PV and Energy Storage at FSEC Buildings

Paul Brooker

FSEC Advisory Board Meeting

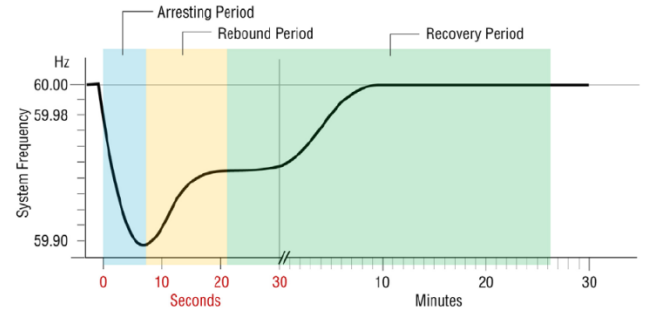
March 30, 2018

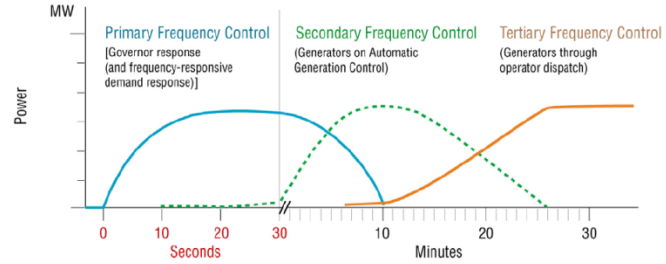
FLORIDA SOLAR ENERGY CENTER®

Creating Energy Independence

Meeting Electrical Demand: Forecasting and Power Plants

- Daily and seasonal variation requires day-ahead forecasting
  - Establish contracts to purchase/sell electricity for the next day
- Actual vs. forecast differences are met through reserves
- "Dispatchable" = plant output can be varied
  - Natural gas power plants
- "Baseload" = constant power output (minor variation acceptable)
  - Nuclear, coal, geothermal





J.H. Eto et al., "Use of Frequency Response Metrics to Assess the Planning and Operating Requirements for Reliable Integration of Variable Renewable Generation" December 2010. LBNL-4142E

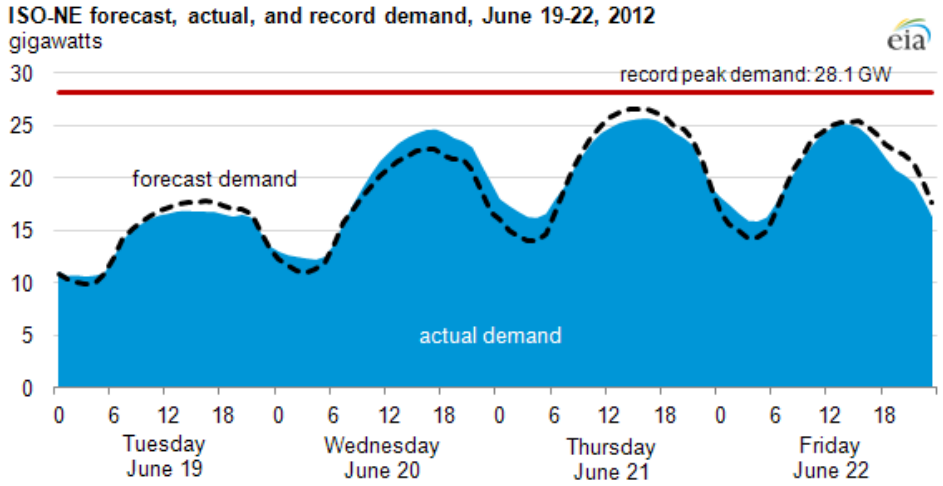
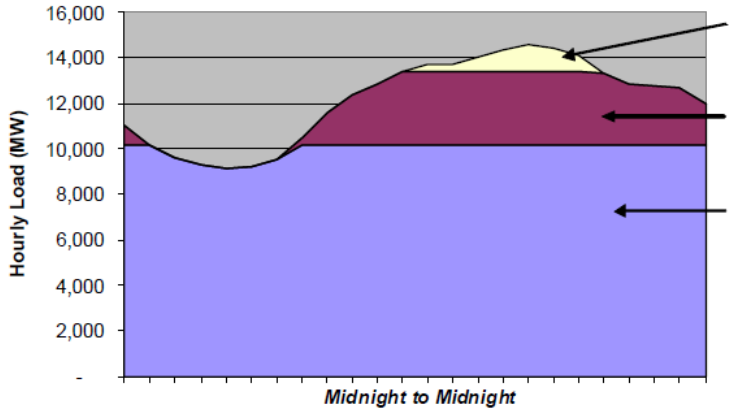


Chart from http://www.eia.gov/todayinenergy/detail.php?id=7070#tabs_PJM-1. Accessed Oct 2016.



Peaker power plants

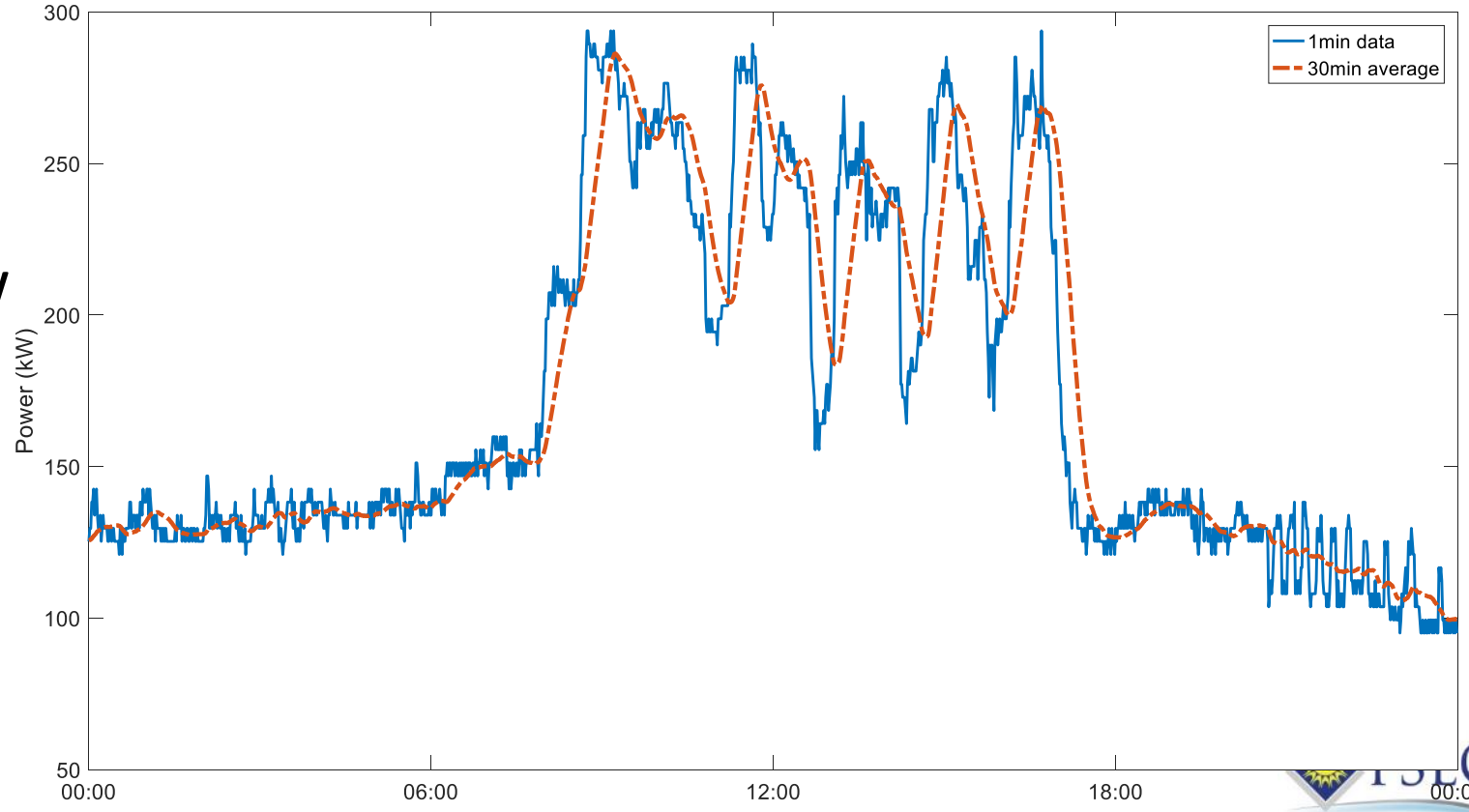
Load-following, spinning reserves

Baseload power plants

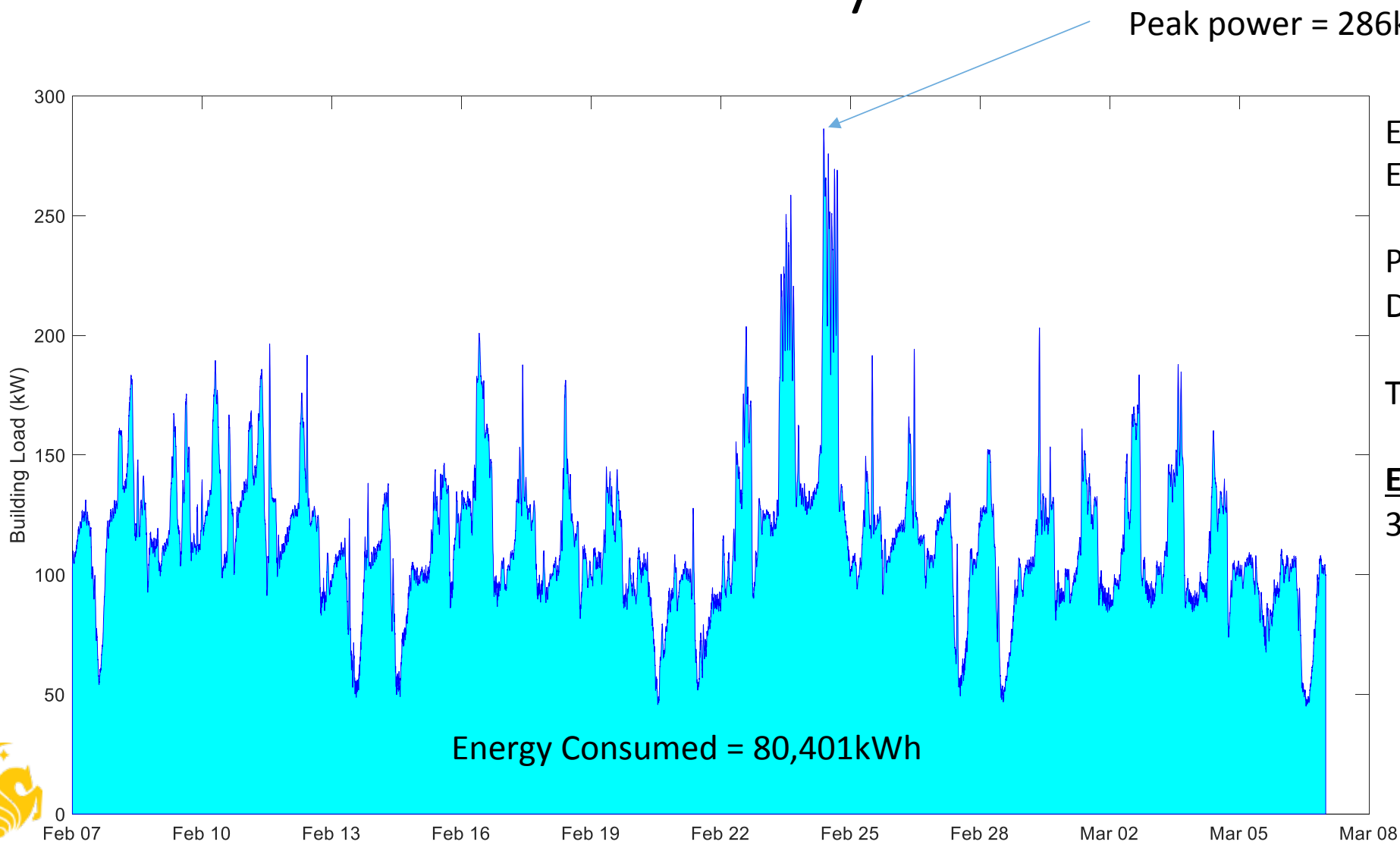
S. Kaplan. "Power Plants: Characteristics and Costs", CRS Report for Congress Order Code RL34746, November 13, 2008

Commercial Electricity Costs

- Based on energy consumption (kWh) and peak power (kW)
  - Energy cost: $0.06/kWh
  - Power cost: $10/kW
- Power determined by averaging 30min window
  - Use maximum power delivered during billing window



Commercial Electricity Costs



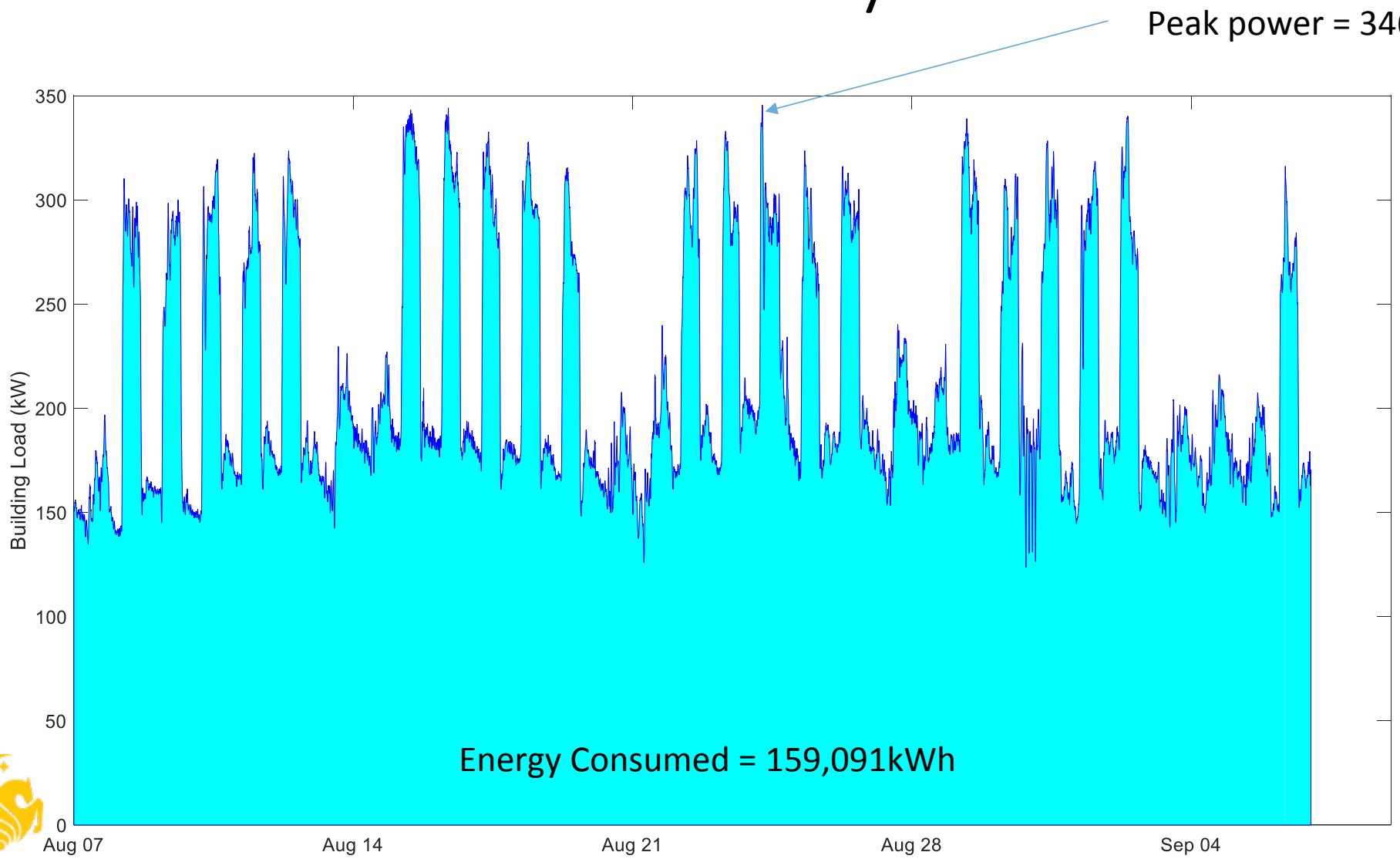
Energy cost = $0.06/kWh
Energy charges = $4,824

Power cost = $10/kW
Demand charges = $2,860

Total monthly bill = $7684

Effective cost = $0.096/kWh
37% demand charges

Commercial Electricity Costs



Energy cost = $0.06/kWh
Energy charges = $9,546

Power cost = $10/kW
Demand charges = $3,460

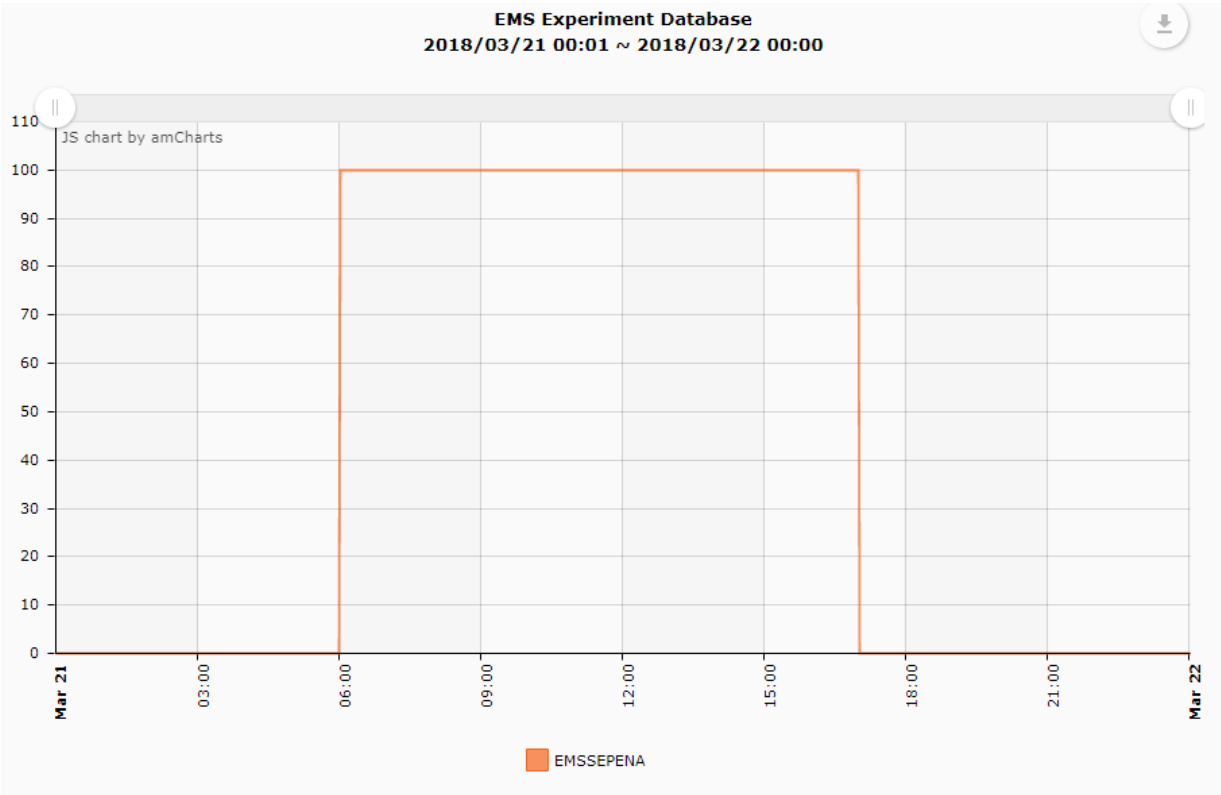
Total monthly bill = $13,006

Effective cost = $0.082/kWh
27% demand charges

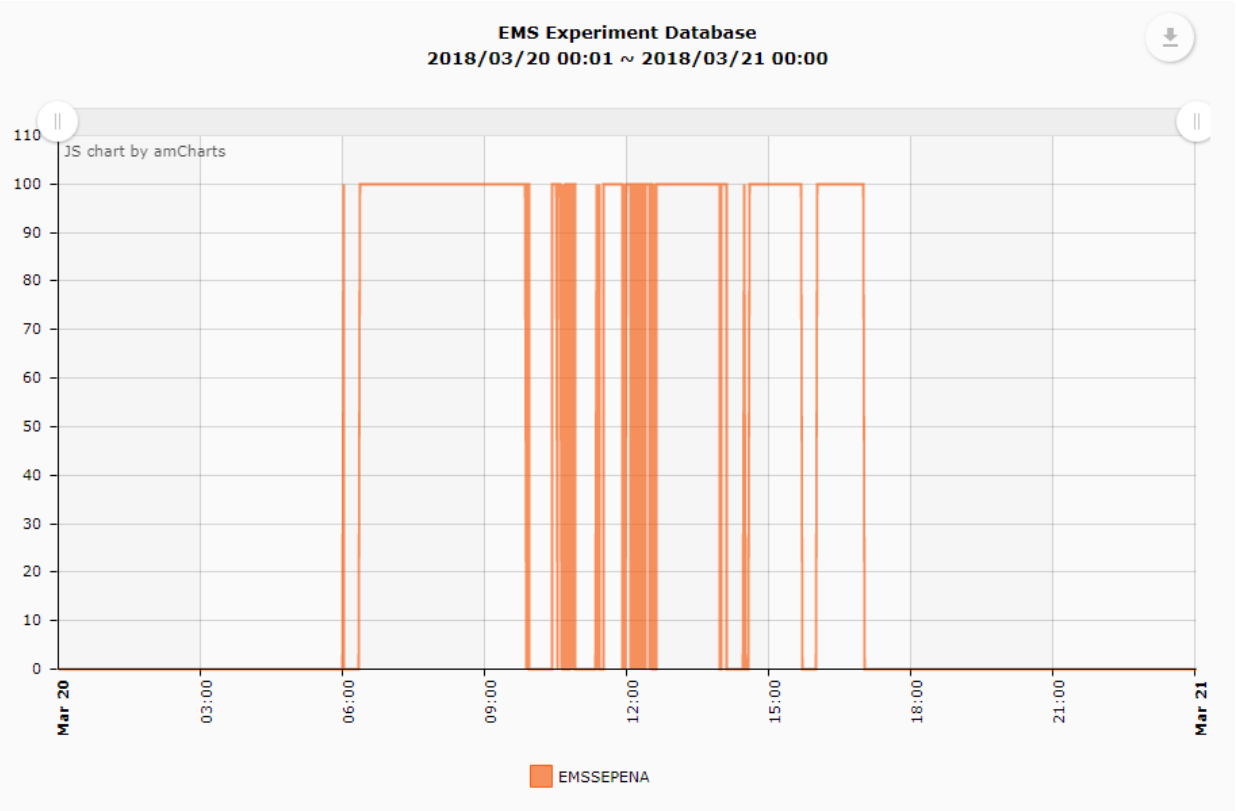
On-Site Energy Systems

- Control chiller plant
  - Send request to limit output to 60% between 5 and 8AM
- Workplace charging stations
  - Turn off chargers when approaching monthly peak
- Public charging stations
  - 40kW fast charger and two 6kW charging stations
- 40+kW PV array
  - Most are instrumented and monitored at 1minute intervals
- Nissan Leaf in Vehicle-to-Building (V2B)
  - Controlled charge/discharge through 30kW bidirectional charger

Workplace Charging Limiting

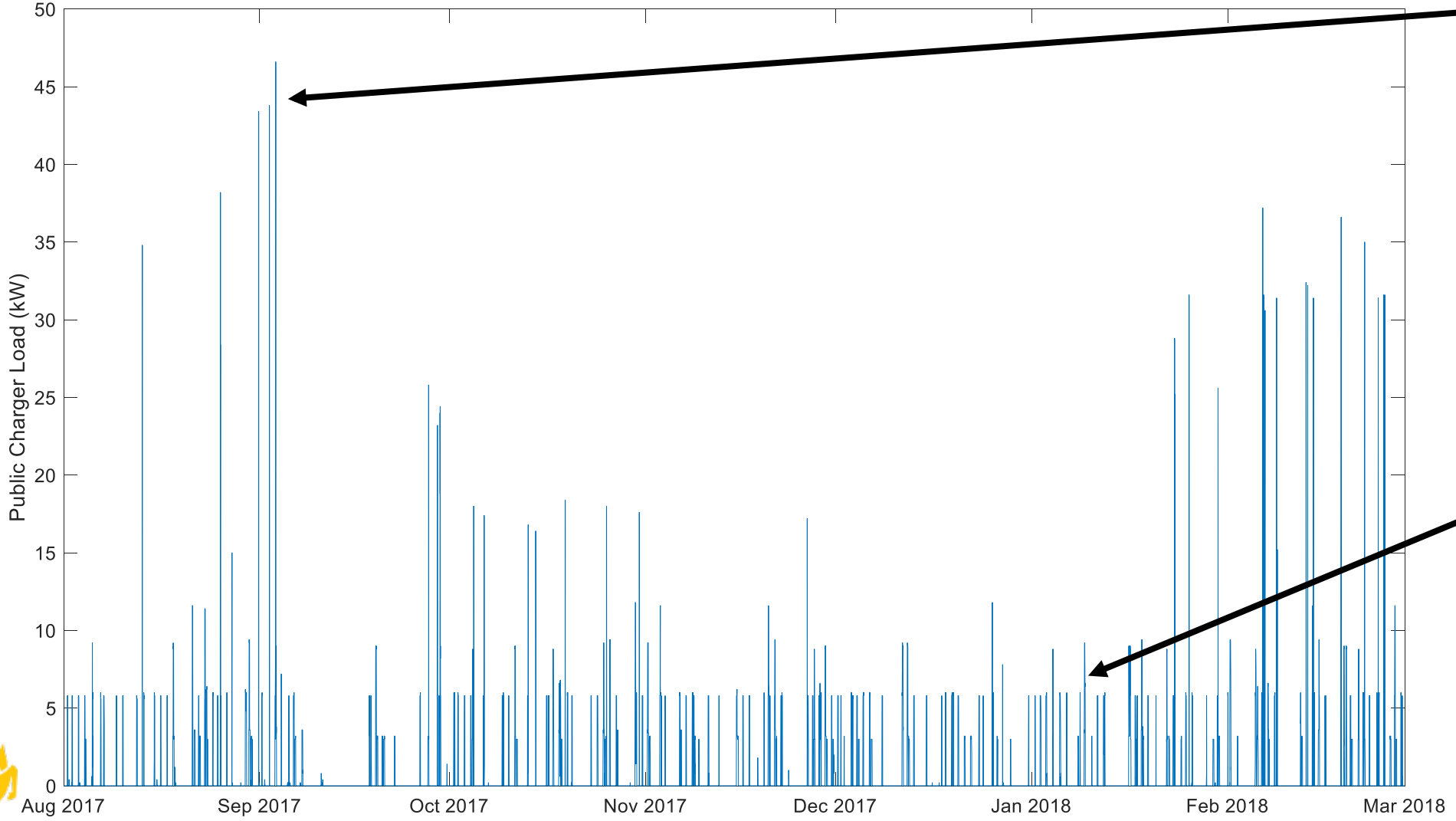


FSEC demand is below monthly peak



FSEC demand is approaching monthly peak
Algorithm uses a 5-minute forecast

Public Charging Events

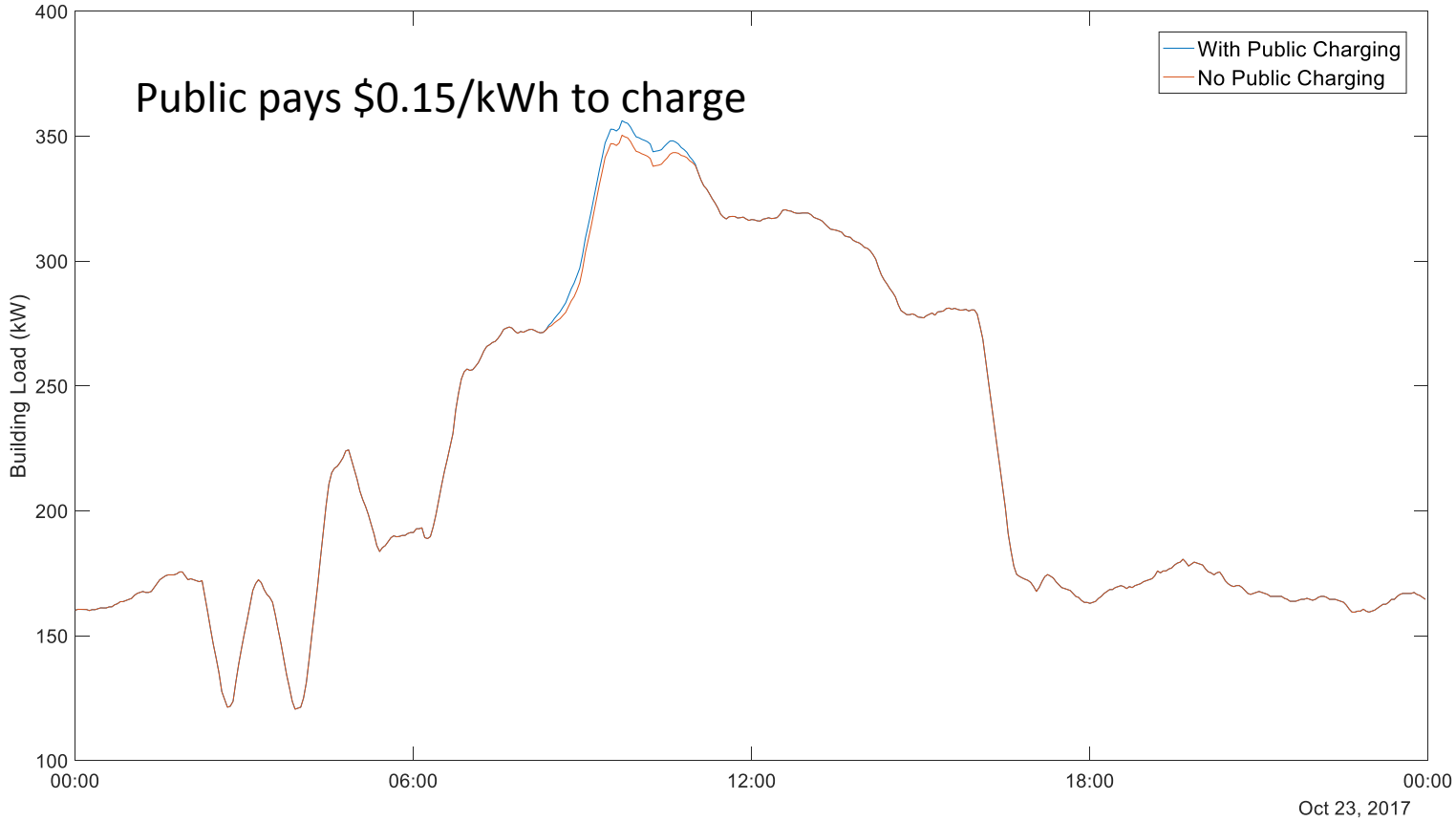


40kW DC Fast Charger

2 x 6kW charger

Impact of Public Charging

- 3 out of last 6 months have had increased peak demand due to public charging
- 4-6kW increase
- DCFC not included



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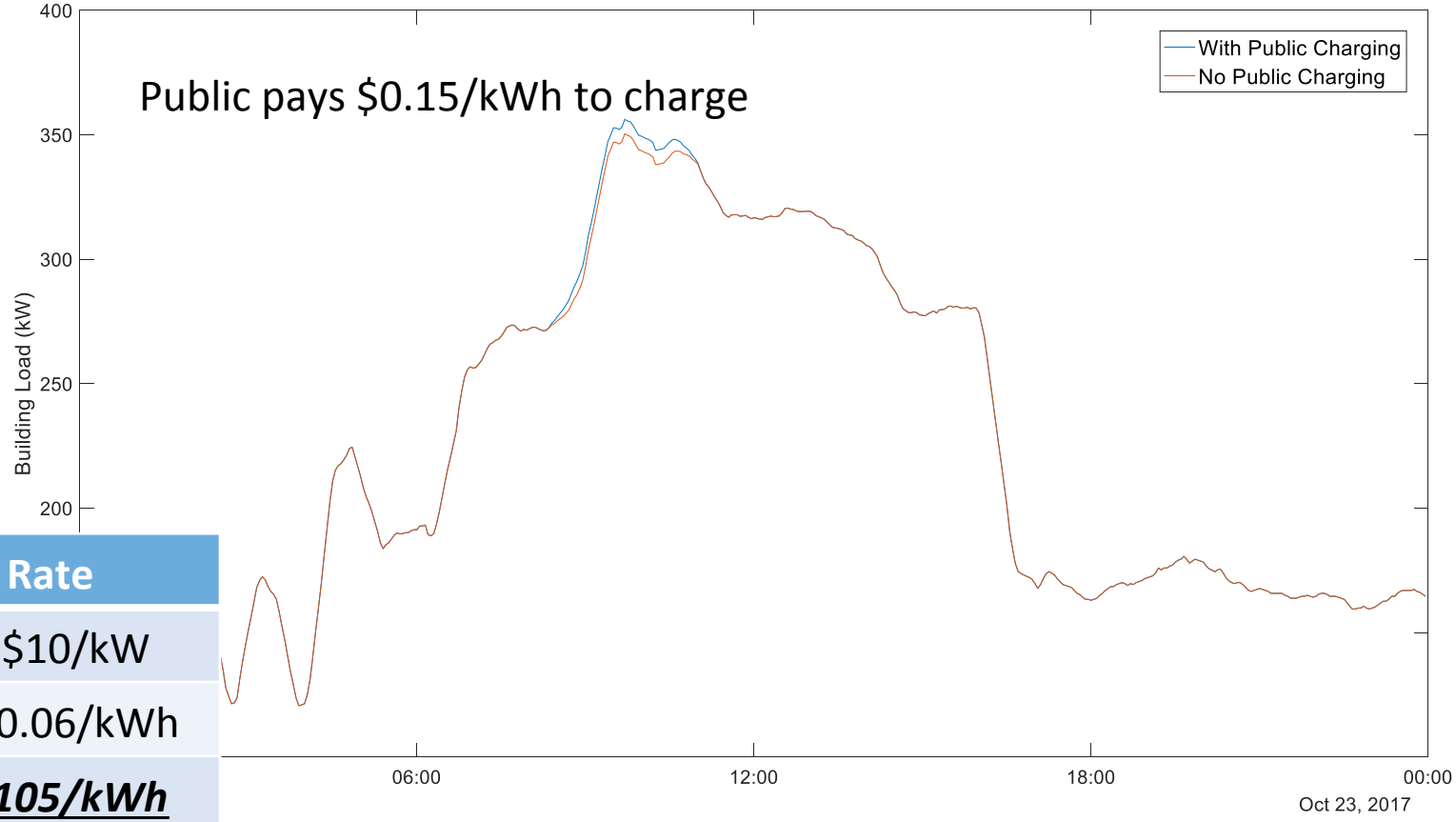
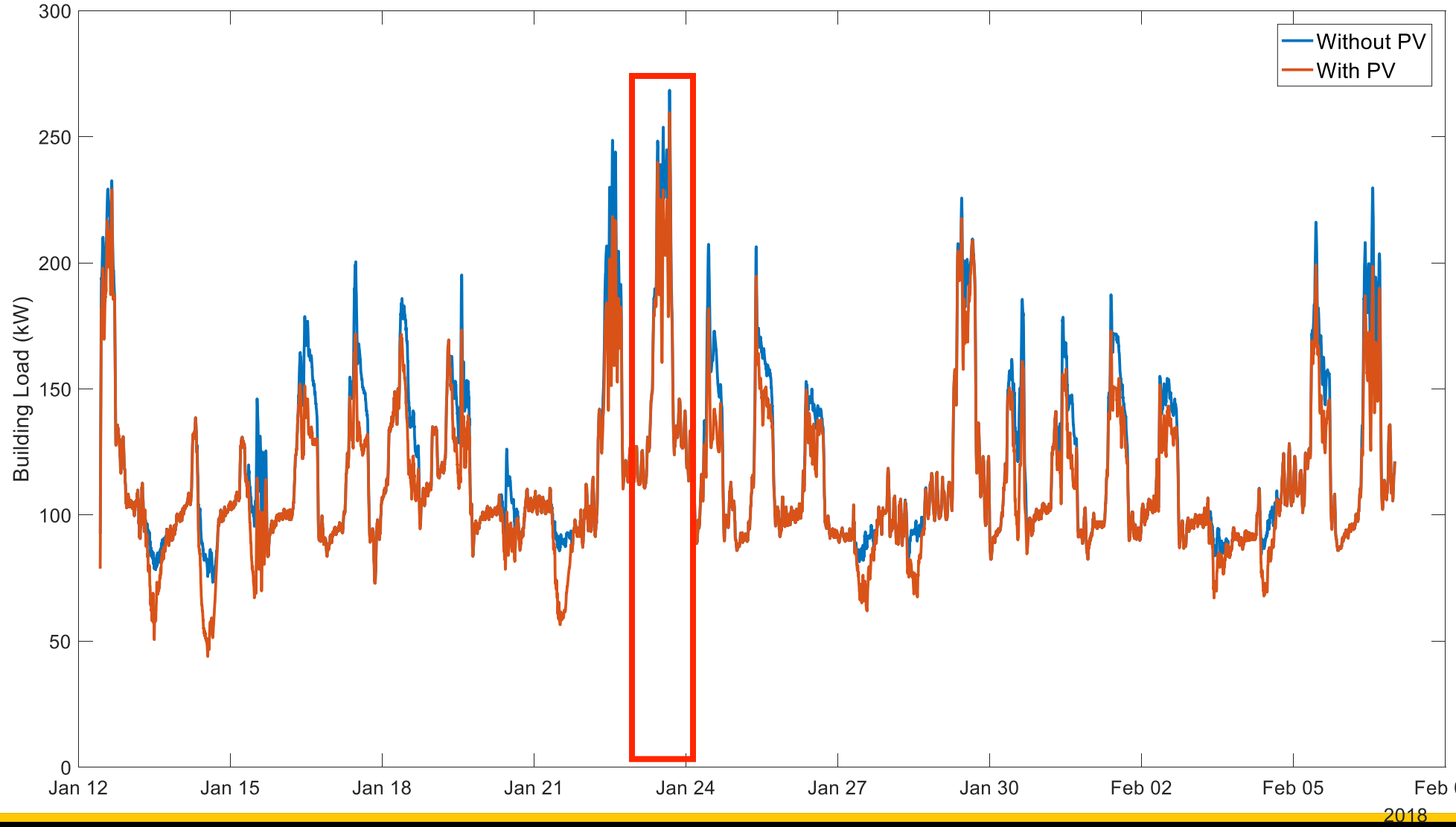
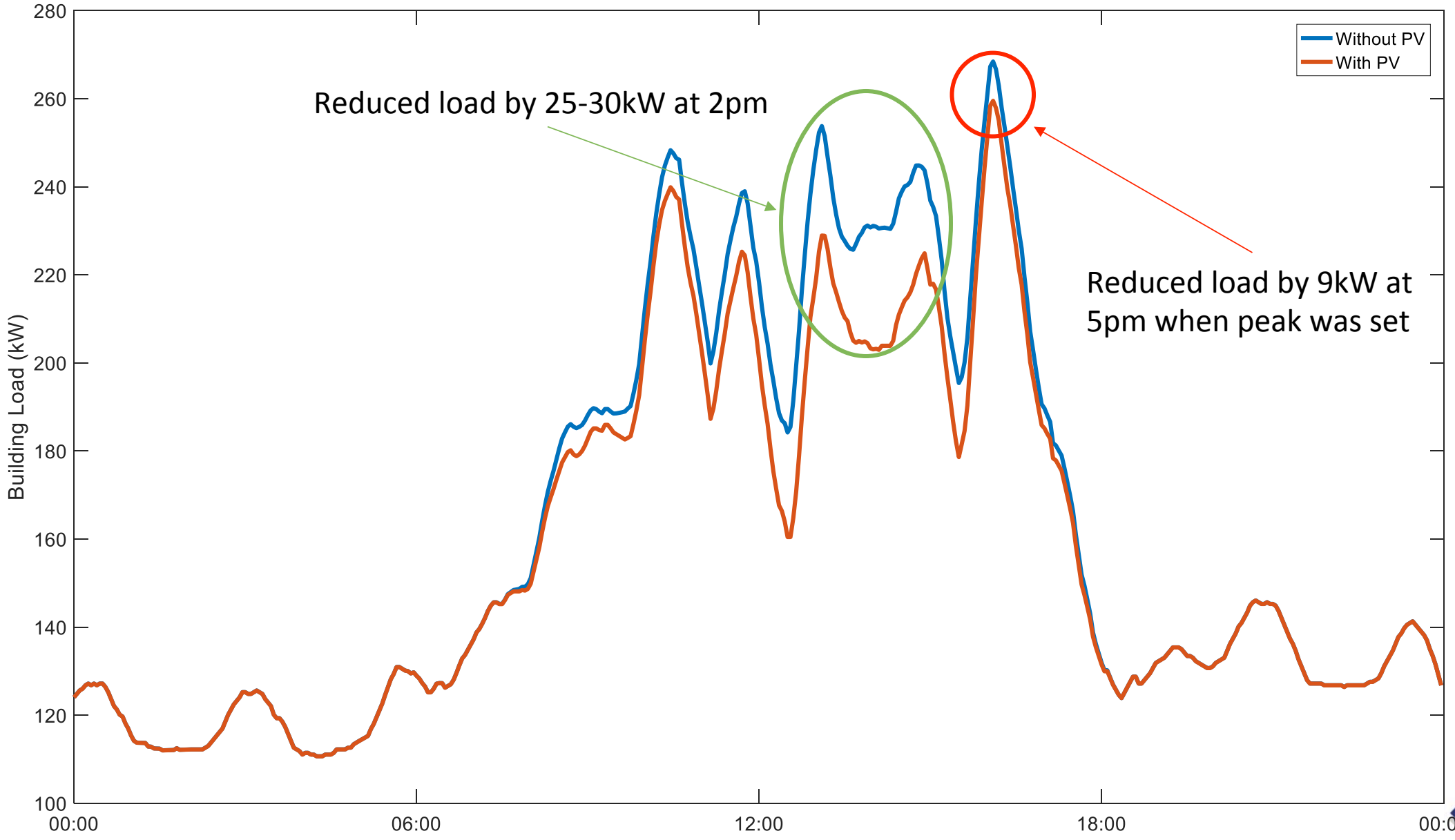


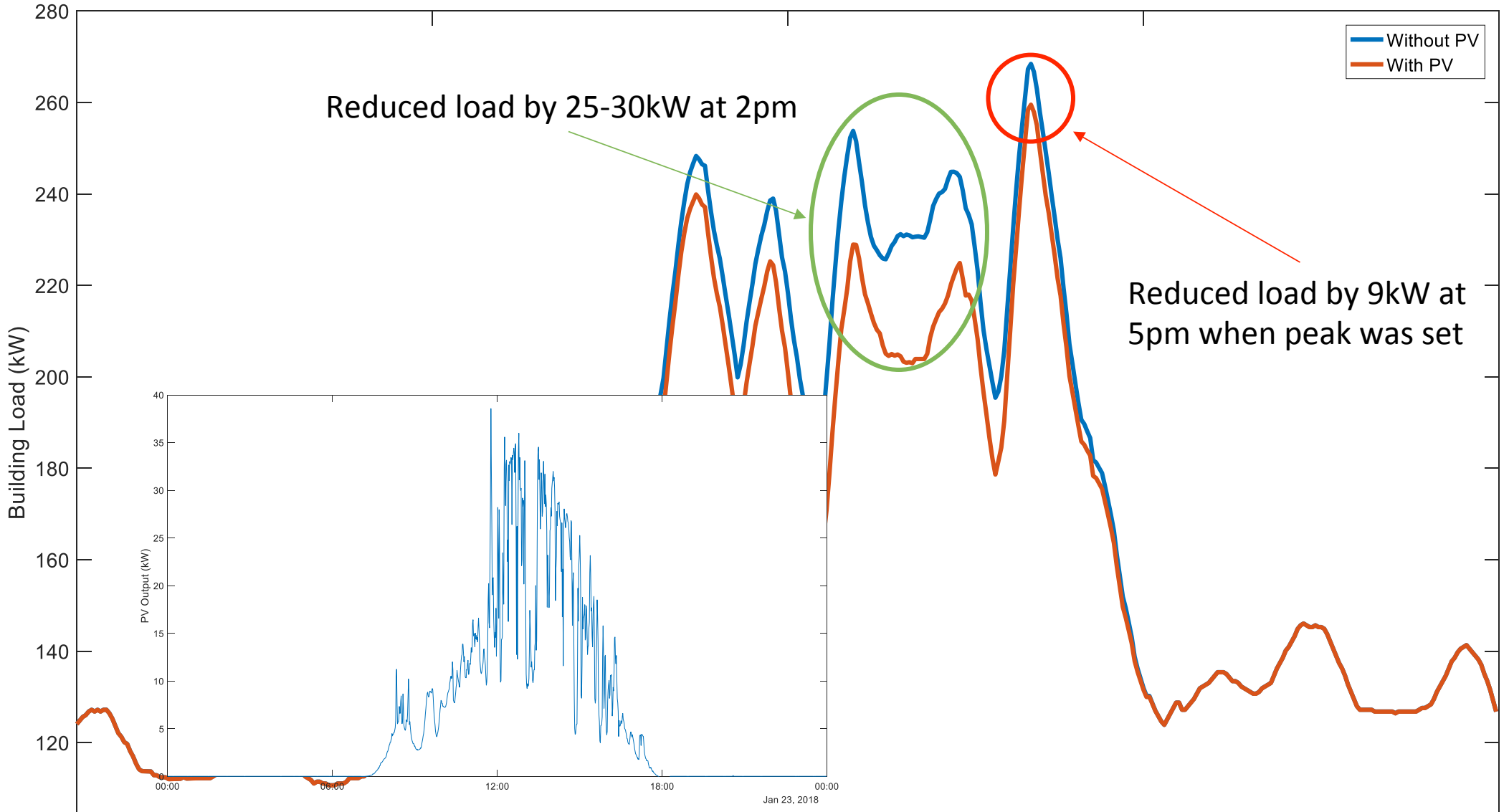
	6-month cost	Rate
Increased Peak	$130	@ $10/kW
Energy Usage	$173	@ $0.06/kWh
Total FSEC costs	**$304**	***$0.105/kWh***
Income*	**$349**	***$0.120/kWh***

* After service fees to ChargePoint

Impact of PV on Building Load




Without PV
With PV
Reduced load by 25-30kW at 2pm
Reduced load by 9kW at 5pm when peak was set
Building Load (kW)
280
260
240
220
200
180
160
140
120
100
00:00
06:00
12:00
18:00
00:00
Jan 23, 2018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With PV
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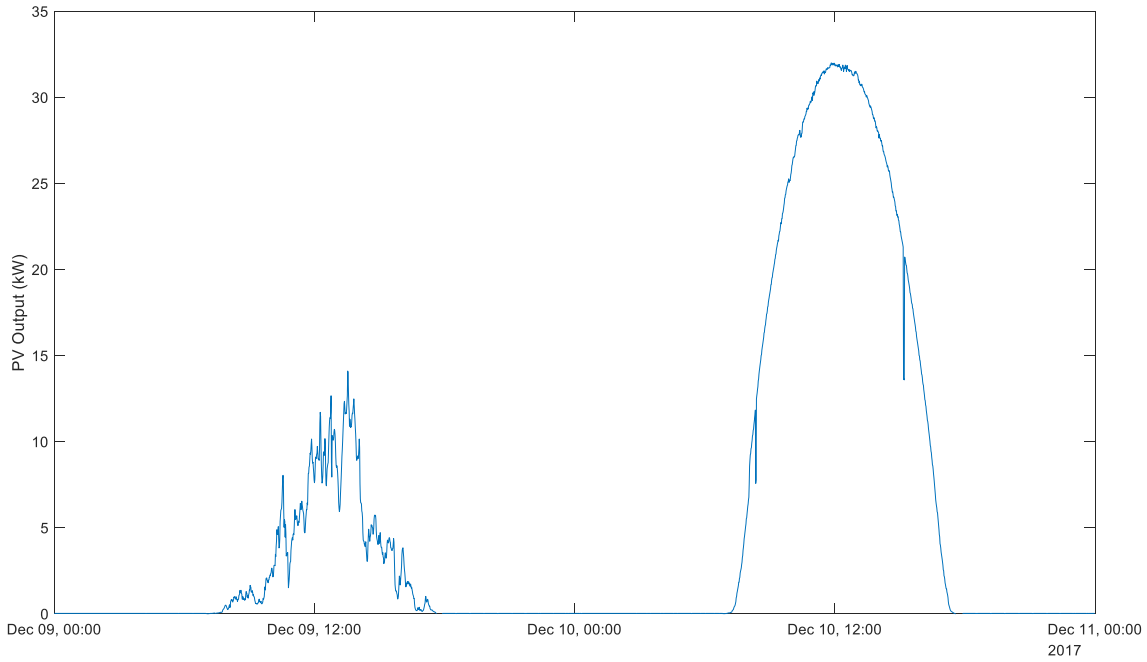
Building Load (kW)
280
260
240
220
200
180
160
140
120
100
00:00
06:00
12:00
18:00
00:00
Jan 23, 2018
PV Output (kW)
40
35
30
25
20
15
10
5
0
00:00
06:00
12:00
18:00
00:00
Jan 23, 2018

PV Impact on Demand Charges

Billing Period	No PV (kW)	With 40kW PV (kW)	Demand Charge Savings
8/7/17 to 9/6/17	408	391	$170
9/7/17 to 10/6/17	332	306	$262
10/7/17 to 11/6/17	356	344	$121
11/7/17 to 12/6/17	274	258	$160
12/7/17 to 1/6/18	298	291	$69
1/7/18 to 2/6/18	268	260	$89
Total Savings from demand charge reduction			**$871**



PV Impact on Energy Charges

- Cost of energy from grid is constant: $0.06/kWh for FSEC
- Cost of energy from PV depends on capital cost and production
  - Typically calculate a levelized cost of electricity (LCOE):

$$LCOE = \frac{\text{Total Cost of PV system}}{\text{Total energy produced over system lifetime}}$$

- LCOE is around $0.04-0.19/kWh, depending on installation

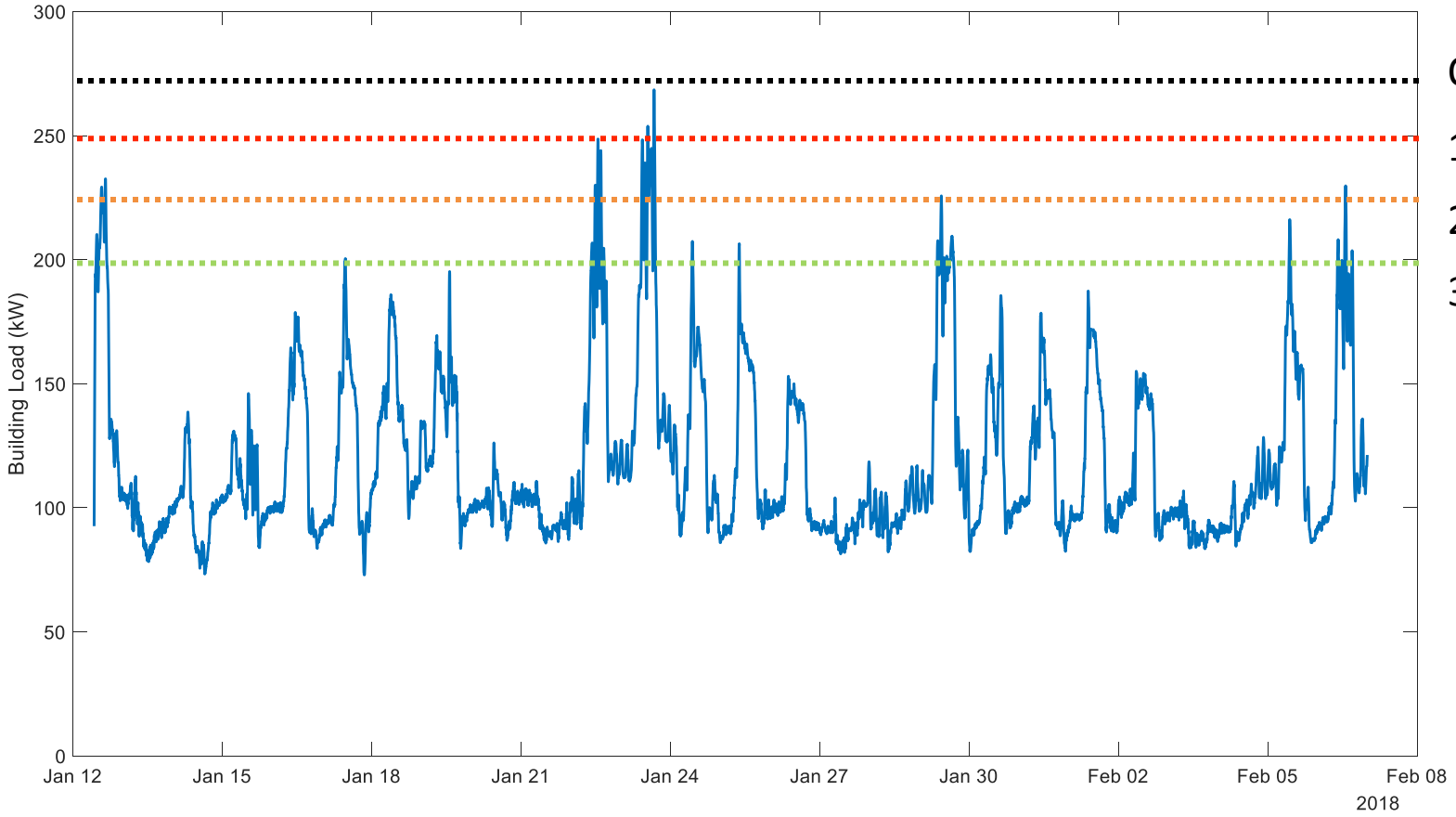
PV Impact on Energy Charges

Billing Period	Energy produced by PV (kWh)	Cost of Grid energy	Savings vs. LCOE		Demand Charge Savings
			$0.04/kWh	$0.10/kWh	
8/7/17 to 9/6/17	4134	$248	$83	$ (165)	$170
9/7/17 to 10/6/17					
10/7/17 to 11/6/17	4725	$284	$95	$ (189)	$145
11/7/17 to 12/6/17	3080	$185	$62	$ (123)	$153
12/7/17 to 1/6/18	3098	$186	$62	$ (124)	$65
1/7/18 to 2/6/18	3814	$229	$76	$ (153)	$218
Net Savings, including demand charge reduction			**$1,277**	**$59**	

Vehicle-to-Building (V2B) at FSEC

- Nissan Leaf connected to 30kW bidirectional charger
  - Charger limits battery to 30-80% SOC (i.e. 10kWh can be accessed)
- Control charge/discharge from vehicle based on building load
- Need to know when to turn on and when not to turn on

How Much to Peak Shave?



Original Peak

10% shave

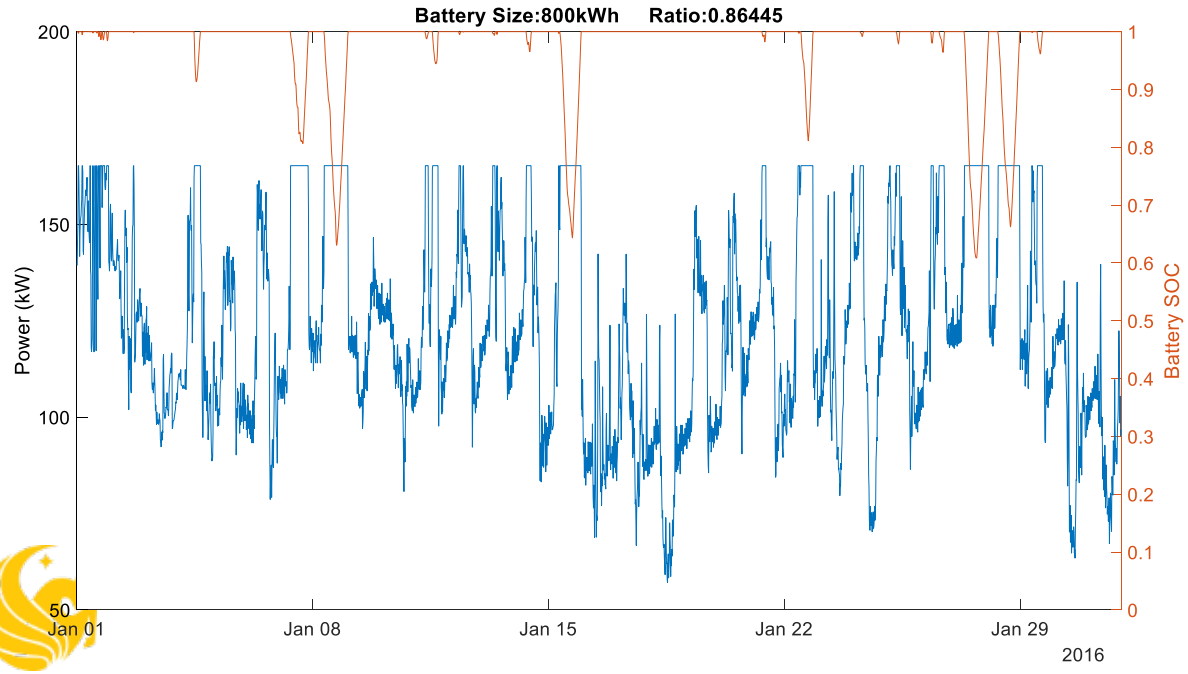
20% shave

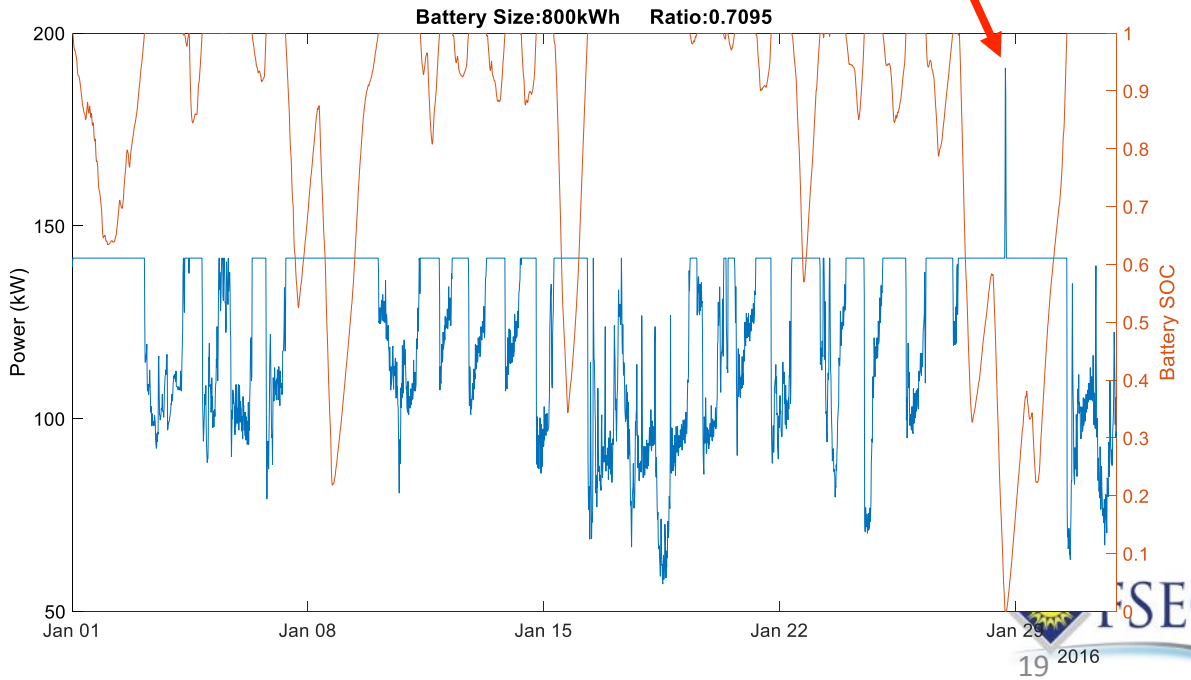
30% shave

Optimizing Storage for Peak Shaving

- Optimized peak shaving vs. battery size
  - "Best" results reduced demand without depleting battery

This point will set the peak for the month





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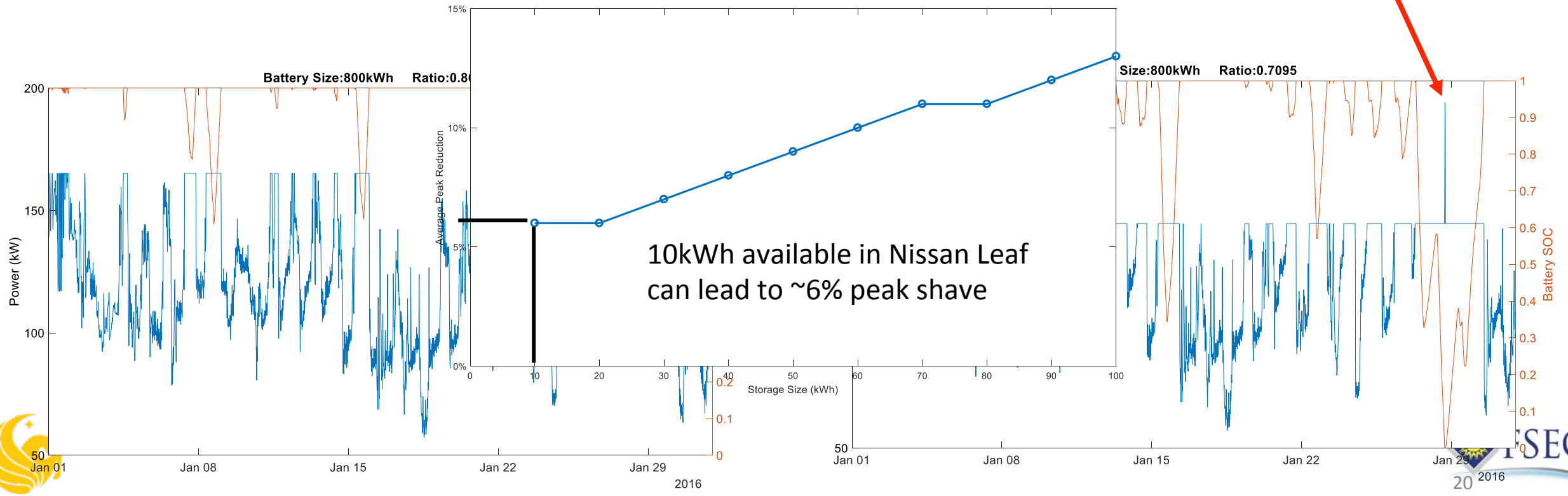
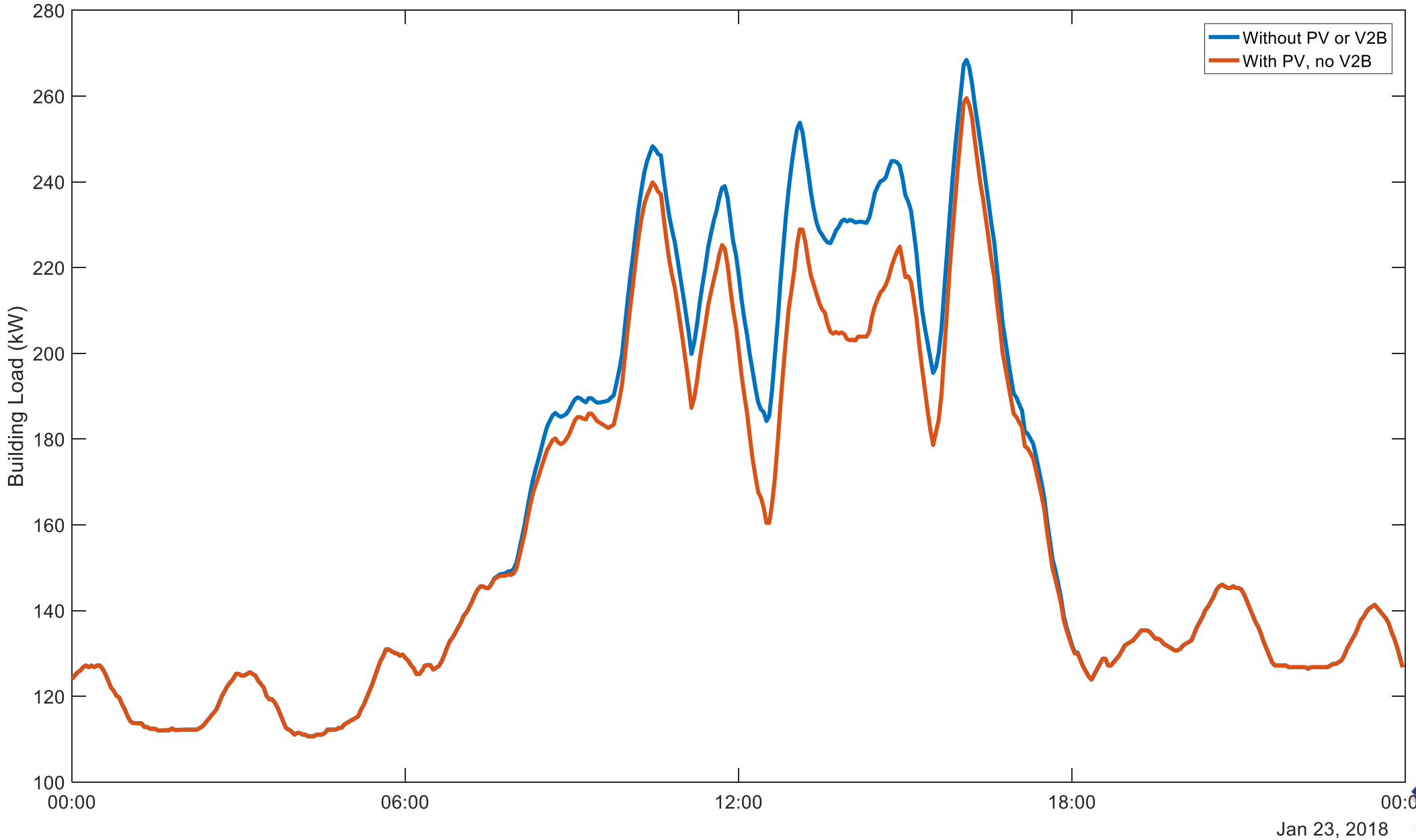
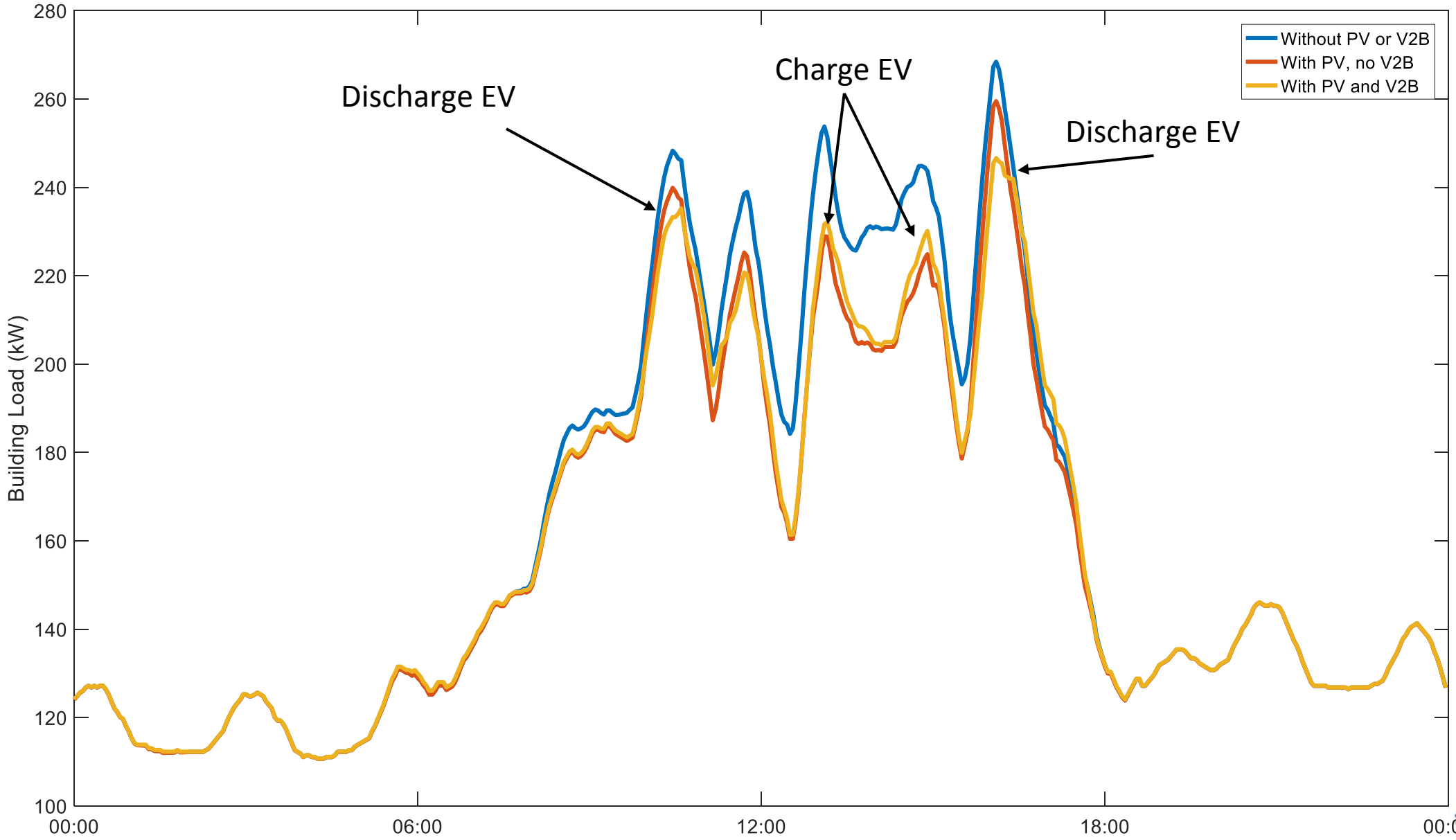


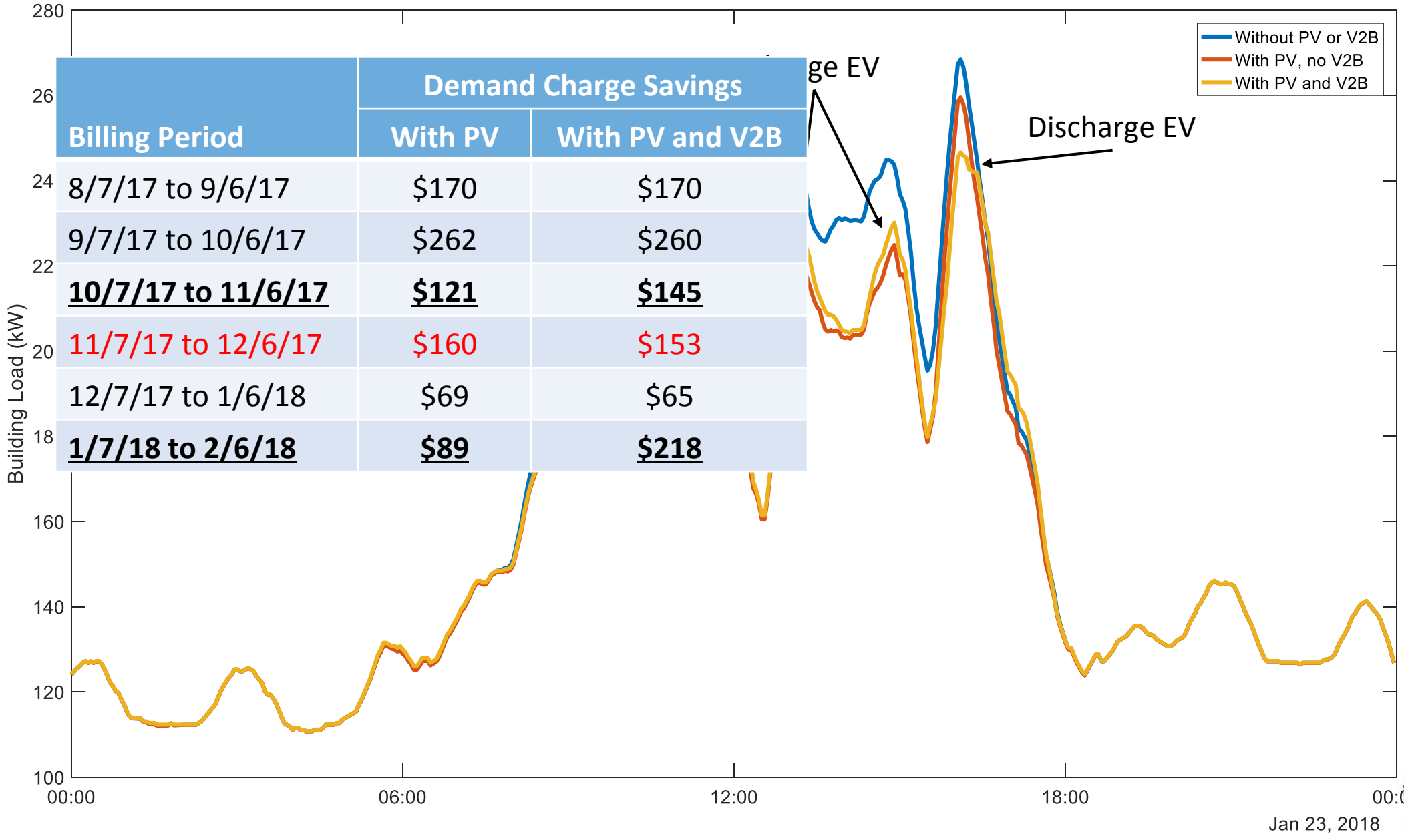
V2B Peak Shaving Strategy

- Identify how much peak can be shaved
  - Simulations suggest about 6-10% may be possible
- Identify a “Peak Threshold”, i.e. when to start shaving peak
  - If the threshold is set too low, the battery will be discharged too early
  - If the threshold is set too high, we’ll miss the peak
- Initially, peak threshold was set by looking at historical data
- Improvements are ongoing (i.e. develop correlations between temperature forecast and building load profile)


Without PV or V2B
With PV, no V2B
Building Load (kW)
280
260
240
220
200
180
160
140
120
100
00:00
06:00
12:00
18:00
00:00
Jan 23, 2018


Without PV or V2B
With PV, no V2B
With PV and V2B
Discharge EV
Charge EV
Discharge EV
Building Load (kW)
280
260
240
220
200
180
160
140
120
100
00:00
06:00
12:00
18:00
00:00
Jan 23, 2018

Billing Period	Demand Charge Savings	
	With PV	With PV and V2B
8/7/17 to 9/6/17	$170	$170
9/7/17 to 10/6/17	$262	$260
10/7/17 to 11/6/17	**$121**	**$145**
11/7/17 to 12/6/17	$160	$153
12/7/17 to 1/6/18	$69	$65
1/7/18 to 2/6/18	**$89**	**$218**

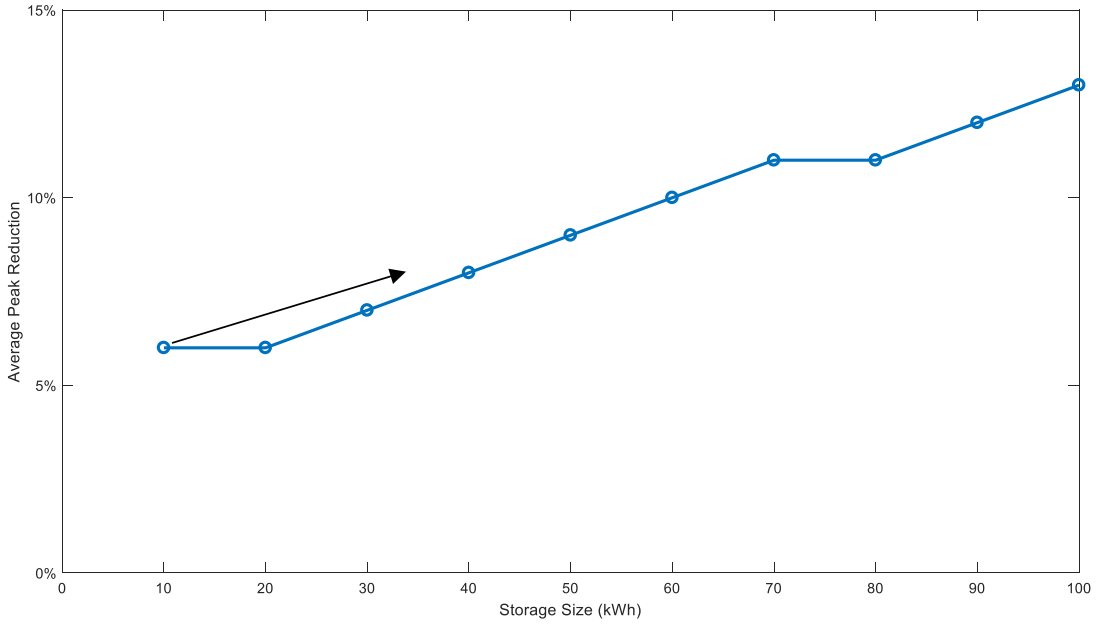


Impact of V2B at FSEC

- Two months saw V2B increased savings from demand charges
- One month saw V2B decreased savings vs. PV
  - Combination of discharging battery too soon and a high peak threshold
  - Battery was likely charging at same time peak was being set
- Some months saw no change
  - Peak threshold was set too high and the battery never discharged
- Challenge is limited by energy and identifying peak

Next Steps

- Currently commissioning a 4kW fuel cell system
  - 6 cylinders of hydrogen = 48kWh additional energy
- Augment V2B application for more peak shaving



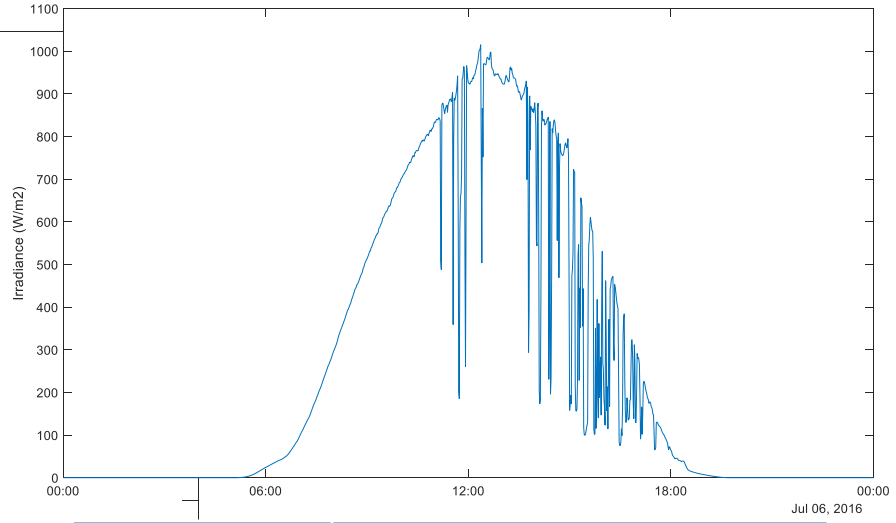
Conclusions

- Several energy management techniques are being employed at FSEC
- Workplace charging can be controlled to limit peak demand
- Public charging can cause an increase in peak demand which will impact profitability
- Finding economic value of PV at commercial sites is complicated
- V2B activities are shaving peaks, but more optimization is required

Paul Brooker
Assistant Research Professor
Florida Solar Energy Center
University of Central Florida

pbrooker@fsec.ucf.edu
321-638-1478

Effect of Solar on Building Demand: 7-Jun to 6-Jul Billing Period



Increased PV introduces shoulder due to low irradiance

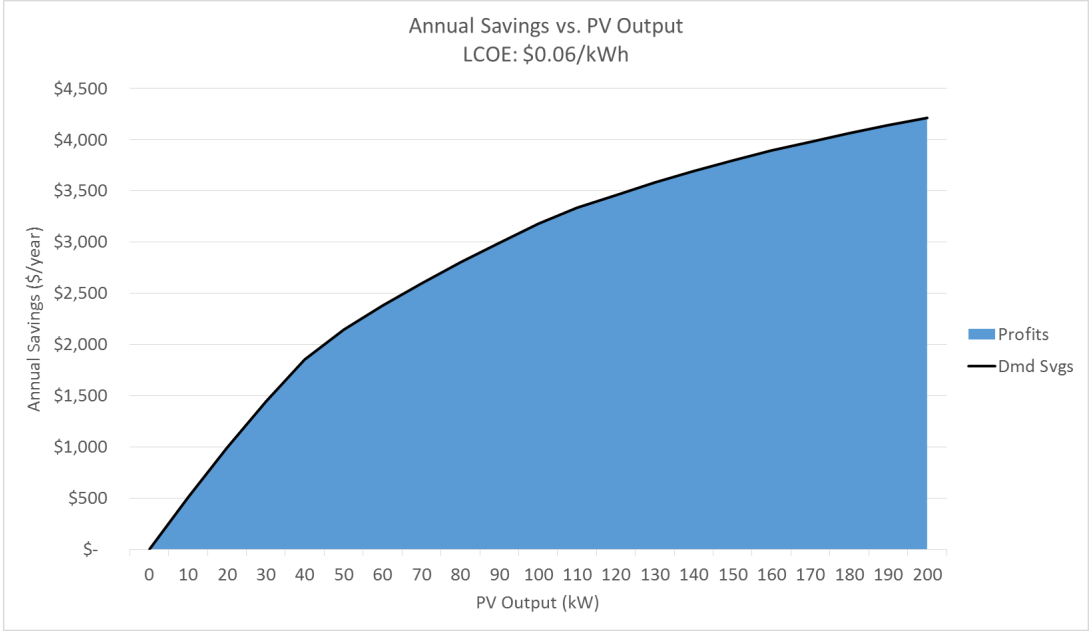
PV Output (kW)	Demand Reduction vs. No PV (kW)
20	10
50	20
100	34
200	52

LCOE for Generation Technologies

Lazard's levelized cost of energy analysis – Version 10.0
https://www.lazard.com/perspective/levelized-cost-of-energy-analysis-100/

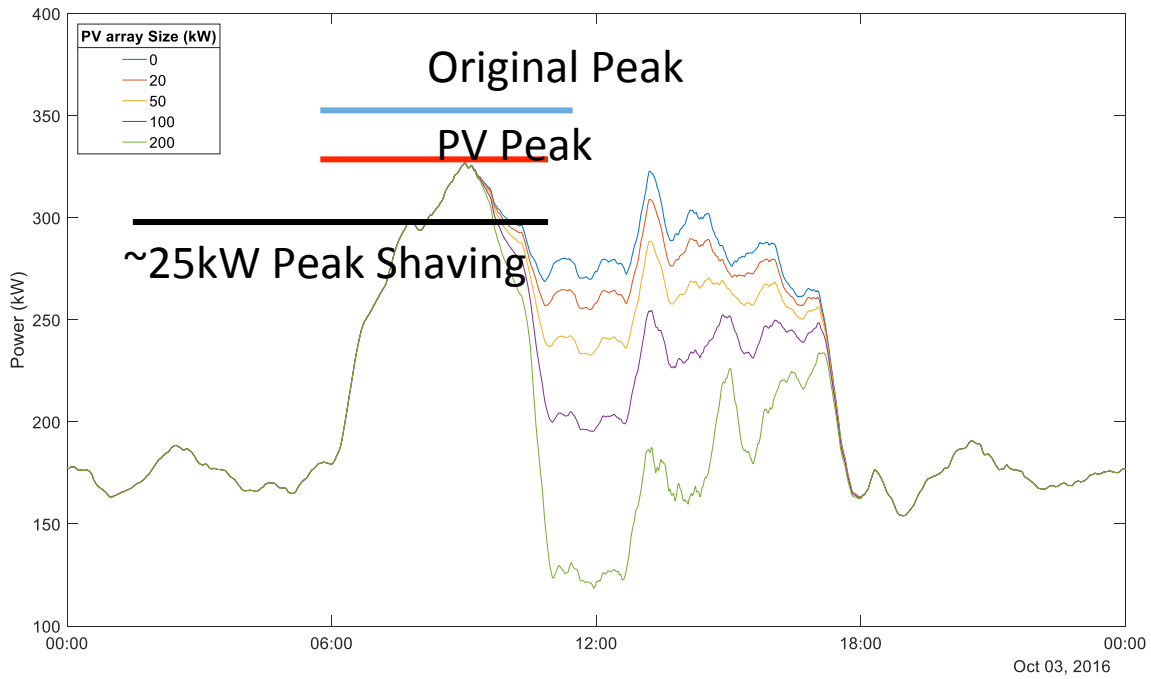
Impact of PV Output on Annual Savings: LCOE = utility energy rate ($/kWh)

- All savings attributed to demand charge reduction
- Impact of demand charge reduction limited for the following reasons:
  - Cloudy days can set a new peak
  - Early AM peaks may be less affected
- Increase East-facing PV panels could improve performance



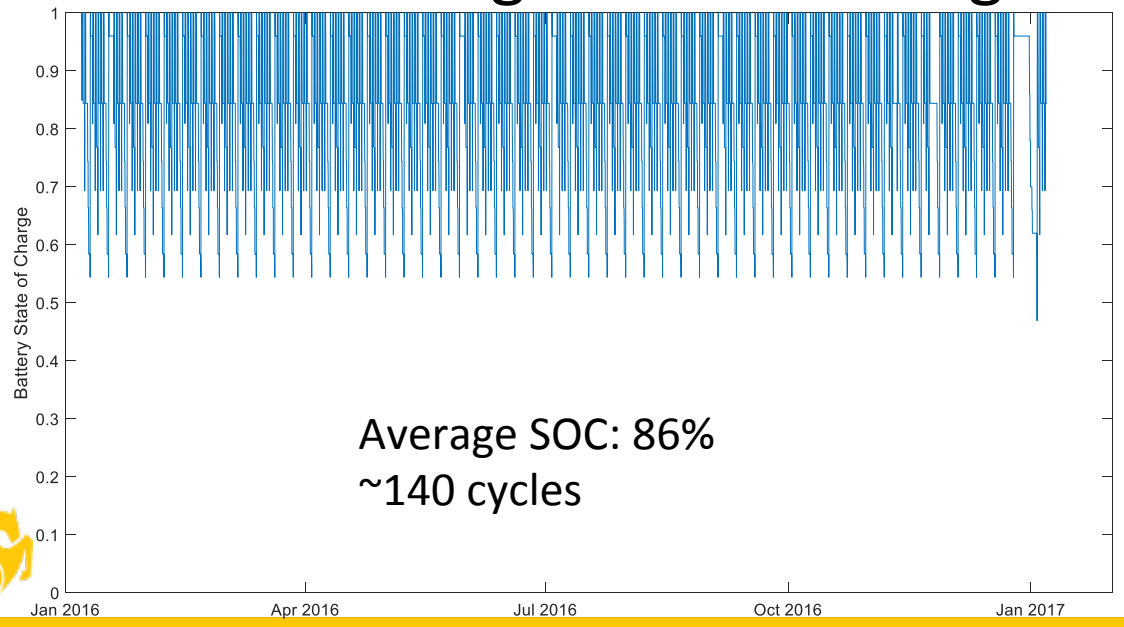
Value of Energy Storage for Peak Shaving

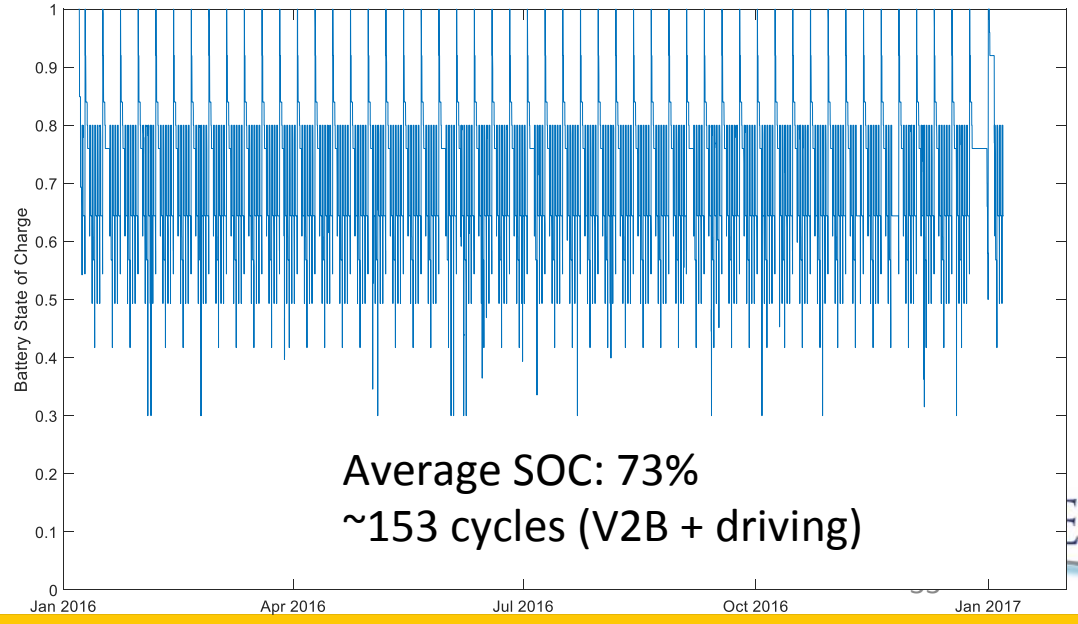
- Limit to demand reduction using only PV
- Additional peaks may be shaved using energy storage
- Requires optimized PV + storage to maximize savings
  - Storage costs offset savings



Improved Battery Life

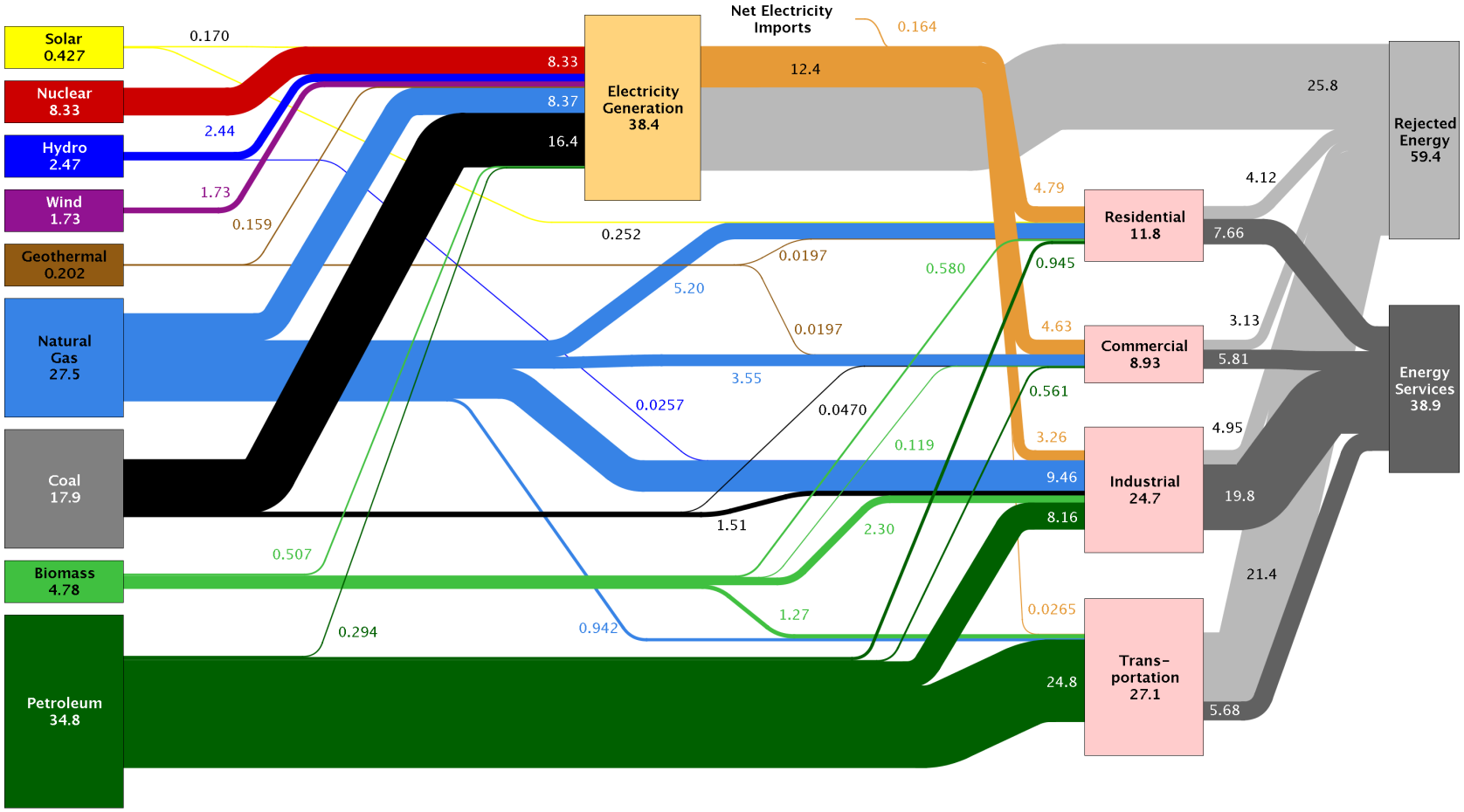
- Battery degradation increases with higher SOC
- When driven normally, SOC can be higher than when employed in V2B
- Reduced degradation through V2B benefits owner





Estimated U.S. Energy Use in 2014: ~98.3 Quads

Lawrence Livermore National Laboratory



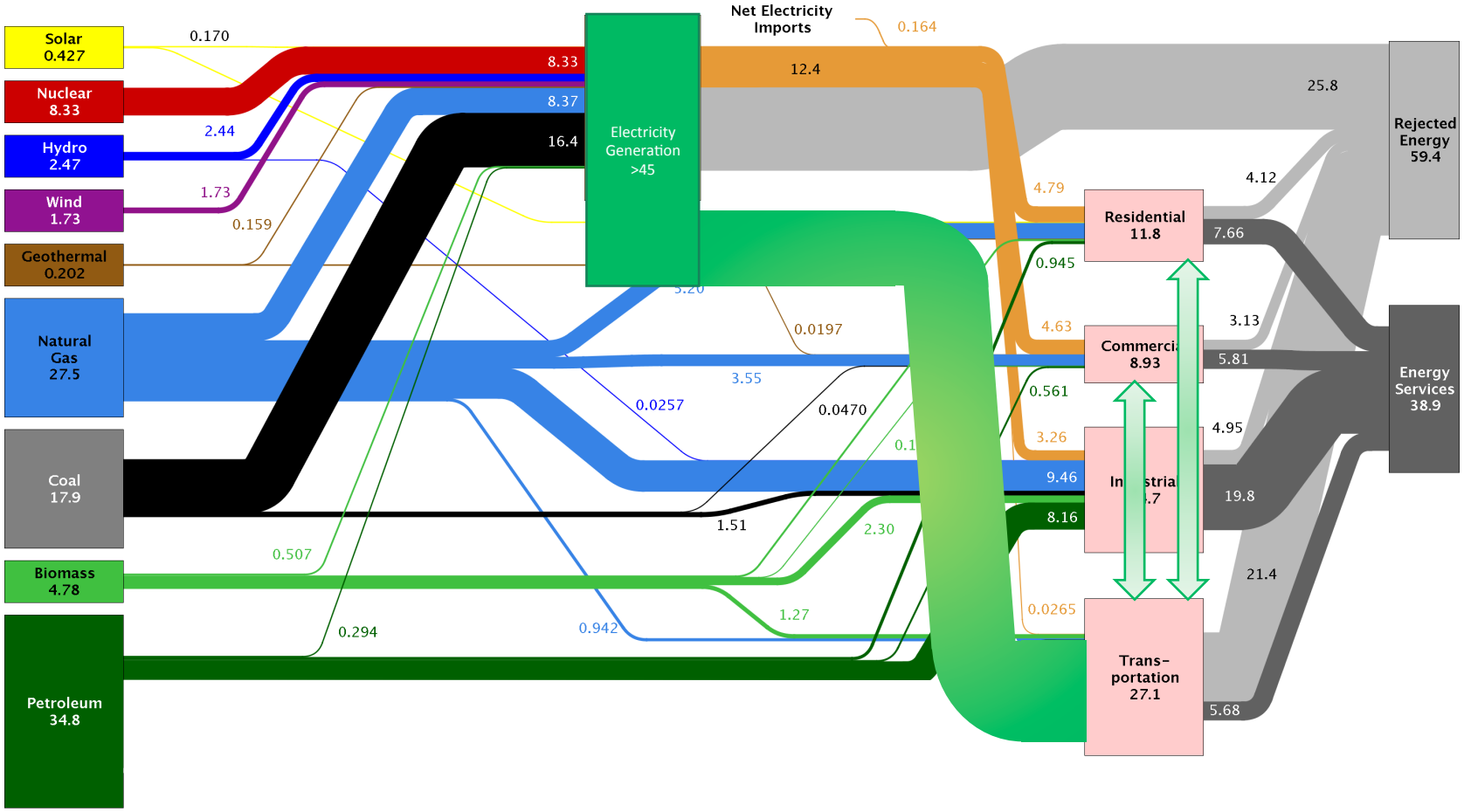
Source: LLNL 2015. Data is based on DOE/EIA-0035(2015-03), March, 2014. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential and commercial sectors 80% for the industrial sector, and 21% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

Image credit: Lawrence Livermore National Laboratory and Department of Energy

https://flowcharts.llnl.gov/commodities/energy

Electrification of Transportation

Lawrence Livermore National Laboratory



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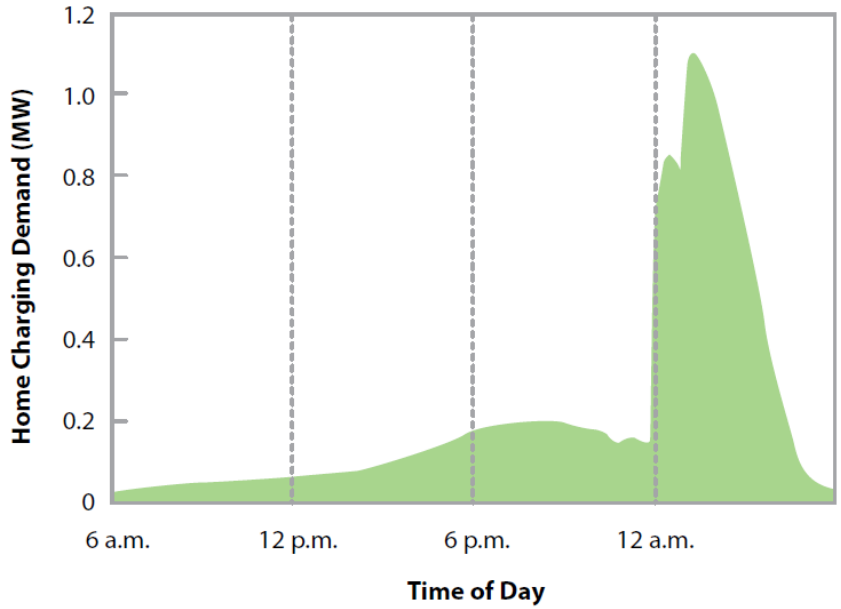
Typical Building loads

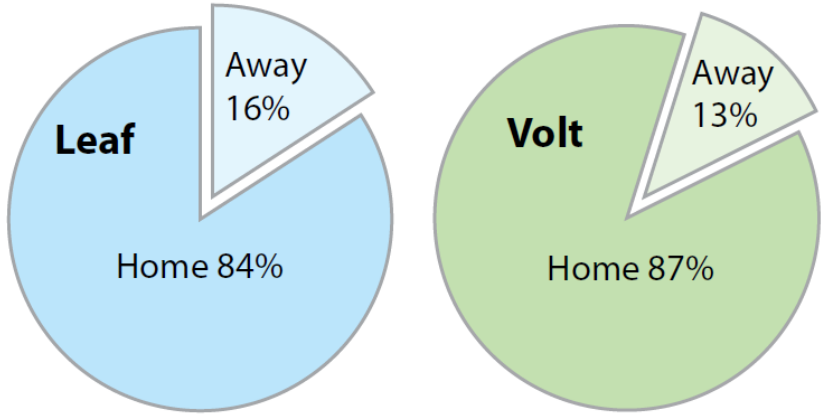
- Demand profiles for different buildings
  - Commercial
  - Industrial
  - Residential
- Other demand profiles to consider due to nev technologies
  - Electric vehicle charging
    - DC Fast Charging (consumer and electric bus)
- Costs associated with electricity
  - C&I = demand charges + flat kWh rate
  - Residential = flat kWh rate or TOU or demand charges?

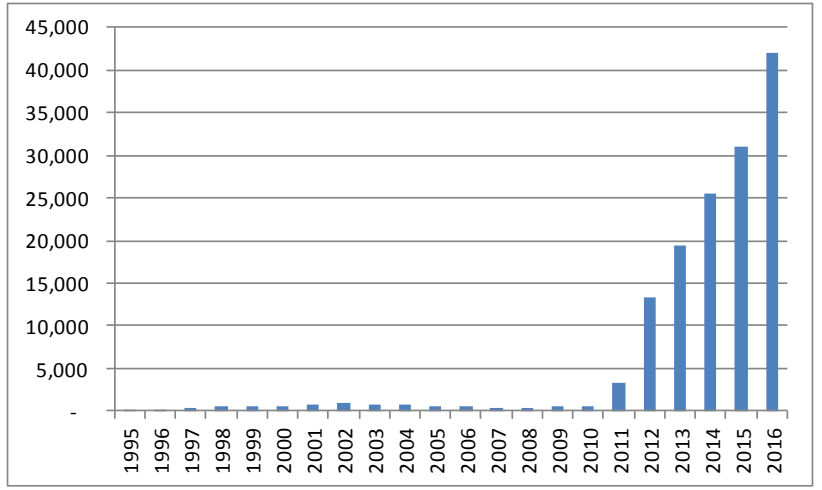
Chart from “Plugged In: How Americans Charge Their Electric Vehicles”, The EV Project, INL



Wait until low TOU rates to charge vehicles

Electric Charger Usage





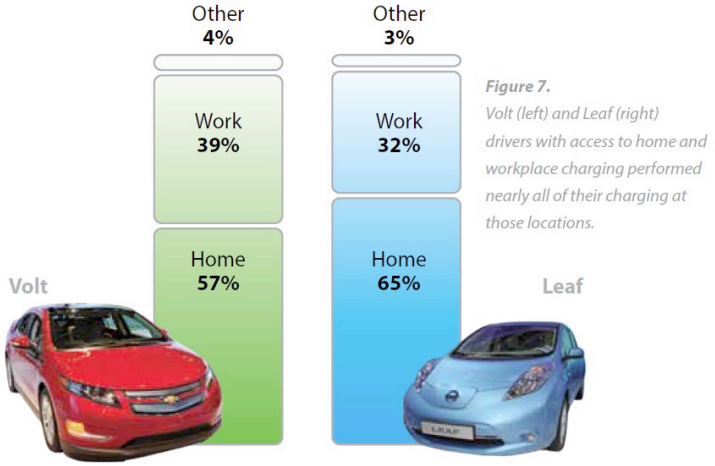
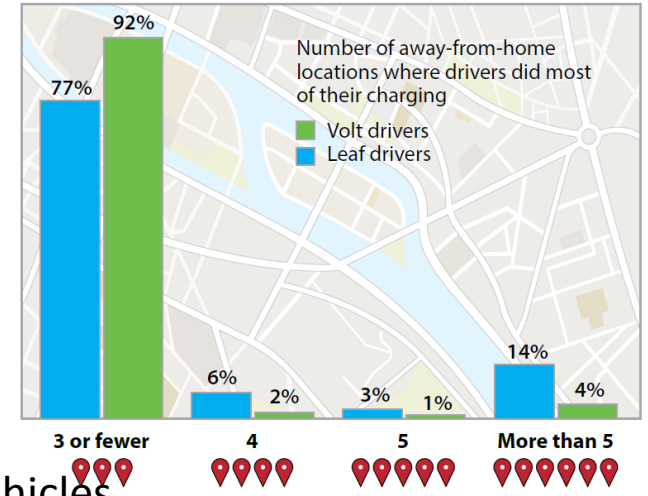


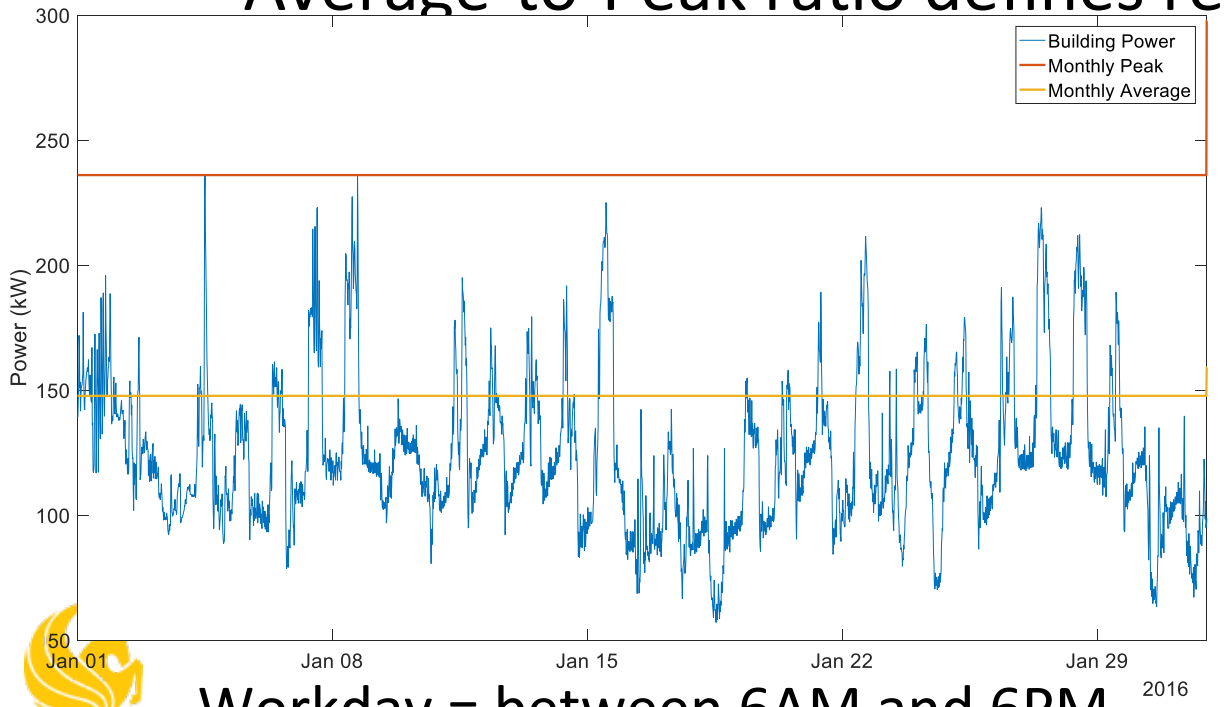
Figure 7.
Volt (left) and Leaf (right) drivers with access to home and workplace charging performed nearly all of their charging at those locations.

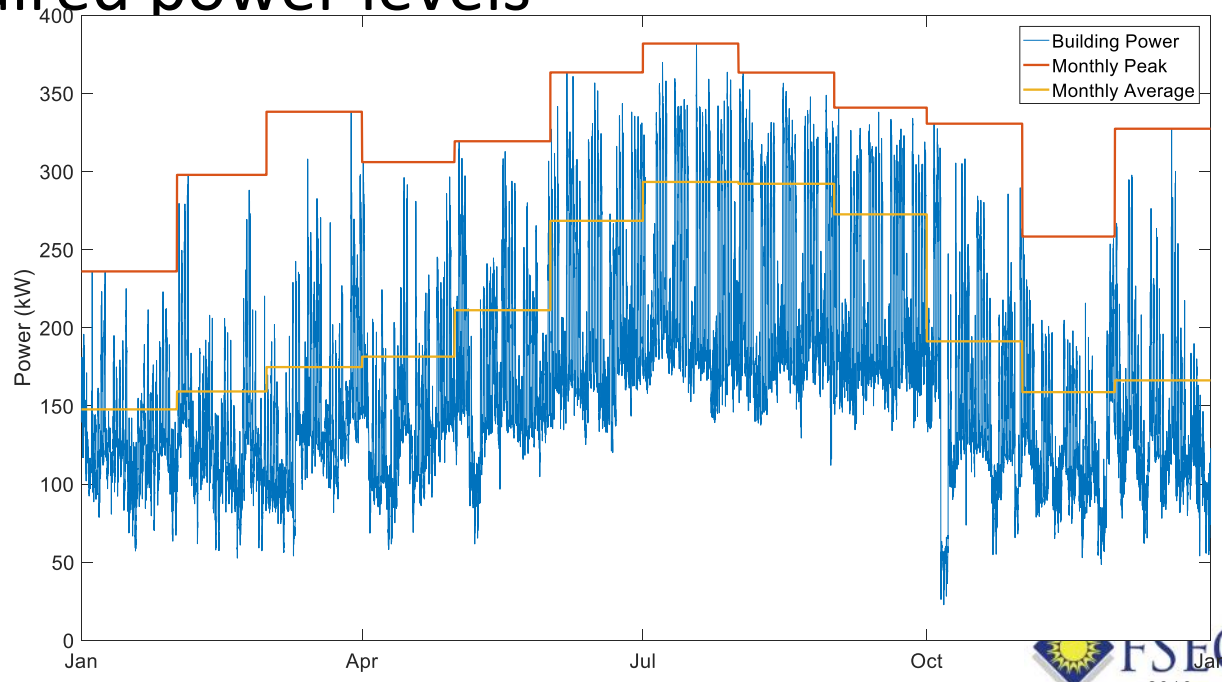


Plugged in: How Americans Charge their Electric Vehicles

Determining Battery Size

- Identifying the size and operation of storage depends on power and energy
- Average-to-Peak ratio defines required power levels

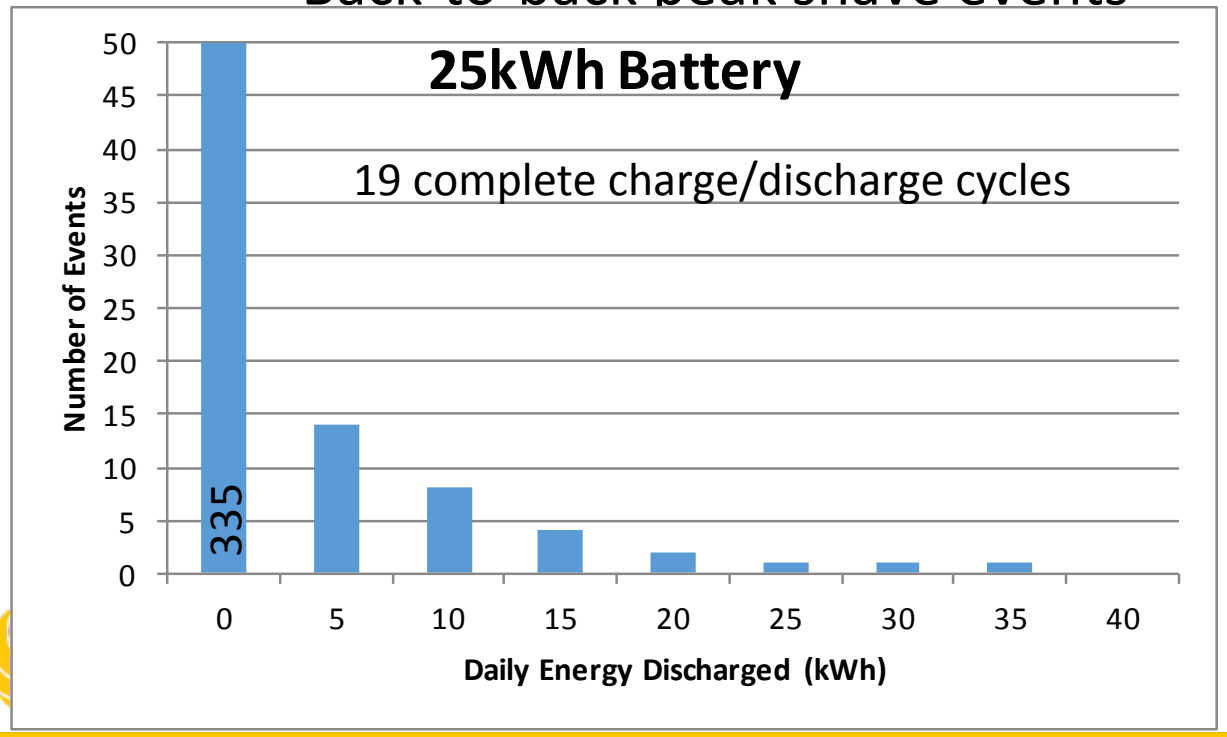


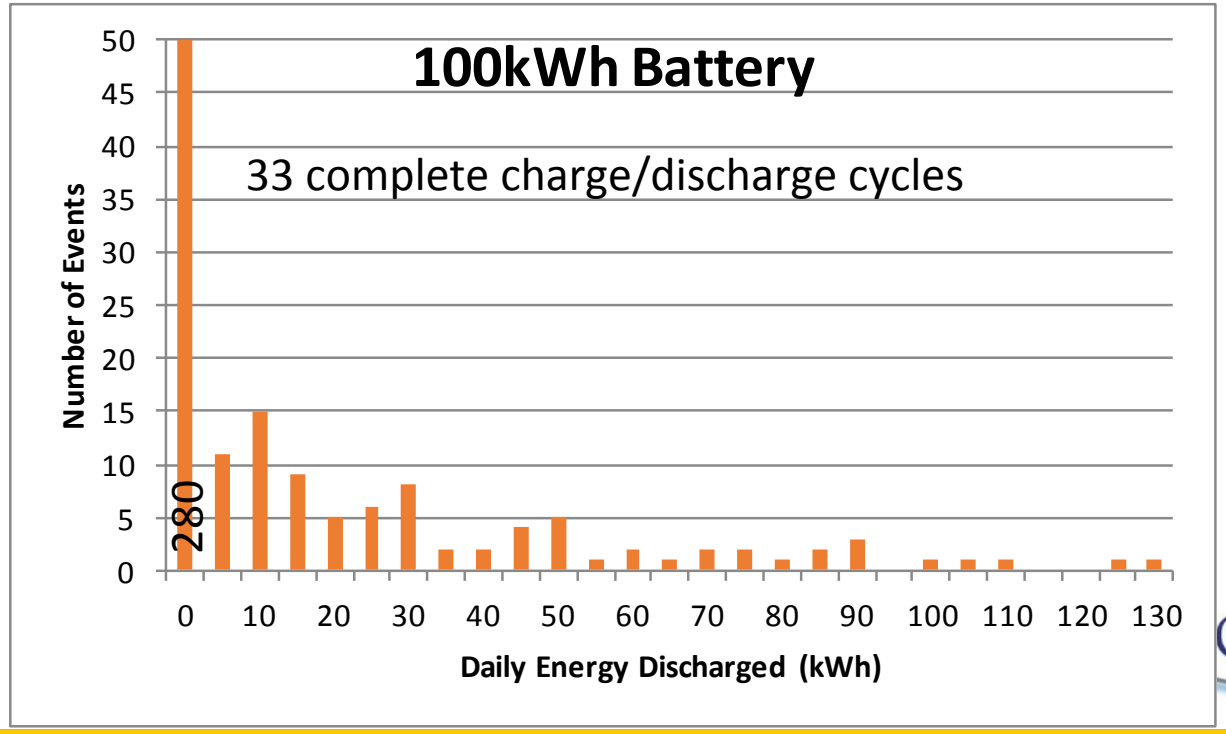


Workday = between 6AM and 6PM

Energy Content of Peak Shaving Events

- Optimized peak shaving results in relatively few cycles
- Daily energy discharged exceeds battery capacity on a couple of days
  - Back-to-back peak shave events





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