ENERGY TRANSITION IN PACIFIC ISLAND COUNTRIES

Major Project Thesis

Submitted by

SRINANDA MONDAL

For the partial fulfillment of the

Degree of Master of Science in

ENVIRONMENTAL STUDIES AND RESOURCE MANAGEMENT

Submitted to

Department of Natural and Applied Sciences

TERI School of Advanced Studies

June 2025

ACKNOWLEDGEMENT

I would like to express my heartfelt gratitude to Dr. Indradip Mitra for his continuous encouragement and unwavering support throughout my internship, which greatly contributed to my ability to work and learn effectively at the esteemed organization IT Power Private Limited.

I am also obliged to Dr. Amit Singh, Dr. Adil Masood, and Dr. Ranjana Ray Chaudhuri for their incessant support and guidance throughout my internship. Also, I want to extend my appreciation to TERI School of Advanced Studies for providing the platform which gave an opportunity for practical work exposure with IT Power Private Limited. This has been an experience enriching both to my academic and professional journey and I am truly grateful for the learning opportunities and personal growth it has brought me.

Srinanda Mondal

SRINANDA MONDAL

Date:16/06/25

DECLARATION

This is to certify that the work that forms the basis of this project “ENERGY TRANSITION IN PACIFIC ISLAND COUNTRIES” is an original work carried out by me and has not been submitted anywhere else for the award of any degree.

I certify that all sources of information and data are fully acknowledged in the project thesis.

Srinanda Mondal

SRINANDA MONDAL

Date:16/06/25

TABLE OF CONTENT

List of Abbreviations

Abbreviation	Full Form
PICs	Pacific Island Countries
SIDS	Small Island Developing States
NDC	Nationally Determined Contribution
RE	Renewable Energy
GHG	Greenhouse Gas
PV	Photovoltaic
BESS	Battery Energy Storage System
IPP	Independent Power Producer
PPA	Power Purchase Agreement
EFL	Energy Fiji Limited
DoE	Department of Energy
LEDS	Low Emission Development Strategy
EIA	Environmental Impact Assessment
GDP	Gross Domestic Product
kWh	kilowatt-hour
MW	Megawatt
kW	Kilowatt
ADB	Asian Development Bank
GCF	Green Climate Fund
UNDP	United Nations Development Programme
IFC	International Finance Corporation
FiT	Feed-in Tariff
SEIAPI	Sustainable Energy Industry Association of the Pacific Islands
IRENA	International Renewable Energy Agency
IEA	International Energy Agency

List of Tables

List of Figures

Abstract:

Pacific Island Countries (PICs), geographically small, span large oceanic areas and are extremely energy- and climate-exposed. Relying on over 80–90% of fossil fuels that are being imported for more than their energy needs, electricity tariff prices in the region are among the highest globally—$0.30 to $0.60/kWh. Concurrently, rural electrification is weak, and a majority of the islands are extremely climate-exposed to risks such as sea-level rise, cyclones, and saltwater intrusion. In this research, the status and the future of the energy transition in ten PICs—Tuvalu, Marshall Islands, Kiribati, Fiji, Samoa, Tonga, Vanuatu, Solomon Islands and Papua New Guinea—are examined by combining quantitative indicators with qualitative policy analysis. Ranking the countries on the most influential transition drivers using Fuzzy TOPSIS, Fiji ranks first with high grid penetration of renewables and institutional readiness followed by Samoa and Tonga. Ranked at the bottom are microstates like Kiribati and Tuvalu with financial, technical, and policy lags. The study says that although ambitious Nationally Determined Contributions (NDCs) have been made, actual renewable integration remains low. Institutional fragmentation, weak regulatory frameworks, and limited access to necessary finance are holding back progress. Climate exposure remains high, with low-lying countries at existential risk from sea-level rise, and natural disasters threatening energy assets. Fiji, Samoa, and Vanuatu have suffered high-impact weather events with GDP losses of up to 20%. Recommendations involve focused investment in decentralized renewable solutions, grid modernization, regional resource pooling, transport electrification, and use of strong climate finance and carbon market mechanisms. The study indicates that a sustainable, climate-resilient future for the power sector in PICs can only be achieved through collective action at the regional level, comprehensive policy reform, international finance, and long-term institutional building.

Key words- Pacific Islands, energy transition, renewable energy integration, energy access, climate vulnerability, sustainable energy systems, policy and regulatory frameworks.

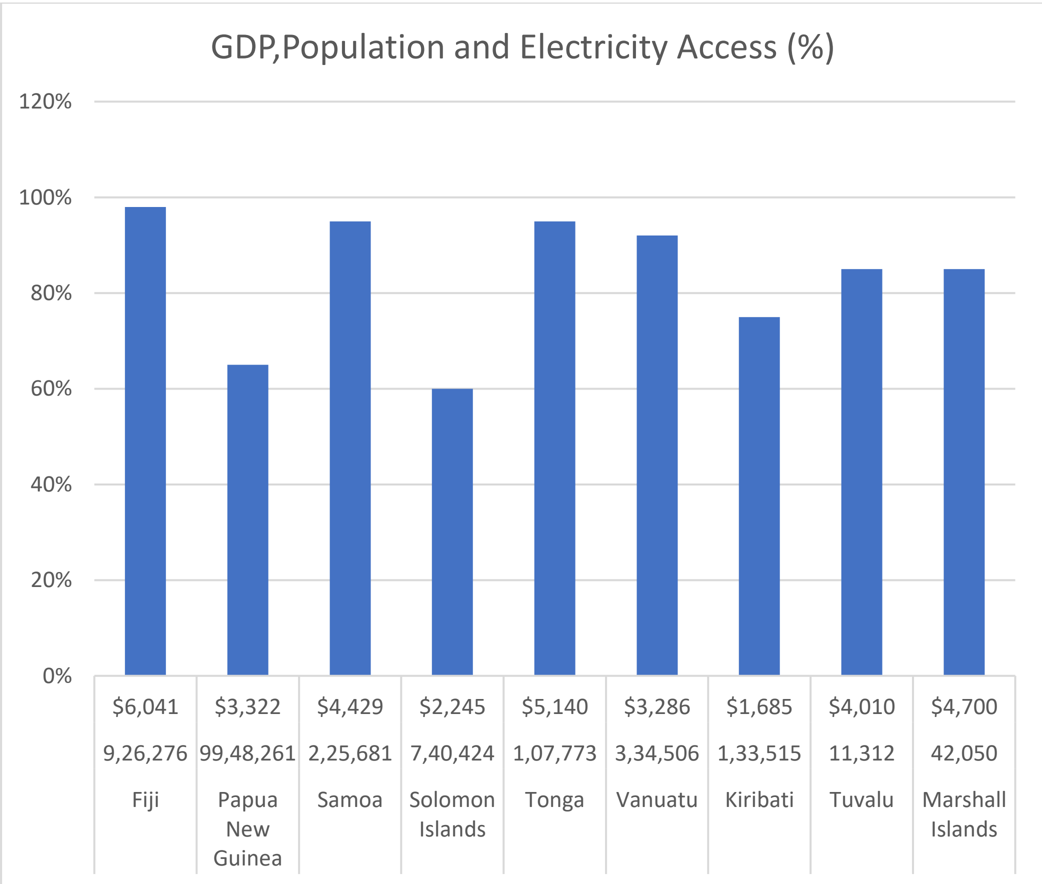
Introduction:

Pacific Island Nations (PINs) are 14 independent countries and some territories scattered across 40 million km² of the Pacific Ocean but only occupying an aggregate land area of 550,000 km². The nations range widely in size from 11,000 people in Tuvalu to 9 million people in Papua New Guinea and are dependent on imported fossil fuels, which supplies over 90% of their energy (IRENA, 2023). This fosters some of the highest electricity prices in the world, between $0.30/kWh and $0.60/kWh, over five times the global average of $0.12/kWh (World Bank, 2022). And still, rural PINs are insufficiently electrified, with some nations having rural access rates as low as below 70% (ADB, 2021). In addition, the countries are extremely vulnerable to the effects of climate change, including sea-level rise, extreme weather, and coastal erosion, substantially undermining energy security. In low-lying atolls such as Tuvalu and the Marshall Islands, as much as 80% of habitable land will be lost by 2050 (IPCC, 2021). Thus, energy transition in PINs is a critical nexus of sustainability, resilience, and survival.

1. **Geographic and Environmental Overview**: The Pacific Island Countries (PICs) are grouped into three main subregions:

- **Melanesia**: Papua New Guinea, Fiji, Solomon Islands, and Vanuatu. These are larger, mountainous islands rich in natural resources like minerals, forests, and agricultural land.
- **Micronesia**: Kiribati, Palau, Marshall Islands, Federated States of Micronesia, and Nauru. These low-lying coral atolls and small islands are extremely vulnerable to sea-level rise, with limited freshwater and land resources.
- **Polynesia**: Samoa, Tonga, Tuvalu, Niue, and Cook Islands. These islands are smaller, tourism-reliant, and highly exposed to cyclones and climate change impacts.

2. **Country analysis:**



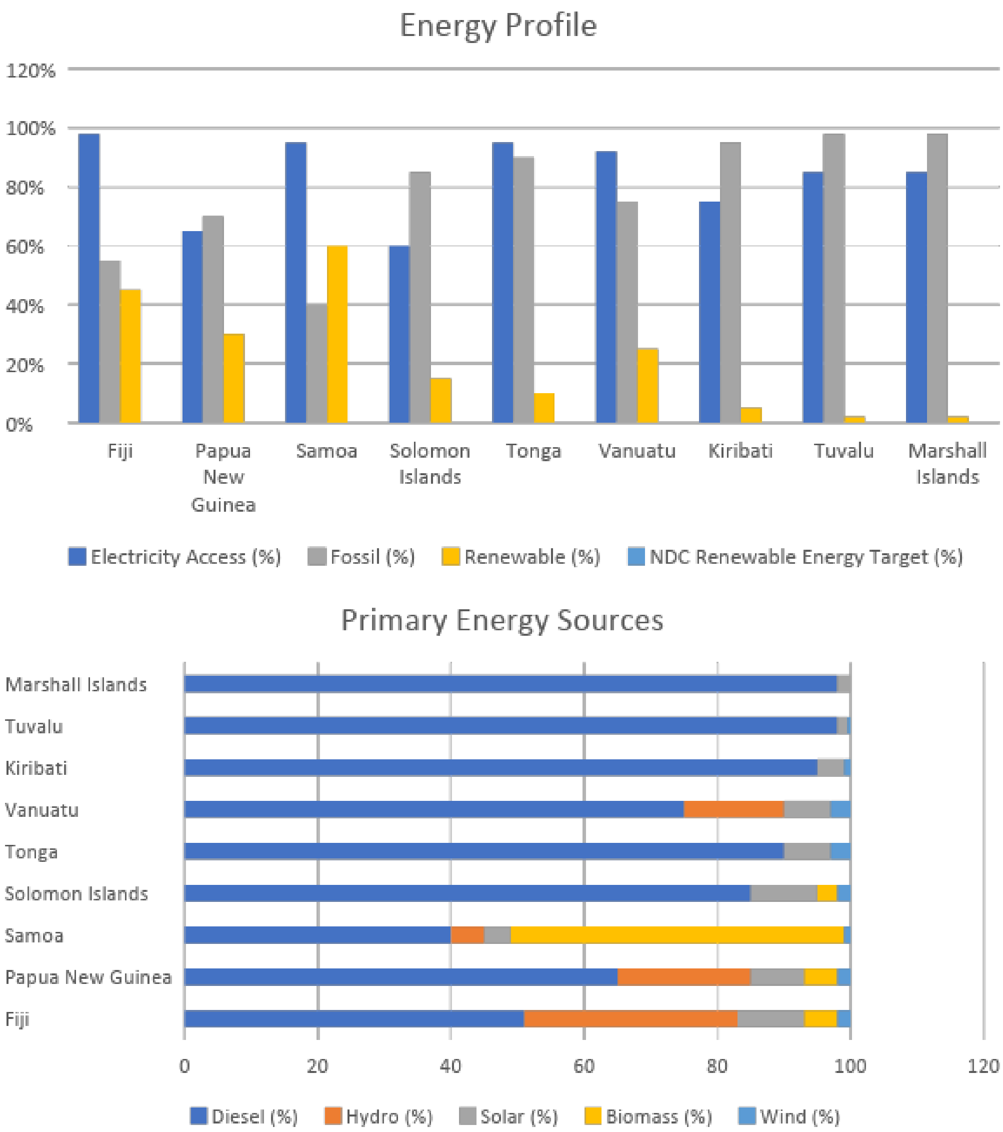


Fig 1: Country analysis

This is a comparative chart of several of the major indicators for ten Pacific Island nations. They are population (2023), GDP per capita (USD), access to electricity (%), and the share of fossil and renewable energy in their energy mix.

1. Size of Population and Economy: Blue bars in the graph denote population, with Papua New Guinea (9.95 million) far ahead of all the rest, with the next being way behind. Compared to this, Tuvalu (11,312)have the least population. This is probably because it has a well-developed tourist industry. Fiji ($6,041) and Tonga ($5,140) are also relatively well off. Kiribati, with only a GDP per capita of $1,685, is the poorest in economic output per capita.

2. **Electricity Access**: Few of the nations on the list have satisfactory electricity access, depicted in grey. Fiji (98%), Samoa (95%), Tonga (95%), Vanuatu (92%), have near universal coverage. Papua New Guinea (65%) and Solomon Islands (60%) trail far behind, a testament to the ongoing infrastructural challenge of reaching far-flung or rural locations.

3. **Energy Mix (Fossil vs Renewable):**The green and yellow bars represent the percentage shares of renewable and fossil energy, respectively. The overarching trend in the region is the consistent dominance of fossil fuels, though the efforts towards transition to renewables vary:

• Marshall Islands, Tuvalu, and Kiribati are highly fossil dependent, with renewables adding only 2% to 5% of their total energy mix.

• Vanuatu, Samoa, and Fiji are diversified with renewable percentages ranging from 25% to 60%. Samoa is unique at 60% due to renewable energy from biomass.

• Tonga and Solomon Islands, while economically smaller, are just as diesel-dependent but have established ambitious renewable transition goals.

4.**Climate Commitments and NDC Targets:** Although not marked on the graph, the supporting table does provide Nationally Determined Contributions (NDCs) information:

• Fiji aims at 100% of electricity from renewable sources by 2036 and 800 MW capacity, showing high commitment.

•Papua New Guinea, with low access rates, is aiming for 78% renewables by 2030 with 1,250 MW planned.

• Smaller nations like Tuvalu and Marshall Islands target 100% renewables by 2030 or 2050, even with minimal current penetration of renewables.

• Samoa, already at 60% renewables level, is aiming for net-zero by 2050 and is a regional leader.

3. Climate Vulnerability and Environmental Challenges

Pacific Island countries like Kiribati, Tuvalu, and the Marshall Islands are among the world's most climate-vulnerable, facing numerous environmental challenges that threaten their economic sustainability and environmental integrity. Sea-level rise is a significant threat, with the World Bank estimating that a 0.5-meter rise could cost them nearly $10 billion, equivalent to two decades of their total GDP. Tropical cyclones, such as Cyclone Lola, have caused significant damage in Vanuatu and the Solomon Islands, resulting in annual GDP losses of up to 20%. Fiji has experienced 12 cyclones since 2016, causing FJ$2.98 billion in damages. Environmental degradation and resource scarcity are also contributing to these issues. Saltwater intrusion in Tuvalu has contaminated freshwater aquifers, leading to declining food production and increased reliance on imported products.

Coral bleaching from ocean warming is causing marine ecosystems and fisheries to die.

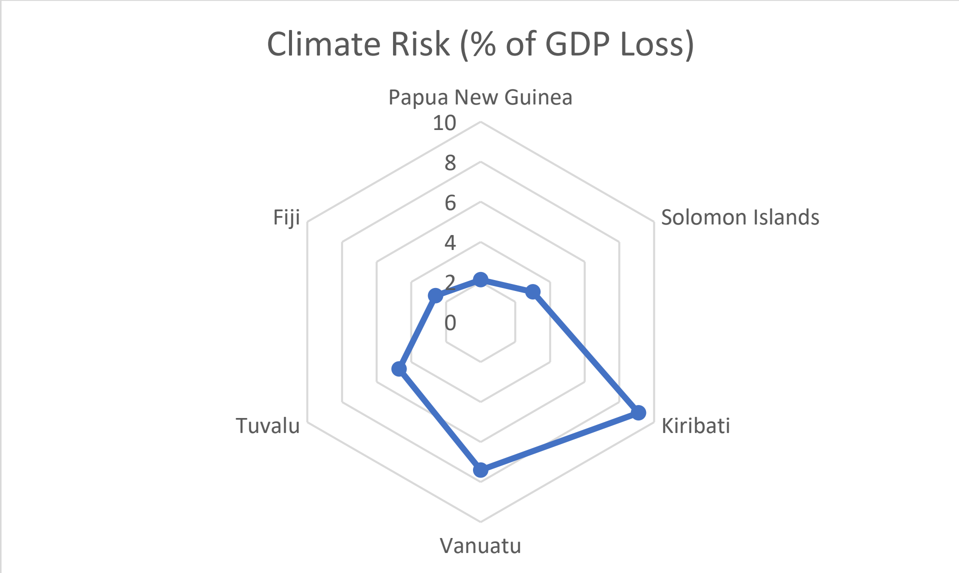


Fig 2: Climate risk (% of GDP Loss)

The Pacific Island Countries (PICs) are facing significant climate change impacts due to their over-reliance on imported fossil fuels, which account for 80-90% of energy consumption. This has exposed them to global oil price uncertainty and undermined their economic and environmental resilience. Despite efforts to initiate energy transitions, they face systemic issues like weak technical capacity, data systems, and inadequate human resources. This study aims to assess current energy landscapes, identify key transition indicators, existing policy and framework analysis, evaluate carbon credit potential and resilience strategies for climate risks and disaster risk reduction and provides necessary recommendations for a just, inclusive, and climate-resilient transition in the Pacific.

Literature review:

Pacific Island Countries (PICs) – small, sometimes remote island nations like Papua New Guinea (PNG), Fiji, Samoa, the Marshall Islands, Tuvalu, and others – have unique energy challenges. Most PICs use primarily imported fossil fuels (oil and diesel), which account for approximately 80% of the UNESCAP (2023) region's total energy supply excluding Australia/New Zealand (UNESCAP, 2023). For example, fuel imports typically account for 5–15% of GDP in every PIC (UNESCAP, 2023). Modern renewables (excluding traditional biomass) accounted for only around 12–17% of Pacific energy through 2017 (SPREP, 2020). In 2021, data indicated that 96–100% of the population in 10 out of 14 PICs had access to electricity (Narayan & Narayan, 2024), but most of the electricity (over 50% on average) was derived by combusting imported fuel (Narayan & Narayan, 2024). Biomass and hydropower (renewable energy sources), however, predominate in exceptional cases. Climate impacts (sea-level rise, cyclones, flooding) even threaten energy assets. The convergence of high energy poverty, climate risk, and narrow resource bases requires the Pacific's need for an energy transition to clean, resilient power systems.

Pacific Island Countries (PICs) are heavily dependent on imported petroleum, which supplies approximately 80% of the region's total energy supply, primarily for transport and electricity (UNESCAP, 2023; Narayan & Narayan, 2024). Whilst countries like PNG and Fiji utilize hydropower and Tokelau has achieved near 100% solar electricity, regional renewable penetration is low—modern renewables supplied only 12.3% of the region's final energy in 2017 (SPREP, 2020). Renewable penetration is significantly different, varying from 37% and 48% for Kiribati and PNG, respectively, and others like Tonga and Tuvalu at less than 2% (Narayan & Narayan, 2024). PICs averaged only 26% utilization of renewable energy between 2004 and 2018, showing poor progress despite widespread electrification (Narayan & Narayan, 2024).

Low Emissions Analysis Platform (LEAP) is widely utilized energy scenario planning software in Pacific Island Countries, facilitating demand-supply modelling for renewable energy transformation (Dornan & Jotzo, 2014). LEAP facilitates the analysis of optimal energy mix strategies and policy simulation impacts, which is essential in small island developing countries with constrained resources (Prasad et al., 2021; Wong et al., 2023). LEAP's ability to combine real-time data and estimate emissions allows countries like the Solomon Islands to synchronize renewable investment with electrification strategies at a controlled cost (Dornan & Jotzo, 2014).

Energy transition in PICs is assessed through four main indicators: electrification rate, renewable energy share, energy security, and decarbonization metrics (REN21, 2022; IEA, 2020).While access has improved like Fiji and Samoa exceed 90%, micro-islands like Tuvalu and Niue have achieved 100%—others like PNG still lag behind (~10–15%) (Dornan & Jotzo, 2014). However, off-grid solar and mini-grids often lack resilience and consistent service quality (Narayan & Narayan, 2024).Renewable Energy Share: Renewable integration remains uneven.

PNG leads with ~61% (mainly hydro/biomass), while Fiji and Samoa average ~44% and Kiribati ~32% (Narayan & Narayan, 2024). Countries like Tuvalu and Tonga remain near-zero. Though ambitious targets (e.g. 100% by 2030) exist under the 2012 Barbados Declaration, actual progress varies due to infrastructural and policy limitations (IRENA, 2021).Energy Security: PICs face high energy insecurity, with over 60% of energy imported in most cases and significant cost volatility (UNESCAP, 2023). Local generation (e.g. solar/diesel hybrids, biomass) can improve resilience, though no standardized security index exists (Narayan & Narayan, 2024). Decarbonization Metrics: PICs have set NDCs and net-zero targets (e.g. Fiji by 2050), but progress is uneven. Common indicators include emissions trends, CO_2/kWh, and diesel displacement. Qualitative indicators such as EV adoption and green fuels in transport also reflect transition progress (UNESCAP, 2023).Socio-economic aspects like community involvement are equally important in driving sustainable outcomes (Maleko & Kumar, 2022). Despite high aspirations, funding, policy coherence, and technical capacity remain persistent barriers (World Bank, 2021; IRENA, 2021).

Pacific Island Countries (PICs) have shown clear political will for renewable energy at the regional and country levels. The 2012 Barbados Declaration was a turning point when the governments of Tuvalu, Niue, and Cook Islands pledged 100% renewable electricity by 2020, and others like Fiji, Vanuatu, and Solomon Islands by 2030 (UNESCAP, 2023). Some countries, like Tokelau, had already almost-100% renewable electricity from an early period, and others have developed national legislative tools—Fiji's Low Emission Development Strategy is for net-zero by 2050, Samoa passed a renewable energy act in 2017, and Tonga has an energy roadmap (UNESCAP, 2023). Policy measures like feed-in tariffs (FiTs) and net metering are prevalent across the region to promote solar and hydro uptake. Regional-scale policies like the Pacific Islands Framework for Action on Energy Security and Low Carbon Development (2010) and institutions like PCREEE promote regional clean energy aspirations (PCREEE, 2017). However, extensive heterogeneity in progress dominates due to institutional and regulatory inefficiencies—most notably, defining clear IPP frameworks and transparent FiT arrangements, which persist as private investment impediments (PIFS, 2020; ADB, 2019). But success stories like the Cook Islands—where open renewable energy legislation encouraged solar adoption—demonstrate what can be achieved through targeted reforms (World Bank, 2019). Comparative learning from advanced Small Island Developing States (SIDS) like Singapore and Mauritius demonstrates the public-private partnership (PPP) imperative to speed up renewable deployment (IEA, 2019).

Several developed Small Island Developing States (SIDS) offer critical insights for Pacific Island Nations (PICs) in advancing their energy transitions. Hawaii has adopted a legally binding 100% renewable energy target by 2045, backed by strong policy frameworks (US DOE, 2020). Denmark's Faroe Islands utilize a diversified mix of wind and hydropower to reduce fossil fuel reliance (REN21, 2021), while Crete in Greece has integrated smart grids and energy storage to stabilize intermittent renewable generation (IEA, 2022). According to Blechinger et al. (2016), PICs can adopt similar pathways by investing in grid stability, storage solutions, and financial mechanisms. Common strategies across these SIDS include setting ambitious renewable targets, implementing diverse technology mixes, advancing grid and storage innovations, and establishing supportive policy and investment environments.

Pacific Island Countries (PICs) are leveraging carbon finance to finance clean energy transitions, accessing rich terrestrial and blue carbon sinks (WWF, 2023; UNFCCC, 2021). High sequestration potential is constrained by voluntary carbon market access through high transaction costs, unclear land and carbon rights, and technical bottlenecks (World Bank, 2021; ADB, 2020). Registries have only accredited 12 voluntary carbon projects to 2023, with PNG having the highest number of credits. PICs, however, are highly vulnerable to energy infrastructure risks from climate disasters like cyclones and sea-level rise (UNFCCC, 2024). Resilience interventions include decentralized solar, hybrid systems, and climate-proof infrastructure under the FRDP framework (SPREP, 2020).

Objectives:

1. **Energy Landscape Analysis** – Assessing the current energy mix, consumption patterns, and resource availability, supply-demand trends, and challenges using LEAP software.
2. **Defining Key Indicators and Measuring Progress of Energy Transition** – Evaluate key indicators such as electrification rate, renewable energy share, energy security, and decarbonization metrics.

3. **Policy and Framework Analysis** – Evaluating existing policies, incentives, and regulatory frameworks supporting energy transition.
4. **Case Study of Small Island Nations** – Analyse successful renewable energy transitions in developed SIDS (e.g., Greece, Denmark, Hawaii) and explore how PICs can implement similar strategies, including decarbonization in hard-to-abate sectors.
5. **Carbon Credit Generation and policy recommendations** – Assess the feasibility of carbon trading, carbon sequestration, and financial mechanisms, and provide policy recommendations to enhance the effectiveness of renewable energy projects.
6. **Climate Vulnerability and Risk Assessment** – Identify the risks posed by climate change to energy infrastructure and develop strategies for resilience and disaster risk reduction.

Materials and Methodology

1. **Study area**: Tuvalu, Papua New Guinea (PNG), Marshall Islands, Samoa, Fiji
2. **Data Sources:**
   - **Primary Data**: Confidential reports of various countries.
   - **Secondary Data**: Government reports, international energy databases including ADB, ISA, world bank, REN 21, IRENA, IEA, UNDP, UNFCCC, academic journals, and policy documents.
3. **Software & Tools**:

   LEAP for energy modelling: LEAP (Long-range Energy Alternatives Planning System) is an integrated modeling software developed by the Stockholm Environment Institute. It is widely used for national and regional energy planning, emissions analysis, and climate mitigation scenario development.
4. **Methodology:**

- Develop LEAP-based energy models for selected PICs to analyze current energy mix, consumption, and future demand-supply scenarios.
- Track and evaluate key energy transition indicators such as electrification rate, renewable energy share, energy security, and GHG emissions over time using Fuzzy TOPSIS to prioritize and rank country-level performance under uncertainty.

- Conduct a literature review and gap analysis of national energy policies and regulatory frameworks to assess their effectiveness in supporting renewable energy adoption and long-term energy transition goals.
- Compare successful energy transition strategies in SIDS like Hawaii, Denmark, and Greece to identify replicable practices for PICs.
- Estimate GHG reductions and carbon credit potential to propose financing models and policy support for clean energy projects.
- Identify climate-induced risks to energy infrastructure and recommend resilience strategies and disaster risk reduction policies to safeguard energy systems.

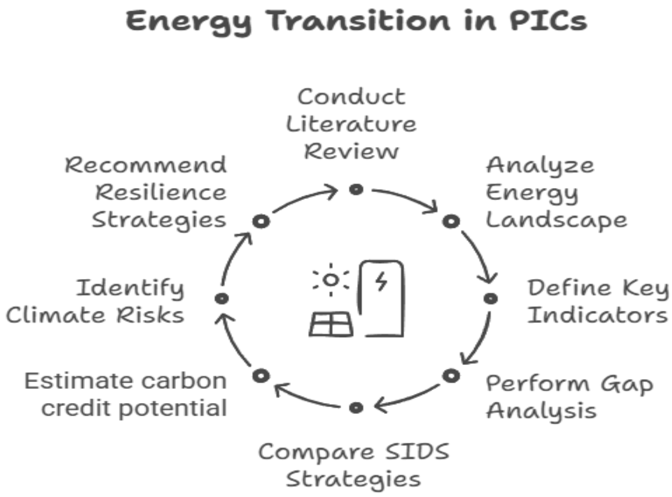


Fig3-Methodology

Results and discussion:

Objective1: Energy landscape:

A.Tuvalu's Energy Landscape

Introduction

Tuvalu is a small Pacific Island nation consisting of nine atolls and a population estimated at 11,733 (CIA, 2024). With an infinitesimal land area (≈26 km²), Tuvalu is blessed with out-of-proportion climate exposure and energy security concerns. Historically, almost all of Tuvalu's energy has been supplied by imported diesel fuel, which represented approximately 96 percent of total energy supply in 2021 (Oberender, 2024). Consequently, Tuvalu has set extremely ambitious targets: 100 percent renewable electricity by 2025 (under the Majuro Declaration and National Energy Policy), near-zero power-sector greenhouse gas emissions by 2030, and a zero-carbon development trajectory by 2050 (Pacific NDC Pacific Hub, 2022; SPC, 2022). With average solar irradiance of about 5–6 kWh/m²/day (Pacific Climate Change Portal, 2024), Tuvalu has immense solar PV potential, which is being rapidly developed through utility-scale and rooftop installations.

Tuvalu's Energy Consumption and Trends:

Tuvalu's installed generation capacity in 2023 was 2.54 MW, with 71% diesel and 29% solar PV. Funafuti and outer islands have 750 kVA diesel sets and 735 kW solar PV systems. Diesel still provided 84% of electricity in 2021, while solar contributed 16%. Solar PV in Funafuti increased from 2% to 16% between 2019 and 2023, and the outer islands recorded 70-90% solar penetration. In 2019, the Asian Development Bank approved a US$6 million grant to increase renewable energy share.

Table 1: Tuvalu's Energy Consumption and Trends

Energy Source	Current Status and Installed Capacity	Key Policies and Regulatory Frameworks
Diesel (HFO)	• 1.80 MW capacity in Funafuti (three 750 kVA units) 71 % of total capacity, • Outer islands: eight diesel units (48–80 kW each; average 176 kW/island) (holding 2023). • Diesel fuel accounts for 84 % of generation (2021) (EBSCO, 2024).	• Majuro Declaration (2013): reduce diesel share, achieve near-zero power emissions by 2030 (Pacific NDC Pacific Hub, 2022). • Fakafoou – Tuvalu National Energy Policy (2009). • Diesel subsidy from Japan NPGA (till 2020; now ending) (SPSC, 2023).
Solar PV (Grid-Connected & Off-Grid)	• 0.735 MW operational in Funafuti (40 kW rooftop initial in 2009, expanded to 170 kW by 2015, then to 735 kW by 2020) • Solar on Motufoua School (46 kW with batteries) (Vaitupu, 2009). • Growing off-grid household PV: 1,200 small systems by 2023.	• Energy Strategic Action Plan (2009): 100 % RE by 2020 (updated to 2025) (SPC, 2022). • Majuro Declaration (2013): 95 % solar target • ADB Solar Project (2019–2025): install 500 kW Funafuti, 224 kW outer islands (ADB, 2020). • National Energy Policy (2009).
Biodiesel	• Pilot usage for 5 % of demand in Funafuti (planned under Majuro Declaration). • Limited actual operational data; trials in 2015–2016.	• Majuro Declaration (2013): biodiesel to meet 5 % of demand. • Biofuel pilot projects (NDC, 2015).
Wind (Feasibility)	• No commercial wind turbines installed (2023). • Feasibility study (2018) with Chinese partner; yet to materialize.	• Majuro Declaration (2013) mandates feasibility assessment (SPSC, 2023).
Battery Storage	• Battery Energy Storage System (BESS) in Funafuti: 2 × 20-ft containers supporting 500 kW PV	• ADB Solar Project (2019–2025): includes BESS in Funafuti (ADB, 2020).

	(commissioned 2021) (ADB, 2020). • Enables higher solar penetration, stabilizes microgrid.	

Energy Access in Tuvalu: Tuvalu achieved nearly 100% national electrification by 2022, utilizing off-grid solar deployment in a high-density island environment. Despite energy reliability issues due to climatic conditions and low generation capacity, Tuvalu has a total installed capacity of 2.54 MW, with fossil fuels accounting for 84% of electricity.

Tuvalu's Nationally Determined Contribution (NDC) Targets in the Energy Sector:

Tuvalu submitted its **First NDC** in 2015 and an **Updated NDC** in November 2022, focusing on energy-sector mitigation. Key conditional targets (dependent on external financing/technology) include:

Table 2. Tuvalu's NDC Targets (2022 Update)

Sector	NDC Target (2022)	Current Status (2023)
Power Generation	• 100 % reduction in GHG emissions (electricity) by 2030 (Pacific NDC Pacific Hub, 2022). • Deploy 100 % renewable electricity by 2025 (Pacific Climate Change Portal, 2024).	• ~50 % of Funafuti's daytime electricity from PV in 2021; aiming for 75 % by 2023 and 100 % by 2025 (Pacific Climate Change Portal, 2024). • ADB project (2019–25) to raise renewable share to 32 % of total (daylight) in Funafuti, >90 % in outer islands (ADB, 2020).
Energy Efficiency	• 30 % increase in energy efficiency (Funafuti grid) by 2030 (Pacific NDC Pacific Hub, 2022).	• IEC-standard LED streetlights installed on Funafuti (2021 pilot). • Energy audits of government buildings (2022–23).
Entire Energy Sector	• Reduce total GHG emissions from energy to 60 % below 2010 levels by 2030 (Pacific NDC Pacific Hub, 2022).	• Total GHG from energy estimated at 8 ktCO_2e in 2020 (base). Current decline to ≈5 ktCO_2e in 2022 (preliminary)—ongoing measurement (SPC, 2022).
Long-Term Vision	• Zero-carbon development pathway by 2050 (Pacific NDC Pacific Hub, 2022; SPC, 2022).	• National Zero Carbon Roadmap under development (2023).

Energy Policies and Schemes in Tuvalu

Tuvalu's strategic energy policies and programs seek to decarbonize power generation, expand renewables, and strengthen institutional capacity.

Table 3. Key Energy Policies and Schemes (2020–2030**)**

Policy/Scheme	**Target**	**Current Status (2023)**
Tuvalu National Energy Policy (TNEP) – 2009	• Achieve 100 % renewable power by 2020 (updated to 2025). • Promote energy efficiency.	• Major revisions in 2021 to extend target to 2025 (SPC, 2022). • Policy integration with NDC and National Climate Change Policy (2022).
Majuro Declaration on Climate Leadership (2013)	• Generate 95 % of power via solar PV; 5 % via biodiesel by 2020. • Assess wind feasibility.	• As of 2021: Funafuti PV≈16 % share; biodiesel pilots ongoing; wind yet to be installed (Wikipedia, 2024). • Updating midcourse to reflect 2025 target.
Tuvalu Updated NDC (2022)	• 100 % reduction in power-sector GHG by 2030. • 60 % below 2010 energy emissions by 2030. • Zero carbon by 2050.	• NDC lodged with UNFCCC, awaiting external financing for full implementation (Pacific NDC Pacific Hub, 2022).
ADB–Pacific Renewable Energy Investment Facility (PREP) Grant (2019–2025)	• Increase renewable share from 15 % to 32 % in Funafuti; 70 % to >90 % in outer islands by 2025. • Install additional 500 kW PV + BESS in Funafuti.	• Funafuti PV expanded to 735 kW (2020); BESS installed (2021). • Over 300 kW PV installed on Nukufetau, Nukulaelae, Nui, Vaitupu (2022). • ADB funds fully disbursed to TEC (2023).
National Off-Grid Electrification Strategy (2021–2030)	• Deploy 1,500 solar home systems (SHS) by 2030. • Establish 50 solar mini-grids on outer islands.	• ~1,200 SHS installed by end-2023 (SPC, 2022). • Four mini-grids operational (Vaitupu, Nukufetau, Nukulaelae, Nui) (2023).
Finance Mechanisms: Climate Funds & Concessional Loans	• Mobilize US $20 million in climate finance by 2025. • Leverage GCF, ADB, GEF resources for renewable projects.	• US $6 million ADB grant (2019–2025) secured. • Tuvalu received US $2.5 million from GCF for microgrid resilience (2022). • GEF project ($3 million) under design (2023).

B. Papua New Guinea's Energy Landscape

Introduction: Papua New Guinea (PNG) is a low-middle-income southwest Pacific nation with a population of 9.4 million, with 85% in rural areas. As of

2024, only 35% of the population had electricity access. The country has 700 MW of installed capacity, with 62% being fossil fuel, 30% hydro, and 8% renewables. The trade deficit is driven by fuel imports. The government has set ambitious climate and energy targets, including the National Energy Policy 2017-2027 and the National Electrification Rollout Plan (NEROP), aiming for 70% electricity access by 2030 using renewable energy technologies. PNG's Second Nationally Determined Contribution to the Paris Agreement commits 500 MW of renewable electricity generation capacity by 2030. Donor-financed schemes are promoting solar PV installations in rural and urban communities.

Papua New Guinea's Energy Consumption and Trends:

PNG's total electricity demand stands at ~700 MW, with an annual peak demand growth rate of 6% (PNG Power Ltd, 2024). The country's electricity generation mix includes:

Table 4. Papua New Guinea's Energy Consumption and Trends

Energy Source	Current Status & Installed Capacity	Key Policies & Regulatory Frameworks
Fossil Fuels (Diesel & HFO)	- 450 MW capacity (62% of total energy mix) (IEA, 2023) - Over 80% of rural areas rely on costly diesel generators (ADB, 2024) - Electricity cost: \$0.30/kWh, among the highest in the Pacific (World Bank, 2024)	- PNG Diesel Fuel Subsidy Reduction Plan (2024-2026) - Independent Power Producer (IPP) Policy for Renewable Transition (2023-2030)
Natural Gas (Gas-to-Power Projects)	- 120 MW installed (15% of energy mix) (ExxonMobil PNG, 2024) - PNG LNG producing 8.5 million tonnes/year (Santos, 2024) - Plans to use gas for domestic power generation	- Gas-to-Power Development Strategy (2023-2030) - Gas Sector Expansion Plan (2024-2025)
Hydropower	- 210 MW operational (30% of energy mix) (PNG Hydropower Authority, 2024) - Yonki Dam (93 MW), Ramu 2 (180 MW planned by 2030) - Potential for 2,000 MW of hydropower development	- National Hydropower Expansion Plan (2023-2035) - Public-Private Partnerships (PPP) for Hydro Projects
Solar Energy (Grid-Connected & Off-Grid)	- 75 MW operational (5% of energy mix) (World Bank, 2024) - Major projects: Port Moresby Solar (50 MW), Daru Solar Hybrid (3 MW)	- Scaling Solar Initiative (World Bank-backed, 2024-2030) - Feed-in Tariff Policy for Solar PV (Updated 2023)
Planned Solar PV (2024-2030)	- Target: 250 MW of solar by 2030 - 100 MW under development (2024-2025 tenders)	- Public-Private Partnership (PPP) Solar Program (2024-2028)
Off-Grid & Rural Solar Applications	- 30,000 solar home systems installed - 200+ mini-grids deployed in rural areas - Solar-powered	- Off-Grid Electrification Strategy (2023-2030) - UNDP & NGOs supporting solar access

	telecom stations, schools, health centers expanding	

Energy Access in Papua New Guinea:

Papua New Guinea (PNG) has one of the Pacific's lowest rates of access to electricity as of 2024, with a mere 35% of the population electrified—80% of the urban population and a mere 20% in rural areas (PNG Energy Ministry, 2023). Installed capacity is 700 MW, with 62% fossil fuel-based and 38% renewable energy-based. PNG aims to raise national access to electricity to 70% by 2030 under its National Electrification Rollout Plan (NEROP).

Papua New Guinea's NDC Targets in the Energy Sector:

This table outlines Papua New Guinea's NDC targets in the energy sector, focusing on renewable power generation and grid integration.

Table 5. Papua New Guinea's NDC Targets

Sector	NDC Target	Current Status
Power Generation	- Renewable capacity target: 500 MW by 2030 - Grid integration of 1,000 MW renewable energy	- 300 MW renewable installed (Hydro, solar, wind) - Grid expansion ongoing
Clean Cooking	- Convert 500,000 households to LPG/biofuels - 20,000 biodigesters by 2030	- 50,000 households converted - Biodigester pilot programs ongoing
Energy Efficiency	- Improve energy efficiency by 20% - Reduce peak demand by 100 MW	- Energy efficiency measures introduced in urban grids

Energy Policies and Schemes in Papua New Guinea:

This table presents key energy policies and schemes in Papua New Guinea, outlining their targets and current implementation status.

Table 6. Energy Policies and Schemes in Papua New Guinea

Policy/Scheme	Target	Current Status
National Electrification Rollout Plan (NEROP)	70% electricity access by 2030	35% achieved, grid & off-grid expansion ongoing
Scaling Solar Initiative (World Bank, ADB)	Deploy 250 MW of solar by 2030	75 MW installed, 100 MW under development
PNG Rural Electrification Program (2023-2030)	200,000 solar home systems, 500 mini-grids	30,000 SHS installed, 200 mini-grids operational
Feed-in Tariff & Net Metering Policy	Encourage private solar adoption	Policy implementation ongoing

C. Marshall Islands' Energy Landscape

Introduction:

The Republic of the Marshall Islands (RMI) faces significant challenges due to its geography and climate change vulnerability. Historically, the islands have relied heavily on imported fossil fuels, accounting for over 85% of commercial energy consumption. However, universal electricity access was achieved in 2022. The RMI aims for 100% electrification of the outer islands by 2015 and 20% by 2020, and a net-zero energy system by 2050. Global investment, including a $60 million World Bank grant and a $17 million Energy Transition Project by the Asian Development Bank, has facilitated this transition. The RMI aims to cut greenhouse gas emissions by at least 32% below 2010 levels by 2025.

Marshall Islands' Energy Consumption and Trends:

RMI's electricity demand is modest but growing, with a total installed capacity of 35 MW and a peak demand growth rate of 3–4% annually (Marshalls Energy Company, 2024). The country's energy generation profile includes:

Table 7. Marshall Islands' Energy Consumption and Trends

Energy Source	Current Status & Installed Capacity	Key Policies & Regulatory Frameworks
Fossil Fuels (Diesel)	- 28 MW installed (80% of energy mix) (IRENA, 2024) - Diesel generators power urban centers, especially Majuro & Ebeye - High cost: $0.40/kWh (ADB, 2024)	- National Energy Policy (2020–2050) - Fuel Import Reduction Strategy (2022–2030)
Solar Energy (Grid & Off-Grid)	- 5.3 MW installed (15% of energy mix) - Projects: Majuro Solar Farm (1.5 MW), Ebeye Hybrid PV (500 kW), outer island microgrids	- Renewable Energy Roadmap (2019–2050) - JICA/ADB-funded Solar PV & Battery Projects
Other Renewables (Wind, Waste-to-Energy)	- 1.7 MW (5% of mix, primarily pilot and hybrid systems) - Limited wind due to low speeds - Some waste-to-energy initiatives under study	- Energy Sector Master Plan (2023) - Green Climate Fund (GCF) Energy Projects
Planned Renewable Expansion (2024–2030)	- Target: 20 MW solar and battery storage - Outer island hybrid mini-grids in 15 atolls planned	- Climate Resilient Energy Strategy (2021–2030) - USAID & UNDP supported Solar Access Programs

Energy Access in Marshall Islands

As of 2024, Marshall Islands has 75% national electrification coverage—95% urban Majuro and Ebeye but only 45% rural atolls, where kerosene and diesel are predominantly utilized. Installed capacity is 35 MW, 80% fossil fuels and 20% renewables. The government targets 90% national electrification by 2030.

Marshall Islands' NDC Targets in the Energy Sector

RMI has submitted an updated NDC (2021) with strong focus on decarbonization, targeting **net-zero GHG emissions by 2050**. The energy sector plays a crucial role in this transition.

Table 8. Marshall Islands' NDC Targets

Sector	NDC Target	Current Status
Power Generation	- 100% renewable electricity by 2050 - Interim target: 50% by 2030	- 20% renewable share (solar & hybrid systems) - Ongoing solar-battery projects
Clean Cooking	- 100% of households using clean fuel or electric stoves by 2040	- Limited progress; pilot LPG & electric cooking projects initiated
Energy Efficiency	- Reduce energy intensity by 15% by 2030 - Improve demand-side energy efficiency	- Urban retrofits underway - Energy-efficient lighting & appliances programs launched

Energy Policies and Schemes in Marshall Islands

The Marshall Islands has adopted multiple policies to transition to a sustainable energy future with the help of development partners and international donors.

Table 9. Energy Policies and Schemes in Marshall Islands

Policy/Scheme	Target	Current Status
National Energy Policy (2020–2050)	100% renewable electricity by 2050	Under implementation; supported by international partners
Outer Island Renewable Energy Project (OIREP)	Electrify 15 atolls with solar-battery hybrid mini-grids	Phase I completed, Phase II ongoing
Solar for Schools & Health Centers Program	Provide 24/7 power to essential services	Over 40 schools & clinics solarized
Feed-in Tariff & Net Metering Regulation	Encourage private rooftop solar installations	Policy framework approved in 2023; implementation in pilot stage
Green Climate Fund (GCF) Renewable Projects	Mobilize $50M for resilience & renewables	2 projects approved; implementation with UNDP and SPREP

D. Samoa's Energy Landscape

Introduction:

Samoa, a South Pacific Island nation with 222,000 inhabitants, faces challenges in energy security, infrastructure, and climate exposure due to its remoteness and weather-related hazards. Historically dependent on imported fossil fuels, Samoa is economically disadvantaged by oil price volatility. Despite this, the nation has made significant progress in renewable energy utilization, with 99% household electrification coverage. The Low Emissions Development Strategy aims for 70% renewable energy in all sectors by the end of the decade. However, Samoa faces constraints such as old infrastructure, high capital costs, limited technical capacity, and climate-related disruptions.

Samoa's Energy Consumption and Trends:

Samoa's total installed electricity generation capacity is approximately 30 MW, with a peak demand of around 25 MW. The energy mix and associated policies are outlined below:

Table 10. Samoa's Energy Consumption and Trends

Energy Source	Current Status & Installed Capacity	Key Policies & Regulatory Frameworks
Fossil Fuels (Diesel)	- Approximately 69% of electricity generation relies on imported diesel (IMF, 2022). - High vulnerability to global oil price fluctuations.	- National Energy Policy (2007) aims to reduce dependence on fossil fuels. - Low Emissions Development Strategy (LEDS) targets 70% renewable energy by 2030 (MNRE, 2022).
Hydropower	- Afulilo Dam: 4 MW capacity, the largest hydroelectric facility in Samoa (Wikipedia, 2024). - Additional small-scale hydro projects contribute to the grid.	- Hydropower development is a key component of the LEDS. - Public-Private Partnerships (PPP) encouraged for hydro projects.
Solar Energy	- Faleata Racecourse Solar Plant: 2.1 MW, commissioned in 2014 (ADB, 2014). - Planned expansion includes up to 40 MW of solar PV and 40 MWh of battery storage on Upolu and Savai'i islands (Samoa Observer, 2024).	- Scaling Solar Initiative supported by ADB. - Feed-in Tariff Policy to encourage private investment in solar PV.
Biomass & Other Renewables	- Afolau Biomass Gasification Plant: 750 kW capacity, producing 5 million kWh annually (MNRE, 2022).	- Biomass development included in the LEDS. - Support from UNDP and other international partners.

	- Biomass contributes to rural electrification efforts.	

Energy Access in Samoa:

As of 2024, Samoa enjoys a 99% electricity access rate and an installed capacity of ~30 MW. Yet, around 69% of generation remains fossil fuel-dependent, and renewables account for ~31%. 100% renewable electricity by 2025 is in the pipeline but reliability in remote areas remains a problem.

Samoa’s NDC Targets in the Energy Sector:

Samoa's Nationally Determined Contributions (NDCs) outline specific targets to reduce greenhouse gas emissions and enhance renewable energy adoption.

Table 11. Samoa’s NDC Targets

Sector	NDC Target	Current Status
Power Generation	- Achieve 100% renewable electricity by 2025. - Reduce GHG emissions by 30% in the energy sector by 2030 compared to 2007 levels (ESCAP, 2021).	- Approximately 31% renewable energy share. - Ongoing projects to increase renewable capacity.
Energy Efficiency	- Implement energy efficiency programs to reduce consumption and emissions.	- Energy efficiency measures introduced in urban grids. - Public awareness campaigns underway.
Clean Cooking	- Promote the use of LPG and other clean cooking solutions to reduce biomass reliance.	- Initiatives in place to distribute clean cooking technologies, particularly in rural areas.

Energy Policies and Schemes in Samoa:

Samoa has implemented several policies and programs to facilitate the transition to renewable energy and improve energy access.

Table 12. Energy Policies and Schemes in Samoa

Policy/Scheme	Target	Current Status
National Energy Policy (2007)	Increase renewable energy contribution to 20% by 2030.	Superseded by more ambitious targets in the LEDS.
Low Emissions Development Strategy (2021–2030)	Achieve 70% renewable energy across all sectors by 2030.	Implementation ongoing with support from international partners.
Scaling Solar Initiative	Deploy up to 40 MW of solar PV and 40 MWh of battery storage.	Projects in development on Upolu and Savai’i islands.
Feed-in Tariff Policy	Encourage private sector investment in renewable energy.	Policy framework established; investor interest growing.

Off-Grid Electrification Program	Expand renewable energy access in remote areas.	Deployment of solar home systems and mini-grids in progress.

E. Fiji’s Energy Landscape

Introduction:

Fiji, a South Pacific archipelago, aims to achieve 100% renewable electricity supply by 2036 through indigenous renewable resources like hydro, solar, wind, biomass, and geothermal energy. The National Energy Policy (NEP) calls for taxes on heavy fuels by 2024, with a cumulative investment cost of $20 billion by 2050. The government has budgeted for projects like Solar Home Systems and solar mini-grids in remote areas. However, challenges persist in extending electricity access to rural and remote areas. The government is focusing on rural electrification through special programs and investment for equitable access. Fiji's renewable energy policy is crucial in combating climate change and ensuring energy resilience. Effective implementation of these policies will reduce greenhouse gas emissions, stimulate economic growth, and improve citizens' quality of life.

Fiji’s Energy Consumption and Trends:

Fiji’s total electricity demand is around 300 MW, with a peak annual growth rate of 4.5% (Energy Fiji Ltd, 2024). Below is a snapshot of Fiji's current energy profile:

Table 13. Fiji’s Energy Consumption and Trends

Energy Source	**Current Status & Installed Capacity**	**Key Policies & Regulatory Frameworks**
Fossil Fuels (Diesel)	- 95 MW installed (32% of total mix) (IRENA, 2024) - Diesel used mostly in outer islands and backup generation	- National Energy Policy (2023–2030) - Diesel Reduction Roadmap (2024)
Hydropower	- 140 MW operational (46% of energy mix) (Energy Fiji Ltd, 2024) - Monasavu Dam (80 MW), Nadarivatu (41 MW)	- Renewable Electricity Roadmap (2019–2036)
Solar Energy (On-grid & Off-grid)	- 35 MW installed (12% of total mix) - Key plants: Nabou Solar Farm (5 MW), Qeleya Solar (3 MW)	- Solar PV Investment Plan (2023–2030) - Feed-in Tariff Framework (2023)

Wind Energy	- Pilot project in Sigatoka (0.3 MW), feasibility studies ongoing	- National Wind Mapping Program (ADB, 2024)
Biomass & Waste-to-Energy	- 10 MW installed (3% of energy mix) - Sugar industry by-products (bagasse) used for cogeneration	- Bioenergy Strategy (2023–2028)
Planned Solar Projects (2024–2030)	- Target: 100 MW solar by 2030 - 40 MW under development including private sector participation	- Independent Power Producer (IPP) Framework - Green Investment Policy
Off-Grid & Rural Solar	- 25,000+ solar home systems deployed - 150+ hybrid mini-grids in outer islands	- Rural Electrification Policy (2023–2030) - UNDP & GGGI support programs

Energy Access in Fiji

As of 2024, Fiji has 96% electricity access, supported by off-grid and mini-grid solar expansion. Its installed capacity is 300 MW, with 68% from renewables and 32% fossil fuel dependency. Fiji targets 100% electrification by 2030**.**

Fiji's NDC Targets in the Energy Sector

Fiji's updated Nationally Determined Contribution (NDC) emphasizes energy sector decarbonization, with a strong focus on renewable electricity generation and efficiency.

Table 14. Fiji's NDC Targets

Sector	NDC Target	Current Status
Power Generation	- 100% renewable electricity by 2036 - 30% GHG reduction by 2030	- 68% renewable energy in mix - Renewable projects underway
Clean Cooking	- Transition 60% of rural households to LPG/biogas	- 35% achieved; biogas digesters introduced in 2022
Energy Efficiency	- 15% improvement in energy intensity by 2030 - Peak demand reduction target	- LED & energy audits in public buildings - Efficient cookstoves promoted

Energy Policies and Schemes in Fiji

Fiji's national energy strategy is grounded in climate resilience and sustainability. The government collaborates with international partners like the ADB, World Bank, and UNDP to finance clean energy projects and build technical capacity.

Table 15. Energy Policies and Schemes in Fiji

Policy/Scheme	Target	Current Status

National Energy Policy (2023–2030)	Universal access & energy security	Implementation underway with focus on renewables
Renewable Electricity Roadmap (2019–2036)	100% renewable electricity generation by 2036	68% renewable achieved; hydro and solar prioritized
Rural Electrification Program (2023–2030)	Electrify remaining 4% through off-grid solar/hybrids	Ongoing installation of mini-grids and SHS
Solar Feed-in Tariff & Net Metering	Encourage rooftop solar & IPP participation	Policy revised in 2023; commercial users increasingly adopting
Green Climate Fund Projects	Climate-resilient energy infrastructure	Several GCF-backed projects in outer islands operational
Fiji Low Emission Development Strategy (LEDS)	Long-term decarbonization of energy sector	Solar, biogas, and efficiency measures included

Leap Analysis for Fiji:

Introduction

The LEAP (Long-range Energy Alternatives Planning) model has been used to evaluate Fiji's current energy system and simulate the country's transition toward a more sustainable, renewable-based energy future. This analysis begins with a baseline year of 2023 and projects the trajectory of energy production, consumption, and emissions up to the year 2050.

Baseline Scenario: Energy Flow in 2023:

The Sankey diagram for 2023 illustrates a system dominated by oil product imports, primarily consumed by the transportation sector, with minor contributions from local biomass, hydropower, and emerging renewable sources like solar and bagasse. Key highlights include:

- Oil Products Imports exceed 90% of Fiji's primary energy supply, feeding directly into oil products (refined) and then into electricity generation and transportation.
- Transportation is the single largest consumer, utilizing the majority of diesel, gasoline, and jet kerosene. This accounts for over 33 million gigajoules (GJ) of final energy demand.
- Electricity Generation derives input from oil, hydropower, biomass, and marginal renewable sources. Despite a hydro share, fossil fuels still account for a large share of power generation.

- Energy Losses, mainly from Transmission and Distribution (T&D) inefficiencies, represent a notable proportion of generated electricity—indicating a need for infrastructure upgrades.
- The household sector consumes energy mainly through electricity and biomass (e.g., wood), while commercial and industrial sectors show diversified usage with smaller loads compared to transportation.

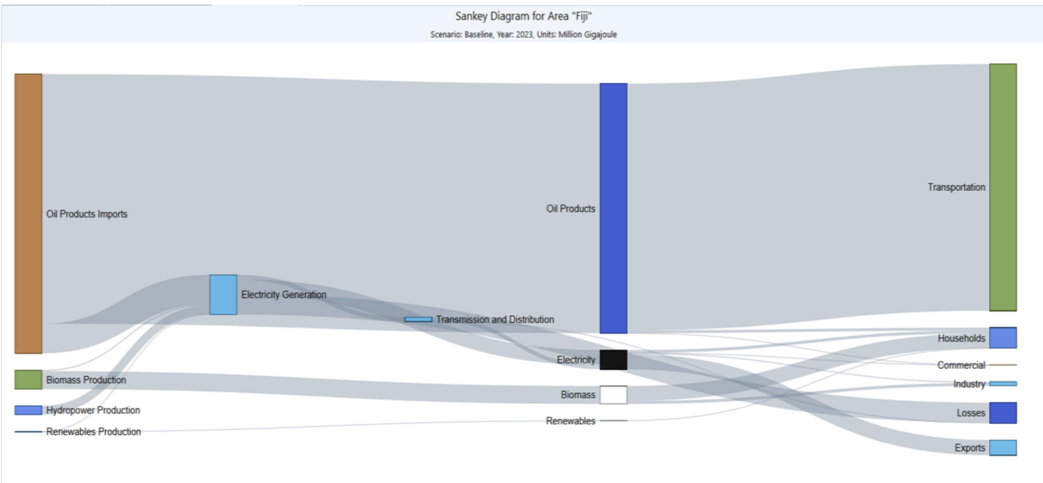


Fig4 : Sankey diagram

Final Energy Demand by Fuel and Sector

The bar graph of final energy demand for 2023 further reinforces the fossil fuel dependency:

- Diesel alone contributes approximately 33.5 million GJ, overwhelmingly consumed by the transportation sector, followed by industrial use.
- Gasoline and Jet Kerosene contribute around 7.5 million GJ and 2 million GJ, respectively.
- Electricity usage remains modest, indicating either lower electrification in rural regions or fossil-based off-grid solutions.
- Biomass (wood) remains a staple for households, with around 3.5 million GJ, while solar, LPG, and bagasse are nearly negligible, each contributing less than 1 million GJ.

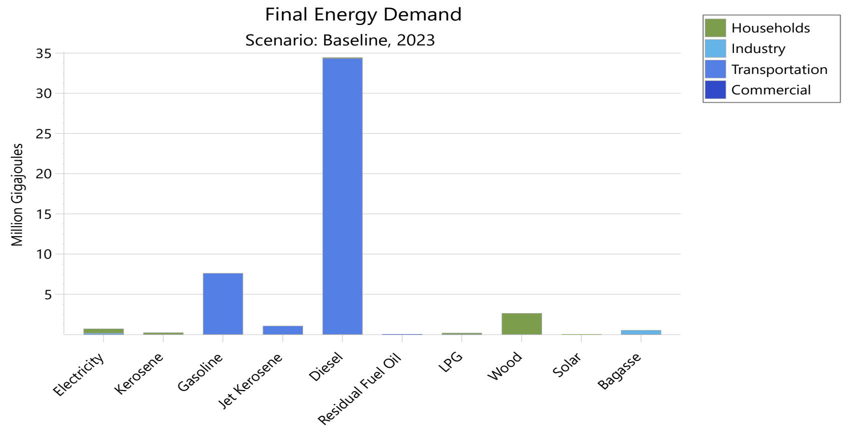


Fig5 : Final energy demand

Projected Energy Outputs by Feedstock (2023–2050)

The third graph shows an encouraging trend of clean energy growth between 2023 and 2050. Based on projected outputs by feedstock fuel:

- Diesel-based output drops significantly after 2023, with a sharp decline by 2025, and continues to taper off toward zero by 2050. This represents Fiji's commitment to reducing fossil fuel dependence.
- Hydropower becomes the dominant fuel source through mid-century, with production growing steadily, reaching over 2,000 thousand GJ by 2050.
- Solar energy, though nearly negligible in 2023, shows exponential growth—rising to over 1,200 thousand GJ by 2050, reflecting aggressive solar deployment strategies (rooftop PV, mini-grids, utility-scale).
- Bagasse, a byproduct of sugarcane, rises from below 100 thousand GJ in 2023 to around 600 thousand GJ by 2050, indicating Fiji's potential for circular bioenergy systems in agro-industrial regions.

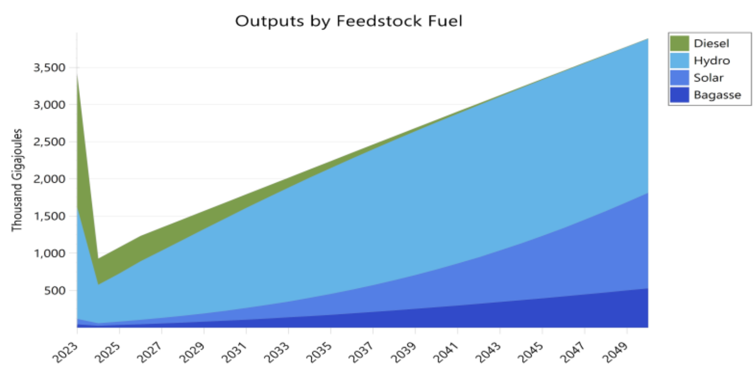


Fig 6: Projected Energy Outputs by Feedstock

System Load Profile:

Fiji's Peak Load Shape graph shows a consistent electricity demand profile, with system load remaining above 70% of peak for nearly 4,000 hours, and only dropping below 60% during the last 2,000 hours of the year. This flat load duration curve indicates high base load requirements, making it ideal for integrating baseload renewable sources like hydropower and biomass. Fiji receives 4.5–5.5 kWh/m²/day solar irradiance, supporting large-scale solar PV deployment, though energy storage systems such as BESS are essential for managing variability. The country already derives about 50% of electricity from hydropower, and expansion can help meet its goal of 100% renewable electricity by 2050. The stable demand profile also makes demand-side management (DSM) effective through ToU tariffs and smart meters. Investments in smart grids, storage, and rural electrification using microgrids are crucial. High base demand ensures better capacity utilization of renewables, improving economic feasibility. Challenges like high upfront costs can be addressed through climate finance and public-private partnerships. Overall, Fiji's load shape supports a technically and economically viable energy transition to a resilient, low-carbon future.

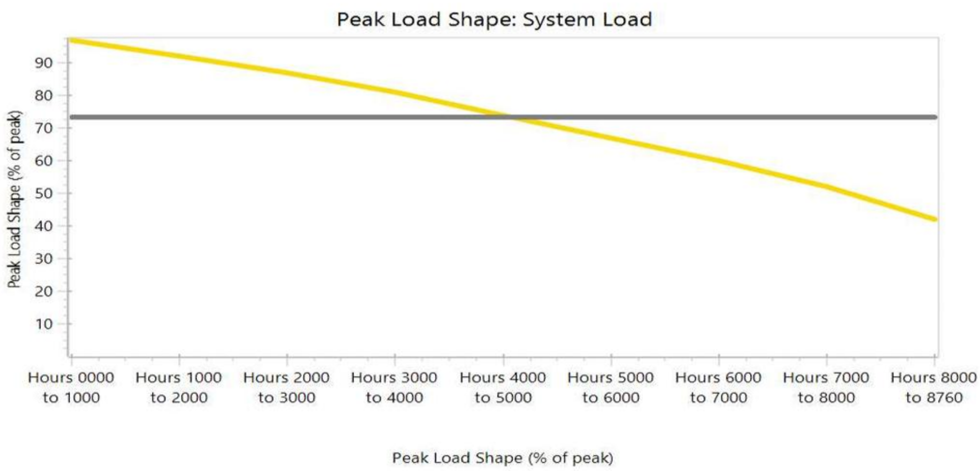


Fig7 : Peak Load Shape

Recommendations:

Based on LEAP scenario analysis (2023–2050), Fiji's energy demand is dominated by oil imports, primarily for transportation, with diesel alone exceeding 33 million GJ in 2023. However, renewable outputs (hydro, solar, bagasse) are projected to rise steadily to over 3,500 thousand GJ by 2050, indicating a strong transition trend. The system load profile shows over 70% of peak demand sustained for 4,000+ hours annually, favoring baseload renewables like hydropower, already contributing nearly 50% of Fiji's electricity mix. To meet 100% renewable electricity goals, investments in storage, smart grids, and electrification of transport are essential. Therefore, Fiji should prioritize solar and hydro expansion, BESS deployment, and demand-side management to enable a resilient and self-sufficient energy future by 2050.

Objective 2: Defining Key Indicators and Measuring Progress of Energy Transition

Introduction:

The energy transition aims to limit global warming to 1.5°C by transitioning the world's energy sector from fossil to zero-carbon sources by mid-century. Despite rising energy consumption, most electricity is supplied by low-emitting sources like solar PV. The IEA's Sustainable Development Scenario requires a 52% reduction in energy-related CO_2 by 2040. Pacific Island countries have set ambitious transition objectives, including 100% renewable electricity by 2030 and net-zero emissions by 2050, despite their small percentage of global emissions.

Energy Transition Indicators:

An energy transition indicator (ETI) is any metric that tracks the trends in the transition to cleaner energy and lower emissions. There is no one number that represents the entire complexity of the transition, so a collection of indicators is employed to "see through" the energy sector's CO_2 emissions and follow drivers beneath. For example, the IEA's clean energy transition indicators framework considers the indicators of energy intensity (energy per GDP), carbon intensity (CO_2 per energy), share of renewable electricity, and investment in low-carbon technologies. They capture the general climate and development ambitions and condense them into tangible measures. For instance, in the SDG framework, SDG 7.2.1 clearly measures the proportion of renewable energy in final energy consumption and SDG 7.1.1 monitors the percentage of population with electricity. By regularly refreshing such indicators, policymakers are able to "take the pulse" of the transition and adapt strategies correspondingly (IEA, 2023).

Key Quantitative Indicators

Table 16. Quantitative Indicators

Indicator	Description
Renewable Energy Share (RES) (%) = (Renewable Energy / Total Final Energy Consumption) × 100	Percentage of energy derived from renewable sources. Increasing RES

	shows progress in decarbonizing the energy mix.
Energy Intensity (EI)= Total Energy Consumption / GDP (in PPP terms)	Amount of energy consumed per unit of economic output. Lower energy intensity implies greater efficiency.
Fossil Fuel Dependency (%) = (Fossil Fuel Energy / Total Energy) × 100	Share of energy supply or generation from fossil fuels. A lower value reflects decreasing reliance on oil, coal, and gas.
Electrification Rate (%) = (Population with Electricity / Total Population) × 100	Proportion of the population with electricity access. Indicates progress toward modern energy.
Carbon Intensity = CO_2 Emissions (tCO_2) / Energy Consumption (PJ or MWh)	CO_2 emissions per unit of energy used. Lower carbon intensity reflects a cleaner energy mix.
Energy Transition Investments (% of GDP) = (Renewable energy investment /GDP) × 100	Financial investments supporting the transition to clean energy, including renewables, grids, storage, and efficiency.

Key Qualitative Indicators:

Table 17. Qualitative Indicators

Indicator	**Description**
Regulatory and Policy Framework	Presence of clear laws, renewable targets, incentives, and mandates; strong policy = strong transition commitment (SPC, 2022).
Institutional Capacity	Effectiveness of governance, technical expertise, and planning tools (e.g., IRPs); well-resourced agencies manage transitions better.
Financial Support and Investment	Access to transition funds, private capital, credit status, and macroeconomic stability; determines ease of financing renewable projects.
Social Acceptance and Awareness	Public support for renewable projects, tech adoption, land use changes, and tariffs; gauged via surveys and local initiatives.
Energy Resilience and Reliability	System’s ability to withstand shocks (e.g., cyclones); decentralized, diversified systems score higher in resilience and adaptation capacity.
Technology and Innovation	Adoption of modern tech (e.g., batteries, smart grids), R&D capacity, and pilot programs; indicates leadership in energy transition.

Quantitative Indicators Analysis:

Below table each quantitative indicator can be calculated annually (using international databases like IEA or World Bank or national energy balances) and compared to baseline values or targets.

Table 18. Quantitative Indicators analysis

Country	Renewable Energy Share (%)	Energy Intensity (USD/TJ)	Fossil Fuel Dependency (%)	Electrification Rate (%)	Carbon Intensity ($kgCO_2/MJ$)	Investment in Renewable Energy (% of GDP)
Fiji	70	900,000	30	98	0.70	2.80
Samoa	55	1,100,000	40	95	1	2.20
Tonga	45	1,200,000	50	92	1.10	2
Tuvalu	40	1,300,000	55	90	1.20	1.90
Papua New Guinea	35	140,000	60	75	1.80	1.60
Vanuatu	30	1,500,000	65	85	1.60	1.40
Kiribati	28	1,550,000	68	83	1.75	1.20
Solomon Islands	25	2,100,000	75	70	1.90	1.10

Qualitative Indicators Analysis:

These Qualitative indicators are generally assessed through literature reviews, expert judgments, country-level analyses, and global reports. For instance, nations with clearly defined and comprehensive energy transition legislation and institutional frameworks tend to receive higher scores under the policy and regulatory framework indicator. Qualitative Indicators analysis

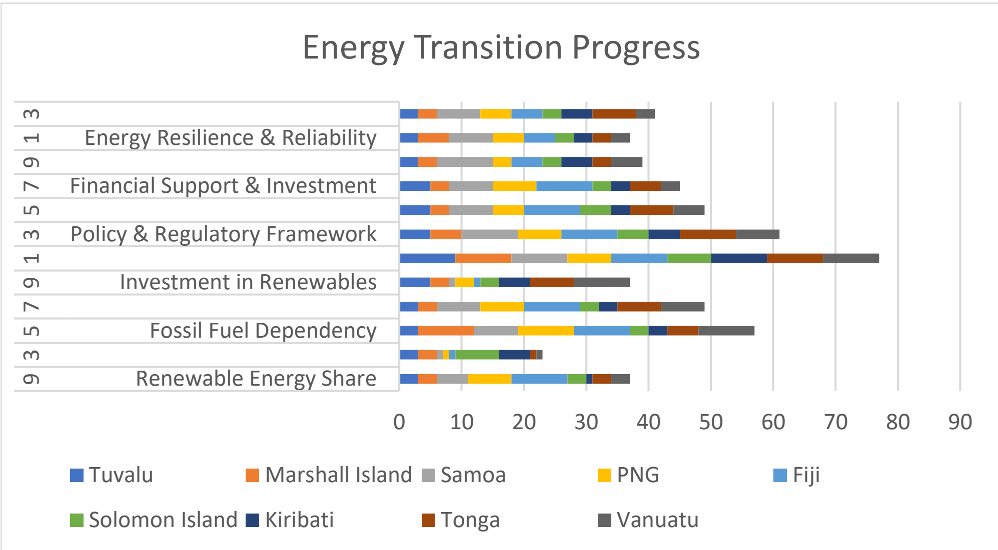
Fuzzy TOPSIS-Based Evaluation of Energy Transition Progress

To aggregate the various indicators of energy transition into one, quantifiable measure across Pacific Island Countries (PICs), this thesis utilizes the Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (fuzzy TOPSIS) approach. It incorporates both quantitative indicators like renewable energy proportion, energy efficiency, dependence on fossil fuel, electrification coverage, carbon intensity, and financial investment, as well as qualitative indicators such as policy strength, institutional capacity, financial preparedness, social acceptance, energy resilience, and technological innovation. Fuzzy TOPSIS allows comparison among nations (alternatives) in terms of proximity to an "ideal" energy transition situation. Whereas quantitative measures are applied directly (e.g., renewable energy as % or investment as % of GDP), qualitative measures are assessed via expert judgment, literature, and country reports. These qualitative indices are converted into fuzzy linguistic words (e.g., "Poor," "Good," "Very Good") and quantified into triangular fuzzy numbers using the following scale:

Table 20. Fuzzy TOPSIS scale

Linguistic Term (Scale)	Low	Medium	High
Very Poor (1)	1	1	3
Poor (3)	1	3	5
Fair (5)	3	5	7
Good (7)	5	7	9
Very Good (9)	7	9	10

After all the indicators are normalized, fuzzy TOPSIS calculates a fuzzy closeness coefficient for every country that represents its relative proximity to both the ideal and the negative-ideal transition points. For instance, the countries with more renewable shares and good energy governance will have greater closeness coefficients, positioning them closer to the ideal solution. This approach, as it was formulated by Chen et al. (2000), makes it possible to combine both objective facts and subjective judgments and offer a comprehensive and transparent mechanism for monitoring energy transition performance. [Fuzzy TOPSIS]



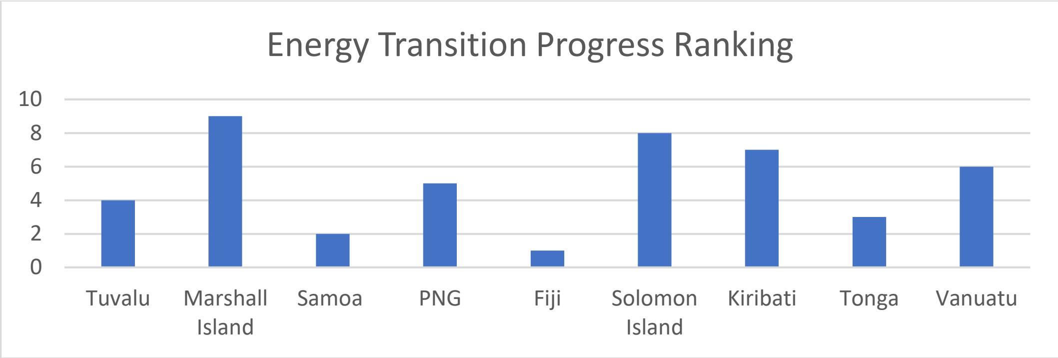


Fig 4 Energy transition progress

The nine Pacific Island Countries' energy transition development has been evaluated using the Fuzzy TOPSIS technique, integrating quantitative indicators (such as the share of renewable energy, carbon intensity, and electrification rate) and qualitative indicators (e.g., policy framework, institutional capacity, and innovation). The first chart indicates every country's performance on 12 indicators. Fiji has the best performance with good ranking on renewable energy penetration, investment, policy, and institutional framework readiness. Samoa and Tonga follow with good improvement, but Marshall Islands and Solomon Islands trail behind because of low investment and poor policy support. The second chart illustrates the general rankings. Fiji holds the top rank, then Samoa (ranked 2nd) and Tonga (ranked 3rd), indicating their superiority in energy transition. Tuvalu (ranked 4th) and PNG (ranked 5th) demonstrate moderate improvements, whereas Vanuatu (ranked 6th) and Kiribati (ranked 7th) have space for growth. Solomon Islands (8th) and Marshall Islands (9th) are ranked lowest. This evaluation assists in determining strengths and areas of deficiency in each nation's transition, facilitating more informed policy-making and investment choices for a sustainable energy future in the region.

Objective3: Policy and Framework Analysis

Introduction

Pacific Island countries are transitioning to renewable energy (RE) to reduce reliance on expensive diesel and address climate vulnerabilities. Some have ambitious targets, like Fiji's 100% by 2030, Samoa's 20%, and Tuvalu's 100% by 2020. However, achieving these targets requires robust policy and regulatory structures like transparent tariffs, net metering, and licensing. Donor and development bank support is crucial for countries without minimal energy laws.

Centralized RE solutions are less feasible due to geographical remoteness and fragmented small grids.

Business models

Throughout the years, various business models have come to be used to facilitate the deployment of renewable energy. From utility-led and community-owned solar farms to public-private partnerships and energy-as-a-service (EaaS) models, resulting in tremendous successes and failures. Choice of the model depends primarily on the nature and goals of the project. Like, the deployment of the renewable energy projects for supply of electricity access to the far-flung population will need a model that is robust on the economic returns rather than merely on the returns financial - which is more appropriate and relevant to the projects that intend to sell power to the grid. Therefore, the business models must be tailored to address to the local needs and suitable to the local situations (Gap Analysis of PICs).

Existing regulatory framework, policies and business models- Fiji

Fiji, being a Small Island Developing State, has a goal of 90% renewable grid-connected electricity by 2035. Though there are challenges related to energy access and sustainability, the major utility Energy Fiji Limited (EFL) is financially sound with assets of FJD 1.51 billion. The Department of Energy leads rural electrification and policy guidance through the National Energy Policy 2023-2030, aiming for close to 100% renewables. The Fiji Competition and Consumer Commission oversees tariffs and licensing. Major legal tools are the Fiji Electricity Act 2017, Electricity Regulations 2019, and Environmental Management Act 2005. Land access is led by iTaukei Land Trust Act. Building codes require renewable integration and efficiency, and Fiji utilizes AS/NZS standards and regional guidelines.

Utility, Governance, Regulation and Policies

- **Electricity Governance and Regulation:** Energy Fiji Limited (EFL) is the main utility firm responsible for electricity generation, transmission, and retail in Fiji's main islands. Established in 1966, EFL manages Power Purchase Agreements (PPAs) with Independent Power Producers (IPPs) for large-scale renewable energy inclusion in the national grid. However, its control over grid infrastructure and project approvals can restrict market entry for new IPPs. In 2023, EFL recorded a loss after tax of FJD 24.80 million. Despite this, EFL has a strong financial standing with total assets of FJD 1.51 billion, equity of

FJD 886.12 million, and a debt-to-equity ratio of 33:67. The Fiji Competition and Consumer Commission regulates grid-connected and off-grid systems, while the Department of Environment manages environmental impact assessments for large renewable projects.

- **Renewable energy targets and operation**: Fiji's National Energy Policy aims to transition to almost 100% renewable electricity generation by 2023-2030, with a goal of 90% by 2035. The Ten-Year Power Development Plan requires FJD 4.3 billion in investments. However, challenges include rainfall variability, rising fossil fuel costs, and procrastination on large hydro projects. Fiji's energy technologies show uneven performance, with diesel power generators having a 35% capacity rate, hydro projects having 49%, and solar power having 17%.

Table 21 Capacity Utilization values for generators in Fiji

Generation Source	Power Capacity (MW)	Capacity Utilisation (%)	Primary Locations
Diesel	171	35%	Kinoya Power Plant, Vuda Power Plant
Hydro power	138	49%	Monasavu Hydro, Nadarivatu Hydro
Biomass	66	20%	Tropik Woods Facility
Solar PV	11	15%	Distributed systems on households and commercial facilities, particularly hotels and resorts
Wind	10	0%	Butoni Wind Farm

Standards and Codes for Renewable Energy in Fiji

- **Electricity Codes**: Fiji's Electricity Codes outline technical, operational, and design requirements for grid electricity systems, including operation codes for outage management and power quality maintenance, planning guidelines for system extensions, and procedures for metering, scheduling, and dispatch. Off-grid systems are guided by design codes and guidelines from regional organizations like the Pacific Power Association and the Sustainable Energy Industry Association of the Pacific Islands.
- **Electricity Standards:** Fiji follows Australian and New Zealand Standards (AS/NZS) for most electrical and structural systems, supplemented by localisation via EFL-specific standards, especially for wind and seismic loads. Where AS/NZS standards are inadequate, International Electrotechnical

Commission (IEC) standards are used. Grid-connected projects need to satisfy both AS/NZS and EFL standards, yet complete off-grid standards are in development.

- **Environmental Impact Assessments for Large-Scale Projects**:Large-scale renewable energy projects also involve technical specifications outlined in contracts, usually by funding organizations and EFL, integrated into the design, procurement, and construction phases. Environmental Impact Assessments (EIAs) for large-scale projects are required by Fiji's Environmental Management Act 2005, including scoping, Terms of Reference (ToR), baseline environmental studies, impact assessment, and risk analysis.
- **Land Use and Zoning**: Land use regulations for renewable energy endeavors are upheld by the Department of Lands under the Ministry of Lands and Mineral Resources, and private lands require consent from the landowners. Compliance with such Acts is typically required in the Environmental Impact Assessment (EIA) approval.
- **Building codes:** The Fiji National Building Code of 2023 requires the incorporation of renewable energy in new buildings, as long as they are grid connected. It requires the utilization of renewable energy sources like solar, wind, and bioenergy for electricity and water heating and demands on-site generation to supply at least 30% of the energy demand where there is no grid powered by renewables. The buildings also must be designed to be able to accommodate future renewable energy installations in case of non-urgent adoption.
- **Workforce and Training:** Fiji experiences human resource issues in the renewable energy industry through the loss of skilled human resources due to emigration. Energy Fiji Limited (EFL) launched a Strategic HR Plan, an Apprenticeship Program, and conducted more than 59,000 training hours in 2023. Availability and retention of sophisticated renewable energy skills are low. Fiji ranks 82.5/100 on the World Bank's Women, Business and the Law Index, which reflects high gender inclusiveness in comparison with other Pacific Island Countries.
- **Public Participation**: Domestic and commercial consumer satisfaction are both good (93.96% and 95.48%) with service through 9 care centers and websites. Public awareness and participation in renewable energy are low.

Efforts by EFL and DoE are now generic for electricity and energy efficiency, without any specific campaigns for renewables.

Business Models in Fiji

The following project classification serves as the foundation for determining the suitability of various business models. Based on project size and scale, the business models have been categorized as Distributed or Decentralized Projects, and Utility Scale Projects. The section also discusses the types of business models that could realistically be used in Fijian context for accelerated growth of solar adoption in the country.

A.Distributed or Decentralized Projects: Distributed / Decentralized projects involve smaller scale RE systems located close to the point of consumption, often for self-use or local distribution.

- **Scale**: Typically <1 MW
- **Ownership**: Individuals, communities, businesses, or cooperatives
- **Revenue/Savings Model**:
  - Self-consumption with savings on electricity bills
  - Net metering or net billing for selling excess electricity to the grid
  - Pay-as-you-go (PAYG), leasing, or energy-as-a-service models in underserved areas
- **Examples:** Rooftop solar PV systems, Solar Pumps, Community solar projects, Microgrids and mini-grids (especially in rural/off-grid areas)

1.Energy as a Service (EaaS) Business Model: The Energy as a Service (EaaS) business model is used to create an energy hub that benefits local communities by providing access to electricity in various forms. Funding comes from various sources, including equity investment, loans, and government grants. Ownership is typically held by the IPP or local community, and the capital investment is recovered through the sale of energy services at fair prices. In Fiji, the University of the South Pacific funded the initial capital of a solar hybrid system in Wainika village, providing energy services to the area.

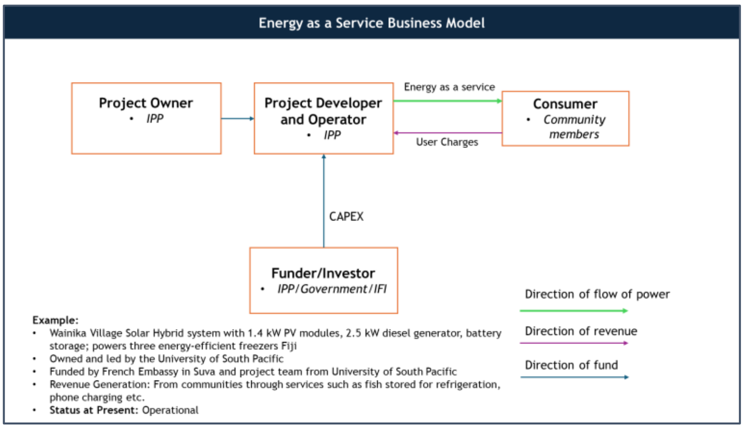


Fig 5: EaaS business model

2.Community Owned Business Model: The Community-Owned Business Model is a sustainable approach to community development, focusing on democratic ownership, shared control, and reinvestment of earnings. This model is often used for electrification projects, such as the Vio Island Electrification project in Fiji. The project involves a solar mini-grid, funded by FREF, and operates for four months. Residents pay a monthly tariff of FJ $18 with an energy allowance of 9,450 watt-hours. The cost is recovered by charging appropriate tariffs to electricity consumers. The project aims to provide rural households with four months of free electricity, followed by tariff collection from the fifth month.

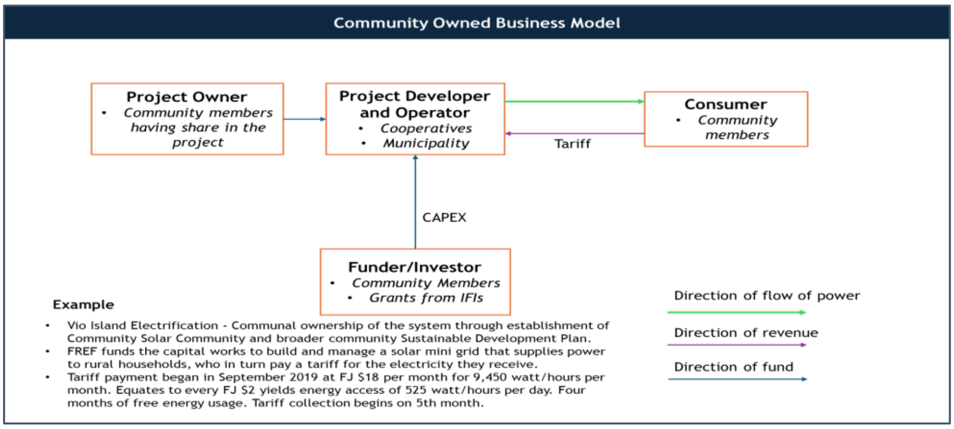


Fig 6: Community-Owned Business Model

3.Captive Based Business Model: The Captive Based Business Model is a system where a customer invests in constructing, owning, and running a power generation plant, usually a clean one such as solar or wind, for end-use electricity usage. The model is extremely cost-effective by minimizing reliance on expensive grid power or diesel generators, while providing energy security and helping in sustainability objectives with the utilization of clean energy. In Fiji, the 250-kW solar power plant at the Namaka Campus of Fiji National University is owned and financed entirely by the university, which is still grid-connected while the solar system provides up to 80% of its energy requirements. CAPEX is financed entirely by Fiji National University, while the running cost OPEX is minimized with lower electricity charges without any financial burden on outside consumers.

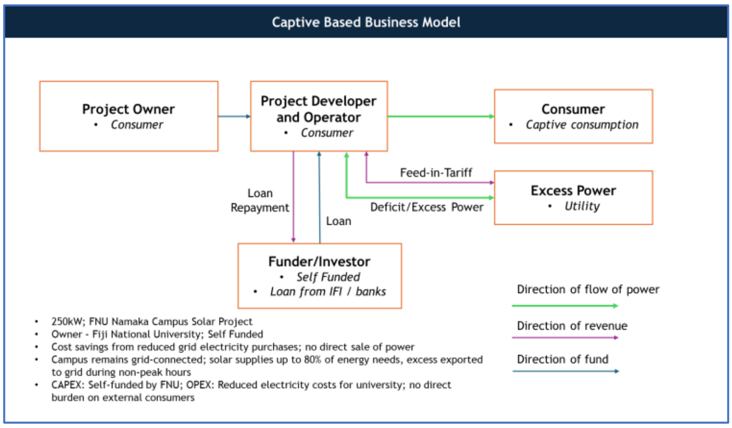


Fig 7: Captive Based Business Model

B.Utility-Scale Projects: These are large-scale renewable energy projects typically connected to the national grid and developed for commercial electricity generation.

- **Scale**: Typically >1 MW (often much larger).
- **Ownership**: Developed by independent power producers (IPPs), utilities, or through public-private partnerships (PPPs).
- **Revenue Model**: Electricity is sold through:
    - Power Purchase Agreements (PPAs) with utilities or large customers.
    - Feed-in Tariffs (FiTs) or auctions.
    - Wholesale electricity markets (in liberalized markets).
- **Examples**: Large solar farms, Onshore/offshore wind farms, Hydropower plants

a. **IPP - PPA Based Business Model:** The IPP-PPA Based Business Model involves an Independent Power Producer (IPP) building, owning, and operating a power generation plant, often renewable energy plants, and selling the generated power to an off-taker on a long-term Power Purchase Agreement (PPA). This model takes on project development, finance, and operation risk, while the off-taker commits to off-taking a set quantity of electricity at a set tariff for the contract term. This structure provides a stable and predictable power supply at predetermined prices, while the IPP has a predictable cash flow to pay back investment costs. The 12 MW Nabou Green Energy Biomass Plant in Fiji generates power directly into the national grid, with capital expenditure financed by the Green Climate Fund, Korea Development Bank, and Mirae Asset Daewoo.

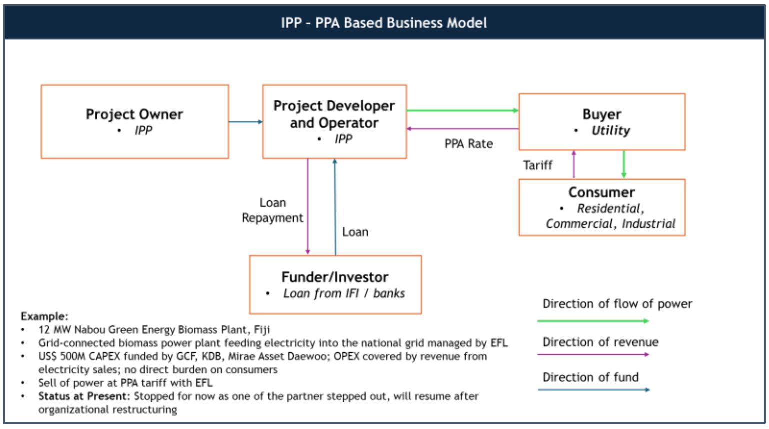
b. 

Fig 8: IPP-PPA Based Business Model

b. Utility Owned Generation Based Business Model: The Utility-Owned Generation-Based Business Model is a business model where a utility owns, operates, and controls power generation facilities. It develops, finances, operates, and maintains power plants and distributes electricity directly to end-users. The utility recovers investment and returns capital through regulated tariffs, typically controlled by government regulators. This model supports centralized generation capacity control and grid stability but can have slower innovation and investment cycles compared to independent producers. EFL owns and operates the 10.175 MW Butoni Wind Farm in Fiji, providing electricity directly to the national grid. The project was financed entirely by EFL after Pacific Hydro Limited withdrew due to commercial viability concerns.

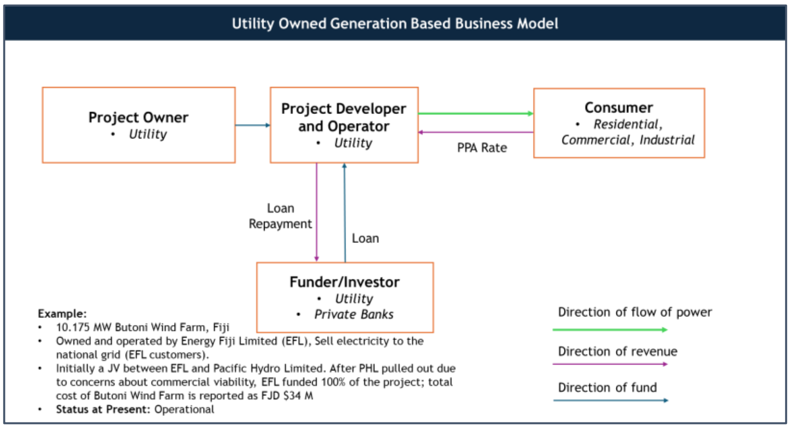


Fig 9: Utility Owned Generation Based Business Model

C.Public Private Partnership (PPP) Business Model: Public-Private Partnership (PPP) Business Model is a partnership model in which the public sector (government or public utility) partners with private firms to co-develop, co-finance, and co-operate renewable energy projects. The model benefits from the complementary capabilities of the public and private sectors—the public sector typically provides land, regulatory services, and partial finance, whereas the private sector provides technical expertise, innovation, and operational performance. Risk-sharing provisions and open contractual arrangements are central to making such a model successful.

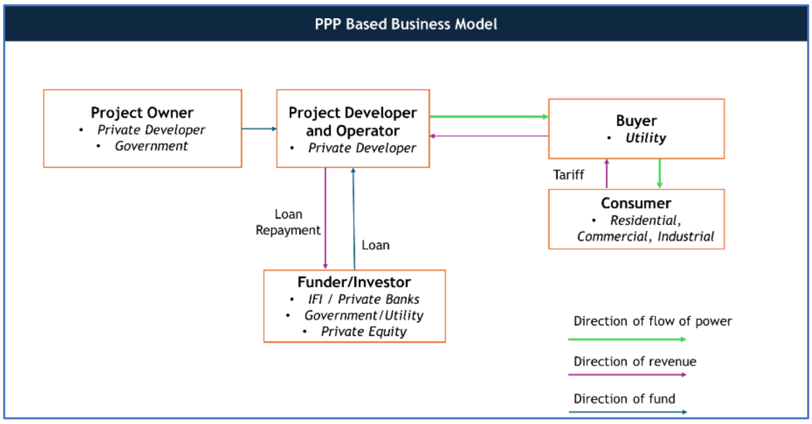


Fig 10: Public Private Partnership (PPP) Business Model

d. RESCO Business Model: The RESCO Model is a service model where a specialized company owns and installs renewable energy systems, services them, and provides electricity or energy services to customers on a fee-for-service basis. This model is particularly effective in rural, remote, or non-served areas with limited grid access. It is particularly suitable for mini-grid or off-grid operations and has been widely used in island nations to increase access to clean, quality energy. Fiji has initiated an SHS program using the RESCO model to electrify rural households in remote areas, offering basic power and lighting services using solar photovoltaic systems.

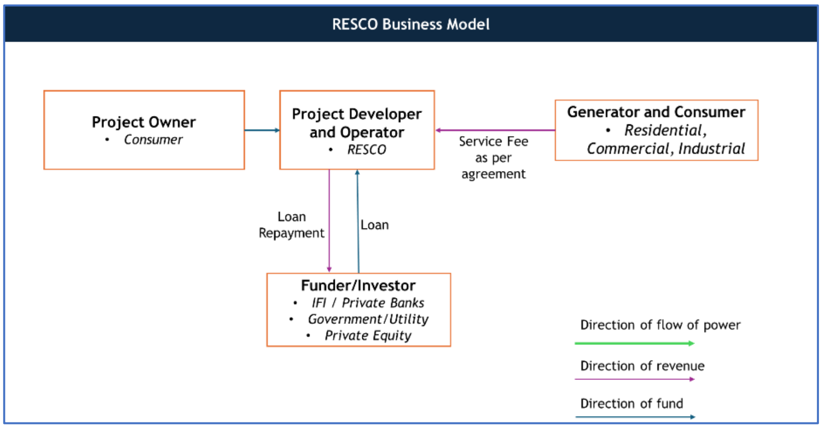


Fig 11: RESCO Model

Fiji Energy Policy Recommendations

Table 22: National energy policy recommendations

Category	Recommendation	Comments
Energy Security and Resilience	Promote competition and competitive neutrality in the electricity sector.	FCCC will be supported with analysis, templates (e.g., PPAs), processes, and mechanisms to attract IPPs and implement transparent PPAs.
	Audit energy infrastructure for exposure to physical risks.	In response to rising climate and disaster risk impacts; findings will inform maintenance and safety updates.
	Allocate additional capacity/resources to DOE and MFSPNDS.	To anticipate and respond to changes in energy demand.
	Improve potential to insure investments in resilient infrastructure.	DOE will coordinate with MFSPNDS, Investment Fiji, and others, in response to high upgrade costs.
	Enable cost-sharing and fair distribution of renewable energy benefits.	DOE to coordinate analysis and support for integrating renewable energy into current operations.
Energy Access and Equity	Expand off-grid and on-grid capacity to close electrification gaps.	Implement the National Electrification Policy and update the Electrification Master Plan.
	Continue the 'Lifeline' electricity subsidy scheme.	To support access for disadvantaged communities.

	Scale up off-grid renewables with cooperative financing models.	Fiji Rural Electrification Fund as an example of collaborative financing and operations.
	Develop training, internships, and capacity-building programs.	DOE and DOT to partner with education/employment ministries and institutions for curriculum updates and financing.
Energy Sustainability	Produce and update investment plans aligned with NDCs.	Includes pipeline of shovel-ready projects supported by grid integration plans.
	Develop consultation processes for land procurement.	Engage iTaukei Affairs, TLTB, and stakeholders to ensure landowner coordination and co-benefits.
	Create financial incentives for renewable energy adoption.	Collaborate via national budget submissions; tools may include tax rebates, grants, and de-risking mechanisms.
	Develop and implement renewable and national energy standards.	To ensure minimum performance, protect markets, and build consumer trust.
	Improve investment attractiveness via competitive bidding and regional funds.	Includes exploring Pacific regional fund, engaging blended finance, and working with the Reserve Bank for lending mechanisms.
	Replace fossil fuel subsidies with clean tech subsidies.	To support cost reduction of renewable energy and efficiency.
	Reform energy tariffs to balance affordability and investment.	Aim for a feed-in tariff structure that promotes technology diversification.
	Institutionalise a long-term guarantee fund for RE deployment.	Builds on World Bank-supported rural energy guarantee experience.
	Explore premium green energy tariffs with utilities.	For CSR-aligned corporate customers to directly fund domestic RE generation.
Energy Governance	Review institutional arrangements for energy governance.	To deliver NEP more inclusively and effectively.
	Review and propose amendments to Electricity Act 2017.	Improve alignment with NEP and climate goals.

	Clarify legal frameworks in the Electricity Act for IPPs and PPAs.	Strengthen regulator autonomy and define off-grid roles, DOE-DOT mandates, and financing needs.
	Strengthen pricing regulations and ensure transparent methodology.	DOE and FCCC will collaborate on tariff and fuel pricing.
	Develop framework for market reform.	Support new financing access and fairness across stakeholders.
	Strengthen inter-stakeholder coordination through NEP Action Plan.	Improve implementation arrangements.
	Engage private sector for PPP guidelines development.	Align public-private investments with national priorities.
	Develop performance KPIs for national energy utilities.	DOE will monitor via proxy or utility reports and publish bi-annual reports.
Equity	Include gender-specific targets in RE initiatives.	Gender co-benefits to be eligibility criteria for bond-funded projects; KPIs to reflect gender targets.
	Promote gender equity in leadership and governance.	Support transition strategies for equal gender representation in boards and executive committees.
Research and Development	Promote national investment in R&D and innovation.	Mobilize financing equivalent to 1% of GDP by 2030 for context-specific research, tech transfer, and innovation.

Table 23: Fiji Renewable Energy Transition Recommendations

Category	**Recommendation**	**Comments**
Regulatory	Complete the transition of all regulatory functions from EFL to FCCC to eliminate potential conflicts.	Ensures independent and conflict-free regulation.
	Strengthen FCCC's technical capacity in energy regulation with specialised expertise.	Supports informed and effective oversight.
	Develop a more transparent tariff methodology balancing utility financial sustainability and consumer protection.	Aligns economic viability with public interest.
	Establish stronger coordination mechanisms between institutions	Enhances policy coherence while avoiding regulatory capture.

	while maintaining appropriate separation.	
	Amend the Electricity Act to clarify the role of renewable energy and provide for off-grid/mini-grid support.	Enables clear legal backing for RE initiatives and rural energy solutions.
Transition Pathway	Establish a dedicated project management office to accelerate renewable project implementation.	Improves delivery timelines and coordination.
	Develop a comprehensive transition roadmap with interim targets from 55% to 90% RE share by 2035.	Provides a clear strategic direction.
	Conduct detailed grid integration studies to prepare for high variable renewable energy (VRE) penetration.	Ensures technical reliability and flexibility.
	Diversify beyond hydropower to increase system resilience to climate variability.	Reduces reliance on climate-sensitive generation sources.
Off-grid	Enable remote communities to collaborate with the private sector to manage off-grid renewable energy systems.	Promotes local empowerment and sustainability.
Investment	Develop an attractive FiT structure to incentivise private (especially rooftop) renewable investment.	Stimulates decentralised clean energy adoption.
	Create standardised and transparent PPA templates and procurement processes.	Reduces complexity and transaction costs.
	Implement risk mitigation tools like partial risk guarantees to improve bankability.	Encourages private financing and investor confidence.
	Develop a clear pipeline of investment-ready renewable projects with completed feasibility studies.	Attracts timely and focused investment.
Development Partners	Establish a formal RE development partner coordination platform with regular meetings.	Avoids overlap and enhances synergy.
	Create a centralised database of all RE projects and studies.	Improves transparency and planning.

	Develop a government-led investment coordination strategy with clear priorities.	Ensures alignment with national goals.
	Conduct joint planning sessions for major initiatives to ensure complementarity.	Promotes collaborative and efficient resource use.
Workforce & Training	Develop a comprehensive workforce strategy identifying renewable energy skills gaps.	Aligns human capital with market needs.
	Establish specialised technical training programs with educational institutions.	Builds technical workforce capacity.
	Create clear career progression pathways for renewable energy professionals.	Improves long-term retention and motivation.
	Streamline licensing processes for renewable energy specialists (e.g., solar PV installers).	Encourages professionalisation and quality assurance.
	Develop formal partnerships with national institutions to design RE-focused curricula.	Ensures training aligns with industry demands.
	Implement retention strategies like competitive compensation for skilled personnel.	Reduces talent attrition.
	Create industry-academia exchange programs to keep training relevant to evolving tech.	Enhances innovation and curriculum responsiveness.
Public Awareness	Launch a public awareness campaign highlighting renewable energy benefits.	Builds public support and acceptance.
	Implement participatory community engagement programs for renewable projects.	Ensures local ownership and trust.
	Develop targeted communication to explain link between tariff changes and RE investments.	Increases transparency and reduces resistance to pricing reforms.

Recommendations: Fiji is making regulatory reforms through transition of oversight from EFL to FCCC and needs to improve technical capacity, tariff transparency, and legislative certainty for promoting renewable energy development. There is a need for a project office and elaborate transition plan to meet the 90% renewable target by 2035. Investment-grade projects, improved FiT designs, and risk management instruments will promote private finance. Off-grid access expansion, workforce capability, and public awareness are essential for transition inclusiveness. Good inter-agency coordination and public engagement will enable sustainable and resilient energy development.

Objective 4: Case Study of Small Island Nations:

Small and remote island communities tend to be substantially dependent on imported fuels, and energy security and decarbonisation are thus matters of pressing concern. The Pacific Island nations, for instance, are nearly completely dependent on imported oil and boast some of the most expensive electricity globally. In response, a number of small island states have set ambitious renewable energy programmes. The Faroe Islands, Denmark, Greece's Aegean islands (e.g. Tilos), and Hawaii have all made significant transitions.

Faroe Islands: The Faroe Islands (Nordic) pledged in 2009 to a 20% CO_2 reduction by 2020, although a period of rapid growth put that on the back burner. The government recently set a new goal for 45% fewer emissions by 2030 (relative to 2022 levels). This is being accomplished by expanding onshore and offshore wind concurrently with current hydropower. SEV (the utility company) is adding ~70 MW of wind with grid-scale batteries and pumped-storage hydro. Heating is transitioning away from oil heaters to heat pumps, and electric heat is used in many homes. Transport is going electric: automobiles are becoming more electric, and fifty percent of Faroes use of oil is ship fuel, so new fuels/EV ferries are being piloted. Industry (fishmeal processing and salmon feed) is using big heat pumps.. Faroese approach emphasizes: increasing wind (off- and on-shore), supplementing storage (batteries, pumped hydro) to manage variability, electrifying transport and heating, and looking at green maritime fuels for shipping.

Denmark.: Denmark is a world leader in district heating and wind. Denmark has targeted eliminating coal by 2030 and electricity and heat being 100% renewable by ~2035. In 2022, Denmark went for net-zero by 2045 and 2030 GHG reductions of 70%. Already in 2020 wind energy provided ~50% of electricity in Denmark, with biomass, waste, and solar also adding to the mix. A national district heating grid (mainly biomass, waste, and heat pumps) delivers cost-effective heat to cities, reducing 30–40% of national emissions over ten years. Onshore and offshore wind farms and solar are being expanded in Denmark's plan, coal-fired power plants decommissioned, and oil-based heating installations replaced. Transport is transitioning to EVs and biofuels, and Danish companies are leading green shipping fuels (e.g. ammonia). Key measures: binding targets (e.g. net-zero by 2050), carbon pricing, renewable subsidies, and grid and storage investment. District energy is an example of the effectiveness of centralized planning and policy (e.g. mandatory connection legislation) in integrating renewables and realizing deep reductions

Hawaii (U.S.): Hawaii has established one of the most ambitious island targets: 100% renewable electricity by 2045 (first U.S. state to establish this target). Under this policy, the three large islands of Kauai, Maui, and Hawaii have earlier deadlines of 2035 for 100%. In 2024 roughly 33% of Hawaii's electricity came from renewables (mostly solar and wind); virtually all other energy (transport, heat) comes from expensive imported oil. To meet its goal, Hawaii is massively expanding solar PV (including rooftop and utility-scale) and onshore wind, while retiring oil-fired power plants. Hawaii Clean Energy Initiative (since 2008) also prioritizes energy efficiency and battery storage. With extremely high electricity prices (three times the U.S. average, Hawaii is aggressively pushing rooftop solar, grid stabilizing batteries, and transportation electrification (electric buses, vehicles) to replace oil. For instance, the state is funding electric bus initiatives and providing rebates for EVs. Policy instruments include renewable portfolio standards with financial incentives and ratepayer-funded green energy programs. Hawaii's strategy shows that even islands with tiny grids can integrate 30–40% solar/wind when backed by storage and demand management.

Greece's Aegean Islands: Greece's numerous islands have been used as experimental grounds for renewables. Greece rolled out ambitious "island energy autonomy" plans under EU funding (e.g. Horizon 2020) to minimize blackouts and fuel consumption. On Tilos (500 inhabitants), e.g., an 800 kW/2.8 MWh battery hybrid solar-wind microgrid has been installed. Tilos is now able to live off the grid and even sell surplus power to neighbors (Kos, Kalymnos), enhancing reliability. Such initiatives needed Greece to reform its legislation for microgrid operation and utility procurement of dispersed power. Likewise, new projects intend 100% renewables on non-interconnected islands such as Othonoi and Ereikoussa using the substitution of diesel generators with "hybrid power stations" (wind + PV + battery). The model usually involves local energy communities operating the systems. Overall, Greece's island policy is to develop solar-wind-battery microgrids, modernize regulation (grid codes, tariffs) and establish community trusts. These minimize diesel consumption (and GHGs) and improve resilience.

Comparative Analysis and Lessons for Pacific Islands

The table below compares key indicators, targets and strategies for the above case studies and for representative Pacific SIDS.

Table24: Lessons for pacific islands

Category / Strategy	Hawaii (USA)	Faroe Islands (Denmark)	Greece (Aegean Islands)	Lessons for Pacific Island Nations (PINs)
Renewable Energy Targets	Legally binding target of 100% renewable electricity by 2045. Some islands aim for 100% by 2035.	No legally binding 100% RE target; CO_2 reduction target –45% by 2030. Reached 40% RE by 2023.	Many Aegean islands aim for 100% RE by 2030. National goal: 60% RE by 2030.	PINs should legislate 100% renewable electricity targets with milestones and enforcement. Legal certainty attracts investment.
Electricity Mix (2023–2024)	33% RE (mostly solar + wind). Remaining 67% from petroleum. High grid costs.	10% RE (2023), plans to increase rapidly via wind, tidal, pumped hydro.	Varies by island. E.g., Tilos is 100% renewable with hybrid solar-wind-battery. Others use diesel + RE hybrids.	Deploy hybrid renewable systems (solar + wind + battery) tailored to each island. Reduce diesel reliance.
Grid Stability and Energy Storage	Large-scale batteries (e.g., AES projects); Virtual Power Plants (VPPs); smart metering.	Pumped hydro storage; wind-to-heat conversion; advanced smart grid controls.	Battery-supported microgrids; local grid control centers; automated demand-response.	Invest in smart grids, energy storage (Li-ion, pumped hydro), and virtual power systems for reliability.
Solar and Wind Deployment	Extensive rooftop solar PV programs; incentives for community	Expansion in onshore & offshore wind; tidal	Solar-wind microgrids dominate; community energy co-ops	Enable solar PV programs with community participation; create incentives

	solar. Wind on large isles.	R&D; solar emerging.	manage assets (e.g., Tilos Project).	for rooftop and microgrid-based wind/solar.
Electric Transport	Electric buses (e.g., Suva project); EV rebates; electric ferries under testing.	Hybrid-electric ferries; electrification of land transport.	EV incentives growing; limited inter-island EV logistics; short-distance EV deployment.	Promote EV adoption with incentives, ferries for short routes, and pilot green shipping tech. Integrate charging stations with RE.
Green Shipping and Maritime	Hydrogen & ammonia fuel pilots; Clean Ports Act mandates zero-emission harbor vessels by 2035.	Hybrid-electric ferries; wind-to-hydrogen for maritime fuel.	Diesel-electric ferry pilots; EU grants support port decarbonization.	Establish green maritime corridors, invest in hybrid ferries, and develop wind-to-hydrogen fuel chains.
Aviation Decarbonization	SAF blending pilot (30%); electric aircraft (e.g., Mokulele Airlines); R&D active.	Limited plans; fleet size small.	No SAF mandate; some participation in EU aviation decarbonization.	Partner with SAF producers; trial electric aircraft for inter-island flights; join regional SAF consortiums.
Industrial Decarbonization	Green Hydrogen Program for cement/steel; 30% CO_2 cuts by 2030; industrial heat pumps.	Electrified fisheries; wind-powered industrial heating in food sector.	Small-scale industries integrating solar water heating; energy audits required under EU rules.	Establish green hydrogen hubs, incentivize industrial electrification, and conduct mandatory energy audits.
Water Desalination	5 MW solar desalination project (2025); floating solar tested for water purification.	Wind-powered water pumping for remote areas; wind-to-water storage.	Islands using solar-powered desalination; battery backup in drought-prone areas.	Deploy off-grid solar and wind-driven desalination; utilize floating solar panels for energy-intensive water treatment.
Financing and Investment Strategy	Green bonds, climate resilience bonds,	Mostly state-backed financing; EU funds; grid	EU Green Deal & Horizon funding support; community-	Secure blended finance (PPPs, green bonds, grants). Encourage

	public-private partnerships (PPPs).	owned by public utility.	owned energy co-ops.	community co-ownership of RE systems to build local trust.
Community Engagement and Education	Consumer Energy Education Programs, Youth & Climate Education in schools.	High public trust in grid operator; energy cooperatives in villages.	Tilos Energy Cooperative; citizen science & energy literacy promoted.	Launch energy education programs, community RE co-ops, and local energy governance models.
Carbon Pricing and Regulation	Renewable Portfolio Standards; Net Metering; Clean Energy Authority oversight.	National carbon tax; maritime fuel emissions priced.	EU Emissions Trading System (ETS); energy permits regulated.	Introduce carbon pricing mechanisms to fund renewables and penalize diesel. Mandate emissions disclosure.

Implementation Strategies and Policy Options for Pacific Islands

The Pacific Island Countries (PICs) can apply the lessons above to their specific contexts. Major strategies are:

• **Scaling Renewable Generation**: Similar to Denmark and Greece, Pacific islands must invest in rooftop and utility solar PV (the sun is highly available), small wind farms, micro-hydropower in mountainous regions, and bioenergy (coconut/biodiesel). Governments need to revise codes (grid codes, permits) to permit hybrid systems and independent power producers, like Greece did. For instance, solar-wind-battery mini-grid development can substitute diesel for remote islands (UN/ADB investment of ~20 solar+battery mini-grids in Fiji is a model project. Pacific utilities can make mid-term targets (e.g. 70–80% RE in 2030) and formulate plans to achieve 100%.

•**Grid Stability and Energy Storage**: Islands with poor grids need to combine variable renewables with storage. Battery banks, pumped hydro storage or flywheels (like in the Faroe Islands) stabilize the grid. Similar is Samoa's investigation of pumped hydro ("like a lithium battery" for water). International support can facilitate the construction of this infrastructure (grid upgrade and storage tend to be beyond local budget.

• **Electrification of Transport and Equipment**: Following Denmark and Fiji, land transport should shift to electric. Islands can promote EVs (cars, buses, motorcycles) through incentives or public procurement. For example, Fiji's climate plan explicitly uses electric buses to cut emissions and Samoa and Tonga are introducing electric buses. Even island-hopping ferries may be powered electrically or by cleaner fuels: Faroe is investing in battery-electric ferries and green shipping fuels and Pacific shipping companies (such as Swire Shipping) are already testing biofuel blends (B30) on regional ships. Promoting such shifts will make "hard" sectors such as shipping and aviation decarbonized that Pacific economies depend on.

•**Efficiency and Demand Management**: Efficiency is the focus in all case studies. An example is Denmark's district heating which reduces losses, and Hawaii strongly advocates building efficiency. Pacific governments need to implement efficiency standards (buildings, appliances) and promote behavioral conservation to lower overall demand.

•**Policy and Regulatory Frameworks**: Targets must be underpinned by policy. Vanuatu's 100%-by-2030 target is underpinned by an exhaustive roadmap and initiatives such as net-metering, which enable consumers to sell surplus solar energy. Fiji has feed-in tariffs for renewables. Pacific states should adopt similar incentives (e.g. FITs, net-metering, tax breaks) and disincentives (tax on fossil fuels, fuel import duties). Carbon pricing or GHG levies (as supported by Pacific leaders in global shipping can raise revenue for clean energy.

•**Finance and International Support**: Almost all PIC renewable strategies are subject to external funding. Nations need to actively pursue climate finance (Green Climate Fund, ADB, UN programs) to finance infrastructure (grids, storage) and capacity development. Public–private partnerships, such as UNDP's invitation for Mini grid developers in Fiji, can mobilize external investment. Yet, writes Nature Climate Action, donor-driven projects have to be culturally suitable: engaging communities through Pacific-style consultation (e.g. talanoa dialogues) promotes local uptake and sustainability.

•**Community Energy Models:** Some islands (Faroe, Greece) have established local energy cooperatives or communities to own/run renewables. Pacific villages can also establish community energy schemes, providing locals with ownership of microgrids or solar farms. This would respect traditional decision-making: involving chiefs and local leaders in the planning is more likely to be successful.

•**Hard-to-Abate Sector**: Pacific countries have little heavy industry, but areas such as food processing, tourism, and mining (phosphate, for instance) need to be decarbonized. Switching pumps and machinery to clean energy (such as Faroe has done in fish processing with heat pumpsnordicenergy.org) can be used. Tourist operators can use solar and electric transport.

Objective5: Carbon Credit potential in Pacific Islands

Pacific Island nations have extensive forests, mangroves, and reefs that are of global importance as carbon sinks. As WWF explains, the Pacific "hosts considerable terrestrial and marine ecosystems of global value for their biodiversity and carbon mitigation potential," and Pacific peoples custodians of a "greater ratio of carbon sequestration potential per capita than any comparable-sized region". Indeed, a hectare of Pacific mangrove may sequester at the order of 1,000–1,700 tCO_2e (e.g. Fiji's Rewa Delta mangroves average ≈1,703 tCO_2e, whereas new mangroves sequester about 90 tCO_2e/ha/year on average. Renewable energy and energy-efficiency projects by contrast yield smaller per-unit reductions (e.g. ~0.25 tCO_2/kWh displaced diesel.

Table25 : Summarizes key project types, assumed baselines and typical mitigation rates (per unit scale)

Project Type	Baseline / Mechanism (per unit)	Carbon Impact (tCO_2e/unit-yr)	Examples
Solar PV	Displaces diesel power (0.25 tCO_2/kWh) 1 MW =2,000 MWh/yr => 500 tCO_2e/yr.	0.25 tCO_2/MWh (diesel baseline) → 500 tCO_2e per MW installed/yr	Fiji targets 100% RE (427 $ktCO_2$ savings) by 2030 -1 MW PV yields 0.5 kt/yr.
Wind / Hydro / Geothermal	Similar principle (displace fossil).	Variable; often 0.2–0.3 tCO_2/MWh if diesel baseline.	Vanuatu has small hydro potential; Papua New Guinea has geothermal prospects.
Bioenergy (biogas, biomass)	Methane capture or biomass replaces fuel. E.g. pig manure: each animal 0.5–1 tCH_4/yr if unmanaged (13–27 tCO_2e avoided). Waste-to-energy displaces imports.	Depends on feedstock. Roughly **10–30** tCO_2e/ha/yr or per facility; a 100-ha energy crop plantation (biomass) could avoid 3000 tCO_2e/yr.	FAO/UNDP studies show pig farms and organic waste could yield substantial methane reductions. Pacific projects: e.g. Solomon Is. biogas feasibility studies.
Afforestation / Reforestation	New forest growth on degraded land. Net uptake 5–10 tCO_2/ha/yr	5–10 tCO_2/ha/yr (e.g. Samoa's coconut	Example: Samoa's plan to replant 3,785 ha agroforest (coconut

	(tropical long-term average).	agroforestry 5.6 t/ha/yr).	palms) yields 21,200 tCO_2e/y - Fiji, Vanuatu and others have large underplanted areas.
Forest Conservation (REDD+)	Avoided deforestation. Baseline high carbon stock (e.g. intact tropical 150–200 tC/ha). Savings equal stock that would have been lost.	Large: preventing 1 ha clear-cut saves 500–1000 tCO_2e (stock) and avoids 5–10 tCO_2e/yr leakage.	PNG and Solomon Tribes (Babatana) are protecting rainforest to sell credits. Ongoing projects: PNG uplands, Solomon rainforests.
Mangrove Restoration (Blue Carbon)	Mangrove soils/biomass sequester 600–1,000 tC/ha (2,200–3,700 tCO_2e/ha). New plantings accumulate 900 tCO_2e/ha over decades (90 tCO_2e/ha-yr).	90 tCO_2e/ha-yr (after establishment); stock 1,000–1,700 tCO_2e/ha.	Example: Restoring 100 ha new mangrove → 9,000 tCO_2e/yr (long term). Mangroves in Samoa: +18.7 ha (5% area) gives 1,683 tCO_2e/yr. Fiji and Solomon have active mangrove projects.
Seagrass and Salt Marsh (Blue Carbon)	Seagrass soils up to 1,000 tC/ha (3,700 tCO_2e/ha); global median 24 tC/ha (0.3 m soil). Seagrass growth slower (few t/ha-yr).	On order of 5–10 tCO_2e/ha-yr (coastal wetland regrowth).	Significant long-term soil storage; Pacific data sparse. Seagrass in NZ/Pacific stores very high carbon. Must be preserved (avoided loss) for credits.

Carbon Market Mechanisms in the Pacific

Carbon credits are sold either on compliance markets (e.g. Paris Article 6, Kyoto's CDM) or voluntary markets (VCM) under private standards. In practice, Pacific Islands have thus far mostly engaged in voluntary schemes. Voluntary carbon trades globally exceeded US$1 billion in 2021, with strong demand for nature-based credits. Pacific engagement is however still in its infancy: WWF records only 12 registered voluntary carbon projects in the Pacific region (Fiji, PNG, Solomon, Vanuatu, etc.), worth ~2.87 million credits (tCO_2e). Papua New Guinea (four projects) and Fiji (three) make up the overwhelming majority (PNG alone ~75% of credits). Most Pacific projects are forestry (REDD+/afforestation) or small energy projects; some (e.g. Fiji's Drawa Rainforest) utilize Plan Vivo or VCS standards. Under the Kyoto Protocol's Clean Development Mechanism, Fiji had four CDM projects (hydro, landfill methane, cookstoves) totaling ~323,000 CERs issued. Three have already completed crediting; only a cookstove project remains potentially active, now shifting to VCS. PNG and Samoa had very minimal CDM activity due to small project scales. As Kyoto schemes are closed, the Paris Agreement's Article 6 is the new compliance track. Fiji's 2021 Climate Act explicitly defines "carbon sequestration property rights" and requires regulatory approval of projects, putting Fiji on the early movers list to access Article 6 and voluntary markets. COP27 Pacific delegations' statements highlighted that Article 6 cooperation could channel climate finance into additional emissions reductions and adaptation. (For example, Article 6.2 ITMOs could facilitate bilateral trades with buyer countries.) Other Pacific governments are still formulating carbon regulations. Notably, PNG has placed a moratorium (March 2022) on new voluntary REDD+ projects until a national carbon markets law is enacted. The Solomon Islands has no specific carbon market framework. In general, Pacific states are exploring a mix of market approaches: some entering the global voluntary carbon market (VCM), others preparing for Article 6, and all considering how these fit with their NDCs.

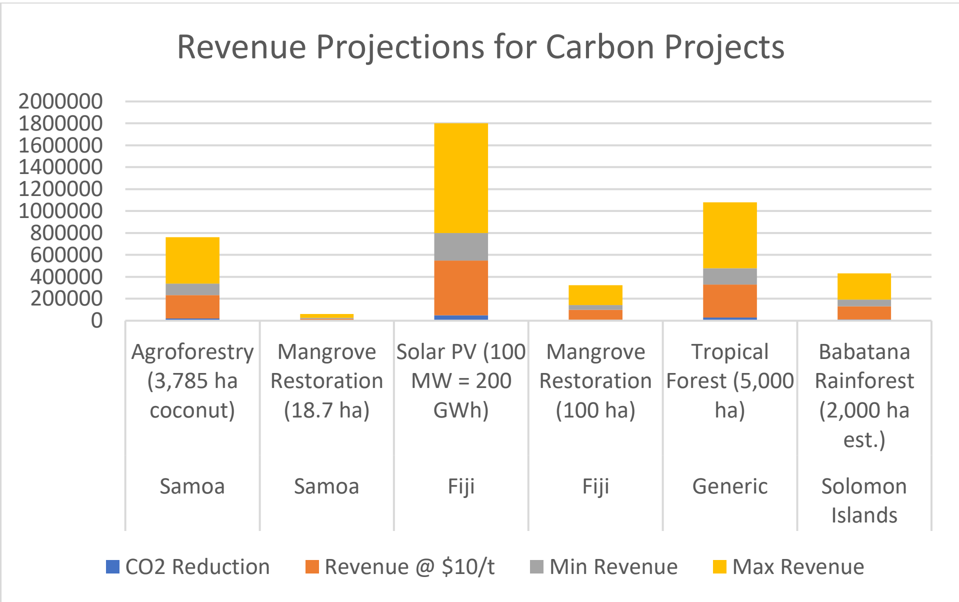


Fig 12: Revenue projections for carbon projects

The graph indicates estimated revenues from various carbon reduction projects in Pacific Island countries, with focus on CO_2 reduction potential. The 100 MW solar photovoltaic project in Fiji is expected to earn the highest revenue, at $1.8 million, followed by a 5,000-hectare tropical forest project with revenues of more than $1 million. Samoa's agroforestry project covering 3,785 hectares also has high potential, with small-scale mangrove restoration in Samoa and Fiji earning slightly lower but significant financial returns. Babatana Rainforest in the Solomon Islands will likely earn moderate carbon revenues. The estimates are made on CO_2

reductions, base price at $10 per ton, and minimum-to-maximum revenues, thus indicating economic viability of nature-based and renewable energy approaches to climate change mitigation.

Barriers to Carbon Projects: Pacific carbon activities face legal, institutional, and technical constraints, including customary land tenure, unclear property rights, and inadequate land-use records. MRV requirements are expensive and burdensome, and shortcuts can compromise project integrity. Most Pacific countries lack full carbon legislation and market exposure, except for Fiji's Climate Change Act. PNG is only beginning to formulate rules, and projects heavily depend on foreign grants. Price volatility, double counting under Article 6, and transport issues in remote areas further hinder progress.

Policy Recommendations

- Legal frameworks must be put in place to regulate carbon rights, enable project approval, and guarantee integration with Article 6 and voluntary carbon markets (VCM).
- Institutional Capacity: Develop national capacity in MRV, carbon accounting, and project design, with support from institutions such as UNDP, GGGI, and SPREP.
- Land Tenure and FPIC: Secure ownership, guarantee benefit-sharing, and maintain local control. Create community forest carbon businesses and new tenure arrangements.
- Project Co-benefits: Highlight biodiversity, resilience, shoreline protection, and livelihoods. Offer incentives (tax relief, grants) to high-integrity projects.
- NDC Integration: Integrate carbon activities into Nationally Determined Contributions (NDCs) and Low Emissions Development Strategies (LEDS). Harmonize with Paris Agreement Article 6 mechanisms.
- Finance and Market Access: Support aggregated project portfolios, regional carbon credit platforms (such as Indo-Pacific Offset Scheme), low-interest finance, and open registries.

Objective 6: Climate Vulnerability and Risk Assessment of Pacific Island Energy Infrastructure

Introduction: Pacific Island Countries (PICs) and Small Island Developing States (SIDS) face significant climate risks due to geographical exposure, aging infrastructure, and diesel dependence. Energy infrastructure, including power plants, fuel storage, and microgrids, is vulnerable to sea-level rise, storm surges, and flooding. Imported diesel dependence, which can reach 10-13% of GDP, can be disrupted by cyclones, heatwaves, drought, and rising seas. The IEA and IPCC warn that SIDS are disproportionately exposed to climate change and need to build resilience to high temperatures, rising seas, and extreme weather. Slow-onset climate threats, such as sea-level rise, groundwater salinization, drought, and rising temperatures, already affect islands. Coastal flood losses are expected to be 10-20 times higher in 2100, and sea-level rise between 2030-2050 could double flood frequency. Catastrophic storms and El Niño/La Niña events also pose significant risks. Resilient future-proof energy infrastructure is crucial for the future of Pacific economies, with standards like FESRIP 2021-2030 aiming for climate-resilient energy transitions.

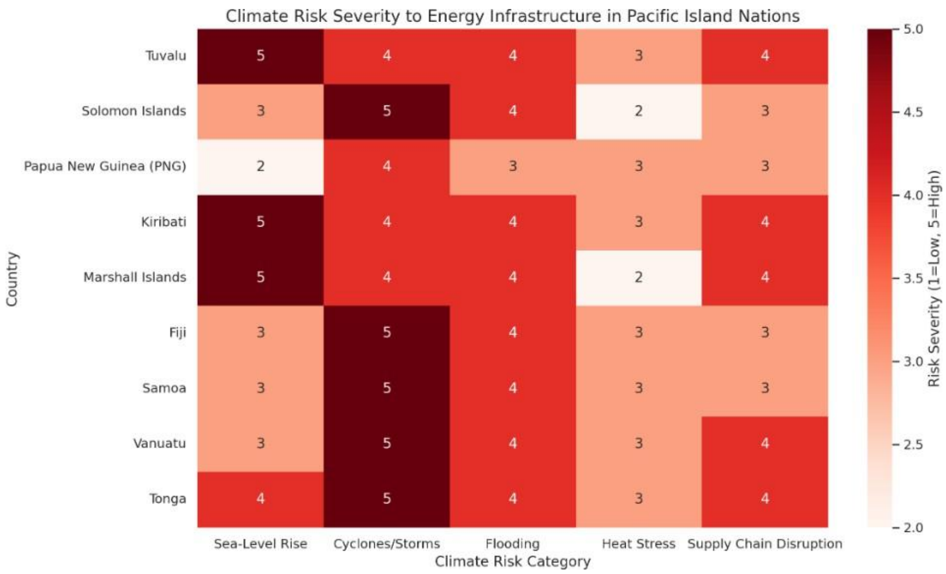


Fig 13: Climate risk category

Conducting a CVRA: Methodological Steps and Tools

A Climate Vulnerability and Risk Assessment (CVRA) follows a structured four-step process: (1) hazard identification, (2) exposure assessment, (3) vulnerability analysis, and (4) risk evaluation.

- **Hazard Identification**: It involves the mapping of gradual and sudden limate threats such as sea-level rise (SLR), storm surges, tropical cyclones, floods, droughts, and heatwaves. This involves the combination of various data sources such as global and regional climate projections such as CMIP6 for storms and rainfalls, histories of disasters for the past as received from EM-DAT or FMS, and observations from national meteorological agencies. Use of scenario analysis through pathways such as RCP4.5 or RCP8.5 facilitates understanding of possible changes in frequency and intensity of hazards. Importantly, participatory methods involving consultations with local communities and indigenous knowledge facilitate the understanding of localized or emergent threats such as salinity intrusion and altered cyclone tracks. Use of tools such as GIS-based storm surge models, global sea-level rise viewers (e.g., NOAA), and NASA and JAXA's databases on hazards facilitates spatial mapping of floodplains, storm-swept areas, and areas prone to drought. Pacific RISA (Regional Integrated Sciences and Assessments) stresses the use of multi-hazard approaches considering that Pacific islands experience compounded climate vulnerabilities.

- **Exposure Assessment**: It is geospatial mapping of energy infrastructure locations and types. This is creating detailed lists of diesel and renewable power plants, fuel storage sites, ports, distribution lines, substations, and microgrids from government GIS maps, utility records, and field surveys. These infrastructure maps are overlaid with hazard zones to determine which energy infrastructure is in high-risk zones. GIS platforms such as ArcGIS or QGIS, and risk visualization tools such as GFDRR Risk Layers or the Pacific Sea-Level Rise portal, facilitate this analysis. Exposure assessments also consider dependency chains, such as how fuel delivery routes or port access could affect energy availability in disasters. Modeling tools such as PSS/E or HOMER can model how outages could cascade through a grid.
- **Vulnerability Analysis:** Evaluate the sensitivity and adaptive capacity of exposed assets. Technical and socioeconomic resilience of the energy infrastructure are analyzed. Technical vulnerability analyzes the performance of the infrastructure under duress; for instance, it includes the comparison of wind speed with turbine design specifications or assessment of tolerance levels for transformer salinity. Socioeconomic vulnerability includes factors like the absence of backup power systems, reliance on single energy sources (e.g., imported diesel), and economic viability of utility providers and families. Vulnerability is generally assessed with the help of indicators like the age of the infrastructure, asset maintenance status, fragility curves, and adaptive capacity of the community. In the energy sector, adaptive capacity includes the availability of alternative energy sources, backup equipment, institutional resilience, and local technical expertise. Small islands are likely to be more

vulnerable due to their remoteness and low human resources base. According to Pacific researchers, the participation of the community is critical: energy resilience planning has to involve local stakeholders to ensure assurance of power continuity under adverse conditions.

- **Risk Evaluation**: It consolidates data from previous steps to measure possible failure or loss. It comprises both qualitative tools, like risk matrices, and quantitative tools measuring expected damage cost or outage probability assuming different climate conditions. For instance, measuring the impact of a 10-year storm or 1-meter sea-level rise on energy infrastructure can help to identify which assets should be prioritized for urgent intervention. Risk is typically calculated by weighing the probability of a hazard against exposure and vulnerability of assets. Outputs include metrics like expected downtime, repair cost, or disruption to service. Risk mapping allows the location of high-risk areas and critical infrastructure to guide targeted resilience measures. Spatial overlays and scenario-based sensitivity analysis tools help planners to visualize overlapping risks and make decisions under uncertainty.

Table26: Infrastructure Resilience and Disaster-Risk Reduction Strategies

Category	**Strategies**	**Key Actions & Examples**
Engineering & Technical Solutions	Physically harden energy infrastructure	Elevate/flood-proof power plants, substations - Underground cables with water-tight enclosures - Design poles/towers for Category 5 cyclones - Shore protection (e.g., seawalls, levees) - Smart grid tech: auto-switches, sensors - Redundancy: multiple feeders, spare transformers - Climate-resilient solar (high-wind panels, secure mounts)- Heat-tolerant batteries, safe placement - Climate-ready designs add ~3% cost, but save 4× in long term
Institutional & Regulatory Approaches	Strengthen policy and utility capacity	CVRA-based asset management plans - Staff training in emergency response - Maintenance for resilience (e.g. vegetation clearance) - Mutual aid pacts for post-disaster recovery - Periodic CVRA mandate by regulators - Early warning links between met agencies & grid ops - R&D in climate data and hazard forecasting

		- Resilience-linked energy pricing or subsidies
Community-Level Strategies	Empower communities for resilience	Promote solar home systems, mini/microgrids - Community ownership/cooperatives - Awareness training (e.g., inverter shutdowns) - "Quick-response" teams with generators, repair kits - Social protection: fuel vouchers, relief support - Rooftop solar on schools/clinics for disaster continuity - Community-run bioenergy or water-energy solutions
Using CVRA for Early Action & Planning	Enable early preparedness and long-term resilience	Identify high-risk assets for early warning - Pre-position spares (transformers, fuel) - Plan storm shutdowns to minimize damage - Inform risk-based insurance (e.g., parametric insurance)

Key Recommendations: Purposefully conduct rigorous, participatory C-VRIAs. Implement the hazard→exposure→vulnerability→risk process in a multi-hazard approach. To build Pacific Island Countries' energy resilience, there must be the proper Climate Vulnerability and Risk Infrastructure Assessments (C-VRIAs) and public consultation. Resilience requirements for energy planning must cover cyclone-resilient infrastructure and resilient technology subsidies. Climate-proofing the grid needs mobilization of adaptation finance through instruments such as green bonds and blended funds. Decentralized renewable investment in solar PV and batteries and microgrids can facilitate disaster recovery. Contingency planning and early warning systems must boost preparedness. Lastly, energy resilience must be mainstreamed in national climate and disaster policies with cross-sectoral coordination.

Roadmap for Sustainable Energy Transition in Pacific Island Countries:

Fig 14: Roadmap for Sustainable Energy Transition

Conclusion:

The study confirms that Pacific Island Countries (PICs) remain greatly dependent on imported fossil fuels, and 80-90% of their energy is still provided by oil and diesel. Penetration of renewables remains patchy and limited, with Papua New Guinea leading at around 61% renewables, Fiji and Samoa at around 40-50%, and microstates like Tuvalu or Tonga having little or no grid renewables. Most islands have less than 30% renewable penetration on average. Diesel and heavy fuel oil still produce over 80% of electricity in most cases. Electrification coverage is also mixed, with larger countries at around 95-98% national access, but coverage drops significantly in more remote areas. Carbon intensity as a whole is high across the region, at around 0.70-1.90 kg CO_2/MJ across measured PICs. Investment in renewables annually is also low. Fuzzy TOPSIS comparison reveals clear leaders and laggards. The top performer with the highest renewable penetration, high investment, and advanced policy/institutional preparation is Fiji. Samoa and Tonga are close behind, whose improved renewable installation and governance are confirmed. Mid-rank performers have moderate development, typically being hampered by small economies or incomplete infrastructures. Kiribati, Vanuatu, Solomon Islands, and Marshall Islands are at the bottom due to low investment, poor energy policy, and technical constraints. Qualitative analysis identifies enduring obstacles to change, e.g., fragmented governance structures, financial capacity, and public acceptance, among others. To achieve these objectives, enhanced policy structures, e.g., adopting transparent regulations and incentives, inclusion of renewable objectives in the national development plans and National Development Goals (NDCs), and climate finance, will be needed. Carbon rights legal structures and MRV capacity building, and regional credit platforms to cluster projects, are proposed. Institutional change is proposed, with joint technical capacities building by governments and donors in planning and project design. Priorities include mass deployment of decentralized renewable systems, grid modernization, transport electrification, increasing energy efficiency in buildings and industry, mobilization of the private sector through public-private partnerships, and regional resource pooling.

References:

1. ADB (2020) *Pacific Renewable Energy Investment Facility – Grant to Tuvalu*. Asian Development Bank.
2. ADB (2021) *Pacific Energy Update 2021*. Manila: Asian Development Bank.
3. ADB (2024) *Pacific Energy Trends and Outlook 2024*. Asian Development Bank.
4. Blechinger, P., Cader, C., Bertheau, P. (2016) 'Remote area power supply in island regions: a review of policy and business models', *Renewable and Sustainable Energy Reviews*, 59, pp. 952–964.
5. CIA (2024) *Tuvalu Country Profile*. Central Intelligence Agency – The World Factbook.
6. Dornan, M. and Jotzo, F. (2014) 'Renewable energy deployment in small island developing states: Successes, setbacks, and the role of international partnerships', *Energy Policy*, 64, pp. 278–285.
7. EBSCO (2024) *Tuvalu: Energy Statistics and Policy Snapshot*.
8. Energy Fiji Ltd (2024) *Annual Energy Report 2024*.
9. ESCAP (2021) *Samoa's National Energy Transition Profile*. Bangkok: UNESCAP.
10. ExxonMobil PNG (2024) *PNG LNG Development Report*.
11. Fiji Department of Energy (2023) *National Energy Policy 2023–2030*.
12. Fiji Ministry of Economy (2023) *Low Emissions Development Strategy 2018–2050*.
13. GGGI (2022) *Pacific Green Finance Framework*. Global Green Growth Institute.
14. IEA (2020) *World Energy Outlook 2020*. Paris: International Energy Agency.
15. IEA (2022) *Smart Grids in Island Systems: The Case of Crete*.
16. IEA (2023) *Clean Energy Transitions Indicators Database*.
17. IMF (2022) *Samoa: Energy Subsidy Reforms*. International Monetary Fund.
18. IPCC (2021) *Sixth Assessment Report: Impacts, Adaptation and Vulnerability*.
19. IRENA (2021) *Renewable Energy Market Analysis: The Pacific*. Abu Dhabi: IRENA.

20. IRENA (2023) *Fiji and the Pacific Energy Landscape*. International Renewable Energy Agency.
21. IRENA (2024) *Global Renewables Outlook 2024*.
22. JICA (2021) *Solar Battery Storage Initiatives in the Pacific Islands*.
23. Maleko, G. and Kumar, A. (2022) 'Community energy models in Pacific SIDS', *Energy Research & Social Science*, 89, p. 102527.
24. Marshalls Energy Company (2024) *REGAIN Project Status Report*.
25. MNRE (2022) *Samoa LEDS Report 2022–2030*. Ministry of Natural Resources and Environment.
26. Narayan, S. and Narayan, P.K. (2024) 'Energy security, emissions, and renewables in Pacific Island Countries', *Energy Economics*, 126, p. 106783.
27. Oberender, D. (2024) *Energy Access and Climate Risk in Tuvalu*. Pacific Research Institute.
28. Pacific Climate Change Portal (2024) *Tuvalu Energy Indicators*.
29. Pacific NDC Pacific Hub (2022) *Tuvalu Updated NDC Submission*.
30. PCREEE (2017) *Pacific Centre for Renewable Energy and Energy Efficiency Annual Report*.
31. PIFS (2020) *Pacific Energy Policy Gaps and Private Sector Readiness*. Pacific Islands Forum Secretariat.
32. PNG Department of Energy (2023) *National Electrification Rollout Plan*.
33. PNG Hydropower Authority (2024) *Hydropower Potential in Papua New Guinea*.
34. PNG Power Ltd (2024) *Annual Generation Report 2024*.
35. Prasad, A., Boulding, R. and Misir, M. (2021) 'Energy modeling for island nations: A LEAP-based analysis for Vanuatu', *Renewable Energy*, 179, pp. 1189–1201.
36. REN21 (2021) *Renewables 2021 Global Status Report*. Paris: REN21.
37. REN21 (2022) *Policy Measures for SIDS Renewable Transitions*.
38. Samoa Observer (2024) *ADB-backed Solar Projects on Savai'i Island*.
39. Santos (2024) *Papua LNG Production Overview*.
40. SPC (2022) *Tuvalu Energy Strategic Action Plan Update*. Secretariat of the Pacific Community.
41. SPREP (2020) *Framework for Resilient Development in the Pacific (FRDP)*.
42. SPREP (2020) *Status of Renewable Energy Deployment in the Pacific*.
43. The Global Economy (2022) *Electrification Rate Database – Tuvalu*.
44. UNDP (2023) *Pacific Energy Access Diagnostics Report*.
45. UNESCAP (2023) *Pacific Energy Progress Report 2023*.
46. UNFCCC (2021) *Voluntary Carbon Market Readiness in PICs*.
47. UNFCCC (2024) *Climate Vulnerability Infrastructure Assessment: Pacific Region*.
48. US DOE (2020) *Hawaii 100% Renewable Portfolio Standard Case Study*.
49. Wikipedia (2024) *Tuvalu Renewable Energy Development*.
50. Wong, C., Prasad, A. and Singh, R. (2023) 'Policy simulations for climate resilience in island energy systems using LEAP', *Journal of Cleaner Production*, 402, p. 136768.