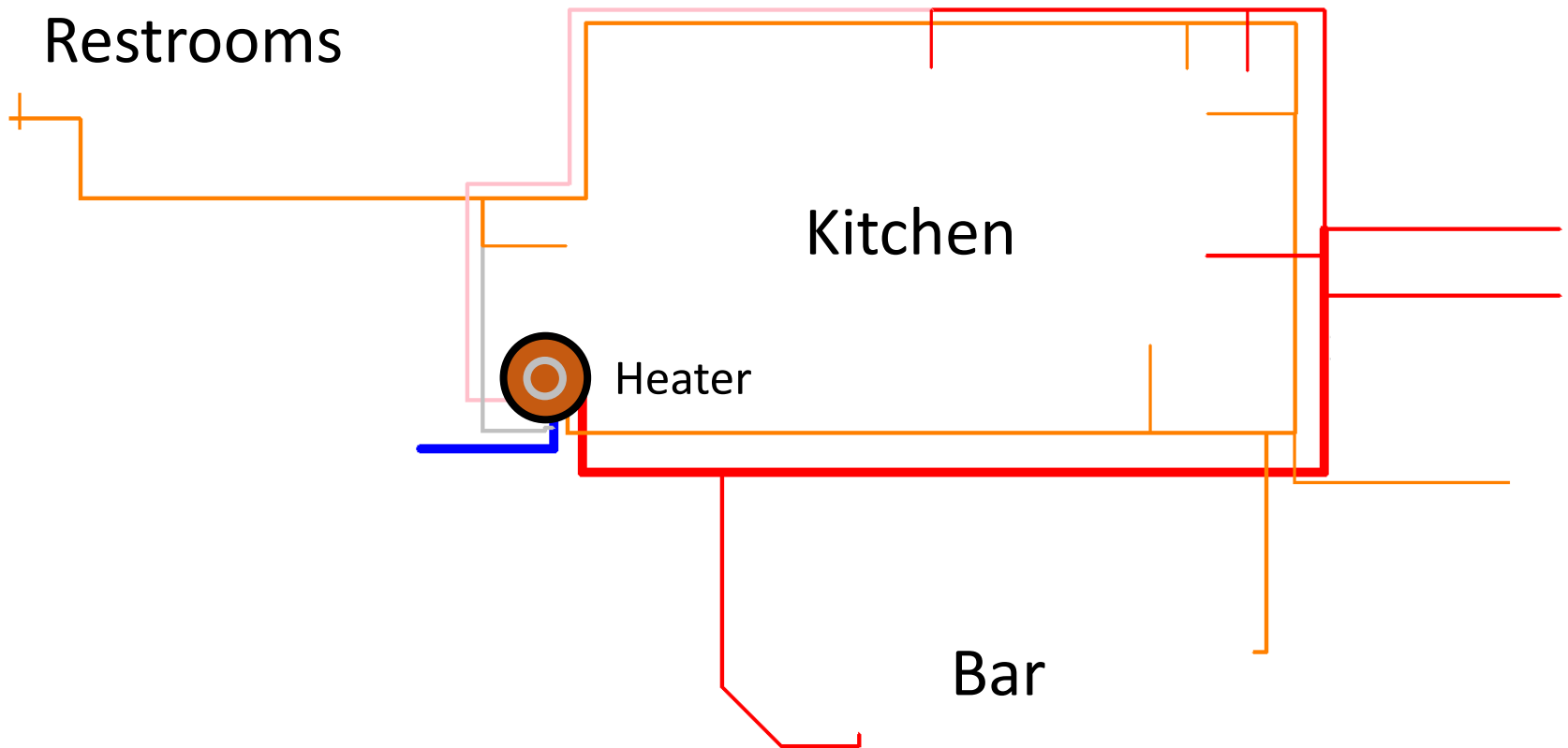


Optimizing the Design of a Water Heating System in a Full-Service Restaurant



Acknowledgements

- Ongoing project is funded primarily by the California Energy Commission commencing in 2014
- Cofunding has been provided by PG&E and SoCalGas
- Equipment for the PG&E Hot Water System Laboratory and field projects has been donated by: ACT Inc., A.O. Smith, Eemax, Hobart, Intellihot, Novothermic
- Project contributors: Fisher Consultants, Gas Technology Institute, kW Engineering, PG&E Applied Technology Services,
- Project guidance from Technical Advisory Committee Members

Project Overview

Project covers:

- Field monitoring in two existing commercial kitchens and follow-up monitoring of both optimized hot water systems
 - Full-service restaurant (FSR)
 - Centralized elementary school cafeteria
- A replica of the baseline and optimized system in the FSR will be built in the laboratory for testing and validation of a diverse array of system layouts and optimization techniques
- Updating Hot Water System Design Guide
- Development of Design Tool and Cost Calculator



Project Status

Project status:

- FSR existing system monitoring complete, health department approval of replacement system design in Dec. 2016
- Commenced monitoring of existing system in school cafeteria in Dec. 2016
- Hot Water Laboratory designed, installed and commissioned, Commenced monitoring in Dec. 2016



Presentation Focus on FSR

Bar and Grill:

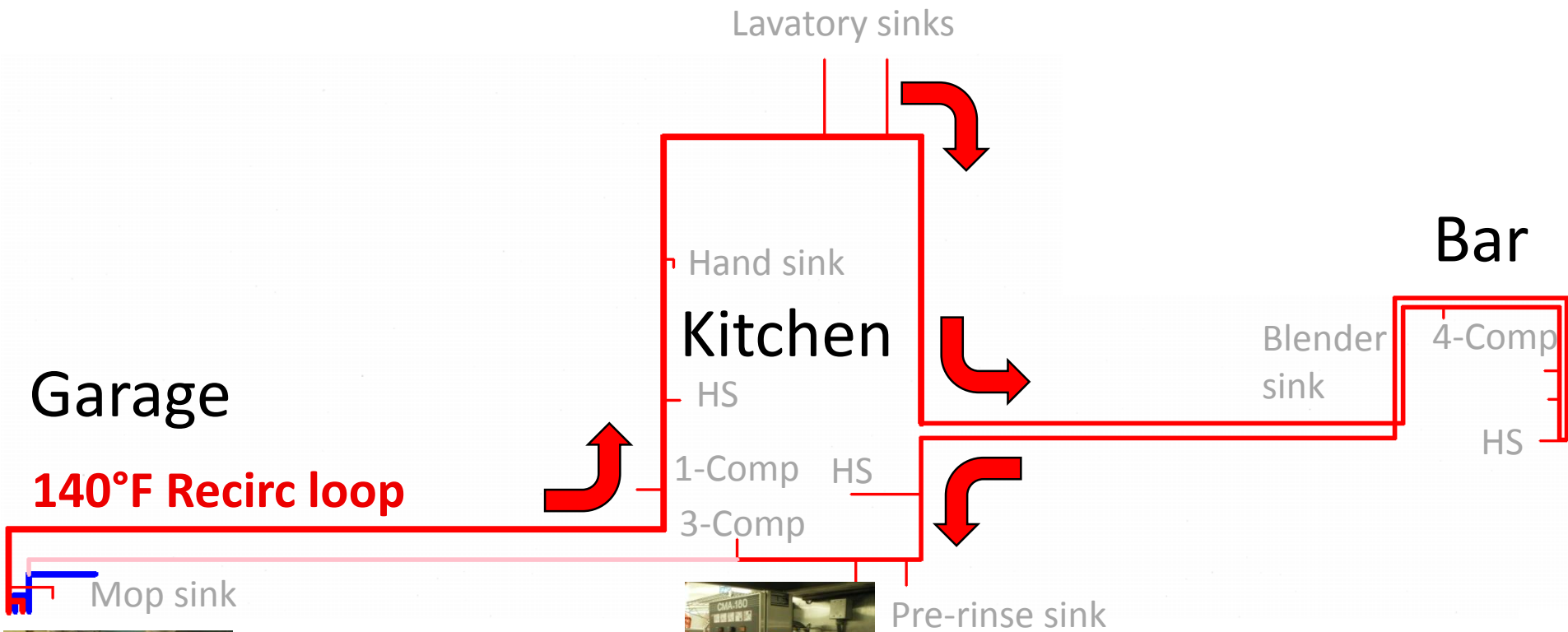
- Medium sized FSR, built in 2011
- Open lunch and dinner (7 days/week)



Goals of Baseline and Replacement Hot Water System Project:

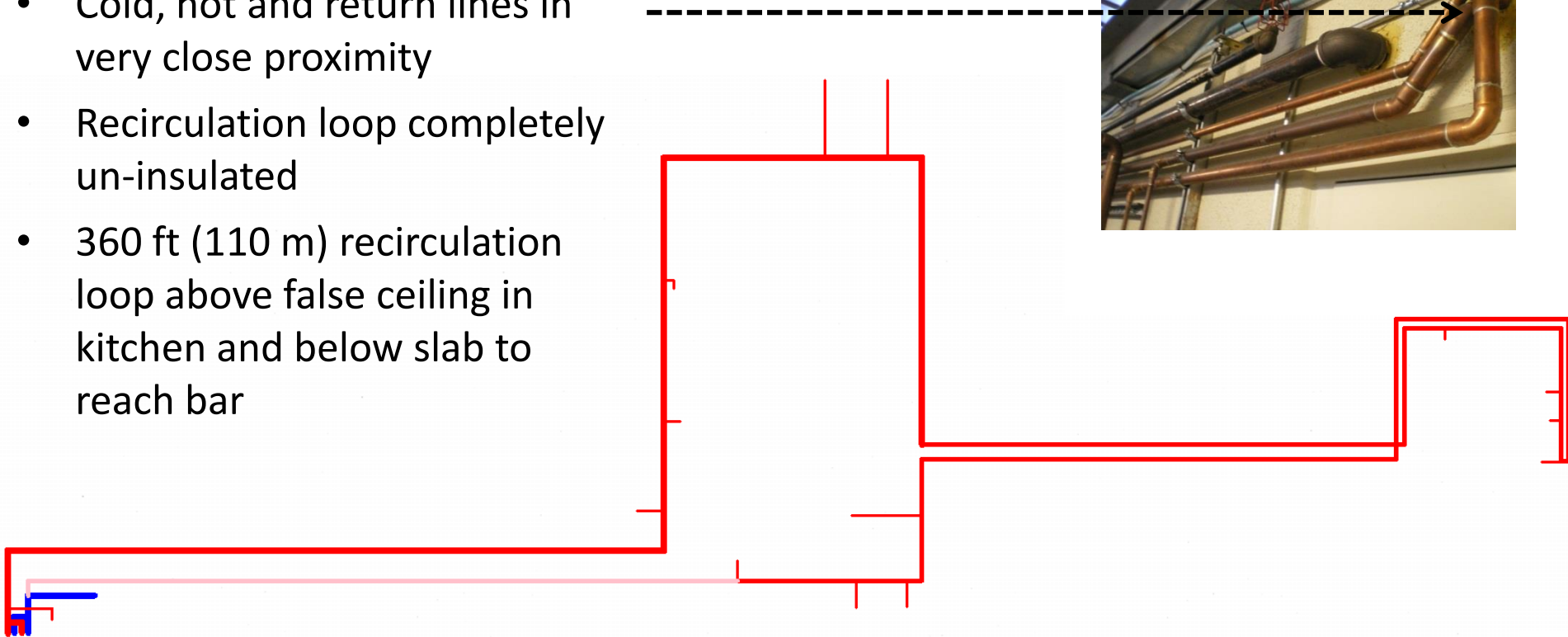
- Monitor hot water heater and each point of use for energy and water use
- Calculate heater efficiency, recirculation line heat loss, and overall system efficiency
- Identify system deficiencies and analyze delivery performance
- Upgrade system components and measure savings

Baseline System (from plumbing drawings)



Estimate of Recirculation System Heat Loss

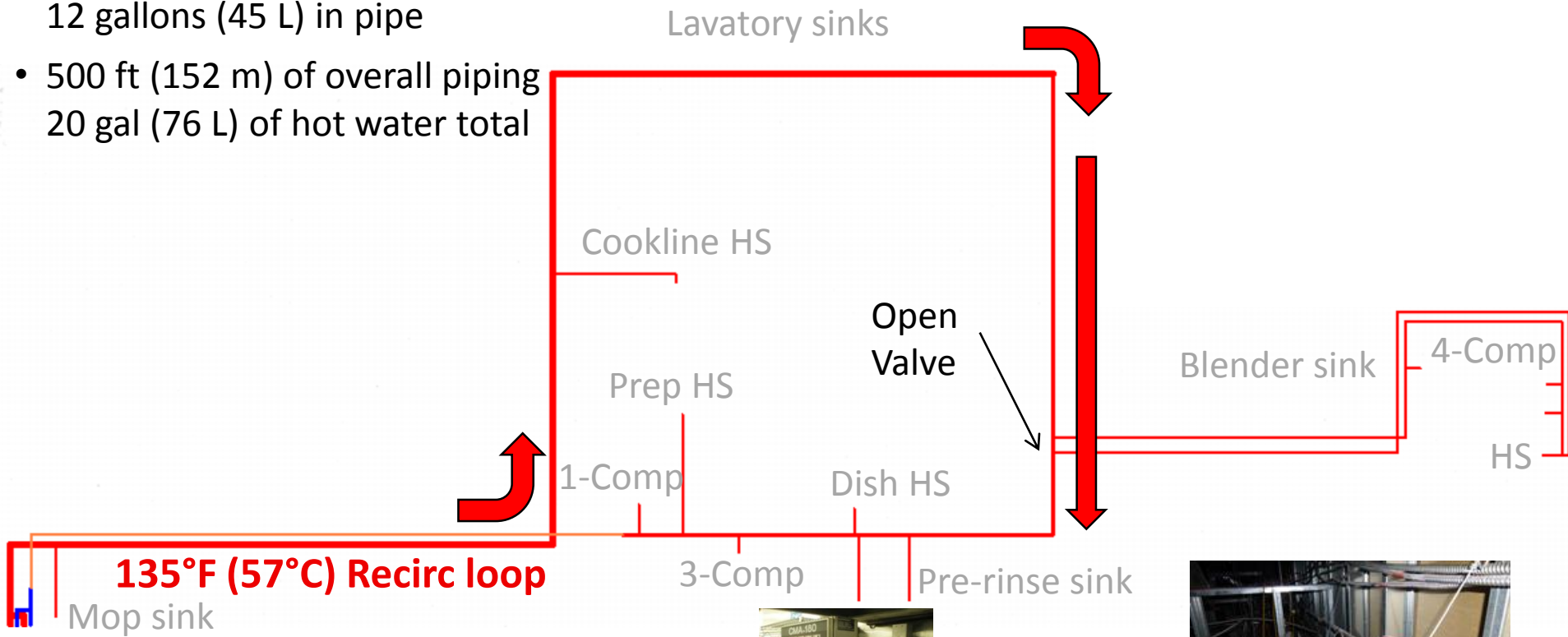
- Cold, hot and return lines in very close proximity
- Recirculation loop completely un-insulated
- 360 ft (110 m) recirculation loop above false ceiling in kitchen and below slab to reach bar



- 18 gallons (68 L) of water in recirculation pipe
- Estimated annual heat loss of 1200 therms (126,600 MJ), cost of \$1200

Baseline System as Installed

- 235 ft (72 m) recirculation loop
12 gallons (45 L) in pipe
- 500 ft (152 m) of overall piping
20 gal (76 L) of hot water total

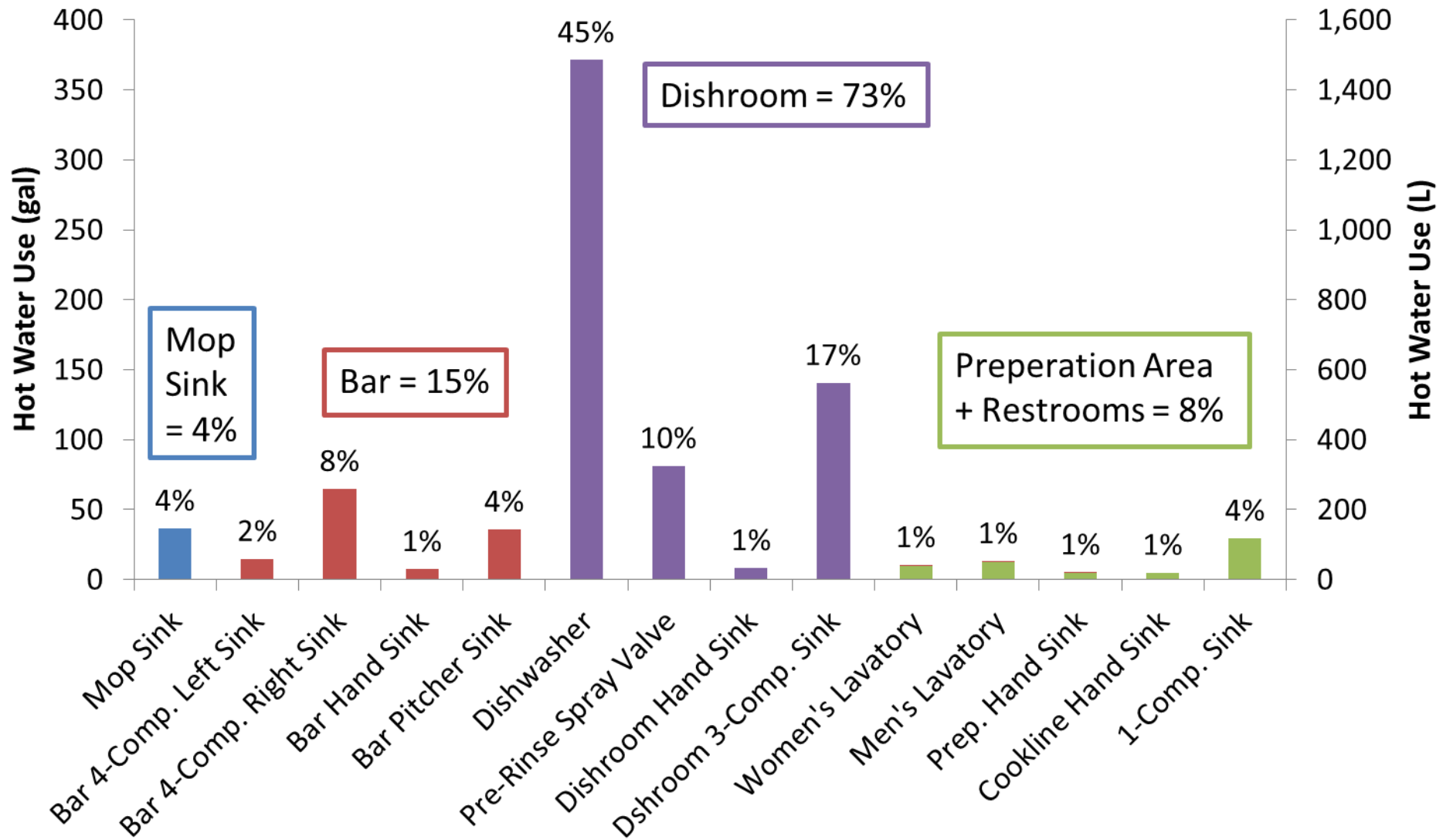


Heavily Instrumented DHW System

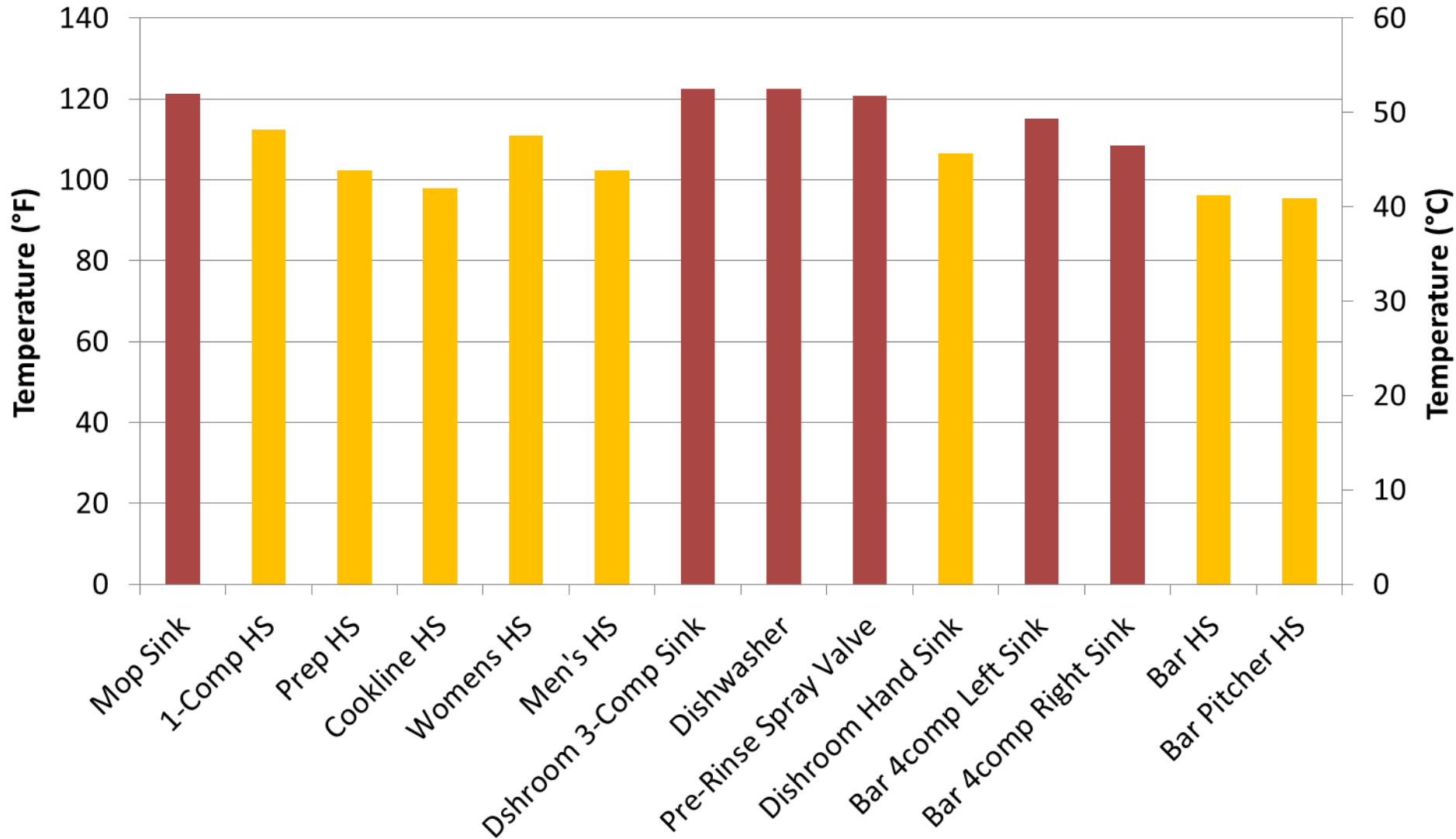
- 3 centralized dataloggers (bar, garage, dishroom)
- 5 end-use loggers
- 36 pulse channels
 - 29 water meters (heater inlet, recirc, all end use)
 - 5 electric meters (dishwasher, booster, water heaters, recirc pump)
 - 2 gas meters (water heaters)
- 35 analog channels
 - 8 pressure sensors (heater inlet and outlet, 6 key end-use locations)
 - 27 thermocouple temperature sensors



Hot Water Use at Each Fixture



Out-of-Wall Hot Water Temperatures

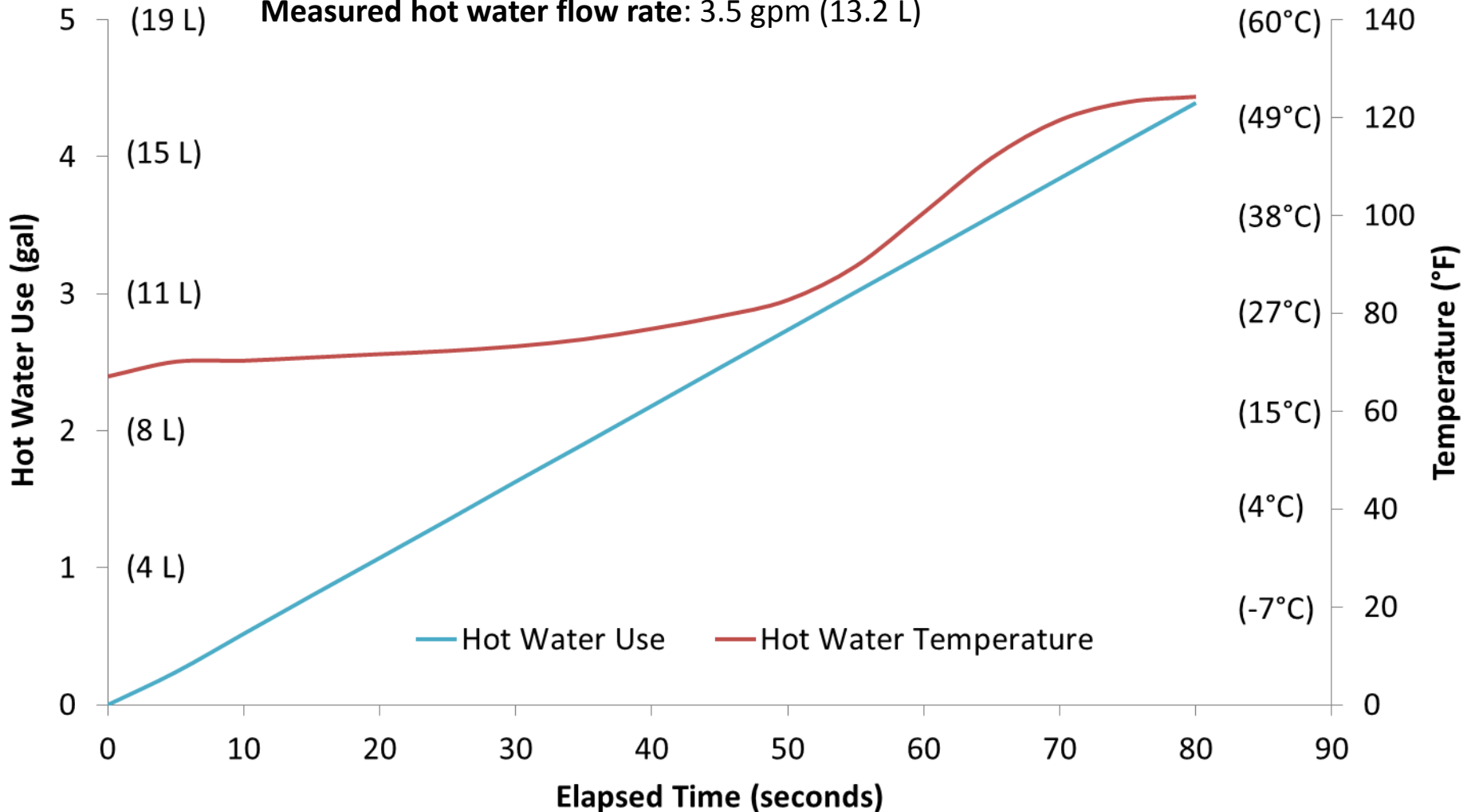


Hot Water Delivery Performance at Bar 4-Comp

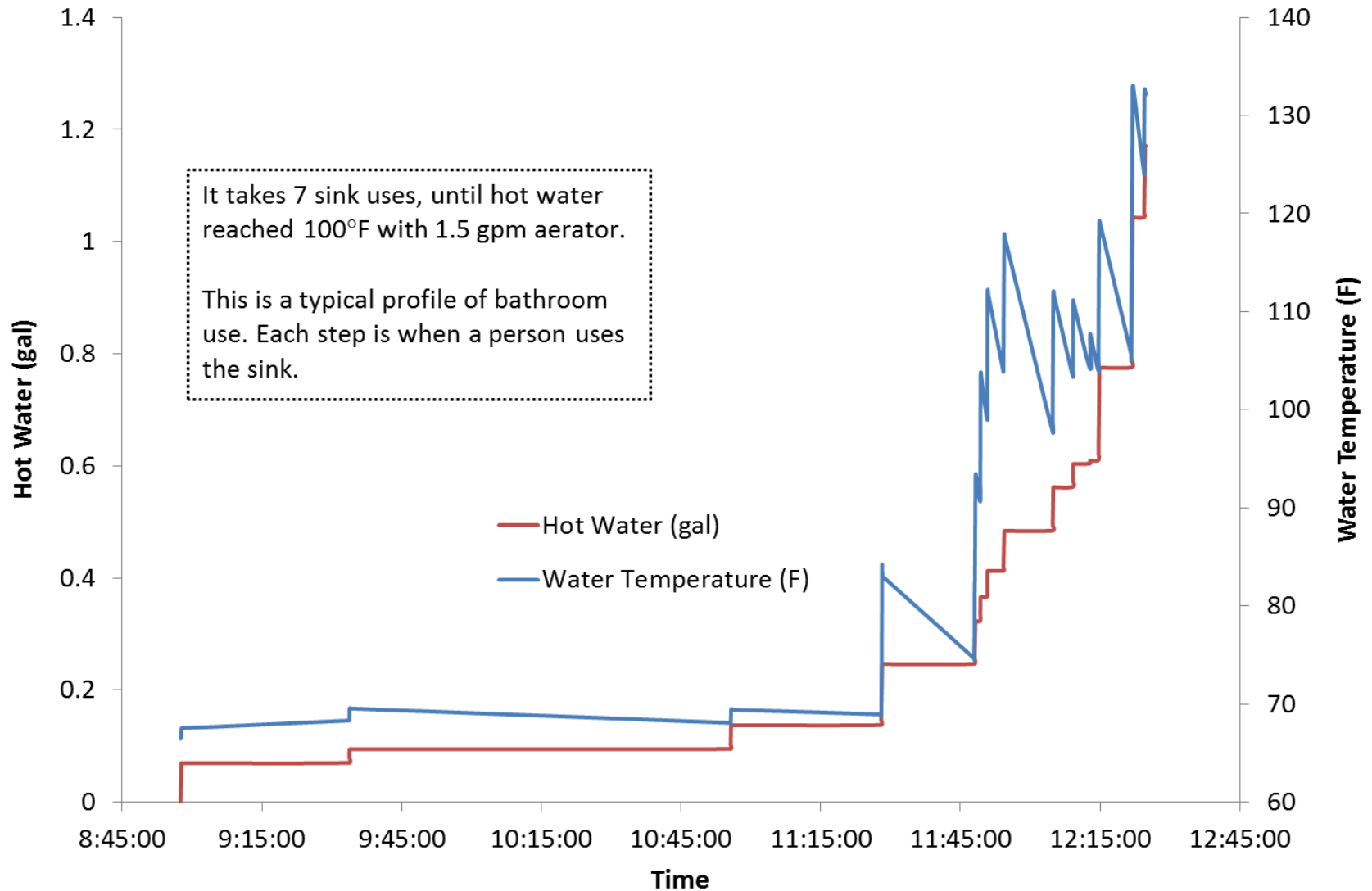
Gallons consumed before temp reaches 120°F (49°C): 4 gal (15 L)

Time elapsed before temperature reaches 120°F: 75 seconds

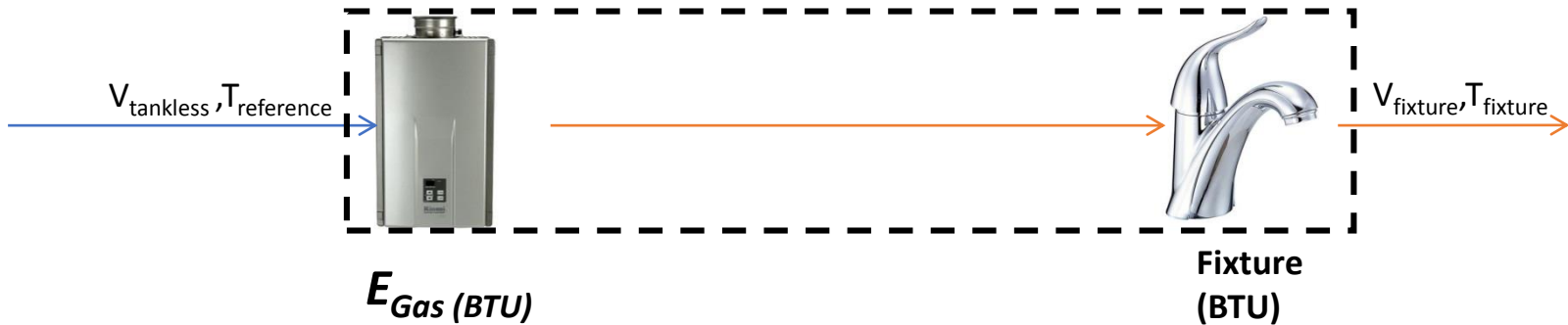
Measured hot water flow rate: 3.5 gpm (13.2 L)



Hot Water Delivery Performance at Woman's Lav



Delivery Efficiency Calculation



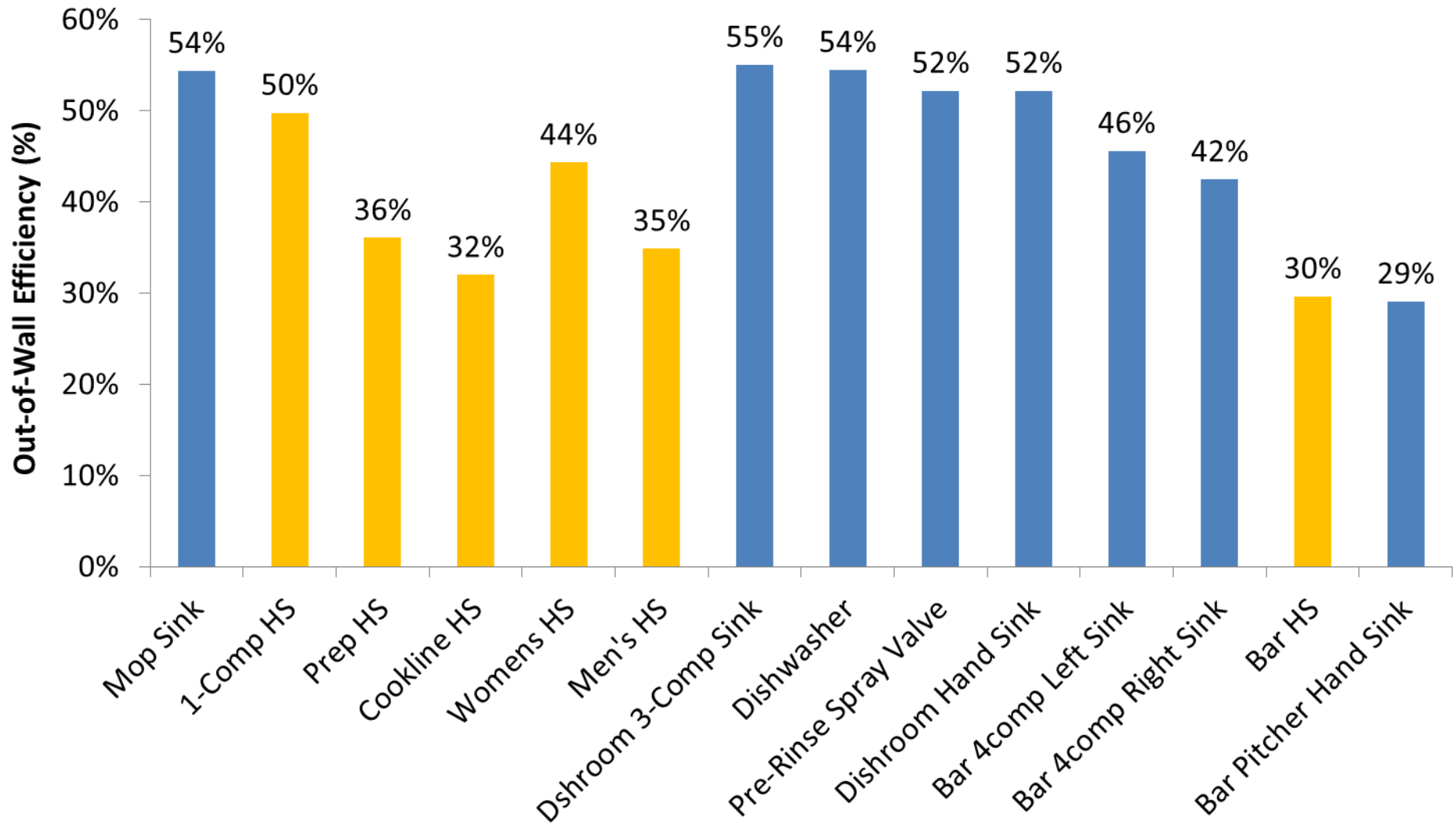
What percentage of the heat in hot water reaches:

Out of wall

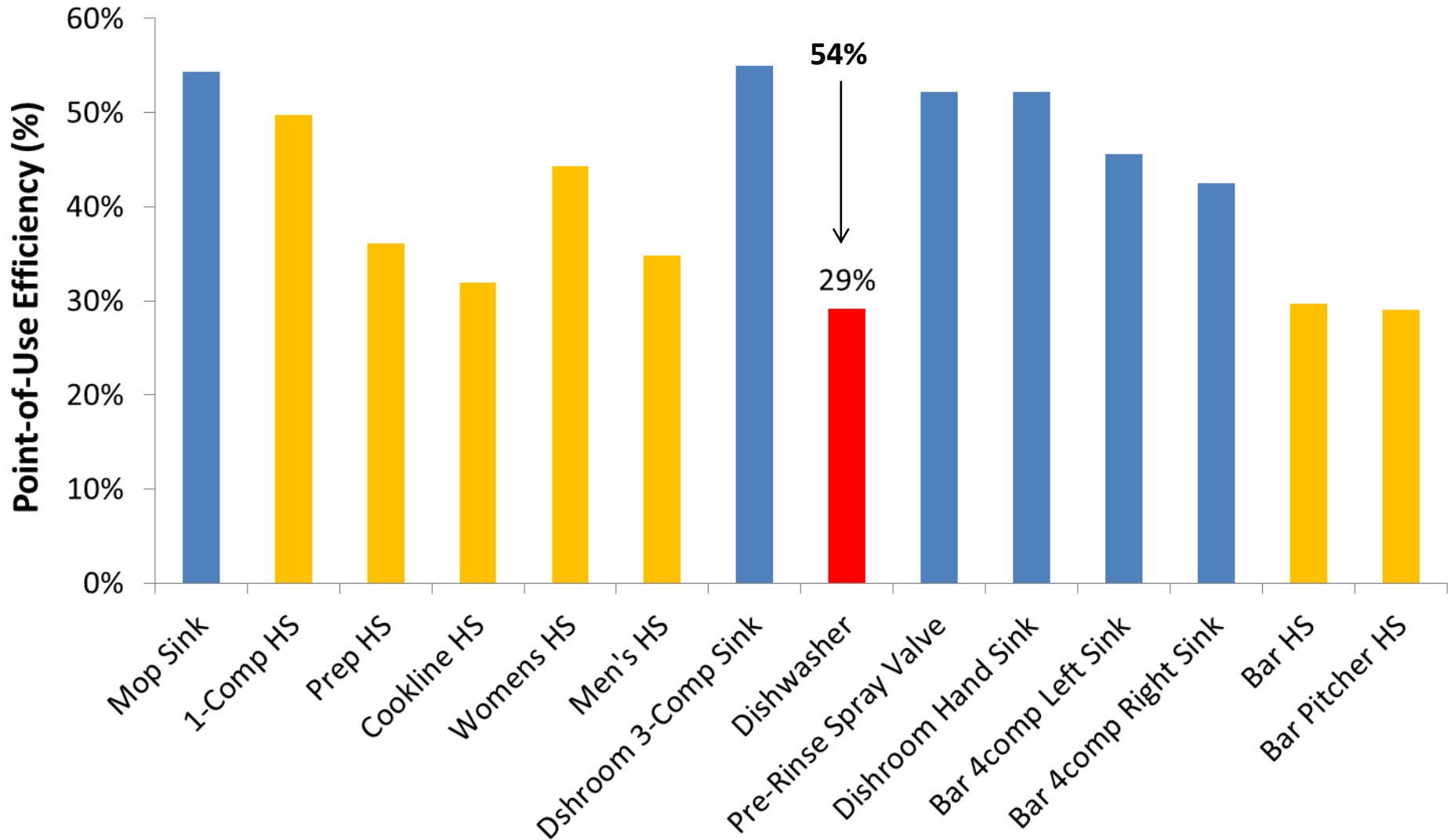
Point of use



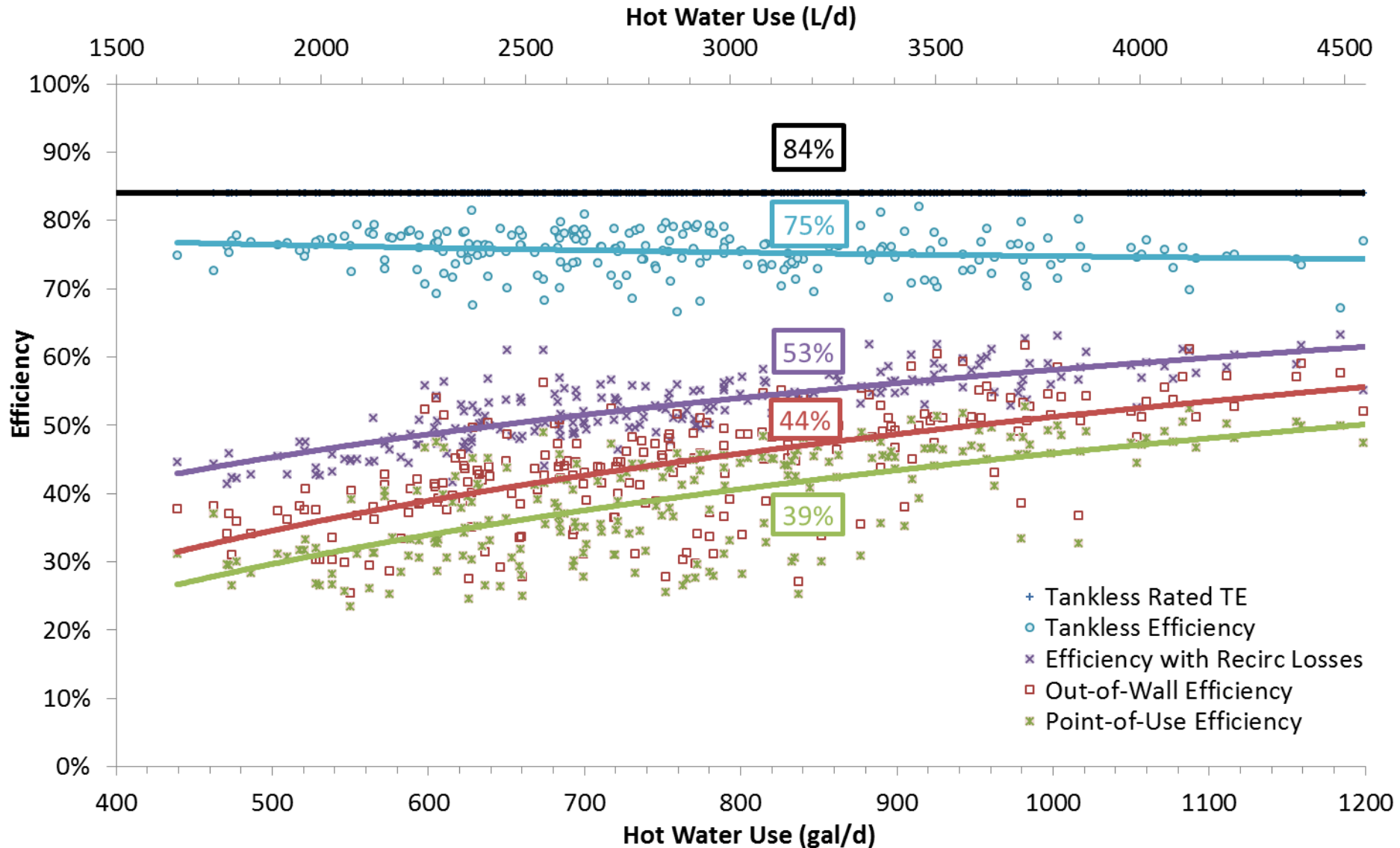
Out of Wall Delivery Efficiency



Point of Use Delivery Efficiency

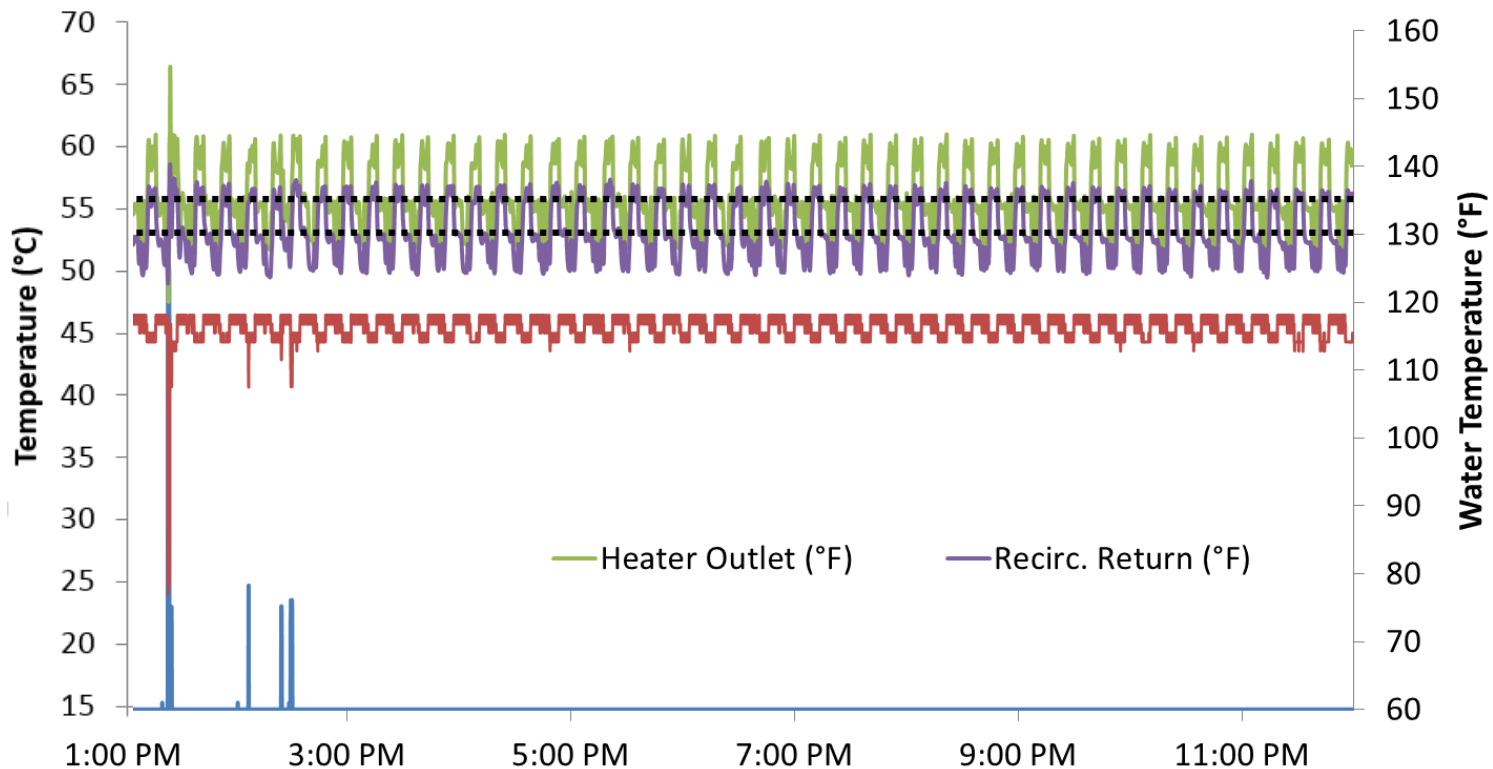


Efficiency Comparisons



Recirculation Line Heat Loss Analysis

- Christmas Day analysis from 3pm-midnight (no water use conditions)
- ΔT of 5°F (3°C) [heater outlet 135.5°F (57.5°C) – recirculation return 130.4°F (54.7°C)]
- Recirculation flow rate: 3.4 gpm (0.21 L/s)
- Recirculation Heat loss = 8,440 Btu/h (2,473 W)



Annual Costs of Existing System

Recirc. Pump and
Recirc. Line Costs:
Gas cost \$1,200
Electricity cost \$155



- **Total Cost: \$19,390**
- Water Cost: \$9,300
- Gas Cost: \$2,860
- Electricity Cost: \$7,230

Water Costs:
AVG. 855 gal/d (3,237 L/d)
Water/Sewer \$9,300

Water Heating Costs:
Gas cost \$1,660
Electricity cost \$25



Dishwasher Costs:
Electricity cost \$7,050

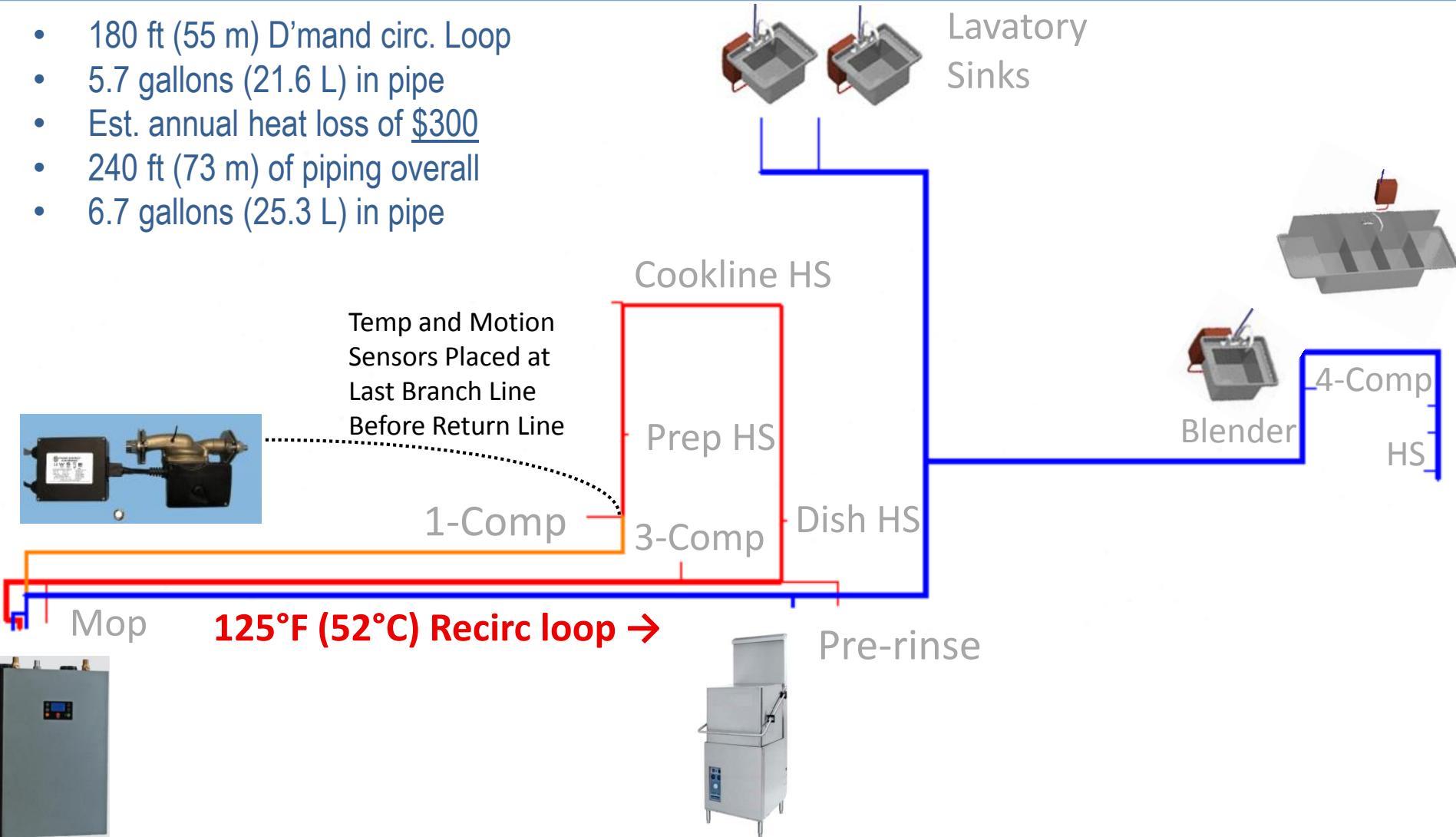


Replacement System Design Attributes

- Relies on distributed generation to eliminate the need for continuous recirculation and minimizes pipe heat losses
- Removing the dishwasher off the hot water system allows us to reduce the outlet temperature from the centralized hot water system, removes the biggest hot water load and reduces the max flow rate of the new system
- Maintains condensing operation at the primary gas condensing heater since no hot water returns back to the unit.

Optimized Hot Water System Design

- 180 ft (55 m) Demand circ. Loop
- 5.7 gallons (21.6 L) in pipe
- Est. annual heat loss of \$300
- 240 ft (73 m) of piping overall
- 6.7 gallons (25.3 L) in pipe



In Closing...

Parts of the optimized system already installed

- Point-of-use heaters installed in lavatories and working well
- Door-type dishwasher with integrated heat recovery system installed
 - Challenge to install, new dishtables + pre-rinse sink fabricated
 - Not performing well out of box, operating at 15 psi (103 kPa)
 - Had to increase water pressure to 20 psi (138 kPa), flow rate increased by 50% over rated, new dishwasher is using more energy than prior unit
 - The heat recovery system takes an additional 30 sec to operate, there is a lock in place so the door is not opened prematurely
 - Didn't train staff on the operation, thus unit got damaged on two occasions
 - Staff have damaged the door-locking device and broken welds on the door



QUESTIONS?

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