

MULTIFAMILY DOMESTIC HOT WATER USE WITH HEAT PUMPS: FIELD RESULTS

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**REDWOOD ENERGY:
SEAN ARMSTRONG, MICHAEL
WINKLER AND GREG PFOTENHAUER**

- Sean and Michael separately began working on off-grid, solar powered houses in 1995-96, Greg in 2010, and they all met at CCAT
- Sean: B.S. in Natural Resources Conservation, Science teacher ('02-05') and Project Manager ('05-'11) for large developer/GC
- Michael: B.S. degrees in Physics and Engineering, careers in telecommunications and fuel cells, CEA, HERS Rater, LEED Rater
- Greg: B.S. in Engineering, solar and biomass engineering at Schatz Lab, HSU teacher, data analyst with RE and BIG



France: Gas explosion in building linked to apparent attempted suicide



French firefighters work in the rubble on Pierre Palliot Street in Dijon, France, after a gas explosion destroyed a building on Sept. 16, 2016. / ROMAIN LAFABREGUE/AFP/GETTY IMAGES

Police & Fire

Final Victim Identified in Silver Spring Apartment Explosion

Investigators say a natural gas leak caused an explosion and fire that killed seven people; identity has been confirmed.

By Deb Belt (Patch Staff) - September 21, 2016 6:10 pm ET | P



San Francisco Chronicle
California's Best Large Newspaper AS RATED BY THE CALIFORNIA NEWSREUTERS PUBLISHERS ASSOCIATION | 5000 *****

Inferno

At least 1 dead as PG&E line explodes, fire levels San Bruno neighborhood



East Village Explosion Ignites Fire, Fells Buildings and Injures at Least 19

By MARC SANTORA and AL BAKER MARCH 26, 2015

f t i s



Witness videos show the scene in the East Village after an explosion caused a fire on Second Avenue, affecting neighboring buildings. March 26, 2015. Photo by Nancy Borowick for The New York Times. Watch in Times Video >

STUDYING ALL-ELECTRIC HOUSING, PARTICULARLY DHW



- High-resolution data from 5 locations
 - Second-by-second data
 - Whole house (n~270) and one “specialty line” per apartment
 - Cooking (range)
 - HVAC
 - Plug loads
 - Living rooms
 - Bedrooms
 - Bathrooms
 - DHW
 - Current, voltage, phase angle
- Low-resolution (yearly/monthly) data from 7+ other locations
- Farmworker, general/family, senior
- Fully electric, LEED Platinum, ENERGY STAR



MULTIFAMILY STUDY SITES

Lakeport



King City



Spring Lake



Dixon



Oxnard

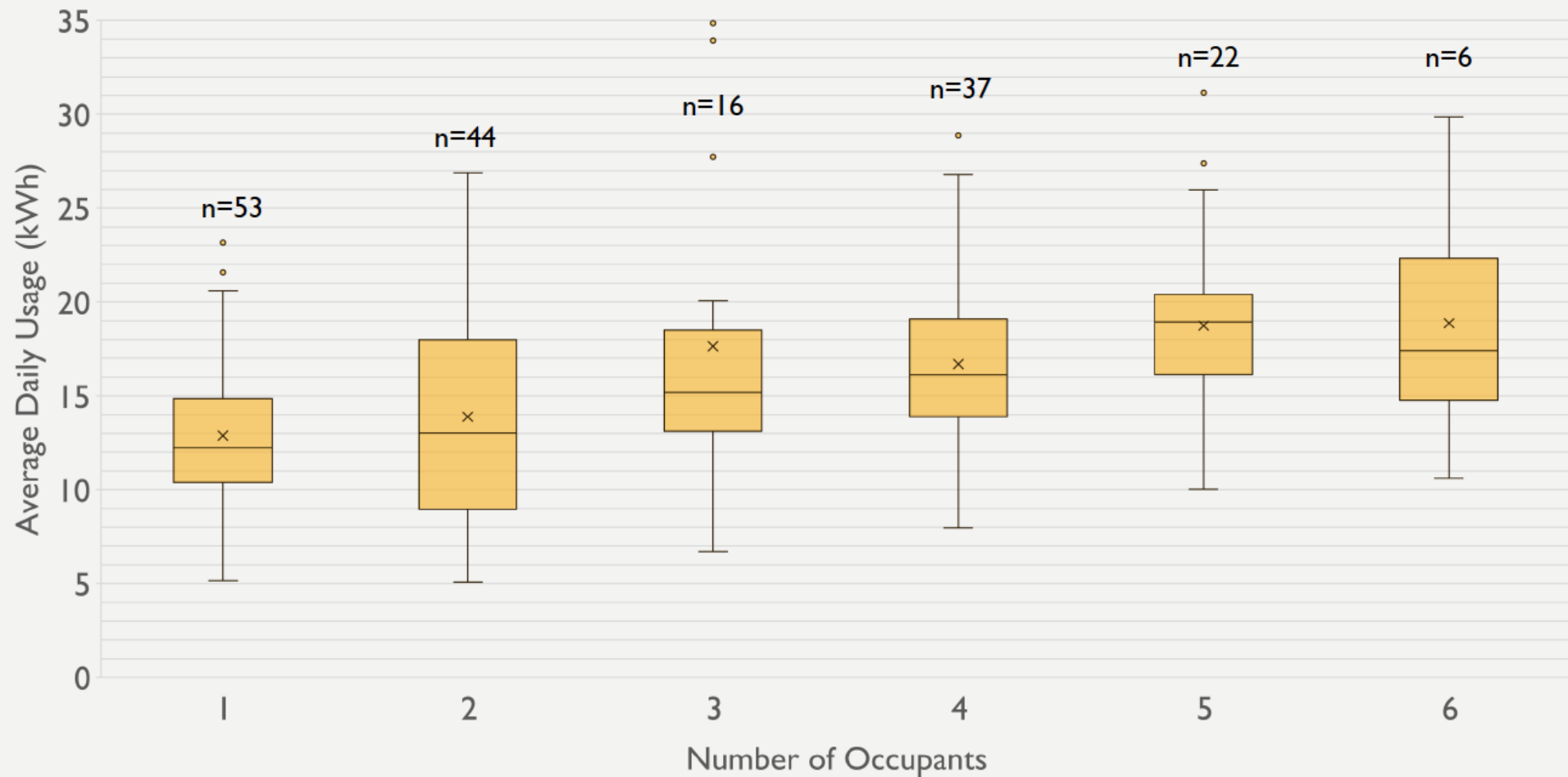


**PRIMARILY GE GEOSPRING EF=2.4
WITH SOME STATE EF=2.33**



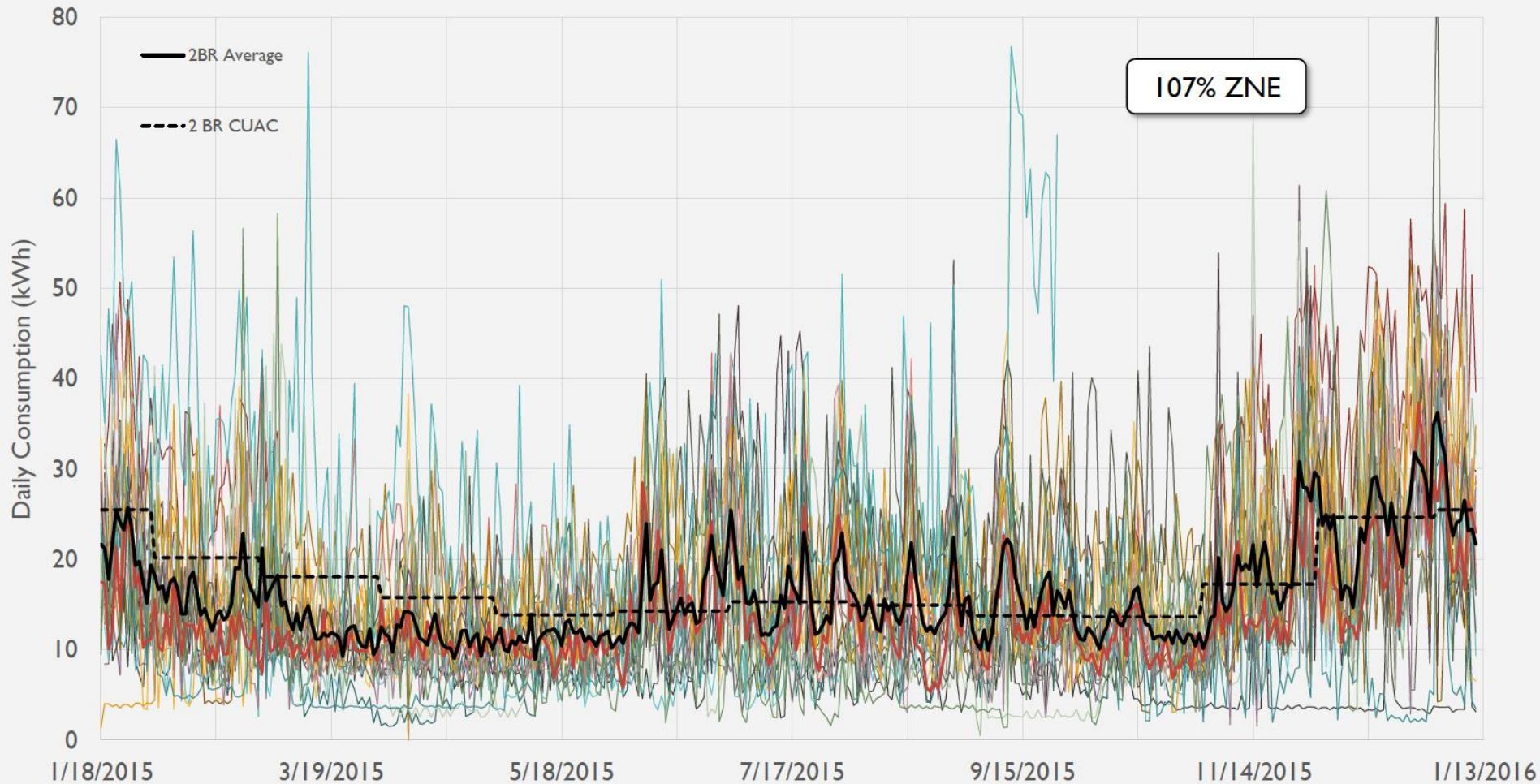
PER CAPITA ELECTRICITY CONSUMPTION

Average Daily Electricity Consumption in All-Electric Multifamily ZNE Homes Homes in Oxnard, Dixon, King City, and Lakeport

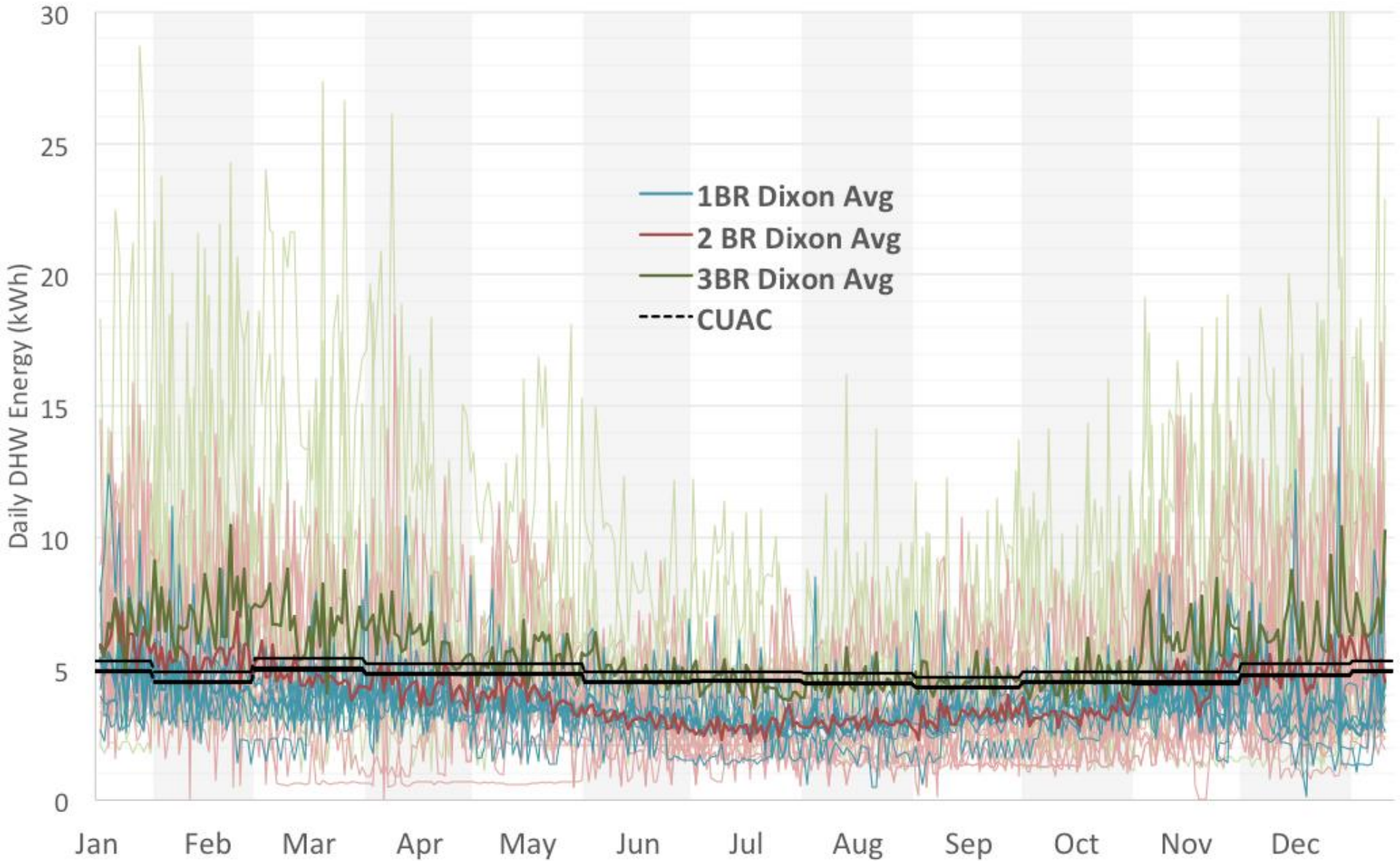


WHOLE HOUSE MODELS PROVE TO BE 86-120% OF METERED HOUSEHOLDS

Daily Electricity Consumption in 2-Bedroom Apartments at Dixon, CA

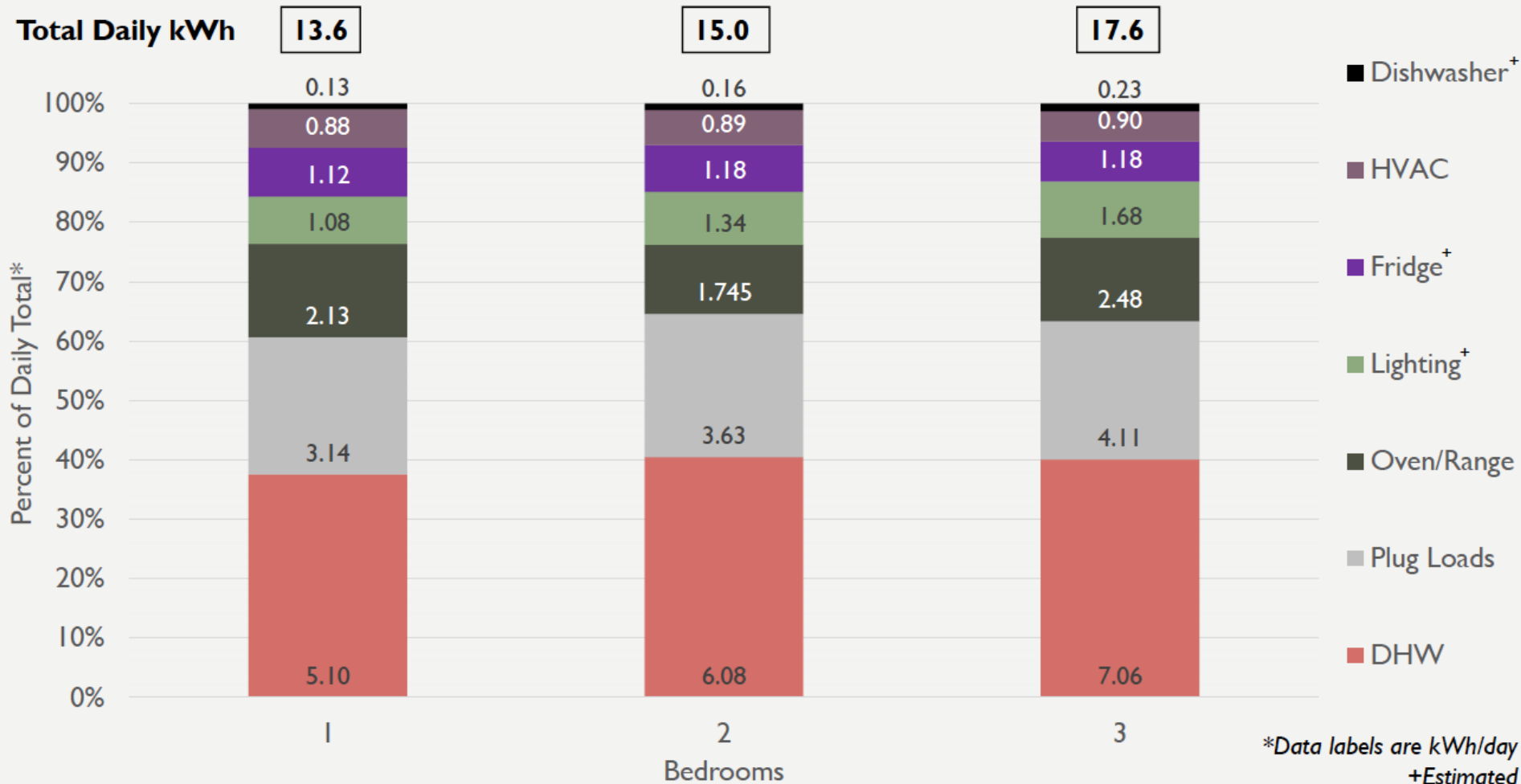


2008 ENERGY PRO DHW MODEL VS RESULTS



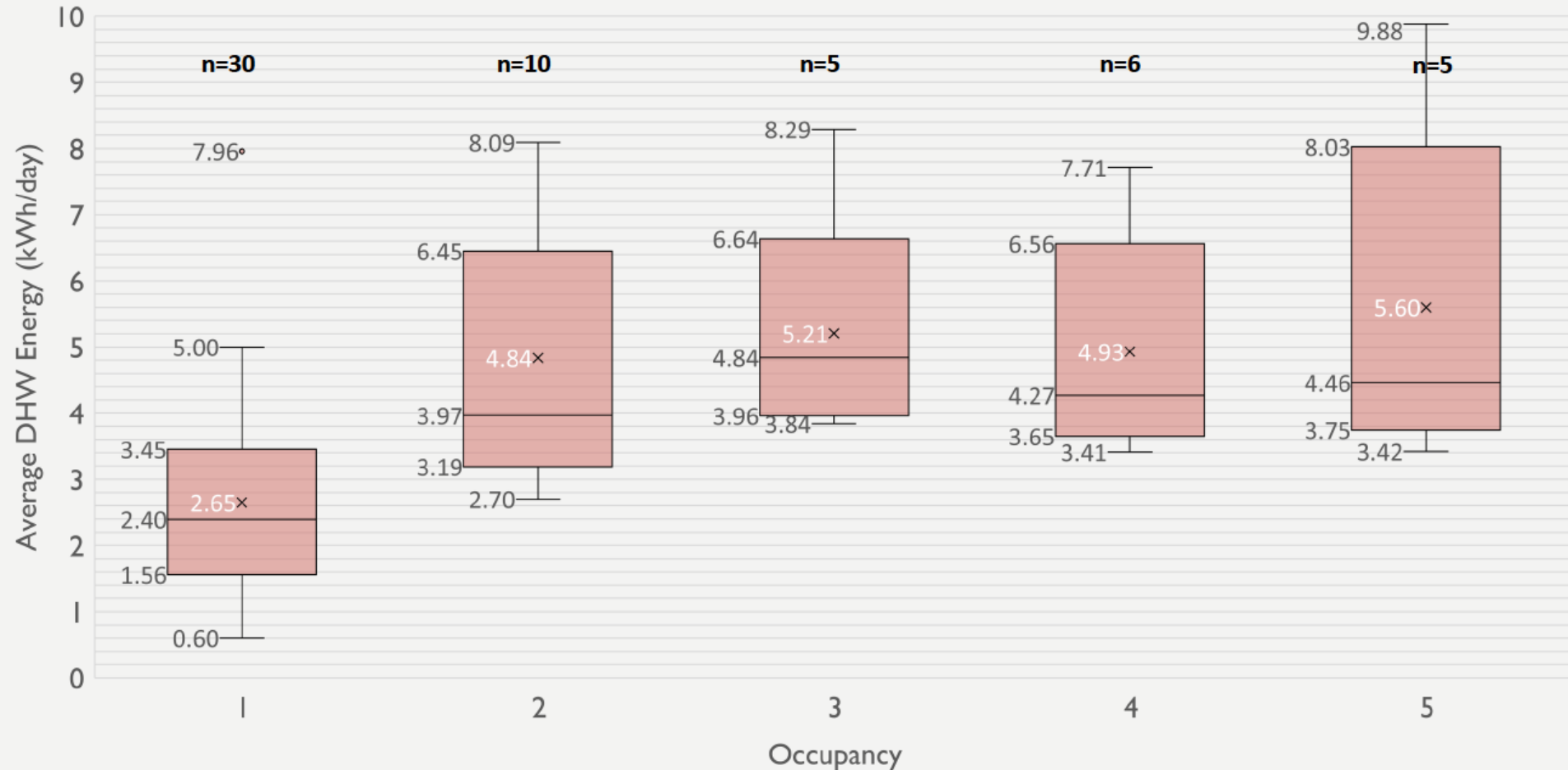
WHAT IS THE LARGEST LOAD?

Energy Profile for Multifamily Homes in King City, CA

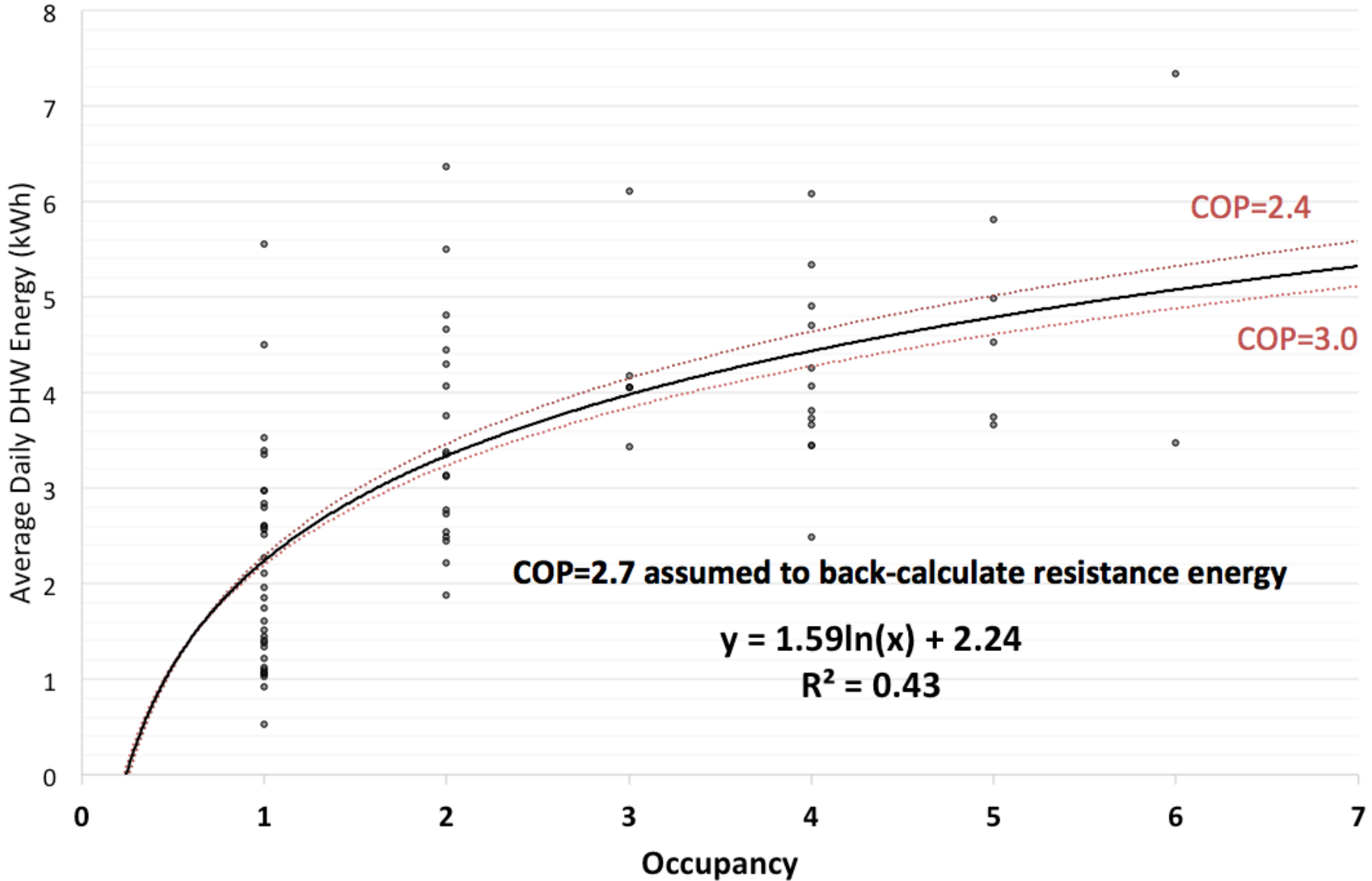


DHW ENERGY USE IS NON-LINEAR

Per-Occupant Daily DHW Usage for Hybrid Electric Water Heaters
King City, Dixon, Lakeport

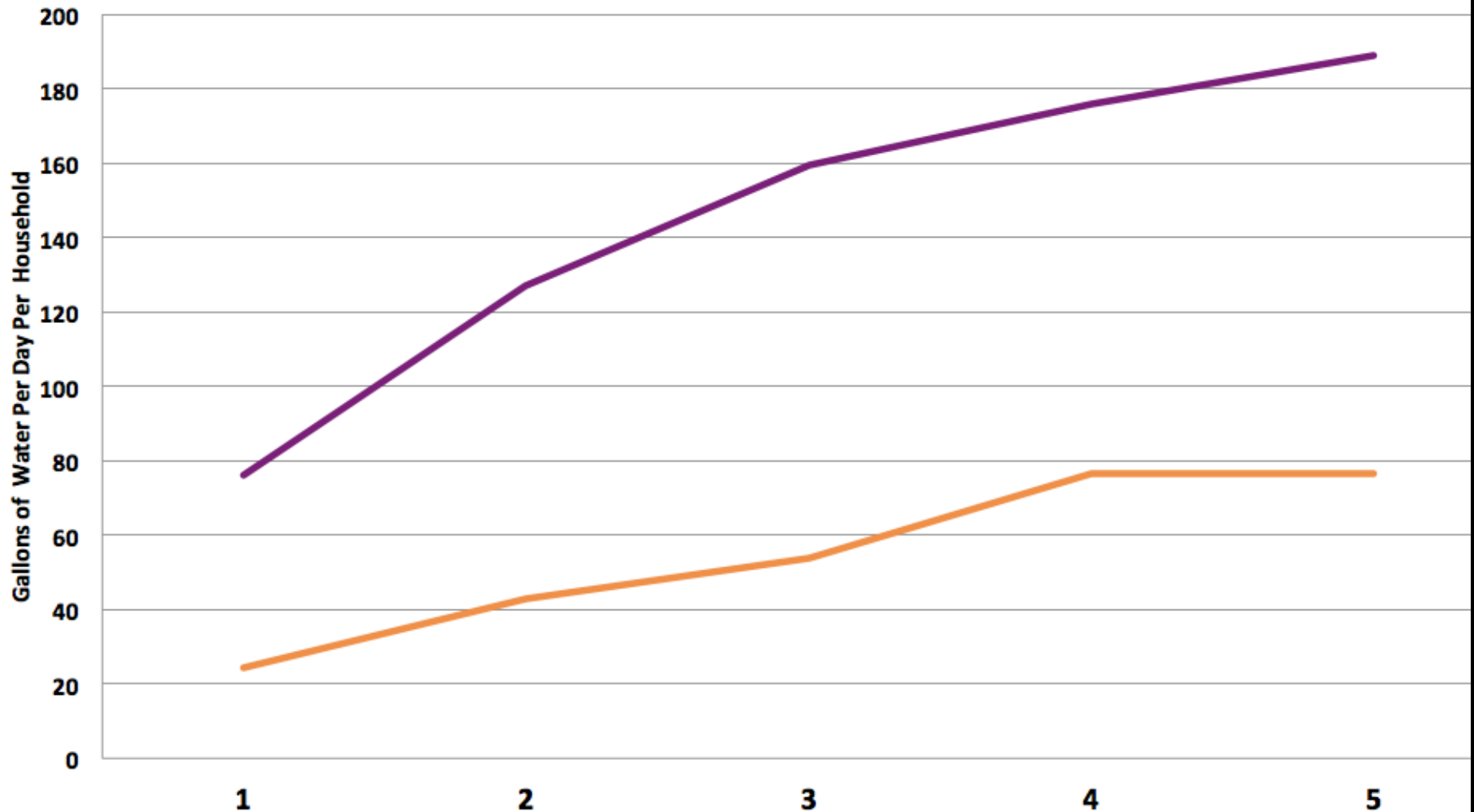


DHW ELECTRICITY USE BASED ON OCCUPANCY



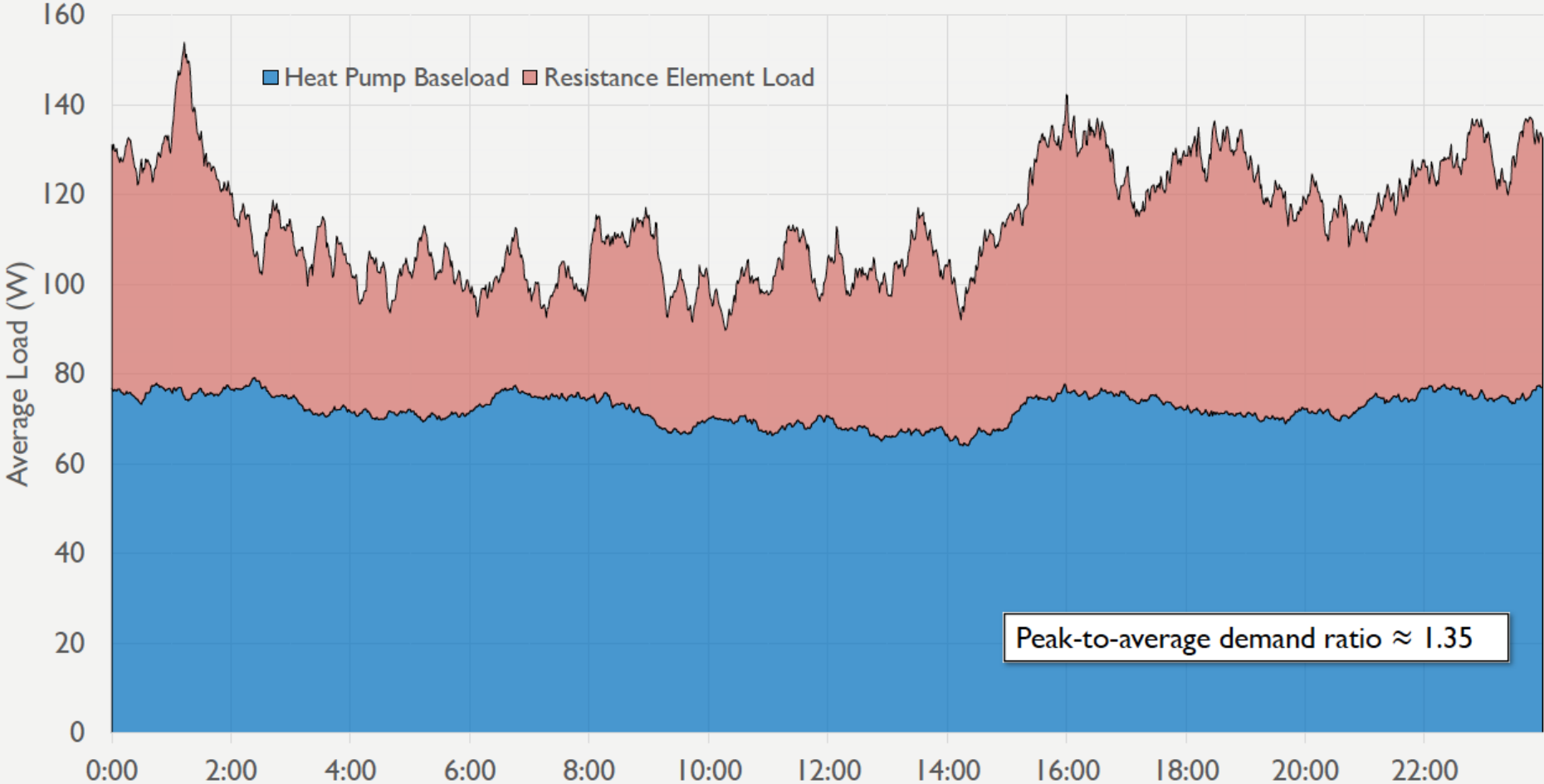
**HOT WATER USE DOES NOT INCREASE AS
STEEPLY AS ELECTRICITY USE**

**Mixed Whole House Water and DHW Consumption vs. Occupancy:
REU2016, n=705, n=96**



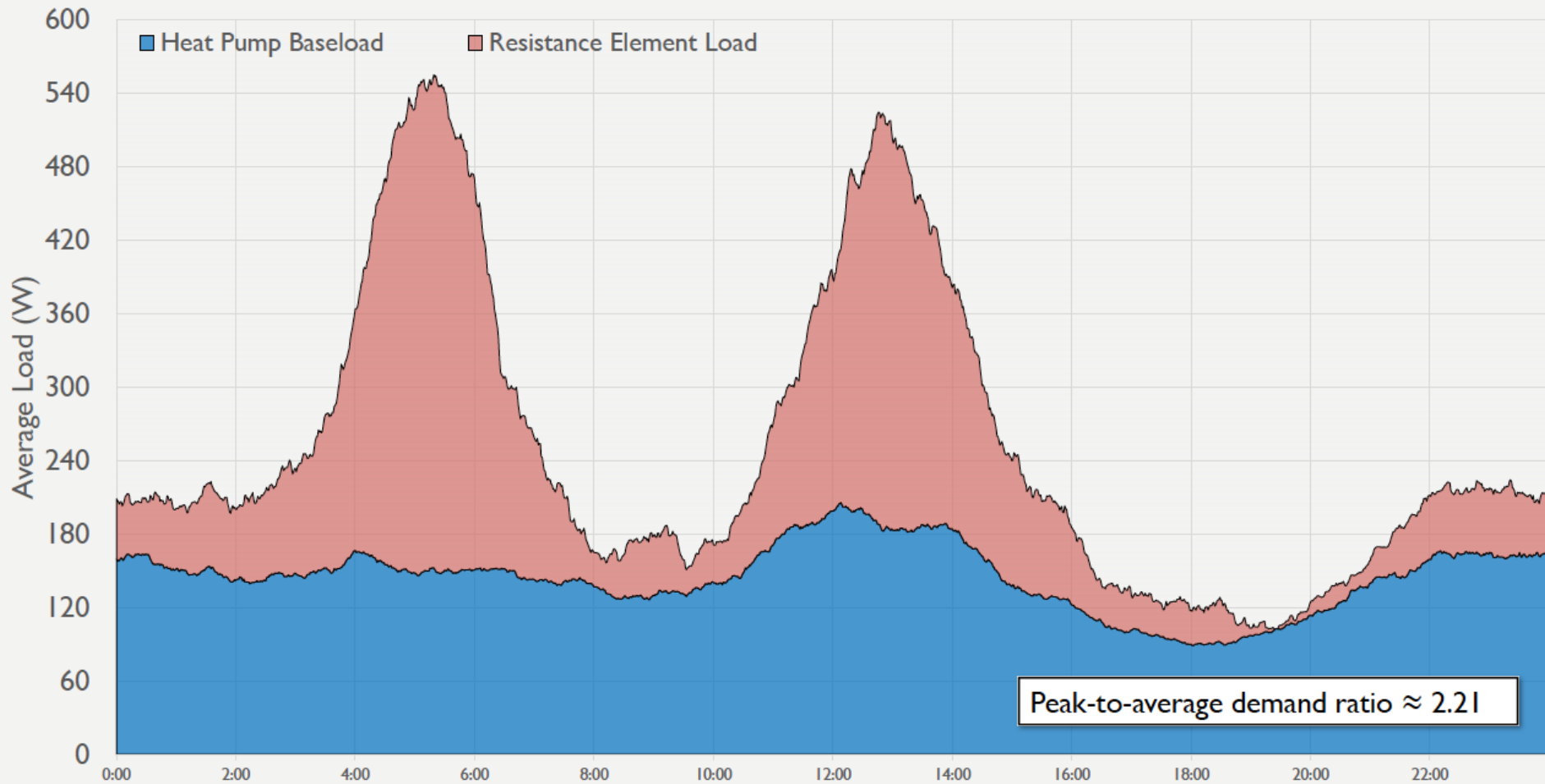
**RESISTANCE BACK-UP MAY BE
THE SOURCE OF NON-LINEARITY**

I-Occupant Daily Weekday DHW Loads
Hybrid Electric Water Heater with Appropriate Thermal Storage



HIGHER OCCUPANCY LEADS TO MORE RESISTANCE BACK-UP

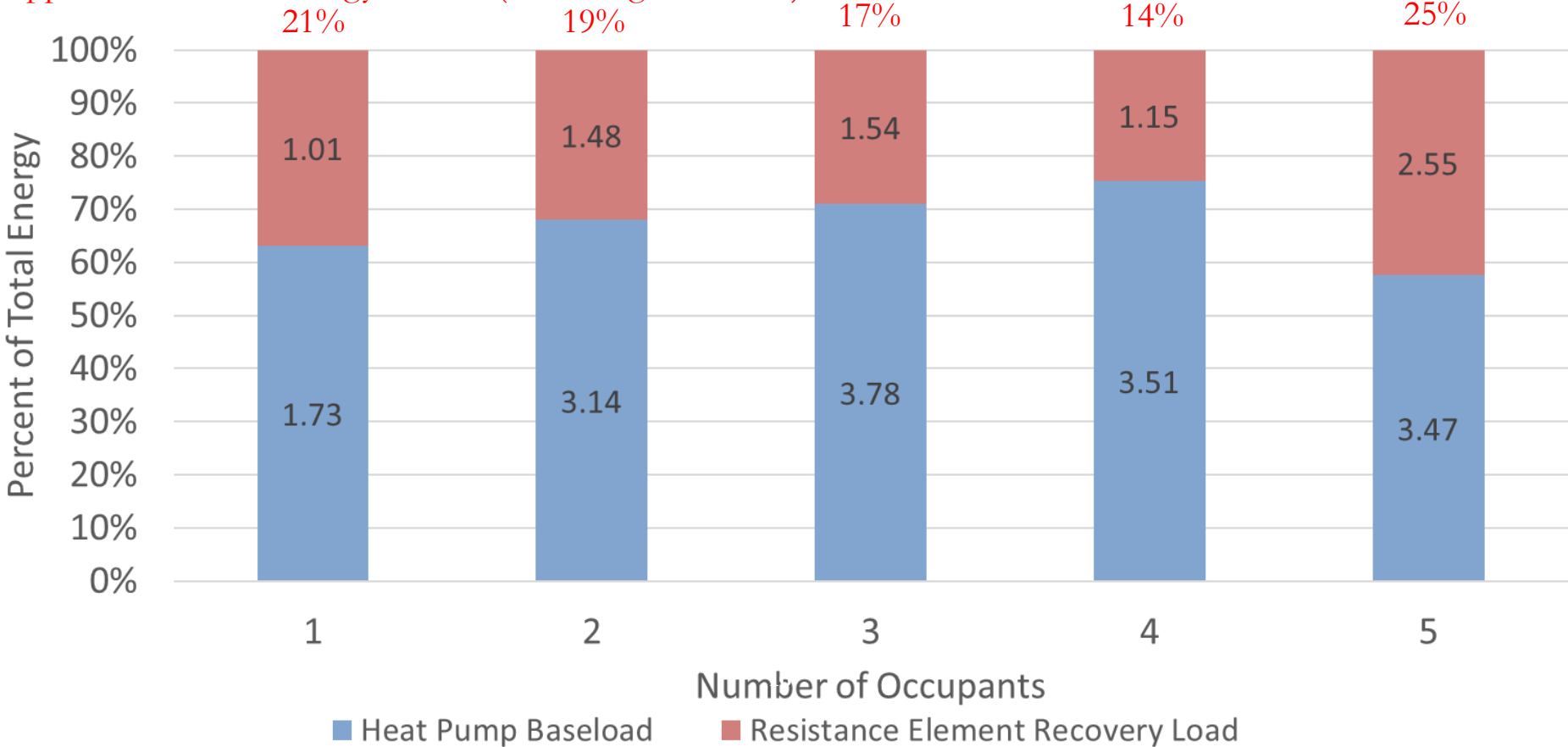
5-Occupant Daily Weekday DHW Loads Hybrid Electric Water Heater with Insufficient Thermal Storage



GREATER THERMAL STORAGE COULD REDUCE RESISTANCE LOADS SIGNIFICANTLY

Weekday Energy Breakdown for Hybrid Electric Water Heaters (Annotated with Average Daily Energy - kWh)

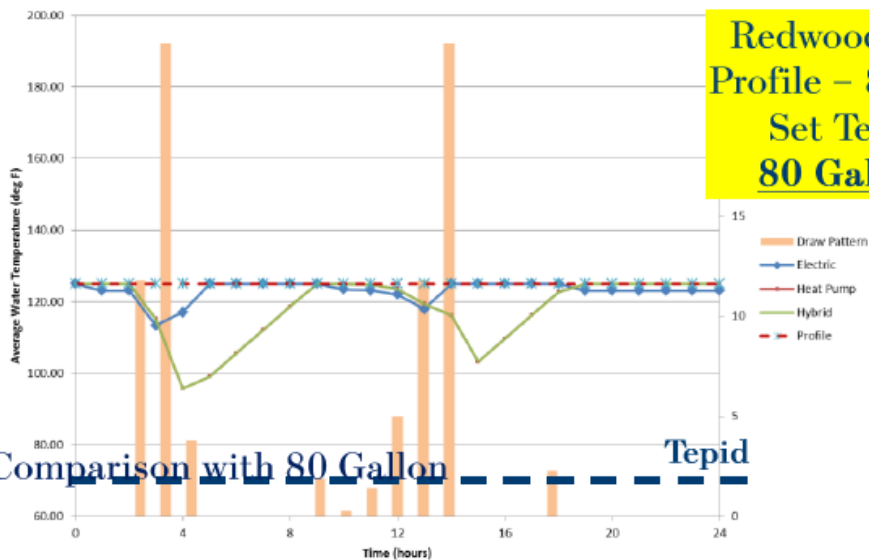
Approximate Total Energy Wasted (Assuming EF of 2.4)



**LOSSES ARE LARGE DUE TO
NEEDLESS RESISTANCE**

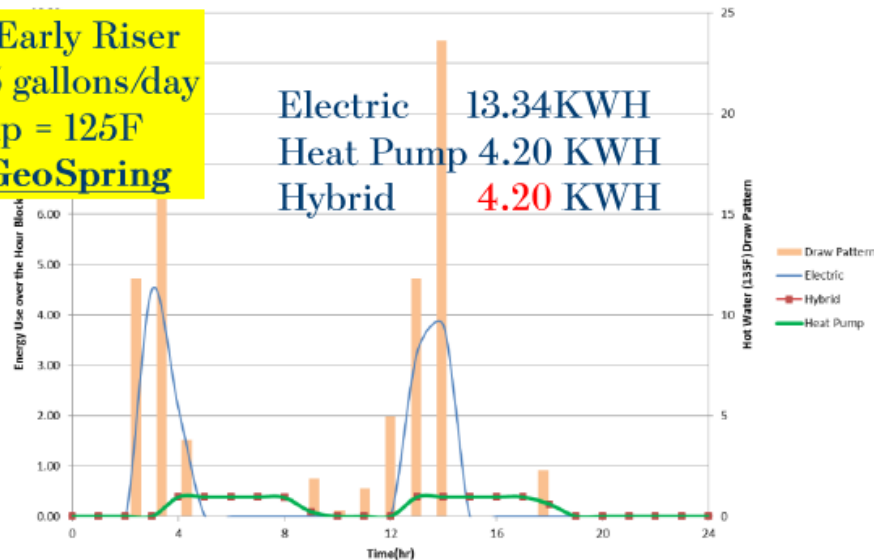
		OCCUPANCY				
		1	2	3	4	5
	Peak-to-average demand ratio	1.35	1.22	1.69	1.40	2.21
Per capita annual losses	Energy (kWh)	231.6	338.6	352.6	262.8	585.8
	\$	\$ 27.79	\$ 40.63	\$ 42.31	\$ 31.54	\$ 70.29
	CO2 (lb)	204	298	309	231	515

Average Water Temperature as a function of Time of Day, Draw Pattern, Set Temperature Profile and Mode of Operation

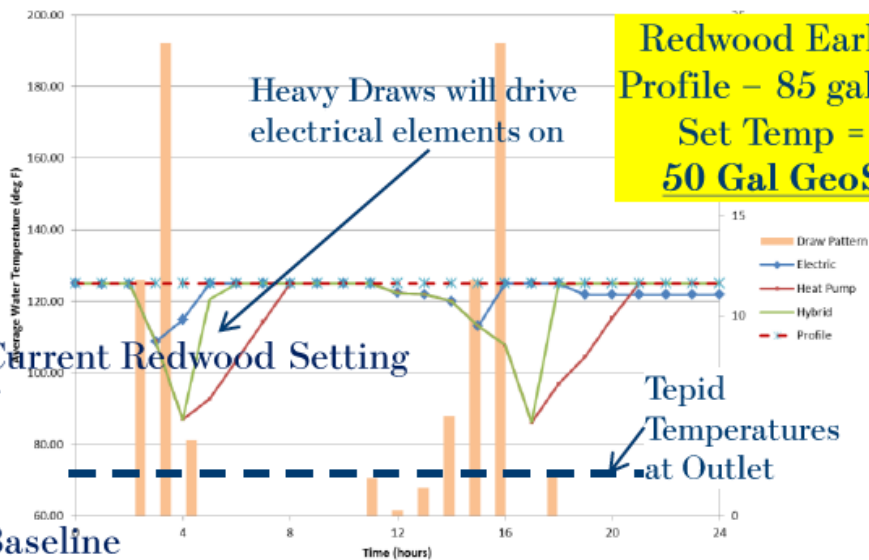


Redwood Early Riser Profile – 85 gallons/day
Set Temp = 125F
80 Gal GeoSpring

Average Power Draw as a function of Time of Day, Draw Pattern, Set Temperature Profile and Mode of Operation

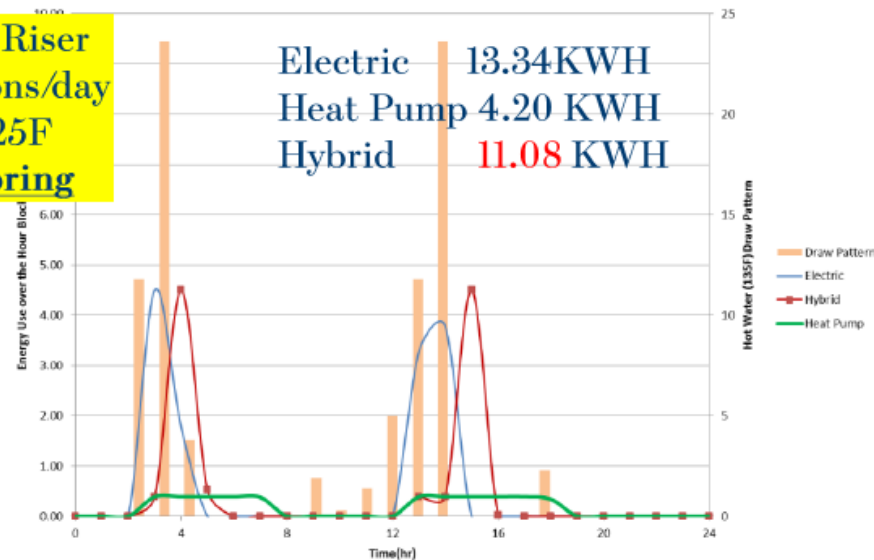


Average Water Temperature as a function of Time of Day, Draw Pattern, Set Temperature Profile and Mode of Operation



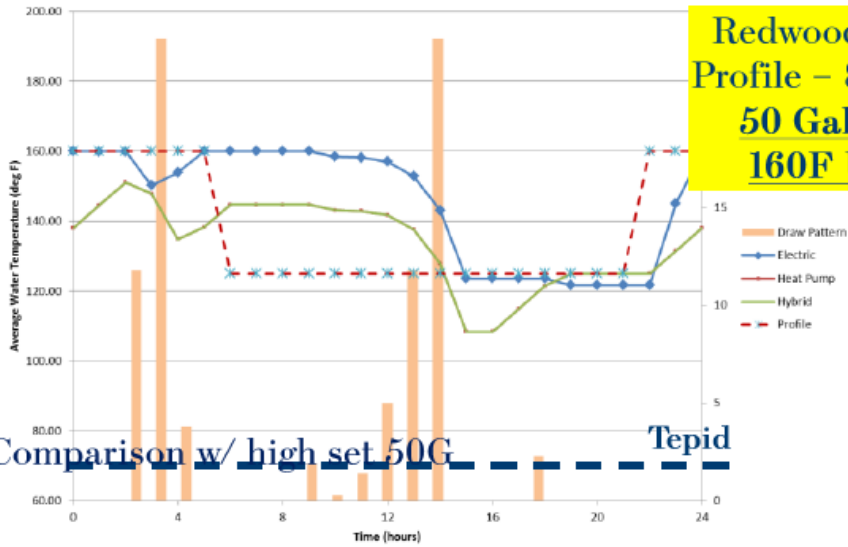
Redwood Early Riser Profile – 85 gallons/day
Set Temp = 125F
50 Gal GeoSpring

Average Power Draw as a function of Time of Day, Draw Pattern, Set Temperature Profile and Mode of Operation



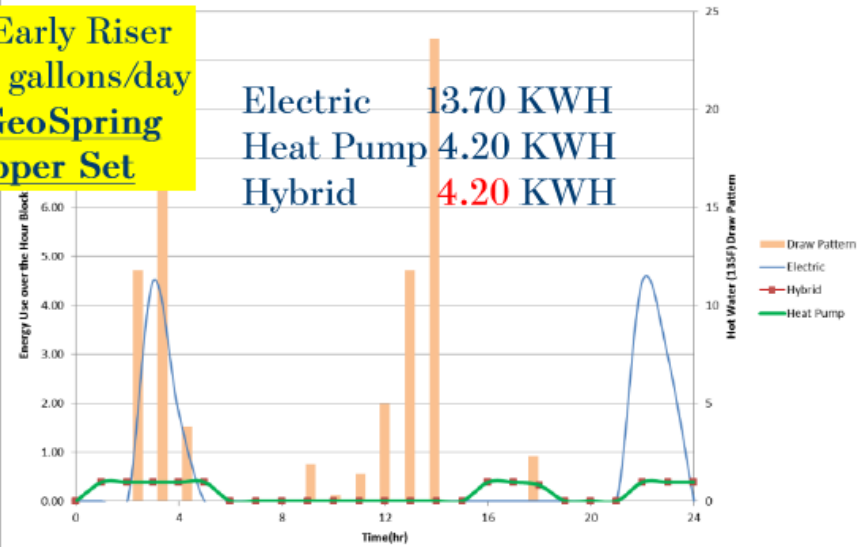
An 80 Gal Tank stores enough thermal energy to avoid the hybrid mode using electrical resistance

Average Water Temperature as a function of Time of Day, Draw Pattern, Set Temperature Profile and Mode of Operation



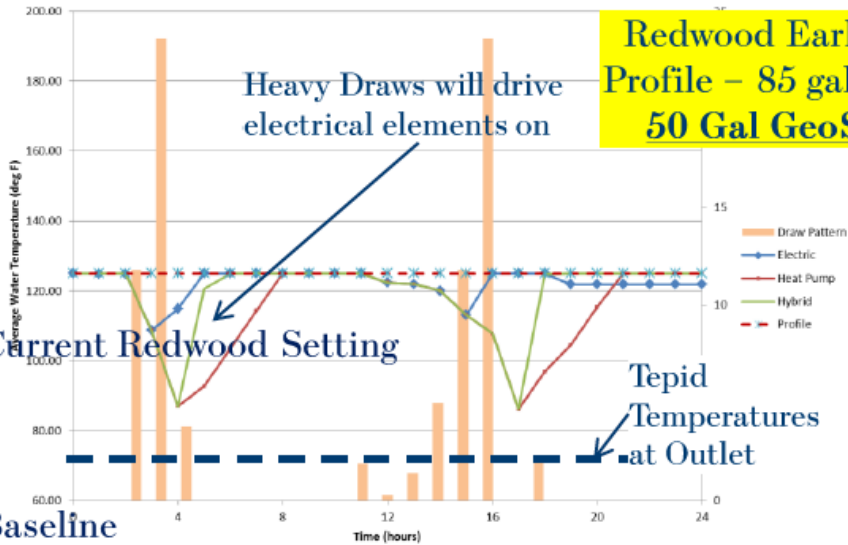
Comparison w/ high set 50G Tepid

Average Power Draw as a function of Time of Day, Draw Pattern, Set Temperature Profile and Mode of Operation



Electric 13.70 KWH
Heat Pump 4.20 KWH
Hybrid 4.20 KWH

Average Water Temperature as a function of Time of Day, Draw Pattern, Set Temperature Profile and Mode of Operation



Heavy Draws will drive electrical elements on

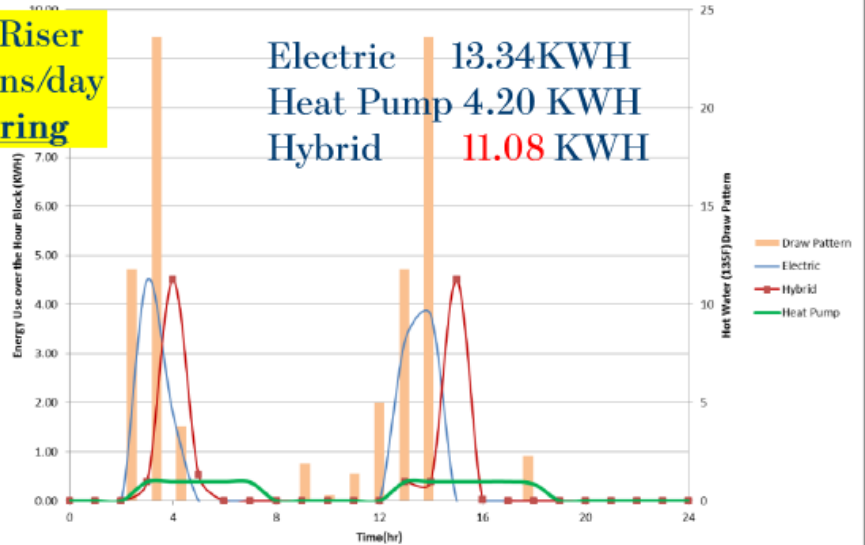
Current Redwood Setting

Redwood Early Riser Profile - 85 gallons/day
50 Gal GeoSpring

Tepid Temperatures at Outlet

Baseline

Average Power Draw as a function of Time of Day, Draw Pattern, Set Temperature Profile and Mode of Operation



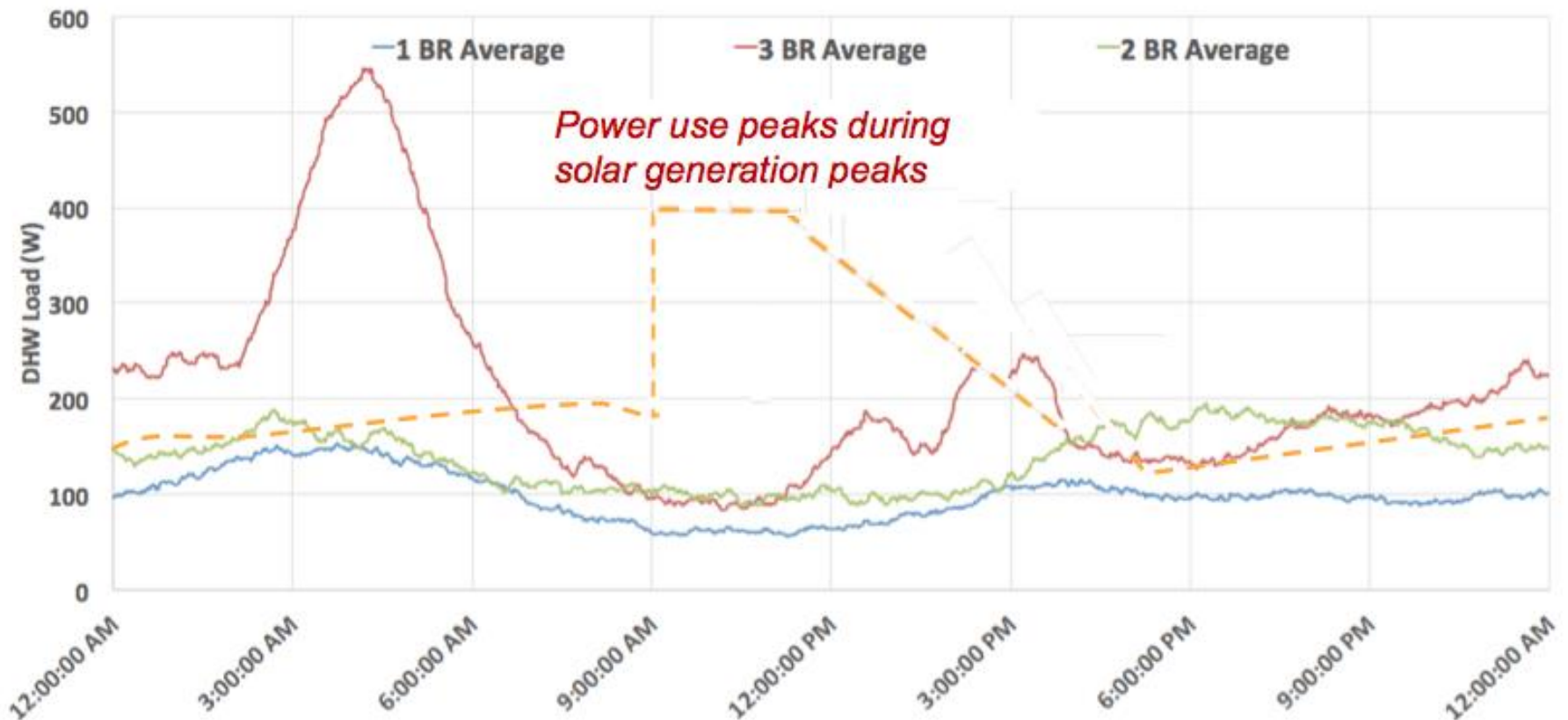
Electric 13.34KWH
Heat Pump 4.20 KWH
Hybrid 11.08 KWH

The ability to adjust set temperatures of the 50 gallon provides similar energy use results to the 80 G, plus more available capacitance

RUNNING THE DHW TO SOAK UP EXCESS SOLAR ENERGY FOR STORAGE

Proposal: Run the Heat Pump DHW in heat pump-only mode, with set point changes to 150F from 9am to noon, then back to 120F

Daily Average Weekday DHW Load Profile for Lakeport, Dixon, and King City Apartments



**EXISTING PRODUCT SOLUTIONS:
150F OUTPUT, 15 AMP INPUT**



STIEBEL ELTRON
Accelera 220 E



MONTERREY PINES: HEAT PUMP DHW RETROFITS MAKE PROJECT PROFITABLE



Introducing
North America's first
CO₂ hot water system



SAN CO₂
Hot water, naturally.

Innovative energy-efficient Heat Pump Water Heater



QUESTIONS?

