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SCALA Private Sector Engagement Facility Report

Feasibility Assessment of Biogas Potential in the Solomon Islands

ABSTRACT

Biogas is a proven and reliable technology to turn a liability like manure into an asset through conversion into a versatile fuel for power generation and cooking. In the Solomon Islands, this technology might contribute to achieving national and regional policy goals. However, biogas systems in the country are poorly developed and managed, with some noteworthy exceptions. This study investigates the feasibility of equipping commercial pig farms with anaerobic digestors to treat the slurry and other organic wastes produced on farm and generate renewable energy to substitute fossil fuels and firewood. The results of this assessment lead to the conclusion that, provided that external support with training on the management of these systems is provided to the country, the private sector has concrete sustainable investment opportunities with biogas.

Key messages

- ↗ Manure management is a source of methane emissions in Solomon Islands.
- ↗ Biogas Technologies can mitigate GHG emissions and help the country adapt its economy to climate change.
- ↗ Biogas potential in the country is not limited to manure management for which it remains particularly high.
- ↗ Technical, environmental and financial performances are expected to be positive in the case of commercial pig farms and likely other sectors.
- ↗ Capacity building and external support is necessary to enable biogas developments to express its potential to contribute to climate action.

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FOREWORD

Climate change has been a major impediment to sustainable development and environmental management in Solomon Islands. As a Least Developed Country (LDC) and Small Island Developing State (SIDS), climate change is the most important environmental and developmental issue for the country, being one of the most vulnerable countries to the adverse impacts of climate change. The battle against climate change is real, and it is the collective responsibility of both the public and private sectors to mitigate the impacts of climate change and manage emission of greenhouse gas produced.

The Government's country climate plans which include NDCs, the National Climate Change Policy, Low Emission Development Strategy (LEDS) and National Adaptation Programmes of Action (NAPA) provide a framework and way forward for scaling up climate solutions, recognizing the urgency of addressing climate change. One of the key outcomes of the climate strategy is the need to increase access to affordable energy in both urban and rural areas, embarking on renewable energy technologies such as biogas. The geographical distribution of islands and remoteness of small communities poses a real challenge in terms of setting up suitable enabling environments that would promote private sector engagement and foreign investments in expanding energy access and waste management activities in the country; therefore, investing in community-based adaptation initiatives is also essential to enhance the resilience of vulnerable populations and ecosystems.

In this context, we are excited to participate in the "Scaling up Climate Ambition on Land Use and Agriculture (SCALA)'s Private Sector Engagement (PSE) Facility. SCALA's aim to support NDCs and NAPs goals and translate them into effective climate solutions in land use and agriculture by engaging multiple stakeholders and promoting public-private collaboration will speed up the execution of adaptation measures, and mobilize crucial resources to guarantee the sustainability of these initiatives in the country. The outcomes of the study will outline the potential for setting up a biogas plant using pig waste at farm level and using residues from various sectors of the economy to generate electricity and gas for heating, cooking, and lighting. It also considers the production of organic fertilizers from residues to contribute to environmental pollution mitigation for sustainable biogas production.

The results of this research will be critical to inform climate policy and to encourage the private sector to invest in climate change strategies and sustainable biogas production. The exploration of diversified investment sources for clean energy production and waste management is paramount for the country to accelerate the country's climate goals, while ensuring more resilient and climate adapted livelihoods, communities, and economies in Solomon Islands.

Permanent Secretariat

The Ministry of Environment, Climate Change, Disaster Management and Meteorology (MECDM)

1. INTRODUCTION

1.1. Background and objective of the study

The Solomon Islands, an archipelago comprising 994 tropical islands and atolls, face critical environmental and developmental challenges.[1] Around 80 percent of their population live in rural, low-lying coastal areas, relying heavily on agriculture, forestry, and fisheries for sustenance and livelihoods.[2] These sectors contribute significantly to the country's GDP, with timber exports accounting for 72 percent of total exports.[3]

Figure 1. Map of Solomon Islands

Source: https://www.mapsland.com/oceania/solomon-islands/detailed-elevation-map-of-solomon-islands-with-other-marks

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[1] Ministry of Environment, Climate Change, Disaster Management and Meteorology Honiara, Solomon Islands, SOLOMON ISLANDS 2021 NATIONALLY DETERMINED CONTRIBUTION (NDC). Available on: https://unfccc.int/sites/default/files/NDC/2022-06/NDC%20Report%202021%20Final%20Solomon%20Islands%20%281%29.pdf

[2] Kereseka, J. 2021. Solomon Islands Ridge to Reef Island Diagnostic Analysis Report. Prepared for the Ministry of Environment Climate Change Disaster Management and Meteorology, Solomon Islands Government, Honiara. Produced and published by GEF Pacific International Waters Ridge to Reef Regional Project, Pacific Community (SPC), Suva, Fiji , 71 pp. Available on: https://www.pacific-r2r.org/sites/default/files/2021-12/Solomon%20Islands_IDA.pdf

[3] Timber trade portal https://www.timbertradeportal.com/en/solomon-islands/147/timber-sector

Being a Least Developed Country (LDC) and Small Island Developing State (SIDS), the Solomon Islands is extremely vulnerable to the adverse impacts of climate change. Its geographical location in the earthquake-prone "Ring of Fire" exposes it to frequent earthquakes, tsunamis, and landslips. The nation is highly susceptible to tropical cyclones, which pose serious threats, resulting in flooding and wind damage.[4]

The Solomon Islands has recognized the urgency of addressing climate change and formulated its National Adaptation Programme of Action (NAPA) [5] in 2008. Key sectors prioritized for support include agriculture, human settlements, water, sanitation, and waste management. The National Climate Change Policy (2012-2017)[6] and the submission of its first Nationally Determined Contribution (NDC) in 2016[7] reflect the country's commitment to climate change mitigation. In alignment with its priorities, the Solomon Islands has set ambitious targets in its NDC, aiming for net-zero emissions by 2050. Renewable energy and energy-efficient technologies, particularly biogas, are central to achieving these goals. The National Energy Policy, formulated in 2014, aims to achieve 100 percent reliance on reliable, affordable, and clean sources of electricity by 2050.[8] Priority renewable energy mitigation actions of the NDC include increasing affordability and accessibility to electricity in both urban and rural areas, improving the enabling environment to foster private investment in the electricity sector and consolidating funding opportunities for programme upgrading and upscaling.

In pursuit of sustainable development and cleaner technologies, the Solomon Islands has engaged in cross-sectoral initiatives. In particular, we can mention the Global Environment Facility's (GEF) Programme *Stimulating Progress towards Improved Rural Electrification in the Solomons* (SPIRES),[9] which focuses on reducing greenhouse gas emissions and enhancing electricity access in rural communities.

Recognizing the importance of private sector engagement, in 2022 the Solomon Islands government expressed interest in the *Scaling up Climate Ambition on Land Use and Agriculture* (SCALA)

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[4] International Climate Change Adaptation Initiative, 2013. Current and future climate of the Solomon Islands. Available on: https://www.pacificclimatechangescience.org/wp-content/uploads/2013/06/13_PCCSP_Solomon_Islands_8pp.pdf

[5] Solomon Islands National Adaptation Programme of Action (NAPA), 2008. Available on: https://www.adaptation-undp.org/resources/assessments-and-background-documents/solomon-islands-national-adaptation-programme-action

[6] Ministry of Environment, Climate Change, Disaster Management and Meteorology (MECDM) , Solomon Islands, 2012. National Climate Change Policy. Available on: https://www.fao.org/faolex/results/details/en/c/LEX-FAOC167158/

[7] Ministry of Environment, Climate Change, Disaster Management and Meteorology Honiara, Solomon Islands, 2016. Nationally Determined Contribution (NDC). Available on: https://unfccc.int/sites/default/files/NDC/2022-06/NDC%20Report%202021%20Final%20Solomon%20Islands%20%281%29.pdf

[8] Ministry of Mines, Energy and Rural Electrification, 2014. Solomon Islands National Energy Policy 2014. Available on: https://policy.asiapacificenergy.org/node/2874

[9] https://www.thegef.org/projects-operations/projects/9787

Programme,[10] which supports countries to build adaptative capacity and reduce greenhouse gas emissions in order to meet targets set out in their National Adaptation Plans (NAPs) and nationally determined contributions (NDCs). Specifically, the government requested support from the SCALA Private Sector Engagement (PSE) Facility to strengthen private sector participation in adaptation initiatives, foster public-private collaborations, and enable private investment in the agri-food sector to bridge the climate finance gap.

Within this framework, the United Nations Framework Convention on Climate Change (UNFCCC), the Ministry of Environment, the Food and Agriculture Organization (FAO), and the United Nations Development Programme (UNDP) collaborated to assist the Solomon Islands in aligning their national objectives. This collaboration focuses on activities that are in line with the scope of support provided by the Private Sector Engagement (PSE) Facility. The aim is to strategically contribute to the nation's overarching goals, leveraging existing adaptation initiatives and conducting evidence-based research. This effort supports the Global Environment Facility's (GEF) program on rural electrification, emphasizing the use of biogas as an alternative.

This study focuses on exploring the potential use of residues from various sectors of the Solomon Islands' economy to generate electricity and gas for heating, cooking, and lighting. This study explores the potential use of residues from various sectors of the Solomon Islands' economy to generate electricity and gas for heating, cooking, and lighting. It also examines the production of organic fertilizers from residues, aiming to enhance cost recovery, reduce carbon footprints, and mitigate environmental pollution. Anaerobic digestion technology supports sustainable biogas production and promotes adaptation through the use of biogas by-products.

The project aims to actively engage the private sector, streamline investment processes, and foster collaboration between public and private entities. Its overarching goal is to create an environment that attracts investments and facilitates sustainable biogas production through anaerobic digestion technology in the Solomon Islands.

[10] https://www.fao.org/in-action/scala/en

1.2. Target sectors and case studies

As introduced, this study centres on investigating the possibility of using organic residues from diverse sectors of the Solomon Islands' economy to produce biogas through anaerobic digestion. The assessment first looks into a large contributor and strategic sector for the economy of the Solomon Islands: pig farming. Subsequently, the results of a pre-feasibility assessment will inform on the opportunity to expand to another key contributor to climate change in the country: organic fraction of municipal solid waste. The assessment, in the second phase of the study (Tier II), will deepen the analyses, validate, refine, and discuss the results with local stakeholders. For each of these sectors and economic activities, the assessment considered a specific case study. The livestock sector in the Solomon Islands is significant for the economy and rural livelihoods, primarily centred around small-scale subsistence farming of cattle, pigs, and poultry.

The study aims to support NDC and NAP's goals. About the livestock sector, the emphasis lies in valorising livestock residues through biogas and organic fertilizer production using anaerobic digestion systems. This technology provides a renewable energy source for households and agriculture while mitigating greenhouse gas (GHG) emissions and soil and water pollution, and through soil quality improvements contributes to increasing the resilience of the country to climate change. The main case study focuses on a representative pig farm within the sector, aiming to conduct a thorough feasibility analysis for establishing a biogas plant that valorises the pig manure produced on the farm. The case study farm was selected since is part of the Solomon Islands Pig Farms Association (SIPFA) and well represents the business model of the sector, including its challenges and opportunities for future development. Moreover, the farm is located conveniently near the capital city of Honiara although in a rural setting, thus facilitating access and data collection activities. Its owner is a prominent member of SIPFA, which ensures effective outreach and sharing of the results to other pig farmers and their engagement in the Private Sector Facility of SCALA. SIPFA counts more than 80 registered farms only in Guadalcanal Island, and the results of this study are going to be disseminated among those members to maximise the scaleup potential of the intervention proposed.

In addition to pig manure/slurry, this study considers other potential agricultural residues as well, evaluating biogas and related energy products production potential. The overarching goal is to replace current energy sources used on farms (diesel for electricity generation and conventional firewood usage from mangroves for cooking), with a focus on creating a lasting impact on individual farms and the wider community through the adoption of energy-efficient technologies.

Figure 2. Fattening pigs in a piggery in Solomon Islands

Note: Usually, the pigs from each litter are kept together until they reach about 25 kg and then are sold to customers.

This study also explores the potential for generating biogas from the organic fraction of municipal solid waste produced in the Solomon Islands, which will be fully presented in the Tier II report. By expanding the scope to include these additional waste streams, we aim to assess the viability of multi-feedstock biogas production systems. This approach not only enhances the environmental benefits but also explores diversified sources for clean energy production and the reduction of pollution as well as several socio-economic issues linked to unsustainable management of waste in Solomon Islands.

An estimated 80 tonnes of municipal waste are generated daily in Honiara. Only about 59 percent of Honiara's households have access to solid waste collection services. Access is much lower in the surrounding peri-urban areas. The Honiara City Council (HCC) and its subcontractors collect, transport, and dispose of waste at the Ranadi dumpsite, which pollutes the adjacent creek and groundwater and may be vulnerable to sea level rise. Industrial and medical waste is not disposed of safely. Honiara lacks widespread and systematic waste segregation. Service provision, the enabling environment for enforcement of existing legislation, and private sector participation are weak. Residents resort to illegal dumping and burning of waste. This situation is common throughout the Solomon Islands, with many people living on the landfill premises and scavengers collecting various residual wastes unaware of the consequences on their health and well-being.

Figure 3. The Ranadi landfill in Honiara

Note: Scavengers living on the surface of the landfill and their improvised sheds are clearly visible.

1.3. Biogas technology

Biogas technology is a sustainable and environmentally friendly solution that exploits the chemical composition of organic waste and the capacity of specific strains of bacteria to produce a versatile energy source: methane gas. It involves the anaerobic digestion of organic matter, such as agricultural residues, animal manure, sewage water, and food waste, by microorganisms to generate biogas, which is a mixture of methane (50 – 60 percent) and carbon dioxide (40 – 50 percent).

This renewable energy resource can be utilized for various applications, including electricity generation, heating, and as a clean fuel for cooking. Biogas technology not only helps address waste management challenges by converting organic waste into valuable energy, but it also contributes to mitigating GHG emissions by avoiding the otherwise inevitable emission of methane resulting from unmanaged manure and slurry production. Furthermore, the residual by-product of the biogas production process, known as digestate, serves as an enriched organic fertilizer, offering an additional adaptation benefit for agriculture since it can increase soil biodiversity and health, in turn enhancing the resilience of soils to climate stresses. The versatility, sustainability, and waste-to-energy aspects of biogas technology make it a compelling solution for promoting energy efficiency and addressing environmental concerns in diverse settings around the world. In the specific case of the Solomon Islands then, biogas production and use can also have a relevant contribution to climate change adaptation, although indirectly. As the majority of the population relies on wood fuels for cooking and lives near or in coastal areas, the encroachment into mangrove woodlands is a prominent aspect. Mangroves are a key ecosystem that protects the coastline from sea level rise and other climate change-induced impacts. By delivering a competitive alternative to mangrove use for cooking, biogas can indirectly reduce pressure on mangroves, thus contributing to effective adaptation while ensuring extended energy access.

Biogas output depends primarily on the quality of organic materials involved, and, as far as manure is concerned, output also varies with the animal species. One tonne of cattle manure will usually yield about 25 m^3 of biogas and poultry manure about 190 m^3, whereas industrial and residential wastes yield approximately 130 m^3. To collect manure for biogas, livestock must be kept confined. Under favourable conditions, a biogas plant brings numerous advantages to end-users. These include the production of energy for lighting, heating, and electricity. It also contributes to improved sanitation by reducing pathogens, worm eggs, flies, and odour. Additionally, it reduces the workload of women and girls by minimizing the need for firewood collection, an activity disproportionally entrusted to this group. Biogas stoves exhibit superior cooking performance compared to wood fuels while minimizing the emission of smoke and other air pollutants, especially in indoor cooking settings. Indoor air quality in fact, is significantly enhanced when biogas is used, since these stoves do not emit black carbon, and emit far lower concentrations of particulate matter (PM) and other harmful chemicals compared to traditional wood fuels or kerosene. On the environmental front, biogas technology offers benefits such as substituting fertilizers and reducing greenhouse gas emissions. Users can benefit from economic savings as biogas replaces the need for expensive fuels and fertilizers. This is especially true in a country like the Solomon Islands, where energy costs are among the highest in the world.

However, this technology holds some barriers. A technical challenge for the efficient production of methane lies in the availability of feedstock with a correct carbon-to-nitrogen (C/N) ratio. This is in turn linked to the main barrier to the adoption of these systems: the need for capacity and training on the fundamentals of anaerobic digestion, which encompasses chemistry and physics. Additionally, the financial aspect poses a hurdle, especially for small to medium-sized farms, as the implementation of biogas systems can incur significant upfront expenses.

1.3.1 Sustainable manure management with biogas production

Biogas systems can be found in diverse sizes, determined by the scale of operation and the quantity of waste. According to this, we can distinguish:

- **Household-scale biogas systems (farms with 5 to 50 pigs)**
  These systems are tailored for individual households or modest farms, generally encompassing a capacity ranging from 1 m^3 to 10 m^3 of daily biogas production. They aptly manage the organic waste generated by a limited number of animals, offering a source of cooking fuel and occasionally household lighting. In the Solomon Islands, on average 5 to 8 pigs are raised in rural areas by the majority of the households.
- **Commercial small-scale biogas systems (farms with 50 to 500 pigs)**
  These systems are commonly deployed within communal setups, agricultural cooperatives, or small-scale commercial farms, like the ones studied in the Solomon Islands. With a capacity ranging from 10 m^3 to 100 m^3 of daily biogas production, they effectively process a greater volume of organic waste from multiple sources, be it several farms or an entire community's organic waste stream. These systems yield energy suitable for cooking, heating, and even modest-scale electricity generation (1 – 5 kW).
- **Commercial large-scale biogas systems (farms with 500+ pigs or community organic waste disposal)**
  These systems are tailored to industrial or commercial requisites, catering to extensive livestock farms and food processing plants or landfills. These systems are frequently integrated with combined heat and power (CHP) setups, a configuration enabling both electricity and heat generation.

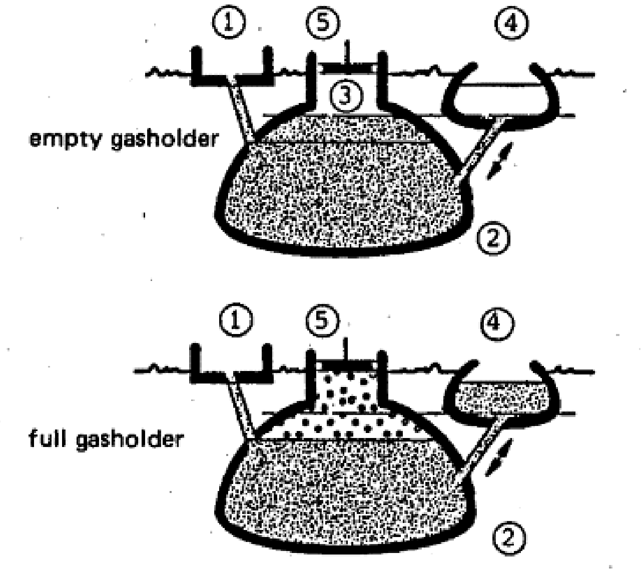
Examples of technical parameters and unit costs for equipment of different capacities of biogas systems

Category	Capacity	Energy capacity	Unit cost (USD)
Small	20–30 kg/day manure	1 m^3 biogas/day	800
Household	60 kg/day manure	2 m^3 biogas/day	800 – 1 000
Small	44 kg/day manure	2.5 m^3 biogas/day	1 500
Medium	1 500 kg/day manure	8 – 10 m^3 biogas/day	3 000 – 5 000
Large	10 tonnes/day manure	30 m^3 biogas/day	22 000 – 30 000

When considering biodigester technologies based on the scale of operation, various options become available. At the household level, common technologies include self-built biogas systems. These are mainly Fixed Dome Biodigesters and Floating Drum Biodigesters.

A Fixed Dome Biodigester is a closed, dome-shaped structure where waste such as manure, dung, and human excrement is introduced. Methanogenic bacteria then digest the waste, producing biogas and slurry (digested waste). This type of digester is suitable for extreme climates due to its design mostly below ground level, protecting it against extreme low as well as high temperatures. Advantages of this type of digester include being relatively cheap and durable, labour-intensive construction providing local employment opportunities, lack of moving parts, and good thermal insulation. However, challenges include the need for high technical skills for gas-tight construction, difficulties in monitoring the digestion process, the requirement for a special sealant for the gasholder, and potential gas leaks if not well-designed.

Figure 4. A schematic sketch of a fixed dome biogas plant

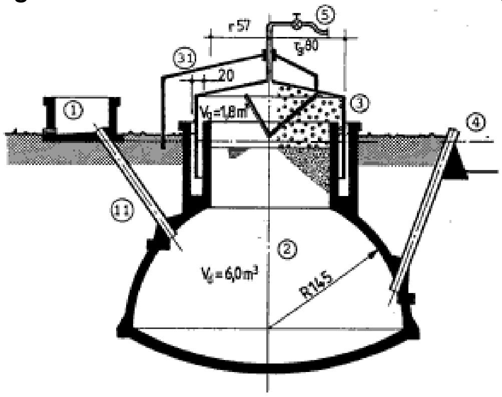


Source: Energypedia.info

Note: 1. Mixing pit, 2. Digester, 3. Gasholder, 4. Displacement pit, 5. Biogas outlet pipe.

Floating Drum Biodigesters are semi-continuous Stirred-Tank Reactors (CSTR) type reactors. Their operation is similar to fixed dome digesters, with the produced gas collected in a movable steel drum (gasholder) guided by a frame. Advantages include easy understanding and operation, airtight gas drums with regular maintenance, and constant gas pressure due to the weight of the drum. However, disadvantages involve the relatively expensive and maintenance-prone steel drum, which may get stuck, the need to ensure the airtightness of the structure and the high likelihood that gas leaks occur undocumented.

Figure 5. A schematic sketch of a floating drum biogas plant

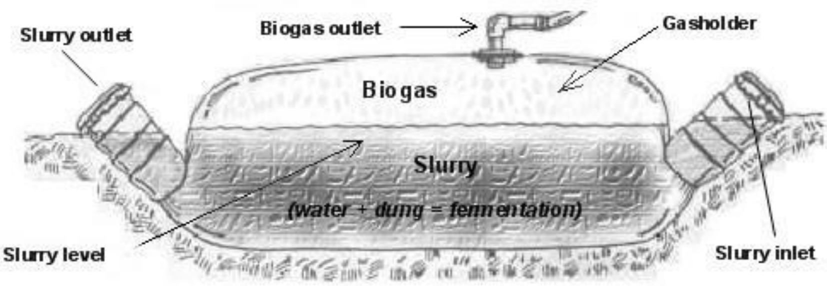


Source: Energypedia.info

Note: 1 Mixing pit, 11 Fill pipe, 2 Digester, 3 Gasholder, 31 Guide frame, 4 Digestate overflow, 5 Biogas outlet pipe.

For commercial applications, PVC Soft Reactors, also known as balloon plants or bag digesters, employ a plastic or rubber bag combining the gas holder and digester in a plug-flow type reactor. Gas is collected in the upper part, and manure is stored in the lower part. The pressure of the gas can be adjusted by placing stones on the bag. Advantages include low costs, simple technology, and uncomplicated cleaning. However, drawbacks include a short lifespan, susceptibility to physical damage, difficulties in repair due to the need for high-quality plastic/PVC, and especially the lack of a stirring system requires periodic emptying and cleaning of the entire system to avoid clogging and inefficiencies.

Figure 6. A bag digester sketch



Source: Energypedia.info

Fibreglass reactors, another commercial technology, share similarities with other categories of digesters but are designed to maximise benefits and reduce the challenges of this technology to the minimum. Advantages include an easy-to-understand and operate design, longer lifespan compared to PVC and soft bags, and efficient biogas production. However, challenges encompass relatively high upfront costs, availability outside the manufacturer's country, difficulty in construction on bedrock and limitations in utilizing these systems in warm temperatures during summer, unless properly shaded and thermally insulated.

For small-size farms (50 to 500 heads), turnkey systems are becoming widely available. These systems enable the production of gas for cooking and/or heating purposes, as well as the simultaneous production of electricity and heat, providing versatile applications within livestock farming and creating additional income streams through potential energy sales or savings from avoided energy expenditures.

Existing on-farm tanks can be utilized for storing slurry and manure. These plants are designed to be powered exclusively by available manure and waste on the farm, with the option to incorporate other agricultural residues or agro-industrial by-products like whey, vegetable, fruit scraps, and so on. Installation involves creating a concrete platform to support the container and digester, along with preparing the excavation for laying connecting pipes. Effluents are drawn directly from the existing collection tank or channelling system present on the farm. Fresh manure or slurry is fed into the digester, where it undergoes fermentation at a constant temperature (39-42 °C), facilitated by a cohort of bacteria in the absence of oxygen, resulting in the extraction of methane-rich gas.

This product is commonly referred to as *biogas* and after a filtration to eliminate possible impurities from the digester, it is transformed into energy in an internal combustion engine and a generator. The plant components include an insulated steel tank topped with a double-membrane gasometer dome, and a container housing all technological components, including a stirring system and gas pressure regulators. The digester, constructed from prefabricated stainless-steel panels with built-in insulation and an internal impermeable membrane to resist chemical aggression, is equipped with internal stainless steel heating pipes, a mixer, a double-membrane cover, sensors and safety protections.

Figure 7. Turnkey biogas system

Note: Photo credit - Puxin Technologies.

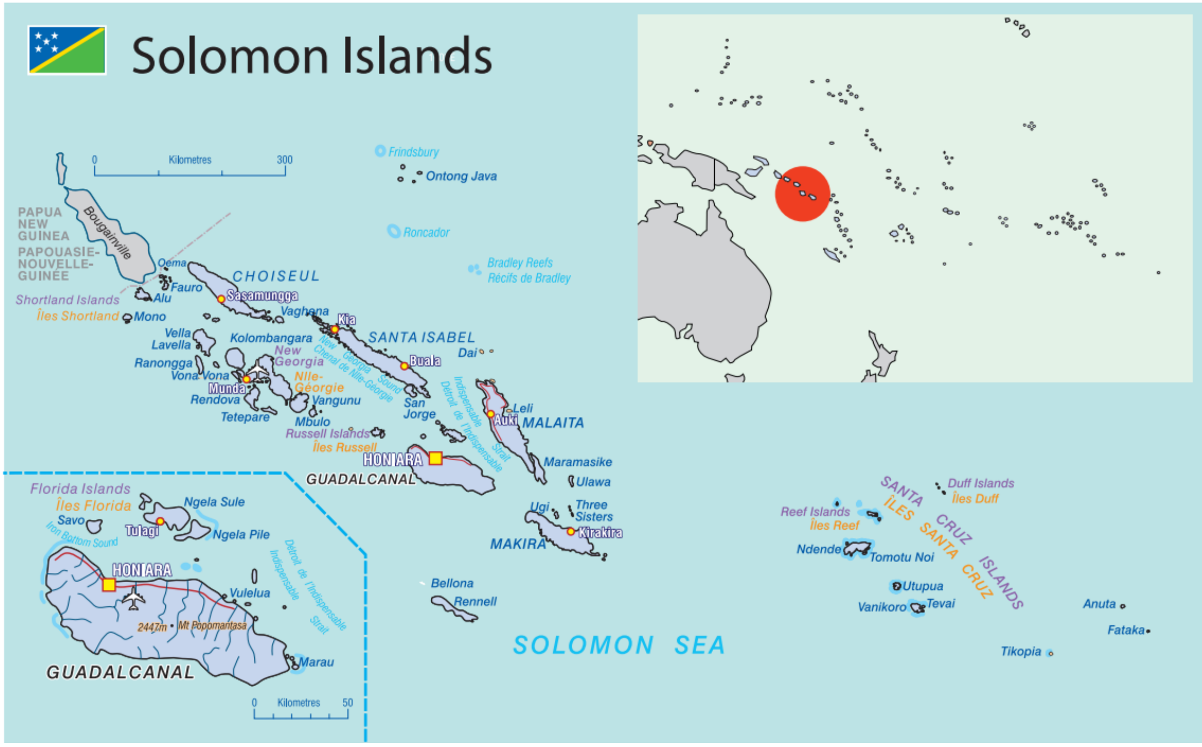
Turnkey systems have several advantages compared to self-built biodigesters, and as these become more available in many countries worldwide, their presence is slowly replacing fixed dome or floating drums.

2. COUNTRY OVERVIEW

2.1. Background

The Solomon Islands, an archipelago nation in the South Pacific, boasts a population of approximately 552 000 people [1].

Figure 8. Solomon Islands map



Source:
https://policy.asiapacificenergy.org/sites/default/files/volume1_solomon_islands_national_energy_policy.pdf

The economy of the Islands is primarily based on agriculture, forestry, and fisheries, with subsistence farming playing a crucial role in the lives of many inhabitants. In 2012, the per capita gross domestic product (GDP) was estimated at SI$ 11 223 (approximately USD 1 582) [2], reflecting the economic conditions at that time. However, despite its economic potential, the Solomon Islands faces challenges such as geographical dispersion, limited infrastructure, and susceptibility to natural disasters.

The capital city, Honiara, is a significant urban centre, accommodating around 78 000 residents. The city has experienced substantial growth, with an estimated annual average of 4.7 percent from 2010 to 2015 [3]. This rapid urbanization brings both opportunities and challenges, influencing aspects such as employment, housing, and social services. The city lacks developed infrastructures, including paved roads and sewage systems that, despite the current efforts, are being completed at a slower pace than its population growth. Moreover, a notable demographic characteristic is the presence of informal settlements in peri-urban areas around Honiara, where approximately 35 percent of the city's population resides. In these areas – as well as in the rest of the country – fundamental infrastructure is inexistent. This dynamic reflects the complex interplay between urbanization, migration patterns, and economic activities in the Solomon Islands. As the Solomon Islands navigates the path of development, understanding the demographic and economic landscape becomes crucial for policymakers and stakeholders working towards sustainable growth, community development, and the overall well-being of the population.

2.1.1 Climate Change

The Solomon Islands are highly vulnerable to climate-related natural hazards, as outlined in the Climate Risk Country Profile edited by the World Bank in 2021 [4].

The archipelago frequently experiences tropical cyclones and associated storm surges, which pose significant risks to coastal communities and infrastructure. These events can cause widespread destruction, displacement, and loss of life, particularly in low-lying areas. Intense rainfall events often lead to flooding, exacerbating the vulnerability of communities located in flood-prone zones. Floods can damage homes, disrupt livelihoods, and contaminate water sources, increasing the risk of waterborne diseases as it happened frequently over the past decade in the country.

The Solomon Islands also face the threat of droughts, which can have severe consequences for agriculture, water availability, and food security. Rural communities reliant on rain-fed agriculture are particularly susceptible to the impacts of prolonged dry spells. Steep terrain and deforestation make the Solomon Islands prone to landslides and soil erosion, especially during heavy rainfall events. These hazards threaten lives, infrastructure, and agricultural land, exacerbating the challenges of climate adaptation and disaster risk reduction. Coastal erosion and rising sea levels are major concerns for the Solomon Islands, with low-lying coastal areas at risk of inundation and land loss and the decreasing protection function of mangroves. Coastal communities face the threat of displacement, loss of property, and damage to critical infrastructure due to erosion and saltwater intrusion. Climate-related natural hazards have profound implications for the livelihoods and well-being of Solomon Islanders, particularly those dependent on agriculture, fisheries, and natural resources. Disruption of these sectors can undermine food security, exacerbate poverty, and hinder economic development efforts.

The Solomon Islands hold unique and biodiverse terrestrial and marine habitats. However, while the majority of the land surface remains covered by tropical rainforest, increasing human pressure, particularly from logging, threatens ecosystem integrity. Indeed, island biodiversity faces a variety of human pressures. Forestry is a particularly critical industry in the Solomon Islands contributing around one-sixth of government income. Output has been estimated to be as much as seven times the sustainable yield and is understood to contribute significantly to income inequality. Climate change and variability may compound these pressures. Sea-level rise, for instance, not only threatens humans residing on Pacific islands but also their unique ecosystem functions and ecology. Past seismic activity provides insights into the potential long-term impacts of sea-level rise. An earthquake in 2007 which induced rapid subsidence and hence 'relative' sea-level rise, highlighted the vulnerability of the Solomon Islands' mangrove.

Figure 9. The barred mudskipper (Periophthalmus argentilineatus) inhabits mangroves across the Pacific and Indian Ocean

Addressing the challenges posed by climate-related natural hazards requires integrated approaches to disaster risk reduction and climate change adaptation. Investing in early warning systems, resilient infrastructure, and community-based adaptation initiatives is essential to enhance the resilience of vulnerable populations and ecosystems. The Solomon Islands hold unique and biodiverse terrestrial and marine habitats. However, while the majority of the land surface remains covered by tropical rainforest, increasing human pressure, particularly from logging, threatens ecosystem integrity. Indeed, island biodiversity faces a variety of human pressures. Forestry is a particularly critical industry in the Solomon Islands contributing around one-sixth of government income. Output has been estimated to be as much as seven times the sustainable yield and is understood to contribute significantly to income inequality. Climate change and variability may compound these pressures. Sea-level rise, for instance, not only threatens humans residing on Pacific islands but also their unique ecosystem functions and ecology. Past seismic activity provides insights into the potential long-term impacts of sea-level rise. An earthquake in 2007 which induced rapid subsidence and hence 'relative' sea-level rise, highlighted the vulnerability of the Solomon Islands' mangrove forests (and hence coastal economies) to climate change, with a 35 percent decline in mangrove forest cover resulting from relative sea-level rise in the range of 30 cm–70 cm in the affected area. Research has also shown that the inundation of low-lying islands has the potential to remove important refuges for migrating sea birds. As climate changes, the suitable range for species to inhabit shifts either upslope or away from the equator. In the Island environment, the capacity for species to shift is extremely limited and as such loss and extinction are becoming increasingly likely. Major concerns have been raised for the terrestrial ecology of low-lying Pacific islands, for example, endemic lizards, which may become trapped in a shrinking habitat.

Figure 10. A lone mangrove plant stands in the coastal area as a reminder of the fast pace that sea level rise is taking in the Solomon Islands

Further research is needed to better constrain the potential impacts of climate change on island ecology, and the potential knock-on effects on ecosystem service provision. From a least-regrets perspective, the risks of climate change only increase the importance of reducing human development impacts which currently undermine the resilience of island ecosystems. Climate change could influence food production via direct and indirect effects on crop growth processes. Direct effects include alterations to carbon dioxide availability, precipitation, and temperatures. Indirect effects include impacts on water resource availability and seasonality, soil organic matter transformation, soil erosion, changes in pest and disease profiles, the arrival of invasive species, and a decline in arable areas due to the submergence of coastal lands.

Climate change has been identified as a major threat to food supply and security in the South Pacific. Issues such as low incomes, poor routes of connectivity and access, and dependence on imports are highlighted as key vulnerabilities. Research into the future productivity of specific crops in the Solomon Islands is relatively limited but optimal crop ranges will likely shift, and productivity levels change.

The climate change impacts on cocoa production have been explored and are broadly negative, particularly under higher emissions pathways and later in the century. Cocoa production typically declines when the maximum daily temperature surpasses 32°C, a phenomenon which could occur regularly under the most extreme projections. Issues related to extreme rainfall have been qualitatively reported in other crops, including root crops, fruit trees, and vegetables. Further research is urgently required first to constrain climate projections, and second to model future crop productivity rates. The Solomon Islands Second National Communication details key climate vulnerabilities by region. A common issue is the degradation of soils. Soil health intersects with both land management practices and climate through the impact of extreme rainfall events. Extended periods of drought, followed by extreme rainfall, can contribute to significant soil erosion and represent a climate threat. Mismanagement of soils exacerbates this situation and there is the impellent need to introduce and scale up sustainable soil management practices, including the use of compost and organic fertilizers. This is a crucial point that relates closely to the co-benefits that a biogas project could have on soil quality in the Solomon Islands. The impacts of climate change can be strongly mitigated through ecological restoration and land stewardship, and soil management practices are a crucial step in the right direction. Studies have thus far emphasised that pressures such as intensification, migration, and logging represent the greatest threat to traditional farming systems in the Solomon Islands, but monitoring will be important as climate changes intensify. An issue identified where adaptive capacity is concerned is the common lack of diversified income sources for smallholders, increasing disaster risk when climate hazards strike. This, coupled with the high costs for agriculture activities – highly dependent on imported fossil fuels – makes it even more important to exploit the energy potential of available agricultural residues.

The Solomon Islands face a range of climate-related natural hazards that pose significant risks to lives, livelihoods, and sustainable development. Urgent action is needed to strengthen resilience, mitigate risks, and build adaptive capacity to safeguard the well-being of present and future generations.

2.1.2 Country's NDC targets

The Solomon Islands' Nationally Determined Contribution (NDC) [5] covers mitigation, adaptation, means of implementation, and equity. Mitigation efforts will be assessed over five-year intervals from 2020 to 2030, targeting a conditional 27 percent reduction in greenhouse gas (GHG) emissions by 2025 and 45 percent by 2030. The NDC places specific emphasis on the energy sector, focusing on power and transportation and encompassing fossil fuels (which constitute 90 percent of the reported national inventory) and forest sequestration. Unconditional contributions prioritize renewable energy and energy efficiency, including hydropower and solar farms, initiatives currently undertaken by the government. Successful execution of conditional mitigation actions is contingent upon capacity building, technology transfer, and timely financial support via grants and bilateral programs.

In the adaptation section, the NDC underscores gaps, barriers, and needs, addressing issues such as institutional challenges, knowledge sharing, and capacity building. Challenges include translating climate science into local languages and overcoming cultural barriers. The Solomon Islands envisions a community-based 'whole of island' approach for vulnerability, adaptation, and management, aiming for direct finance for resilience projects. Plans are in motion to fortify institutional structures, enhance community capacity, and establish a national climate change trust fund supported by market-based mechanisms. Despite being a minor contributor to GHG emissions, the Solomon Islands acknowledges that realizing long-term sustainable development aligned with emission reduction relies on accessible external funding.

2.1.3 National Adaptation Programme of Action

The Solomon Islands is one of the most vulnerable countries to the adverse impacts of climate change. Climate change is expected to limit greatly the country’s ability to meet sustainable development goals by impacting negatively on economic and social sectors. The estimated costs of adaptation will be disproportionately high compared to the gross domestic product (GDP) of the Solomon Islands. The National Adaptation Programme of Action includes key activities for each target sector of the economy, including agriculture, energy, and waste management. Agricultural productivity and food security in the Solomon Islands are heavily influenced by weather patterns. With 60 percent of the land being hilly or mountainous and only 1 percent arable, most communities reside on narrow coastal plains or higher lands, which are prone to soil erosion and landslides. Traditional subsistence farming is transitioning to cash crops, but this shift has shortened fallow periods, exacerbated soil erosion and reduced soil fertility. Population pressure and slash-and-burn practices further deteriorate the land, leading to pollution and pest outbreaks, ultimately lowering crop yields. The Ministry of Agriculture and Livestock (MAL) aims to promote sustainable agriculture and improve food security through education, research, and extension services. Key initiatives include controlling destructive pests, researching resilient crop varieties, and enhancing weather forecasting tailored for agriculture. The Agricultural Research Division focuses on practical solutions for diverse cropping systems, establishing experiment stations across various climatic zones. The National Adaptation Programme of Action (NAPA) for agriculture targets sustainable land management programs as one of the main actions to adapt to the changing climate, by reclaiming degraded lands through the use of soil enhancement practices, including organic fertilizer use. The protection of mangrove areas is another key resource in the fight against climate change and sea level rise included in the NAPA. Decreasing any form of pressure on this precious resource is key to ensuring the resilience of the country against marine water ingress episodes into the scarce arable land found in the country's lowlands. The energy sector is going to be affected by climate change in several ways. As with most Pacific Islands Countries, the majority of energy used in the Solomon Islands is from biomass, mainly for cooking and drying coconut and cocoa for export. Accessible fuel wood is increasingly scarce due to over-harvesting and in areas where mangroves are harvested for fuel, there can be coastal erosion. People dependent on biomass for fuel often live a subsistence lifestyle and are reliant on transport by dugout canoe or outboard motor and inter-island shipping by diesel ferry. Climate change will affect even energy generation in the country as flooding and associated cloud cover will impact photo-voltaic (PV) generation and wind power. The diversification of the renewable energy portfolio for the Solomon Islands must be coupled with efficient bioenergy technologies that make use of available waste resources instead of encroaching further into fragile mangrove lands. Waste management, particularly organic wastes is a major issue in the Solomon Islands, and climate change, with its flooding and drought events, exacerbates the impacts of unmanaged organic wastes – including septic and sewage liquids – on the livelihoods of people. The NAPA encourages waste management practices along with climate change considerations to decouple these two factors and reduce the magnitude of their impacts.

2.1.4 Energy sector overview

As introduced, the majority of the population in the Solomon Islands resides on the six major islands, with about 350 of these islands being inhabited. Furthermore, 76 percent of the population resides in rural communities. The dispersion of the rural population across numerous islands poses a challenge in establishing a centralized national electric grid and hinders the provision of electricity to the entire population. Only around 14 percent of the Solomon Islands' residents have access to electricity, which is supplied by the state-owned utility, Solomon Islands Electricity Authority (SIEA). While the more densely populated provinces of Guadalcanal and Western Province have higher electricity access rates, the other more remote provinces experience significantly lower rates.

Most of the Solomon Islands' energy is generated using fossil fuels, particularly diesel fuel, which accounts for approximately 97 percent of the country's energy generation. The remaining 3 percent comes from renewable sources such as hydropower and solar. Since there is no domestic source of diesel, it all needs to be imported. This reliance on imports results in high and unpredictable energy costs, posing additional challenges to electrification efforts. As of March 2020, the Solomon Islands had the world's highest electricity costs, which is at least 30 percent higher than the costs in neighbouring Pacific Island countries, according to the Economics Association of Solomon Islands (EASI). These high rates make it difficult for businesses to afford and discourage individuals from purchasing electricity.

Due to the limited access to electricity, many residents of the Solomon Islands resort to alternative energy sources such as kerosene, wood, gas, and charcoal. However, these alternatives present health hazards due to emissions from burning and flammability. Those without access to the main grid heavily rely on kerosene lamps, with a smaller percentage using solar, diesel generators, and wood for lighting.

Regarding energy policy, the Ministry for Development Planning and Aid Coordination in 2016 updated the National Development Strategy (NDS) for the Solomon Islands, outlining countrywide and cross-sector strategies over twenty years. In 2014, the Ministry of Mines, Energy, and Rural Electrification formulated the National Energy Policy and Strategic Plan (SINEP) to guide policy decisions and enhance the effectiveness of the energy sector. Aligned with the 2011-2020 NDS, SINEP aims to increase access to reliable, affordable, and clean energy through six specific goals assigned to subsectors.

Among other renewable technologies that could contribute to a transformation of the energy sector, biomass and waste-to-energy (WTE) emerge as key solutions. These technologies convert organic materials into electricity through burning, or conversion to gas or liquid fuel. Biomass feedstocks may include crop waste, forest residues, food waste, and organic waste. Malaita's coconut, cassava, and cocoa production offer potential feedstocks. Coconut husks, shells, and oil can be utilized, while cassava can be processed into biodiesel or biogas. Cocoa pod husks can be burned or converted to syngas. However, challenges exist in sourcing feedstock, especially if they are used for other purposes, and in the collection and transport of feedstock to power facilities. Assessing these factors early in projects is crucial to identify potential issues and ensure successful implementation.

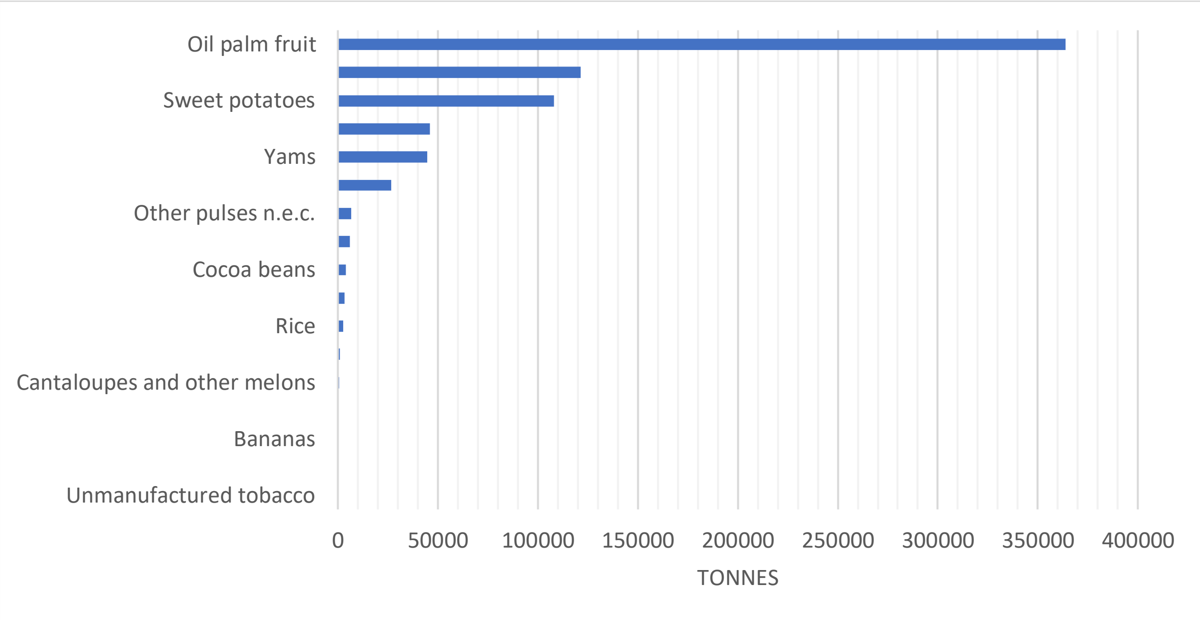
The energy sector in the Solomon Islands operates within a framework of various legal instruments and regulations, covering aspects such as production, distribution, consumption, and conservation of energy resources. These legal frameworks are essential for shaping the energy sector, ensuring compliance, promoting sustainability, and fostering innovation. Key legal instruments include the Petroleum Act of 1996, Customs and Excise Act of 2012, Electricity Act of 1996, Electricity Regulations of 1993, Electricity Tariff Regulations of 2016, Consumer Protection Act of 1995, State Owned Enterprises Act of 2007, Price Control Act of 1982, Weights and Measures Act of 1972, and the Environment Act of 1998. These regulations are overseen by various government agencies and ministries, ensuring the safe handling, transport, and distribution of energy resources while providing consumer protection and promoting environmental sustainability [12].

2.2. Agriculture sector

In the Solomon Islands, the agricultural sector is the most important sector for the economy accounting for 16 percent of the national GDP and while 80 percent of the population lives in rural areas, agriculture is the foundation of livelihoods in the country. Agriculture consists of three sub-sectors, namely subsistence smallholder farming, a commercial sub-sector, and large plantations. Subsistence agriculture is the predominant occupation of the rural population and in many cases the sole source of livelihood for these communities. Livestock and animal husbandry are vastly practiced.

Many rural communities also depend on forest products such as leafy vegetables, nuts, honey, and fruits, and coastal communities on fish to supplement their food consumption. The main agricultural products in the Solomon Islands include coconuts, cocoa, palm oil, rice, and various fruits and vegetables such as taro, yams, and bananas. These crops are grown both for subsistence and for export. The country relies heavily on agricultural exports, with copra (dried coconut meat) historically being one of the primary exports. However, cocoa and palm oil have become increasingly important in recent years.

Figure 11. Primary crop products (2022 data)



Source: FAOSTAT.

Despite its potential, the agriculture sector faces several challenges. These include limited access to markets and transportation infrastructure, lack of modern farming techniques and technology, vulnerability to natural disasters such as cyclones, and the impacts of climate change, including rising sea levels and changing weather patterns. Subsistence farming is prevalent in rural areas, where small-scale farmers grow crops primarily for their consumption on farms having an average surface of 1-2 ha. Traditional farming methods are still widely practiced in these communities. Commercial farming is developing yet several constraints affect this sector. The government of the Solomon Islands has implemented various initiatives to support the agriculture sector, including providing training and extension services to farmers, promoting sustainable farming practices, and investing in infrastructure development. Land tenure issues are a major issue in the country that hinders agricultural development, as land ownership in the Solomon Islands is largely customary, and disputes over land rights arise often.

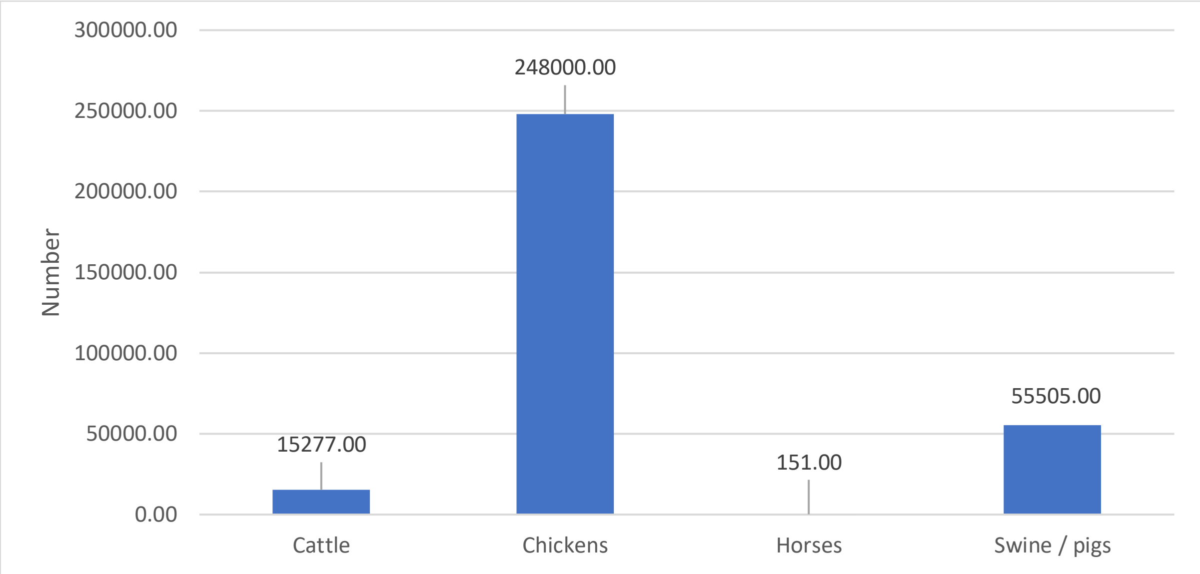
The fisheries sector in the Solomon Islands is characterized by the significant roles of subsistence and offshore industrial fishing. Subsistence fishing is crucial for the nutrition of the population, particularly in remote rural areas where 90 percent of the people reside. In 2016, total fisheries production was 66 400 tonnes, with tuna and similar species making up over 85 percent of the catch. While aquaculture is limited, successful seaweed farming has become a noteworthy venture, with around 11 000 tonnes harvested annually for export. The country boasts the largest seaweed farming in the Pacific. Per capita consumption in 2019 was 30.5 kg.[11] Offshore fisheries contribute substantially to formal employment and serve as a major source of exports, notably in processed and raw tuna. Licensing foreign vessels for offshore fishing in the Exclusive Economic Zone (EEZ) is a significant revenue stream for the government.

Local offshore fisheries see annual catches ranging from 14 000 to 22 000 tonnes, primarily through purse seining, pole-and-line fishing, and longlining. Tuna comprises 90 percent of the catch, with bycatch accounting for the remaining 10 percent. Foreign fleets surpass local vessels in catch volumes. The Solomon Islands is committed to international agreements such as the UN Convention on the Law of the Sea, the UN Fish Stocks Agreement, and the Convention on the Conservation and Management of Highly Migratory Fish Stocks. It hosts the Secretariat of the Pacific Islands Forum Fisheries Agency and participates in various treaties related to regional fisheries management [13].

The livestock sector is also an important component of agriculture in the Solomon Islands as it contributes to food security, income generation, and cultural practices in the Solomon Islands.

[11] FAO, 2019. Globefish, 2019. Country Profile: Solomon Islands. https://openknowledge.fao.org/server/api/core/bitstreams/2eb2cef2-fbb4-43a2-9ae1-e83c3d02fbee/content

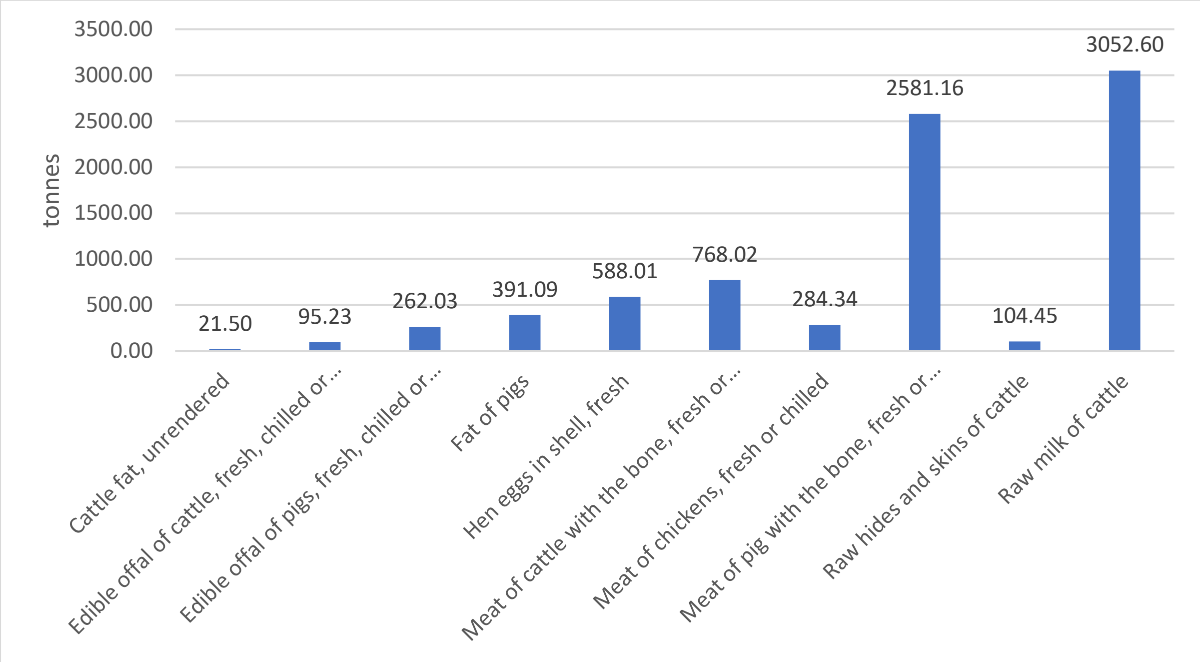
Figure 12. Live animals in Solomon Islands (2022 data)



Source: FAOSTAT.

Commercial livestock activities are mainly centred around pig and poultry farming. Pigs are raised for various purposes, including household consumption, cultural events, and sale in local markets. Pig farming in the Solomon Islands often follows traditional practices, with pigs being raised in smallholder systems, where families keep a few animals (2 – 8 heads) in their backyard or on communal land. These pigs are typically free ranging, scavenging for food in the surrounding environment, but several farms in more populated rural areas keep the animals in a semi-confined fashion. Pigs hold significant cultural value in the Solomon Islands, often being used in ceremonies, rituals, and as a form of wealth. Additionally, pig farming provides income opportunities for rural communities, as surplus pigs can be sold in local markets or to traders.

Figure 13. Livestock primary products in Solomon Islands (2022 data)



Source: FAOSTAT.

Despite its importance, in small-scale farms, pig raring faces various challenges, including limited access to veterinary services and medications, diseases such as African Swine Fever (ASF), inadequate infrastructure for transportation and marketing, and conflicts between traditional and modern farming practices. ASF is a significant threat to pig farming in the Solomon Islands, as it can lead to high mortality rates and economic losses. Efforts to control ASF include quarantine measures, public awareness campaigns, and collaboration with international organizations for disease surveillance and management, as well as best practices to be implemented at the farm level. These include the segregation of animals into relatively controllable pens (5-8 heads maximum in each), so to ensure that contact among the animals is limited to those in the same litter and the potential spread of diseases is somewhat contained. There are opportunities to improve pig farming in the Solomon Islands through the adoption of modern management practices, such as improved housing and feeding systems, selective breeding for desirable traits, disease prevention and control measures, and value-added processing of pork products (such as communal slaughterhouses) and the valorisation of residues, including slurry for biogas production.

Overall, pig farming plays a vital role in the livelihoods of rural communities in the Solomon Islands, contributing to food security, income generation, and cultural practices. Despite facing challenges, there are opportunities for sustainable development and improvement in the livestock sector with proper support and investments.

Figure 14. Pig farming in Solomon Islands

2.3. Waste sector

The estimated total solid waste generation rate in the Solomon Islands is 0.75–1.0 kilograms per person per day, encompassing both household and non-household waste [1]. With a population of around 80 000, the Honiara urban area generates approximately 80 tonnes per day or 29 000 tonnes per year at a rate of 1.0 kg/person/day. Significantly, 50-60 percent of this waste is organic. If the urban population continues to grow at the current rate, solid waste generation is anticipated to double within 18 years.

The Honiara City Council's Environmental Health Division manages household waste collection within the city and transports it to the Ranadi dump site. However, less than half of Honiara City's population receives waste collection services, particularly those residing in large informal settlements outside the municipal boundary. Open burning and illegal dumping are prevalent due to insufficient waste collection, posing serious public health and environmental risks. Honiara is divided into ten residential waste collection zones, with collection schedules somewhat unreliable. While the Honiara City Council and private contractors handle commercial waste collection, there is no segregation of wastes, and organic waste, including compostable material, is mixed into the general waste stream [14].

Figure 15. An informal dumpsite where unsegregated waste is dumped in New Georgia island. Odour, insects and fires are common as most of the waste is organic material

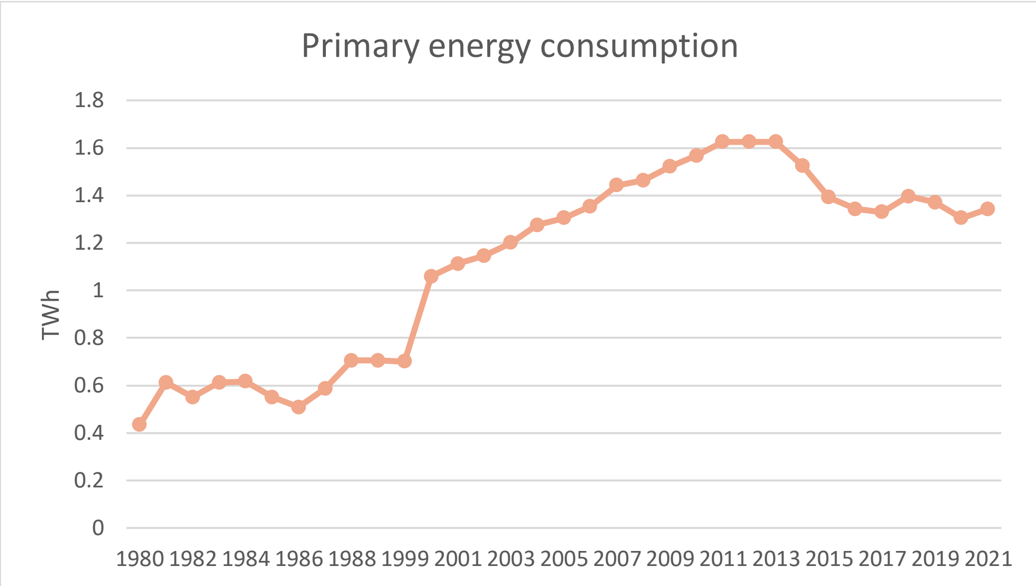
The Ranadi dumpsite, managed by the HCC Environmental Health Division, covers about 1.5 hectares and historically lacked proper management. It is estimated that 29,000 MT of waste is delivered to the site per year, 60 to 80 percent of which is made of organic material. Upgrading efforts began in 2013, introducing new waste compaction cells, removal of bulky items, and basic leachate control. However, informal scavenging persists, providing income for nearby residents. Although several private recycling companies operate in Honiara, they predominantly focus on metals, leaving a gap in the management of organic waste. Limited commercial composting exists, with a local organization promoting small-scale composting for organic farming. The legislative framework for solid waste management in the Solomon Islands faces challenges, including overlapping responsibilities between government divisions and limited enforcement. Implementation of existing regulations and strategies is constrained by financial and human resource limitations. The Honiara City Council's budget for solid waste management is limited, relying on grants from the national government and property taxes. Collection rates for property taxes are low, and HCC charges fees for waste collection services to offset costs.

2.4. Energy sector

2.4.1 Energy supply and demand

The Solomon Islands heavily relies on imported fuels to fulfil energy needs in transportation, electricity generation, mining, and households. In 2020, the energy intensity was 4.4 megajoules per USD of GDP, with 76 percent of the population having access to electricity and only 10 percent to clean cooking solutions. Renewable energy accounted for 44 percent of the total energy supply, including 79 percent solar, 14 percent bioenergy, and 6 percent hydropower in 2022. Fuel imports for power generation constituted 1 percent of GDP in 2019. While fuel prices are regulated and reviewed monthly, occasional supply shortages affect local prices. The country imports diesel, unleaded petrol, dual-purpose kerosene, and liquefied petroleum gas. However, data on fuel use across sectors remains insufficient [11].

Figure 16. Primary energy consumption in Solomon Islands

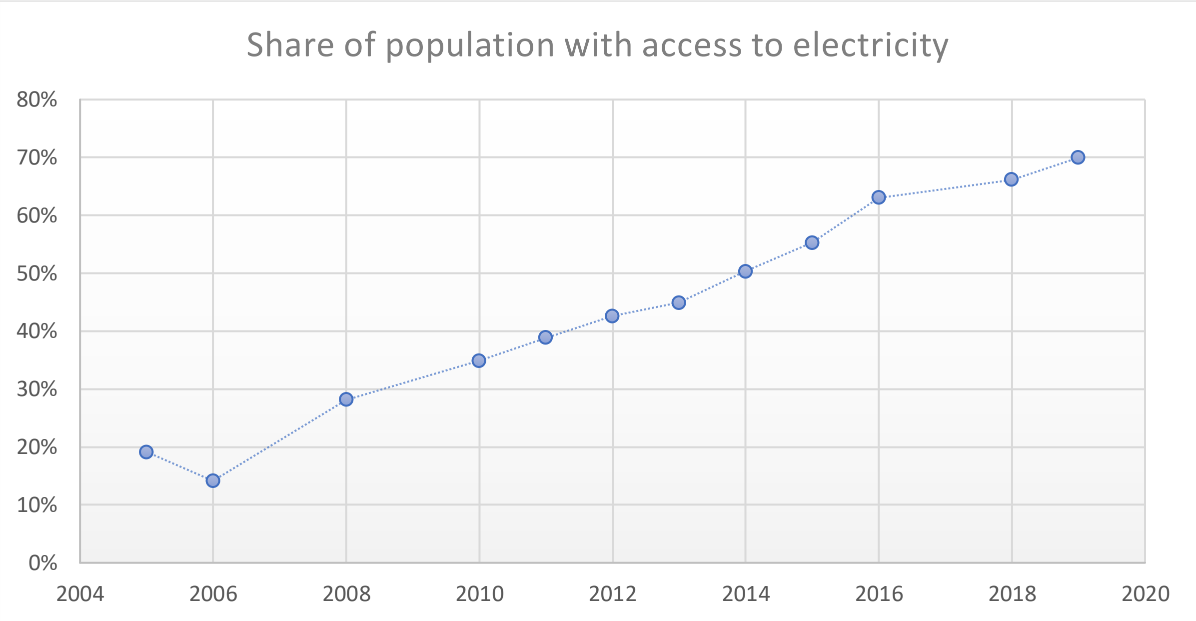


Source: US Energy Administration (2023), Energy Institute - Statistical Review of World Energy (2023). Available on: OurWorldInData.org/energy

The Solomon Islands Electricity Authority (SIEA), operating as Solomon Power, is a state-owned utility based in Honiara, serving eight provinces with 11 outstations. The Honiara grid, primarily diesel-based, supplies power to the township and surrounding areas. Despite efforts to expand access, many rural communities lack electricity due to logistical and financial constraints. Only 2 percent of installed grid-connected energy is renewable, but the government aims for 50 percent renewable electricity by 2035, with Solomon Power targeting 100 percent by 2030. The Tina Hydropower Development Project is expected to contribute significantly to these goals. Electricity production has grown alongside population growth, with an increase in supply capacity from 79.1 million kWh in 2010 to 98.9 million kWh in 2020. Solomon Power engages independent power producers (IPPs) through power purchase agreements, with ongoing efforts to enhance regulatory frameworks. Financial stability allows for small-scale projects, but major investments rely on donor funding. Grid infrastructure resilience is a concern, requiring ongoing maintenance. High fuel costs persist, highlighting the need for increased renewable energy deployment to reduce diesel demand.

Access to electricity in the Solomon Islands has increased significantly from 35.4 percent in 2010 to 76.3 percent in 2021, with similar trends observed in both rural and urban areas. However, access to clean cooking remains low, especially among urban populations, highlighting the need for energy-efficient and clean cooking initiatives. Electricity tariffs, regulated since 2016, comprise network access, fuel, and energy charges. Solomon Power's customer base grew by 37 percent between 2015 and 2020, serving 24 372 customers by 2020, predominantly post-paid and pre-paid customers in Honiara. Tariff charges in the Solomon Islands are the highest in the Pacific region, with rates varying for different user groups. In remote and rural areas, solar lighting systems are prevalent for various household needs. In 2009, many households relied on rooftop solar photovoltaic systems and refrigerators for electricity in rural communities.

Figure 17. Share of population access to electricity



Data source: World Bank. Available on: OurWorldInData.org/energy

2.4.2 Existing biogas facilities in the Solomon Islands

According to data collected through field surveys and interviews, in the Solomon Islands, there are only four (4) biogas plants in operation. These have all been built or procured in the context of a project led by trained personnel. A handful more will soon start operations, but all of these are small-scale, household level or small-community level (less than 20 m^3 digesters). Several digesters have been built and subsequently abandoned throughout the country, and in none of these cases there have been trained personnel working on the setups and maintenance operations. This finding emphasizes the potential and the interest towards the technology on one hand, but it also underlines the key role of training and knowledge sharing for its correct functioning in a challenging environment like that of the Solomon Islands. Most biodigesters have a fixed-dome or a polyethene tube structure, and none is equipped with an internal stirring and mixing tool. COVID-19 severely impacted many projects by reducing either the supply of residues or the demand for energy products, resulting in the abandonment of the initiatives.

Design	**Status**	**Capacity**	**Feedstock**	**Feedstock source**	**Energy use**	**Upfront investment**	**Funding source**	**Digestate: amount and use**	**Notes (e.g., web links, inform sheets etc.)**
Biogas typology	**In operation**								
Low-Cost Polyethylene Tube Digester	Yes, since 2022	3.85 m^3	Kitchen Waste	Kitchen waste	Cooking, heating up to max of 2-4 hrs/ day	Yes	The Government of Israel through Israeli Consulate in Honiara	0.59 m^3/ week or 84L/day of liquid fertiliser (same as input)	Homebiogas 4.0 system Photo credit: James Kana, Ueniusuunu Agribusiness Group Facebook Page
Low-Cost Polyethylene Tube Digester	Operation to start November 2024	3.85 m^3	Kitchen Waste/Cow slurry	School cattle farm	Cooking, heating up to max of 2-4 hrs/ day	Yes	The Government of Israel through Israeli Consulate in Honiara	0.59 m^3/ week or 84L/day of liquid fertiliser (same as input)	Homebiogas 4.0 system Photo credit: James Kana, Ueniusuunu Agribusiness Group Facebook Page

Low-Cost Polyethyle Tube Digester	To be completed December 2024	3.85 m	Kitchen Waste	Own production	Cooking, heating up max of 2-4 hrs/ day	TBC	The Government of Israel throug Israeli Consulat in Honiara	0.59 m^3/ week or 84L/day of liquid fertiliser (same as inpu	Type 4.0 Homebiog system
Low-Cost Polyethyle Tube Digester	To be completed November 2024	3.85 m	Kitchen Waste	Own production	Cooking, heating up max of 2-4 hrs/ day	Yes	The Government of Israel through Israeli Consulate in Honiara	0.59 m^3/ week or 84L/day of liquid fertiliser (same as inpu	Type 4.0 Homebiog system
Low-Cost Polyethyle Tube Digester	To be completed October 202	3.85 m	Kitchen Waste/Pig Slurry	Own production	Cooking, heating up max of 2-4 hrs/ day	Yes	The Government of Israel through Israeli Consulate in Honiara	0.59 m^3/ week or 84L/day of liquid fertiliser (same as inpu	Type 4.0 Homebiog system
Low-Cost Polyethyle Tube Digester	No, expecte date unknow	3.85 m	Kitchen Waste, Market, et	Own production	Cooking, heating up max of 2-4 hrs/ day	Yes	The Government of Israel through Israeli Consulate in Honiara	0.59 m^3/ week or 84L/day of liquid fertiliser (same as inpu	Type 4.0 Homebiog system
Low-Cost Polyethyle Tube Digester	Expected December 2024	3.85 m	Kitchen Waste, Cocoa pul etc	Own production	Cooking, heating up max of 2-4 hrs/ day	Yes	The Government of Israel through Israeli Consulate in Honiara	0.59 m^3/ week or 84L/day of liquid fertiliser (same as inpu	Type 4.0 Homebiog system

Low-Cost Polyethylene Tube Digester	Expected December 2024	3.85 m^3	Kitchen Waste	Own production	Cooking, heating up to max of 2-4 hrs/ day	TBC	The Government of Israel through Israeli Consulate in Honiara	0.59 m^3/ week or 84L/day of liquid fertiliser (same as input)	Type 4.0 Homebiogas system
Fixed Dome	Since 1970s	NA	Human dejections	Own production	Cooking, heating	NA	Pioneer SSEC Missionaries to Solomon Islands	NA	
Fixed Dome	2016; in use	15 m^3	Pig waste	Slurry produced from YWAM pig farm	Cooking gas for kitchen & staff houses; lighting use discontinued due to high maintenance cost of Genset not practical for rural settings	$ 2 - $ 6 K Maximum cost if includes pig farm	YWAM School	used as organic fertilizer in the farm	YWAM offered short training on biogas startup to at least 20 students. Training ceased in 2019 due to Covid plus challenges to implement knowledge in rural areas due to high startup costs
Fixed Dome (alternative layout)	2016; in use	5 m^3	Pig waste	Slurry produced from YWAM pig farm	Cooking gas for kitchen & staff houses	$ 2 K	YWAM School	used as organic fertilizer in the farm	
Floating Drum	2016; currently used for demonstration purposes only	5 m^3	Kitchen waste	Own production	N/A	$ 2 K	YWAM School	used as organic fertilizer in the farm	
Fixed Dome	2016; discontinued	8 m^3	Pig waste	Slurry produced from farm	Cooking and lighting	N/A	Republic of Kazakhstan	used as organic fertilizer in the farm	

Fixed Dome	2019; discontinued	20 m^3	Pig waste, Kitchen waste	Own production	Cooking, and lighting 3.6 Kva Biogas Generator	$11,500	The Ministry of Environment, Climate Change, Disaster Management and Meteorology (MECDM), Solomon Islands Govt	used as organic fertilizer in the farm	
Fixed Dome	2017-2019, project abandoned in 2020 due to Covid19 which disrupts travel of international experts from Australia to advance project to next stage.	0.2 m^3	Pig slurry, kitchen waste	Farmers & households in Tuvaruhu community	Cooking & heating	$100	Oxfam, Solomon Islands	used as organic fertilizer in the community farms	
Fixed dome	Since 2014; decommissioned in 2019	5 m^3	Pig Manure	Pig farm operated by TTM	Cooking, heating. Digester produces 1 hr of cooking gas/ day.	NA	Republic of China (Taiwan)	Organic fertiliser for crops	
NA	2015; not implemented	NA	Pig Manure	Pig farm	Cooking & heating	NA	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), US AID	Never used due to lack of commitment from the Ministry of Agriculture to set up the piggery farm as originally planned	

NA	1985; planned abandoned due to high investment cost	NA	Pig Manure	Pig farm (800-2000 pigs)	NA	NA	Ministry of Agriculture & Livestock, Solomon Islands Government	NA	
NA	2018; discontinued in 2020 during Covid Outbreak, lack of feedstock	5 m^3	Kitchen Waste, animal manure, biomass	Own production	2 m^3 biogas of biogas/ day, 2-3 hrs heating & cooking time/ day. Also used for lighting	1900	Purchased from Sol-Bridge, new trading name as Garden Biogas	Organic fertiliser	

2.4.3 Policies supporting Renewable Energy

The Ministry of Mines, Energy and Rural Electrification (MMERE) in the Solomon Islands is tasked with overseeing the development of various sectors including minerals, petroleum, energy, water resources, and rural electrification. Their mission is to sustainably develop both renewable and non-renewable resources for the social and economic benefit of the people. The MMERE Corporate Plan emphasizes consolidating service delivery and sustainable resource development. The Energy Division, a part of MMERE, focuses on energy policy, planning, and management. Despite having extensive functions, the division faces challenges such as limited staffing and funding resources yet it manages to develop key policies for the development of renewable energy in the country. Most notably, the National Energy Policy (SINEP) 2020-2030 guides the planning and management of energy sector development during the 10-year plan period. Targets increasing electricity access for urban households to 80 percent and for rural households to 35 percent by 2025. Calls for increasing the renewable energy share in power generation to 50 percent by 2035 in urban and rural areas, and for improving energy efficiency and conservation in all sectors to 10 percent by 2030.

This important policy piece works in synergy with other statutes, such as the Renewable Energy Roadmap 2021 of MMERE, which targets the achievement of a 100 percent renewable energy supply in the country by 2030. The main renewables targeted by these instruments are geothermal and hydropower (200 MW and 300 MW respectively), whereas surprisingly solar and biomass have a minor weight in the overall roadmap (1 MW and 0.5 MW respectively). SINEP estimates that about USD 60 million would be necessary to ensure the achievement of renewable energy generation goals of the Solomon Islands and it considers the role of the private sector crucial to the effective deployment of RE technologies, as the energy branch of the Ministry only has a development budget of USD 796,000 per year.

The Solomon Islands national development effort is complemented by regional policy frameworks on regional energy development, climate change and security. Two main regional frameworks have been adopted by the Pacific countries to guide sustainable energy sector development, namely the Framework for Resilient Development in the Pacific (FRDP) 2017-2030 which is a high-level instrument to guide towards a more resilient society, and the Framework for Energy Security and Resilience in Pacific Islands (FESRIP) 2020-2030, which intends to create the condition to support renewable energy projects. All policies struggle to keep up with their respective roadmaps for implementation due to lack of funding and private sector investments, making the outcomes of this study particularly relevant [6].

2.4.4 National development policies

Below is a list of all relevant policies impacting the development and growth of the energy sector [6,7,10].

National Development Strategy (NDS) 2016-2035	• Improve social and economic livelihoods of all Solomon Islanders. • Energy prioritized for sustainable economic growth, health, and education. • Targets: • Reduce homes without electricity to 50% by 2035. • Increase homes using solar power from 15% to 50% by 2035.
National Energy Policy (SINEP) 2020-2030	• Objective: Unlocking the development potential of Solomon Islands' economic base through a dynamic and effective energy sector. • Broad outcomes: ○ Develop energy legislation. ○ Increase urban household electricity access to 80% by 2025. ○ Increase rural household electricity access to 35% by 2025. ○ Improve access to safe, affordable, and reliable petroleum fuels in outer islands and remote rural locations. ○ Raise renewable power generation in urban and rural areas to 50% by 2035. ○ Enhance the development and penetration of gaseous fuels and alternative liquid fuels from indigenous raw materials. ○ Improve energy efficiency and conservation in all sectors by 10% by 2030. • Estimated budget: USD 151 million ○ Governance: USD 4.18 million ○ Electric power (urban): USD 64 million ○ Electric power (rural): USD 14.95 million ○ Renewable energy: USD 60.05 million ○ Petroleum and alternative and gaseous fuels: USD 1.67 million ○ Energy efficiency and conservation: USD 6.29 million • Institutional Framework: ○ Energy Advisory Committee (EAC): Consists of 12 ministries, serving as a multi-sectoral committee responsible for administrating and overseeing the implementation of SINEP. ○ Technical Working Group (TWG): Supports and reports to the EAC on project implementation and progress. Membership includes government agencies, industry experts, and donor partners. ○ Leadership and Coordination: ○ Ministry of Mines, Energy and Rural Electrification (MMERE): Leads the coordination and implementation of SINEP, monitoring progress through a log-frame matrix.
Renewable Energy Roadmap 2021	• Provide pathway for achieving 100% renewable energy by 2030. • Propose essential reforms in policy, legislation, institutions, finance, and management to achieve the goal.
Minimum Energy Performance Standards Labelling Policy 2016	• Enforce minimum efficiency standards for electrical appliances such as refrigerators, freezers, air conditioners, and lighting.
Solomon Islands Electrification Strategy 2022 (NEP) Electrification Strategy and Implementation Report; Implementing the NEP	• Outline electrification development priorities and reforms for the next decade. • Specify national targets for improving energy access in both urban and rural communities by 2025.
Policy Roadmap for E-Mobility in Solomon Islands 2022	• Provide guidance for deploying and scaling up electric vehicles to meet national emission targets. • Propose a coordinated approach to enhance EV affordability, develop infrastructure, and build skills and capacity, while minimizing environmental impacts.

Nationally Determined Contribution (NDC) 2015, 2021	● Set national targets to reduce GHG emissions by 12% below 2015 levels by 2025 and 30% by 2030, compared to business-as-usual. ● International assistance can further decrease emissions by 27% by 2025 and 45% by 2050. ● Updated ambition in 2021 aims for achieving net-zero emissions by 2050.
National Climate Change Policy 2012-2017	● Outline strategies to mitigate climate change and promote low-emissions development. ● Emphasize the use of renewable energy and relevant mitigation technologies to achieve these goals.

The Solomon Islands possesses substantial renewable energy resources, offering a local alternative to imported fossil fuels. According to the Solomon Islands National Energy Policy (SINEP) for 2020-2030, geothermal has an estimated potential capacity ranging from 20 to 200 MW. Small hydropower is estimated at 11 MW, while total hydropower has a potential capacity of 300 MW. Solar energy for off-grid applications is estimated to be around 1 MW. Traditional biomass, including timber, wood/forest waste, and biofuel, has a potential capacity of 20 MW. Off-grid biomass and biogas schemes for rural communities are estimated to have a capacity of 500 kW. Wind energy requires a detailed study to determine its potential capacity [10].

2.4.5 Regional development policy frameworks

The national development effort is complemented by regional policy frameworks on regional energy development, climate change and security. The main regional instruments are:

- Framework for Energy Security and Resilience in Pacific Islands (FESRIP) 2020-2030 – Secretariat for the Pacific Community, which introduces three strategies for transitioning to a resilient and renewable energy system: (i) implementing policies to formulate robust renewable energy plans, enact legal frameworks, and strengthen NDC; (ii) facilitating the development of renewable energy and energy efficiency projects; and (iii) fostering investment attraction in the sector [8].
- Framework for Resilient Development in the Pacific (FRDP) 2017-2030 – Pacific Islands Forum Secretariat, which aims to strengthen resilience to climate change and disasters while promoting sustainable development in the Pacific. It focuses on three goals: (i) integrating adaptation and risk reduction, (ii) advancing low-carbon development, and (iii) enhancing disaster preparedness. Implemented through the Pacific Resilience Partnership, it emphasizes inclusivity, partnership, integrity, quality, and leadership. Renewable energy transition is central to achieving low-carbon development by improving energy efficiency, conserving ecosystems, fortifying energy infrastructure, and reducing greenhouse gas emissions [9].

2.4.6 Financing renewable energy projects in the Solomon Islands

The country is actively developing its energy sector to meet emission reduction targets. It relies on external funding and collaboration with international institutions. The current plan allocates around USD 151.14

million, with a previous investment of USD 574.12 million. Many projects receive grants, particularly for renewable energy initiatives aimed at improving access, reducing emissions, and building capacity.

Several renewable energy projects have been funded in the Solomon Islands, facilitating sustainable development and reducing reliance on fossil fuels. The Tina Hydropower Development Project, supported by the Asian Development Bank (ADB), World Bank, IRENA ADFD, GCF, and others, aims to generate hydroelectricity with a total financing of USD 241.88 million. Another initiative, the Solar Power Development, backed by ADB, involves a USD 2.24 million loan for a grid-connected solar power plant. Additionally, the Provincial Renewable Energy Project, funded by ADB with a USD 6 million grant, focuses on the construction of a hydropower plant. The Energy and Rural Electrification project, supported by JICA with a USD 3.99 million grant, expands rural electrification benefiting 2 000 households. Other projects include the Solar PV Plant in Honiara, SPIRES, Community-Based Renewable Energy Mini-grids, EAEP, Solomon Islands Power Development, and Solomon Island Renewable Energy Project, collectively contributing to the country's sustainable energy goals.

The nation has six local financial institutions offering loans to support local entrepreneurs and households in starting new businesses or buying energy-efficient appliances. These institutions extend loans for various purposes such as personal needs, new business ventures, and home purchases. Notably, the Development Bank of Solomon Islands provides the Livelihood and Investment Facility (LAIF), offering loans ranging from USD 600 to USD 9 000 for the purchase of small solar power systems, solar lighting units, refrigerators, and other solar products at a 13 percent interest rate with a 5-year term. The Bank of the South Pacific offers personal and business loans with a minimum balance requirement of USD 50 000 and variable interest rates over terms ranging from 1 to 10 years. Additionally, the Australian and New Zealand Banking Group (ANZ) provides rural banking services and personal loans with variable interest rates. Furthermore, microfinance/group savings schemes assist women vendors and others in raising venture capital for their businesses with interest rates ranging from 14 to 20 percent.

2.4.7 Transport

The transport sector in the Solomon Islands relies entirely on imported fuel, contributing significantly to greenhouse gas emissions. Decarbonizing this sector is challenging, requiring a mix of policy, technology, and market solutions. The urban population growth in Honiara has led to increased pressure on transportation, with the number of registered vehicles projected to rise substantially. Efforts towards cleaner transport options, such as electric vehicles (EVs), have been limited but are guided by national policies and roadmaps. Trials with solar-powered and biofuel vehicles have been conducted, but their market potential remains uncertain. Incentives and policy structures are needed to drive the adoption of alternative fuels like LPG. The international market for renewable transport options is expanding, offering potential benefits if supported by effective policy frameworks and market incentives. However, EVs alone will hardly suffice, necessitating additional measures like stricter fuel consumption/emission standards, support for public transport, integrated planning, hybrid vehicles, and better management of older vehicles.

2.4.8 Energy efficiency

Energy efficiency presents significant potential for cost savings for both the economy and households while reducing dependence on imported fuels. The Solomon Islands has set energy efficiency targets outlined in its National Energy Policy 2020-2030, aiming for a 10 percent improvement by 2025. Past initiatives have focused on increasing awareness through media outreach and education by Solomon Power. Energy labelling and rating of appliances are also part of efforts to promote efficiency, with the majority of consumers recognizing labels from New Zealand and Australia. Minimum energy performance standards (MEPS) have been enforced since 2016, covering various appliances. Solomon Power has undertaken infrastructure upgrades, resulting in reduced distribution losses and improved network performance metrics. Government adoption of national standards for solar PV equipment and regional initiatives further contribute to efficiency gains. In the transport sector, incentives for energy-efficient vehicles and restrictions on importing older models are proposed, alongside time-of-use tariffs and improvements to public transport networks. Extensive awareness campaigns, training, and technology demonstrations are necessary to promote energy efficiency, along with data collection and evaluation for effective long-term planning [11].

2.4.9 Cooking

In the Solomon Islands, energy sources for cooking vary between urban and rural remote communities based on resource availability. Approximately 9 percent of the population has access to clean cooking, with the Energy Efficiency and Conservation Policy of 2019 promoting efficient cooking technologies [6,7]. The Household Income and Expenditure Survey 2012-2013 identified wood and coconut shells as the primary cooking fuels for around 90 percent of households, particularly prevalent in rural areas. Gas is the second most common fuel, especially in urban households. Traditional wood stoves pose health risks and require significant time and effort for fuel collection, with women spending considerable time on this task. While some improved cooking technologies like sawdust stoves exist, most households still rely on traditional methods. Renewable energy options, such as solar cookers and biogas, offer opportunities to reduce labor-intensive cooking efforts, particularly for women, and improve health conditions. Expanding these technologies from small-scale to broader applications could have significant benefits.

Biogas production at small-scale and household levels, utilizing organic waste materials like animal manure and kitchen scraps, offers a renewable and locally available alternative to traditional wood stoves. Implementing biogas systems at such levels would indeed reduce environmental pressures associated with deforestation while enhancing indoor air quality and overall health conditions.

3. METHODOLOGY

3.1. Pre-feasibility assessment (Tier I)

The initial focus is on assessing the feasibility of biogas production for each case study as a pilot within the targeted sector. According to the Scope of Work, the project is subdivided into two Tiers. Tier I is the pre-feasibility assessment, and it is meant to provide the project team with a preliminary understanding of the potential for biogas production in the Outback Piggery, the case study farm. This first step is necessary to ensure that the limited resources available in the context of this project are wisely managed to derive the most relevant recommendations for future implementation. The case study farm was selected in light of its representativeness of a commercial piggery found in the Solomon Islands. Moreover, the farm belongs to the Solomon Islands Pig Farms Association (SIPFA) and its owner is the President of the association, ensuring the dissemination of the results to all members for extended outreach to private sector entities. The Outback Piggery will also serve as a demonstration site for pig farmers of the commercial application of waste resources for energy purposes from the agribusiness perspective, contributing to country targets and diversified livelihoods, providing evidence-base data for decision-making.

The outstanding hypothesis behind the approach selected for this feasibility assessment coincides with the high number of variables involved in this research. Therefore, a conservative approach has been followed to produce informed decisions on how to prosecute the study. The result of the Tier I study can confirm or confute the hypothesis, for which the case study farm *has* the potential to be equipped with a biogas unit that is useful, economically viable, environmentally sound, and socially acceptable. The result of this assessment will be considered *positive* if the hypothesis is indeed confirmed and supported by statistically significant data. On the contrary, the hypothesis will be confuted, and the result of the pre-feasibility considered *negative* if there will be reasonable doubts about the feasibility of biogas at the Outback Piggery. In case of a positive outcome of the Tier I study, the Tier II analysis will deepen the level of detail of the assessment, refine its results and provide all necessary information to the owner to equip its farm with a biogas plant. This will include a detailed, true to scale, set of engineering drawings for the construction or purchase of a complete biogas system sized effectively for the case study farm and crucially, a clear roadmap for financing the investment and supporting tools to manage the system. In case of a *negative* outcome of Tier I, the second part of the project will look at what are the limiting factors impeding the feasibility of biogas in pig farms in the Solomon Islands through a set of sensitivity analyses.

The methodology for the Tier I phase derives from the FAO Bioenergy and Food Security approach (BEFS) and it involves a thorough data collection, energy demand and supply analysis, cost calculation and potential savings and/or sales estimation. Additionally, consideration is given to the impacts of specific enabling policies. The first step of the study involves conducting a comprehensive overview and analysis of the national legislative framework governing the use of renewable energy. This includes the examination of existing policies and financial instruments aimed at supporting and promoting the deployment of renewable energy technologies throughout the country. Following this initial step, we proceed to conduct a focused appraisal of biomass resources' availability. This concentrated effort specifically targets materials suitable for biogas production within the farm's vicinity, ensuring a rapid yet detailed assessment of the biomass landscape in the targeted area.

Subsequently, the assessment turns towards the baseline energy demand of the farm and the surrounding areas. This phase involves a comprehensive evaluation of both power and cooking needs, considering the supply chain for traditional fuels and other energy sources commonly utilized in the region. The next step revolves around the financial feasibility of the proposed investment which consists of estimating the size and technical requirements of the energy system, calculating capital investment costs of comparable technologies, and providing figures for building and installation expenses for suitable biogas systems and crucially, generate different investments scenarios to cover the funding options available to private sector entities in the Solomon Islands.

To ensure a comprehensive assessment, the study then evaluates the social and environmental feasibility through the assessment of selected tailored sustainability indicators. These indicators provide insights into the overall impact and viability of the proposed renewable energy initiative.

3.1.1 BEFS approach overview

The Bioenergy and Food Security (BEFS) Approach, a key element of the FAO's Sustainable Bioenergy Support Package, is designed to assist countries in formulating and implementing sustainable bioenergy policies and strategies. The overarching goal is to ensure that bioenergy development contributes to both food and energy security, fostering agricultural and rural development in a climate-smart manner. In the context of the SCALA programme, the BEFS approach has been adapted to the specific scale and scope of the Private Sector Engagement Facility, by defining the appropriate borders of the assessment and carrying out only the relevant activities within such limits.

FAO's Approach incorporates two sets of methodologies and tools for conducting sustainable bioenergy assessments:

- BEFS Rapid Appraisal: Excel-based tools offering a preliminary indication of a country's sustainable bioenergy potential.
- BEFS Detailed Analysis: Providing accurate results to inform policy-making, this includes an in-depth analysis of potential environmental and socio-economic impacts of bioenergy development.

Both methodologies cover Natural Resources Analysis, Biomass Potential Assessment, Techno-economic Analysis, and Socio-economic Analysis. Sustainability and food security considerations are integrated, for instance, through the exclusion of protected areas and the prioritization of biomass use for food. In the context of the SCALA programme, the rapid appraisal route has been selected and appropriately adapted to the scope of work.

The standard BEFS approach comprises **six components**:

A. Scoping.
B. Stakeholder dialogue and capacity building.
C. Sustainable bioenergy assessment.
D. Support to policy formulation.
E. Impact monitoring, evaluation, and response.
F. Risk prevention, management, investment screening.

In the context of the SCALA programme, applicable components are A, B and C. The primary objectives of the BEFS Approach include understanding the country's situation, concerns, and priorities related to energy, agriculture, food security, and the environment. This coincides with A and it defines the context in which the project operates. Following this first step, FAO's approach aims to identify existing bodies or to form dedicated Working Groups to bring together relevant stakeholders for discussions on bioenergy development and food security. This action (B) has been carried out throughout the project, starting with a stakeholder mapping exercise and culminating with the Biogas Workshop held in Honiara on 25 March 2024, where all relevant private sector stakeholders have gathered to discuss the project and its impact, interacting with both FAO and UNDP staff as well as with Government Institutions and Financing Institutions active in the Solomon Islands. The approach further seeks to formulate a roadmap for biogas implementation in the country, illustrating what options exist for the case study farm – and similar farms throughout the country – and their potential costs and benefits (C.). Due to the peculiar nature of SCALA's Private Sector Engagement Facility, this component of FAO's approach has been split into two sections. One section deals with sustainable biogas potential assessment, effectively coinciding with the final results of the Tier I assessment, while the second part is focused on the development of a roadmap and tools for implementing biogas technology in the case study farm, which will be illustrated in the Tier II section of the report.

Integral to the BEFS Approach are training modules at both technical and policy levels. These modules aim to enhance understanding of the relationship between bioenergy, sustainability, and food security, build technical skills for related analyses, and facilitate a multistakeholder dialogue on bioenergy and food security while strengthening the institutional framework. Within the scope of work of the SCALA programme, knowledge transfer of biogas potential, challenges, and technical solutions for the deployment of these systems has been carried out.

3.1.2 Data sourcing, handling, editing, and elaboration

Data for this study were collected through a combination of literature review and surveys. The literature review provided a solid base of existing knowledge, while the surveys offered direct insights and perspectives, ensuring a well-rounded and reliable dataset. Tier I data collection was carried out primarily by a National Consultant entrusted with this task in addition to liaising and maintaining relationships with active stakeholders. The project generated two separate datasets, one for the case study farm and one for other registered commercial pig farms. Concerning the case study farm, the dataset was conducive to building an information base of satisfactory depth to assess baseline and investment scenarios for the specific case study farm. Regarding the dataset for all commercial farms registered, the goal was to obtain an overview of the existing commercial entities that share key characteristics with the case study farm and from which feasibility reasoning could be inferred.

Figure 18. Data Entry Sheet for the case study farm

1 FARM OVERVIEW

Include all available information about the Case Study Pig Farm

Province	Heads	Farming style	Farm Type	Farm Location (address or town, or GPS coord.)	Type of floor	Bedding material	Amount of bedding per head	Average manure production (kg/head/day)	Manure collection efficiency (%)	Manure management	Use of Manure (predominant)	Share of use	Use of Manure (secondary)	Slaughterhouse
Guadalcanal														
Farm 1 - Case Study Farm	300	ndoor intensiv	Farrow-to- finish	Henderson, Central Guadalcanal	Concrete	concrete		3kg/head/day	100%	Open space near stables	Green fertilizer	25%	Green fertilizer	No - animals sold alive
Outback Farm			breeding											

1. Farm products*

Product	Description	Total annual production (tonnes/yr)	On-farm residues production (include also possible additional farm products, if any) tons/year	Annual electricity demand (kWh)* Annual electricity consumed from utility bills/contracts/ generators fuel purchase	Farm expenditure for electricity (SI$/year)	Annual heat demand (kWht)* Annual electricity consumed from utility bills/contracts/ firewood or fuels purchase	Farm Expend. for feed cooking (SI$/year)	Estimated diesel fuel consumption (l/year)	Farm expenditure for heat generation/cooking (SI$/year)	Presence of power outages and a generation set (diesel, gas, kerosene) and power output (kW installed)	Annual usage of power genset (hours/year or days/year)	In case of crops, annual usage of organic fertilizers (in kg/year)	Notes
1	Pork meat	25	30.000	2.200	30.000	22.000	12.000	2.400	25.000	Genset for power ou	2,200 kWh/ year		1). Farmer uses a diesel genset to supply up to 6 hours of electricity/day to pump bore water, heating, lighting & construction needs. 2). Cooking pig feed is mostly done manually at the kitchen using wood fuel purchased & transported from the outskirts of Honiara. That comes at a separate cost. Heat demand is estimated to be ~60 kWht/ day needed for cooking.
2	Potatoes	15	10	0						Select one option…		1200 kg for cassava (1 ha)	
3	Vegetables	10	5	0						Select one option…		700 kg for the vegetables	
4										Select one option…			
5										Select one option…			
6										Select one option…			
Total										Select one option…			

You can add rows if needed

*Examples: live animals, Slaughtered animals, Packed meat, Piglets for sale, etc but also include additional products that might be produced on-farm, if any, like crops, feed, etc

Source: Author's elaboration.

3.1.3 Financial analysis

This assessment employs a standard Cost-Benefit Analysis (CBA) approach to unveil potential net profits, with the aim to:

- Evaluate the consolidated investment's profitability, comparing scenarios with the project (WP) against those without (WoP).
- Gauge the profitability for investors.
- Outline cash flows that form the foundation for calculating socio-economic costs and benefits.

Aligned with the CBA framework outlined by the European Commission [15], impact categories were identified and associated with the alternative scenario involving biofuel production within the respective countries. However, impacts beyond the countries' borders, such as global market distortions, were not taken into consideration. Reference values, conversion factors, prices, and other pertinent information vital for the analysis are presented in Tables, details of which can be found in the respective sections.

The annual net benefits of producing biogas can be expressed as follows:

$$\pi b(Q) = Pb(Qb) - (wLb + fFb + nNb + eUb - mMb)$$

Table 1. Considered variables for the annual net benefits of producing biogas

Symbol	Description
b	Biogas
πb(Q)	Annual net benefits
Pb	Price of biogas as the final product in the market
w	Unit wages
Lb	Quantity of labour force (salary)
f	Unit price of feedstock (if feedstock is purchased)
Fb	Quantity of feedstock required per unit of biogas production
n	Per unit cost of inputs
Nb	Related inputs
e	Price of utilities, including electricity, biogas, and coal
Ub	Miscellaneous
m	Market price of by-products
Mb	Amount of by-products generated during the digestion process

Source: Author's elaboration

Cost figures have been collected through surveys from the National Consultants to the case study farm based on a set of data collection sheets provided by the team of FAO International Consultants. Following up this first round of data collection, the review of the data and their interpretation preliminary understanding of cost conditions needed to be researched further. A virtual meeting with the owner of Outback Farm was organised to go over all cost (and other data) figures and verified.

Figures were reported originally in local currency, these have then been converted to USD using the average exchange rate of January 2024. This exercise led to the production of a second, reviewed data entry sheet with adjusted and verified figures.

Following the methodology elucidated in the Guide to Cost-Benefit Analysis of Investment Projects by the European Commission [EC, 2014], the determination of investment revenues and expenditures facilitated the assessment of project profitability. This measurement is characterized by the financial net present value (NPV) and financial internal rate of return (IRR) on investment. Financial discount rates were identified as advised by discussions with local commercial banks. Notably, salvage values attributed to key investments contribute to the calculation of NPV and are integrated into the final year's cash flow (Sn).

The formula for calculating NPV is as follows:

$$NPV = \sum_{t=0}^{n} a_t S_t = \frac{S_0}{(1+i)^0} + \frac{S_1}{(1+i)^1} + \cdots + \frac{S_n}{(1+i)^n}$$

Table 2. Variables of the financial Net Present Value NPV

Symbol	Description
s	Annual financial net benefit
t	Time
at	Financial discount factor
i	Financial discount rate

Source: Author's elaboration

While the IRR is given by the following equation:

$$0 = \sum \frac{S_t}{(1 + FRR)^t} \quad (3)$$

Table 3. Variables of the financial Internal Rate of Return IRR

Symbol	Description
S	Balance of cash flow
t	Time
at	Financial discount factor
i	Financial discount rate

Source: Author's elaboration.

The preliminary results of financial indicators have been presented and discussed with stakeholders during the in-country workshop. These will be included in the Tier I assessment of the case study.

In Tier II, following the methodology described by Boardman 2066 and EC 2014, the project will assess investment risks by carrying out the following analyses:

i) Sensitivity analysis.
ii) Qualitative risk analysis.
iii) Risk prevention and mitigation.

The sensitivity analysis allows for the identification of the critical variables with the largest impact (positive or negative) on the project. A variable is defined as critical when a variation of ±1 percent in its initial value gives rise to a variation of more than ±1 percent in the value of the NPV (EC, 2014). Switching values were calculated and a scenario analysis was completed by combining the critical values. Subsequently, qualitative risk analysis considered a list of adverse events, and a risk matrix was developed and analysed.

3.2. Private sector engagement strategy

Engaging private sector stakeholders in the livestock and waste disposal sectors to participate in climate change-related projects requires a multifaceted approach. SCALA's Private Sector Engagement Facility (PSEF) approach [16] highlights the importance of private sector engagement in building resilience to climate change and achieving sustainable development goals. This sees engagement actions through the lens of three main groups of actions:

- Outreach, Opportunity Mapping and Facilitating Multi-Stakeholder Engagement.
- Assessing Risks and Business Opportunities.
- De-risking and Enabling Private Sector Investments.

The Ministry of Environment, Climate Change, Disaster Management and Meteorology requested support in the area of Assessing Risks and Business Opportunities, specifically in the field of conducting feasibility studies on relevant private sector-oriented initiatives within the land use and agriculture sector that contribute to meeting climate action goals.

To connect with the private sector there is the need to understand deeply the country and business contexts in which these entities operate and formulate sensible proposals that wake their interest. Given the diverse array of priorities among entrepreneurs and private business operators, conducting a comprehensive analysis of the country and business contexts can offer valuable insights into their key concerns and priorities.

Any private business, by nature, is devoted to reaching economic benefits from its operations. This is why showcasing potential economic benefits is instrumental to ensuring an effective connection with private sector representatives. Highlighting the economic advantages of participating in climate change projects, such as cost savings through efficiency improvements or new technology implementation as in the case of biogas, is a clear winning action to gain interest and trust from private sector operators.

In addition, the facilitation of knowledge sharing through the organization workshops, seminars, and training sessions to disseminate information about climate-smart practices and technologies studied, are also paramount to ensure the adoption and understanding of new technologies.

In this regard, a workshop and training session were conducted in the Solomon Islands during March 2024. The knowledge sharing consisted of the dissemination of results of previous case studies and best practices to help businesses understand the benefits and implementation strategies for biogas systems. In particular, in the case of a local farmer who is building his own *"do it yourself"* biodigester, knowledge sharing consisted of the evaluation of design features and anticipation of inefficiencies and possible flaws, the discussion of possible corrective actions and especially the examination of alarm bells concerning the functionality of the system. Providing technical assistance and advisory services is key to helping businesses navigate the complexities of adopting climate-smart technologies and practices.

Figure 19. Training on biogas systems operations at YWAM University, Honiara

Figure 20. Workshop on Biogas Potential for Private Sector Engagement in Honiara

The scope of work Tier I does not include actions to demonstrate return on investment (ROI) for biogas systems as this parameter can be enabled only at the Tier II level, thus once economic feasibility is proven, this can be quantified. This will be instrumental to demonstrate the positive impact of climate change initiatives on business performance, resilience, and to build the reputation of biogas systems in the country. Concrete evidence of ROI can persuade hesitant stakeholders to participate and scale up the penetration of biogas technologies in the country. Private sector engagement is essential for effective mitigation and adaptation planning and implementation. By leveraging the expertise, resources, and innovation of the private sector, countries can build resilience to climate change and achieve sustainable development objectives.

Figure 21. Knowledge sharing with a local farmer who requested support to the SCALA programme on biogas design and construction techniques

The lessons learned from past UNDP and FAO projects provide valuable insights for policymakers, practitioners, and stakeholders seeking to enhance private sector engagement in adaptation efforts as demonstrated by the high receptivity of private sector stakeholders in Solomon Islands.

4. CASE STUDY ASSESSMENT: Outback Piggery

4.1. Background and baseline

The Outback Piggery was established in 2015 with a total of 5 pigs, as most farms in Solomon Islands. Over the years the farm has grown to more than 300 pigs and is registered as a commercial breeding farm. The farm extends over a surface of 1 ha and is located in Henderson, about 2 km south of Honiara's International Airport. The farm hosts a total of 300 heads at any given time, including 35 sows and fattening pigs at various ages and growth stages. Each pig is sold at approximately 25 kg live weight, which is the preferred size for customers. Mr. John Kwaita, the owner of Outback Farm, is a successful agricultural entrepreneur and farmer and is managing his farm successfully, despite numerous constraints, which in recent years have been further exacerbated by the impacts of climate change.

Figure 22. Aereal view of Outback Piggery case study farm and main shed/pig house (1). The second shed hosts the operations of feed cooking (2). In the upper corner is possible to see the creek and stream system (3) into which most of the pig slurry is dumped

The farm was visited in January 2024 by the National Consultant, to collect a first round of data to establish the baseline scenario. The energy needs of the farm have been preliminarily assessed and a summary is presented in Table 4. The main challenge for the operations of Outback Piggery is the high cost of energy for the production cycle. The farm is not connected to the national electricity grid, like most other commercial and non-commercial farms in the Solomon Islands, and it relies on a diesel generator for the generation of power and heat. Electricity is used to power water pumps, as the farm needs periodic washing of pig pens to ensure that the manure is removed from the concrete floor and the hygiene levels are maintained in the sheds. Pumping bore water requires approximately 6 kWh per day, every day of the year, for a total of 2 200 kWh of electricity. In addition, another important share of the energy demand of the farm comes from the heating lamps used by the farmer to keep the newborn piglets warm during rainfall events and at night. An additional 2 700 kWh of electricity is necessary for this operation and to ensure the maximum survival rate for the piglets. The generator used by Mr. Kwaita is a 5 kW diesel generator.

Figure 23. The diesel generator used at the case study farm

Fuel consumption of this generator is indicated by the manufacturer at 0.280 kg/kWh, or a total of 1 600 litres of diesel per year in the case of the case study farm.

The other major share of the farm's energy demand comes from the feed preparation process. The 300 pigs are fed twice a day with a meal made of rice, palm oil kernel cake, vegetable residues and food scraps that are cooked and mixed in this area of the farm. The main source of energy for this process is fuelwood. Fuelwood is predominantly purchased from local vendors who, in turn, acquire it informally and without any traceability. Observations of the logs revealed the presence of mangrove timber in the mix of fuel wood used and the risk that these are logged at unsustainable rates exists.

Figure 24. In this image, a view of the shed used on farm for the preparation of the meal for the pigs

The data collected on farms revealed that the energy demand for feed processing reaches approximately 12 kg of wood per day (60 kWht per day), or a total of approximately 21 900 kWht per year.

Table 4. Energy demand of the pig farm

Item	Amount	Unit
Farm Energy demand		
Electricity use for power (diesel generator)	2,200	kWhe year
Electricity use for heating piglets (diesel generator)	2,700	kWht year
Energy demand for feed cooking (firewood)	21,900	kWht year

Source: Author's elaboration

In addition to pigs, the farm grows vegetables for the nearby markets and household consumption. This operation does not rely on chemical fertilizers, as it uses about 20 percent of the manure produced by the piggery to grow a variety of crops, from greens, tomatoes and peppers, as well as fruit and nuts. The remaining amount of pig slurry is in part spread over land and the rest is dumped in a creek nearby.

The creek eventually reaches the Lunga River and thus the ocean east of Honiara.

The country context assessment and policy review highlighted the absence of water quality and wastewater discharge control regulations and systems in place in the Solomon Islands for commercial pig farms. As a result, farmers (as well as any other business) are not required to dispose of their waste by any standard and this coupled with the lack of sewage infrastructure, is conducive to an unregulated and arbitrary disposal of any farm waste. Odour and eutrophication of the streams are a real problem for the population living near commercial pig farms.

Figure 25. A view of the storage of feed ingredients for the pig's meals. Rice is the main element, followed by oil palm kernel cake, and kitchen offcuts and food scraps

4.2 Technical and environmental viability

The first calculation in the context of this pre-feasibility looks at assessing the biogas and methane production potential of the farm. The methodology selected for this pre-feasibility must be accurate yet expedited enough to enable the understanding of biogas potential without the need for sample collection, laboratory analyses and testing in the field. In Tier II, data will be validated, and calculations corrected as required.

The Intergovernmental Panel on Climate Change (IPCC) was created to provide policymakers with regular scientific assessments of climate change, its implications, and potential future risks, as well as to support countries and scientists with reference methodologies for climate change impact assessments.

A simplified approach to calculating methane emissions from livestock is included in the methodological guidance on assessing GHG emission in Volume 4 – Emissions from Agriculture – and it relies on default emission factors drawn from the literature. IPCC's Tier I method is likely to be suitable for most animal species in countries where enteric fermentation is not a key source category, as in the case of the Solomon Islands, or where enhanced characterization data are not available, as in the case study farm at this stage of the assessment. This methodology for calculating methane emissions from pig manure is a guided process that starts with the selection of the livestock type, and the subsequent characterization of the case study to refine the accuracy of the results. The methodological guidance includes livestock categories, relevant emissions factors, formulas, and tables to complete the stepwise process and estimate GHG emission potential.

The amount of methane generated by the pigs in the case study farm was derived as follows:

Methane (CH_4) emissions from pig slurry in the Pacific Islands area comprised between 13 – 24 kg of CH_4 per head per year (depending on pig size and diet). For this preliminary exercise, the average value of 19.5 kgCH_4/yr was used to estimate the total amount of methane gas produced by the farm.

The calculation of methane production from pig slurry in the case study farm is as follows:

300 heads x 19.5 kgCH_4/head/yr = 5,850 kg of methane gas are emitted yearly by the slurry produced in the case study farm.

The first indicator calculated with this preliminary estimate is the GHG emission intensity of manure management in the case study farm. According to the IPCC Assessment Report 6 (AR6), the emission intensity of methane from non-fossil origin is 27.2 times that of CO_2, thus by multiplying the generated amount of methane by its Global Warming Potential (GWP), the CO_2 equivalent emissions from manure of the farm have been calculated at 159,120 kgCO_2eq per year.

Figure 26. Fattening pigs of various sizes at the Outback pig farm in Honiara

If appropriately captured through a biogas system, the methane generated by the pig slurry produced on the case study farm can be used to generate electricity. The energy generation potential of such a system was then estimated starting from the available feedstock and the electricity and heat potential output was established by using the appropriate conversion factors for commercially available biogas generators. The manure produced in the Outback farm can generate some 14 000 m^3 of biogas per year with a composition of roughly 60 percent methane, or approximately 8 700 m^3 of this energy-rich gas. In energy terms, such an amount translates into 308 915 Megajoules (MJ) or 85 817 kWh (0.2778 kWh/MJ). Considering the conversion efficiency of modern biogas generators (0.35) the total electricity production of the biogas plant at the Outback farm could reach 30 000 kWh per year. Biogas systems can be equipped with gas bags that act as a reservoir or storage tank for the gas when this is not used, however, to estimate the potential electricity generation potential, this study assumed that the generator operates 24/7 non-stop, minus the necessary maintenance time, the total production could be spread over 8,000 operating hours per year.

The generator could have a nominal capacity of 4 kW output and generate 3.66 kW of DC (roughly 30 000 kWhe per year). The homestead studies include the farm, with its pig house and sheds, as well as 4 households that host the family of the farm owner, and the workers active on his farm and their families. This assessment considers separately the farm portion and the household portion of the homestead.

The farm currently uses 4 900 kWhe per year or about 1/5 of the potential electricity that it could generate from its biogas potential. This opens several possibilities for the farm to diversify its income stream, and it certainly allows for the substitution of the diesel employed on the farm for power generation, and the substitution of the heat energy used for the cooking of the feed. Specifically, during the data collection, this amount of energy was estimated at 60 kWht per day or 21 900 kWht per year. Since the electric conversion efficiency of modern internal combustion engines (ICE) biogas generators is roughly 0.35, the amount of biogas needed to generate the farm's electricity demand of 4 900 kWhe is 2 279 m^3 per year. The heat demand for the cooking of pig's feed is 21 900 kWht that are contained in about 3 565 m^3 of biogas.

From a technical standpoint then, this preliminary feasibility returns a positive result in that the biogas plant using the slurry available on the farm could cover entirely the energy needs for both power and heat of the farm.

Since the slurry available on the farm can generate more than 14 000 m^3 of biogas, while some 2 300 and 3 600 m^3 would substitute the diesel used in the generator and the firewood used for the cooking of meals respectively, roughly 8 100 m^3 of biogas could still be used by the other component of the homestead – the four households – for their energy needs. Such consideration is relevant to completing the techno-economic feasibility assessment. The section on CBA of biogas production of this report provides further details and scenarios to demonstrate the economic impacts of the technology applied to the case study homestead, thus expanding financial considerations to the entire energy substitution potential of the biogas investment and contemplating energy costs incurred at whole homestead level.

Tier I estimates and calculations are preliminary and Tier II will refine these calculations to more accurate site-specific and validated figures.

Figure 27. Pigs resting in a fattening pen on concrete floor

Note: This flooring is relatively easy to clean and has several advantages, but it requires labour and energy to pump the water for its maintenance.

The preliminary estimates made using Tier I methodology highlight the potential for the outback farm to generate enough electricity and heat to substitute the entirety of its diesel and firewood use. Concerning the environmental perspective then, the implementation of biogas in the case study farm could lead to GHG emissions reduction estimated at 159 tCO_{2eq} per year from the avoided emission of methane into the atmosphere, and an additional 24 tCO_{2eq}/year resulting from the displacement of diesel used in the generator at baseline. One of the co-products of anaerobic digestion of animal slurry is biodigestate.

This product contains the indigestible solids left behind during the anaerobic fermentation process, and it is rich in organic carbon, macro, and micronutrients. Digestate is widely used as an organic fertilizer and soil conditioner. Since no nutrients are lost during biogas production, farmers can close the nutrient cycle and reuse these minerals, with positive impacts on the economics of the farm and the environment. Digestate use can have a positive impact on soil quality, including boosting microfauna resilience to climate stressors.

The liquid fraction of the slurry currently leaches into the nearby creek, polluting its waters with the nutrient overload, thus contributing to eutrophication mechanisms, and it contaminates the streams with the load of *E. coli* that it contains. Diverting the slurry stream away from the bodies of water in the area via the biogas process will have enhanced positive impacts on the environmental conditions of the case study area. This is why, from an environmental point of view, this preliminary assessment also returns a positive outcome.

4.3 Financial Cost Benefit Analysis of biogas production

A comprehensive financial cost-benefit analysis (CBA) was conducted to evaluate the feasibility of implementing a biogas biodigester at the studied pig farm. The primary objective of the study was to assess the economic viability of substituting conventional energy sources, namely diesel for electricity generation and firewood for thermal energy in feed preparation, with biogas.

The homestead's energy requirements were also quantified, revealing an annual consumption of approximately 4 937 litres of diesel to generate 15 200 kWh of electricity and 30 tonnes of firewood to produce approximately 66 500 kWh of thermal energy for cooking food and feed (Table 4). These figures include both energy demand strictly related to farm activities (pumping water, heating the piglets, as well as cooking feed, and so on) as well as energy for households' activities (lighting, power for appliances, cooking food, and so on). This broader utilization underscores the multifaceted benefits of transitioning to sustainable energy sources, as it not only enhances operational efficiency but also contributes to overall homestead livelihood.

Table 5. Aggregated yearly energy consumption homestead

Item	Amount	Unit
Energy consumption		
Aggregated electricity consumption (diesel generators)	15,200	kWhe year
Aggregated energy consumption for feed cooking (firewood)	66,500	kWht year
Energy expenses		
Aggregated expenses for diesel	6,500	USD year
Aggregated expenses for firewood	3,000	USD year

Source: Author's elaboration

The capital expenditure (CAPEX) associated with the biogas production system sized according to the available feedstock (slurry + vegetable residues) totalled USD 23 947, encompassing costs related to digester materials and assembly, pre-treatment tanks, gas purification unit, storage tanks, appliance installation, and generator procurement. Notable expenses included USD 9 345 for the membrane digester assembly, USD 600 for the gas purification unit, and USD 1 370 for a 5kW biogas generator. Additionally, expenditures for onsite construction materials and labour amounted to USD 2 000 (Figure 28).

Operational expenses (OPEX) incurred by the biogas system are estimated at USD 200 annually, primarily covering maintenance and replacements (Figure 28). Although marginal at present, these ongoing costs are crucial for ensuring the system's sustainable and efficient operation, contributing to long-term viability, and reducing dependence on conventional energy sources.

Figure 28. Screenshot of the CAPEX and OPEX of the investment from the excel CBA tool

	Biogas plant - 15x3m2 Solomon			
	Item	Qty	Unit price USD	Amount USD
Costs/CAPEX	**Assembly Biogas Digester**			
	Assembly Membrane Digester 15m3(B) (with steel frame)	3	3,115.00	9,345.00
	Circulating pump 0.75kw(with pipe fittings)	3	408.00	1,224.00
	Pretreatment system			
	Sewage pump with knife 2.2KW	3	252.00	756.00
	Fermentation powder	3	3.00	9.00
	Biogas purifying system & Gas Storage			
	Biogas desulfurizer PX-20L(with filter inside)	3	200.00	600.00
	Fe2O3 replace filter	3	40.00	120.00
	Biogas Dehydrator PX 10L	3	150.00	450.00
	Biogas storage bag 10m3	1	318.00	318.00
	Pressure release valve	3	257.00	771.00
	Biogas Appliances			
	Biogas Pipe/Fitting	3	21.00	63.00
	Biogas pump PX 100	3	225.00	675.00
	Ultrasonic biogas flow meter BF 2000	3	82.00	246.00
	Shipment of biogas system	1	5,000.00	5,000.00
	Site construction/ installation			
	Materials	1	1,000.00	1,000.00
	Labour	1	1,000.00	1,000.00
	Generator			
	5kW Biogas Generator	1	1,370.00	1,370.00
	Shipment of generator	1	1,000.00	1,000.00
	Total capital expenses			**23,947.00**
Costs/OPEX	Maintenance	1		100.00
	Replacements			100.00
	Water			0.00
	Labour			0.00
	Total operative expenses			**200.00**

Source: Authors' elaboration

Financial analysis indicated substantial potential savings from transitioning away from diesel and firewood. Replacement of diesel with biogas could result in annual savings of approximately USD 6 500 per year, while substituting firewood could yield savings of around USD 3 000 (Figure 29). This replacement accounts for approximately 100 percent of the diesel demand and 75 percent of the total firewood demand of the homestead, further contributing to cost reductions and sustainability efforts (Figure 29).

However, the initial investment requires careful consideration, with a turnkey biogas system costing approximately USD 24 000. To provide a complete overview of the financial viability of such investment, two scenarios have been prepared. The first scenario (Scenario 1) looks at a realistic and likely approach for investing in such technology by considering that 60 percent of the CAPEX costs was financed through a loan at a fixed interest rate of 12 percent over a 5-year term. Based on the data available, these parameters are quite standard in the Solomon Islands. The second scenario (Scenario 2) looks at a more optimistic approach where CAPEX costs are fully provided as equity by the farm owner, thus not relying on financing.

Detailed analysis of loan impact underscored the significance of prudent financial planning to mitigate associated financial burdens. Concerning Scenario 1, despite these challenges, the project demonstrated promising financial prospects, boasting a positive Net Present Value (NPV) of USD 33 650, an Internal Rate of Return (IRR) of 28 percent, and a payback period of 5 years. These metrics indicate favourable project economics and suggest that the project is financially attractive and capable of recouping initial investments within a reasonable timeframe (Figure 29).

Figure 29. Detailed CBA worksheet for Scenario 1 (40% equity, 60% loan)

Biogas Plant Solomon Islands							
Year	0	1	2	3	4	5	5 to 25
FARM							
Energy consumption							
Liter of Diesel (L/year)	4,937	4,937	4,937	4,937	4,937	4,937	4,937
Firewood (t/year)	30	30	30	30	30	30	30
Diesel market price (USD)	1.32	1.33	1.33	1.34	1.35	1.36	1.50
Firewood market price (USD)	100.00	100.50	101.00	101.51	102.02	102.53	113.28
Feed in tarif Electricity							
Biogas price							
Avoided expenses							
Replaced diesel expenses		6,549	6,582	6,615	6,648	6,681	7,382
Replaced firewood expenses		3,015	3,030	3,045	3,060	3,075	3,398
Operating costs							
Maintenance		100.00	100.50	101.00	101.51	102.02	112.72
Replacements		-100.00	-100.50	-101.00	-101.51	-102.02	-112.72
Water		0.00	0.00	0.00	0.00	0.00	0.00
Labour		0.00	0.00	0.00	0.00	0.00	0.00
Revenues							
Replaced diesel (Litres)(Surplus)		-	-	-	-	-	-
Replaced diesel expenses (Surplus)							
Capital depreciation		- 958	- 958	- 958	- 958	- 958	- 958
Cash Flow							
+ Avoided expenses and Revenues		9,564.37	9,612.19	9,660.25	9,708.56	9,757.10	10,780.57
Operating costs + Labour		- *200.00*	- *201.00*	- *202.01*	- *203.02*	- *204.03*	- *225.43*
Operating Cash Flow	-	**9,364**	**9,411**	**9,458**	**9,506**	**9,553**	**10,555**
- Investments	- 23,947	-	-	-	-	-	-
Loan annuity		3,986	3,986	3,986	3,986	3,986	
Total Cash Flow	- **23,947**	**5,378**	**5,425**	**5,472**	**5,520**	**5,567**	**10,555**
Cumulative Cash Flow	- *23,947*	- *18,569*	- *13,143*	- *7,671*	- *2,151*	*3,416*	*204,833*
Payback Year						*Payback*	
CF shareholders	- 9,579	5,378	5,425	5,472	5,520	5,567	10,555
Cumulative Cash Flow	*9,579*	*4,200*	*1,225*	*6,697*	*12,217*	*17,784*	*219,201*
Payback Year	-	-	*Payback*	-	-	-	-
Project's Impact on P&L	-	**4,421**	**4,467**	**4,514**	**4,562**	**4,608**	**8,597**
Loan and Capital structure							
Equity private financing	- **9,579**						
Loan	- **14,368**	**60%**	of initial investment				
Constant interest rate	**12%**						
Duration of loan (years)	5						
Grace period (year)							
Loan repayment plan	Constant installments						
Loan outstanding (BoP)	**14,368**	**14,368**	**12,107**	**9,573**	**6,736**	**3,559**	-
Interests		1,724	1,453	1,149	808	427	
- Capital repaid		2,262	2,533	2,837	3,178	3,559	-
Loan outstanding (EoP)	**14,368**	**12,107**	**9,573**	**6,736**	**3,559**	-	-
Project profitability							
NPV	33,650.08 USD						
NPV to shareholders	46,478.83 USD						
Project IRR	**27.9%**						
IRR to shareholders	60.8%						
payback (years)	5						
Shareholders payback (years)	2						

Source: Authors' elaboration.

Concerning scenario 2, the project transitioning to biogas energy without acquiring a loan revealed promising financial prospects. The investment cost remained at USD 24 000, yet the absence of loan-associated costs led to substantially improved financial outcomes. The Net Present Value (NPV) significantly increased to USD 46 478, primarily driven by the elimination of interest expenses (Figure 30). The Internal Rate of Return (IRR) also saw a remarkable improvement to 40 percent, reflecting an excellent return on investment. Furthermore, the payback period decreased to just three (3) years (Figure 30), considerably faster than the 5 years noted in Scenario 1 when loan repayments were included. These metrics suggest not only favourable project economics but also indicate that the project is financially attractive, capable of recouping initial investments within a significantly shorter timeframe.

Figure 30. Detailed CBA worksheet for Scenario 2 (100% equity, 0% loan)

Biogas Plant Solomon Islands							
Year	0	1	2	3	4	5	5 to 25
FARM							
Energy consumption							
Liter of Diesel (l/year)	4,937	4,937	4,937	4,937	4,937	4,937	4,937
Firewood (t/year)	30	30	30	30	30	30	30
Diesel market price (USD)	1.32	1.33	1.33	1.34	1.35	1.35	1.50
Firewood market price (USD)	100.00	100.50	101.00	101.51	102.02	102.53	113.28
Feed-in tarif Electricity							
Biogas price							
Avoided expenses							
Replaced diesel expenses		6,549	6,582	6,615	6,648	6,681	7,382
Replaced firewood expenses		3,015	3,030	3,045	3,060	3,076	3,398
Operating costs							
Maintenance		100.00	100.50	101.00	101.51	102.02	112.72
Replacements		-100.00	-100.50	-101.00	-101.51	-102.02	-112.72
Water		0.00	0.00	0.00	0.00	0.00	0.00
Labour		0.00	0.00	0.00	0.00	0.00	0.00
Revenues							
Replaced diesel [Litres](Surplus)		-	-	-	-	-	-
Replaced diesel expenses (Surplus)							
Capital depreciation		- 968	- 968	- 968	- 968	- 968	- 968
Cash Flow							
+ Avoided expenses and Revenues		9,564.37	9,612.19	9,660.25	9,708.56	9,757.10	10,780.57
Operating costs + Labour		- *200.00*	- *201.00*	- *202.01*	- *203.02*	- *204.03*	- *225.43*
Operating Cash Flow	-	**9,364**	**9,411**	**9,458**	**9,506**	**9,553**	**10,555**
Investments	23,947						
- Loan annuity	-	-	-	-	-	-	-
Total Cash Flow	- **23,947**	**9,364**	**9,411**	**9,458**	**9,506**	**9,553**	**10,555**
Cumulative Cash Flow	*23,947*	*14,583*	*5,171*	*4,287*	*13,792*	*23,345*	*224,762*
Payback Year	-	-	-	*Payback*	-	-	-
CF shareholders	- 23,947	9,364	9,411	9,458	9,506	9,553	10,555
Cumulative Cash Flow	*23,947*	*14,583*	*5,171*	*4,287*	*13,792*	*23,345*	*224,762*
Payback Year	-	-	-	*Payback*	-	-	-
Project's Impact on P&L	-	**8,406**	**8,453**	**8,500**	**8,548**	**8,595**	**9,597**
Loan and Capital structure							
Equity private financing	- **23,947**						
Loan	-	0%	of initial investment				
Constant interest rate	12%						
Duration of loan (years)	5						
Grace period (year)	-						
Loan repayment plan	Constant installments						
Loan outstanding (BoP)	-	-	-	-	-	-	-
- Interests		-	-	-	-	-	-
- Capital repaid							
Loan outstanding (EoP)	-	-	-	-	-	-	-
Project profitability							
NPV	46,478.83 USD						
NPV to shareholders	46,478.83 USD						
Project IRR	**39.6%**						
IRR to shareholders	39.6%						
payback (years)	**3**						
Shareholders payback (years)	3						

Source: Authors' elaboration.

Furthermore, a Tier II analysis will be conducted to refine the depth of the assessment, incorporating sensitivity analysis techniques, and considering additional scenarios to enhance decision-making and optimize returns. This rigorous approach will provide comprehensive insights into the project's financial viability and resilience, ensuring informed decision-making and maximizing overall returns.

5. Tier II Assessment

5.1 Introduction

As per Scope of Work (SoW), the preliminary results of the assessment of biogas potential in the case study farm (Tier I) influenced the development of further stages of the work. The SoW foresaw two alternative outcomes for the Tier I assessment. Depending on such outcomes, two options for Tier II have been identified. Option 1 would materialize if results delivered by the study highlighted the existence of the conditions to consider biogas as a viable and sustainable technology to be applied to pig farms in the Solomon Islands. With this option, the study would then deepen the assessment by verifying data collected on the ground and crossing information from the literature with interviews, questionnaires and multistakeholder discussions. Following this passage, the project would then look at creating the necessary set of conditions for the private sector to invest in the technology by preparing a market-based procurement plan of available technologies listing all necessary components for the construction of the biogas plant and providing the pilot farm with a detailed set of engineering drawings to build the biogas system on the farm. Conversely, if the outcome of the pre-feasibility assessment returned insufficient elements to support the feasibility of biogas investments in the pilot farm, a critical analysis of barriers and possible countermeasures would have been carried out (Option 2). The results of the pre-feasibility study (Tier I) have identified the existence of the necessary conditions to enable sustainable biogas production on the pilot farm, therefore the next step of the assessment (Tier II) will implement Option 1.

5.2 Data validation

Central to informing any further development of this assessment is the validation of data collected during the Tier I phase of the project. This initial step of Tier II was composed of two actions, namely i. the verification of data via remote and in-person discussions with stakeholders, and ii. a direct survey performed in the context of a field visit in the case study farm. In addition to data validation, the survey also enabled the possibility to collect geo-referenced information and perform accurate and extensive measurements of the case study site.

During the discussions with stakeholders, the original data entry sheets have been reviewed critically and updated to the latest values recorded for several category items. These have then been edited in the context of the field survey at the Outback Farm.

A total of 312 pigs were present at the time of the assessment. The case study farm is a breeder farm, therefore births are recorded on a quasi-daily basis, which makes the actual total headcount of newborns vary continuously. Piglet mortality affects farms in the Solomon Islands with an incidence of about 8 – 12 percent of newborns before they reach sale weight. Moreover, the farm is open to the public for sales which occur regularly but with unpredictable numbers, which in turn contributes to herd size oscillations. The actual average weight of the pigs was estimated based on the headcount under each size category present on the farm. The related feed intake remains steady year-round as it does not oscillate much with the variation in herd size due to a compensation mechanism for feed availability to the animals. The farm hosts about 50 sows (live weight >120 kg) and 10 boars (LW >150 kg), and the vast majority of the animals weigh less than 25 kg. Although it was not possible to measure slurry production and composition on site, an estimate based on live-weight-to-slurry-production indexes was used to derive a more accurate estimation of slurry production. The average slurry production was estimated at 1.9 kg/head/day. This value is considerably lower than the previous amount recorded during Tier I of 3 kg/head/day. This variation was factored in the refined analyses included in the Tier II assessment as the potential biogas output of the farm is primarily related to manure availability. All other data collected during the first phase of the study have been validated with the same methodology and no major deviations have been found.

5.3 Updated Validated Technical and Environmental Feasibility

Based on the validation of data on slurry availability, the original calculation carried out under Tier I has been revised. This step edited the original assessment of the biogas and methane production potential of the farm.

The methodology selected for this updated assessment used computational methods based on a literature review of four assessments – adequately adapted to the conditions of the case study - and was subsequently compared to IPCC methodology, used in Tier I, but with updated and validated values.

Biogas production potential from pig slurry was calculated based on Pinheiro Silva et al (2018),[12] where the amount of slurry produced per head per day (1.9 kg) is used as the basis for the calculation of biogas production potential and then, based on the average biomethane yield of biogas (60 percent vol), the total energy production potential was derived.

The amount of methane generated by the pigs in the case study farm was derived as follows:

1.9 kg of pig slurry has an average Volatile Solids content of 42.6 g/kg of manure, according to IEA-Bioenergy (2016).[13] This leads to a biogas production potential of about 21 kg per head per year (13.1 kgCH_4 per head per year), or a total of roughly 9,385 m^3 of biogas per year. Considering an average biomethane yield per unit of biogas of 60 percent by volume, an estimated 5,866 m^3 of biomethane can be produced by the case study farm. This amount is 36 percent lower than the projected biogas yields obtainable at the Tier I stage, where the manure production rate was 3 kg/head/day vs 1.9 kg/head/day. Interestingly, the recalculated biogas yield at Tier II is 31 percent lower than the amount calculated using Tier I methodology. The delta between the two values Is attributable to the more detailed methodology employed in Tier II and the refined conversion factors used in this second phase of the project.

According to IPCC, methane emissions from pig slurry in the Pacific Islands area are comprised of between 13 – 24 kg of CH_4 per head per year (depending on pig size and diet).

Using the lower value in the range of 13 kgCH_4/yr per head, the total amount of methane gas produced would be 5,821 m^3CH_4 per year or 9,313 m^3 of biogas per year.

The first indicator calculated with this preliminary estimate is the GHG emission intensity of manure management in the case study farm. According to the IPCC Assessment Report 6 (AR6), the emission intensity of methane from non-fossil origin is 27.2 times that of CO_2, thus by multiplying the revised amount of methane generated (5,821 m^3) by its Global Warming Potential (GWP), the CO_2 equivalent emissions from manure of the farm have been calculated at 106,080 kgCO_2eq per year.

[12] Pinheiro Silva et al., 2018. Energy efficiency of a micro-generation unit of electricity from biogas of swine manure. Available here: https://doi.org/10.1016/j.rser.2017.10.083
[13] IEA-Bioenergy Task 43, 2016. MOBILISING SUSTAINABLE SUPPLY CHAINS – BIOGAS CASES.

As in the case of Tier I, the methane generated by the pig slurry produced on the case study farm can be used to generate electricity and heat to substitute existing fossil products as well as firewood. The energy generation potential of the manure produced in the Outback farm can generate some 9,300 m^3 of biogas per year with a composition of roughly 60 percent methane, or approximately 5,800 m^3 of methane. In energy terms, such an amount translates into 205,943 Megajoules (MJ) or 57,211 kWh (0.2778 kWh/MJ). Considering the conversion efficiency of modern biogas generators (0.35) the total electricity production of the biogas plant at the Outback farm could reach 20,024 kWh per year. Biogas systems can be equipped with gas bags that act as a reservoir or storage tank for the gas when this is not used, however, to estimate the potential electricity generation potential, this study assumed that the generator operates 24/7 non-stop, minus the necessary maintenance time, the total production could be spread over 8,000 operating hours per year.

The generator could have a nominal capacity of 3 kW output and generate 2.67 kW of DC, provided that electricity demand is steady throughout the year. By modulating the peaks and lows of energy demand, the actual potential maximum power output might change, however, for the sake of this study this variable was not taken into account. Like in the Tier I assessment, the case study is a homestead which includes the farm, with its pig house and sheds, as well as 4 households that host the family of the farm owner, and the workers active on his farm and their families. Also, the Tier II assessment considers separately the farm portion and the household portion of the homestead.

The farm currently uses 4 900 kWhe per year or about 1/4 (24 percent) of the potential electricity that it could generate from its biogas potential. Despite being lower than in Tier I estimation, the energy demand of the farm component can still be fully covered by the production potential of the biogas plant. Residual electricity generated can displace diesel fuel employed to generate power for the homestead for about 10,300 KWhe in addition to covering the needs of the farm component alone, and at least in part, heat energy needs for cooking can be covered by the residual energy generated by the biogas plant to substitute firewood. Specifically, during the data collection, the energy required for cooking the feed was estimated at 60 kWht per day, or 21,900 kWht per year. The residual biogas available for heat generation and firewood substitution calculated in Tier II is 15,860 kWht per year, or 72.4 percent of the cooking energy demand of the farm.

From a technical standpoint then, the feasibility assessment for Tier II returns a positive result in that the biogas plant using the slurry available on the farm could cover entirely the power needs of the homestead and partially the heat demand of the farm.

The assessment highlights the potential for the outback farm to generate enough electricity and heat to substitute the entirety of its diesel and partially its firewood use. Concerning the environmental perspective then, the implementation of biogas in the case study farm could lead to GHG emissions reduction estimated at 106 tCO_{2eq} per year from the avoided emission of methane into the atmosphere, and an additional 24 tCO_{2eq}/year resulting from the displacement of diesel used in the generator at baseline. One of the co-products of anaerobic digestion of animal slurry is biodigestate. This product contains the indigestible solids left behind during the anaerobic fermentation process, and it is rich in organic carbon, macro, and micronutrients. Digestate is widely used as an organic fertilizer and soil conditioner. Since no nutrients are lost during biogas production, farmers can close the nutrient cycle and reuse these minerals, with positive impacts on the economics of the farm and the environment. Digestate use can have a positive impact on soil quality, including boosting microfauna resilience to climate stressors. The liquid fraction of the slurry currently leaches into the nearby creek, polluting its waters with the nutrient overload, thus contributing to eutrophication mechanisms, and it contaminates the streams with the load of *E. coli* that it contains. Diverting the slurry stream away from the bodies of water in the area via the biogas process will have enhanced positive impacts on the environmental conditions of the case study area. This is why, from an environmental point of view, this feasibility assessment also returns a positive outcome.

Based on the results of the feasibility assessment, the SoW of the project foresees the production of detailed engineering drawings for the biogas plant to be built on the case study farm or any comparable farm in the Solomon Islands. The next section of this report will provide a narrative of the methodology used to carry out the planning and design of the biogas plant.

5.4 Financial Assessment and risk analysis (Tier II)

Tier II analysis reframes the financial assessment carried out in Tier I in light of the revised production potential and related energy product substitution. In addition, it also presents a deeper financial analysis following the profitable outcomes observed in Tier I. This refined approach aims to optimize investment decisions, particularly regarding methane emission reduction strategies and adaptation to climate change via energy security and extended access to rural homesteads.

5.4.1 Comparison between TIER I and TIER II

In comparing Tier I and Tier II investments, several significant differences emerge, influencing both their performance and economic implications.

One key distinction lies in the analysis of feedstock availability at the farm level. In the case of Tier II, more detailed information has been gathered regarding the quantity of manure available for biogas production. This investigation revealed that a large portion of pigs within the studied farm are young (less than 25 kg), resulting in a lower amount of manure generated. Consequently, this data prompted a recalculation of the potential biogas production and necessitated a resizing of the digester accordingly.

The outcome of such adjustments is reflected in the comparative data presented in Table 6 below. Tier II systems exhibit a lower total methane (CH_4) production rate of 5,821 m^3 per year compared to Tier I's 8,437 m^3. As a consequence of reduced production potential, a smaller biodigester and an accordingly reduced size of ancillary systems were factored in. The revision led to a reduction in the total capital expenditure (CAPEX) for the Tier II system, which stands at USD 19,194 compared to USD 23,947 for Tier I. Despite the lower methane reduction rate, the biogas system sized accordingly to Tier II production potential offers annual savings of USD 7,637, albeit slightly less than the USD 9,517 achievable with the production potential considered in Tier I (Table 6). Interestingly, operational expenditure (OPEX) remains consistent between the two tiers, standing at USD 200 per year, as these consist mostly of the replacement of filtering materials, O-rings, and other smaller parts.

Table 6. Comparison of Tier I and Tier II Methane Mitigation Systems: Methane Production, Savings, and Costs

TIER I vs TIER II	Total m^3 of CH4/year produced	Total savings (USD/year)	Total CAPEX USD	Total OPEX USD/year
TIER I	8,437	9,517	23,947	200
TIER II	5,821	7,637	19,194	200

Source: Author's elaboration.

More in detail, Table 7 compares the utilization of CH_4 in Tier I and Tier II for both electricity generation and cooking energy. In both tiers, the same amount of methane (4,264 m^3/year) is used to generate electricity, resulting in the replacement of 15,200 kWh/year of electricity use at the homestead level. This substitution leads to annual savings of USD 6,517 in both Tier I and Tier II simulations (Table 7).

Table 7. Comparison of Methane Utilization for Electricity and Cooking Energy in Tier I and Tier II analysis at homestead level (farm + households)

TIER I vs TIER II	m^3/year CH_4 used for electricity	kWhe/year replaced	Savings (USD/year)	m^3/year CH_4 available for cooking	kWht/year replaced	Savings (USD/year)
TIER I	4,264	15,200	6,517	4,173	42,500	3,000
TIER II	4,264	15,200	6,517	1,557	15,860	1,120

Source: Author's elaboration.

The distribution of methane usage differs when it comes to cooking energy. In Tier I, 4,173 m^3/year of methane was available for heat purposes, which replaced 42,500 kWh/year of thermal energy (kWht) used by the farm (21,900 kWht/year) and the households on the homestead (20,900 kWht/year). This substitution resulted in additional savings of USD 3,000 per year. In contrast, the results of the technical feasibility of Tier II's biogas are capable of providing a smaller amount of CH_4 (1,557 m^3/year) for cooking energy, capable of replacing 15,860 kWht/year out of 21,900 kWht/year used for feed cooking, leading to annual savings of USD 1,120 (Table 7).

Therefore, it's noteworthy that due to the reduced methane available for thermal energy from the biogas system as per Tier II assessment, a portion of the thermal energy demand of the farm and homestead will not be covered by biogas. The results of this feasibility assessment represent a direct contribution to the SPIRES project (Stimulating Progress towards Improved Rural Electrification in the Solomons) managed by the Ministry of Energy and Mines. Biogas plants using pig waste at the farm level have demonstrated the potential to have a lasting impact at farm and community level, contributing to the target of substituting firewood from mangroves for cooking by fostering clean energy production.

This contribution is therefore not only towards the country's mitigation goals but also adaptation to climate change finds an important aid in this technology that can safeguard mangroves and their ecosystems. A healthy mangrove forest can more effectively protect the coastline from rising sea levels and floods thus adapting the country to the changing climate.

Table 8 provides a breakdown of capital expenses (CAPEX) and operational expenses (OPEX) for Tier I and Tier II biogas plant components.

Table 8. Comparison of Capital Expenses and Operational Expenses for Tier 1 and Tier 2 Biogas Plant Components

Biogas plant	TIER 1			TIER 2		
Item	Q	Unit price USD	Amount USD	Q	Unit price USD	Amount USD
Assembly Biogas Digester						
Assembly Membrane Digester 15m3(B) (with steel frame)	3	3,115.00	9,345.00	2	3,115.00	6,230.00
Circulating pump 0.75kw (with pipe fittings)	3	408.00	1,224.00	2	408.00	816.00
Pretreatment system						
Sewage pump with knife 2.2KW	3	252.00	756.00	2	252.00	504.00
Fermentation powder	3	3.00	9.00	2	3.00	6.00
Biogas purifying system & Gas Storage						
Biogas desulfurizer PX-20L (with filter inside)	3	200.00	600.00	2	200.00	400.00
Fe2O3 replace filter	3	40.00	120.00	2	40.00	80.00
Biogas Dehydrator PX-10L	3	150.00	450.00	2	150.00	300.00
Biogas storage bag 10m3	1	318.00	318.00	1	318.00	318.00

Pressure release valve	3	257.00	771.00	2	257.00	514.00
Biogas Appliances						
Biogas Pipe/Fitting	3	21.00	63.00	2	21.00	42.00
Biogas pump PX-100	3	225.00	675.00	2	225.00	450.00
Ultrasonic biogas flow meter BF-2000	3	82.00	246.00	2	82.00	164.00
Shipment of biogas system	1	5,000.00	5,000.00	1	5,000.00	5,000.00
Site construction/ installation						
Materials	1	1,000.00	1,000.00	1	1,000.00	1,000.00
Labour	1	1,000.00	1,000.00	1	1,000.00	1,000.00
Generator						
Biogas Generator	1	1,370.00	1,370.00	1	1,370.00	1,370.00
Shipment of generator	1	1,000.00	1,000.00	1	1,000.00	1,000.00
Total capital expenses			**23,947.00**			**19,194.00**
Maintenance			100.00			100.00
Replacements			100.00			100.00
Water			0.00			0.00
Labour			0.00			0.00
Total operative expenses			**200.00**			**200.00**

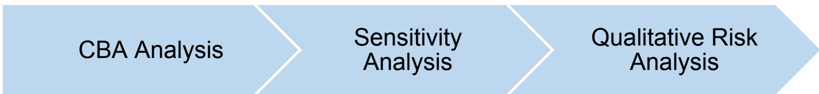
Source: Author's elaboration.

The primary difference between Tier I and Tier II biogas plants lies in the capacity of the digesters and related ancillary equipment. Tier I installations are equipped with three 15 m^3 biodigester units, whereas Tier II installations utilize only two digesters. As a result, all accompanying components in Tier II, such as circulating pumps, sewage pumps, biogas appliances, and site construction materials, undergo a reduction in quantity or capacity to reflect the reduced feedstock amount available as pig slurry. This reduction significantly influences the total capital expenses (CAPEX), thereby contributing to the lower overall CAPEX of Tier II compared to Tier I. The upfront cost of the correctly sized biogas plant of Tier II is USD 4,753 lower than in the pre-feasibility estimate made using Tier I data and methodology.

5.4.2 Methodology

The Cost-Benefit Analysis (CBA) methodologies employed in Tier II follow the approach outlined in Chapter 4.3 for Tier I. While the methodology remains consistent, Tier II utilizes different datasets to reflect the updated information and insights gathered during the refinement of the analysis.

Figure 31. Methodology scheme of financial analysis



Source: Author's elaboration.

As done in Tier I analysis, to provide a complete overview of the financial viability of such investment, two scenarios have been prepared. The first scenario (Scenario 1) looks at a realistic and likely approach for investing in such technology by considering that 60 percent of the CAPEX costs was financed through a loan at a fixed interest rate of 12 percent over a 5-year term. Based on the data available, these parameters are quite standard in the Solomon Islands. The second scenario (Scenario 2) looks at a more optimistic approach where CAPEX costs are fully provided as equity by the farm owner, thus not relying on financing. Additionally, a risk assessment was included in the study, based on the results obtained from the CBA. The risk assessment deals with the uncertainty that always permeates investment projects, mainly exogenous factors. The identified methodology considered steps for assessing the project risks, namely (i) sensitivity analysis; (ii) qualitative risk analysis; and (iii) risk prevention and mitigation. The sensitivity analysis involved the main variables of prices and costs: Diesel market price (USD); Firewood market price (USD); Investment costs (CAPEX); Operating costs (OPEX) + Labour. The sensitivity analysis allowed for the identification of the critical variables with the largest impact (positive, negative) on the project. A variable was defined as critical when a variation of ±5 percent in its initial value gives rise to a variation of more than ±15 percent in the value of the Net Present Value (NPV). The qualitative risk analysis, conducted by the international consultants, included risks which were categorized into these six main areas. Each risk was evaluated on a scale from no risk, low risk, to high potential risk, based on discussions held during one-to-one meetings with stakeholders, field visits, and the inception workshop. Strategies to mitigate the identified risks were also identified and discussed.

5.4.3 Results and discussions

<u>Cost Benefit Analysis</u>

Concerning Scenario 1, the investment pay-back period is 6 years (for example, less than half the service life), the NPV is 11,407.55 USD (consequently, positive), and a profitability ratio of return to investment of 59 percent and an IRR of 21 percent (both well above the interest rates of the economy) (Figure 32).

Figure 32. Detailed CBA worksheet for Scenario 1 (40% equity, 60% loan)

Biogas Plant Solomon Islands

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	16 to 15
FARM																
Energy consumption																
Litre of Diesel (L/year)	4,037	4,037	4,037	4,037	4,037	4,037	4,037	4,037	4,037	4,037	4,037	4,037	4,037	4,037	4,037	4,037
Firewood (t/year)	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Diesel market price (USD)	1.32	1.33	1.33	1.34	1.35	1.35	1.36	1.37	1.37	1.38	1.39	1.39	1.40	1.41	1.41	1.42
Firewood market price (USD)	100.00	100.50	101.00	101.51	102.02	102.53	103.04	103.55	104.07	104.59	105.11	105.64	106.17	106.70	107.23	107.77
Feed in tariff electricity																
Biogas price																
Avoided expenses																
Replaced diesel expenses		6,549	6,582	6,615	6,648	6,681	6,715	6,748	6,782	6,816	6,850	6,884	6,919	6,953	6,988	7,023
Replaced firewood expenses		1,126	1,131	1,137	1,143	1,148	1,154	1,160	1,166	1,171	1,177	1,183	1,189	1,195	1,201	1,207
Operating costs																
Maintenance		100.00	100.50	101.00	101.51	102.02	102.53	103.04	103.55	104.07	104.59	105.11	105.64	106.17	106.70	107.23
Replacements		100.00	100.50	101.00	101.51	102.02	102.53	103.04	103.55	104.07	104.59	105.11	105.64	106.17	106.70	107.23
Water		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Labour		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Revenues																
Replaced diesel (Liters)(Surplus)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Replaced diesel expenses (Surplus)																
Capital depreciation	-	-1,290	-1,290	-1,290	-1,290	-1,290	-1,290	-1,290	-1,290	-1,290	-1,290	-1,290	-1,290	-1,290	-1,290	-1,290
Cash Flow																
+ Avoided expenses and Revenues		7,674.97	7,712.35	7,751.12	7,790.87	7,829.81	7,869.77	7,908.12	7,947.98	7,987.40	8,027.33	8,067.17	8,107.05	8,148.05	8,188.03	8,230.01
Operating expenses	-	-200.00	-201.00	-202.01	-203.02	-204.04	-205.05	-206.06	-207.11	-208.14	-209.18	-210.22	-211.28	-212.31	-213.46	-214.49
Operating Cash Flow	-	6,186	6,233	6,270	6,308	6,346	6,384	6,422	6,461	6,500	6,539	6,578	6,617	6,656	6,696	6,736
- Investments	-19,194	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
- Loan annuity	-	-3,195	-3,195	-3,195	-3,195	-3,195	-	-	-	-	-	-	-	-	-	-
Total Cash Flow	-19,194	3,001	3,038	3,076	3,113	3,151	6,384	6,422	6,461	6,500	6,539	6,578	6,617	6,656	6,696	6,736
Cumulative Cash Flow	-19,194	-16,193	-13,155	-10,079	-6,966	-3,815	2,569	8,991	15,452	21,952	28,491	35,069	41,686	48,342	55,038	61,774
Payback Year	-	-	-	-	-	-	Payback	-	-	-	-	-	-	-	-	-
CF shareholders	-7,678	3,001	3,038	3,076	3,113	3,151	6,384	6,422	6,461	6,500	6,539	6,578	6,617	6,656	6,696	6,736
Cumulative Cash Flow	7,678	4,677	1,639	1,437	4,550	7,701	14,085	20,507	26,968	33,468	40,007	46,585	53,202	59,858	66,554	73,290
Payback Year				Payback												
Project's impact on P&L		3,001	3,038	3,076	3,113	3,151	6,384	6,422	6,461	6,500	6,539	6,578	6,617	6,656	6,696	6,736

Loan and Capital structure																
Equity private financing	-7,678															
Loan	-11,516	60% of initial investment														
Constant interest rate	12%															
Duration of loan (years)	5															
Grace period (year)																
Loan repayment plan	Constant instalments															
Loan outstanding (BoP)	11,516	11,516	9,704	7,673	5,399	2,852	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
- Interests		1,382	1,164	921	648	342	-	-	-	-	-	-	-	-	-	-
Capital repaid		1,813	2,031	2,274	2,547	2,852	-	-	-	-	-	-	-	-	-	-
Loan outstanding (EoP)	11,516	9,704	7,673	5,399	2,852	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0

Project profitability	
NPV	11,?07.55 USD
NPV to shareholders	21,8??.05 USD
Project IRR	20.9%
IRR to shareholders	46.1%
payback (years)	6
Shareholders payback (years)	3

Source: Authors' elaboration.

In Scenario 2, the investment pay-back period is 4 years (for example, less than half the service life), the NPV is 21,690.05 USD (consequently, positive), and a profitability ratio of return to investment of 113 percent and an IRR of 32.4 percent (both well above the interest rates of the market) (Figure 33).

Figure 33. Detailed CBA worksheet for Scenario 2 (100% equity, 0% loan)

Biogas Plant Solomon Islands

Year		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
FARM																	
Energy consumption																	
Litres of Diesel (l/year)		4,937	4,937	4,937	4,937	4,937	4,937	4,937	4,937	4,937	4,937	4,937	4,937	4,937	4,937	4,937	4,937
Firewood (m³/year)		11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Diesel market price (USD)		1.32	1.33	1.33	1.34	1.35	1.35	1.36	1.37	1.37	1.38	1.39	1.39	1.40	1.41	1.42	1.42
Firewood market price (USD)		100.00	100.50	101.00	101.51	102.02	102.53	103.04	103.55	104.07	104.59	105.11	105.64	106.17	106.70	107.23	107.77
Feed in tariff electricity																	
Biogas price																	
Avoided expenses																	
Replaced diesel expenses			6,549	6,582	6,615	6,648	6,681	6,715	6,748	6,782	6,816	6,850	6,884	6,919	6,953	6,988	7,023
Replaced firewood expenses			1,125	1,131	1,137	1,143	1,149	1,154	1,160	1,165	1,171	1,177	1,183	1,188	1,195	1,201	1,207
Operating costs																	
Maintenance			100.00	100.50	101.00	101.51	102.02	102.53	103.04	103.55	104.07	104.59	105.11	105.64	106.17	106.70	107.23
Replacements			100.00	100.50	101.00	101.51	102.02	102.53	103.04	103.55	104.07	104.59	105.11	105.64	106.17	106.70	107.23
Water			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Labour			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Revenues																	
Replaced diesel (Litres) Surplus																	
Replaced diesel expenses (Surplus)			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Capital depreciation			1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280
Cash Flow																	
+ Avoided expenses and Revenues			7,674.07	7,713.35	7,751.91	7,790.67	7,829.63	7,868.77	7,908.12	7,947.65	7,987.40	8,027.33	8,067.47	8,107.81	8,148.35	8,189.09	8,230.03
Operating costs – Losses			200.00	201.00	202.01	203.02	204.03	205.05	206.08	207.11	208.14	209.18	210.23	211.28	212.34	213.40	214.45
Operating Cash Flow		-	6,195	6,233	6,270	6,308	6,346	6,384	6,422	6,461	6,500	6,539	6,578	6,617	6,656	6,696	6,736
- Investments	-	19,194	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Loan amount																	
Total Cash Flow	-	19,194	6,195	6,233	6,270	6,308	6,346	6,384	6,422	6,461	6,500	6,539	6,578	6,617	6,656	6,696	6,736
Cumulative Cash Flow		*19,194*	*12,999*	*6,766*	*496*	*5,812*	*12,158*	*18,543*	*24,965*	*31,426*	*37,926*	*44,464*	*51,042*	*57,659*	*64,315*	*71,011*	*77,747*
Payback Year						*Payback*											
CF shareholders	-	19,194	6,195	6,233	6,270	6,308	6,346	6,384	6,422	6,461	6,500	6,539	6,578	6,617	6,656	6,696	6,736
Cumulative Cash Flow	-	*19,194*	- *12,999*	- *6,766*	- *496*	*5,812*	*12,158*	*18,543*	*24,965*	*31,426*	*37,926*	*44,464*	*51,042*	*57,659*	*64,315*	*71,011*	*77,747*
Payback Year		-	-	-	-	*Payback*	-	-	-	-	-	-	-	-	-	-	-
Project's impact on P&L		-	6,195	6,233	6,270	6,308	6,346	6,384	6,422	6,461	6,500	6,539	6,578	6,617	6,656	6,696	6,736

Loan and Capital structure																	
Equity private financing	-	**19,194**															
Loan		-	**0%**	of initial investment													
Constant interest rate		**12%**															
Loan duration (years)		**5**															
Grace period (years)																	
Loan repayment plan		Constant Installments															
Loan outstanding (BoP)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
- Interests																	
- Capital repaid			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Loan outstanding (EoP)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Project profitability	
NPV	21,690.05 USD
NPV to shareholders	21,690.05 USD
Project IRR	32.4%
IRR to shareholders	32.4%
payback (years)	4
Shareholders payback (years)	4

Source: Authors' elaboration.

Sensitivity Analysis

The sensitivity analysis, conducted with a five percent variation in key variables, highlighted the significant impact of diesel market price and Capital Expenditure (CAPEX) on the Net Present Value (NPV) of the project. When diesel market prices varied by five percent , NPV fluctuated by -18 percent and +18 percent respectively. Similarly, a five percent variation in CAPEX resulted in an NPV change of +15 percent and -15 percent (Table 9). This underscores the importance of meticulous consideration and potential mitigation strategies for these variables in project planning and decision-making.

Table 9. Sensitivity Analysis Results: Impact of Variable Variation on Net Present Value

SENSITIVITY ANALYSIS (5%)									
Variables	**Variation of variables**			**Variation of NPV**					
	95%	**100%**	**105%**	**95%**	**100%**	**105%**	**95%**	**100%**	**105%**
Diesel market price	1.254	1.32	1.386	9,366	11,408	13,449	-18%	0%	18%
Firewood market price	95	100	105	11,057	11,408	11,758	-3%	0%	3%
Investment costs (CAPEX)	18,234	19,194	20,153	13,168	11,408	9,647	15%	0%	-15%
Operating costs (OPEX) + Labour	190	200	210	11,470	11,408	11,345	1%	0%	-1%

Source: Author's elaboration

A further step considers only the selected variable that exceeds 15 percent of NPV fluctuation. Table 10 illustrates the impact of varying Diesel market prices (USD/litre) and Investment costs (CAPEX) on the Net Present Value (NPV) of the investment. As the Diesel market price increases from 40 percent to 160 percent of its original value, the NPV ranges from -13,033 to 35,848 USD. Similarly, changes in CAPEX from 7,678 to 30,710 USD lead to corresponding NPV fluctuations.

The sensitivity analysis further demonstrated the robustness of the investment by revealing that both diesel market price and Capital Expenditure (CAPEX) require a variation exceeding 20 percent to render the NPV negative. This resilience underscores the project's ability to withstand significant fluctuations in these key variables without adversely affecting its overall profitability (Table 10).

Table 10. Impact of Variable Variation on Net Present Value for Diesel Market Price and Investment Costs

	Diesel market price (USD/l)		**Investment costs (CAPEX)**	
	NPV USD	Variable USD/liter	NPV	Variable
160%	35,848	2.11	-9,713	30,710
140%	27,804	1.85	-2,674	26,872
120%	19,451	1.58	4,367	23,033
100%	11,408	1.32	11,408	19,194
80%	3,364	1.06	18,448	15,355
60%	-4,989	0.79	25,489	11,516
40%	-13,033	0.53	32,528	7,678

Source: Author's elaboration

Qualitative risk analysis and mitigation actions

The qualitative risk analysis for investing in biogas projects from pig manure in the Solomon Islands reveals several significant challenges across six main categories: Legislative, Financial, Research, Teamwork, Local Support, and Training. Each category is evaluated for potential risks, with scores ranging from 0 (no risk) to 2 (high potential risk) (Table 11).

Table 11. Results of the qualitative risk analysis of the Solomon Islands case study

Legislative	**Potentially High**
Instability and low reliability of the legal framework and support scheme	
Lack of support scheme for energy production from biogas	
Lack of legislation to clarify the digestate value and its final use	
Financial	**Low**
High operational costs and long pay-back periods (>15 years)	
Difficulty in obtaining bank loans due to high risks projects	
Limited public funds managed by authorities targeting different goals	
Research	**Potentially High**
Underfunding of the research sector	
Undersized Research & Development system	
Low frequency of national calls for project proposals, on average every 3 years	
Low confidence of potential partners to collaborate with modest innovators	
Team work	**Low**
Development programs are not complementary to achieving the goal	
Lack of inter-ministerial collaboration and synchronicity between segments (research, technology transfer, implementation to the beneficiary etc.)	

Local support	No risk
Low interest in providing local information on feedstock availability	
High bureaucracy in obtaining permissions and approvals	
Poor involvement in actions aimed at increasing public acceptance	
Low administrative capacity for preparing projects funded by international funds	
Trainigs	**Low**
Lack of experts makes investors skeptical about investing in biogas projects	
Lack of educational programs in schools and universities to train specialists	
Lack of training courses for end-users Low relevance of the target groups for the training area	

Source: Author's elaboration

As presented in Table 11, the legislative environment in the Solomon Islands is unstable, posing significant risks to biogas investment. Financial challenges, including high operational costs and limited access to bank loans, further hinder investment prospects. The underfunded research sector and lack of collaboration opportunities exacerbate these difficulties. However, local support is robust, with streamlined bureaucratic processes and strong public engagement. Training-related risks are low but require more targeted programs. Addressing legislative instability, financial constraints, and research funding gaps is crucial for fostering a conducive environment for biogas development. Proposed strategies aim to mitigate these risks and promote investment in the Solomon Islands.

Table 12. Strategies to address and mitigate the identified risks

Category	Risk	Prevention and Mitigation Strategies
Legislative	Instability and low reliability of the legal framework and support scheme	- Advocate for stable and consistent policies - Engage with policymakers to develop long-term support schemes
	Lack of support scheme for energy production from biogas	- Lobby for dedicated biogas support programs - Promote biogas benefits to government stakeholders
	Lack of legislation for biomethane access to natural gas grids and transport	- Work with legislators to draft and pass relevant laws - Educate lawmakers on the importance of biogas integration
	Lack of legislation to clarify the digestate value and its final use	- Propose clear regulations for digestate use - Demonstrate successful case studies from other regions
Financial	High operational costs and long pay-back periods (>15 years)	- Seek subsidies and grants to offset initial costs
	Difficulty in obtaining bank loans due to high-risk projects	- Develop risk-sharing mechanisms with financial institutions - Present robust business plans to potential lenders
	Limited public funds managed by authorities targeting different goals	- Align biogas projects with national priorities (NDCs) - Apply for international funding and partnerships
Research	Underfunding of the research sector	- Lobby for increased research funding - Collaborate with international research institutions
	Undersized Research & Development system	- Invest in building local R&D capacity - Create partnerships with universities and private sector
	Low frequency of national calls for project proposals (every 3 years)	- Advocate for more frequent funding calls - Secure alternative funding sources
	Low confidence of potential partners to collaborate with modest innovators	- Build a track record of successful projects - Enhance transparency and communication with partners

Team Work	Development programs are not complementary to achieving the goal	- Ensure alignment of programs with strategic goals - Foster inter-program communication and cooperation
	Lack of inter-ministerial collaboration and synchronicity	- Establish inter-ministerial working groups - Promote regular meetings and shared objectives
Local Support	Low interest in providing local information on feedstock availability	- Conduct awareness campaigns to highlight benefits - Engage local communities in feedstock supply
	High bureaucracy in obtaining permissions and approvals	- Simplify and streamline approval processes - Provide support services for navigating bureaucracy
	Poor involvement in actions aimed at increasing public acceptance	- Launch public awareness and education campaigns - Involve community leaders in project promotion
	Low administrative capacity for preparing projects funded by international funds	- Offer training on project preparation and management - Utilize consultancy services for complex applications
Trainings	Lack of experts makes investors skeptical about investing in biogas	- Organize training programs for local experts - Partner with international experts for knowledge transfer
	Lack of educational programs in schools and universities to train specialists	- Provide scholarships and incentives for specialized studies
	Lack of training courses for end-users; low relevance of the target groups for the training area	- Design targeted training programs for end-users - Ensure training content is relevant and practical

Source: Author's elaboration

To address the instability and low reliability of the legal framework and support schemes, advocating for stable policies and engaging with policymakers to develop long-term support is crucial. Lobbying for dedicated biogas programs and educating lawmakers about biogas benefits can create a supportive legislative environment. Drafting relevant laws for biomethane integration and clarifying digestate regulations will further mitigate legislative risks.

Mitigating financial risks involves seeking subsidies and grants to offset technology upfront costs. Developing risk-sharing mechanisms with financial institutions and presenting robust business plans can facilitate easier access to loans. Aligning biogas projects with national priorities (particularly the ones contained in the NDCs, NAP and other national policies) and applying for international funding can address limited public funds.

Similarly, enhancing the research sector requires lobbying for increased funding and collaborating with international institutions. Investing in local Research & Development (R&D) capacity and creating partnerships with universities and the private sector can strengthen innovation. Advocating for more frequent project proposal calls and securing alternative funding will help mitigate research-related risks. Building a track record of successful projects and enhancing transparency with partners can boost the confidence of private sector actors to engage in biogas production in their businesses and farms.

Ensuring development programs are complementary to strategic goals involves fostering inter-program communication and cooperation. Establishing inter-ministerial working groups and promoting regular meetings with shared objectives can enhance collaboration. Increasing local support entails conducting awareness campaigns to highlight biogas benefits and engaging local communities in feedstock supply. Simplifying approval processes and providing support for navigating bureaucracy can reduce hurdles. Launching public awareness campaigns, involving community leaders, and offering training on project preparation can further bolster local support.

Addressing the lack of experts involves organizing training programs for local specialists and partnering with national and international experts for knowledge transfer. Developing biogas-related curricula in educational institutions and providing scholarships for specialized studies can improve opportunities. Designing targeted training programs for end-users and ensuring relevant content will enhance training effectiveness.

5.5 Biogas plant planning and engineering drawings

The case study farm has the technical potential to be equipped with a biogas system that produces electricity and heat, while the financial assessment demonstrated economic viability for private sector investments in this technology. One of the main enabling factors that emerged from the barrier and risk analysis is the lack of capacity and support to plan, design and deliver a state-of-the-art biogas system to farmers in the Solomon Islands. This feasibility study then, is completed by a detailed, case-specific, biogas system planning coupled with engineering drawings necessary to deploy a biogas plant sized according to the feedstock availability of the Outback farm as per the technical specifications in Chapter 5.3.

The planning and design of the biogas plant at Outback farm required an attentive survey of the site to collect actual spatial data and information about the conditions of the case study farm. A spatial data survey is commonly the mix of a mapping exercise, especially where cadastre records and maps exist, and direct measurements are carried out by a crew of technicians.

The elaboration of available maps and field measurements requires extensive work and often subsequential measures verification and repetition of the surveys. Traditional surveying involves the direct measurement of distances, angles, and elevations using specialized equipment. Surveyors physically walk the area taking measurements at specific points to create accurate maps, plans, and land records. This method has been the industry standard for many years, as it delivers precise results in projects. The potential accuracy of this method is often overshadowed by its costs and time requirements necessary to carry out a mapping exercise with surveys. Taking measurements of every item in the case study and measuring every angle and distance is tedious and long work, requiring several days to be completed. Moreover, if the experts' surveyors are not local, their measurements cannot be repeated swiftly shall any missing information be noticed while processing the data collected. Photogrammetry, on the other hand, uses the power of imagery and computer algorithms to extract spatial data. By capturing photographs from various vantage points and angles, photogrammetry constructs 3D models and maps, often without the need for physical contact with the surveyed area. This approach takes advantage of modern technology and it returns impressive results with a fraction of the time and resources when compared to traditional surveys.

5.5.1 Photogrammetric site survey

Photogrammetry is the process of authoring a digital asset using multiple photos of the original real-world object or area. This technique is gaining prominence due to its numerous advantages compared to traditional field surveys, including:

- Cost-Efficiency: Traditional surveying is labour-intensive and costly, especially for large-scale projects. Photogrammetry reduces expenses by minimizing the need for on-site personnel and equipment, and time spent taking measurements.
- Rapid Data Collection: Photogrammetry accelerates data acquisition. By utilizing drones or aircraft to capture aerial images, vast areas can be surveyed in a fraction of the time it would take using traditional methods.
- Safety: Surveyors often work in challenging or hazardous environments. Photogrammetry keeps personnel out of harm's way by allowing data collection from a safe distance.
- High Precision: Modern photogrammetry software can produce highly accurate results, often rivalling or surpassing traditional surveying in terms of precision.
- Versatility: Photogrammetry is suitable for a wide range of applications, from construction and environmental monitoring to archaeological site preservation.
- Preservation: Photogrammetry can be used to create detailed 3D models without causing any physical impact on objects and areas.

While both traditional surveying and photogrammetry have their merits, the advantages of photogrammetry are increasingly evident in today's fast-paced world. Its cost-efficiency, rapid data collection, and versatility make it an invaluable tool in a wide range of industries.

Photogrammetry was applied to surveying the area of the Outback farm to prepare an accurate tri-dimensional (3D) model of the case study area, with centimetre precision and the recreation of a true-to-scale replica of every existing feature and building on the farm, including the relative dimensions (height, length, width) and volumes of buildings, piles, structures, trees, or even grass, and any other feature on the landscape.

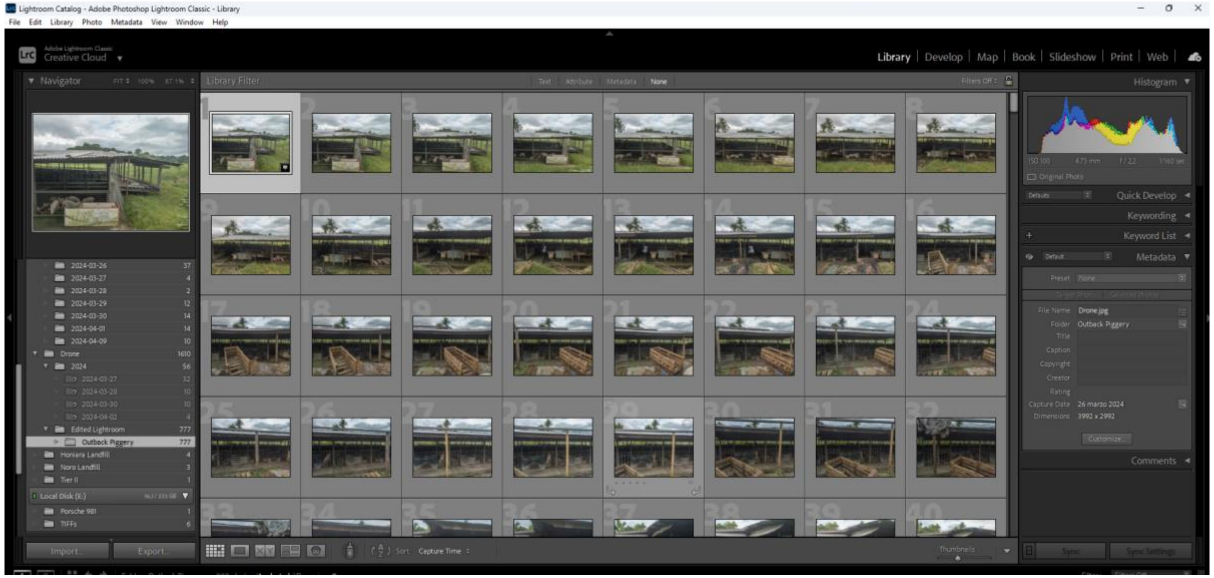
Figure 34. Drone photogrammetry survey at the Outback Farm

The workflow for photogrammetric surveys is divided into two major parts: Capture and processing. Capture is about taking photos of an object covering its entirety. The first step is to gather multiple photos of the object from various angles. It is also necessary to gather extra information for reference, scale metrics and correctly expose the photos. During the field survey on Outback Farm in April 2024, an authorized drone pilot completed the photogrammetry capture survey by flying a GPS-equipped drone over the Outback farm with a pathway circling first, and then spiralling around the entire farm, to collect a sufficient number of photographs to be fed into the processing software. The Outback farm is located 3 km south of the Henderson International Airport and this required additional authorization to fly the drone in such airspace. The SCALA programme through the local consultant obtained the authorization to fly in the no-fly zone from the Civil Aviation Authority of Solomon Islands.

During the sortie, the drone captured 777 photographs of the Outback Farm from various angles and heights flying in a spiral path around a pivot represented by the centre of the pig house. Each photo overlapped for at least 30 percent with the next, a key requirement of the processing software for stitching all images and connecting them. The drone camera was set on manual shutter speed of 1/320 of a second to ensure the sharpness of each shot taken. The focal length and aperture are fixed on the drone camera model employed, at 24 mm and f 2.8 respectively. The drone was equipped with a Natural Density (ND) filter over its camera to ensure that the maximum dynamic range was captured by the sensor with the consistent settings described above. Moreover, the sortie took place between 12:30 and 1:40 pm, to minimize the presence and appearance of shadows in each picture taken from different angles, relative to the position of the sun in the sky. These settings and precautions were chosen to ease the processing of images and enhance the result of the photogrammetry workflow.

Processing is about generating the mesh and texture data from the photos. First, the photos need to be calibrated (white balanced) and harmonized in terms of colour scheme and grading. This action is crucial to deliver the best images possible to the photogrammetry software to work with. The features that make images apt to be used in photogrammetry are the low contrast and the absence of harsh shadows, crushed blacks and highlights. The resulting image should therefore appear as having a “flat” colour profile which retains information without inducing chromatic aberrations. Colour-balanced photos are divided into groups characterized by main light conditions (for example, top-down images or backlit images and plain light images) and harmonized. In harmonization, colours are modified to resemble a midpoint in terms of saturation and vibrance, exposure, white balance and once again contrast. When all groups are harmonized, the images are calibrated and ready for the reconstruction software. In the context of this project, colour calibration was carried out using the Adobe Lightroom Classic 2023® software. Each of the 777 images was colour-balanced and harmonized to provide an even basis for the 3D editing software to work with. During the balancing, 33 photographs presented non-harmonizable features (colour aberrations) and were excluded from the lot. A total of 744 photos were then consolidated for 3D model reconstruction.

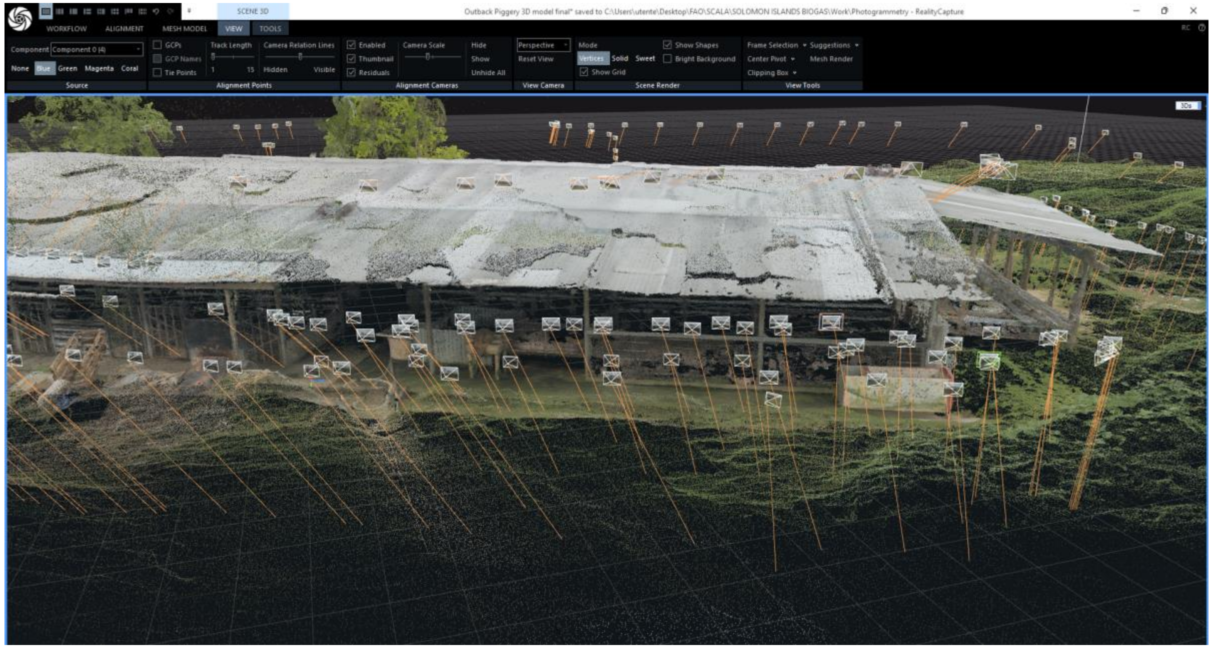
Figure 35. Colour balancing in Adobe Lightroom Classic 2023



Source: Author's elaboration.

The reconstruction application compares the shapes in the photos (Alignment) to generate a high-resolution 3D mesh. The colour contained in the pictures is then transferred to either the mesh's vertex colours (Colorization) or to textures used on the surface of the mesh. Next, a low-resolution mesh for the baking process needs to be created: A medium to low-resolution mesh is exported from the reconstruction software and modified in a 3D software tool to be used as the destination of the baking tools. Baking is a process through which colour textures are generated. The software used for this crucial step of the workflow is Reality Capture® Version 1.4.1.

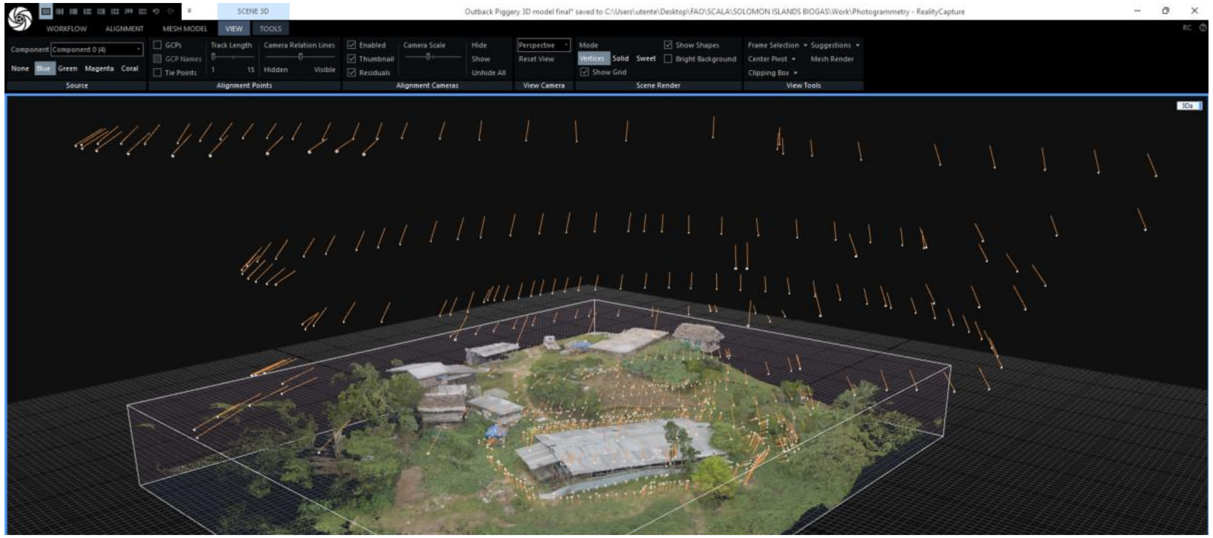
Figure 36. The aligned 744 images in Reality Capture create a point cloud of the 3D space



Source: Author's elaboration

Each picture taken from the drone is aligned by the software to reconstruct the point cloud of the 3D space (Figure 36). A point cloud is a large collection of points that are placed on a three-dimensional coordinate system. Point cloud files greatly speed the design process by providing a real-world context where the referenced objects can be re-created or additional models can be inserted, in a virtual reality environment. Each point in the point cloud exists in space as it is recognized by the software or the operator in at least three pictures taken in different positions. By triangulating recognizable points (pixels in the case of high-resolution digital images) the software can recreate a virtual tri-dimensional (3D) space with effective relative distances and true-to-scale dimensions. The exact location of each picture taken is represented in space by the small thumbnails and orange residual lines (figure 36) tracking in this case the position of the camera. Figure 37 displays the entire capture pathway followed by the drone.

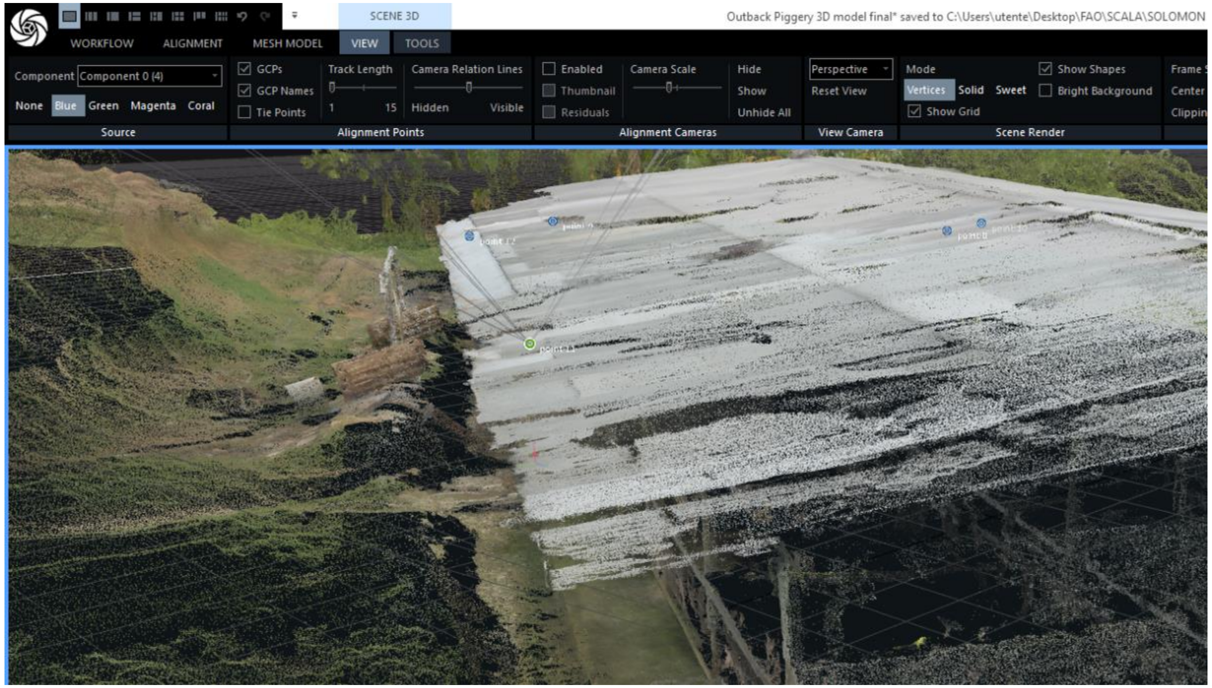
Figure 37. The 744 selected photos and the drone pathway for capturing the entire scene of the Outback farm



Source: Author's elaboration

After the first point cloud is formed, the programme checks for unaligned images, and these require manual work from the operator to identify a common Control Point that needs to be placed in space by using at least three (better four or five) pictures where such point is visible. A sharp corner or high-contrast area (like a stone or a nail on the roof) was used for this purpose. A total of 25 Control Points have been manually placed and verified in at least 3 images each.

Figure 38. Control Points are marked as blue dots that are visible and manually spotted by the operator in three or more photos

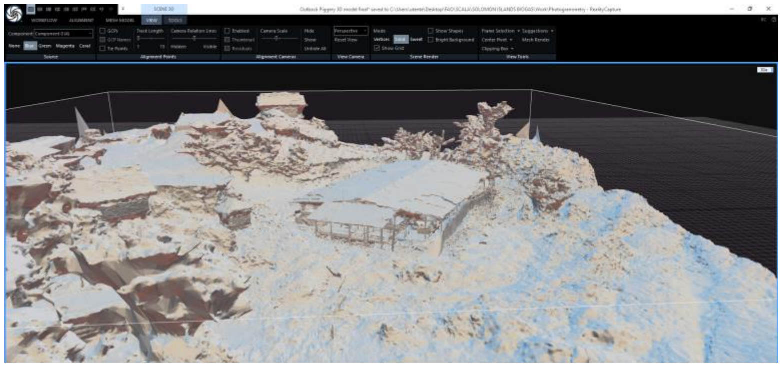


Source: Author's elaboration

The software can also use control points to fix known distances and accurately reproportion the entire object to fit into a certain scale. With this operation, the processing software can build a solid 3D object (.obj of .fbx extensions) and provide exact measurements of every feature of the 3D model.

A 3D model is the result of the connection of triangles formed by the points detected in the point cloud. The 3D model of the Outback farm is composed of 37 million triangles, each with its list of attributes such as distances, angles, and exact location in space. Even modern powerful software and computer hardware struggle to process several million triangles simultaneously and a useful action that allows swift visualization of the 3D model while retaining all attributes and parameters of the virtual object is a model simplification. Reducing the number of triangles by a factor of 10 (for example, from 37 million down to 3.7 million triangles), reduces the accuracy of the model only by 0.002 percent, while enabling swift visualization of the model also on less powerful computers or mobile devices. This step is also capable of enabling the transfer of the object to a local builder or construction company over the internet thus reducing costs and increasing the availability of the product.

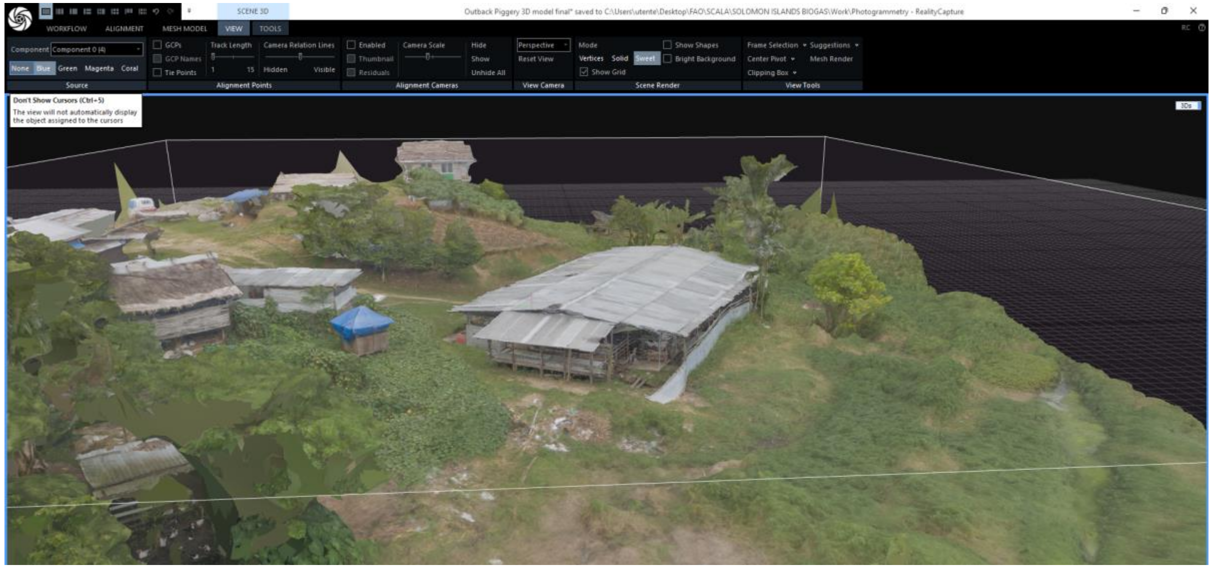
Figure 39. Above the Point Cloud with vertexes is transformed into a solid 3D object that has continuous surfaces instead of individual points in space. The 3D object is then simplified to reduce its complexity and weight while retaining its characteristics and information



Reality Capture displays the mesh as a point cloud, but internally it converts it to a mesh with vertices. The photo colour is transferred to the vertex colours. This requires only a .ply file (which handles vertex colour), which is easier to manipulate compared to an ".obj file" with big textures. The production of a dense model can benefit from the application of textures for visualization purposes and possible modifications once the 3D model is exported to another software (for example for architectural uses). Together with the solid 3D model, texturization is key to enabling a feature of photogrammetry that truly speeds up and enhances the production of engineering drawings in the true-to-scale environment: orthophotos.

Through orthophotos, CAD software can use a reference system based on real images that are non-perspective to represent and superimpose a model or engineering drawing to an existing feature.

Figure 40. Texturized 3D model of the Outback Piggery in Reality Capture



Source: Author's elaboration

From the texturized 3D model of the Outback farm, all sections and views can be extracted as orthophotos. With traditional surveys, this operation would require months and related costs for personnel and service providers.

Figure 41. Orthophoto from top. The picture is now correctly oriented towards the magnetic north, and in non-perspective scale

Orthophotos are the basis for any CAD software to take measurements as the starting point for drawing the biogas plant.

5.5.2 Design of a biogas plant for the case study farm

Detailed drawings were produced to guide a team of builders when constructing the biogas plant, or to provide a lead while assembling a turnkey biogas system correctly sized. The computer-aided design software Autodesk AutoCAD 2022® was used for drawing the biogas plant layout out of the Outback Farm. This is the fixed dome biogas plant which uses modern greenhouse metal frames in which a polycarbonate plastic bag is enclosed. For systems of this size (total cumulated digesters capacity 30 m^3), this solution is the most reliable, efficient and cost-effective.

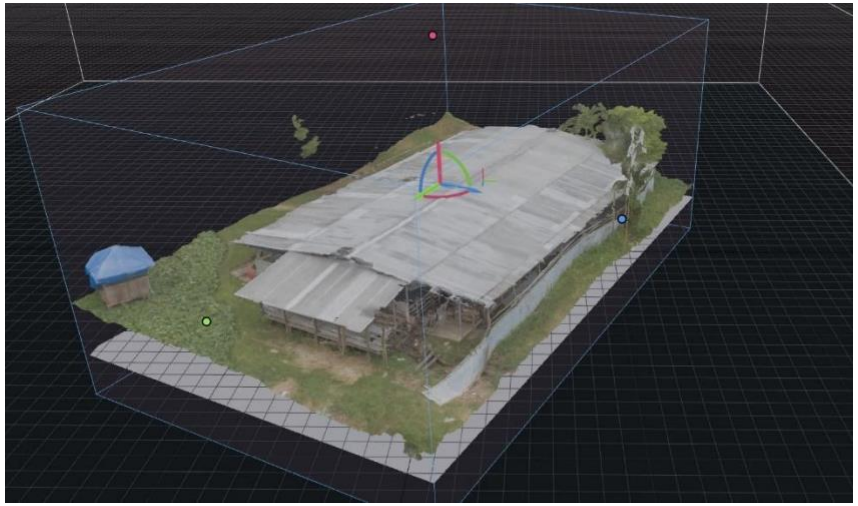
Table 13. Main equipment and components of the biogas plant for the Outback farm

Assembly Biogas Digester
2 x Assembly Membrane Digester 15m^3 (with steel frame)
Circulation pump 0.75 kW (with pipe fittings)
Pretreatment system
Sewage pump with knife 2.2 kW
Fermentation powder
Biogas purification system & Gas Storage
Biogas desulfurizer PX-20L (with filter inside)
Fe_2O_3 replace filter
Biogas Dehydrator PX-10L
Biogas storage bag 20 m^3
Pressure release valve
Biogas Appliances
Biogas Pipe/Fitting
Biogas pump PX-100
Ultrasonic biogas flow meter BF-2000
Generator
5 kW Biogas Generator

Source: Author's elaboration

The main components of the system are the digester tanks, and the pre-treatment tank, equipped with a shredder with knives and a sewage pump to transport the homogenized slurry to the two membrane digesters. For this biogas system a two-stage digester design has been chosen. This design offers advantages in terms of digestion efficiency as well as practicality in distributing the volumes of the biogas plant. The two digesters are interconnected and equipped with circulation pumps. The digesters are connected to a 20 m^3 biogas storage bag. This reservoir ensures that biogas pressure and feed to the systems downstream are constant and that no gas starvation takes place. The downstream systems are crucial components to ensure an extended life for the biogas plant. Firstly, a gas purification system is provided. This is composed of a desulfurized unit, a dehydration unit and a pressure release valve. The purified and pressure-controlled gas is then fed through a valved T junction to the biogas generator and to a gas piping system connected to a gas burner, for the cooking of feed on the farm. All components listed and drawn exist on the market and can be purchased singularly or collectively from various providers. These are listed in Table 13. Each of these components' specifications (for example, external sizes, contact points, and so on) have been taken from the actual specification sheets of producers and correctly transferred to the drawings.

Figure 42. Orthophotos directions to draw the biogas plant



Source: Author's elaboration

Figure 42 presents the perspective views identified with the green, magenta, and blue dots: the green dot identifies the standing point for the *front view* of the pig house, and the exact location of the related horizontal orthophoto denominated “Front view”. Similarly, the blue circle identifies the standing point for the *side view* of the pig house, as well as the exact location of the second horizontal orthophoto denominated “Side view”. Lastly, the magenta circle identifies the standing point for the *top view* of the pig house, which is also the location of the vertical orthophoto denominated “Top view”. By creating these views, exact measurements of each feature in the case study area have been taken and considered for the construction of the biogas plant. The natural elevation model of the farm has led the owner to plan the outlet of the slurry in the lower corner of the pig house so that, by gravity, the slurry flows out of the pen house towards the creek and flat area next to the farm. The slope is visible in Figure 43 which represents the orthophoto of the “front view” section of the farm profile.

Figure 43. Front view orthophoto of the Outback farm

Source: Author's elaboration

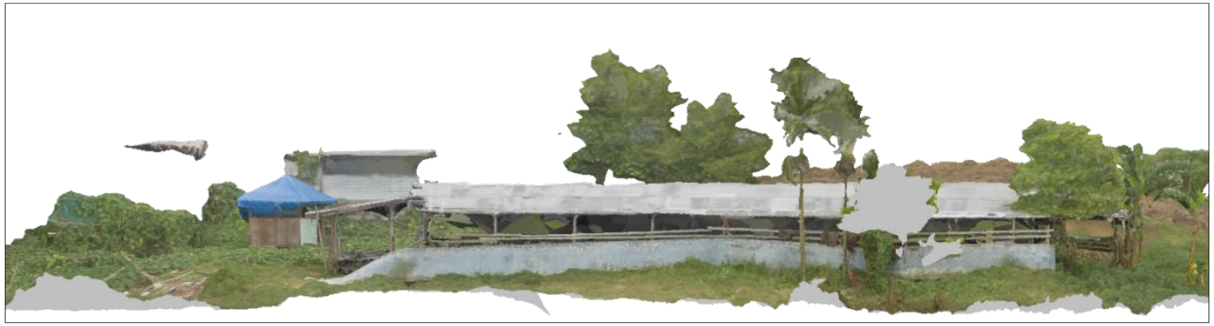
Orthophotos have been extracted also for the Top and Side views of the Outback farm, to reconstruct the relative CAD drawings and build the biogas plant design using this true-to-scale measure. This is possible because orthophotos are non-perspective representations of tri-dimensional objects, in other words, the visualized dimensions of all elements present in the photo are not affected by perspective which would give the sense of depth by making objects in the distance appear smaller in comparison to those in the foreground.

Figure 44. Top view orthophoto of the Outback farm

Source: Author's elaboration.

The non-perspective feature of orthophotos is fundamental to taking measurements of all objects and transposing them into the CAD software. Engineering drawings are bi-dimensional (2D) objects and the sense of perspective of classic photos would impair the reference system employed in the drawing canvas.

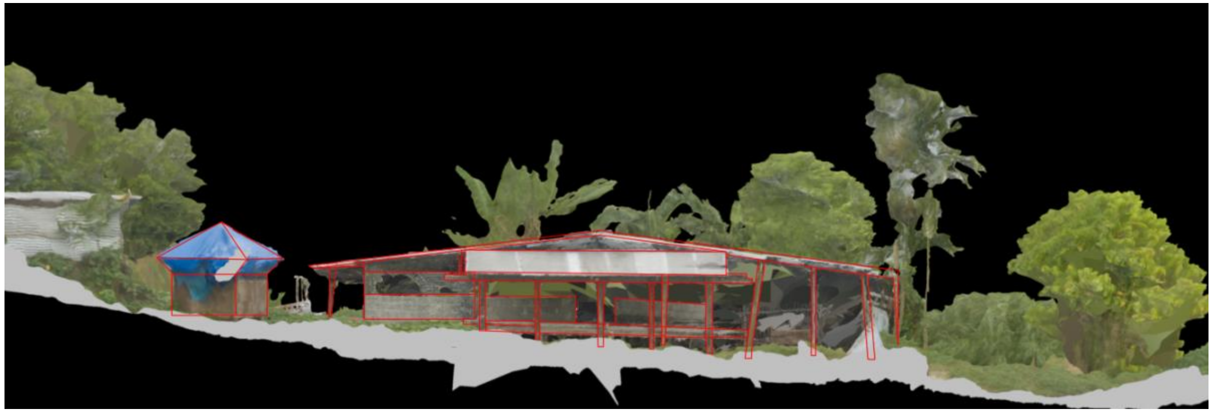
Figure 45. Side view orthophoto of the Outback farm



Source: Author's elaboration.

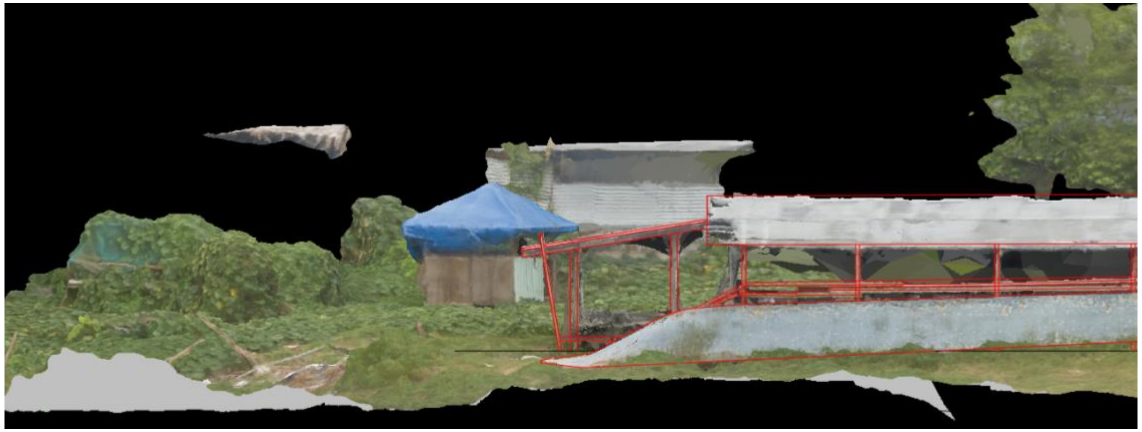
The reconstruction in AutoCAD of the elements composing the farm is presented in Figures 46 (front view), Figure 47 (top view) and Figure 48 (side view) with the superimposition of the main lines for each distinctive element of the pig house and surrounding shed drawn in red.

Figure 46. CAD reconstruction of farm elements (main pig house and service shed to the left) from Front view orthophoto



Source: Author's elaboration.

Figure 47. CAD reconstruction of farm elements (main pig house with porch) from Side view orthophoto



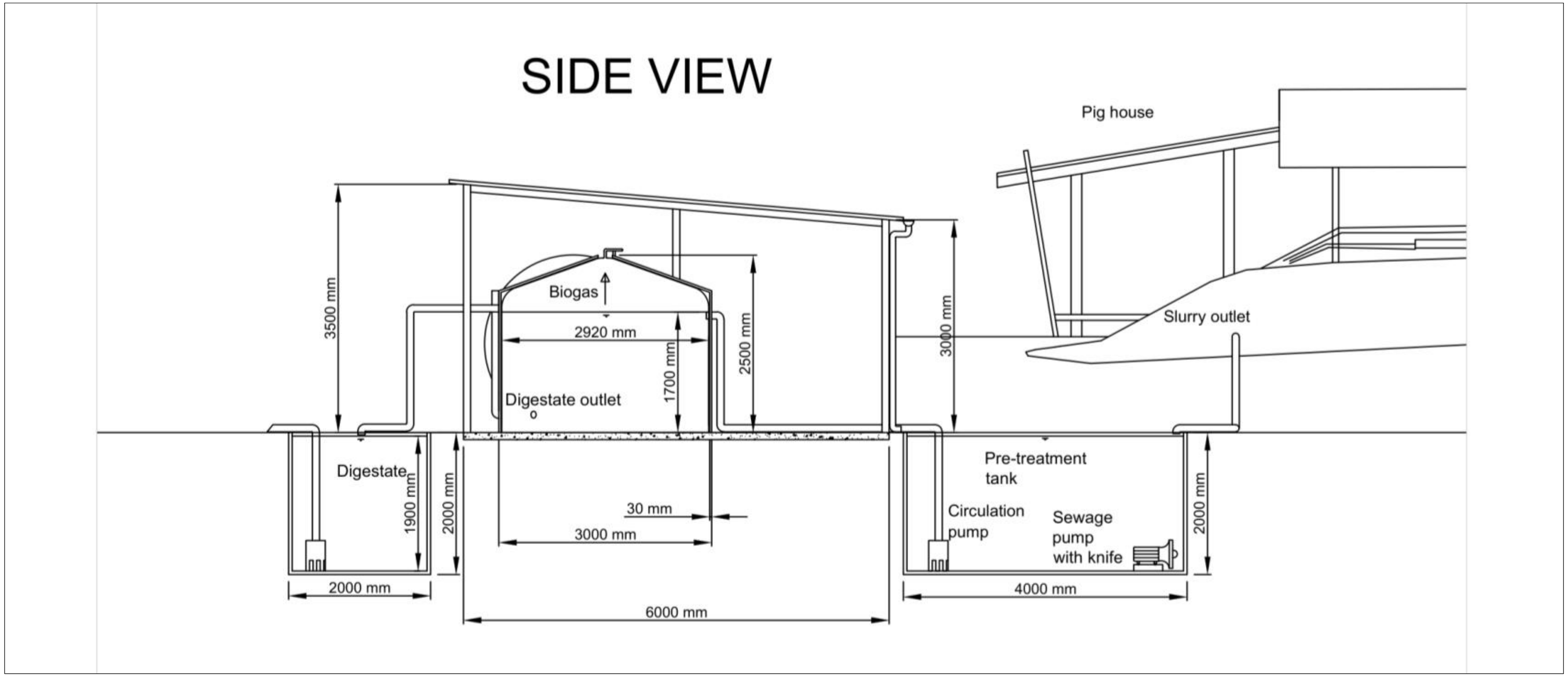
Source: Author's elaboration.

Figure 48. CAD reconstruction of farm elements (main pig house with both porches and steel foil wind barrier) from Top view orthophoto

From the projected features of key farm elements (and their true-to-scale measurement), the biogas plant was developed considering slopes and necessary earthworks to clear the area for the construction of the plant.

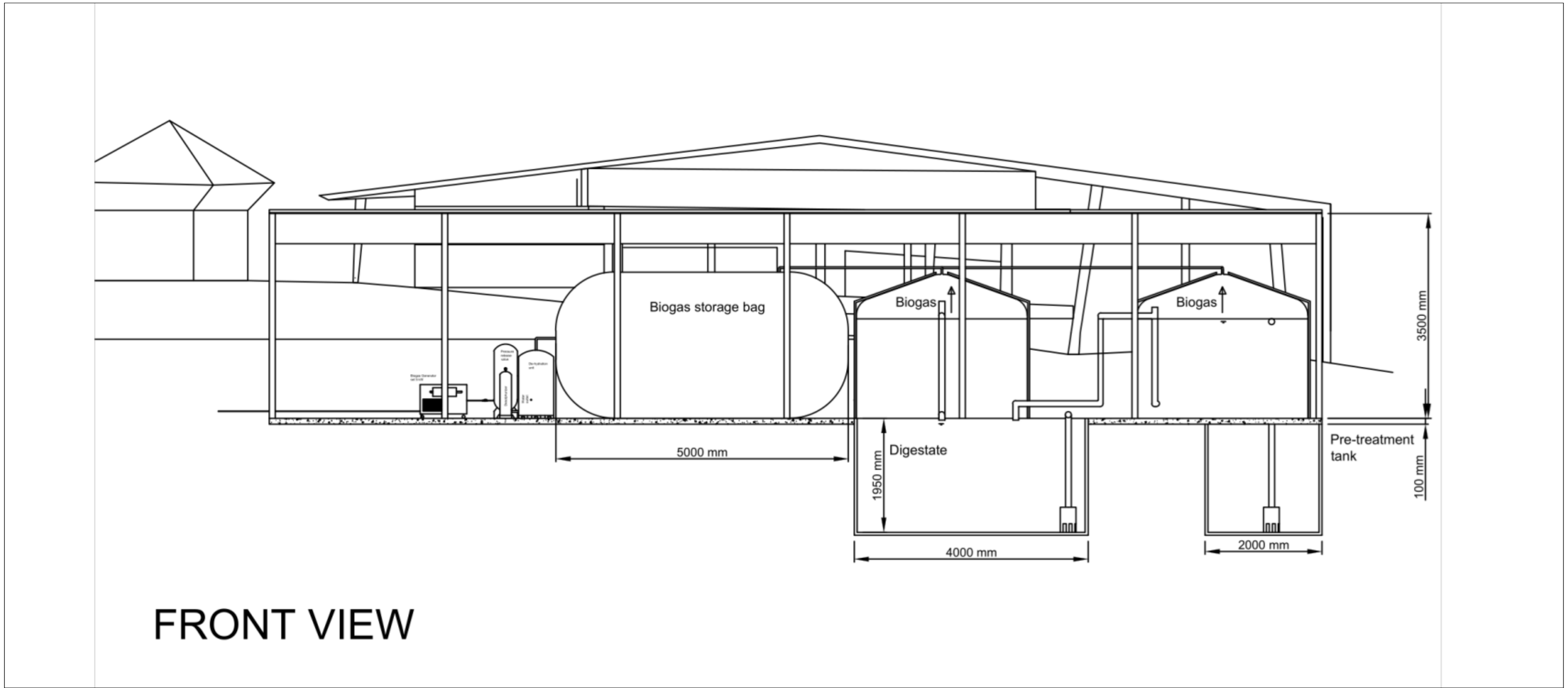
5.5.3 Complete set of Engineering drawings for a 300-head commercial pig farm in the Solomon Islands

Figure 49. Engineering drawing (side view) of the biogas plant at the Outback Farm



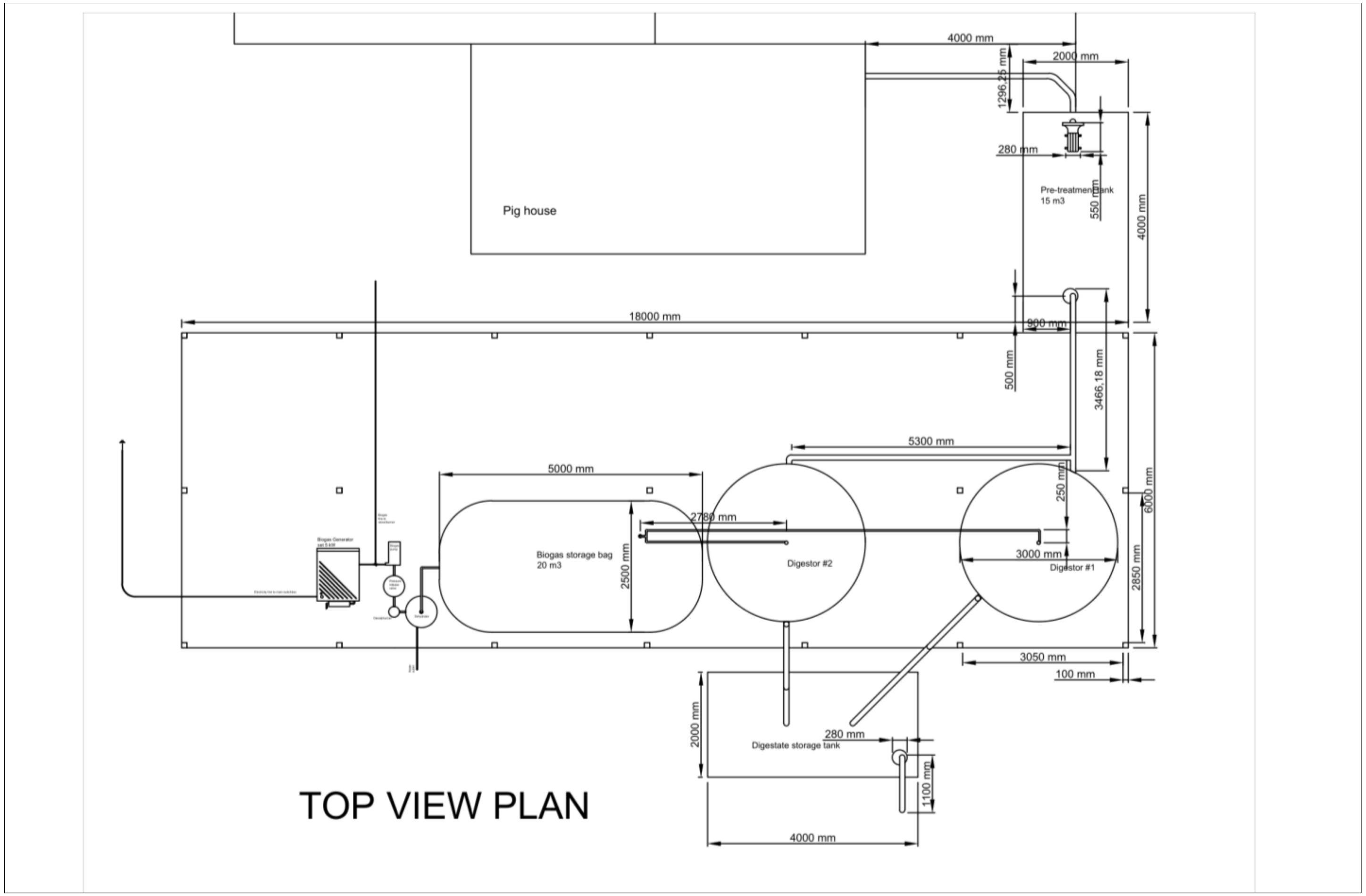
Source: Author's elaboration.

Figure 50. Engineering drawing (front view) of the biogas plant at the Outback Farm



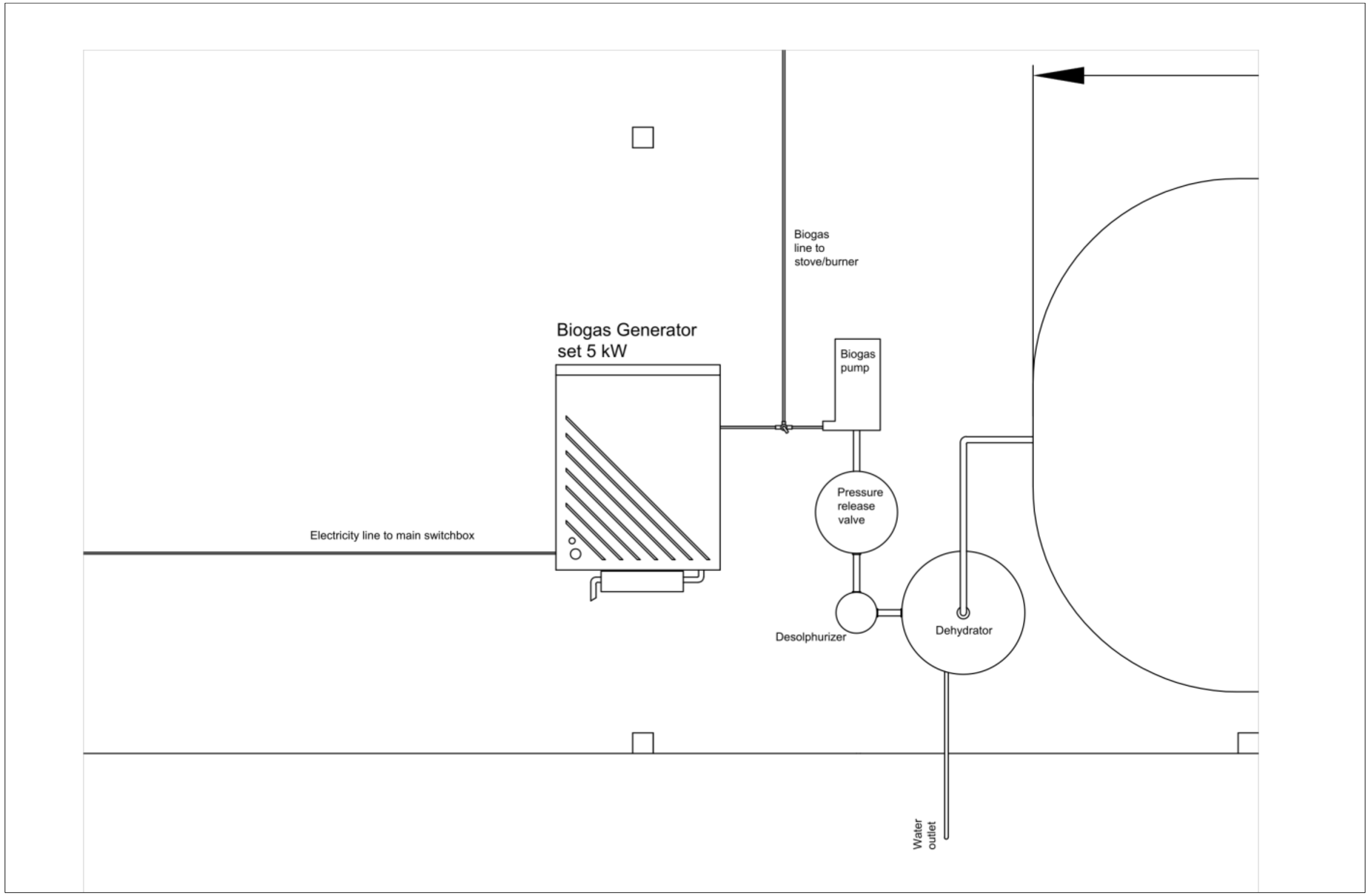
Source: Author's elaboration.

Figure 51. Engineering drawing (top view) of the biogas plant at the Outback Farm



Source: Author's elaboration.

Figure 52. Engineering drawing: detail view of biogas purification system, pump and generator



Source: Author's elaboration.

6. CASE STUDY ASSESSMENT: Ranadi Landfill (Guadalcanal province)

6.1 Background and baseline

The Solomon Islands generate between 0.75 and 1.0 kilograms of solid waste per person per day.[14] Literature indicates that organic waste (food, wood/ timber, garden organics and other organics) is the largest component of solid waste in many parts of the Solomon Islands.[15] Other estimates indicate that 40–50 percent of waste is organic.[16]

A waste characterization study by Sinclair Knight Merz[17] provided baseline data showing high proportions of plastics (over 16 percent) and biodegradable material (65 percent). On the other hand, in a 2023 waste audit conducted by the Secretariat of the Pacific Regional Environment Programme (SPREP)[18] through the PacWastePlus project, supported by the European Union, it was found that organic waste in the Islands ranges from 45 percent (Honiara) to 87 percent (Ambu) of the total sample weight. The audit also revealed that metals, including aluminium cans, aluminium recyclables, steel cans, and other metals, are the second most prevalent material in Solomon Island household waste, with many of these being recyclable. In urban areas like Honiara (11 percent) and semi-urban areas like Guadalcanal (18 percent), aluminium beverage containers make up a significant portion of household waste. Additionally, plastics are the third most prevalent material by weight in the audited areas, with higher proportions in urban and semi-urban regions due to consumption patterns.

In the country, many households lack access to waste collection services and are therefore compelled to dispose of waste by dumping, burning, or burying it. Burning is the most widely used method, particularly in rural areas without collection services. While urban and rural communities on Guadalcanal generally exhibit low rates of dumping waste into water bodies (oceans, rivers, or creeks), this practice is prevalent in other rural areas. For rural communities in Guadalcanal, land dumping is the second most common disposal method after burning.

In the Solomon Islands, landfilling is managed locally by the works division of the town council or provincial government. On the outer islands, where government-managed landfills are absent, waste is typically disposed of through informal dumpsites, burning, or burying.

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[14] https://www.adb.org/sites/default/files/publication/42662/solid-waste-management-solomon-islands.pdf
[15] Solomon Islands : waste management and pollution control strategy 2017-2026. (sprep.org)
[16] Solid Waste Management in the Pacific: Solomon Islands Country Snapshot (adb.org)
[17] Sinclair Knight Merz, Solid waste characterisation for Solomon Island (pg. 14), SPREP, 1990
[18] https://www.gefislands.org/sites/default/files/downloads/best-practices/Solomon-Waste-Audit-Report.pdf

The Ranadi landfill, located 6 kilometres from Honiara City near the coastline, serves as the main waste disposal site for Greater Honiara. The Honiara City Council (HCC) Environment Division and Works Division takes care of waste collection, policies, and monitoring. According to a 2019 Cefas audit, the waste collection service covers between 42 and 60 percent of the urban area.[19]

Originally a wetland behind a sand berm in a light industrial area, the Ranadi landfill now receives waste collected by the HCC and self-hauled material. The landfill, east of the Port of Honiara, spans approximately 5 hectares with a height of 25 meters. Unrestricted access allows all types of waste, leading to the site exceeding its design capacity. The HCC has identified a new site for a second landfill, but currently, there is no waste separation at disposal or collection points. In Honiara, with a population of around 80 000 and a waste generation rate of 1.0 kg per person per day, this results in approximately 80 tonnes of waste daily or 29 000 tonnes annually.[20]

The Honiara City Council operates with only two functioning waste compactors, donated by the Japanese and Chinese governments. Two additional vehicles are out of service due to lack of parts. Private citizens and companies, for a small fee, transport most waste to the landfill, with 50 to 60 loads (around 1 tonne each, mostly organic) dropped daily. The HCC also receives 5 to 10 cubic meters of sewage from septic tanks and hazardous waste from hospitals and clinics daily. Hazardous waste is disposed of in soil pits and often burned openly, posing significant health and environmental risks.

[19] https://www.gefislands.org/sites/default/files/downloads/best-practices/Solomon-Waste-Audit-Report.pdf
[20] https://www.adb.org/sites/default/files/publication/42662/solid-waste-management-solomon-islands.pdf

Figure 53. Aerial view of Honiara's landfill

Note: This image shows the extent of the site and above all its proximity to the coast, and the settlements all around it. In the lower left corner open burning is taking place and the smoke can be seen.

The landfill site faces severe social issues, with at least 40 people living there under hazardous conditions. These residents, including children born and raised on the landfill, live in makeshift shelters exposed to heavy rains and health dangers. The situation requires urgent international aid to address the environmental pollution and health risks affecting both the landfill residents and the broader community.

The HCC's Waste Management Department is understaffed, underfunded, and underequipped. Immediate action is necessary to prevent dramatic consequences for people and the environment. Implementing a proper waste management system with waste differentiation, separation, and diversified treatment (for example, biogas production from organic matter, pyrolysis oil from plastics, and recycling of aluminium and glass) is imperative. Such a system would provide significant benefits to landfill residents, who could be employed by the local administration, and improve conditions for the entire city.

Figure 54. Aerial view of the landfill

Note: *In this image, the settlements of the scavengers living on the landfill are visible all around the main levels of the site. At least 50 people, including toddlers and infants, live on this site.*

6.2 Waste-to-Energy: technology overview

Anaerobic Digestion (AD), a Waste-to-Energy (WtE) technology recognized as a circular bioeconomy pathway, has garnered increasing attention from researchers worldwide. AD involves a complex multi-step biochemical process in which anaerobic microbes degrade organic waste, allowing the recovery of resources such as energy and nutrients in the form of biogas and digestate. The primary product obtained from AD is biogas.

AD holds particular promise for treating Organic Fraction of Municipal Solid Waste (OFMSW) in developing countries due to several factors:

- A significant portion of organics in Municipal Solid Waste (MSW) (40–60 percent).
- An anticipated increase in MSW generation.
- High energy costs associated with energy generation systems. Decentralized systems closer to the site of consumption offer potential cost savings and more efficient energy utilization.

OFMSW is ideal for AD as it contains high levels of organic matter with high calorific values. However, implementing AD for OFMSW treatment requires waste segregation either at the source or through mechanical sorting, such as mechanical-biological treatment plants.[21]

[21] https://doi.org/10.1016/j.jenvman.2023.118993

This assessment aims to equip the Ranadi landfill with a biogas production plant to address the high proportion of organic waste in the Solomon Islands and the associated waste management challenges, such as landfill overflow and inadequate collection services. This approach involves implementing Anaerobic Digestion (AD) technology to efficiently treat the Organic Fraction of Municipal Solid Waste (OFMSW). By doing so, this assessment not only addresses waste management issues but also looks at quantifying renewable energy and mitigating environmental pollution.

6.3 Technical and environmental viability

As a starting point, a feasibility study for the installation of a biogas plant at the Ranadi landfill was conducted.

For the study, only the organic share of the 29 000 tonnes per year of Municipal Solid Waste (MSW) delivered to the site annually was considered (approximately 60 percent), equivalent to 17 400 tonnes of Organic Waste (OW) per year. On this basis, the potential biogas production was estimated at around 1 740 000 cubic meters per year. This was calculated by considering a biogas yield from OFMSW equal to 100 cubic meters per tonne of OFMSW, by the "rule of thumb" for biogas production from MSW as suggested by the Global Methane Initiative (GMI).[22] Once known the amount in cubic meters of biogas that could be produced, we calculated the potential for the electricity generation, considering a Lower Heating Value (LHV) for biogas equal to 22 MJ per cubic meter[23] and a conversion efficiency from biogas to the electricity of 35 percent.[24] This corresponds to an electricity generation of approximately 3 800 000 kWh. Thus, the capacity of the biogas plant to be installed at the landfill will be approximately 470-500 kW.

Below, a list of equipment composing the biogas plant for OW and a description are presented:

- A separation system to screen the organic material for the AD system and separate the various materials arriving at the landfill site. Options for separation include manual sorting of the waste up to fully automated recovery of the organics which need to include different steps like crushing, sorting, screening and washing of the waste, depending on the waste composition. Further investigation on waste composition is recommended to select the most suitable pre-treatment system once separation is performed. Tentatively, separation is assumed to be performed manually by local labour, once opportunely trained and equipped with protective items (gloves, glasses, shoes, suits). The labour force is abundant in the area and recruited

[22] Singh, A. (2020). Translating the Paris Agreement into Action in the Pacific. Translating the Paris Agreement into Action in the Pacific.

[23] https://www.iea.org/reports/outlook-for-biogas-and-biomethane-prospects-for-organic-growth/an-introduction-to-biogas-and-biomethane

[24] https://www.iea.org/reports/outlook-for-biogas-and-biomethane-prospects-for-organic-growth/an-introduction-to-biogas-and-biomethane

should target – to the extent possible – those living in the surroundings and on the surface of the landfill, to ensure a source of regulated employment and monitoring of health and safety conditions for these people.

- A liquid storage and handling system. This system ensures the storage and handling of the processed liquid from the biogas plant. It is composed of a tank and valves for efficient mixing and handling of the liquid.
- An anaerobic digestion system. This system includes the anaerobic digestion process, which converts organic matter into biogas. It also includes gas handling, such as a cogeneration unit and flare, to manage the biogas produced. The anaerobic digestion system is designed to operate at optimal conditions for microbial degradation, with temperature control and mixing to ensure efficient biogas production.
- A storage system for digestate. The digestate, which is the residue left after biogas production, is stored for subsequent use as a high-quality agricultural liquid fertilizer or other applications. This liquid is rich in nutrients and microorganisms, making it an excellent fertilizer for agricultural purposes. Further investigation on how the digestate can be reused in this context is recommended.

The costs associated with both initial capital (CAPEX) and operational expenditures (OPEX) are significant hurdles influencing the adoption of anaerobic digestion (AD) technology. Implementing AD systems requires investment not only in biodigester infrastructure but also in ancillary technologies such as plant design, construction, monitoring systems, and power generation.

Based on the information provided by technology providers active in the Pacific, the estimated CAPEX for the anaerobic digestion (AD) system ranges from approximately 3 to 3.5 million USD (average USD 3.2 million), depending on the final digestion volume, generator/energy configuration, and grid connections. Additionally, the Capital cost for the separation system is estimated to range from 300 000 to 1.5 million USD. The average value of this range (USD 900,000) is selected as most of the separation activities will be carried out in this scenario by local labour, thus reducing greatly the CAPEX costs for equipment. In addition, literature sources[25,26] indicate that the OPEX for an OFMSW biogas plant of 500 kW, including wages for the labour force, is approximately 1 million USD per year.

[25] Water | Free Full-Text | Performance of a Full-Scale Biogas Plant Operation in Greece and Its Impact on the Circular Economy (mdpi.com)

[26] https://www.dima.univr.it/documenti/Avviso/all/all643921.pdf

6.4 Financial Cost Benefit Analysis of biogas production

A Cost-Benefit Analysis (CBA) was conducted to evaluate the financial profitability of the case study. The methodology used adhered to the standard CBA approach applied to other TIER I case studies and is explained in paragraph 3.1.3.

Table 14 below, provides essential data for evaluating a biogas production facility and highlights both the productive output and financial considerations involved in implementing and operating a biogas-based electricity generation facility.

The annual biogas production of 1,740,000 cubic meters indicates a significant potential for renewable energy generation. With 3,828,000 kilowatt-hours (kWh) of electricity produced per year, the facility demonstrates efficient conversion of biogas into usable energy. A total capital expenditure (CAPEX) of 4,100,000 USD reflects the initial investment in infrastructure and technology necessary to establish the plant. Annual operational expenses (OPEX) amounting to 1,000,000 USD encompass ongoing costs such as maintenance, labour, and operational management. The plant's capacity of 500 kWh underscores its operational capability and contribution to the energy grid.

Table 14. Summary characteristics of the biogas system at Ranadi landfill

Biogas produced (m3/year)	Electricity produced [kWh/year]	Total CAPEX [USD]	Total OPEX [USD/year]	Plant capacity [kWh]
1,740,000	3,828,000	4,100,000	1,000,000	500

Source: Author's elaboration

The initial investment, CAPEX, required careful consideration, with infrastructure enhancements costing approximately USD 4,100,000, 50 percent of which was assumed to be financed through a loan at a fixed interest rate of 12 percent over an 8-year term. Due to the absence of a national feed-in tariff for electricity, two scenarios were developed based on different potential tariffs.

SCENARIO 1 considered the national rate for electricity supply charges, by the Electricity Act (Cap. 128) and the Electricity (Charges for Supply) Regulations of 2021. This scenario applied the lower commercial tariff (market price) for industrial customers, which is 0.73 USD/kWh.

Recognizing that feed-in tariffs are often lower than the standard supply rates, a second scenario, SCENARIO 2, was tested with a 30 percent reduction in the feed-in tariff, resulting in approximately 0.51 USD/kWh (Table 15).

Table 15. Summary parameters for scenario comparison

Scenario	Feed-in tariff (USD/kWh)
1	0.73
2	0.51 (-30%)

Source: Author's elaboration

Results for SCENARIO 1 indicate a 4-year investment payback period, with a Net Present Value (NPV) of 6,487,655.00 USD, demonstrating strong profitability and an Internal Rate of Return (IRR) of 32 percent, both significantly above prevailing market interest rates (Table 15).

In contrast, SCENARIO 2, with the reduced feed-in tariff, shows a longer 9-year payback period but still maintains a positive NPV of 375,512.00 USD and a profitability and IRR of 13.2 percent, which also exceed market interest rates (Table 15).

These results underscore the financial feasibility and attractiveness of the biogas-based electricity generation project under varying tariff conditions, emphasizing its potential for sustainable energy production and economic viability. Scenario 1 demonstrates that leveraging existing commercial tariffs can lead to a shorter payback period and higher returns on investment, showcasing potential financial benefits. In contrast, Scenario 2, with a reduced feed-in tariff, although resulting in a longer payback period, still maintains economic viability, albeit with slightly reduced financial metrics. These findings emphasize the importance of carefully considering tariff structures.

Figure 55. Scenario 1 for Ranadi landfill biogas plant

MSW Biogas Plant Solomon Islands						
Year	0	1	2	3	4	5 to 25
FARM						
Energy consumption						
Organic waste (tonnes/year)	17,400	17,400	17,400	17,400	17,400	17,400
Conversion rate	100	100	100	100	100	100
Biogas production (m3/yr)	1,740,000.00	1,740,000.00	1,740,000.00	1,740,000.00	1,740,000.00	1,740,000.00
Electricity generated (kWh/yr)	3,828,000.00	3,828,000.00	3,828,000.00	3,828,000.00	3,828,000.00	3,828,000.00
Feed-in tariff Electricity (USD/kWh)	0.73	0.73	0.71	0.74	0.75	0.83
Revenues						
Electricity production (USD/year)	-	2,811,490	2,825,347	2,839,675	2,853,073	3,168,998
Operating costs						
Maintenance (USD/year)		1,000,000.00	1,005,000.00	1,010,025.00	1,015,075.13	1,127,159.78
Fixed costs						
Capital depreciation (USD/year)		- 164,000	- 164,000	- 164,000	- 164,000	- 164,000
Cash Flow						
Operating Cash Flow		**1,647,490**	**1,656,547**	**1,665,650**	**1,674,798**	**1,877,839**
- Investments (USD)	- 4,100,000	-	-	-	-	-
- Loan annuity (USD/year)	-	- 412,671	- 412,671	- 412,671	- 412,671	-
Total Cash Flow (USD/year)	**4,100,000**	**1,234,819**	**1,243,877**	**1,252,979**	**1,262,128**	**1,877,839**
Cumulative Cash Flow	*- 4,100,000*	*- 2,865,181*	*- 1,621,304*	*- 368,325*	*893,802*	*36,610,202*
Payback Year	-	-	-	-	*Payback*	-
CF shareholders	2,050,000	1,234,819	1,243,877	1,252,979	1,262,128	1,877,839
Cumulative Cash Flow	*- 2,050,000*	*- 815,181*	*428,606*	*1,681,675*	*2,943,802*	*38,660,202*
Payback Year	-	-	*Payback*	-	-	-
Project's impact on P&L	-	**1,070,819**	**1,079,877**	**1,088,979**	**1,098,128**	**1,713,839**
Loan and Capital structure						
Equity private financing	- **2,050,000**					
Loan	- **2,050,000**	**50%**	of initial investment			
Constant interest rate	12%					
Duration of loan (years)	8					
Grace period (year)	-					
Loan repayment plan	Constant installments					
Loan outstanding (BoP)	**2,050,000**	**2,050,000**	**1,883,329**	**1,696,658**	**1,487,586**	**-**
- Interests		246,000	226,000	203,599	178,510	-
- Capital repaid		166,671	186,671	209,072	234,161	-
Loan outstanding (EoP)	**2,050,000**	**1,883,329**	**1,696,658**	**1,487,586**	**1,253,425**	**-**
Project profitability						
NPV	6,487,655.85 USD					
NPV to shareholders	8,318,013.00 USD					
Project IRR	**31.9%**					
IRR to shareholders	61.4%					
payback (years)	4					
Shareholders payback (years)	2					

Source: Author's elaboration.

Figure 56. Scenario 2 for Ranadi landfill biogas plant

MSW Biogas Plant Solomon Islands						
Year	0	1	2	3	4	5 to 25
FARM						
Energy consumption						
Organic waste (tonnes/year)	17,400	17,400	17,400	17,400	17,400	17,400
Conversion rate	100	100	100	100	100	100
Biogas production (m3/yr)	1,740,000.00	1,740,000.00	1,740,000.00	1,740,000.00	1,740,000.00	1,740,000.00
Electricity generated (kWh/yr)	3,828,000.00	3,828,000.00	3,828,000.00	3,828,000.00	3,828,000.00	3,828,000.00
Feed-in tariff Electricity (USD/kWh)	0.51	0.51	0.52	0.52	0.52	0.58
Revenues						
Electricity production (USD/year)		1,968,043	1,977,883	1,987,773	1,997,711	2,218,299
Operating costs						
Maintenance (USD/year)		-1,000,000.00	-1,005,000.00	-1,010,025.00	-1,015,075.13	-1,127,150.78
Fixed costs						
Capital depreciation (USD/year)		164,000	164,000	164,000	164,000	164,000
Cash Flow						
Operating Cash Flow		**804,043**	**808,883**	**813,748**	**818,636**	**927,139**
Investments (USD)	4,100,000					
- Loan annuity (USD/year)	-	- 412,671	- 412,671	- 412,671	- 412,671	-
Total Cash Flow (USD/year)	**- 4,100,000**	**391,372**	**396,212**	**401,077**	**405,966**	**927,139**
Cumulative Cash Flow	*4,100,000*	*3,708,628*	*3,312,416*	*2,911,339*	*2,505,373*	*14,908,397*
Payback Year	-	-	-	-	-	-
CF shareholders	2,050,000	391,372	396,212	401,077	405,966	927,139
Cumulative Cash Flow	*- 2,050,000*	*- 1,658,628*	*- 1,252,416*	*- 851,339*	*- 455,373*	*16,258,007*
Payback Year						
Project's Impact on P&L	-	**227,372**	**232,212**	**237,077**	**241,965**	**763,139**
Loan and Capital structure						
Equity private financing	**- 2,050,000**					
Loan	**- 2,050,000**	**50%**	of initial investment			
Constant interest rate	**12%**					
Duration of loan (years)	**8**					
Grace period (year)	-					
Loan repayment plan	Constant installments					
Loan outstanding (BoP)	**2,050,000**	**2,050,000**	**1,883,329**	**1,696,658**	**1,487,586**	**-**
- Interests		246,000	226,000	203,599	178,510	-
- Capital repaid		166,671	186,671	209,072	234,161	-
Loan outstanding (EoP)	**2,050,000**	**1,883,329**	**1,696,658**	**1,487,586**	**1,253,425**	**-**
Project profitability						
NPV	375,512.46 USD					
NPV to shareholders	2,205,869.81 USD					
Project IRR	**13.1%**					
IRR to shareholders	23.6%					
payback (years)	9					
Shareholders payback (years)	6					

Source*:* Author's elaboration.

7. CONCLUSIONS AND RECOMMENDATIONS

- Biogas is a mature and commercially available technology. Several systems and technology levels exist and the selection of the most appropriate is the result of a multicriteria assessment. Self-built systems have relatively low initial set-up costs compared to other, more modern, and better-designed alternatives. However, in the context of small-scale commercial farms in the Solomon Islands, the assessment highlighted the need to engage the private sector with a proven and reliable technology.
- The analysis suggests that turnkey preassembled biogas systems, although more expensive than self-built ones, would be a preferable choice for early off-takers as they have improved designs and reliability.
- Turnkey systems have come a long way in design features as well as concerning automation of the operations and provide superior control over anaerobic digestion dynamics. These systems are designed by experts have been proven in many scenarios and have superior design and efficiency and are far more reliable than self-built systems. In the Solomon Islands, several biogas projects have failed in the past due to poor design and building quality of biodigesters. Having a proven and reliable design is the most important aspect to enable the successful implementation of this technology particularly on a small scale. Moreover, these systems offer improved monitoring gauges that self-built digesters cannot implement. Last but not least, turnkey systems benefit from the manufacturer's customer support in case of problems, especially during maintenance operations. However, capacity needs are still a crucial enabling factor for biogas projects' sustainability.
- At the Tier II level, the assessment deepened the investigation of actual biogas production potential and corrected previous estimates. The technology selected is the result of available parts of turnkey systems with a bespoke design to best fit the needs of the case study site.
- In Guadalcanal alone, there are at least 45 farms with comparable characteristics, therefore the scale-up and replication potential of these designs is vast.
- For a successful investment, it is imperative to develop the capacity of farm personnel to manage the systems through training and knowledge transfer activities. With these pillars in place, the Tier I assessment revealed the promising technical, financial, and environmental feasibility of biogas investments in the case study farm.
- Through the available manure and other organic wastes, the farm could fulfil its entire energy demand for both power and heat and contribute to a quasi-complete displacement of other energy sources currently employed in the homestead. The avoided emissions from manure and energy generation sources could contribute significantly to curbing climate change contribution of the livestock sector in the Solomon Islands. Additionally, the co-products of anaerobic digestion are widely recognized as a crucial component of climate-smart agriculture and can

contribute to climate change adaptation by providing more resilient soils and protecting mangroves.

- From a financial standpoint, both optimistic and realistic test scenarios lead to positive results in terms of feasibility. This is due to the economic burden of energy sources in the farm and homestead's budget, with energy prices among the highest in the world in one of the Pacific's poorest countries. The results of the Tier I assessment have been further refined in the second stage of the project, by compiling additional targeted information and validating initial data collected to date (Tier II).
- The Tier II assessment revised data collected and cross-checked values with the information collected during the scoping mission. Particularly relevant are the data collected on average pig size and related manure production, which is likely to change the validated energy generation potential, and the actual disaggregation of energy demand between the components of the homestead: farm vs households. Once these values were verified, technical specifications of a biogas plant to suit the characteristics of demand and supply for the case study farm were produced. These were coupled with engineering drawings for the building of a biogas plant with said technical specifications. All parts used as reference in the drawings are actual components available on the market, and the drawings report their exact specifications.
- The production of engineering drawings for the specific conditions of the case study farm required an attentive farm survey and the generation of a true-to-scale tri-dimensional (3D) digital reconstruction of the site and the design of the additional elements that will compose the biogas system. These will be made available to the case study farm owner and to other piggery owners in the Solomon Islands to have a better understanding of the design needs and available options. With such digital reconstruction, piggery owners will be able to assemble a turnkey system or purchase pre-assembled components for a correctly sized and planned biogas system, ready for the valorization of the slurry as a substitute for diesel and firewood, and the co-products of the anaerobic digestion, including the digestate with its high nutritional value as a fertilizer.
- The importance of organic waste management in the Solomon Islands was felt as a priority during the scoping workshop and the following stakeholder consultations. Tier II deepened the understanding of the biogas production potential for the Ranadi landfill in Honiara. As an additional result of Tier II, the assessment provided CBA scenarios of the implementation of a biogas plant to turn the organic fraction of municipal solid wastes collected in the Solomon Islands into bioenergy and highlight private sector investment opportunities in this field.
- The main outcome of this exercise is the environmental, social and economic viability of a 500 kW biogas plant that uses the organic fraction of municipal solid waste disposed at Ranadi to generate electricity.
- The breakeven point was calculated for two alternative scenarios in which different feed-in tariffs are considered. In the worst-case scenario, a breakeven point of 9 years has been

estimated with an Internal Rate of Return for the investment higher than optimistic national interest rates.

- Environmental and social co-benefits of this perspective plant are immense as currently, about 50 families live on the landfill premises in desperate conditions from the sanitation, schooling as well as employment standpoint. This study demonstrated the viability of involving these residents in a training and job placement programme that allows them to escape extreme poverty while enhancing their livelihoods. The separation of biomass from the rest of the waste stream and its segregation in a biogas production system will also lead to important returns in terms of pollution avoidance and reduced GHG emissions, water quality enhancement and coastal protection, contributing to climate change mitigation and especially adaptation efforts.

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Annex 1 - LIST OF STAKEHOLDERS MAPPED

S/N	Organization	Type of stakeholder	Description	Contribution to Research	Value Chains	Position in the Value Chain	Location
1	Ministry of Environment	Public	Government entity responsible for management and coordination of environmental activities	Information on environmental priorities in the country, available policies, and possible challenges for effective response	pig slurry, tuna canning, waste sector, timber	Government entity or regulator	Honiara
2	Ministry of Forestry	Public	Government entity responsible for managing and coordinating all activities related to forests	Insights on biomass availability and sustainability, developing regulations, and addressing challenges for effective implementation.	Timber	Government entity or regulator	Honiara
3	Ministry of Fisheries and Marine Resources	Public	Governmental institution responsible for management and regulation of activities related to fisheries and aquaculture within Solomon Islands	Information on fish waste streams, facilitate collaboration among stakeholders	Tuna canning	Government entity or regulator	Honiara
4	Ministry of Mines & Energy	Public	Governmental institution responsible for management and regulation of activities related to mineral extraction, mining operations, and energy production within Solomon Islands	Data on energy demand and infrastructure, and facilitating partnerships with industry stakeholders, provide insights on available incentives or funding opportunities	Pig slurry, tuna canning, waste sector, timber	Government entity or regulator	Honiara
5	Ministry of Agriculture and Livestock	Public	Governmental institution responsible for coordination of agriculture activity in Solomon Islands	Background information on the value chains in Solomon Islands	Pig slurry, tuna canning, timber	Government entity or regulator	Honiara
6	Ministry of Culture & Tourism	Public	Governmental institution dedicated to fostering and promoting the cultural heritage and tourism industry within Solomon Islands	Background information on the tourism/resort sector in the Solomon Islands	Waste sector	Government entity or regulator	Honiara
7	Honiara City Council WMPCD	Public	Municipal entity responsible for overseeing and managing waste disposal and pollution control efforts within Honiara City	Data on local waste generation rates, waste composition analysis, and insights into existing waste management infrastructure	Waste sector	Municipal entity or regulator	Honiara
8	Solomon Islands Pig Farmers	Private	Collective organization representing pig farmers across the	Information about pig farming and manure	Pig slurry	Production/Cooperatives	Honiara

	Association (SIPFA)		Solomon Islands aimed to promote and support the interests of pig farmers	management, facilitate collaboration among farmers, technology providers, and authorities			
9	Youth With A Mission YWAM/ J.kana/Zaina Tina Farm)	Private	Community Development School	Runs successfully a biogas plant and trains local students on management of biogas technology	Pig slurry	Production/Cooperatives	Honiara
10	Guadalcanal Plains Palm Oil Plantations Limited (GPPOL)	Private	Company in the Solomon Islands focused on cultivating oil palm trees for palm oil production	Extensive production of waste water (Palm Oil Mill Effluents) and interest in investing into biogas technology	Palm oil	Processor	Honiara
11	SolTuna	Private	Major tuna processing company based in the Solomon Islands	Information on tuna canning wastewater quantity and characteristics, Information on challenges faced	Tuna canning, timber	Processor	Noro
12	Kolombangara Forest Products Ltd (KFPL)	Private	Forestry company operating in the Solomon Islands	Supply sustainably sourced biomass from timber operations, assistance in logistical aspects	Timber	Processor	Honiara
13	Value-Added Timber Association (VATA)	Private	Private organization representing businesses involved in the timber industry	In-depth information private sector on challenges and opportunities in target value chains	Timber	Business Association	Honiara
14	Solomon Islands Timber Processors and Exporters Association (SITPEA)	Private	Private organization representing businesses engaged in timber processing and export in the Solomon Islands	In-depth information private sector on challenges and opportunities in target value chains	Timber	Business Association	Honiara
15	Tourism Association	Private	private organization dedicated to promoting and advancing the tourism industry in the Solomon Islands	In-depth information on private sector challenges and opportunities in target value chains	Waste sector	Business Association	Honiara
16	Kokonut Pacific Solomon Islands (KPSI)	Private	private company that specializes in producing and processing coconut-based products in the Solomon Islands	In-depth information private sector challenges and opportunities in target value chains	Coconut	Processor	Honiara
17	Solomon Power	Public (State Owned Enterprise)	state-owned and primary electricity provider in the Solomon Islands	Data on grid infrastructure, insights into regulatory frameworks and permitting processes	Pig slurry, tuna canning, waste sector, timber	Services	Honiara
18	Commodity Export Marketing Authority (CEMA)	Public (State Owned Enterprise)	government agency responsible for promoting and regulating the export of agricultural and forestry products	In-depth information on the value chain	Timber	Trader/Exporter	Honiara
19	Central Bank of Solomon Islands (CBSI)	Public Entity	Central banking institution responsible for formulating and implementing monetary policy, regulating the	Information of financial mechanisms	pig slurry, tuna canning, waste	Financial Institution	Honiara

			financial sector, and managing the nation's currency and reserves		sector, timber		
20	World Bank	Financial Institutions	international financial institution that provides loans, grants, and technical assistance to developing countries for development projects and programs aimed at reducing poverty and promoting sustainable development	Information of financial mechanisms	Pig slurry, tuna canning, waste sector, timber	Financial Institution	Honiara
21	Asian Development Bank (ADB)	Financial Institutions	regional development bank aimed to promote economic and social progress in Asia and the Pacific	Information of financial mechanisms	Pig slurry, tuna canning, waste sector, timber	Financial Institution	Honiara
22	Development Bank of Solomon Islands (DBSI)	Financial Institutions	financial institution aimed to support economic development and growth in the Solomon Islands	Information of financial mechanisms	Pig slurry, tuna canning, waste sector, timber	Financial Institution	Honiara
23	International Finance Corporation (IFC)	Financial Institutions	member of the World Bank Group focused on promoting private sector development in developing countries	Information of financial mechanisms	Pig slurry, tuna canning, waste sector, timber	Financial Institution	Honiara
24	Bank South Pacific (BSP)	Financial Institutions	bank in the South Pacific, providing financial services across multiple countries in the region	Information of financial mechanisms	Pig slurry, tuna canning, waste sector, timber	Financial Institution	Honiara
25	FAO	United Nations	specialized agency of the United Nations that leads international efforts to defeat hunger, improve nutrition, and promote sustainable agriculture	Implement project	Pig slurry, tuna canning, waste sector, timber	Implementing Agency	Honiara
26	UNDP	United Nations	specialized agency of the United Nations tasked with helping countries eliminate poverty and achieve sustainable economic growth and human development	Coordination	Pig slurry, tuna canning, waste sector, timber	Implementing Agency	Honiara
27	Strongim Bisnis	Development Organization	economic growth program funded by the Australian Government aimed to strengthen the private sector, create jobs, and improve economic opportunities for Solomon Islanders.	Information of financial mechanisms	Pig slurry, tuna canning, waste sector, timber	Donor Project	Honiara
28	Pacific Horticultural and Agricultural Market Access Plus Program (PHAMA Plus)	Development Organization	Australian government initiative aimed at enhancing export opportunities for Pacific Island countries in the agriculture and horticulture sectors	Information of financial mechanisms	Pig slurry, tuna canning, waste sector, timber	Donor Project	Honiara

29	Solomon Islands Provincial Governance Strengthenin g Program (SPIRES)	Development Organization	initiative aimed at improving governance and service delivery at the provincial level in the Solomon Islands	Information of financial mechanisms	pig slurry, tuna canning, waste sector, timber	Donor Project	Honiara
30	Solomon Islands Chamber of Commerce (SICCI)	Private	Support industry working groups on key commodities; coconut, cocoa, horticulture, sawn timber & seafood.	Gathers private sector stakeholders with energy needs and waste production issues	Coconut , cocoa, horticult ure, sawn timber & seafood	Lobby institution	Honiara
31	Solomon Islands National University (SINU)	Public	The only public national university of the country offers affordable and quality education programmes to Solomon Islanders	Possible repository of information and knowledge for capacity building activities around renewable energy	Renewa ble Energy	Education and training	Honiara

Source*:* Author's elaboration.

Scaling up Climate Ambition on Land Use and Agriculture through Nationally Determined Contributions and National Adaptation Plans (SCALA), funded by the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) through the International Climate Initiative (IKI).

SCALA responds to the urgent need for increased action to cope with climate change impacts in the agriculture and land use sectors. The programme will support at least twelve countries in Africa, Asia and Latin America to build adaptive capacity and to implement low emission priorities.

Country support includes strengthening policies, adopting innovative approaches to climate change adaptation and removing barriers related to information gaps, governance, finance, gender mainstreaming and integrated monitoring and reporting. To achieve this shift, the programme will engage the private sector and key national institutions.

SCALA supports countries to develop the capacity to own and lead the process to meet targets set out in their National Adaptation Plans and Nationally Determined Contributions under the Paris Agreement, and to achieve the Sustainable Development Goals. The SCALA initiative builds on another FAO-UNDP led programme, Integrating Agriculture in National Adaptation Plans (2015-2020) which is currently phasing out.

Food and Agriculture Organization of the United Nations
www.fao.org/in-action/scala/en

United Nations Development Programme
www.adaptation-undp.org/scala

International Climate Initiative (IKI)
www.international-climate-initiative.com

German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV)
www.bmuv.de/en/

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