



Lana'i La Ola IEEE PVSC-35 Addendum

Abbas Akhil
Sandia National Laboratories
Distributed Generation and Energy Storage
aaakhil@sandia.gov
(505) 844-7308

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Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND2009-2801P

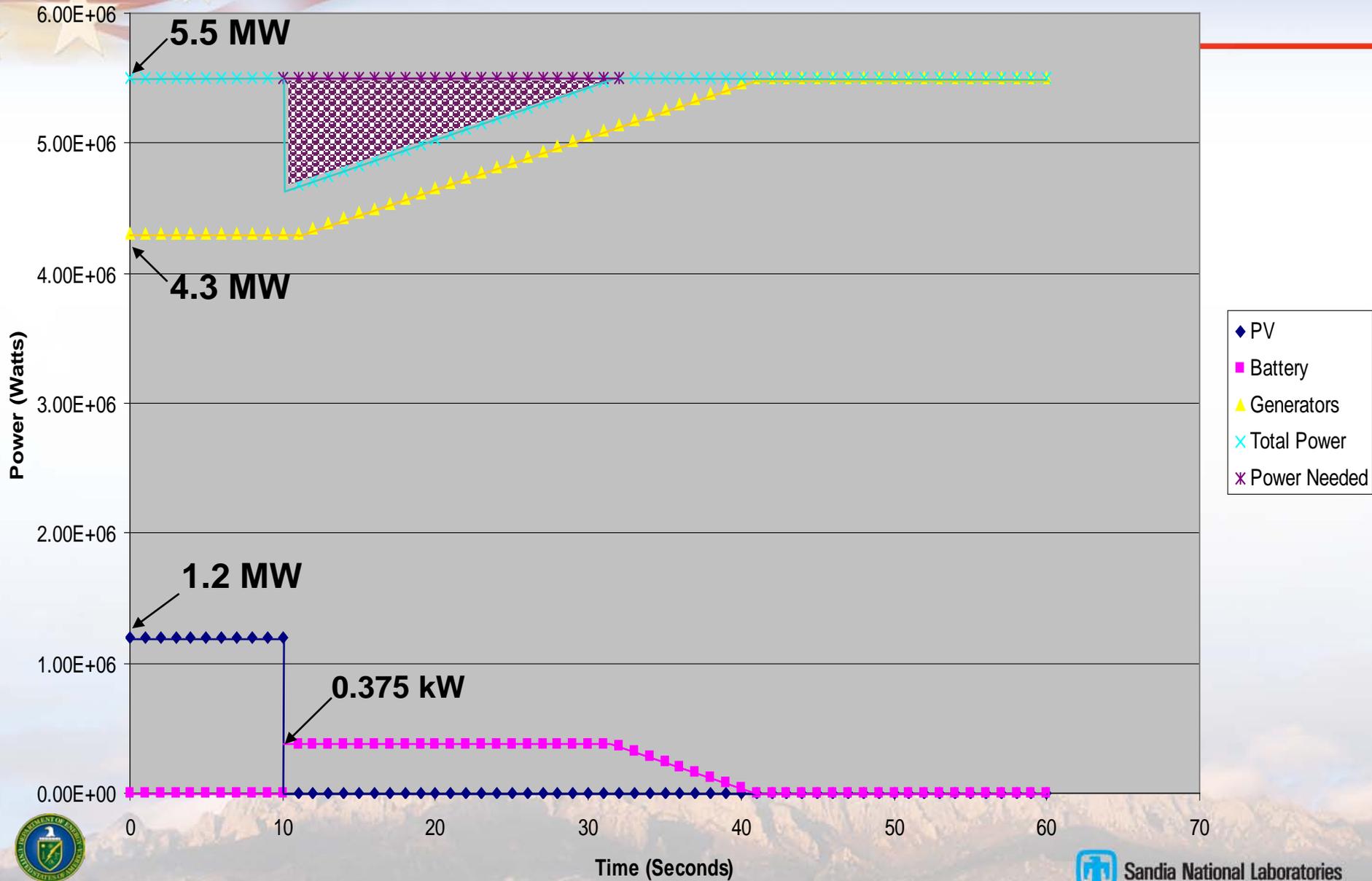


Energy Storage in Island Grids

- **PV and wind are inherently intermittent**
- **Combining “inertia-less” sources with rotating machines with inertia**
 - Ramp rate limitations
 - “Power” application
- **Storing energy from renewable sources for later use or capturing “spilled” energy**
 - “Energy” application



Energy Storage for Ramp Rate Support (Simplified Example)





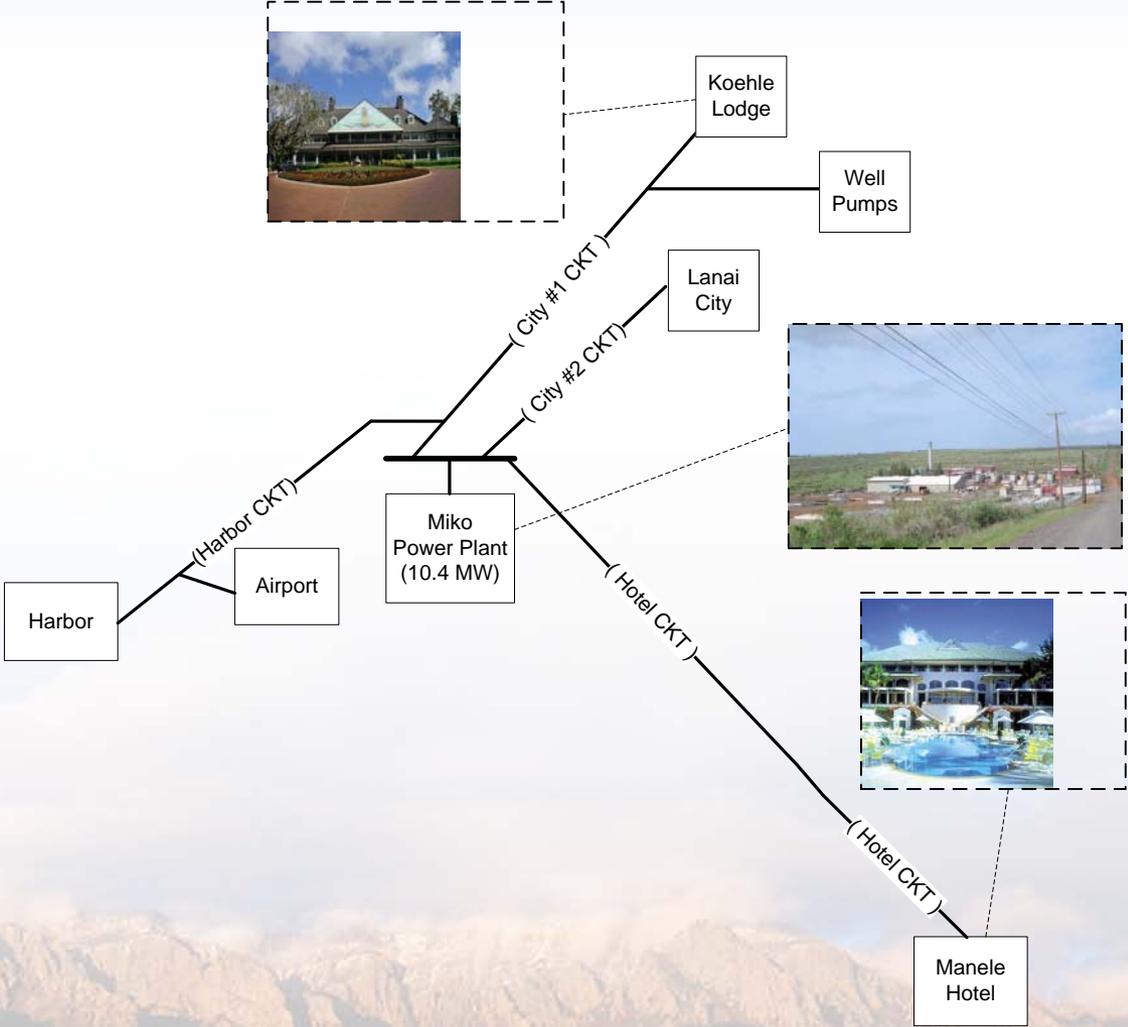
Lanai Grid



Miko
Power Plant
(10.4 MW)

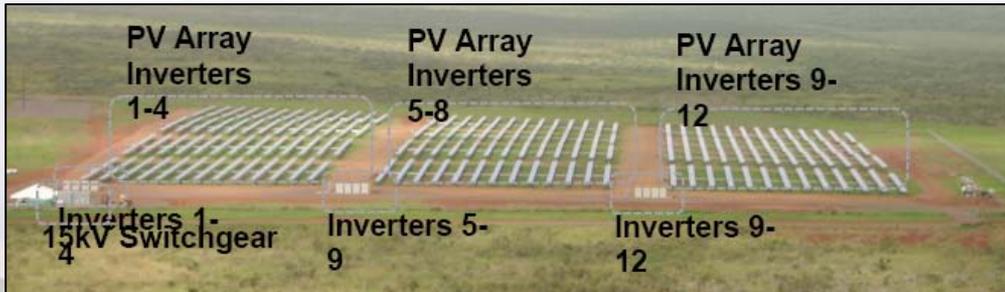
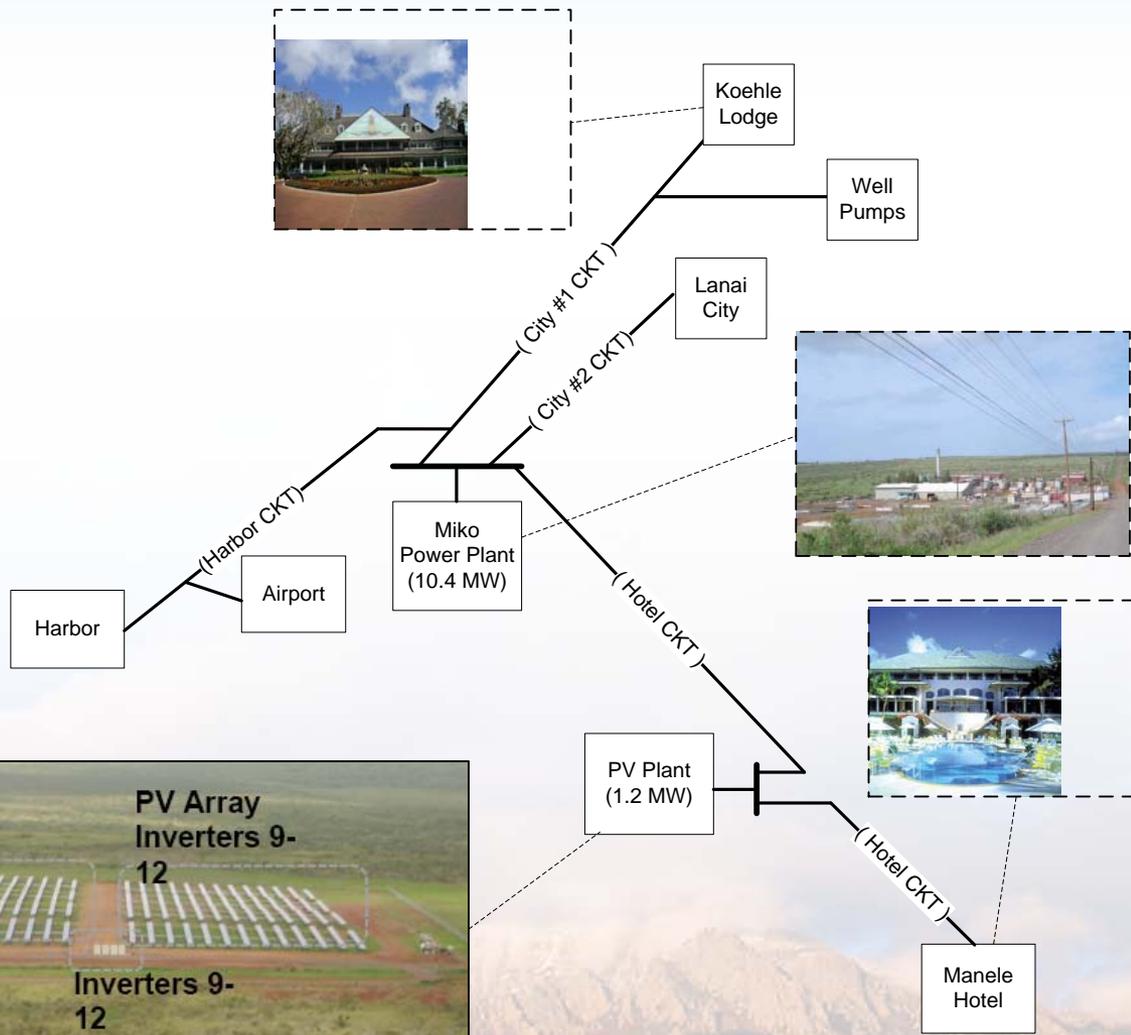


Lanai Grid



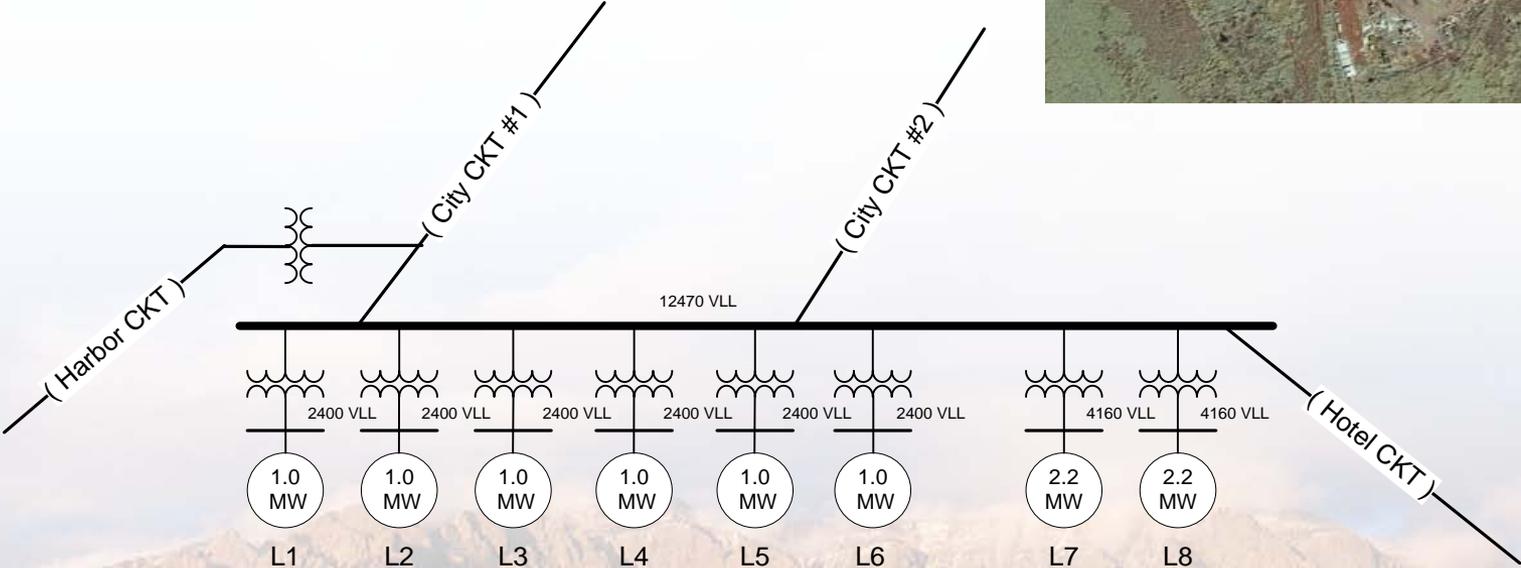


Lanai Grid with La Ola PV

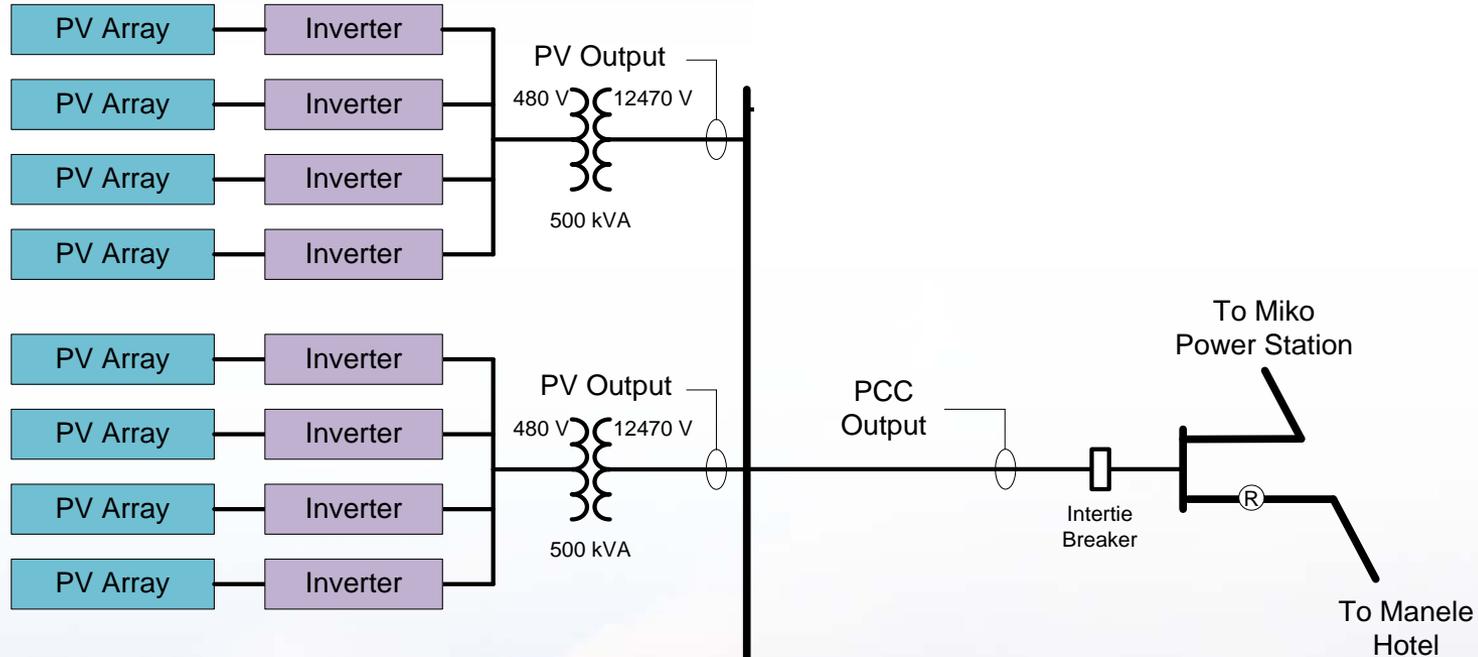


Miki Basin Power Station

- (6) 1.0 MW EMD Diesel Generators
- (2) 2.2 MW Caterpillar Diesel



La Ola PV





La Ola Battery Specification

- **Battery type and size specified in Power Purchase Agreement**
- **Battery type: Flow battery manufactured by VRB**
- **250 kW power with 3 hours of energy storage; 750 kWh**
- ***PPA required mostly grid support functions***





Evolution of La Ola Battery Design

- **VRB ceased commercial operations in late 2008**
- **3 hours of storage was excessive for ramp rate control**
 - Need power, not energy
 - Flow batteries are “energy” batteries
- **La Ola’s return to investor is maximized if every kWh generated is sold immediately**
 - Energy storage has a roundtrip efficiency “overhead”
 - Battery charging energy comes from PV or purchased from MECO





Transition Concepts

- **Re-Evaluated battery size:**
 - Need power, not energy
 - Suitable sizes ranged between 450 kW – 750 kW; 1 hour storage

- **Evaluated other battery technologies:**
 - Lead-acid, Sodium/Sulfur and Lithium Ion

- **At year end 2008:**
 - Lead-acid battery system
 - 405 kW; 1 to 3 hours of storage
 - Air conditioned building to house battery system
 - Identified turnkey system supplier and obtained firm price quotations



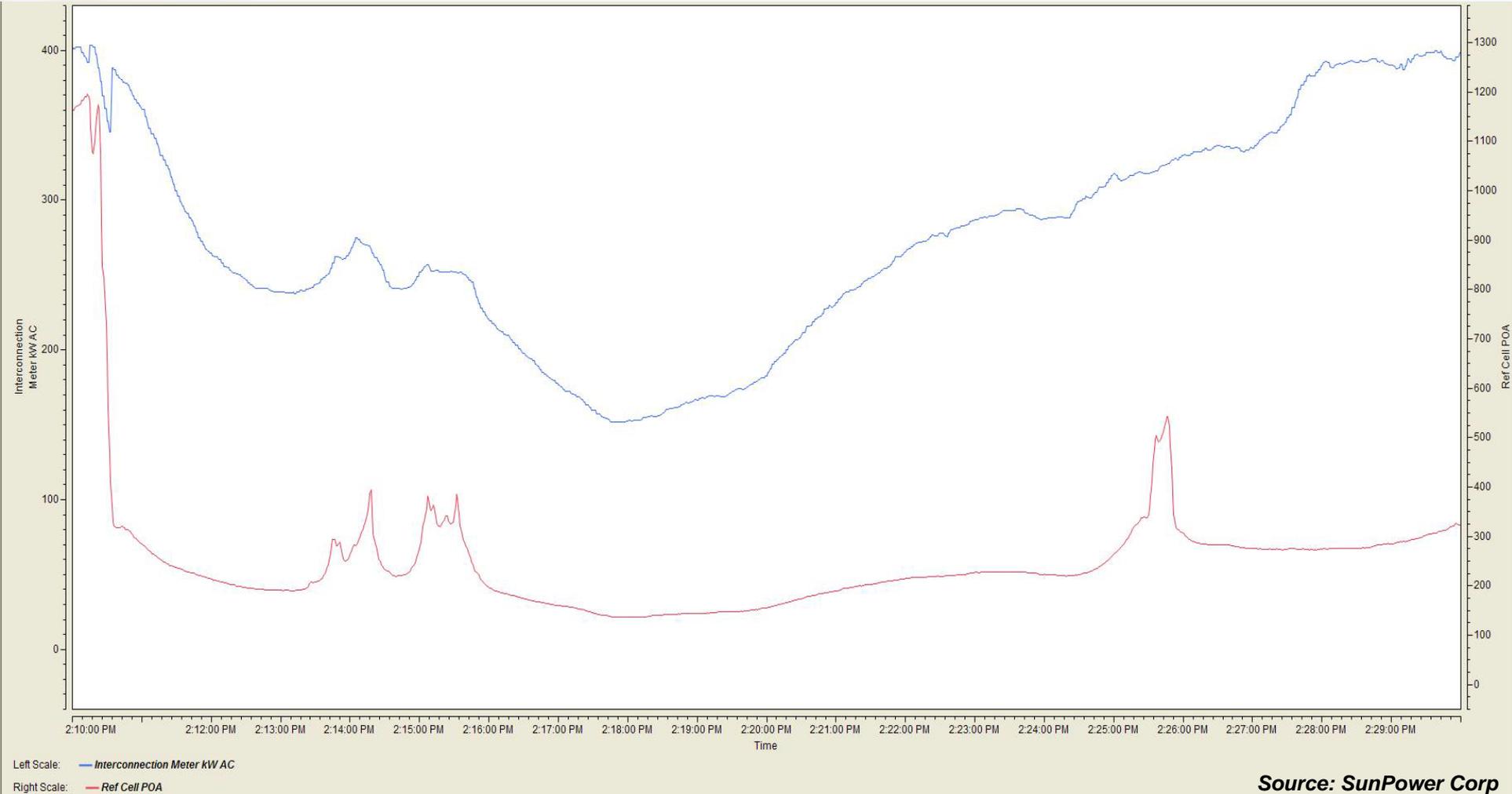


In-Depth Analysis

- **Battery sizing analysis by SunPower, Sandia Labs and NREL in early 2010**
 - 1 second power and irradiance data from similar-sized PV farm
 - 10 months field-recorded data
 - Three independent approaches using common input data set
- **Battery sizing considerations: Ramp rates, duration and frequency of ramps**
- **Challenges: Vast amount of data; random ramp rate pattern; uncertainty that all “events” are captured**
- **Battery size: 450 – 700 kW; 250 – 500 kWh energy required to meet ramp rate support requirements**



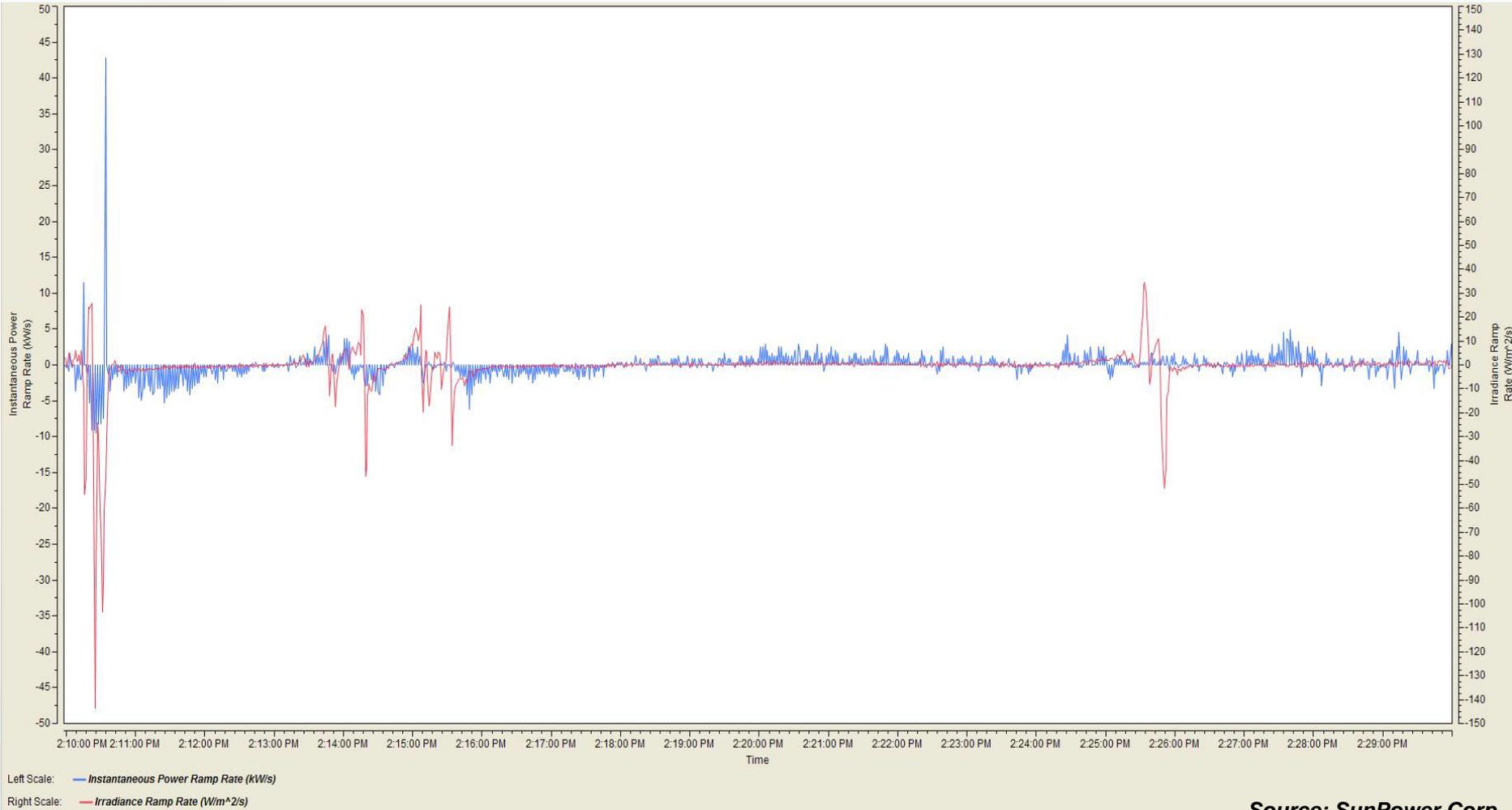
Irradiance and Power Output



Source: SunPower Corp



1 Second Ramps in Plant Output



Source: SunPower Corp





Final Lanai Battery Outcome

- **Castle and Cooke selected Xtreme Power: a turnkey battery system supplier**
 - Contract negotiations underway
- **Battery system size: 1.125 MW; 500 kWh storage capacity**





Kauai Island Utility Co-op Energy Storage Study

**Performed by
Sandia National Laboratories**





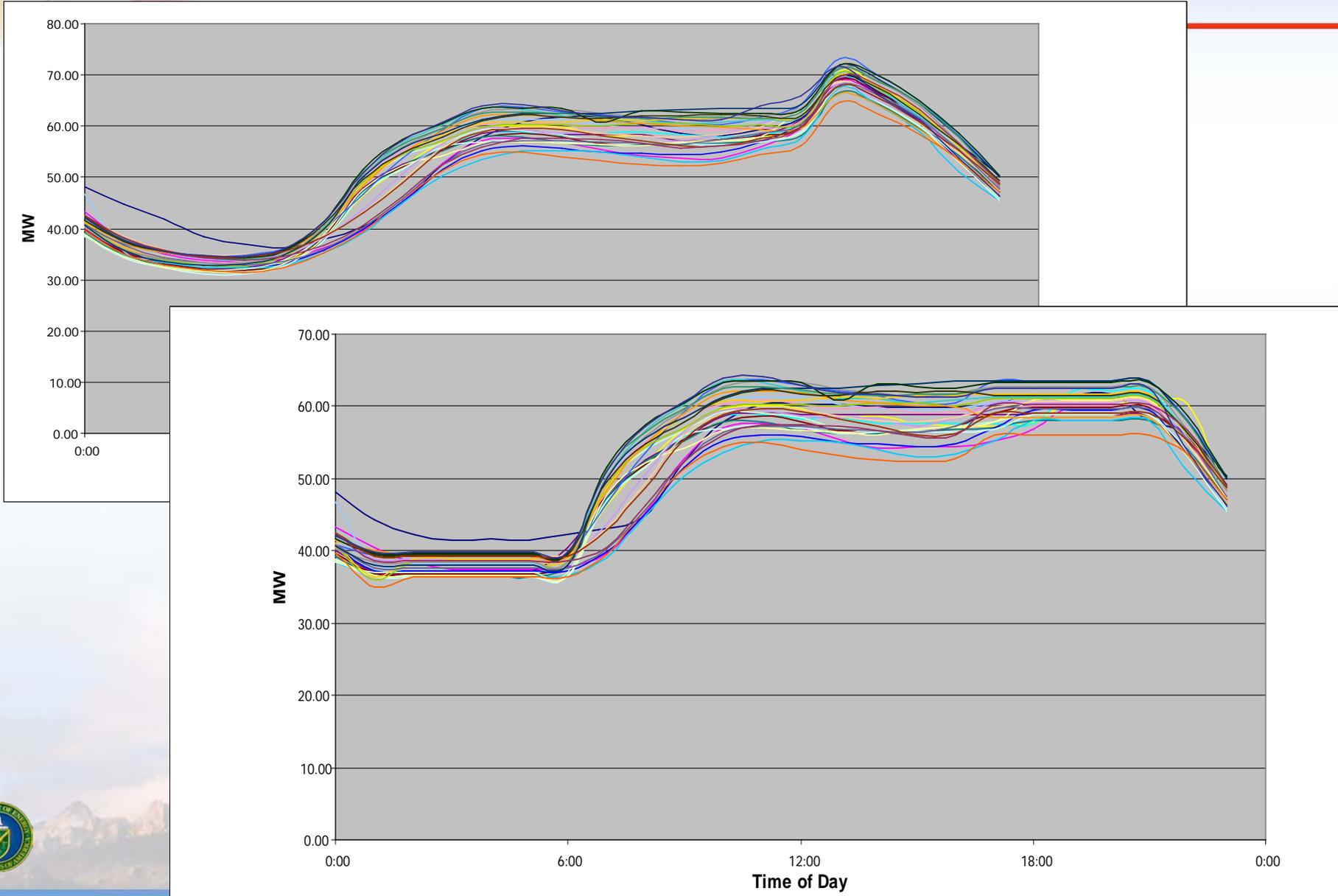
Study Objectives

- ***Primary Objective:***
Identify the benefits of energy storage and define a storage system that best meets KIUC needs:
 - ◆ Reduce diesel fuel consumption
 - ◆ Improve system reliability and stability
- ***Secondary Objective:***
Develop a stability model of the KIUC system based on PSCAD



Daily Load Curve – January 2006

16 MWh Energy Storage – 15% R/T Losses





Impact on Generation





Study Results

