Hot Water System Performance: Mimicking a Full-Service Restaurant in the Laboratory

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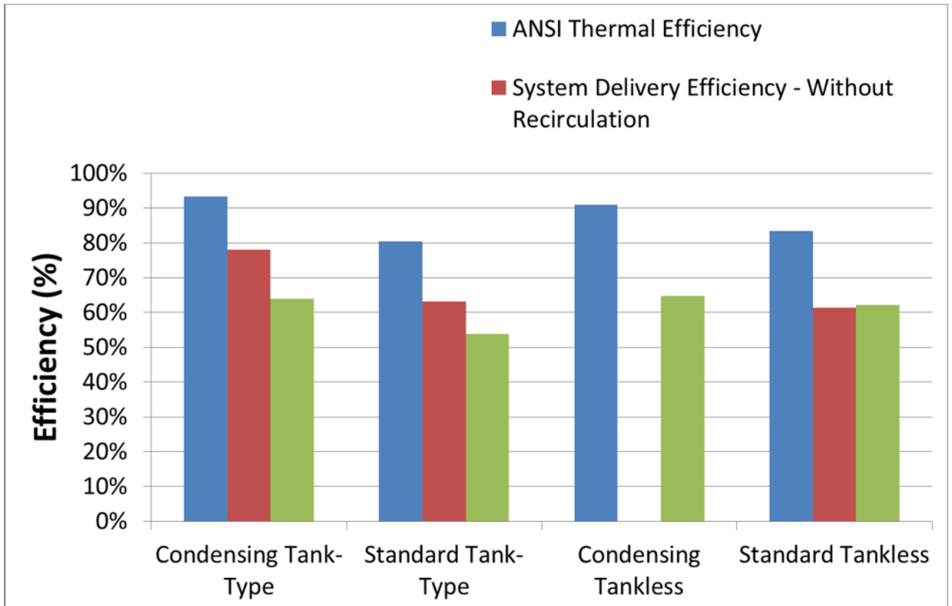
CALIFORNIA ENERGY COMMISSION

FRONTIER energy

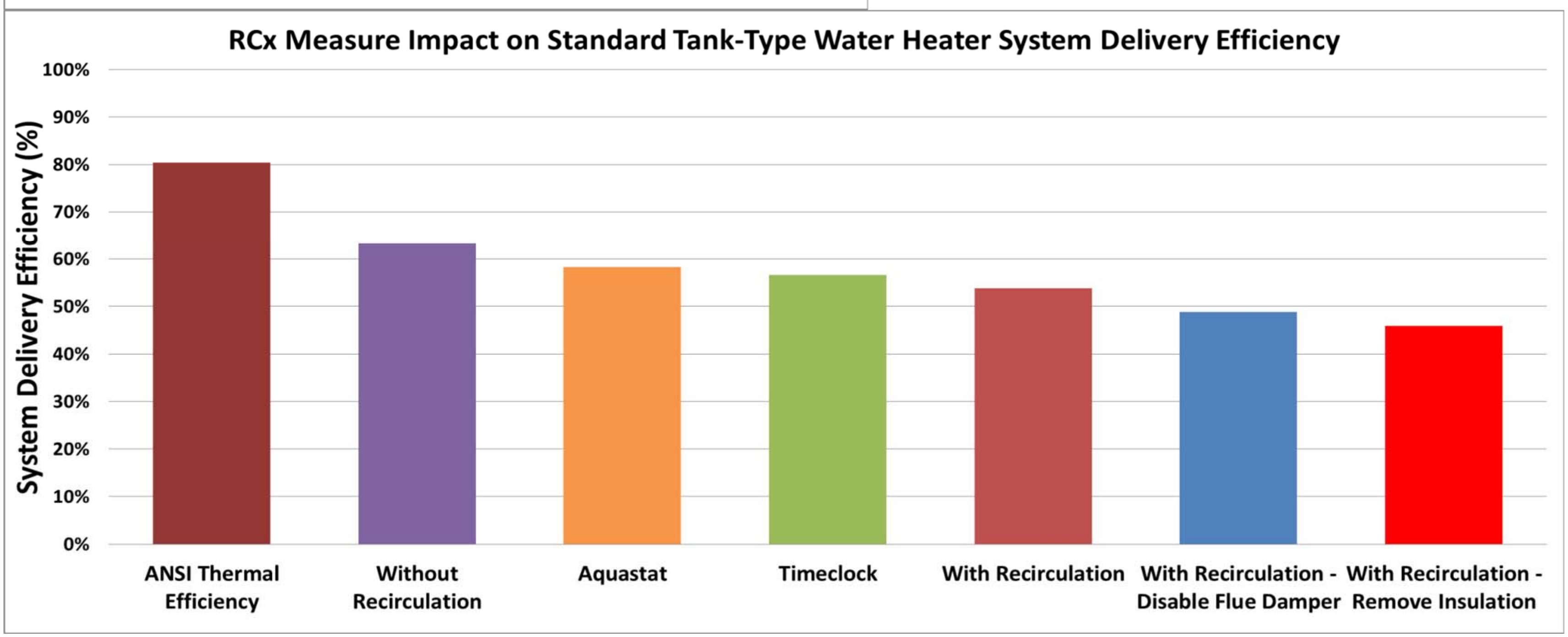
Past California Energy Commission Research Objectives

- Stimulate the purchase of high-efficiency [condensing] water heaters for both retrofit and new construction
- Secure energy savings through a water heater RCx initiative including operational flue-damper, insulation, and optimizing distribution
- Understand the impact that preheating inlet water will have on the performance of high-efficiency water heaters
- Expand on best practice guidelines for designing and operating water heating systems in commercial food service

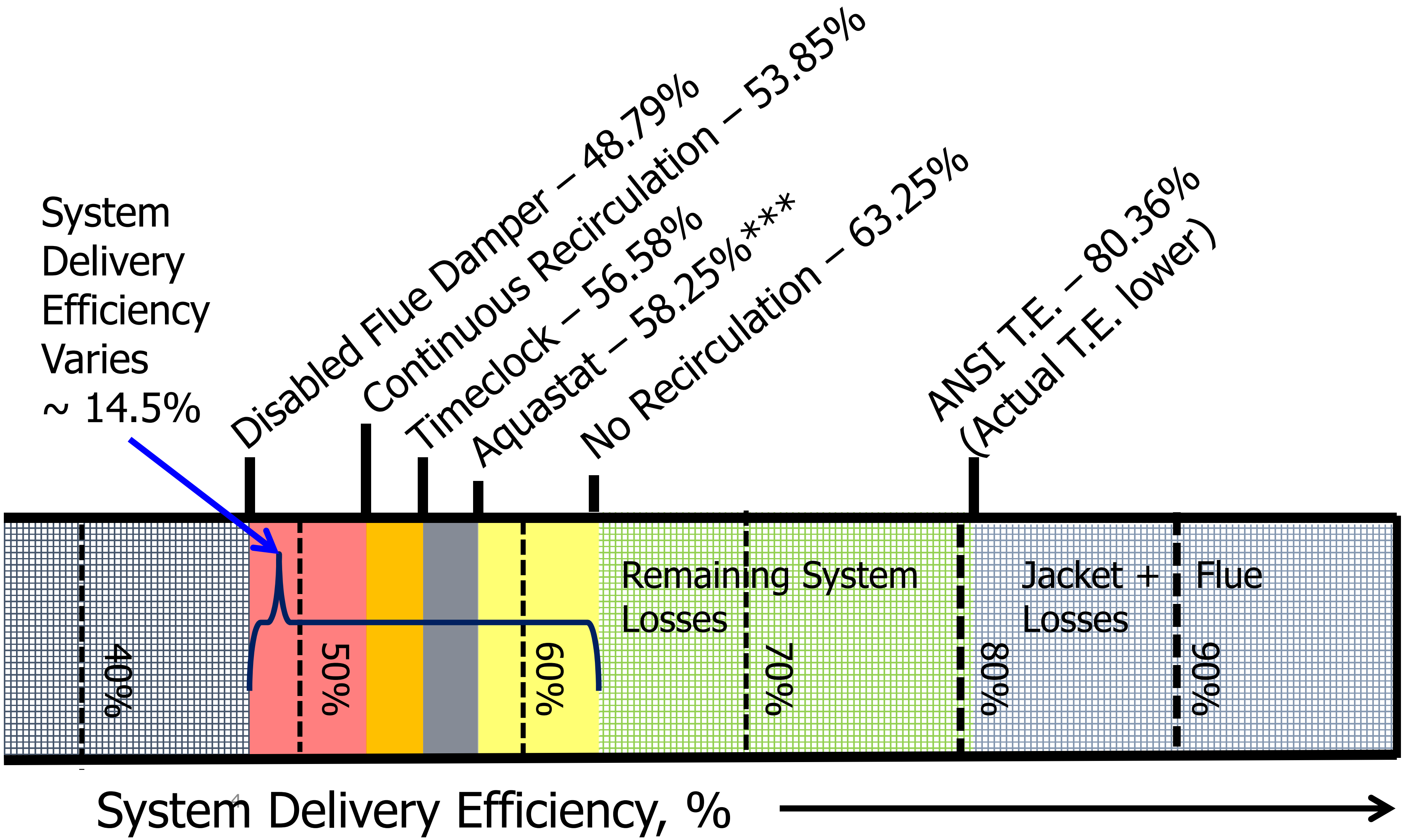
Results - Past PIER Effort (PIER RFP 500-07-503)



- Condensing Tank-Type Water Heaters supplying insulated systems without recirculation yield System Delivery Efficiencies (S.D.E.) as high as 78%
- Standard Efficiency Tank-Type Water Heaters supplying non-insulated systems yield S.D.E. as low as 46%
- S.D.E. can degrade further below 46% in a non-insulated system with a disabled flue damper (42% S.D.E.)



System Energy Performance Impact – RCx and Retrofit
24 hr. Draw Profile - Standard Efficiency Tank-Type Water Heater Insulated System

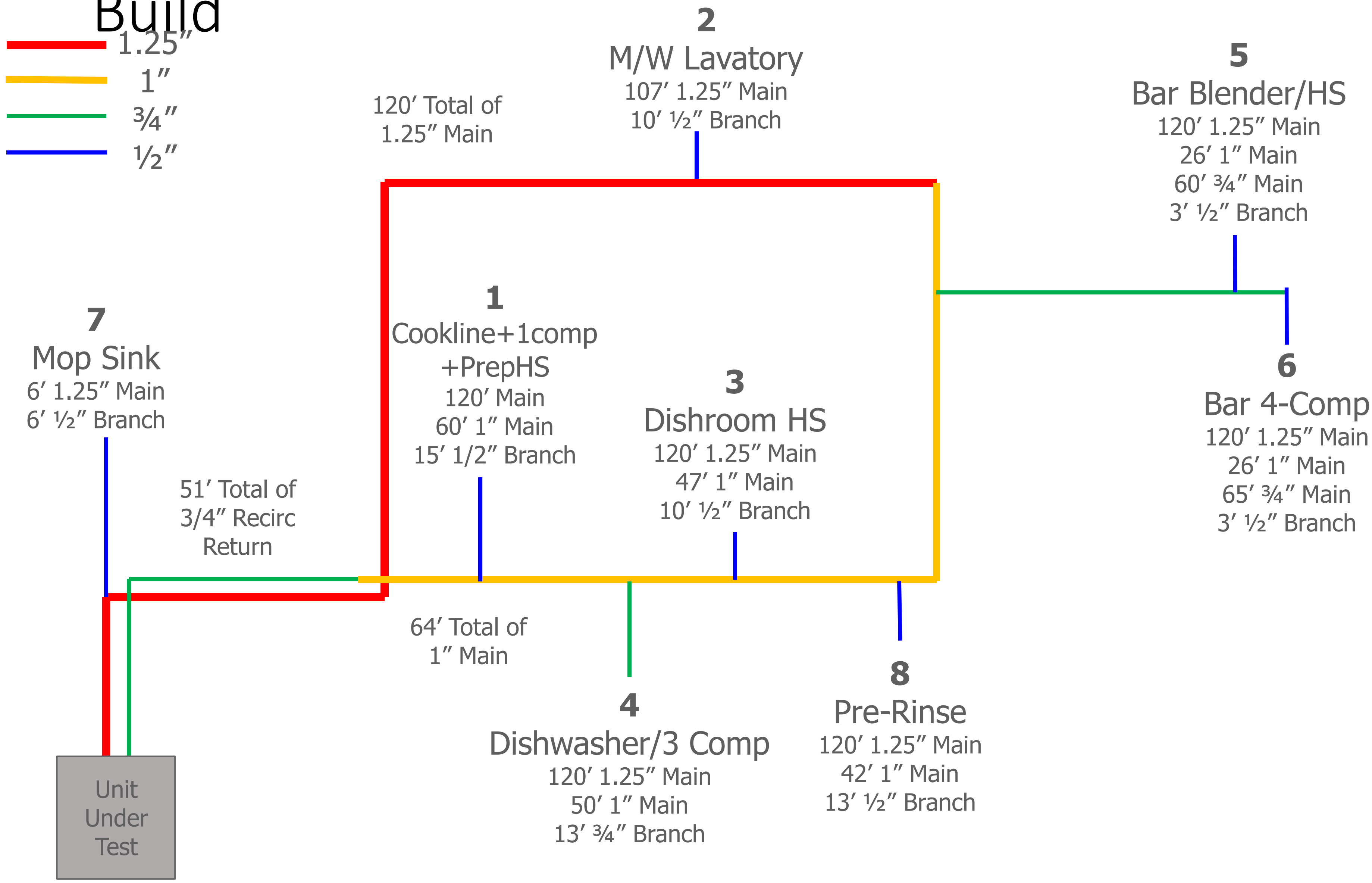


ATS' Task in Support of EPIC PIR 14-006 (cont'd)

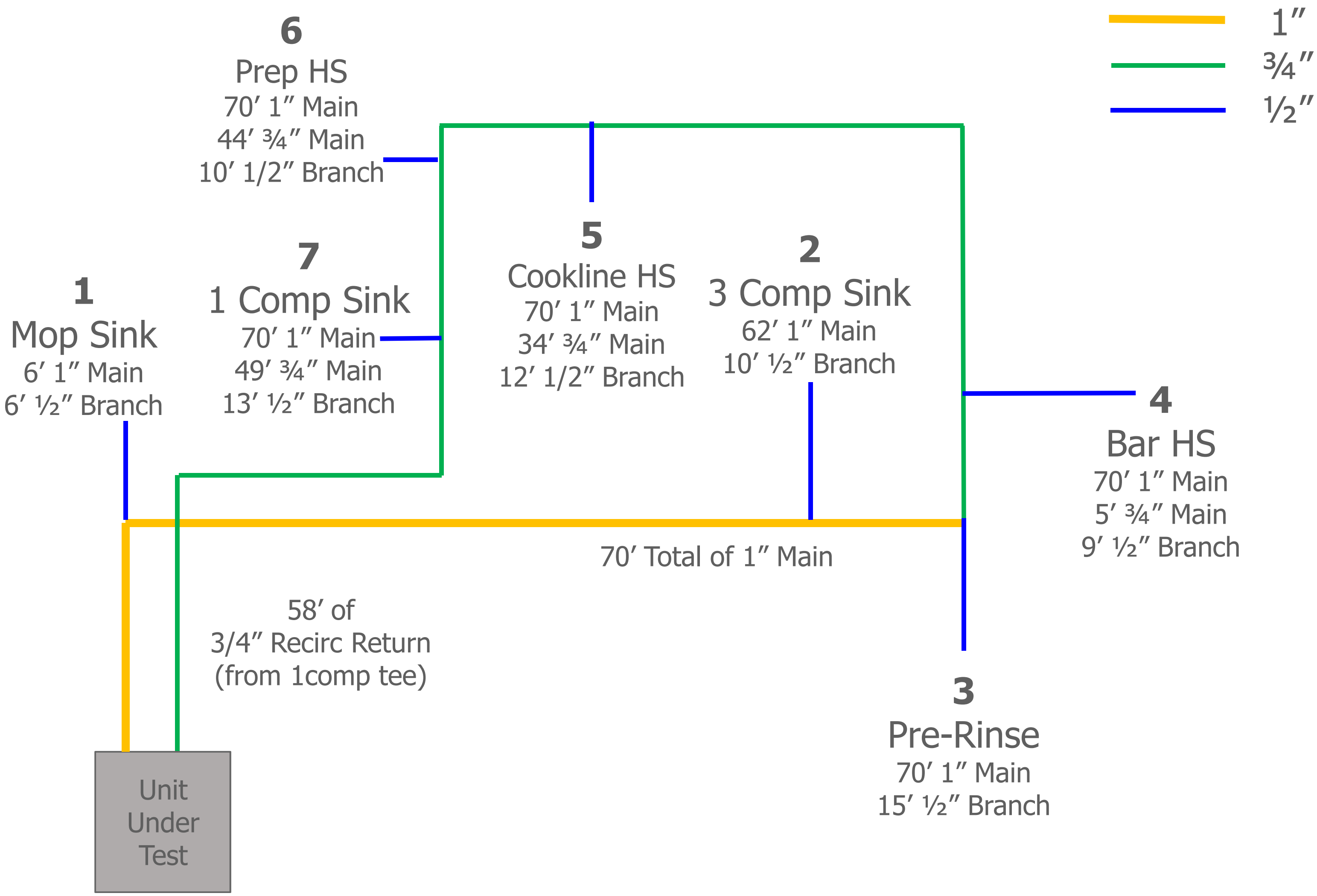
Isolate the performance impact using both the baseline and optimized distribution system:

- Demand Side
  - Recirculation loop length
  - Electrical POU Heating
  - Continuous Recirculation
  - Demand circulation control
  - End-use heat recovery (Enhance Condensing)
  - Hand sink aerator selection
  - Vertical branch drop pipe diameter
  - Aquastat
  - Time Clock
  - Insulation

Baseline Distribution System – Laboratory Build



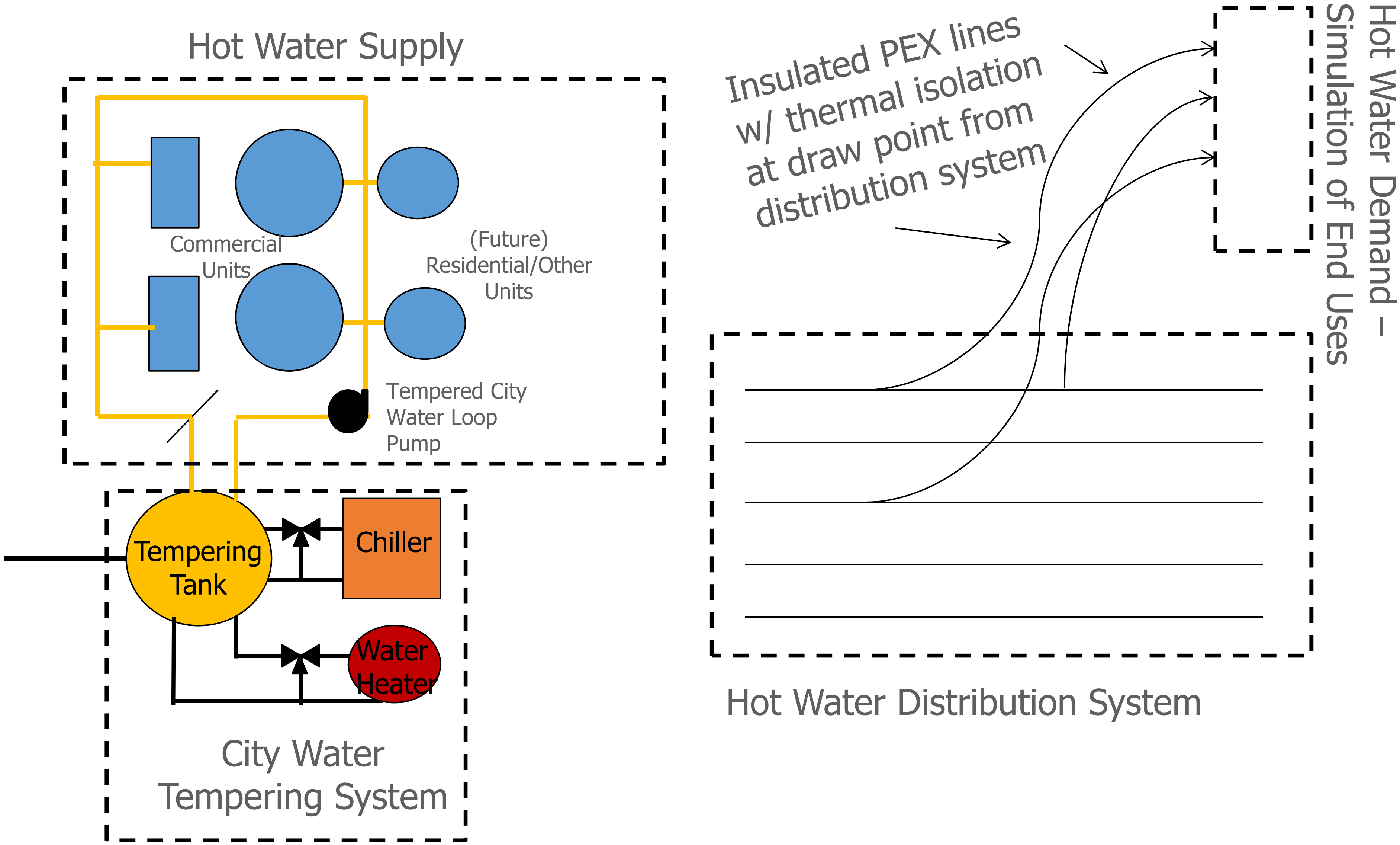
Proposed Distribution System – Laboratory Build



Summary of Test Parameters to Vary

- **Distribution System** – Baseline and Optimized
- **Supply Side** – Up to 4 Water Heater Options
  - (2) Standard Efficiency Tankless Units (199,000 Btuh ea)
  - (1) Condensing Tankless (250,000 Btuh)
  - (1) Standard Efficiency Tank (199,000 Btuh)
  - (1) Condensing Tank (199,000 Btuh)
- **Parameters to vary** - Recirc On/Off, Recirc Return Location, Insulation/No Insulation, Timeclock On/Off, Aquastat On/Off, D'mand circulation (Timeclock + Aquastat)
- **Other Parameters to vary** - Run a variety of flow profiles if time permits, anything else?
- 2 Systems * 4 Heaters * 5 Recirculation Conditions (Recirc All On/All Off/Timeclock On/Aquastat On/Timeclock+Aquastat On) * 2 Insulation Levels (On/Off) + ~5 central return port tests = **85 possible tests**.

Applying the Vision by Going Modular with Layout



Clustered Tankless and Storage Heaters

Supply Side: Heater 1 – Standard Efficiency Tank

Heater 1 – A.O. Smith Master Fit

- 100 Gallon Tank
- 199,000 Btuh Firing Rate
- Standard Efficiency

Why to Test this Unit?

- Provide a “baseline” representation of what might be commonly found in the field
- Baseline data point for calculation tool

Supply Side: Heater 2 – High Efficiency Tank

Heater 2 – A.O. Smith Cyclone

- 100 Gallon Tank
- 199,000 Btu/h Firing Rate
- High Efficiency-Modulating-Recirc. Return Port

Why to Test this Unit?

- Provide an idea of the benefits of condensing units, and some pitfalls
- Another data point for design tool
- Enables the lab to quantify the efficiency improvements from a modulating burner and central return port

Supply Side: Heater 3 – Paralleled Standard Efficiency Tankless

Heaters 3 – Paralleled Rinnai Tankless

- 199,000 Btuh Firing Rate
- Standard Efficiency

Why to Test this Unit?

- Provide a “baseline” representation of what might be commonly found in the field
- Another data point for calculation tool

Supply Side: Heater 4 (If Available) – High Efficiency Tankless

Heater 4 – High Efficiency Tankless

- 200,000 Btuh Firing Rate
- High Efficiency
- Built-in recirculator
- 0.5 gal tank

Why to Test this Unit?

- Provide information for an efficient wall mounted alternative
- Another data point for calculation tool

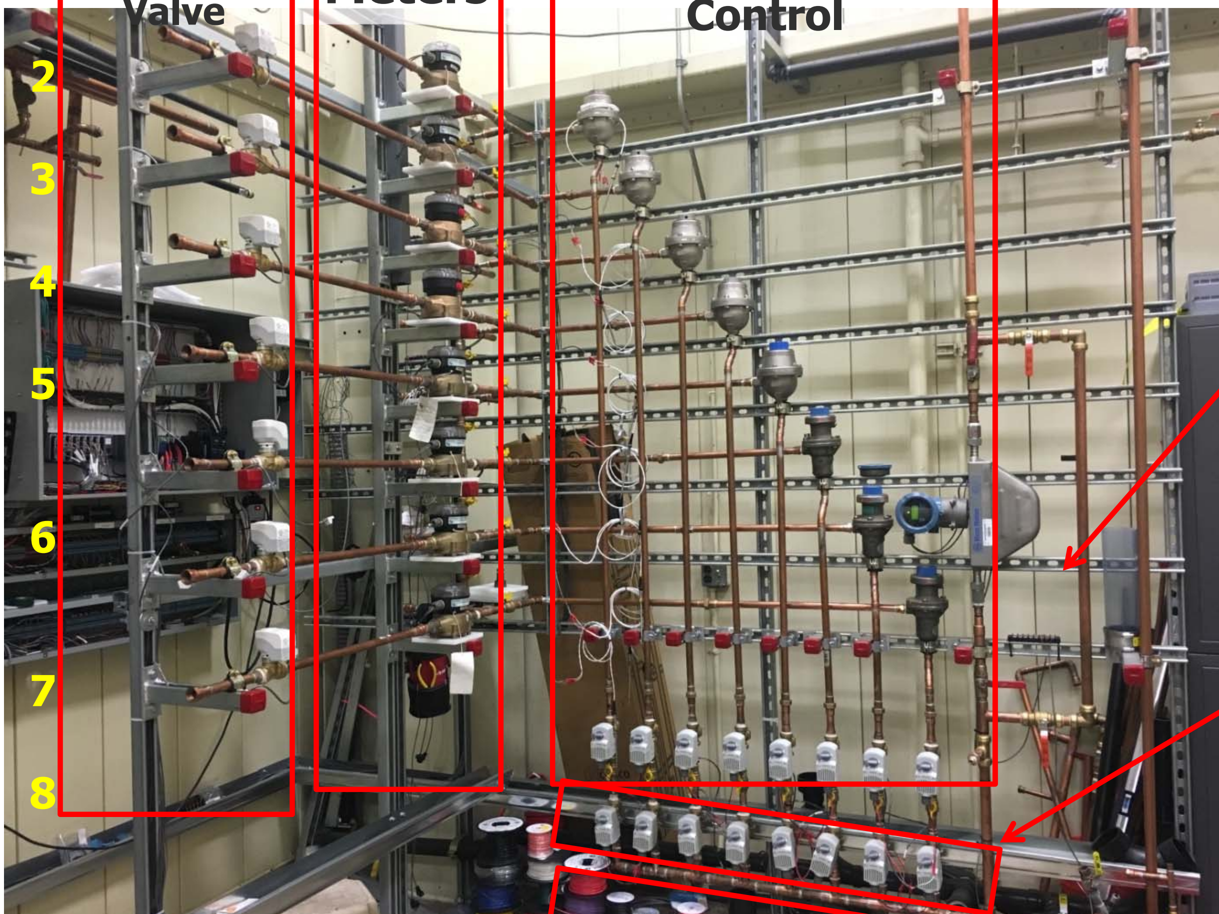
Distribution System – Piping Rack

Baseline distribution system

Optimized insulated distribution system under current testing

Hot Water Draw Simulation – Flow Measurement and Control (Constant, Staged and Variable Volume)

Hot Water Draw Simulation – Flow Measurement and Control (Constant, Staged and Variable Volume)

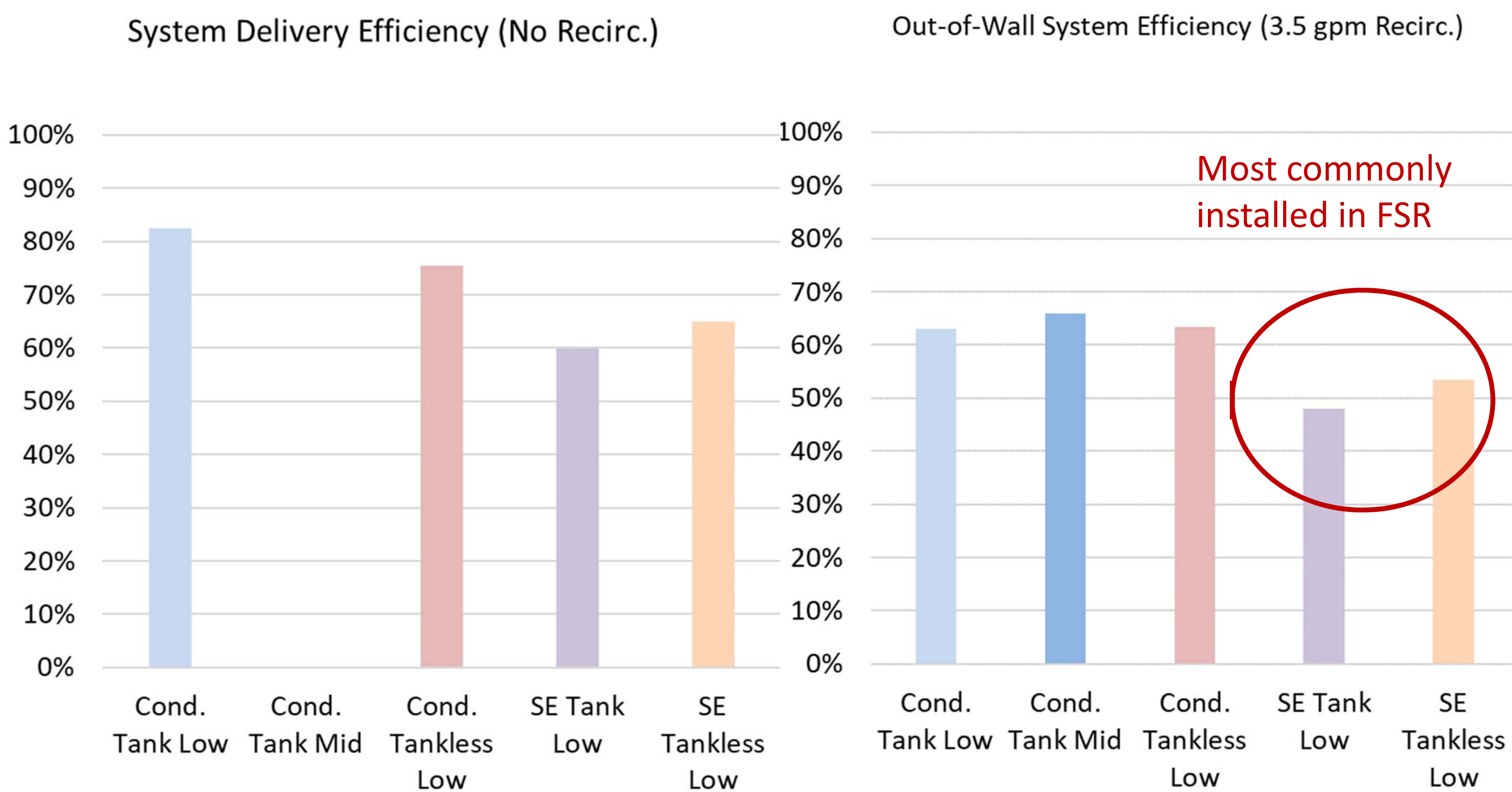


Test Scenarios

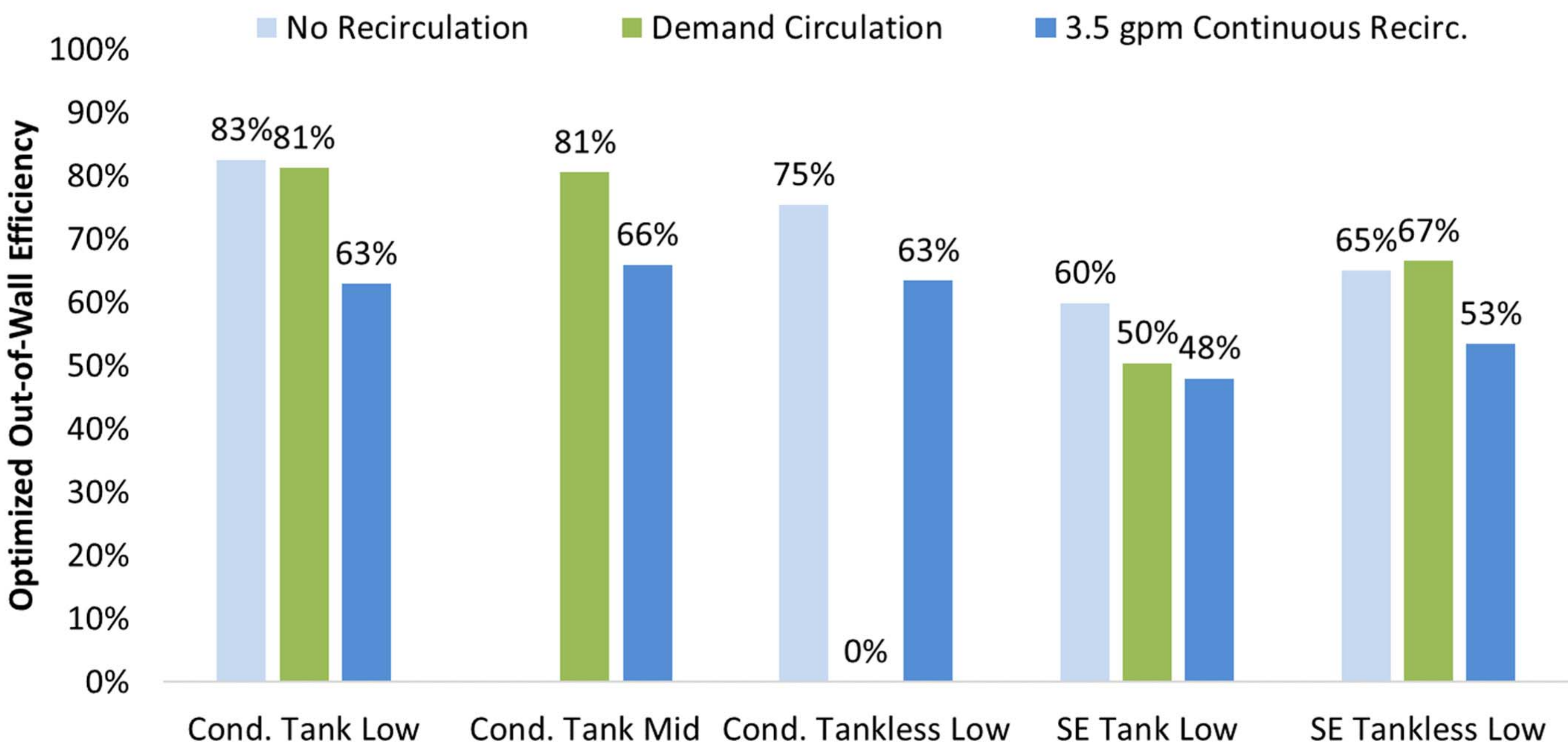
Test No.	Distribution System (Baseline, Optimized)	Water Heater (CTL, CTK, STL, STK)	Recirc. Control (On, Off, DMC, TC, Aq), (Recirc. Return Location)	Recirc Rate (gpm)	Insulation (On, Off)	Modified Drop (w/, w/o Aerator)
1	Optimized	CTK	Off		On	N
2	Optimized	CTK	On, Low	3.5	On	N
3	Optimized	CTK	On, Mid	3.5	On	N
4	Optimized	CTK	On, Mid	6.0	On	N
5	Optimized	CTK	On, Mid	1.0	On	N
6	Optimized	CTK	DMC, Low	3.5	On	N
7	Optimized	CTK	DMC, Mid	3.5	On	N
8	Optimized	CTK	TC, Low	3.5	On	N
9	Optimized	CTK	TC, Mid	3.5	On	N
10	Optimized	CTK	Aq, Low	3.5	On	N
11	Optimized	CTK	Aq, Mid	3.5	On	N
12	Optimized	CTLHy	Off		On	N
13	Optimized	CTLHy	On	3.5	On	N
14	Optimized	CTLHy	On	1.0	On	N
15	Optimized	CTLHy	DMC	3.5	On	N
16	Optimized	CTLHy	On with TC	3.5	On	N
17	Optimized	CTLHy	On with Aq	3.5	On	N
18	Optimized	STK	Off		On	N
19	Optimized	STK	On	3.5	On	N
20	Optimized	STK	DMC	3.5	On	N
21	Optimized	STK	On with TC	3.5	On	N
22	Optimized	STK	On with Aq	3.5	On	N
23	Optimized	STL	Off		On	N
24	Optimized	STL	On	3.5	On	N
25	Optimized	STL	On	1.0	On	N
26	Optimized	STL	DMC	3.5	On	N
27	Optimized	STL	On with TC	3.5	On	N
28	Optimized	STL	On with Aq	3.5	On	N
29	Optimized	CTK	On	3.5	On	Y, w/
30	Optimized	CTK	On	3.5	On	Y, w/o
31	Optimized	CTK	On	3.5	Off	N
32	Optimized	CTLHy	On	3.5	Off	N
33	Optimized	STK	On	3.5	Off	N
34	Optimized	STL	On	3.5	Off	N

Test No.	Distribution System (Baseline, Optimized)	Water Heater (CTL, CTK, STL, STK)	Recirc. Control (On, Off, DMC, TC, Aq), (Recirc. Return Location)	Recirc Rate (gpm)	Insulation (On, Off)	Modified Drop (w/, w/o Aerator)
35	Baseline	CTK	Off		Off	N
36	Baseline	CTK	On, Mid	3.5	Off	N
37	Baseline	CTK	On, Low	3.5	Off	N
38	Baseline	CTK	DMC	3.5	Off	N
39	Baseline	CTK	On with TC	3.5	Off	N
40	Baseline	CTK	On with Aq	3.5	Off	N
41	Baseline	CTLHy	Off		Off	N
42	Baseline	CTLHy	On	3.5	Off	N
43	Baseline	CTLHy	DMC	3.5	Off	N
44	Baseline	CTLHy	On with TC	3.5	Off	N
45	Baseline	CTLHy	On with Aq	3.5	Off	N
46	Baseline	STK	Off		Off	N
47	Baseline	STK	On	3.5	Off	N
48	Baseline	STK	DMC	3.5	Off	N
49	Baseline	STK	On with TC	3.5	Off	N
50	Baseline	STK	On with Aq	3.5	Off	N
51	Baseline	STL	Off		Off	N
52	Baseline	STL	On	3.5	Off	N
53	Baseline	STL	DMC	3.5	Off	N
54	Baseline	STL	On with TC	3.5	Off	N
55	Baseline	STL	On with Aq	3.5	Off	N
56	Baseline	CTK	On	3.5	On	N
57	Baseline	CTK	Off		On	N
58	Baseline	CTK	DMC	3.5	On	N
59	Baseline	CTK	On with TC	3.5	On	N
60	Baseline	CTK	On with Aq	3.5	On	N
61	Baseline	CTLHy	On	3.5	On	N
62	Baseline	CTLHy	Off		On	N
63	Baseline	CTLHy	DMC	3.5	On	N
64	Baseline	CTLHy	On with TC	3.5	On	N
65	Baseline	CTLHy	On with Aq	3.5	On	N
66	Baseline	STK	On	3.5	On	N
67	Baseline	STK	Off		On	N
68	Baseline	STK	DMC	3.5	On	N
69	Baseline	STK	On with TC	3.5	On	N
70	Baseline	STK	On with Aq	3.5	On	N
71	Baseline	STL	On	3.5	On	N
72	Baseline	STL	Off		On	N
73	Baseline	STL	DMC	3.5	On	N
74	Baseline	STL	On with TC	3.5	On	N
75	Baseline	STL	On with Aq	3.5	On	N

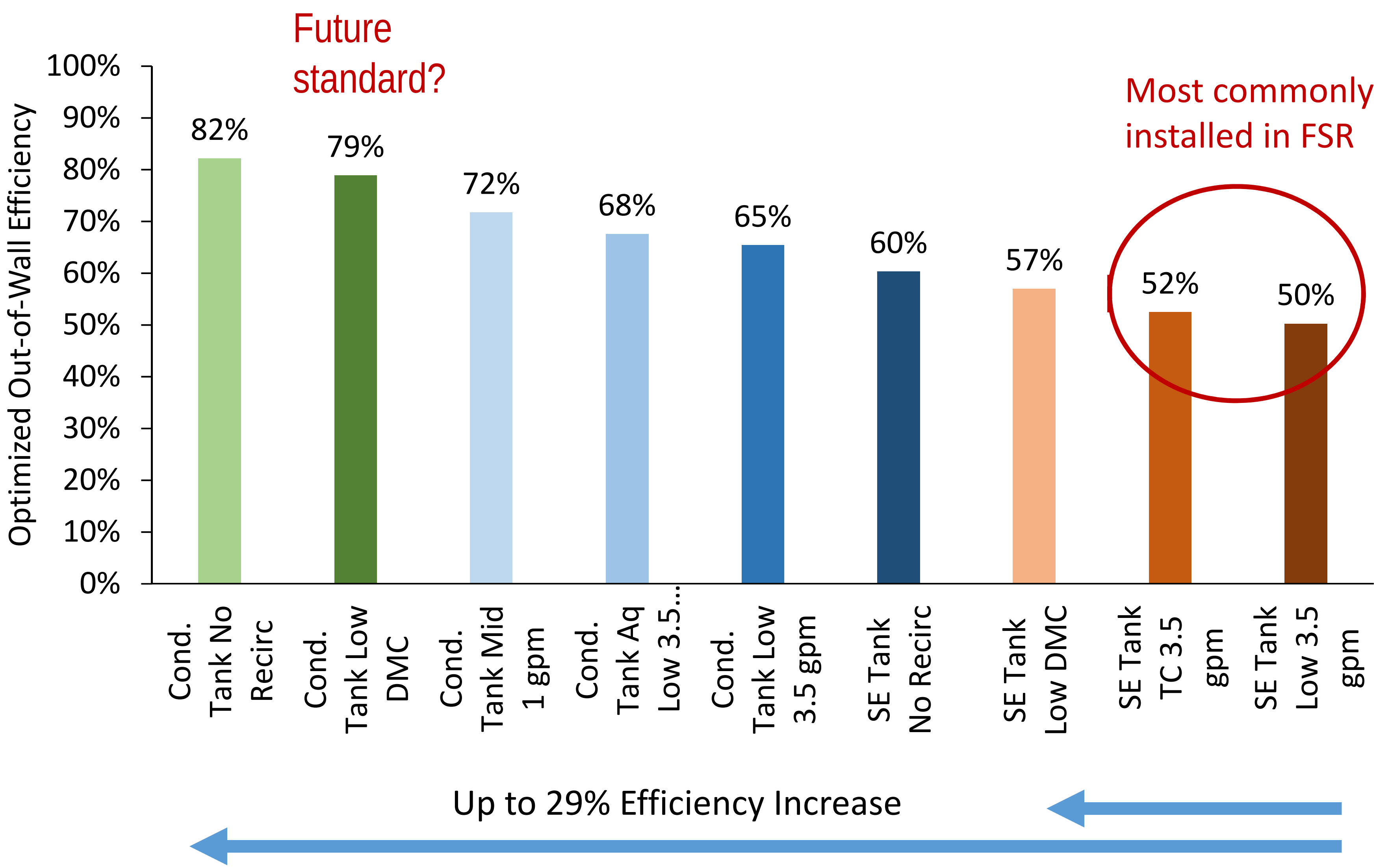
Results consistent with past testing in QSR



D'MAND Control is Almost as Efficient as No Recirc



Promising efficiency results



Design Tool and Cost Calculator

Goals:

- The baseline scenario and optimized scenario can be compared side by side for installed cost (new facility) and operating costs
- Main purpose is to support designers and engineers with transforming the industry from a business as usual approach
- Provides utilities a method to estimate savings and calculate rebates
- Supports expansion of utilities' EE programs
- Increase market penetration of emerging tech
- Future Title 24 implications
  - Working towards establishing minimum system delivery efficiencies for various foodservice facility types while maintaining hot water delivery performance
  - Hot water system designs can be modeled and system delivery efficiency calculated to meet a minimum Title 24 standard

Design Tool Components

Type of Facility and Location

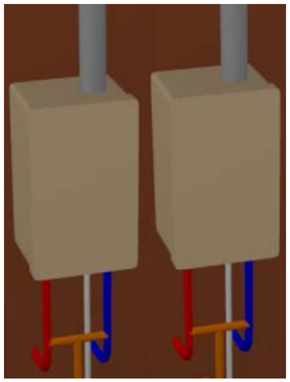
- Café, Quick-Service, Full Service, School...

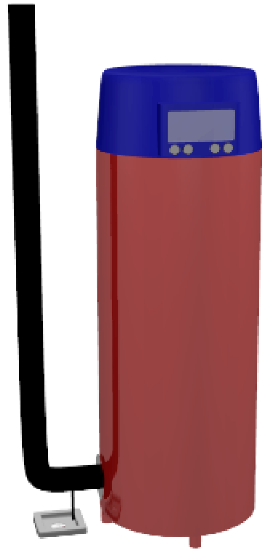
Utility Costs

- Water Use ($/HCF), Sewer Use ($/HCF), Electricity Use ($/kWh), Gas Use ($/therm), Demand Charge ($/kW)

Type of Centralized and Decentralized Water Heaters

- Gas or Electric
- Standard and High Efficiency
- Storage, Tankless, Hybrid
- HE Storage will include modulating and return port options





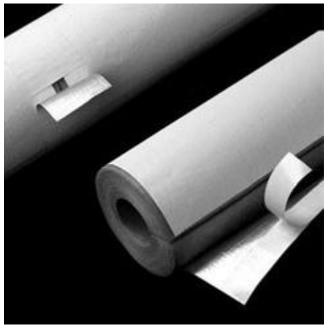
Design Tool Components

Heater Cold Water Supply and Outlet Setpoint Temp

- 45°F to 185°F, increment of 5°F

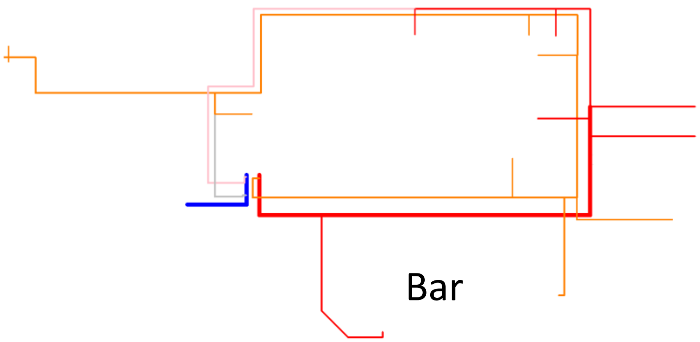
Type of Distribution System

- No circulation, Continuous, D'mand Circ
- Controls—Timeclock, Temperature
- Insulation—No Insulation, 1"-thick Insulation



Type of End Use Equipment

- Number of restrooms, attached or island bar
- Dishwasher type—Low temp, HT, w/ HR



Full Service Restaurant Hot Water System Design Tool and Cost Calculator

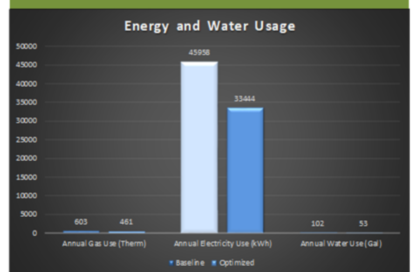
Input	Baseline	Optimized
Facility Location	Los Angeles	Long Beach
Hot Water Use (gallons)	200	100
Primary Water Heater	STK	CTK
Heater Thermostat Temperature (°F)	140	140
Distribution System	Centralized	Centralized
Water Pump	ECM	ECM
Recirc. Control	DMC	DMC
Recirc FlowRate (gpm)	3.5	3.5
Insulation Thickness	On	On
Dishmachine	Energy Star	Energy Star
PRSV	WaterSense	WaterSense
Hand Sink Aerator (gpm)	1.5	1.5
Secondary Water Heater	N/A	N/A

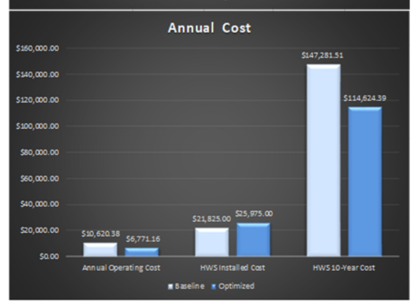
Warning	Baseline	Optimized
Lavatory Sink Cold Start Delivery Time to 100°F (seconds)	27	27
Lavatory Sink Delivery Performance (Pass, Fail)	Fail	Fail
Average Lavatory Sink Hot Water Delivery Temperature (°F)	94	94
Percentage of Users that Got Hot Water in 10 seconds (%)	50	50
Error Flags	Lav Sink fails delivery performance, health department will be upset.NullNullNull	Lav Sink fails delivery performance, health department will be upset.NullNullNull

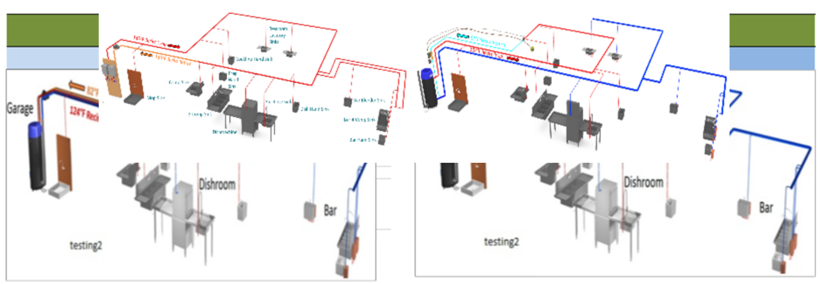
Update Output

Output	Baseline	Optimized
Energy Efficiency		
Water Heater Operating Efficiency	75%	107%
Point-of-Use Efficiency	65%	89%
Energy and Water Usage		
Annual Gas Use (Therm)	603	461
Annual Electricity Use (kWh)	45958	33444
Annual Water Use (Gal)	102	53
Energy Price		
Electricity ($/kWh)	$0.19	$0.18
Gas ($/therm)	$1.15	$0.90
Water & Sewer ($/Gal)	$11.76	$6.37
Cost Item		
Annual Operating Cost	$10,620.38	$6,771.16
Equipment Purchase Cost	$17,275.00	$1,450.00
Plumbing Materials Cost	$1,450.00	$1,450.00
Labor Cost	$3,100.00	$3,450.00
HWS Installed Cost	$21,825.00	$25,975.00
Utility Incentives Credit		$5,037.18
HWS 10-Year Cost	$147,281.51	$114,624.39

Chart







Water Use (gal)	102
Gas Use (therm)	603
Electricity Use (kWh)	45958
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Input		
	Baseline	**Optimized**
Facility Location	Los Angeles	Long Beach
Hot Water Use (gallons)	850	350
Primary Water Heater	STL	CTK
Heater Thermostat Temperature (°F)	140	125
Distribution System	Centralized	Decentralized
Water Pump	Baseline	ECM
Recirc. Control	On	DMC
Recirc Flow Rate (gpm)	6	1
Insulation Thickness	Off	On
Dishmachine	Baseline	Best-in-Class
PRSV	Baseline	Best-in-Class
Hand Sink Aerator (gpm)	1.5	0.5
Secondary Water Heater	N/A	Best-in-Class

Warning		
	Baseline	**Optimized**
Lavatory Sink Cold Start Delivery Time to 100°F (seconds)	27	27
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Output		
	Baseline	**Optimized**
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Water Heater Operating Efficiency	75%	98%
Point-of-Use Efficiency	65%	89%
Energy and Water Usage		
Annual Gas Use (Therm)	603	461
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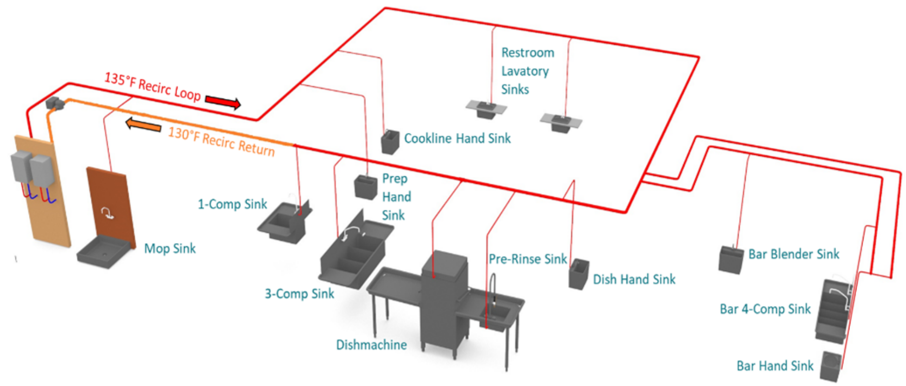
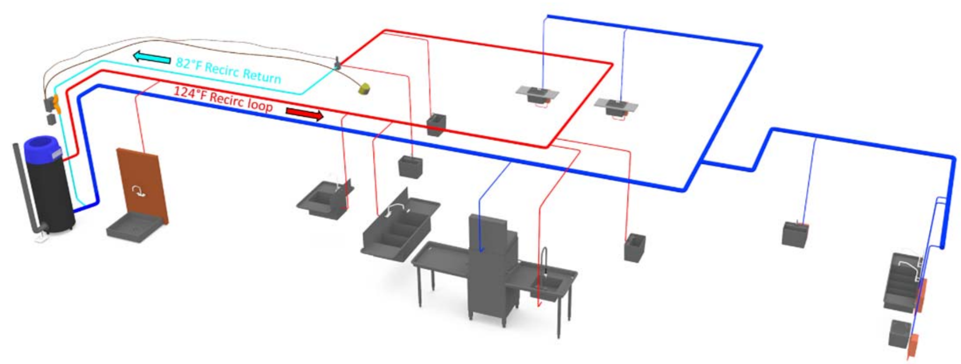
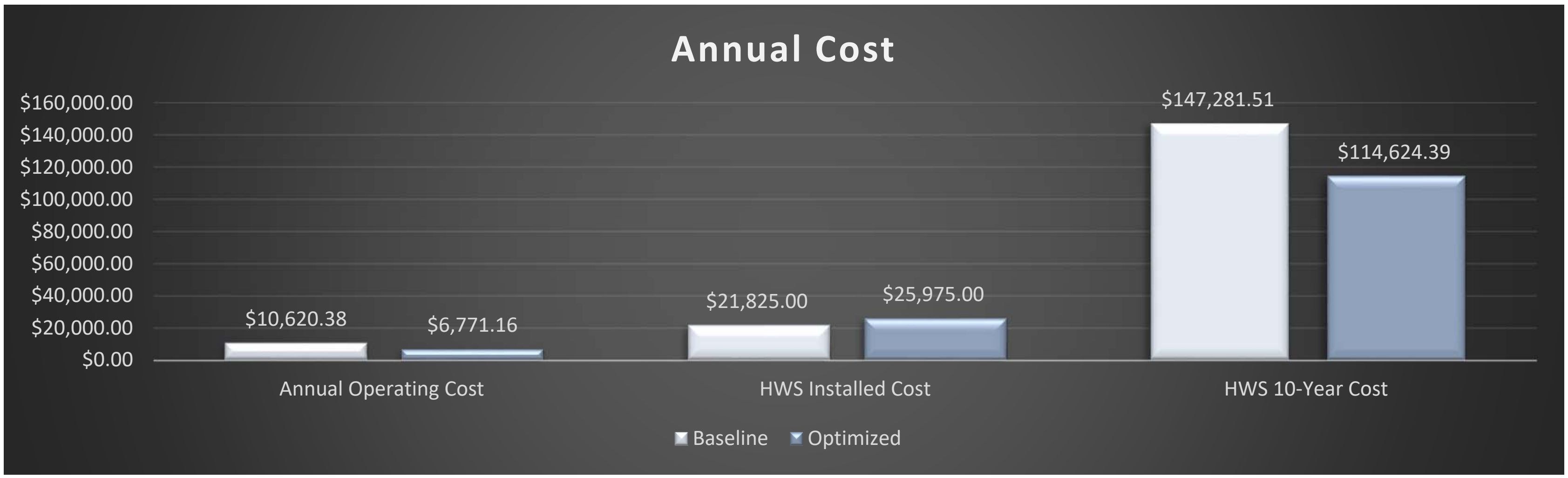
Display	
Baseline	**Optimized**





Cost Calculator



- Equipment Cost
- Total Installed Cost
- Yearly Utility Cost
- Total 10 year Cost
- California Rebates

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