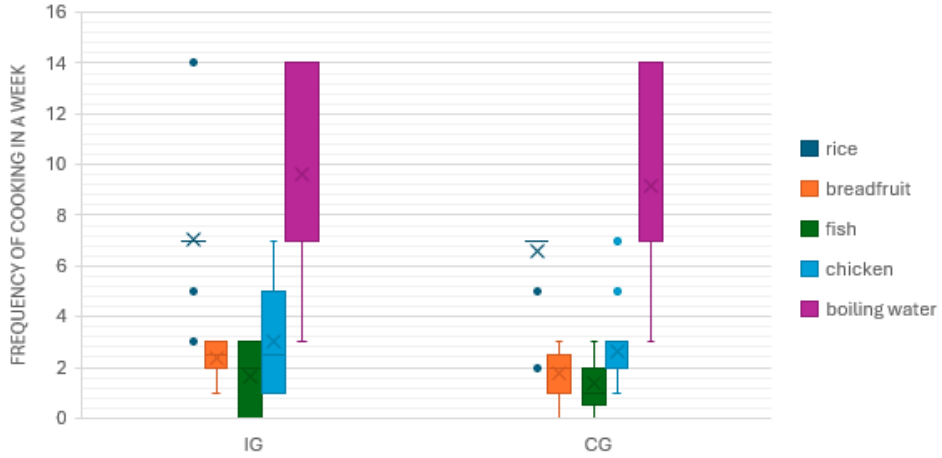
5. **A biogas stove is a viable option for cooking**

   a. Cooking patterns and popular dishes: Commonly prepared dishes included rice, chicken, fish and boiled water for drinking or bathing. Over 80% of female respondents in both groups cooked these items weekly. Breadfruit preparation was lower, with only 50% of IG and 76% of CG households cooking it weekly, reflecting limited access to breadfruit trees, lack of market availability, and the crop's seasonal nature.

   b. Frequency of meal preparation: As seen in Figure 4, rice and boiled water were the most frequently prepared items, with rice cooked about seven times a week and water boiled nine or ten times a week. The consistent cooking of rice highlights its daily importance in Tuvaluan diets, while other dishes are generally prepared one to three times a week.

   c. Biogas stove adoption and impact on stove usage: Biogas stoves were notably adopted in IG households, with 30–50% of main cooks using biogas for various dishes. Chi-squared analysis indicates a significant correlation between stove type and group, suggesting biogas systems positively influence stove choice among IG households. The presence of biogas stoves offers an alternative cooking option, allowing IG respondents to use multiple stoves for meal preparation, especially for rice. In contrast, CG households rarely use multiple stoves concurrently, indicating the added flexibility provided by biogas.

FIGURE 4. Frequency of cooking different food in a week for IG and CG households.

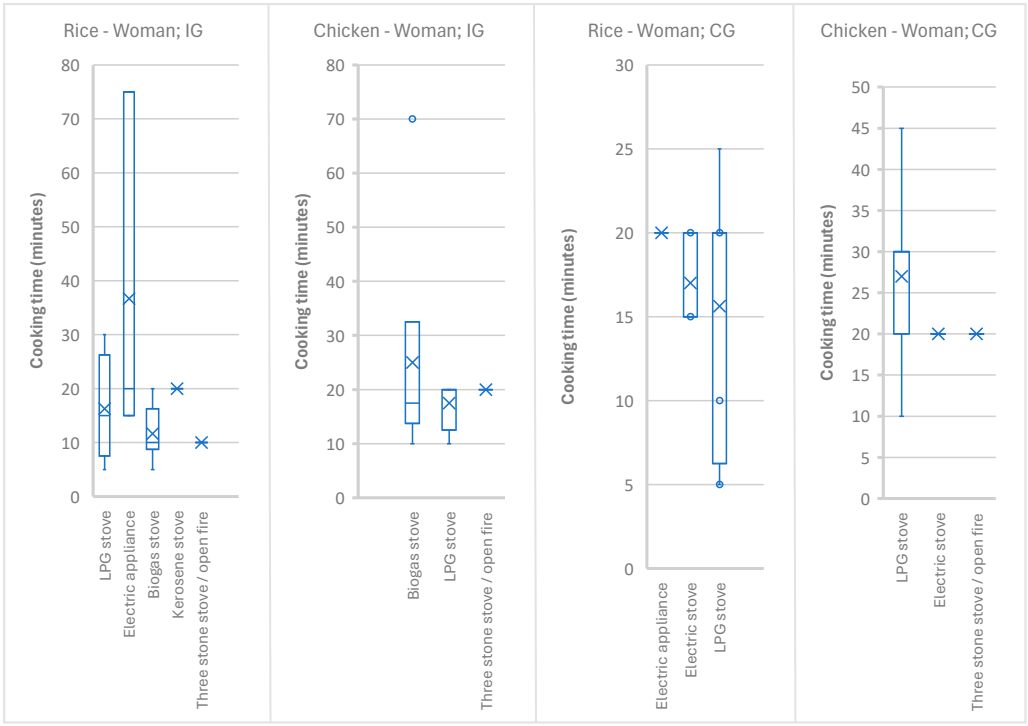


6 Cooking time analysis and stove efficiency

a. Survey results

- **Variation in breadfruit cooking time:** Respondents provided cooking times for each dish in minutes, highlighting a large variance in breadfruit cooking time between the IG and CG. This difference may be attributed to household size differences, with IG households averaging 7.94 members compared to 5.41 in CG households.
- **Comparable cooking time for biogas stoves with other stoves:** Rice: Cooking with biogas stoves was faster (11.6 minutes) compared to electric stoves (36.7 minutes) and LPG stoves (16.3 minutes) in IG households, as seen in Figure 5. Breadfruit: Open-fire stoves had the shortest cooking time. Fish and chicken: Biogas cooking times were similar to LPG and open-fire stoves in both groups. Water boiling: Biogas was equally efficient compared to other stoves.
- **Statistical insights:** No significant differences in cooking times were found between IG and CG, suggesting that biogas stoves perform comparably to conventional options (LPG).

FIGURE 5. Cooking time for rice and chicken on different stoves – noted during the survey



b. From the uncontrolled cooking test: Comparing the specific energy consumed by biogas and LPG stoves in IG and CG households, IG households used relatively less specific energy (an average of 1.8 MJ of biogas per kilogram of cooked dish in IG households compared to 6.2 MJ in CG households) and less specific time (an average of 12.4 minutes per kilogram of cooked dish in IG households compared to 54.3 minutes per kilogram in CG households). This implies that biogas stoves use less fuel and less time to cook a kilogram of a dish compared to LPG stoves.

c. Field water boiling test: The results show that the performance of biogas stoves and LPG stoves is comparable. There is no significant difference between the stoves in terms of their thermal efficiency (biogas – 37.5% and LPG – 31.9%), specific energy (MJ per kg of water heated) and specific time (minutes per kg of water heated).

d. Stove use monitors (SUMs): Installation data reveal some households (HH) use biogas stoves optimally, while in others, biogas stove use is minimal, as seen in Table 1. The recommended use of biogas stoves is three to four hours per day, according to the manufacturer. However, SUM data show that most households are not using biogas stoves to their full capacity.

TABLE 1: Average daily cooking times (minutes per day)

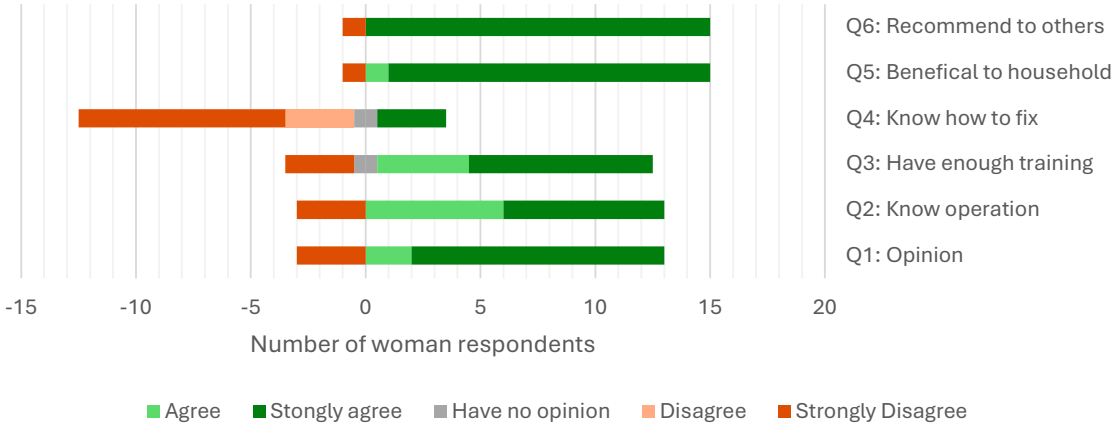
INTERVENTION GROUP					CONTROL GROUP	
Household ID	Cooking time (minutes per day) for different stove type				Household ID	Cooking time (minutes per day)
	Biogas	LPG	3 Stone	Kerosene		LPG
101	20.4	25.1			202	48.4
102	111.6	314.9			210	196.3
117	84.6				204	63.5
104	2.4	49.9			211	52.5
116	27.7				212	84.4
115	16.8	793.1			207	150.6
107	216.4	78.7			223	112.5
108	21.1		46.3	21.5		
121	1.4	166.8	31.9			
Average min/day	56	238	39	22		101
Average hours/day	0.9	4.0	0.7	0.4		1.7

7 **Household energy affordability and energy poverty:** Analysis shows that IG households spent, on average, 14–24% of their monthly income on energy costs, while CG households spent around 10-13%. IG's higher spending could be due to larger family sizes. Both groups spent more than 10% of their income on fuel each month. According to Al Kez at al. (2024), in developed countries, households that spend more than 10% of their income on energy are considered to be in energy poverty.

8 **Pig ownership rates and pen usage:** All male respondents and 76.5% of female respondents in the CG reported owning pigs. For female respondents in the IG, 100% of households had pigs, after adjustments. For female respondents, 70–75% reported using dedicated pig pens, with IG households averaging more pens (3.08) than CG households (1.17).

9 **Households' knowledge of biogas systems:** Figure 6 presents women participants' responses to a series of statements (Q1–Q6) assessing their knowledge of biogas systems. The data reveal a notable variation in their understanding. Specifically, a significant proportion of women disagreed with the statement: "I know how to fix biogas systems", indicating a lack of practical knowledge. In contrast, most male respondents reported a general understanding of biogas systems and expressed confidence in their ability to perform repairs where necessary.

FIGURE 6. Women respondents' opinion on their knowledge of biogas systems



Meauke feeding the biogas system at his home

10 Positive impacts of biogas systems on households

a. **Changes in fuel spending:** The introduction of biogas systems significantly reduced household fuel expenditures. Nearly all respondents (100% men and 93.8% women) reported lower fuel spending post-biogas, with an average reduction of 67.4%, from AUD 106.76 to AUD 32.50 per month. Notably, some households reported zero fuel spending after switching to biogas use.

b. **Savings – more than 10 years of free gas usage:** Conducting a simple payback assessment shows that, with an average expenditure of AUD 85 every 1.4 months per household, and if all LPG cooking is replaced with biogas, a 4.0 biogas system costing AUD 2,400 would take approximately 40 months to recover the initial cost. This means that, given a 15-year lifetime for a biogas system, households could enjoy around 11.6 years of free gas.

c. **Cooking time and effort:** Cooking with biogas generally reduces cooking time, with 61.1% of women and 50% of men reporting quicker cooking. Additionally, 62.5% of women and 75% of men noted that cooking with biogas required less physical effort, representing a notable improvement over previous cooking methods.

d. **Time availability:** Biogas usage affected personal and household time, with 77.8% of respondents reporting a change. Half of the respondents gained more time for other activities, such as recreational pursuits, household chores, and farming, and 71.4% of other household members experienced increased time for leisure and caregiving, although some reported less time for farming and sleep.

e. **Health and safety risks for cooking:** The survey assessed health and safety risks associated with cooking environments and practices in Tuvaluan households. Most households in both the IG and CG cook indoors, often in the main house, with some using outdoor or detached spaces. While all households reported having some ventilation, none had chimneys. Instead, 70–80% relied on windows to release smoke and heat. Health issues associated with cooking, such as burns, eye irritation, respiratory issues and chest pains, were included in the survey but only two cases of burns were reported. Two women in the IG reported burns: one incident involved an LPG stove with medical treatment sought, while the other involved an open-fire stove with repeated occurrences treated traditionally. This suggests a higher risk of burns with open-fire stoves compared to LPG, indicating potential health benefits from cleaner and safer cooking technologies.

f. **Cookstoves used in business:** Among female respondents, 37.5% in IG and 23.5% in CG reported owning a business that required the use of a cookstove. No male respondents indicated such businesses in their households. IG business owners used a wider variety of stoves – including LPG, biogas, open-fire, and charcoal – whereas CG business owners primarily used LPG or open-fire stoves. The IG respondents also reported higher average earnings from their cooking-related businesses compared to the CG, likely influenced by factors such as stove type, product offerings, and customer base. These businesses produced a variety of dishes, including rice, breadfruit, chicken, and chips, showcasing the economic contribution of cooking ventures in these communities. Among those with cooking-related businesses, 75% reported higher earnings due to biogas use, while the remaining 25% saw no improvement. All business owners reported that biogas reduced cooking time and eliminated the need for costly LPG.

g. **Potential for biogas by-products in home gardens:** The survey revealed that 56.3% of female respondents in IG and 47.1% in CG had home gardens, while none of the male respondents in the IG reported having one. These gardens are typically used for household consumption or sharing, with minimal sales. This suggests an opportunity to use biogas slurry as fertilizer, enhancing garden productivity without additional cost. Nearly all biogas systems were reported as operational, which supports the feasibility of repurposing biogas by-products for home gardening, potentially boosting food security and sustainability at the household level.

h. **Liquid fertiliser:** The liquid slurry by-product from biogas systems was used by 55.6% of respondents as fertiliser for home gardens. Most reported improvements in garden yield and soil quality, though no formal soil analysis was conducted. Some households also re-feed the liquid slurry into the system to enhance its productivity.

11 Challenges for biogas

The following challenges were highlighted in the survey, focus group discussions, key informant interviews and the stakeholder validation workshop.

a. **Infrastructure and space constraints:** Five out of seven (71%) of the key informants (KIs) stressed that, on the main island, there was limited availability of adequate space for a biogas system set-up. Also, one KI mentioned that the design of the piggery does not allow efficient and maximum manure collection.

b. **Operational and maintenance (O&M) issues:**

- **Labour and time:** 57% of the KIs raised the issue that routine operation and maintenance is labour-intensive and time-consuming, discouraging regular use. This was also stressed during the survey; participants reported that all IGs had to visit the piggery daily to collect waste, spending 15–20 minutes on this task. On average, each household devoted about 8 hours weekly to biogas-related activities, such as cleaning pig pens, feeding the pigs and transporting waste. Additionally, 22% reported having less time for housework and paid work. This implies that users and potential users need to understand these time commitments and effort needed to ensure continuous use of biogas systems.
- **Local experts:** Around 43% of the KIs noted the absence of local maintenance experts, leading to reliance on overseas technicians which caused delays and higher costs.
- **Spare parts:** One KI pointed out that limited access to affordable spare parts and tools reduced biogas system reliability. Community stakeholders at the validation workshop noted that the shops on the island do not currently sell gardening tools or spare parts, limiting home garden upkeep and biogas system maintenance.
- **Training:** Two KIs and community stakeholders at the validation workshop noted a lack of training for household members, especially women, leading to operational challenges. The survey also indicated that men primarily handled biogas tasks, with 75% of women unaware of how to repair the system, highlighting the need for inclusive biogas O&M training
- **Capacity:** Approximately 30% of KIs reported that the amount of biogas produced was insufficient for daily cooking needs. This was due to limited system capacity or refill delays caused by insufficient manure or fresh water for cleaning pig pens and refilling the biogas system.

c. **Lack of resource and material availability:** 71% of the KIs noted limited availability of adequate organic waste for consistent biogas generation. Dependence on regular manure supply is challenging due to lack of collection strategies and the distance between piggeries and systems. Given Tuvalu's atoll geography, freshwater scarcity is a concern; one KI mentioned that systems require a significant amount of water, which is hard to store in some households. Additionally, some IG households used ocean water to clean pig pens due to freshwater scarcity, introducing salt into the manure and reducing system performance. Consequently, 22% of IG respondents observed slower biogas production, likely due to quality issues.

d. **Initial upfront high cost of the biogas system:** A 4.0 cubic meter home biogas system costs about AUD 2,400, which is too expensive for many families in Tuvalu. This was noted by approximately 30% of KIs and was confirmed during the validation workshop. The survey indicated that both groups (IG and CG), spent 30–75% of their monthly income on household expenses. Additionally, shipping costs and delivery times for equipment are barriers for average households. Moreover, one KI mentioned that no funds are allocated for maintaining and monitoring the biogas systems.

e. **Socio-cultural and behavioural challenges:** 57% of KIs noted that interest in biogas systems often fades, leading to low long-term usage. Biogas diaries, focus group discussions and the survey revealed that most participants rely on boys and/or men to manage and operate the system and care for the pigs and pig pens. When men are unavailable, there is extra physical labour for women and girls, which disrupts the biogas system's functionality.

f. **Awareness and knowledge gaps:** 43% of KIs noted that communities lack knowledge about operation and maintenance. There was also no communication channel for biogas users, and overseas technical assistance may be hindered by language barriers. One KI mentioned the absence of awareness programmes on system operation and biogas benefits. During the validation phase, stakeholders highlighted the need for future users to know: (i) space requirements for household biogas units, (ii) benefits and challenges of biogas systems, and (iii) factors for site selection to avoid damage from rough seas and strong winds.

g. **Challenges in transportation logistics:** One KI reported that scattered project sites complicate installation and maintenance logistics. Shipping materials to Tuvalu also adds costs and delays.

Letia collects manure from the piggery to feed the biogas system at his home

3 Policy recommendations

1. **Prioritise biogas in national energy policies:** Prioritise biogas systems within national energy and sustainability policies to reduce energy poverty. Biogas offers a cleaner cooking alternative, reduces health risks associated with traditional fuels, and supports energy affordability. Biogas will also increase the options for households to transition to cleaner fuel stacking while maintaining relatively the same efficiency levels as that of LPG stoves. It is recommended that biogas models be included in future power generation plans.

2. **Promote agricultural farms/home gardens:** Encourage agricultural farming or home gardens, utilising biogas slurry to grow vegetables and fruits, thus enhancing food security and promoting healthier eating habits.

3. **Support small-scale businesses using biogas:** Government incentives should be provided to businesses selling biogas slurry or using cookstoves to generate income, including female-led businesses. Scaling up biogas production can supply both cooking energy and electricity, supporting small-scale enterprise development.

4. **Fund research and development:** The Government of Tuvalu, regional organisations and funding organisations should invest in research focusing on, but not limited to:
   - biogas systems' tolerance to salt water;
   - empirical studies that analyse factors affecting biogas production, such as temperature, feedstock input, amount of input, time of input, and cultural norms;
   - exploring alternative feedstocks, such as seaweed, as an input for biogas systems;
   - feasibility studies of centralised biogas systems on smaller islets in Tuvalu;
   - exploring options for excess biogas produced, such as compressing and selling biogas;
   - the environmental impacts of biogas systems and slurry; and
   - similar studies conducted in other outer islands where the results may be different, as traditional gender roles are more diligently upheld in these areas compared to the capital (Funafuti) where this study was conducted.

5. **Develop and action strategies for effective biogas operation and maintenance:** Strategies should include:
   - establishing communication channels for reporting issues so that users can raise issues about biogas system use, and can get prompt responses on how to resolve an issue;
   - training locals in operation and maintenance of biogas systems and stoves;
   - educating users (men and women) on basic trouble-shooting;
   - providing training to trainers to deliver micro-credentials related to biogas systems;
   - allocating funds in future programmes or projects on biogas systems for maintenance, monitoring, transportation, provision of water tanks at pig pen sites, tools for maintenance, and garden tools so that biogas systems are utilised to their full capacity and potential; and
   - creating biogas service providers in Tuvalu and disposal strategies for end-of-life systems.

6. **Strengthen awareness programmes on biogas systems:** Awareness programmes are crucial due to the under-utilisation of biogas stoves, and locals not fully informed on the strengths and challenges of biogas as an energy source. The Department of Energy and community leaders should:
   - form teams to promote continuous biogas use;
   - organise regular peer-to-peer knowledge exchange sessions;
   - raise awareness about biogas benefits, electricity potential, and economic value of pig manure; and
   - address misconceptions and manage risks through pilot programmes.

7 **Maintain momentum of biogas operation in Tuvalu:** To ensure sustained use, the Department of Energy should:

- conduct quarterly household assessments on operation of biogas stoves;
- build user capacity regarding optimal pig ownership for biogas systems; and
- train users in livestock and gardening production.

8 **Address infrastructure and logistical challenges.** This can be done:

- by reviewing piggery designs for efficient manure and rainwater collection – led by the Department of Agriculture and Department of Energy; and
- by providing incentives to households to transport manure from their piggery to their home.

9 **Promote gender inclusive and equitable approaches, including training women in biogas operations and maintenance:** This can be done:

- by involving women and girls in training programmes on operation and maintenance of biogas systems. This will alleviate their burden of domestic work and ensure proper functioning of biogas systems.
- by referring to *Biogas systems in Tuvalu: Gender impact assessment*. This has recommendations on gender-inclusive and equitable approaches in biogas policies and programmes that support women's capacity and empowerment and the involvement of more women in the planning, installation, operation, training and management of biogas technologies.

Puaolele watering her home garden. Biogas slurry can be used as fertiliser to enhance home garden productivity

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