Case study 3

Capacity Building for financing institutions – Establishing energy loan program – Technical component

Case Study based on Republic of Palau National Development Bank experience of establishing its Energy Loan Program. This is the third of three case studies to be prepared under a training contract with SPREP. This Case Study emphasizes the technical component, including details in the development of the energy loan program in Palau to be replicated in other Pacific Islands.

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Part 1: Development of a standard grid-connected PV module for financing by the Palau Development Bank

Introduction

The success of the National Development Bank of Palau (NDBP) Energy Efficiency Home program indicated that a renewable energy focused program for existing homes could also be accepted by Palau homeowners. With the increasing cost of electricity and the gradually decreasing cost of solar installations, the bank had decided to develop a program to finance the purchase, installation and maintenance of a roof mounted, grid-tied solar installation that would largely offset the use of grid delivered energy. This case study covers the design and purchasing of materials for the National Bank of Palau grid-connected solar financing program.

The intent of providing this case study is to assist those financial institutions elsewhere in developing a similar program. While the specific components used in the 2009 Palau program have been changed due to changes in the inverter technology, the concept and core process for developing the standard system module and its procurement remains the same.

Background

Initially, the NDBP had planned to offer grid-connected solar financing to households and businesses. It was first thought that the private sector would be able to mobilize themselves to provide on-grid solar technology to the market and all that was necessary was a financing mechanism. The reality was that an industry would need to be created, government policy would need to be developed, and the development bank would need to drive the process. Fortunately, expertise and support was available in the region.

In 2009, the Palau Energy Office (PEO), together with the United Nations Development Program (UNDP), began a project to establish a Renewable Energy Fund Window (REFW) at the NDBP. It was part of the Sustainable Economic Development through Renewable Energy Applications (SEDREA) project in Palau, which was a national climate change mitigation project that was approved by the Global Environment Facility (GEF) in 2008.

The initial offering through the REFW was for grid-connected PV installations for residences and small businesses. Discussions with the Palau Public Utilities Corporation (PPUC) resulted in their agreement to allow no more than six NDBP REFW solar customers to connect to the PPUC grid. Customers outside of the NDBP program that wanted to connect solar to the grid had to negotiate individual arrangements with the utility. The NDBP connected customers all paid on the basis of net metering whereby daily solar generation in excess of that used by the customer was credited for later use by that customer. Based on that agreement, the NDBP began planning the financing process for the proposed installations. Several criteria were established by the bank for the program that could be considered as key success factors. They were:

- The intent of the project was to use the solar to offset the electricity used in the residence, not to generate surplus for provision to the grid. Therefore the solar installations should be sized to approximately match the electricity usage of the residence. This approach helped convince the PPUC to support the program since losing loads from a relatively small number of the heavily cross-subsidized residential customers would have little effect on their net income and should generation by the solar be somewhat greater than is needed by the residence it would be received by the utility at no cost and would help offset fuel costs.
- To market the solar installation finance, the cost of power from the solar would need to be about the same as that of the electricity from the grid. Since in 2008 when the program design was begun, solar energy installations generated electricity at a cost higher than that of the Palau residential tariff, some subsidy was required to lower the price of generation by the solar to make it more attractive. It was decided to provide a capital subsidy sufficient to reduce the effective cost of the solar to a level that gave a cost of generation comparable to the cross-subsidized residential tariff, approximately USD 0.25 per kWh in 2008 and 2009.
- The Development Bank also agreed to provide financing at its most favorable terms, 6% interest and 100% financed, to increase the affordability of the loan repayments while not unduly raising risks to the Bank.
- The system design should require all installations to use the same basic components so the cost could be reduced through quantity procurement and so training, warranty and spare parts requirements could be kept as simple as possible. Once the design was set, all future installations financed by the NDBP would use the same components or ones that would be directly interchangeable with the ones initially chosen for the standard design.
- To simplify the design of the individual PV systems, a basic system module consisting of solar panels, mounting rails, DC switches, AC switches, inverter, wiring and metering had to be created. The module size had to be sufficient to provide an average of around 150 kWh per month in order to match the average residential usage of homes without air-conditioning. For homes with air-conditioning additional system modules could be added to cover the extra energy usage.
- Warranties for major components needed to be 10 years or longer to ensure that the systems would not have excessive repair costs before the bulk of the finance repayments were completed.
- Because at that time there were no businesses selling or installing grid-connected solar systems in Palau, the NDBP created the technical design, purchased the components for an initial batch of installations and directly financed their sale to the customers. As the equipment was financed with grant funds, the NDBP recovered the subsidy portion of the equipment installed for customers and it was placed in a revolving fund to be used for future purchases of equipment.
- The design of the procurement specifications and selection process included the participation and support of donors and the Palau Energy Office. The procurement procedures used were for the Bank. The Bank was also fortunate to have a project manager that had prior experience with the procurement office at the utility so was familiar with equipment acquisition and purchasing

issues. It was also important to have access to the internet to communicate with bidders who were from around the world, including the USA, Laos, France, Australia and Fiji.

- The Development Bank originally planned to offer the inventory of equipment to a preferred retailer but the retailer did not have the necessary space to accommodate the equipment. When the equipment arrived on the island it was stored at the Bank and with one of the Bank's key contractor's facility. Note both the retailer and contractor were approved vendors from the Bank for installation and servicing of on-grid solar equipment under the Bank's program.
- The NDBP would sponsor training of local contractors in the installation and maintenance of those standard solar installations. Once the training was completed, a list of contractors acceptable to the NDBP would be created and customers could make a choice of which contractor they preferred for their installation.
- The launch of the on-grid financing program included a promotional campaign and culminated in a raffle drawing and energy fair at the Bank. The first group of customers chosen allowed the Bank's contractors to train during the installation. Limiting the first installations to a smaller group also allowed the Bank to prove installation and address any issues that arose.
- The launch of the program was also limited to the largest market closest to the main office of the Bank and its partners. This would limit the possible problems that could arise from logistical challenges such as long distances and transportation availability.

SYSTEM DESIGN

The design of Palau's system was based on the average usage of households in Palau's main market. The usage for households targeted would be able to afford the on-grid solar systems that were being offered and the financing would be sufficient to finance this equipment at reasonable terms without unduly raising risks. The design also considered technology that was proven in the harsh ocean environmental conditions found in Palau and required vendors, suppliers, and installers to back their products through warranties. Insurance would be required as part of the financing package and funding would be included for replacement of equipment during the life of the loan.

The equipment designed would be for households and small businesses that operated in facilities that were similar in size to households. Larger businesses would be supported but would require specific system design by consultants hired by the Bank. As businesses should be more capable of analyzing investments and understanding the long term benefits of the solar installation, the subsidy is smaller than that for a residence and an equity contribution is required.

1.1 Solar Array

The design basis was the delivery of an average of around 150 kWh per month in the Palau conditions. Based on the data available, the annual average solar radiation for Palau is around 5,5 kWh/m^2/day, Losses in the solar panel were estimated as:

- Reduction in output due to cell temperature above 25°C = 15%

- Reduction due to orientation errors (roof top not oriented for the best solar output) = 10%
- Reduction due to uncompensated reflections from panel glazing = 7%
- Reduction to compensate for ageing over the useful panel life = 10%
- Reduction due to dirt on the panel = 3%
- Reduction assuming panel rating is below its rated value = 5%

Total reduction in output over the ideal = 41%

- Energy from the panel per Wp = 5.5 – (5.5 x 0.41) = 3.25 Wh/day/Wp of panel capacity
- Monthly energy from the panel per Wp =

3.25 Wh/day/Wp X 30days = 97.5 Wh/month/Wp

Additional losses include:

- Wiring losses = 2%
- Inverter losses = 6%
- Making the monthly AC Wh that can be delivered to the grid = 89.8 Wh/Wp/month
- Therefore the Wp that would be needed to generate 150 kWh per month =

150,000 Wh / 89.8 Wh/Wp/month = 1,670 Wp or **1.7 kWp of solar panels**

The array would be expected to deliver between 300V and 450V to the input of the Inverter since that is within the range of voltages commonly available for panels and wiring and is typical for inverter inputs in this power range. It is also a voltage range that does not require unusual characteristics of panels, switches or wiring since virtually all panels, and wiring can accept up to 600V without problem. With a 400V average input, the Isc current required from the panels would be around 1700/400 = 4.25 A. This implies the use of a 10 panel string at 170 Wp per panel for each input to the inverter.

1.1 Inverter

It was expected that the majority of residences desiring to finance roof-top solar would be using air-conditioning as that is common in Palau. For those homes, two of the 1.7 kWp system modules would be needed to approximately offset the total electricity use of the home. For this reason it was decided to use an inverter that could operate with high efficiency both at a panel input equivalent to 1.7 kWp of panels or with an input double that at 3.4 kWp of panels. Thus for homes either with or without air-conditioning the same single inverter that has two inputs, one for each 1.7kW array, would be required. The primary criteria for the inverter were therefore:

- At least 95% conversion efficiency (DC from the panels to AC for the grid) from an input ranging from 1 kW to 3 kW and better than 90% for all inputs above 0.3 kW. This covers the range of inputs expected with either 1 or 2 system modules (1.7 kWp or 3.4 kWp of panels).
- DC Inputs for two strings of 1.7kWp each producing a string voltage of between 300 and 450V DC.
- Operating temperature up to 45°C without reduction in power output
- All electronics sealed against salt and moisture entry with cooling accomplished by external heat sinks that conduct the heat from the electronics through the sealed enclosure.

- Suitable for connection to US Standard grid systems
- Isolation transformer included in the inverter
- Certified to meet international standards for automatic disconnection should the grid power fail to maintain a proper standard.
- Must allow external data logging of all operational parameters to permit NDBP and the maintenance contractor to properly monitor the installations.

1.1 Balance of system

- Panel mounting system suitable for installation over sheet metal covered, wood framed roofs. Adequate up to 100 mph gusts with panels installed.
- Wiring of a size sufficient to reduce wire losses to 2% or less and with insulation certified for use in continuous full sun conditions.
- DC panel disconnect switches suitable for the disconnection and connection of at least 450V at 5A DC.
- AC disconnect rated for the capacity of the inverter installed
- Data logger to log all parameters of operation at frequent intervals including DC input to the inverter and AC output from the inverter and any errors in operation that occur.
- Hardware and other materials needed for panel mounting, DC and AC switch mounting, meter mounting, inverter mounting and wiring installation.

TENDER SPECIFICATIONS

Based on the above criteria, a tender specification for the module components was prepared. Because in the past there had been bad experiences with grid-connected solar in Palau and in the Federated States of Micronesia (FSM) due to the use of inverters that were not suitable for the local conditions and failed early, the specifications were written specifically to fit the environmental and usage conditions anticipated in Palau. In order to assure a full understanding of the specifications, a solar panel and an inverter were prequalified for inclusion. Those prequalified units were ones that were from manufacturers with excellent records in the Pacific Islands and therefore inspired confidence that they would also work well for this project. In the case of the solar panels, Suntech model PLUTO-205 Ade and Kyocera model KD210GH-2pu were prequalified for the tender. In the case of inverters, the SMA Sunny Boy 3000 US was prequalified. Other manufacturer's equipment could be offered but had to meet all the requirements of the specification before being accepted.

Sections 4.1 through 4.7 that follows provides the full specifications that were prepared for the grid-connected systems based on the above criteria.

1.1 Photovoltaic Panels

- The photovoltaic panels shall be warranted to provide their rated output at standard conditions within ±20% for a minimum of 20 years under the harsh tropical, coastal conditions at the sites. A copy of the complete warranty terms must be provided with the tender.
- Photovoltaic panels of the model offered must have been tested by an internationally recognized testing facility and certified by that facility to meet internationally accepted standards.

- The construction must allow the safe maintenance of at least 600V differential between the panel frame and internal cell wiring.
- Cells will be made of monocrystalline or polycrystalline silicon. Amorphous or thin film type construction is not acceptable.
- PV modules must be framed with aluminum or marine grade stainless steel with appropriate seals to prevent water and corrosion damage to the active components of the panel.
- High strength glass must be used for the transparent cover. The backing of the panel may be high strength glass or other material impermeable to water that is accepted under the applicable international standards.
- By-pass diode and blocking diode protection for reverse current and shading effect reduction are not required for individual panels but individual panel by-pass diodes may be included.
- Panel Wp ratings shall be no less than 170 Wp nor no more than 225 Wp
- Panel Voc shall not be less than 30 V nor more than 70 V
- Connections shall be by standard "quick connect" type socket and plug wiring

The contractor will include as a part of the tender response at least the following information for the panels to be supplied:

- Voc, Isc, Impp, Vmpp, and Wp at standard conditions
- The relationship between temperature and module output over the cell temperature range 25°C to 75°C
- The IV (current/voltage) curves for 250, 500, 800, and 1000 W/m2 solar inputs
- Physical size and weight
- Details of the materials used in construction, including the frame, the connection boxes, the backing material and the encapsulation material.
- Number of cells per panel
- Type of cells provided (monocrystalline or polycrystalline)

The results of type tests carried out on the module type at ESTI (or an equivalent institution) using the CEC Specifications No. 503 or to International Standard IEC-61215 shall be provided.

A statement of warranties in effect for the proposed module type must be provided with full details of the terms of those warranties for both physical defects and capacity loss.

The **SUNTECH model "PLUTO-205 Ade" and the Kyocera model "KD210GH-2pu"** are pre-approved for purchase and a quotation for these units are specifically requested as well as quotations for other competing units the vendor may offer.

1.2 Photovoltaic module support structures

All arrays are expected to be mounted on good quality metal roofing fastened to wooden purlins that are in turn fastened to wooden trusses however mountings should also be suitable for use with pre-fabricated steel buildings. For panel mounting rails, a spacing of 600 mm between purlins is to be assumed. The installations of on-grid solar systems would be preceded by an inspection of the facility by the Client's chosen installer. The roof system would need to be strong enough to support the solar equipment installed and installation location and access to the meter base would be important conditions to address for installation.

The panel mounting framing must support the panels in a manner that allows adequate air flow between the metal roofing and the back of the panels to keep heating of the panels to a minimum. A spacing between the back of the panel and the highest part of the roofing metal that is between 60mm and 100mm will be acceptable. All metal components and fastening hardware that are in actual contact with the steel roof must be marine grade stainless steel or a non-conducting material.

Direct aluminum to steel contact at any point in the assembly will not be acceptable. The tilt and direction of the roof surface will be maintained in the PV array therefore there is no requirement to provide a mounting that is not parallel to the roof surface. The fastening method will be such as to always penetrate the corrugated metal at a high point on its surface and will include appropriate seals that prevent roof leaks due to the panel attachment for the life of the installation which is to be at least 20 years.

All structures must be able to resist at least 20 years of outdoor exposure in the location's harsh tropical marine environment without any appreciable corrosion or structural fatigue.

Full technical specifications and detailed assembly instructions shall be provided with the quotation showing the construction and assembly of the mounting structures and the details of the mounting of the modules and their attachment onto the supporting structure. These must specifically include physical size, and details of materials used in construction.

Panel mountings supplied shall be standard commercial units manufactured specifically for mounting of solar panels on metal roofing and shall be adjustable to fit standard solar panels in the 150-250Wp range.

1.3 Grid Tie Inverters

The inverter shall conform to **UL 1741** and **IEEE 1547** standards and be compatible with the **US National Electrical Code** for its connections to the grid and to the solar array. The voltage and frequency ratings will be consistent with single phase grid connections in residential applications in Palau (United States electrical power standards). A transformer type inverter of 3,000 Watt capacity is required.

Experience in other island installations has shown that electronic devices with cooling fans blowing ambient air directly on circuitry have a much higher rate of failure than devices that use passive cooling or where cooling fans blow only on heat sinks or inactive components of the device. Therefore it is required that inverters and associated components must have the cooling system associated only with the transformer and heat sinks. All electronic circuitry must be in a separate sealed section of the inverter.

- The inverter electronic circuitry shall be completely protected against salt caused corrosion.
- Inverters must have an operating efficiency of at least 80% at 10% of specified power and greater than 90% at greater than 70% of specified power.
- Total harmonic distortion should be less than 3%.
- Programming should not be lost if DC input power is disconnected.

The inverter system must be protected against damage due to:

- Short circuits on the AC side of the inverter
- Over temperature conditions

A fused string combiner and appropriately rated DC disconnect switch will be included with the inverter.

The inverter shall meet AS4777 or equivalent international standards to provide for automatic disconnection from the grid should power on the grid cease or fall below acceptable quality standards of frequency or voltage.

Full English language technical specifications for the inverter and any associated equipment shall be provided with the quotation for each inverter model proposed.

A statement of warranties in effect must be provided for each inverter model proposed. If extended manufacturer warranties (up to 20 years) are available at additional cost, the supplier should offer the extended warranty as a separate listed item in the quotation.

The **SMA Sunny Boy 3000 US** has been prequalified as acceptable for supply. Other inverter models will be considered but no variation from the above specifications and special conditions will be allowed due to the stringent requirements of the environmental conditions at the sites.

A LAN (Ethernet network) connection in and out of the inverter will be included and, if necessary to activate the connections, a compatible LAN card will be included with the inverter

1.4 Data Logger Specifications

The data logger must work without modification with the inverter that is supplied. It will accept removable flash memory such as USB Flash Drives, SD cards, etc. Communication will be through a standard RS485 data exchange system.

A computer connected to the data logger through the LAN connection will be able to access data logs and display the logged information in tabular or graphic form through a Windows compatible program provided with the data logger. An internal modem will be included to allow remote access through the Internet via a telephone line.

Power requirement will be 120V 60Hz.

All data provided by the inverter will be collected and made available for display through the data logger. Data gathering intervals shall be no longer than 10 minutes.

The SMA Webbox is prequalified for purchase and a quotation for this unit will be specifically requested as well as quotations for other competing units the vendor may offer that meets the above specifications.

1.5 Wiring

Panel wiring shall be single conductor double insulated stranded copper wire with the conductor at least $4mm^2$ in cross-sectional area or AWG 10 or larger. The minimum insulation voltage specification for the supplied cable will be 600VDC. The outside insulation sheath shall be specifically intended for outdoor use in high UV and high ambient temperature environments. Supplier will provide full specifications for the wire and insulation materials that are supplied. Wire specifically intended for use in grid-connected solar systems will be given preference.

1.6 Junction Boxes

Any junction boxes for the connection of panel strings to inverters will be IP65 or equivalent rated for external use in direct sunlight. Junction boxes specifically intended for use in grid-connected solar systems will be given preference. Combiner boxes that are an integral part of the inverter are preferred.

1.7 Array disconnect switches

Array string disconnect switches shall be capable of safely switching up to 10A at 500 VDC and shall be specifically designed for use for solar array disconnection. It is preferred that they be an integral part of the inverter provided.

An additional requirement noted in the tender was that if the prequalified inverter was not supplied, the tender response should note the history of the use of the proposed inverter in the Pacific Islands in grid-connected solar installations. Preference would be given to inverter types that have a prior, high reliability history in the Pacific.

The NDBP reserved the right to pick and choose – that is select some of the components from different suppliers although in the end that option was not used, all the materials came from one supplier.

Tender documents were distributed to solar companies in the Pacific region. The criteria for their evaluation were:

Technical Evaluation Criteria

- The tenders were evaluated by a tender committee that could include representatives of UNDP, PEO and ReEx Capital Asia (consultants to the project) under the management of NDBP.
- Tenders were to be ranked according to their combined technical (St) and financial (Sf) scores using weights (T= 0.6, the weight given to the Technical Proposal; F = 0.4 the weight given to the Financial Proposal; (T + F =1).
- The lowest price (Fm) was given a financial score (Sf) of 100 points. The financial scores (Sf) of the other tenders were computed according to the formula:

  Sf = 100 x Fm/F,

  (In which Sf was the financial score, Fm was the lowest price and F the price of the proposal under consideration.
- The Total score was determined by:

  S (Total Score) = (St x 0.6) + (Sf x 0.4)
- The firm achieving the highest combined technical and financial score was invited for negotiations.
- The following table displays the technical evaluation criteria and their respective weights:

Technical Tender Evaluation Criteria

Qualification of Company (Weight)	20%
(i) Track record with PV grid connect systems	70
(ii) Experience with overseas sales and shipping	30
Total Points	100

Qualification of Product (Weight)	50%
(i) Conformity with Specifications	40
(ii) Ability to be operated and maintained in Palau	30
(iii) Redundancy	30
Total Points	100

After Sales Service (Weight)	20%
(i) Proximity of agent	20
(ii) Spare parts access (dispatch and delivery modality)	40
(iii) Warranty duration	40
Total Points	100

Delivery Time (Weight)[1]	10%
(i) Delivery time (Fastest)	100
Total Points (Possible)	100

The key element in the evaluation was that the components offered met and/or exceeded the specifications and performance requirements as described in this Request for Quotation. Warranties offered, delivery time and the competence and experience of the supplier in delivering similar systems were all of importance. As the NDBP reserved the right to select components from different bidders, the final total price, whether sourced from one or more than one supplier, influenced the decisions on which offers to accept. To minimize the potential additional cost of shipping from more than one location, fully compliant bids from well qualified suppliers were, subject to pricing, preferred.

Seven tenders were received including two from Fiji, one from Laos, one from Australia, one from France, one from the USA and one from Guam. After evaluation of both financial and technical submissions, the Australian firm of Eco-Kinetics was selected as the supplier of all the materials.

Progress of On-Grid Solar Financing Program

As of mid-2014, the supplied equipment has been installed on 10 buildings under the program for a total of 20 kits installed (20 panels and one inverter) with more expected to be financed in the future. This indicates that the Bank was correct in its design of installations for each household. Larger businesses have not taken advantage of the program, choosing instead to work with other consultants on island

[1] Delivery time score = S*dt*: (S*dt* = 100 x D*tf*/D*t*)
D*tf* is the shortest proposed number of weeks required to completion after signing of contract and D*t* is the completion time of the bidder

and using subsidy support from Japan. These additional installations were only possible because of the Bank's work with the Utility that opened the way for the on-grid installations in Palau. All installations have worked as designed and thus far have had no reliability problems.

Prices dropped dramatically following the first procurement by the Bank. This price reduction will allow the Bank to maintain the higher subsidy levels for the new equipment to be procured. The challenge will be to offer the existing equipment at the lower price to consumers. A local contractor has offered to purchase the equipment for the Bank so that the Bank will no longer be required to act as a supplier. Pricing and specifications of equipment have been accepted by the Bank. The financing program will continue though without the bank having to handle the bulk purchasing of components.

Photos of the first residential grid-connected solar installation in Palau

Final cleaning of the panels

Completed panel installation

Inverter and meters

Data logger

Part 2

Development of a standard off grid PV module for financing by the Palau Development Bank

While the grid-connected solar specifications of Part 1 are almost universally acceptable for any of the Pacific Islands, that is not the case for the off-grid solar installations that were developed for financing by the Palau Development Bank. The market for off-grid solar in Palau is very different from that in most of the island countries and the specifications were designed to fit the Palau market only. In the case of Palau, households that are off grid and are in the market for solar electricity are generally not the homes of cash poor subsistence farmers but rather are either the homes of salaried or business persons that do not have affordable access to a grid connection or are the second homes of relatively well-to-do persons who have their main house on Koror, the business center of Palau, and their rural property is used as a weekend retreat or small hobby farm. As a result, the expected electrical services tend to be substantially greater than those expected by the mainly subsistence farmers populating other rural island locations in the Pacific. The services desired for Palau rural homes can range from basic lighting and entertainment services to essentially full, urban quality electrification though off-grid. None of the other Pacific Islands appear to have a significant off-grid market of this type so the design solution used in Palau is not recommended for direct transfer to other countries though the concepts may be of interest.

The basic design problem for marketing off-grid systems is providing a relatively wide range of capacities to meet different customer requirements while retaining the same basic components, particularly batteries. Batteries do not store well, even batteries that are delivered “dry charged” (without including acid in the cells) as even they have a shelf life of only around two years. Sealed batteries or batteries that already have acid in the cells must be kept on a charger or at least recharged every two or three months in order to prevent rapid internal damage to the cells. If different types of batteries need to be stocked for each different size of installation, the cost of maintaining a spares stock and the likelihood of at least some of that stock becoming damaged while in storage would not be acceptable. Therefore a major design requirement for the off-grid systems to be financed by the NDBP was that only one battery type would be acceptable for all sizes of installations. With a single battery type, there are two ways to increase the overall battery capacity: connect cells in parallel (with positive terminals connected together and negative terminals connected together), which in essence creates one larger cell of the same voltage and twice the capacity, or connect two cells in series (the positive pole of one cell connected to the negative pole of the second cell) to double the voltage available and thereby also doubles the overall energy storage capacity. The path chosen for the Palau designs was to increase the voltage by adding cells in series. Adding cells in parallel can work for two cells, but more than two in parallel is not good practice since any problem with any cell creates a similar problem for the other cells in parallel and in general all cells have a decreased lifetime. Since the replacement of batteries is the main ongoing cost for off-grid solar, keeping the batteries in service as long as possible is a major cost-saving measure.

Three sizes of off grid “kits” were created for the Palau market. The basic solar home system included six battery cells in series to provide operation at 12V DC. Panel size was set at a total of 400 Wp of solar, roughly double the usual size of subsistence farmer type installations seen in the rest of the Pacific outer islands. That size is sufficient to operate a small DC fan, several lights and a radio. With the inclusion of a small 12V inverter, AC power sufficient to operate a standard AC table fan and a small portable TV for as much as an hour a day would be available.

For customers desiring more electrical capacity in order to operate larger video systems, more lights and a ceiling fan, doubling the panels to 800 Wp and increasing the battery to 24V (by putting two strings of 6 cells together into one 12 cell string) could provide that level of service while still using the identical panels, batteries and charge controller that are used for the 400Wp 12V system.

For customers intending to have a small refrigerator or freezer as well as the lights, fans and entertainment services of the smaller installations, four of the 400Wp basic kits could be connected in series to provide 1,600 Wp of solar at 48VDC. While the same batteries and panels can be used for this large installation, it would be for AC only and would require the installation of an inverter with an input voltage of 48V – which is a standard input voltage for most residential style inverters. Many inverters include a charge controller in the package. If the inverter that is chosen does not include a charge controller, it is recommended that an MPPT (Maximum Power Point Tracking) type of unit be included in the kit.

In the case of the off-grid kits, as with the on-grid kits, certain items that were known to be reliable in the Pacific Island environment were prequalified for purchase. Therefore the design consultant selected specific charge/discharge controllers, specific low power inverters and specific batteries as prequalified items for purchase through competitive bid. The controllers and inverters made by MorningStar (USA) were prequalified because of their well demonstrated reliability in the island environment. A Philippine manufacturer was selected as the sole supplier of batteries partly because the batteries had been successfully used in off-grid projects in the Philippines but mainly because of the ease of quickly obtaining replacement batteries by way of the frequent and relatively low cost shipping from the Philippines.

The panel specified was of a dual voltage type that was readily available at the time of the 2009 tendering process but in recent years has become difficult to find. However, two separate panels that are each suitable for charging 12V batteries (36 cell panels for the Pacific environment) can simply replace the single dual voltage panel specified though at slightly higher cost caused by the additional the mounting and connection labor.

For reference, the actual specifications for the off-grid components is provided below.

Detailed Specifications of System and Components

Photovoltaic Panels

- The photovoltaic modules shall be warranted to provide their rated output at standard conditions within ±20% for a minimum of 20 years under the harsh tropical, coastal conditions at the sites. A copy of the complete warranty terms must be provided with the tender.

- Photovoltaic modules of the model offered must have been tested by an internationally recognized testing facility and certified by that facility to meet internationally accepted standards.
- The construction must allow the safe maintenance of at least 600V differential between the panel frame and internal cell wiring.
- Cells will be made of monocrystalline or polycrystalline silicon. Amorphous or thin film type construction is not acceptable.
- PV modules must be framed with aluminum or marine grade stainless steel with appropriate seals to prevent water and corrosion damage to the active components of the panel.
- High strength glass must be used for the transparent cover. The backing of the panel may be high strength glass or other material impermeable to water that is accepted under the applicable international standards.
- By-pass diode and blocking diode protection for reverse current and shading effect reduction are not required for individual panels but individual panel by-pass diodes may be included.
- Panel Wp ratings shall be no less than 160 Wp nor no more than 250 Wp.
- Panel shall contain 72 solar cells in two 36 cell strings that can be connected in parallel for 12V battery charging or in series for 24V battery charging.
- Connections may be either by standard “quick connect” type socket and plug wiring or by screw type terminals. Screw type terminals are preferred.

The contractor will include as a part of the tender response at least the following information for the panels to be supplied:

- Voc, Isc, Impp, Vmpp, and Wp at standard conditions
- The relationship between temperature and module output over the cell temperature range 25°C to 75°C
- The IV (current/voltage) curves for 250, 500, 800, and 1000 W/m2 solar inputs
- Physical size and weight
- Details of the materials used in construction, including the frame, the connection boxes, the backing material and the encapsulation material.
- Number of cells per panel
- Type of cells provided (monocrystalline or polycrystalline)

The results of type tests carried out on the module type at ESTI (or an equivalent institution) using the CEC Specifications No. 503 or to International standard IEC-61215 shall be provided.
A statement of warranties in effect for the proposed module type must be provided with full details of the terms of those warranties for both physical defects and capacity loss.

Photovoltaic Module Support Structures

- Arrays are expected to be mounted on good quality metal roofing fastened to wooden purlins that are in turn fastened to wooden trusses; however mountings should also be suitable for use with pre-fabricated steel buildings or on stand-alone poles with a locally fabricated wooden rack designed specifically for the panels supplied.
- The panel mounting framing must support the panels in a manner that allows adequate air flow between the metal roofing and the back of the panels to keep heating of the panels to a minimum.
- A spacing between the back of the panel and the highest part of the roofing metal that is between 60mm and 100mm will be acceptable.
- All metal components and fastening hardware that are in actual contact with the steel roof must be marine grade stainless steel or a non-conducting material.
- Direct aluminum to steel contact at any point in the assembly will not be acceptable.
- The tilt and direction of the roof surface will be maintained in the PV array therefore there is no requirement to provide a mounting that is not parallel to the roof surface.
- The fastening method will be such as to always penetrate the corrugated metal at a high point on its surface and will include appropriate seals that prevent roof leaks due to the panel attachment for the life of the installation which is to be at least 20 years.
- All components must be able to resist at least 20 years of outdoor exposure in the location's harsh tropical coastal environment without any appreciable corrosion or structural fatigue.
- Full technical specifications and detailed assembly instructions shall be provided with the quotation showing the construction and assembly of the mounting structures and the details of the mounting of the modules and their attachment onto the supporting structure. These must specifically include physical size, and details of materials used in construction.
- Panel mountings supplied shall be standard commercial units manufactured specifically for mounting of solar panels on metal roofing and shall be adjustable to fit standard solar panels in the 150-250Wp range.

Solar Charge Controller

- The charge controller must be capable of charging either 12V or 24V open cell lead acid batteries.
- High voltage cut-off shall be no less than 14.4V.
- Low voltage cut-off shall be no higher than 11.7V.
- The controller shall be capable of either PCM or "on-off" type of control.
- The rated amperes shall be no less than 15A.
- The controller supplied must have a history of reliable use in the Pacific Islands or similar environments for at least five (5) years.

The Morningstar model ProStar 15 A 12/24V controller is prequalified.

Wiring

- Panel wiring shall be single conductor double insulated stranded copper wire with the conductor at least 4mm2 in cross-sectional area or AWG 10 or larger.

- The minimum insulation voltage specification for the supplied cable will be 600VDC.
- The outside insulation sheath shall be specifically intended for outdoor use in high UV and high ambient temperature environments.
- Supplier will provide full specifications for the wire and insulation materials that are supplied.
- Wire specifically intended for use in off grid-connected solar systems will be given preference.
- Indoor wiring shall be standard two conductor house wiring 12AWG or 2.5 mm2 stranded or solid copper wire.

Dedicated Inverters

- Inverters supplied shall provide pure sine wave output at 120V 60Hz.
- Continuous power rating shall be no less than 300 W.
- The unit shall be capable of providing 600W for at least 5 seconds without overheating.
- Protection against reverse polarity, over current and over temperature will be included.
- Units should be capable of supplying power to video systems and small refrigerators.
- The input voltage shall be 12V DC.
- Units should be sealed against moisture and salt entry

The Morningstar SureSine model is pre-qualified for supply.

DC lights and sockets

- For 12VDC installations, 12VDC CFL type lights in the range 12W to 15W will be supplied.
- Lights will be expected to operate reliably over a voltage range of 10.7V to 16V DC.
- Rated life will be at least 2,500 hours of operation.
- Sockets supplied will be suitable for use with the DC CFL lights supplied.
- Screw type connections with capacity for connection to 10 AWG wire are required.

Batteries

- The preferred manufacturing and shipping source is Motolite/Oriental battery models from the Philippine Battery Corp.2
- Cells supplied will be Oriental Stationary Battery model PS210
- Lead-Acid batteries shall consist of either multiples of 2V cells, multiples of 6V batteries or 12V batteries connected in series to reach the required end use voltage.

[2] As future replacement batteries will be ordered in small quantities, batteries of Philippines manufacture are desired since shipment from the Philippines will be easy as many partially filled containers originate in the Philippines for delivery and shipment to Palau. Also, the batteries specified are designed to be used with small off-grid systems similar to the systems that will be in operation in Palau, this ensures maximum system efficiency. Although there are batteries from other brands that are also designed for use with small off-grid systems, none of these batteries are produced in the Philippines and referring to the explanation above, it was not recommended to accept batteries from other sources.

- Cells shall have an Ampere Hour rating of 180-220 Ah at C10.
- Batteries shall be designed for deep cycle operation and long cycle life.
- Batteries shall be provided in dry charge state and the proper tropical region electrolyte provided with at least 10% extra provided to allow for spillage.
- Batteries will be shipped dry with the electrolyte needed to activate the cells also included.
- The 12V configuration will require 6 PS210 cells. The 24V configuration will require 12 PS210 cells. The 48V configuration will require 24 PS210 cells.

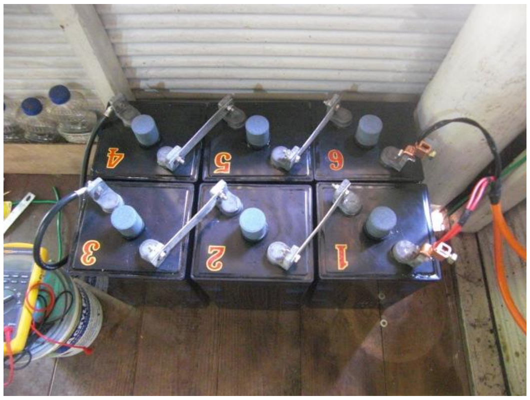
Although the specifications for the panel mounts were for roof mounting, at the request of the owner, the first installation had the panels mounted on a pole beside the house (see photos below). The panel mounting was fabricated on site from wood.

As of this writing (2014), the installation is more than 3 years old. The system has performed as expected and no major problems have been experienced. The Installation of the off-grid PV system at a small farm house has been much appreciated by the owner. The charge controller continues to show that the panels are generating the proper amount of electricity and the batteries are storing that charge for later use. The inverter has not been used as much as was expected indicating the main need of the system has been for lighting. In the remote area where the house is located, the quietness of the system is also appreciated. Payments to the Bank are low and the owner indicates that a higher monthly payment for the loan would not be objectionable in order to accelerate pay-down of the loan. Inspections and maintenance of the system by the Bank contractor has been carried out as expected since the installation. The only maintenance has been the monitoring of battery water levels and refilling with distilled water as needed. Water levels are checked each month. Cleaning of equipment has been also necessary due to the accumulation of dust though it is not a frequent problem. The 12V DC CFL bulbs have lasted a long time but there may be a problem locating replacements as they are not a common item in the local shops. It is recommended that the NDBP work with the shops or maintenance contractors to make sure they are available for these types of off-grid installations.

Photos of the first NDBP financed residential off-grid solar installation in Palau

Solar Panels

Panel connection box, charge controller and inverter



12V Battery

Charge/Discharge Controller