Tanna Island Safehouses and Mini Power Systems Status Update December 2019

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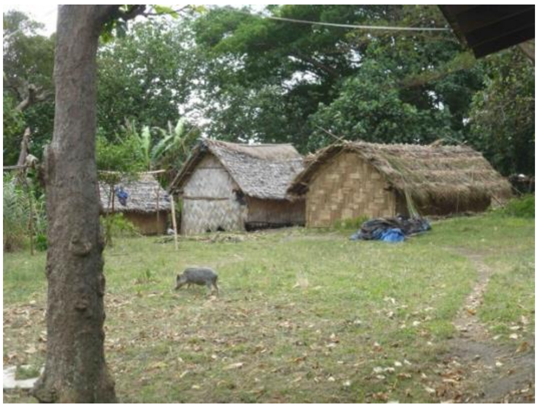

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1. Introduction

Professor Brendan Mackey and Melissa Jackson from Griffith University visited Vanuatu in November 22-28, 2019 as part of the final stages of the Tanna Safehouses project.

The aims of this visit were:

1. To assess the current functionality of the systems;
2. To deliver community training in basic use and maintenance of the solar power systems, helping ensure that once fixed they are not subjected to misuse and to increase the longevity of the assets;
3. To brief key stake holders including the National Department of Energy, Tafea Provincial Government and Tanna Council of Chiefs on the project's status and progress and to discuss the need for establishing governance arrangements, local suppliers and community capacity building as a critical part of the success of small-scale remote area power supplies (RAPS).

The following provides an overview of progress against each of these aims.

2. MPS and Battery Function Status Update

It was intended that this component of the visit would be aligned with the technicians from Green NRG who could attend part of the training and provide guidance and input for the communities while at the same time repairing the systems where possible. With their last minute absence, the GU team along with Allan Dan, our Tanna community liaison and a respected local Tanna Chief, and Mr Timothy (Tim) Loughman, who had been involved in supporting Green NRG with the original installations of the mini power systems and holds certification in electrical work in Vanuatu, undertook an audit of the Mini-Power Systems (MPS) with the objective of providing a report that can be used by Green NRG in undertaking their site visit. Fortunately, we were able to borrow a multi-meter from the manager of the Evergreen Resort in order to test the battery changes. We also undertook some minor repairs as detailed below.

Of the thirteen huts with the smaller systems, only four power systems were functioning – at buildings 1,2, 5 and 12 (see Figure 1). This is down from six that were still functioning in June 2019 (see *Tanna Safehouses and MPS Audit Report July 2019* for details).

The battery status for the 5kW systems (each with 4 batteries = 52 total), can be summarised as:

- 12 batteries are functioning within the ideal charge rate (noting this was measured during the day, so may be affected by power production);
- 37 batteries are assumed to be dead (unrecoverable as below 10.5V and likely damaged from being under this level of charge for prolonged period), and should be replaced with new ones.
- 3 may be recoverable with recharge (tested between 10.5 and 12V) but maybe not, depending on how long they have been at that charge state for or if any sulphuration has occurred within the battery);

In the battery bank for the longhouse (20kW system), of the 16 batteries:

- 1 has sufficient charge remaining;
- 11 are assumed dead (below 10.5V) and requiring replacement; and
- 3-4 may be recoverable upon recharging (10.5-12V).

Overall, of the 68 batteries:

- 13 batteries are still working (but need to be tested and confirmed again at the GNRG visit).
- 48 need replacing, (possibly more if the 6-7 that are above 10.5V are not successfully recharged)
- 6-7 may be recoverable upon recharging;

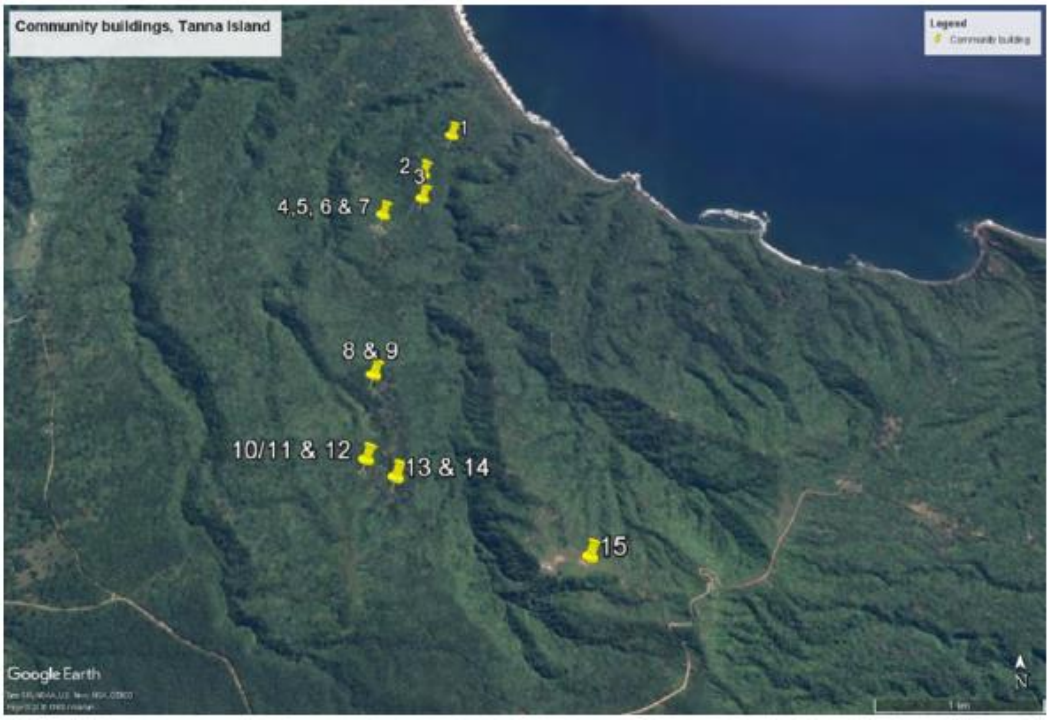


Figure 1 - Tanna Safehouses location of hut and power systems

Eight 'new' batteries were collected by the team from Tanna Lodge (Hugh's place where they were stored by GNRG) and are all still holding charge. The voltage test showed: 12.50V, 12.68, 12.7, 12.4, 12.4, 12.6, 12.7, 12.2 respectively. Given that for Gel type lead acid batteries, 12.8V is considered 100% charged (see Appendix A), only 3 are close to this level, with a few in the mid-range charge state. All are above the 20% minimum. Ideally all the batteries will receive a top-up recharge before use.

These 8 'new' batteries are now stored in Hut 12 (next to longhouse/clinic, where Day 2 training was held). We will be paying Allan and Timmy to take the highest charged four batteries (three at approx. 12.7V and one at 12.6) to test the other non-functioning systems. By connecting these functioning batteries it will be possible to check if the MPS will function when the battery bank is charged. We will send the results to GNRG to assist with the planning for their next repair visit. Once each of the non-functioning systems are tested, those batteries can then be connected up to complete one of the systems to fully functioning prior to the GNRG technicians visit. Alternatively, if Allan and Tim are able to purchase/borrow a battery charger, and have the time to top up the charge from one of the working systems (will take a number of days to do them all), all of the 'new' batteries can be charged up and connected to systems prior to the GNRG visit. We have asked Allan to inquire as to whether a battery charger can be purchased in Port Villa. Also, we will pay Tim to replace/fix the cable/wiring that has been shoddily installed by locals at the school buildings (#5, Figure 1) from the middle hut out to the teachers building – as it currently dangerous.

No other equipment was provided by Hugh to the team, although Anthony had provided a list that included additional equipment. There are also discrepancies in the overall count of equipment initially supplied through this project including an MPS and batteries. We recommend an internal stocktake to account for all equipment purchased.

The following table summarises the status of the power systems and batteries (note: green highlights indicate the charged batteries) recorded at the November 2019 site visits. Proposed next steps are also listed (final column) that will progress towards getting the systems into full functionality as soon as possible.

Table 1 Power system and battery status update November 2019 including proposed next steps

Hut number*, village (tribe)	Description	MPS Working	Battery voltage (when looking from front on)				Detailed observations and comments	Proposed Next Steps
			Top Left	Top Right	Low Left	Low Right		
1 Ianbrapem (Tasikamine)	Bottom hut (pastors place)	Yes	12.78	12.79	12.82	12.79	MPS cabinet on rollers. Power point fitted was very loose so may be reason for the reported "intermittency" as plugs not connecting properly. Replaced power board and replaced LED light bulb closest to door. Safety and info posters put up. At the training, were told there is no circuit breaker for this system.	This system appears to be working well. Monitor over next two visits to determine if intermittency issues reported are persisting or fixed i.e. check in with the pastor and locals to ask if working more reliably. The issue may simply be due to power generation not meeting demand rather than a fault. GNRG to explain why no circuit breaker installed here. GNRG to test system components on next visit.
2 Lawenui (Tasikamine) (has logger)	2nd lower (with little garden around and water tank)	Yes	13.30	12.90	13.50	13.00	MPS cabinet on rollers. At the training, were told there is no circuit breaker for this system. Mentioned intermittent power. Replaced both LED lights, the one closest to door replaced light fitting also due to corrosion/breakage. Safety and info posters put up. Collected logger data for this building.	This system appears to be working well. Ongoing monitoring needed. Follow up with users to ask if any problems since visit. GNRG technicians to follow up test system components on next visit.
3 Enmatagi (Tasikamine)	3rd lower (near hut 2)	No	5.2	5.4	0.1	0.4	No circuit breaker in this building. Need to ask why was not installed. Advised that it was working this year, so at some point the batteries have lost charge and not been sufficiently recharged. 2 "new" batteries. Safety and info posters put up.	All four batteries need replacing and old ones disposed of safely and environmentally on next GNRG technician visit. GNRG to advise if any recovery possible of low charge batteries and what is required to do so in advance (tested/charged from the grid, i.e. taken to Lenakel, to see if any are suitable for reuse in the systems or for other uses). GNRG to

								explain why no circuit breaker installed here and install for safe operation.
4 Enkatalei (Tasikamine)	Lower school hut	No	3.7	15.2	0.01	15.2	As per previous site inspection in June, the system is not working.	Replace two non-functioning (TL, BL) then test system to see if it works after battery replacement. Allan and Tim can do this. If works, GNRG technicians can just run routine check when they come to see if batteries holding charge or whether other factors influencing system function. If does not function, need to record this and advise for GNRG planning to ensure appropriate equipment is brought over. GNRG to fit rollers to cabinet.
5 Enkatalei (Tasikamine)	Middle school hut (where first training held)	Yes	4.0	6.85	7.01	7.04	BM noted battery voltage. However this needs clarification from GNRG – how can this system be working fine if batteries not charged? From conversations with Anthony understood that the systems won't work at all (trigger shutdown) if batteries drained. May need to re-test voltage on these to double check. The LED screen on the system would not cycle through when pressing the correct buttons, seemingly a fault. Also panel input recorded 0 the whole time. Could this be that the system still works without battery? Safety and good care posters put up (Bislama and English). As per previous, cable connected from this functioning system through the upper school hut (via dangerous wiring) to the teachers buildings.	Tim and Allan to return and double check the charge levels in these four batteries. If similar or lower values, replace all four batteries with new ones and store old ones safely for GNRG to consider recharge potential/safe disposal. Tim to replace/fix the cable/wiring from the middle hut out to the teachers building – so it is no longer dangerous. Interim fix until the system is up and working. By prioritising fixing MPS (by replacement of all non-functioning batteries?) in all three school huts, it is likely that less cables and wiring will be "illegally" connected or installed by the locals and hence less safety risk. If the batteries all need replacing, GNRG to give clear (written) explanation about what factors (charge levels) trigger shutdown in the system in relation to battery charge, to inform the teachers and users of the systems for ongoing management. Need to provide a safe alternative option for

								connecting the teachers building given there are no solar panels on that building, but the community will likely continue to connect it to the school huts.
6 Enkatalei (Tasikamine)	Upper school hut	No	6.12	11.07	1.12	11.27	As per previous site inspection in June, the system is not working.	As per Hut 4 plan: Allan and Tim use **2** of the stored new batteries to replace non-functioning (TL, BL) to check if system is back on line with 2 or 4 working batteries. Store old ones for GNRG to safely dispose (or attempt to recharge the others). GNRG technicians to test system components on next visit and recharge the batteries that have not been replaced (may need to bring additional 2 batteries here for the 11V charge if they don't recover).
7 Enkatalei (Tasikamine)	Community hall – opposite field from school huts	No	4.0	6.85	7.0	7.0	As per previous site inspection in June, the system is not working.	GNRG technicians to test system components on next visit and install four new batteries. Advise if any of old batteries are recoverable with such low charge.
8 Imarup (Namalgang)	Left (lower)	No	1.0	4.1	0.1	4.01	As per previous visits, wiring hooked up to next building as. 4 "new" batteries dead. Presumably from having both huts connected. Cable going to "sister hut" that we were told was connected by the GNRG technicians the last time as an interim fix because they couldn't fix the MPS is apparently oversized according to Tim. This will need to be replaced (ideally removed as soon as the other system is back in and both are working). The wiring on this system is a complete mess, dangerous and needs to be redone. Locals advised that some health staff had come and run a workshop here and had	Priority to fix this system as it was used regularly for weaving. Allan and Tim to replace four batteries and Tim to replace old wiring with new. Disconnect cable to other hut – which needs to be fixed as a matter of priority by technicians next visit. GNRG to fit rollers to cabinet.

							connected up new wiring so now it is a big mess at the back of this system. Cello tape used on wiring at back of system. This is where the "fire" occurred only a few weeks before, which presumably was caused by the poor wiring that had been tampered with recently. Significant safety risk. Tiles between new batteries, no rollers for cabinet. Safety and good care posters put up (English version only)	
9 Imarup (Namalgang)	Right (upper)	No	0.5	4.5	3.0	4.0	No MPS here, as per previous visits – removed by GNRG technicians who did not bring enough to replace it. A generator is sitting next to the MPS. 4 older batteries are dead. Power board that is on the wall behind the systems in other huts is inside the cabinet, which is inaccessible to most without keys and we have just provided training to keep people away from the back of the systems. Therefore this needs to be remedied (there is a power point on the other side of the room which is inaccessible and so further unsafe wiring has been connected to it). Very unsafe extension cords have been hooked up to the power point on top of structural beams. We attempted to unplug these (see photos) as they were hanging down at head level and serving no purpose, but the fitting was so brittle that it broke. This will need replacement along with the system and batteries and wiring. Safety and good care posters put up (English version only)	GNRG technicians to replace the MPS that was taken away in 2018 and replace all four batteries with new. Appropriate power board needs to be fitted to wall. GNRG to fit rollers to cabinet.
10-11 Enarawia (Namalgang)	Longhouse – health clinic	No					Building not being used. Batteries underneath exposed. Lock broken off (rusted through) – need to replace with key	Only one battery up to charge, but a number of others salvageable with long

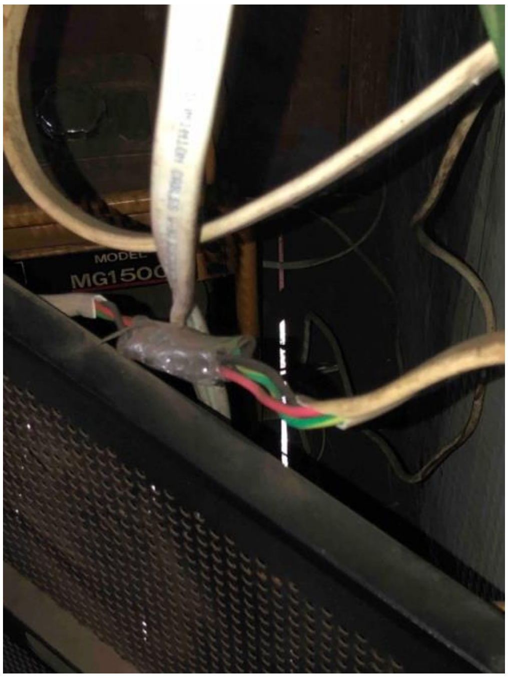
							locks (not combination – nobody knew the combo). Battery V listed below relates to view when on northern side of building looking toward building at battery cage.	recharge (will need to be taken down to town most likely to charge off the grid).
			12.2	10.0	7.0	9.2		
			7.8	9.3	10.8	7.0		
			7.0	11.2	11.6	6.5		
			10.39	6.2	6.3	9.9		
12 Enarawia (Namalgang)	Next to longhouse where we held 2nd training	Yes	13.74	13.77	14.0	0.05	MPS was same LCD panel as hut 3, 5 and hut 15 – different to the "newer systems". Alarm starts when switched off and on (during training). This took quite a few goes to stop the alarm, but unclear on the problem. Upon return in late afternoon, alarm was again going off. Jessie (our community liaison) said it happens every evening when the sun gets low. Could assume that there is a problem with the system relying solely on battery power? Unable to troubleshoot this successfully. Could be something to do with the 1 flat battery? Perhaps only running of panels, but understood that they would work? Cabinet not on rollers. The LED screen was same as Hut 5 (middle school hut),but unlike Hut 5, seemed to be working fine. Also showed input from panels and percentages. Safety and good care posters put up (Bislama and English).	Allan and Tim to re-test voltage as there is uncertainty about these figures. Replace one battery and see if the alarm issue is fixed. Take a wire brush and clean off corrosion around battery terminals. GNRG to diagnose problem with the system and what is causing alarm. Fit rollers to cabinet. Put covers on battery terminals (this appears to be quite effective in protecting the other batteries that have them).
13 Enarawia (Namalgang)	Left	No	Top top right 9.6	2.8	11.4	3.2	1 battery bottom left, 3 on right. Old battery piled on top right has been painted (but has more remaining charge than others - likely only one that can be recharged). We were told by Allan this is where the batteries were originally "stolen" and returned much later. May explain the cut wires to battery –	All four batteries to be replaced at next technicians visit. Wiring needs to be fixed as it has been cut between batteries and MPS (see photos)

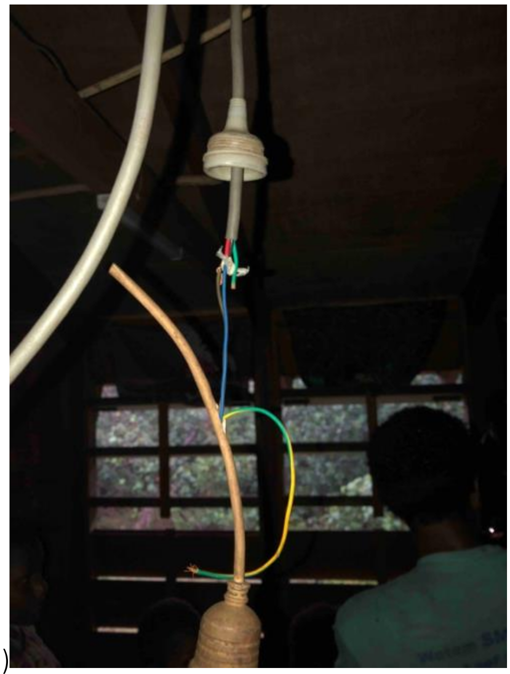
							(unsure how long this has been cut as we did not have access on last visit to inside this hut). Wiring needs fixing here. MPS appears to be different system again to other two types noted – older version again? Air intake at back of MPS metal protectors are completely rusted and rust is likely to be sucked into the system once working again (see photo). Safety and good care posters put up (English version only). In this building a lot of mattresses lined up on the side where apparently footballers came and stayed.	
14 Enarawia (Namalgang)	Right	No	8.2	12.1	12.2	7.4	Two batteries still have small amount of charge. Bags of cement stored (and spilled on ground) all around the MPS, cabinet was unlocked and on rollers, had been rolled to the side to put the bags there (seemed unnecessary as they could have been stored in any other part of the hut – more education needed?). 2 of the trainees from day before helped to clean up and relocate the bags away from the power system which was moved back into place. Building apparently used for weaving (stored in corners and bags hanging up with prices on) Safety and good care posters put up (English version only).	Prioritise replacement of two lower charge batteries and test system to see if it works with just this replacement. The two higher charged batteries will still need recharging, but this may be enough to get the system working. Potentially replace all. See if the two replaced batteries could be recharged potentially down at Lenekal and used later. Will need to be tested by GNRG technicians at their visit.
15 Loanialu (Tumah)	"airfield" cloud forest exposed and harsh conditions. Most shutters broken. Ceiling mouldy and peeling away.	No	4.8	1.3	3.5	1.5	Was being used regularly (informed by Australian woman working for church school via email) before batteries went flat (early to mid 2019).Cabinet unlocked on both sides when we got there. It is on rollers. Earthing wire exposed outside and pulled out. Tim tried to reconnect, but left it loose. MPS same as other (older style?) where LCD is	All four batteries to be replaced at next technicians visit. Determine if the locals are aware of how much load can be used with these panels (effectively a 2kW system) to maintain battery storage. May be a good site to add a couple of panels to, but depends on cloud cover. Batteries may need to be more regularly charged.

							simple and does not match the user guide. Only 8 panels, so presumably with cloud forest weather patterns (i.e. localised clouds) power generated is being used up and batteries being drained too much. There is a different lighting set up here. May have been added afterwards (see photos) – approx. 8 lights all with cords plugged into a number of fittings on the rafters and additional extensions/power boards. Not sure if it was installed this way or has been put in by locals. Nobody from Loanialu attended the training.	

* Numbering from GU Final Report - 1 at bottom of hill, 15 at top (airfield)

The following images (Figure 2a, 2b, 2c, 2d) show some of the issues with wiring and state of equipment in the huts:

a) 

b) 

c) 

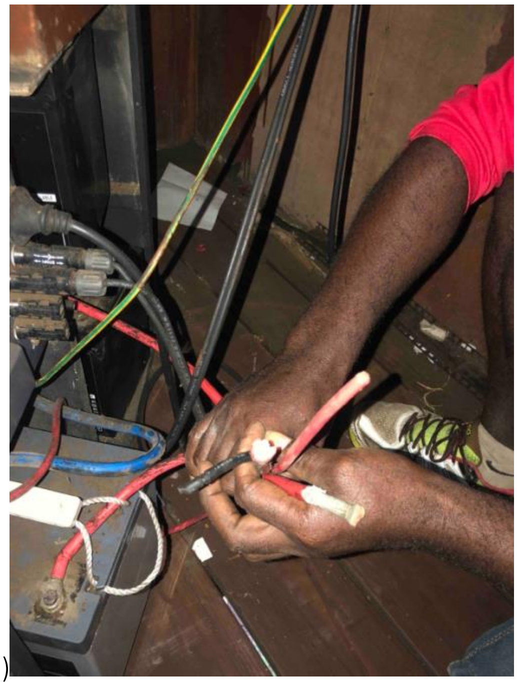
d) 

Figure 2 Images of poor state of electrical wiring that needs repairing: a) cellotape used to cover open wires at back of MPS in hut 9; b) homemade connections of extension cords in hut 8,c) broken socket in rafters of hut 8, d) wiring between MPS and batteries in hut 13

Recommendations and Next Steps – Repair of Power Systems

Within this project, the next steps are for:

- Tim and Allan to consolidate batteries and get all currently charged batteries into functioning systems prior to the GNRG technicians visit:

- Hut 4 & 6 – replace 2 batteries in each and check if this gets the systems up and running again
- Hut 5 – test the batteries again and see if the system is storing charge overnight or not
- For the remaining 4 good batteries install in either Loanialu (Hut 15 by airfield) or Hut 14 (decision needs to be made in conjunction with the communities) they are keen to use the hut for weaving in evenings in both huts but are unable to do so in evenings anymore.
- Check the battery still functioning under the "health clinic" and move next door to hut 12 to create a full set of charged batteries (i.e. replace the one that is completely dead).

For this visit key materials needed (in addition to a good electricians toolkit- we assume Tim has the necessary equipment or will inform us if not) include:

- Multimeter tool to check voltage
- 8 new batteries (currently stored in Hut 12)
- Appropriately sized cable/wiring
- Electrical tape to seal exposed connections that don't need replacing
- Plug fitting to replace broken one in Hut 9
- Clips to fit to walls, beams etc. to clip wiring to so it doesn't hang down (e.g. Hut 15 inside and earthing wire, Hut 9 and others)
- Remaining power boards and adapters Mel left with Tim at end of November visit.
- Ideally, a battery charger (Potentially borrow from someone on Tanna or purchase from Port Vila and get shipped over, however GNRG have a second one they are bringing after the original one has been misplaced somewhere between Tanna Lodge and the communities).

Following this interim fix, and once a follow up report is shared with them, the Green NRG technicians need to plan an approach for completing all repairs and maintenance on the systems as soon as possible, weather permitting.

In terms of the ongoing sustainability these systems, we recommend engaging one of the solar power suppliers in Port Vila as a means to provide cost-efficient and ongoing support and maintenance beyond the end of this project for the community. Currently, the community is dependent upon external (Australian and Chinese) companies for maintenance and repair of the systems (which in turn are dependent upon the donor funding agency) and up until this training have had no internal capacity to do so themselves. This is an unsustainable arrangement financially and operationally which may be somewhat mitigated by involving more locally based suppliers in the final repair and replacement and further discussions with the initiating group of chiefs to explore possibilities for generating income which can support ongoing maintenance from within the communities. This would involve requesting quotes for replacement of equipment and ongoing support (i.e. annual maintenance visits).

3. Community Training

A basic training course was offered to the members of the communities. The aim was to provide a foundational understanding to ensure that basic operation and maintenance practices are understood to ensure that once systems are in place and functioning that users do not contribute to dysfunction in the system operation. This training aimed to fill a gap in knowledge and overcome some barriers that have prevented the systems being operated safely, and in alignment with the system requirements. Two trainings were offered: on the 26th November for the Tasikamine tribe (lower huts) and held in the middle school hut (Hut 5); with the second training following on 27th November for the Namalgang and Tumah tribes (upper huts) held in Hut 12.

In preparation for the training days, our key community liaison, Mr Allan Dan recruited Miss Jessie Nalau, a member of the community (based in Lenekal), to communicate with community members about the objectives and to seek feedback and gauge interest. Very little feedback was provided in advance and so the training was aimed at building a base level of understanding and on the assumption that many of the community members are illiterate and that even some foundational concepts would need explanation verbally and practically rather than relying on written manuals. However, supporting materials were also developed to support the training for those who were sufficiently literate (see Appendix B). These were developed specifically to include visual references and plain language based on the more technical user manuals the GNRG had for their power systems.

The trainings (and supporting materials, in Appendix B) were designed and delivered by Melissa Jackson and translated by Alan Dan into Bislama and local languages as required. Mr Timothy Loughman was also in attendance and provided technical support and guidance and worked through some of the practical steps with participants in local language. This was invaluable given the absence of the Green NRG technicians who were originally planned to play a support role in the training. Professor Mackey introduced the training, input to content and presented awards to the participants at the end of both sessions.

The training was conducted from approximately 10am to 3pm with lunch provided, cooked by the local women.

In total 35 community members participated in the training (with 3 coming from other areas).

- 24 (16 male, 8 female) including the chief, pastor and 3 school teachers
- 10 (all male)

Key topics covered included:

- Basics of solar power and solar power generation systems – functions and component parts;
- Operation of the power systems and troubleshooting of basic problems;
- Cleaning and maintenance; and
- Safety risks, hazards and good practice

The training was designed for an interactive and flexible delivery to meet the needs of the locals and to ensure time to ask and respond to questions (Figure 3 and Figure 4).

Figure 3 Practical training given at the site of the power systems

Figure 4 Melissa Jackson, Tim Loughman and Allan Dan teaching community members about basic functions of the solar power system

All attendees were awarded a Certificate of Participation from Griffith University and given a gift of a shirt, cap or drink bottle (see Figure 5 and Figure 6).

Figure 5 Each participant was awarded a participation certificate from Griffith University and gift of GU hat, shirt or water bottle

Figure 6 Participants and trainers at the end the first Basics of Small-scale Solar Systems training (outside Hut 5)

A number of participants expressed interest in undertaking further technical training about the operation of the systems. From discussions with other key stakeholders at the provincial and national government level, there appears to be a gap in the rural electrification programs being rolled out that are missing the grassroots capacity building and good governance arrangements for small-scale remote area power systems (RAPS).

We also reflected on the difficulty of engaging the women in the training due to their heavy workloads during the day. It is well accepted within development literature and practice that investing in education and capacity building for women is a critical pathway to bringing communities out of poverty. Although our intention was to have a balance of genders participating in the training and we had good levels of participation on day 1, in no small part due to Jessie's involvement in the preparations, there were no females in the second day's training. In future, a specific training for women should be arranged in conjunction with the community liaison/s to more effectively tailor and engage the training to women's needs, such as holding the training on a Sunday, when other duties are relaxed somewhat. This will help to maximise female participation and to ensure a gender balance in local capacity building.

Recommendations and Next Steps – Community Engagement

Building on the training and community engagement that was conducted in November, the following actions are recommended:

- The deployment of solar technicians to repair and replace non-functioning parts as soon as possible (as per section 1.1) will help to facilitate learning and translating the theoretical and practical training into skilful practice. Delays will reduce the effectiveness and impact of the training.
- At least three of the systems have different LCD screens and user interfaces (Figures 7a, 7b, 7c), however the User manual provided by GNRG, is different to these interfaces and thus the community summary guide designed based on the information provided by GNRG (to clearly indicate how community members can navigate and diagnose basic issues via these interfaces) are not accurate. GNRG need to provide exact user manual instructions for each different model of 5KW system to Griffith researchers for inclusion in the guides prior to translation taking place.
- Arrange for translation of the updated Community User Manual and Safe Use Posters in Bislama and French to distribute across the huts/power systems.


a)


b)

c) 

Figure 7 Three different displays/user interface of mini power systems provided by Green NRG

4. Engagement of Key Stakeholders

In addition to engaging the communities in which the huts and power systems are installed, the team met with a number of key stakeholders during this visit, both in Port Vila and on Tanna, briefing departmental staff and giving presentations about the project. Discussions revolved around the key lessons from the implementation in the Middle Bush villages on Tanna and implications for rollout in other regions, within Vanuatu and across the Pacific, and how to integrate lessons learnt to streamline project uptake and improve sustainability outcomes. The key stakeholders consulted were:

- Vanuatu Department of Energy (DOE);
- The Secretariat of the Melanesian Spearhead Group (MSG)
- Vanuatu Kaljoral Senta (national cultural centre);
- TAFEA Provincial Government (Figure 8); and
- The Tanna Council of Chiefs (Figure 9).

Through these meetings a number of promising pathways were identified for progressing a strategic and scaled approach to good governance and implementation of remote area power systems.

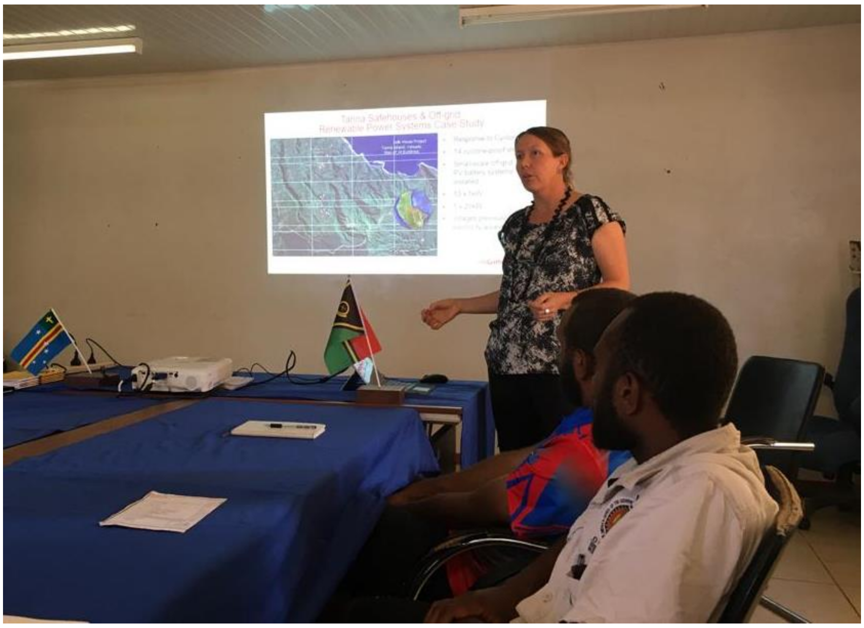


Figure 8 Melissa Jackson from Griffith Uni presenting to Tanna Provincial Government Area Coordinators about the Tanna Safehouses Project

Figure 9 Griffith University team members meeting with Tanna Council of Chiefs representatives in Lenekal

Recommendations and Next Steps – Engaging Stakeholders

It is recommended that further engagement of the government (Provincial and National) following up on initial conversations continue in order to promote a partnership approach for developing guides and capacity to implement future projects more effectively from a socio-technical perspective. Specifically, actions that would progress this agenda include:

- Co-development of a regionally-applicable guide to good practice for funding, designing and implementing small-scale RAPS in the rural Pacific;
- Co-development with DOE and other key stakeholders of a technical training program for unskilled community members receiving RAPS infrastructure projects. This could be potentially linked to an electrical systems certification program in conjunction with Vanuatu education

and training department, and be offered to the communities for those who expressed interest in taking a more hands-on approach to the long-term operation and maintenance of the systems. This could be developed with a view to standard community training rolled out across the region as RAPS systems are installed as part of rural electrification goals.

- In addition, we have designed a RAPS learning module that uses data from the data loggers in three of the power systems on Tanna, to be included as part of an electrical engineering undergraduate course at the University of the South Pacific. The Griffith University team have held initial conversations with representatives of the Science faculty and Teaching and Learning at the University of South Pacific (USP) and the Science teacher at Tafea College on Tanna. Although USP staff were not available at the time of this field visit, further conversations will be progressed in early 2020 with the aim of planning for integration of the draft module into an undergraduate course and transitioning to ensure the data from this project is used to build capacity of teachers and students on Tanna and more widely in the Pacific region.

Appendix A - Information on battery state of charge and recharging

Deep cycle battery voltage & state of charge

Source: https://www.energymatters.com.au/components/batteries/

If determining how much charge left (also known as "state of charge"), most people view the battery voltage as a measure of this. While not totally accurate, the easiest way to determine this is with a multimeter if your solar regulator or charge controller doesn't have a voltage readout. State of charge does vary a little between a sealed lead acid, flooded, gel and AGM deep cycle battery types and also between brands. Even the weather can play a role.

The table below shows the voltage and approximate state of charge for each type of battery.

Note: The figures are based on open circuit readings. That is, when the deep cycle battery isn't under load and hasn't been under load for a few hours. This scenario may not occur very often in a battery based system that's in continual use. So, the best time to take the reading is early in the morning before the sun hits your panels, in the evening as the sun is setting, or when it's very overcast. If you take a reading while the battery is receiving charge, it could read anything up to 14.5 volts.

If you take the reading when the panels aren't exposed to the sun, as there will likely be power being drawn at the time, you can assume that whatever the voltage reading, it's a conservative estimate. Once all load is removed from a battery, voltage can bounce back up substantially.

General rule of thumb: the less your deep cycle battery discharges before recharge, the longer it will last.

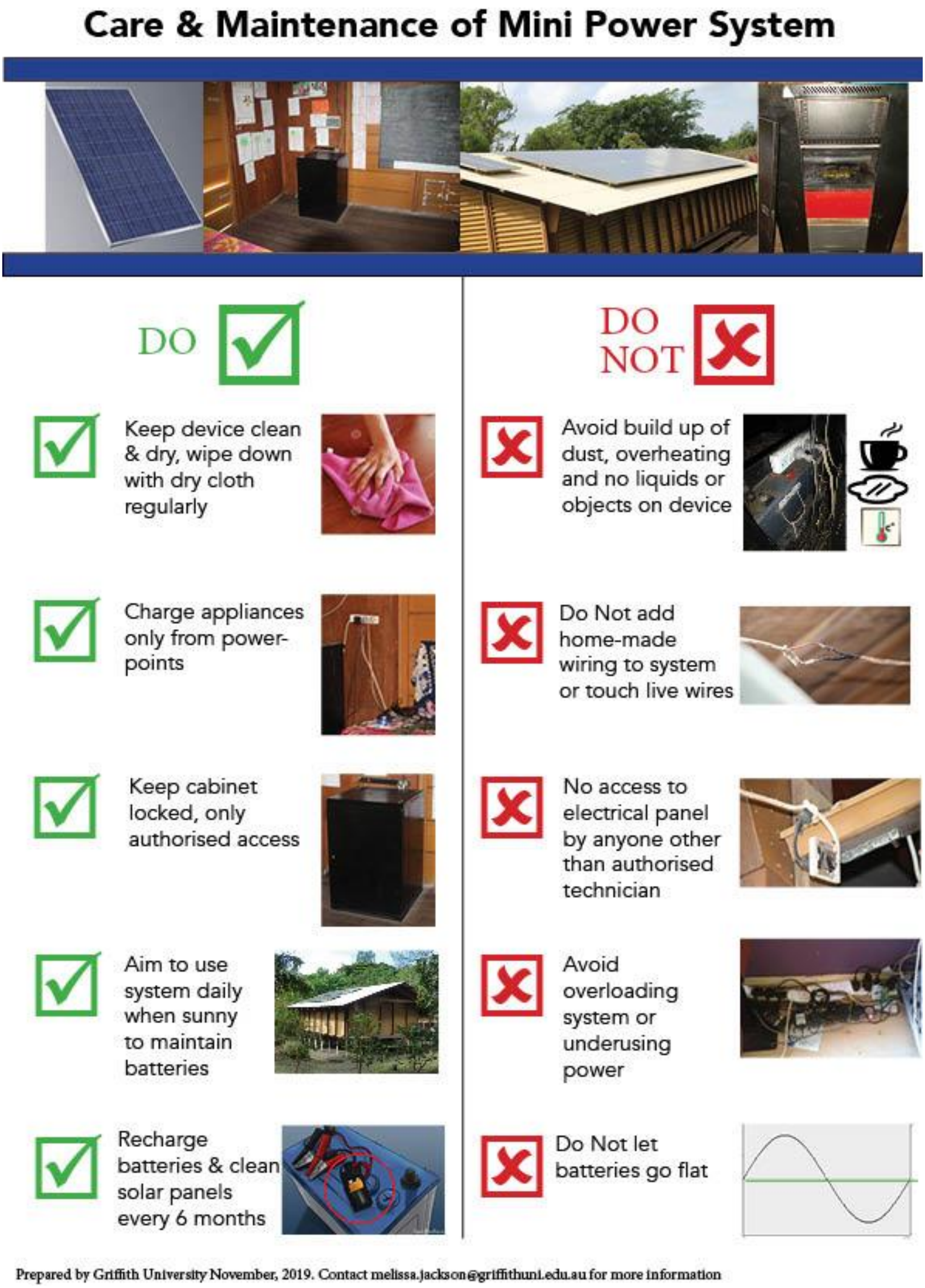
State of Charge	Sealed or Flooded Lead Acid battery voltage	Gel battery voltage	AGM battery voltage
100%	12.70+	12.85+	12.80+
75%	12.40	12.65	12.60
50%	12.20	12.35	12.30
25%	12.00	12.00	12.00
0%	11.80	11.80	11.80

Note that the batteries in the Tanna huts (Gel batteries) were tested at varying times of day and levels of sunshine (which is only relevant to the four that are functioning) potentially affecting the voltage reading.

"A battery with 12.7 volts is fully charged, 12.5 volts is 90% charged. If the battery drops below 10.5 volts after the floating surface charge is removed (wait three hours after disconnecting charger), you have a shorted out cell (electric short between plates). You can remove the caps and measure each cell's voltage with a tester. Shorted out cells in sealed case batteries cannot be repaired. Replace the battery."

Source: https://electronics.stackexchange.com/questions/11883/how-can-i-try-to-revive-this-agm-deep-cycle-battery-which-started-to-perform-dra

<u>Appendix B – Training Poster – Do's and Don't's</u>



Appendix C Community Training Manual (English version)

SAFE USE AND MAINTENANCE GUIDE

FOR

OFF-GRID SOLAR POWER SYSTEMS

Version 1
November, 2019

Introduction

This guide has been developed by Griffith University researchers to support community members in using the mini power systems installed in their buildings. The information in this guide is based on a detailed user manual from the solar power company Green NRG Co www.greennrgco.com who supplied and installed the equipment. This guide aims to ensure the power systems are operated safely and as intended and their useful life is maximised.

Griffith UNIVERSITY

Throughout this guide the following symbols are used to highlight key points:

IMPORTANT INFORMATION

SAFETY WARNING

Disclaimer:

This is not a technical installation of instruction manual and should not replace qualified advice.
All care should be taken when using electrical equipment. Any movement or operation or opening the protection board must only be done by a qualified electrician or authorised technician.

Safety Warning

The solar power systems are a source of electricity and care should always be taken when working in and around them.

As a source of electricity, unsafe handling may result in electric shock, injury or even death.

Only a qualified electrician should undertake any work other than the uses outlined in this guide.

When the switch is disconnected, the high voltage risk still exists inside the device. Any movement or operation or opening the protection board must be done by **authorized or qualified electrician or technician only**.

The following basic safety precautions should be followed for the power system:

- Avoid damp and do not use liquids near the power system (inverter and battery bank) and never place any liquid containers on the equipment
- Avoid direct sunlight.
- Avoid overheating.
- Avoid dust.
- Always turn the power off before cleaning
- Always supervise children near or around the power system
- Do not connect any equipment that may overload the devices or DC load
- Do not conduct any additional wiring to the system
- If a battery becomes corroded, do not touch, the electrolyte can cause injuries to eyes and skin. In the event of any body contact, wash with plenty of water and seek medical advice
- In case of a fire – DO NOT USE water to extinguish!

Features and functions of the solar power system

OVERVIEW

During the day the solar energy on the PV panels on the roof charge the inverter and the batteries at the same time. The inverter changes the electrical input (DC) into the (AC) output for use by appliances. The time that the mains charge the battery every day can be set. When the solar power input is low, the battery will provide the power to the inverter.

There are three main parts to the power system:

Solar panels

On the roof of each building is an array of solar panels. Each panel is made up of between 60-72 solar cells that convert sunlight into electrical energy. The energy travels down the wires into the main system and inverter.

Inverter and control panel

The inverter changes the electrical energy from the panels into a form that appliances run on e.g. phones, computers; termed AC or Alternating Current. Inside the mini power system cabinets the inverter and controls are on top with four batteries below.

The LCD screen (liquid crystal display) allows query of the status of the power system and you can view real-time power generation.
See Appendix A for settings and functions of the LCD screen.

Batteries

When there is no electricity grid in a region, batteries are essential for storing the energy generated by the solar panels during daylight hours, for use at other times. There are four batteries for each 5kW power system (and 16 for the 20kW system stored under the building).

Just like a phone or car battery, the batteries for the power system need to be regularly used – discharged and charged - to stay healthy. The battery charges from PV panels through inverter and discharges when appliances and devices are plugged in or lights are on, or if left unused, the battery will lose power and drain down.

When the battery terminals short circuit or over-discharge, it is easy to damage cells and may cause a fire.

Other key components

Circuit breaker

There is a fusebox/circuit breaker that will trip (automatically switch off) if the system is overloaded. This protection measure is built in to ensure safety and to avoid overloading or damaging the system, electric shock, or injury to users.

Electrical outlet (powerpoint or plug)
This is where appliances and equipment should be safely plugged in.

Data logging equipment
In three of the fourteen buildings data logging equipment has also been installed to allow for monitoring of the systems and power use.

DO NOT UNPLUG the data loggers from the powerboard or the data will not be available to monitor the system.
See instructions in Appendix D on accessing the data logged by the logger.

Using the power system for long-life and safe use

The power system functions best when used regularly (daily) (to at least a third or half load) and allowed to recharge back up to full charge regularly.
Since installation in 2016, many of the power systems installed have been under-used (not used to their full capacity).
There is potential to increase the load on many of the systems once functioning.
Regular discharge and recharge helps the batteries last longer than if they were either left fully charged without being used or completely drained without recharging regularly. If underused, the batteries won't discharge. If overloaded, the system has an automatic shut-down level that is tripped (see troubleshooting section).

In ongoing cloudy weather, the solar panels will produce less power and therefore the batteries may not be recharged fully. Trained community members can keep an eye on this by checking the LCD display regularly (daily) for the level of generation and battery charge and advising others as to how much load

If a battery is stored or not used for more than 6 months, it will need to be recharged (even if fully charged before). Otherwise the batteries may fail and cannot be guaranteed to operate normally.
It is recommended to recharge each of the batteries every 4-6 months for about 4 hours.

In figure 1, some typical types of appliances and their rated load are given.
The device/equipment run times are also given to indicate how long it could run for. For example, a smart phone could be recharged on its own over 300 times.
These are indications only as actual will be influenced by weather conditions, type of device (e.g. laptop or desktop, size of TV, and so on), and how many are being used at the same time.
Note that these are examples given for a smaller (3kW) system, so values given are a minimum.

Home appliances	Smart phone/tablet	Computer	TV	Lamp
Power	9 W	200 W	70 W	20 W
Time	300 times	15 h	45 h	150 h

Home appliances	Fan	Printer	Electric blanket	Audio equipment
Power	60 W	250 W	60-150 W	200 W
Time	48 h	12 h	18-48 h	15 h

Figure 1. Average power consumption for 3kW power system

Basic maintenance and care

To maximise the life of the equipment, the power systems should be kept clean, dry and free from dirt, dust, ash and other matter.

Cleaning Solar Panels
Solar panels should have a productive lifespan of 25 years. Can help to achieve this by regular (every 6 months) cleaning of the panels to ensure they are free from dust, ash, dirt, leaves and other materials.

Accessing the roof to clean solar panels can be dangerous and should be done safely using a ladder and securing to the roof with a second person as support.

Cleaning batteries

- Batteries can be wiped down with a soft, dry cloth every 2-3 months.
- After being cleaned, check that the terminals are free from rust and corrosion. Regular application of a small amount of Vaseline (or similar) will help to protect the battery terminals.

Cleaning MPS and Inverter

- Disconnect all appliances and Long press "ON/OFF" switch to shut down the device (see
- Use dry (or slightly damp) cloth to wipe the surface of the equipment.

All other battery and power system maintenance must be carried out by an authorized professional.

Danger

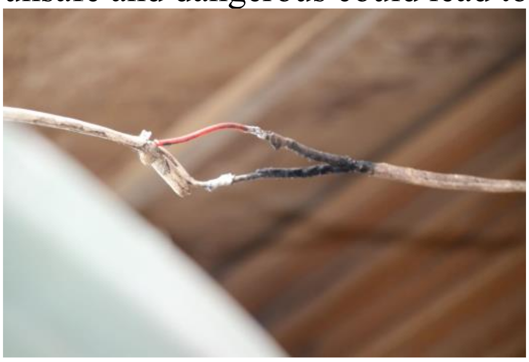
Do not use detergents or corrosive solvents to clean the equipment.
Do not let any liquids flow onto or into the machine.
Ensure the vents of the equipment are not blocked.

General maintenance of batteries
Battery life can be extended also through regular use within load limits. Regular use with charge and discharge cycles is important for battery health. Full discharge of batteries (i.e. draining them to empty) regularly should be avoided by monitoring the LCD display panel to check battery status.

Danger

It is dangerous for unqualified people to tamper with or attempt to fix any electrical wiring to the power systems. All loads should be plugged into the power points, any overload will be picked up by the system and

In the image below, wires connecting non-functioning power systems is very unsafe and dangerous could lead to electrocution and/or fire.



Example of dangerous wiring connected to MPS

Identifying and fixing problems

If the system stops working there could be a number of reasons.

The power systems have protective functions for overcharge, over-discharge, overload, short-circuit, low voltage and high temperature. This means that the power systems will automatically shut down if any of these issues occurs.

There are some simple troubleshooting steps users can take to see if a problem is easily resolved or whether a technician will need to be brought in.
Table 1 gives some basic guidance to identify and troubleshoot problems.
If any of the suggested actions fail to restore the system, a qualified electrician/technician will need to be called in.

Table 1. Troubleshooting

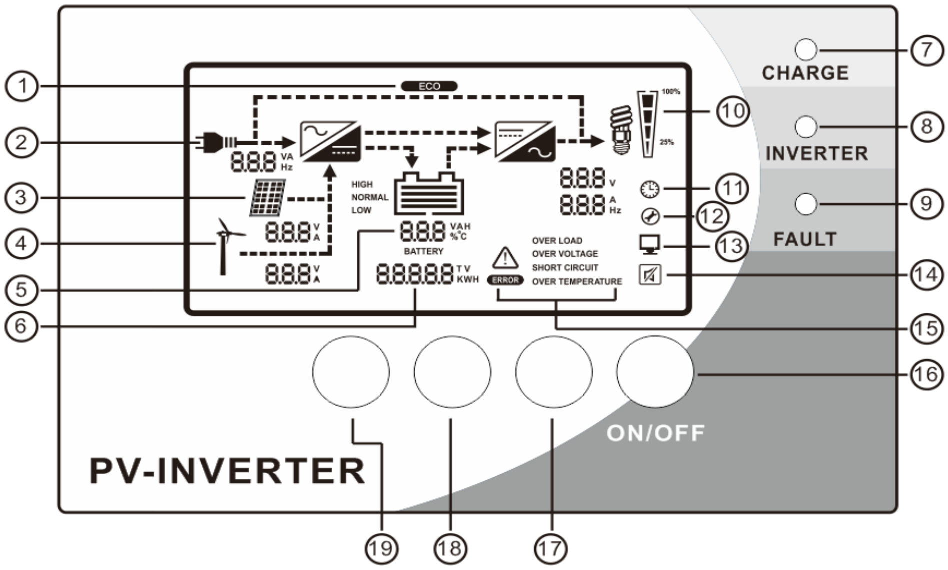
Issue	**Possible problems**	**Check for…**
1. Alarm sounding - "beep beep beep"	System overloaded. Circuit-breaker has tripped	Check circuit-breaker switch; if it has tripped, switch it back on. If switches immediately off again, remove some load and switch back. If this doesn't work, check whether the input fuse is damaged or circuit breaker is damaged; If yes, qualified technician needs to change fuse. If no, shut down and restart the system with load removed (follow the restart procedure in Appendix B). Gradually add more load.
2. A light is on the LCD panel	Could be a fault, or battery is under or overcharged, or	Check which light is on – battery, inverter, fault; switch system off and restart after removing all load. If battery, check whether the external battery connection of the equipment is normal, whether the battery is damaged or not; if fault – call a technician; if inverter follow restart procedure.
3. No power at all	Could be one or all batteries are drained	Check circuit-breaker switch; follow steps in 1 above. Turn off/unplug all devices from the power system. Remove and recharge each of the four batteries before switching on the system. Has it been cloudy for a number of days while the systems have been used? The batteries may not be being charged up by the panels. Wait for sunny days before using.

APPENDIX A – Display Panel Features

Image of and LCD display from one of the mini power systems installed

Note the difference between the actual displays and the instruction manual image below due to upgraded technology (e.g. On/Off button along right side rather below LCD screen), however the functions operate similarly.

Display Panel Appearance



① Energy saving mode
② Mains input
③ Solar panel
④ Wind turbine
⑤ Battery capacity
⑥ Power generation/Parameter display
⑦ Charging LED
⑧ Inverter LED
⑨ Fault LED
⑩ Load indication
⑪ Date/Time setting indication

⑫ Setting indication
⑬ PC connection indication
⑭ Mute indication
⑮ Warning indication
⑯ K1
⑰ K2
⑱ K3
⑲ K4

Keyboard functions

K1 ON/OFF/MOVE/ENTER
K2 DOWN (parameters positive)
K3 UP (parameters negative)
K4 Settings/NEXT/ESC

APPENDIX B – Start/Restart and Shutdown Procedure

Startup steps

- Put external battery box switch at "ON" position;
- Long press "ON/OFF" key on the front panel to boot (3-5 seconds);
- Turn the mains input switch to "ON" position;
- Wait for at least 30 seconds until the output voltage is stable;
- Then connect the external load.

- Press K1 for 3-5 seconds to start the inverter;
- if it does not enter the setting mode, press K1 for 3-5 seconds to shut down the machine.

Shutdown Steps

- Disconnect all loads (appliances and equipment)
- Long press the "ON/OFF" button (3-5 seconds) to turn off the device;
- Set the user input switch and any other switches to "OFF" position;
- Make sure all the switches and the circuit breaker of the device are disconnected;

i If the power is completely shut down, all LED lights will be extinguished, if any lights remain on, repeat the shutdown procedure until they go off.

Restart Steps

i If due to fault or need, the power system has been shut down while the batteries have no charge, the system settings need to be reset. To do this, follow the instructions below.
If the system has been shut down or has automatically shut itself down but the batteries still have charge, you DO NOT need to reset the system parameters.

- After startup, long press K4 button to enter setting mode, long press again to exit setting mode (if 30 seconds without pressing, it will exit the settings automatically).
- After entering the setting mode, a short press K4 can switch to another parameter setting mode (see table below).
- Short press K1 can move the flashing position, press K2 / K3 which can change the flashing number and long press K1 can save the current settings.

The following table shows the numbers and associated parameters that are set displayed.

No.	Parameters	Function description
1	2015	Year
2	0112	Month / Date
3	0706	Hour / Minute
4	0709	Starting time for mains charging (Hour/Minute) (not relevant for Tanna installations)
5	0710	Ending time for mains charging(Hour/Minute) (not relevant for Tanna installations)
6	0444	Low voltage point of the battery – set this to 0444 as shown
7	0548	Battery voltage to recover to inverter status (charging for another an hour)

Appendix C - Technical Specification Table

Mode	NB-5000W
Power	5000W
System voltage（VDC）	48VDC
Solar energy input voltage range（VDC）	60-84VDC
Maximum input current of solar energy（A）	60A
Wind turbine voltage grade	48V
Maximum power of Wind turbine	1000W
Rated charging current of Wind turbine	20A
Maximum output current of Wind turbine	25A
Maximum allowed voltage connecting to PV	84VDC
Maximum allowed charging current to PV	60A
Maximum allowed power to Wind turbine	1000W
Maximum allowed charging current to Wind turbine	20A
Mains input range	240VAC±20%
Input frequency range	50Hz±5%
Mains charging current	35A (Max)
Inverter output voltage	240VAC±3%
Inverter output frequency	50Hz±5%
Inverter output waveform	Pure sine wave
Mains voltage stabilizing function	No
Transfer time	≤10ms
Inverter output Waveform distortion /THD	≤5%
Transfer efficiency（Linear load）	≥83%（100%load）
Crest factor	3 ：1（Max）
Low voltage protective point	44VDC
Recovering voltage point	50.4VDC
Overload capacity	120% 30s ; 150% 2s ; 200% protect immediately.
Protective functions	Input overvoltage, low voltage protection, overload protection, over temperature protection, short circuit protection, output over voltage, low voltage protection, wind turbine protection.
Noise (>1m)	≤55db
Working temperature	0℃～40℃
Storage temperature	-20℃–55℃
Relative humidity	0～90% No condensation
Altitude	≤1500m， Higher than 1500m, de-rating usage
Dimension（L*W*H） mm	499mm×483mm×271mm (net height 266mm)

Appendix D – Extracting power data from the data logger

Procedure for Data Transfer from the Data Logger to the USB memory device

1. Insert the USB memory device into the DataTaker data logger.
2. Allow the data logger to read the USB memory device for a few seconds while the "reading" message appears on the screen.
3. Once the reading is complete press the "FUNC" button.
4. Use up or down arrows to locate the command "Copy all data".
5. Press the "Edit" button.
6. Allow the data logger to transfer the data to the USB memory device. While the transfer is realised the LCD screen of the data logger presents a progress bar.
7. Once the data transfer is complete the message "Done" is displayed on the screen.
8. Press the "FUNC" button.
9. Use up or down arrows to select "Remove USB".
10. Press the "Edit" button.
11. Remove the USB memory device.

Procedure for Data Transfer from the USB memory device to the Computer

1. Insert the USB memory device into the Computer.
2. Go to "Computer" and locate the "Removable Disk".
3. Double click on the "Removable Disk".
4. Locate the file with filename the serial number of the data logger, e.g. "SN107520". Then double click on the file.
5. Locate the file with filename "JOBS", then double click on the file.
6. Locate the file with filename the latest data logger version, e.g. "GU-1V0" or a later version if it exists. Then double click on the file.
7. Locate the latest .CSV file that exists in the folder.
8. Attach the latest .CSV file identified in step 7. to an email.
9. Send the email to the Griffith University Representative listed below.

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