Yap State Energy Master Plan

Final Report to the Department of Resources and Development

June 2018

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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 Yap 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.

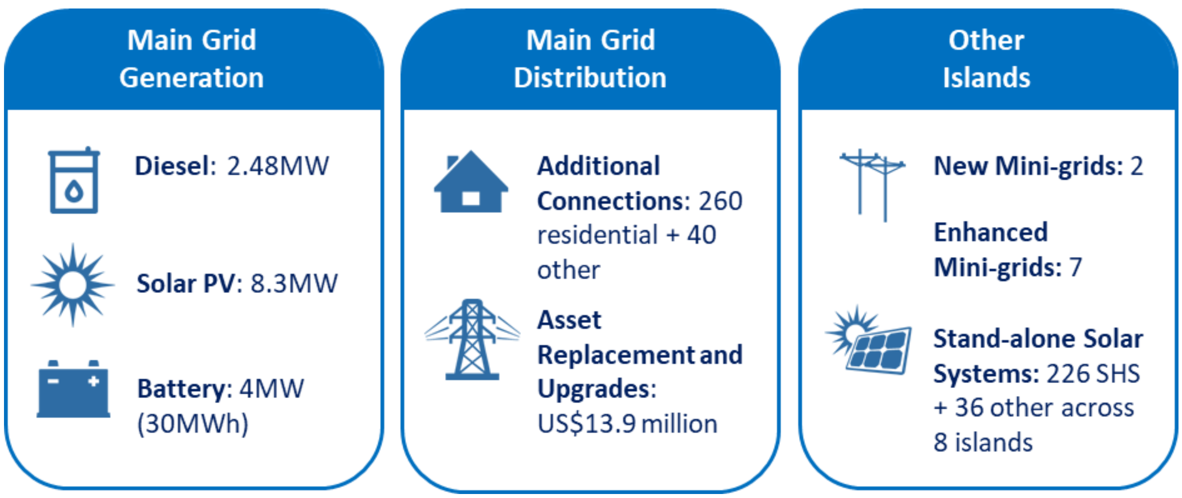
Kosrae will need to manage the transition to planned maintenance and asset replacement more carefully, but generally will be in a position to fully fund the implementation of the Master Plan at the current level of tariffs in real terms. Tariffs could be reduced over time with greater reliance on concessional 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 Yap will need to invest US$58.9 million in new and replacement electricity infrastructure over the next 20 years

New infrastructure includes adding renewable generation capacity on Yap Proper, adding grid connections on Yap Proper, and developing electricity infrastructure in other regions of Yap State (Figure ES.2—this does not include replacements of existing generation infrastructure).

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



The total investment requirement will be:

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

	2018	2019–2023	2024–2028	2029–2033	2034–2037	Total
New Main Grid Generation	0.00	5.97	6.94	9.15	5.95	28.00
Main Grid Generation Replacement	0.70	$0.00	1.69	1.65	4.17	8.20
Main Grid Distribution	0.45	6.31	2.74	2.93	2.63	15.06
Mini-grids	0.12	1.36	1.33	0.89	0.17	3.86
Stand-alone Solar	0.00	0.63	0.53	1.16	0.63	2.94
Total	1.27	14.26	13.22	15.77	13.55	58.07

The Master Plan would provide all households in Yap with electricity access from 2025. From 2019 onwards, the share of RE in Yap's electricity generation would be about 40 percent or above.

1 Introduction

This Report presents the Energy Master Plan for Yap 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 Yap 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 Yap 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.

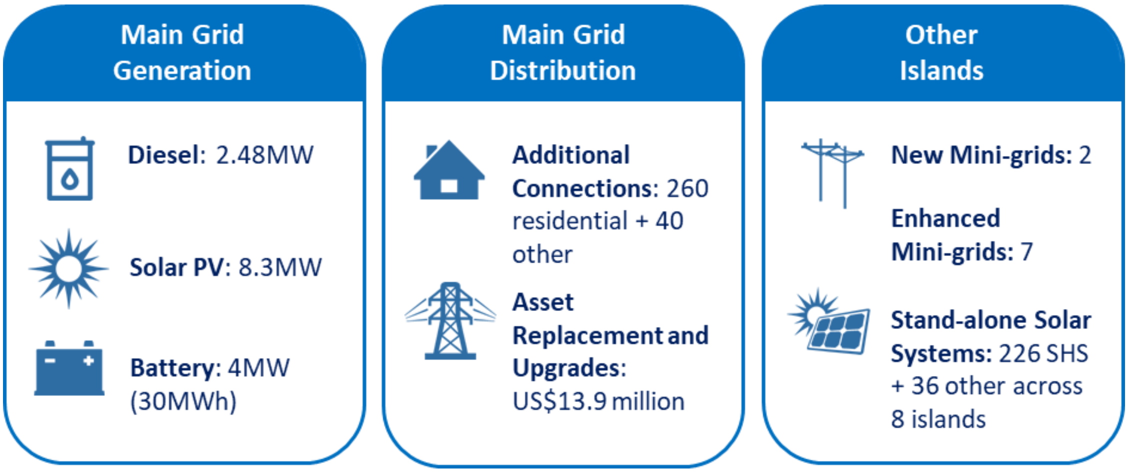
3 Technical Plan

The Technical Plan outlines required upgrades and improvements to the grid on Yap Proper, and the least-cost options for achieving the desired level of service on all other islands in the State of Yap.

On Yap Proper, the plan includes investment in new solar PV capacity to reduce the cost of electricity, as well as diesel to ensure security of supply. Distribution asset replacements and upgrades are already being planned by Yap State Public Service Corporation (YSPSC). The Plan also allows for additional connections on the main grid for households not currently connected, and the growth we have forecast for number of households and new businesses. Outside Yap Proper, the plan includes the upgrade of 7 existing mini-grids, construction of 2 new mini-grids and provision of stand-alone solar systems on the remaining 8 inhabited islands in Yap.

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

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



3.1 Yap Proper Main Grid

Over the 20-year Master Plan period the main grid on Yap Proper needs investment in: new generation capacity, replacement or refurbishment of existing generation assets, extension of the distribution network to connect new customers, and replacement of existing distribution assets.

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.

Investing in new RE generation capacity provides an opportunity to reduce overall costs

Over the 20 years of the Master Plan, we recommend that 8.3MW of new solar PV generation is installed alongside 30MWh of battery storage. New solar PV capacity will reduce the average cost of electricity by reducing YSPSC 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 to optimize diesel capacity in the 2029–2033 period will help maintain service standards as energy consumption increases.

We assume the 875kW wind farm is operational by 2018. We do not identify expansion of the wind farm as one of the least-cost options, so this is not included in the investment plan.

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

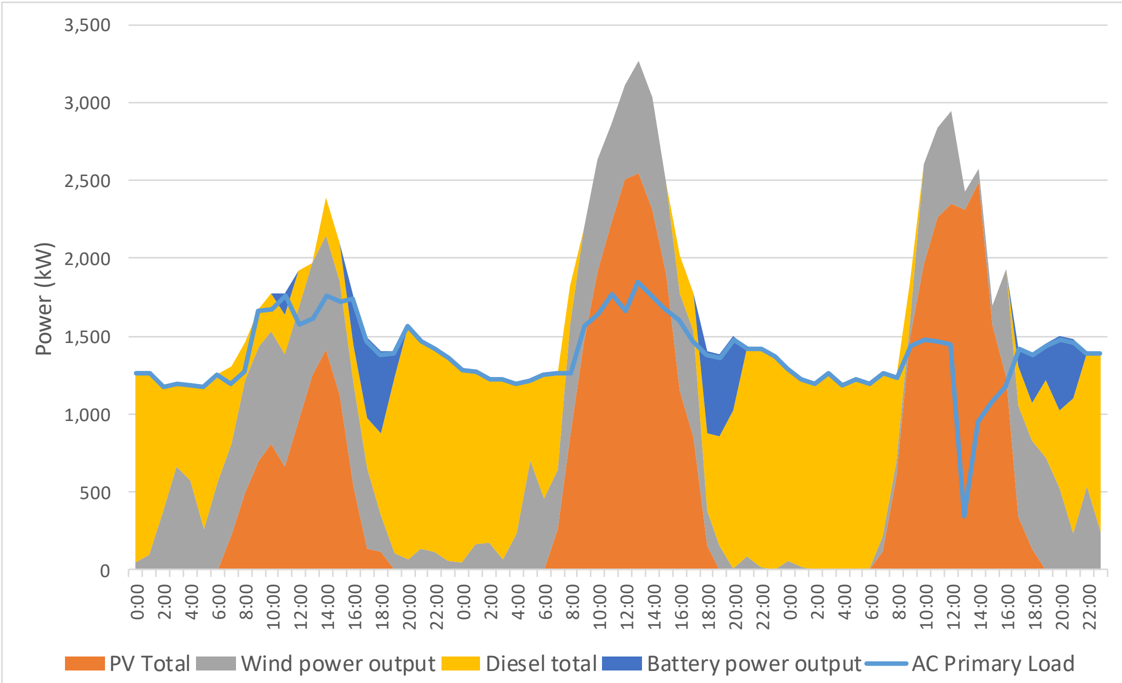
	2018	2019–2023	2024–2028	2029–2033	2034–2037
Diesel	-	0.83MW	-	1.65MW	-
Solar PV	-	2MW	2MW	2.5MW	1.8MW
Battery inverter	-	0.5MW	1.5MW	0.5MW	1.5MW
Battery storage	-	3MWh	7MWh	10MWh	10MWh

In the period 2019–2023:

- A second 830kW diesel generator should be added. This has been included at YSPSC's request, to allow the power station operators to manage the run hours on smaller generators better and extend their lives. YSPSC reported that the existing 830kW generator is currently being run hard in response to fluctuations in wind farm generation, and it is not expected to last more than 5 years. The second 830kW will allow YSPSC to reduce the run hours on the existing generator so that it will not require replacement for at least 10 years. This may defer the need for a new 830kW generator later in the Master Plan period
- 2MW of solar PV capacity should be developed at one or more sites. Some of the capacity could be deployed behind the meter on government or commercial buildings, but additional options such as ground-mounted and floating systems may also be needed
- Energy storage should be deployed at the Yap power station, providing 0.5MW of capacity and 3MWh of storage to manage integration of the wind turbines and PV plants and increased use of RE
- The recommended investments in solar and storage will meet a large proportion of Yap Proper's demand in 2023, reducing the use of diesel and therefore the cost of electricity (Figure 3.2).

[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: Yap Load Duration Curve and Contribution of Generation Sources, 2023



In the period 2024–2028:

- 2MW of solar PV capacity should be developed. This could be at one of the existing solar sites
- The battery inverter capacity should be increased by 1.5MW and storage capacity by 7MWh. This could be deployed at the Yap power station, at one of the solar sites, or at the wind farm.

In the period 2029–2033:

- A new CAT 1,650kW unit (to match the other two generators) should be added in this period. A 3.2MW Deutz generator is retired in this period and the new CAT will ensure N+2 is met. One of the existing 1,650kW CAT generators should be replaced in this period
- 2.5MW of solar PV capacity should be developed. This could be at one of the existing solar sites
- The battery inverter capacity should be increased by 0.5MW and storage capacity by 10MWh to address growth in the load.

In the period 2034–2037:

- 1.8MW of new solar PV capacity should be developed at one of the solar sites
- The battery inverter capacity should be increased by 1.5MW and storage capacity by 10MWh to address growth in the load and maintain reliability standards
- Two diesel gensets should be replaced in this period (1 x 1,650kW + 1 x 830kW). Both of these are required to maintain N-2 security criteria.

Replacement of new renewable generation assets will also be needed to maintain generation capacity

The current PV solar plants will reach their end of life during the period of the Master Plans and we assume they will be replaced. We assume energy storage will achieve a 10-year life and will be replaced at least once during the Master Plan timeframe. An estimate of the total cost of generation replacement capital including both diesel and renewables for each period of the Master Plan is included in Table 4.1.

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 increases

New connections will be needed for the increase in number of households that we have forecast. We also estimate two new commercial or government entities being connected each year on average. 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	13	13	13
New Commercial & Government Connections	2	2	2	2	2

We do not propose a way to provide electricity access in Rumung, reflecting the community's request not to be provided with electricity.

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 (or US$40,000 on average each year), with an additional US$100,000 in the 2033-2037 period.

In addition, it will cost US$3.5 million over 5 years to implement YSPSC's proposed distribution network enhancements. These enhancements include 21 miles of overhead medium-voltage (MV) cables (new cables and reinforcements), 5 miles of underground MV cables (from the power station to the airport and hospital), and reclosers.

We used the asset register to make replacement estimates. Details of asset lifespans and replacement costs are in Appendix B.

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

	2018	2019–2023	2024–2028	2029–2033	2034–2037
Age-based Asset Replacement	409,125	427,908	460,978	496,605	530,972

3.2 Other Islands

Based on the numbers and distribution of households, and the existing infrastructure, our modeling suggests that solar/diesel hybrid mini-grids[3] are the least-cost option for: Fadrai, Asor, Fais, Satowal; Falalop, Ulithi; Falalop, Woleai; Mogmog; Ifalik; and Lamotrek.

We propose stand-alone solar systems for all other islands: Nugulu, Tahoilap, Sileap, Wottegai, Falalus, Eauripuk, Faraulep 1, Faraulep 2, and Elato.

Fadrai, Asor, Fais, Satowal

These islands already have mini-grids that are 100 percent solar. The existing systems are over-sized relative to current load to allow for vegetation (which is important for cyclone protection), which prevents the solar PV modules from performing to their maximum capacity. Even so, our analysis suggests that the existing systems have enough capacity to satisfy demand over the Master Plan period. No significant load growth is expected because consumers are already at an established level of consumption and the population is not expected to grow.

Batteries will need to be replaced about every 10 years. If additional PV capacity turns out to be needed then it can be added at low cost.

To meet the reliability standards, the investment plan includes a 20kW diesel generator on each island. To meet the standards without using diesel, the solar capacity would need to be supplemented with additional batteries—which would be more expensive. Appendix B sets out the extra cost of this option, compared to using diesel. However, there may be logistical and environmental benefits to doing this.

We understand that some islands have more than one mini-grid. YSPSC could consider interconnecting these as a way of meeting N+1 redundancy. This is not currently included in the Master Plan and would require more detailed analysis.

Falalop, Ulithi; Falalop, Woleai; and Mogmog

We have modeled these islands with their existing generators and networks to establish the least-cost generation mix.

As all have existing networks, we do not model any new network costs. The costs of maintaining the existing networks are in Appendix B.

For **Falalop**, **Ulithi**, the generation capacity needed is presented in Table 3.4. The existing system was modeled with 6kW of grid-connected PV and a 90kW generator.[4] We added a second diesel generator to provide the required redundancy.

The solar includes the 6kW of existing PV and would need another 80kW. This could include the 60kW currently being built if it is grid-connected rather than stand-alone.

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[3] In all cases we use hybrid systems, as our analysis suggests that diesel is the least-cost way to meet the required reliability standards. However, following discussions with YSPSC, we appreciate that there may be some practical, logistical, and environmental benefits to using 100 percent solar PV systems with battery storage. Therefore, we outline in Appendix B the additional cost of meeting these standards using batteries instead, in case YSPSC wishes to pursue this option for some islands.

[4] YSPSC asked us to consider, for islands with existing diesel mini-grids, whether solar PV could be added, to be used in the day, with the diesel being used at night. We modeled new solar PV and battery systems for the existing diesel mini-grids in Yap to identify the least-cost generation mix. In all cases, adding PV and storage reduces the cost of energy compared to diesel only.

Table 3.4: Falalop, Ulithi Mini-grid Capacity[5]

Asset Type	Capacity
Diesel	200kW
Solar	86kW
Storage	140kWh
Converter	80kW

Table 3.5 presents the capacity required in **Falalop, Woleai**. The diesel generation includes the existing 50kW genset as well as one new 50kW genset.

It may be possible to integrate the existing PV capacity into the new system, but this would require a more detailed assessment of the condition and set-up of the existing system.

Table 3.5: Falalop, Woleai Mini-grid Capacity

Asset Type	Capacity
Diesel	100kW
Solar	40kW
Storage	130kWh
Converter	30kW

The generation capacity required for Mogmog is in Table 3.6. Mogmog has an existing 24kW diesel genset. A second identical genset is required to provide redundancy.

The existing 47kW PV system will be integrated into the mini-grid and new solar PV capacity will not be needed until 2029–2033.

Table 3.6: Mogmog Mini-grid Capacity

Asset Type	Capacity
Diesel	24kW
Solar	10kW
Storage	30kWh
Converter	10kW

Ifalik and Lamotrek

We propose mini-grids for Ifalik and Lamotrek. The generation requirements needed for each are set out in Table 3.7. The requirements are the same because of similar numbers of households in these two municipalities.

[5] We understand that YSPSC is in the process of collecting more reliable load data that would help determine the optimal size for this system.

Table 3.7: Ifalik and Lamotrek Mini-grid Capacity

Asset Type	Capacity
Diesel	40kW
Solar	20kW
Storage	30kWh
Converter	10kW

To meet the reliability standards, the investment plan includes a small diesel generator on each island. To meet the standards without using diesel, the solar capacity would need to be supplemented with additional batteries—which would be more expensive (see Appendix B).

We suggest an LV underground network for distribution on both islands. Estimated costs are in Appendix B.

Stand-alone solar systems

For the remaining islands, stand-alone solar systems are the most efficient option due to the lower number of households.

There are 343 solar home systems (SHS) in Yap. However, the investment plan assumes starting from scratch as no information exists on what condition the existing SHS are in and when they would need to be replaced. If follow-up surveys are carried out and some SHS are still considered useable, the capital expenditure requirement can be adjusted.

Table 3.8 shows the number of stand-alone solar systems required in each place. These numbers include residential, schools, dispensaries, and other facilities.[6] The sizes assumed are:

- 200W/1.2kWh for home systems[7]
- 10kW systems for schools[8]
- 2kW systems for other users such as dispensaries and shops.

The proposed SHS are smaller than the existing ones in Yap (500W). Our analysis suggests smaller systems could satisfy expected demand, at lower cost than the larger systems.

6 Other facilities may include commercial entities or community centers.

7 For the purposes of the Master Plan we assume that all households use 200kW systems. However, we recognize that some households may want larger sizes. As an illustration, Appendix B outlines the additional cost for two larger sizes of SHS.

8 Although the existing school systems are smaller than this, the 10kW is intended to allow the system to support wider community activities.

Table 3.8: Number of Stand-alone Solar Systems by Customer Type

Islands	Household	School	Dispensary	Other
Nugulu	18[9]	1	1	2
Tahoilap	21	1	1	2
Sileap	27	1	1	2
Wottegai	34	1	1	2
Falalus	23	1	1	2
Eauripuk	26	1	1	2
Faraulep 1	21	1	1	2
Faraulep 2	31	1	1	2
Elato	25	1	1	2
Total	226	9	9	18

The total number of SHS is lower than the number currently in Yap. This is because some places that currently have SHS will be provided with mini-grids instead.

The entire system will need to be replaced about every 8 years (provided it is well-maintained). We have factored in quarterly trips to each island for maintenance.

[9] We have mixed information on the number of households in Nugulu. To ensure the Master Plan has sufficient budget to electrify the entire community, we take a conservative approach and assume 18 households (based on waypoint data). If there are fewer households the cost will be lower.

4 Financing Plan

The total amount needed to cover capital expenditure across the lifespan of the Master Plan is US$58.1 million

Half of the capital expenditure over the 20-year Master Plan period is on new generation capacity for the grid on Yap Proper (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 network upgrades currently being planned by YSPSC. The timing of capital requirements for the mini-grids and stand-alone solar systems is determined by when this infrastructure is rolled out. We recommend spreading the rollout over the first two 5-year blocks of the Master Plan to ensure YSPSC has sufficient capability to manage the rollout.

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

	2018	2019–2023	2024–2028	2029–2033	2034–2037	Total
New Main Grid Generation	0.00	5.97	6.94	9.15	5.95	28.00
Main Grid Generation Replacement	0.70	0.00	1.69	1.65	4.17	8.20
Main Grid Distribution	0.45	6.31	2.74	2.93	2.63	15.06
Mini-grids	0.12	1.36	1.33	0.89	0.17	3.86
Stand-alone Solar	0.00	0.63	0.53	1.16	0.63	2.94
Total	1.27	14.26	13.22	15.77	13.55	58.07

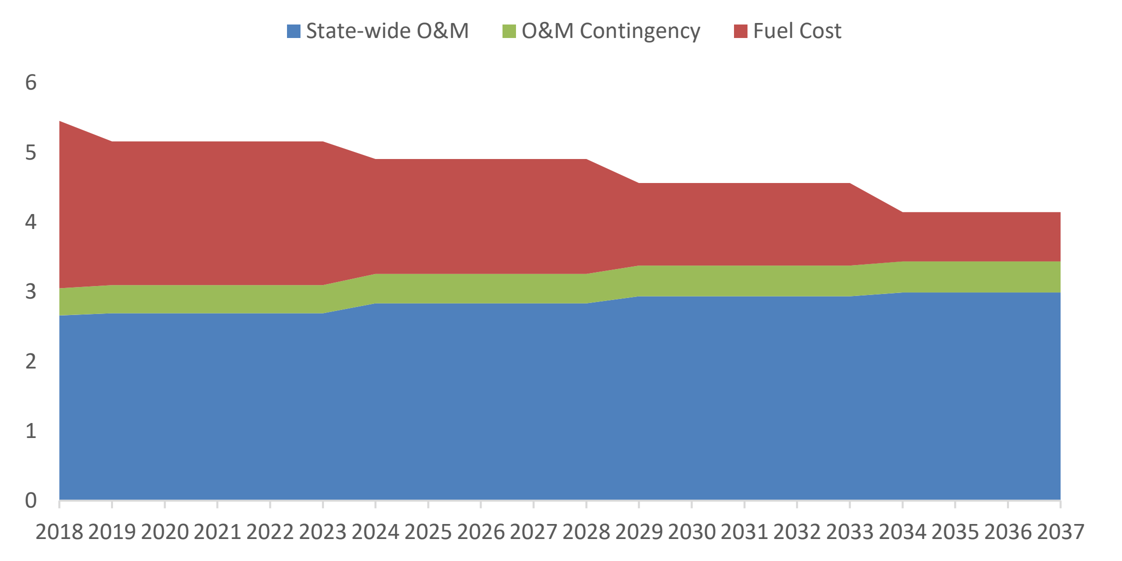
Operating expenses include:

- Yap Proper generation O&M cost
- Yap Proper distribution O&M cost
- Yap Proper fuel cost
- Mini-grid generation O&M cost
- Mini-grid distribution O&M cost
- Mini-grid fuel cost
- Stand-alone solar O&M costs
- 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$1.3 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 Yap Proper because of lower run hours for diesel generators. State-wide operating expenses—excluding the fuel cost—increase over the Master Plan period. This increase is because administration and general costs, and distribution costs on Yap Proper, grow with load growth; and operating expenses for new mini-grids and stand-alone solar systems are added. The net effect of lower fuel cost and growing operating and maintenance costs is a reduction in operating expenses each year of US$1.3 million from 2018 to 2037.

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



The financial spreadsheet provided to YSPSC 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 on mini-grids and stand-alone solar systems is paid for with grant funding. Capital expenditure on Yap Proper is financed with concessional loans. Details of assumed loan terms offered by donor organizations are available in Appendix C
- Scenario 3: Capital expenditure on the mini-grids and stand-alone solar systems is paid for with grant funding. Capital expenditure on Yap Proper is financed with commercial loans. (This scenario approximates the cost of getting IPPs for solar and storage as well as of YSPSC 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 all three scenarios, power sales revenue earned from keeping tariffs at their current level is sufficient to cover the cash requirements

Even in the higher-cost Scenario 3, where the revenue requirement grows over time, electricity consumption grows at a sufficient rate to enable tariffs to remain constant.

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

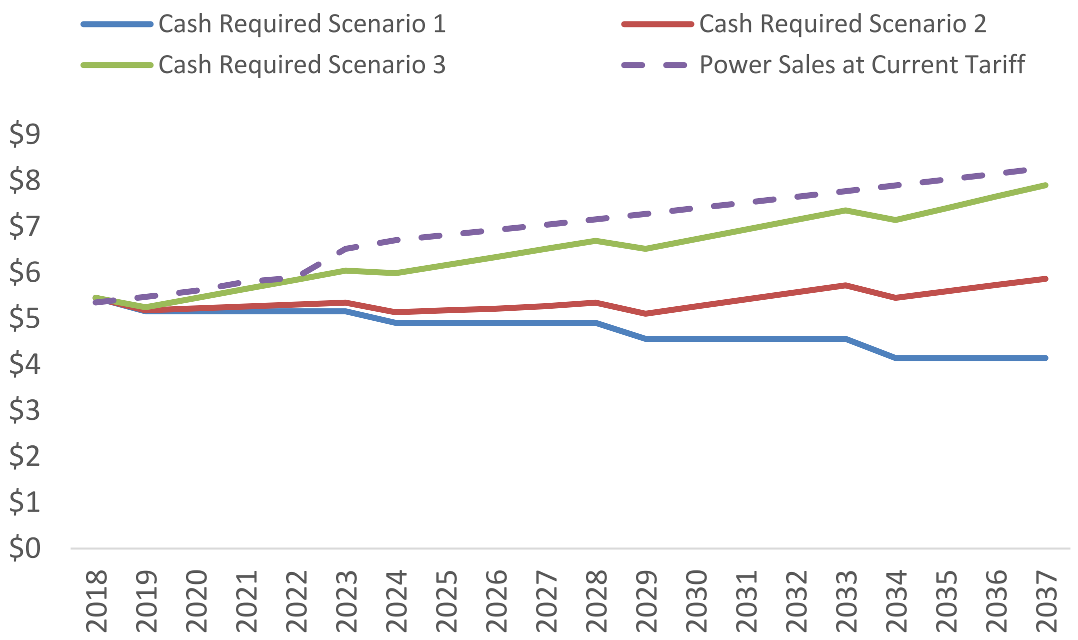


Table 4.2: Average Tariff Required to Cover Cashflows by 5-year Period and Customer Segment, US$ per kWh[10]

	Current	2018	2019–2023	2024–2028	2029–2033	2034–2037
Scenario 1						
Residential	0.41	0.42	0.36	0.29	0.25	0.21
Commercial	0.49	0.50	0.43	0.35	0.30	0.25
Government	0.77	0.78	0.68	0.55	0.47	0.39
Scenario 2						
Residential	0.41	0.42	0.37	0.31	0.30	0.29
Commercial	0.49	0.50	0.44	0.37	0.35	0.34
Government	0.77	0.78	0.69	0.58	0.55	0.54
Scenario 3						
Residential	0.41	0.42	0.40	0.38	0.38	0.38
Commercial	0.49	0.50	0.47	0.45	0.45	0.46
Government	0.77	0.78	0.74	0.70	0.71	0.72

We recommend that YSPSC develop a medium-term smoothed tariff path once the financing package is confirmed.

[10] 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.

5 Implementation Plan

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

In the funding and financing plan, we have ensured YSPSC 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).

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

We include a schedule for replacing or retiring existing diesel generators in the rollout plan. Existing solar panels are replaced in the Master Plan period as they are already 5–10 years old. New solar panels are expected to last the entire Master Plan period, but batteries and inverters will need require replacing within the Master Plan period.

We assume all consumers in unserved islands are electrified by 2025. We have sequenced the rollout to start with the most accessible communities to test out the technology, billing, logistics, and management approach before rolling out to less-accessible islands.

Table 5.1: Rollout Plan for Yap

Year	2018	2019–2023	2024–2028	2029–2033	2034–2037
Main Grid	**Additional connections** ▪ 13 new residential connections a year ▪ 2 new commercial connections a year	**Generation capital projects** ▪ New 0.83MW diesel ▪ New 2MW solar ▪ New 0.5MW (3MWh) storage **Additional connections and lines** ▪ Underground cable from airport to hospital—5 miles ▪ 21.4 miles of overhead cable plus poles ▪ 13 new residential connections a year ▪ 2 new commercial connections a year	**Generation capital projects** ▪ New 2MW solar ▪ New 1.5MW (7MWh) storage **Additional connections** ▪ 13 new residential connections a year ▪ 2 new commercial connections a year	**Generation capital projects** ▪ New 1.65MW diesel ▪ Replacement of 1.65MW CAT ▪ Retirement of one 3.2MW Deutz ▪ New 2.5MW solar ▪ New 0.5MW (10MWh) storage **Additional connections** ▪ 13 new residential connections a year ▪ 2 new commercial connections a year	**Generation capital projects** ▪ Replacement of 1.65MW CAT ▪ Replacement of 0.83MW CAT ▪ New 1.8MW solar ▪ New 1.5MW (10MWh) storage **Additional connections** ▪ 13 new residential connections a year ▪ 2 new commercial connections a year
Mini-grid: Fadrai, Asor, Fais, Satowal		**Replacement and generation capital projects** ▪ Battery replacement on existing mini-grids. Assess state of other components ▪ 20kW diesel		**Replacement** ▪ Genset replacement ▪ Battery replacement ▪ Solar panel replacement	
Mini-grid: Falalop, Ulithi		**Generation capital projects**		**Replacement**	**Replacement**

Year	2018	2019–2023	2024–2028	2029–2033	2034–2037
		▪ 200kW diesel ▪ 86kW solar ▪ 140kWh storage ▪ 80kW converter		▪ Genset replacement ▪ Battery replacement	▪ Converter replacement
Mini-grid: Falalop, Woleai		**Generation capital projects** ▪ 100kW diesel ▪ 40kW solar ▪ 130kWh storage ▪ 30kW converter		**Replacement** ▪ Genset replacement ▪ Battery replacement	**Replacement** ▪ Converter replacement
Mini-grid: Mogmog		**Generation capital projects** ▪ 24kW diesel ▪ 10kW solar ▪ 30kWh storage ▪ 10kW converter			**Replacement** ▪ Genset replacement ▪ Battery replacement
Mini-grid: Ifalik			**Generation capital projects** ▪ 40kW diesel ▪ 20kW solar ▪ 30kWh storage ▪ 10kW converter	**Replacement** ▪ Genset replacement ▪ Battery replacement	**Replacement** ▪ Converter replacement
Mini-grid: Lamotrek			**Generation capital projects** ▪ 40kW diesel ▪ 20kW solar		**Replacement** ▪ Genset replacement ▪ Battery replacement

Year	2018	2019–2023	2024–2028	2029–2033	2034–2037
			▪ 30kWh storage ▪ 10kW converter		
Stand-alone solar systems		**Stand-alone solar systems installation** ▪ Install about 116 stand-alone solar systems on 4 islands	**Stand-alone solar systems installation** ▪ Install about 146 stand-alone solar systems on 5 islands	**Capital replacement** ▪ Replace all 116 initial stand-alone solar systems	**Capital replacement** ▪ Replace the next 146 stand-alone solar systems

5.2 Implementation Capacity

To implement the Master Plans, YSPSC will need additional staff

We have considered whether each utility has the capacity to implement the activities required in the plan. Table 5.2 highlights the additional capacity that would 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 YSPSC

	1–5 Years	5–10 Years
Main grid	1 new engineer trained in RE and control systems 1 existing engineer trained in RE and control systems 2 new technicians trained in RE and control systems Electrification manager/outer islands manager 1 new billing support staff to assist with billing for outer islands	1 new engineer trained in RE and control systems 2 new technicians trained in batteries, RE and control systems, to support outer islands
Mini-grids	1 new electrical technician trained in RE for each existing mini-grid	4 new staff per new mini-grid, including 1 electrical technician trained in RE and batteries and ideally 1 mechanic
Stand-alone solar systems	1 casual employee on each island, to do basic maintenance and assist with billing	1 casual employee on each lagoon island, to do basic maintenance and assist with billing

YSPSC will take lead responsibility for implementing the Master Plan investments. Even if YSPSC 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

Here we highlight the main risks specific to Yap. Appendix E highlights various risks associated with the types of technology and investments proposed in this Plan. Many of these are common to all states using the same technology.

New investments in remote areas need to reflect previous experience

Many remote communities in Yap already have electricity access via mini-grids or stand-alone solar systems. It will be important, both technically and socially, to ensure that new investments implemented through the Master Plan are consistent with the existing infrastructure.

For cost reasons, investments should, as far as possible, complement—rather than duplicate—existing infrastructure. In terms of institutional arrangements, YSPSC already has experience it can learn from in relation to the payment collection, maintenance, and management of equipment on outer islands. For example, YSPSC advised that it has faced significant challenges in collecting fees for SHS on remote islands. The investment plan will address this concern by providing Cashpower meters to all stand-alone solar (and mini-grid) customers.[11]

From a social perspective, there are both benefits and challenges from starting from a point of partial electrification. Many remote communities in Yap are accustomed to electricity and already understand the benefits—and so may be more likely to buy-in to the electrification program and have high 'readiness' for such a program. They are already used to paying for electricity and have existing structures in place to manage them (even if some refinements may need to be made to these structures).

Sites for solar PV capacity will need to be identified

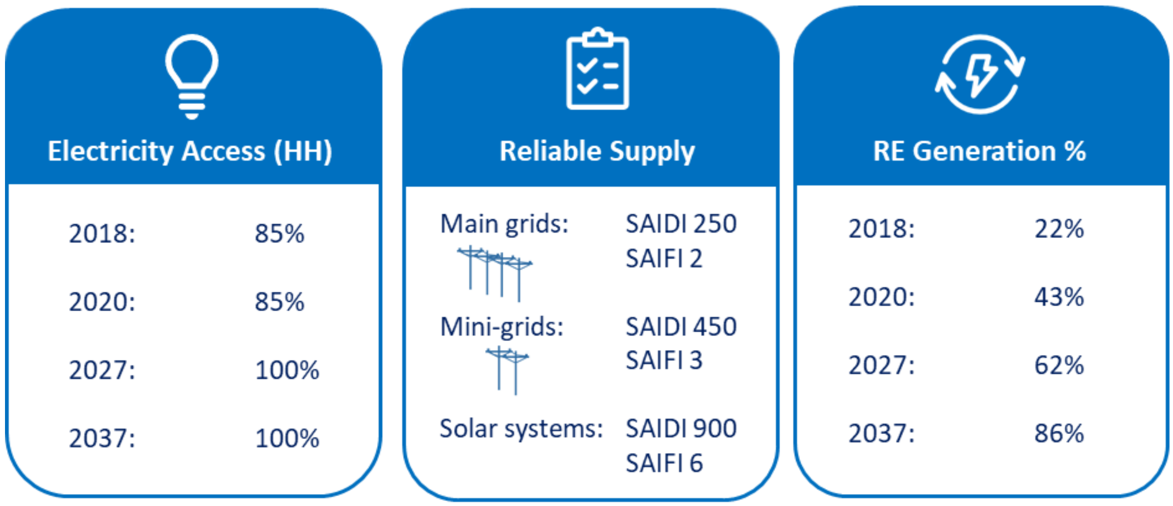
The Master Plan recommends 8.3MW of new solar PV capacity on Yap Proper. This would require an area of about 83,000m2 (about 893,000 square feet). Preliminary indications are that the roofs of government buildings may be able to accommodate only up to 1MW. A 1.2MW floating solar PV project is being considered for Global Climate Fund (GCF) funding. Private land could potentially be acquired for ground-mounted systems, and private roof sites could also be considered. The ongoing feasibility study on additional solar PV in Yap will provide further information.

[11] For islands that do not have adequate telecommunications services, we recommend providing radios. They can be used to communicate Cashpower transactions, as well as to report faults on systems.

6 Outcomes

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

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



The main outcome of the Master Plan is that, by 2025, 100 percent of households, businesses, and public facilities in Yap will have access to a reliable, affordable electricity service. 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.

Yap State is aiming for 30 percent of electricity generation on Yap Proper to come from renewable sources by 2020, and 50 percent by 2030.[12] The plan sees Yap meet both these targets. Figure 6.2 shows the percentage of RE generation for the stand-alone solar systems, mini-grids, and main grid. It also shows the weighted average RE percentage for the whole state.

[12] Yap State Energy Action Plan, revised version of February 2017.

Figure 6.2: RE Percentage of Generation for Yap

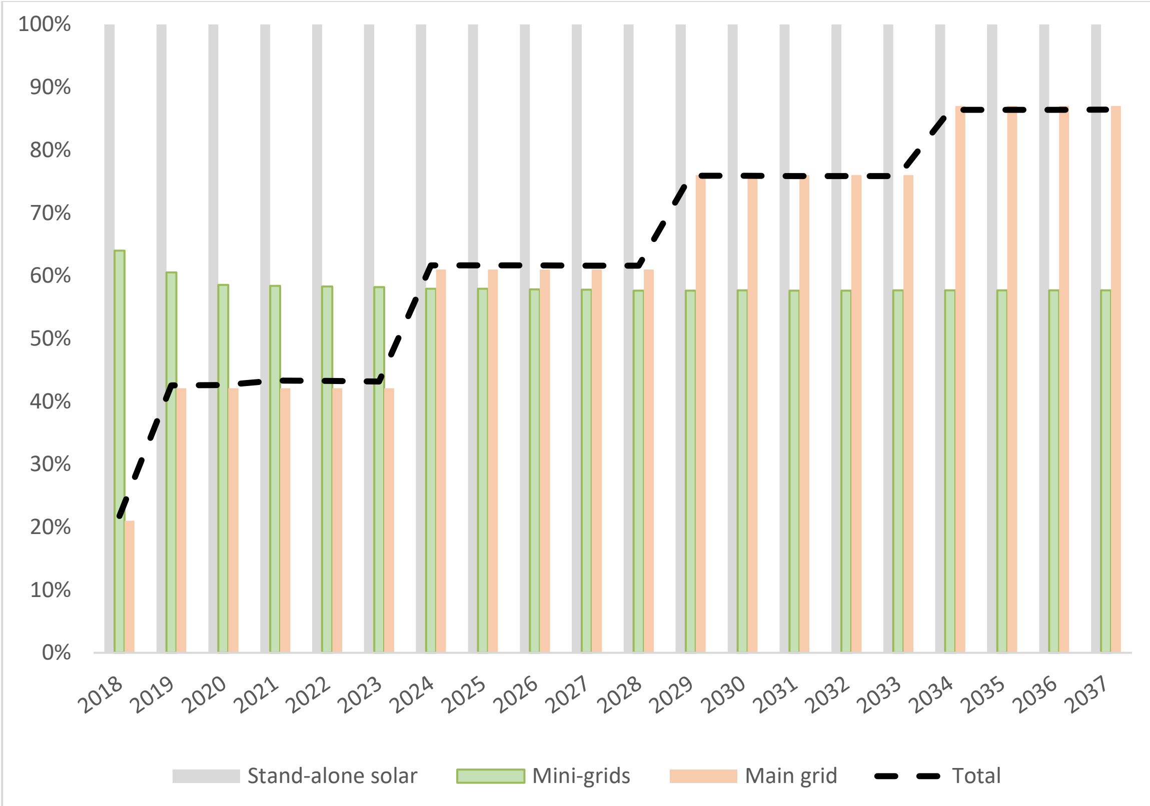


Table 6.1 shows the significant decline (78 percent) in CO_2 emissions and diesel use over the 20-year period. These numbers include the main grid and all mini-grids.

Table 6.1: Yap Emissions and Diesel Use

	2018	2019–2023	2024–2028	2029–2033	2034–2037
CO_2 emissions (tonnes/year)	7,376	5,496	4,091	2,792	1,616
Diesel used (gallons/year)	713,745	531,801	395,833	270,186	156,349

YSPSC also aims to supply 100 percent of the outer island population (14 islands with a total population of about 2,600) with 100 percent RE by 2020. The Master Plan supplies 100 percent of the outer island population with electricity. However, to meet the required service standards in the least-cost way, there would need to be a mixture of diesel and solar (even for mini-grids that are currently 100 percent solar). In Appendix B, we consider what the additional costs would be for the mini-grids to provide the same service standards without diesel.

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