

DOCKETED

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Domestic Hot Water



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March 29, 2016



DHW Revision Consultant Team

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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

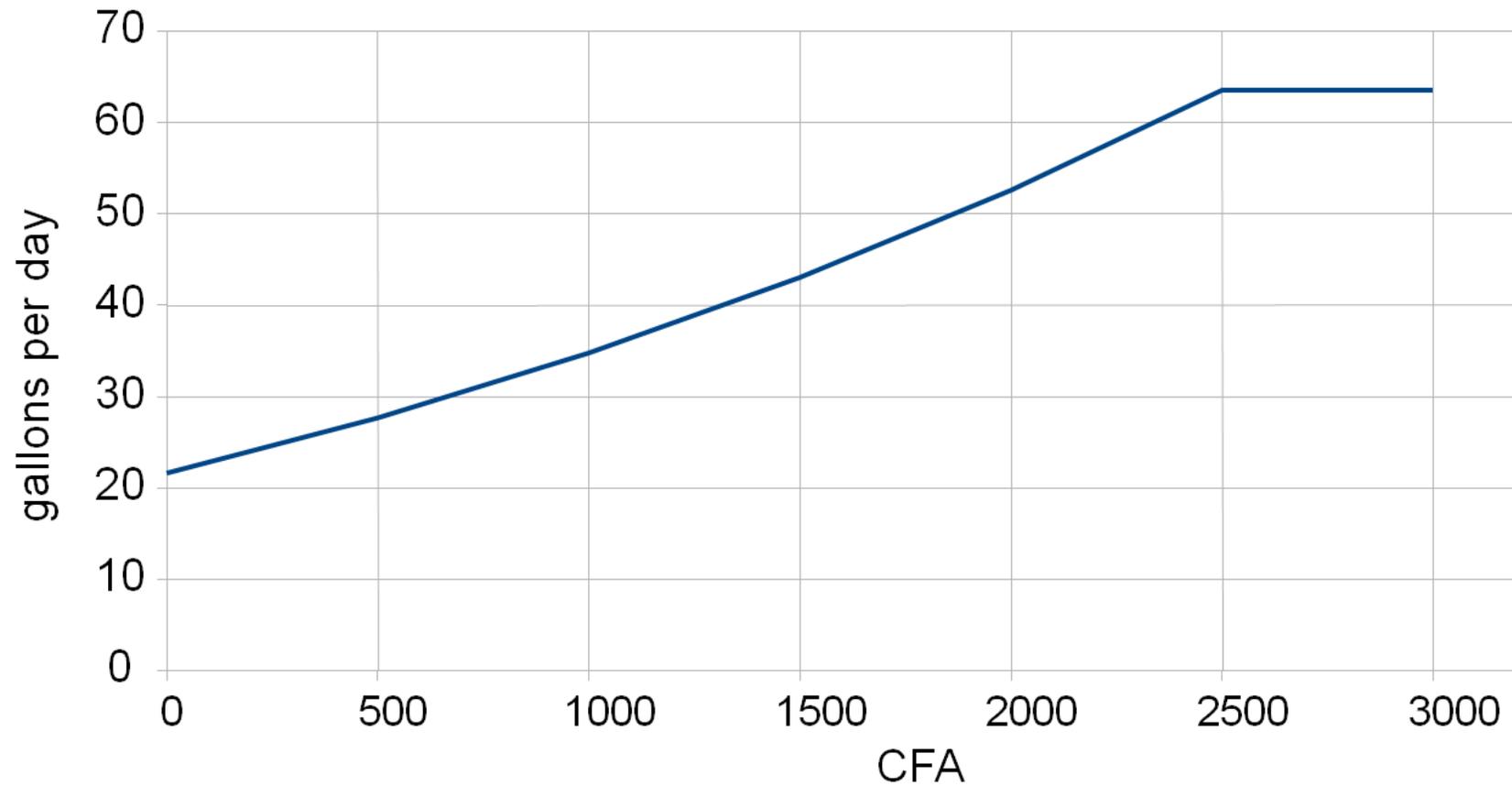


Domestic Hot Water (DHW) End Uses

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

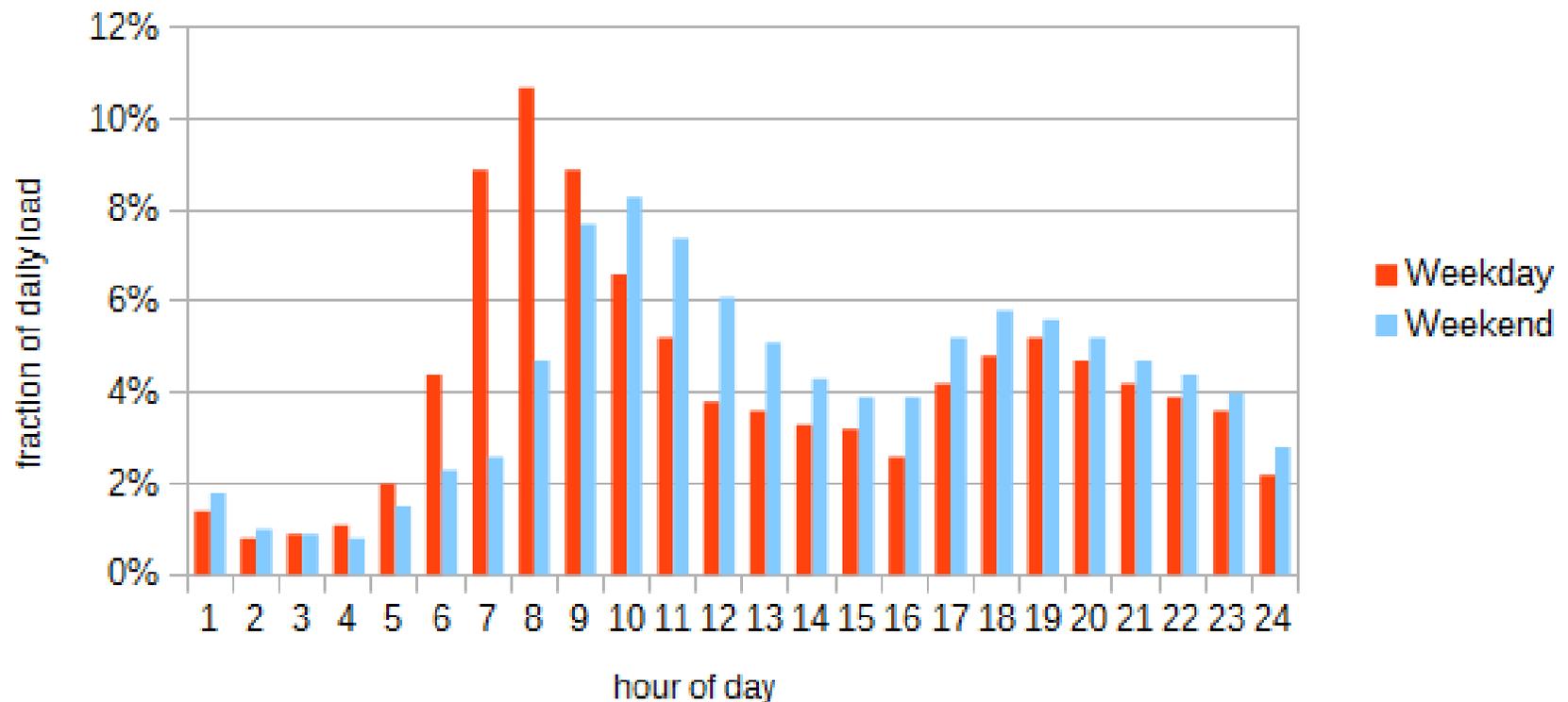


Current CA DHW Load Model





Current Water Heating Schedules



Domestic Hot Water



Current water heater energy use model

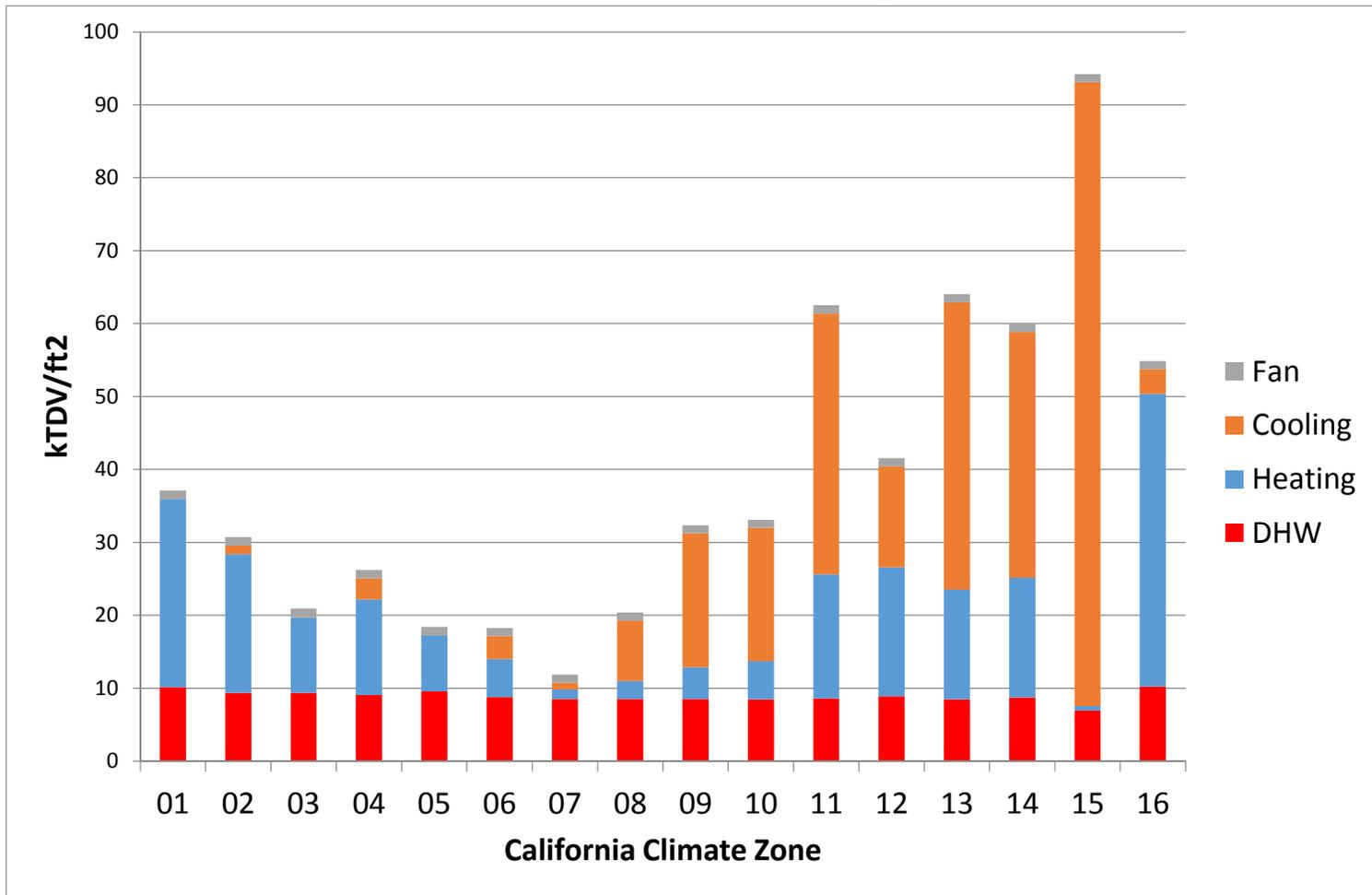
DOE rated Energy Factor (EF) is efficiency input

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

With some adjustments



Current Single Family DHW Energy (current CBECC-Res for Instantaneous gas water heater)



Domestic Hot Water



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

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CONSULTANT REPORT

2009 CALIFORNIA RESIDENTIAL
APPLIANCE SATURATION STUDY

Executive Summary

Prepared for: California Energy Commission
Inc.

OCTOBER 2010
CEC- 200- 2010-004-ES



Domestic Hot Water



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 Occupants	Age	Fraction of each age group in the total population of families of that size				
		0-5	6-18	19-34	35-54	55-64
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

The cover of the report "California Single Family Water Use Efficiency Study". It features a green shield-shaped sign with "CALIFORNIA 1" on a road signpost, a photo of a house, and text detailing sponsors, managers, and the preparer.

**California
Single Family
Water Use
Efficiency Study**

Sponsored by:
The California Department of
Water Resources

Managed by:
The Irvine Ranch Water District

FINAL REPORT

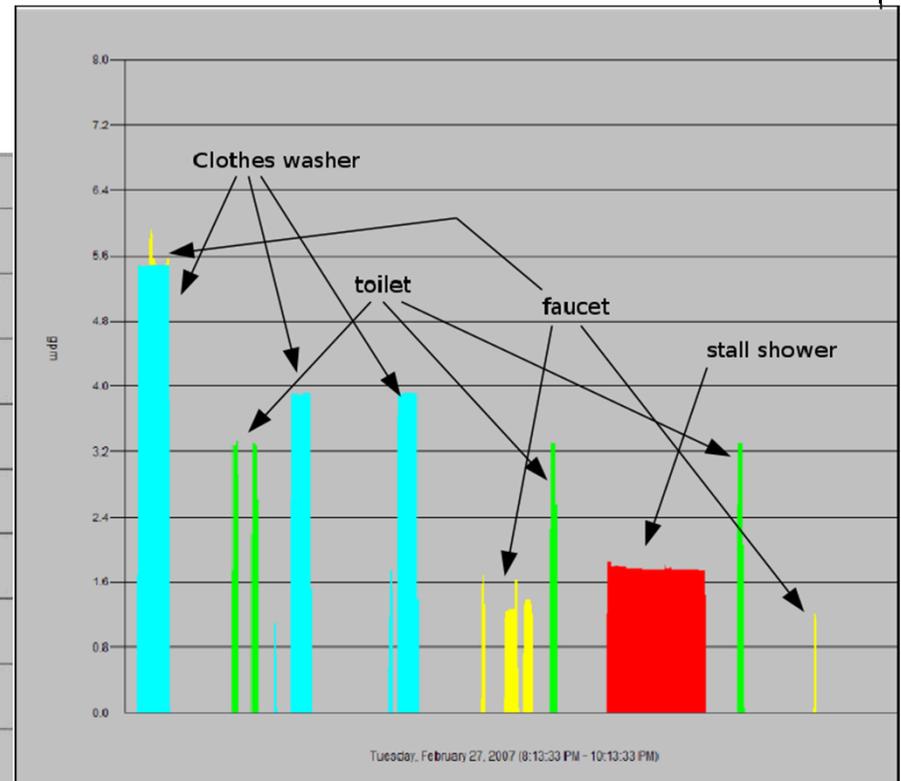
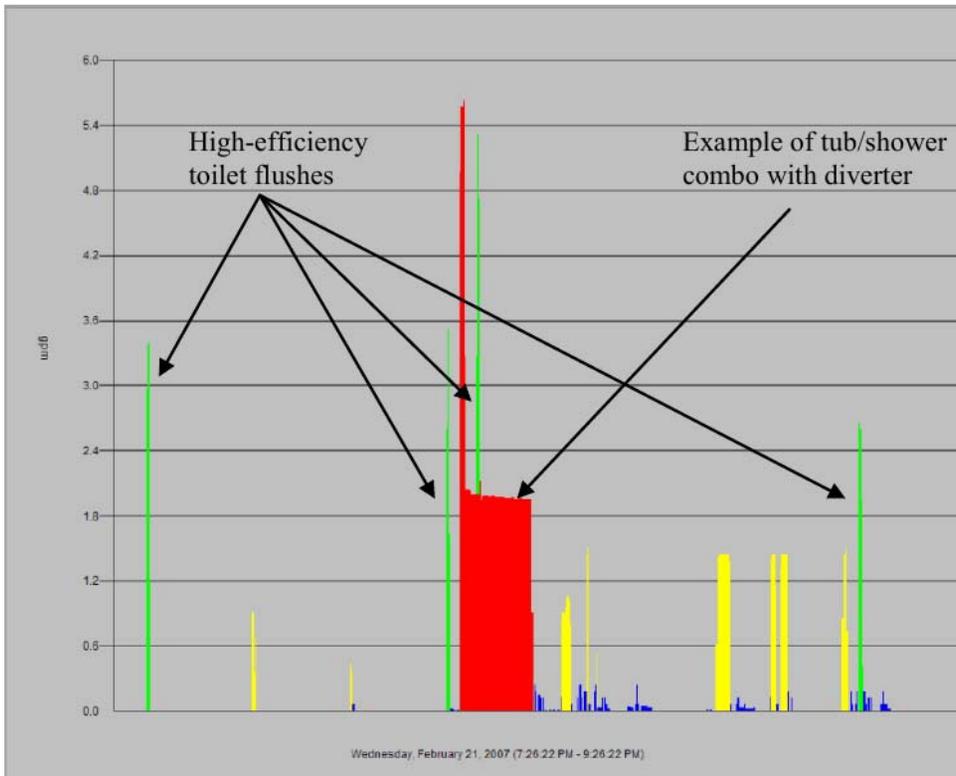
Prepared by:
 Aquacraft
WATER ENGINEERING & MANAGEMENT

with Stratus Consulting & the Pacific Institute

and other studies
by Aquacraft

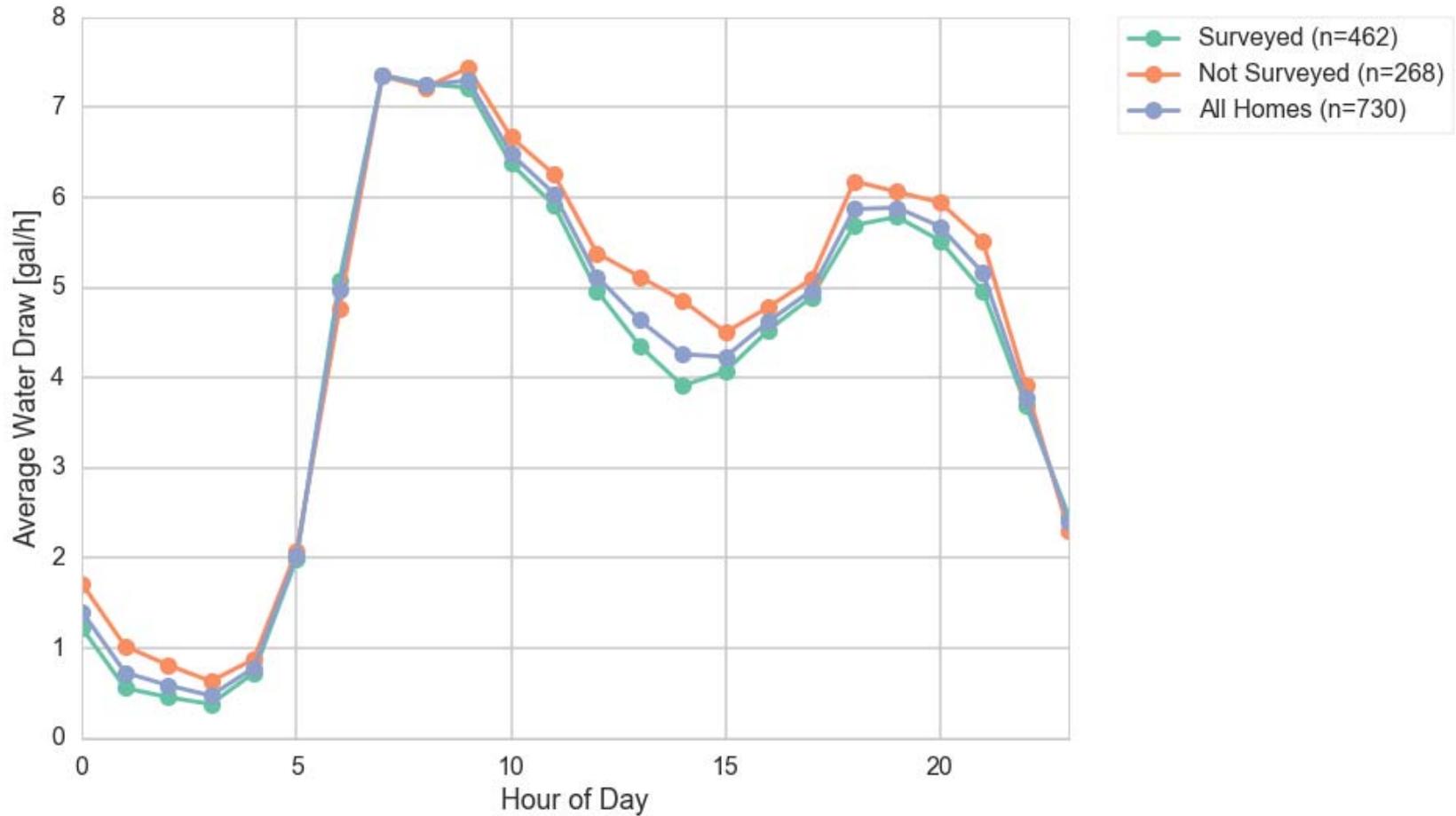


Water Meter 10 sec Flow Trace Analysis





CA SF Total DHW Related Water Use (showers, faucets, clothes washers, dish washers, baths)



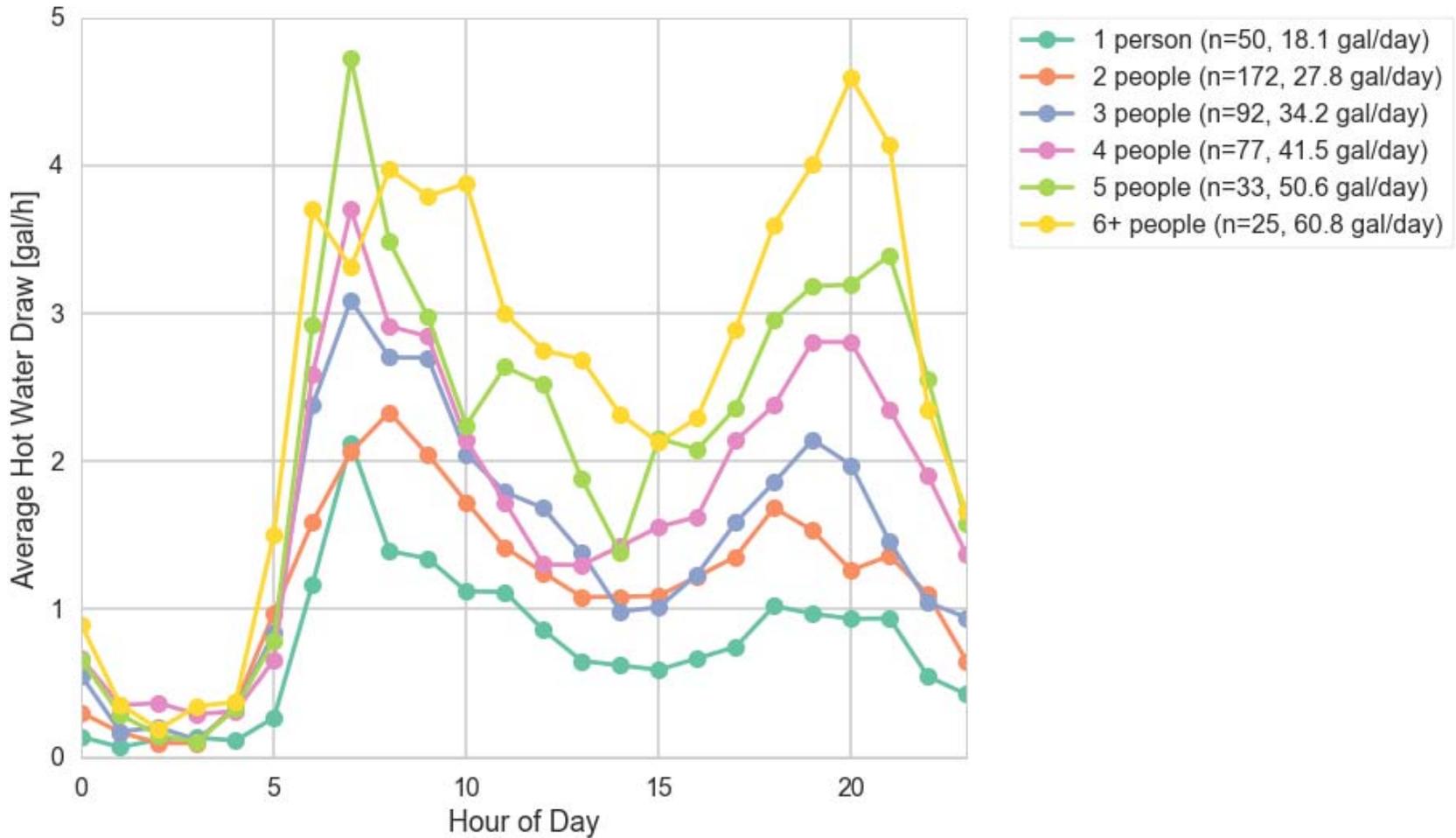


Getting to Hot Water at the Heater in 2017

- 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

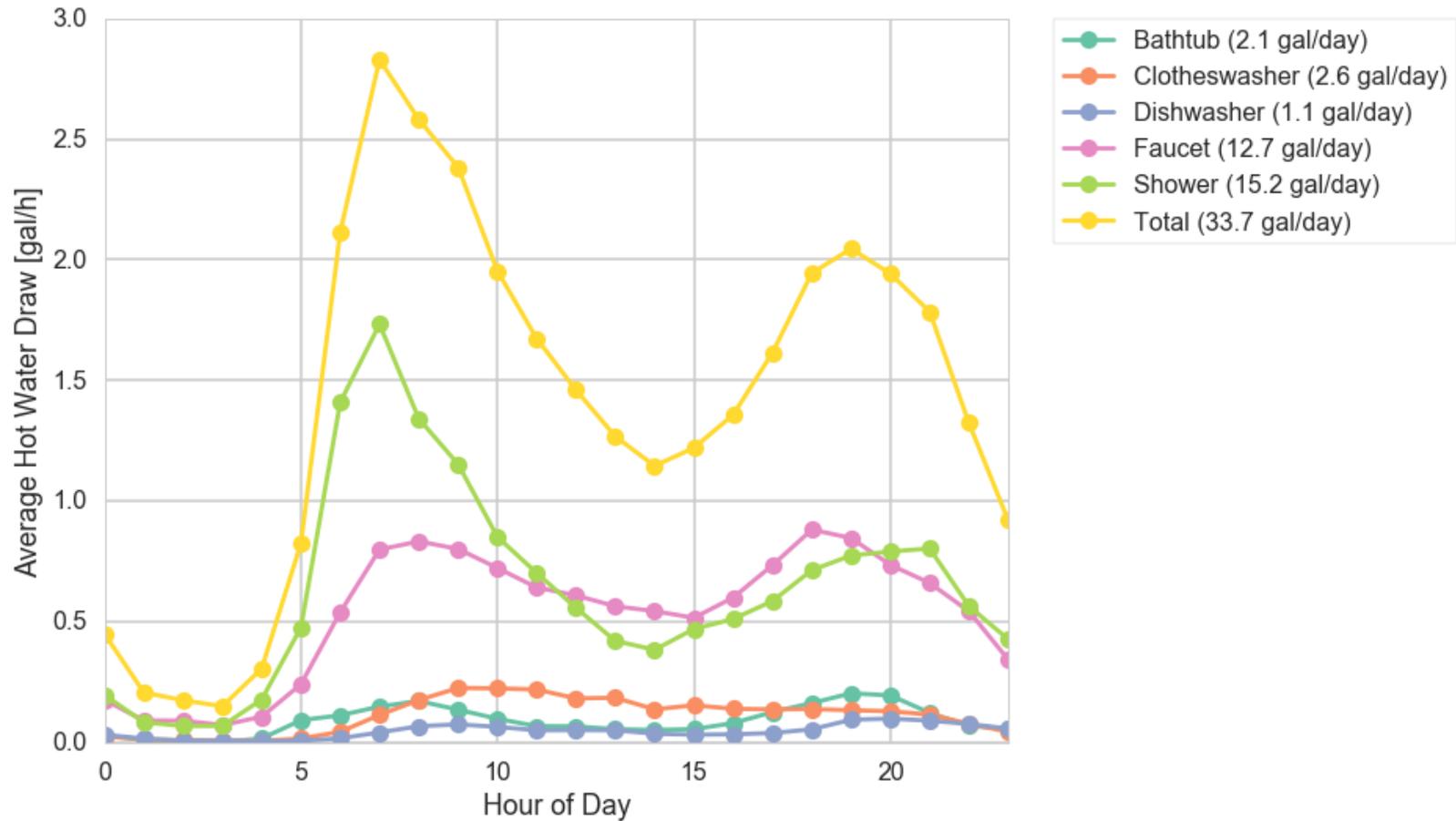


Hot Water Use by Hour and Occupants



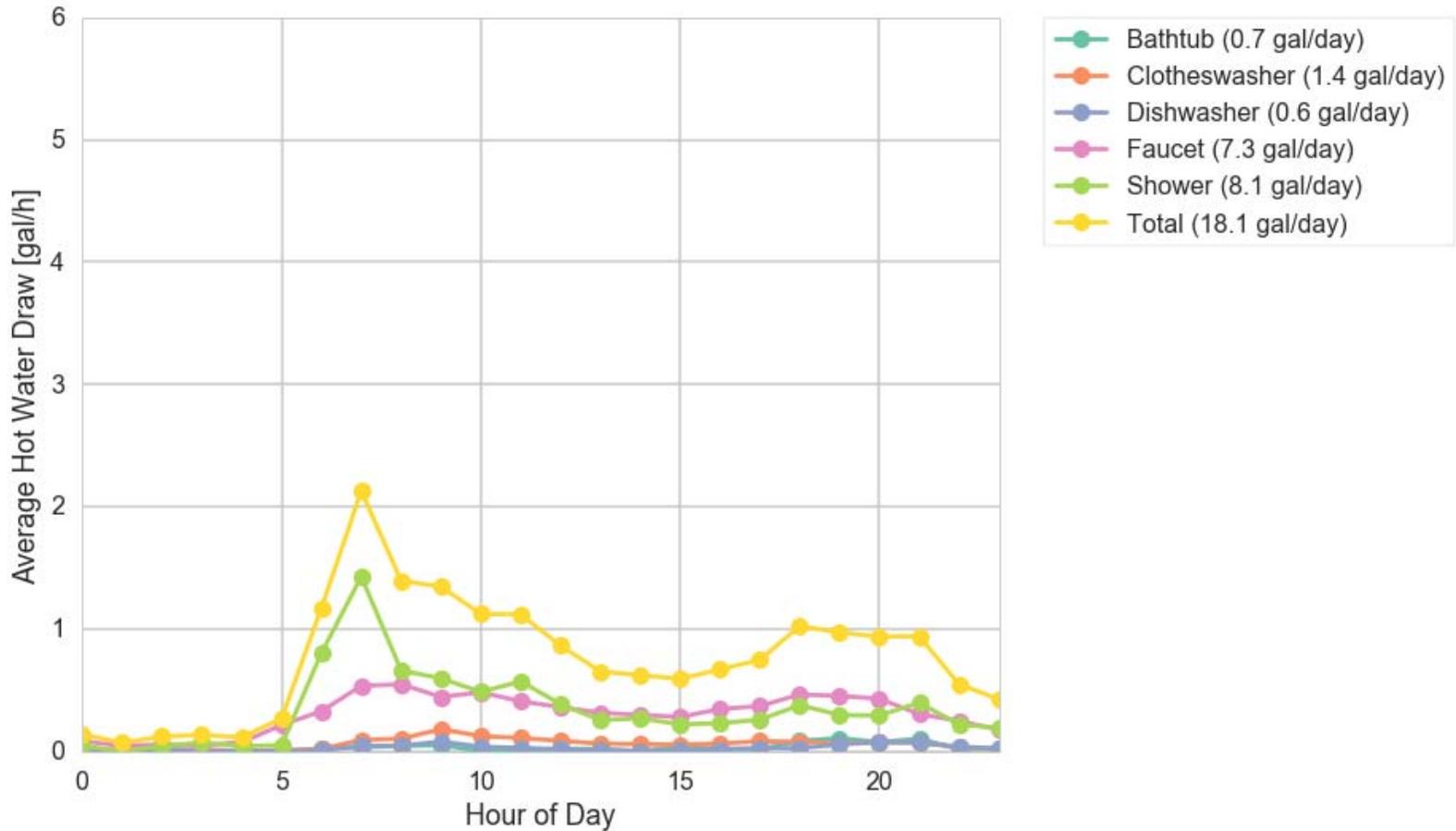


Average Hourly Hot Water by End Use



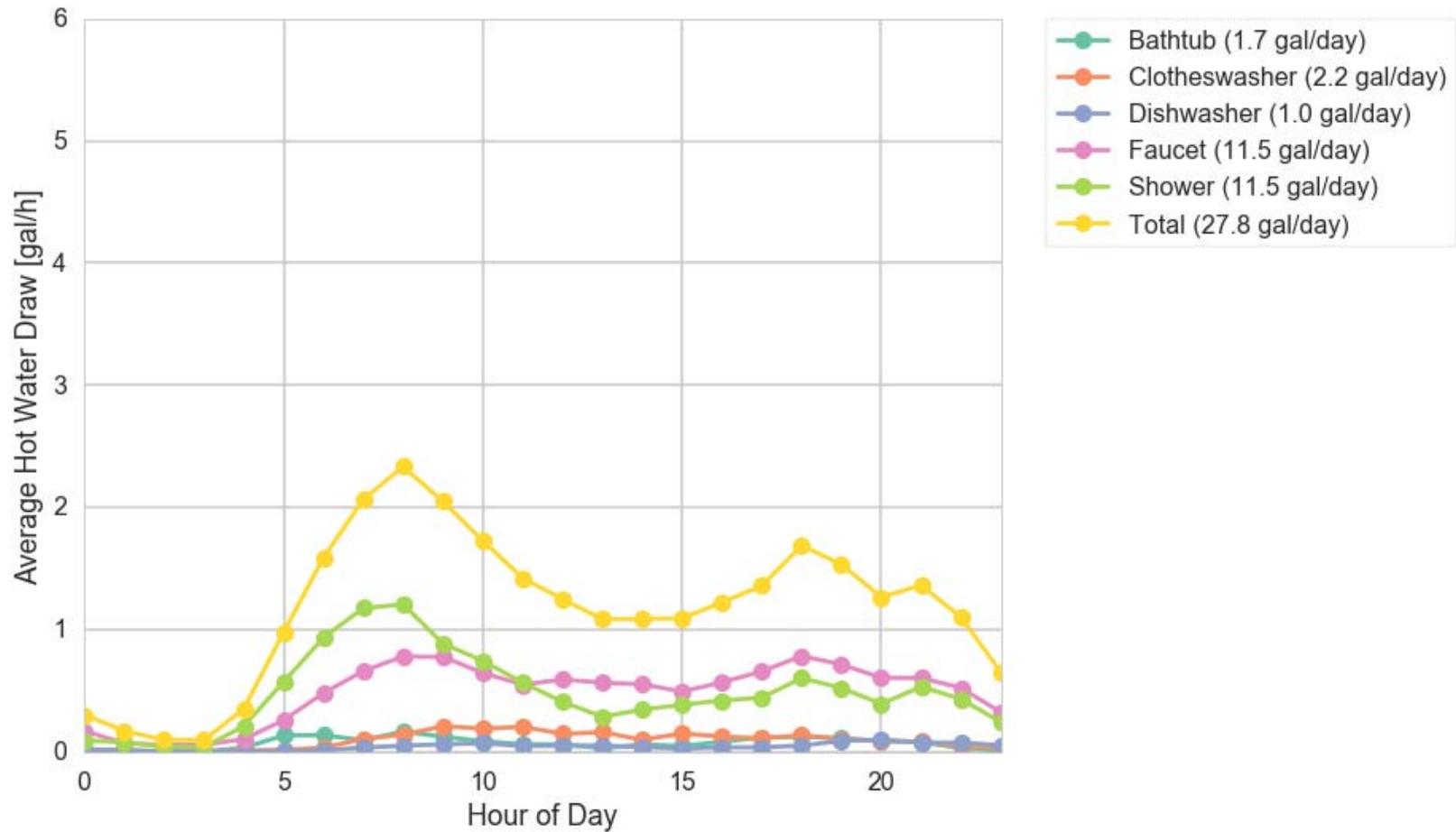


Average Hourly Hot Water for 1 Person



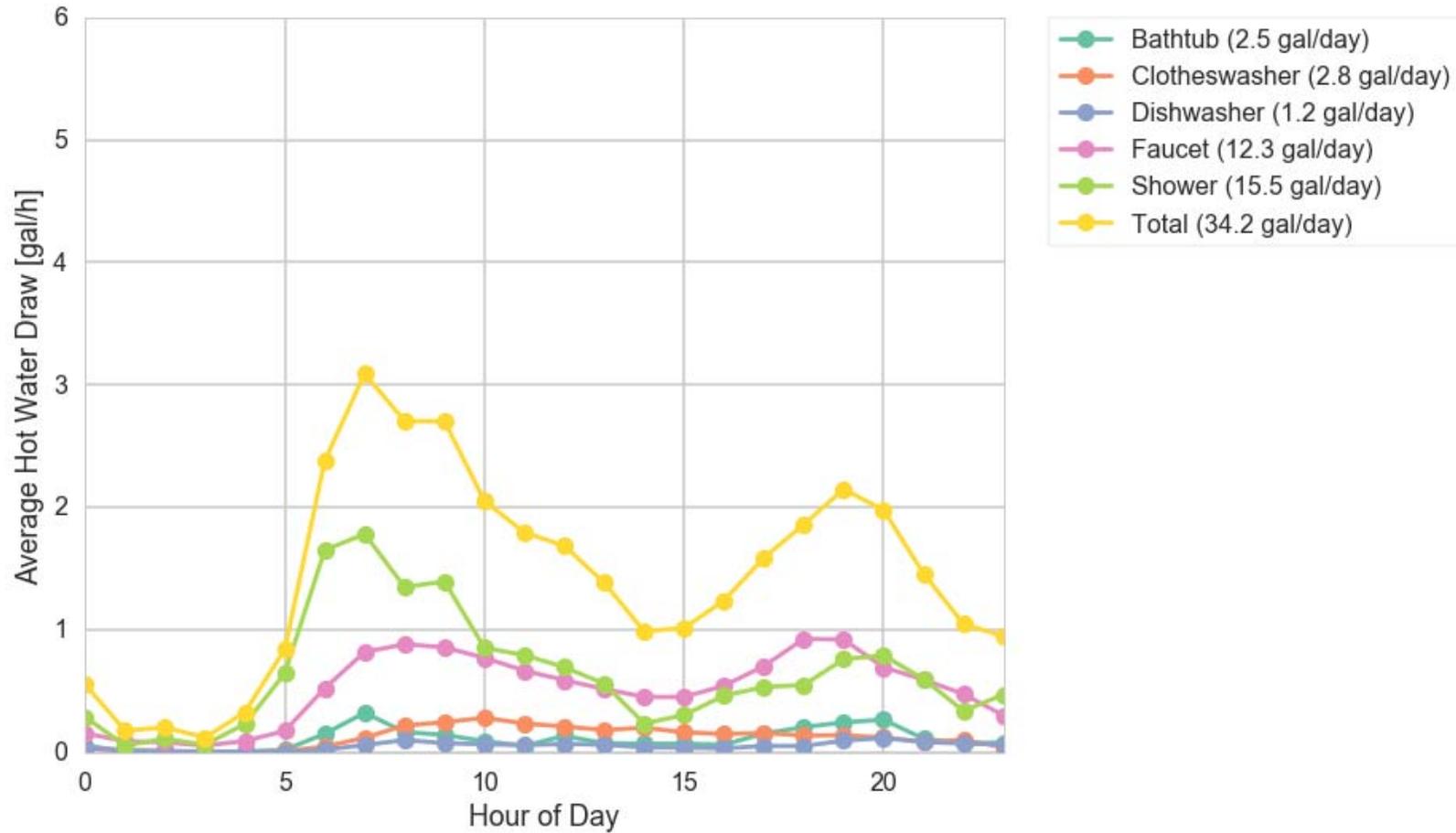


Average Hourly Hot Water for 2 Persons



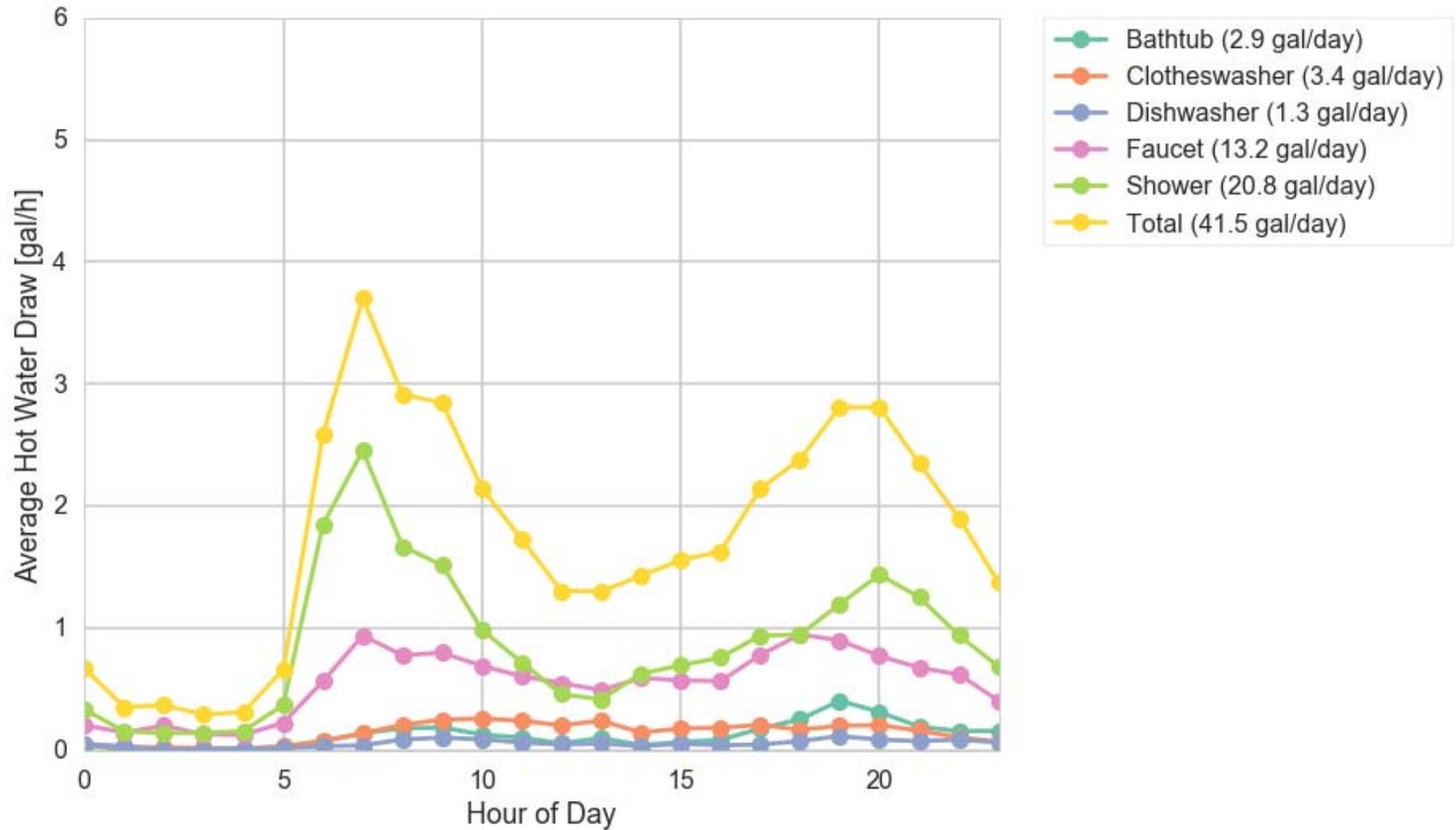


Average Hourly Hot Water for 3 Persons



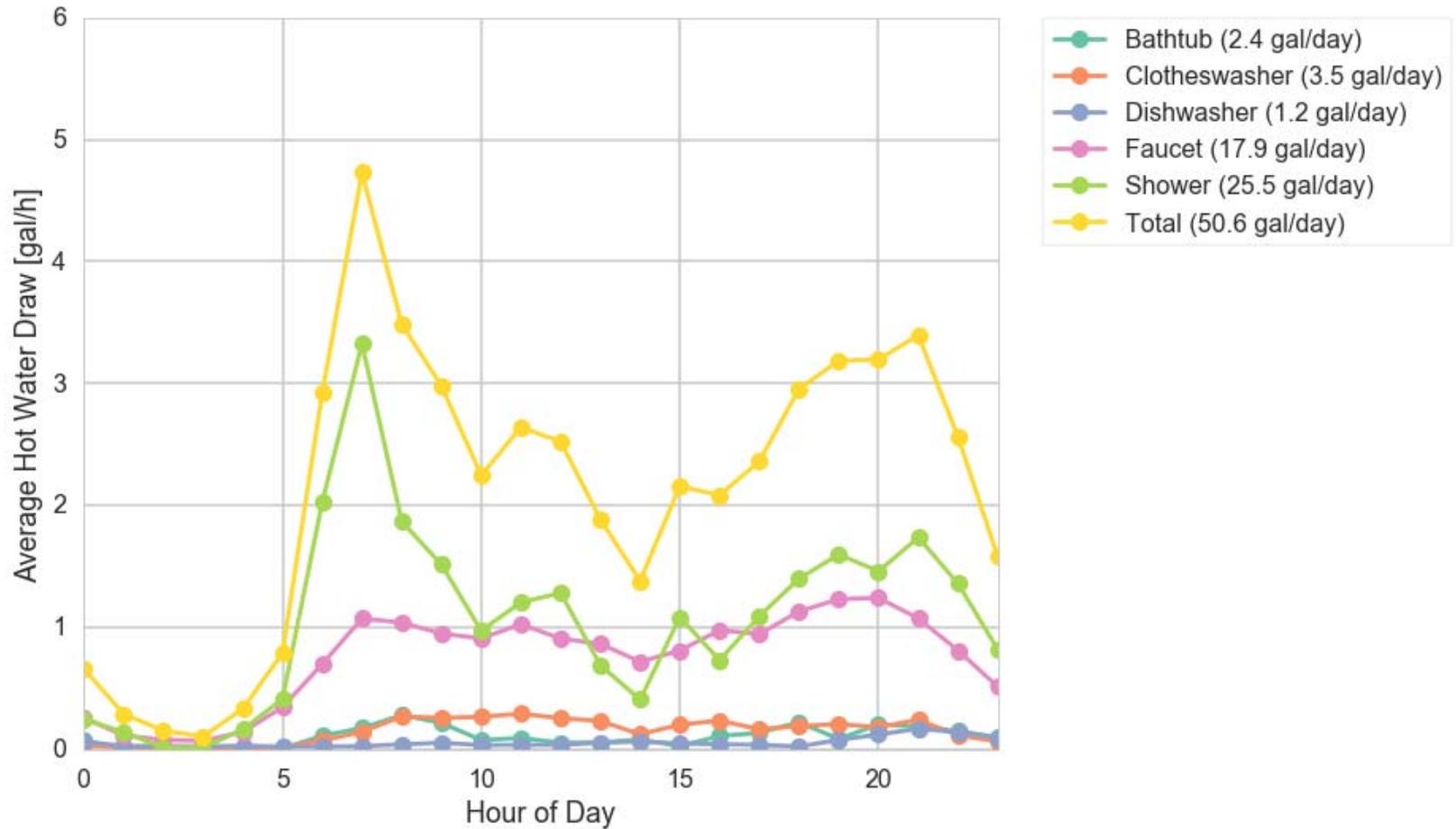


Average Hourly Hot Water for 4 Persons



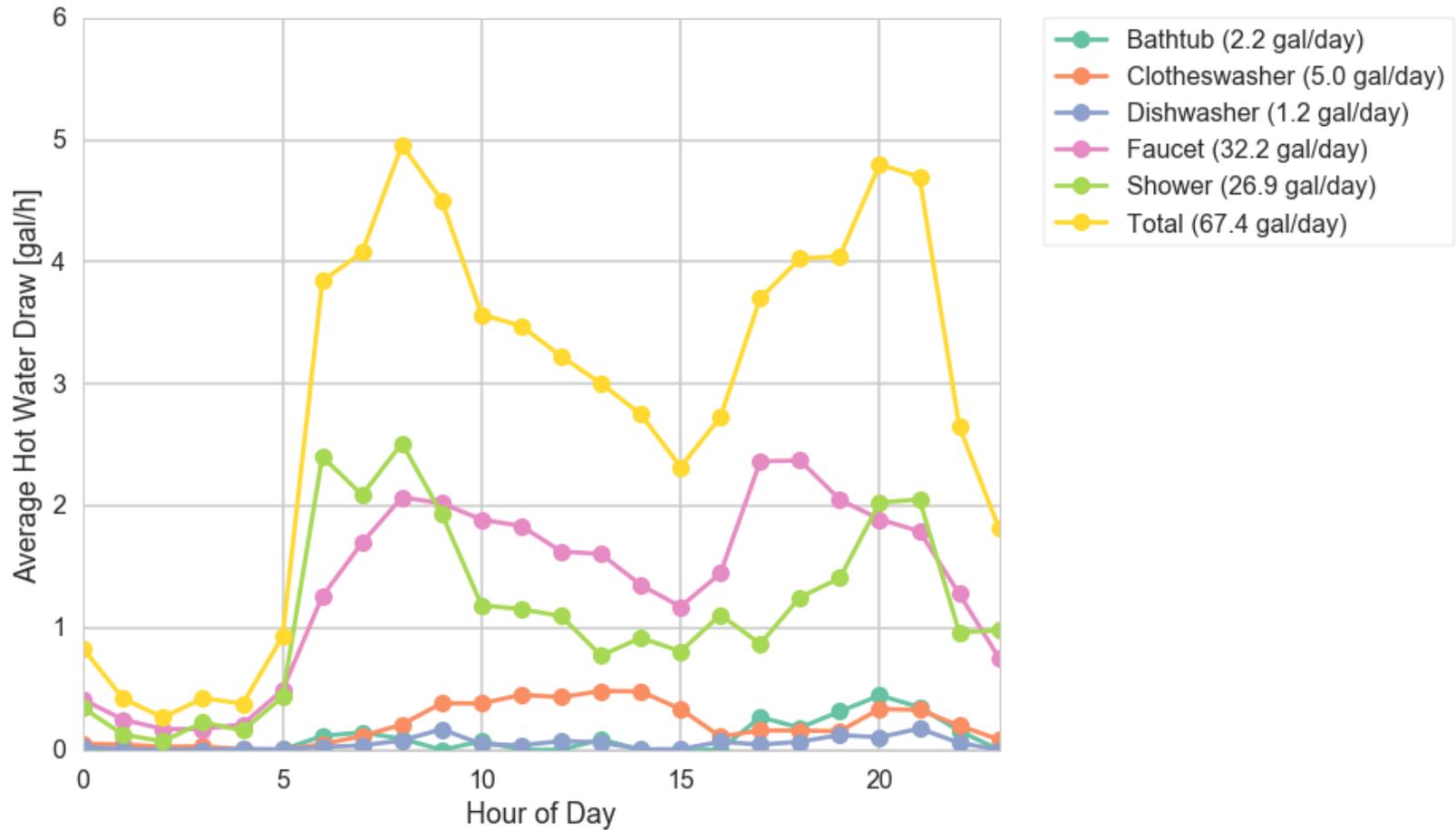


Average Hourly Hot Water for 5 Persons



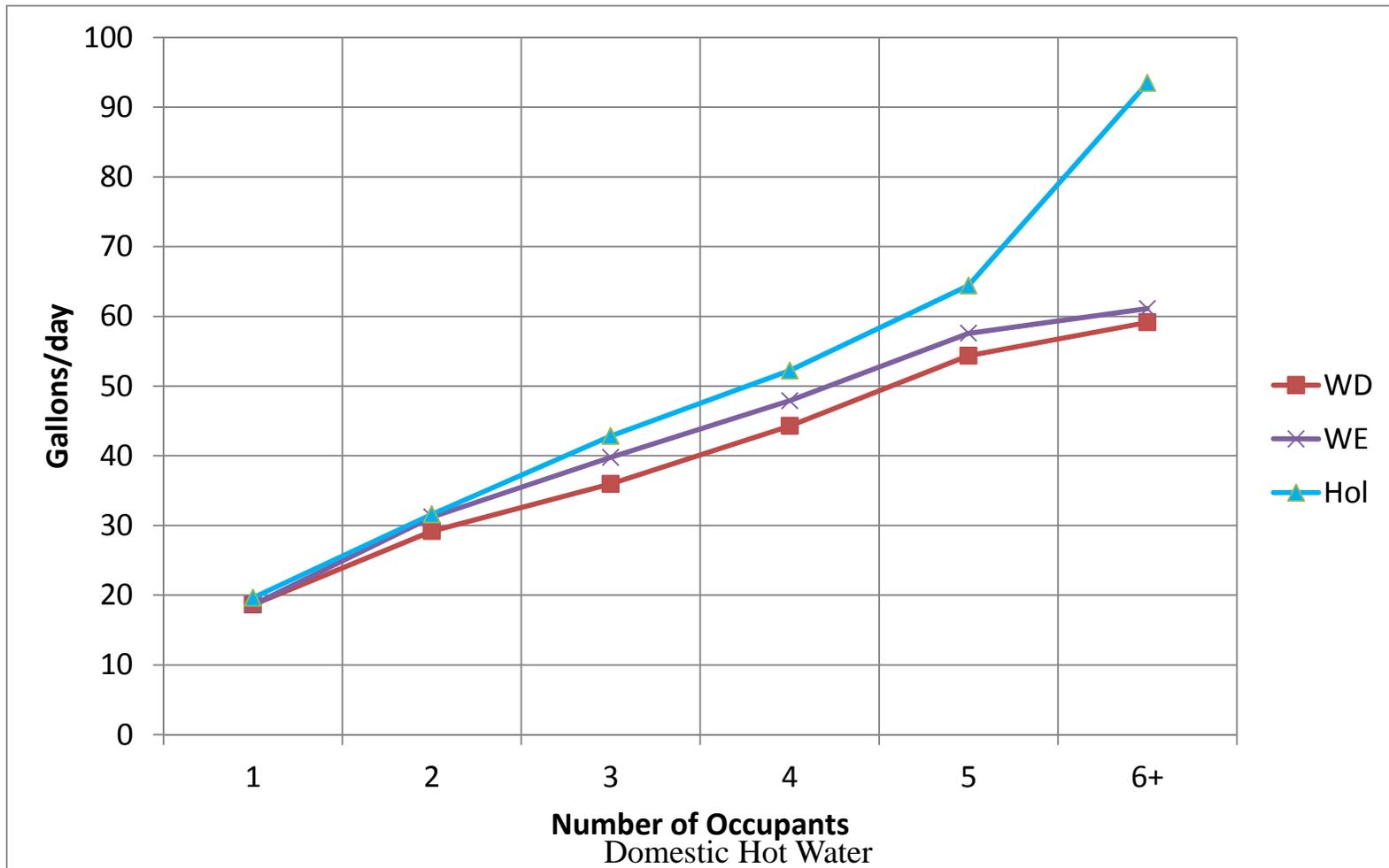


Average Hourly Hot Water for 6 Persons





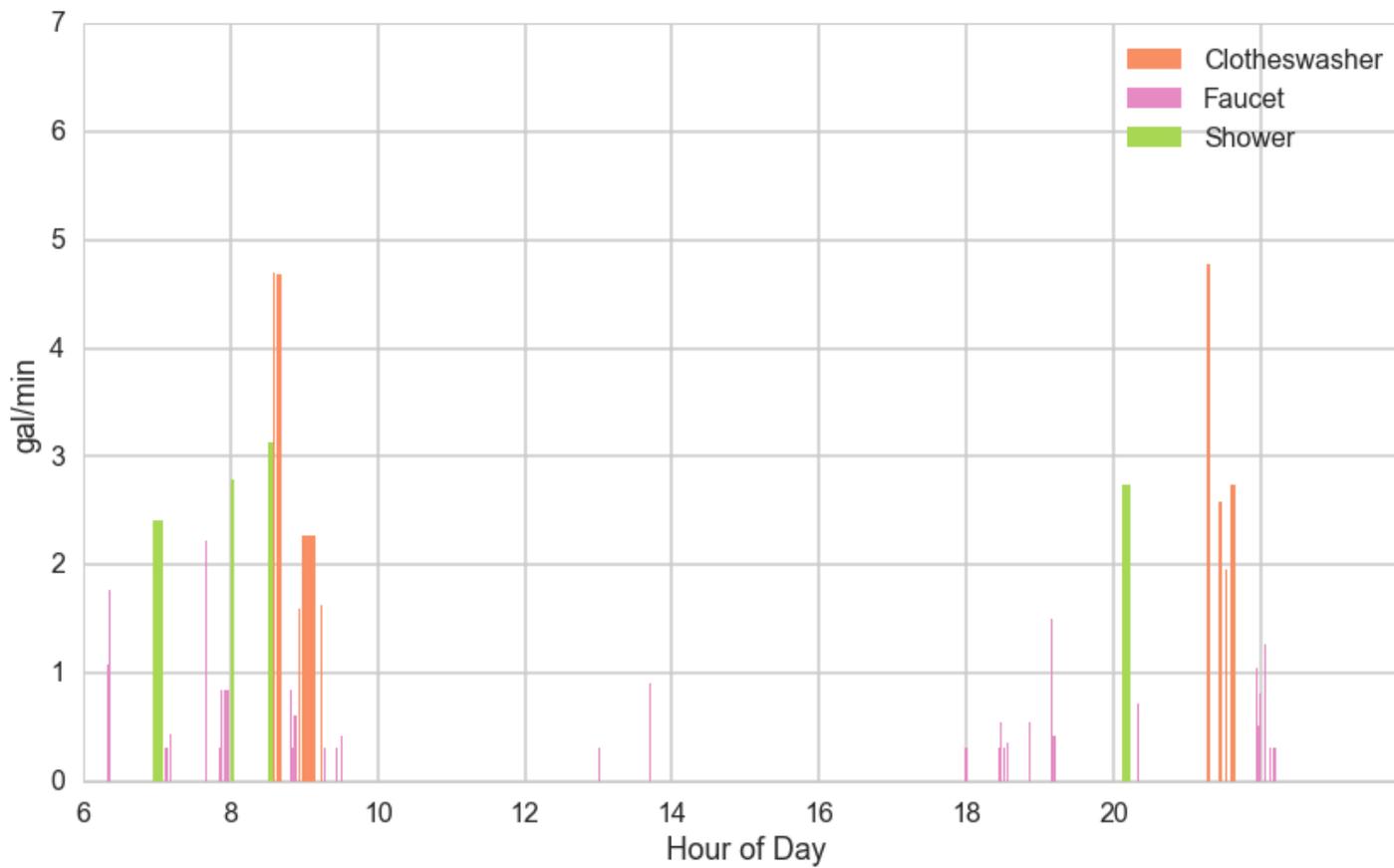
Gal/day by Day Type and Occupants





Hot Water Draws for a Home on 1 Day

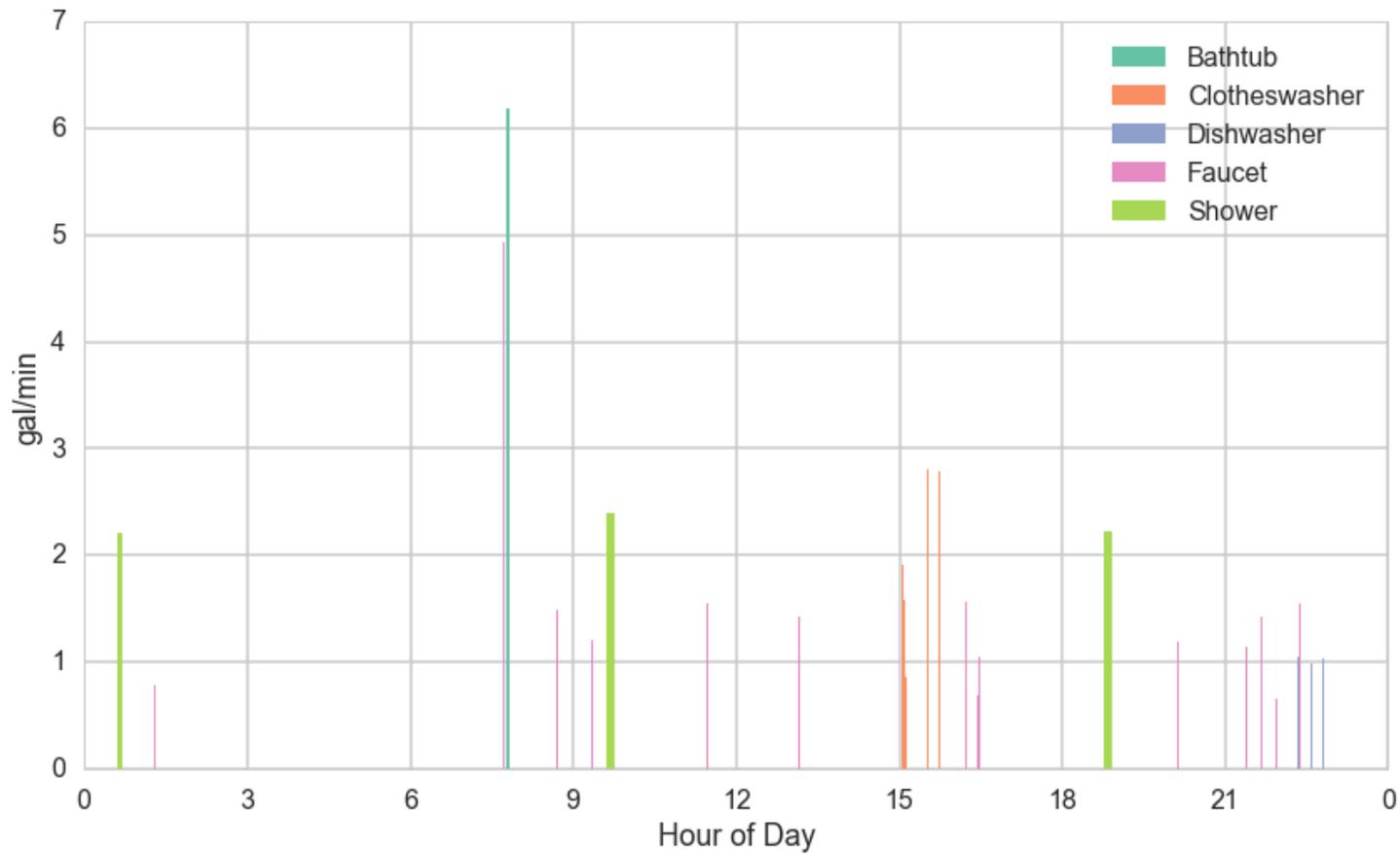
House: 15156, 4 Occupant(s)





Hot Water Draws for 2nd a Home on 1 Day

House: 17197, 4 Occupant(s)



Domestic Hot Water



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

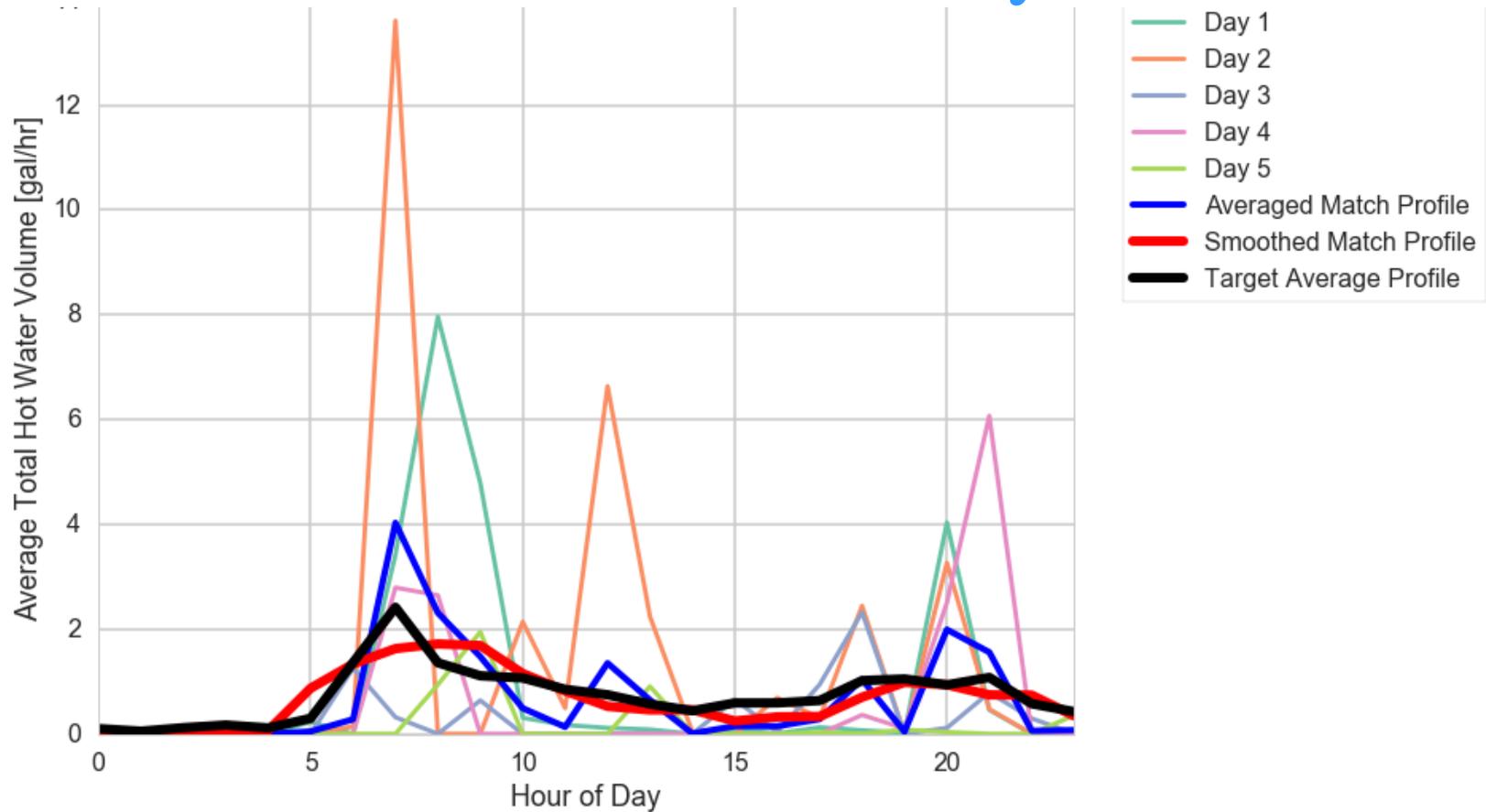


Resulting Draw Schedules

- 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

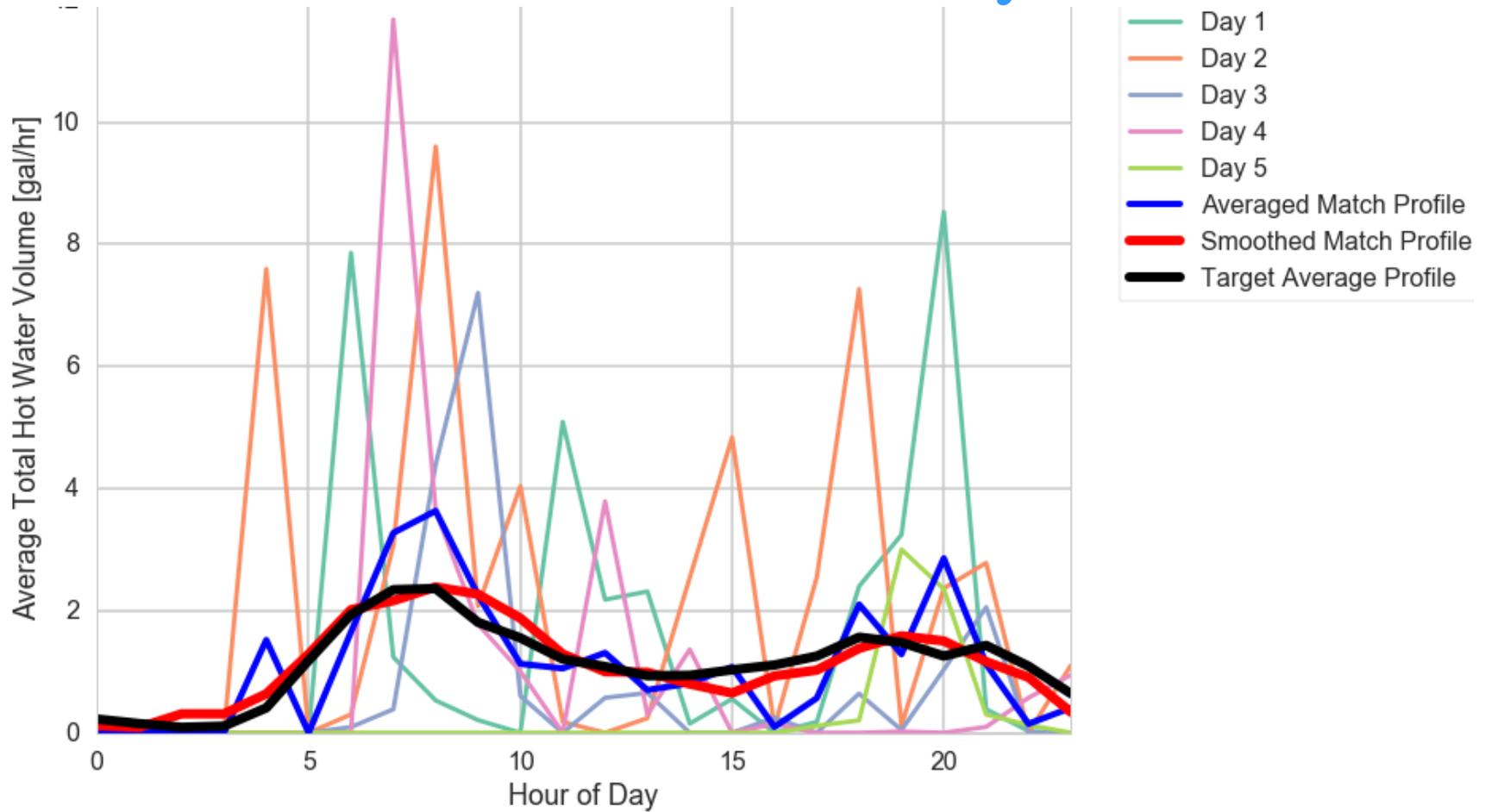


1 Person Selected Weekday Profile



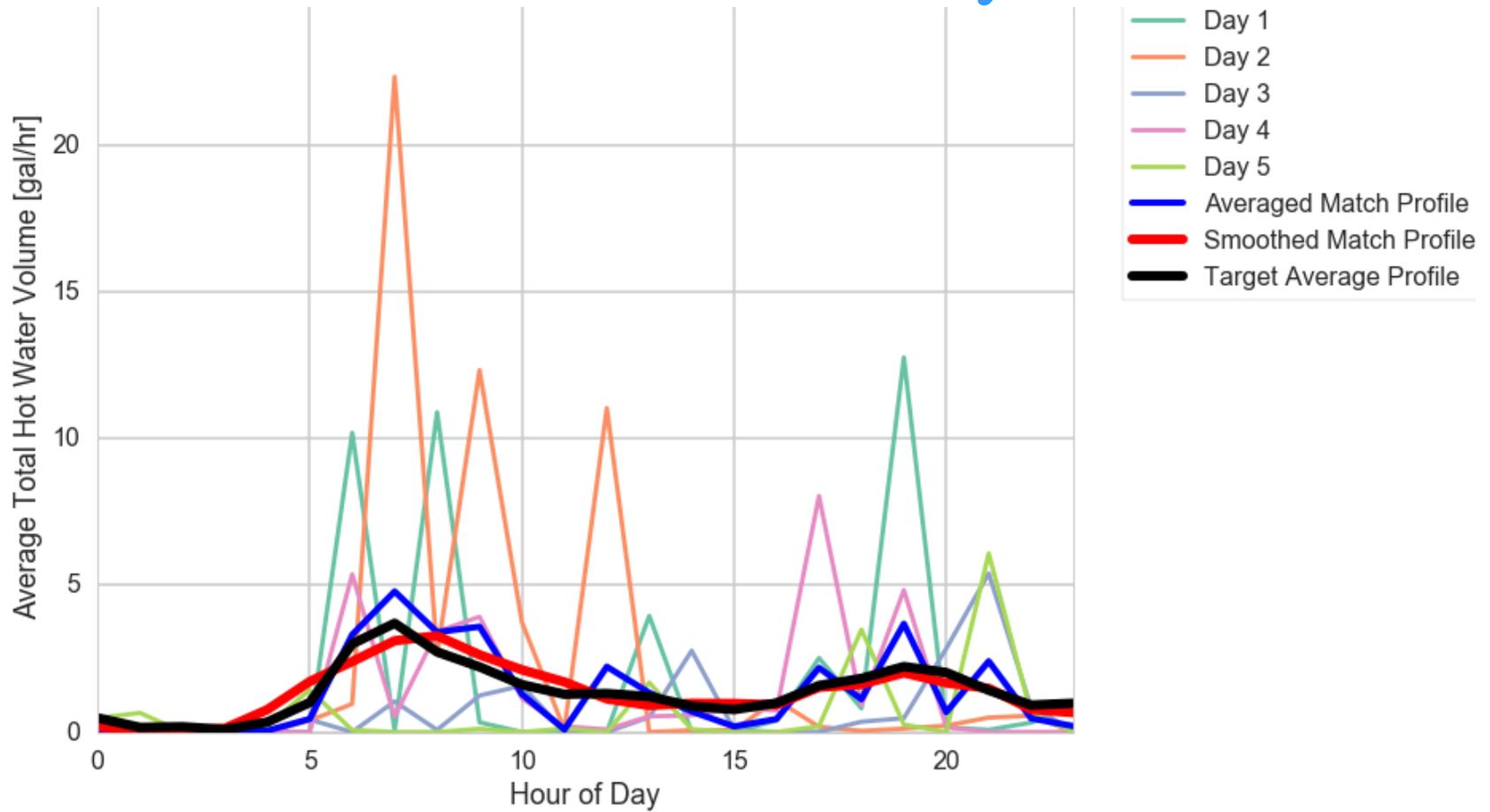


2 Person Selected Weekday Profile



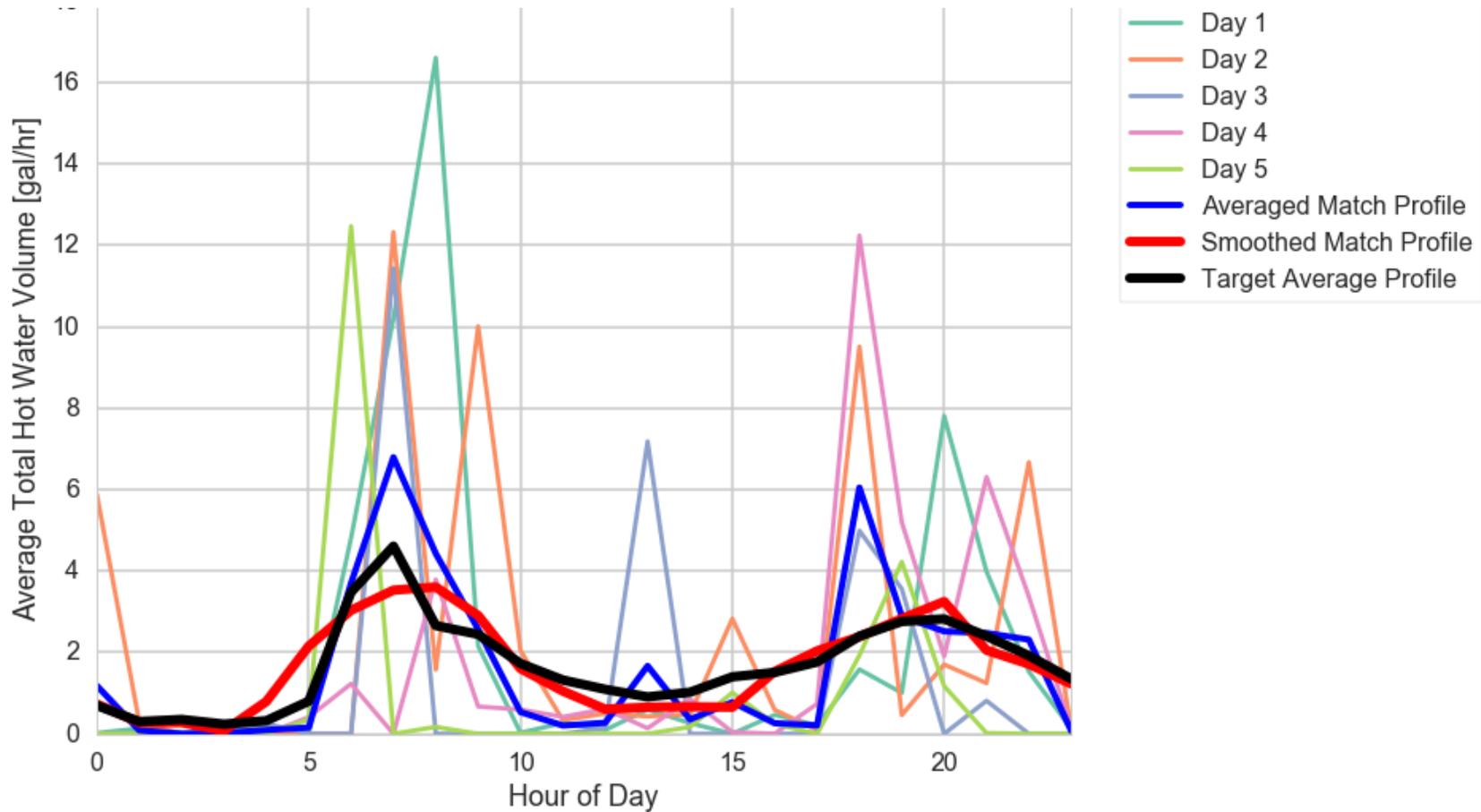


3 Person Selected Weekday Profile



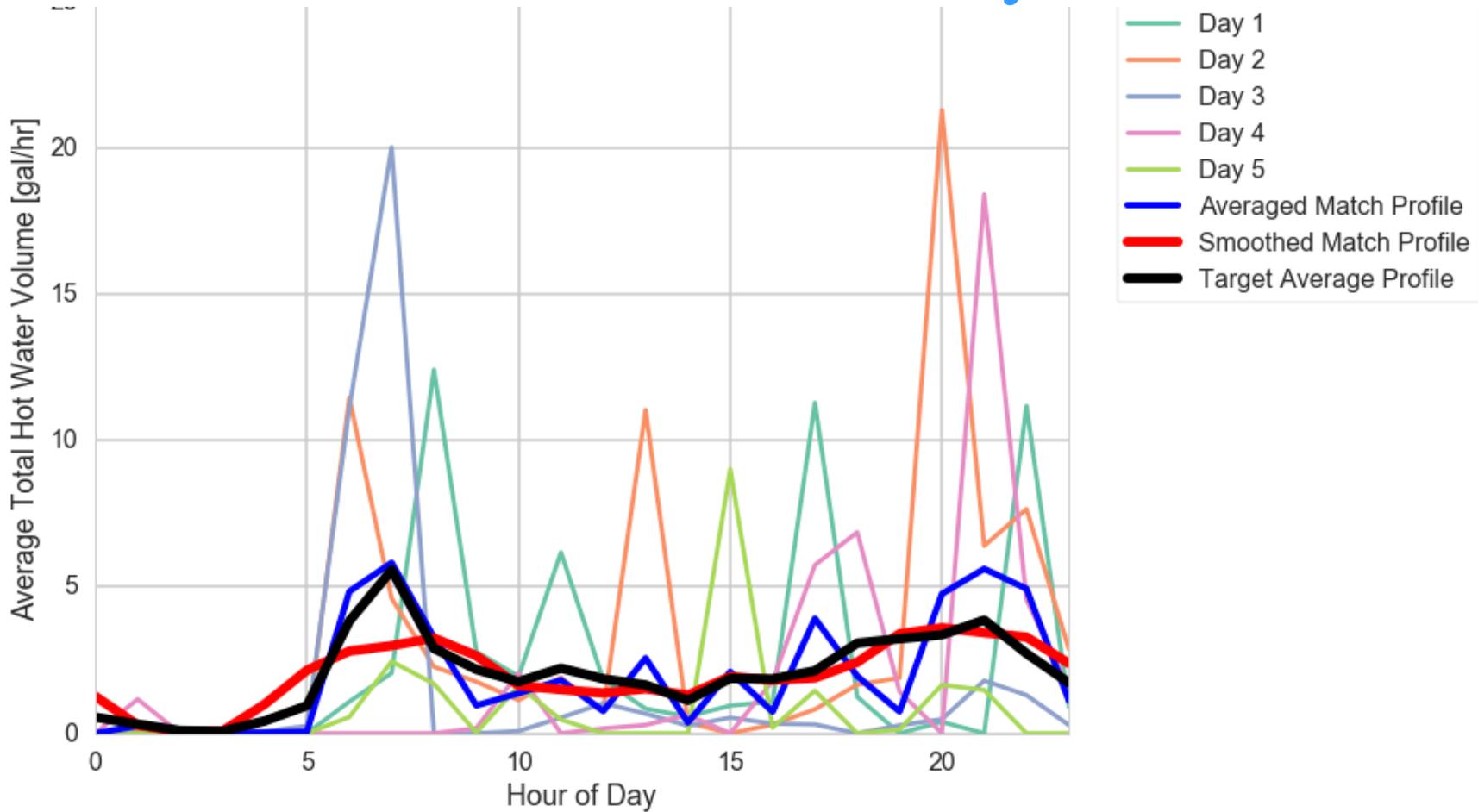


4 Person Selected Weekday Profile



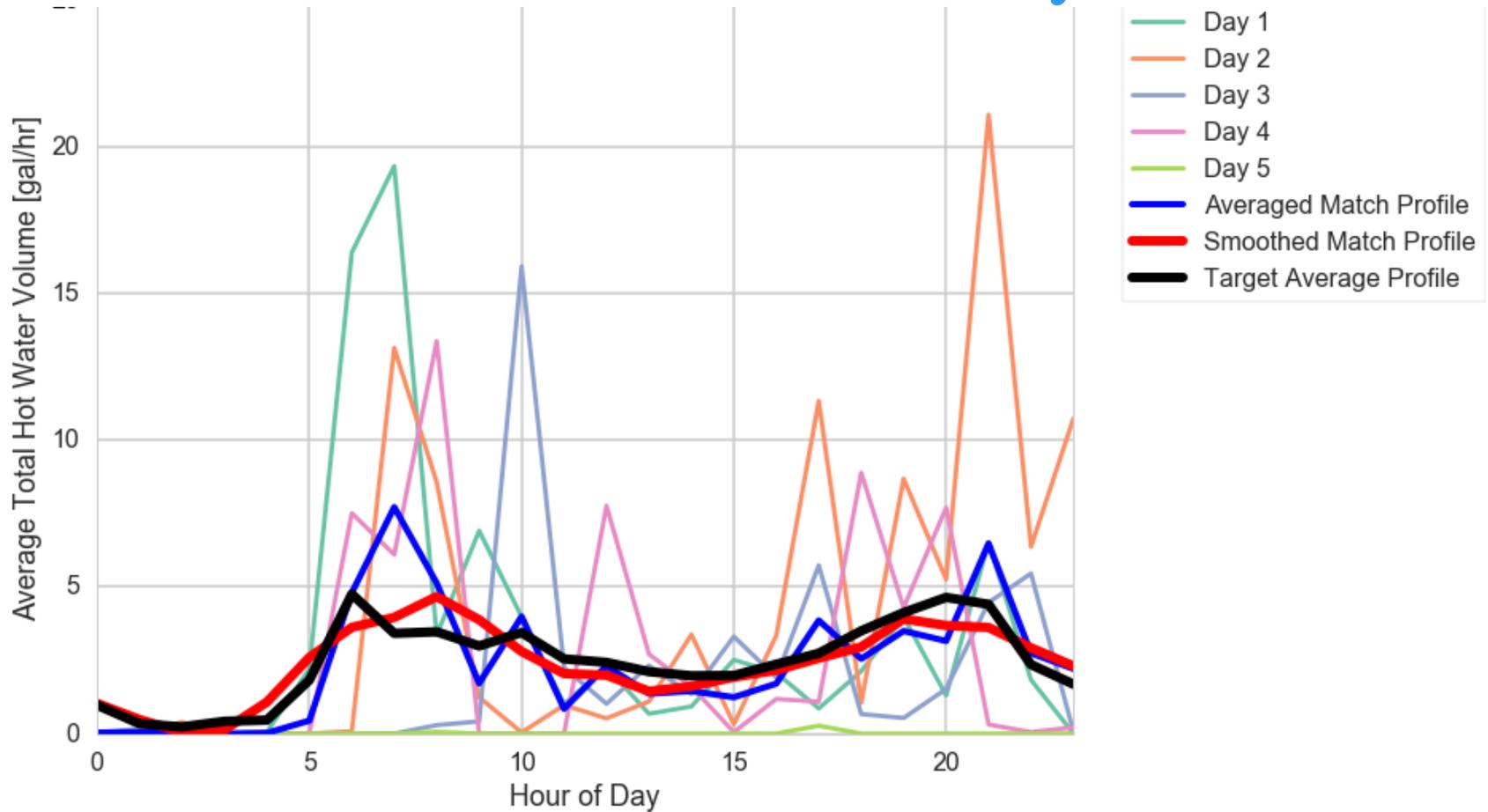


5 Person Selected Weekday Profile





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

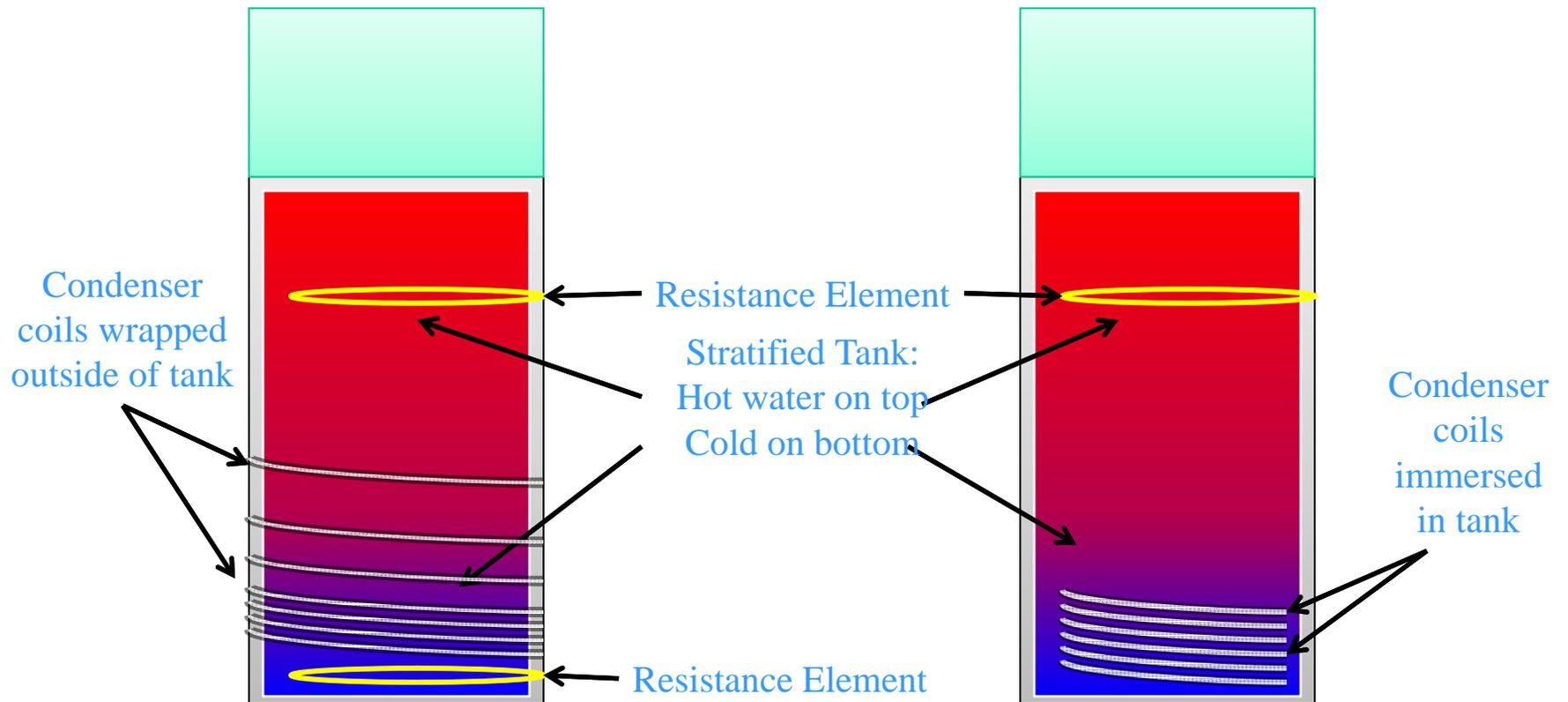


Ecotope/NEEA HPWH Model

- 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





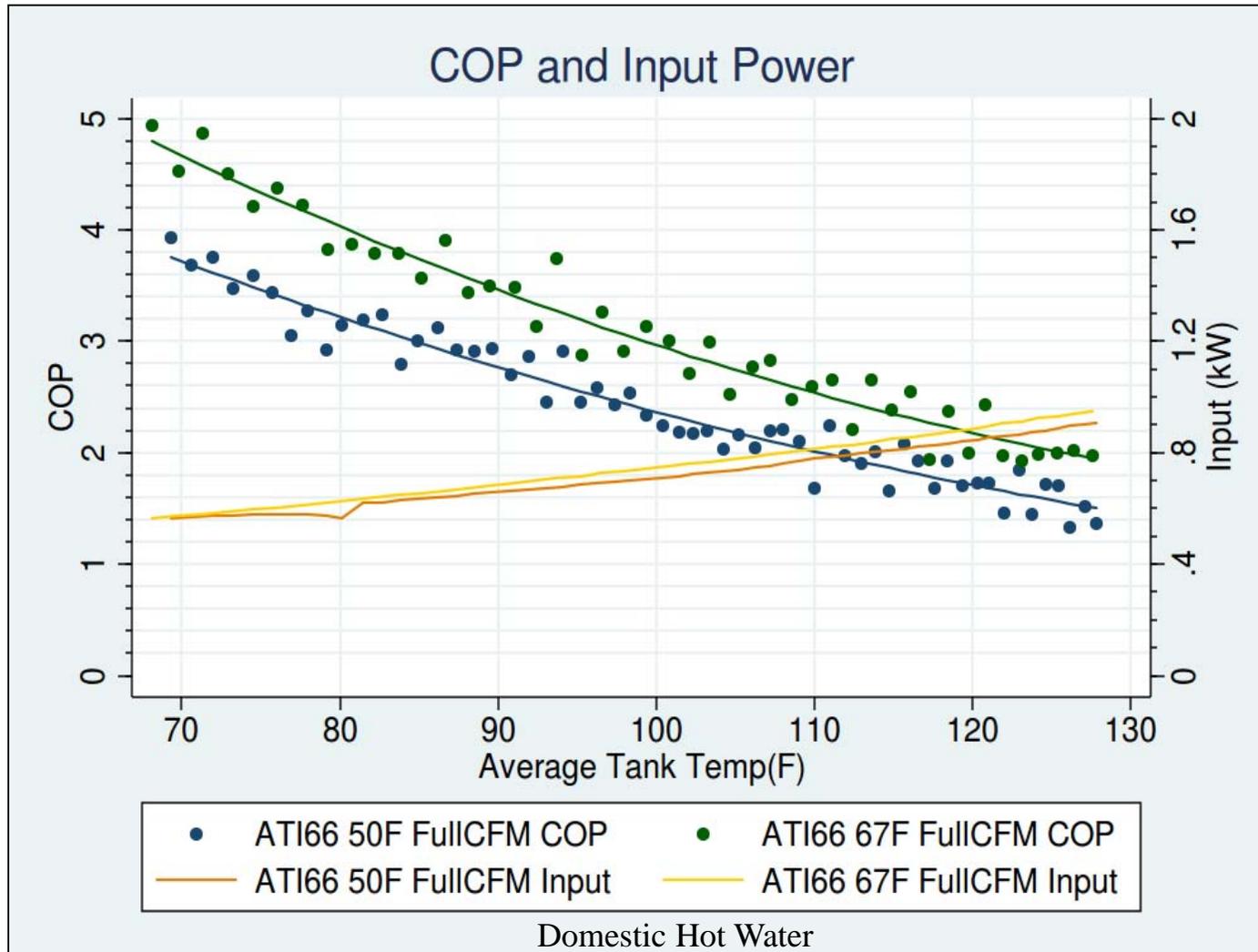
Lab Data

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



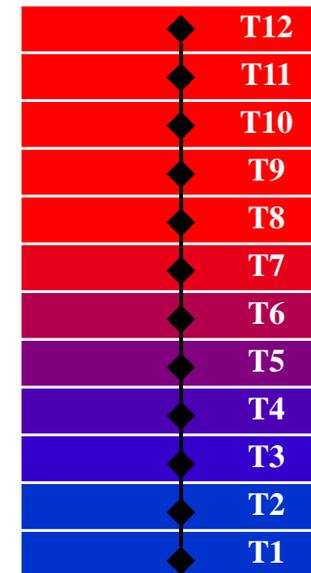
Lab Measured Performance Curves





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

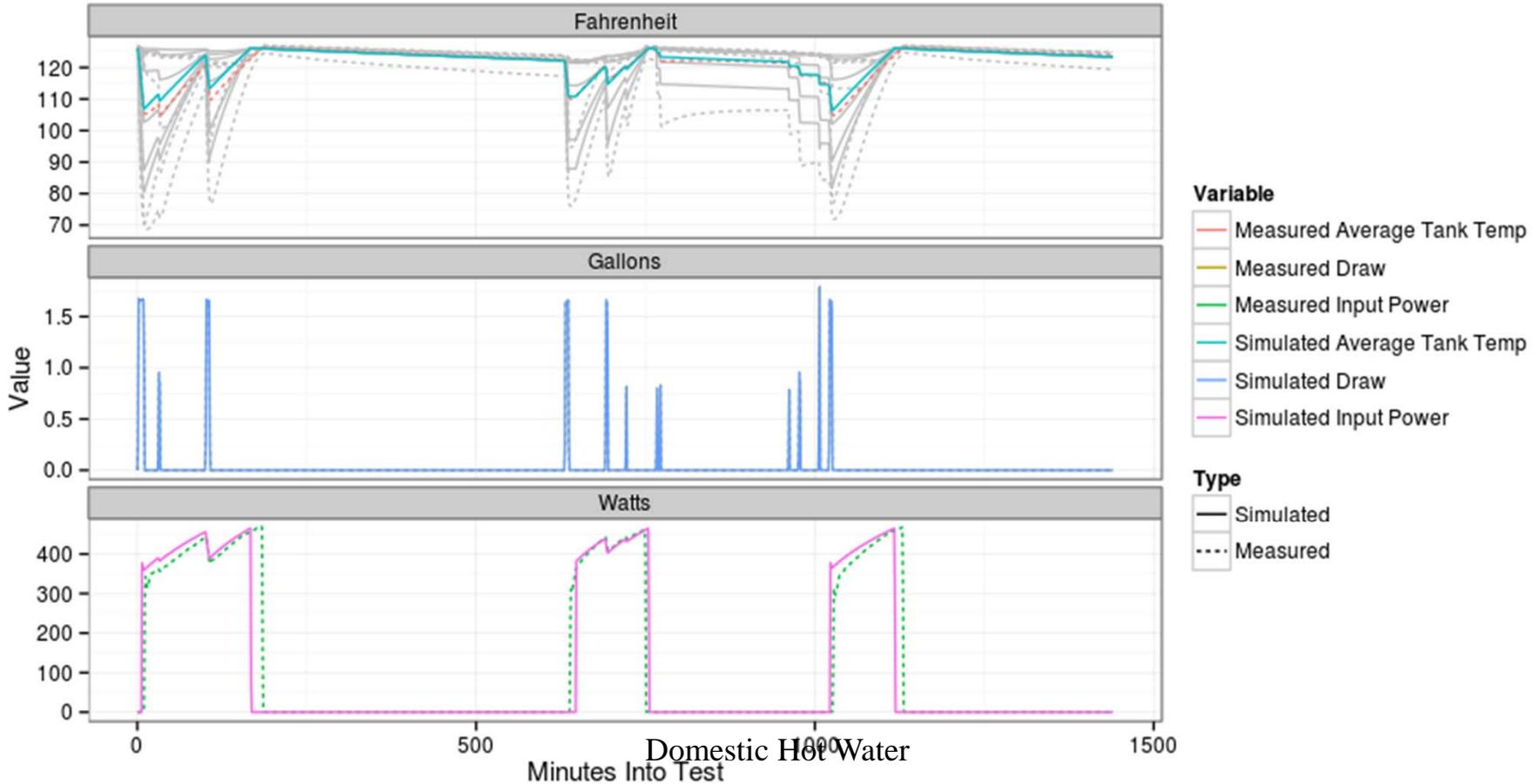




Model Validated Against Lab Data

DOE 24hour Test Pattern on a 50 gallon HPWH

kWh Measured: 2.68 kWh Simulated: 2.56

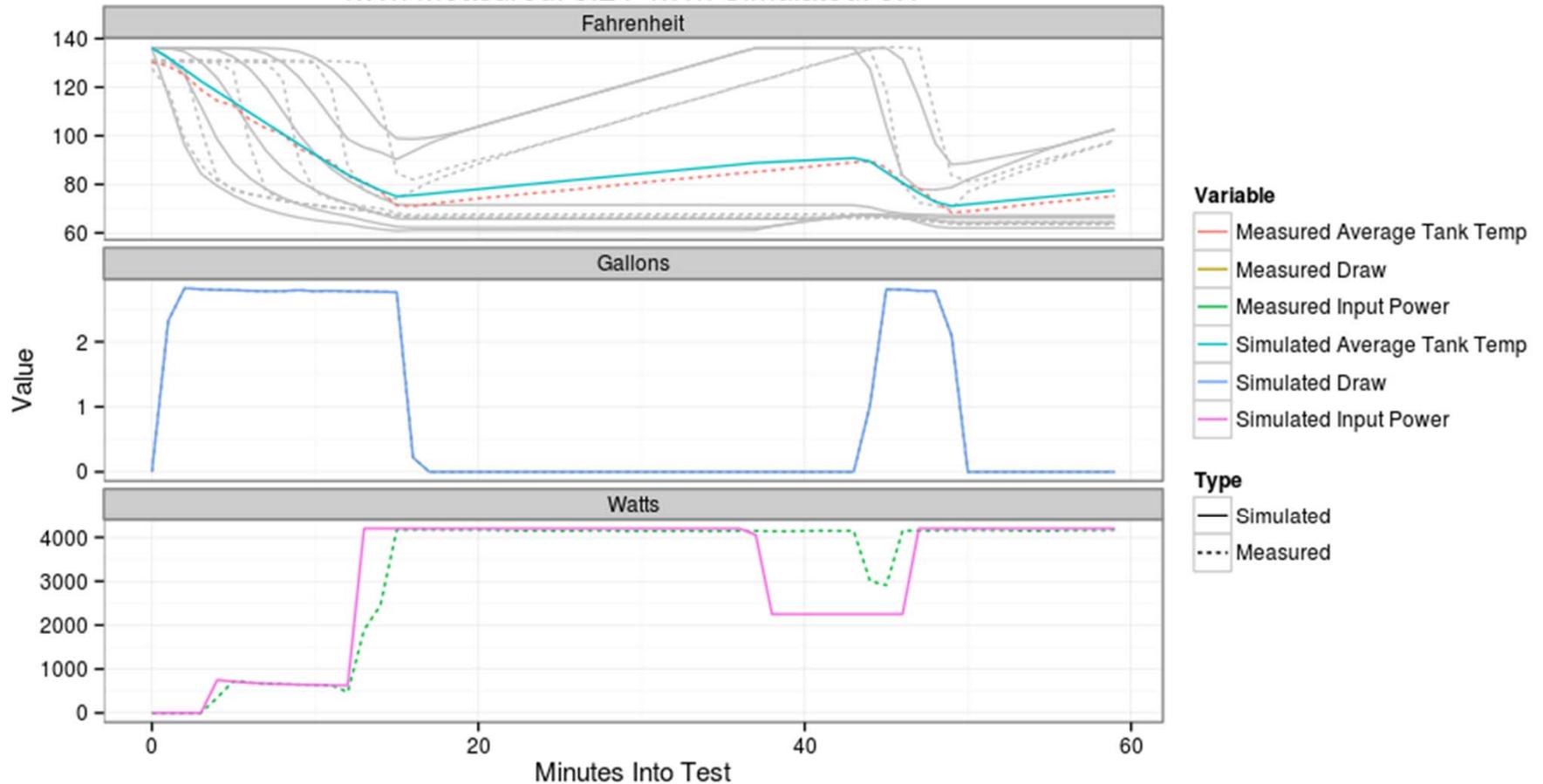




Model Validated Against Lab Data

DOE 1hr Test on a 50 gallon HPWH

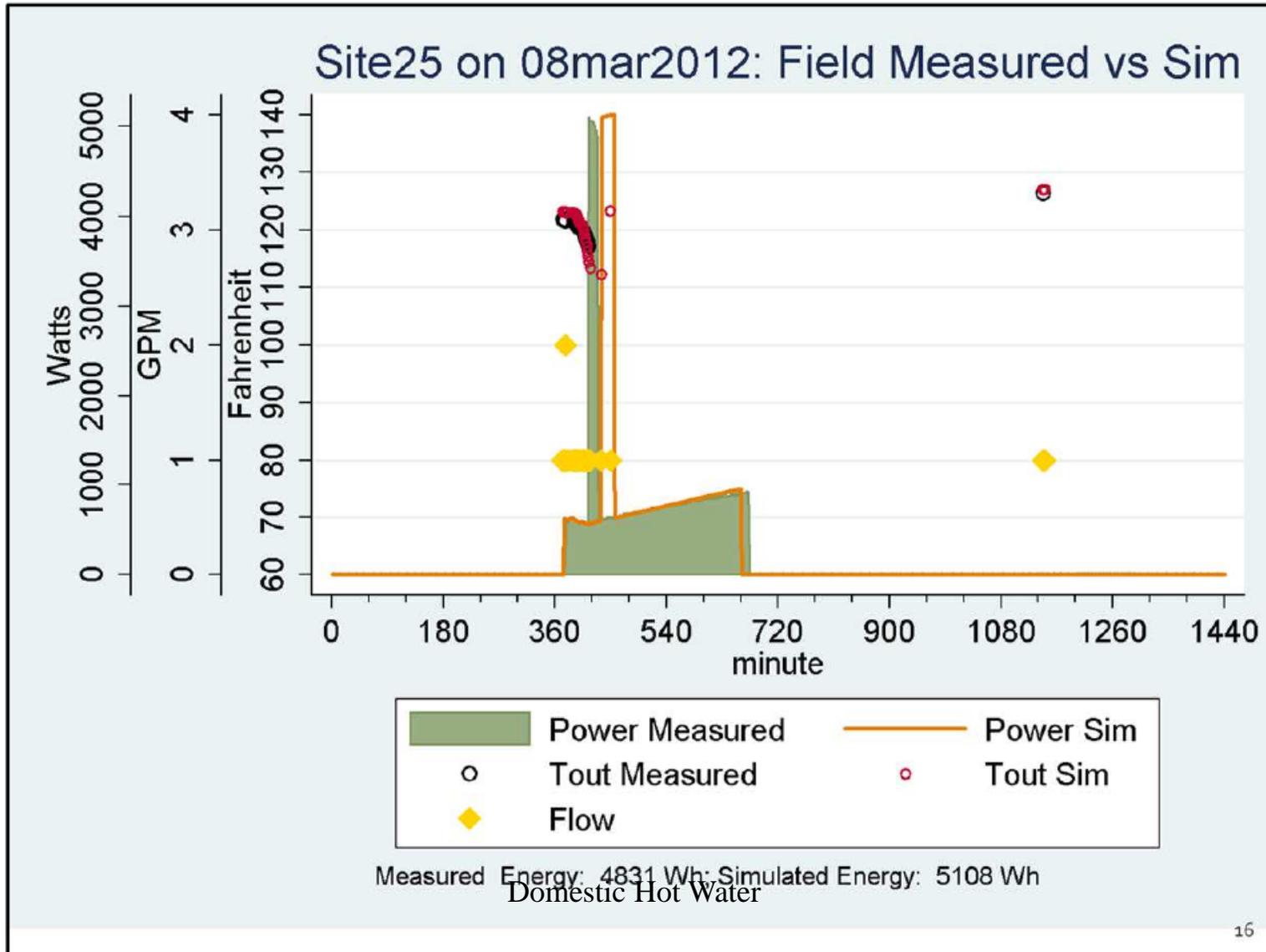
kWh Measured: 3.24 kWh Simulated: 3.1



Domestic Hot Water



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