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GRID MODERNIZATION
LABORATORY CONSORTIUM

Strategies for Reducing Peak Load using Residential Storage Systems

Update Meeting
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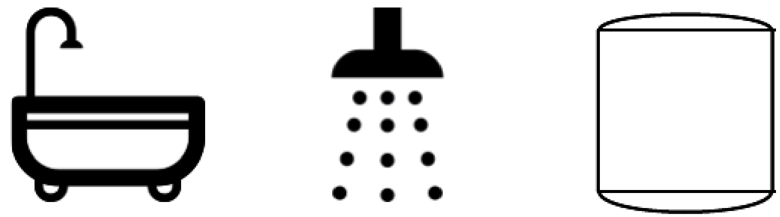
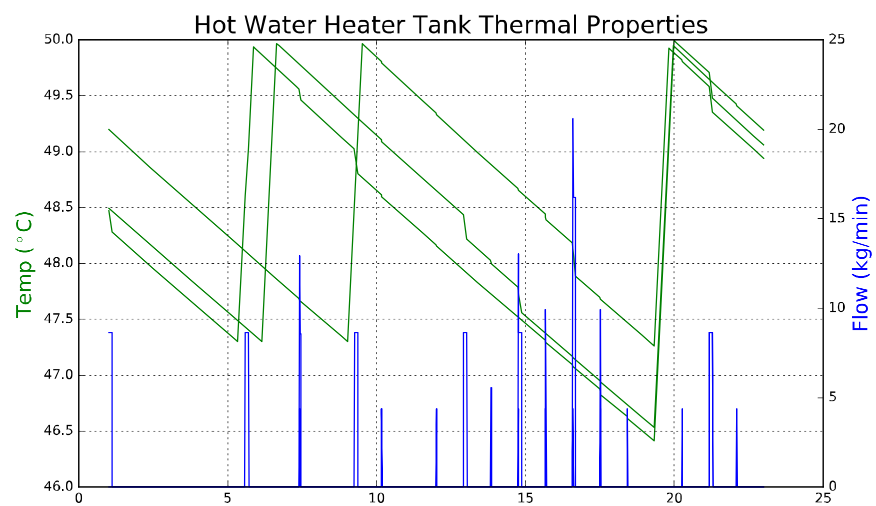
Presentation Outline

- Question & Hypothesis
- Methodology
  - Overview
  - Demand Forecast
  - Electric Water Heater
- Simulation Results
  - Peak Shaving Results
  - Rebound Reduction Strategy
- Next Steps
- Questions





Question & Hypothesis

Question:

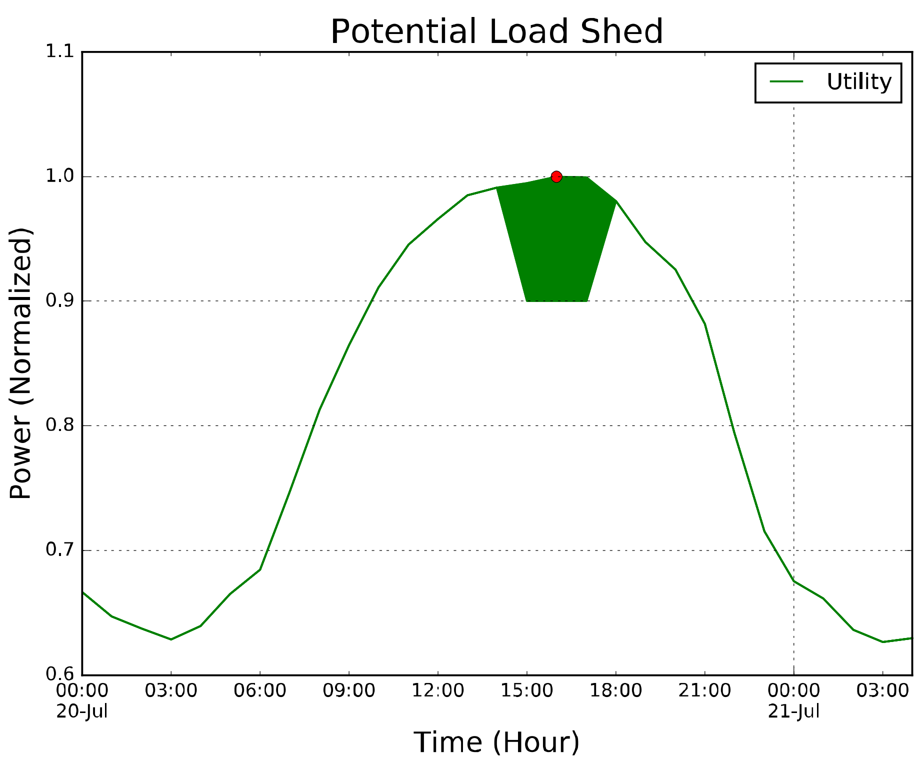
- Can centralized control of electric water heaters (EWH) provide peak shaving?
- Control strategies that consider
  - limit rebound
  - minimize occupant discomfort

Hypothesis:

- EWH can be controlled to reduce the peak
- Forecast provides accurate 1-2 hour window for peak demand
- Occupant discomfort can be limited to 3-4 hours

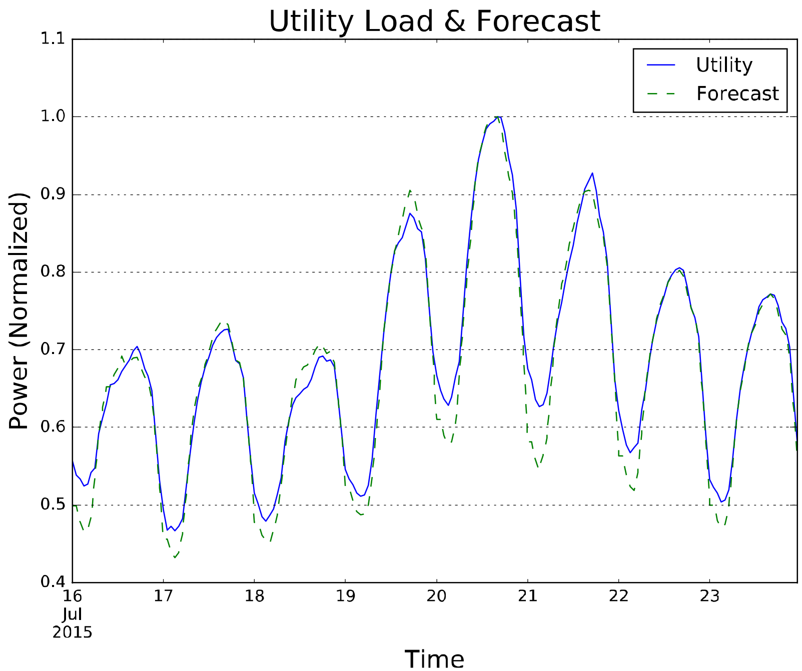
Methodology

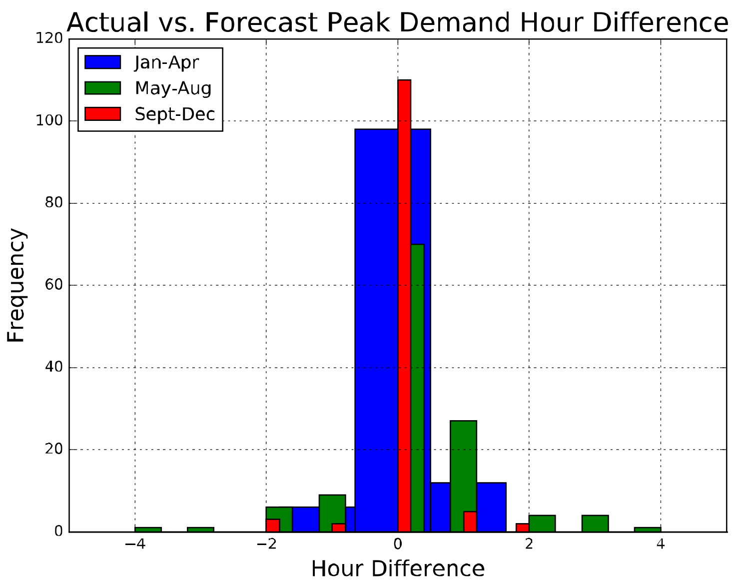
- Goal:
  - Shed load at ISO peak
- Approach:
  - Predict time of peak
  - Control strategy
    - Turn off EWH at peak
  - Test strategies
    - Avoid excessive rebound
    - Reduce impact on customers (time system can not charge)



Demand Forecast

- ISO Forecast
  - Predict utility demand
  - ISO prediction match well with utility





- Forecast Accuracy
  - Hour difference
    - Actual peak time vs Predicted peak Time
  - High probability that peak within ± 1 hour

Electric Water Heater

- Thermal Model

$$M\frac{dT_T}{dt} = Q_e + \dot{m}C_p(T_s - T_T) + UA(T_{amb} - T_T)$$

where:

M: mass of water in the tank (kg)

T_T: tank temperature (°C)

Q_e: heating element power (Watts)

T_s: inlet temperature (°C)

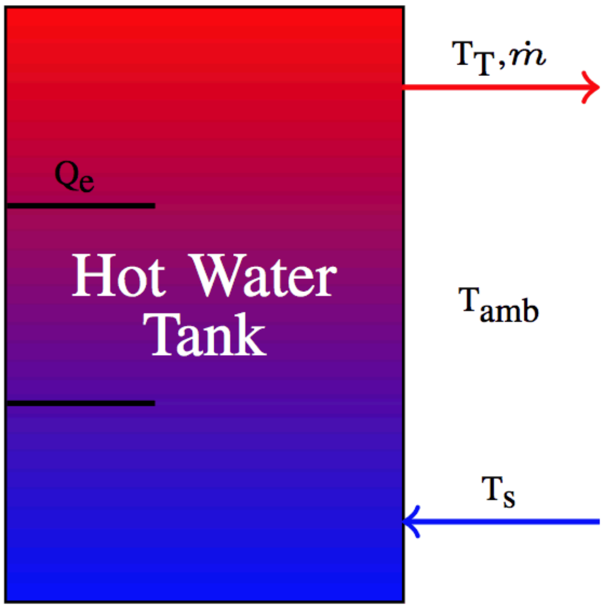
T_{amb}: ambient temperature (°C)

$\dot{m}$: mass flow rate (kg/s)

C_p: specific heat of water (4.18J/g °C)

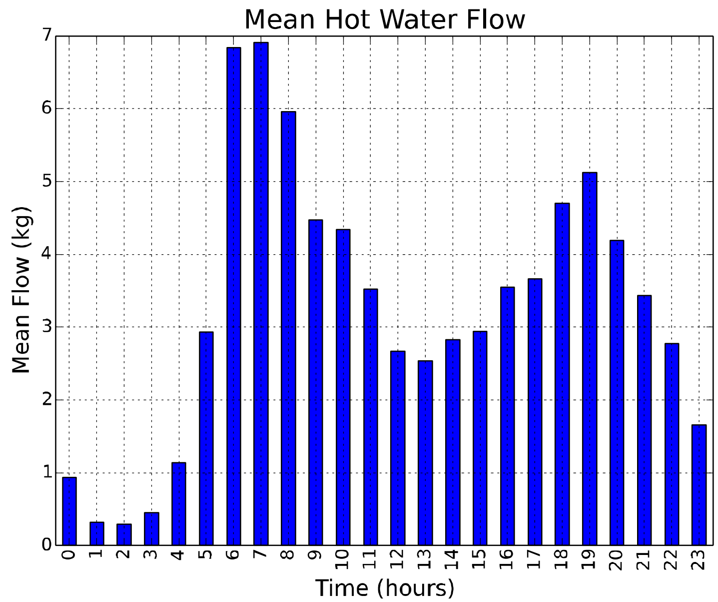
U: heat transfer coefficient (W/m^{2}K)

A: area of the tank surface (m^2)



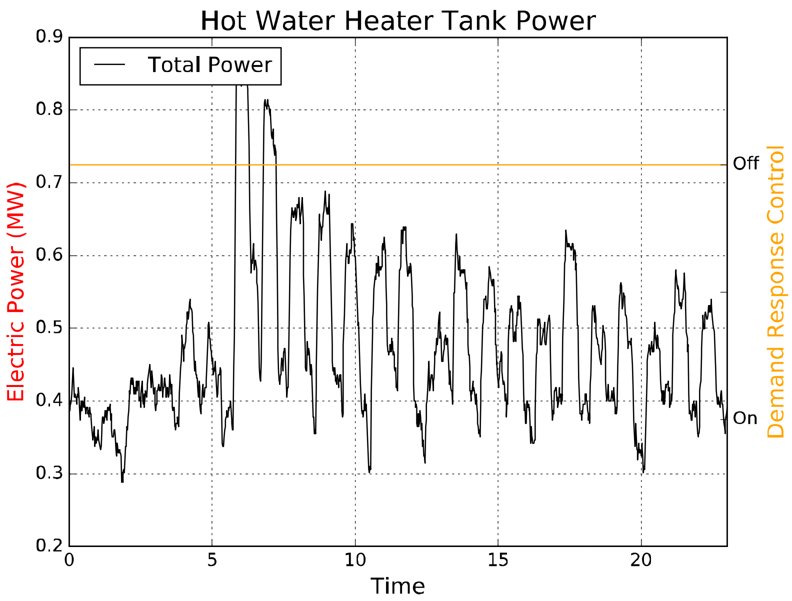
Electric Water Heater Results

- Realistic residential draw profiles[1]
- Randomly applied to simulation



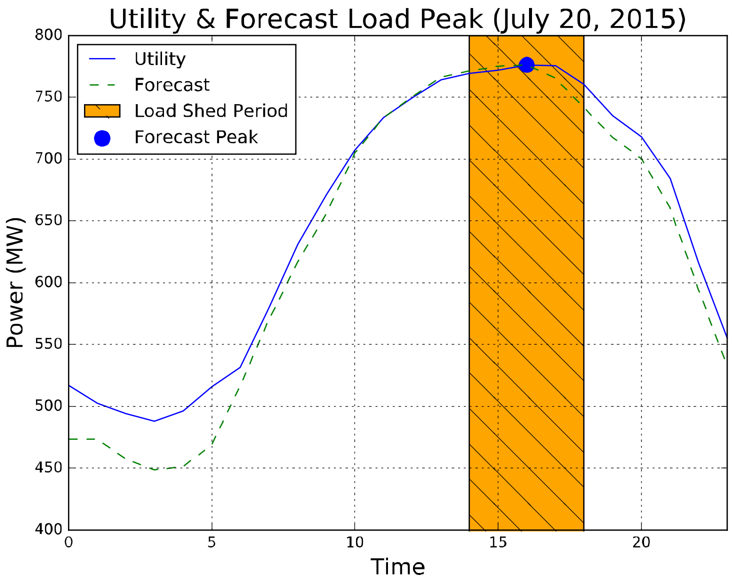
1. Hendron, Bob, Burch, Jay, and Barker, Greg, “Tool for Generating Realistic Residential Hot Water Event Schedules” in 2010 SimBuild, New York, NY, August 15-19, 2010

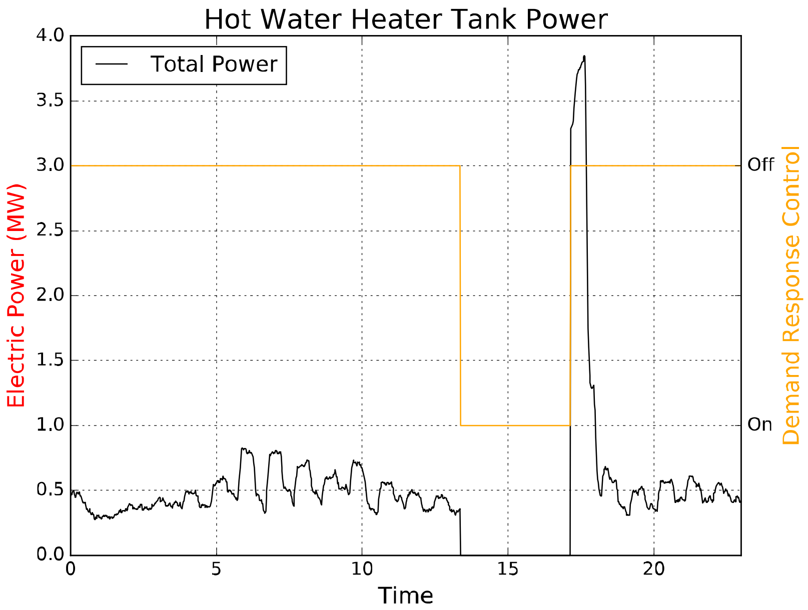
- Electric demand for 3,000 water heaters
- Max = 0.9 MW between 7 and 8 am
- Shed potential ~0.4-0.6MW



Peak Shaving Results

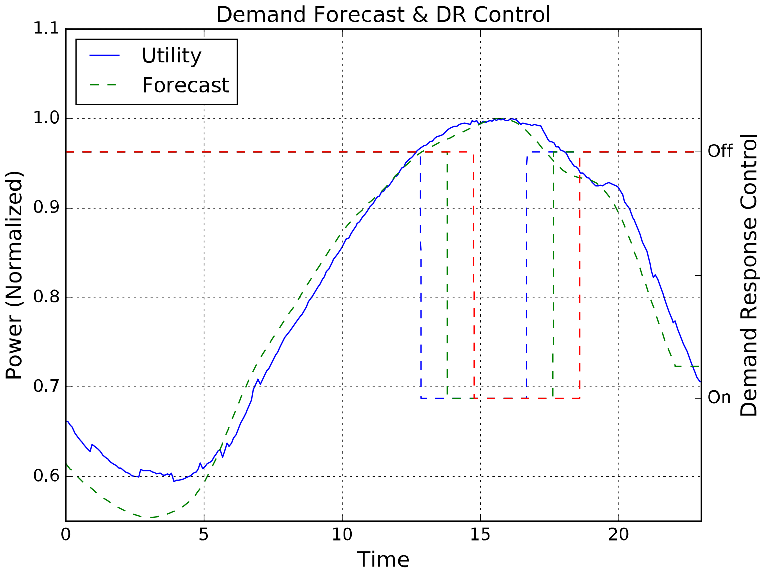
- Single Bin Approach
  - Turns off all EWH
  - Centered on Peak
  - Control
    - Off at $t_{peak} - 2$hrs
    - On at $t_{peak} + 2$hrs
- Power Reduction
  - 3,200 EWH
  - Reduce demand by
    - 0.3 – 0.5 MW
  - Rebound
    - > 3.5 MW

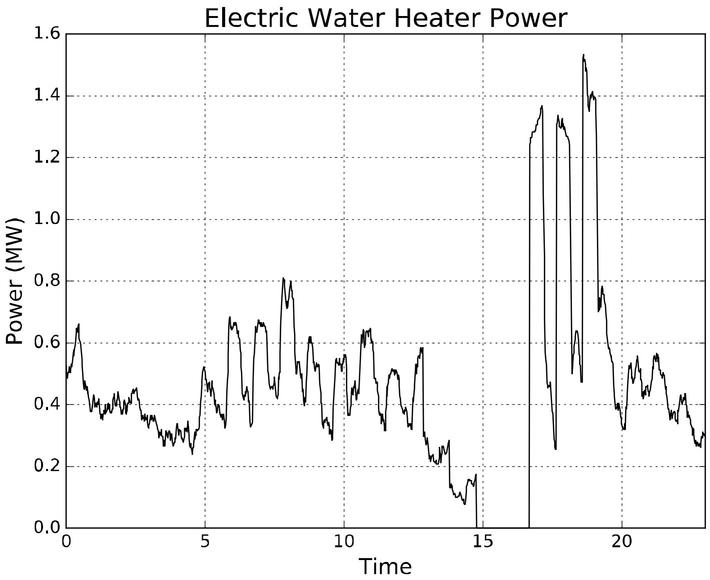




Rebound Reduction Strategy

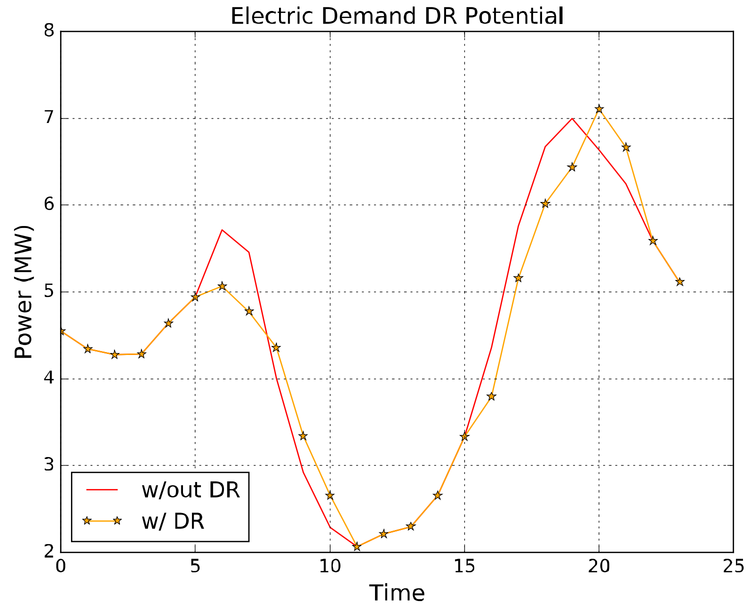
- Multiple Bin Approach
  - Staged control
  - Centered on peak
  - All off
    - $t_{peak} \geq t_{peak}$ - 1hrs
    - and at $t_{peak} \leq t_{peak}$ + 1hrs
- Power Reduction
  - 3,200 EWH
  - Reduce demand by
    - 0.3 – 0.6 MW
  - Rebound
    - ~ 1.5 MW
    - 57% reduction





Next Steps

- Implement more peak shaving controls
  - Extended bins
  - Tank temperature set point control
  - Dead band control
  - Etc.
- Integrate electric batteries
- Test controls in Grid Simulation w/ NREL
- Implement PV integration controls
  - Improve ramp rates



PVSC 44 Abstract:
Jones, C.B, Lave, Matthew, Johnson, Jay, and Broderick Robert, “Demand Response of Electric Hot Water Heaters for Increased Integration of Solar PV” in PVSC 44, Washington DC, June, 2017

Thank You

Questions?

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