Kosrae State Energy Master Plan

Final Report to the Department of Resources and Development

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Acronyms and Abbreviations

ADB	Asian Development Bank
BESS	Battery Energy Storage Systems
COL	Concessional OCR loans
CO_2	Carbon dioxide
CPUC	Chuuk Public Utility Corporation
DSM	Demand-side management
EE	Energy Efficiency
EPA	Environmental Protection Agency
ESS	Energy storage systems
FSM	Federated States of Micronesia
GCF	Global Climate Fund
GHG	Greenhouse gas
IBRD	International Bank for Reconstruction and Development
IDA	International Development Association
IMF	International Monetary Fund
INDC	Intended Nationally-Determined Contribution
IPP	Independent power producer
JICA	Japanese International Cooperation Agency
KUA	Kosrae Utilities Authority
LRMC	Long-run marginal cost
LV	Low-voltage
MD	Maximum Demand
MDB	Multilateral Development Bank
MFD	Maximising Funds for Development
MFAT	New Zealand Ministry of Foreign Affairs and Trade
MV	Medium-voltage

NEP	National Energy Policy
NEW	National Energy Workgroup
NGO	Non-government organization
NPV	Net Present Value
O&M	Operations and maintenance
ODA	Overseas Development Assistance
OCR	Ordinary Capital Resources
PPA	Power Purchase Agreement
PSC	Public sector comparator
PUC	Pohnpei Utilities Corporation
PV	Photovoltaics
R&D	Research & development
RE	Renewable energy
SEW	State Energy Workgroup
SHS	Solar home system
tCO_{2}-e	Tonnes of CO_2 equivalent
TOR	Terms of reference
US$	United States dollars
VfM	Value for money
YSPSC	Yap State Public Service Corporation

Executive Summary

This report presents the Energy Master Plan for Kosrae State. The Master Plan has been prepared in conjunction with the Master Plans for the other three Federated States of Micronesia (FSM), and for the nation.

These Master Plans have been developed during the period of unprecedented technological change. The last few years have seen remarkable and disruptive improvements in renewable energy (RE) technologies and battery storage. Further expected reductions in the costs of these technologies provide FSM with an opportunity to combine achievement of its environmental targets with ensuring that electricity production remains affordable.

At the same time, FSM faces a significant challenge of delivering electricity to people living on outer islands. At present, there is significant social and economic divide: people living on the four main islands enjoy almost universal access to the main electricity grids. By contrast, people on outer islands and in outlying communities have almost no access to electricity. The Master Plans are designed to address this divide in a financially and socially sustainable way.

The modeled plans can be fully funded and financed and will achieve the National Vision Statement for Energy

The plans will provide **electricity access**, at good quality service standards, to more than 80 percent of FSM households by 2020 and to almost every household by 2023. We define access as the practical ability of each household to be able to receive affordable electricity

The plans achieve FSM's **RE, diesel reduction, and emissions reduction** objectives.

Figure ES.1: Summary of National-level Outcomes of State Energy Master Plans

Electricity Access (HH)	RE Percentage	Diesel Use (million gallons)	Electricity CO_2 Emissions (tonnes)
2018: 67%	2018: 9%	2018: 4.2	2018: 43,490
2020: 82%	2020: 49%	2020: 2.9	2025: 21,980*
2027: 100%	2027: 66%	2027: 2.1	2027: 21,980
2037: 100%	2037: 79%	2037: 1.5	2037: 15,769

*We show 2025 for comparison with UNFCCC emissions target for 2025.

The plans were developed using two types of modeling:

- HOMER modeling, incorporating best available information on the current and future costs of various technologies, as well as the technical characteristics of various generation units, was used to develop the optimal generation fleet and distribution network
- Financial modeling was used to estimate the annual cash needs of all utilities, on the expectation that cash revenues would fully cover operating and maintenance

costs (including fuel costs) and the costs of debt service (interest payments and repayment of principal), as well as provide a cushion for contingencies.

RE, emissions, and diesel reduction objectives can be achieved at no extra cost to consumers (compared to meeting demand using diesel)

The generation mixes we propose in the plans exceed the state-level and national RE generation targets at a lower cost than any other generation mix (including greater use of diesel) and without compromising reliability. In all states, increasing RE generation is the least-cost way to meet future electricity demand (with support from diesel generation and storage to ensure reliability). The reduction in the use of diesel more than compensates for the additional investment cost. As a result, from 2019, the Master Plans together achieve an overall national RE contribution of over 40 percent (against a national target of 30 percent by 2020).

Although diesel will continue to play an important role in ensuring security of supply, the use of diesel for electricity generation falls by over 60 percent. There is a corresponding decline in carbon emissions.

Our analysis, presented in the Appendices and the accompanying models, demonstrates that there is no longer a trade-off between least-cost electrification and achieving climate change and RE targets.

The State Energy Master Plans set out a technically feasible, financeable, and implementable pathway for each state to provide a reliable and environmentally sustainable electricity service to all residents

Our proposed investment strategy has four limbs:

- Some new diesel generation capacity to ensure security of supply
- A large amount of new solar PV capacity (with storage) to reduce reliance on diesel and meet demand growth. This also lowers the cost of generating electricity
- Re-investment to sustain the distribution network, along with minor expansions to connect new customers
- Investment to serve unelectrified communities.

The electricity tariffs required to fund the implementation of the Master Plans will depend on two factors:

- The cost of finance—The total financing package for the initial implementation of the Master Plans (for the period to 2023) will need to be assembled during 2018. While some donors have already made commitments to grant funding, the final financing package may consist of a mix of grants, concessional loans and commercial finance (including independent power producers, IPPs). The cost of finance will depend on the composition of the financing package
- The rate of transition from the current reactive maintenance to full planned maintenance and planned asset replacement.

We have modeled several financing scenarios on the common assumption of immediate transition to planned maintenance and replacement, as well as building in a financial “cushion” for contingencies. Based on these reference scenarios, Yap and Pohnpei would be able to fully fund the implementation of the Master Plans while gradually reducing tariffs over time.

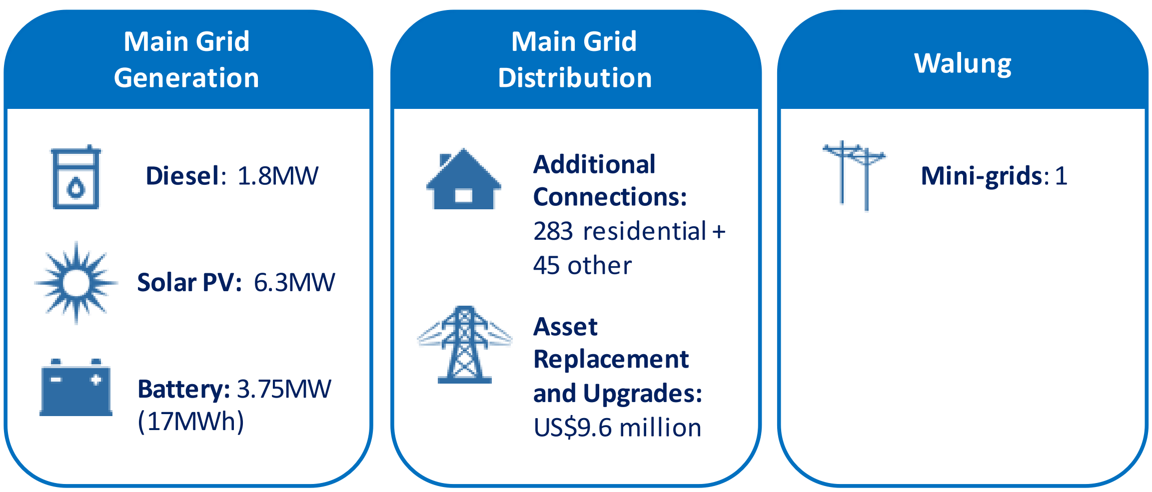
Kosrae will need to manage the transition to planned maintenance and asset replacement more carefully, but generally will be in a position to fully fund the implementation of the Master Plan at the current level of tariffs in real terms. Tariffs could be reduced over time with greater reliance on concessional finance.

Chuuk faces the greatest challenge as it has the highest proportion of unelectrified households on isolated outer islands. Once they are electrified, they will be costly to serve. Even with full grant funding for the roll-out of mini-grids to isolated communities, Chuuk may need to consider small tariff increases over the next 4 to 5 years. Over time, growth in demand will enable tariffs to return to their current levels. As a better option, we recommend that the FSM Government work with donors and consider application of its own grant funds to cover the initial operating costs of the new mini-grids. Such transitional funding would enable Chuuk to keep tariffs at a stable level in real terms.

Our modeling suggests that Kosrae will need to invest US$37.3 million in new and replacement electricity infrastructure over the next 20 years

New infrastructure includes adding renewable generation capacity on to the main grid, adding grid connections on the main grid, and developing electricity infrastructure in Walung (Figure ES.2).

Figure ES.2: Summary of New Infrastructure in Kosrae Technical Investment Plan



The total investment requirement will be:

Table ES.1: Capital Expenditure Requirements for Kosrae (US$ million 2016)

	2018	2019–2023	2024–2028	2029–2033	2034–2037	Total
New Main Grid Generation	2.49	6.42	6.71	3.18	2.67	21.47
Main Grid Generation Replacement	0.00	0.50	0.16	1.75	2.57	4.97
Main Grid Distribution	0.28	4.64	1.74	1.86	1.61	10.12
Mini-grids	0.00	0.47	0.04	0.08	0.11	0.70
Total	2.77	12.03	8.64	6.86	6.96	37.26

The objective is to ensure that by the end of 2019 Walung consumers have access to electricity. The share of RE in Kosrae's electricity generation would be above 50 percent from 2019 onwards. Kosrae would also reach its target of doubling solar PV capacity.

1 Introduction

This Report presents the Energy Master Plan for Kosrae State.

This State Energy Master Plan contributes to the National Vision Statement for Energy: to "improve the life and livelihood of all FSM residents with affordable, reliable and environmentally sound energy". It sets out what investments are required to achieve this vision in the electricity sector over the next 20 years, and how the investments will be financed and implemented.

The Plan was developed in close collaboration with the Department of Resources and Development and the Kosrae State Energy Workgroup. A wide range of government, private sector, community, and other stakeholders also provided valuable input throughout the process (see Appendix A).

The main body of this report:

- Describes our **approach** to developing the Master Plan (Section 2)
- Presents the **Technical Plan** that outlines the generation and distribution assets that need to be purchased for the state to be able to provide a reliable, sustainable electricity service to all residents at least-cost (Section 3)
- Presents the **Financing Plan** that outlines how the Technical Plan can be feasibly financed and funded (Section 4)
- Presents the **Implementation Plan** that discusses key considerations for and risks of rolling out the Technical Plan (Section 5)
- Highlights the key **outcomes** the Master Plan will help Kosrae achieve (Section 6).

The appendices set out supporting information, including the underlying assumptions, methodologies, and context underlying the Plan. All data are available in an electronic format.

2 Approach

Each State Energy Master Plan includes a Technical Plan, a Financing Plan, and an Implementation Plan. These components of the Master Plans were produced after several iterations based on consultations and other feedback. In this section we outline the approach used to develop the components of the Master Plans and the inputs used. Details of the inputs and calculations are provided in the appendices and in the accompanying spreadsheets.

It is important to emphasize that master planning should be seen as a process, rather than as a one-off exercise for the next 20 years. All plans should be regularly updated to reflect the best available information and to incorporate the lessons from implementation. The State Energy Master Plans are forward-looking documents, based on load forecasts, expected technological developments (including the costs of various technical components), diesel price projections, and the forecasts of future economic and financial conditions. Inevitably, the future will not be quite as forecast. For this reason, the models, inputs, and calculations that have been provided to the FSM counterparts are designed to be easily and regularly updated.

Finally, while the Energy Master Plans set out the development of FSM's electricity sector over the next 20 years, the focus is on the next 4 to 5 years. While there will be both the need and the opportunity to revisit and revise the Plans for the period after 2023, the Energy Master Plans for the 2019-2023 period require immediate commitment and implementation.

2.1 Technical Plan

We developed a technical generation and distribution plan for each of the four states of the FSM. The plans are least-cost solutions to meet each state's access, reliability, social, and environmental objectives. We separated each state into three service areas: main grids, mini-grids, and stand-alone solar systems, to provide cost effective and implementable electrification solutions across the FSM.

The main grids are located on the main island of each of the four states. We developed least-cost generation plans for the main grids using HOMER. Key inputs for the main grid HOMER modeling were: natural energy resources, energy forecasts, peak demand forecasts, agreed reliability targets and generation planning criteria, diesel price projections, generation asset capital costs, operating costs, and maintenance costs. The technical distribution plans were developed through expert engineer judgment based on data from similarly islanded grids, and information on existing and planned distribution networks provided by utilities. Details of inputs to the main grid generation and distribution plans are available in Appendix B.

We recognize that these technical plans are being developed during a period of unprecedented technological change in the electricity sector. The costs and the reliability of RE technologies, particularly solar PV and battery storage, have been undergoing disruptive changes. Only a few years ago, governments faced a trade-off between achieving environmental and other social objectives through promoting the use of new technologies, and keeping the costs of electricity systems at affordable levels. For countries such as the FSM, where least-cost reliable generation was previously provided by diesel, this trade-off no longer exists. Combination of solar PV and battery storage is now economically competitive with diesel generation.

On current projections of future diesel prices and battery storage costs, the Master Plans still recommend some new and replacement investment in diesel capacity to ensure security of supply. However, these projections will need to be kept under constant review. Further disruptive changes, such as greater than expected declines in battery storage costs or unexpected spikes in diesel prices may make it more economic to achieve reliability through greater use of battery storage capacity. The analytical tools provided as part of these Master Plans will allow such decisions to be made in the future.

For areas outside the main grids, we recommend either mini-grids or stand-alone solar systems. The decision on whether mini-grids or stand-alone solar system were best for each island and/or village were based on factors such as the size of the community, population density, and the availability of regular transport to deliver fuel supplies. In assessing these factors, we relied on a combination of geospatial analysis, census data, and engineering judgment.

We developed least-cost generation plans for mini-grid areas using HOMER. Key inputs for the main grid HOMER modeling were: energy forecasts, peak demand forecasts, agreed reliability targets and generation planning criteria, diesel price projections, generation asset capital, operating costs, and maintenance costs. For all mini-grids we recommend hybrid diesel and solar with storage generation to provide cost-effective generation while maintaining security of supply. Distribution plans for each mini-grid were developed through expert engineer judgment. Details of inputs to the mini-grid generation and distribution plans are available in Appendix B. As with the main grids, the requirement for diesel capacity will need to be kept under review as technology costs and diesel prices change. However, the Master Plans envisage that most of the proposed mini-grids will be rolled out over the period to 2023. In practice, this means that investment decisions on the components of the mini-grids will need to be made based on the best currently available information.

Generation plans for stand-alone solar systems include one system per household, school, dispensary, and other community buildings. We sized household systems based on World Bank energy access tiers. Systems for other buildings were sized to allow for their requirements, and school systems given additional capacity to allow for other community uses. Details of inputs to the stand-alone solar generation plans are available in Appendix B. No distribution network is required in areas with stand-alone solar systems.

2.2 Financing Plan

Achieving the objectives of the Master Plans will require upfront capital investment in new generation and distribution capacity, and ongoing operations and maintenance (O&M) spending to keep the system functioning. Capital investment cost must either be paid for by grant funding or be spread over time through financing.

The Master Plans are not mere wish lists. They are designed to be financially viable. Financial viability means that the plans can be fully funded and financed within the means available to the Government and consumers of the FSM.

Our approach to confirming the financial viability of the Master Plans is based on developing a financial model for each state to estimate the annual cash requirement by the electricity utility to cover the costs associated with the Master Plans.

We note that FSM utilities are not profit-making organizations. It is common for non-profit utilities, such as consumer cooperatives, to set tariffs on the "cash need" basis. For example, this is the approach adopted in the United States and in the Philippines. Cash need should cover all costs as well as providing any required financial "cushion" for the on-going stable operation of the utilities.

The annual cash need consists of the sum of the operating expenses and any debt service payments. Operating expenses include O&M expenses for generation and distribution assets, administration and general expenses[1], and fuel cost. Our assessment is that FSM utilities generally need to spend more on maintenance of their existing assets. We develop an estimate of maintenance expenses based on a move from the current reactive maintenance to scheduled maintenance. For all new assets added as part of the Master Plans, we estimate the costs of scheduled maintenance. We also include an O&M contingency to account for FSM-specific challenges in maintaining assets in isolated locations.

The estimated revenue requirements are significantly influenced by the rate of transition from reactive to planned maintenance and by the degree of "cushion" required, including contingencies. This allows for a degree of financial flexibility and will help utilities smooth their cash flow requirements.

Estimates of capital investment and operating expenses (including fuel costs) for generation and distribution assets come from the technical modeling outlined in Section 2.1. We also incorporate the costs of new connection and internal house wiring into the investment program, to enable consumers to pay off connection costs over time. Administration and general expenses are estimated based on current spending and growth in consumption. Expected power sales in each state are based on the electricity consumption forecasts we developed. Details of inputs to the financial model are available in Appendix C.

Debt service payments cover the total amount required each year to service outstanding loans taken for capital investment. We have included a debt service coverage margin on top of debt service coverage payments because many lenders will require a minimum debt service coverage ratio to secure loans.

Some multilateral and bilateral donors have already indicated commitments to provide some grant funding over the next 4 to 5 years. The Government of the FSM also has some resources that can be made available to the electricity sector. However, the full financing package for the initial implementation of the Master Plans—that is, the investment program to 2023—will need to be assembled over the remainder of 2018 in close consultation with donors, lenders, and potential investors.

We modeled several financing scenarios based on different levels of grant funding and on different combinations of concessional and commercial financing. The financing package will have a material effect on the cash need of the utilities. Details of our financing assumptions are available in the State Energy Master Plans and in Appendix C.

Cash in is estimated as tariff multiplied by the forecast electricity consumption, adjusted for the level of collection. The Master Plans are viable if cash need is fully covered by cash in. Overall, we find that the Master Plans are viable over a broad range of financing scenarios:

- For Pohnpei and Yap, the implementation of the Master Plans will unambiguously lead to lower tariffs over time
- For Kosrae, full reliance on commercial financing may require an increase in tariffs over the medium-term. However, we discuss options for Kosrae to achieve the implementation of the Master Plan without an increase in tariffs

[1] Administration and general costs include fixed costs such as staff salaries and training.

- Chuuk faces the greatest challenge as it has the highest proportion of unelectrified population. Some increase in tariffs may be unavoidable. However, we consider various options that may allow Chuuk to keep any such increase to a minimum
- The current tariffs are affordable, in the sense that consumers are demonstrably able and willing to pay those tariffs.

In considering the financial viability of the Master Plans, we are mindful of the desire of the FSM and State Governments to achieve a reduction in electricity tariffs. Clearly, paying less for electricity would be beneficial for consumers. Lower tariffs would also enable businesses to expand production. At the same time, tariffs must continue to cover the full cost of the electricity system. Increased grants from donors would enable tariffs to be lowered and could have a material effect on the economic well-being of FSM.

However, if the increased grants are not available, FSM would still be better off fully implementing the proposed Master Plans with more expensive sources of financing than constraining the implementation to the available grant funding.

We assume that the current tariff structure between customer segments will be maintained. We have considered time-of-use and seasonal tariffs. However, we found that the electricity consumption pattern is relatively flat both during each 24-hour period and across the seasons. There is relatively little to be gained from smoothing consumption further. The additional cost of more sophisticated metering infrastructure required to implement a more complex tariff structure does not appear to be justified.

Within the current tariff structure, we recommend a uniform tariff that would be paid by all consumers in a customer segment (residential, commercial, and government) in that state—regardless of location. While this involves a cross-subsidy from consumers on the main grid to consumers on outer islands, we believe that a uniform tariff would:

- Ensure that consumers on outer islands can afford to pay for electricity, and hence provide for meaningful access
- Create a sense of social solidarity, and hence improve collections on outer islands
- Give residential consumers on outer islands access to the same level of cross-subsidy from government and commercial users as is currently enjoyed by the residential consumers on the main grid.

We note that over time, FSM utilities should consider changes in the structure of the tariffs to reduce cross-subsidies from commercial to residential consumers. We also recommend that Yap consider including a variable fuel charge component into its tariff structure to make fuel price adjustments more automatic and less politically complex.

2.3 Implementation Plan

The Master Plans rely on more than just money flowing in. If that money cannot be used in an efficient and timely way, the objectives of the Plans will not be met.

We consider three aspects of implementation:

- Rollout of physical capital
- Implementation roles and capacity
- Implementation risks.

In Appendix H, we also discuss implementation approaches, such as outsourcing. Functions would not be outsourced because the utility doesn't have the resources, but rather because outsourcing can deliver superior value for money (VfM) than the utility performing the function internally.

Rollout of physical capital

We separate activities to be carried out over the 20-year period of the Master Plans into generation capital projects and distribution improvements. We then create a rollout plan that outlines the sequencing of these activities.

The rollout plan includes all the projects that the utilities have already committed to. We then add the new generation and distribution projects from the technical plans. On the main grids, we use the timing and sequencing of projects that our modeling recommends. For unelectrified islands, we start with the most accessible islands first to test out the technology, billing, logistics, and management approach before rolling out to less-accessible islands. For stand-alone solar systems in particular, it will be important to test out and monitor a prepayment system in an accessible location first. In all cases, community buy-in will be critical, with at least a majority of households in the community ready and willing to receive, pay for, and make the best use of, the infrastructure.

If stakeholders prefer different sequencing, the costs and benefits of this would need to be carefully considered. Providing electricity to all schools and dispensaries first may be a priority, but it will be much more efficient to electrify whole communities at once due to fixed costs like training staff and transporting materials.

Implementation roles and capacity

We have carefully reviewed the utilities' current engineering, planning, and financial analysis capabilities. We discuss the roles of the utilities and others in implementing the Master Plans, and what additional capacity they are likely to need to successfully perform those roles. The costs we have estimated for implementing the State Energy Master Plans reflect the additional human capacity required. In the National Energy Master Plan, we include a budget allowance for technical assistance and various coordination, monitoring and evaluation, and administrative functions related to Master Plan implementation.

Implementation risks

We highlight state-specific risks that exist because of the use of specific technologies (for example, additional hydropower in Pohnpei) or the state's particular geographic or social context. In Appendix E, we then discuss risks that are common to all four states. Common risks arise from states using similar technologies, infrastructure, and institutional arrangements.

2.4 Outcomes

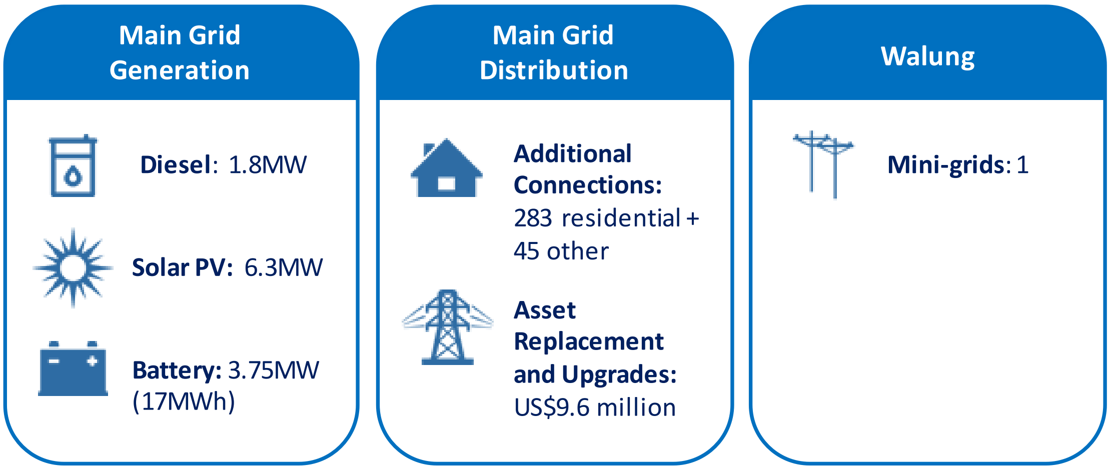
We show how the Master Plans achieve state and national targets for: electricity access, reliability, the proportion of electricity generated from renewable sources, lower diesel reliance, and lower greenhouse gas (GHG) emissions.

3 Technical Plan

The Technical Plan outlines required upgrades and improvements to the grid on Kosrae. In addition, we recommend a mini-grid as the least-cost option for achieving the desired level of service in Walung. On the grid, the plan includes investment in new solar PV capacity to reduce the cost of electricity, as well as in new diesel capacity to ensure security of supply. Distribution asset replacements and upgrades are needed to improve system reliability, while connections on the main grid are for the growth we have forecast for number of households and new businesses. There is also a need to move part of the distribution inland because of coastal erosion. We have incorporated this project into the Master Plan.

Figure 3.1 summarizes the new infrastructure required in Kosrae (not including replacements of existing generation infrastructure).

Figure 3.1: Summary of New Infrastructure in Kosrae Technical Investment Plan



3.1 Kosrae Main Grid

Over the 20-year Master Plan period the main grid on Kosrae needs investment in: new generation capacity, refurbishment and replacement of existing generation assets, refurbishment and replacement of existing distribution assets, and shifting the distribution network inland to account for coastal erosion.

We have labelled recommended generation capacity 'new' if the assets change the makeup of the generation system. All other capital is included as 'replacement', and includes totally replacing an asset, large asset refurbishment, and replacing major components of an asset. Diesel generators are categorized as 'new' if they add additional generation capacity or are purchased when a generator of different capacity comes offline. Capital investment in diesel generators is categorized as 'replacement' when a like for like replacement of a generator is made or when a major refurbishment of an existing generator is undertaken. Table 3.1 shows the new generation capacity our modeling suggests is required. In the text we explain the new generation investments, as well as discuss when replacements or refurbishments are required.

Upgrades to the existing diesel generation capacity are already under way

Three diesel gensets are currently being installed in the new Kosrae power station. We assume that these will come online in 2018 or 2019, along with 0.3MW of solar PV. This new capacity (combined with the existing diesel and RE capacity) is sufficient to meet electricity demand on the main island over the 20-year period of the Master Plan, and allows the existing diesel gensets to be retired over the life of the Plan, as the new RE assets are progressively installed.

New RE capacity provides an opportunity to reduce overall costs

Over the 20 years of the Master Plan, we recommend that 6.3MW of new solar PV generation is installed alongside 17MWh of battery storage. The proposed mix of storage and solar PV in Kosrae is slightly different to the other states.

New solar PV capacity will reduce the average cost of electricity by reducing the Kosrae Utilities Authority's (KUA) diesel fuel use and therefore expenditure on diesel fuel. The upfront capital cost of solar PV will be either paid for through grants or smoothed over time with cheap concessional financing so the cost per kWh will be lower than that provided by diesel generation. Investment in diesel generation in 2018 is still required to ensure security of supply.

Table 3.1: Kosrae New[2] Generation and Storage Capacity for Main Grid

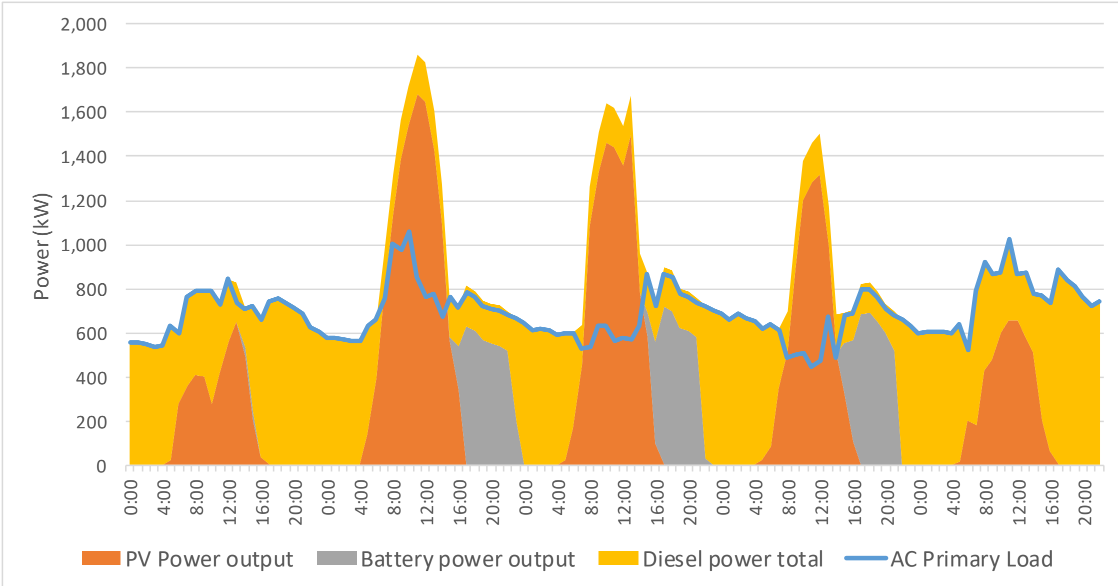
	2018	2019–2023	2024–2028	2029–2033	2034–2037
Diesel	1.8MW	-	-	-	-
Solar PV	0.3MW	2MW	2MW	1MW	1MW
Battery storage	-	1.25MW	1.25MW	0.75MW	0.5MW
Battery inverter	-	5MWh	8MWh	3MWh	1MWh

In the period 2019–2023:

- 2MW of PV should be developed at one or more solar sites. Some of the capacity could be deployed behind the meter on government or commercial buildings
- Energy storage should be deployed at the Kosrae power station, providing 1.25MW of capacity and 5MWh of storage to manage integration of the PV plants and increased use of RE
- The recommended investments in solar and storage will meet a large proportion of Kosrae's demand in 2023, reducing the use of diesel and therefore the cost of electricity (Figure 3.2)
- Genset #4 should be retired in 2020.

[2] New only includes new generation assets that change the generation mix. Like for like replacement of retired assets is not included.

Figure 3.2: Kosrae Load Duration Curve and Contribution of Generation Sources, 2023



In the period 2024–2028:

- Genset #8 should be retired in 2024
- 2MW of PV should be developed at one or more solar sites. This could also be deployed behind the meter on government or commercial buildings
- The battery inverter capacity should be increased by 1.25MW and 8MWh of storage to address load growth and maintain reliability standards.

In the period 2029–2033:

- 1MW of solar PV capacity should be developed to offset increasing use of diesel generation as loads increase. This capacity could be developed at a new site, added to an existing solar site, or deployed behind the meter on government or commercial buildings
- The battery inverter capacity should be increased by 0.75MW and storage capacity by 3MWh to address load growth and maintain reliability.

In the period 2034–2037:

- Genset#6 should be retired in 2034
- 1MW of solar PV capacity should be developed
- The battery inverter capacity should be increased by 0.5MW and storage capacity by 1MWh.

Replacement capital will also be needed to maintain existing generation capacity

The current PV solar plants will reach the end of their lives during the period of the Master Plan, and our analysis suggests they should be replaced. We assume energy storage capacity achieves a 10-year life and so will need to be replaced during the Master Plan timeframe. Diesel gensets will likely need to be replaced, depending on the duty cycle and level of RE contribution.

The spreadsheets that will be provided as part of data handover break down the replacement capital needed over the 20-year period.

New connections will be needed as the number of households increase

Apart from Walung, Kosrae is completely electrified. However, our forecast shows that the number of households will increase by about 1 percent each year, which will require new connections.

We assume two new commercial and government connections each year, except in the period between 2019 and 2023, when we expect an extra connection from the refurbishment of a water bottling plant.

Table 3.2 shows the new residential, commercial, and government connections. The costs of these connections are provided in the accompanying spreadsheets.

Table 3.2: Average Annual New Connections

	2018	2019-2023	2024-2028	2029-2033	2034-2037
New Residential Household Connections	13	13	14	15	15
New Commercial & Government Connections	2	3	2	2	2

The existing distribution network will need upgrades and maintenance

General network and demand growth includes minor feeder extensions and updating transformers as peak demand gradually increases and the expenditure cannot be tied to any specific large customer load project. Our analysis suggests that this will cost US$200,000 every 5 years.[3]

We used the asset register to make replacement estimates (see Table 3.3). Details of asset lifespans and replacement costs are in Appendix B.

Table 3.3: Distribution Network Asset Replacement (average annual figures, US$)

	2018	2019–2023	2024–2028	2029–2033	2034–2037
Age-based Asset Replacement	252,000	263,569	283,939	305,883	327,052

We are aware that the KUA plans to relocate part of the 13.8kW distribution lines further inland, to reduce the risk of damage from coastal erosion. We assume 10km (6.2 miles) of line is relocated, at a cost of US$3 million.

[3] The network expansion requirement is likely to be quite limited due to network layout and because Kosrae is a small island. However, to be conservative we include a general allowance for some expansion/augmentation that is not specifically directed to one customer or project.

3.2 Walung Mini-grid

We recommend a mini-grid for Walung. We compared connecting Walung to the main grid versus building a mini-grid, and found that the mini-grid was the least-cost option.[4]

A mini-grid will be more expensive than stand-alone solar systems (given the small number of households), but is expected to provide a higher quality of service. It can help achieve a balance between cost and stakeholders' desire for Walung (the only unelectrified community in the state) to have a service level closer to that experienced by the rest of Kosrae.

We recommend a mixture of diesel, solar, and storage for the mini-grid (see Table 3.4), as the least-cost way to meet the demand at the required service standards.

Table 3.4: Walung Mini-grid Capacity 2018–2037

Asset Type	Capacity
Diesel	2x 20kW
Solar	40kW
Storage	120kWh
Converter	15kW

We suggest an LV underground network for distribution. The initial costs are higher than an above-ground network, but less maintenance is needed and it is more weather resistant. The estimated cost is US$110,000.

4 The capital cost of the line was nearly double that of the mini-grid, and the operating costs would also be higher with the cable. However, there may be some advantages to KUA to managing an integrated network.

4 Financing Plan

The total amount needed to cover capital expenditure across the lifespan of the Master Plan is US$37.3 million

Over half of the capital expenditure over the 20-year Master Plan period is on new generation capacity for the main grid (Table 4.1). We recommend ongoing investment in solar PV with storage to lower the cost of generation and reduce reliance on diesel generation. Required expenditure for the main grid distribution network includes the US$3 million cost of moving part of the distribution network inland.

Table 4.1: Capital Expenditure Requirements (US$ million 2016)

	2018	2019–2023	2024–2028	2029–2033	2034–2037	Total
New Main Grid Generation	2.49	6.42	6.71	3.18	2.67	21.47
Main Grid Generation Replacement	0.00	0.50	0.16	1.75	2.57	4.97
Main Grid Distribution	0.28	4.64	1.74	1.86	1.61	10.12
Mini-grids	0.00	0.47	0.04	0.08	0.11	0.70
Total	2.77	12.03	8.64	6.86	6.96	37.26

Operating expenses include:

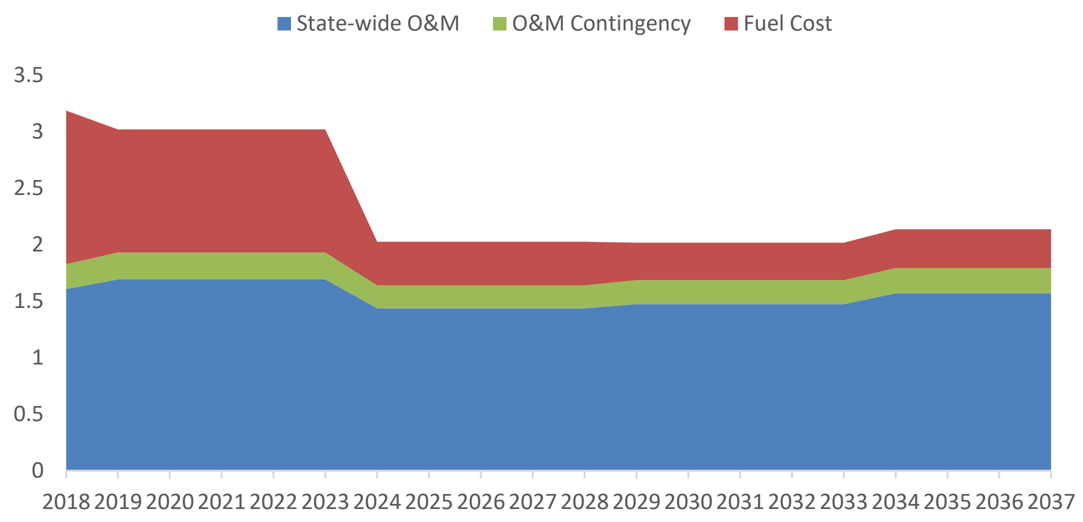
- Main grid generation O&M cost
- Main grid distribution O&M cost
- Main grid fuel cost
- Walung mini-grid generation O&M cost
- Walung mini-grid distribution O&M cost
- Walung mini-grid fuel cost
- Administration and general fixed costs
- A 15 percent contingency on all technical O&M expenditure
- Project preparation costs (5 percent of total capital investment) for new capital projects (includes owner's engineer, procurement, and so on).

Operating expenses fall by US$1.05 million a year between 2018 and 2037 because of a reduction in diesel use

Fuel cost makes up almost 50 percent of total operating expenses in 2018. As new RE capacity comes online, fuel consumption declines and fuel cost falls to less than 20 percent of operating expenses. The shift from diesel to renewables also leads to a fall in generation operating and maintenance costs on Kosrae because of lower run hours for diesel generators. State-wide operating expenses (excluding the fuel cost) increase from 2024 onward. This is because administration and general costs, and distribution costs on Kosrae, grow with load growth; and operating expenses for the new Walung mini-grid are added.

The net effect is a reduction in operating expenses of US$1.05 million per year from 2018 to 2037.

Figure 4.1: Estimated State-wide Operating Expenses, US$ million



The financial spreadsheet provided to KUA and the FSM Department of Resources and Development includes a more detailed breakdown.

We calculate debt service payments for three scenarios

The debt service payment made each year will include a repayment of the principal of the loan(s) (capital amortization) as well as an interest payment (cost of financing). We have calculated debt service payments for three scenarios:

- Scenario 1: All capital expenditure is paid for with grant funding
- Scenario 2: Capital expenditure for the mini-grid in Walung is paid for with grant funding. Capital expenditure on the Kosrae main grid is financed with concessional loans. Details of assumed loan terms offered by donor organizations are available in Appendix C
- Scenario 3: Capital expenditure for the mini-grid in Walung is paid for with grant funding. Capital expenditure on Kosrae's main grid is financed with commercial loans. (This scenario approximates the cost of getting IPPs for solar and storage as well as of KUA financing the replacement of the network on its own balance sheet.) Details of assumed loan terms offered by commercial banks are available in Appendix C.

In Scenario 1 and Scenario 2, the power sales revenue earned from keeping tariffs at their current level covers the cash requirements over the 20-year Master Plan period

The net present value (NPV) of net cashflow over the 20 years of the Master Plan is positive in Scenario 1 and approximately zero in Scenario 2 if tariffs are kept at their current level in real terms. Cash required exceeds the expected revenue from current tariffs in all years to 2024. From 2024 onward, as revenue grows with electricity demand and new renewable investment lowers operating expenses, expected revenue exceeds cash required in all years.

Unlike other states, Kosrae is not expecting a significant increase in demand. For this reason, in Scenario 3 the NPV of net cashflow over the 20 years is negative if tariffs are kept at their current level in real terms.

Figure 4.2: Cash Requirements in the Three Financing Scenarios, US$ million

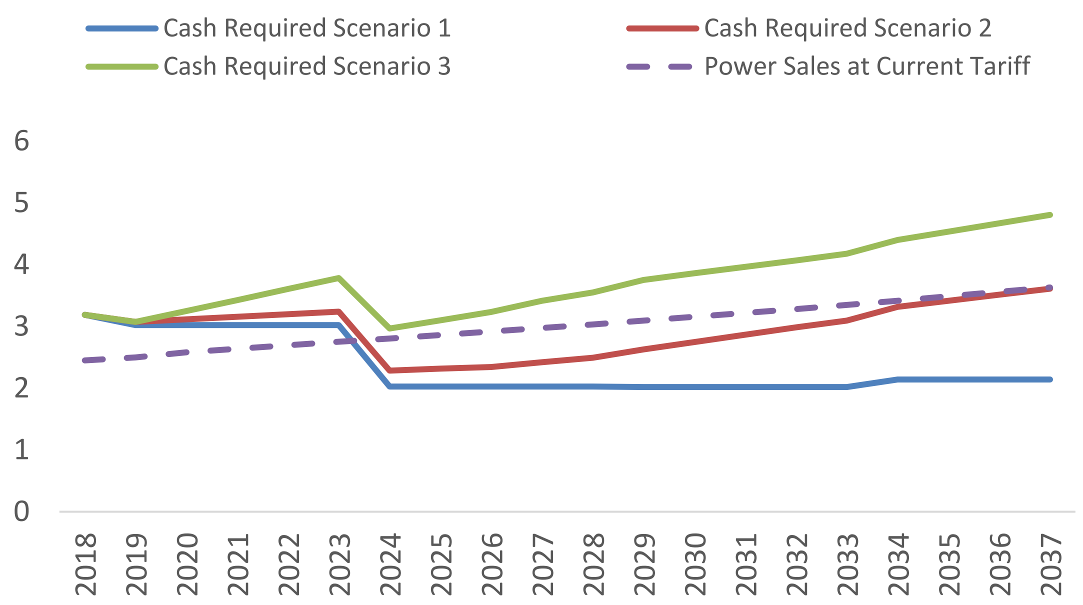


Table 4.2: Average Tariff Required to Cover Cashflows by 5-year Period and Customer Segment, US$ per kWh[5]

	Current	2018	2019–2023	2024–2028	2029–2033	2034–2037
Scenario 1						
Residential	0.44	0.57	0.50	0.31	0.28	0.27
Commercial	0.48	0.62	0.55	0.33	0.30	0.29
Government	0.52	0.68	0.60	0.36	0.33	0.32
Scenario 2						
Residential	0.44	0.57	0.53	0.36	0.39	0.43
Commercial	0.48	0.62	0.58	0.39	0.43	0.47
Government	0.52	0.68	0.62	0.42	0.46	0.51
Scenario 3						
Residential	0.44	0.57	0.57	0.49	0.54	0.57
Commercial	0.48	0.62	0.62	0.54	0.59	0.63
Government	0.52	0.68	0.68	0.58	0.64	0.68

We propose that Kosrae work with donors and lenders to develop a financing package that would allow the Master Plans to be implemented without an increase in tariffs. One option would be to bid out solar/storage investment through IPPs on the basis that the full charge

[5] We assume tariff structure across customer segments is unchanged, and adjust current tariffs for each segment by a constant percentage to calculate the tariff requirements.

by the IPP should not exceed the cost of avoided diesel. Such pricing by IPPs would allow KUA to access private financing without having to maintain a cushion of revenue to cover the debt service cover ratio itself. This may also allow KUA to avoid the operating cost contingency.

We recommend that Kosrae announces a commitment to a medium-term stable tariff path.

5 Implementation Plan

Here, we discuss the rollout of investments, and what additional capacity within KUA will be needed to implement and maintain these investments.

In the funding and financing plan, we have ensured KUA has all the resources it needs to successfully implement the investment plan. However, outsourcing is a possibility if it provides greater value for money. This is discussed in Appendix H.

5.1 Rollout of Physical Capital Projects

We separate activities to be carried out over the 20-year period of the Master Plan into generation capital projects, and distribution improvements. The rollout plan outlines the sequencing of these activities (Table 5.1).

When sequencing the rollout plan we consider already committed/funded capital projects. These include:

- The new Japanese International Cooperation Agency-funded power plant (2x600kW diesel gensets), which we assume will be operational in 2018
- The new World Bank-funded 600kW genset located in the old power station building to provide backup capacity, which we assume will be operational by 2019
- The relocation of 6.2 miles (10km) of the main feeder to align with new road construction.

We include new connections in the rollout plan. On top of this, asset-based replacement and general network upgrades will be ongoing as peak demand increases.

Table 5.1: Rollout Plan for Kosrae

Year	2018	2019-2023	2024-2028	2029-2033	2034-2037
Main Grid[6]	**Generation capital projects** ▪ 1.8MW diesel ▪ 300kW solar PV **Additional connections** ▪ 13 new residential connections ▪ 2 new commercial connections	**Generation capital projects** ▪ 2MW solar PV ▪ 1.25MW (5MWh) storage **Additional connections** ▪ 13 new residential connections a year ▪ 2 new commercial connections a year ▪ Water bottling plant connection **Distribution** ▪ Relocation of distribution lines further inland	**Generation capital projects** ▪ 2MW solar PV ▪ 1.25MW (8MWh) storage **Additional connections** ▪ 14 new residential connections a year ▪ 2 new commercial connections a year	**Generation capital projects** ▪ 1MW solar PV ▪ 0.75MW (3MWh) storage **Additional connections** ▪ 15 new residential connections a year ▪ 2 new commercial connections a year	**Generation capital projects** ▪ 1MW solar PV ▪ 0.5MW (1MWh) storage **Additional connections** ▪ 16 new residential connections a year ▪ 2 new commercial connections a year
Mini-grid: Walung		**Mini-grid construction** ▪ 2x20kW diesel ▪ 40kW solar PV ▪ 120kWh storage ▪ 15kW converter ▪ LV underground network	**Replacement** ▪ Replace one diesel genset	**Replacement** ▪ Replace second diesel genset ▪ Replace batteries	**Replacement** ▪ Replace converter

[6] Generation capital projects for the main grid show new capacity but not replacements, overhauls, or retirements of existing capacity.

5.2 Implementation Capacity

To implement the Master Plans, KUA will need additional staff

We have considered whether KUA has the capacity to implement the activities required in the plan. Table 5.2 highlights the additional capacity that will be needed.

The requirements in Table 5.2 relate to ongoing operational, managerial, and maintenance functions and do not include building the new infrastructure (for which we assume contractors will be engaged). The table shows when these staff would need to be engaged or trained, but once engaged they would continue their work throughout the whole Master Plan period (and beyond), unless otherwise stated.

Table 5.2: Capacity Requirements for KUA

	1–5 Years	5–10 Years
Main grid	2 new engineers hired and trained in RE and control systems	1 new engineer trained in RE and control systems 2 new electrical maintenance technicians
Walung mini-grid	4 operators hired and trained for the Walung mini-grid. At least 1 should be an electrical technician. Ideally 1 should be a mechanic, but if this is not possible a mechanic could be sent from town as needed An existing engineer or technician from KUA should be given responsibility for technical support to Walung 1 casual billing assistant in Walung (most of the administration would be done from KUA's head office) An existing KUA staff member should be given explicit responsibility for coordinating the electrification program for Walung (part-time role)	

KUA will take lead responsibility for implementing the Master Plan investments. Even if KUA chooses to outsource some project implementation tasks, it would still need to manage these contracts and oversee implementation.

The State Energy Workgroup (SEW) has an interest in providing strategic guidance and in monitoring progress and results to ensure that the desired state-level policy outcomes are met. SEW does not have the capacity to fulfil this role.

The Master Plan includes a budget for technical assistance to fulfil the various monitoring, coordinating and administrative functions (the National Energy Master Plan provides more details). We assume this will be covered by a grant and do not include it in the tariff calculation.

5.3 Implementation Risks

We discuss the main risks specific to Kosrae. Appendix E then highlights various risks that are common to all states using the same technology and investments proposed in this Plan.

Managing the mini-grid in Walung will present a new challenge for KUA due to its limited experience with mini-grids

From a technical perspective, the main risk is inexperience with the battery and control system. One of KUA's engineers will need to be trained in how the system works and should be involved in the design, construction, and commissioning. A web-based monitoring system that can be accessed from KUA main office will also help with this.

To avoid any difficulties with collecting payments, the Master Plan provides all mini-grid customers in Walung with Cashpower meters. We also propose that a KUA staff member be given explicit responsibility for coordinating and monitoring the electrification of Walung.

Kosrae's small population might make it difficult to find and retain skilled staff

Knowledge sharing and support across the four states could help mitigate this risk.

Land

The additional 4.5MW of solar capacity on the main grid will need about 45,000m^2 (about 484,000 square feet) of land (or roof space). There is potential to use the government land at the center of Kosrae island (Figure 5.1). This land is not developed and would need to be cleared and levelled before it could be used. We understand that an area of government land outside the main town may be available. There may also be a possibility of installing floating PV capacity on the calm water between the airport and the mainland.

Some of the required PV capacity can be housed on government buildings. The government stated during consultations that it will work with KUA to put grid-integrated PV with storage on the roofs of government buildings. Previously the Government had intended to install stand-alone solar without storage.

A feasibility study currently being undertaken by Entura is checking the feasibility of specific sites for solar PV in Kosrae. Once these sites have been identified, a meeting among relevant stakeholders in Kosrae will be held to see what can be made available.

Figure 5.1: Government Land in Kosrae

Source: Kosrae Island Resource Management Authority

We assume that the Walung mini-grid generating units will be located on public land. The solar systems are small enough to be accommodated on public buildings such as the school and church. The community—as the only one in Kosrae State without electricity access—is likely to be engaged in the program and may be able to help facilitate land access for distribution lines.

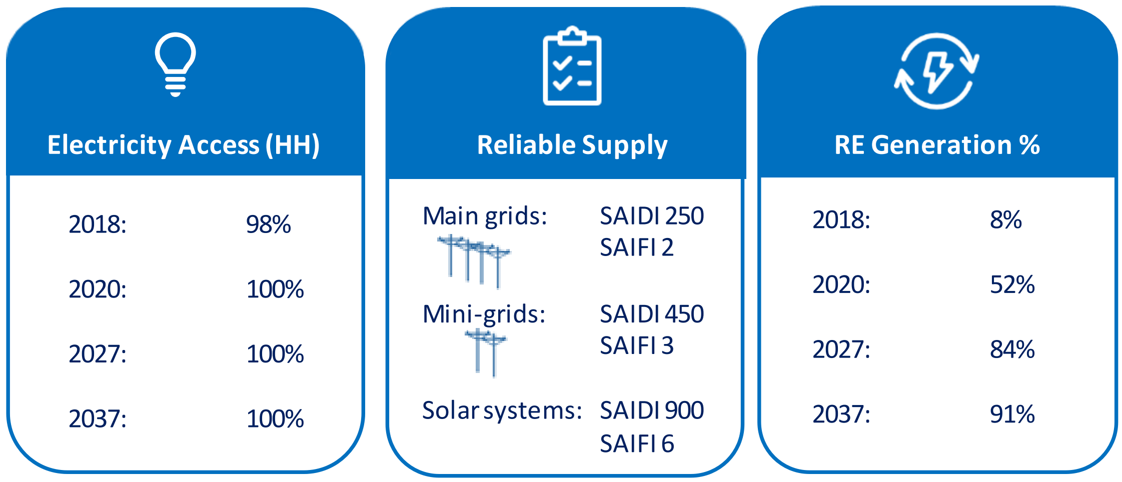
Coastal erosion

During consultations, stakeholders in Kosrae highlighted the risk of coastal erosion. KUA is already planning to relocate part of its road and electricity distribution network in response to this risk. If households very close to the shore request connection to the electricity network, KUA will need to assess the risk of coastal erosion before installing the new distribution infrastructure and house wiring.

6 Outcomes

If Kosrae implements the above plans it can expect to meet its main energy sector objectives. Figure 6.1 summarizes the outcomes the plans will help Kosrae achieve.

Figure 6.1: Summary of the Outcomes of the Kosrae State Energy Master Plan

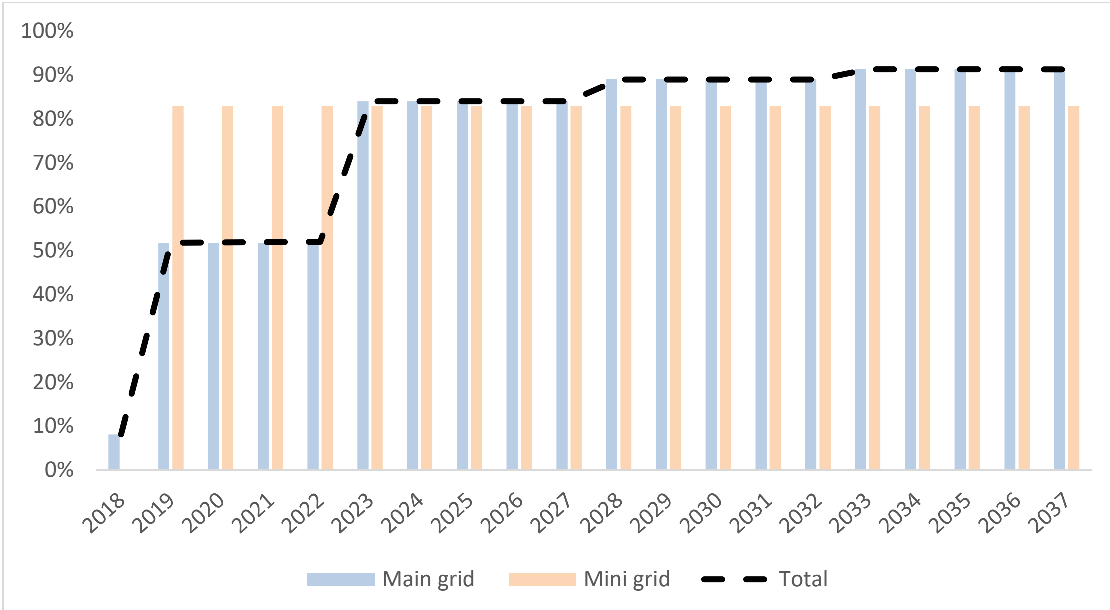


The main outcome of the Master Plan is that 100 percent of Kosrae will be electrified once the Walung mini-grid is built in 2019. In addition, during the 20 years of the Master Plan the percentage of electricity generated from renewable sources will increase, and carbon dioxide (CO_2) emissions and diesel use will fall.

Figure 6.2 shows RE as a percentage of total generation for the main grid and the Walung mini-grid. The total line shows the weighted average for the whole state.

The share of RE in Kosrae's electricity generation would increase from eight percent in 2018, to 84 percent in the first 5 years—exceeding the national target of 30 percent.

Figure 6.2: RE Percentage of Generation for Kosrae



CO_2 emissions and diesel use would decrease by 84 percent (Table 6.1).

Table 6.1: Kosrae Emissions and Diesel Use

	2018	2019–2023	2024–2028	2029–2033	2034–2037
CO_2 emissions (tonnes/year)	4,734	2,868	955	775	778
Diesel use (gallons/year)	458,107	277,498	92,406	74,971	75,251

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