FLORIDA SOLAR ENERGY CENTER™

Creating Energy Independence

Evaluating DSM Opportunities with Real Time Energy End Use Measurement

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USA's Largest EUEC 2017

Energy, Utility & Environment Conference

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A Research Institute of the University of Central Florida

FSEC and Building America

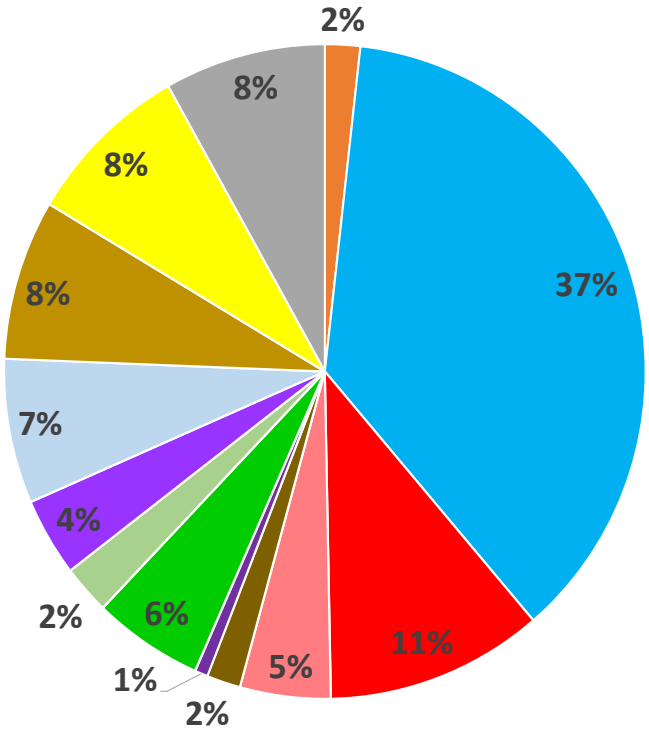
- Goal: Large energy use reductions in new and existing homes
- Construction and remodeling: perceived risk to innovation
- BA $ detailed investigation of energy reduction opportunities
- How does industry fund upfront costs?
- Appealing to utilities: real world evaluation of performance measures and technologies both energy & peak
- 2012 – Phased Deep Retrofit (PDR) Project: partnership with FPL targeting retrofit packages – shallow and deep, and advanced technology evaluation

- Evaluate and measure consumer acceptance and interactions

  (e.g. what are realistic savings of connected thermostats)
- Build on the PDR pilot in California…

Cooling Largest Energy End-Use

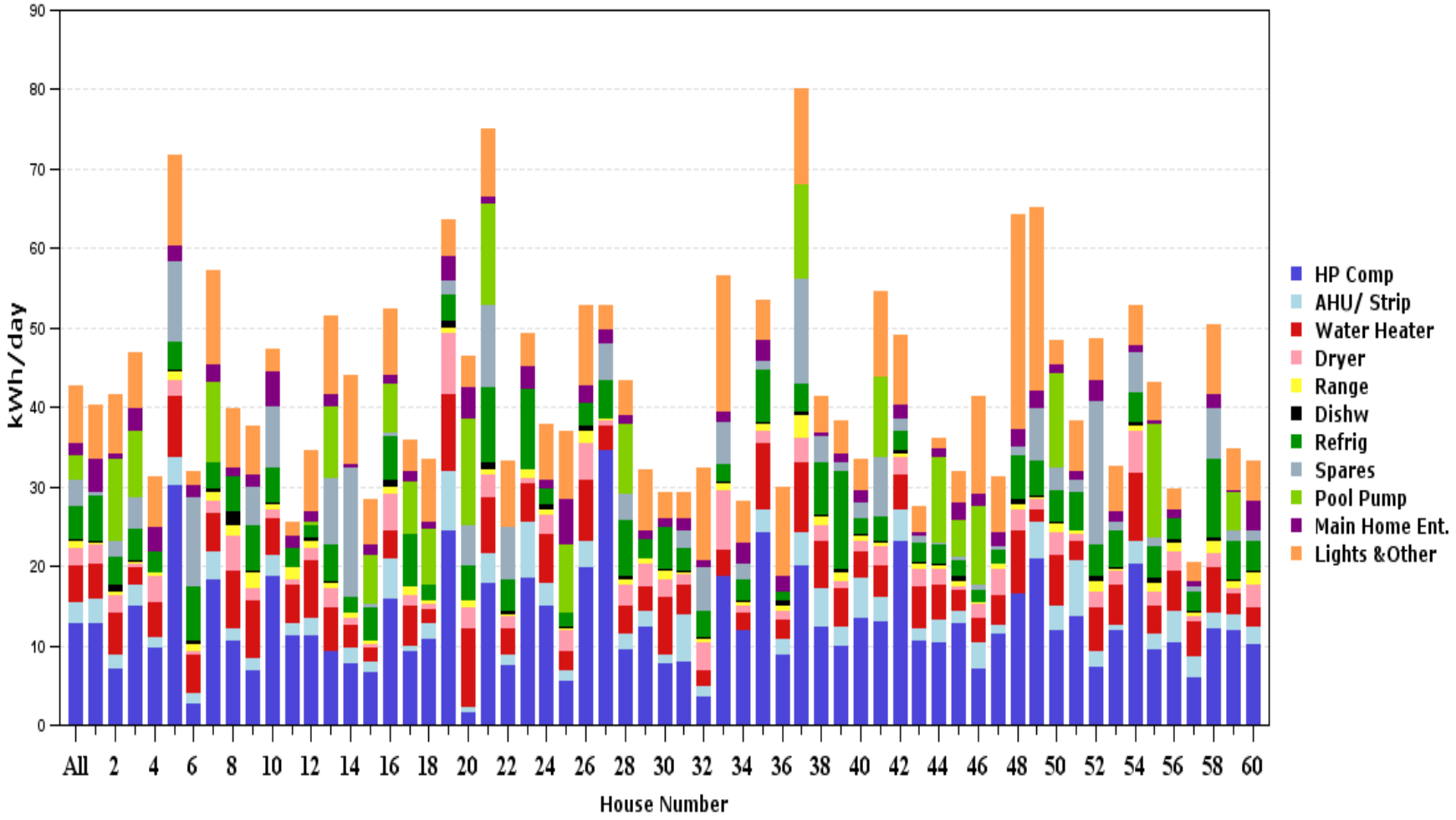
- Average Home Total = 44.1 kWh/day; 16,080 kWh/year



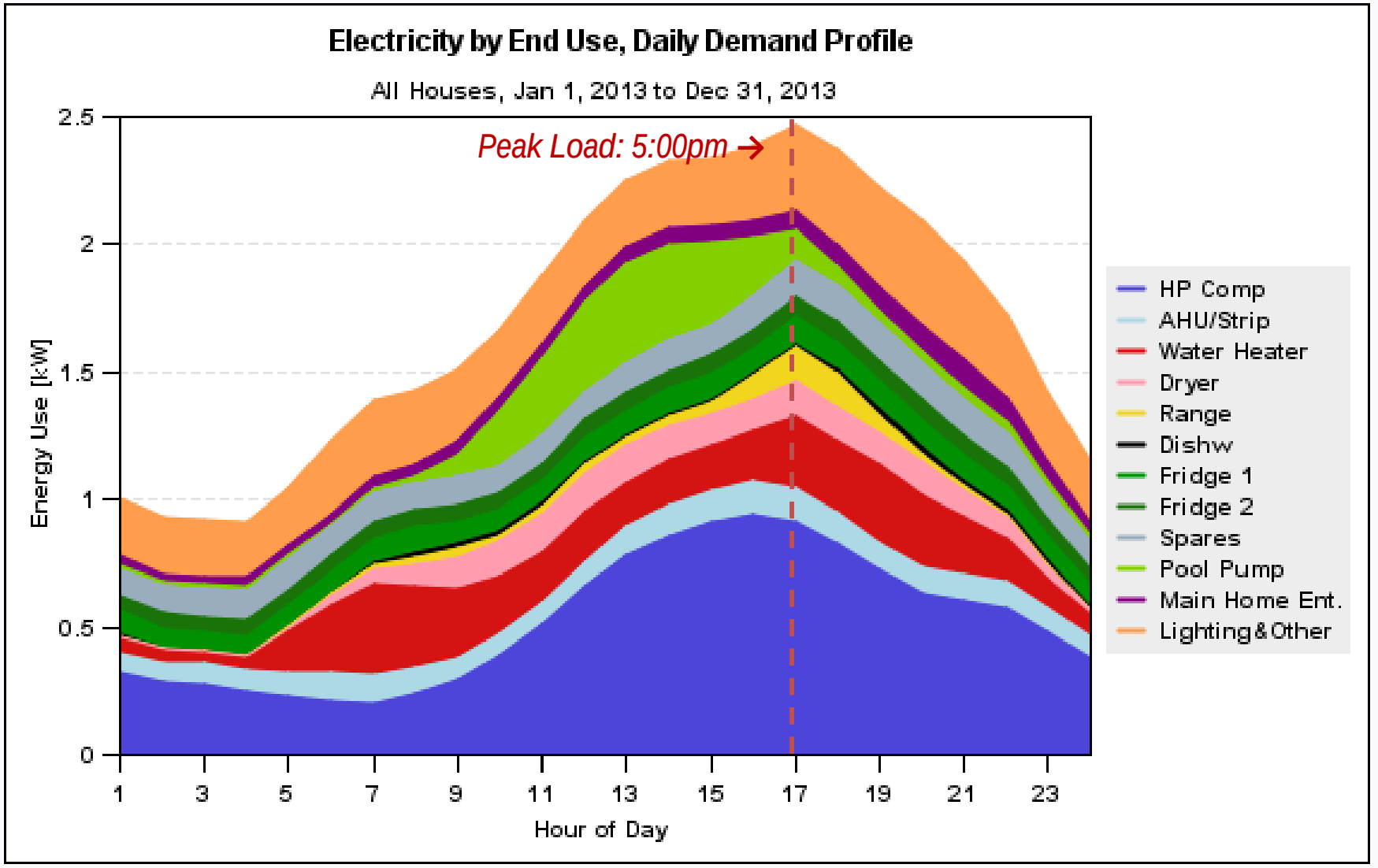
End Use	kWh/day	kWh/yr
Heating	0.78	285
Cooling	16.29	5946
DHW	4.83	1763
Dryer	2.01	734
Range	0.75	274
Dishwasher	0.29	106
Refrigerator	2.44	891
2nd Refrigerator	1.07	391
Main TV	1.71	624
Pool Pump	3.15	1150
Spares	3.49	1274
Lighting	3.67	1340
Plugs & Fans	3.58	1307
	44.06	**16,082**

No single end-use dominates; Conventional loads (space heat/cool & water heat) only 45% of total; lighting & plug loads large difficult to address category

It's Complicated: Mix & Size of End-Uses at Each Site Unique

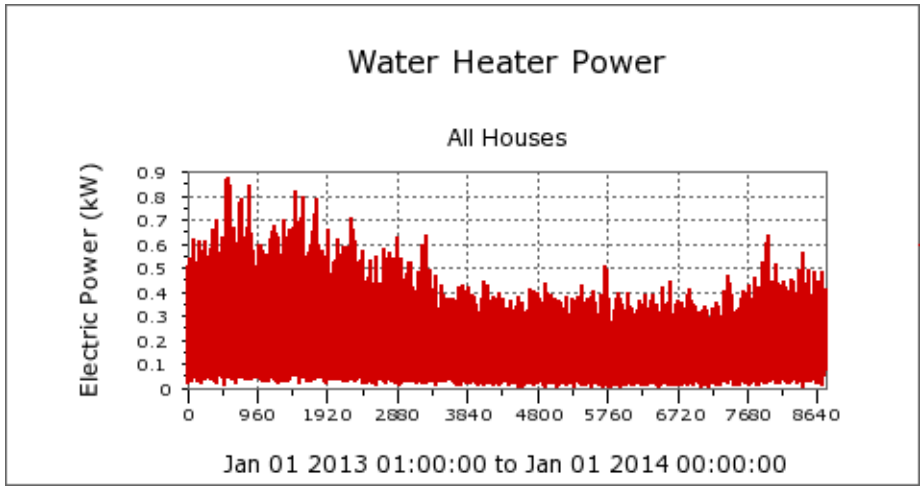


What Makes Up the Peak Load?



Hot Water: Detailed Data on Load Shapes

Hourly



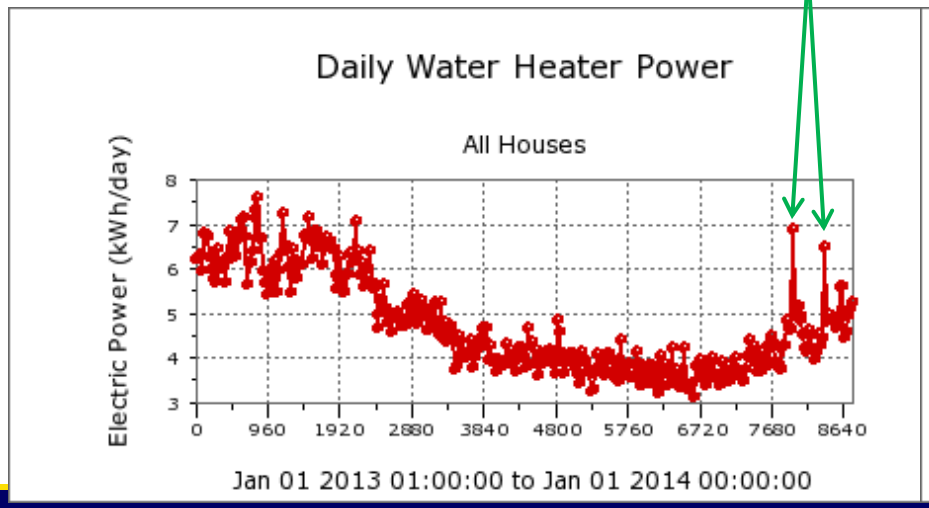
Example: High Quality Water Heating

Load Shape Data: Available for Each End Use for an Entire Year

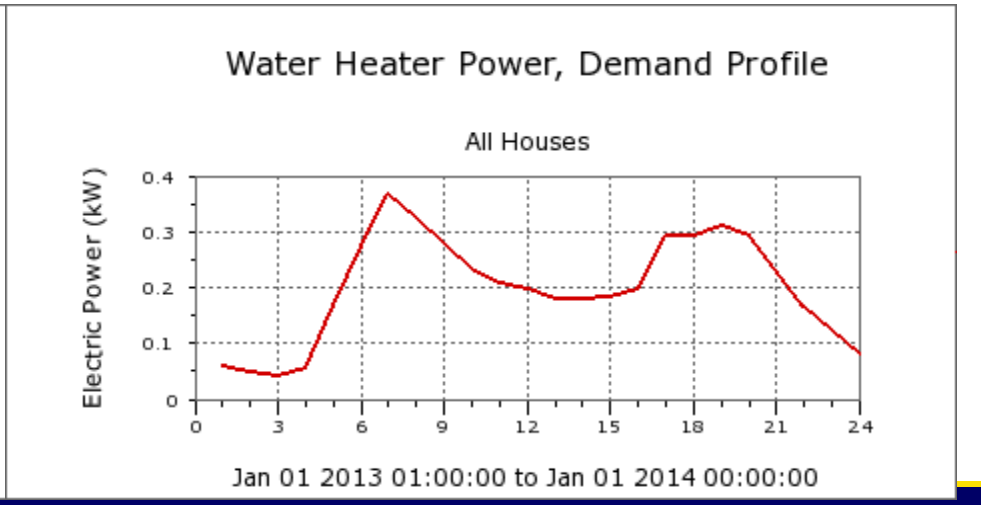
2:1 Difference winter to summer

Daily

Thanksgiving/Christmas



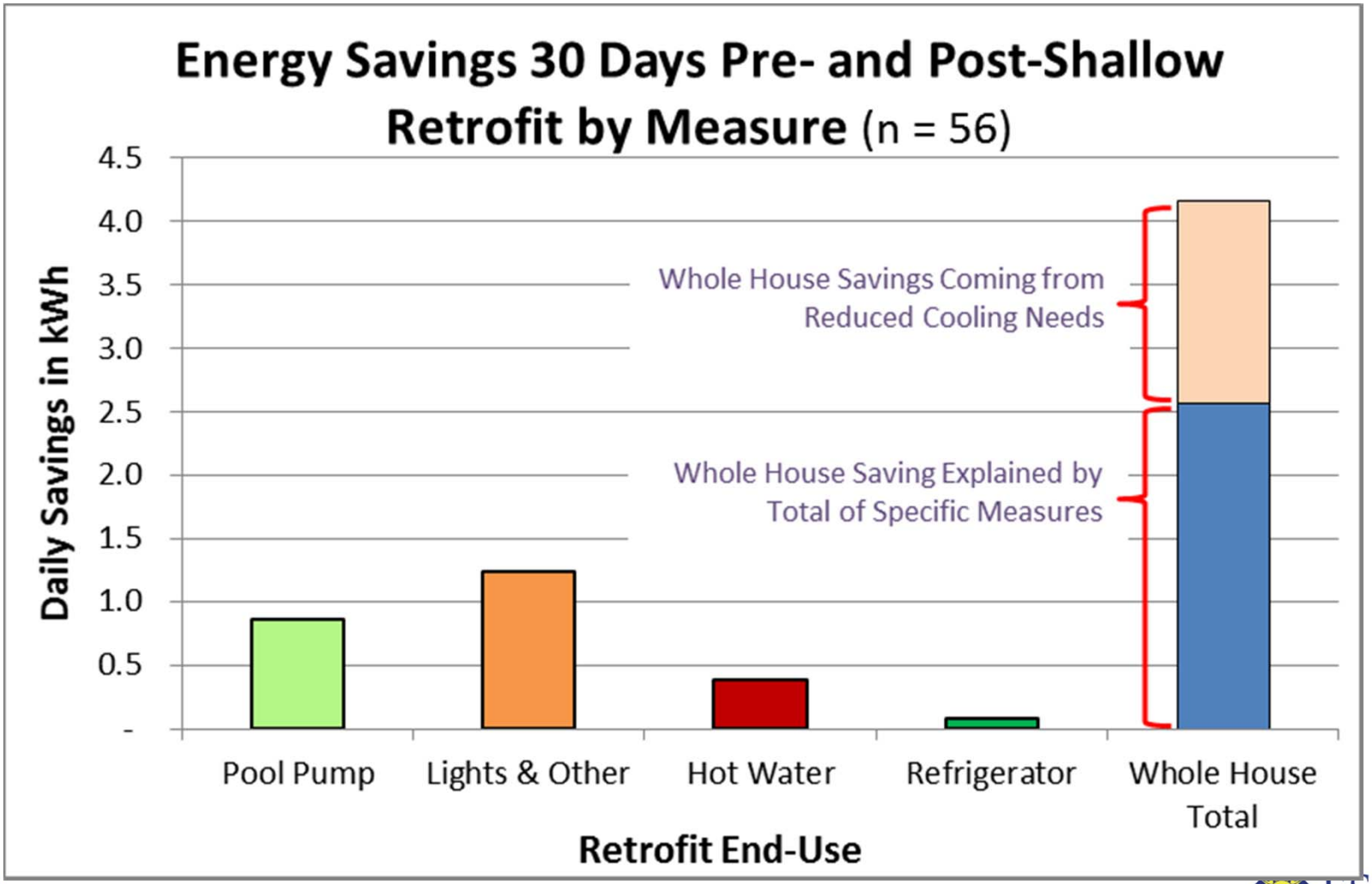
Time of Day



Shallow Retrofit Measures

- CFL or LED lighting
- Exterior insulation on hot water tank and hot water pipes
- Low-flow shower fixtures if measured flow > 2.2 gpm
- Pool pump hours set to >= 5 hours per day
- Clean refrigerator coils
- Smart power strip if continuous standby power loads > 10 Watts

Savings by Measure: 9%

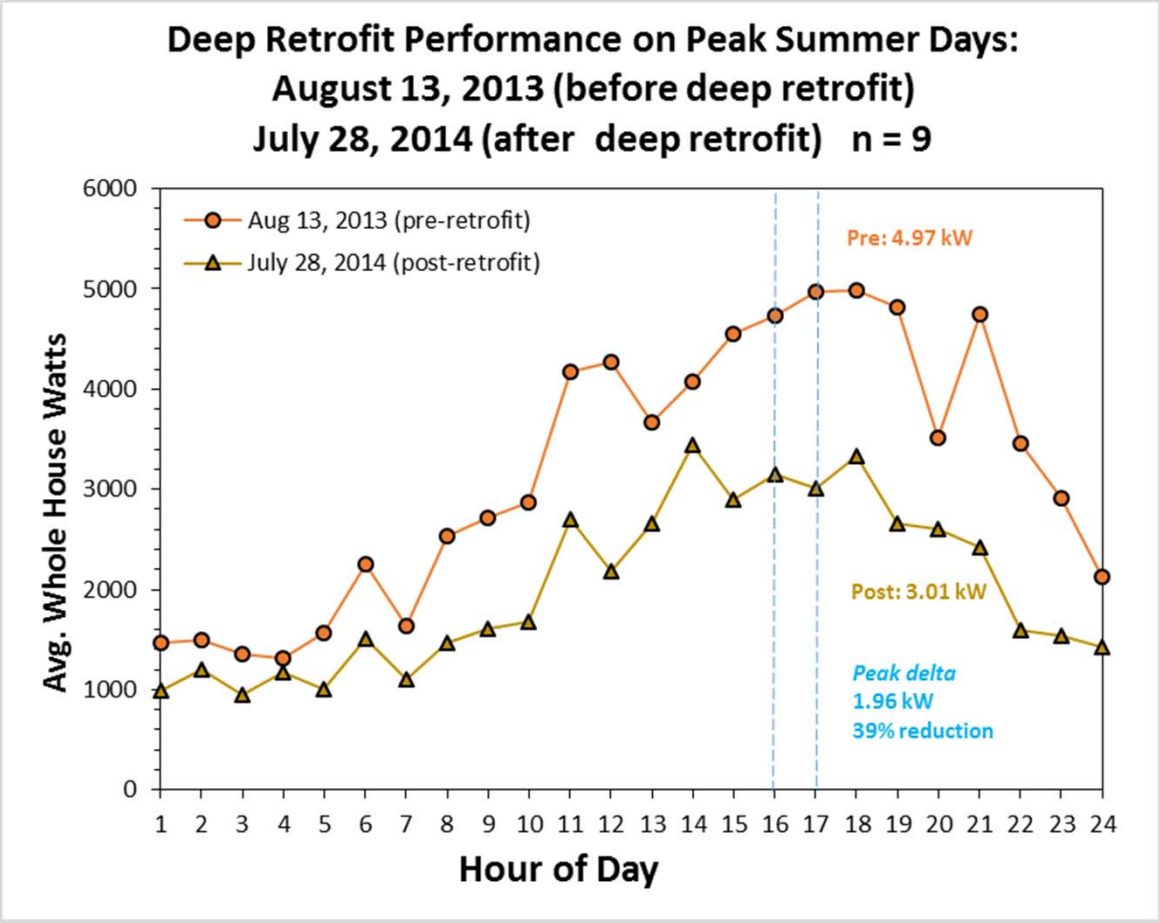


Deep Retrofit Measures

- Measures for 10 deep retrofit sites:
  - High-efficiency HVAC
  - Smart thermostat
  - Duct sealing
  - House sealing
  - Energy Star appliances
  - Heat pump water heater
  - Variable-speed pool pumps
- **Average: 38% savings**
- Percentage wise: site saved most with old AC systems/pools

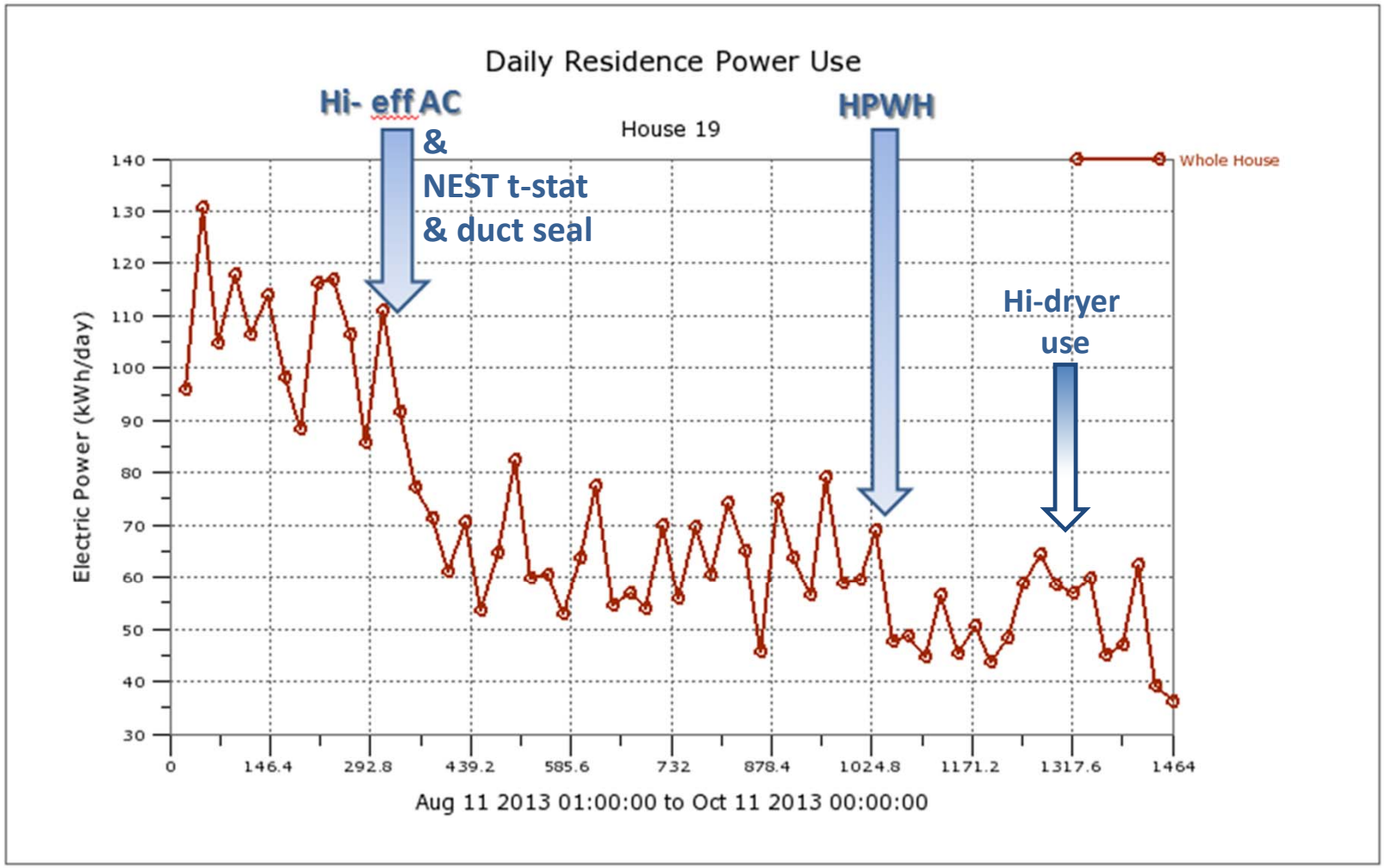
Site	Weather-normalized Energy Use (kWh/Day)		Total Savings %
	Pre	Post	
7	67.6	32.7	52%
8	41.9	27.9	33%
10	53.0	32.6	38%
19	67.1	36.9	45%
26	54.8	31.4	43%
30	38.1	24.5	36%
37	74.4	58.3	22%
39	38.2	26.0	32%
40	33.2	20.9	37%
51	42.5	26.1	39%
n=10	**51.1**	**31.7**	**38%**

Deep Retrofit Peak Demand Reduction



1.96 kW, 39% peak summer hour demand reduction

Deep Retrofit in Site #19



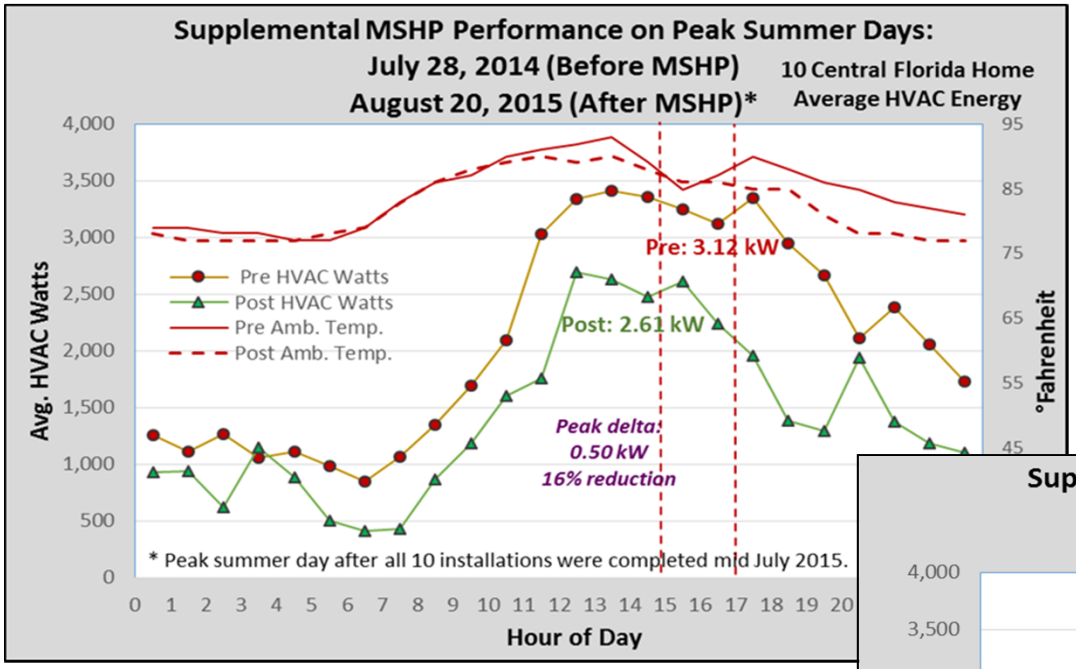
Total Consumption from 110 kWh/day to 40 kWh/day:

Sometimes Surprised: Supplemental Mini-split Heat Pump

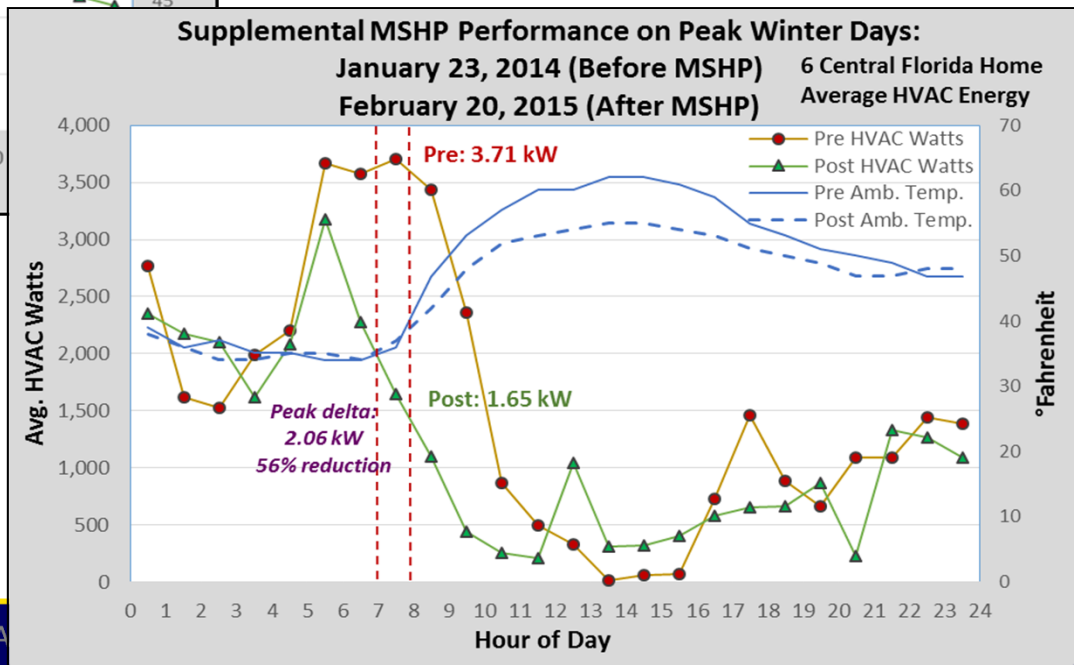
- Installed 1-ton, 25.5 SEER, 12 HSPF, var. speed ductless mini-split heat pump
  - In main living area
  - MSHP set point generally 2°F below central system (2°F higher for heating)
- **Robust results from small sample:**
  33%; 2,007 kWh for cooling
  59%; 390 kWh for heating (no resistance)
- $3,860 investment
  - Improved economics with market maturity
- Attractive to Utilities: peak….

FSEC™

Pre- and Post-Demand on FPL System Peak Summer and Winter Days



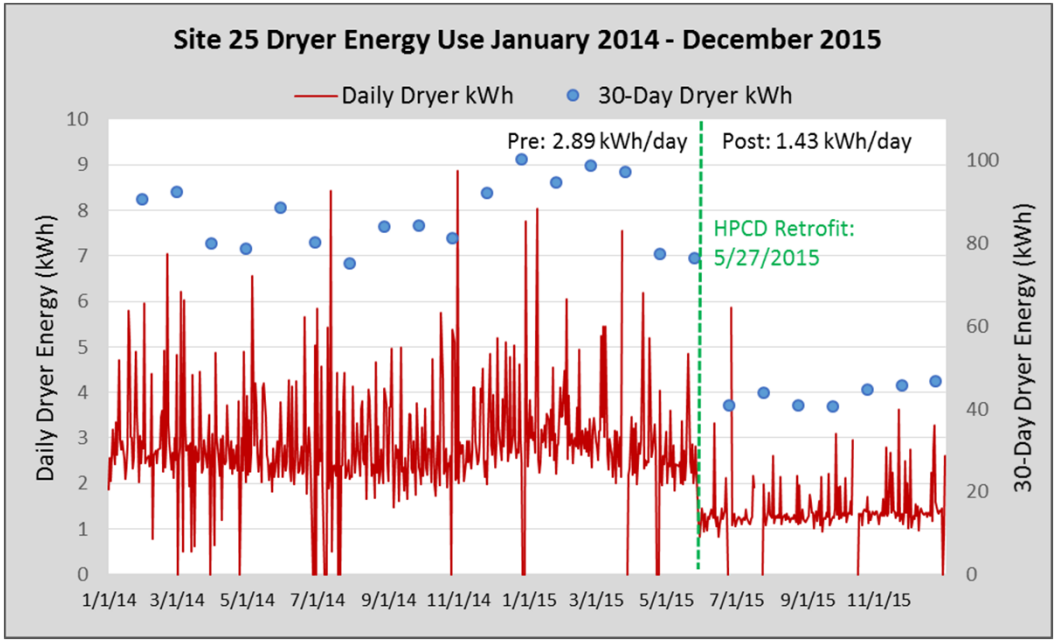
0.50 kW, 16% peak summer day demand reduction



2.06 kW, 56% peak winter day demand reduction

Ventless Heat Pump Clothes Dryer

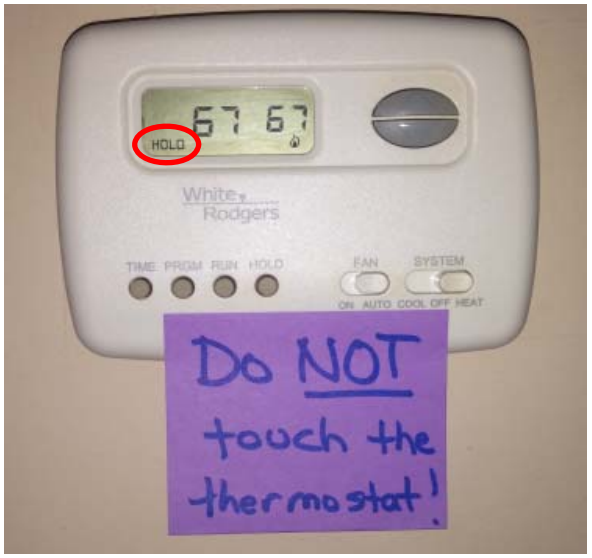
- **Median annual savings in 8 home sample: 264 kWh/y, 34%**
- Current retail of $948, incremental cost of $248 = 8 yr payback

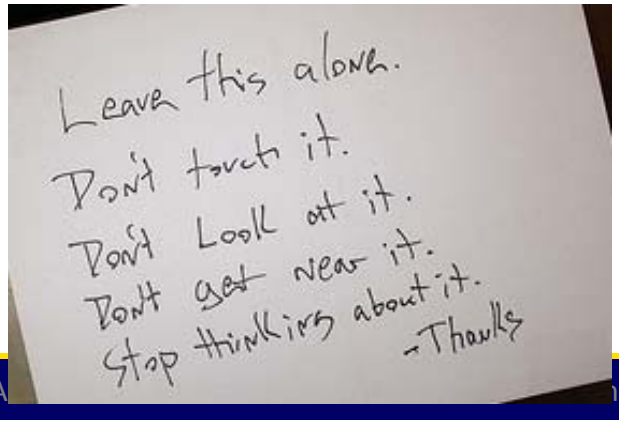


- Advanced washer removes 25% more moisture
- DHW energy savings not included
- Ventless appliance caused room temperatures exceed 95 F!
- LG makes vented HPCD; research will likely show specific tech works better in one climate vs. the other

Un-utilized Programmable Thermostats

- Difficult to program: often set to *HOLD*…
- Seldom used= low effectiveness
- Studies verified shortfall:
  - No Savings (Nevius & Pigg 2000)
  - Increased cooling in Florida (Lopes & Agnew 2010)
  - Only 25% program; too difficult, annoying (Meier et al. 2011)

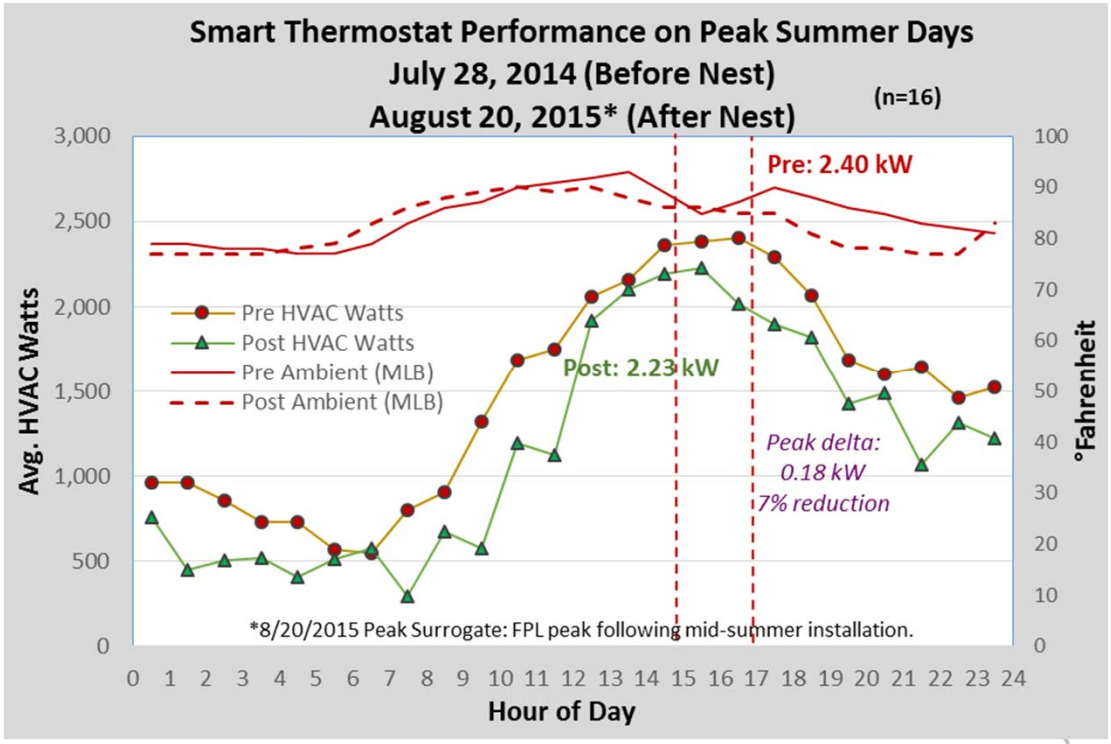




Nest Evaluation Results

- One year before & after w/ measured temp & sub-metered HVAC
- **Average energy savings: 9.6% heating & 9.5% cooling**
- Robust for sample, but unpredictable for any particular site (depends on pre install habits)

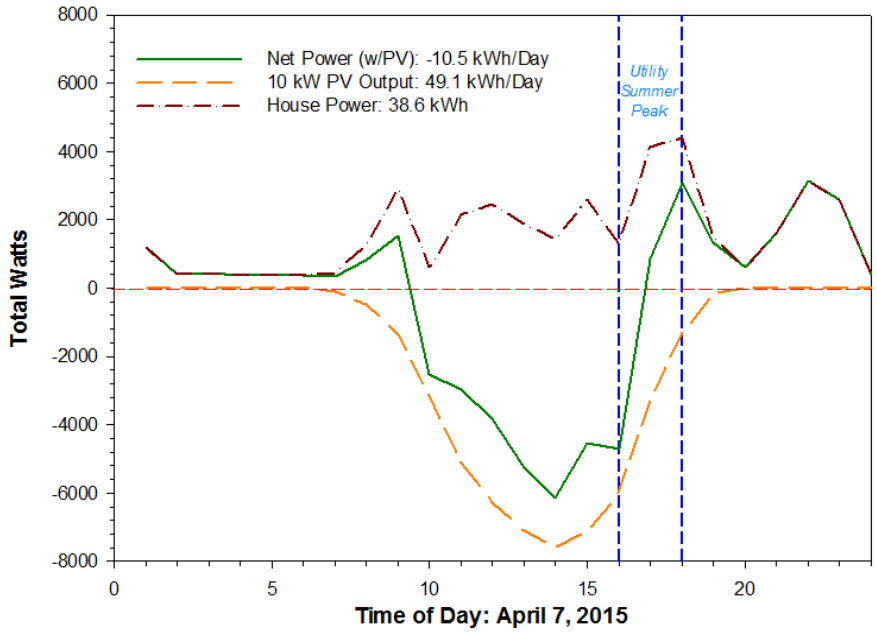
0.18 kW, 7% peak summer hour demand reduction



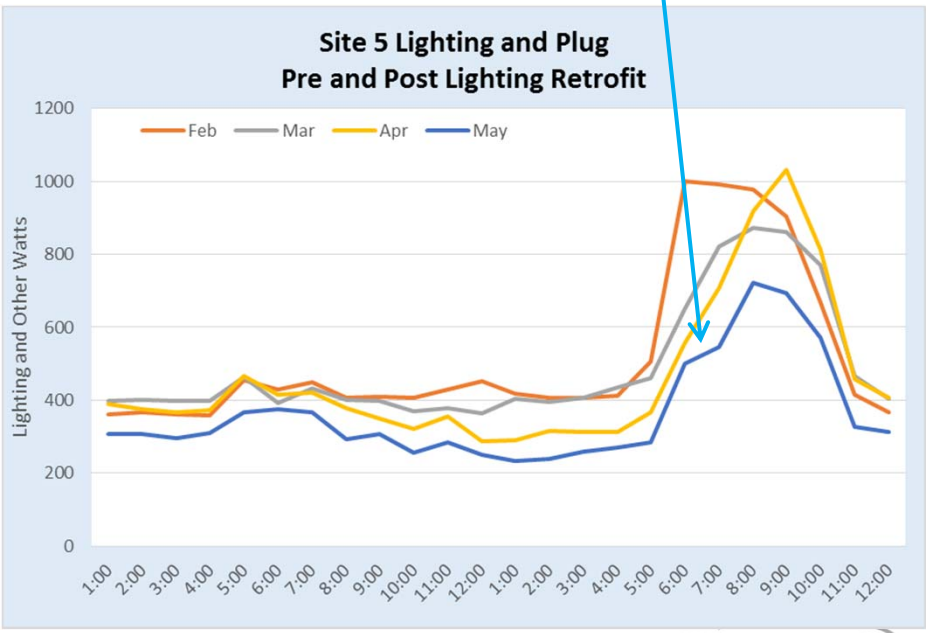
Why Consider PDR in California?

- Data on residential electricity and natural gas load profiles across the state; bolster RASS survey estimates
- Assess summer & winter peak components
- Evaluate shallow & deep retrofits in CA existing homes
- Learn most effective means for existing CA homes to reach Net Zero Energy + with load profile improvement
- Assess duck curve components
- Evaluate PV across geography and with and without electrical storage
- Evaluate specific technologies including electric vehicles & storage
- Provide realistic assessment of smart metering load disaggregation along with estimation improvement
- Create legacy sample for long-term tracking of CA energy consumption

Fabled "Duck Curve" kW rise w/PV: What can we learn? Components!

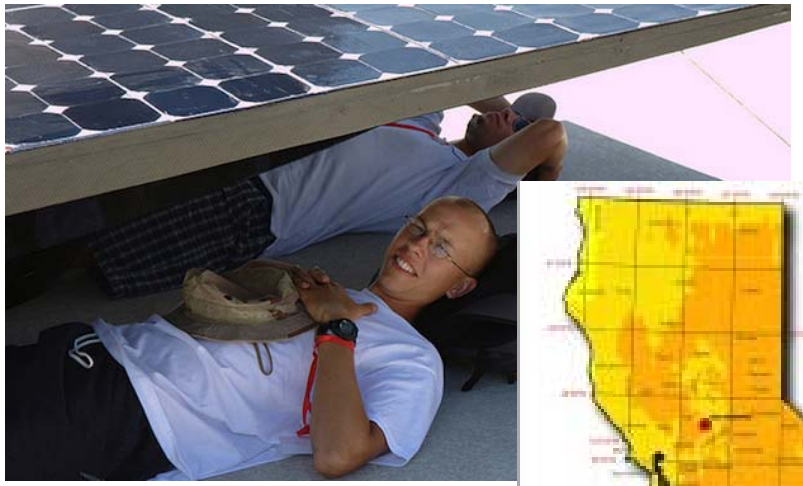


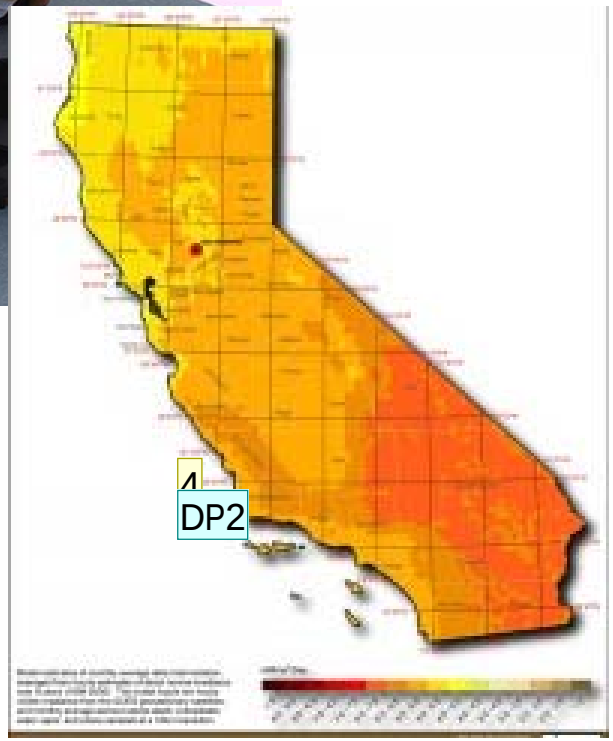
Addressing lighting efficiency has large influence In rate of kW rise after PV output drops: note Drop after efficient lighting after April



Distributed PV Resource: What can we learn?

- How PV varies with orientation & tilt
- How it varies with time, weather & geography
- Cooling influence?
- Electrical storage
  - How can it smooth demand?
- How storage stacks up against efficiency:
  - Base
  - Shallow retrofit
  - Deep Retrofit
  - With pre-cooling strategy informed by weather forecast





Slide 19

4 Please explain briefly the gist of what this section is.

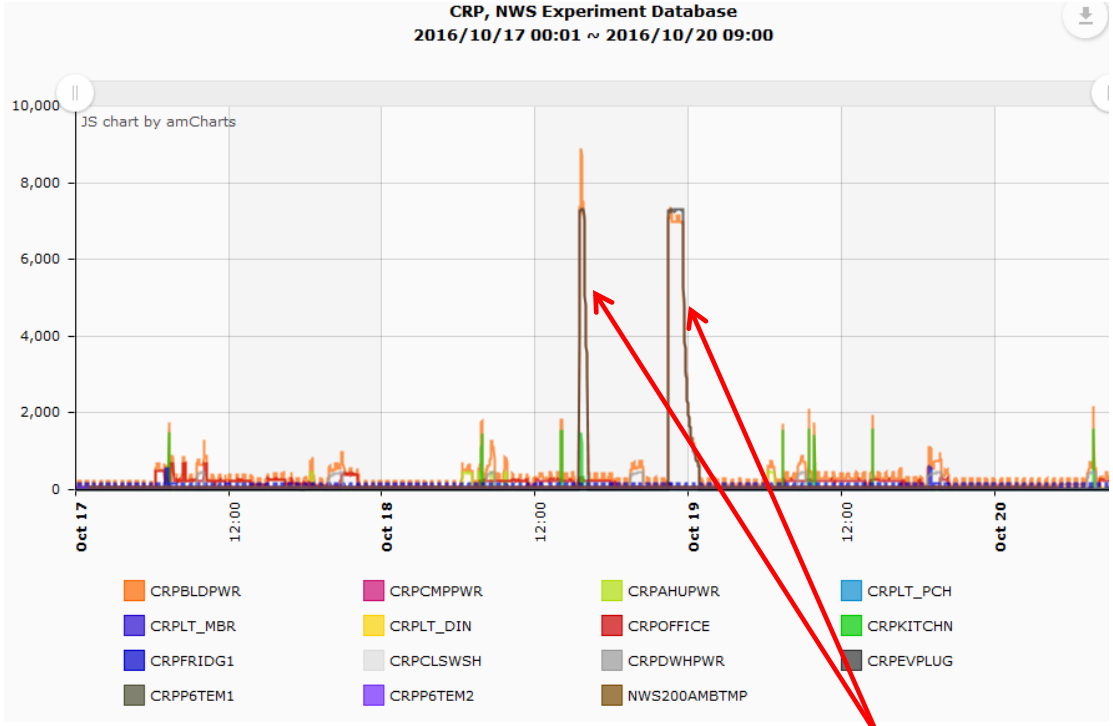
Do you mean, is storage more cost effective than measures?

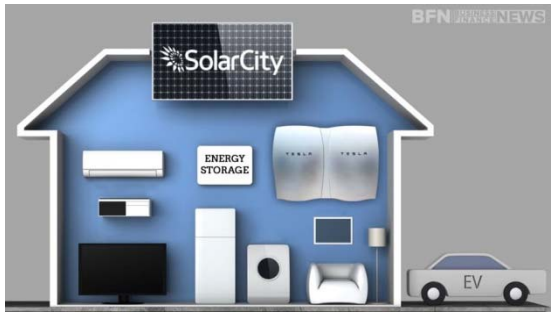
How does pre cooling fit in?
KFS, 2/4/2017

DP2 Pre-cool bldg when PV is high in summer; load shed after sun going down by bumping up tstat by 2 F.
Danny Parker, 2/5/2017

What is Impact of EVs on Electric Loads?

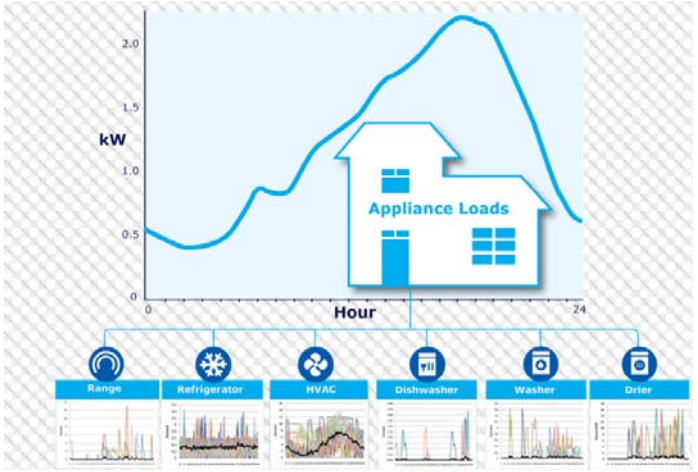
- Saturation of EV s slated to increase dramatically in CA
- What are impacts on energy, TDV & peak?
- Important aspect: 40% of homes with EVs have solar PV
- How do EVs and PV mix?
- Load shape

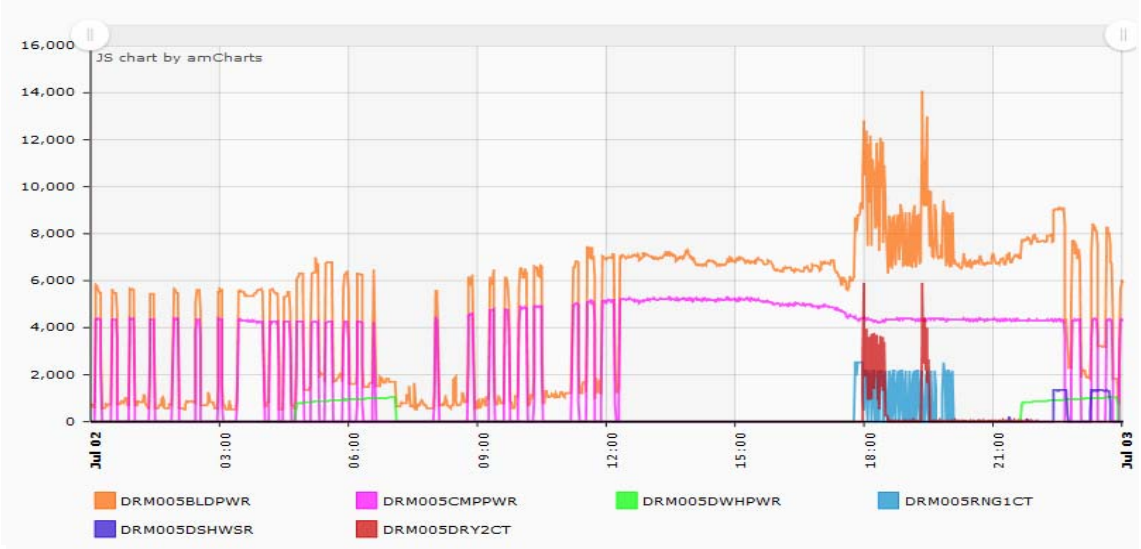




Effectiveness of AMI Disaggregation?

- How effective are Automated Metering Infrastructure disaggregation schemes?
- Several firms claiming smart meter end-use load disaggregation
  - Opower, HEA, Bidgely?
- PDR can verify/improve
  - Improve estimates?
  - Allow evaluation of uncertainties?
  - Provide additional insight
  - Evaluate effectiveness of peak shed schemes?





Conclusions

- Findings from a detailed field metering FL pilot study point to home energy savings retrofit packages:
  - Shallow (9% savings)
  - Deeper retrofits (38% savings)
  - Technologies that could be targeted for peak shaving/ load profile adjustment
- Larger-scale study in CA could provide similar insights (retrofits & technologies) for state and data on residential electricity and natural gas load profiles; bolster RASS survey estimates
  - Effective means for existing CA homes to reach Net Zero Energy
  - Realistic assessment of smart metering load disaggregation
  - Evaluation of PV across geography, with and without electrical storage
  - Legacy sample for long-term tracking of CA energy consumption trends
    - What are the emerging loads?

Thank you

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Extra slides

Site Characteristics

- 60 All Electric Homes (56 over analysis period)

	Average	Range
Area	1,777 ft2	1,000 - 2,650 ft2
Vintage	1984	1942 - 2006
Occupancy	2.6 persons	1 - 6 persons
Ceiling Insulation	R-22	R-8 - R-38
Airtightness	8.5 ach50	4.4 – 16.4 ach50

- Typical Study Home:
  - Single-glazed windows
  - Slab-on-grade foundation
  - R-3 masonry walls
  - Asphalt shingle roof
  - Electric resistance water heating
  - 2003 Air conditioner
  - 1/3 Pool homes
- Pre-Study Annual Use: ~17,000 kWh

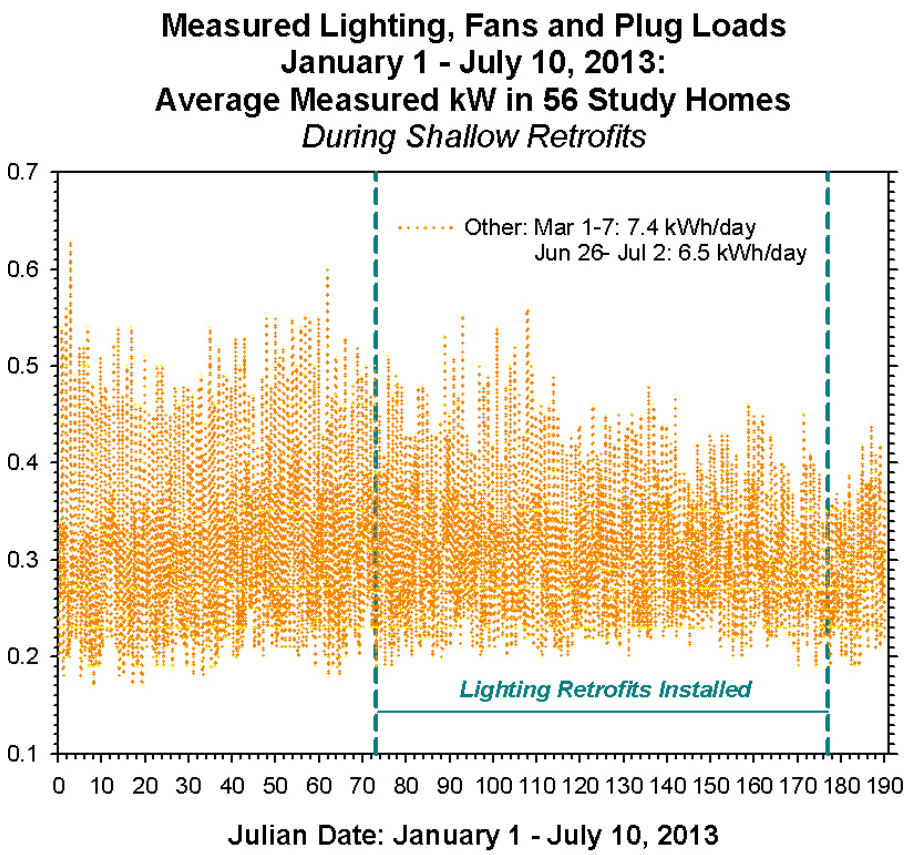
Cost Analysis: Caution FL Numbers

Shallow Retrofits

- Costs average: $370/site (inc. labor)
- Saves: 1,310-1,530 kWh/yr ($15/mon)
- **Rate of Return: ~50%, 2 yr payback**
- *Disadvantage: invisible to consumer*

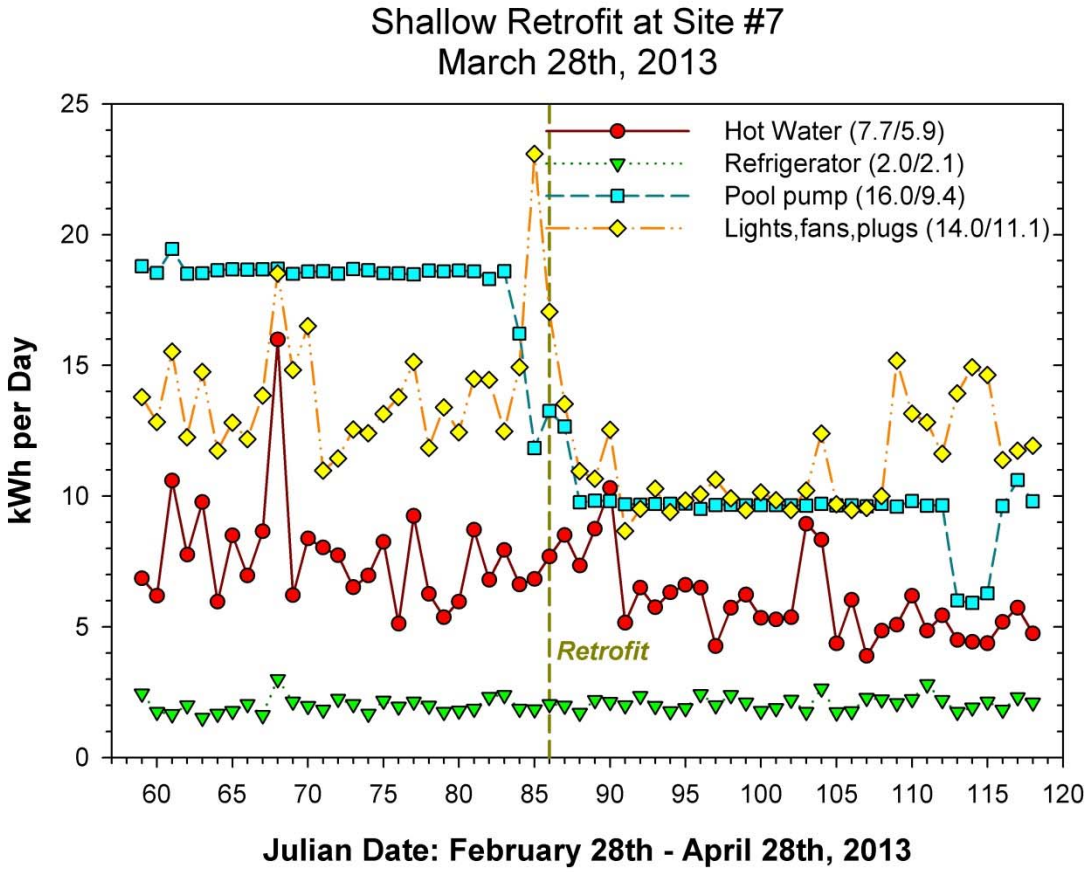
Deep(er) Retrofits

- Outright cost average: $14.2K/site
- Incremental cost: $7K
  - **Replace at burnout**
- Savings: ~ 7000 kWh/yr ($70/month)
  - **38% (Range: 22%-52%)**
- *Highly visible to consumer*
- Rate of Return: ROR/SPB:
  - **Outright: ~6%, 17 yr payback**
  - **Incremental: ~12%, 8 yr payback**
- ***Takeaway: advantage retrofit coincides w/ major equipment & appliance replacement***



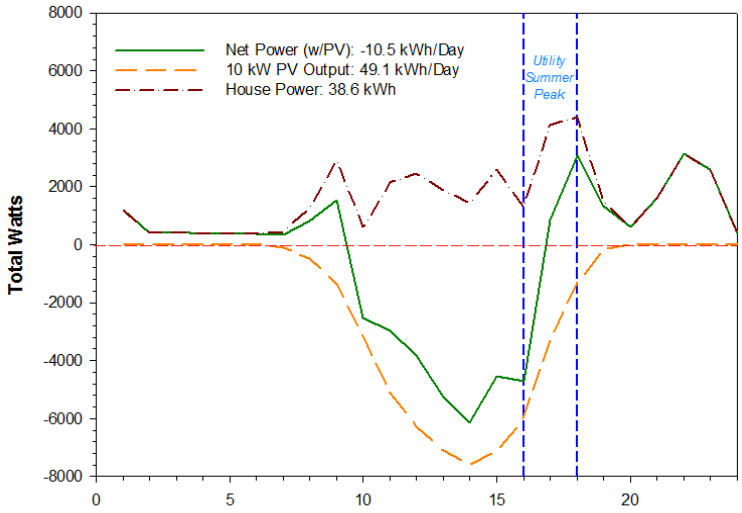
Easy Shallow Retrofits: What can we learn?

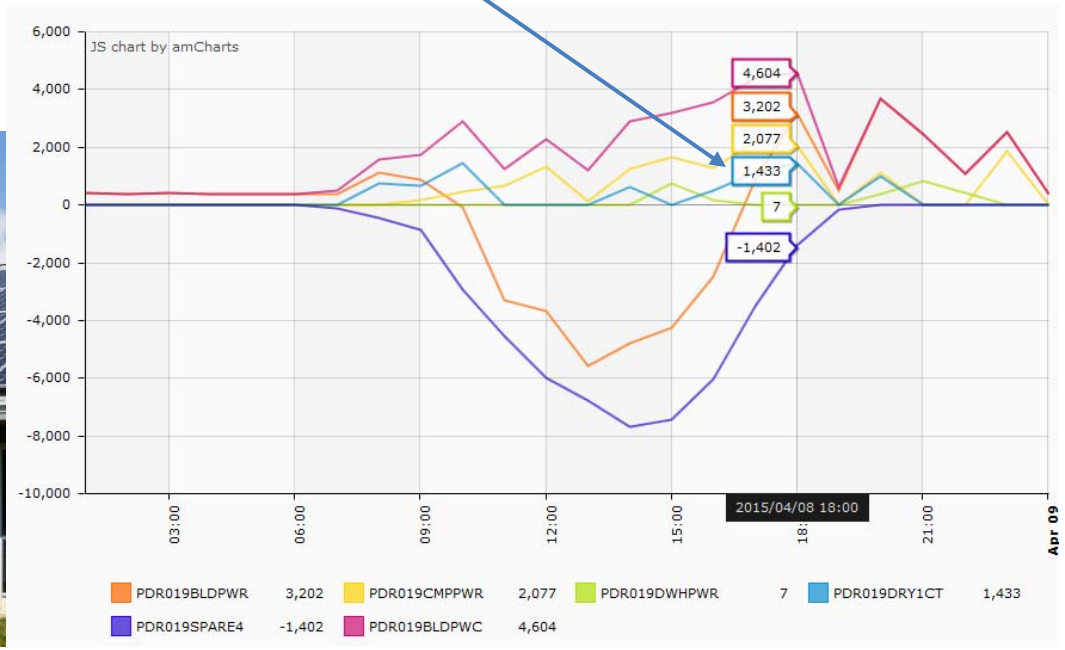
- Florida experience suggests potential:
  - Lighting
  - Hot water tank insulation
  - Shower heads
  - Learning thermostats
- Peak impacts?



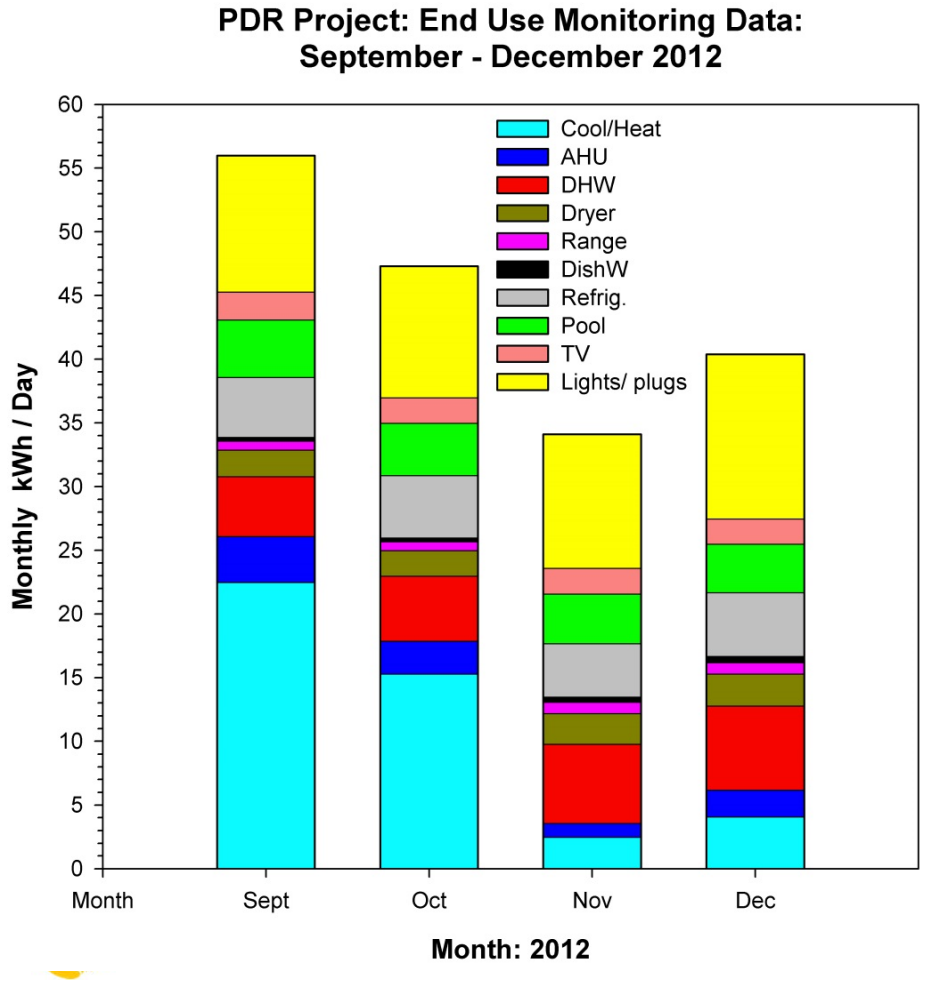
Monitoring: Insight on PV & Efficiency

- What makes up rapid rise during the 5-7 PM peak?
- Duck curve..
- Yes AC, but clothes dryer!





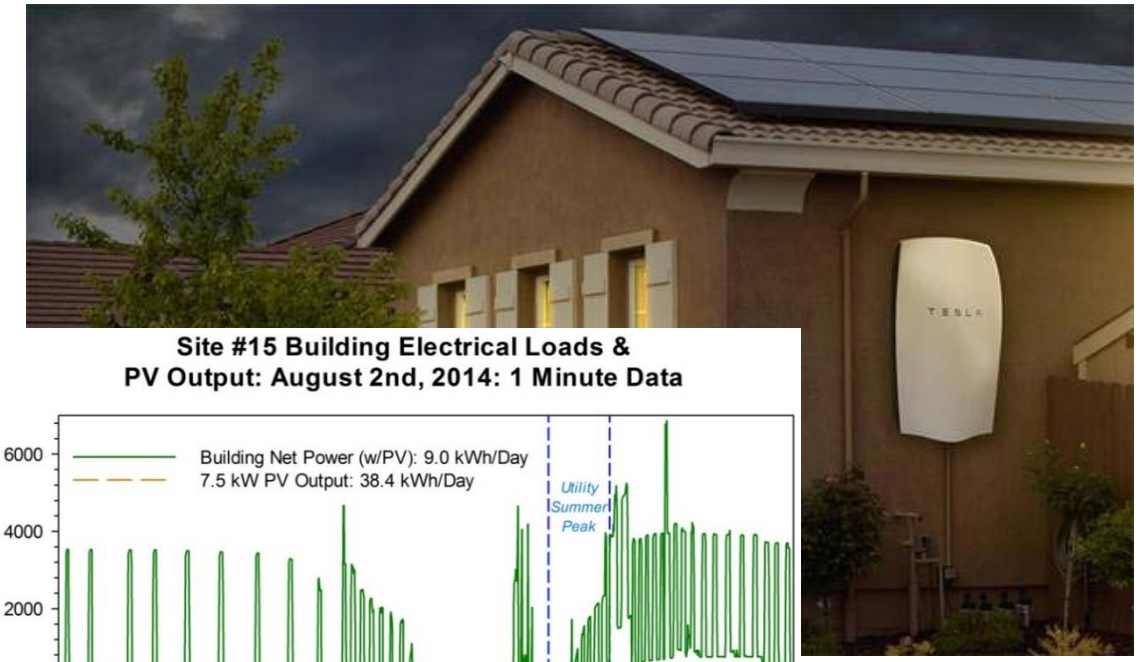
What are End Use Loads like in California Homes: What can we learn?

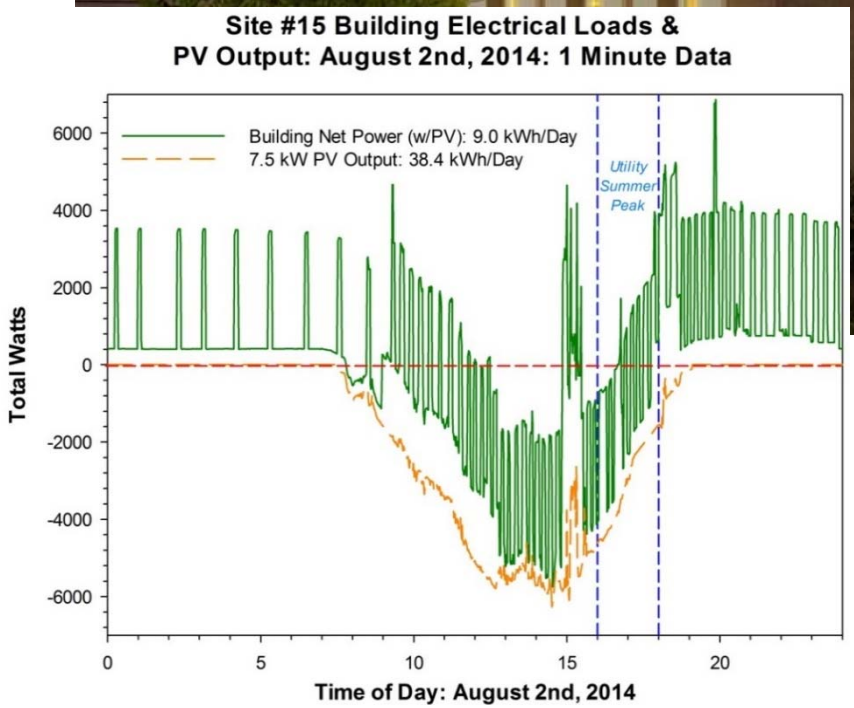


- How it varies vintage (kWh & therms)
- Fuel mix (heat, hot water, dryer, cooking)
- How it varies: time, weather & geography
- Impacts from PV & EVs?
- How are loads evolving?

What is Potential of Distributed Electrical storage with PV

- Add a 5-10 kWh battery system
- PV & net load profiles
- Cut evening peak
- Smooth demand?
- How does efficiency compare with electrical storage?
- Pre-cooling; thermal storage?



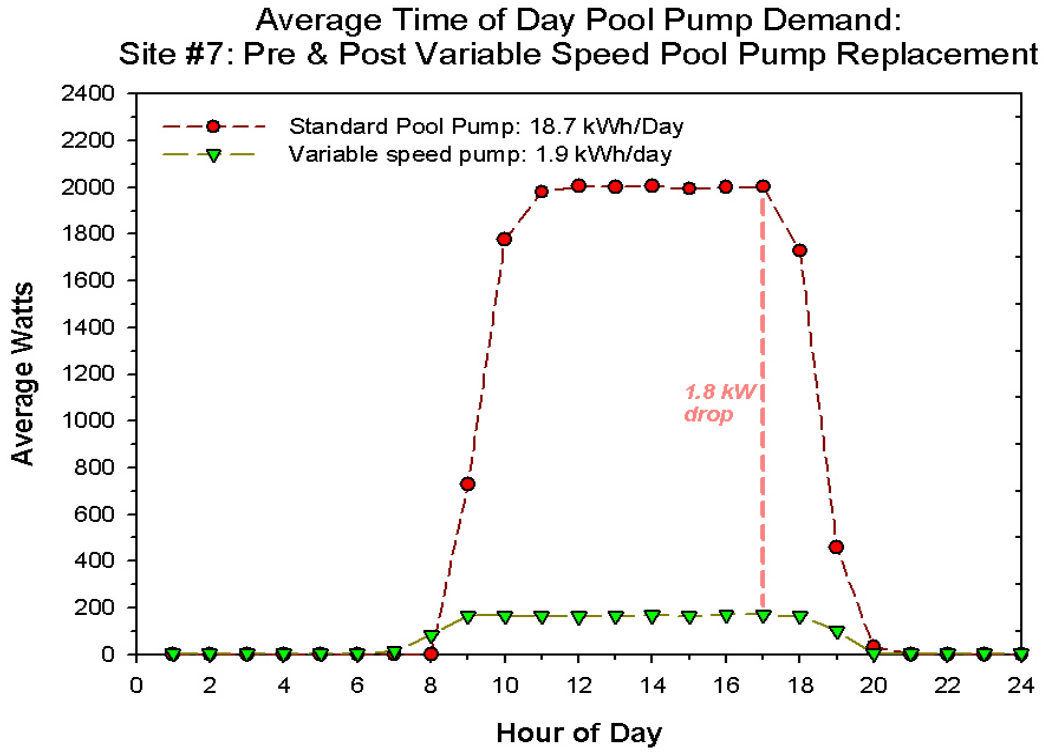


What is natural progression of energy end-uses in California homes?

- New end uses difficult to anticipate
- Before: torchieres/PCs
- DVRs
- Computers
- Gaming computers
- Home entertainment
- Home Robots?
- Establish LEGACY SAMPLE
  - Tracking natural changes in CA residential energy use
  - Pristine part of sample

Variable Speed Pool Pump

- Site #7: 18.7 kWh/day pre
- 1.9 kWh/day after replacement: ***90% savings***
- Avg. 70% savings: Huge demand reduction: 1.8 kW @ 5 PM!



Heat Pump Water Heaters

- Dependable savings vs. electric resistance water heaters
- 80 gal. models: 4+ person households
- **68% overall savings (5.3 kWh/day)**
- 80 gal: 74% savings (7.6 kWh/day)