Executive Summary: Powering the future of Saibai: A hybrid Solar system to reduce diesel reliance

Design Area(s): 4.1 Clean, affordable energy for small coastal urban environments
Keywords: Photovoltaic (PV), Piezoelectric, Battery Energy Storage System (BESS), Lead Zirconate Titanate(PZT), State of Charge (SoC), Energy harvesting, Microgrid, Inverter, Capacitor, State of energy (SoE)

Proposal Summary

As per the EWB challenge this project aims to create a solution to produce clean, renewable and reliable energy for the remote island community of Saibai Island. This project aims to address Saibai's over-reliance on diesel powered energy as it is non-renewable, environmentally unsustainable and economically non-viable by reducing Saibai's usage of it [diesel generators] by 80%.

Overview of Design

Our solution harnesses a hybrid system that combines solar energy with piezoelectric whilst retaining the preexisting diesel generators as a backup to ensure consistent energy generation. Solar panels are located on residential houses, the local hospital and Taigai State College to generate most of the island's electricity. Excess energy from the solar panels is stored in batteries for later use which is managed by the hybrid inverter in each solar set. Additionally, piezoelectric tiles in the community hall generate power for the community hall and promote cultural awareness and cultural practices during ceremonial dancing. Diesel energy is retained as back-up and is only used if battery levels drop below 5% and turn off at 40%, this is managed by the Battery Energy Storage System (BESS) units found within each solar set and can run autonomously whilst being monitored. in each solar set which is activated by a hybrid inverter. A community-led renewable energy initiative on Saibai Island combines solar PV systems with piezoelectric tiles that generate electricity from dance traditions on the island. These tiles are planned for installation in high-traffic public areas where festive are taken place in collaboration with community leaders and the Torres Strait Island Regional Council (TSIRC).

This report presents a hybrid renewable energy solution for Saibai Island, integrating solar photovoltaic (PV) systems and piezoelectric flooring to deliver clean, reliable, and culturally respectful power. Developed in collaboration with the Saibai community and the Torres Strait Island Regional Council (TSIRC), the design follows a six-phase plan grounded in community consultation, co-design, and capacity building (EWB Challenge, 2024). Solar panels will be installed on rooftops and open land, while piezoelectric tiles will convert the mechanical energy of dancing/movement into usable energy to power lighting and small appliances in the community hall.

Key considerations include sourcing and logistics: specialised components such as piezoelectric tiles, batteries, and inverters will be shipped from China, while basic materials like sand and concrete can be locally sourced to reduce cost and boost community participation (TSIRC, 2023). Maintenance will require locally trained technicians, supported by a simple bilingual user manual and a schedule of monthly inspections by skilled personnel to ensure long-term system performance and safety. Cultural and environmental factors such as land blessings, avoidance of sacred sites, and flexible scheduling around community events are fully integrated.

Design assumptions include strong local interest, basic digital literacy, and available labour. Next steps involve securing funding through renewable energy and climate adaptation grants, finalising procurement, and continuing community workshops and training. The project reflects Engineers Without Borders' principles of sustainability, equity, and human-centred design (EWB Australia, 2023).

Proposed Materials and Cost Summary

Purchased materials:

- **104 sets of solar sets** to be installed at residential houses, the water treatment plant, local businesses, the local hospital and Tagai State College. Each solar set consists of 22×460W Mono Solar Panels, 1 × Growatt Hybrid Inverters, 1 × roof/ground mounting, 3 × ELEBOX-HV 10kWh Batteries, 14 × pairs of MC4 waterproof connectors and 100 metres of DC Wires. (Cost equals AUD 3,113.33 each which amount to $323,786.32)
- **100 sets of 50x50 PZT ceramic piezoelectric tiles** (Cost equals $42,260.40)
- 26501L of diesel for preexisting diesel generators (Cost equals $98,053.70)
- Total cost of purchased materials: $464,100.42

Labour Requirements:

- Total workers required = 19
- Labour costs (accommodation and salaries of workers) = $98,268
- Accommodation for these workers will be located at the contractor accommodation supplied on Saibai Island ($184.20 p/day for single room, $332.50 p/day for double etc.) and the Council houses ($193.50 p/day for single room, $348.00 for double room etc.) The total cost of accommodation for the workers is $31128.
- Type of workers required (no. required) = Community coordinator (1), local representatives (3)(, financial officers (1), solar technician (1), local labourers (6), local trainees (2), flooring specialist (1), skilled trainers (1) and local workers (3)
- Hourly wage for skilled workers (i.e. solar technicians) = $40, semi-skilled = $30 and unskilled (i.e. trainees) = $25

Other materials: General Construction and Installation Materials: Concrete, cement, bolts, nuts, washers, insulation materials, waterproof and weatherproof paint/ coatings, Personal Protective equipment (helmet, gloves, safety glasses), cable ties, safety signage.

Estimated total cost: The estimated total cost of our design is $591,012.61. This consists of labour (i.e. worker's salaries and accommodation) materials (solar sets, piezoelectric tiles and diesel), transportation (shipping from China, Weipa and then Saibai + import and clearance fees) and miscellaneous fees associated with infrastructure development (i.e. Improvements to local government areas and roads)

Design Area: 4
Project Opportunity: 4.1 Clean, affordable energy for small coastal urban environments
How Might We Statement: How might we utilise the combination of solar panels and piezoelectric energy to provide Sabai residents with a clean, affordable, and sustainable source of electricity—while also considering key stakeholders consisting of the Indigenous peoples of Saibai, the Queensland Government and the Torres Strait Regional Council, in addition to the island's geographical, sociocultural and economic characteristics?
Tutorial Number and Zone: Tutorial 6-Energy
Group Name: Team100

Group Declaration

Table 1: Team member contributions to Assessment Task 2a Draft Report (prior to Week 7)

Group Member Name	Report and Project Contributions	Team Agreement
Adit Lohani	Created the doc template, completed the background with Azlan and Syed. Wrote and made the figure for centralized hybrid power and hydrogen energy	Agreed
Syed Ali-Haider	Did background with Adit and Yusuf, Researched and wrote about Wind power	Agreed
Yusuf Kilic	Introduction with Daniel and Chai, Researched and wrote about biomass.	Agreed
Daniel Mutero	Introduction with Yusuf and Chai, Researched and wrote about piezoelectric plates	Agreed
Azlan Shah	Compiled research for and wrote sections of background. Researched and wrote about "Cables from PNG"	Agreed
Chaitanya Kothawade	Introduction with Daniel and Yusuf. Researched and wrote about Tidal Energy.	Agreed

Table 2: Team member contributions to Assessment Task 2b Final Report (after Week 7)

Group Member Name	Report and Project Contributions	Team Agreement
Adit Lohani	Added Background (written by Adit, Syed and Azlan), wrote 3.2 design requirements, 7 prototype, made figures and detailed calculation for 9. Cost analysis, completed the entire 10 discussion and helped writing the conclusion and recommendation	Agreed
Syed Ali-Haider	Design selection with Yusuf and Daniel, created a comparison line to compare various design solution, which helped in picking up the right design choice.	Agreed
Yusuf Kilic	Design options with Daniel, detailed design, edited people's work, cut down words to meet criteria, edited the final document, created the implementation diagram with Chaitanya, created the decision matrix and edited the design selection with Syed, analysed figure 10.3 and 10.4.	Agreed

Daniel Mutero	Cost analysis, Design options, Team Acknowledgement, Executive Summary, helped conclusion and recommendation, editing for final report (+ cutting down word count), helped with project scope, helped with problem description Significantly helped with discussion.	Agreed
Azlan Shah	Helped with cost analysis. Researched and wrote for a possible solution (running a power cable from PNG) including justification for why it is not possible.	Agreed
Chaitanya Kothawade	Did the Project scope which involved the problem description and the how might we statement. Also did the Implementation plan with Yusuf and made the diagram.	Agreed

Team Acknowledgement
Team100 would like to acknowledge and pay our utmost respect to both the Gadigal people of the Eora Nation upon whose ancestral lands the Ultimo campus [of UTS] of which we learn from stands and the Koeybuway and Moegibuway peoples of Saibai Island on whose lands and seas our design solution is based. We acknowledge the Indigenous peoples of both Australia and the Torres Strait Islanders as the original arbiters of enduring knowledge, culture and connection to the land and sea of these places. We would also like to pay respect to the Elders past, present, and emerging, within the Indigenous community. We acknowledge that it always was and always will be and that sovereignty was never ceded.

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1. Introduction

Saibai Island is a remote northwestern Torres Strait community, located 140km from the northern extremity of the mainland Australia (Cape York) (Indigenous, n.d.). The island faces ongoing energy generation challenges that significantly impact the daily lives of its residents. Within a population that is heavily reliant on diesel powered electricity, the community experiences high diesel costs of $3.70/L (Engineers Without Borders Australia. 2024), logistical difficulties (diesel must be imported) and the threat of environmental repercussions associated with fuel transportation and consumption in electricity generation. (DCCEEW, 2020) These challenges are amplified by Saibai's isolation from mainland Australia and frequent inundation and harsh climatic conditions, which increases the island's vulnerability to climate change. (EWB, 2024) Additionally, Saibai faces severe economic hardships, a lack of technical expertise within the island, which further diminish its energy production, storage and distribution capabilities, hindering the development of reliable, durable and sustainable energy infrastructure. Considering these issues is vital to improving the quality of life, promoting sustainability and fostering economic resilience for the people of Saibai.

The purpose of this report aligns with the 2024 EWB challenge's aims of providing clean and affordable energy to small coastal communities, which seeks to develop innovative and sustainable solutions for communities facing complex infrastructural issues (Engineers Without Borders Australia. 2024). Within the design brief, this report specifically focuses on energy generation on Saibai Island through renewable and alternative energy solutions. It explores how a hybrid solar-diesel system, supplemented by an innovative piezoelectric dance floor, can meet the local energy needs in a way that is technically feasible, economically viable, environmentally sustainable and culturally aware. By utilising sustainable technology, the project aims to reduce the community's reliance on diesel fuel, lowering costs and improving the resilience of the island's energy infrastructure.

2. Background

Saibai's remoteness from mainland Australia makes energy generation, storage and waste management (battery disposal and recycling) difficult. Additionally, there is need to respect the community's deep cultural heritage in all development projects. Thus, this report focuses on community-centred, sustainable solutions tailored to the island's specific needs, including energy, infrastructure, and climate adaptation.

Saibai is particularly vulnerable to climate change due to its low-lying geography, making sustainable and resilient infrastructure a critical priority. Historically, the island has relied on diesel generators, but high operational costs and environmental concerns have driven a shift toward renewable energy solutions such as solar photovoltaic (PV) systems (TSRA, 2021). EWB support these sustainability-based systems, as they align with the community's values of preserving natural settings (Engineers Without Borders Australia, 2024; Solar Quotes, 2024).

The key to integrating renewable energy solutions lies in understanding and incorporating local knowledge while respecting Saibai Island's cultural heritage. The EWB Challenge encourages students to develop innovative designs that integrate sustainability and local community engagement while addressing these critical areas (Engineers Without Borders Australia, 2024).

2.1. Socio-Cultural Aspects

The people of Saibai place immense value on the land and waterways. While many significant sites are not publicly disclosed, they include old village sites, wells, shell and bone arrangements, and various canals (TSRA, n.d.). The entire island is culturally significant to the Traditional Owners, as it is the land from which their stories originate. Storytelling plays a crucial role in preserving and passing down culture through generations (ReconciliationAus, 2015).

2.2. Economic Aspects

The median weekly salary for a household in Saibai is $911(ABS,2021), placing Saibai Island in the bottom 14% nationally as of January 2021(Microburbs, n.d.). The absence of significant manufacturing, mining, or large-scale agricultural operations limits economic diversification on Saibai Island. Thus, Torres strait islands like Saibai heavily rely on government funding and the financial grants from the commonwealth tax revenue. (TSIRC, 2024, p.16)

2.3. Environmental Aspects

Due to Saibai's muddy, swampy and low-lying typography infrastructure expansion is difficult. This makes implementing energy solutions that rely on extensive infrastructure being built (ie. wind turbines) is challenging due to difficulties in both installation and maintenance imposed by the island's physical characteristics.

3. Project Scope

This project aims to assess the feasibility of adopting a hybrid energy system combining solar photovoltaic (PV) technology and diesel generators, supplemented by revolutionary technologies like piezoelectric energy. Solar PV systems offer a clean and renewable form of energy that reduces the reliance on diesel fuel. However, their efficiency could be affected by Saibai's weather conditions, including dense rain and cloud cover. With diesel generators incorporated, there is a continuous power supply during periods of low solar radiation.

Also, the project considers the feasibility of piezoelectric flooring, which produces electrical energy from mechanical energy generated from foot traffic and dance movements. While the technology has been successfully employed in venues like Club Surya in London, where it supplies up to 60% of the club's energy needs on busy nights, its application in Saibai's environment must be weighed against considerations such as patterns of foot traffic as well as installation cost.

The scope of this report encompasses: (for detailed scope please refer to Appendix 5)

- Assessment of Current Energy Infrastructure
- Feasibility Study of Solar PV Integration
- Evaluation of Piezoelectric Technology
- Economic Analysis
- Environmental Impact Assessment
- Community and cultural engagement strategy

By addressing these areas, the report seeks to provide a comprehensive roadmap for transitioning Saibai Island towards a more sustainable, affordable, and resilient energy future.

3.1. Problem Description

How might we utilise the combination of solar panels and piezoelectric energy to provide Sabai residents with a clean, affordable, and sustainable source of electricity—while also considering key stakeholders consisting of the Indigenous peoples of Saibai, the Queensland Government and the Torres Strait Regional Council, in addition to the island's geographical, sociocultural and economic characteristics?

Saibai currently relies on diesel generators which require imported fuel, contributing to greenhouse gas emissions (Engineers Without Borders Australia). (2024). Saibai's low-lying topography presents an additional challenge in the installation and maintenance of infrastructure needed for renewables (eAtlas, n.d.). Cultural considerations must be made to ensure projects avoid disrupting sacred sites. In addition, procuring funds for renewable infrastructure is usually a complex process, even with scheme incentives like ARENA's Regional Microgrids program (Renewable Energy Agency) (ARENA). (n.d.). It is a need and challenge to achieve this shift.

3.2. Design Requirements

3.2.1. Grid Stability and Reliability

Description: The system shall provide consistent and stable power for residential and commercial users, ensuring minimal fluctuations and blackouts (≥90% uptime). The system shall maintain stable power output during low-energy generation periods, such as nighttime, low solar irradiance, or reduced solar availability.

Justification: Energy use is mostly attributed to essential services, such as water treatment plants, schools, and hospitals. (EWB, 2024) Thus, any disruption or outages in energy will impact these vital services, making grid stability necessary.

Metric: Able to meet peak load (~500 kW) (Ener-G Management Group, 2021, pg.9) the description and critical loads during worst-case 3-day low-sun periods without blackout (e.g., through diesel backup).

3.2.2. Harsh Weather Operation

Description: The system shall operate efficiently in extreme weather conditions, including storms, high humidity, and heavy rainfall.

Justification: Saibai Island is badly affected by storms and King Tides (Australian climate case, n.d.). Similarly, it's humidity and temperature accelerate battery degradation hindering operation and energy storage.

Metric: Structures rated for Region C cyclone (safety factor); panels elevated >4m(usual king tide size) (Wellauer and Ruddick, 2024); equipment rated ip65+ for increased protection from water.

3.2.3. Economic Affordability

Description: The system's total cost, including installation and maintenance, shall be lower than the current diesel generators, i.e. < $1,000,000

Justification: Government of Australia has reduced the financial assistance grants from 1% of tax revenue to 0.55%. Cost-effectiveness improves Saibai's financial viability and accessibility (TSIRC, 2024, p.16).

3.2.4. Accessibility, Usability and Safety Compliance

Description: The system shall be easy to install and maintain by local personnel with minimal technical training and shall be locally available or easily transportable to remote coastal areas. The system must meet Queensland electrical safety standards.

Justification: Complex systems are not feasible on Saibai due to a lack of technical skills. Just 7.2% of inhabitants have a bachelor's degree or above, and just 19.6% have finished Year 12 (ABS, 2021), highlighting the need for a simple, user-friendly solution. Simplifying installation and maintenance also encourages widespread adoption and usability.

Metric: System passes an electrical inspection and meets Australian Standards (AS/NZS 3000 wiring rules, AS 4509 for stand-alone power systems, etc.).

3.2.5. Environmentally Sustainability

Description: The system shall minimize environmental impact during operation and end-of-life disposal, including battery disposal and recycling.

Justification: Saibai's remote location complicates waste management, making battery disposal and recycling challenging (EWB,2024). Saibai is already at risk of rising sea level and is impacted by climate change. So, sustainable design reduces pollution and promotes long-term ecological benefits.

Metric: Simulated renewable energy output vs. Total consumption (kWH/year) ~ 70%.

3.2.6. Scalability and Modularity

Description: The system shall be designed to accommodate future expansions in energy demand and technological advancements.

Justification: As Saibai's population and energy grow, the system must support upgrades without requiring complete replacement, ensuring long-term viability and cost-effectiveness.

Metric: System block diagram showing independent sub-systems, like a Norton's-equivalent circuit such that adding modules is straightforward.

4. Design Solution Options

4.1. Centralised hybrid energy system (Tidal, Biomass, Wind, Solar, Diesel and Piezoelectric Energy)

This design solution combines piezoelectric panels, a solar array, biomass fuel, wind turbine(s) and the existing diesel generators to provide energy to Saibai all year round. The solar array produces most of the energy with any excess [energy] being stored in the smart grid to be used during adverse weather conditions. The tidal generator is operational 24/7 and harnesses Saibai's high tidal currents to produce energy consistently. Moreover, the medium-sized wind turbines offer a secondary weather-independent energy source that is clean and sustainable. (Peni Hausia Havea et al., 2024; Rezaei et al., 2024). Biomass generators although producing minimal energy output promotes a circular economy by converting agricultural waste into usable energy which will encourage proper recycling and reduce landfill. Piezoelectric panels produce minimal energy but promote the cultural practice of dancing through producing sufficient energy to power the lights in the community hall. As a backup, diesel generators are retained but are only used when energy supplies are low to ensure sustainable energy generation. To offset the carbon emissions, particularly from biofuel and diesel trees will be planted around the island. The hybrid infrastructure will be controlled by a smart grid with AI-powered demand forecasting, remote sensing and priority load management (towards the school and hospital); which will cut diesel consumption by 75% (IEEE, 2023, p. 44) and subsequently reduce diesel import costs.

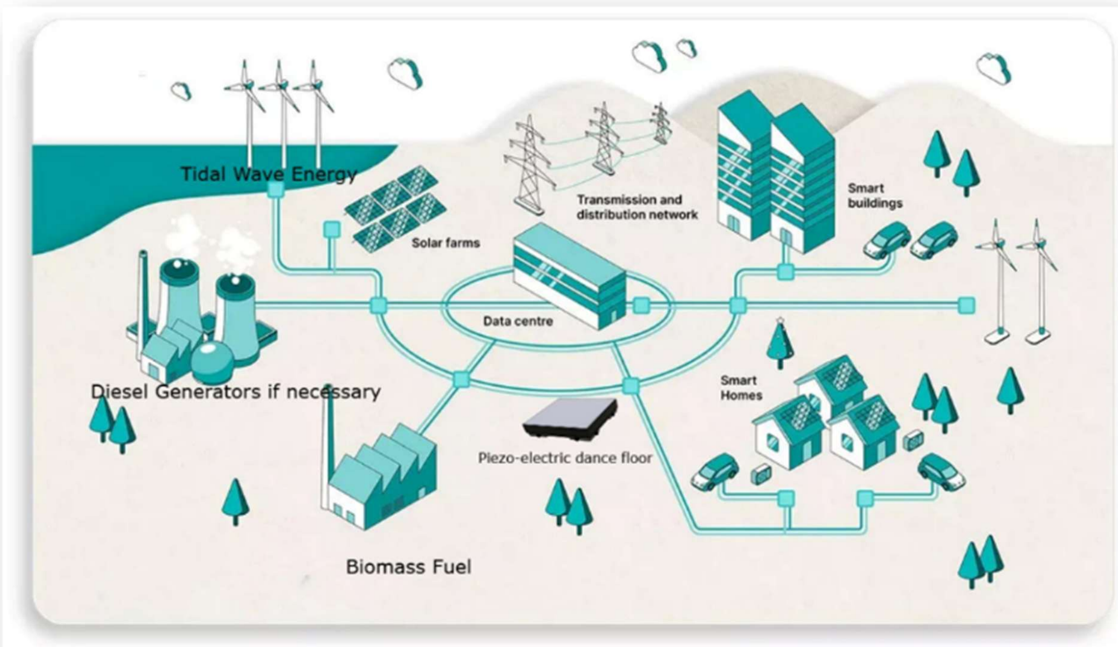


Figure 4.1: Model of the hybrid system (Adapted from Envolio,(n.d.)) https://envelio.com/smart-grid

4.2. Decentralised hybrid energy system (Solar, Piezoelectric and Diesel)

The decentralised hybrid energy system utilises solar energy and piezoelectric flooring to generate most of the total energy produced. This is supplemented by the pre-existing diesel generators which are activated by the Battery Energy Storage System (BESS) system when the solar battery (located in each instance of the solar system) falls to 5% and continues charging until 40% where it is deactivated. The solar sets (including solar panels) which total 104, are located on residential homes, local business, Taigai State College and the local hospital. Additionally, the piezoelectric PZT uses foot traffic, and the energy produced from ceremonial dancing to power the community hall. The entire system is monitored and controlled by hybrid inverters which are controlled by the BESS system within each building/household (in which the solar system is present).

4.3. Cable from PNG

This method involves running a submarine power cable from Papua New Guinea to Saibai Island, as depicted in type 1 of figure 1. Although AC reduces the maximum operational distance of the cable due to reactive power loss it is far superior to DC utilising cables (types 4 and 5 as depicted in Figure X) as it can be stepped up or down at transformers at both landmasses as required. As per the 2021 Census, there were 77 occupied dwellings on Saibai Islands. (Australian Bureau of Statistics [ABS], 2021)) Accounting for the 4-year difference we assume there are now 85 occupied dwellings on Saibai Island which is an extremely large estimate as the change between 2016 to 2021 was –1 (ABS, 2021) (ABS, 2016). Using the standard Australian electricity supply per household of 240V, 20400V would be required in total (Office of Environment and Heritage, 2016). As the type 1 submarine cable chosen can carry 33000V this leaves an additional 12600V for use for local businesses or facilities (e.g. school and hospital) on Saibai Island (Note: calculations above don't account for power loss). Thus, the energy transported between PNG and Saibai Island is sufficient to power Saibai and is a viable solution.

Type	1	2	3	4	5
Rated voltage	33 kV AC	150 kV AC	420 kV AC	320 kV DC	450 kV DC
Insulation	XLPE, EPR	XLPE	Oil/paper or XLPE	Extruded	Mass-impregnated
Typical application	Supplying small islands, connection of offshore wind turbines	Connecting islands with large populations, offshore wind parks export cables	Crossing rivers/straights with large transmission capacity	Long distance connections of offshore platforms or wind farms	Long distance connection of autonomous power grids
Maximum length	20—30 km	70—150 km	<50 km	>500 km	>500 km
Typical rating	30 MW	180 MW	700 MW/three cables	1000 MW/cable pair	600 MW/cable

Figure 4.2: Submarine cables
https://www.sciencedirect.com/science/article/pii/S1364032118305355#bib17

5. Design Selection

DECISION MATRIX

DESIGN REQUIREMENTS	DESIGN OPTION 1	DESIGN OPTION 2	DESIGN OPTION 3
GRID STABILITY AND RELIABILITY	GOOD	VERY GOOD	ACCEPTABLE
HARSH WEATHER OPERATION	ACCEPTABLE	ACCEPTABLE	POOR
ECONOMIC AFFORDABILITY	POOR	GOOD	EXTREMELY POOR
ACCESSIBILITY, USABILITY AND SAFETY COMPLIANCE	GOOD	GOOD	POOR
ENVIRONMENTALLY SUSTAINABILITY	GOOD	GOOD	POOR
SCALABILITY AND MODULARITY	GOOD	GOOD	POOR

Figure 5.1: Table of Decision Matrix

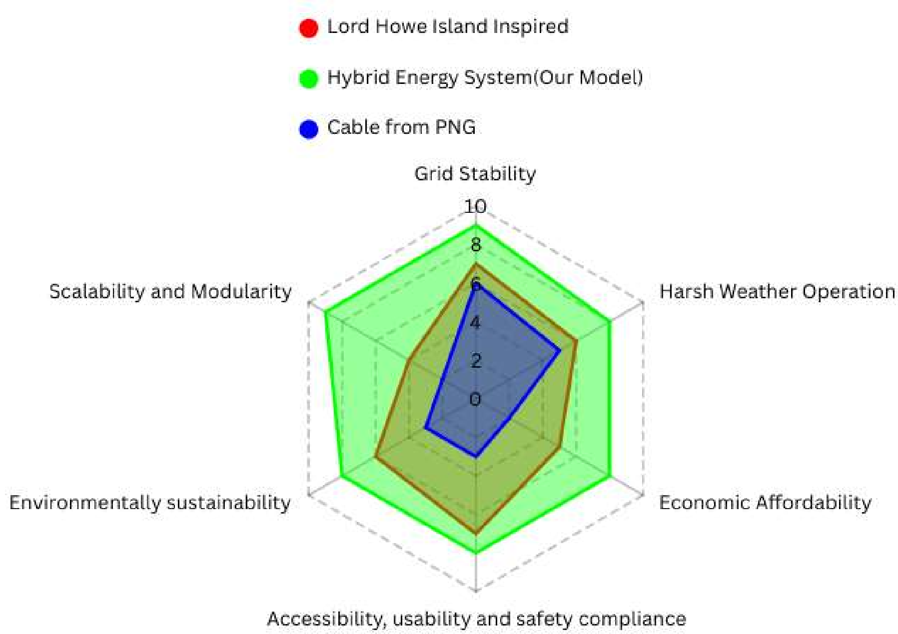


Figure 5.2: Radar Chart of Decision Matrix

Design option 2 was selected as team 100's final design as it directly supports the 2024 EWB Challenge objective to provide clean, affordable energy in a sustainable and community-driven manner. Furthermore, design solution 2 aligns with the team's design requirements and indicates the highest possibility of success. This was further solidified through the decision matrix which displays design Option 2 as the most suitable solution for the Saibai Island as it provides a reliable, cost-effective, and culturally appropriate energy solution that reduces environmental impact. Thus, through the decision matrix design option 2 was the most appropriate solution for the Saibai Island.

6. Detailed Design

The selected hybrid system utilises solar, piezoelectric panels and diesel energy to create reliable and clean energy for the Saibai Island, solving their frequent power outage issue. The solar energy being harnessed is the main contributor of energy towards this system. Solar energy will be generated through Photovoltaic (PV) panels which will be installed on all individual houses and commercial buildings on Saibai alongside solar batteries, generating electricity for all buildings/households. Each house will be installed with solar batteries as is it promotes equity of use, requires less cooling and reduces possible conflicts. However, commercial entities according to Ergon energy, consume 4 times (Ergon Energy, 2023) more electricity, so a total of 104 sets of 22 solar panels will be installed to account for this power usage. Furthermore, solar energy is clean, efficient and can always be tailored to the needs of a community like Saibai. This main energy source is supplemented by piezoelectric tiles placed in the community hall of the Saibai Island. By considering their cultural practices, the piezoelectric tiles allow the Saibai culture to flourish, potentially increasing cultural participation as it can generate electricity from the movements utilised in ceremonial dancing. The electricity produced by the piezoelectric tiles, will be effective when powering the lights in the community hall. Moreover, to ensure the stability and reliability of this system, the diesel generators remain as backup power generation. During times of poor weather, leading to low solar radiation, the batteries may not be unable to charge due to the lack of energy input. In cases like this, if a battery falls below 5% charge, the diesel generators will be turned on. The diesel generators will continue to power the battery until it reaches a charge of 40%. Once the battery reaches 40% the diesel generators will turn off. This hybrid system will be controlled by a Growatt SPH 10000TL-HU-US 10kW hybrid inverter which ensures the system runs smoothly, and energy is supplied all around the island. This hybrid inverter will significantly reduce Saibai's diesel reliance by approximately 60% basing it of the Lord Howe Island Data (*Lord Howe Island Renewable Energy Project System Design Report,* 2021), as it will only turn on the diesel generators when it reaches the preset criteria. The Battery Energy Storage System (BESS) installed in each house controls the hybrid inverter and in times of communication loss, can control the diesel generators through pre-loaded power frequency droop settings. The BESS is almost fully independent and is not reliant on outside communication making it perfect for the Saibai Island.

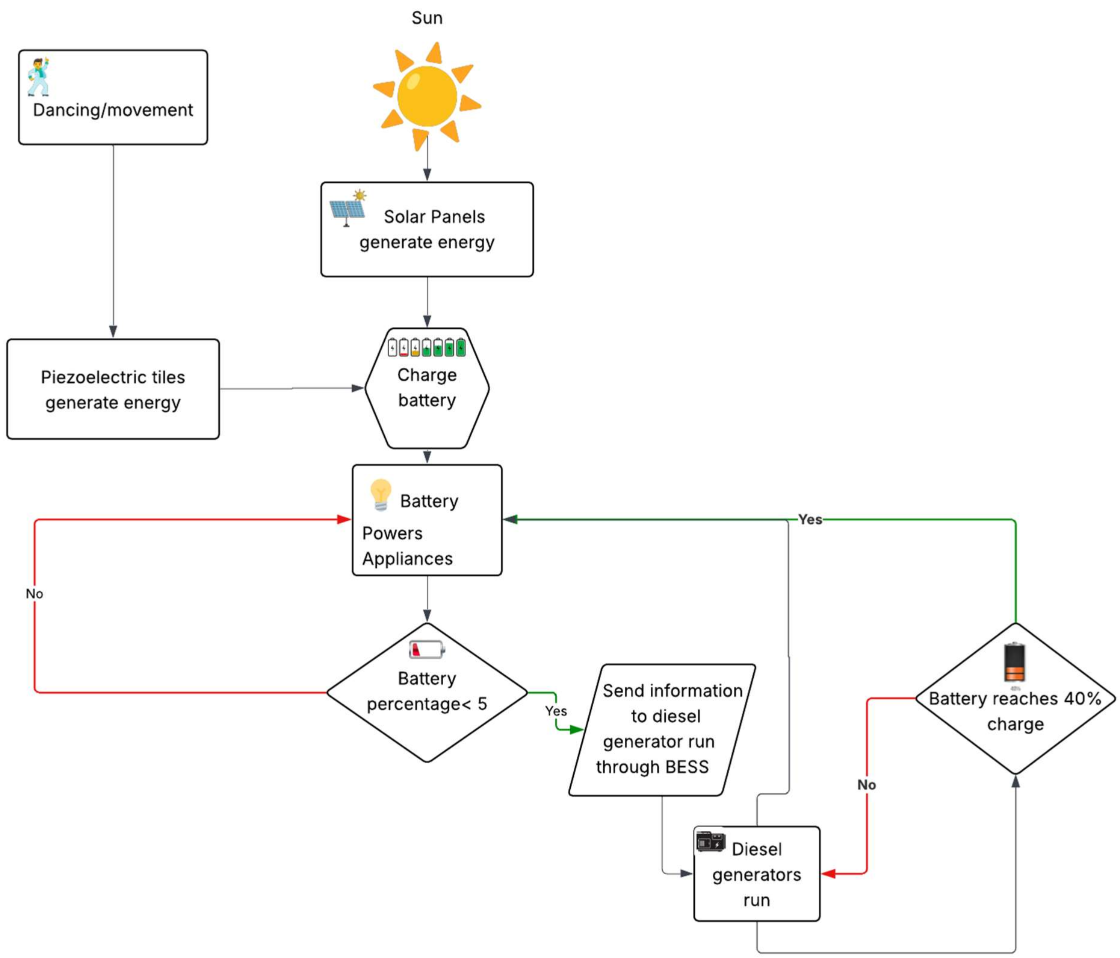


Figure 6.1: Schematic flowchart depicting the hybrid solar, piezo and diesel system

7. Prototyping

To optimise time and resources, the project prototype focuses on the piezoelectric dance floor concept and a small-scale simulation of the solar-diesel controller logic, rather than experimenting with different types of solar panels. A miniature solar panel, sourced directly from the market, was used to replicate the real-time scenario in Saibai, as solar panels have already been extensively tested and proven to be an effective resource, particularly on Saibai Island, where the solar irradiance averages 5.81 kilowatt-hours per square metre per day over the course of a year (Solar Quotes, n.d.). Furthermore, approximately 4% of households on Saibai Island have already installed solar panels (Solar Choice, n.d.).

7.1 Prototyping Objectives and Plan:

- Verify that a piezoelectric floor tile can generate usable electrical power and determine how multiple tiles might scale.
- Demonstrate the control strategy (turning a generator on/off based on battery State of Charge (SOC) and load) on a small scale to ensure stability and proper logic, possibly using a microcontroller or software simulation.

- Build a miniature integrated system (if possible): e.g., a solar panel charging a battery, powering an LED (simulating load), and a piezo sensor adding power when stepped on.

7.2 Piezoelectric Floor Tile Prototype

Figure 7.2.1: First piezoelectric parallel connection (without acrylic cover)

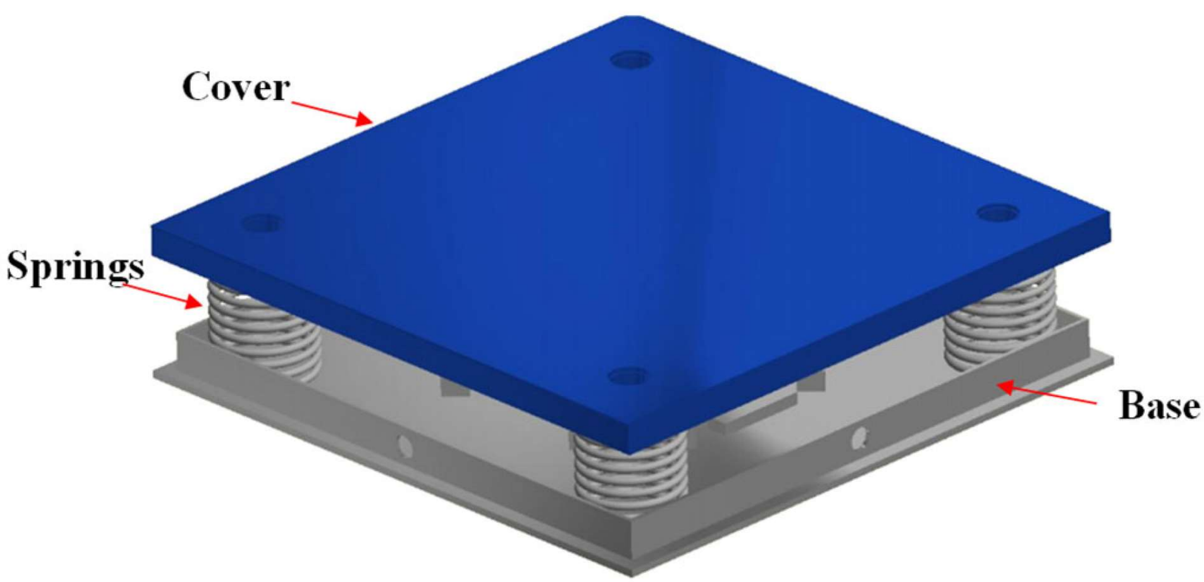


Figure 7.2.2: (Source: https://www.mdpi.com/2072-666X/14/5/1058)

Process: The project team constructed a 30 cm × 30 cm test tile using readily available piezoelectric disks (Murata 7BB-35-3L0 (35 mm)) sandwiched between acrylic plates. Then the foam padding was placed such that stepping on the tile would flex the piezos. The project team connected 20 piezo disks in parallel to a bridge rectifier (1N4001) and smoothing capacitor (12V, 22,000 µF), then to a resistor load (to simulate charging a battery or lighting an LED).

Prototype Testing: When one of our team members (~70 kg) stepped firmly on the tile, the team measured a voltage spike of around 30 V open-circuit, and with a 100Ω load the team got about 5–10 V sustained briefly, yielding ~0.5 W of power (it lit a 5 W LED faintly for a second). The project team iterated by adding a spring and lever mechanism to amplify motion (like how commercial tiles work). This improved output to around 2 W per footstep in our lab setup, enough to brightly light an LED cluster while pressure is applied.

The project team then built a second tile and tested two in combination. The team found that with asynchronous stepping, you get a more continuous output. Two people mimicking a dance rhythm could light a string of 12V LED strip fairly well. The energy was still small (e.g., dancing for one minute) charged a 12V, 22000 µF capacitor (SLPX223M025E7P3) to run a small DC fan (GDSTIME 12V 40mm x 40mm x 10mm Brushless Cooling Fan) for ~10 seconds.

Outcomes and suggestions: This prototype validated that piezo floors do produce power, though small yet effective to power small devices like lights. The documented power output per step was roughly 2-4 joules. Extrapolating this result with heavy dancing (2 steps per second) by 10 people could produce ~20-40W continuously. Over an hour, that is ~0.04 kWh – enough to charge a phone or run 4x10W LED for an hour. Intensive pressure to these crystals might damage it thus for further iterations, it needs a robust way to mount piezo without breaking. Some approaches are using shock absorbers and springs, or just buying commercial tiles designed for longevity.

Figure 7.2.3 Final Iteration with Spring setup and capacitor, inspiration: (CMU, 2019)

7.3 Microgrid Control Simulation

We created a simulation model in TinkerCAD and implemented it practically to mimic the solar battery-diesel system. We input a typical load profile (estimated from similar communities – peaks morning and evening, total ~25 kWh/day). We input solar generation profiles based on Saibai's irradiation (clear sky and some cloudy days). The control logic was coded to keep diesel off until battery SOC <30% or load > inverter capacity; when diesel on, run at 80 kW output until load can be met by other sources. To simulate a realistic scenario, the SOC was decreased by 10% during solar power generation lesser than 30W to replicate battery consumption acceleration during nighttime.

Results: The simulation ran over a week with varied weather showed the system mostly using solar and battery for 5 days, and diesel kicking in on 2 very cloudy days. The diesel runtime dropped by ~65% compared to a baseline diesel-only scenario (consistent with ~60-70% solar contribution). We observed the battery cycling between 30% and 90% SOC on daily basis, which is acceptable. One key test was ensuring when diesel starts, the inverters ramp down to not overload the system – our control loop successfully prevented any oscillation by using a 5-minute decision interval and hysteresis (i.e., don’t stop the diesel until SOC >75% to avoid on-off rapid cycling)

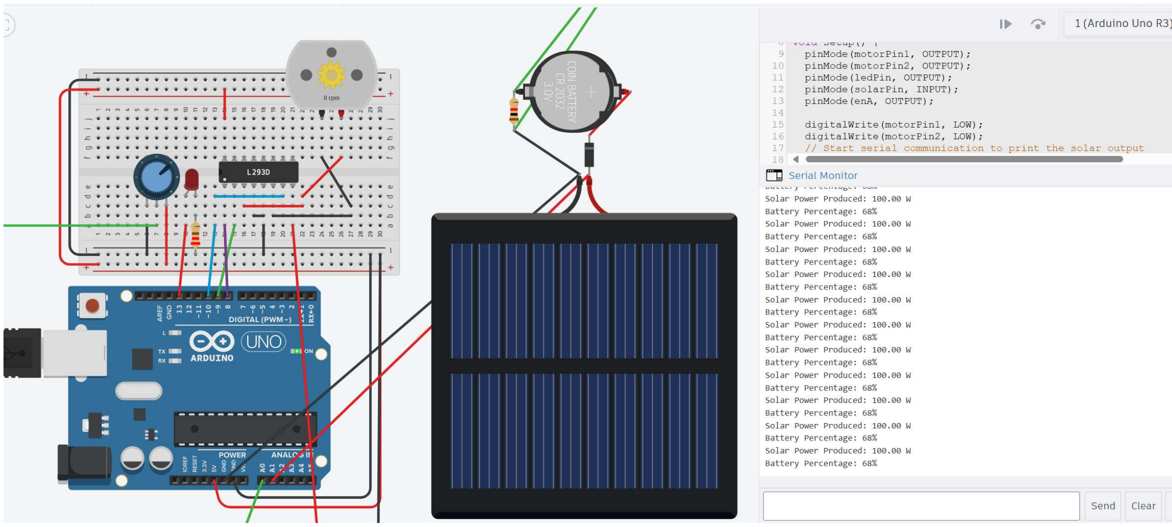
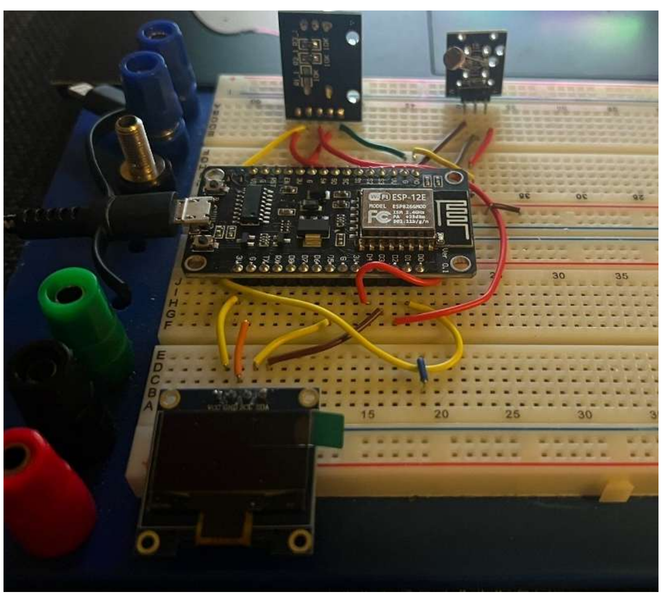
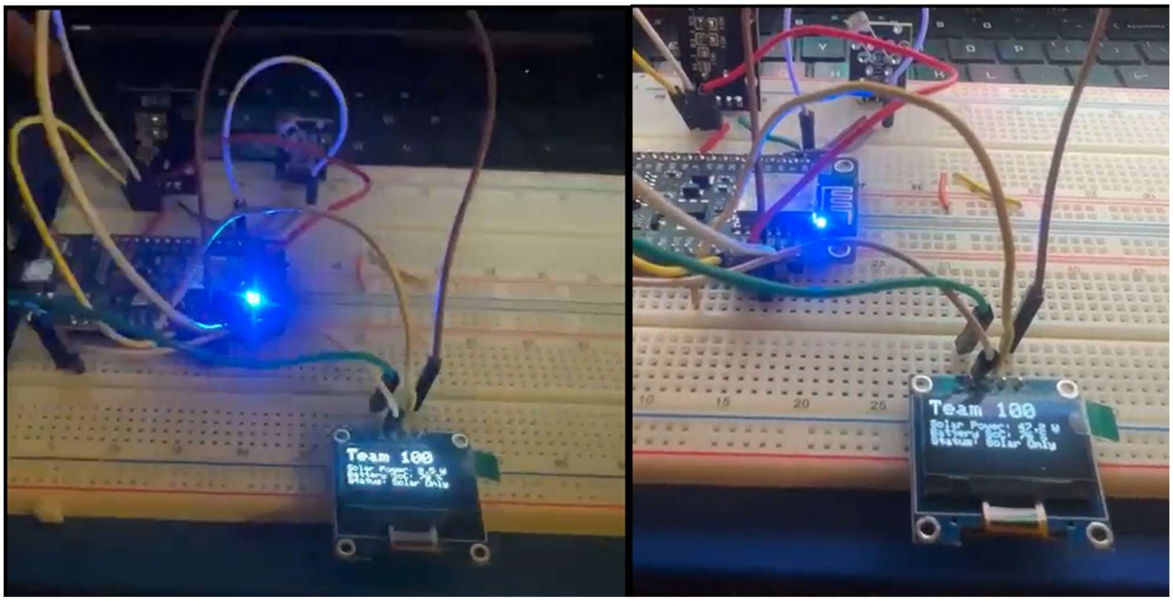


Figure 7.3.1: First: TinkerCAD Simulation and C++ code for solar prototype and BESS



7.3.2: Second Real Life Implementation using ESP32



7.3.3: Final Iteration: OLED Implementation and BESS Testing.

7.4 Prototype Outcomes Summary

Testing Successes: Verified viability of dance floor power concept, validated control algorithms, and engaged potential users with interactive demo. The results give confidence that our design will function as intended and meet performance goals (no technical showstoppers).

Testing Limitations: Our prototype tile wasn't full-scale size or durability. The simulation of the microgrid, while detailed, is not a substitute for actual full load testing – but given the conventional nature of solar-diesel hybrids, we rely on known industry practice for real deployment.

All the prototypes are explained in detail in the appendix 6,7,8 with figures and data for transparency. The next step is translating this into real-life implementation on Saibai, which is outlined in the subsequent Section 8.

8. Implementation Plan

Phase 1: Community Consultation and Co-Design (Months 1–3)

Activities:
- Present design to Saibai community leaders and TSIRC.

Gather feedback on:
- Solar array placement.
- Rooftop installation buildings.
- Dance floor location.
- Cultural concerns (e.g., land approval, blessings/ceremonies).
- Discuss local employment and training interest.
- Adjust design if significant community issues are raised.

Community Involvement:
- Conduct workshops to demonstrate a prototype kinetic tile.
- Invite community ideas (e.g., tile shape, artwork integration).

Phase 2: Funding and Procurement (Months 2–6)

Activities:
- Finalize budget and secure funding from:
- Queensland Renewable Remote Power Programme.
- Indigenous infrastructure grants.
- Climate adaptation funds.
- TSIRC budget allocations.
- Use bill of materials to get supplier quotes (solar panels, batteries, etc.).
- Order long-lead items (e.g., batteries, inverters, piezo tiles).

Community Involvement:
- Organize local fundraisers for smaller items.
- Encourage labor or material contributions (e.g., sand/aggregate collection).
- Engage local artists to decorate the dance floor or solar area.

Phase 3: Construction of Solar PV and Power Systems (Months 7–12)

Activities:
- Site preparation: clear and level area, pour footings.
- Rooftop solar installation on clear days.
- Install battery container and inverter/control systems.
- Coordinate diesel integration with Ergon for safe connection.
- Begin testing solar and battery systems by ~Month 10.

Community Involvement:
- Hire local workers where possible.
- Form a team of 4–5 local "trainees" to work alongside contractors.
- Ensure Elder presence during land clearing for cultural protocols.
- Avoid construction during culturally significant days
- Share weekly progress at community meetings.

Phase 4: Dance Floor Installation and Commissioning (Months 11–15)

Activities:
- Wait until major electrical work is complete.
- Build raised platform or install kinetic tiles at chosen site.
- Bring in tile supplier experts if needed.
- Test floor with volunteers for safety and function.
- Connect output to hall lighting and verify operation.

Community Involvement:
- Host an "Energy Dance Day" for community to try the floor.
- Use event to educate the community about the whole energy system.
- Motivate youth to take ownership (e.g., cleaning, monitoring).

Phase 5: Training, Handover, and Operationalize (Months 13–18)

Activities:
- Train council workers and selected community members in:
- Panel cleaning (quarterly, morning/evening).
- Battery health monitoring.
- Diesel generator testing.
- Dance floor maintenance (e.g., checking tile bolts).
- Provide user manual in plain English and local language.
- Set up monthly maintenance and monitoring schedule.

Community Involvement:
- Ensure 2–3 trained community members can manage basic tasks.
- Create a local Energy Committee to review and share system data.
- Integrate system into school curriculum for student engagement.

Phase 6: Monitoring and Support (Ongoing, post-commissioning)

Activities:
- Provide remote monitoring by TSIRC or EWB partner for 1+ years.
- Address teething issues and coordinate warranty repairs.
- Track system performance and cost savings.
- Plan for expansion if successful.

Community Involvement:
- Celebrate milestones (e.g., "1 year, diesel use cut by 50%!").
- Keep momentum with ongoing events and transparency.

Figure 8.1. **Detailed Implementation plan**

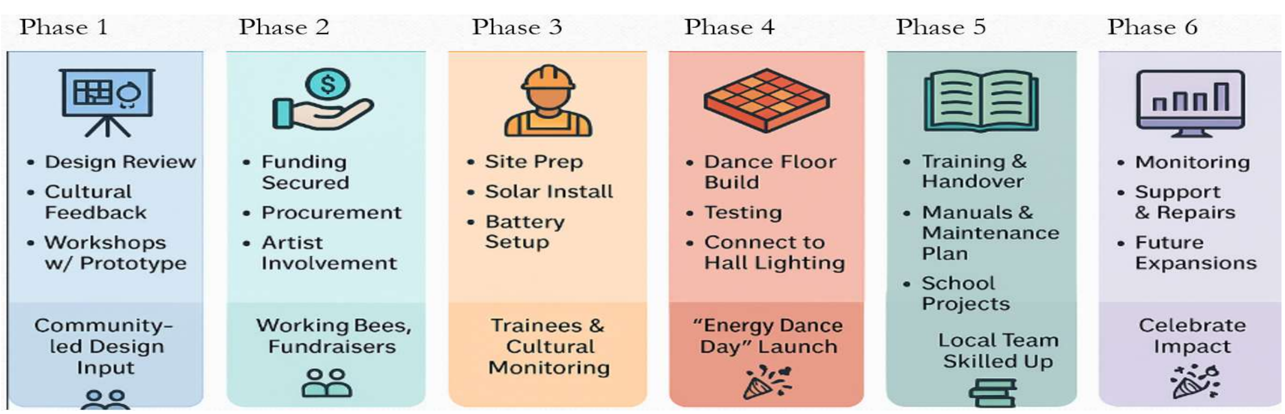


Figure 8.2: Phases 1-6 of Implementation plan

9. Cost Analysis

9.1. Bill of Materials and Capital Costs

- As depicted in Figure 9.3 the initial cost for the solution is $591,012.61 and consists of materials, labour and shipment as depicted in the Figure 9.1 (materials bill)
- The cost of materials is <u>**464,100.42**</u> as per figure 9.1
  - 104 solar sets (22 solar panels in each set, BESS, hybrid inverter, ground/roof mounting, battery, 100 metres of DC wires, waterproof connectors) were purchased
  - 100 50x50cm PZT piezoelectric panels ($42,260.42)
  - 26501 litres of diesel
- Labor cost is $98,268 (accounts for worker's salaries and accommodation)
  - Workers required is 19
  - Workers categorized as skilled (i.e. solar technician), semi-skilled (trainees in process of learning) and unskilled (trainees beginning learning) as per Figure 9.2.
  - Hourly salaries correspond to worker's skill levels →skilled is $40, semi-skilled is $30 and un-skilled is $25.
  - Worker's accommodation is at council houses and Indigenous homestays (single and double rooms available for rent). (Fees & Charges for Torres Strait Island Regional Council, n.d.) Accommodation for these workers amounts to <u>**$31,668**</u>
- Shipment of required materials (via freight) initially costs <u>**$11,176**</u>. China →Weipa → Saibai
- Disposal of batteries and solar panels at the end-of-life cycle (15 years batteries, 30 years solar panels); in which we will ship back to Weipa (where we shipped materials from to Saibai initially) then to China.

Raw Materials Bill

Team 100
niversity of Technology Sydney (UTS)
Ultimo Campus

BALANCE DUE $464,100.42

To:
EWB Australia,
552 Victoria St, North Melbourne VIC 3051
&
Residents of Saibai Island

Date: 10/05/2025

#	Item name	Description	Quantity	Price	Amount
1	Residential Solar Set	Complete Solar Set for residential homes	85	3113.33	$264,633.05
2	Saibai Water Treatment Plant Solar Set	Solar Waste Water treatment (+1 for security and backup)	5	3113.33	$15,566.65
3	Small Business and Service Providers Solar Set	Saibai takeaway and catering services , Services Australia agent, Saibai ibis store	5	3113.33	$15,566.65
4	Solar Set for Saibai Island Primary health Care	Solar Solution for the only hospital in Saibai (+1 for security and backup)	5	3113.33	$15,566.65
5	Solar Set for Tagai State College (TSC)	Solar Set for Tagai State Colleç	4	3113.33	$12,453.32
6	Piezoelectric dance floors	PZT ceramic (50cm × 50 cm)	100	422.60	$42,260.40
7	Diesel cost	Diesel for backup	26501	3.70	$98,053.70
				Total	$464,100.42

Note
All prices are in Australian Dollar,
with the forex of **1USD =1.56 Australian Dollar**
Business consumption takes ~4 times more power than residential consumption (Calculated using Ergon Energy's (data to share) (121.3666/29.5117 =~4)
The 'Solar Set' consists of :
22 pcs of 460W MONO Solar Panels (Total 10 kW)
1 set of Growatt Hybrid Inverter 10kW
1 set of Roof Mounting/ Ground Mounting
3 pcs of ELEBOX-HV 10kWh Batteries (Total 30kWh)
14 pairs of MC4 Waterproof Connectors
100 meters of DC Wires

Figure 9.1: Materials bill; total $464,100.43

LABOUR COST CALCULATOR

Project Name	Number of Hours	Workers Count	TOTAL
Hybrid Energy Project	49	19	
Hourly Wage (Skilled)/hr	Hourly Wage (Semi-Skilled)/hr	Hourly Wage (Unskilled)/hr	**$98,268**
$40	$30	$25	

COST BREAKDOWN

Phase	No.	Designation	No. of Staff Required	Hourly Wage	Hours Worked	Days Worked	Total Wage
1	1	Community Coordinator	1	30	4	7	840
	2	Local Representatives	3	25	4	7	2100
2	1	Financial Officer	1	40	4	20	3200
3	1	Solar Technician	1	40	4	35	5600
	2	Local Trainees	2	30	5	35	10500
	3	Local Labourer	4	25	6	35	21000
4	1	Flooring Specialist	1	40	4	20	3200
	2	Local Labourer	2	25	7	20	7000
5	1	Trainer (Skilled)	1	40	4	20	3200
	2	Local Workers	3	25	7	20	10500

RENT BREAKDOWN

Phase	No. of Workers	No. of Single Rooms	No. of Double Rooms	Cost Of Single Room per Week	Cost Of Double Room per Week	Duration (Weeks)	Total Cost
1	4	0	2	504	984	1	1968
2	1	1	0	504	984	3	1512
3	7	1	3	504	984	5	17280
4	3	1	1	504	984	3	4464
5	4	0	2	504	984	3	5904

Figure 9.2: Labour costs for the installation and maintenance of hybrid solar systems

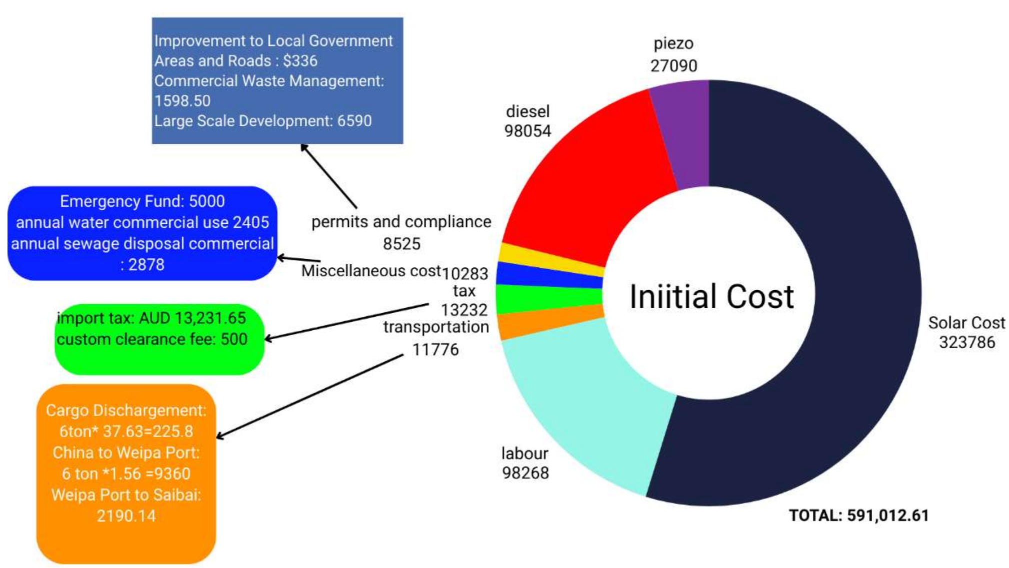


Figure 9.3: Data used: (made-in-china(a), made-in-china(b), lgsolution, fast courier)(n.d.), (Solban, Moussa; 2020) For detailed calculation please see Appendix 1

9.2. Funding Sources and Strategy

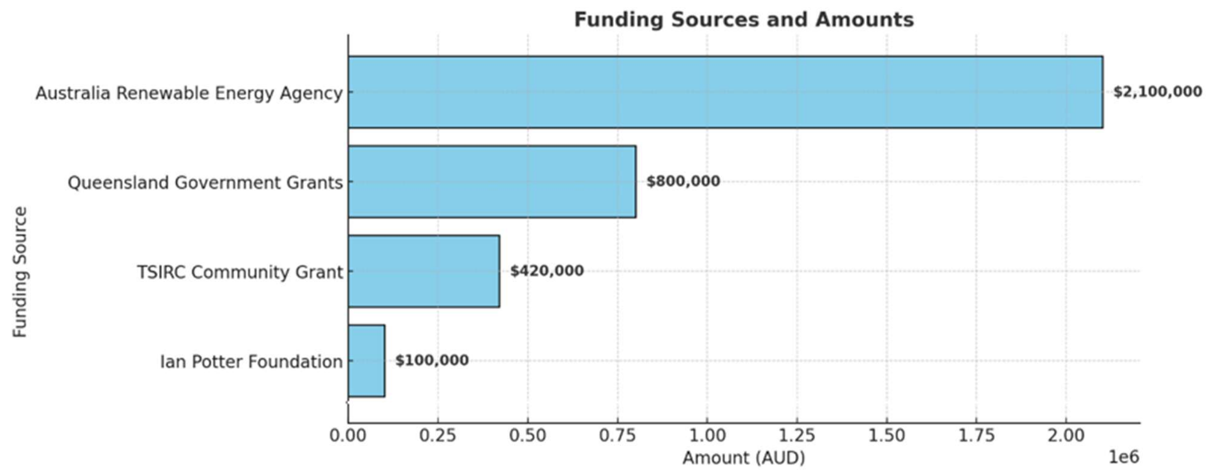


Figure 9.4: Funding Sources for design (please see Appendix 3 for more detail).

As per Figure 9.4 the total funding accessible is $3.42 million consisting of a range of public and private sources:

- **QLD Government Grants** ($800k) on the graph refers to the state's Building Our Region (BOR). This is the same program used for the Saibai Fuel Infrastructure upgrade (Funded Projects, 2024) which received $826,900. Therefore, we have estimated that due to our similarities with the earlier project the likelihood of success is increased.
- Australia Renewable Energy Agency ($2.1 million) funds off-grid solutions. For example, the $11.85 million Lord Howe was funded $4.5 million. As our model has half the battery capacity and lesser PV cell capacity, we estimated our received funds to be $2.1 million.
- **TSIRC Community Grant** ($420K) prioritizes projects which focus on clean/renewable energy.
- **Ian Potter Foundation** ($100K) is private sponsorship that funds community infrastructure.

9.3. Cost-Benefit Analysis

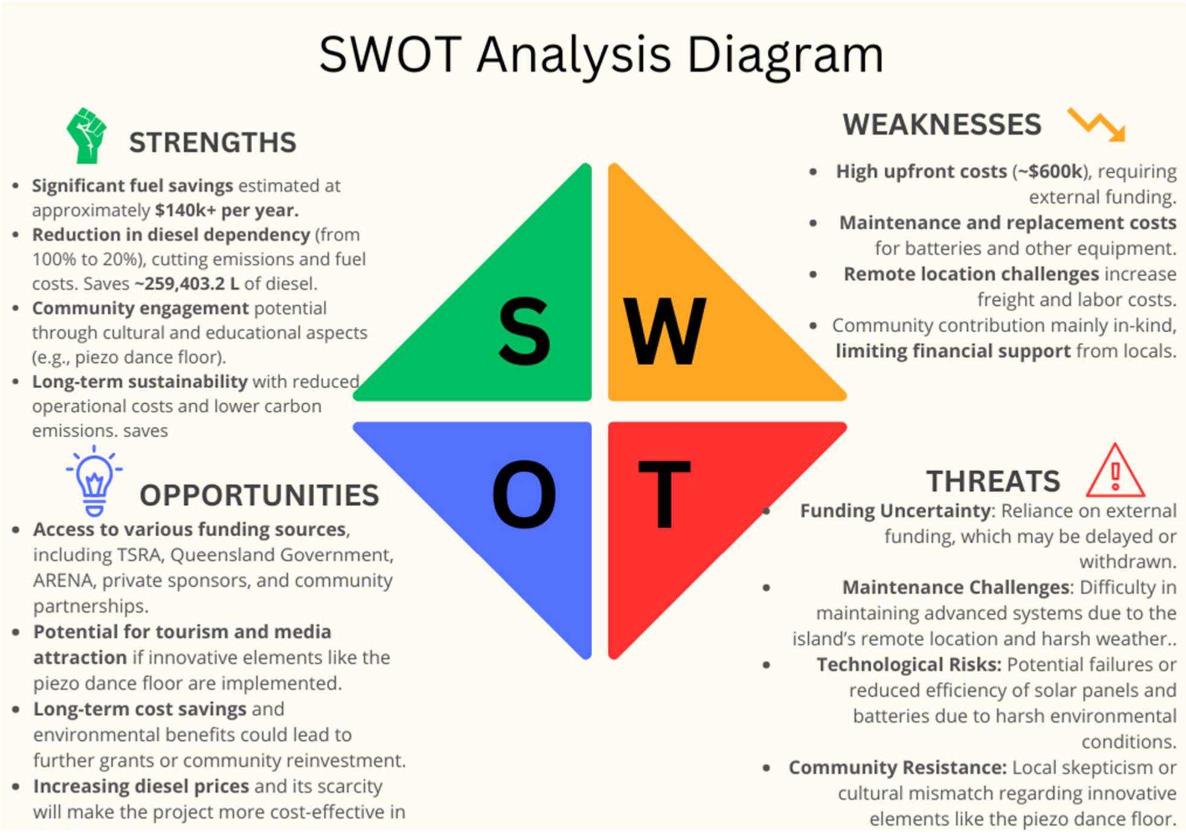


Figure 9.5: SWOT Analysis of the financial implications of our design

10. Discussion

10.1 Meeting Community Needs and Priorities

The hybrid solar solution directly addresses the community's need for stable and sustainable power. With improved energy reliability (solar + battery reducing diesel fuel reliance by 80%), essential services (i.e. local hospital) will have increased support to operate to their full capacity due to a decreased likelihood of generator failures or fuel supply issues which was a key priority for the Saibai residents. (Li, et al., 2023) Additionally, by retaining the diesel generators in a reduced role, it increases the reliability of the energy system as they can be activated if the battery falls to 5% to ensure consistent power generation.

10.2 Cultural Alignment and Inclusivity

By integrating a piezoelectric floor [designed for the purposes of dancing] we are resonating with Saibai's cultural traditions. Instead of imposing an external technology, we've embedded the familiar cultural practice of dancing into the solution. This demonstrates respect for local culture by valuing it as part of the solution, not an obstacle.

Respect for Traditional Owners: We will engage, involve and consult with Elders and community representatives from Saibai during the entire implementation process. example, in the designing of the piezoelectric tiles we will consult the local community and artists on potential designs Additionally, we will seek permission and guidance especially on land use and any spiritual implications. For instance, through consolation with local elders the team will ensure the site of any infrastructure (is not on a culturally significant place (i.e. burial ground) which will ensure cultural respect and increased communal belonging to the project.

Language and Communication: Although English is common on Saibai, the team will encourage the use of local language names. This can be implemented by possibly naming the system in Kala Kawaw Ya or Brokan and making signage bilingual to instil communal pride and cultural awareness (tstlanguages, n.d.).

Overall, the project is culturally inclusive allowing the solution to be driven by the community's cultural practices rather than override it. This is a model of culturally informed engineering, aligning with principles of "Engineering on Country" that EWB Australia, (2023) emphasizes.

10.3.1 Positive Environmental Benefits and Impacts

Significant reduction in greenhouse gas emissions by cutting diesel use as quantified (approx. 75 tonnes CO_2) less per year. (See Appendix 9) Fewer diesel shipments mean a reduced risk of spillage in the ocean or land. Additionally, it indicates decreased local pollution as the diesel generator emits particulate matter and noise pollution (WorkSafe Victoria, n.d). By cutting the runtime of diesel generators as our design proposes there will be improved air quality and reduced noise pollution which makes the environment more pleasant. (as was noted at Lord Howe after hybridization, the island became "more peaceful than it has been for decades" (Filatoff, 2021) due to less generator noise). The solar panels provide a small co-benefit of providing shade to the building which increases the operational life of the batteries by mitigating overheating due to excess humidity in island environments (Wang et al., 2025, p.3)**.**

10.3.2 Potential Negative Impacts and Mitigations:

- Mishandling batteries can cause fires or chemical leakage (energysafe Victoria, n.d.). To mitigate these risks, we shall utilise regulation with *AS/NZS5139* rule (WorkSafe Qld, 2023), provide safety inductions for battery management and ensuring the battery is fit-for-use beforehand.
- Diesel generator still runs occasionally, so all the emissions aren't gone. Mitigation measures include to plant native plants like mangroves to achieve overall carbon neutrality.
- The manufacturing and shipping of panels/ batteries will have embodied emissions, but there are offset by clean generation within a few years.

10.4 Economic and Long-Term Sustainability

Economically, this project is likely to save money in the long run as can be seen in figure 9.7. It reduces operation costs which is crucial for a low-income community. Instead of relying on diesel, which is $ 3.7/L, it is relying on solar energy which is cheaper and requires minimal maintenance beyond cleaning and rarely easy-to-handle repairs (Queensland Treasury, 2025).

Comparison between diesel to hybrid model

Metric	Before (Diesel Only)	After (Hybrid: Diesel + Solar + Piezo)	Change (%)
CO_2 Emissions (tonnes/year)	1,168.02	233.6	-80.00%
Diesel Consumption (litres)	444,114.67	88,822.93	-80.00%
Renewable Share (%)	5	90	+1700.00%
Energy Cost ($/year)	1,643,224.29	591,012.61	-64.03%
Reliability (uptime %)	100	90	-10.00%
Maintenance Cost ($/year)	22,200	17,600	-20.72%
Total Energy Produced (kWh)	10,675.83	12,375.59	+15.92%

Figure 9.7: Comparison of diesel generators vs hybrid model

Figure: 10.1: Fulfilment of SDGs.

The project directly accomplishes 6 out of the 17 Sustainable Development Goals (SDGs), represented with large figures in Figure 10.1, and indirectly addresses an additional 4 SDGs, depicted with small figures in Figure 10.1. Both sets of SDGs are further elaborated in Figure 10.2.

Sustainable Development Goal (SDG)	Focus	Targets Addressed
SDG 7: Affordable and Clean Energy	Transition Saibai Island from diesel to renewable energy (solar and piezoelectricity).	7.1: Universal access to modern energy services 7.2: Increase share of renewable energy 7.a: Enhance clean energy tech
SDG 8: Decent Work and Economic Growth	Reduce diesel fuel costs, create jobs, and provide technical training.	8.2: Higher levels of economic productivity 8.5: Full and productive employment for all
SDG 9: Industry, Innovation, and Infrastructure	Introduce innovative energy solutions (piezoelectric flooring) and optimize infrastructure (solar PV).	9.1: Resilient infrastructure 9.4: Sustainable industrialization through clean technologies
SDG 11: Sustainable Cities and Communities	Enhance sustainability and resilience of Saibai Island with reliable, eco-friendly energy.	Target 11: Inclusive, safe, resilient, and sustainable human settlements
SDG 12: Responsible Consumption and Production	Reduce diesel reliance, promote sustainable consumption, and plan battery/solar panel recycling.	12.5: Substantially reduce waste generation
SDG 13: Climate Action	Decrease diesel usage, lower greenhouse gas emissions, and increase climate resilience.	13.1: Strengthen resilience to climate hazards 13.2: Integrate climate change measures
SDG 3: Good Health and Well-being	Reduced air pollution improves community health.	-
SDG 10: Reduced Inequalities	Affordable and reliable energy reduces community disparities.	-
SDG 16: Peace, Justice, and Strong Institutions	Community engagement fosters social cohesion and cultural alignment.	-
SDG 17: Partnerships for the Goals	Collaboration with Engineers Without Borders, Queensland Government, and Torres Strait Regional Council.	-

Fig: 10.2: Justification of SDG mentioned on Figure 10.1

Similarly, the broader and long-term sustainability has been further explained using the 10.3 brain map and 10.4 sustainability Venn diagram which discusses the cultural, environmental and economic aspect of the project.

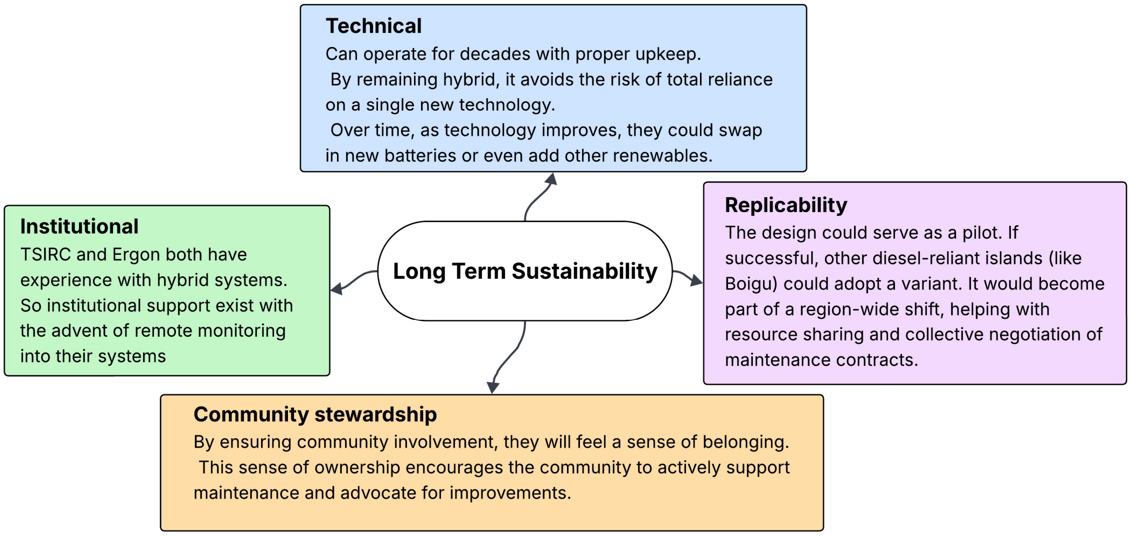


Figure 10.3: This figure displays how long-term sustainability is achieved through our solution. Our design can serve as a stepping stone for many other islands all over the world serving a purpose in the future. It also promotes community involvement/support, allowing for future generations to grow up in a better environment where energy is readily available, creating a sense of belonging.

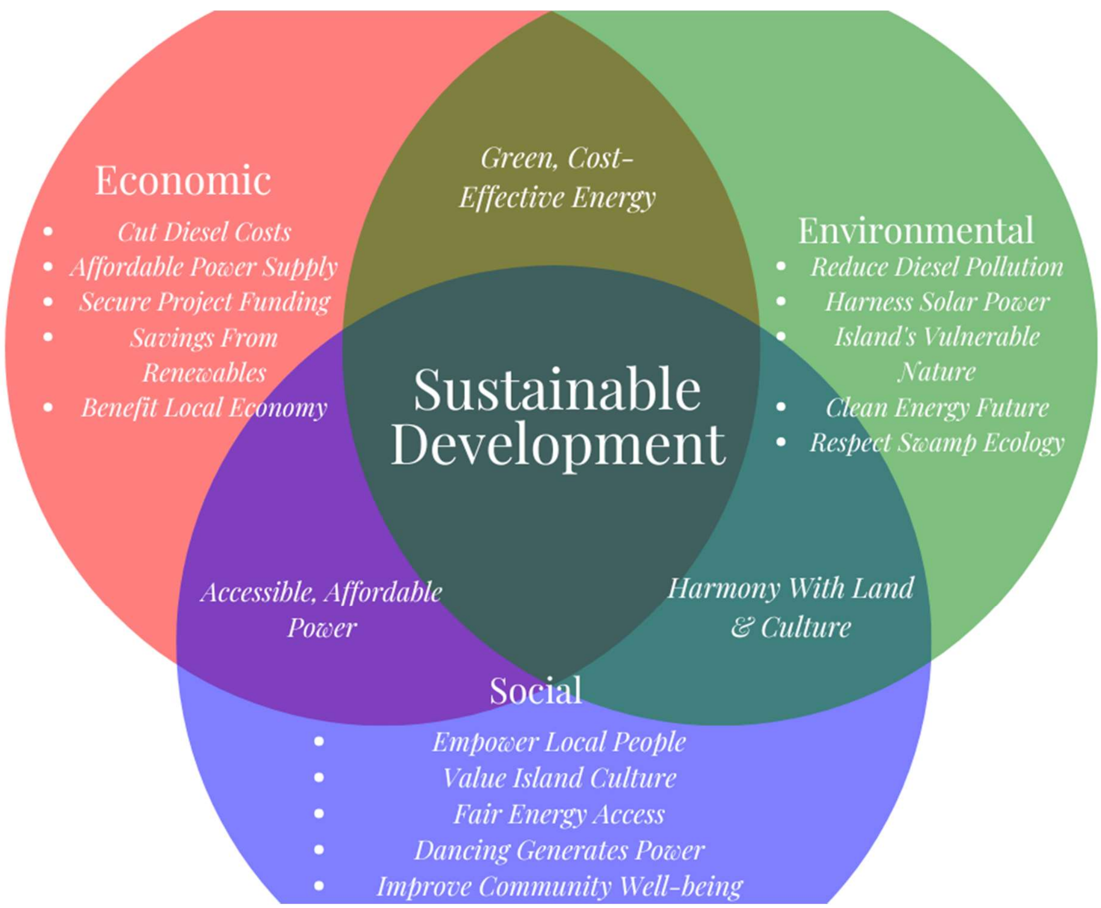


Figure 10.4: Sustainable Development

For a solution to be sustainable, it needs to consider economic, social and environmental factors. Our hybrid system as seen in figure 10.4, it incorporates all factors, allowing it to be a successful solution for the Saibai people. It cuts diesel costs significantly, reduces diesel pollution and increases well-being, targeting all the factors of sustainability.

10.5 Design Dynamics: Analysing Strengths, Weaknesses, and Future Prospects

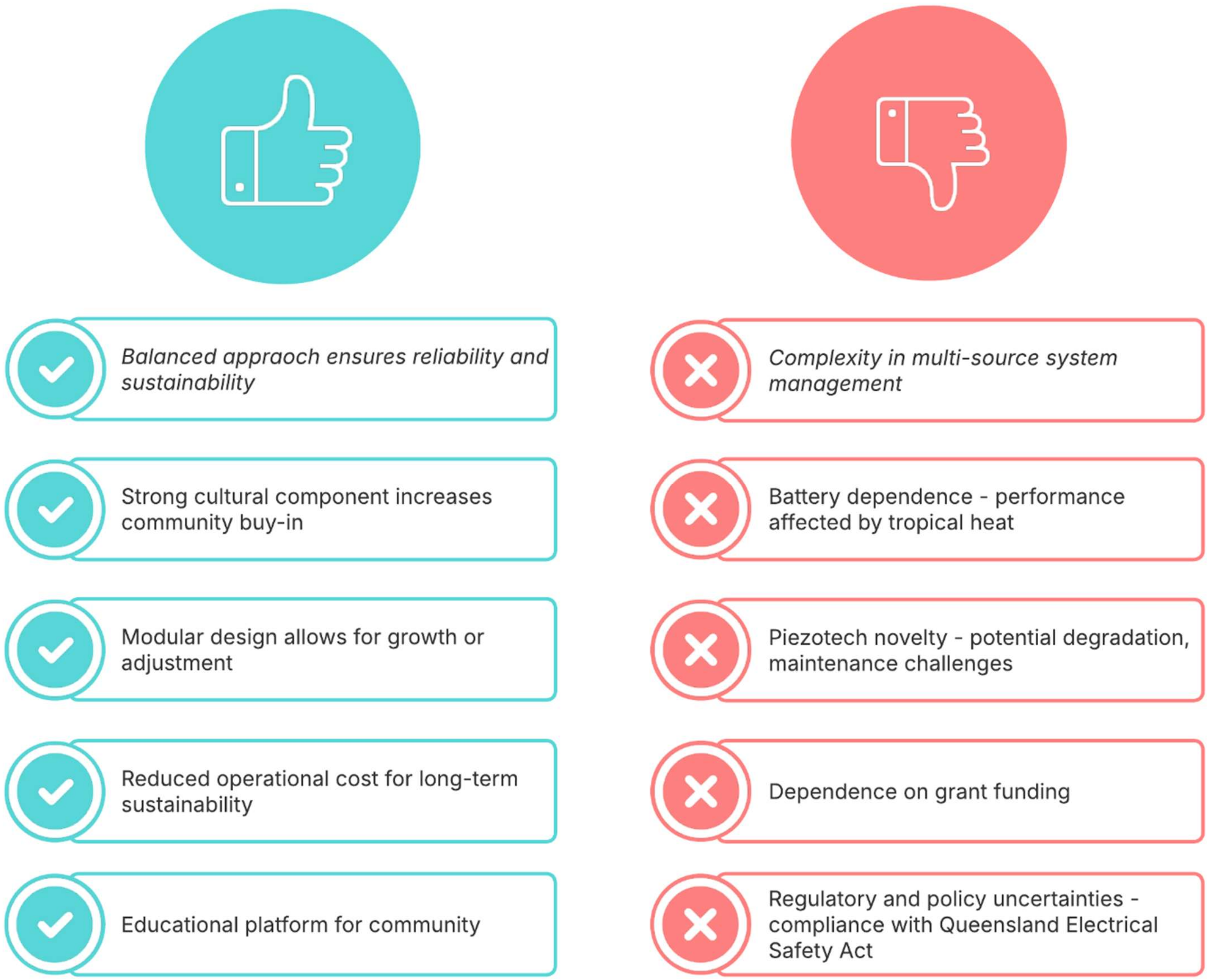


Figure 10.5: This figure shows the varying positive and negatives or our hybrid system. The positives include a modular design that is easily scalable and adjustable when demand is increased. Furthermore, it provides and educational platform for the community. Some negatives include the dependence on grant funding to fulfill the solution and the dependence on battery which negatively performs in tropical and humid climates.

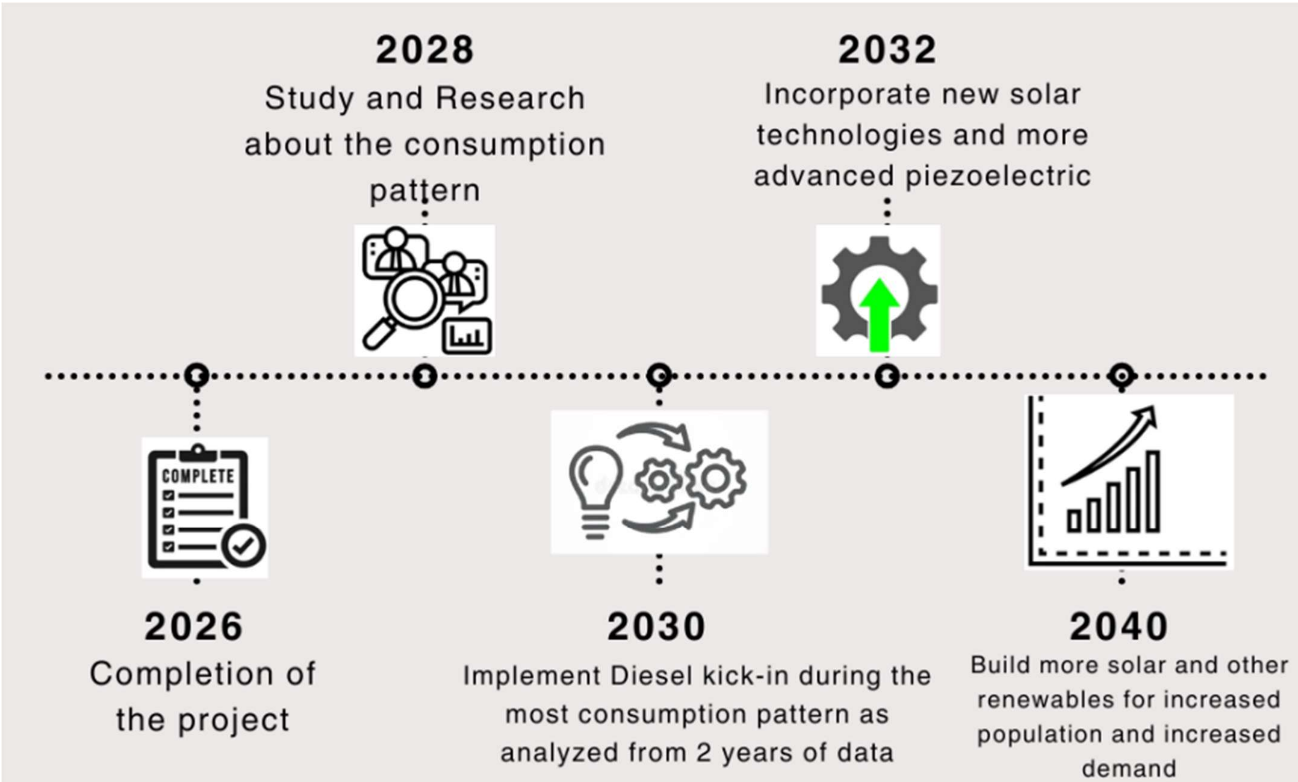


Figure 10.6: Future development of our solution

As per figure 10.6 the project will be completed within 1.5 years. Following completion, data on energy production [by the hybrid system] and consumption by the island's population will be collected to finetune the solution. Using the collected data, the diesel generators will increase production during periods of greatest consumption to ensure consistent energy generation. A similar process will occur to increase the number of solar panels (given the number of houses increase) 2 years following diesel kick in. Additionally, more effective piezoelectric plates will be utilised to maximise energy generation. Finally, the design will be scaled by integrating more solar technology and potentially other renewables to meet increased demand and integrate developing technologies within the hybrid system.

10.6 Stakeholder Dynamics

Figure 10.7: Influences vs Interest stakeholders' matrix

Stakeholder dynamics: The project team anticipates broad support from all the stakeholders and their roles are mentioned in the above figure. The only potential point of contention may arise if Ergon's role is not clearly defined (however, given TSIRC's partnership, this issue is likely to be addressed). Another potential challenge could be community resistance to new initiatives; however, with proper community engagement and discussion, this is considered unlikely, as some residents are already adopting solar panels, and communities generally welcome improved power solutions. Managing expectations is crucial, clarifying that diesel usage will not be eliminated. Some residents may mistakenly believe the system will immediately achieve 100% renewable energy and question continued diesel use or fuel deliveries. Therefore, it is important to communicate the need for occasional diesel use and emphasize the significant reduction in fuel consumption to avoid undermining the project's perceived success.

11. Conclusion and Recommendations

The development and implementation of the hybrid system will significantly improve the current energy provision for Saibai Island, helping to preserve the community's way of life. Extensive research into the conditions in Saibai Island and the existing energy infrastructure from Ergon Energy guided the design, addressing stakeholders' needs and energy generation challenges. The hybrid system design combines solar and piezoelectricity, reducing diesel reliance and promoting sustainability, ensuring a reliable, cost-effective energy supply with minimal environmental impact. However, achieving the ideal solution requires continuous testing and stakeholders' feedback. Therefore, ongoing community engagement is essential, using feedback to refine the design and better meet stakeholder needs. This project supports the Saibai people's commitment to protect the land and sea country they depend on, while fostering sustainable practices and balancing the relationship between the people and the ecosystem. By providing an efficient energy generation method for Saibai Island, this initiative empowers the community to access vital resources and work toward self-sufficiency within their natural habitats.

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Appendices

Appendix 1: Detail Calculated for Section 8 (Cost Analysis)

To calculate the price for the total number of photovoltaic panels, we first need to figure out how many panels are required. According to the Australian Photovoltaic Institute (APVI), only 4% of the total dwellings in Saibai Island's postcode, 4875, have photovoltaic panels installed (APVI, 2024). However, this also includes other islands such as Badu Island, Erub Island, and many other islands located in the Torres Strait region. Therefore, this 4% cannot be used as a certain number. Although the explicit number of photovoltaic panels installed is not available, it has been stated that Saibai Island does currently use solar energy for water heating, thus, showing that solar energy is somewhat integrated into Saibai Island. Furthermore, in various pictures of Saibai Island (ABC Saibai, 2023; Part 7 - Saibai Island, n.d.), many houses have photovoltaic panels installed. Using the tool available on solarchoice, n.d., the average system size of the houses with photovoltaic systems installed is less than/around 1kW. Using the previously provided number from the APVI of 4% of houses having solar energy, we will assume only 5% of dwellings in Saibai Island have sufficient photovoltaic panel systems to sustain energy for themselves. Although most houses which have been checked using Solar Choice's tool have 20% of the required system size, using 5% as an estimate is better in terms of cost at this stage to account for any extra cost which may come from having to possibly replace the older panels as well as install systems for houses which do not have any solar system. Including visitor only houses, there are a total of 113 houses in Saibai Island. 5% of this would mean only 6 houses have sufficient solar infrastructure, requiring a total of 107 5kW solar systems to be built on Saibai Island.

Appendix 2: Solar Tariff Calculator (Raw data for cost breakdown)

Solar Panel Capacity	10 kW	made in china, n.d.						
Inverter Efficiency	93%	made in china , n.d.						
system efficiency (wires + battery + hysteresis	75%							
Combined Efficiency	69.75%	0.93*0.75						
Mean monthly Production	for 10kW solar							
		Table from Solar Quotes		Solar Power & Battery Systems: Saibai Island, QLD, 4875				
Month	Production	Energy Consumption per day	Days	Total Consumption	Production with the efficiency	Surplus	Tarif per kwh	
January	1335.664	29.511748	31	914.8642	931.62564	16.76144	0.12377	2.074563
February	1173.801	29.798333	28	834.3533	818.7261975	-15.6271	0.12377	0
March	1386.203	30.133621	31	934.1423	966.8765925	32.73434	0.12377	4.051529
April	1390.395	30.290678	30	908.7203	969.8005125	61.08018	0.12377	7.559893
May	1400.643	27.788456	31	861.4421	976.9484925	115.5064	0.12377	14.29622

June	1292.578	26.477665	30	794.3299	901.573155	107.2432	0.12377	13.27349
July	1400.643	26.334701	31	816.3757	976.9484925	160.5728	0.12377	19.87409
August	1588.358	26.333798	31	816.3477	1107.879705	291.532	0.12377	36.08291
September	1669.871	27.509353	30	825.2806	1164.735023	339.4544	0.12377	42.01427
October	1819.381	29.307713	31	908.5391	1269.018248	360.4792	0.12377	44.61651
November	1725.767	32.802909	30	984.0873	1203.722483	219.6352	0.12377	27.18425
December	1559.478	34.753249	31	1077.351	1087.735905	10.38517	0.12377	1.285373
REMARKS/ REFERENCE	Data from SolarQuotes	Data from Ergon Energy to share	English Calendar days in months	=energy consumption per day × Days	= production × 0.93× 0.75, 0.93= solar panel efficiency	=production with efficiency - total consumption	Data from qld solar tarrif	Total yearly income 212.3131
					0.75 = system's efficency			
Feed in Tarrif	12.377 cents per kilowatt hour.		Ergon Energy	Solar feed-in tariff changes | Ergon Energy				

Appendix 3: MAXIMUM FUNDING

Given Saibai's limited internal funds, the project will rely on external funding, but likely a combination:

- **Torres Strait Regional Authority / TSIRC:** TSIRC provides community grants for boosting the opportunities for social, cultural, athletic, recreational, and economic development with grantus up to 2500 per individual or 10000 per community organization which is capped at 420,000. Furthermore, TSIRC has prioritized fundings for renewable and clean energy. However, a quantifiable value is not mentioned. TSRA's Climate Change Strategy often supports renewable projects (TSRA 2012 plan suggested solar installations on islands; by 2021 TSRA might have dedicated transition funds).

- **Queensland Government Grants:** Saibai qualifies for "Isolated Communities Energy Fund" as it is off- grid. Also, since the project reduces carbon emissions, synergy with QLD Climate Action grants is possible. However there is no proper information about the metric for any of these grants. Queensland Government had funded TSIRC for Saibai Island's Fuel Infrastructure Upgrade through Building our Regions Project, which had total project cost 1.006 million and was given 826,900. So, in a similar fashion, we estimated the funding of ~800k.

- **Federal Grants:** The Australian Renewable Energy Agency (ARENA) funds innovative off-grid solutions. They funded Flinders Island Hybrid Energy Hub 5.5 million in which the total project cost was about 13.38 million (Flinders Island Hybrid Energy Hub - Australian Renewable Energy Agency (ARENA)),
  Lord Howe (4.5million for which 11.85m was the total cost). Since our model has half the battery capacity and slightly lesser PV cell capacity, we estimated the funds to be 2.1 million
  The *Regional Australia's Renewables (RAR) Community and Regional Renewable Energy (CARRE) Program* guidelines indicate that the initiative has **up to $400 million** allocated for financial assistance to the I–RAR and CARRE programs. Microsoft Word -

CARRE_Guidelines.docx
A hybrid with a community engagement twist might attract ARENA pilot funding. There's also an *Indigenous Advancement Strategy* that supports infrastructure in indigenous communities – energy might qualify if tied to outcomes (economic, education).

- **Private Sponsors:** Possibly corporations interested in reconciliation or renewable demonstration might chip in (e.g., a mining or energy company sponsoring part of it to show corporate social responsibility). Or philanthropic: for example, the *Aboriginal Benefits Foundation* or *Ian Potter Foundation* 100,000 Environment | The Ian Potter Foundation sometimes fund community infrastructure.

Appendix 4: Lord Howe Design Model

The hybrid energy system utilises a 1.2 mWP solar photovoltaic (PV) array, (Lord Howe Island Hybrid Renewable Energy System, n.d.), with a 3.2 mWh battery storage (allows energy access during peak times) and existing diesel generators (which become a supplementary energy source when battery charge reaches 5% as depicted by Figure 4.1. (Lord Howe Island Renewable Energy Project System Design Report, 2021). The hybrid system although almost fully self-sufficient is controlled by the Battery Energy Storage System (BESS) which in the incident of communication loss initiates the Tesla Micro Grid Controller (MGC) to vary system output (PV plant and diesel generators) via pre-loaded power frequency drop settings. (Lord Howe Island Renewable Energy Project System Design Report, 2021). Overall, islands of a similar geographical context to Lord Howe (ie. Saibai) by implementing this system can reduce diesel reliance by at least 67%. (*Lord Howe Island Renewable Energy Project System Design Report*, 2021).

Automatic Mode / Control Hierarchy		PV Plant	BESS	Diesel Generators
Sufficient Solar Radiation Present	Status	On	On/Grid Forming	Off
	Function	Servicing Island Load Charging BESS	Charging Ancillary Services	Stand-by
Sufficient Solar Radiation Present BESS Charged (95%)	Status	On/Curtailed	On/Grid Forming	Off
	Function	Servicing Island Load (Load following)	Ancillary Services	Stand-by
Insufficient Solar Radiation BESS SOE (95%-5%)	Status	Off	On/Grid Forming	Off
	Function	Stand-by	Servicing Island Load Ancillary Services	Stand-by
Insufficient Solar Radiation BESS SOE (5%)	Status	Off	On/Grid Forming	On
	Function	Stand-by	Ancillary Services	Servicing Island Load

Figure 4.1: (Lord Howe Island Renewable Energy Project System Design Report, 2021)

Appendix 5: Project Scope

The scope of this report encompasses:

- Assessment of Current Energy Infrastructure: Evaluating the existing diesel-based energy system, its costs, and environmental impact.
- Feasibility Study of Solar PV Integration: Analysing solar irradiance data, potential energy yields, and system design tailored to Saibai's conditions.
- Evaluation of Piezoelectric Technology: Investigating the practicality and potential energy
- contributions of piezoelectric flooring in community spaces.
- Economic Analysis: Estimating capital and operational expenditures, potential savings, and return on investment for the proposed hybrid system.
- Environmental Impact Assessment: Comparing greenhouse gas emissions between the current diesel system and the proposed hybrid solution.
- Community Engagement Strategy: Ensuring that the proposed solutions align with the cultural values and needs of the Saibai community.

Appendix 6: Piezoelectric Prototype.

1. Piezoelectric Floor Tile Testing Data:

Test No.	Weight Applied (kg)	Voltage Spike (V)	Sustained Voltage (V)	Load Resistance (Ω)	Power Output (W)	Duration of LED Illumination (seconds)	Output Power per Step (J)
1	70	30	5	100	0.5	1	2
2	70	32	6	100	0.6	1.5	3
3	70	30	10	100	1.0	2	4
4	70	28	8	100	0.8	1.8	3.5
5	75	35	12	100	1.2	2.5	4.5

2. Combined Tile Testing Data:

Configuration	No. of People	Steps per Minute	Total Voltage (V)	Power Output (W)	LED Strip Length (m)	Illumination Quality	Fan Run Time (seconds)
Single Tile	1	120	10	2	1	Dim	5
Two Tiles	2	120	20	4	2	Bright	10
Two Tiles	4	240	25	8	3	Very Bright	15
Two Tiles	10	300	40	20	4	Extremely Bright	30

3. Solar Panel Prototype Data:

Test No.	Solar Irradiance ($kWh/m^2/day$)	Panel Size (cm^2)	Output Voltage (V)	Output Power (W)	Battery Charge Time (hours)	LED Run Time (hours)
1	5.81	100	6	0.5	10	1
2	5.81	150	9	1.0	5	2
3	5.81	200	12	1.5	3.5	3

4. Simulated Generator Control Logic Testing:

Test No.	Battery SOC (%)	Load Power Demand (W)	Generator Status	Output Voltage (V)	Generator Run Time (minutes)
1	80	50	Off	12	0
2	40	75	On	12	30
3	20	100	On	14	60
4	95	30	Off	12	0

Appendix 7: Tinkercad Prototype.

https://www.tinkercad.com/things/1TiQPmiXWNR-frantic-migelo/editel?returnTo=https%3A%2F%2Fwww.tinkercad.com%2Fdashboard

```
int socPin = A0; // SOC input from potentiometer
int motorPin1 = 9; // L293D Input 1
int motorPin2 = 10; // L293D Input 2
int solarPin = A1; // Solar panel brightness (simulated by potentiometer)
int ledPin = 13; // LED to simulate generator status
int enA = 8;

void setup() {
  pinMode(motorPin1, OUTPUT);
  pinMode(motorPin2, OUTPUT);
  pinMode(ledPin, OUTPUT);
  pinMode(solarPin, INPUT);
  pinMode(enA, OUTPUT);

  digitalWrite(motorPin1, LOW);
  digitalWrite(motorPin2, LOW);
  // Start serial communication to print the solar output
  Serial.begin(9600);
}

void loop() {
  int socValue = analogRead(socPin); // Read battery SOC from potentiometer
  int solarBrightness = analogRead(solarPin); // Read solar panel brightness
  float correctedSolar = 0.0;
  if (solarBrightness <=884){
    correctedSolar = (solarBrightness/884.0)*25.0;
  }
  else if (solarBrightness <=963){
    correctedSolar = 25.0 + ((solarBrightness-884.0)/(963-884.0))*25.0;
  }
  else if (solarBrightness <=998){
    correctedSolar = 50.0 +((solarBrightness-963.0)/(998.0-963.0))*25.0;
  }
  else if (solarBrightness <=1023){
    correctedSolar = 75.0 +((solarBrightness-998)/(1023-998.0))*25.0;
  }
  // Map SOC to percentage (0-100)
  int socPercent = map(socValue, 0, 1023, 0, 100);
  float solarPower = map(solarBrightness, 0, 1023, 0, 100);
  // Simulate lower SOC when solar brightness is low (nighttime)
  if (correctedSolar < 30) {
    socPercent -= 10; // Discharge battery faster at night
  }
  if (socPercent < 0){
    socPercent = 0;
  }
  // Calculate solar power produced (simulating in watts)
  // Map solar brightness (0-1023) to a range of solar power (e.g., 0-100W)


  // Print the solar power produced to the Serial Monitor
  Serial.print("Solar Power Produced: ");
```

```
  Serial.print(correctedSolar);
  Serial.print(" W");
  Serial.print("\n");
  Serial.print("Battery Percentage: ");
  Serial.print(socPercent);
  Serial.print("%");
   Serial.print("\n");

  // Turn on motor (generator) if SOC is low
  if (socPercent < 30) {
    analogWrite(enA, 255);
    digitalWrite(motorPin1, HIGH); // Turn motor on (diesel generator)
    digitalWrite(motorPin2, LOW); // Motor direction
    digitalWrite(ledPin, HIGH); // LED ON (generator running)
  } else {
    digitalWrite(motorPin1, LOW); // Turn motor off
    digitalWrite(motorPin2, LOW); // Motor OFF
    digitalWrite(ledPin, LOW); // LED OFF (generator off)
  }

  delay(1000); // Delay to stabilize readings
}
```

Appendix 8: ESP 8266 Code and Results

```
#include <Wire.h>
#include <Adafruit_GFX.h>
#include <Adafruit_SSD1306.h>

// OLED display settings
#define SCREEN_WIDTH 128
#define SCREEN_HEIGHT 64
#define OLED_RESET    -1
Adafruit_SSD1306 display(SCREEN_WIDTH, SCREEN_HEIGHT, &Wire, OLED_RESET);

// Pin definitions
#define CLK 2
#define DT 5
#define SW 4
#define LDR_PIN A0

int lastCLKState;
int currentCLKState;
int soc = 50;  // Start at 50%
bool dieselOn = false;

unsigned long lastPrintTime = 0;
unsigned long lastDischargeTime = 0;
const unsigned long dischargeInterval = 3000;  // Simulate discharge every 3s

// Custom I2C pins (for ESP8266)
#define SDA_PIN 0
#define SCL_PIN 14

void setup() {
  pinMode(CLK, INPUT);
  pinMode(DT, INPUT);
  pinMode(SW, INPUT_PULLUP);
  Serial.begin(9600);

  Wire.begin(SDA_PIN, SCL_PIN);

  lastCLKState = digitalRead(CLK);
  if (!display.begin(SSD1306_SWITCHCAPVCC, 0x3C)) {
    Serial.println(F("SSD1306 allocation failed"));
    while (true);
  }

  display.clearDisplay();
  display.setTextSize(1);
  display.setTextColor(SSD1306_WHITE);
  display.setCursor(0, 0);
  display.println("Initializing...");
  display.display();
  delay(1000);
}

void loop() {
  currentCLKState = digitalRead(CLK);

  // Detect rotary encoder rotation
  if (currentCLKState != lastCLKState && currentCLKState == LOW) {
    if (digitalRead(DT) != currentCLKState) {
      soc += 1;  // Turned clockwise
    } else {
      soc -= 1;  // Turned counter-clockwise
    }

    if (soc > 100) soc = 100;
    if (soc < 0) soc = 0;
  }

  lastCLKState = currentCLKState;
```

```

  // Reset with push button
  if (digitalRead(SW) == LOW) {
    soc = 50;
    delay(200);  // Debounce
  }

  // Simulate battery discharge
  if (millis() - lastDischargeTime >= dischargeInterval) {
    soc--;
    if (soc < 0) soc = 0;
    lastDischargeTime = millis();
  }

  // Diesel hysteresis logic
  if (soc < 25) {
    dieselOn = true;
  } else if (soc >= 40) {
    dieselOn = false;
  }

  // Display every 500ms
  if (millis() - lastPrintTime >= 500) {
    int lightVal = analogRead(LDR_PIN);
    float watts = (1023 - lightVal) / 10.23;

    Serial.print("Light Power: ");
    Serial.print(watts);
    Serial.print("W\t");

    Serial.print("Battery SoC: ");
    Serial.print(soc);
    Serial.print("%\t");

    Serial.print("Diesel: ");
    Serial.println(dieselOn ? "ON" : "OFF");

    display.clearDisplay();

    display.setTextSize(2);
    display.setCursor(0, 0);
    display.println("Team 100");

    display.setTextSize(1);
    display.setCursor(0, 20);
    display.print("Solar Power: ");
    display.print(watts, 1);
    display.println(" W");

    display.print("Battery SoC: ");
    display.print(soc);
    display.println(" %");

    display.print("Status: ");
    display.println(dieselOn ? "Diesel ON" : "Solar Only");

    display.display();
    lastPrintTime = millis();
  }
}
```

Appendix 9: Detailed Calculations for the environemtnal benefits.

Month	Energy Consumption per day/kWh	Days	Total Consumption kWh	Total diesel/l consumed	Total CO2 produced before/kg	Total CO2 produced after/ kg
January	29.511748	31	95145.88	38058.35	102757.5	5998.677
February	29.798333	28	86772.75	34709.098	93714.57	5470.775
March	30.133621	31	97150.79	38860.318	104922.9	6125.082
April	30.290678	30	94506.92	37802.766	102067.5	5958.393
May	27.788456	31	89589.98	35835.993	96757.18	5648.394
June	26.477665	30	82610.31	33044.126	89219.14	5208.346
July	26.334701	31	84903.08	33961.23	91695.32	5352.898
August	26.333798	31	84900.16	33960.066	91692.18	5352.714
September	27.509353	30	85829.18	34331.673	92695.52	5411.286
October	29.307713	31	94488.07	37795.227	102047.1	5957.204
November	32.802909	30	102345.1	40938.03	110532.7	6452.566
December	34.753249	31	112044.5	44817.79	121008	7064.086
Total	351.0422	365	1110287	444114.67	1199110	70000.42

Appendix

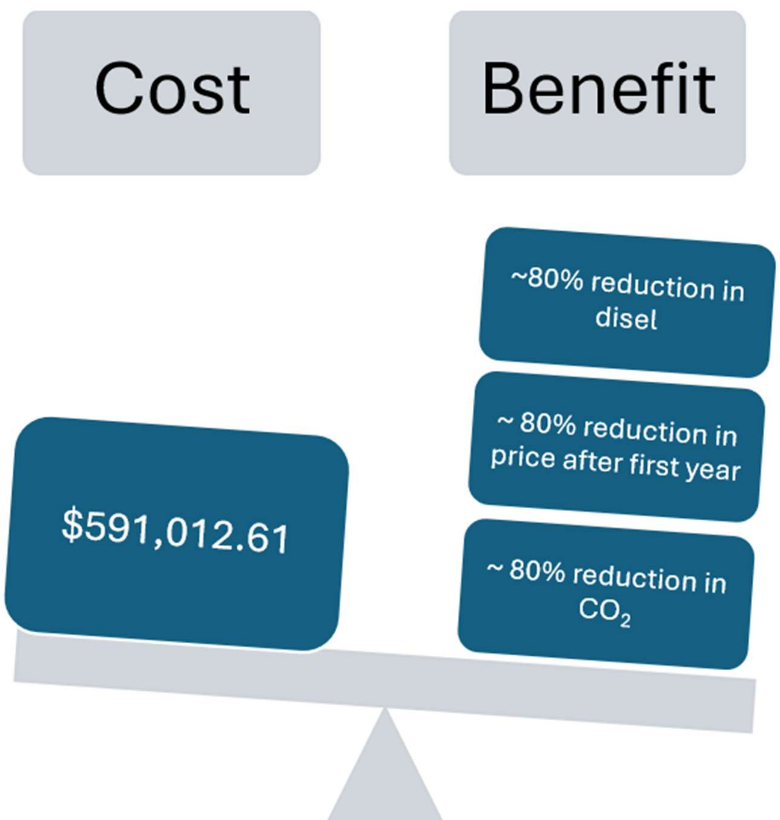

Figure 9.6