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Optimal sizing of energy storage and photovoltaic power systems for demand charge mitigation

Jeremy Neubauer, Mike Simpson
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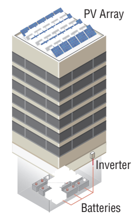
BACKGROUND

Commercial facility utility bills are often a strong function of demand charges, a fee proportional to peak power demand rather than total energy consumed.

Behind-the-meter solar power generation decreases energy costs but its variability means that peak load – and thereby demand charges – remain unaffected.

Controllable behind-the-meter energy storage can reduce demand charges, but is expensive. When is it a cost-effective solution?



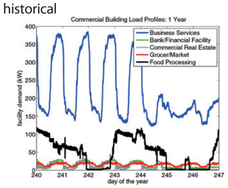
APPROACH

Load Data from Enernoc

- 12 consecutive months, 5 minute resolution, 5 facilities in Los Angeles
- PV power added using load-synchronized historical solar irradiance data from Los Angeles

PV fraction = nameplate PV power / peak facility demand

Facility	Size (sq.ft.)	Annual Peak Demand (kW)	Average Daily Energy (kWh)
1. Business Services	1700k	651	79,800
2. Bank/Finance	496k	67	5,900
3. Commercial Real Estate	295k	49	3,400
4. Grocer/Market	49k	27	5,500
5. Food Processing	4.7k	172	11,600



Rate Structure

- Southern California Edison's TOU-GS-2 option B rate structure

Charge	Time	Cost	Units
Facilities Related Demand Charge	—	$13.94	$/kW
Time Related Demand Charge	On-Peak	$16.20	$/kW
	Mid-Peak	$4.95	$/kW

Energy Storage System Specification

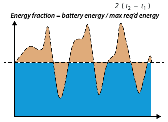
- System performance modeled on Saft VL41M li-ion cells and a 93% efficient inverter
- Available energy and max inverter power defined relative to facility load profile

Power fraction = inverter power / peak facility demand

Energy fraction = battery energy / max req'd energy storage

$$\text{Max Req'd Energy Storage} = \frac{\int_{t_1}^{t_2} |L - L_{avg}|\,dt}{2\,(t_2 - t_1)}$$

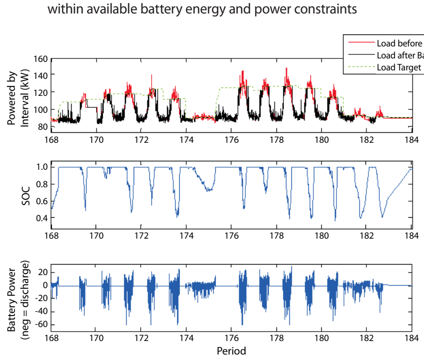
Energy fraction = battery energy / max req'd energy



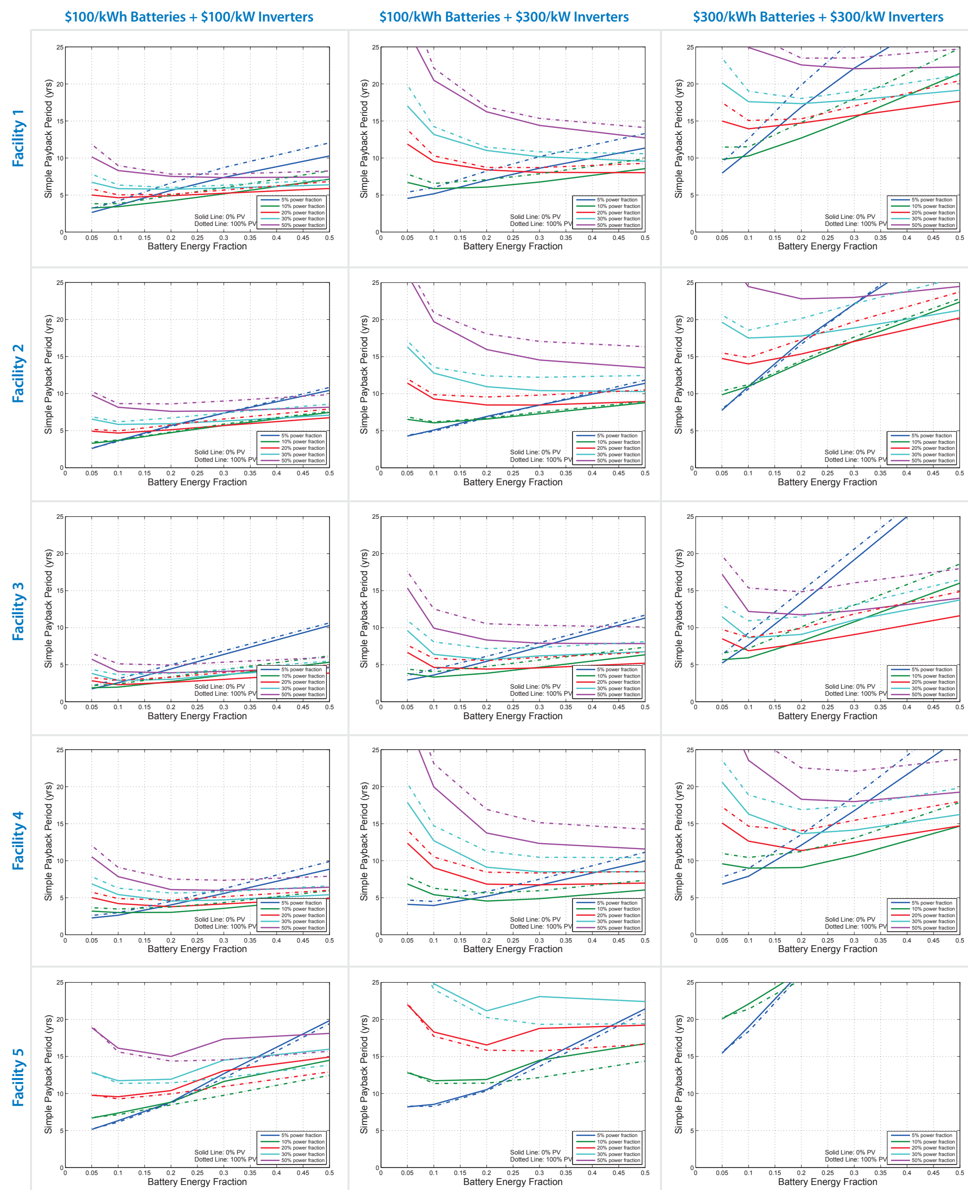
Peak Shaving Algorithm

Objective: Maximize the reduction in peak load using the available power and energy of the battery

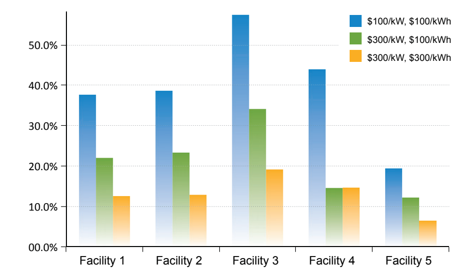
Approach: Forecast future demand and PV production, then optimize load reduction within available battery energy and power constraints



SIMPLE PAYBACK RESULTS



ANNUALIZED RATE OF RETURN FOR OPTIMAL SYSTEM CONFIGURATION



CONCLUSIONS

- **Payback periods and annualized rate of return can vary significantly between facilities, especially when the price of hardware is high.**
- **However, payback period trends as a function of power and energy fraction are similar across facilities.**
- **Minimal payback always occurred at an energy fraction ≤ 10% and a power fraction ≤5% for the cases we studied.** Trends suggest smaller storage systems may further decrease payback period.
- **Sensitivity to PV fraction is low.** However, PV systems tend to reduce peak demand, thus they can slightly reduce the economic incentive to install an energy storage system for demand charge management.
- **When optimized for a given facility, energy storage systems priced ≤ $300/kW + $300/kWh could economically serve as a demand charge management resource in the mass market.**

FUTURE WORK

- Results are heavily dependent on load shape and rate structure. Future work will evaluate additional demand profiles under other utility rate structures to better gauge market potential.
- Add in effects of battery thermal response and battery wear to evaluate life time performance and economics.
- Analyze the ability of repurposed automotive batteries to supply DCM services

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- Technical questions should be directed to Jeremy Neubauer at *jeremy.neubauer@nrel.gov*

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