

## DOCKETED

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# Domestic Hot Water



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March 29, 2016



## DHW Revision Consultant Team

- Chip Barnaby
- Jim Lutz
- Neal Kruis, Big Ladder Software
- Bill Deoreo, Aquacraft
- Ben Larson, Nick Kvaltine, Michael Logsdon, Ecotope
- Danny Parker, Florida Solar Energy Center



# Domestic Hot Water (DHW)

## Agenda

- Background
- DHW Loads Model
- Hot water draw schedule
- Heat pump water heater simulation
- Compliance results
- Status and plan



## Background

- What is Domestic Hot Water (DHW)
- Current DHW load
- Current CA water heater energy use model
- Current DHW energy use estimate

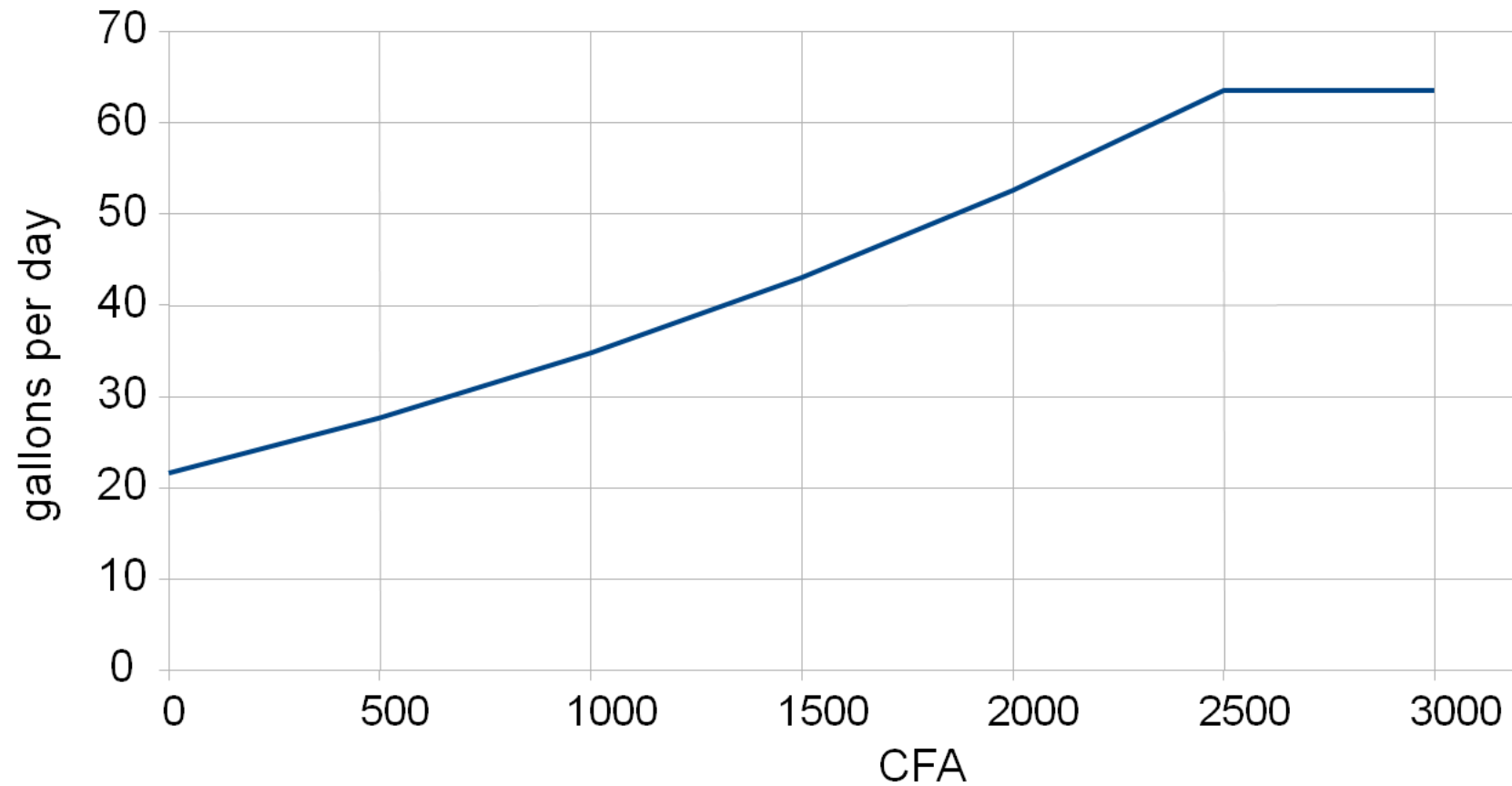


## Domestic Hot Water (DHW) End Uses

1. Showers
  - mixed with cold to get ~105 F out of the nozzle
2. Faucets in kitchens, bathrooms etc.
  - ~50% hot water
3. Clothes washers
  - ~22% of total water use is hot
4. Dishwashers
  - 100% hot water
5. Baths
  - Mixed with cold similar to showers

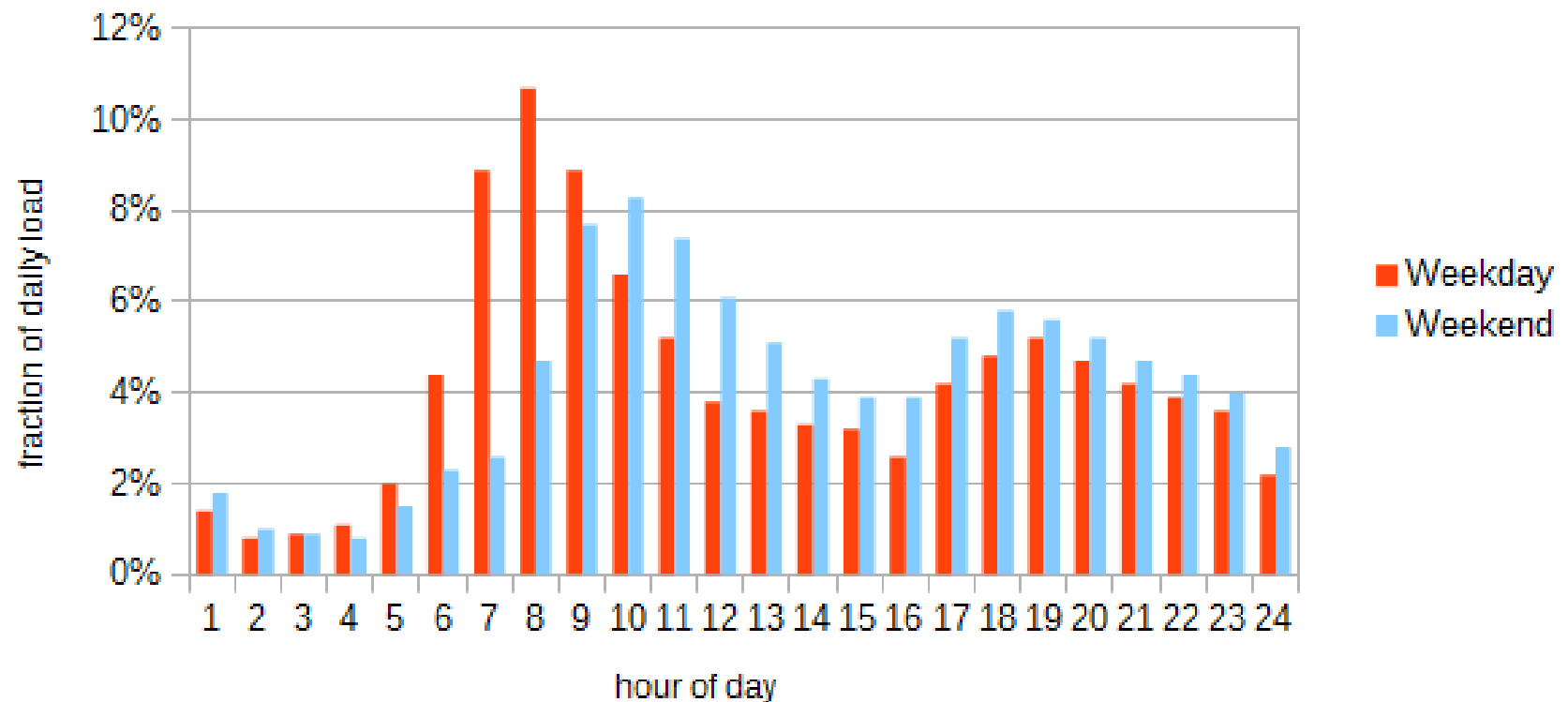


## Current CA DHW Load Model





# Current Water Heating Schedules



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## Current water heater energy use model

DOE rated Energy Factor (EF) is efficiency input

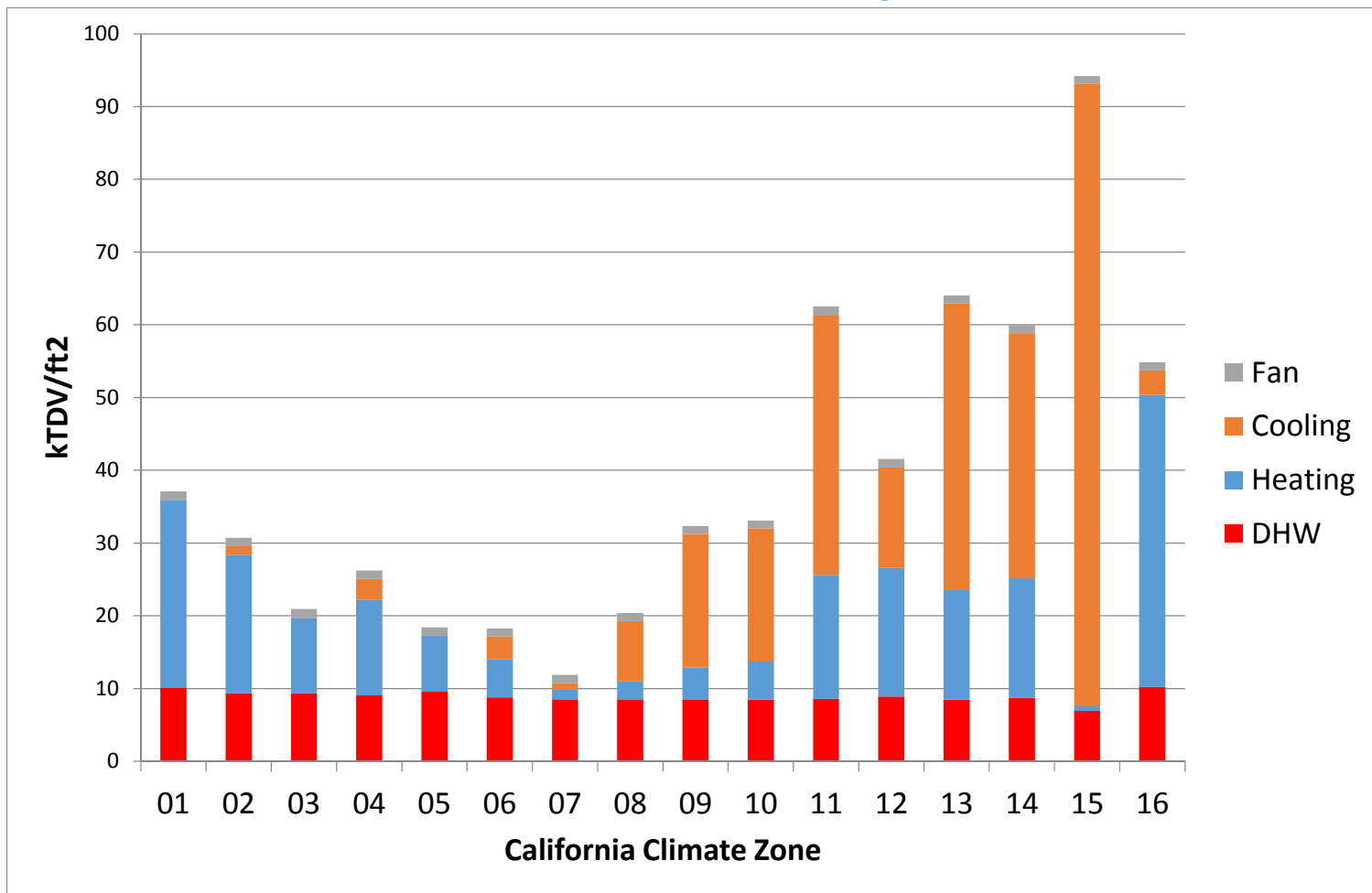
$$\text{Energy} = \text{Load (gph)} / \text{EF}$$

With some adjustments



# Current Single Family DHW Energy

(current CBECC-Res for Instantaneous gas water heater)



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## New Improved DHW Loads Model

- Completely new DHW loads model for California Homes
  - Based on a representative sample of 730 California families living in single family homes
  - Characteristics data for a subset of 462 families
  - Measured end use water consumption at the fixture
  - Load at the hot water heater estimated from similar non-California research that included water heater meters
  - Load by end use allows precise credit for end use efficiency measures

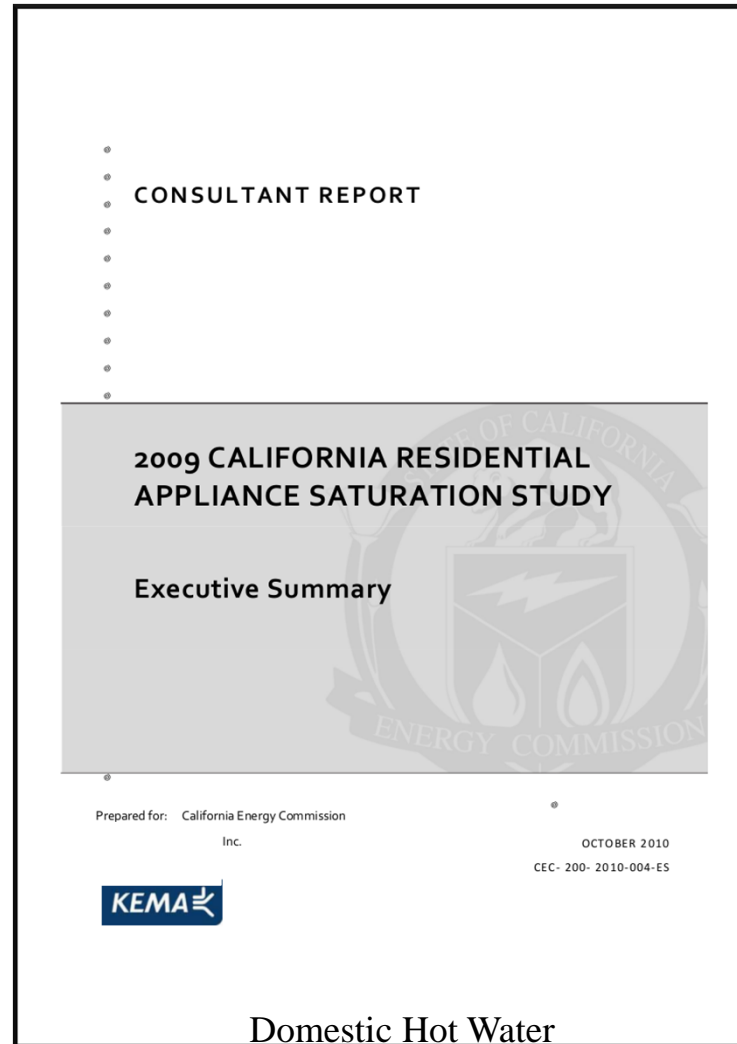


## Why the New DHW Loads Revision

- DHW is a big part of getting to ZNE
- Heat Pump Water Heaters may be part of the solution
  - Time of DHW electricity use is important for TDV
  - Making the draw schedule realistic because HPWH efficiency depends on load
    - Diverse rather than average loads
    - Include peaks that cause HPWH backup resistance heat
- People use hot water, not houses
  - Occupancy of homes changes over their lives
  - Need to consider DHW loads for the full range of families



# RASS: CA Data About People and Homes





## Family Size Related to Number of Bedrooms

Weighted fraction of single family units by occupants and bedrooms						
	Number of Bedrooms					
Occupants	1	2	3	4	5	6
1	0.42	0.26	0.14	0.07	0.06	0.06
2	0.33	0.39	0.37	0.28	0.17	0.17
3	0.10	0.14	0.18	0.17	0.14	0.14
4	0.12	0.08	0.16	0.27	0.23	0.23
5	0.02	0.07	0.08	0.13	0.17	0.17
6	0.00	0.03	0.04	0.04	0.12	0.12
7	0.00	0.00	0.01	0.02	0.06	0.06
8	0.00	0.01	0.00	0.01	0.01	0.01



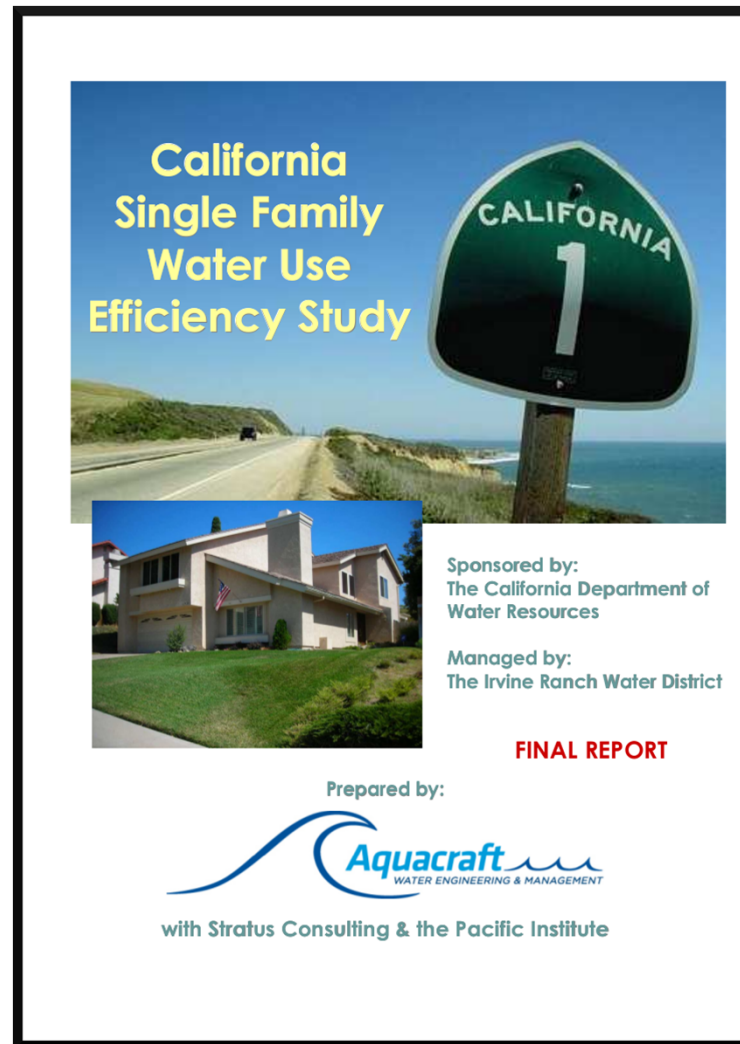
## Population Fraction by Age and Family size

SF	Age	Fraction of each age group in the total population of families of that size				
Occupants	0-5	6-18	19-34	35-54	55-64	65-99
1	0.04	0.00	0.03	0.14	0.22	0.57
2	0.03	0.01	0.06	0.19	0.27	0.44
3	0.07	0.12	0.18	0.31	0.17	0.14
4	0.12	0.24	0.17	0.33	0.09	0.06
5	0.128	0.283	0.189	0.285	0.06	0.05
6	0.14	0.30	0.19	0.24	0.07	0.06

Single Family Homes



## Measured CA Data for Hot Water Draws



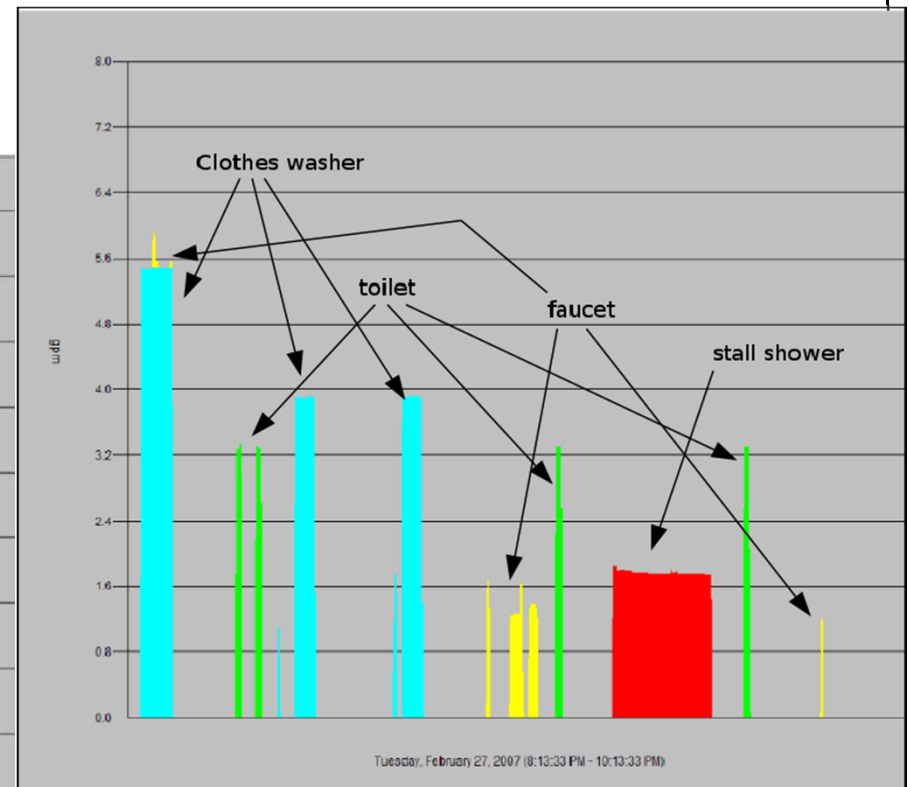
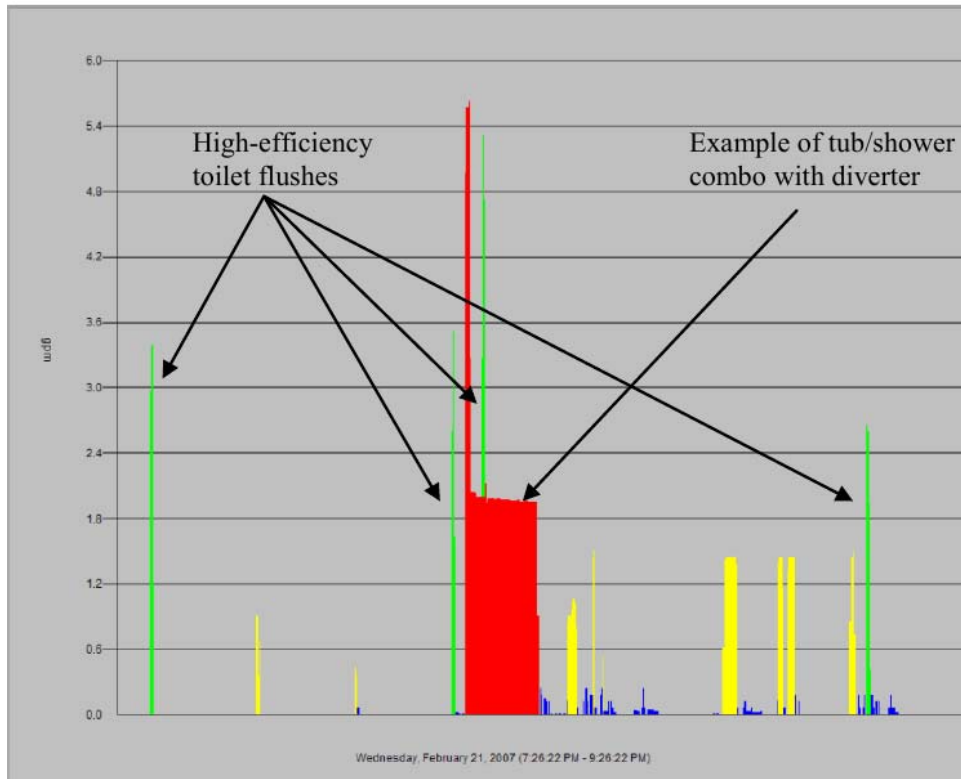
and other studies  
by Aquacraft

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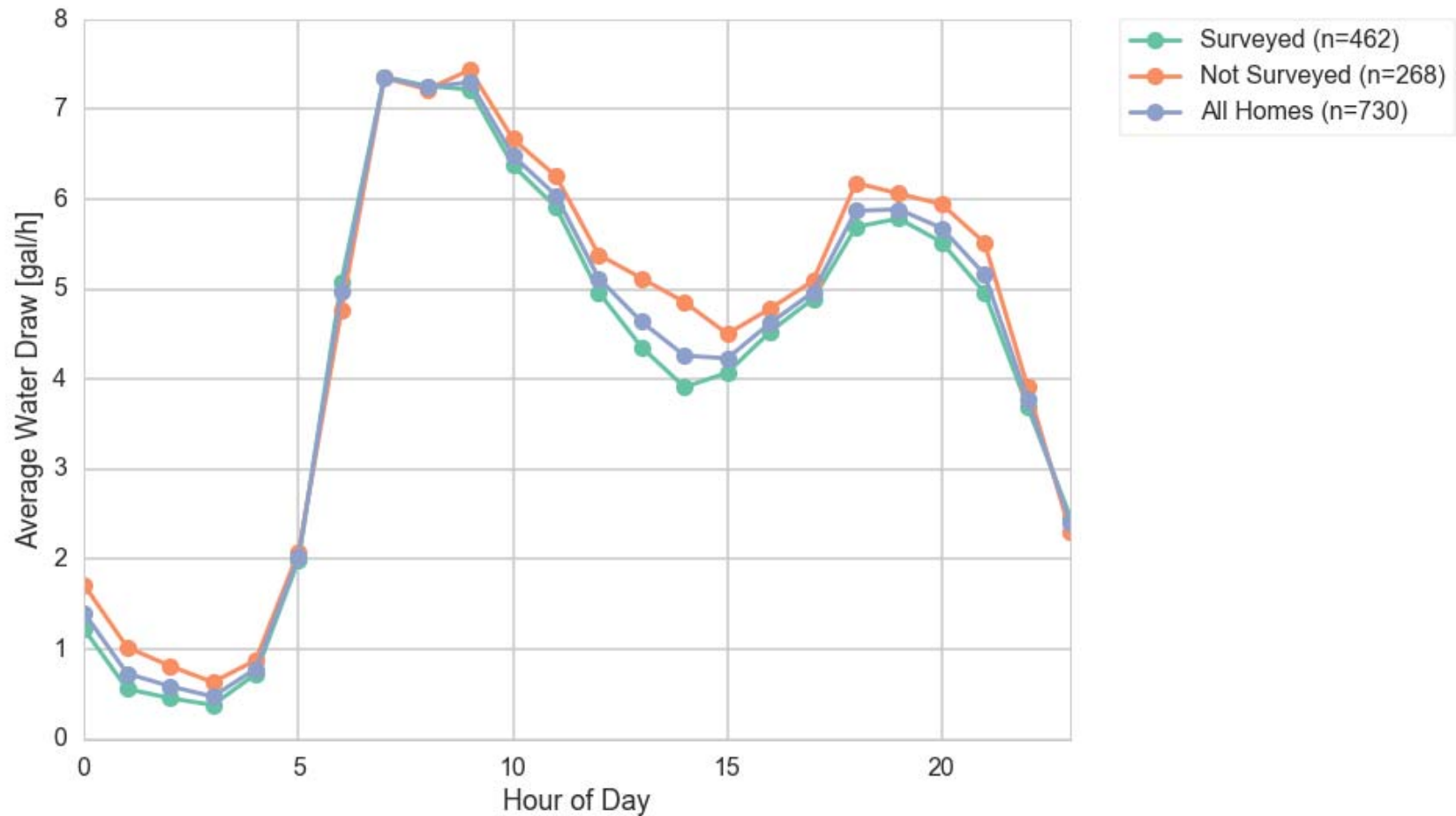
# Water Meter 10 sec Flow Trace Analysis





# CA SF Total DHW Related Water Use

(showers, faucets, clothes washers, dish washers, baths)



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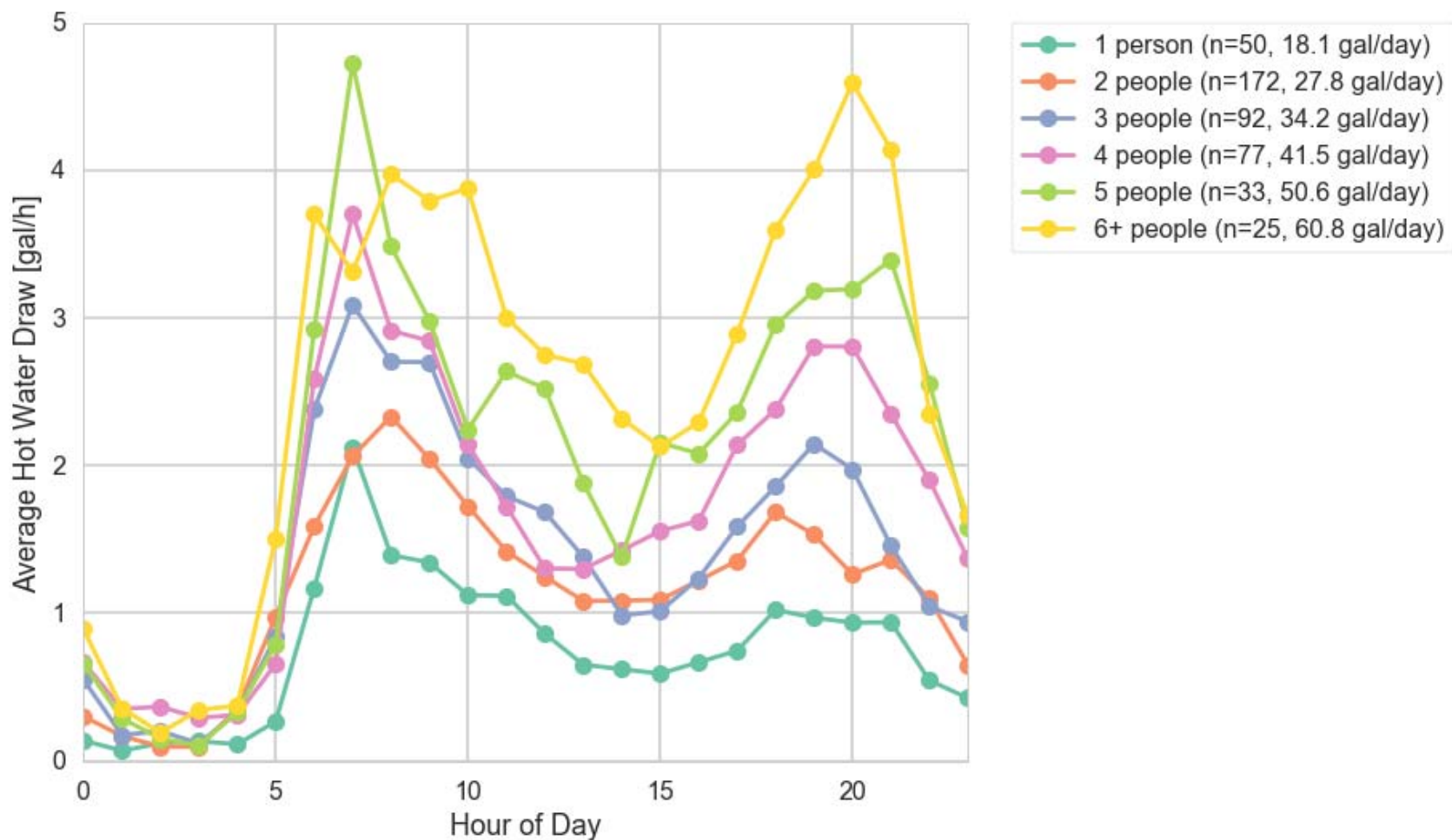


## Getting to Hot Water at the Heater in 2017

- Everything adjusted for Distribution Losses using current multipliers (loads measured at the fixture)
- Showers adjusted for ~105 F out and new CA Standard of 2 gpm or less
- Faucets adjusted for 50% hot water fraction and lower flow rate Standard for faucets
- Clothes washers adjusted for 22% hot water fraction and latest DOE water use standard
- Dishwashers adjusted for latest DOE water use standard
- Baths adjusted for 105 F

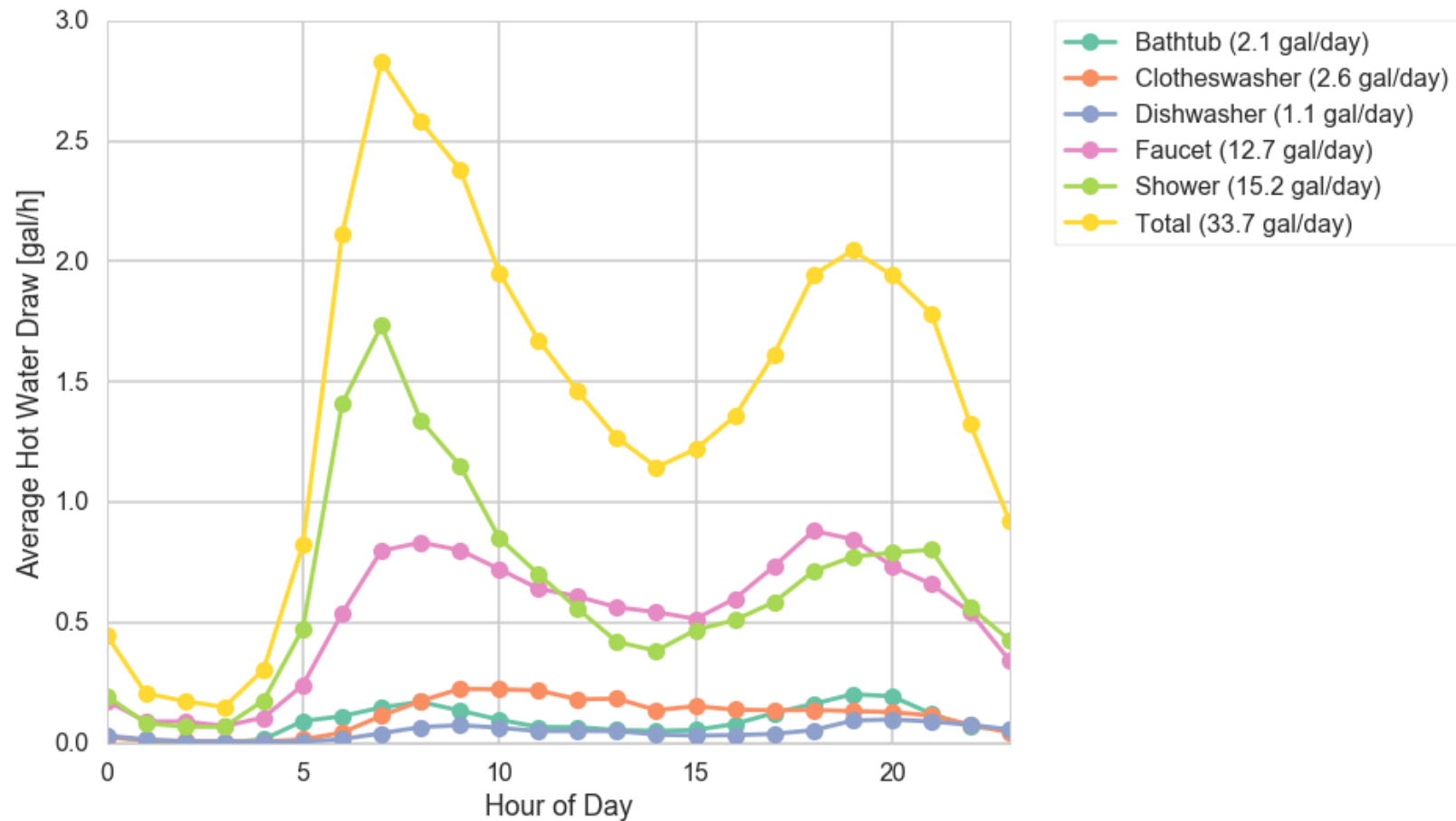


## Hot Water Use by Hour and Occupants



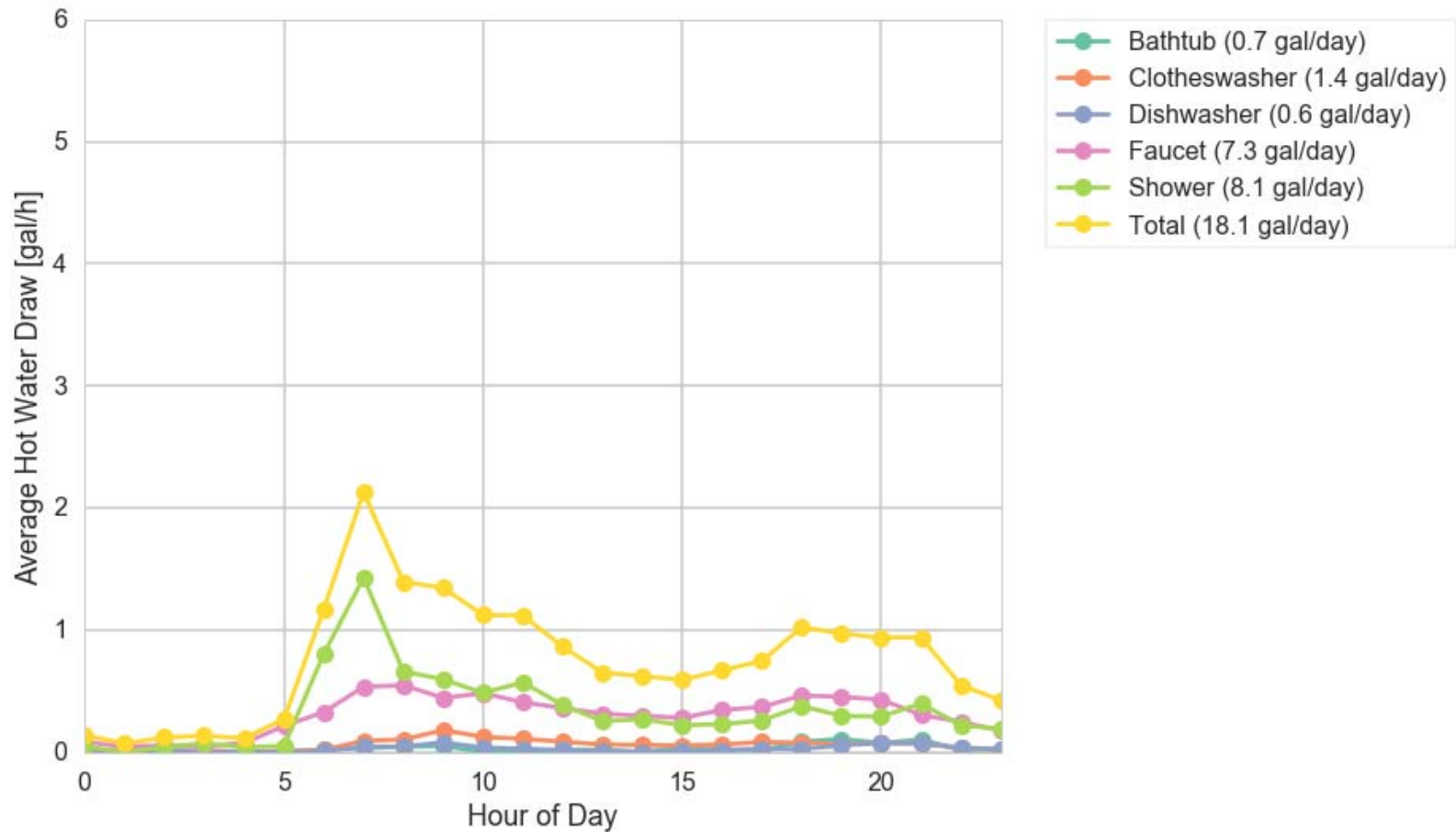


## Average Hourly Hot Water by End Use



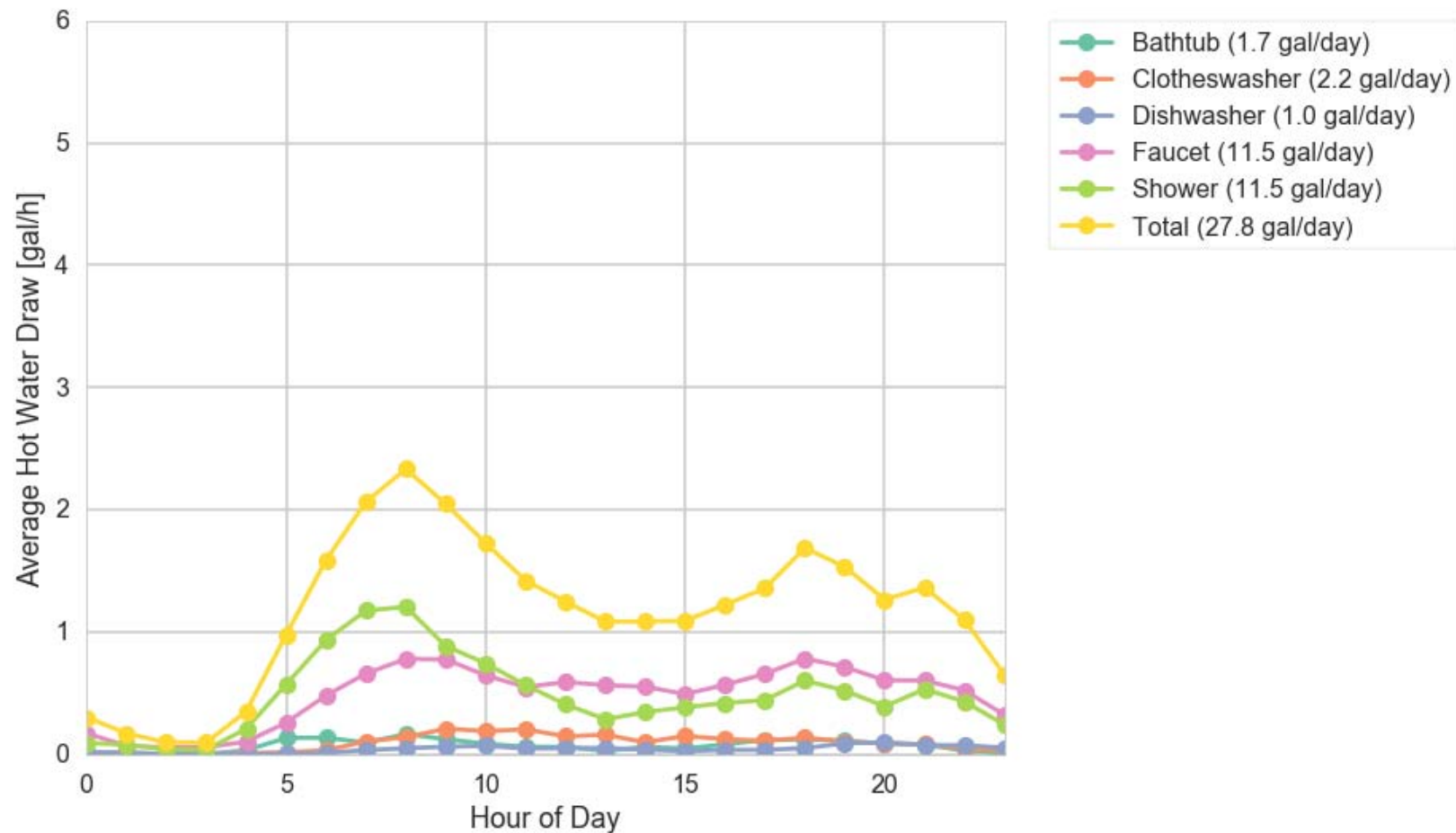


## Average Hourly Hot Water for 1 Person



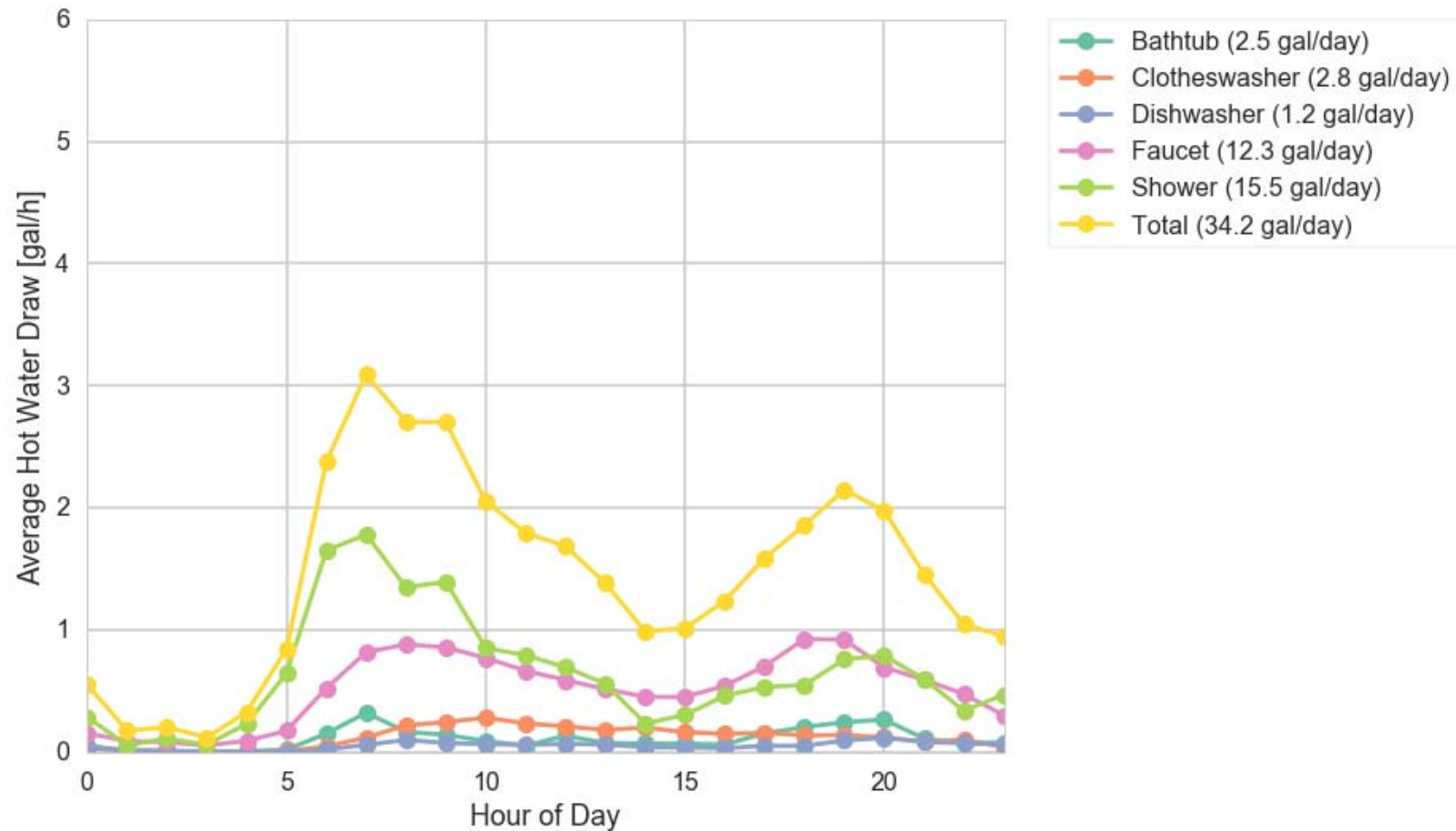


## Average Hourly Hot Water for 2 Persons





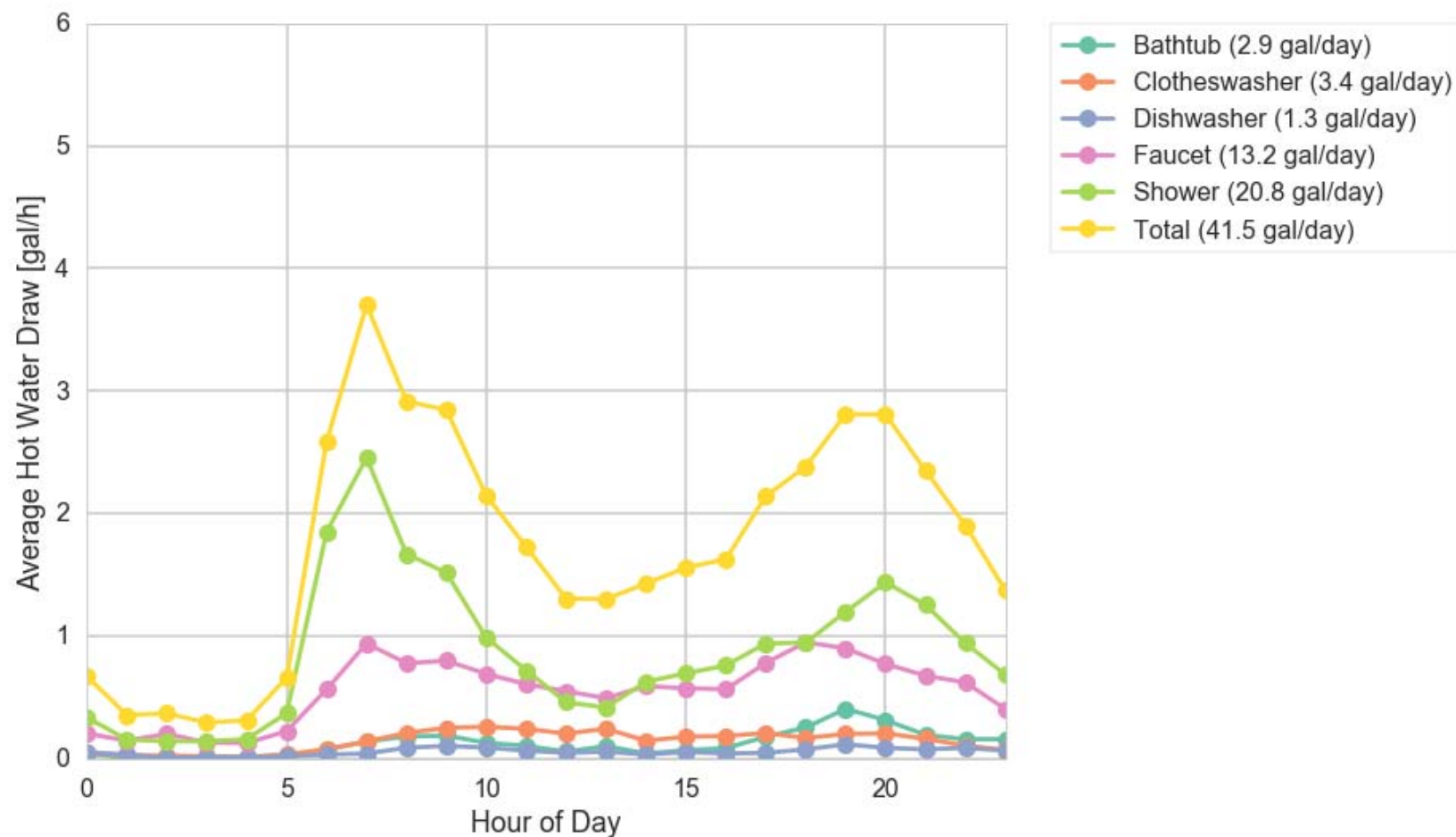
## Average Hourly Hot Water for 3 Persons





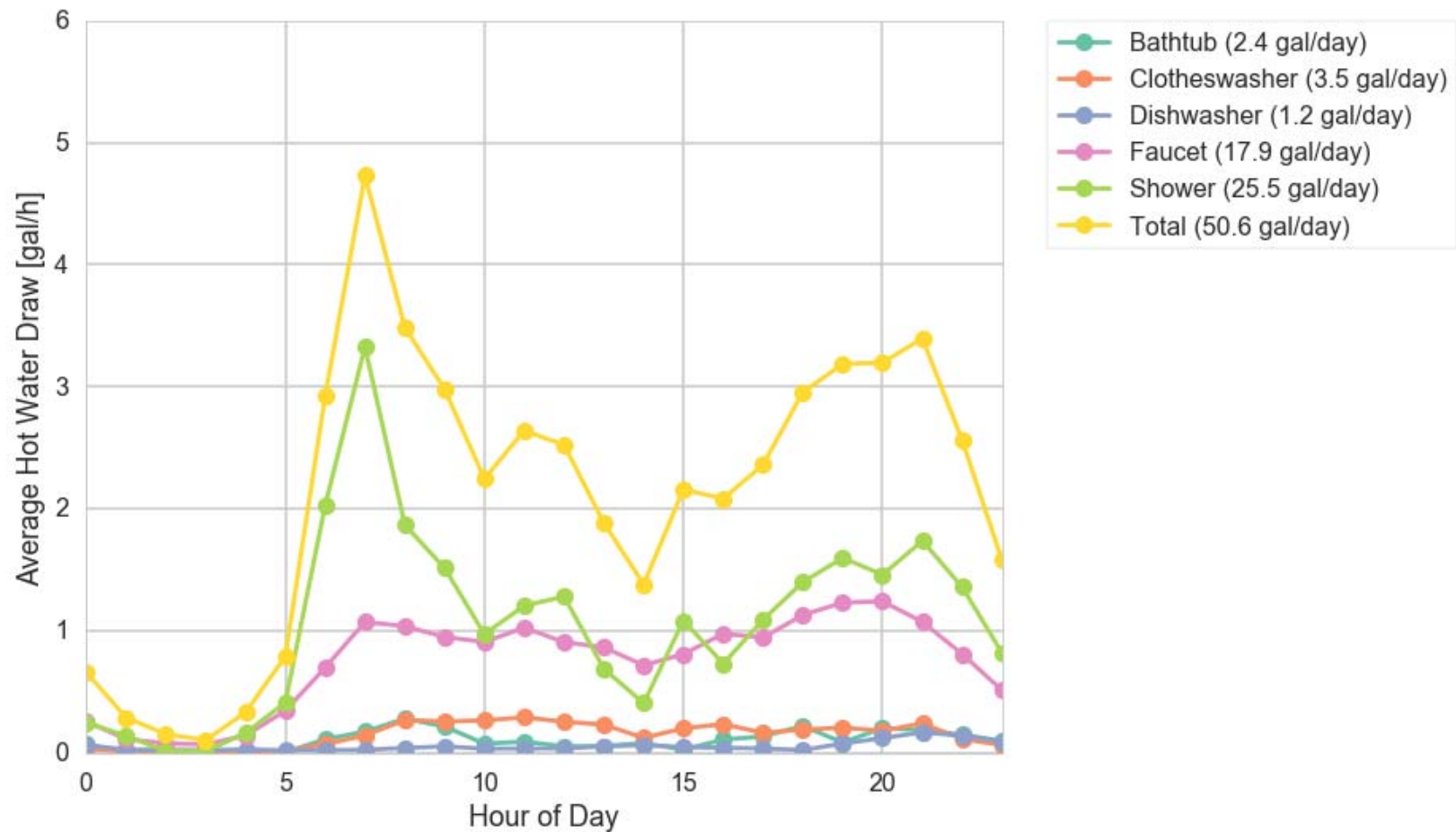


## Average Hourly Hot Water for 4 Persons



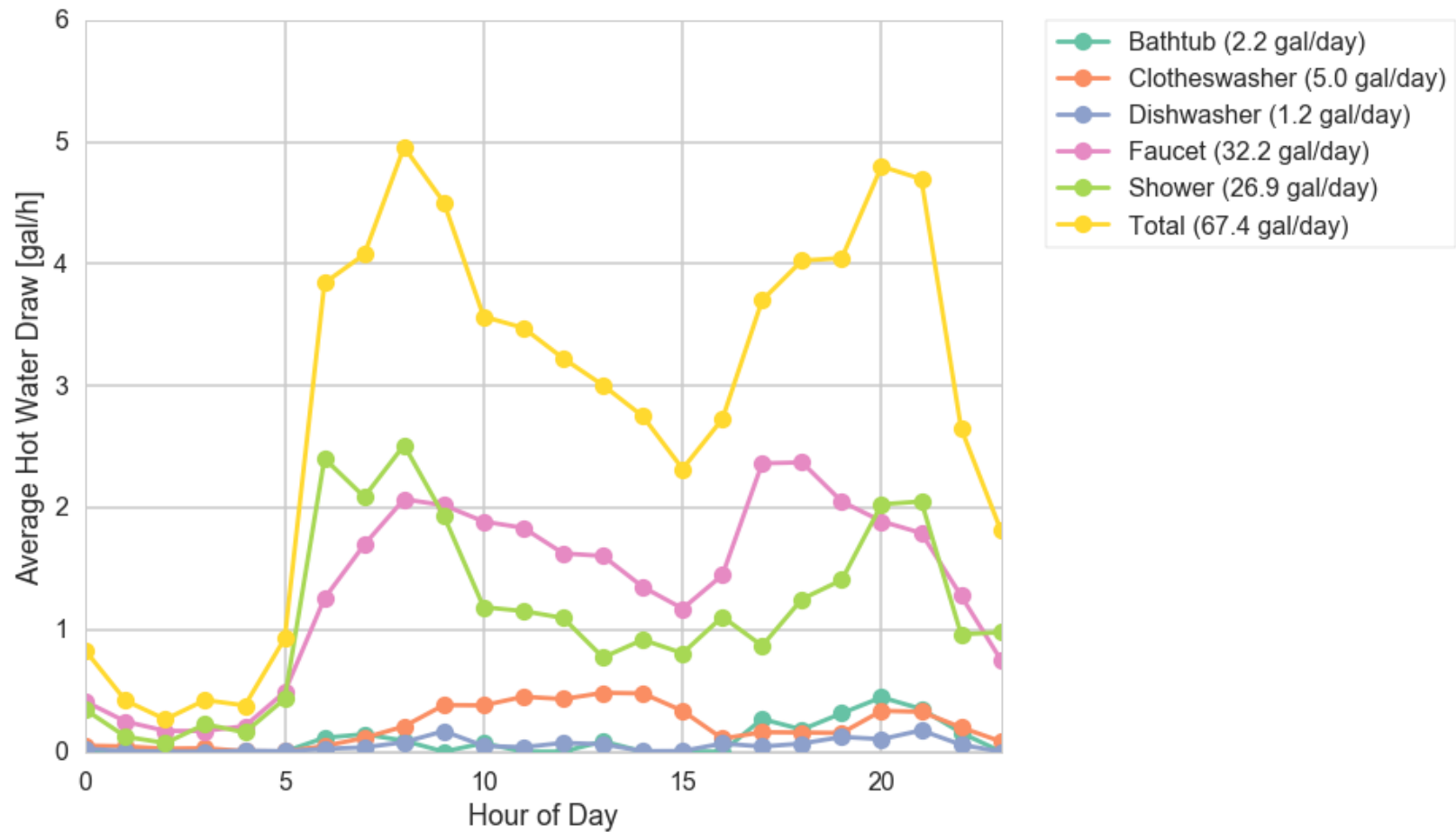


## Average Hourly Hot Water for 5 Persons





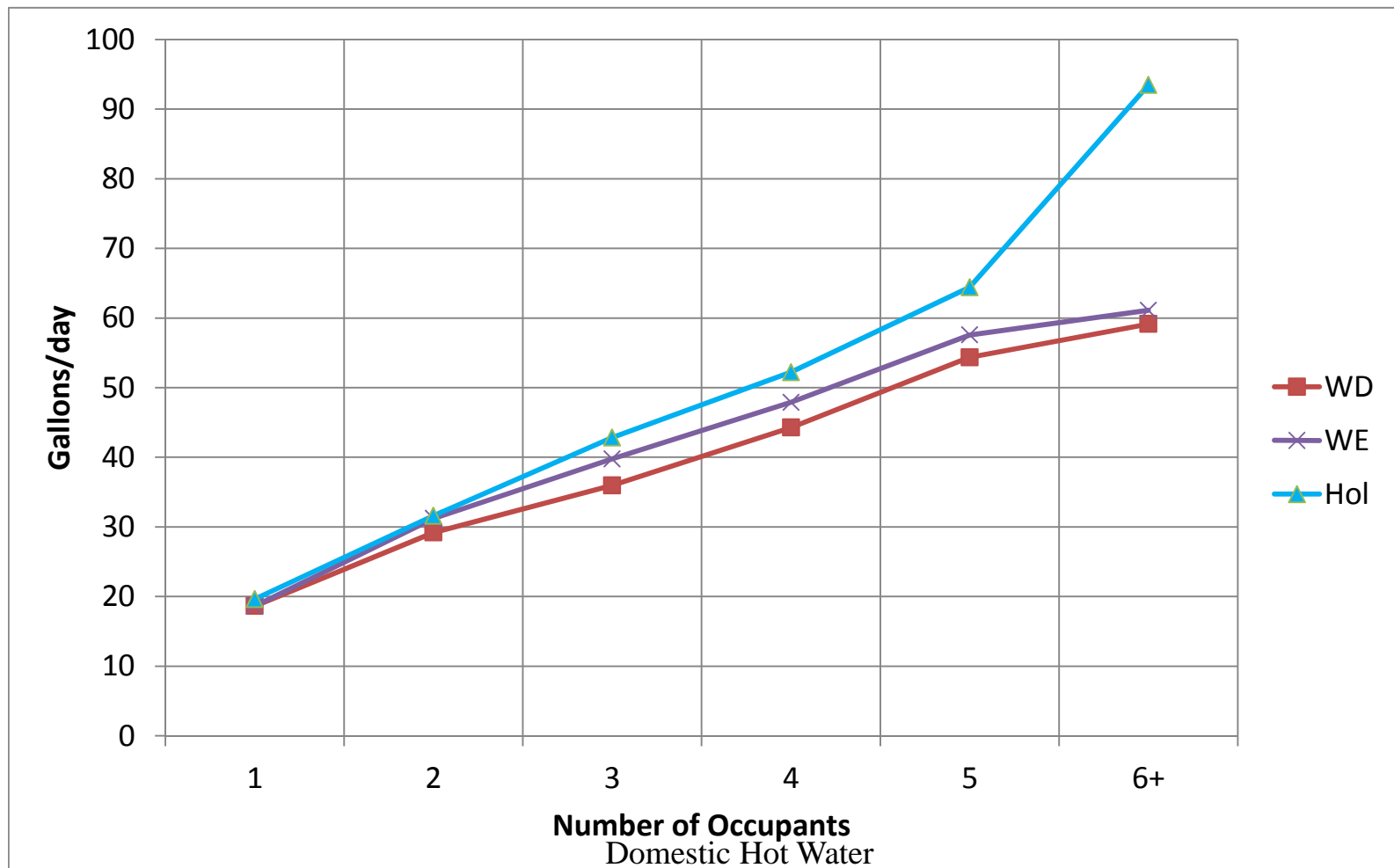
## Average Hourly Hot Water for 6 Persons



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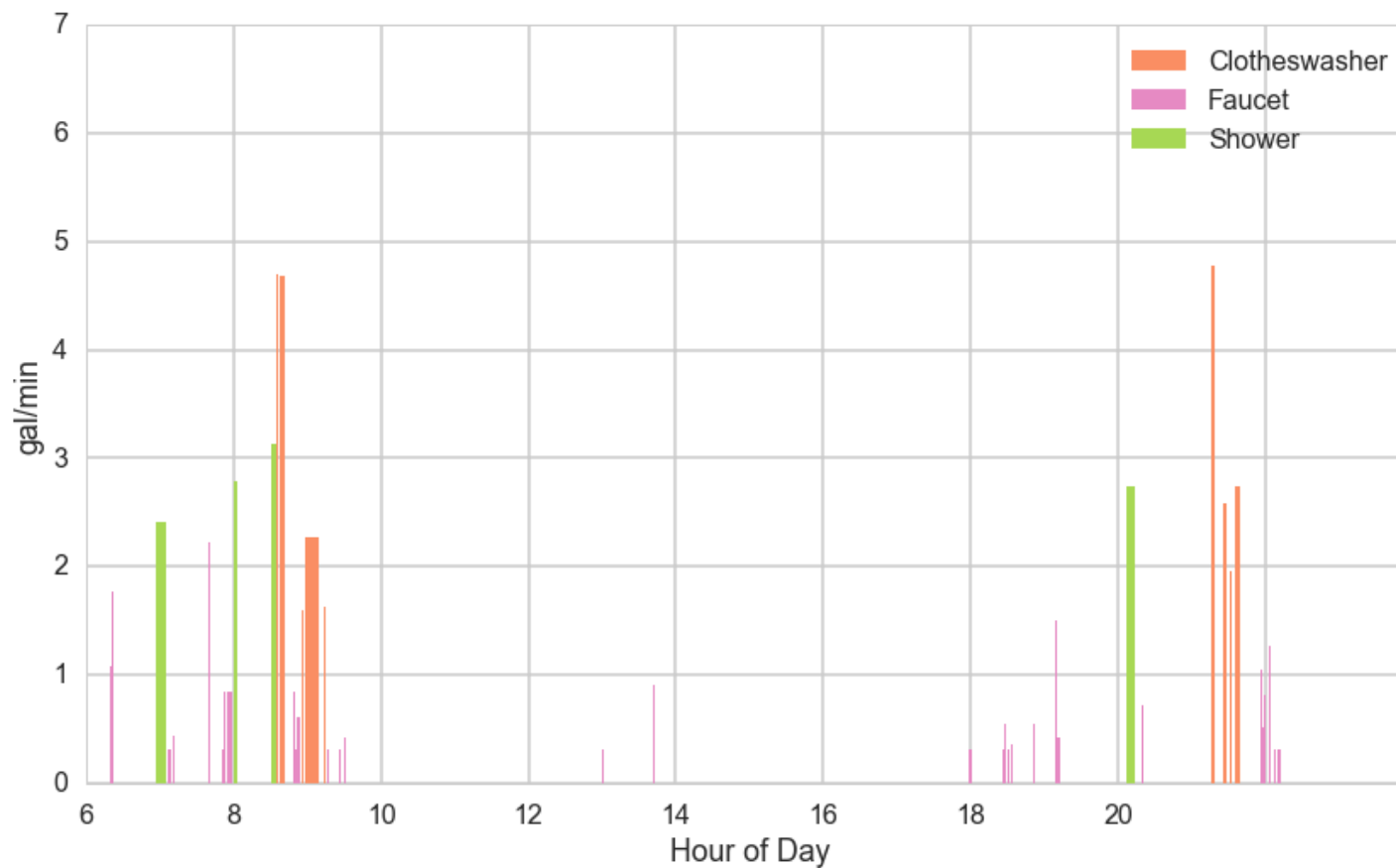
## Gal/day by Day Type and Occupants





# Hot Water Draws for a Home on 1 Day

House: 15156, 4 Occupant(s)

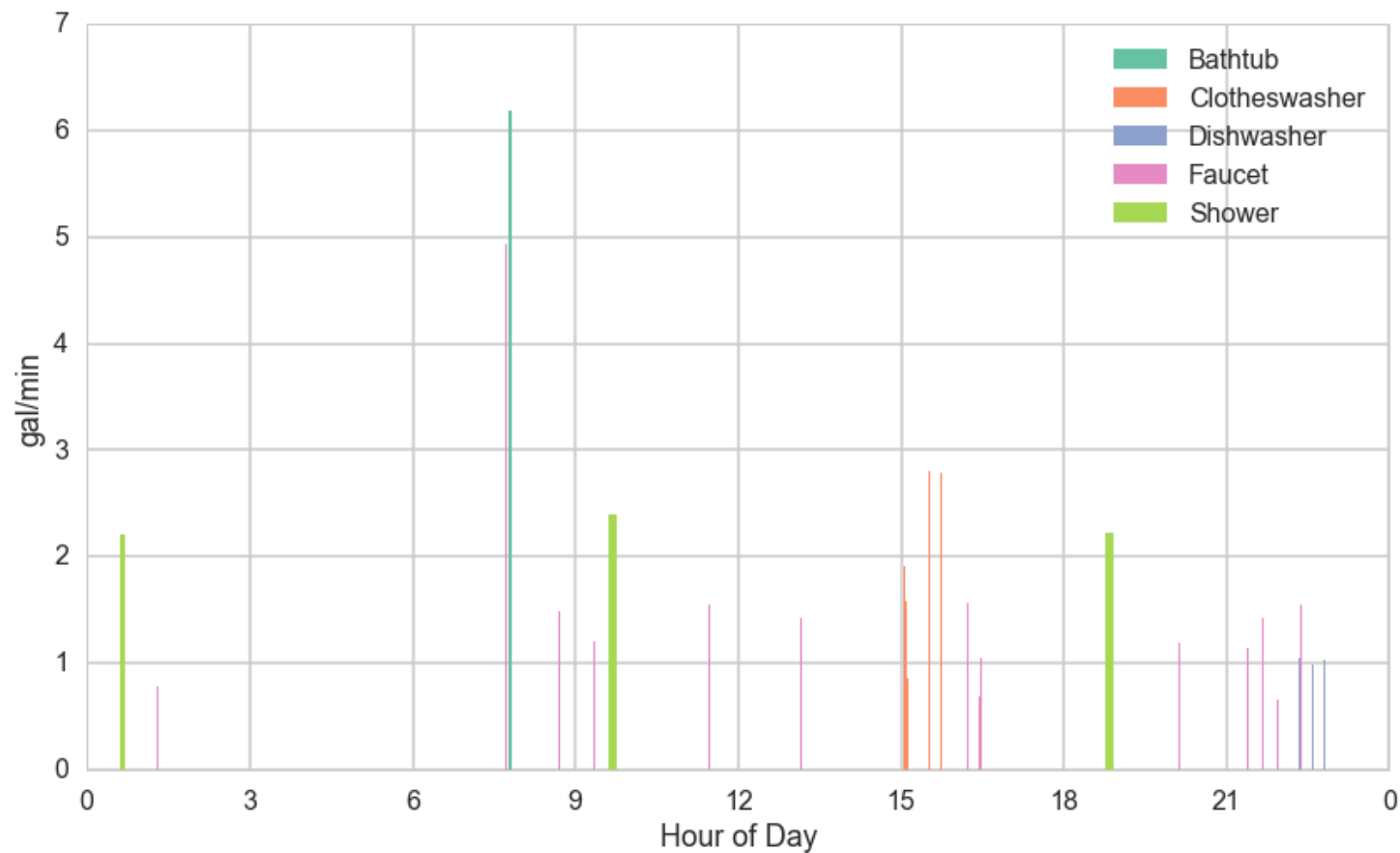


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# Hot Water Draws for 2<sup>nd</sup> a Home on 1 Day

House: 17197, 4 Occupant(s)



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## Selecting Real Data For the Draw Schedules

- Separately for each subgroup by of Number of Occupants, on Weekdays, Weekends and Holidays
- Calculate the total DHW GPD each monitored day
- Divide the subgroup days into strata (5 WD, 2 WE) based on GPD
- Select one day from each strata so that the RMS error is minimized for:
  - Gal/hr compared to the average Gal/hr for the subgroup
  - Gal/day for each end use compared the average for the subgroup



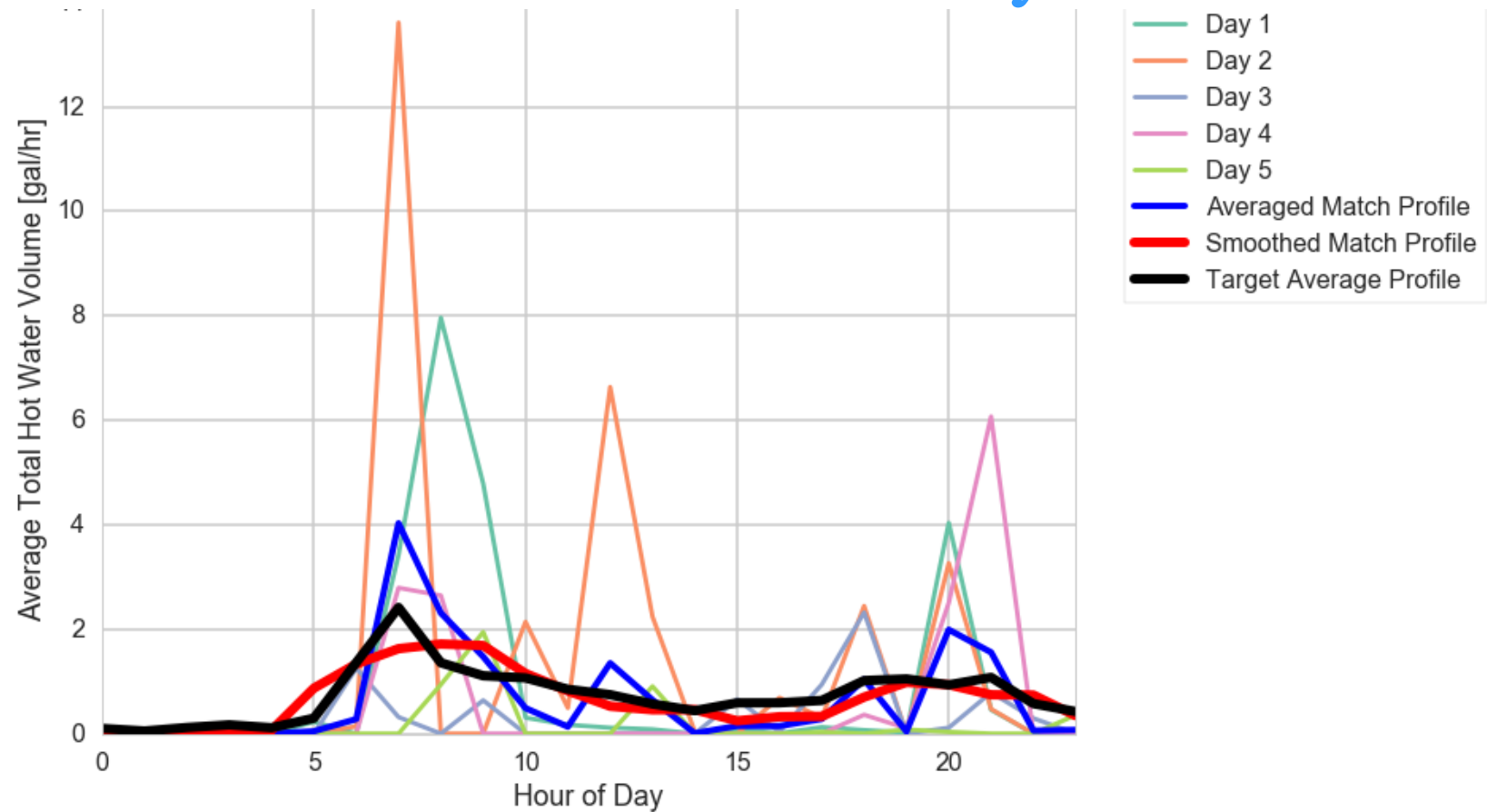
## Resulting Draw Schedules

- One 7 day week plus 1 holiday for each number of occupants (1 - 6+)
  - 5 weekdays
  - 2 weekend days
  - 1 Holiday
- Annual schedule for each number of Bed Rooms
  - Fraction of days with number of occupants = RASS for single family and multi-family separately
  - Randomly assigned by weekend, weekday, holiday to the weather file/TDV calendar
  - Same schedule for every analysis of each number of BR



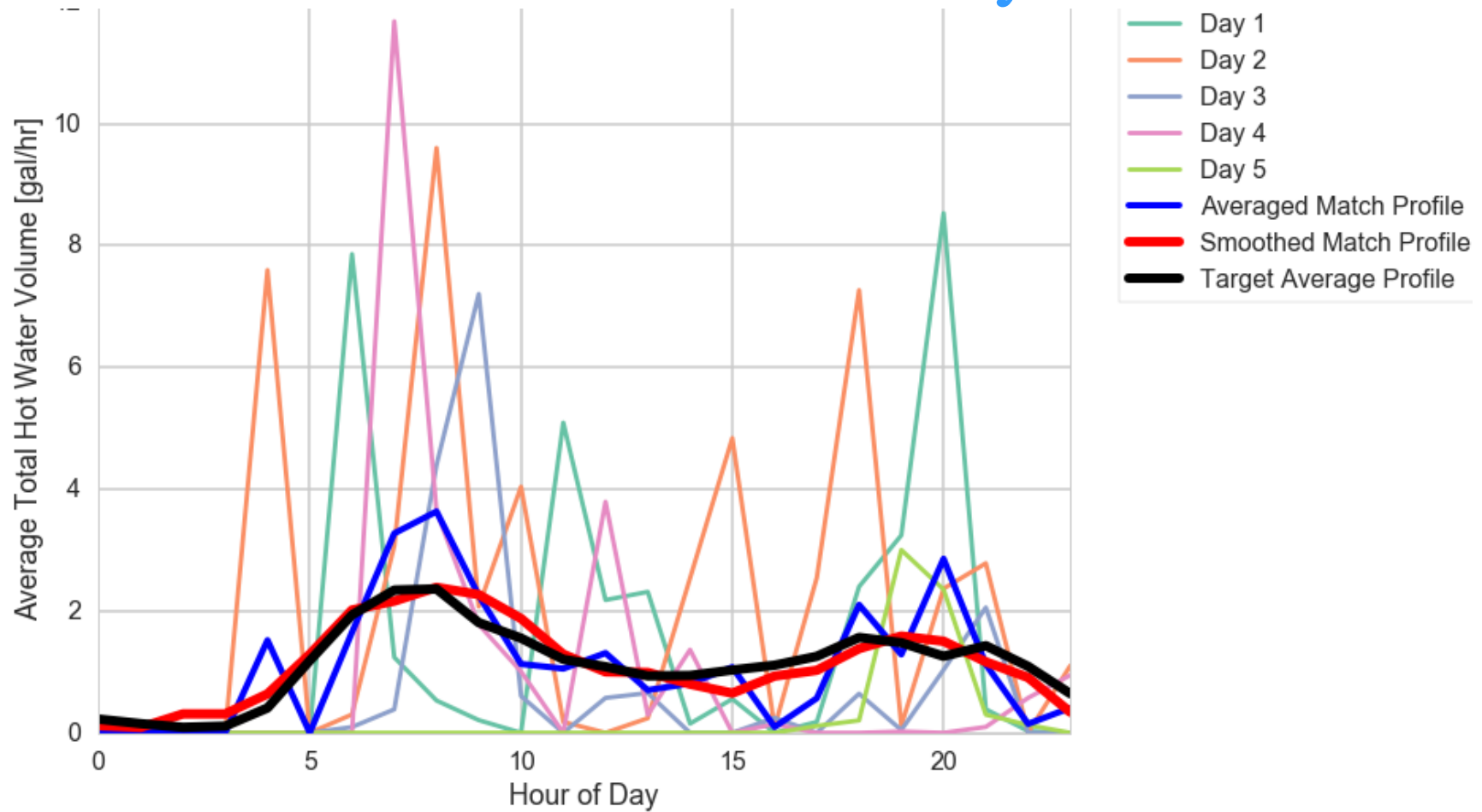


## 1 Person Selected Weekday Profile





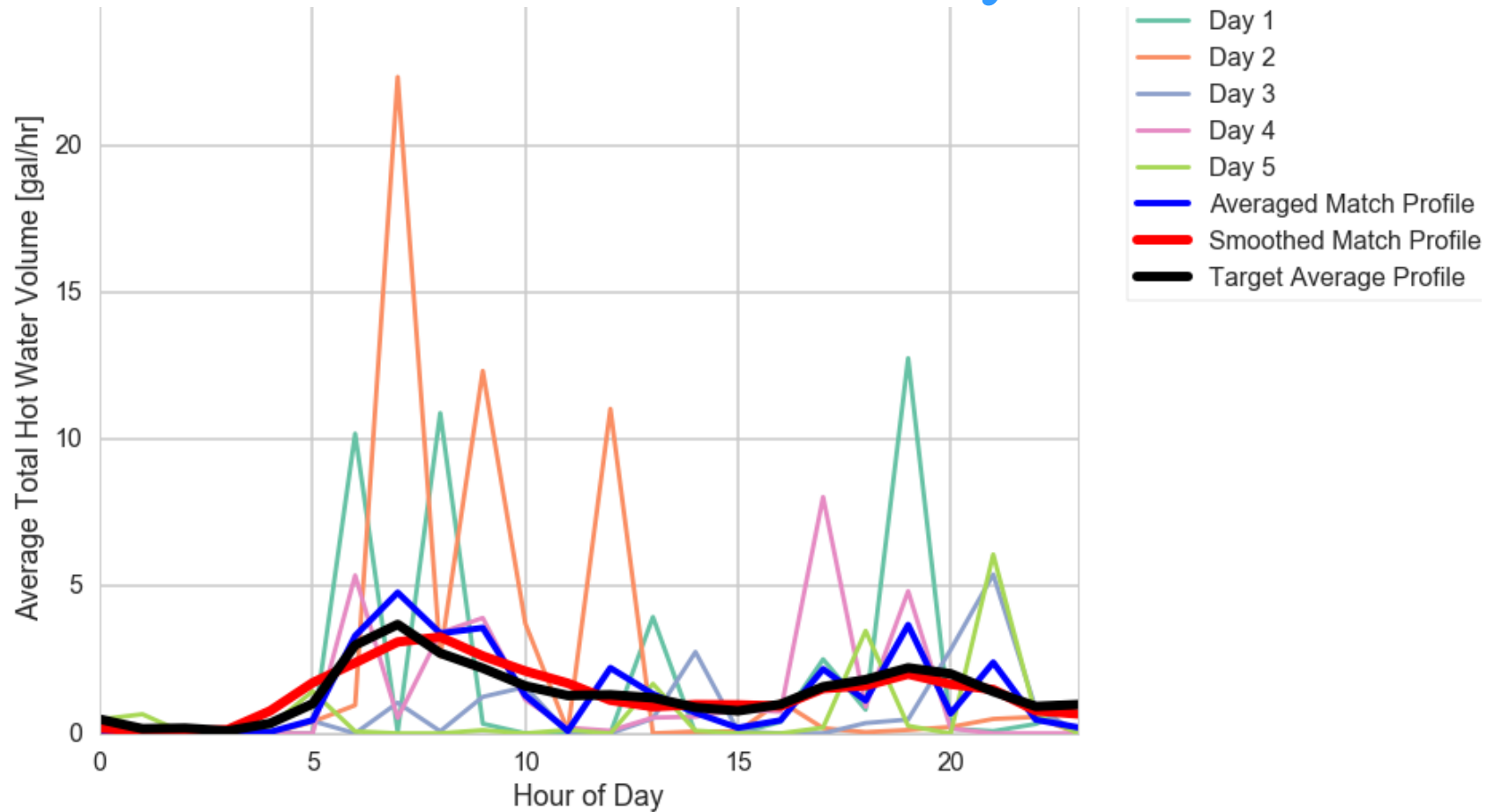
## 2 Person Selected Weekday Profile



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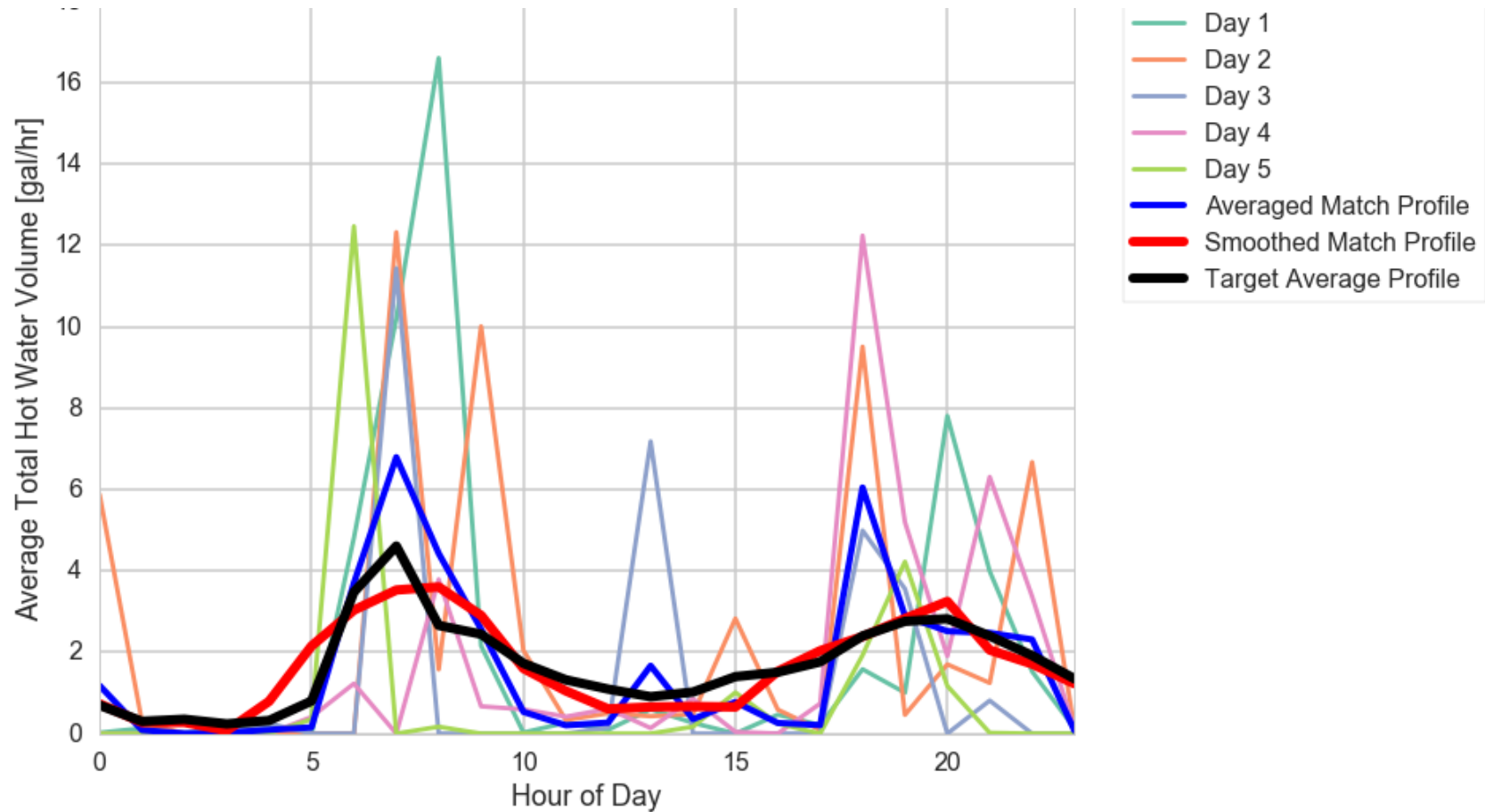
## 3 Person Selected Weekday Profile



Domestic Hot Water



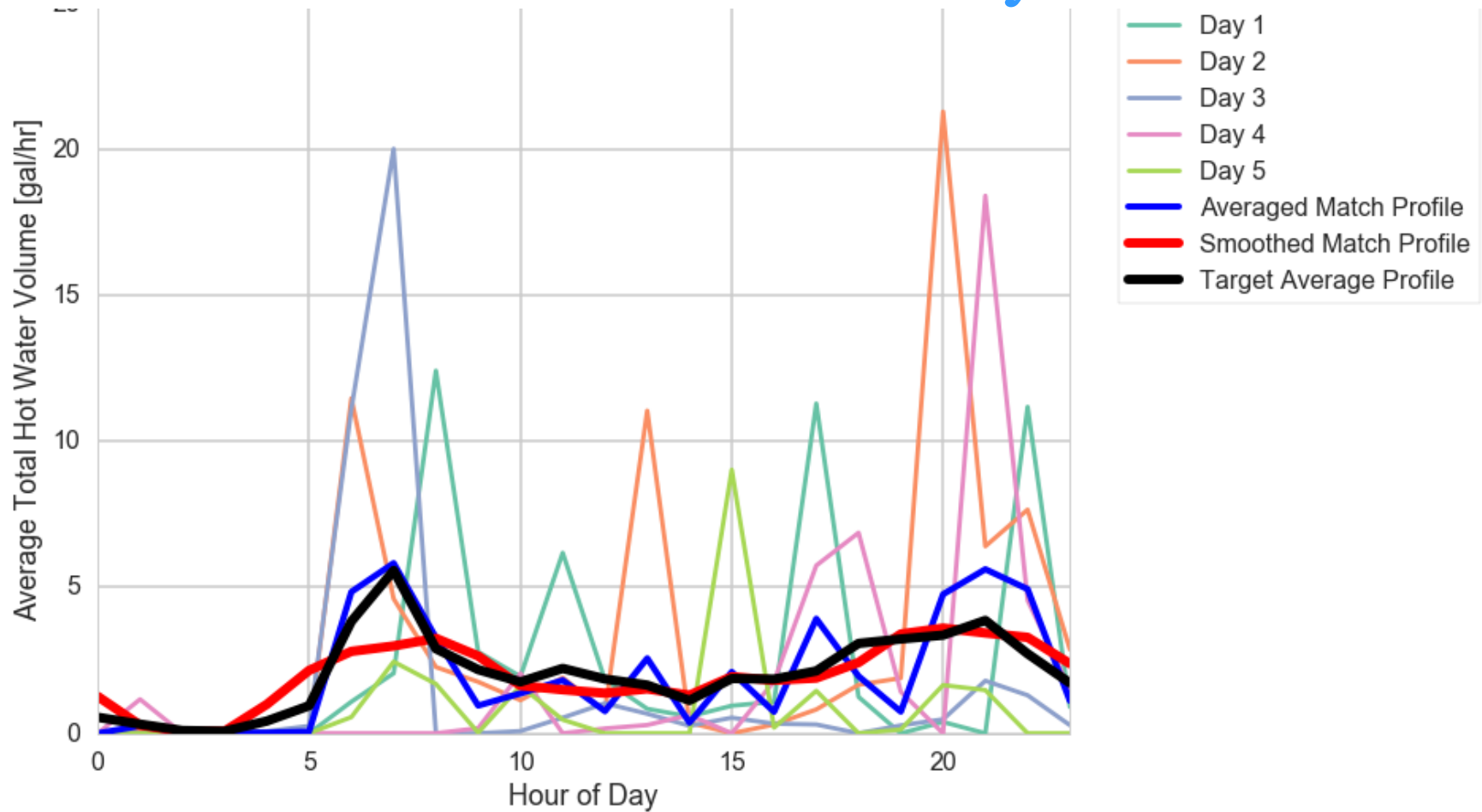
## 4 Person Selected Weekday Profile



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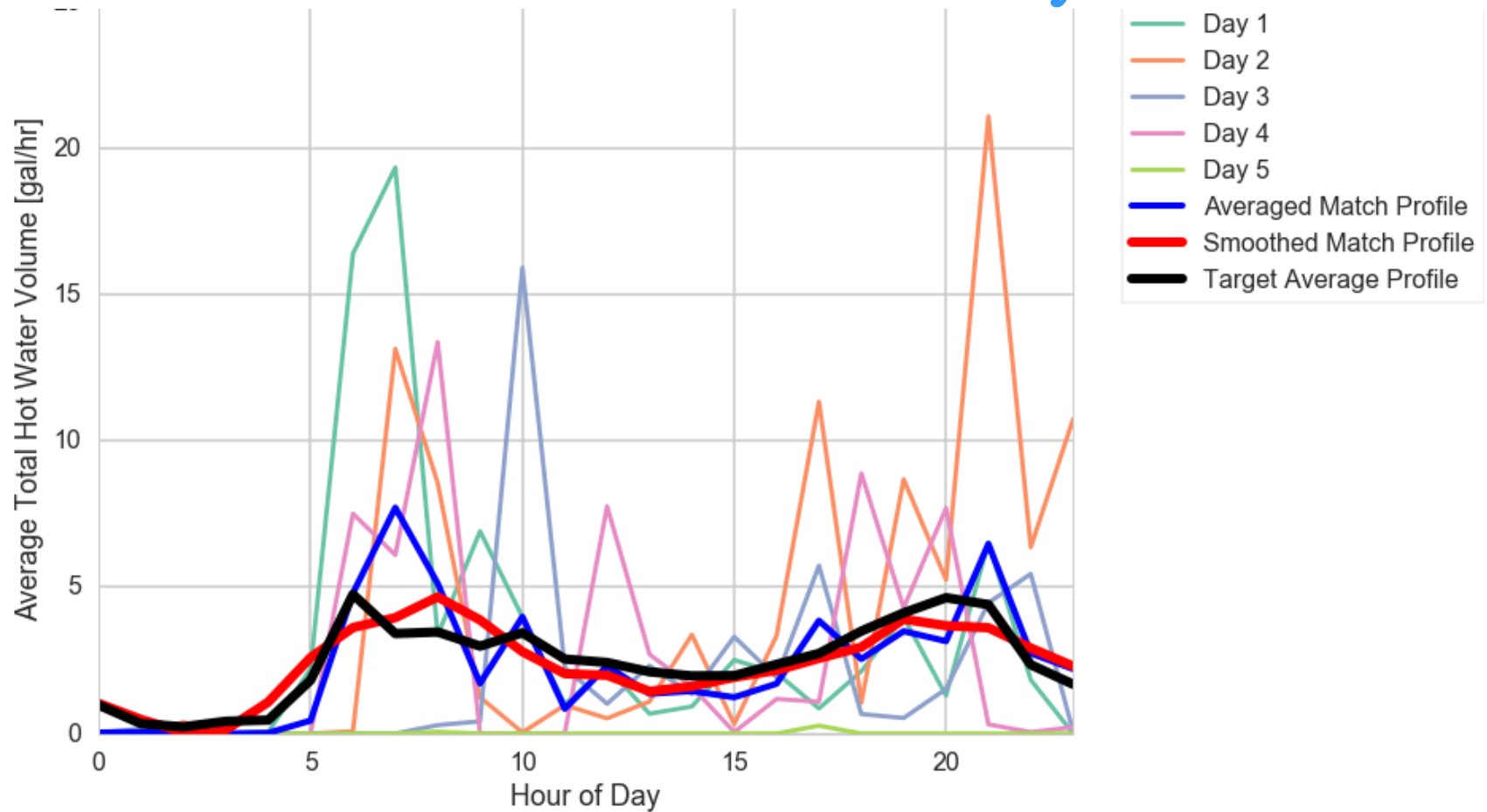
## 5 Person Selected Weekday Profile



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## 6+ Person Selected Weekday Profile





## Water Heater Model Revision Goals

- Improve efficiency calculations particularly for Heat Pump Water Heaters (HPWH)
  - High efficiency electric water heating is of interest for meeting the State Zero Net Energy goal for the 2019 Standards.
  - Current Energy Factor (EF) based model is inadequate for TDV
  - Model the interaction of the HPWH and the building heating and cooling



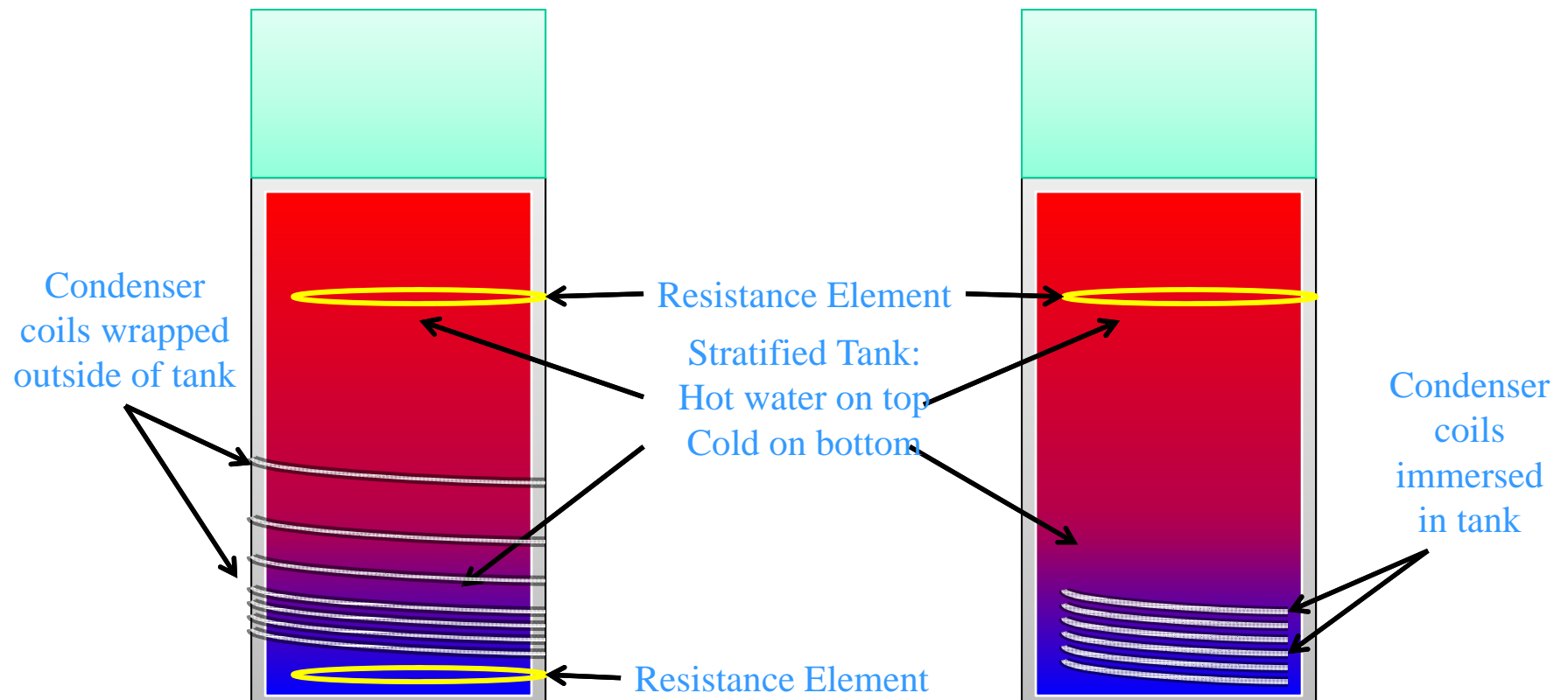
## Ecotope/NEEA HPWH Model

- Open source model developed and supported by NEEA, adapted for CBECC-Res
- Interactive engineering simulation of the HPWH system
  - Compressor efficiency depends on temperatures
  - Stratified tank model with losses to environment, heat exchanger and backup heater
  - Resistance heater control simulation
  - 1 minute simulation time step
  - Running inside CBECC-RES and testing





## HPWH Designs





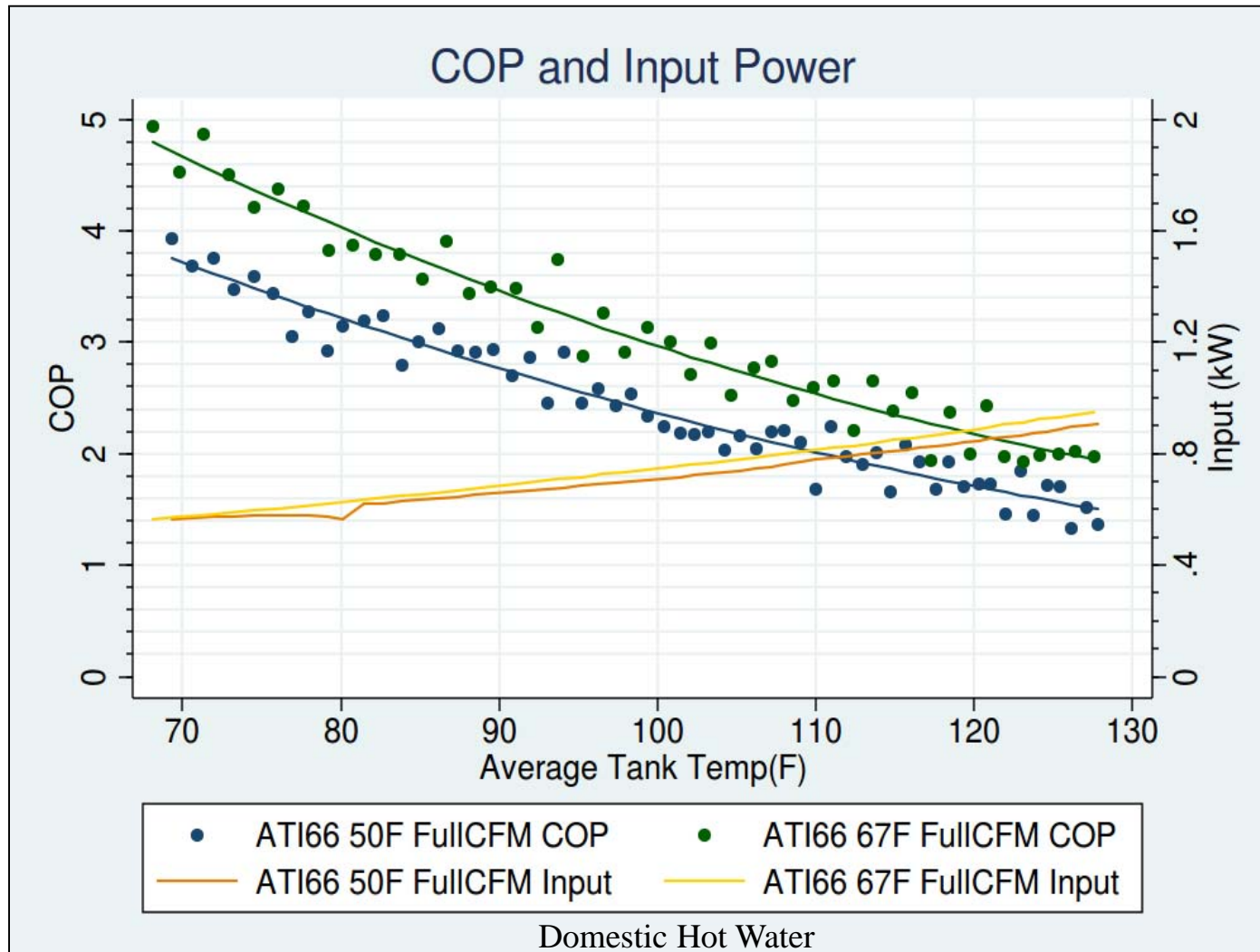
## Lab Data

Information needed for a simulation:

- Input Power –  $f(T_{\text{ambient air}}, T_{\text{tank water}})$
- COP –  $f(T_{\text{ambient air}}, T_{\text{tank water}})$
- Control logic
- Tank heat loss rate (UA)
- Distribution of added heat



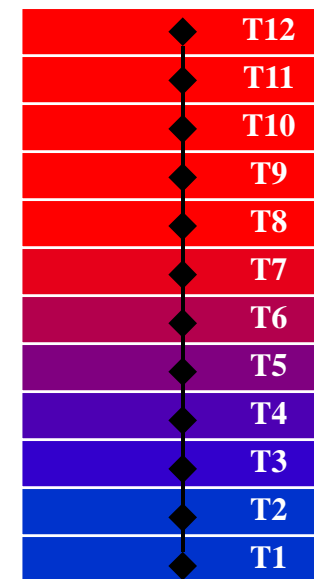
## Lab Measured Performance Curves





## Simulation Design

- 12-node, 1-dimensional tank model
- 1 minute time steps
- Each step:
  1. Calculate standby losses
  2. If draw present, shift water column upward
    - No heat transfer calculated between nodes
  3. Control logic activates or deactivates heating component
  4. If heating component active, calculate COP, input power, and update temperature nodes
    - Lower element
    - Upper element
    - Heat pump

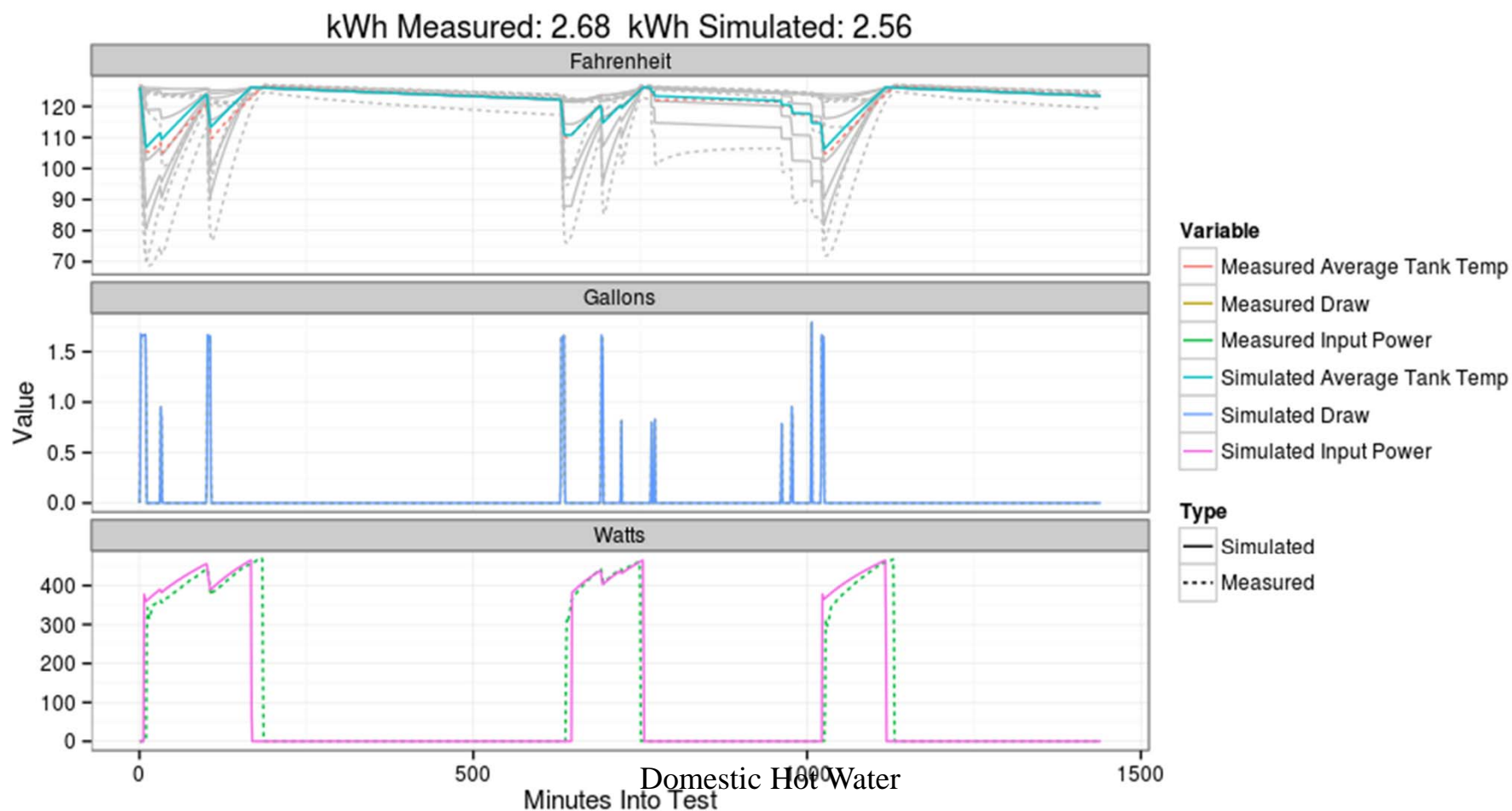




## CALIFORNIA ENERGY COMMISSION

# Model Validated Against Lab Data

DOE 24hour Test Pattern on a 50 gallon HPWH

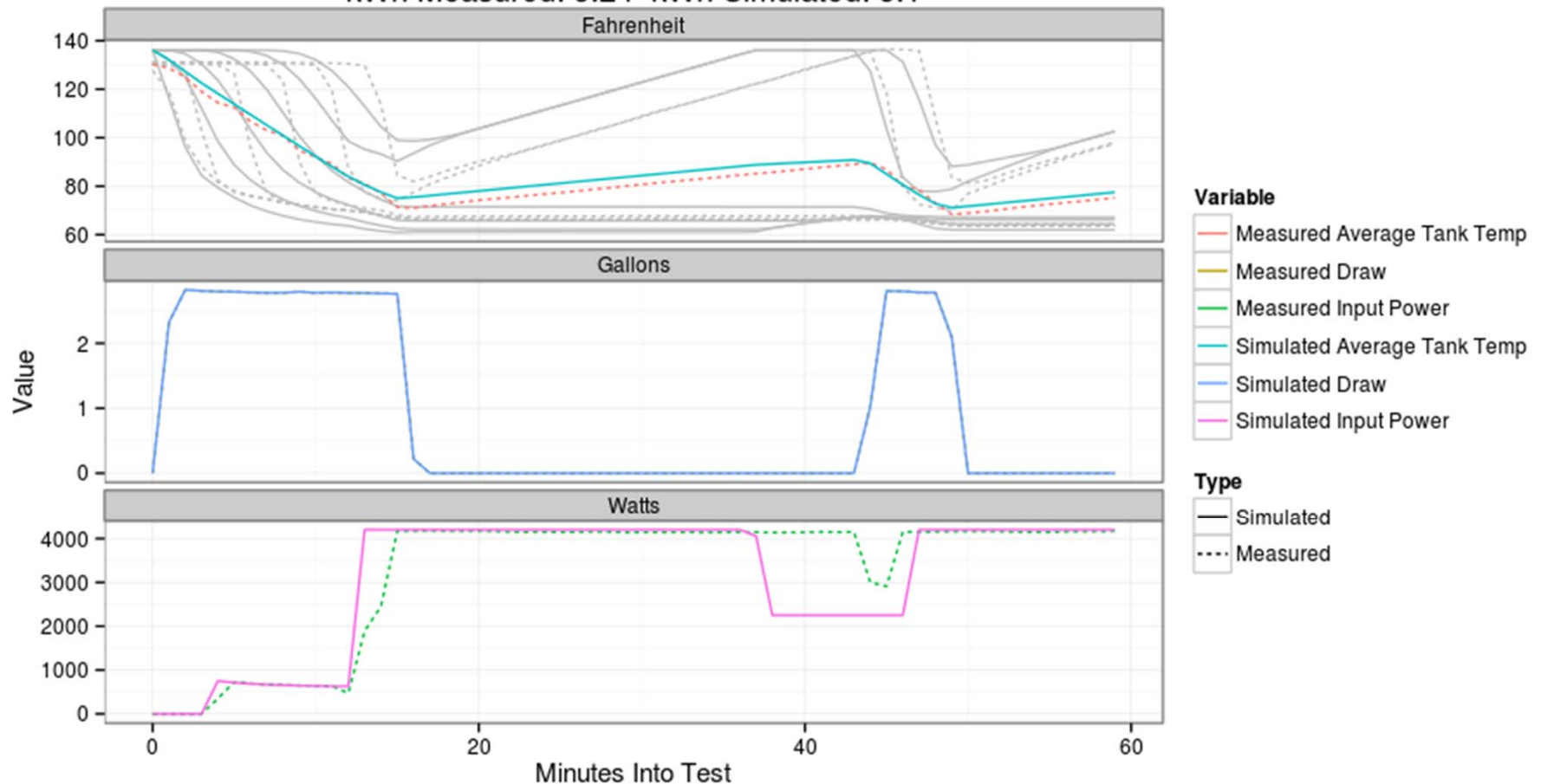




# Model Validated Against Lab Data

DOE 1hr Test on a 50 gallon HPWH

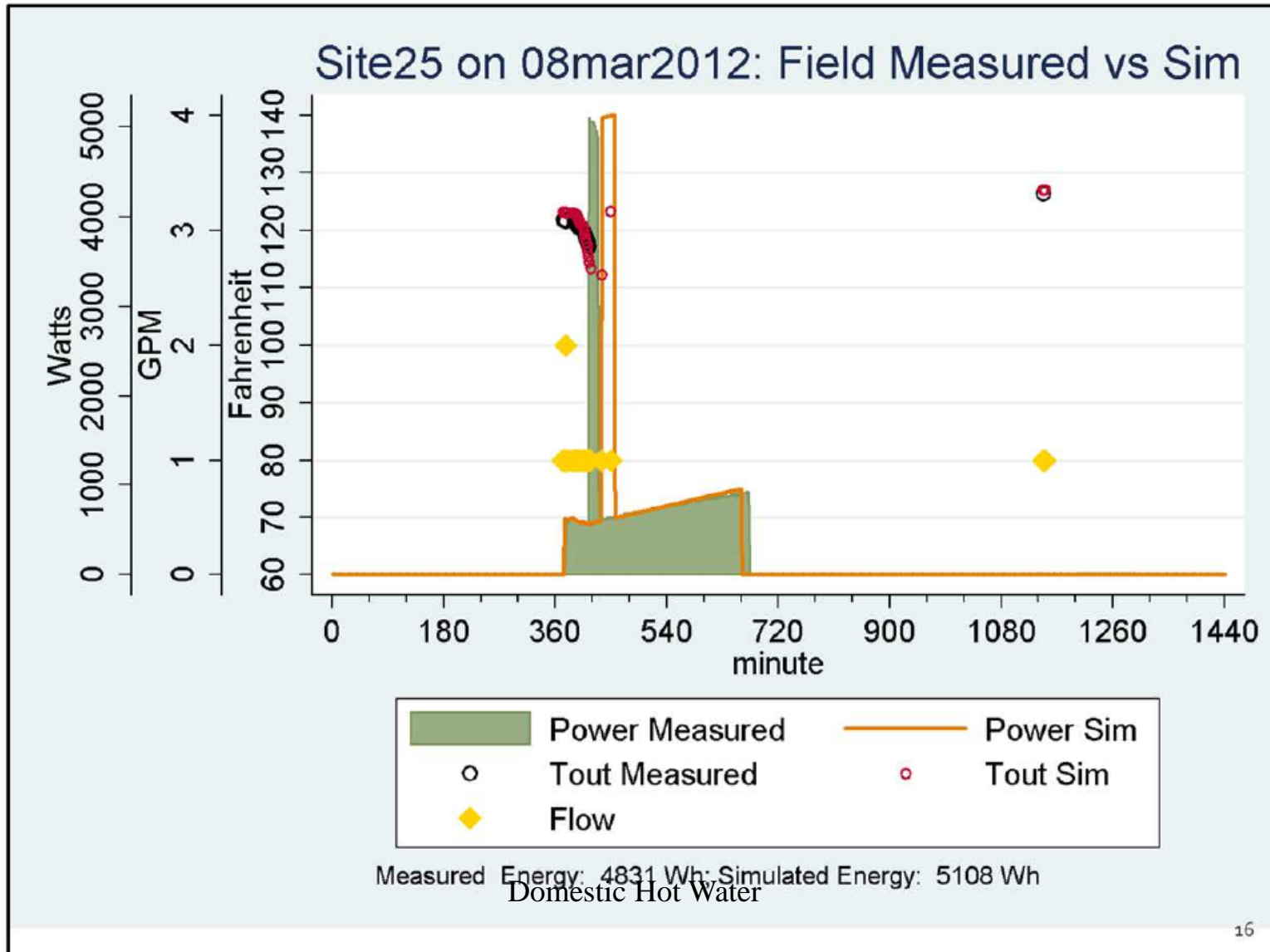
kWh Measured: 3.24 kWh Simulated: 3.1



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## Model Validated Against Field Data





## Updated DHW Compliance Results

Software not completely tested yet so nothing formal:

- New model DHW loads are more seasonal, with smaller summer and larger winter energy use than current
- Heat Pump Water Heaters have higher capacity, are more efficient and use less electricity in the summer at higher temperatures with the new model
- Electricity in CA is most valuable (highest TDV values) on the hottest summer afternoons
- The new model heat pump water heater annual TDV is significantly lower than current model TDV





## Status and Plan

- Draft DHW loads model complete
- Draft Heat Pump Water Heater model complete
- Software team testing under way now
- Commission review next
- Draft software for public review April 15
- CBECC-Res 2016.2.0 software and ACM manual Certification and Release in June