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Measured Performance of Natural Gas Tankless and Storage Water Heaters

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Full report:

http://mncee.org/Innovation-Exchange/Reports-and-Technical-Documents/Actual-Savings-and-Performance-of-Natural-Gas-Tank/

Or

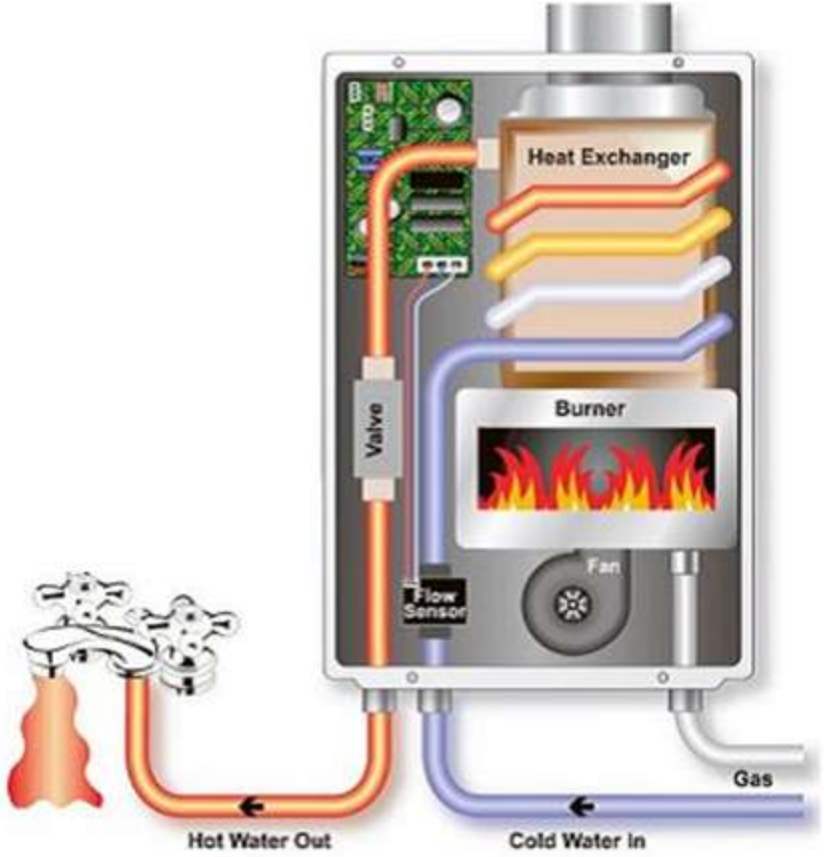
goo.gl/TuFsJ

This project was funded by
Minnesota Department of Commerce – Office of Energy Security
Minnesota Statutes § 216B.241, subd. 1e
and
Center for Energy and Environment

Field Study overview

- Objectives
  - To determine installed performance of TWH
  - To monitor hot water consumption behavior
- Methodology
  - 10 sites
  - 25 water heaters
    - 8 Tank Water Heaters (TANK)
    - 9 Non-Condensing Tankless Water Heaters (TWHs)
    - 7 Condensing Tankless Water Heaters (CTWHs)
  - 4 week alternating mode test
  - Extensive data logging
  - Homeowner surveys

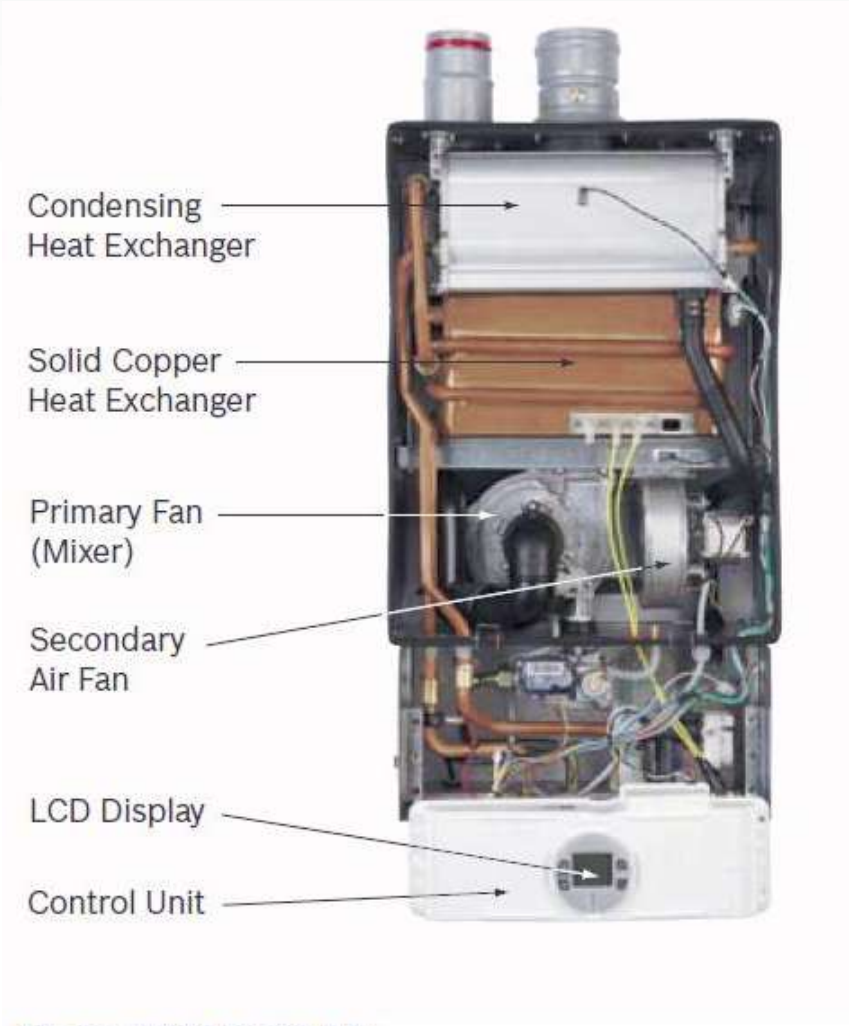
How Do Water Heaters Work?



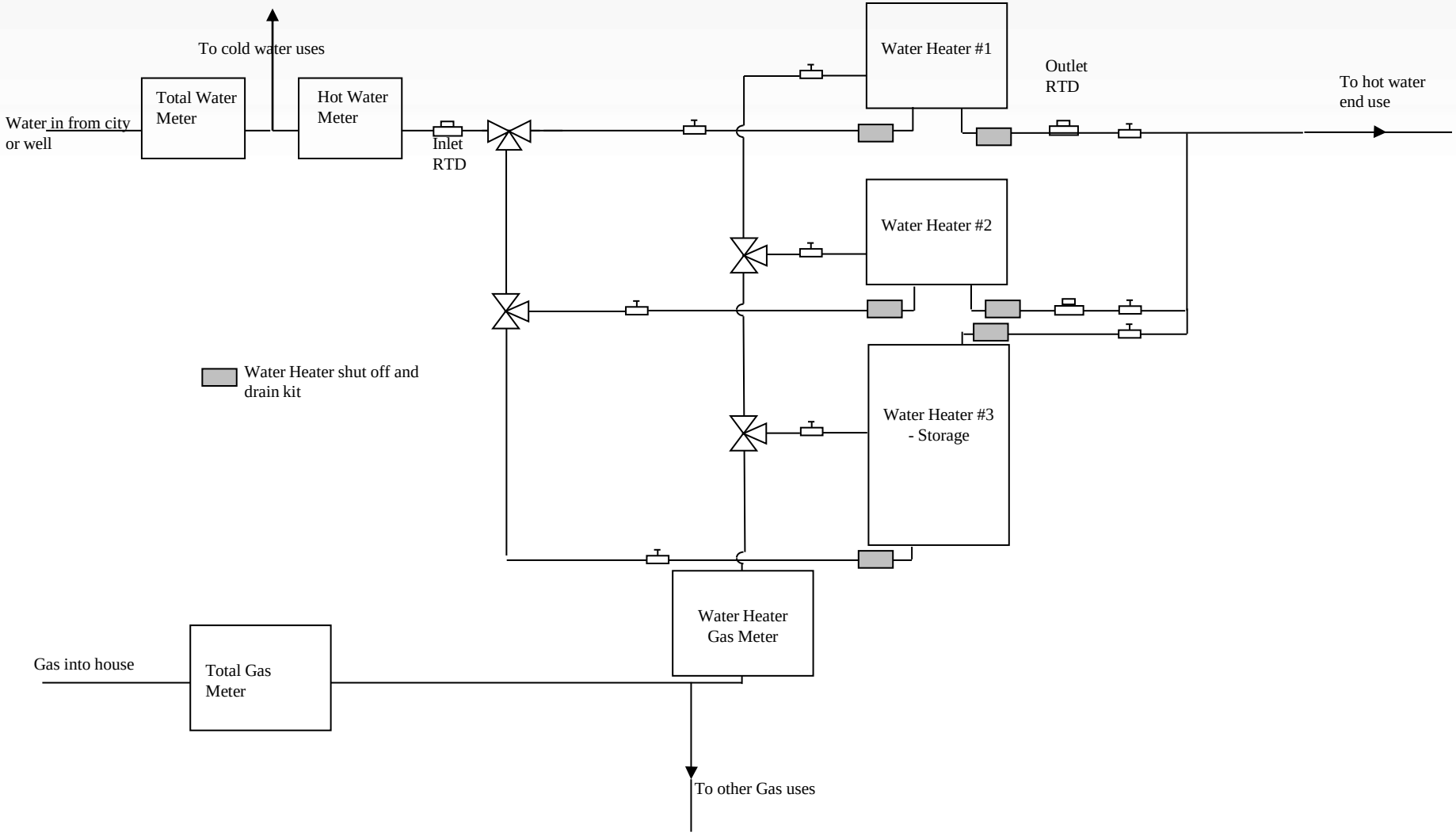
StWH

NTWH

CTWH

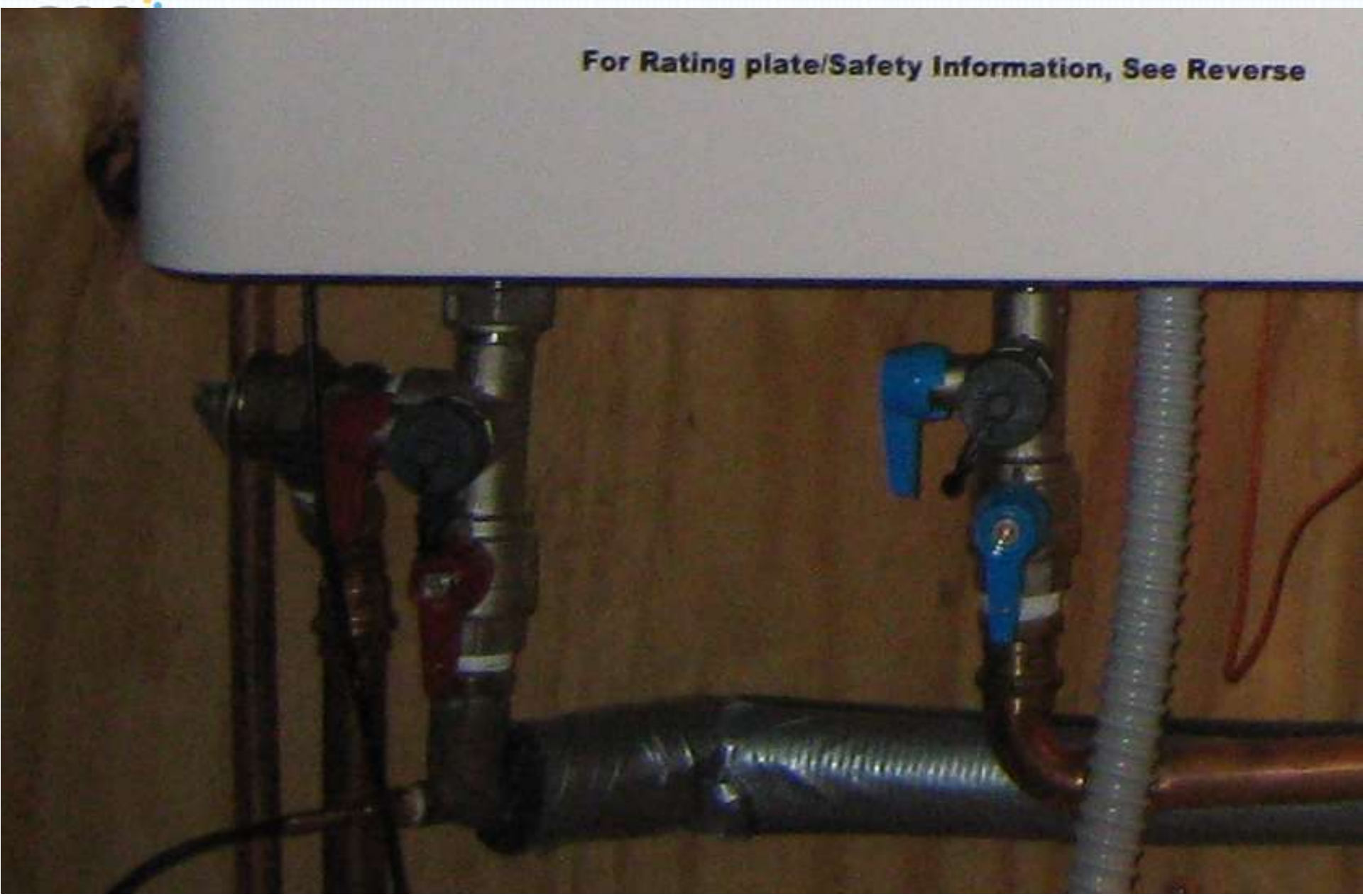

Condensing
Heat Exchanger
Solid Copper
Heat Exchanger
Primary Fan
(Mixer)
Secondary
Air Fan
LCD Display
Control Unit
Model GWH C 800 ES

CTWH1


To cold water uses
Water Heater #1
Outlet
RTD
To hot water
end use
Water in from city
or well
Total Water
Meter
Hot Water
Meter
Inlet
RTD
Water Heater #2
Water Heater shut off and
drain kit
Water Heater #3
- Storage
Water Heater
Gas Meter
Gas into house
Total Gas
Meter
To other Gas uses


Navien
A.O.Smith
ProMax
ENERGY GUIDE


CREATOR
NAVIEN


For Rating plate/Safety Information, See Reverse


NOT FOR PRESSURE
NOT FOR PRESSURE
NOT FOR PRESSURE
FOR PRESSURE

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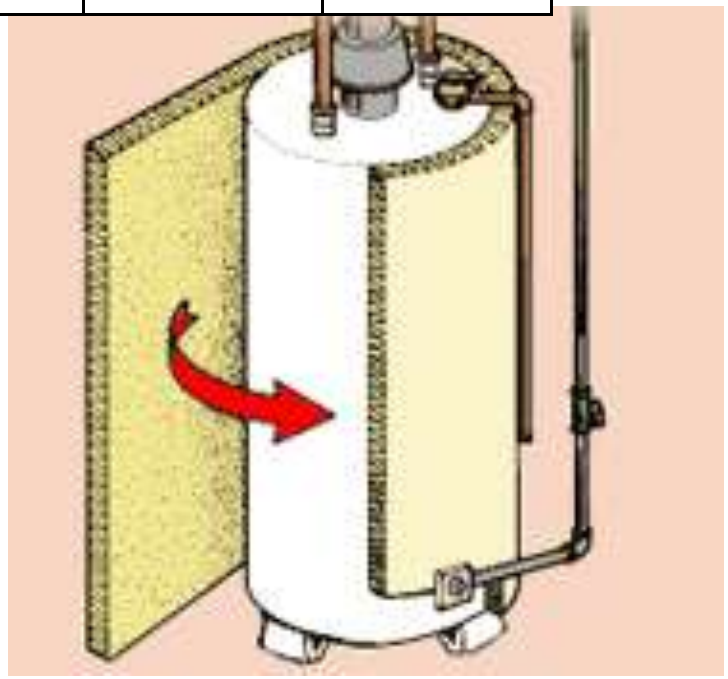
Tank Type Water Heaters

Tank Water Heater Blanket

		Gas Consumption per Year, therms/year		Savings, therms/year	
W/ Blanket Tset=120			210.0	5.5	3%
W/ Blanket Tset=130			198.3	11.4	6%
W/ Blanket Tset=140			201.8	14.6	7%

	Cost	Payback, yrs
Contractor	$ 18	1.2 - 3.3
Home-Owner	$ 22	1.5 - 4.0

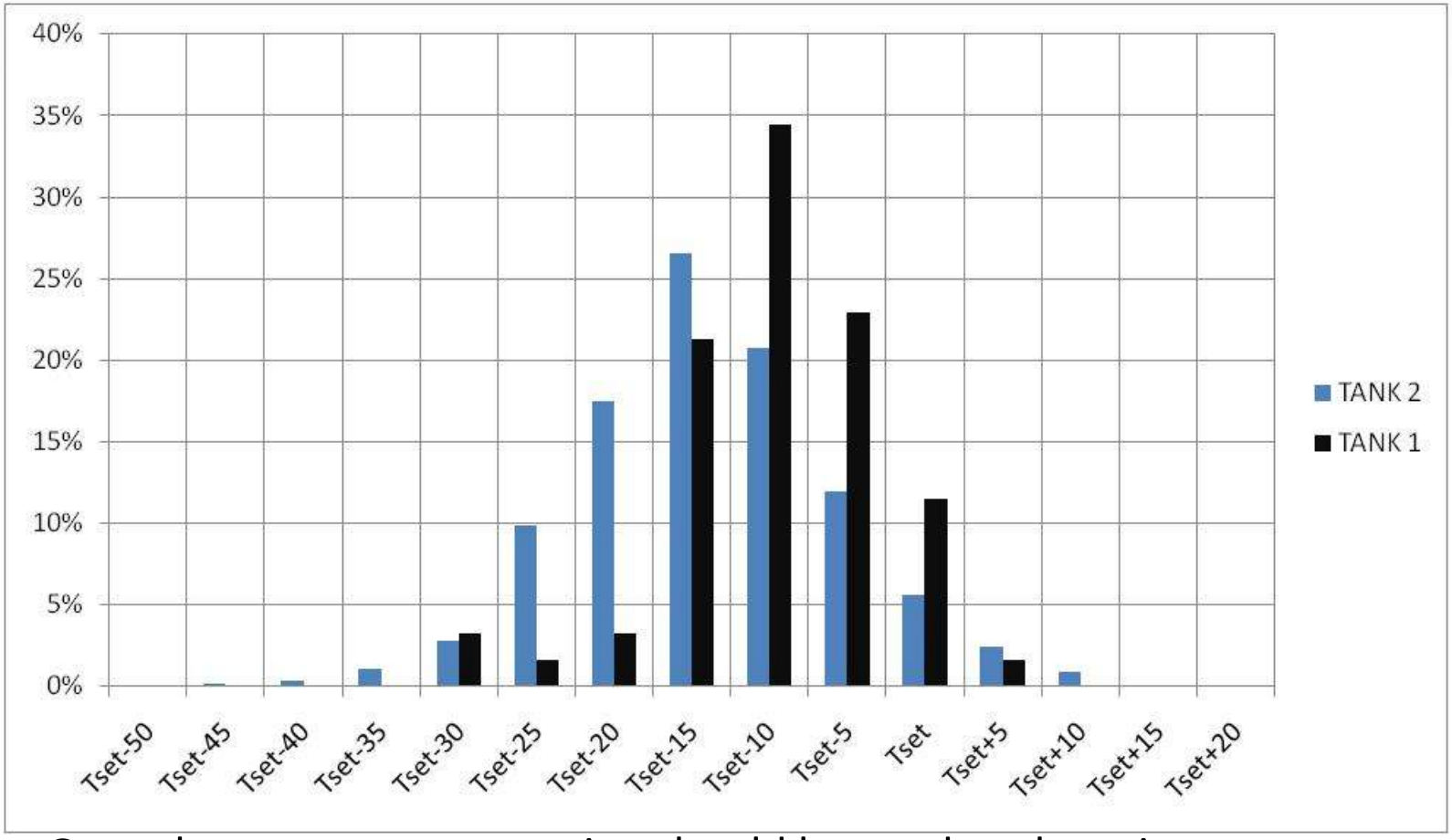


Turn Down of the Temperature Setting on Storage Water Heaters

Tset	Savings	
Setback °F	therm/dy	therm/yr
5	0.02	7.3
10	0.04	14.6
15	0.06	21.9
20	0.08	29.2
25	0.1	36.5

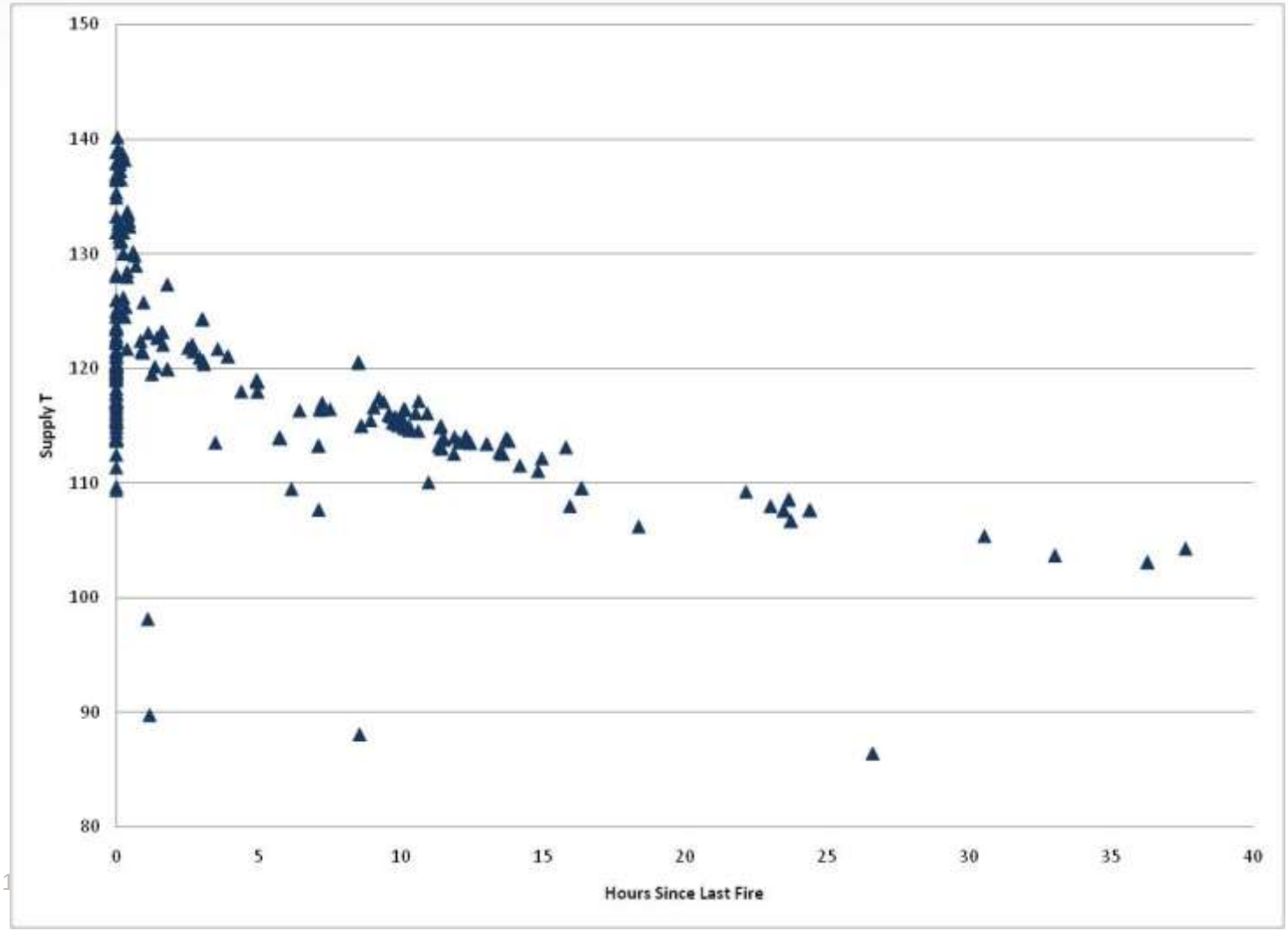
Can assume costs of approximately $1/therm

Storage Water Heater Outlet Temp



- Gas value temperature setting should be used as the primary
- Hot water tap temperature measurement can be used to for check extreme errors

Water heater dead band and time between firing



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Tankless Water Heaters

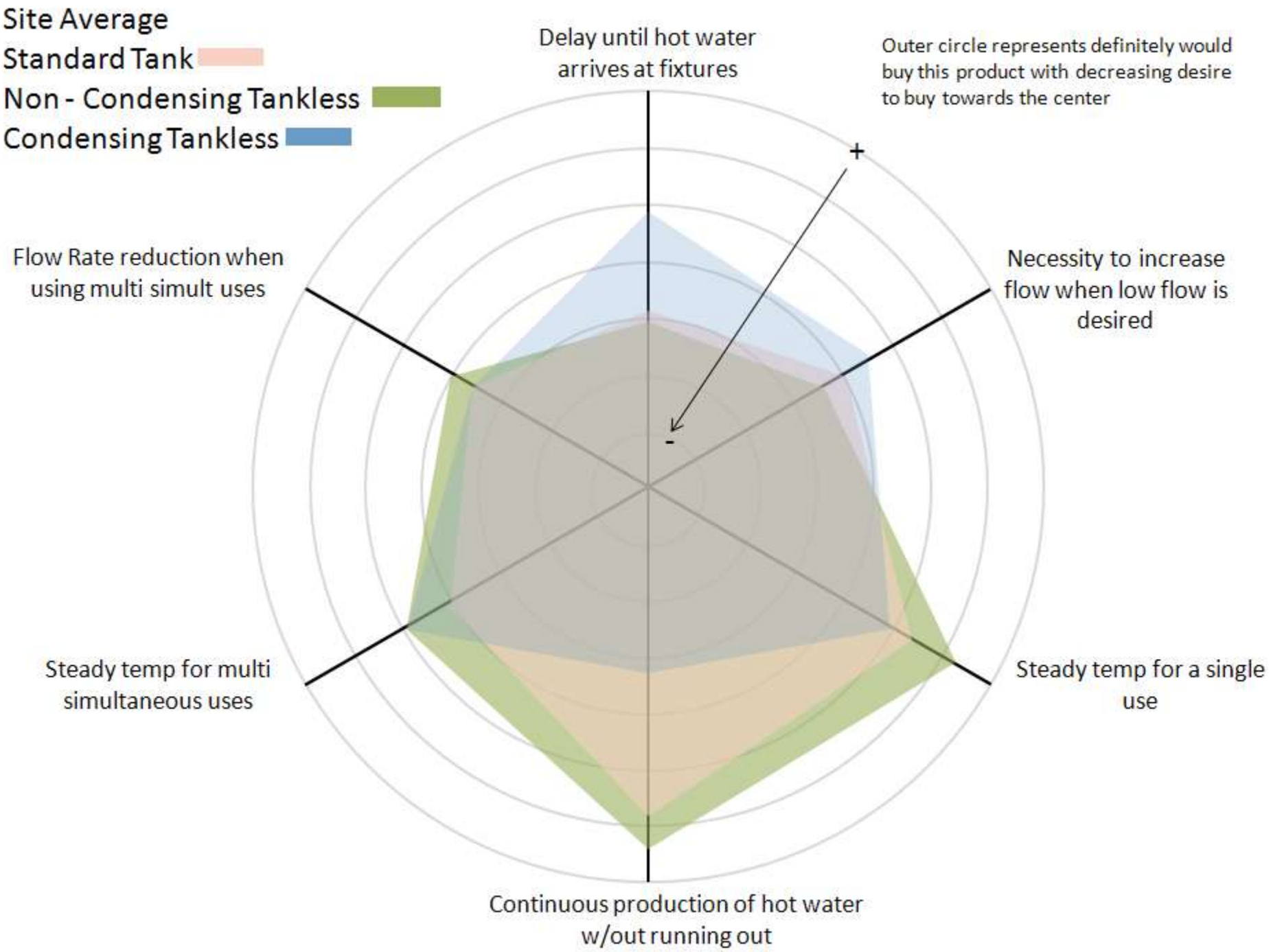
Issues Facing Tankless Water Heaters

- Hot water quality
  - Delayed delivery time
  - Cold water sandwich
  - Consistent Supply temperature
  - Minimum flow rate for firing
  - Performance for multiple simultaneous uses
- Higher installation costs
- Maintenance costs

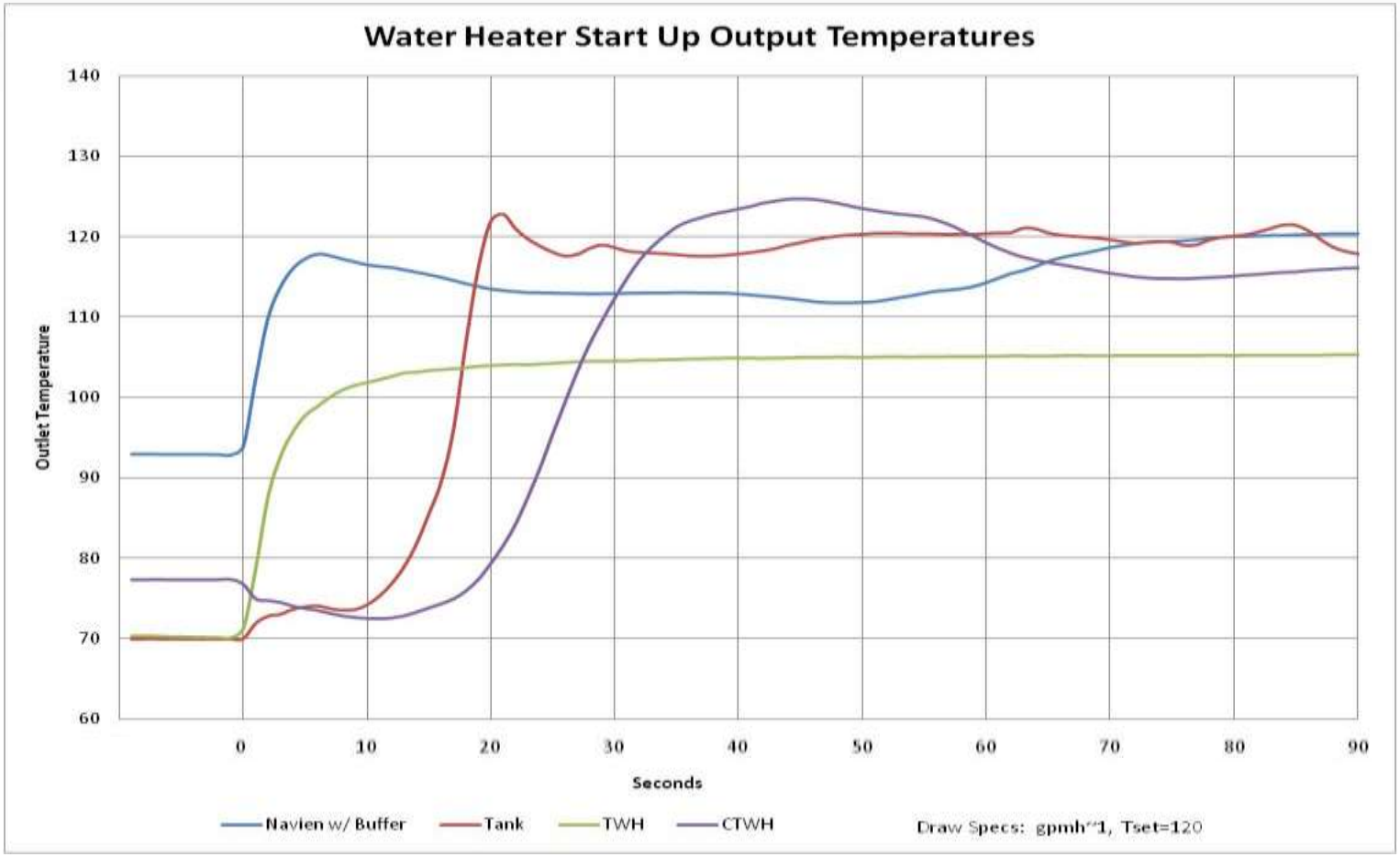
Home Owner Surveys

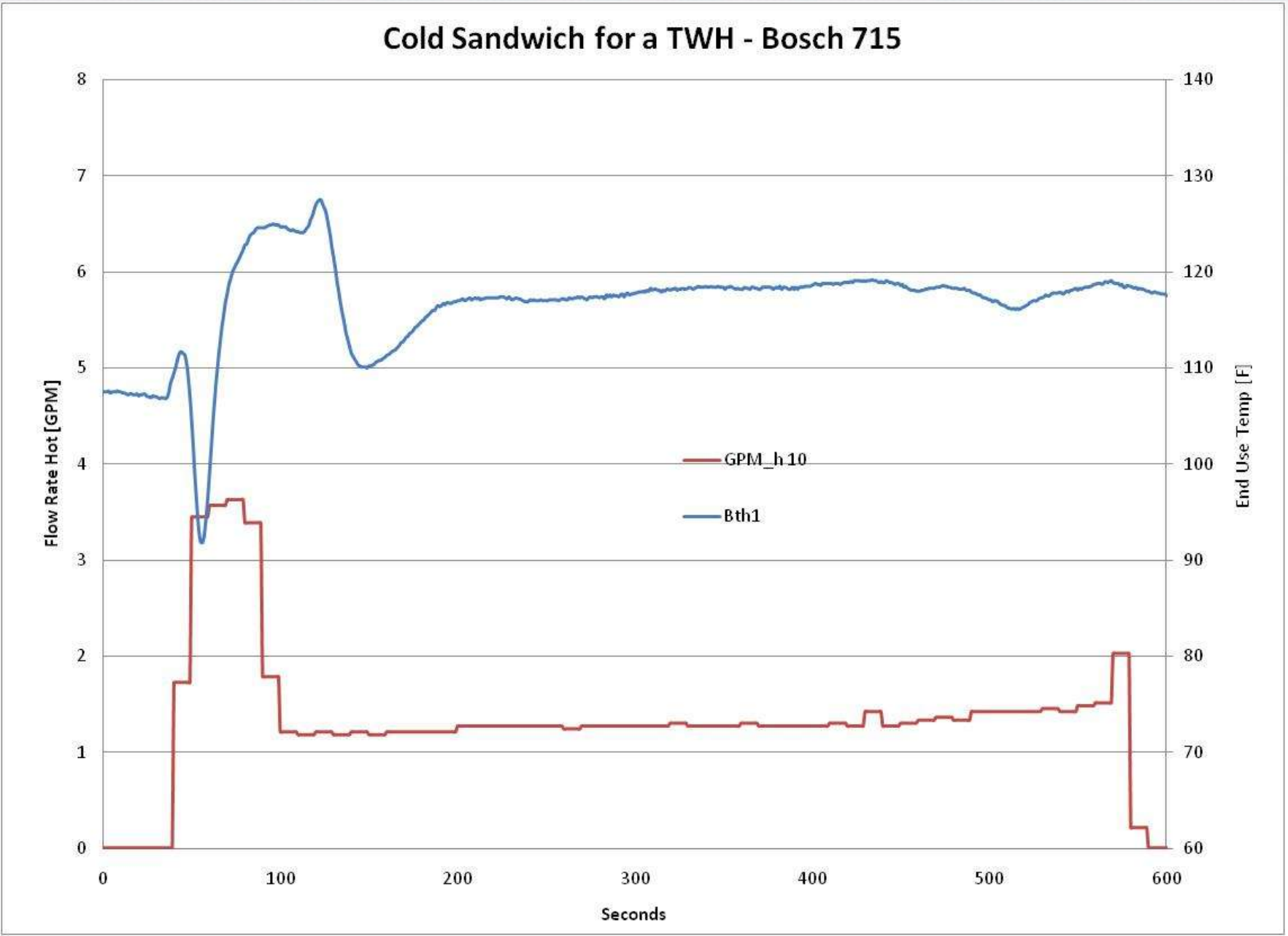
+ Occupants were asked about how hot water quality would effect their decision to purchase each water heater.
+ Surveys were given to home owners at the end of each operating period and asked to review the last four weeks

- Hot water quality indicators homeowners were asked about
  - Delay time until hot water arrives at the fixture
  - Necessity to increase flow when low flow is desired
  - Continuous hot water production without running out
  - Consistent temperature for a single use
  - Consistent temperature for multiple simultaneous uses
  - Flow rate reduction when using multiple simultaneous uses

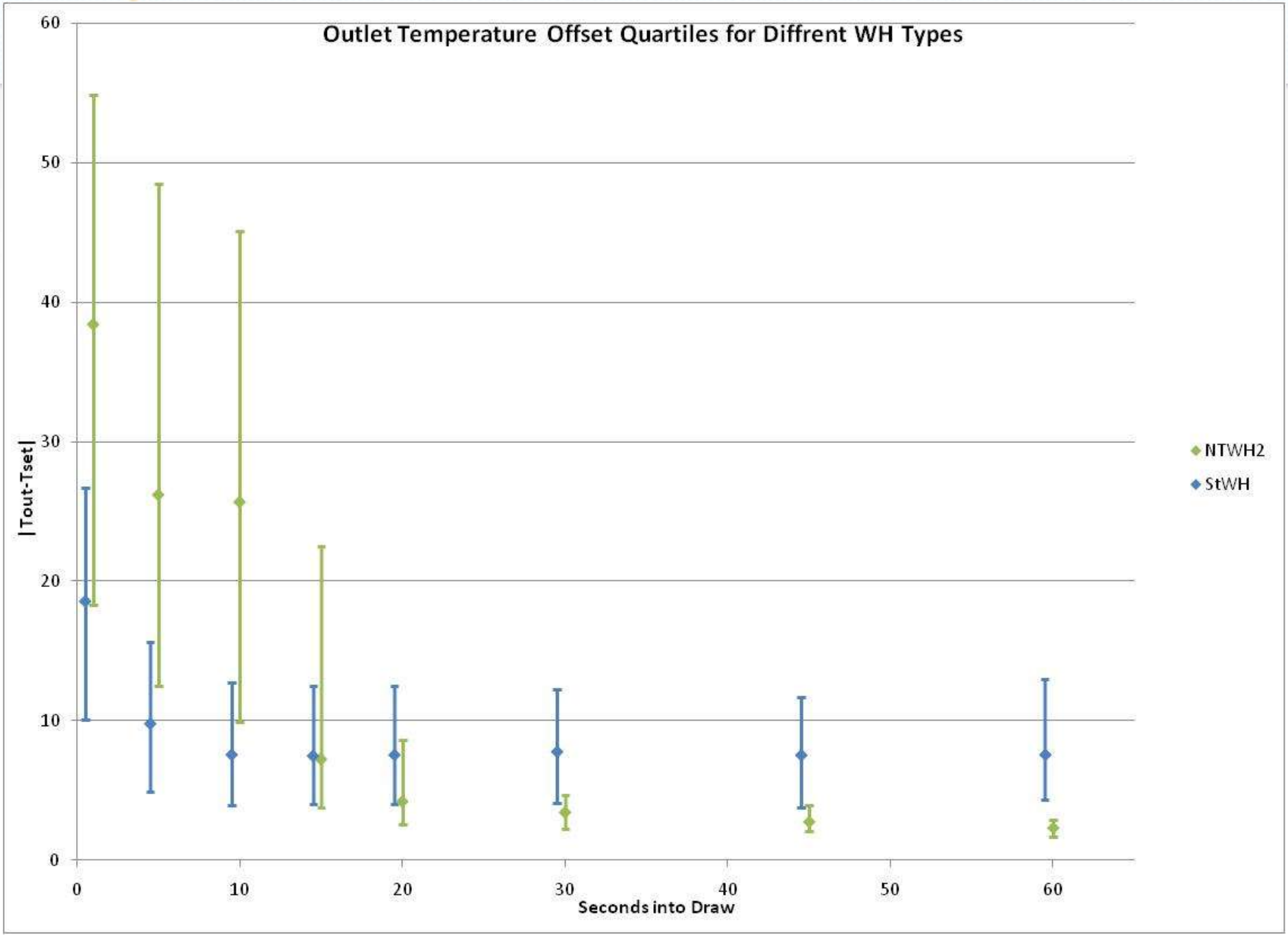

Site Average
Standard Tank
Non - Condensing Tankless
Condensing Tankless
Delay until hot water arrives at fixtures
Outer circle represents definitely would buy this product with decreasing desire to buy towards the center
+
-
Necessity to increase flow when low flow is desired
Steady temp for a single use
Continuous production of hot water w/out running out
Steady temp for multi simultaneous uses
Flow Rate reduction when using multi simult uses

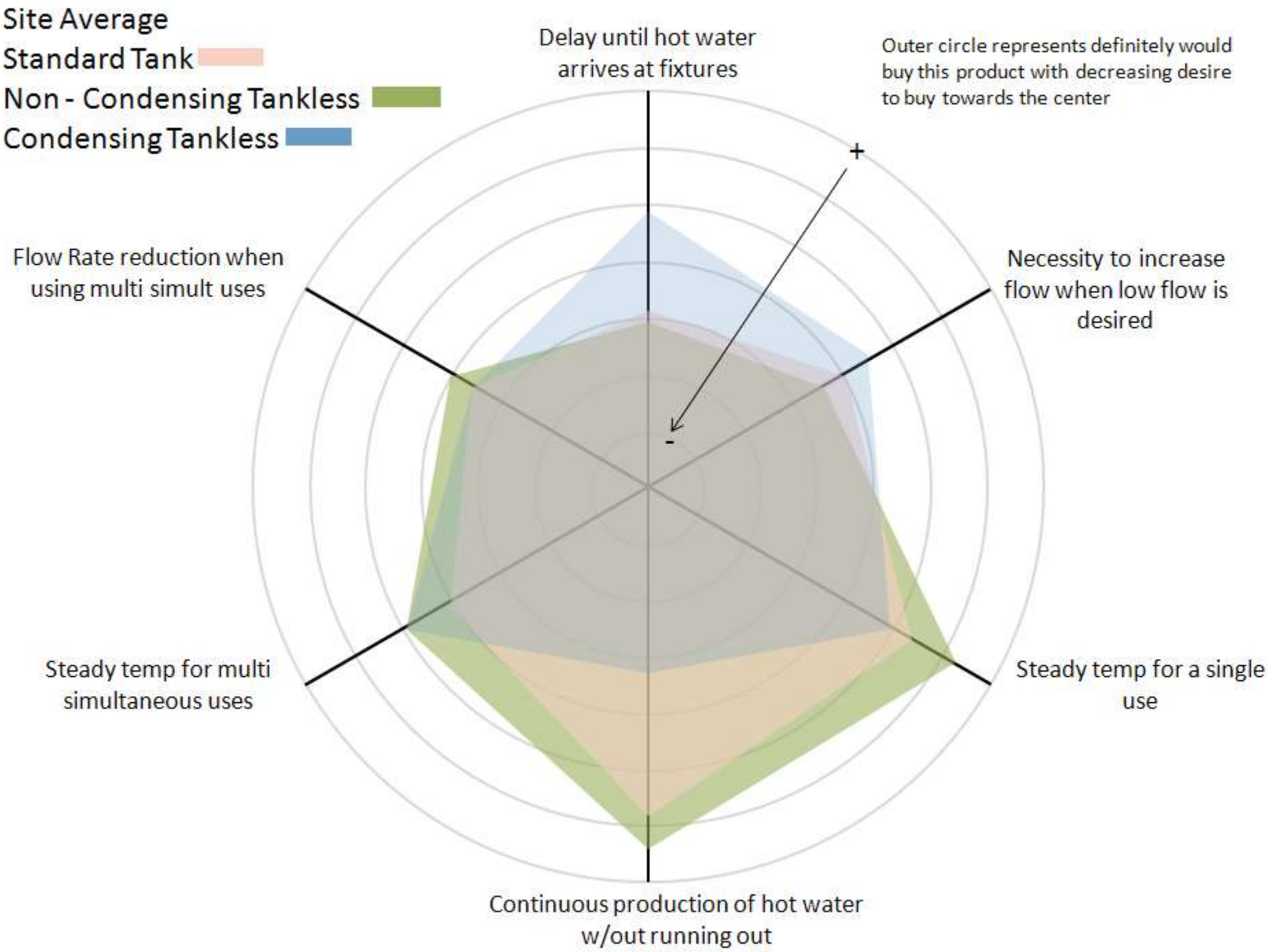
Delayed Delivery Time




Cold Sandwich for a TWH - Bosch 715
Flow Rate Hot [GPM]
End Use Temp [F]
Seconds
GPM_h 10
Bth1
0
1
2
3
4
5
6
7
8
60
70
80
90
100
110
120
130
140
0
100
200
300
400
500
600


Cold Sandwich in TWH Rinnai r75
End Use Temp [F]
GPM h
Axis Title
125
120
115
110
105
100
95
90
85
80
6
5
4
3
2
1
0
-1
0
10
20
30
40
50
60
70
80
90
100


Outlet Temperature Offset Quartiles for Diffrent WH Types
|Tout-Tset|
Seconds into Draw
0
10
20
30
40
50
60
NTWH2
StWH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Non - Condensing Tankless
Condensing Tankless
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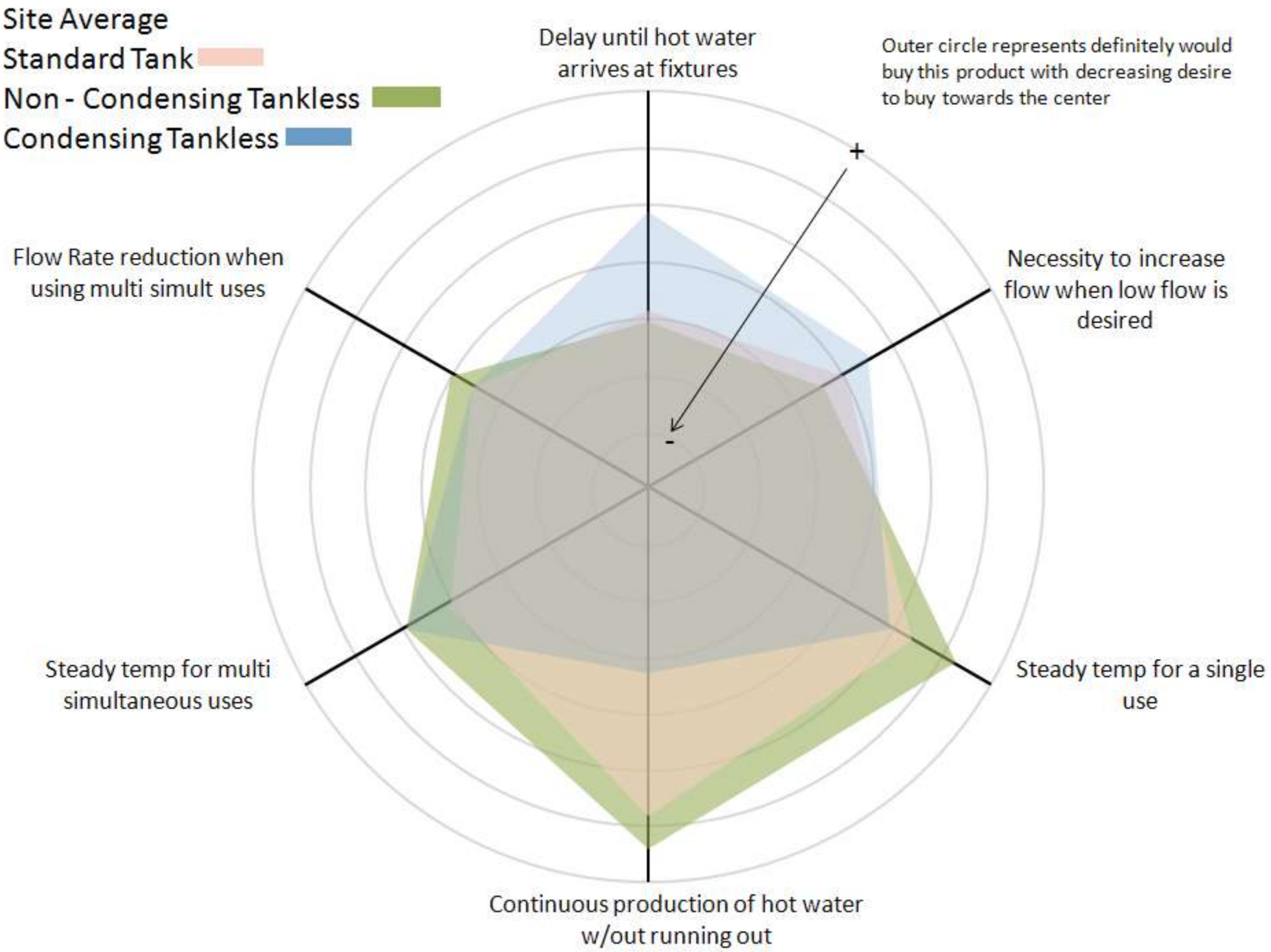
Continuous production of hot water w/out running out
Steady temp for multi simultaneous uses
Flow Rate reduction when using multi simult uses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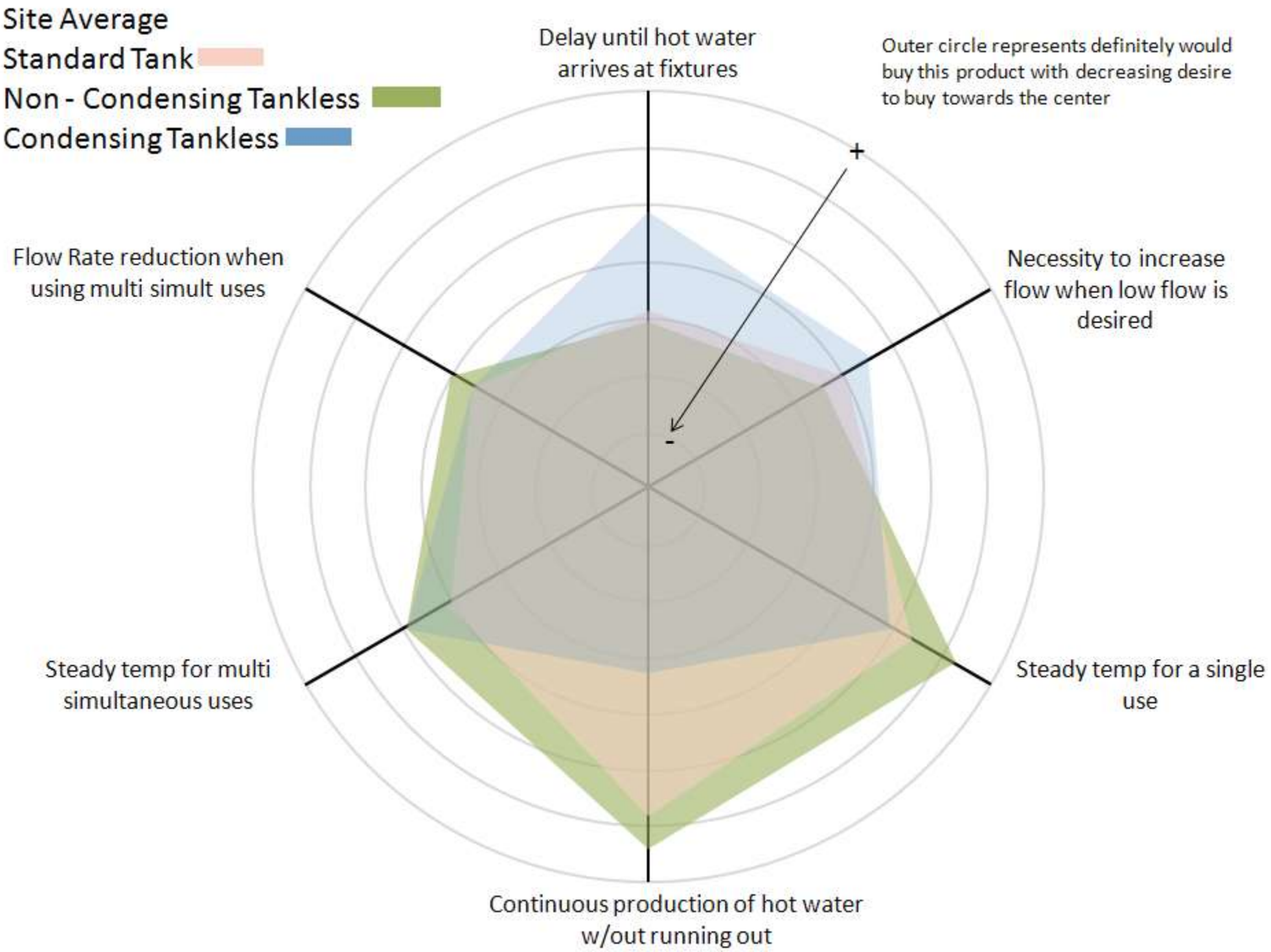
Min. Flow Rate for THWs to Start

+ Minimum flow rate to start is 0.4 GPM (Max. is 0.66 GPM)
+ 40% of THW require between 0.40 and 0.50 GPM
+ 60% of THW require between 0.60 and 0.64 GPM

		Input Rate	Min GPM (to start)		Max GPM	Max GPM	EF
Manuf.	Model	kBtu/hr	Spec Sheet	Lab	at ΔT 70F	at ΔT 35F	
Rinnai	RC98HPi	9.5-199	0.40		5.4	9.8	0.94
Takagi	T-K3	11-199	0.50		5.0	7.0	0.84
Rheem	RTG 66 DV	11-180	0.50	0.63	4.2	8.4	0.82
Noritz	N-0631S-DVMC	25-180	0.50		4.1	7.1	0.83
Navien	CR-210	17-175	0.50		5.1	9.8	0.95
Takagi	T-H2-DV	13-199	0.50		5.2	8.0	0.93
Noritz	N-0841-DVMC	11-199.9	0.50	0.49	5.3	10.2	0.91
Rinnai	R75Lsi	15-180	0.60		4.2	7.5	0.82
Rinnai	R94Lsi	15-199	0.60		4.8	9.4	0.82
Bradford White	TG-180I-N	15-180	0.60		3.8	7.5	0.82
Bradford White	TG-199I-N	15-199	0.60		4.7	9.4	0.82
GE	GN94DNSRSA	??-199	0.64		4.7	9.4	0.82
GE	GN75DNSRSA	??-180	0.64		3.8	7.5	0.82
Bosch	GWH-715 ES	19-199.9	0.65		4.7	9.2	0.81
Bosch	GWH-c800 ES	19.9-199	0.65		5.1	10.1	0.89
Noritz	N-0751-DVMC	12-199.9	0.66		4.8	9.8	0.82
Paloma	PH-28R DVSN	19-199.9	0.66		4.9	9.7	0.82
Navien	CR-240A	17-199	None		5.8	11.1	0.95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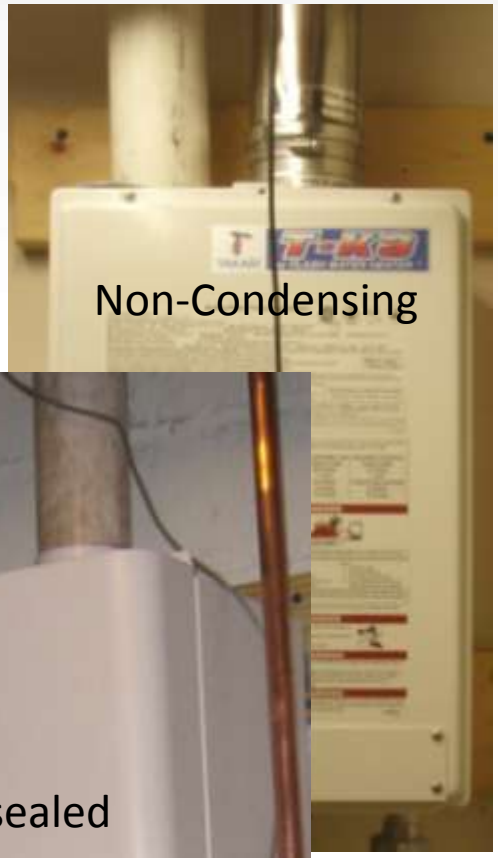
Gas Line Upgrades

+ 0 of 10 sites in our study required street side or meter upgrades

+ 4 of 10 sites required a increased size gas line from the water heater to the gas meter

Venting



Locating terminations

Vertical Exhaust

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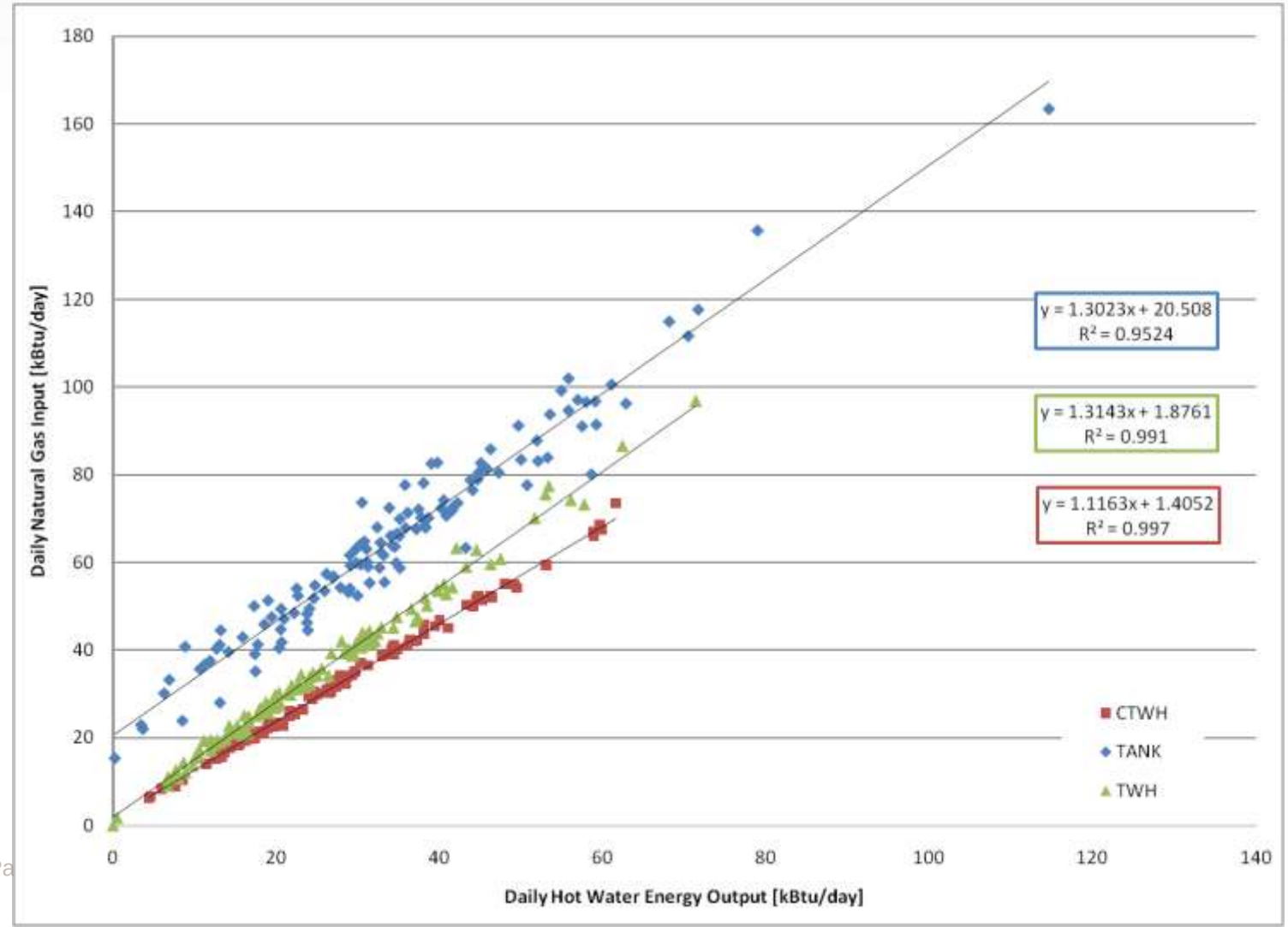
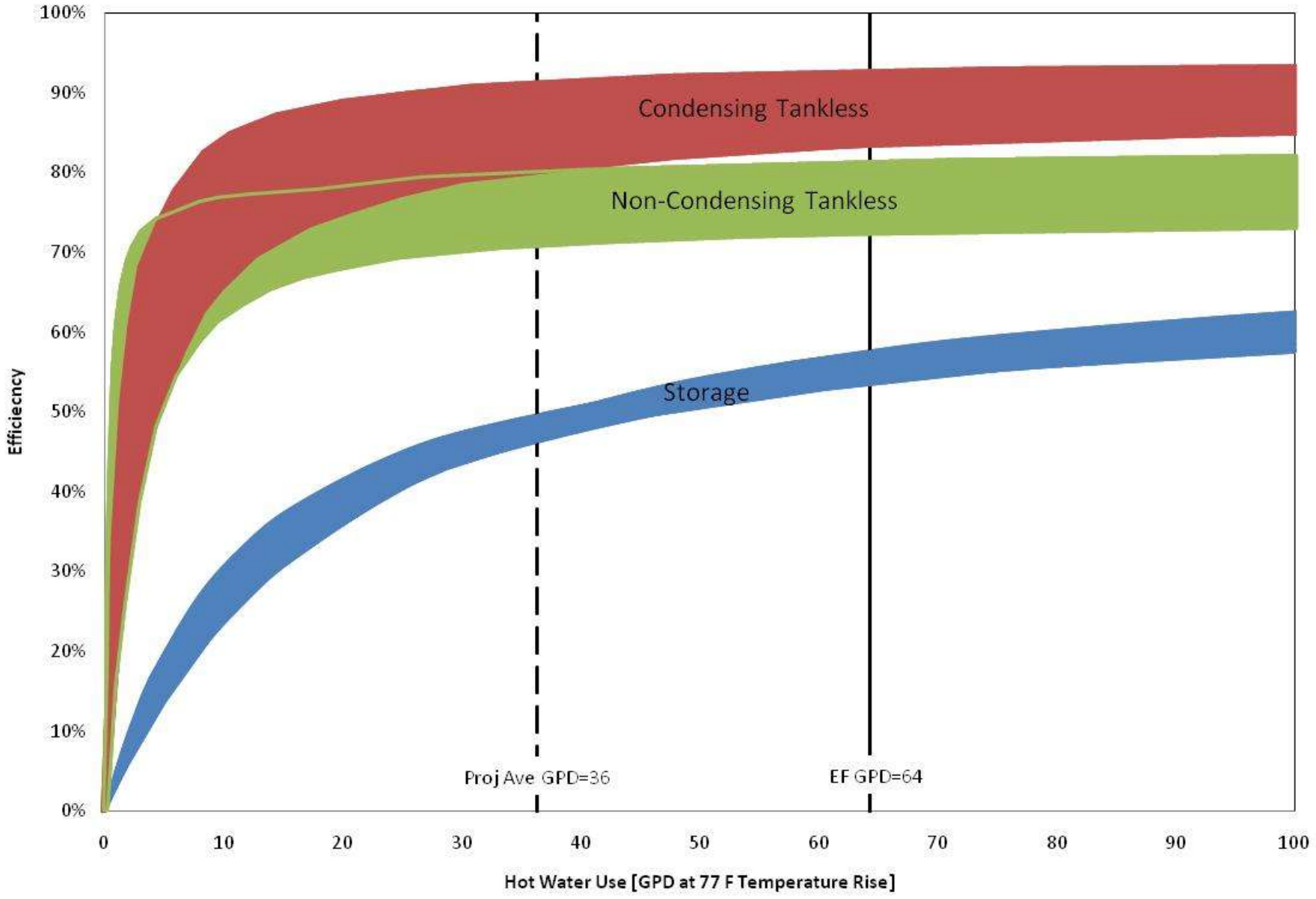
Efficiency, Energy Use, and Energy Costs

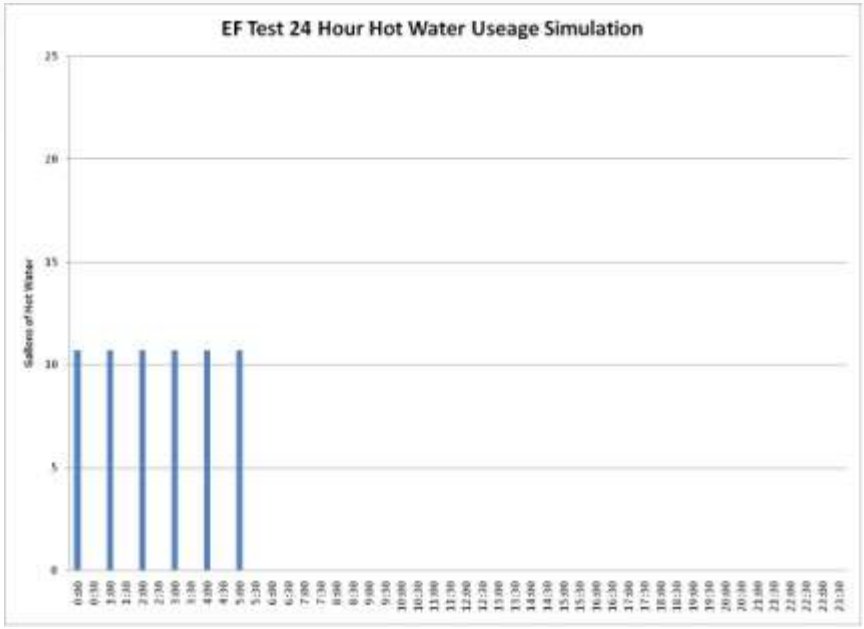
Input Output Curve For 3 WHs



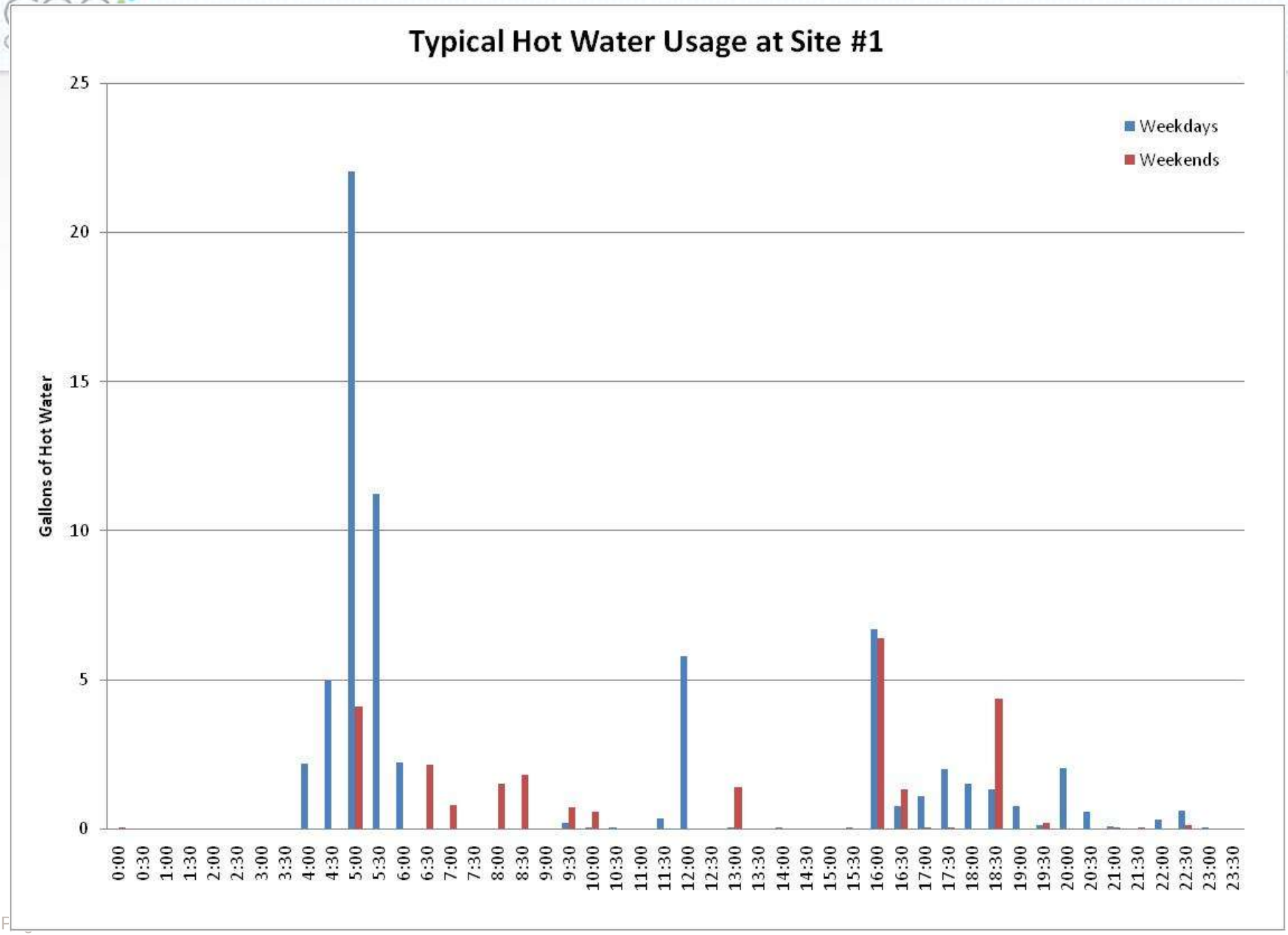

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Efficiecncy
Condensing Tankless
Non-Condensing Tankless
Storage
Proj Ave GPD=36
EF GPD=64
0
10
20
30
40
50
60
70
80
90
100
Hot Water Use [GPD at 77 F Temperature Rise]

DOE Energy Factor Rating

- 24 hour simulated use test
- EF rating is similar to an efficiency but not meant to represent actual performance
- Used to estimate annual energy use and compare different water heaters



- Simulated use profile does not represent actual house hold use
- Assumed daily hot water usage is higher than the amount measured in real homes
- Differences in EF profile and real work profile favors some water heaters


Typical Hot Water Usage at Site #1
Gallons of Hot Water
25
20
15
10
5
0
Weekdays
Weekends
0:00
0:30
1:00
1:30
2:00
2:30
3:00
3:30
4:00
4:30
5:00
5:30
6:00
6:30
7:00
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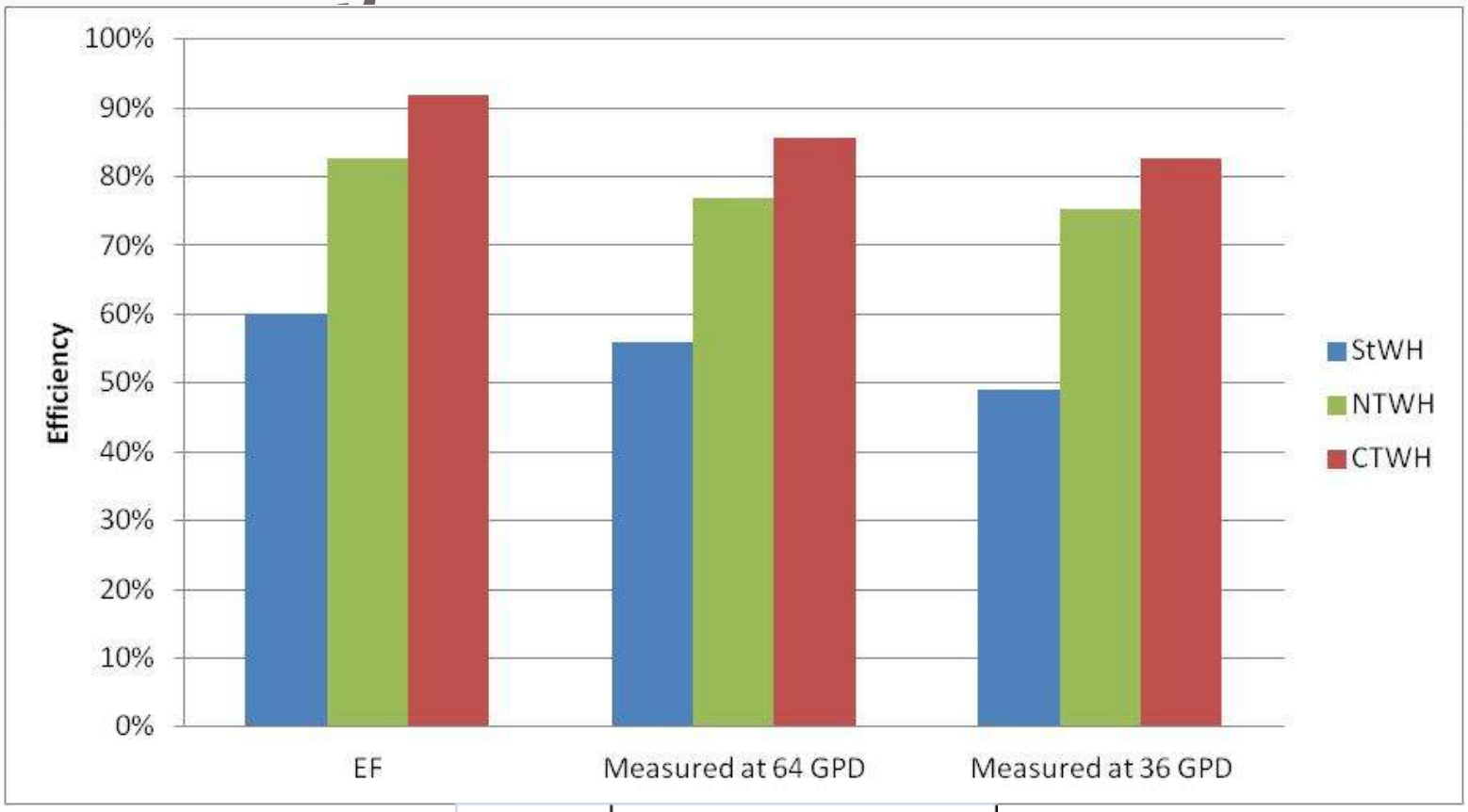
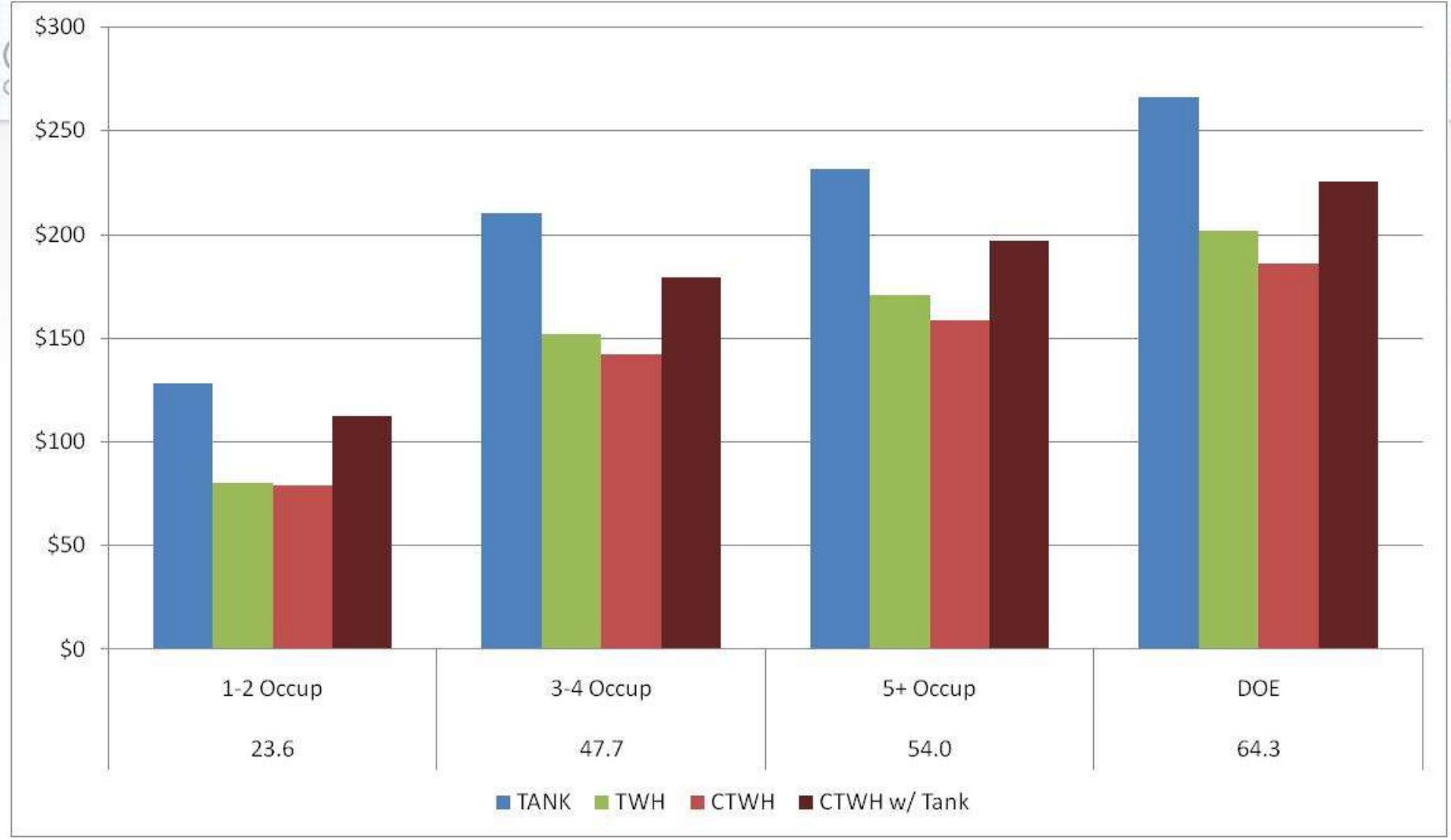
22:30
23:00
23:30

EF Rating vs Measures Efficiencies

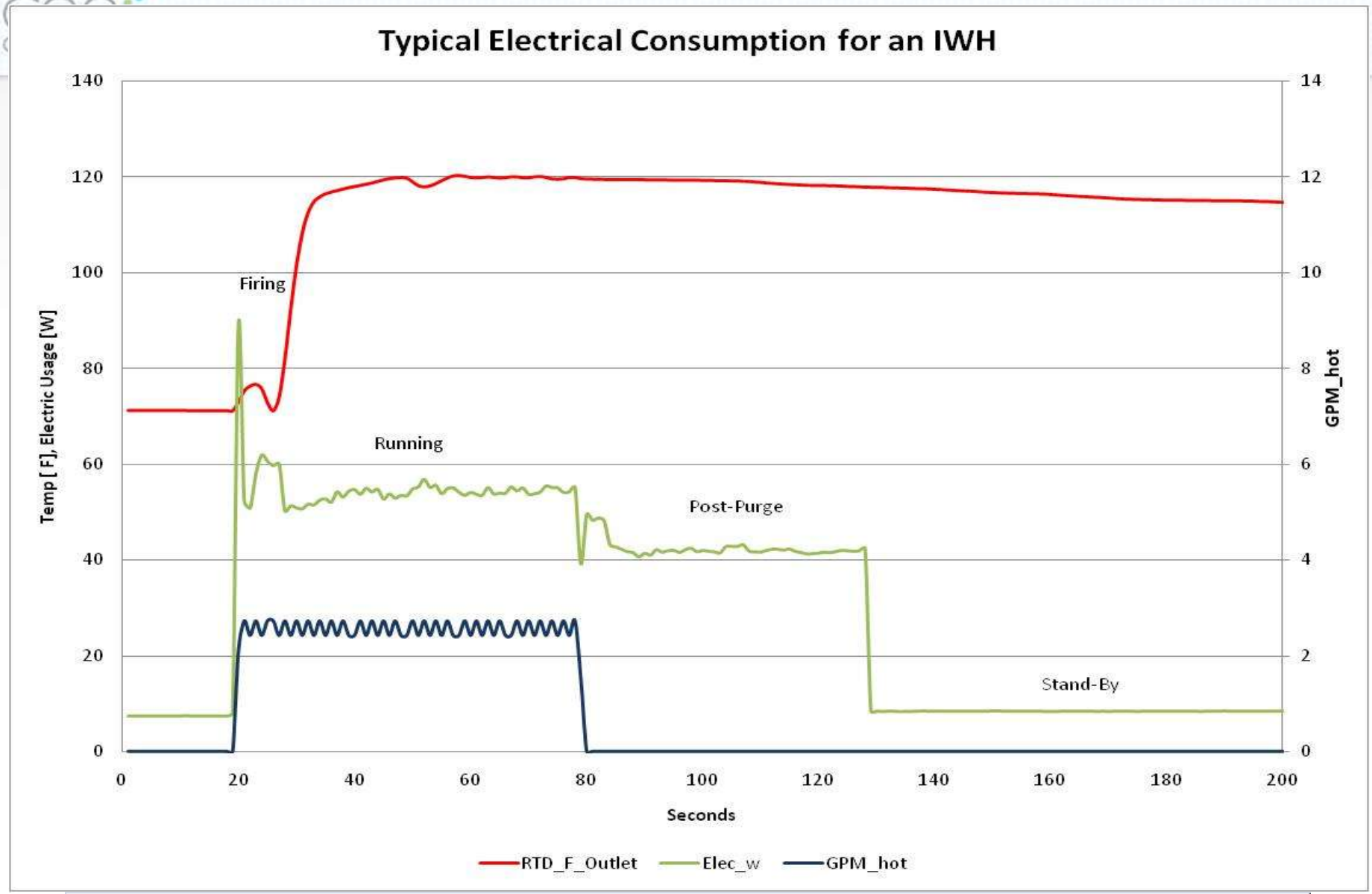


	Actual Measured Efficiency Reductions	
	at 64 GPD	at 36 GPD
STWH	0.04	0.11
NTWH	0.06	0.07
CTWH	0.06	0.09

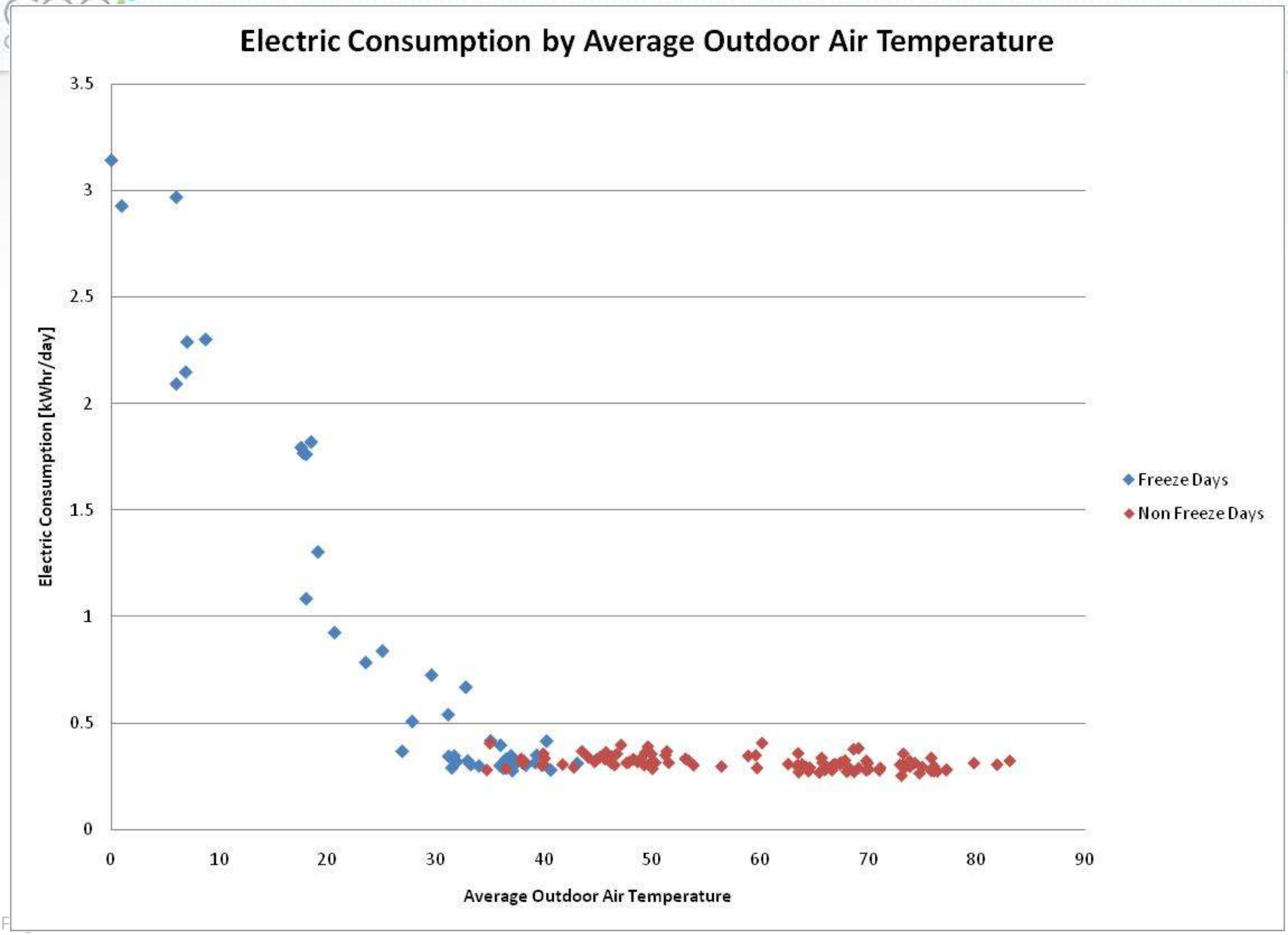


	NG therms/yr			
	1-2 ppl	3-4 ppl	5+ ppl	doe
TANK	128.30	210.2	231.4	266.5
TWH	73.17	144.6	163.1	193.8
CTWH	67.76	130.3	146.6	173.4
CTWH w/ T	98.83	163.9	180.8	208.6

	Savings over StWH					
	1-2 ppl		3-4 ppl		5+ ppl	
	$/yr	%	$/yr	%	$/yr	%
NTWH	$ 48	38%	$ 58	28%	$ 61	26%
CTWH	$ 49	38%	$ 68	32%	$ 73	31%
CTWH1	$ 16	12%	$ 31	15%	$ 35	15%



Range of Consumption [Watts]											
Standby			Firing			Running			Post Purge [Whrs]		
Min	Typical	Max	Min	Typical	Max	Min	Typical	Max	Min	Typical	Max
4	8	11	35	70	110	30	50	80	0.1	0.5	4.8


Electric Consumption by Average Outdoor Air Temperature
Electric Consumption [kWhr/day]
3.5
3
2.5
2
1.5
1
0.5
0
0
10
20
30
40
50
60
70
80
90
Average Outdoor Air Temperature
Freeze Days
Non Freeze Days

Estimated Electrical Consumption for each Tankless Water Heater

	Electric Consumption				
	HW + Standby		Freeze Protect		Total
	kWhr/day	kWhr/yr	kWhr/day	kWhr/yr	kWhr/yr
Rheem RTG 66DV	0.10	38	0.05	3	41
Rinnai R75Lsi	0.10	37	0.27	23	61
Bosch GWH-715ES	0.20	72			72
Takagi TK-1	0.21	78			78
Nortiz N-0751-MCDV*	0.35	126	0.38	4	130
Navien CR210	0.13	46			46
Navien CR240A	0.30	111			111
Bosch GWH-c800ES	0.41	148			148
Noritz N-0814-DVMC*	0.30	111	1.37	140	251
	*Only one of two sites had freeze protection				

Estimated Simple Payback

+ TWH+CTHW installed costs: $2500-$5000
+ TANK Installed costs: $1000
+ Average Savings from TWH + CTWH

	1-2 Occup	3-4 Occup	5+ Occup	DOE
	24 GPD	48 GPB	54 GPD	64 GPD
CTWH Savings, $/yr	$ 49	$ 68	$ 73	$ 80
Payback , yrs	30 to 80	22 to 59	21 to 55	19 to 50
TWH Savings, $/yr	$ 48	$ 58	$ 61	$ 65
Payback , yrs	31 to 82	26 to 69	25 to 66	23 to 62

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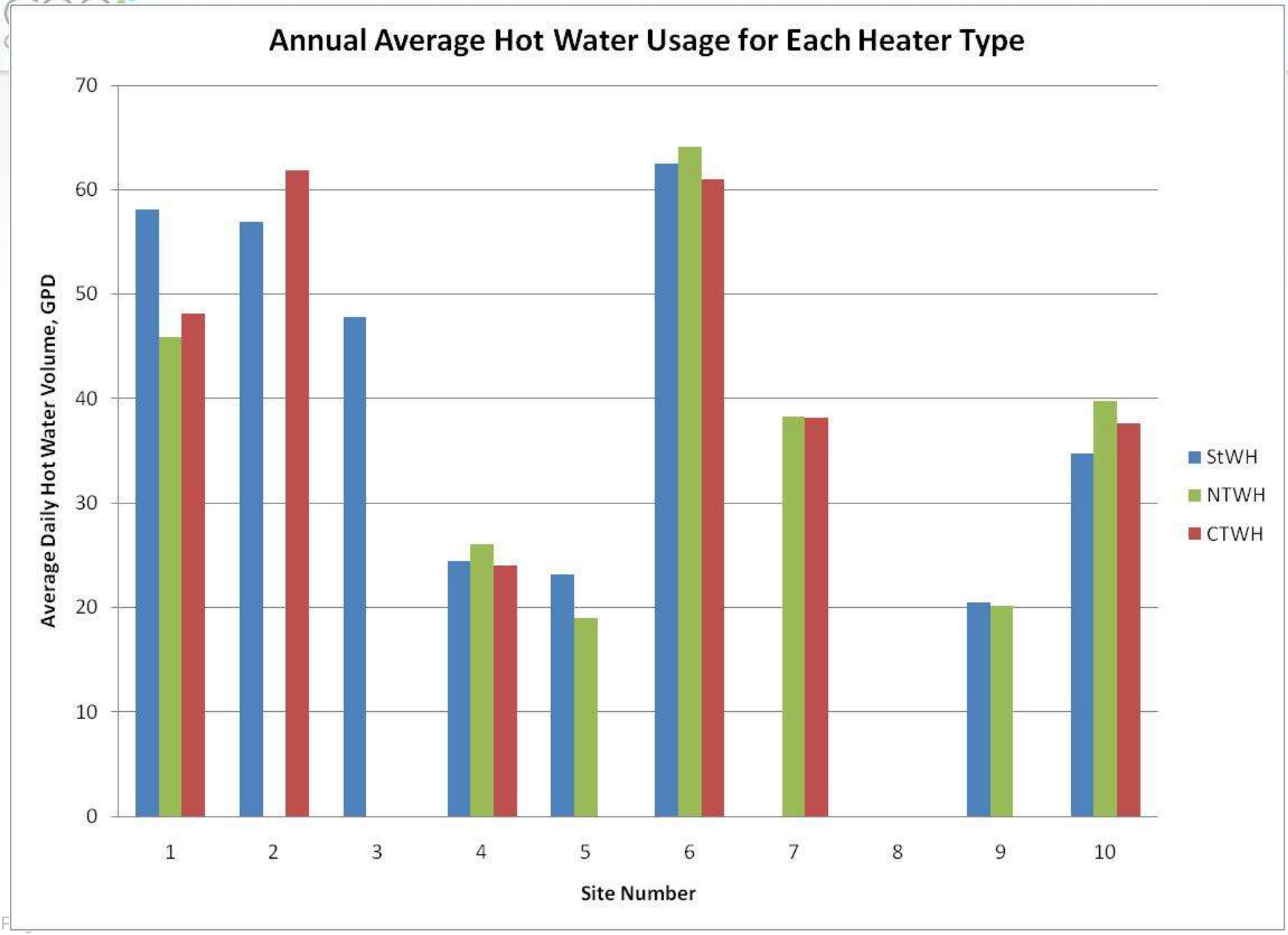
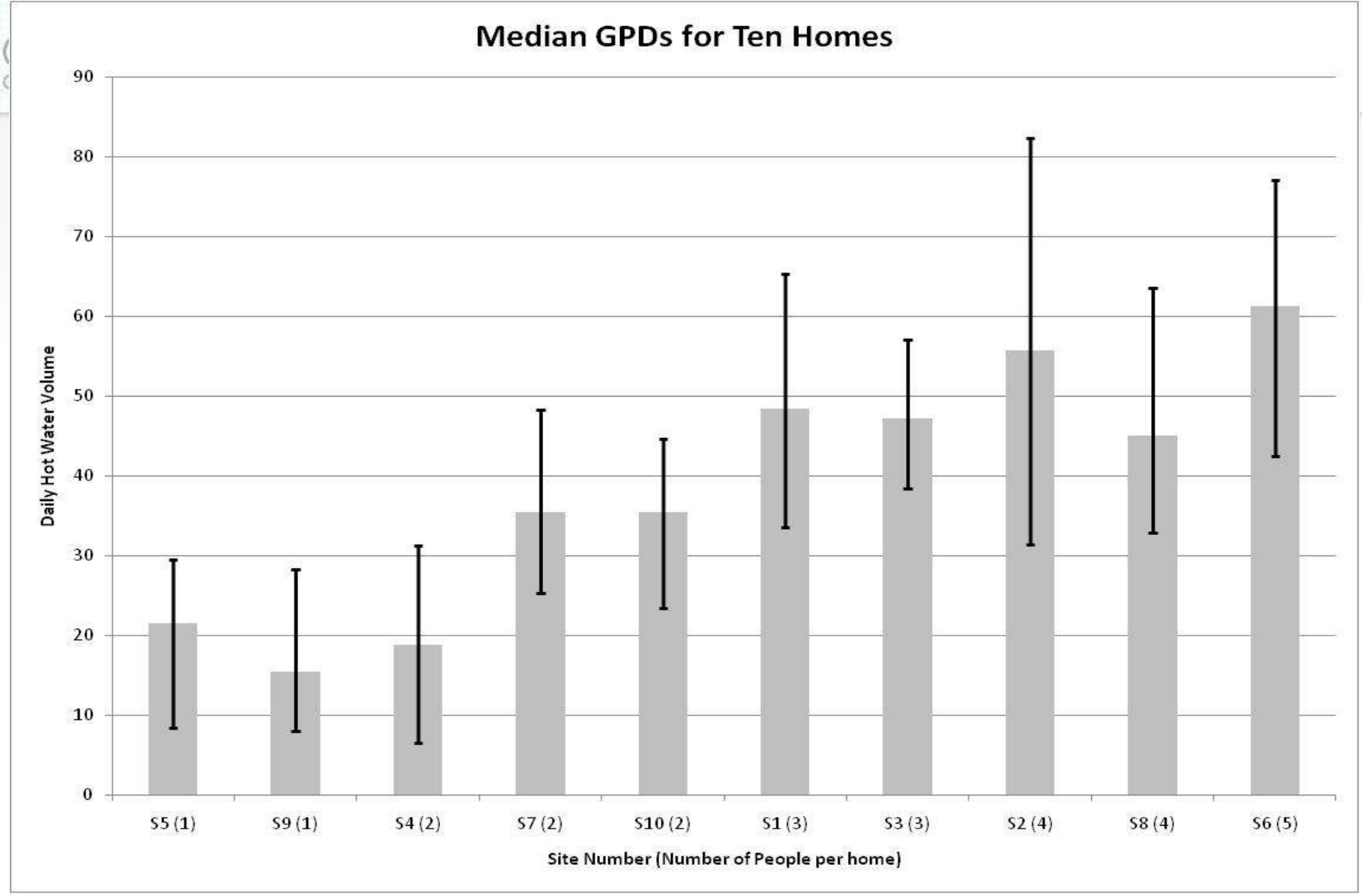
Hot Water Use

Difference In Hot Water Use

+ 0 of 10 sites in our study – no significant difference in water use between tank and tankless heaters

+ 1 of 10 sites – slight increase in hot water energy demand

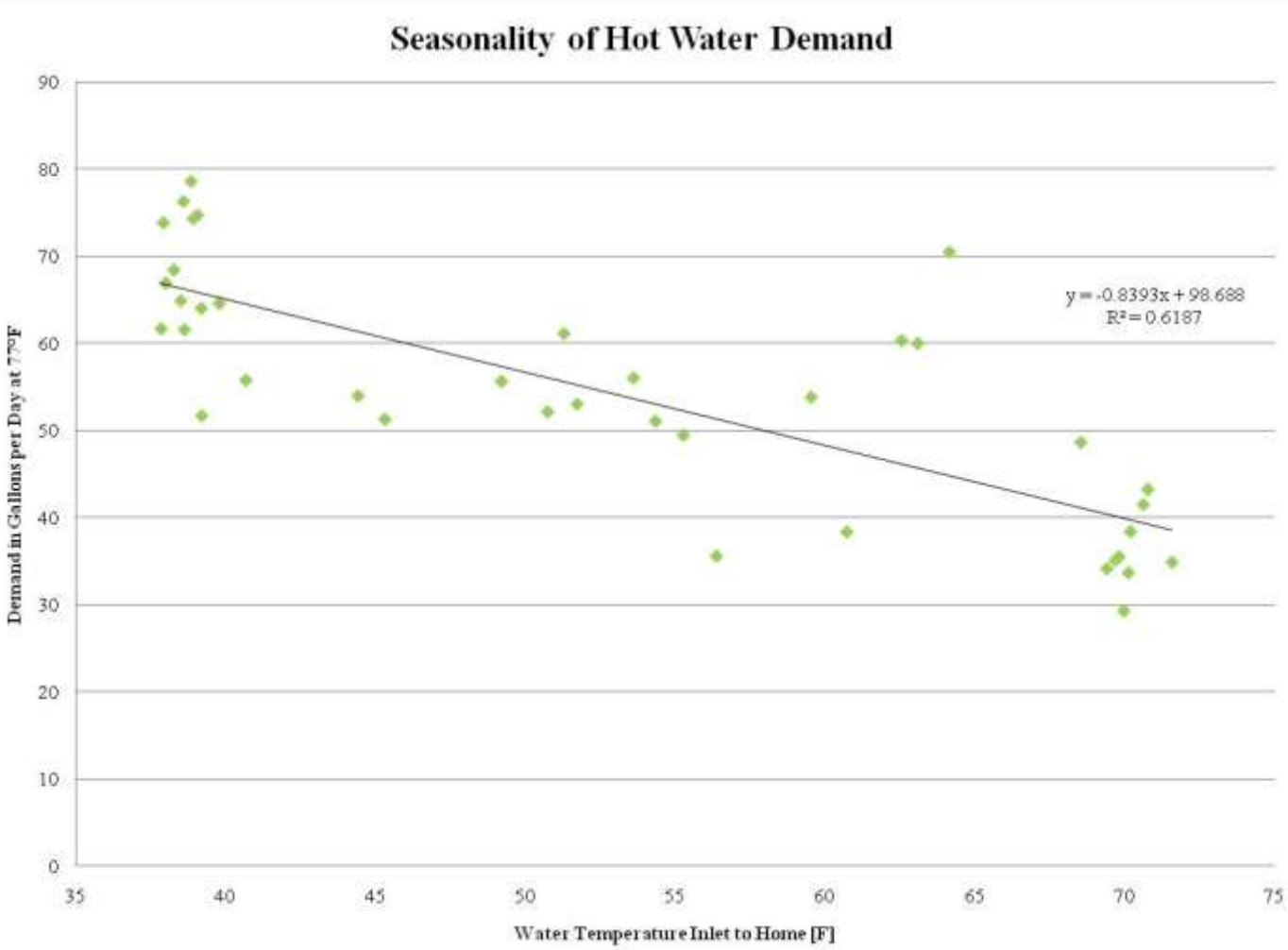

Annual Average Hot Water Usage for Each Heater Type
Average Daily Hot Water Volume, GPD
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
Site Number
StWH
NTWH
CTWH

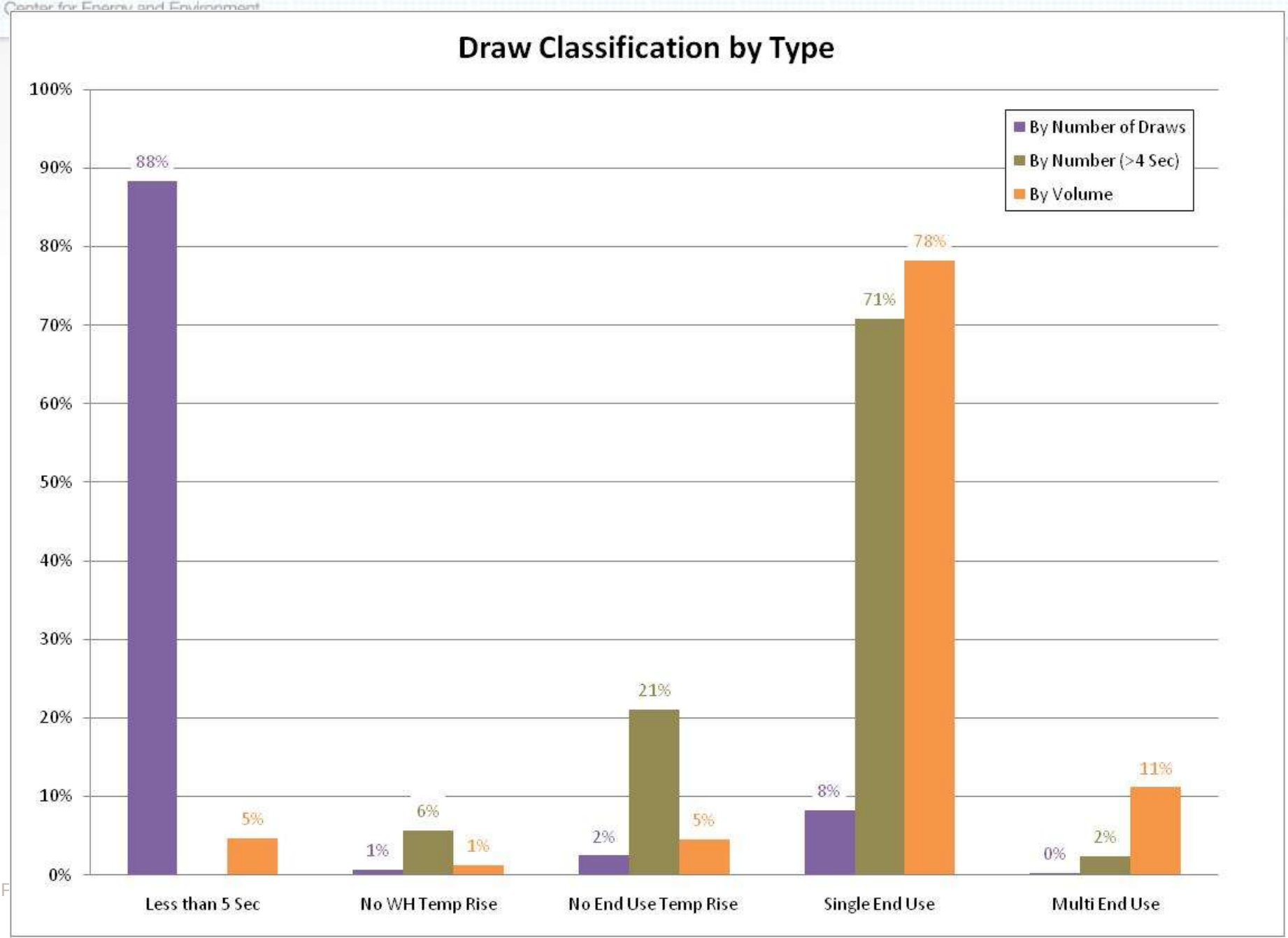


Project Average
36 GPD
26 DpD

	Hot Water Gallons per Day										
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Ave
Average	37.8	34.9	22.6	20.4	11.6	29.3	19.6	32.7	16.0	18.6	24.4
Standar	31.0	59.2	48.7	22.3	20.4	58.8	37.3	29.2	19.6	35.9	36.2
CV	82%	59%	46%	91%	57%	50%	53%	89%	82%	52%	66%

Seasonality of Water Heating Demand

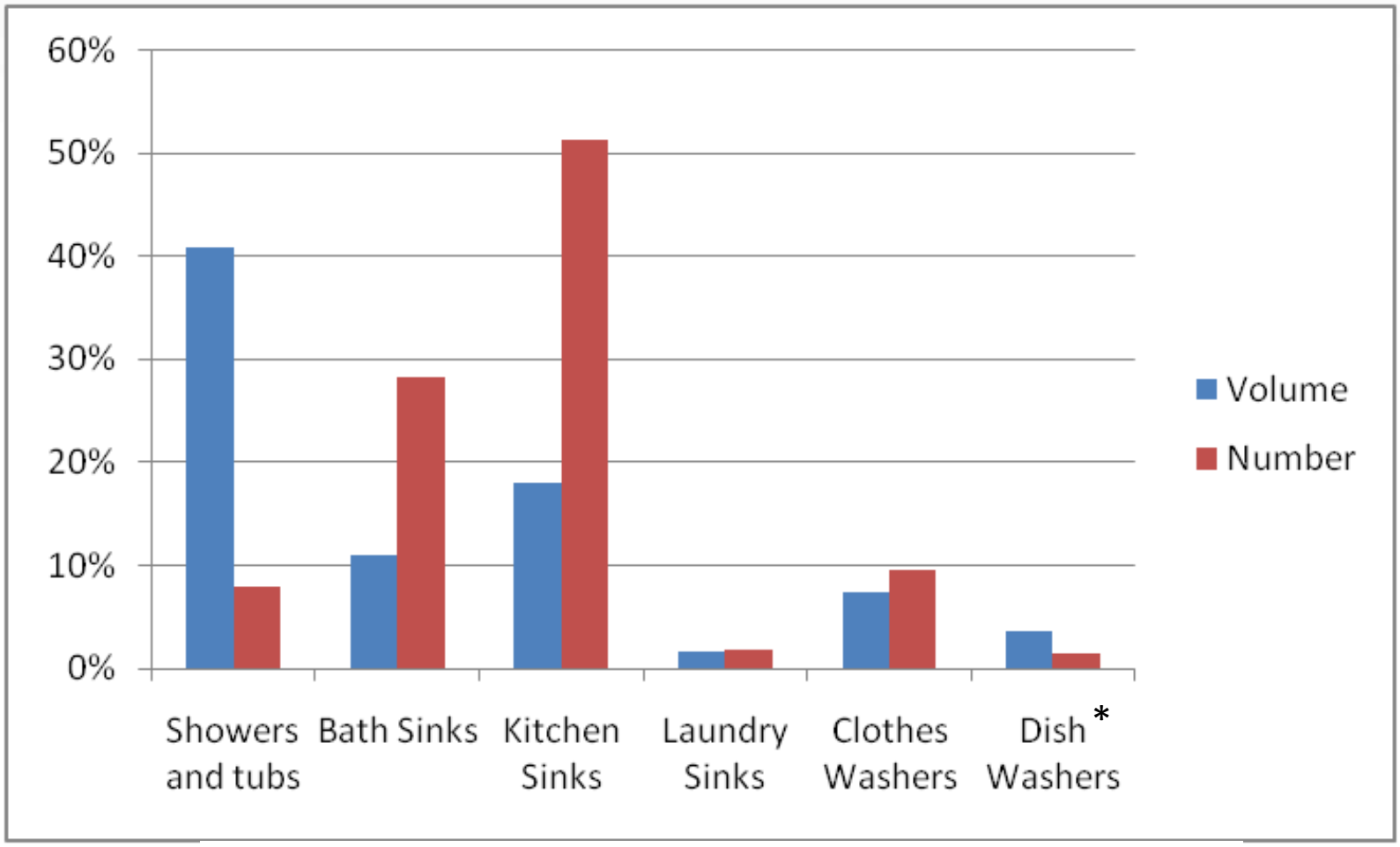



Draw Classification by Type
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
By Number of Draws
By Number (>4 Sec)
By Volume
88%
5%
1%
6%
1%
2%
21%
5%
8%
71%
78%
0%
2%
11%
Less than 5 Sec
No WH Temp Rise
No End Use Temp Rise
Single End Use
Multi End Use

Draw Categories

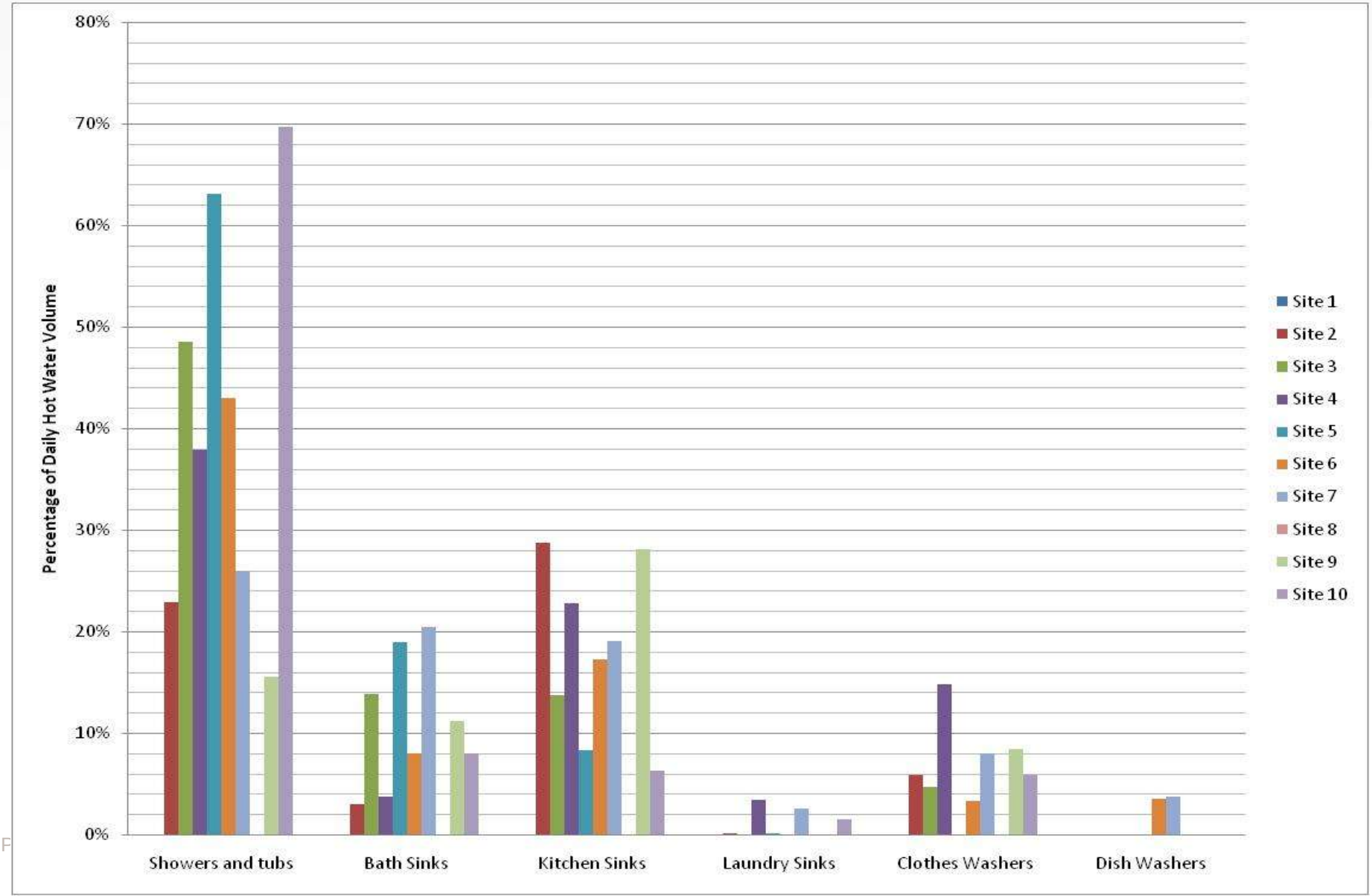
- Less than 5 seconds (LT5) – All draws that are less than 5 seconds
  - Large number, small volume, small energy
  - Some of these draws are not necessarily actual hot water events, just water/pressure shifts in the plumbing system
- No temp rise at water heater outlet (No_WH_Rise)
  - Much more common with TWH and StWH type
- No temp rise at end use (No_End_Rise)
  - Water heater outlet was hot but fixture never received hot water
- Single end use draw (Single_End)
  - One fixture got hot water
- Multiple end use draw (Multi_End)
  - Two or more fixtures had hot water

Single End Use Draws by Fixture



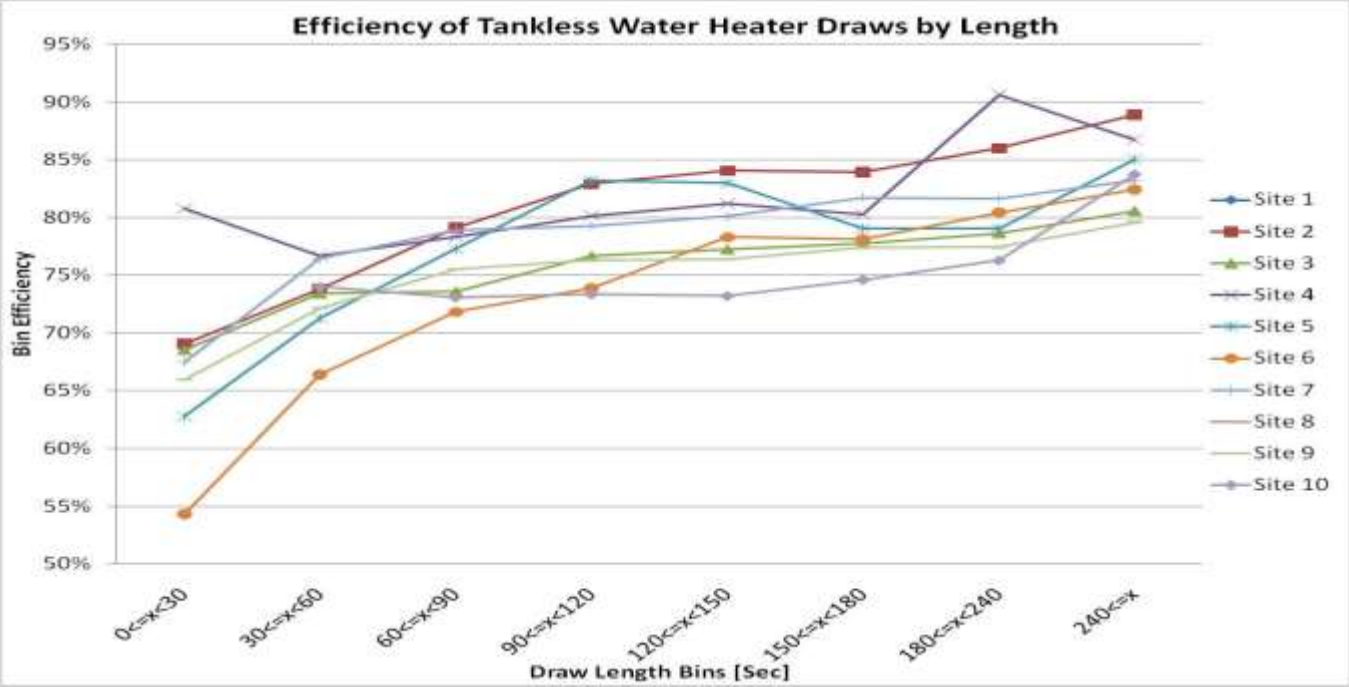
*Only averaged over the 4 sites that had dishwashers

Percentage of Total Daily Volume for Single End Use Fixtures



Energy Consumption by Draw Type

Comparision of Energy Consumption, Demand and Volume by Draw Type						
	% of total Energy Input		% of total Energy Outpu		% of total Volume	
	StWH	TWH	StWH	TWH	StWH	TWH
Lt5 draws	6%	1%	5%	1%	7%	3%
No Rise Draws - No_WH_Rise, No_End_Rise	6%	6%	5%	5%	6%	7%
End Use Draws - Single_End, Multi_End	89%	93%	89%	94%	87%	89%



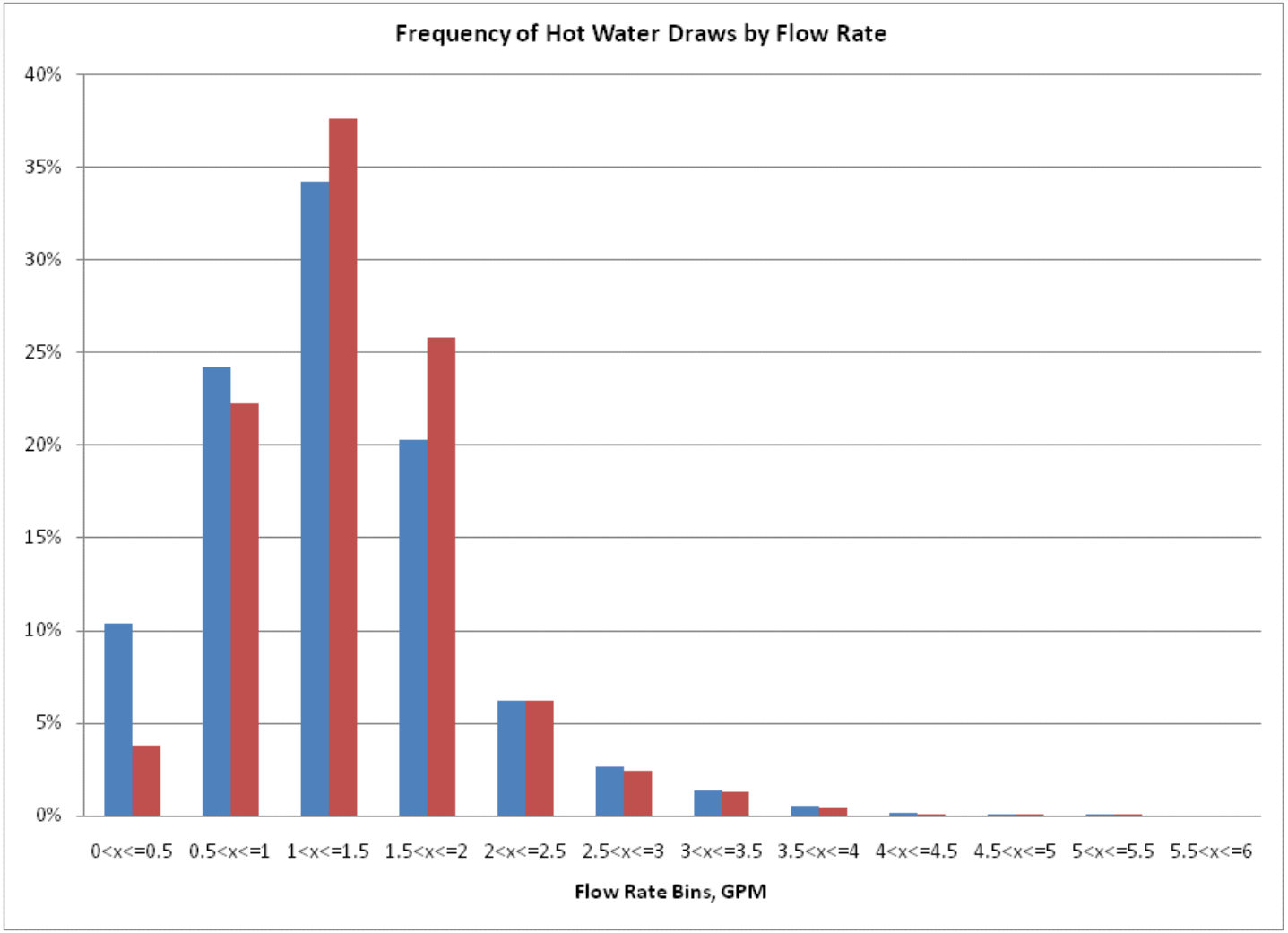
Average Draw Characteristics

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10
Draws per day (no LT5)		47.8	34.6	8.5	16.2	27.7	36.8		19.6	16.5
Volume, gal		0.4	1.4	2.6	1.2	1.9	1.0		0.9	2.1
Length, Sec		13.4	59.2	98.6	49.0	81.8	40.4		38.6	103.9
Flowrate, GPM		0.8	1.3	1.8	1.2	1.2	1.2		1.2	1.2
Idle periods greater than 17 hrs		0.1%	0.0%	0.0%	0.2%	0.1%	0.1%		0.4%	0.4%

	Ave	EF
Draws per day (no LT5)	26.0	6
Volume, gal	1.4	10.7
Length, Sec	60.6	214.3
Flowrate, GPM	1.2	3
Idle periods greater than 17 hrs	0.2%	17%

See full report for this project to see how this difference effects WH ratings.

Typical hot water flow rates



Summary

+ Low flow (1 gpm) response time vary by model and is a drawback for tankless.

+ Tankless “endless” water draw is a positive and they operate at setpoint more consistently.

+ Tankless need to increase flow slight drawback

Summary - continued

+ Actual efficiency typically 3 – 5% lower than rated for all heaters
+ Efficiency varies by water demand. Savings are fairly consistent
+ Electric use varies (37 – 148 kWhr/yr) is not insignificant – freeze protection high for some
+ No observed difference in water use

Questions?

Full report:
http://mncee.org/Innovation-Exchange/Reports-and-Technical-Documents/Actual-Savings-and-Performance-of-Natural-Gas-Tank/
Or
goo.gl/TuFsJ

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