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Jacobs School *of* Engineering

Energy Storage Research At UC San Diego

CER Seminar

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UC San Diego 42 MW Microgrid

Campus Quick Facts

With a daily population of over 45,000, UC San Diego is the size and complexity of a small city.

As a research and medical institution, we have **TWO** times the energy density of commercial buildings

12 million sq. ft. of buildings, $200M/yr of building growth

Self generate 92% of annual demand

- **30 MW natural gas Cogen plant**
- **2.8 MW of Fuel Cells installed**
- **2.2 MW of Solar PV installed, with another 0.8 MW planned in 2013**

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Objectives

- **Accommodate Higher Levels of Renewable Generation:** Mitigate impacts and accommodate higher levels of renewable generation
- **Improve Operational Capability of Energy Storage:** Develop and test new control algorithms and integrate solar forecasting
- **Grid Integration of Energy Storage:** Identify energy storage integration issues and develop cost effective solutions (i.e. smart inverters, advanced controls, etc.)
- **Advance Energy Storage Technology:** Test new energy storage technologies and battery chemistries to improve cost effectiveness and performance
- **Promote Commercial Development:** Provide a test bed for energy storage companies to test their technology, Energy Research Park development capable of grid connected testing of multiple energy storage systems
- **Optimize Resources, Microgrid Operations:** UCSD's energy storage projects are also designed and controlled to optimize generation resource utilization and reduce microgrid operational costs and greenhoue gas emissions.

Energy Storage Projects at UCSD

Operational (2014)

- 10 kW, Sunverge, Scripps Institute of Oceanography
- 108 kW, 180 kWh BMW, demonstration of application of 2 nd use EV batteries, coupling to 330 kW PV, and Fast EV Level 2
- 3.8 Million Gallon Thermal Energy Storage Tank

In Design (To be operational 2015)

- 2.5 MW, 5 Mwhr, SGIP Advanced Energy Storage, Lithium-ion from BYD
- 25 kW / 40 kWh Amber Kinetics, Flywheel energy storage
- 28 kW, Maxwell Labs, Ultracapacitors, CPV smoothing of intermittency, coupled with solar forecasting
- MCV 35 kW, 35 kWh Compact Li-Ion energy storage system
- NRG 100 kWh Li-ion, PV integrated energy storage with EV DC Fast Charging

Future Planned

- 730 kW, 1460 kwhr SGIP PV Integrated, five off campus sites

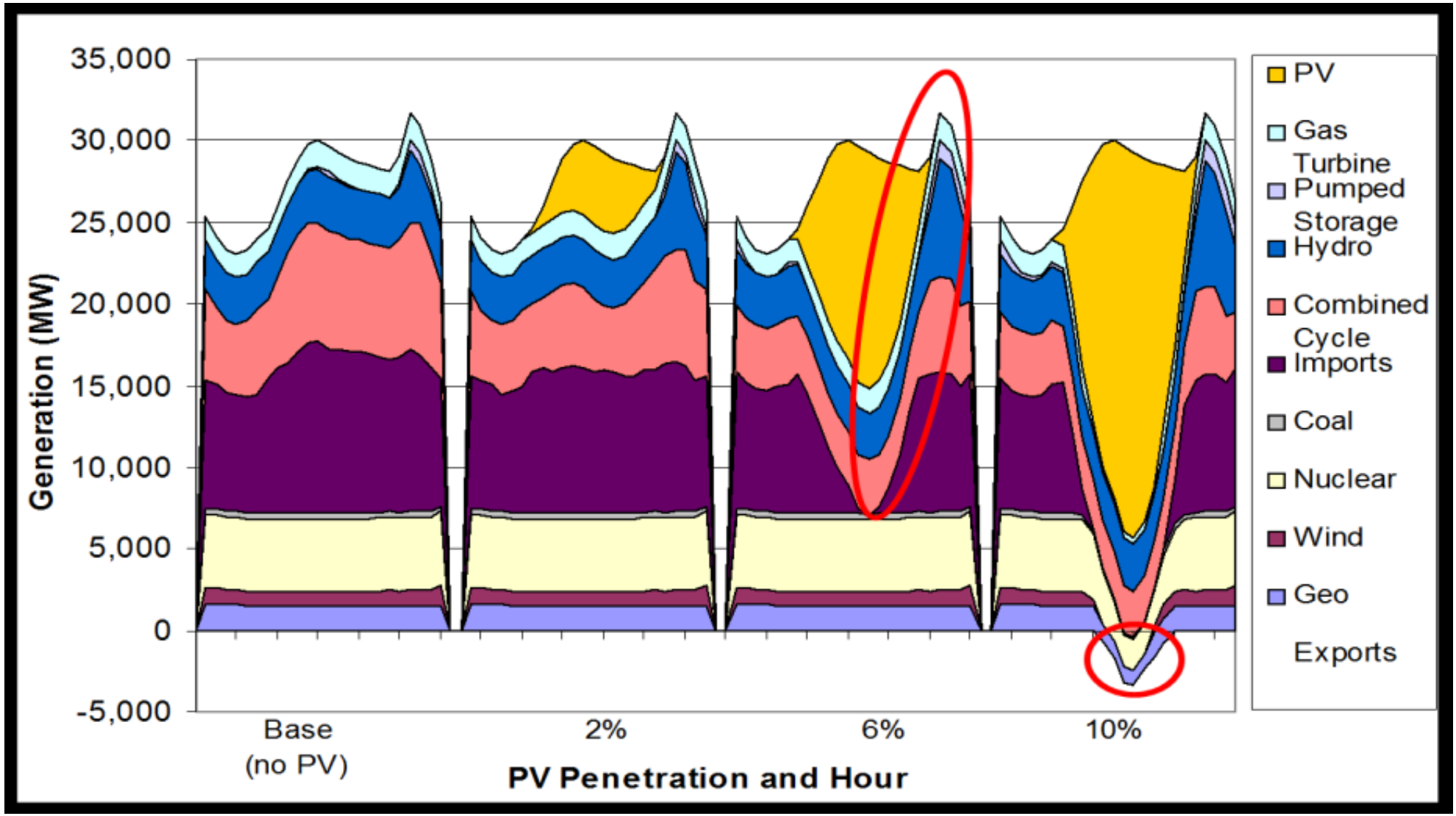
De-commissioned

- 30 kw, 30 kWh, 30 kW PV integrated, Li-Ion battery
- ZBB 100 kW/ 300 kWh kW Flow Battery

ARPAe Testing of Advanced Batteries

- Establish major third party battery testing facility on West Coast
- Both lab testing and grid connected testing capability
- Tests protocols will represent real world grid scale applications
- Up to 100 kva batteries, capability to test 10 battery packs simultaneously
- Lab cell diagnostics and performance evaluation
- Economic valuation and commercial viability assessment

Higher Levels of Renewables Driving Energy Storage



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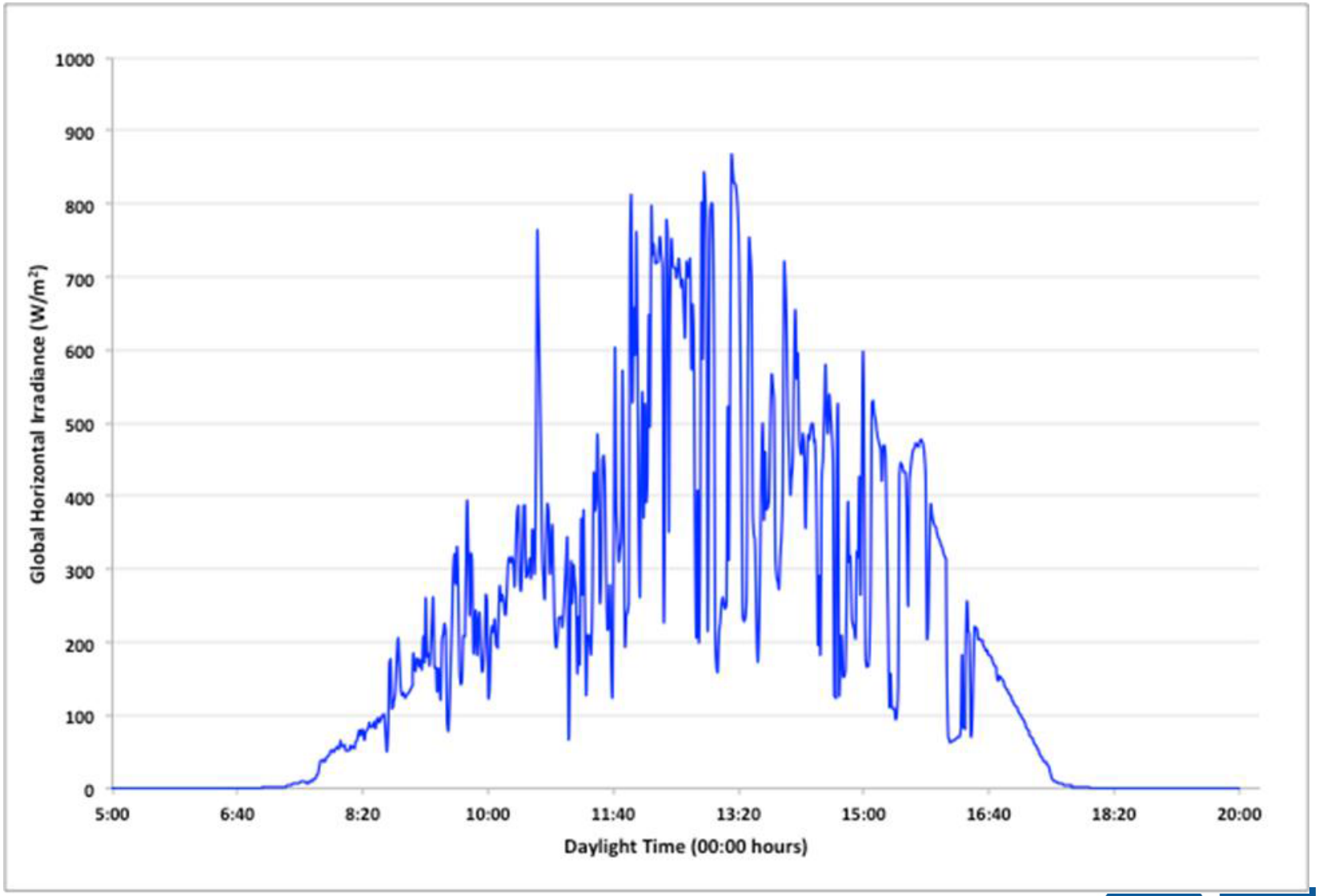
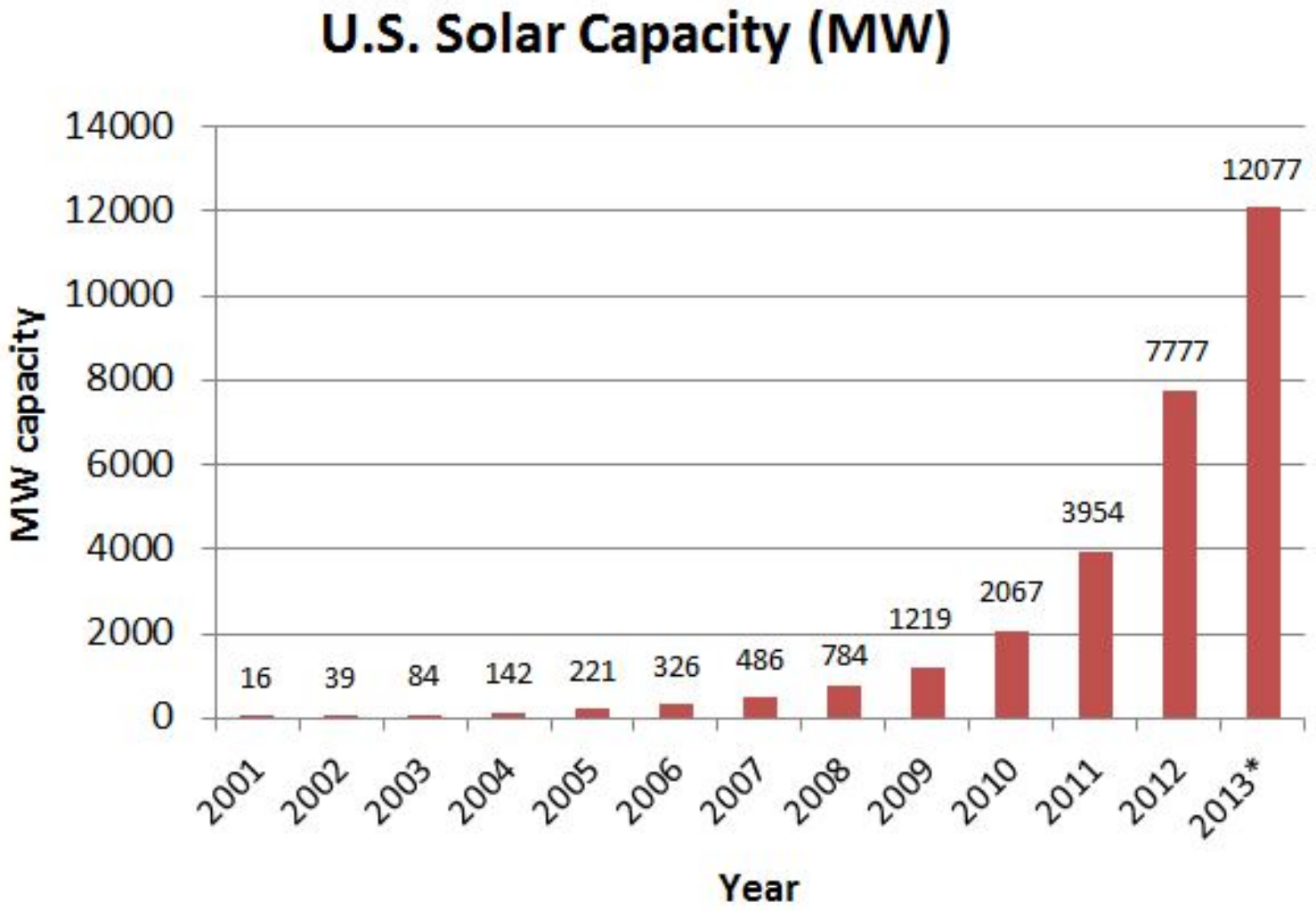
Variability and Intermittency Impact Mitigation



Installation of Solar PV Is Rapidly Increasing



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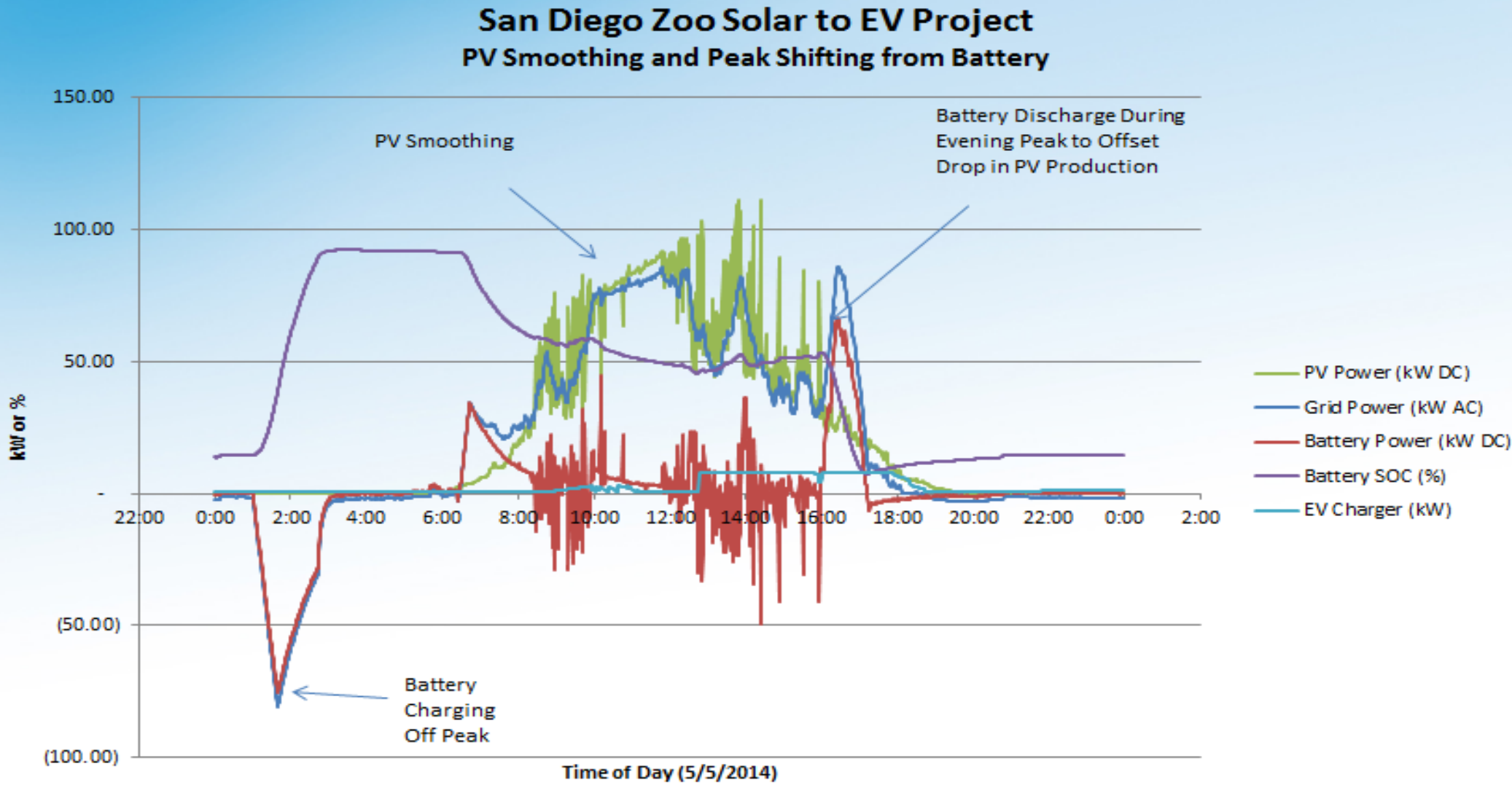
Solar-to-EV Project – Peak Smoothing



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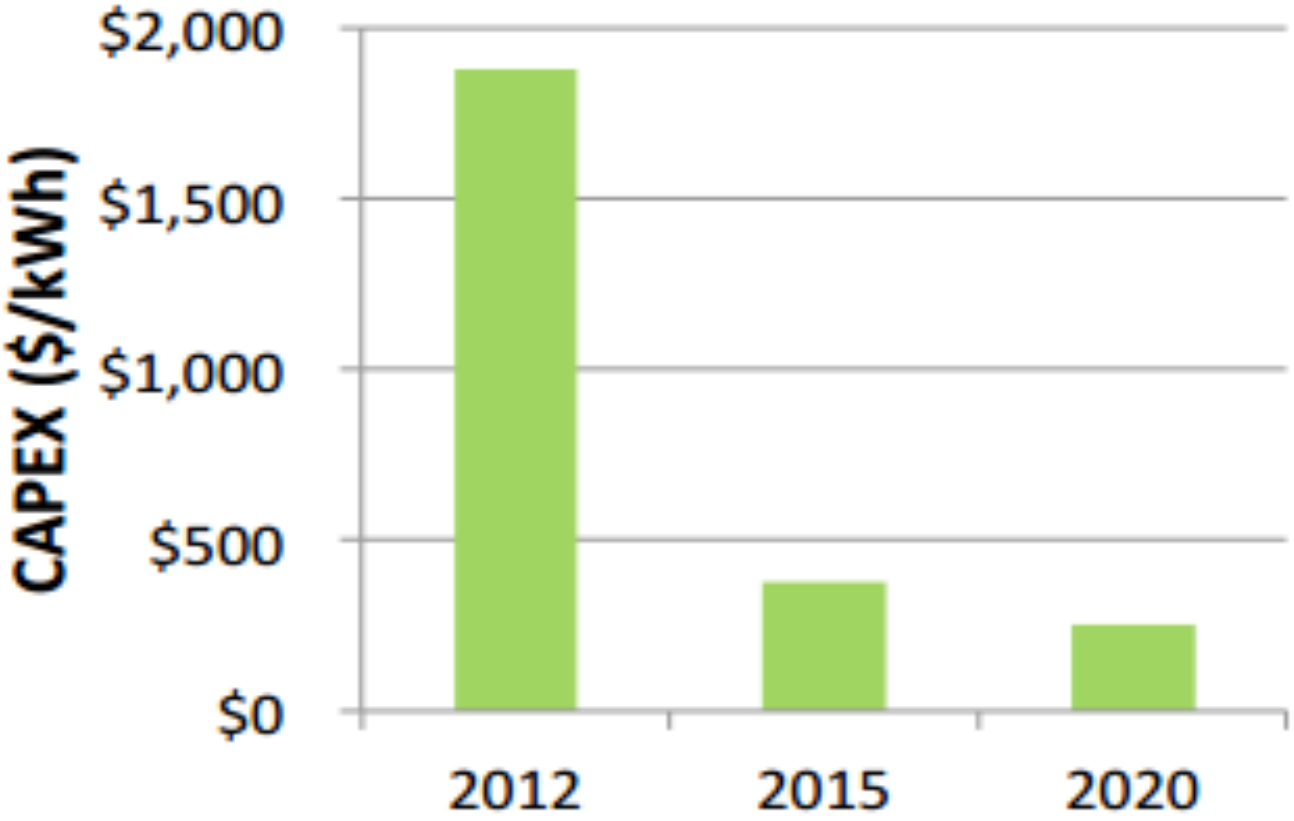
California Energy Storage Procurement Targets

	Sample Uses or Services	Procurement Targets (Total: 1325 MW)			
		2014	2016	2018	2020
TRANSMISSION	• Bulk Storage (Stand-Alone and Co-located) • Ancillary Services • Voltage Support	110 MW	145 MW	192 MW	253 MW
DISTRIBUTION	• Substation Energy Storage • DG Storage	67 MW	90 MW	115 MW	153 MW
BEHIND THE METER (CUSTOMER	• Load Shifting • Vehicle Charging	23 MW	35 MW	58 MW	84 MW
		Total: 200 MW	Total: 270 MW	Total: 365 MW	Total: 490 MW

Expected Cost Reduction of Energy Storage

NEDO/DOE 2010 Li Ion Cost Projections



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Energy Storage Use Case Applications

Energy Storage Applications

Electric Energy Time-shift
Electric Supply Capacity
Load Following
Area Regulation
Electric Supply Reserve Capacity
Voltage Support
Transmission Support
Transmission Congestion Relief
T&D Upgrade Deferral
Substation On-site Power
Time-of-use Energy Cost Management
Demand Charge Management
Electric Service Reliability
Electric Service Power Quality
Renewables Energy Time-shift
Renewables Capacity Firming
Wind Generation Grid Integration

Important Metrics per Duty Cycle

1)Annual operational days/hours

2)Number of cycles per given time period

3)Average DOD per cycle

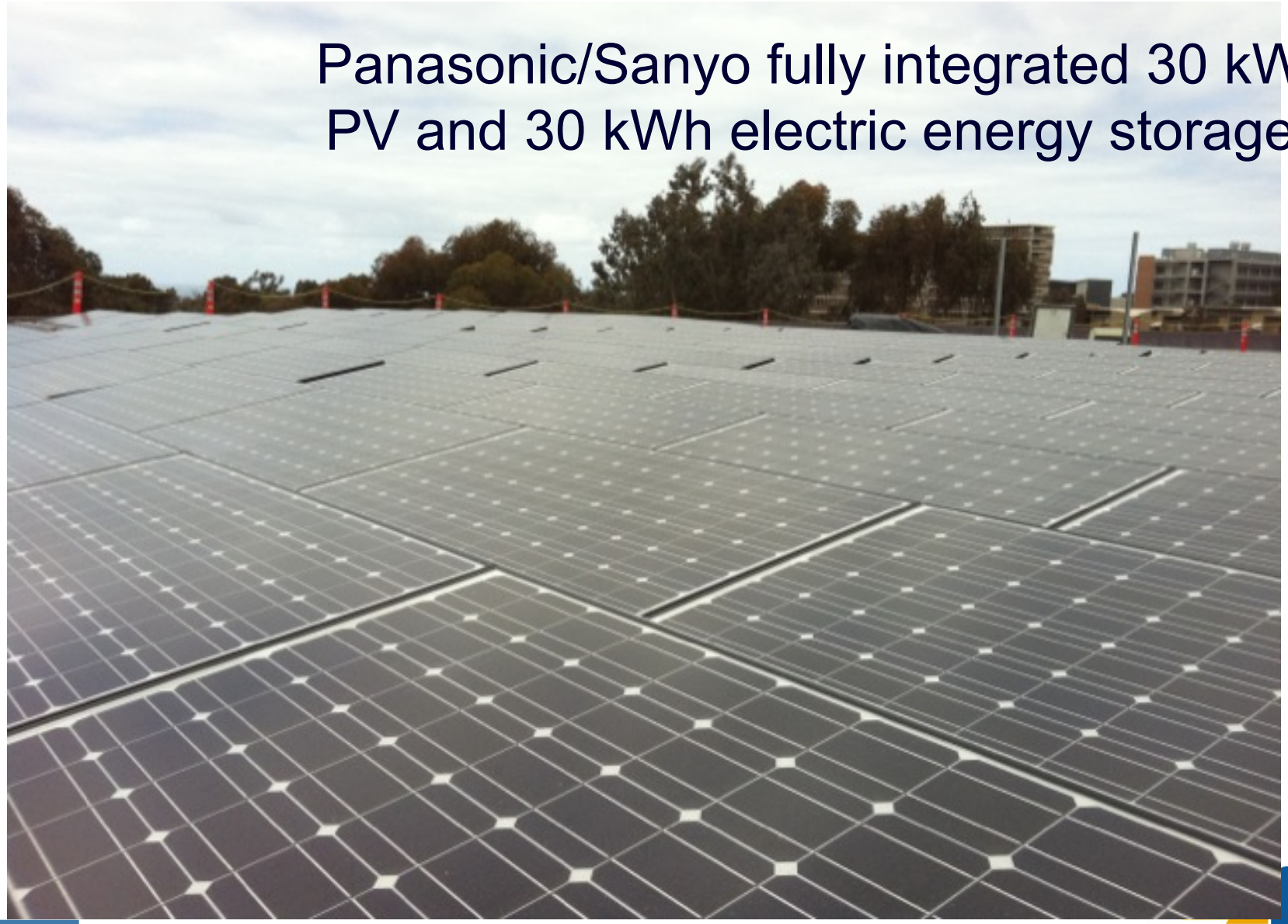
4)Energy throughput per kWh of available capacity

5)Financial value per kWh

6)Value per kWh of available energy capacity and C-rate

Panasonic/Sanyo PV Integration Storage

Demonstration of PV Intermittency Smoothing



Panasonic/Sanyo fully integrated 30 kW PV and 30 kWh electric energy storage

- Solar Forecasting System coupled to energy storage controls to mitigate intermittency
- Peak shaving to reduce the energy use/cost.
- Provide stable and efficient energy.
- Ancillary Function (emergency power back up for communication etc

Energy Storage PV Intermittency Smoothing

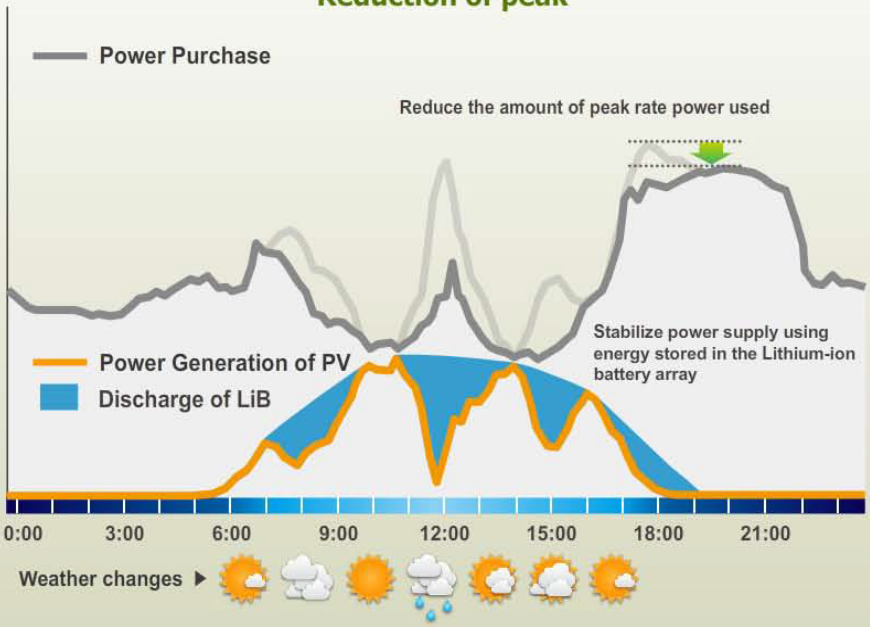
Smart Energy System

SANYO

Example : Minimize grid power purchasing

Case3 : Using Lithium-ion Batteries with PV

Reduction of peak

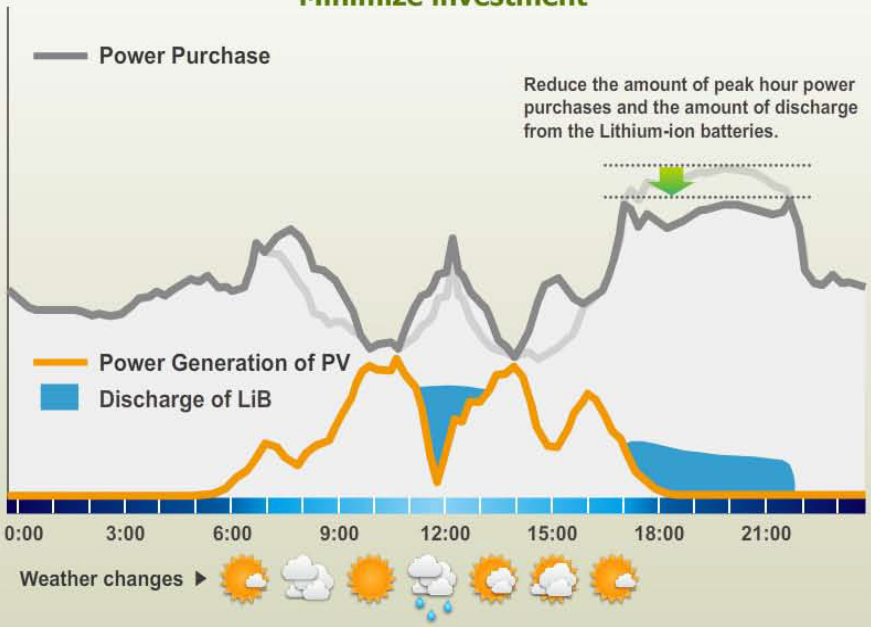


With lithium-ion batteries used together with the PV system, the power "gaps" can be filled with the energy stored in the batteries to reduce the amount of peak hour power purchases. This will require a lot of power to be discharged from the batteries, however.

Case4 : PV + Lithium-ion batteries + Solar Forecasting※

※ Researching in UCSD

Minimize investment

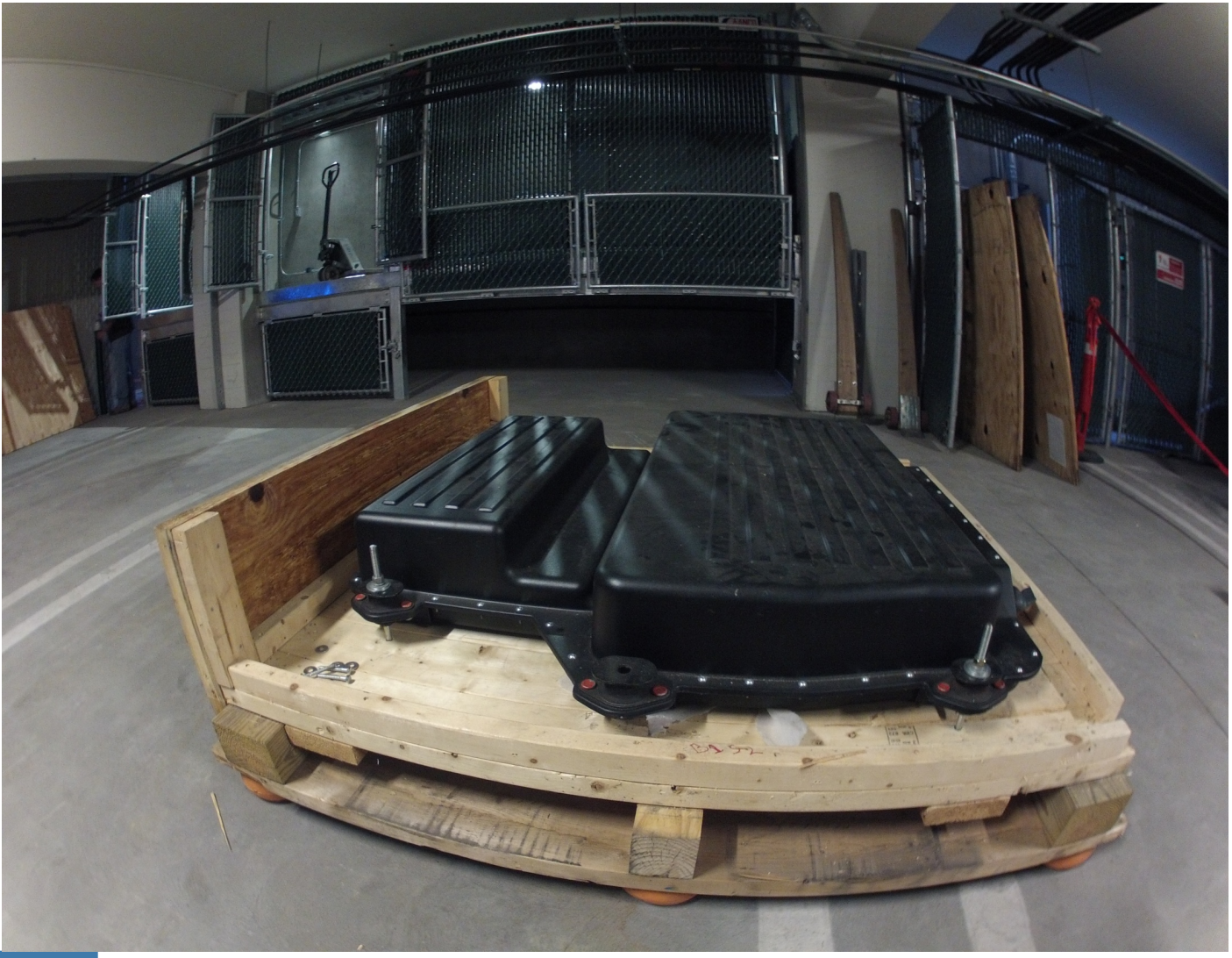


Solar Forecasting can be used to predict the amount of PV power generation with weather changes. With this information, the lithium-ion batteries can be used more efficiently. This will result in a reduction of not only peak power purchased but battery capacity.

ZBB/Sunpower / DNV Kema CSI Flow Battery

- ZBB EnerStore V3 - 25 kW / 50 kWh
- DC Efficiency up to 76%
- Six units with 300 kWh total capacity
- Directly coupled with 60 kW of roof top PV
- Control system designed to reduce peak load demand requirements at East Campus Chiller Plant

Repurposed (2nd Life) Electric Vehicle Battery Testing



- 120 kW/ 60 kWh of total energy storage capacity
- Test stand linked to Microgrid control system and remotely controlled.
- Plug-in vehicle batteries degraded to 70-80% of original power or energy capacity are insufficient for automotive use
- May provide a low cost source for stationary energy storage applications

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BMW 2nd Use EV Battery Energy Storage

Objective:
Demonstrate the feasibility of integrating and controlling multiple 2nd life repurposed MINI E battery systems, with additional integration of PV solar array and the UCSD micro grid for a three year period.

Research possibilities and value:

- Investigate test applications and load profiles.
- Results will lead to better understanding of different use cases and possible B2U scenarios
- Identify control issues related to managing multiple repurposed EV batteries with a different state of charge.
- First full scale energy storage system with repurposed EV batteries..

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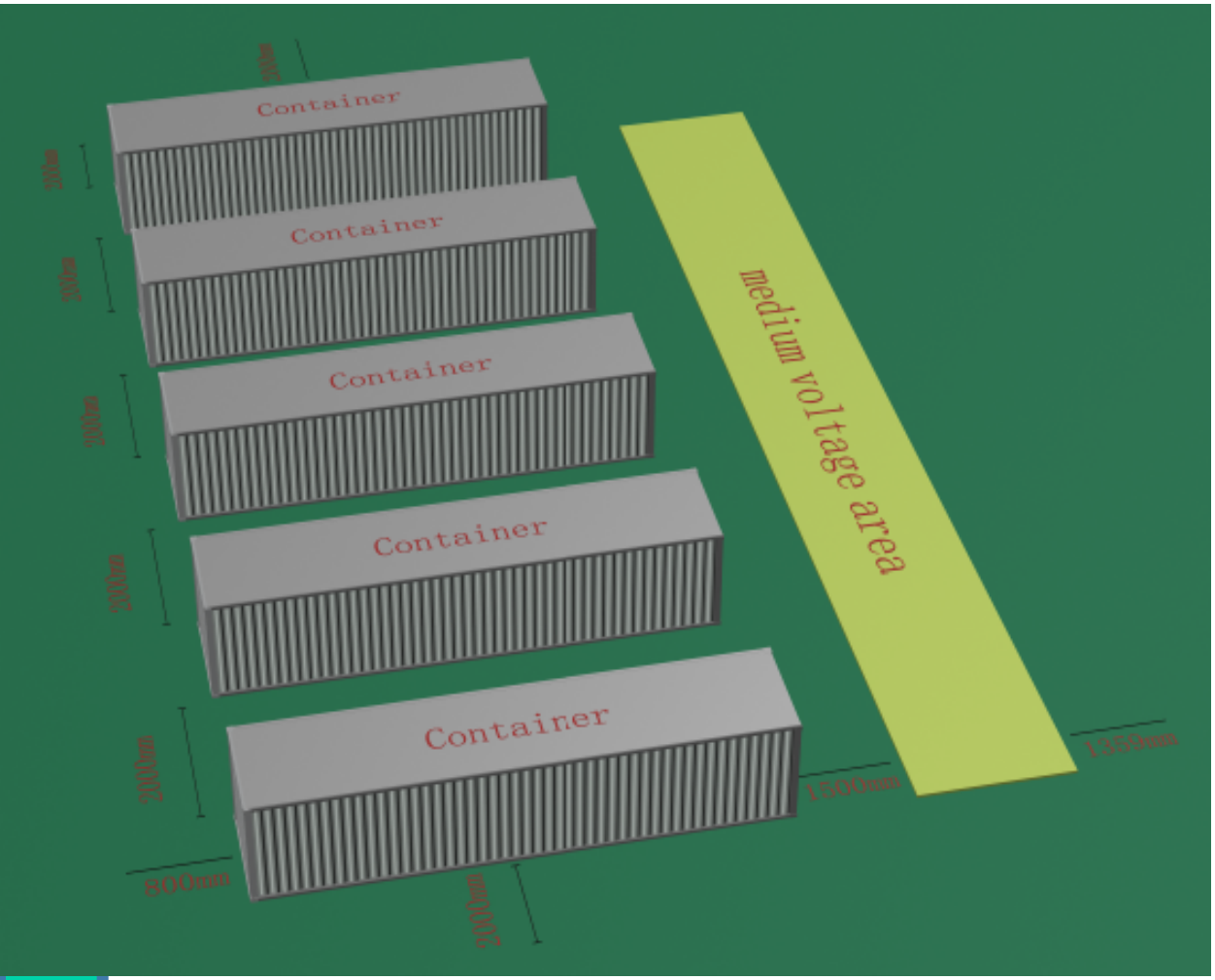
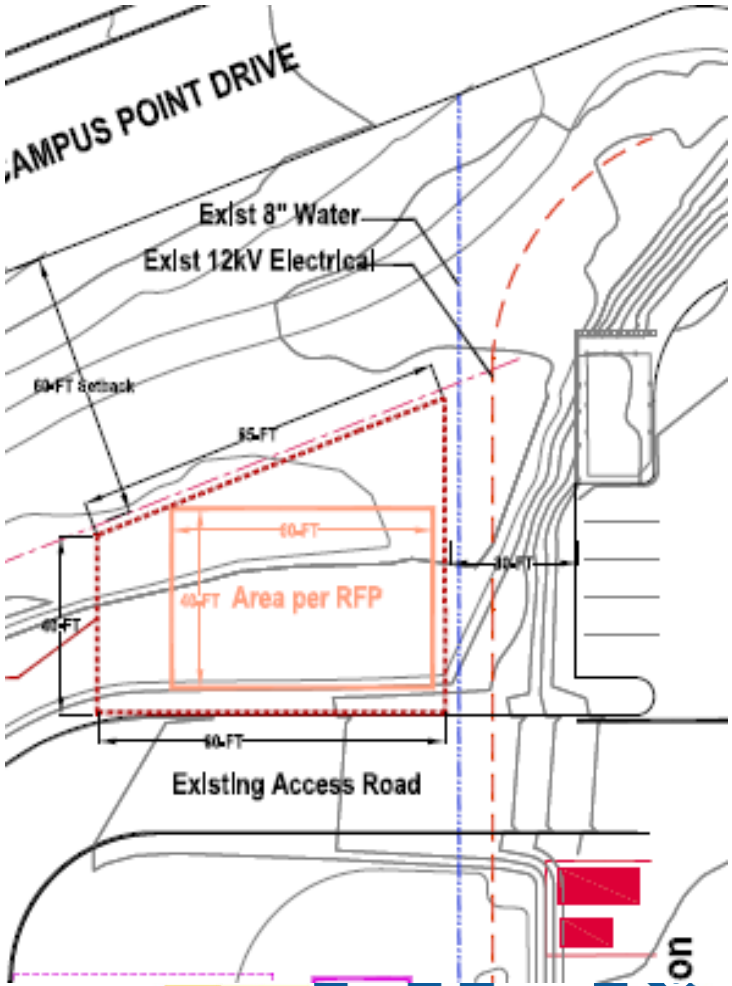
UCSD SGIP Bulk Energy Storage Project

- 2.5 MW, 5 MWhr, bulk energy storage
- Reduce Peak Campus demand energy cost production
- Integrated with PV and fuel cell and campus cooling load





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Maxwell Labs Ultracapacitor Energy Storage

Key Design Parameters

- Phase I: 28 kW, 5 minute energy storage
- Phase II: 250 kW, 5 minute energy storage
- PV solar smoothing and firming, improve PV ramping
- Coupled with 28 kW Concentrated PV
- Control Strategies to be tested
- Solar predictive forecasting coupled with cont systems
- Schedule: June, 2013 – Nov. 2015

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Real Time Control of High Resolution Data

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Your Extended Forecast

Today	Tomorrow
High 74°/Low 70° Partly cloudy	High 73°/Low 69° Areas of low clouds

Thursday	Friday
High 71°/Low 68° Increasing cloudiness	High 76°/Low 68° Mostly cloudy

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UCSD

LOCAL IMPACT, NATIONAL INFLUENCE, GLOBAL REACH

Power Analytics Capacity Assessment

25000.0 37500.0 50

Power Network Capacity Used 32425.49 kW

25000.0 37500.0 50000.0

Power Network Capacity Design Limit 38261.05 kW

0.0 25.0 50

Power Network Percent Remaining 18.00 %

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Quality of Power

	Daily	Monthly	Year-To-Date
Total Campus Load	253954.10 kW	3122146.00 kW	3652462.75 kW
Co-Gen	13753.00 kW	169081.00 kW	197800.50 kW
Total Solar	24.94 kW	306.59 kW	358.66 kW
Carbon Footprint	17700.12 lbs	217607.81 lbs	254569.97 lbs
Total Imported from SDGE	5717.98 kW	70297.59 kW	82238.35 kW

viridityenergy

0 40 80 120 160 200

Supply Costs ($)

0 40 80 120 160 200

Net Economic Benefit ($)

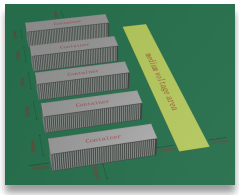
	Daily	Monthly	Yearly
Optimized Costs	$ 49482.53	$ 1484475.90	$ 18061123.45
Base Costs	$ 51906.26	$ 1557187.80	$ 18945784.90
Cost Savings	$ 2423.73	$ 72711.90	$ 884661.45
Carbon Output	185024.36 (lb)	5550730.80 (lb)	67533891.40 (lb)

Go To VPower Report **Real-Time Price:** 27.70 ($/Mw) **Real-Time Date:** 2011-06-27T16:07:41.654Z

Control and Dispatch of Distributed Energy Storage

UCSD Campus Load and Generation Requirements

2.5/ 5 Mwhr EnergyStorage System



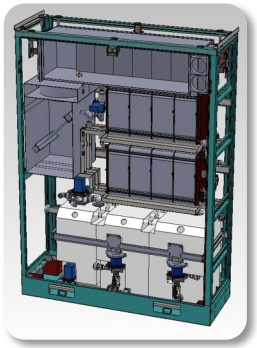
2nd Life EV Battery Test Stand

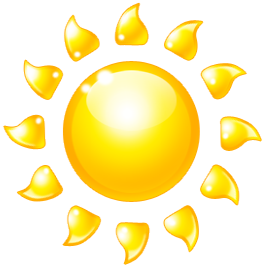
Sanyo 30 kW/ 30 kWh Energy Storage

Master Microgrid Controller

BMW B2U 108 kW/ 180 kWh

ZBB 125 kW/ 300 kWh Flow





Maxwell 28 kW Ultra Caps

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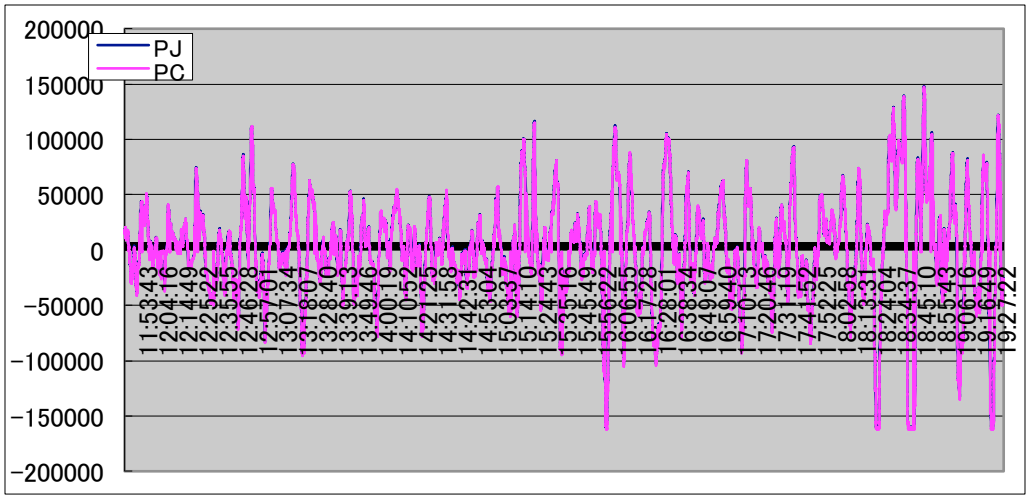
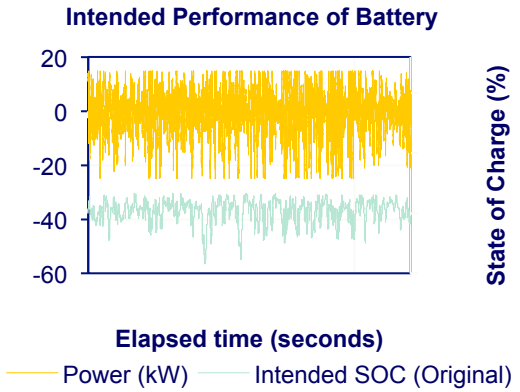
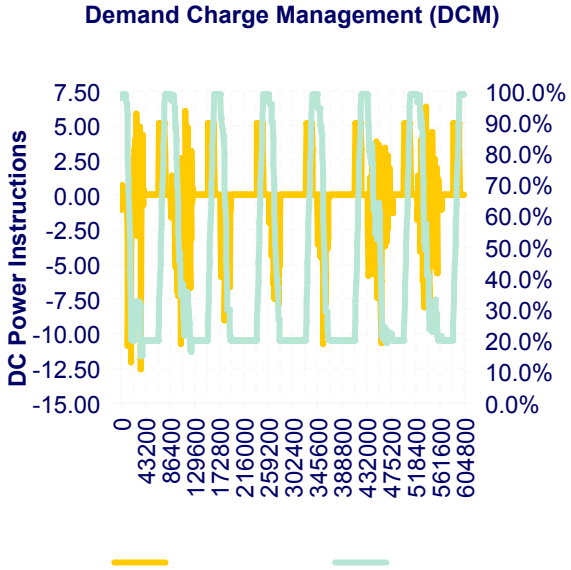
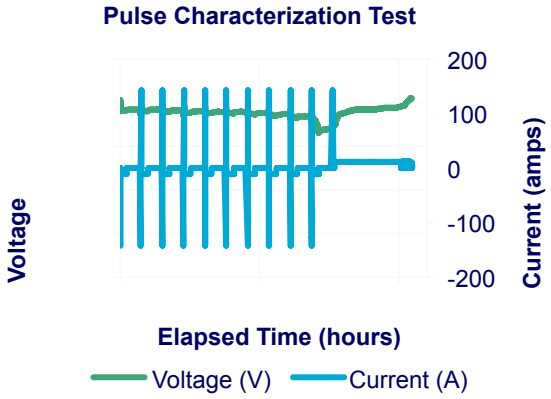
Energy Storage Control Algorithms









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Summary of UCSD's Energy Storage Program

- Large diversified energy storage projects in university setting
- Planning to grow collaboration with DOE/SNL on energy storage
- Centralized and Distributed intelligence to control energy storage fleet dispatch
- Living laboratory for testing and determining the benefits for various energy storage technologies
- Lab To Market proven capability
- Valuable research to aid integration of increasing levels of renewables
- Opportunity to realize benefits in a true microgrid operational setting

Thank You !

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