**Increasing Renewables in California and Need for Energy Storage**

Solar energy will become a main source of energy in the future:  
- Germany has 36GW of installed PV (>50% of power demand).  
- In California, PV production is contributing to 15% of peak demand.  
- U.S. Solar Industry is a $11.5 Billion market with the growth of 34% in 2012.

**Forecasted Impact of Renewables on California Load Curve**

High PV penetration and Wind generation is expected to drastically alter the net load and resources curve in California in the future:
- Energy storage is needed to ensure resource adequacy due to the variability and uncertainty of dispatch.
- Capture of PV solar mid-day can be used to reduce the evening peak and increase overall efficiency and flatten the “duck” curve.
- Energy Storage coupled with solar forecasting can be used to improve dispatch-ability of renewables and unit commitment.

**Peak load shaving control with Short-term Solar Forecast for Storage System**

Control with Sky Imager Solar Forecast was developed for a 31 kW PV tied to a 31 kW Li-ion at Hopkins parking structure at UCSD, CA. The solar forecasts was used to optimize the charge/discharge cycling for peak load shaving and battery life longevity. The strategy for peak load shaving is “Time-of-use Energy Cost Management Plus Demand Charge Management” (Eyler and Corey, 2010).

**Summary of Energy Storage Research at UCSD**

**Goal**: To test and demonstrate various types of energy storage to support integration of high penetration of renewable generation for microgrid operations.

- 30 kW, 30 kWh Sanyo/Panasonic Li-Ion battery energy storage system, integrated with 30 kW PV
- 35 kW, 35 kWh MCV Energy, Community Energy Storage
- 10 kW, 25 kWh Flywheel, Amber Kinetics, CEC
- 108 kW, 181 kWh BMW, demonstration of application of 2 nd use EV batteries, coupling to PV, and EV charging
- 2.5 MW, 5 MWhr, SGIP Advanced Energy Storage, design underway
- 730 kW, 1460 kwhr SGIP PV Integrated, five off campus sites
- 30 kW, Maxwell Labs, Ultracapacitors, CPV smoothing of intermittency, coupled with solar forecasting
- 3.8 Million Gallon Thermal Energy Storage

**Central Microgrid Control of Energy Storage Dispatch Test and Developed at UCSD**

**Demand Charge Management Example Using UCSD Building Load**

- 30 kW/30 kWh Li-Ion Energy Storage, Integrated with 30 kW PV
- 35 kW Community Energy Storage - MCV
- 25 kW/5 kWh Battery Energy Storage System
- 2.5 MW/5 MWh Li-Ion Energy Storage

**Frequency Regulation Energy Storage Power Output**

- 100 kW / 160 kWh Li-ion Repurposed BMW EV batteries

**Results in table below shows that the incorporation of forecast data was shown to dramatically increase system lifetime (6 years extra) and its lifetime profit (360% increase on a 31 kWh storage system).**

<table>
<thead>
<tr>
<th>Optimization with PV Power Output and Load Forecast</th>
<th>Off-Peak/On-Peak without PV Power Output and Load Forecast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual energy bill cost reduction [1]</td>
<td>31,200</td>
</tr>
<tr>
<td>Number of cycles at 80% DoD [cycles/yr]</td>
<td>212</td>
</tr>
<tr>
<td>Battery lifetime [years]</td>
<td>14.2</td>
</tr>
<tr>
<td>Fixed cost simple payback time [years]</td>
<td>5.7</td>
</tr>
<tr>
<td>Total profit at end of battery lifetime (annual energy bill savings x battery lifetime - fixed costs) [$/yr]</td>
<td>281,000</td>
</tr>
</tbody>
</table>