FRONTIER energy

Lab Testing Heat Pump Water Heaters for Modeling Load Shifting

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Outline –Providing lab data to modify simulation tools, and performing experiments showing CA compliance benefits

- Introduction and Background
- Project Description
- Lab Testing Plan
- HPWHsim Modification
- TDV Savings Demonstration
- Conclusions

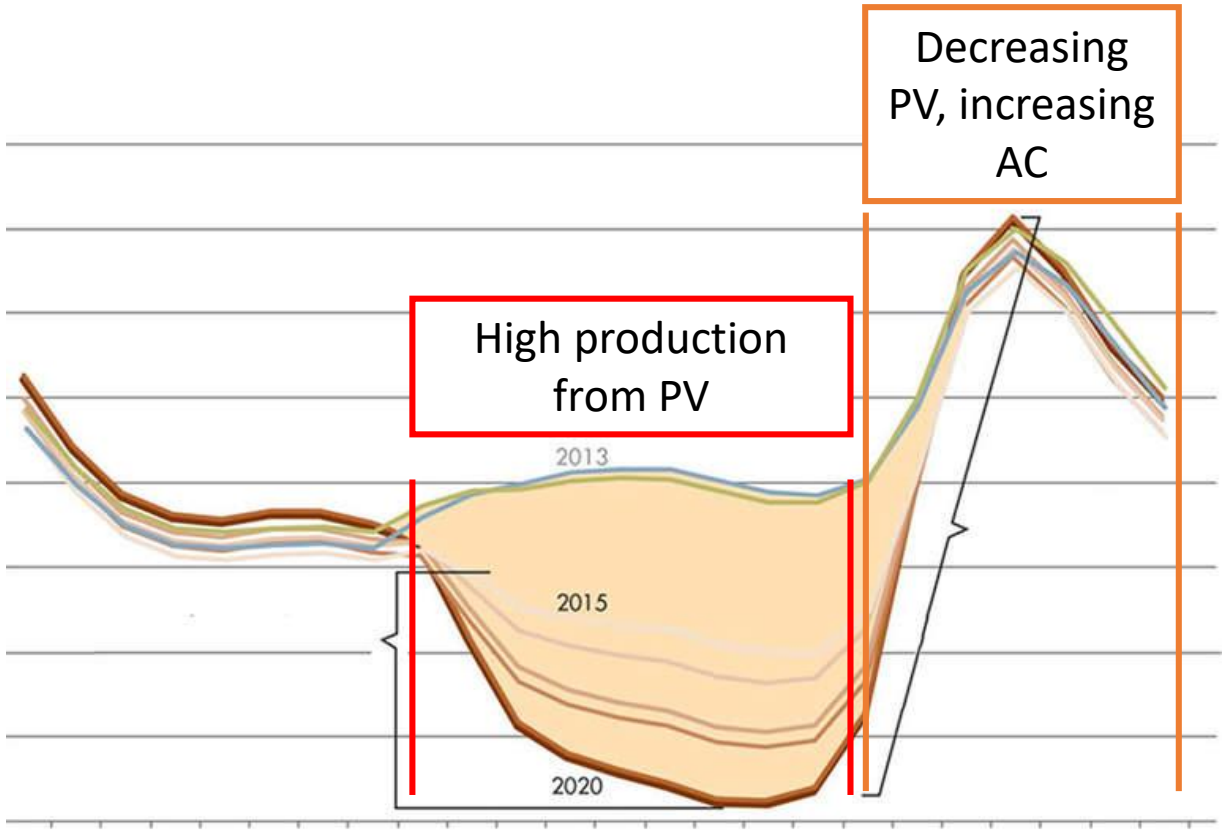
Introduction and Background – Title 24

- Title 24 => California's building energy code
- CBECC-Res => Simulation engine used to demonstrate Title 24 compliance
- Compliance Option => A measure in CBECC-Res that builders can use to achieve compliance
- Time Dependent Valuation => The societal cost of providing the needed energy. Essentially time of use rates

Title 24 Introduction

- New option to achieve compliance in CA
- Based on Time Dependent Valuation (TDV)
- Analogous to time of use pricing

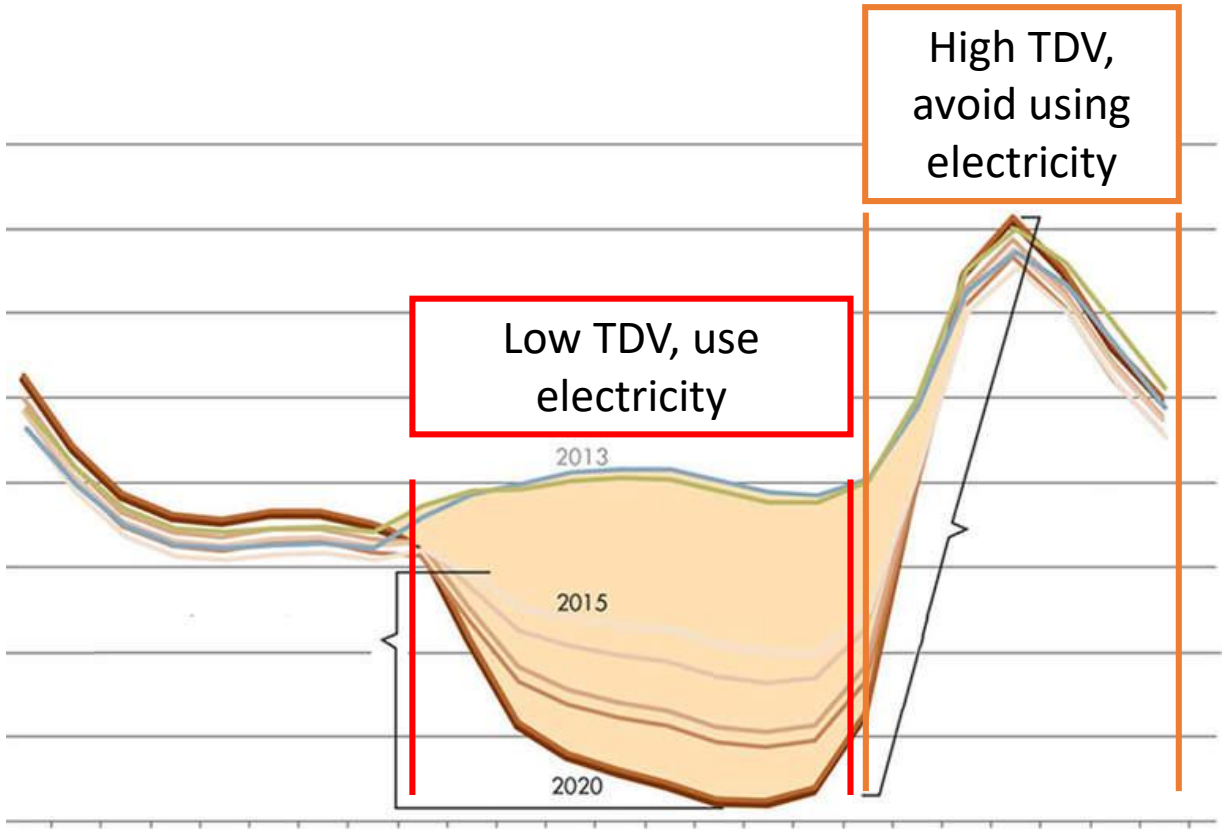
Introduction and Background – The "Duck Curve"



Causes

- LOTS of PV production during the day
- Home AC use increases ad PV production decreases

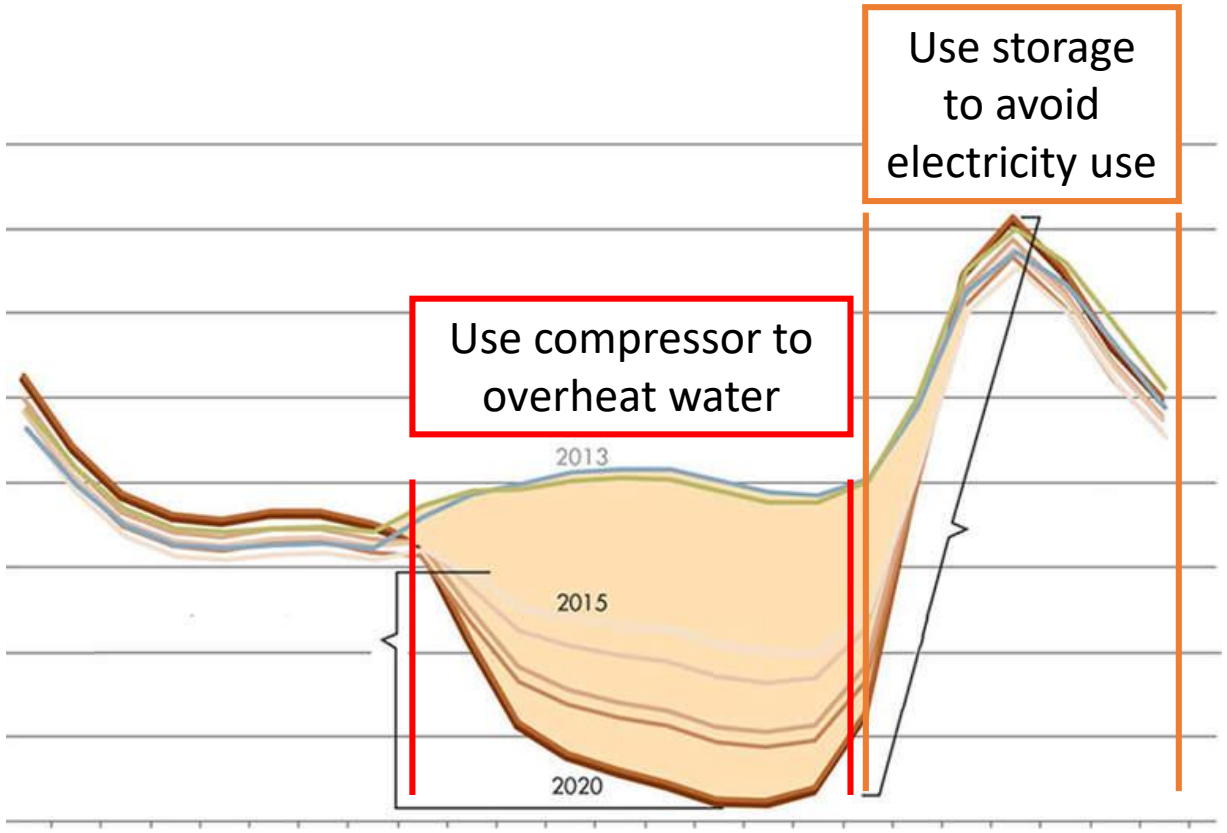
Introduction and Background – TDV Strategy



Impacts

- Low TDV rates during the day
- High TDV rates in the late afternoon/early evening

Introduction and Background – Load Shifting



Control Ideals

- Use compressor during day
- Avoid electricity in late afternoon/early evening

Introduction and Background – Questions to Address

- Develop compliance option for load shifting with HPWHs
  - How to model?
    - On/off compressor control
    - Predicted time of use rates
    - 24 notice of anticipated DR events
    - Standard credit
    - Simulation study comparing options
  - Add modified version of HPWHsim to CBECC-Res
    - Allows calculation of compliance benefits for builders

Main Topics

- How should HPWHs be controlled for load shifting?
- Modifications to HPWHsim are needed to complete simulation study

Lab Testing Plan - Overview

- Modifications to HPWHsim
  - Expand COP curve to higher tank temperatures
    - Data showing COP as a f(T) up to max set point
  - Identify control logic with changing set temperature
    - Data showing compressor & resistance element operation
  - Validate changes
    - Data showing performance over 24 hr draw profiles
- Demonstrate TDV benefits
  - Data comparing TDV with/without load shifting control

Modify HPWHsim

- Bigger range on COP curve
- Understanding of HPWH control logic when load shifting
- Validation

Demonstration

Show TDV implications to homebuilders in CA

Experimental Needs – Test Plan

- Three Test Types
  - COP_f(T)
    - HPWH in HP only mode
    - Water in tank as cold as possible (Limit – Avoid resistance element)
    - Allow compressor to heat to maximum temperature
    - Ambient: 1) 50°F, 58% RH; 2) 67.5°F,50% RH; 3) 95°F, 40% RH
    - Identify COP as tank temperature increases

COP f(T)

- Identify COP as tank temperature changes
- Range: As cold as possible to max setpoint
- Three different ambient conditions

Experimental Needs – Test Plan

- Three Test Types
  - Behavior with Changing Setpoint
    - HPWH in Hybrid mode (Default factory setting)
    - Set to 120°F, allow to reach setpoint and stabilize
    - Increase setpoint to maximum
    - Observe behavior – Compressor v resistance element operation
    - Reduce setpoint to 120 °F
    - Initiate draw
    - Observe behavior – Compressor v resistance element operation

Control Logic

- HPWH in Hybrid mode
- Allow to stabilize at 120 °F setpoint
- Increase to max, observe
- Decrease to 120°F, initiate a draw, observe

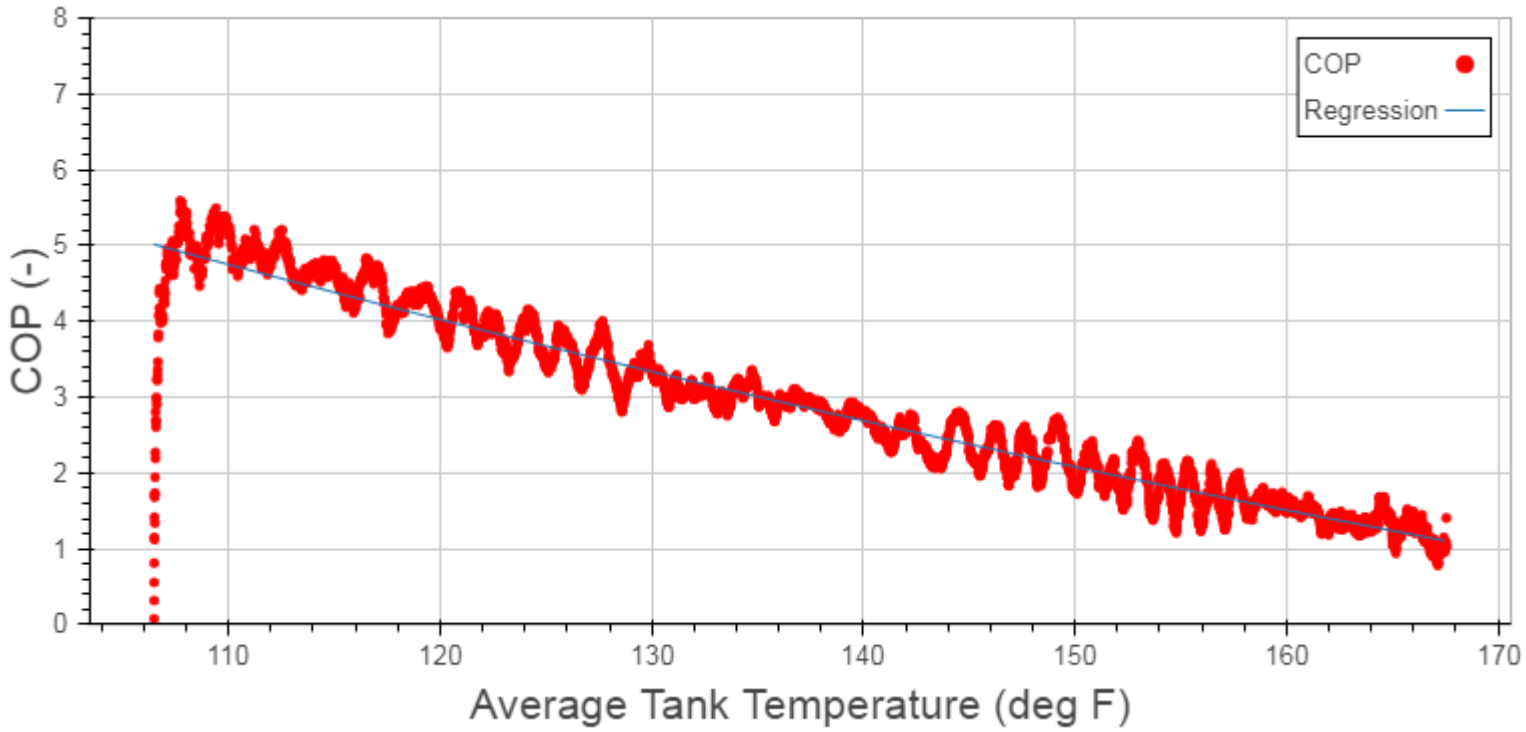
Experimental Needs – Test Plan

- Three Test Types
  - Draw Profiles
    - Use three different draw profiles from Title 24
    - High peak use, moderate peak use, low peak use
    - Use simple load shifting control (Compressor on 9/5)
    - Identify total energy consumption, peak energy consumption, TDV

Draw Profiles

- Performs tests mimicking specific days from Title24
- Use simple control strategy
- Identify impacts on energy use, and TDV

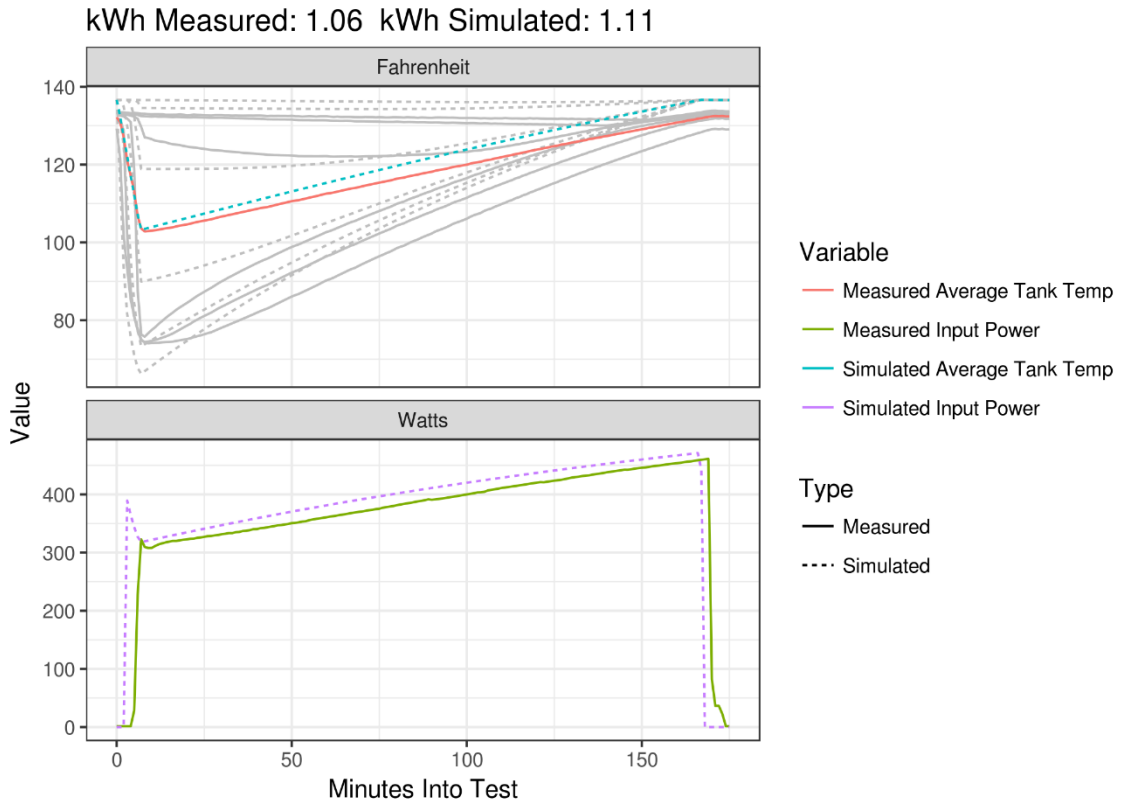
HPWHsim Modification – COP f(T)



COP f(T) Result

- Min tank temp = 106 °F
- HPWH used resistance element when colder ***even in HP Only mode***
- Smooth curve up to 168 °F

HPWHsim Modification – COP f(T)



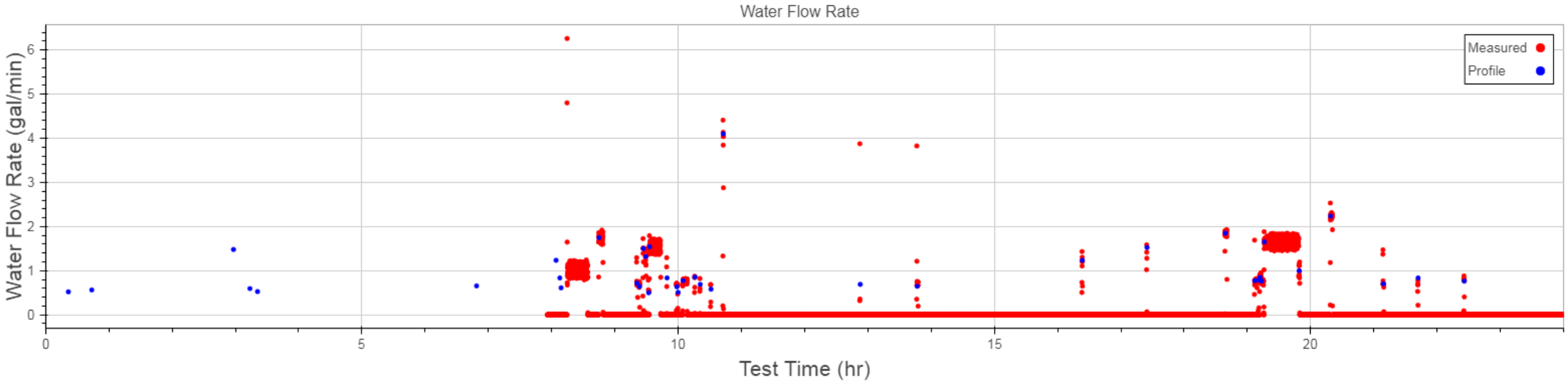
Meas v Sim Comparison

- Results match quite closely – 0.05 kWh difference
- Slightly higher temp, slightly higher power (Slightly lower COP)

TDV Savings Demonstration – Draw Profile

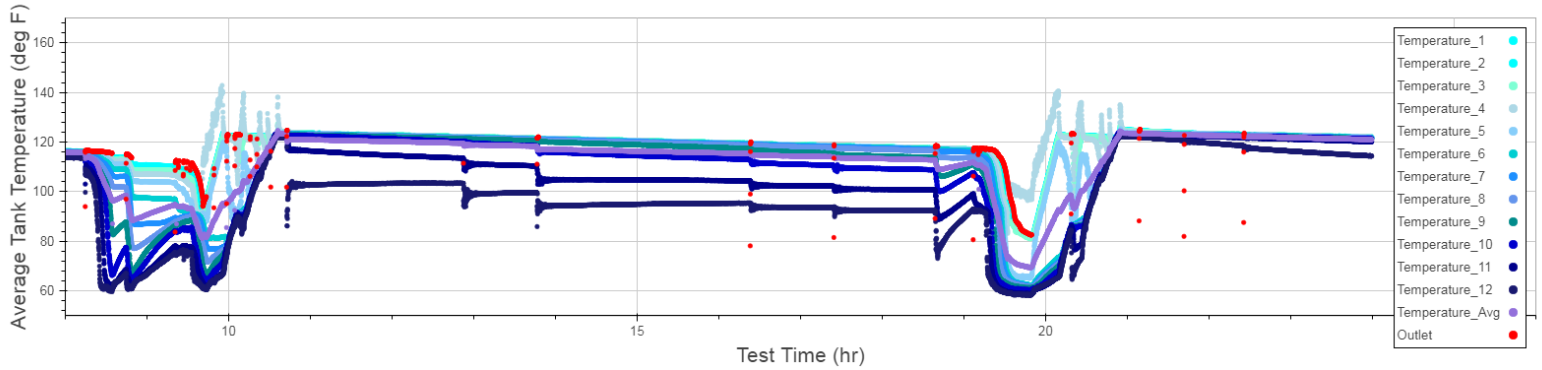
Draw Profile from CBECC-Res

- Very high peak use (40 min shower at 7:30P)
- Inlet temp = 50 °F

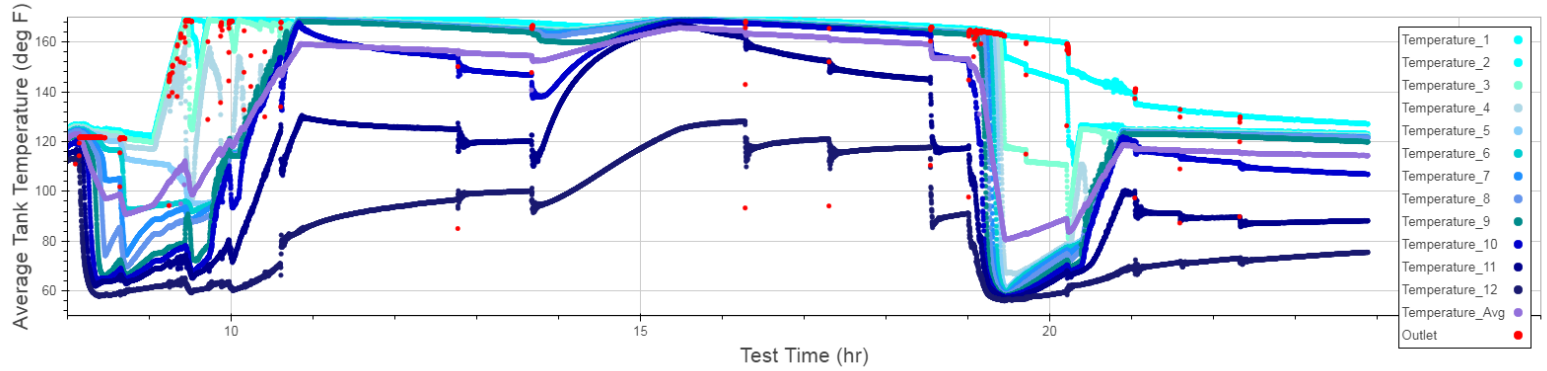


TDV Savings Demonstration – Tank Temperatures

- 125 °F Setpoint:



- 125/165/125 °F Setpoint:

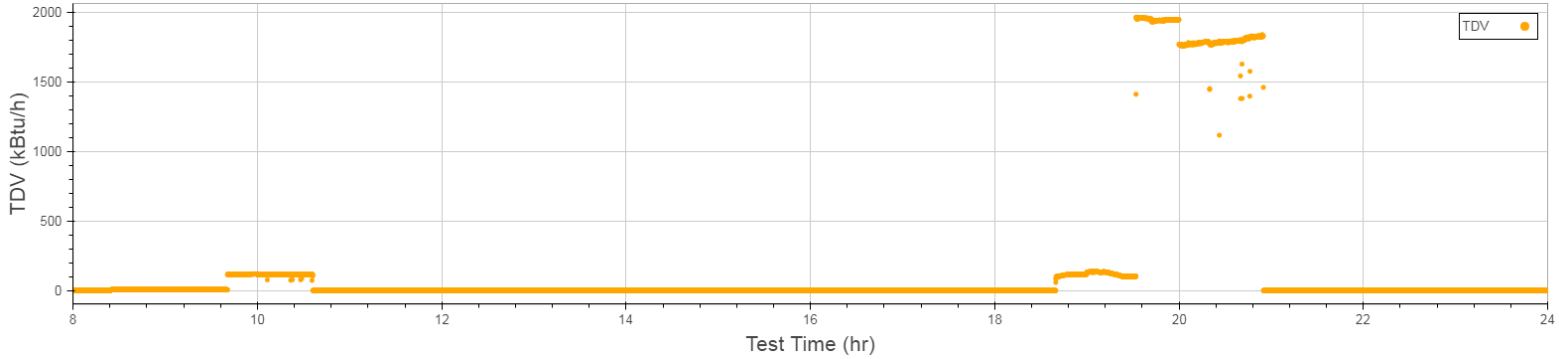


Tank Temperatures

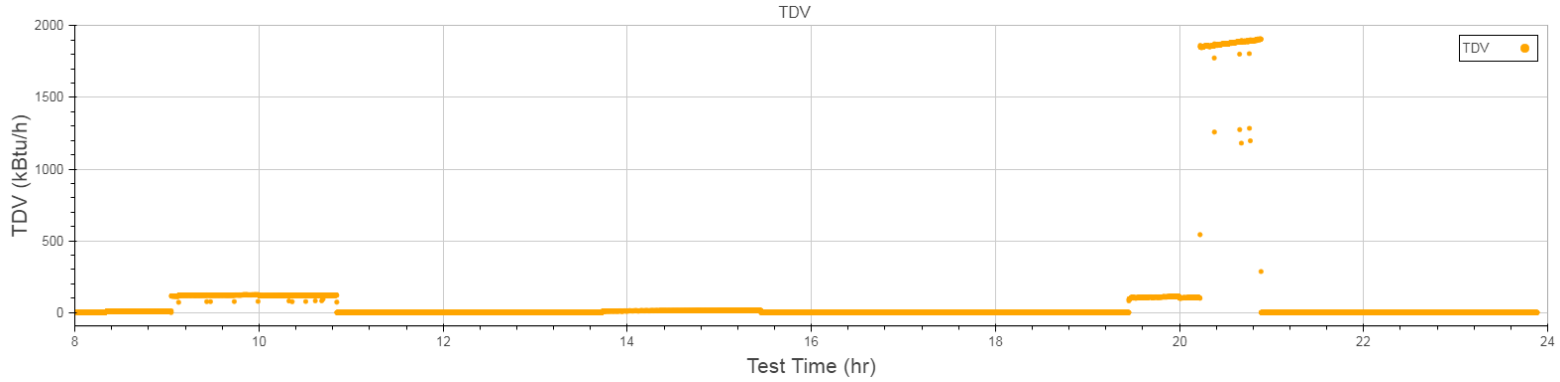
- Static control => T_out down to 81°F during peak
- Unit does use resistance element when 125°F => 165°F
- Dynamic control => T_out never below 130°

TDV Savings Demonstration – TDV

- 125 °F Setpoint:



- 125/165/125 °F Setpoint:

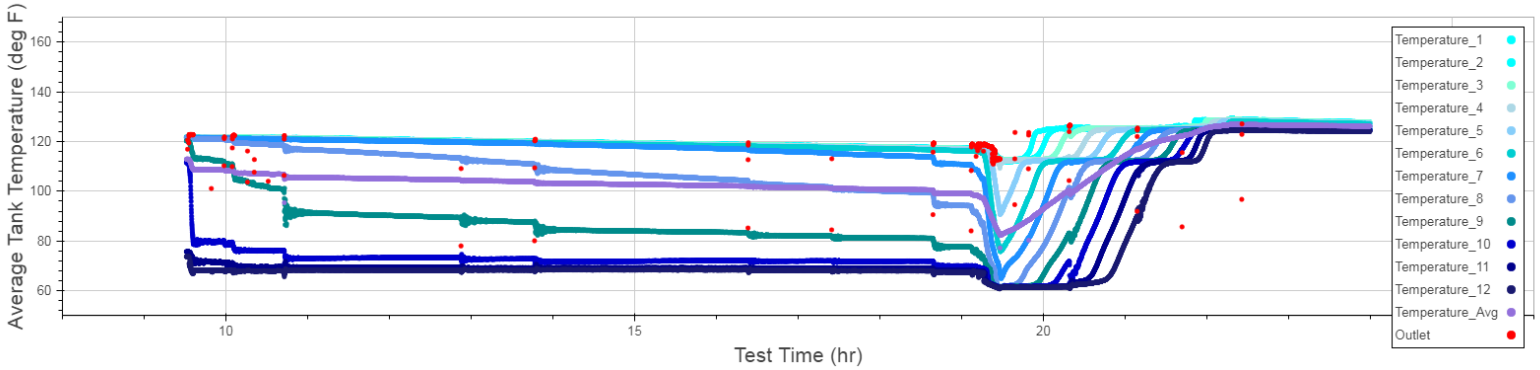


TDV

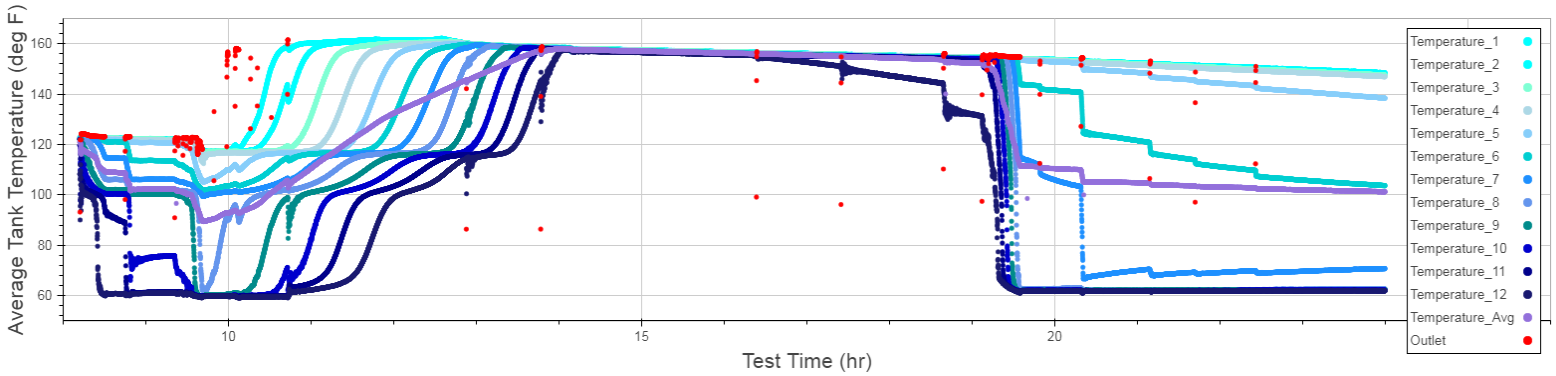
- 50 gallons storage
- Static => 2764 kBtu
- Dynamic => 1563 kBtu
- Both used resistance elements
  - More storage?

TDV Savings Demonstration – Tank Temperatures

- 125 °F Setpoint:



- 125/160/125 °F Setpoint:

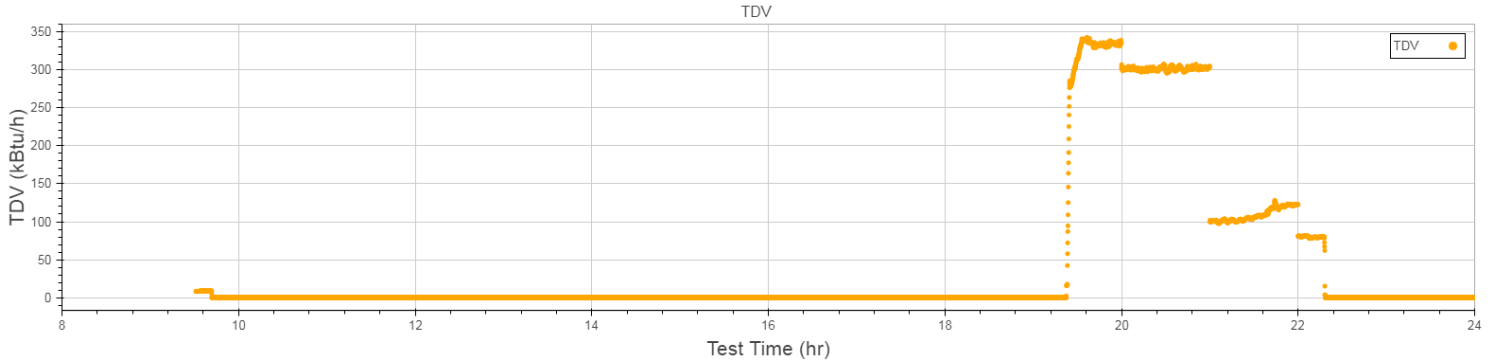


Tank Temperatures

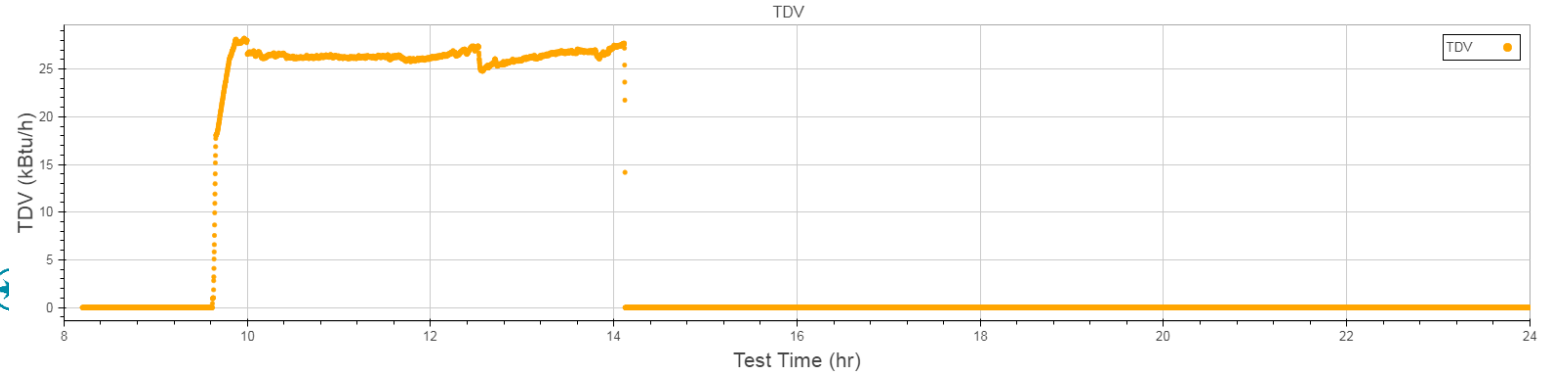
- Static => T_out > 105°F in all draws
- Static => Compressor activates 7:15P to 10:30P
- Dynamic => T_out never below 120°
- Dynamic => Compressor on 9:40A-2P

TDV Savings Demonstration – TDV

- 125 °F Setpoint:



- 125/160/125 °F Setpoint:



TDV

- 80 gallons storage
- No resistance element!
- Static => Used compressor during peak
- Static => 633 kBtu
- Dynamic => 117 kBtu

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Conclusions

- California focused on load shifting to avoid the “duck curve”
- Three project goals:
  - Create a lab for rapid, repeatable, and accurate data collection
  - Support creation of compliance option in CBECC-Res
  - Demonstrate potential TDV savings for builders
- Provided data sets to support simulation modeling improvements
- Significant compliance improvement demonstrated with 50 and 80 gal HPWH

Conclusions

- Supported simulation improvements
- Significant TDV savings demonstrated with 50 gal HPWH
  - Better results with more storage

Questions?

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