



National Defense Center for
Energy and Environment

Photovoltaic (PV) Power Systems for Enhancing Energy Security

Clark Boriack, NDCEE/CTC
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Outline

- Demonstration Overview
 - Camp Katuu Site Review
 - Camp Katuu Demonstration Goals
- Development and Design Considerations
 - PV Layout Development
 - Component Selection
 - Operating Modes
 - Operating Environment
 - Availability
- System Options
 - Palau PV System Results
 - Alternative Systems to Enhance Energy Security

Site Review



- Camp Katuu, located near Koror, Palau; latitude of 7° 30' North
- Remote location
 - Fragile local electrical utility powered by diesel generation
 - High electricity costs
- Corrosive environment
- Abundant sunshine

Demonstration Goals

- Camp Katuu Installation
 - Increase civil outreach and nation building with Palau Government
 - Reduce environmental footprint at Camp Katuu
 - Increase use of alternative energy
 - Demonstrate the feasibility of using alternative energy in the region
 - Quantify PV system performance/capability
 - Train 249th Engineer Battalion to install photovoltaic systems
 - Train Palau Civic Action Team to operate and maintain system
 - Validate camp electrical costs reduction
- Future Installations
 - Leverage design aspects for other remote installations (grid frequency and voltage regulation, corrosion, high electricity costs)
 - Next generation to include off-grid operation capability with energy storage

PV Layout Development

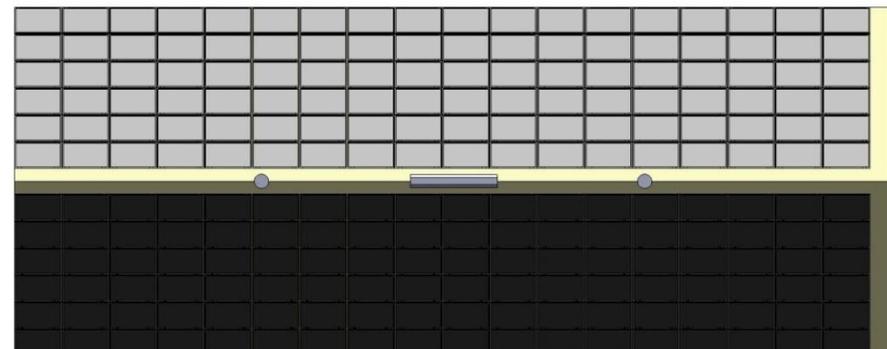
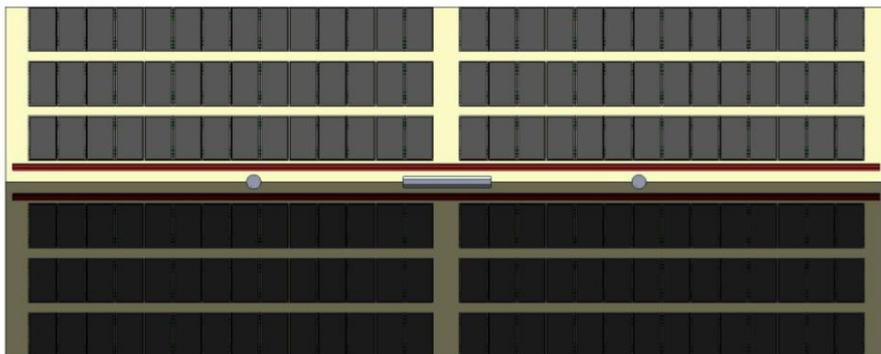
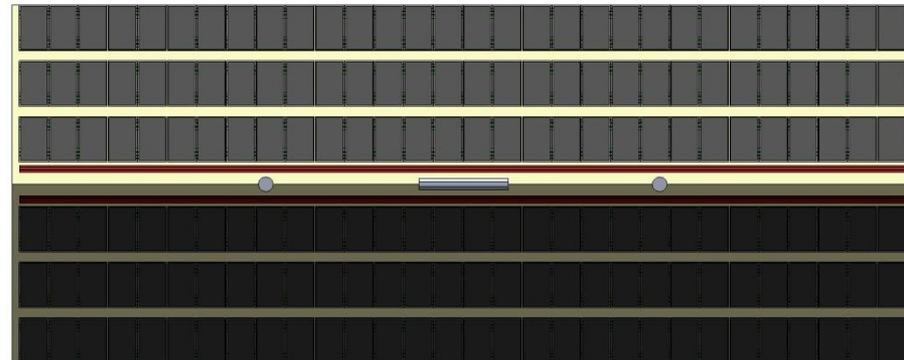
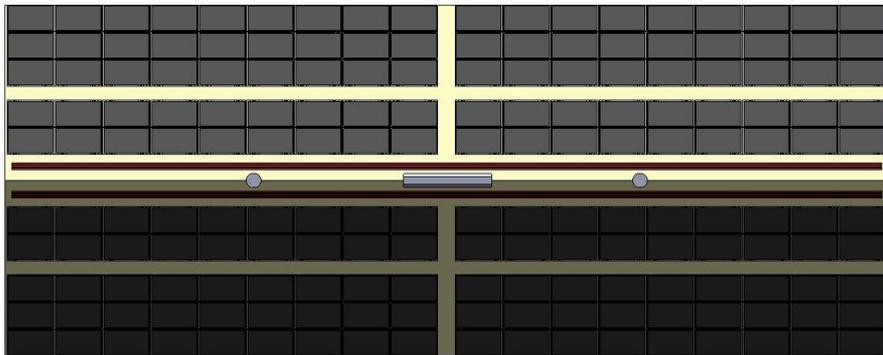
- Sustainability Considerations
 - Safety, maintenance, and reliability
 - Access ways for installation, maintenance, repair
- Performance
 - Simple, intuitive, and robust installation
 - Reliability and electrical costs reduction
 - Roof mounting maximizes capability given limited camp footprint



Camp Katuu Builder's Shop – PV Array Installation Location

PV Layout Development (cont.)

- PV System Layout Options Considered



PV Layout Development (cont.)

- PV System Layout Considerations and Comparisons

| PV LAYOUT OPTION SUMMARY | | | | | |
|--------------------------|------------------------------|--|---|--|----------------------------------|
| No. | Consideration | Option 1 | Option 2 | Option 3 | Option 4 |
| | | 5 Horizontal Rows | 3 Vertical Rows | 3 Vertical Rows with Center Walkway | 6 Vertical Rows |
| 1 | Amount of rail mounting (lf) | 1440' | 1800' | 1800' | 1440' |
| 2 | Ease of rail installation | some rail cutting required to clear walkway | requires two level rail mounting system | requires two level rail mounting system | no rail cutting required |
| 3 | Ease of wiring | Intuitive circuit pattern | Very Intuitive circuit pattern | Very Intuitive circuit pattern | odd circuit pattern |
| 4 | Maintenance access | 21" horizontal & vertical walkway, does not have direct access to all panels | Accessible with 15" walkways | Direct access to each panel and has a center walkway | No direct access to most panels |
| 5 | System DC Rating (kW DC) [1] | 42.300 | 42.300 | 39.480 | 50.760 |
| 6 | System AC rating (kW AC) [2] | 32.571 | 32.571 | 30.400 | 39.085 |
| 7 | Fall Protection System | accommodates rail system | accommodates rail system | accommodates rail system | does not accommodate rail system |
| 8 | | | | | |

Color Legend

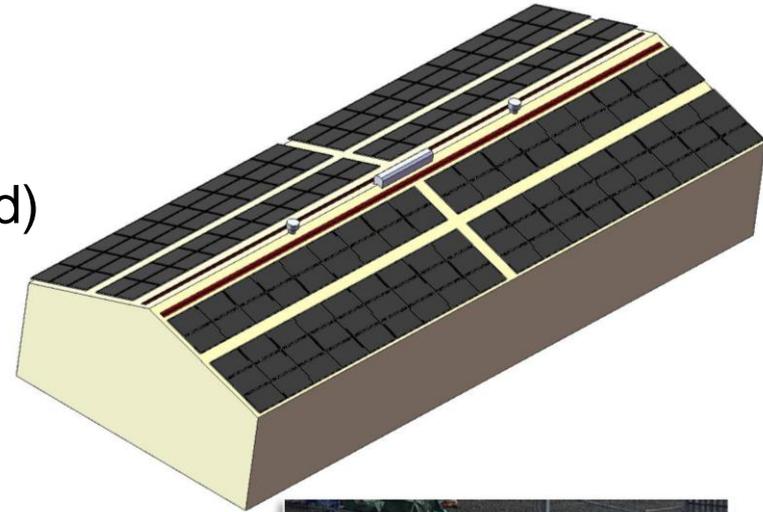
| | |
|--|-----------------|
| | most favorable |
| | more favorable |
| | least favorable |

Note [1] System DC Rating based upon use of 235W solar panels

Note [2] System AC Rating based upon typical .77 conversion factor from DC power to AC power

PV Layout Selected – Option 1

- Easiest to Implement and Sustain
 - Safety rails
 - Access ways (beginning to be required)
 - Intuitive circuitry/wiring
- Performance
 - Met power requirements



OPTION 1 CONSIDERATIONS

| No. | Consideration | Impact |
|-----|------------------------------|--|
| 1 | Amount of rail mounting (lf) | 1440' |
| 2 | Ease of rail installation | some rail cutting required to clear walkway |
| 3 | Ease of wiring | Intuitive circuit pattern |
| 4 | Maintenance access | 21" horizontal & vertical walkway, does not have direct access to all panels |
| 5 | System DC Rating (kW DC) [1] | 41.400 |
| 6 | System AC rating (kW AC) [2] | 31.878 |
| 7 | Fall Protection System | accomodates rail system |

Color Legend

- most favorable
- more favorable
- least favorable

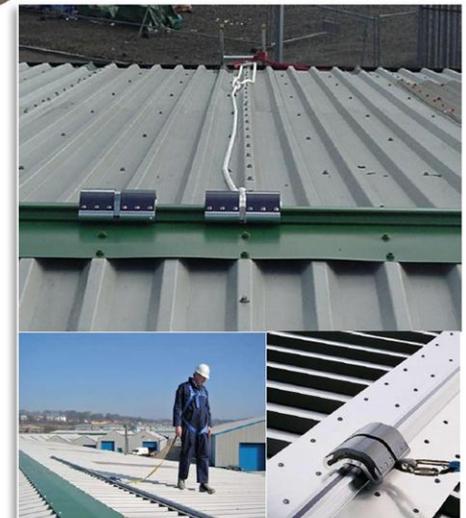


Figure 7: Rail Type Fall Protection System

Component Selection PV Module



CS6P

220/225/230/235/240/245/250P



On-grid Module

CS6P is a robust solar module with 60 solar cells. These modules can be used for on-grid solar applications. Our meticulous design and production techniques ensure a high-yield, long-term performance for every module produced. Our rigorous quality control and in-house testing facilities guarantee Canadian Solar's modules meet the highest quality standards possible.

Applications

- On-grid residential roof-tops
- On-grid commercial/industrial roof-tops
- Solar power stations
- Other on-grid applications

Quality Certificates

- IEC 61215, IEC 61730, IEC 61701, UL 1703, CECE Listed, CE, KEMCO and MCS
- ISO9001: 2008: Standards for quality management systems
- ISO/TS16949:2009: The automotive quality management system
- QC080000 HSPM: The Certification for Hazardous Substances Regulations

Key Features

- Top ranked PVUSA (PTC) rating in California for higher energy production
- 6 years product warranty (materials and workmanship); 25 years module power output warranty
- Industry leading plus only power tolerance: +5W (+2%)
- Strong framed module, passing mechanical load test of 5400Pa to withstand heavier snow load
- Ultra reliable in corrosive atmosphere, verified by IEC61701 "Salt Mist Corrosion Testing"
- The 1st manufacturer in the PV industry certified for ISO:TS16949 (The automotive quality management system) in module production since 2003
- ISO17025 qualified manufacturer owned testing lab, fully complying to IEC, TUV, UL testing standards

- Best value (\$/watt)
- Tested for corrosion
- Stock item
- **Common Attributes!!**

| PV Module Specifications | Canadian Solar |
|--|----------------|
| Mechanical Attributes | |
| Length(in) | 64.5 |
| Width (in) | 38.7 |
| Thickness (in) | 1.57 |
| Weight (lbs) | 44.1 |
| Electrical Attributes [1] | |
| Nominal Maximum Power Output at STC (Pmax) | 235 Watts |
| Voltage at Pmax (Vmp) | 29.8 Volts |
| Current at Pmax (Imp) | 7.9 Amps |
| Open Circuit Voltage (Voc) | 36.9 Volts |
| Short Circuit Current (Isc) | 8.09 Amps |
| [1] Standard Test Conditions for panel ratings: 1,000 Watts/M ² , AM 1.5, 25 C | |

Component Selection

Inverter

SUNNY BOY 5000-US / 6000-US / 7000-US / 8000-US



UL Certified

Efficient

Safe

Simple

UL US

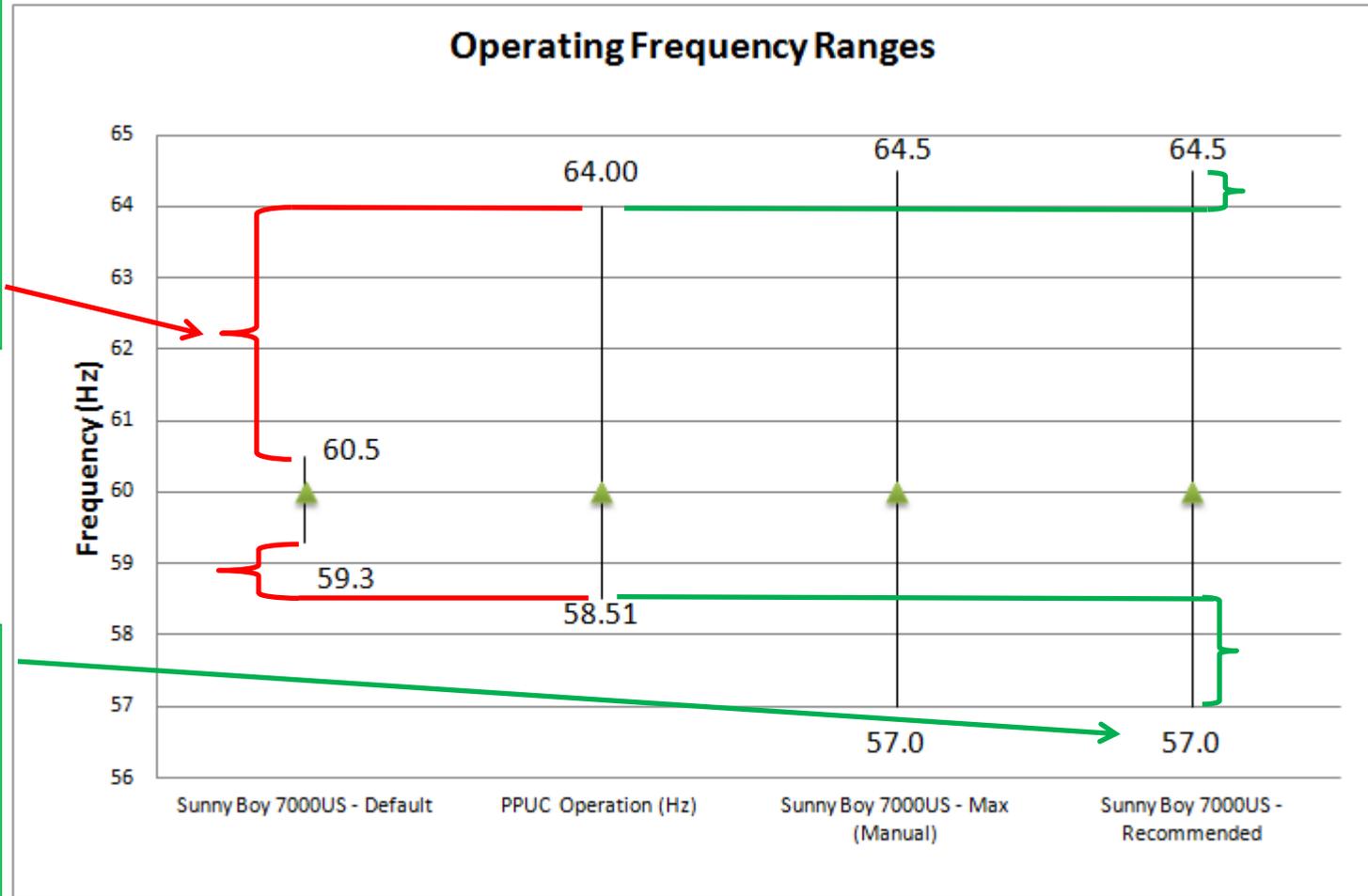
38 5000US / 38 6000US / 38 7000US / 38 8000US

The image shows a red SMA Sunny Boy inverter mounted on a grey base. The inverter has a small display screen on its front panel. The SMA logo is visible in the top right corner of the image area. The UL logo is in the bottom right corner. The text 'SUNNY BOY 5000-US / 6000-US / 7000-US / 8000-US' is at the top. The text '38 5000US / 38 6000US / 38 7000US / 38 8000US' is on the left side. The bottom section contains four columns of text: 'UL Certified' (For countries that require UL certification (UL 1741/IEEE 1547)), 'Efficient' (97% peak efficiency, OptiCool™ active temperature management system), 'Safe' (Galvanic isolation), and 'Simple' (Patented automatic grid voltage detection*, Integrated DC disconnect switch).

- Six SMA 7000US inverters for grid-tied system
- Reliable product
- Very low maintenance
- Rated for outdoors use
- Simple, informative interface
- Integral DC disconnect
- Stock item
- Can accommodate electricity grids with poor voltage and frequency regulation

Component Compatibility

Issue – Utility upper operating frequency range exceeds inverter default settings; *nuisance trips will occur!!*



Solution – Increase inverter operating frequency range based upon electrical utility operations and input

Default Frequency Operating Range is not compatible

Camp Katuu Results

- Installed by 249th Engineering Battallion (Prime Power) and Camp Katuu Civic Action Team
 - *All wiring correct per installation drawings*
 - *Very quick commissioning*

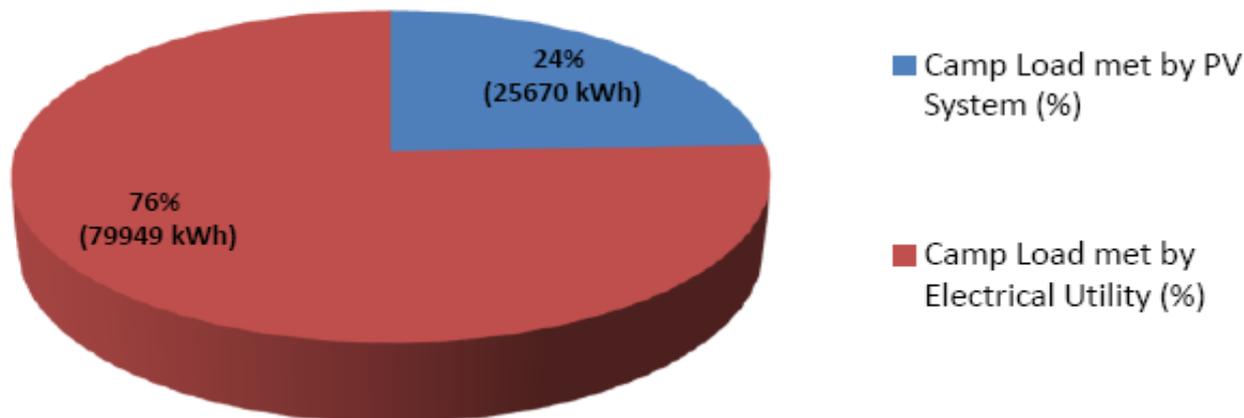


- System Reliability During 6 Month Sustainment Period:
 - *No failures or repairs*
 - *System automatically restarted after each grid outage*

Camp Katuu Results (cont.)

- System Performance During 6 Month Sustainment Period:
 - *Electrical cost savings exceeded estimates by*
Adjusted: 17% (\$25.5k versus \$21.8k annually)
Actual: 10% (\$23.9k versus \$21.8k annually)
 - *Production met expectations, given rainy season, achieving 94% of annual estimate (53.9MWh versus 57.9MWh)*

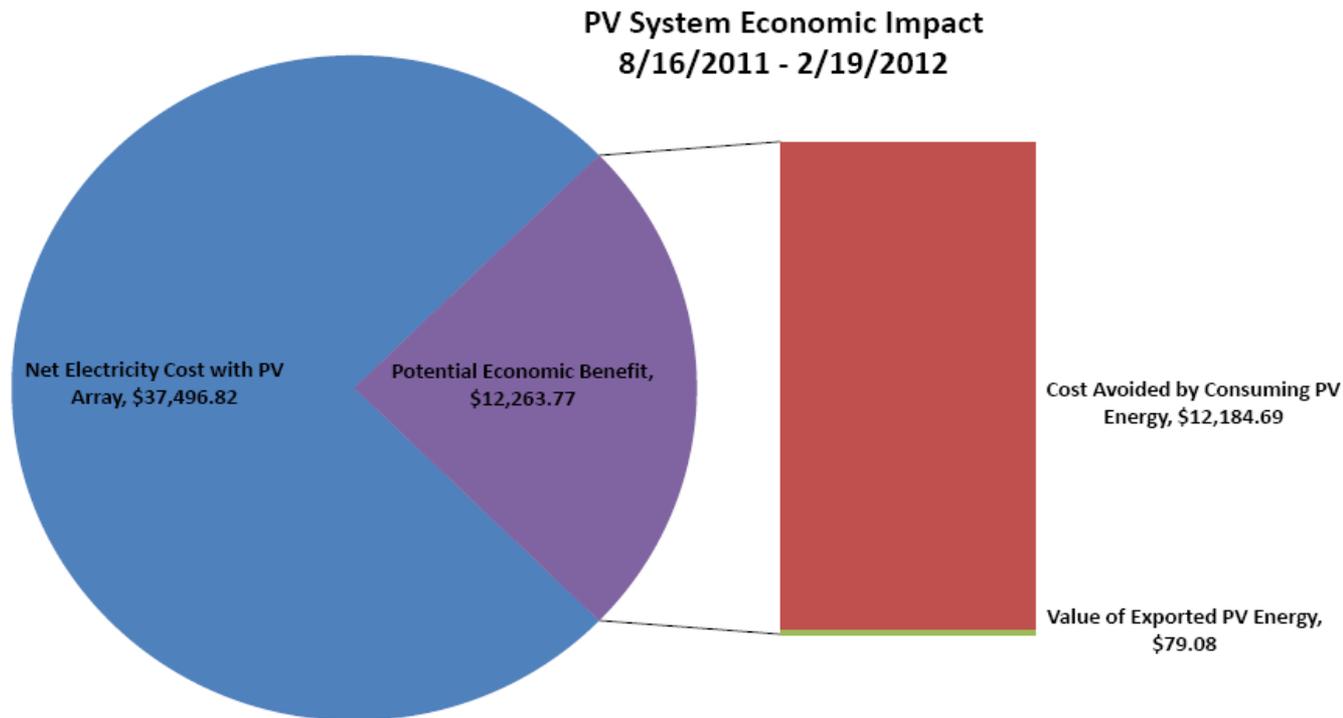
Camp Energy Consumption by Supply
8/16/2011 - 2/19/2012



Camp Katuu Results (cont.)

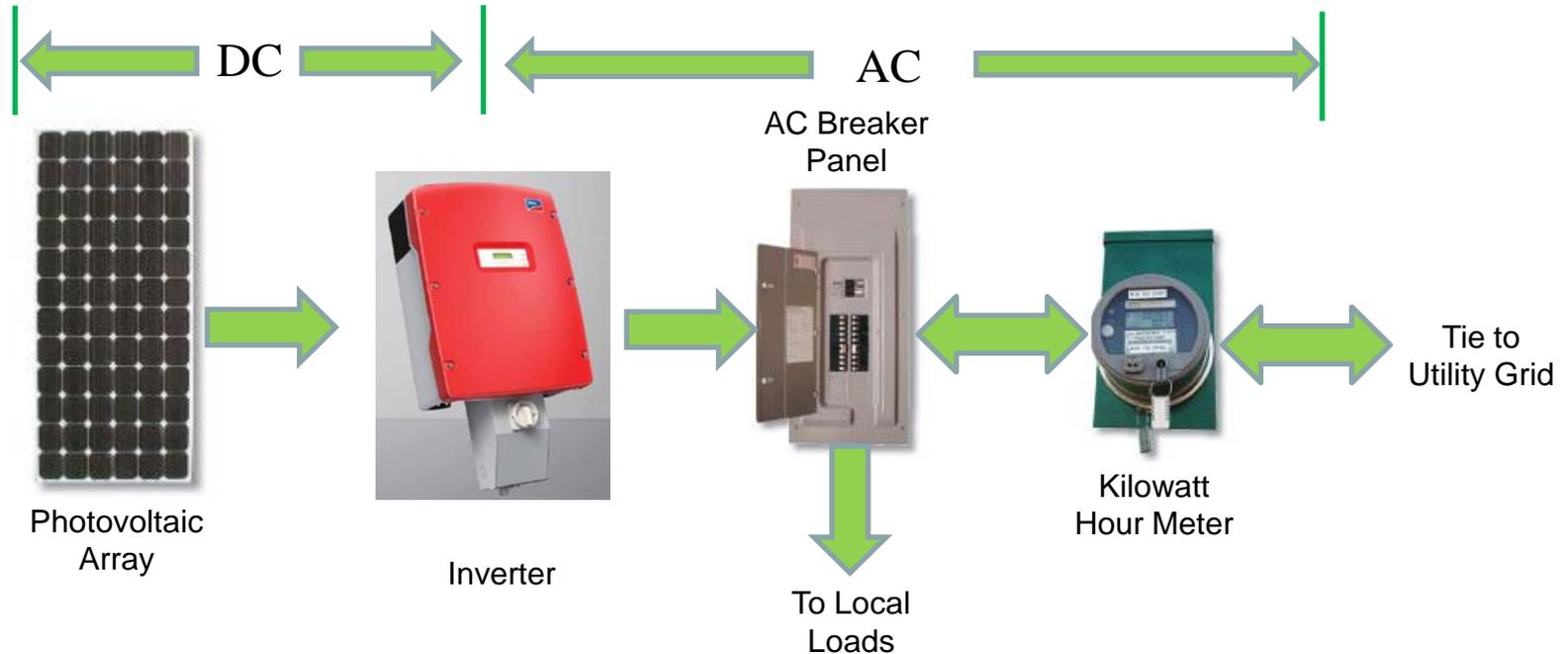
- System Performance During 6 Month Sustainment Period:

- *Energy cost estimate without PV array :* **\$49.8k**
- *Energy cost with PV array:* **\$37.5k**
- *Camp energy cost reduction by PV array:* **25%**



System Options

- Grid - Tied System
 - Camp Katuu System



Alternative Systems to Enhance Energy Security

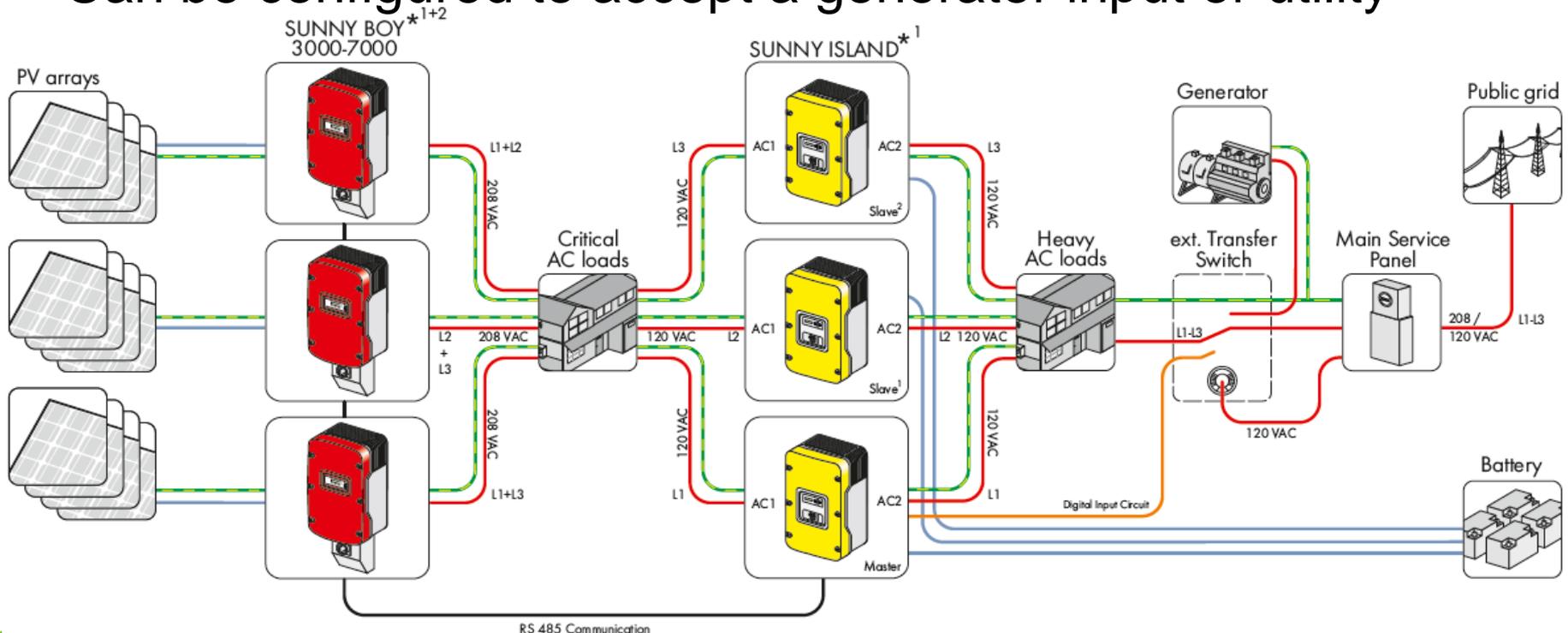
- Grid - Tied System
 - Key Benefits
 - Simple to install
 - Easy to maintain
 - Reduces electrical costs
 - Grid can serve as a load for exporting excess renewable energy
 - Very sustainable
 - Key Considerations
 - Requires grid to operate
 - Very few products compatible with unstable grids

SMA's Sunny Island

- Major Components:

- Battery bank w/ monitoring
- Sunny Island

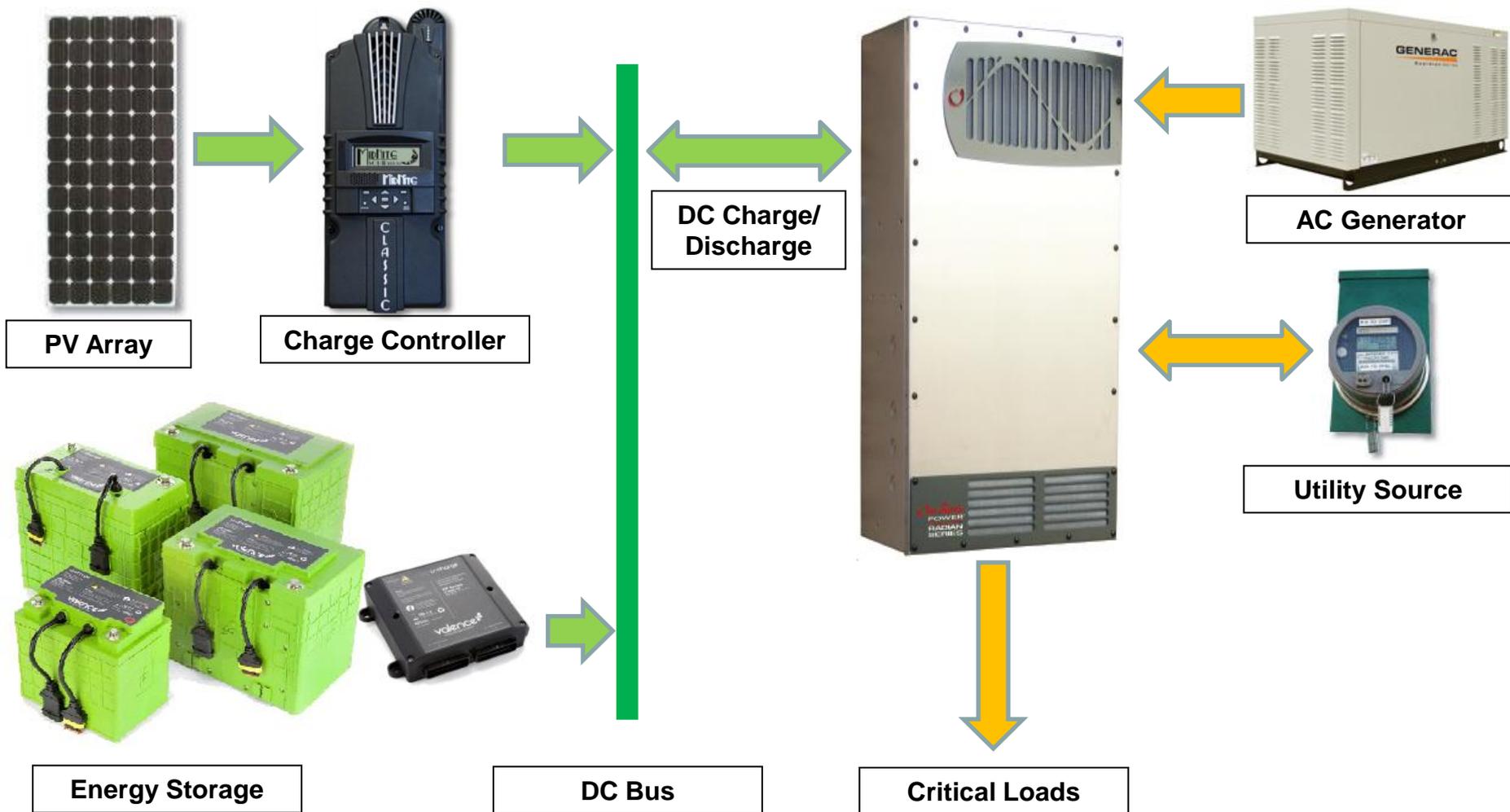
- Can be configured to accept a generator input or utility



SMA's Sunny Island

- Island System - SMA
 - Leverages multiple energy sources
 - Wind, solar
 - Battery bank
 - Generator or utility
 - Key Considerations
 - Not intended for export
 - Number of components to build system
 - Desired system voltage:
 - Single phase 120/240VAC
 - Three phase 120/208, 277/480

Outback's Radian Inverter



System Options

- Hybrid System - Outback
 - Leverages Multiple Energy Sources
 - Solar
 - Battery bank, bi-directional
 - Generator
 - Utility
 - Can export
 - Key Considerations
 - Must meet UL1741 for export
 - 120/240 VAC rated system

Summary

- Power Systems to Enhance Energy Security Include:
 - Grid - Tied: simple, few components, no off-grid support
 - Off - Grid: simple, more components than off-grid, requires energy storage
 - Hybrid Systems: few options, but can leverage numerous energy resources to achieve energy security



Questions?

Palau PV System Ribbon Cutting Ceremony Celebrating:
*Nation building through the successful implementation of
renewable energy systems*



Left to right: **Ambassador Helen Reed-Rowe, SFC Daniel Husak, 1st Lt Melissa Jumper, LCDR Grant Watanabe, Clark Boriack (CTC Technical Lead)**



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