



Energy Storage Requirements for On- and Off-grid Systems

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Classic Use of Storage in the Electric Grid

- **Very large quantity of energy storage using pumped hydro to profitably capture variation in marginal cost**
 - **Hundred to thousand MW's with 10+ hours of capacity**
 - **Environmental impacts; Rocky Mountain, GA, was last facility commissioned in 1995, 800+ MW**
 - **US Storage capacity = 21,461MW** (Source EIA/Electric Power Annual 2006)



Battery Energy Storage

- **Cannot match pumped hydro in performance and scale**
 - **Size of battery string**
 - **Footprint**
 - **Maintenance logistics**

- **Large battery energy storage built in utility grids**
 - **27/46 MW: Fairbanks, AK: Golden Valley Electric Assoc., 2003**
 - **20 MW: San Juan, PR: PR Electric Power Authority, 1994**
 - **10 MW: Chino, CA: Southern California Edison, 1988**

Different Approach to Battery Storage

- **Target electric grid apps that are more compatible with battery system performance**
 - **Lead by DOE/Sandia Labs and EPRI in late 1980's**
 - **System Specific Studies with four electric utilities and co-ops identified T&D and Customer-side applications**
(http://infoserve.sandia.gov/sand_doc/1993/931754.pdf)
 - **Result was to identify applications that require smaller battery system size and shorter discharge times**

One Battery Many Uses

- **Golden Valley Electric Association's battery system size is 27 MW/15 minutes**
- **Performs seven functions:**
 - **Spinning Reserve (highest priority)**
 - **Automatic Scheduling**
 - **Support for Scheduled Load Increases**
 - **Automatic Generator Control**
 - **VAR Support**
 - **Power System Stabilization**
 - **Battery Charging**

Multiple Uses for Battery Storage

- Several reports have documented multiple applications and benefits of energy storage:
 - *Energy Storage Benefits and Market Analysis Handbook : A Study for the DOE Energy Storage Systems Program.*
http://infoserve.sandia.gov/sand_doc/2004/046177.pdf
 - *Energy Storage Concepts for a Restructured Electric Utility Industry.*
http://infoserve.sandia.gov/sand_doc/2000/001550.pdf
 - *Battery Energy Storage : A Preliminary Assessment of National Benefits (The Gateway Benefits Study).*
http://infoserve.sandia.gov/sand_doc/1993/933900.pdf

Benefits Suitable for Battery Energy Storage

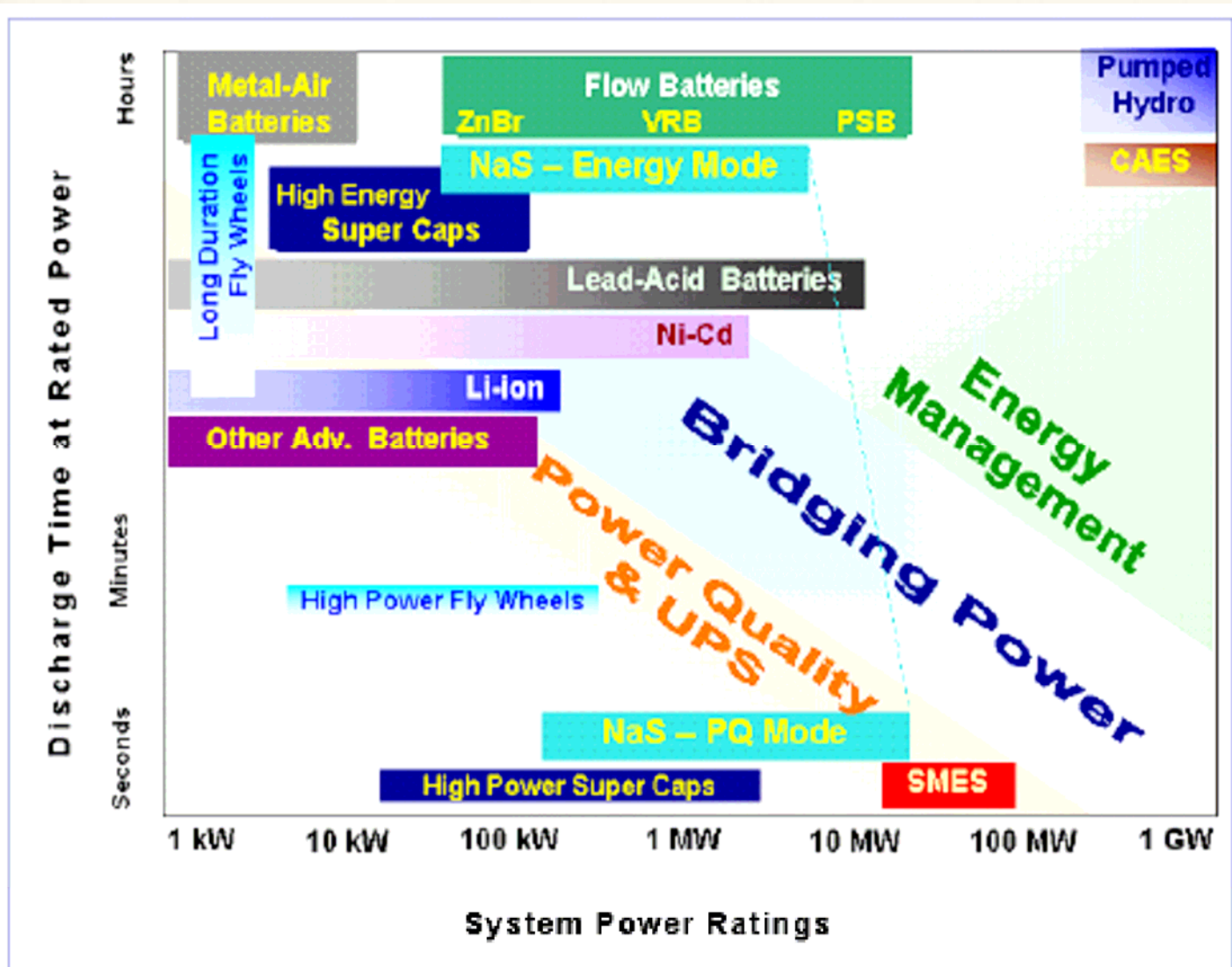
- **Ancillary Services**
 - *Frequency regulation, Spinning reserve, etc.*
- **Transmission Support**
- **Transmission Congestion Relief**
- **Distribution Upgrade Deferral**
 - *American Electric Power applications using Sodium-Sulfur*
- **Time of Use Energy Cost Management**
- **Demand Charge Management**
- **Electric Service Reliability**
- **Electric Service Power Quality**
 - *S&C PureWave commercially available*
- **Renewable Capacity Firming**
 - *Common application with most small PV systems*

Many of these benefits have been demonstrated by existing battery energy storage systems

Applications and Energy Requirements

Application	Storage Support Time
Frequency Regulation	1 – 5 minutes
Spinning Reserve	15 – 20 minutes
Distribution Upgrade Deferral	1 – 4 hours
Time-of-Use Cost Management	15 minutes – 1 hour
Demand Management	15 minutes – 1 hour
Power Quality	Seconds to 5 minutes

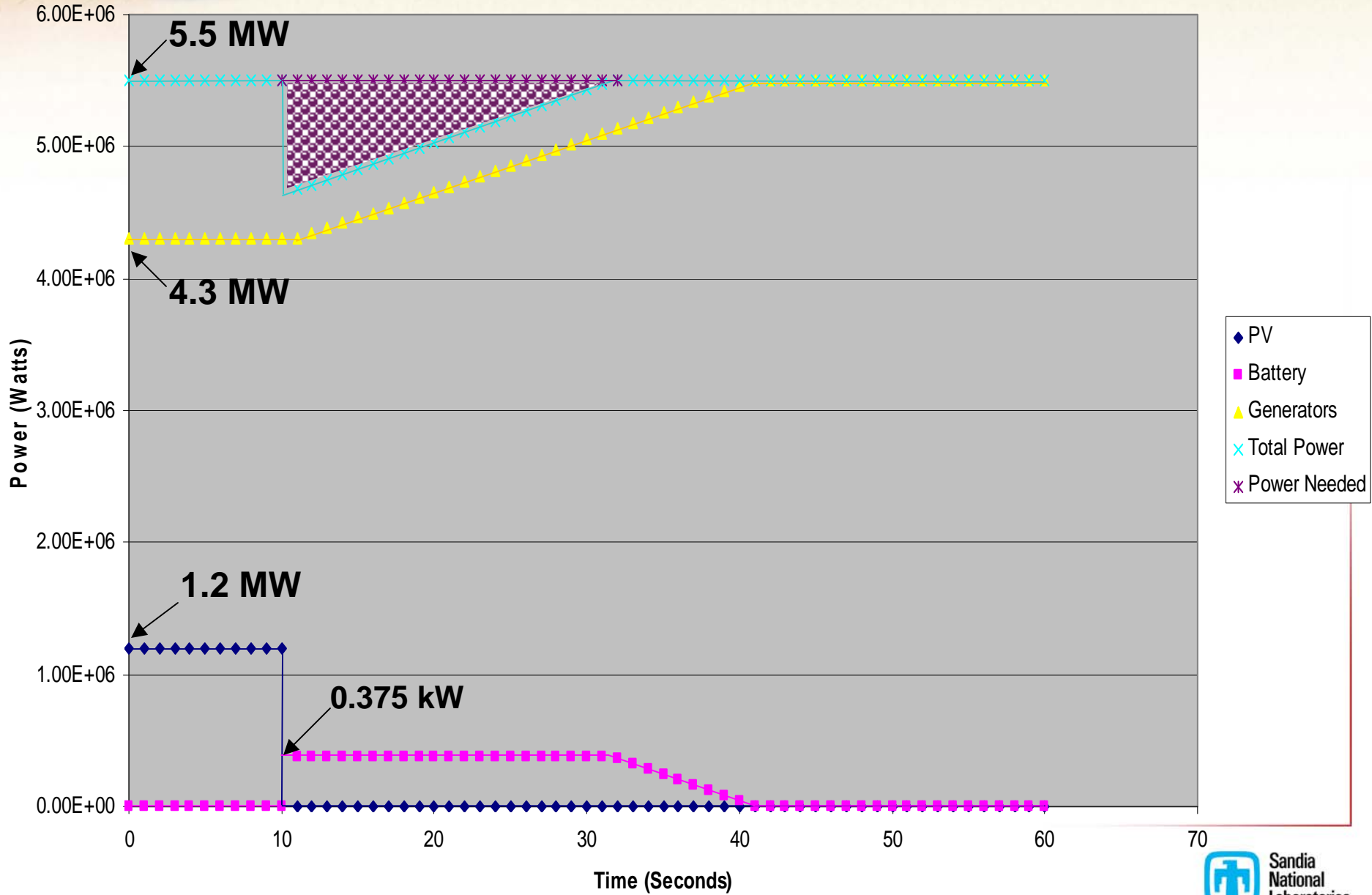
Energy Storage Requirements



Off-grid Battery Storage

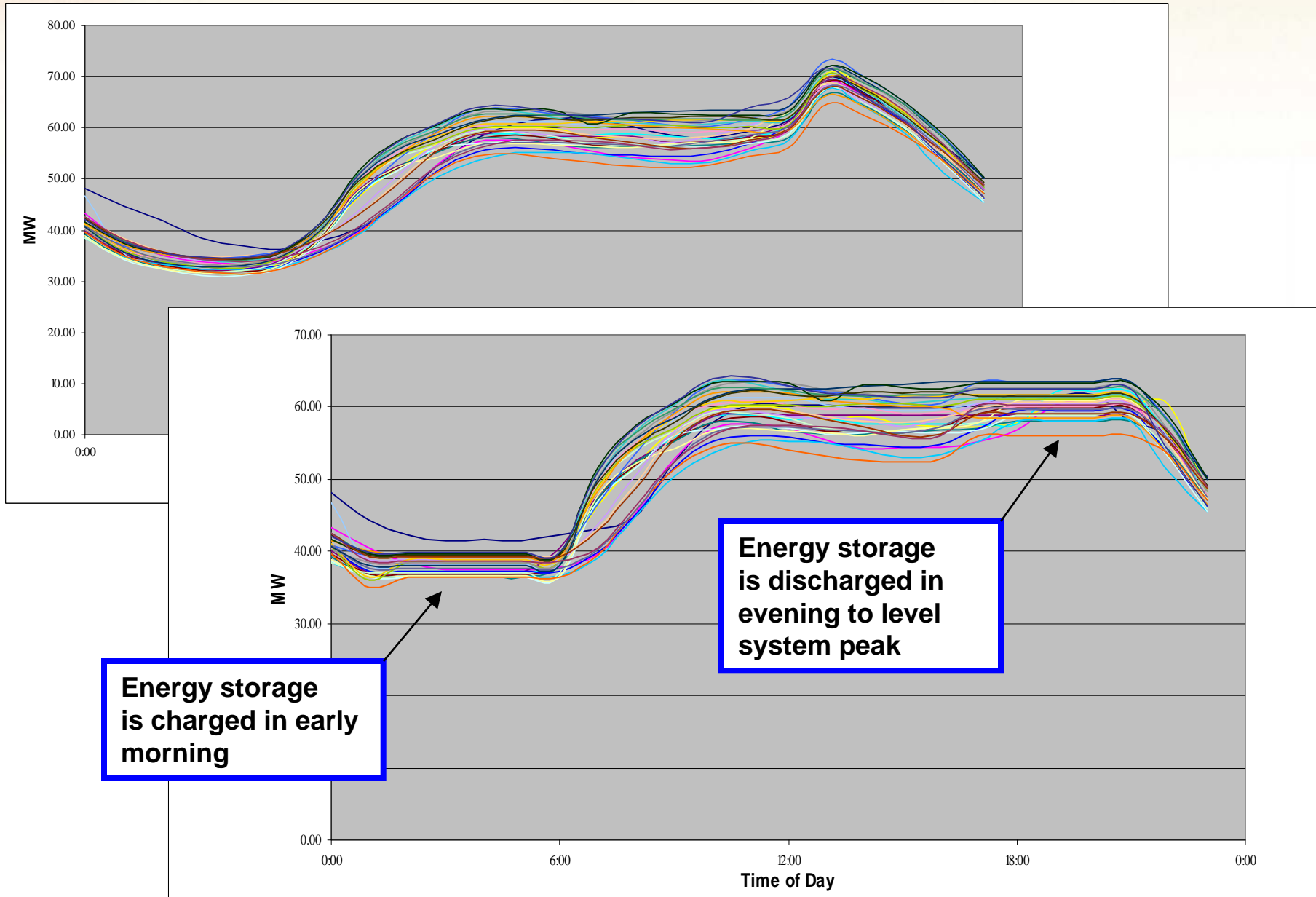
- **Ramp support, stability and transition support in microgrids**
- **System stability and reliability for Island Grids**
 - **Metlakatla Battery System – 1.2 MW/1.2 MWh**
 - **Lanai battery storage needs – 250+ kW/1 – 3 hrs**
 - **Kauai studies performed by Sandia Labs and GE**
4 – 6 MW/4 hours
- **PHEV applications**
- **Interactive management of PV systems with advanced metering**

Lanai Power System



Daily Load Profiles for January 2006

16 MWh Energy Storage – 85% Efficiency Storage



KIUC Peak Shaving Analysis

Commodities model was re-run to include 16 Mwh of storage

Result shows a net *reduction* in fuel usage and maintenance costs for KIUC system

- Kapaia fuel (naphta) usage increases with corresponding increase in maintenance costs
- EMD fuel (diesel) usage and maintenance costs are reduced
- Aggregate annual savings are tabulated below:

	Diesel Maint. Cost	Diesel Fuel Cost	KPA Maint. Cost	KPA Fuel Cost	Net Savings
W/85% Eff . Storage	\$2,882,283	\$32,202,627	\$1,912,872	\$24,006,818	\$61,004,600
W/O Storage	\$2,942,087	\$32,456,405	\$1,901,483	\$23,838,446	\$61,138,421
	-\$59,804	-\$253,778	11,389	168,372	-\$133,821

GE's Involvement in Battery Storage

- **GE designed and built PCS for four battery systems:**
 - **SCE Chino Battery, 1988; 10 MW**
 - **PREPA San Juan Battery, 1994; 20 MW**
 - **GNB Vernon Battery, 1995; 3 MW**
 - **Metlakatla Battery System, 1996; 1.2 MW**



Thank You

Questions and Discussion