



Energy-Efficiency Options for Residential Water Heating

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Duluth Energy Design Conference
February, 2015

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- Energy Program Design and Delivery
- Engineering Services
- Innovation Exchange
 - Research
 - Education and Outreach
- Sound Insulation Program
- Public Policy
- Lending Center



Acknowledgements

This project was supported in part by a grant from the Minnesota Department of Commerce, Division of Energy Resources through a Conservation Applied Research and Development (CARD) program



Sponsors and Partners

- NorthernSTAR - A DOE Building America Research Team
- Sustainable Energy Resources for Consumers Grants



- Center for Energy and Environment
- Sustainable Resources Center
- University of Minnesota
- The Energy Conservatory

Building America Solutions Center

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Agenda

- Natural Gas Water Heating
- Electric Water Heating
- New Developments in Water Heating



Water Heating Technologies

- Natural Gas
 - Storage Water Heaters
 - Tankless Water Heaters
 - Hybrid Water Heaters
- Electric
 - Storage Water Heaters
 - Tankless Water Heaters
 - Heat Pump Water Heaters
 - ETS Water Heaters

Gas Water Heating



Storage Water Heaters

- Water stored at temperature
- When tank temp drops below certain temp burner fires
- Typically volumes greater than 30 gallons and burners around 40,000 btu/hr for whole house

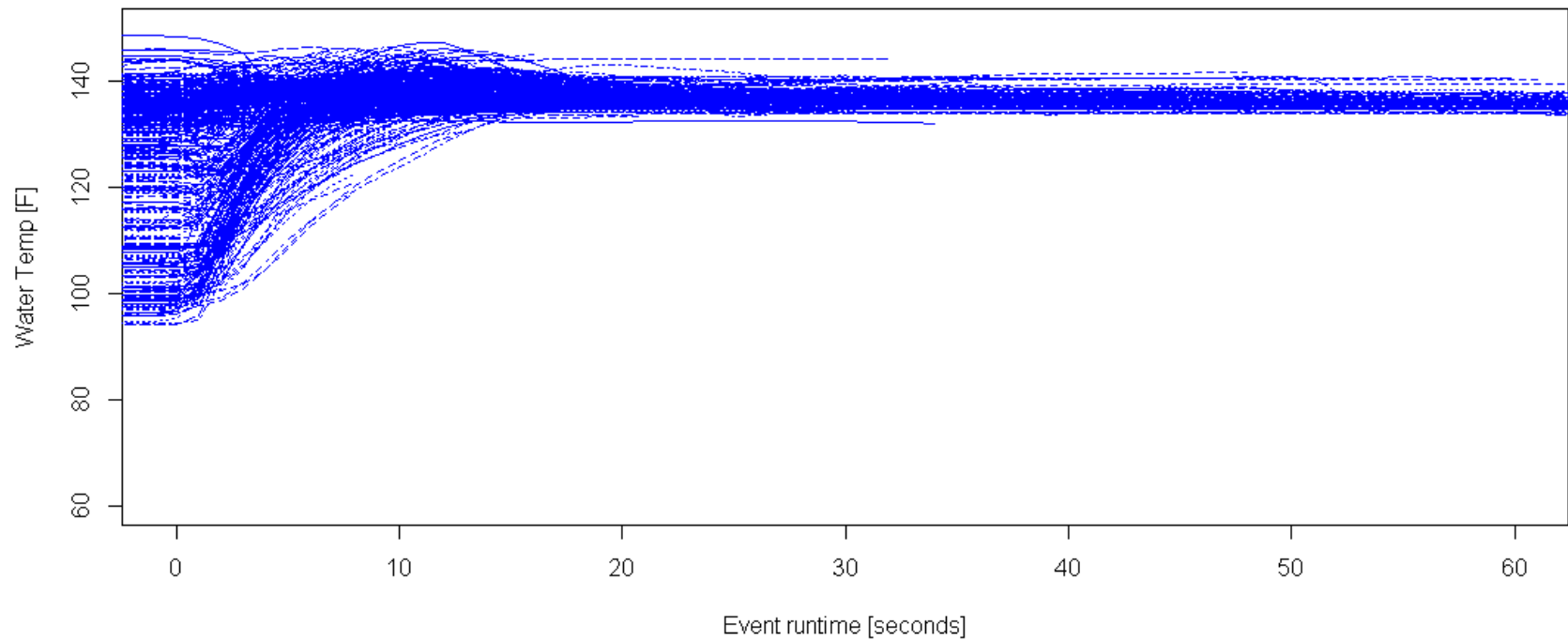


Storage Water Heaters

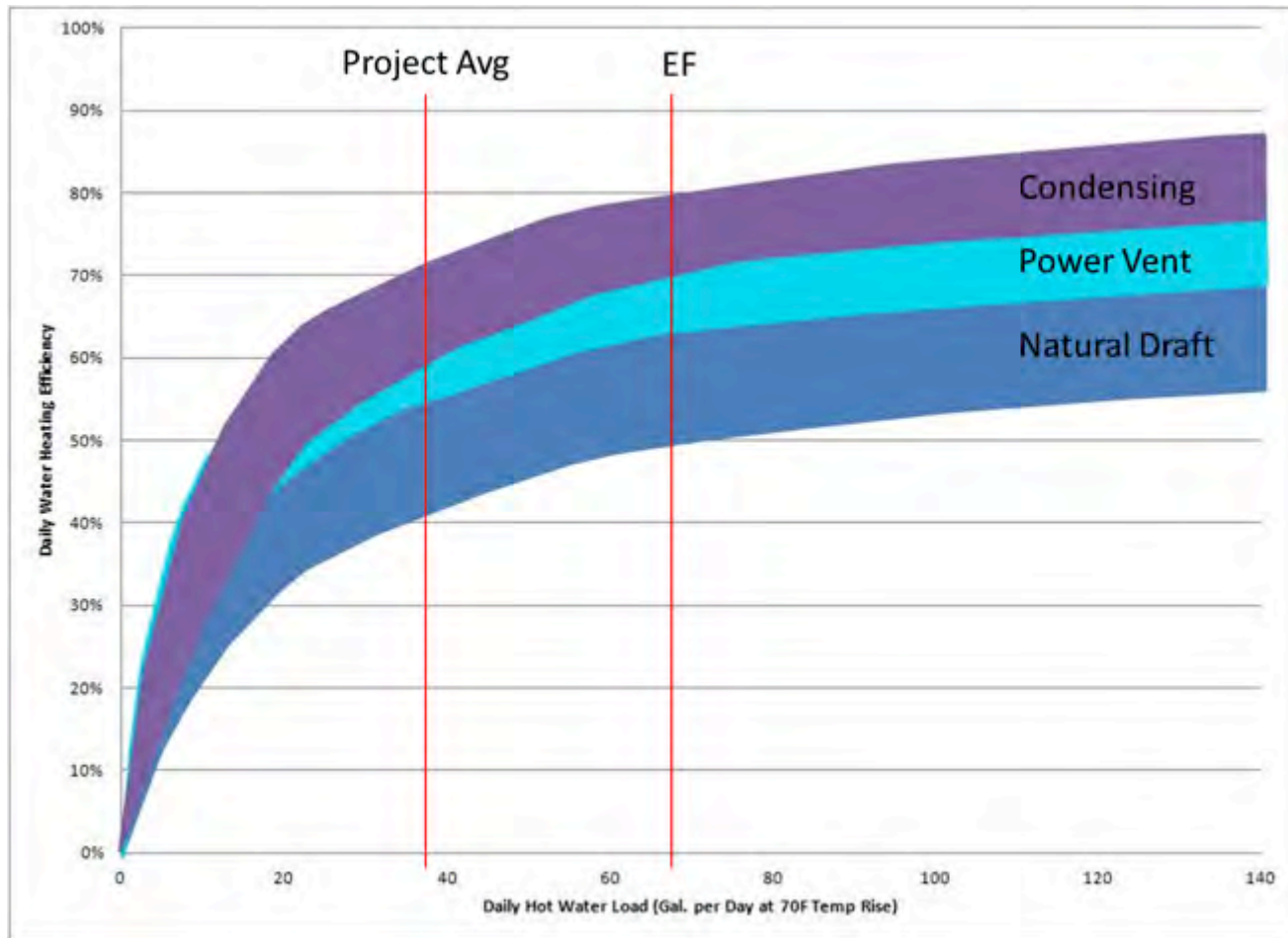
- Types:
 - Natural Draft
 - Power Vent
 - Condensing
- Operation:
 - Quick response
 - Higher stand-by loses
 - Potential to run out of hot



Hot Water Delivery



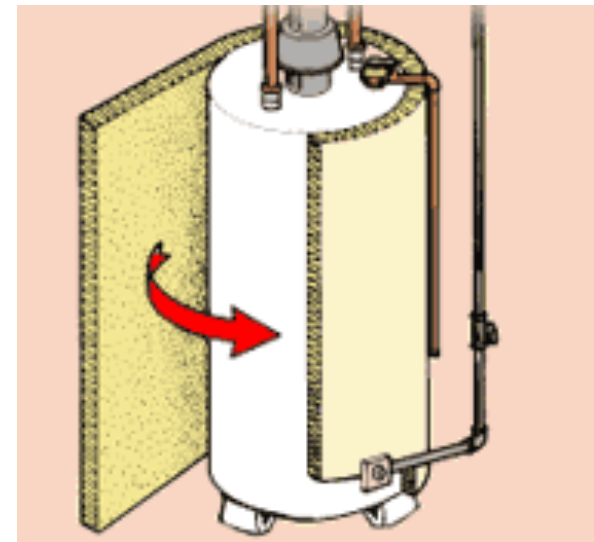
Efficiency



Improving Efficiency

Reducing stand-by loses with an insulation blanket

Temperature Setpoint (F)	Annual Savings		Payback (years)
	(therms)	(%)	
120	5.5	3%	4.8
130	11.4	6%	2.3
140	14.6	7%	1.8



Assumes \$20 cost and \$0.75/therm

Improving Efficiency

Reducing stand-by loses by reducing temperature

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

- Set Temperature Impacts
 - Delivered water temperature
 - Risk of scalding
 - Risk of legionella

Gas Tankless Water Heaters

- Types
 - Condensing
 - Non-condensing
- Operation
 - No storage, water is heated as needed
 - Eliminate stand-by loses
 - 80%-95% EF



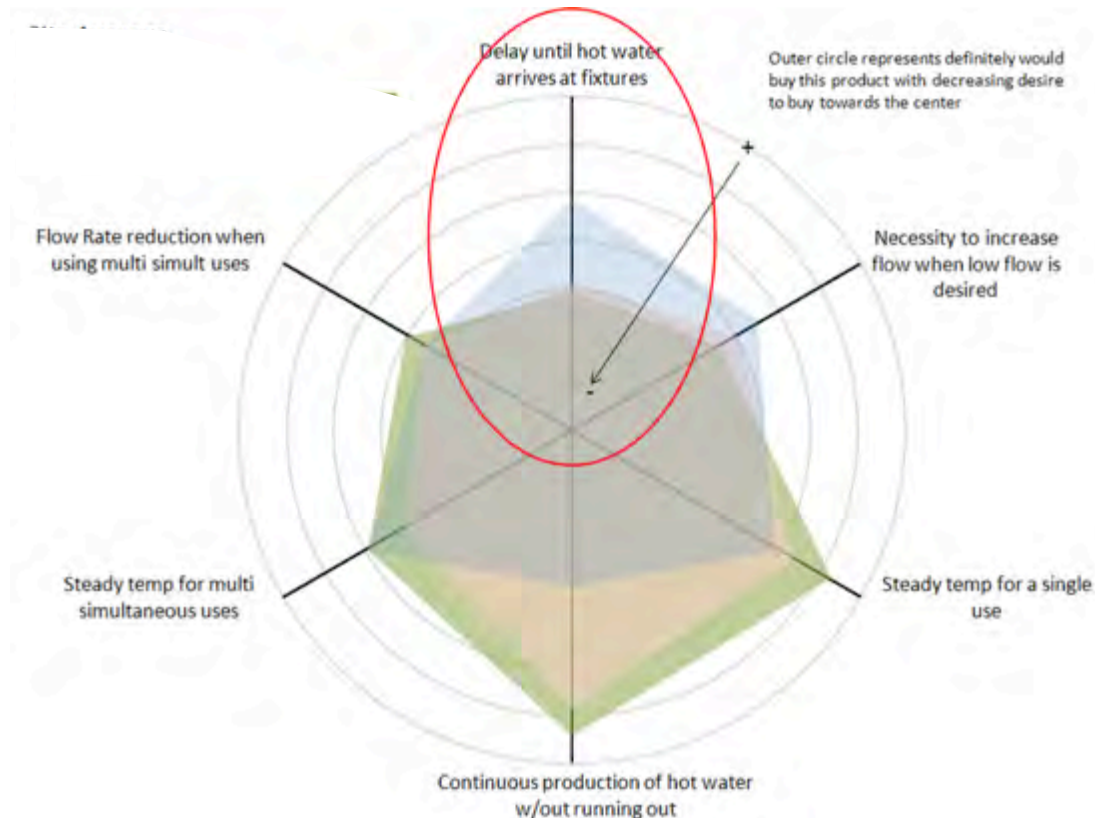


Issues Facing Tankless Water Heaters

- 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

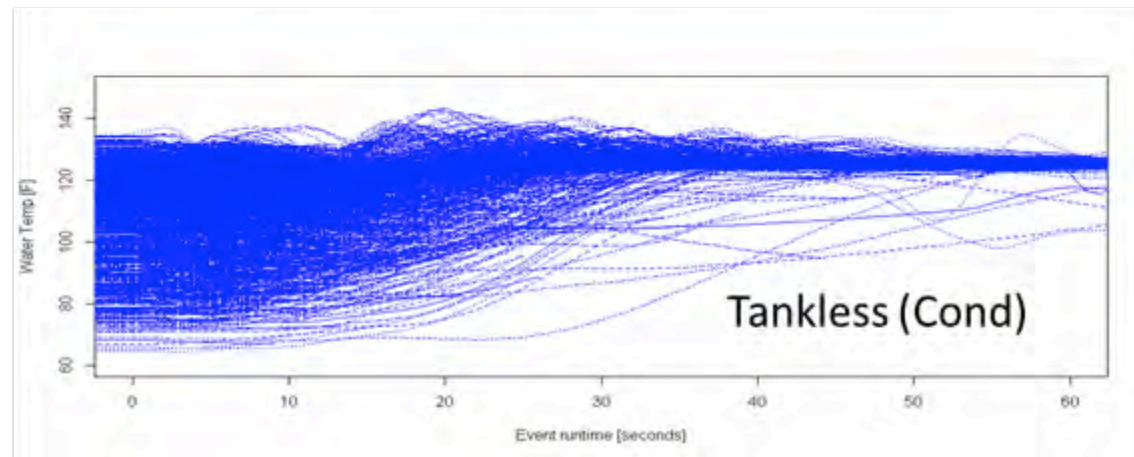
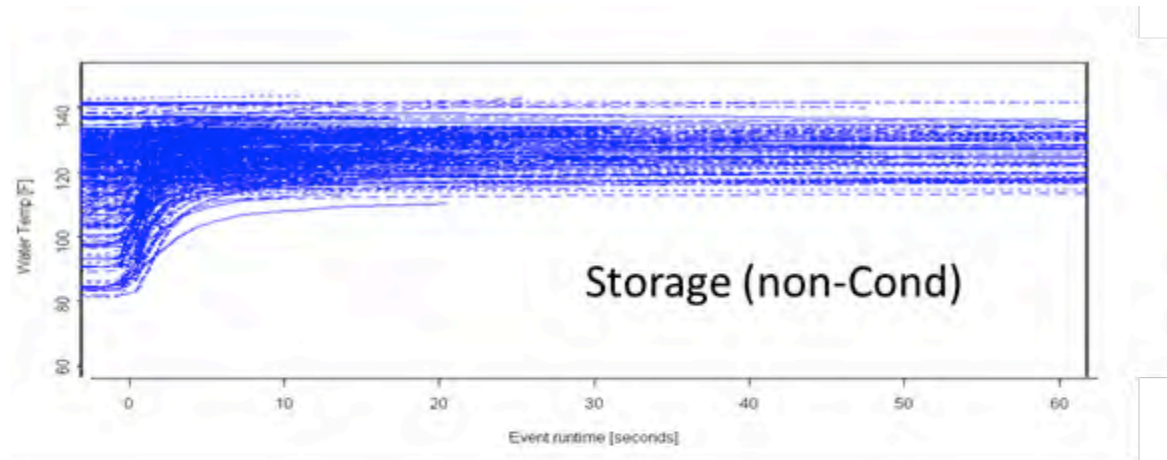
Home Owner Survey – hot water delay

	Storage Heater			Tankless Heater		
	Unfavorable	No Effect	Favorable	Unfavorable	No Effect	Favorable
Delay Time Until Hot Water Arrives	22%	11%	67%	72%	17%	11%

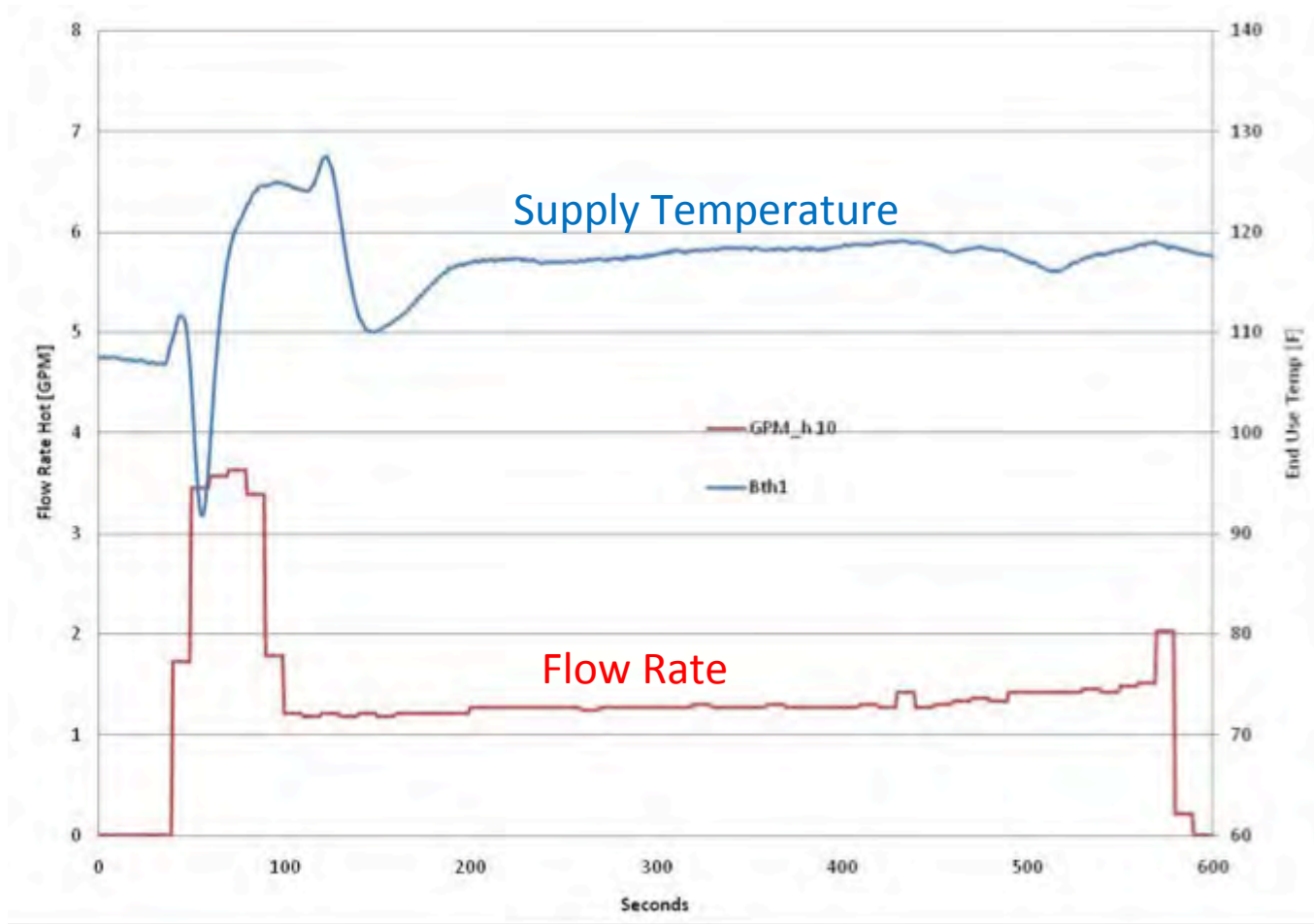


Blue = storage heater

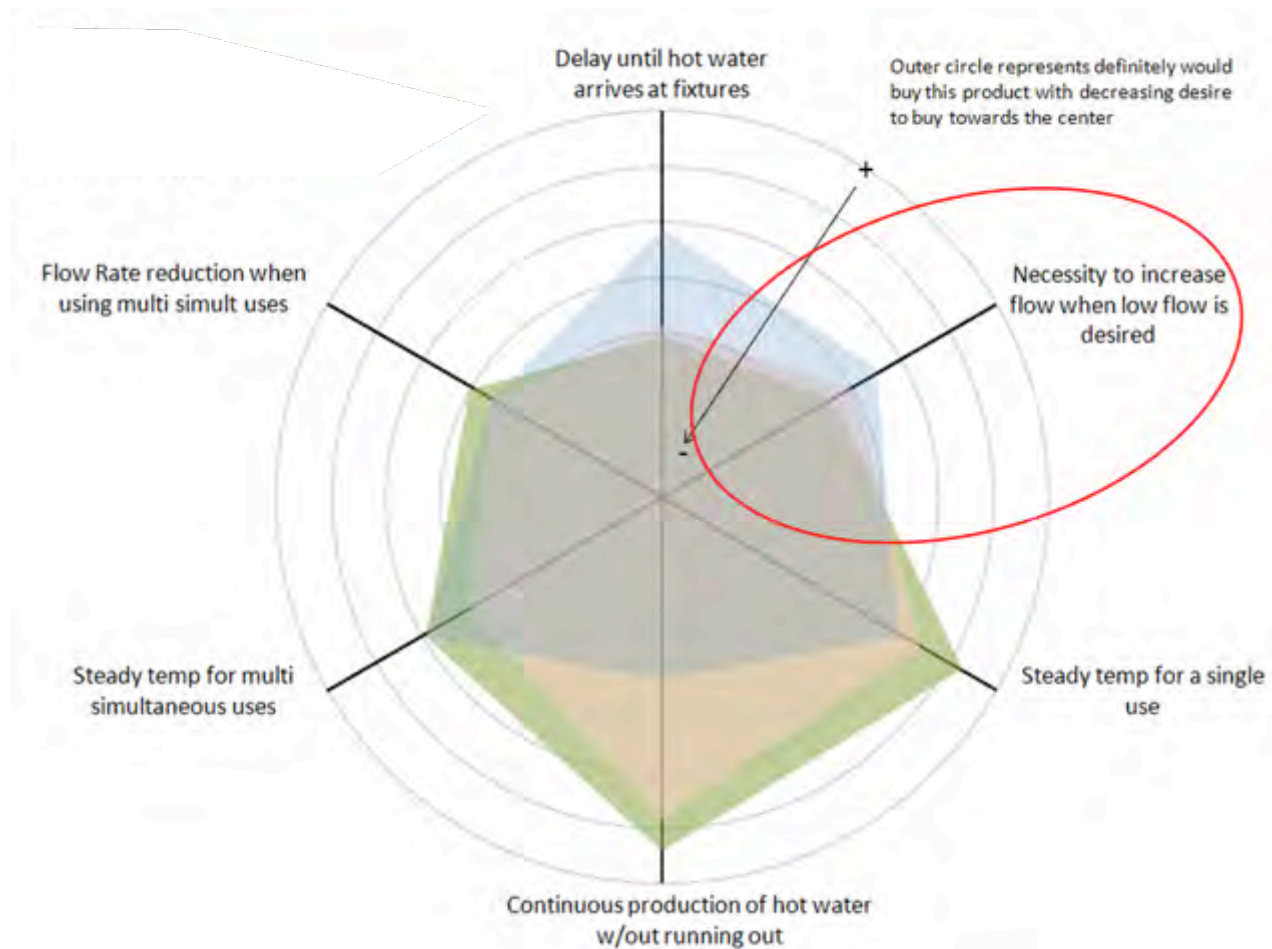
Temperature Profiles



Cold Water Sandwich



Home Owner Survey – need to increase flow to get hot water



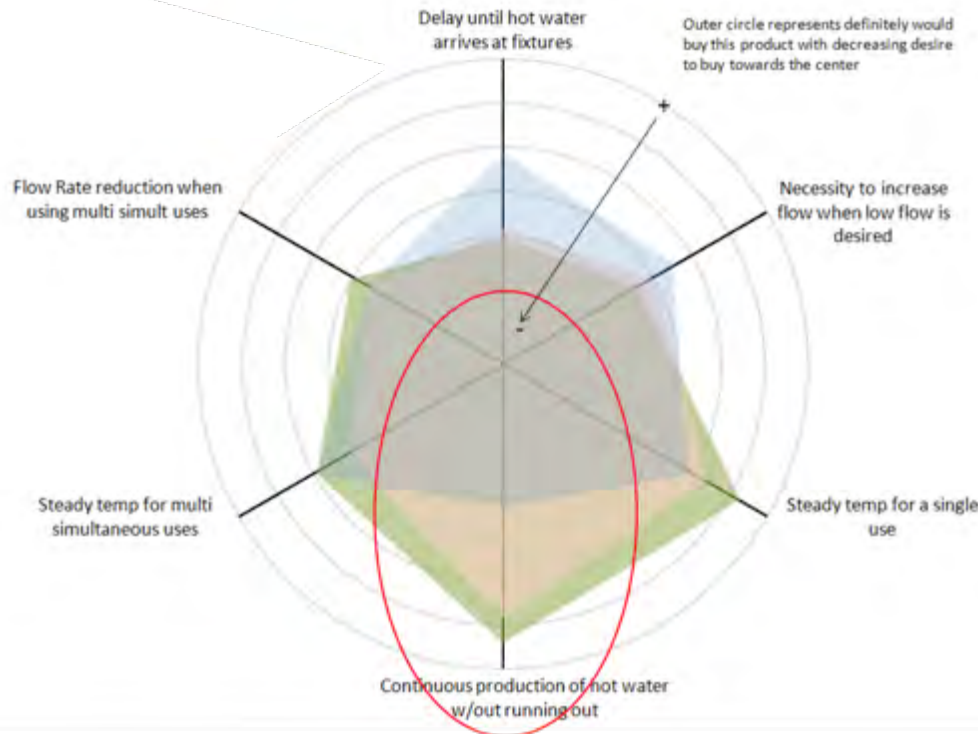


Minimum flow rate to fire

- Minimum flow rate to start is 0.2 GPM
- Maximum is 0.66 GPM
- Minimum flow rates have improved over time
- Some models have “buffer” tanks to reduce minimum rates to 0
 - Stand-by losses are increased for these units

Home Owner Survey – continuous supply of hot water without running out

	Storage Heater			Tankless Heater		
	Unfavorable	No Effect	Favorable	Unfavorable	No Effect	Favorable
Delay Time Until Hot Water Arrives	22%	11%	67%	72%	17%	11%
Not Running Out of Hot Water	56%	11%	33%	6%	11%	83%

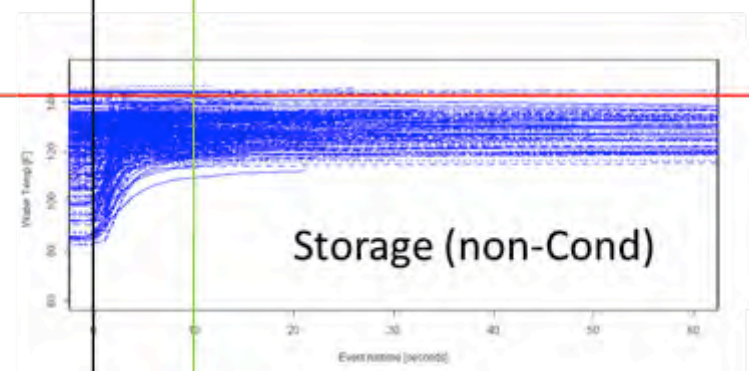
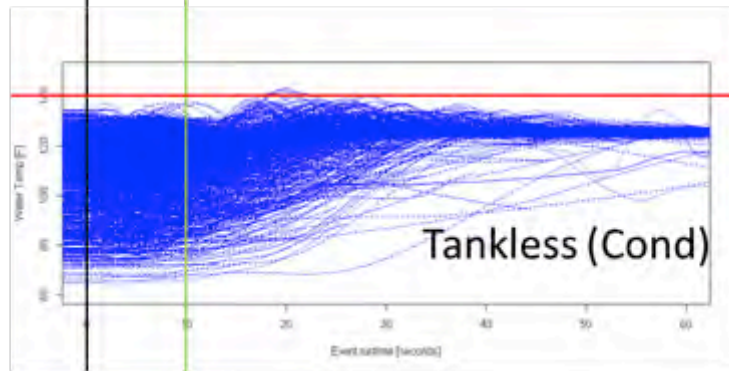
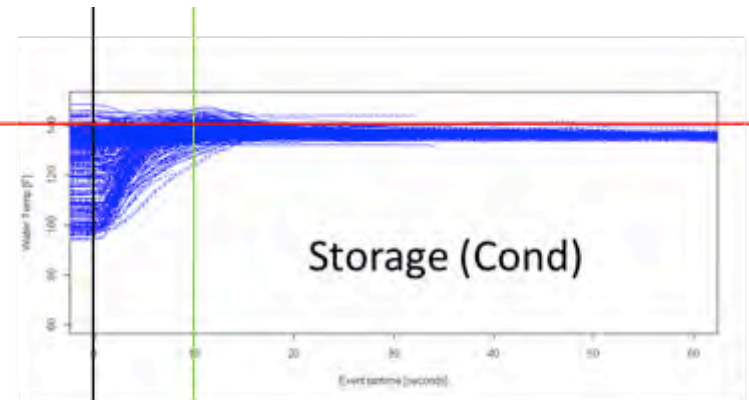
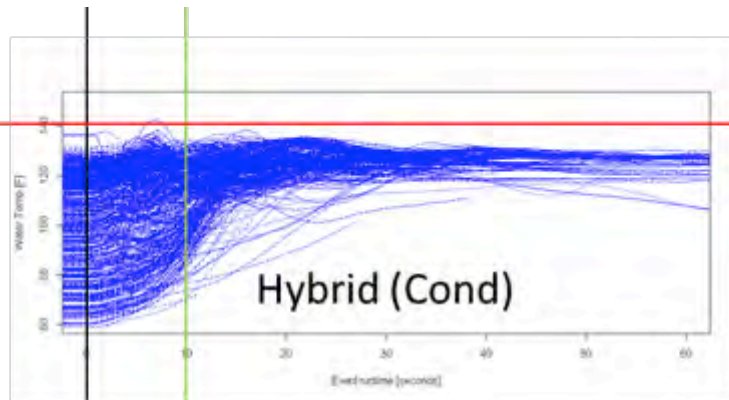


Gas Hybrid Water Heaters

- Types
 - Small tank (0.5 to 2 gallon) and big burner (up to 199,000 Btu/hr)
 - Medium tank (around 20 gallon) and medium burner (100,000 Btu/hr)
- EF 85% to 95%
- Balances benefits and drawbacks of tanks and tankless
 - Water delivery
 - Stand-by Losses

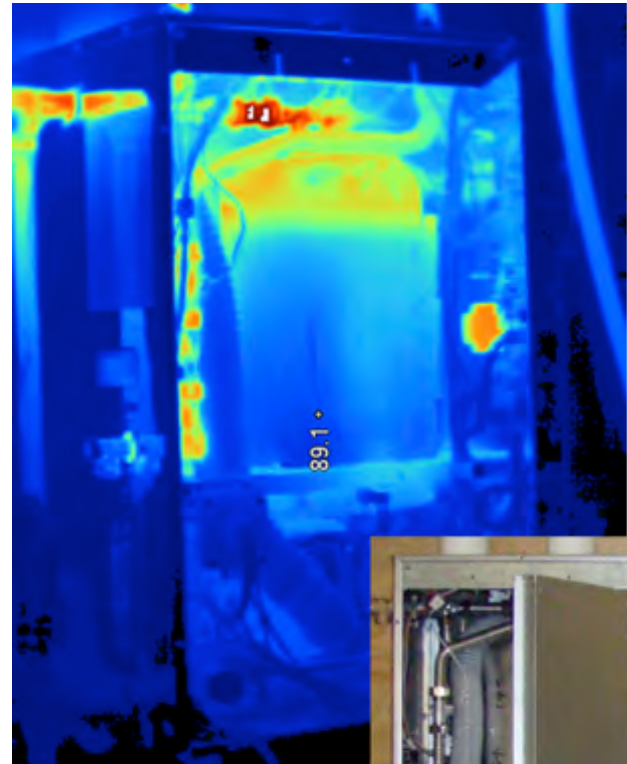


Water Delivery Temperature



• Stand-by Loses

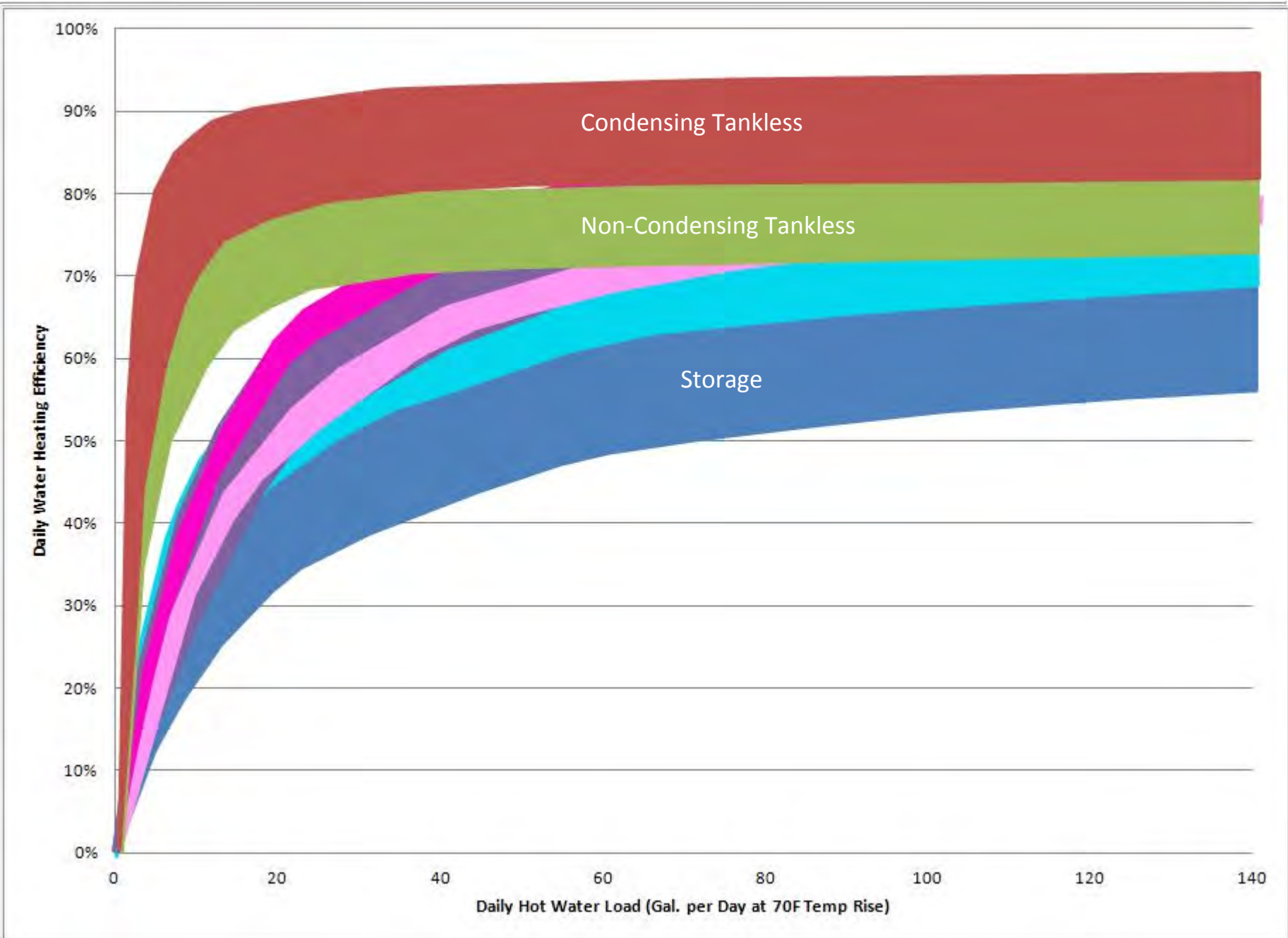
- Vary dramatically from unit to unit
 - Storage volumes
 - Controls
 - Insulation levels
 - Vent loses



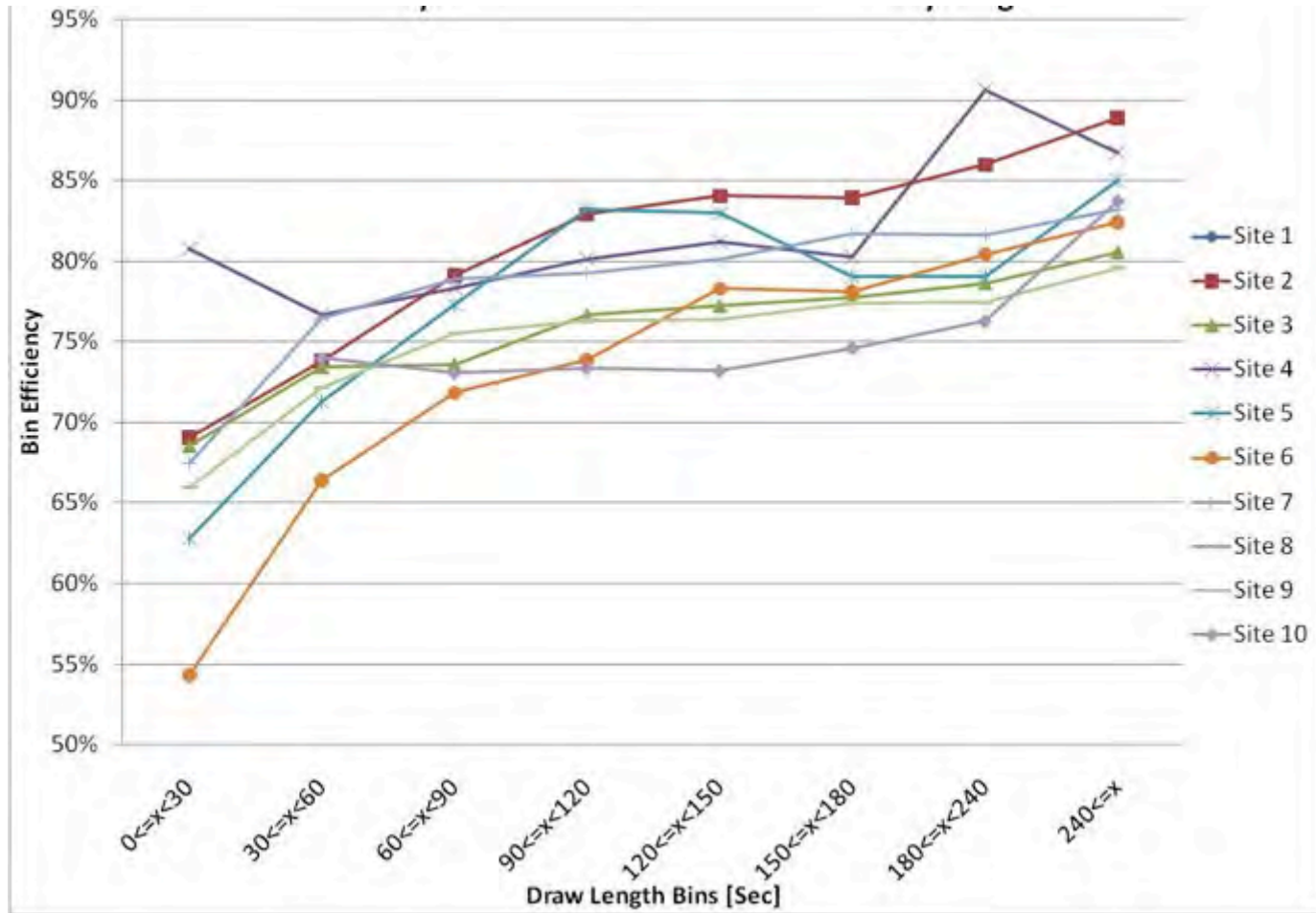


Gas Water Heater Comparison

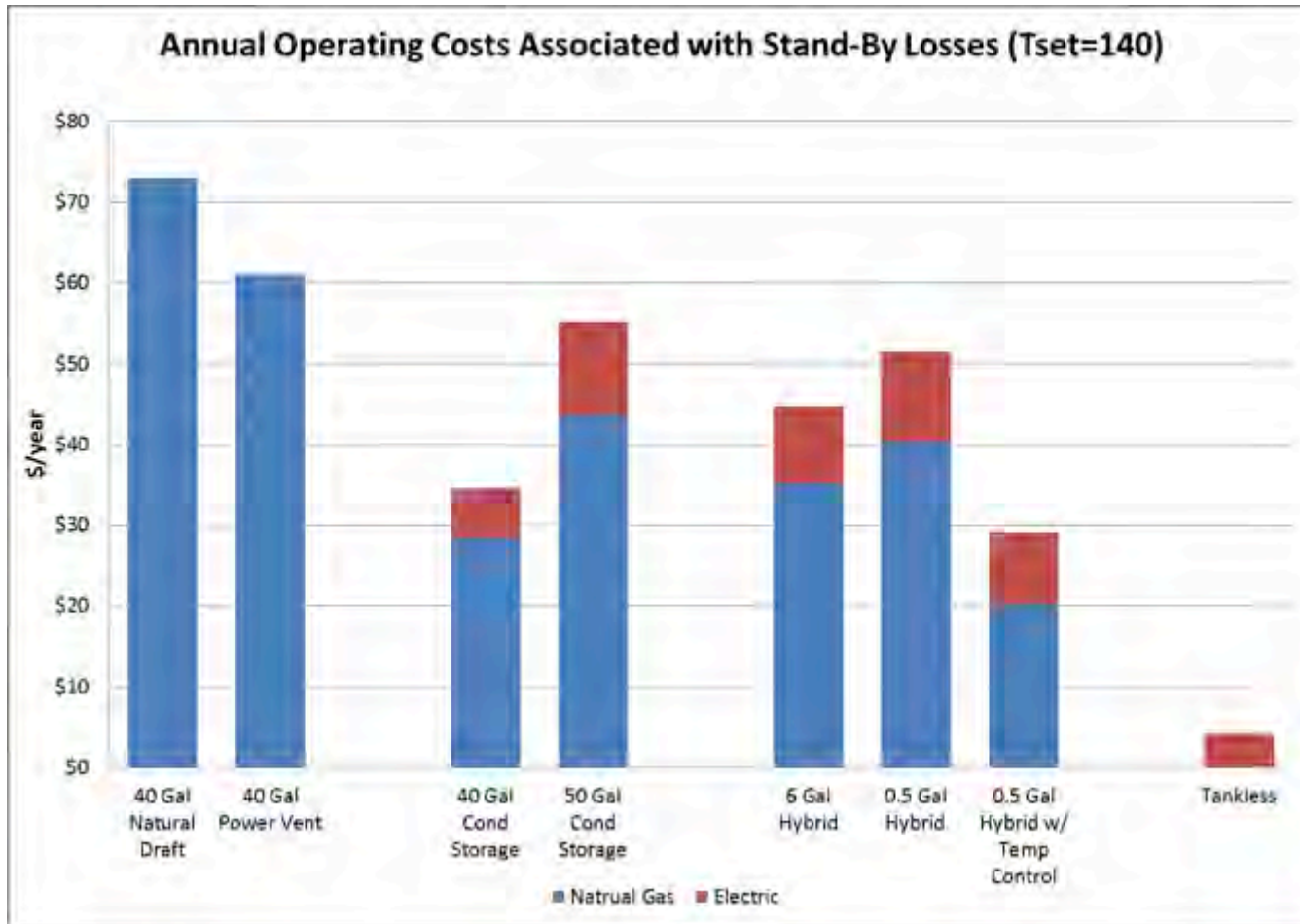
- Efficiency
- Installation
- Safety
- Economics



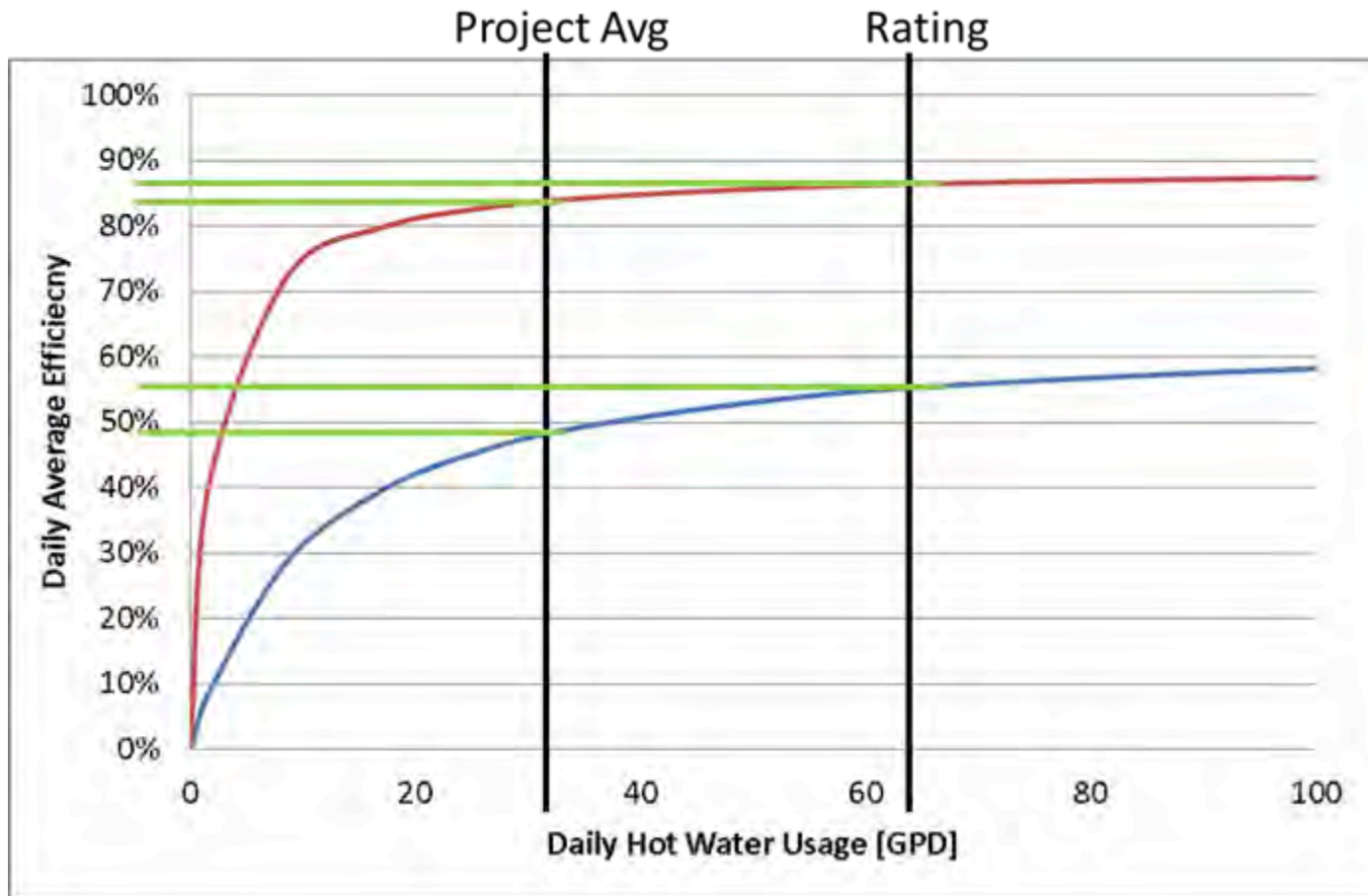
Tankless Efficiency by Draw Length



Impact of Stand-by Loss



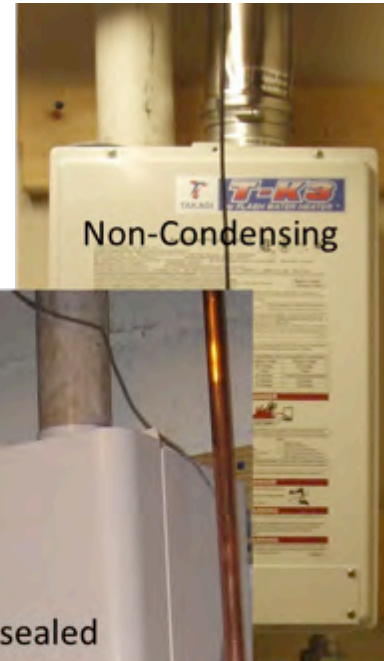
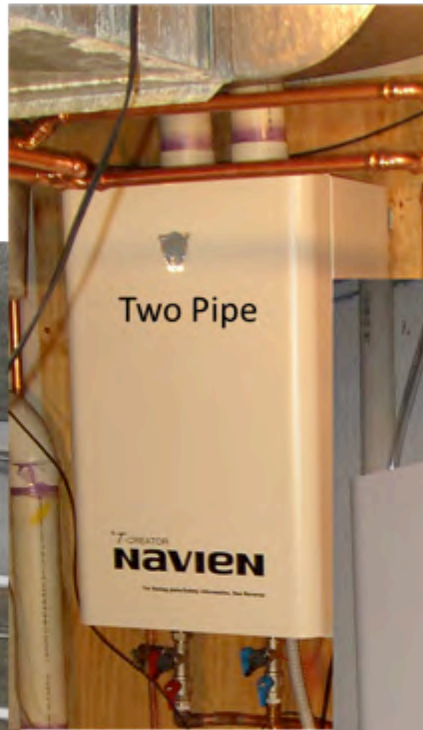
Impact of Stand-by on Efficiency



Installation: Venting



Installation: Venting





Larger Burners = Gas Line Upgrades

- Water heaters with burners greater than 100,000 Btu/hr
 - Most tankless
 - Some condensing storage
 - Some hybrid
- Occasionally require a meter upgrade (more common in older homes and/or homes with lots of gas uses)
 - 0 of 25 in our studies
- Sites commonly required a increased size gas line from the water heater to the gas meter
 - 14 of 25 in our studies

Installation: Other Additions

Condensate Drainage



Electrical

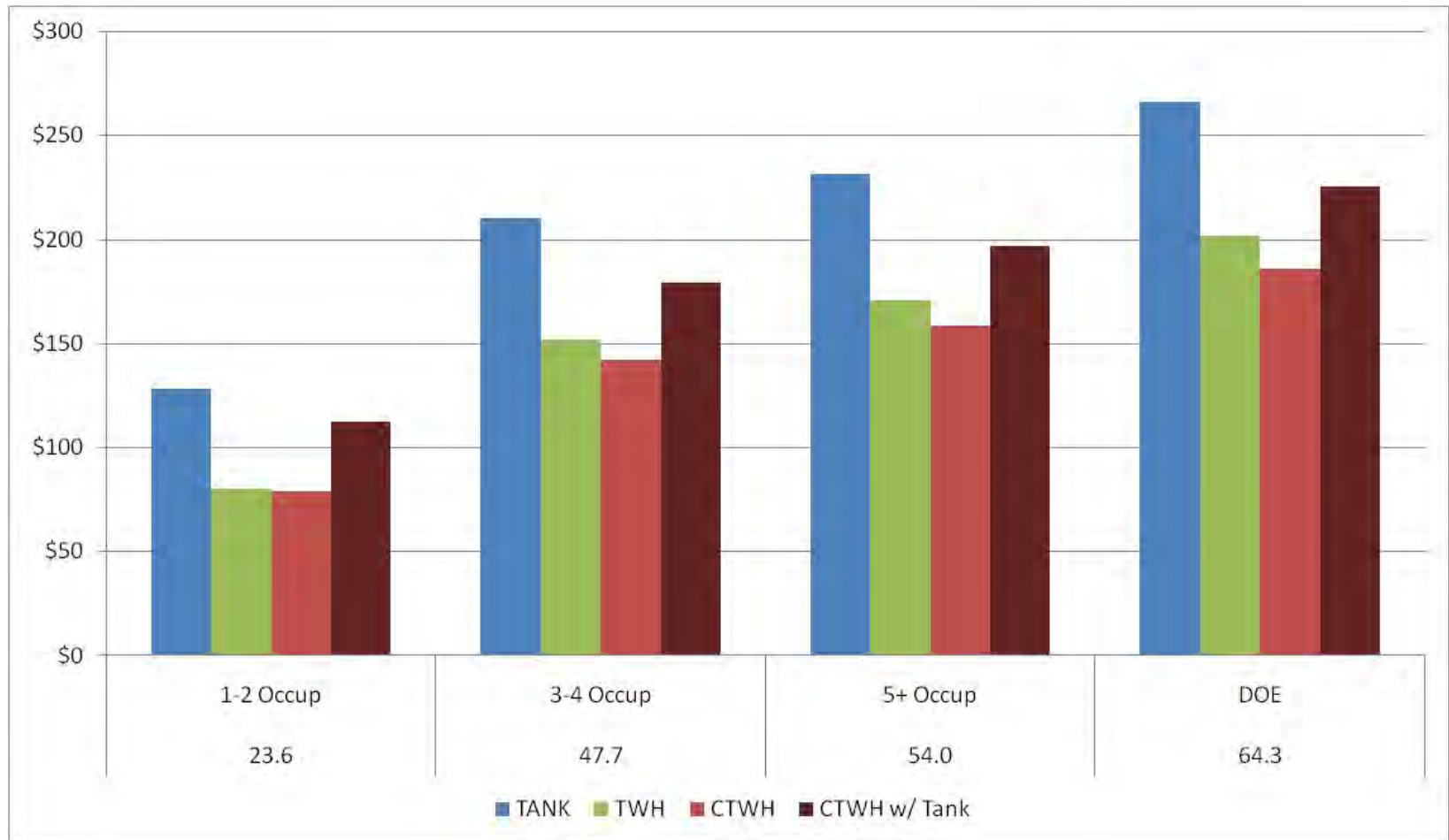


Safety

- Combustion safety
 - Lower efficiency natural draft units can have issues
 - Power vented and sealed combustion units are safer
- Scalding
 - All water heaters

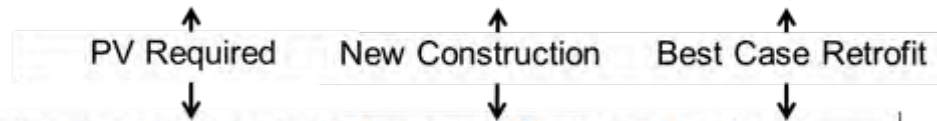
Water Temperature Setting	Exposure Time
Water at 120 degF	5 minutes
Water at 130 degF	30 seconds
Water at 140 degF	5 seconds
Water at 150 degF	1.5 seconds
Water at 160 degF	.5 second

Savings



Paybacks

Paybacks for Non-Condensing Tankless Water Heater			
	Incremental Cost		
Load	\$500	\$750	\$1,000
Small (24 GPD)	10	16	21
Medium (48 GPD)	9	13	17
Large (64 GPD)	7	10	13
Very Large (90 GPD)	6	9	12



Paybacks for Condensing Tankless Water Heater			
	Incremental Cost		
Load	\$500	\$750	\$1,000
Small (24 GPD)	10	15	20
Medium (48 GPD)	7	11	15
Large (64 GPD)	5	8	11
Very Large (90 GPD)	5	7	9

Electrical Water Heating





Electric Storage

- Water stored at temperature
- When tank temp drops below certain point elements turn on
- Rated EF from 0.89 to 0.95
 - Insulation levels main difference
- Typical input: 4 to 6 kW
- Typically 40 to 60 gallons of storage
- No burner venting results in lower storage losses than similar gas units
- Hot water delivery similar to gas storage WHs



Electric tankless

- Major market as point of use heaters
 - 3.5 kW on regular electric service – 1 sink
 - 5 kW on 240 volt – 1 bathroom
 - Reduce distribution losses compared to central system
- Whole house units available for small homes
 - Require larger electric hook ups
- Rated EF of 0.90 to 0.95

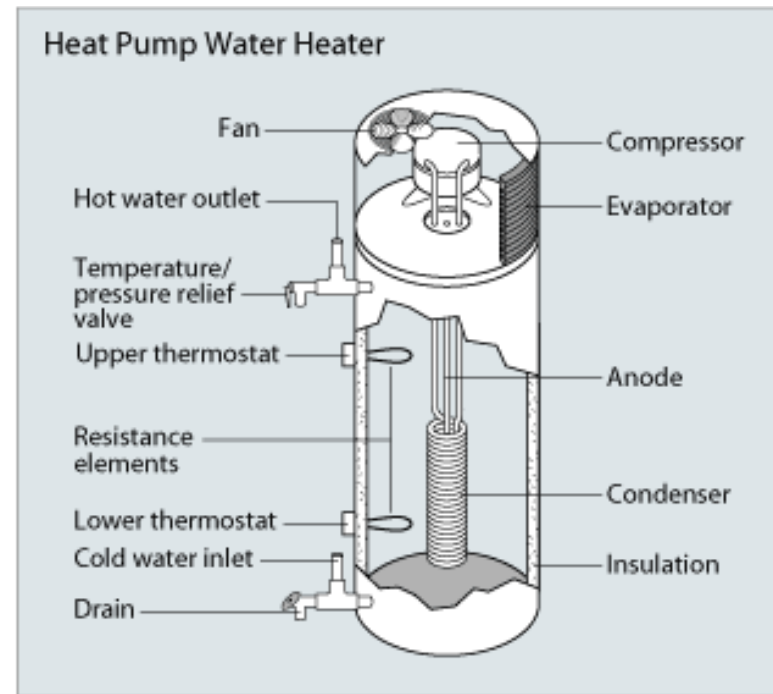


Distribution efficiency

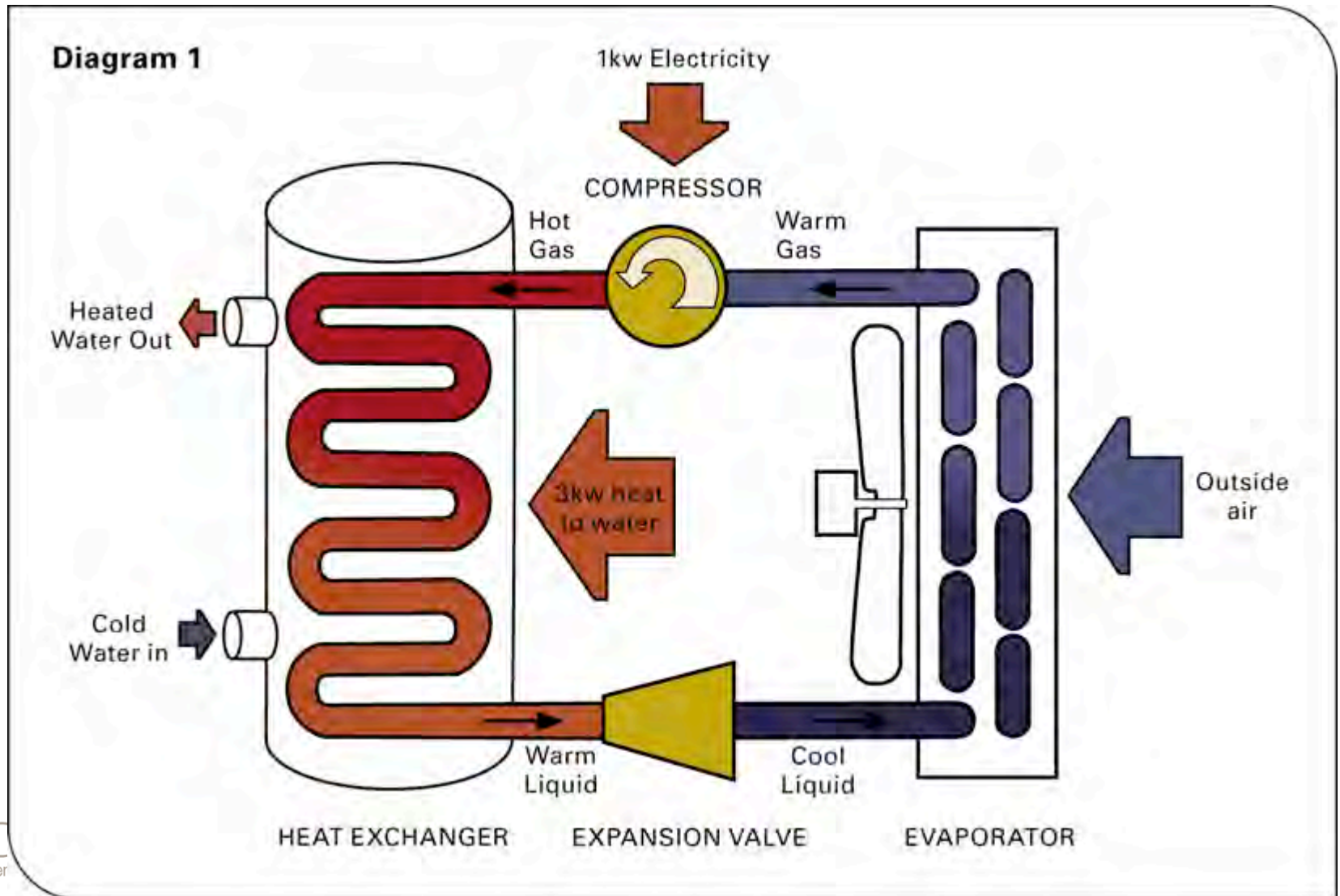
- 5% to 27% of hot water is from draws where fixture is never gets hot (by volume)
- Draws lost 2-8 °F, 3% to 12% loss
- Depending on usage patterns, hot water left in pipes can reduce total system efficiencies to less than 25%
 - If draws are well grouped these losses are very small
- Point of use heaters can reduce these losses to almost zero

Heat Pump Water Heaters

- Integrated heat pump and storage
- 50 to 80 gallons
- COP ~ 2 to 2.5
- Optional ducted venting
- Cooling capacity of 15 to 30 kBtu/hr (~1.2 to 2 tons)
- Multiple modes of operation
 - Heat pump only
 - Hybrid
 - Resistance only



How HPWHs work



Heap Pump Water Heater Performance

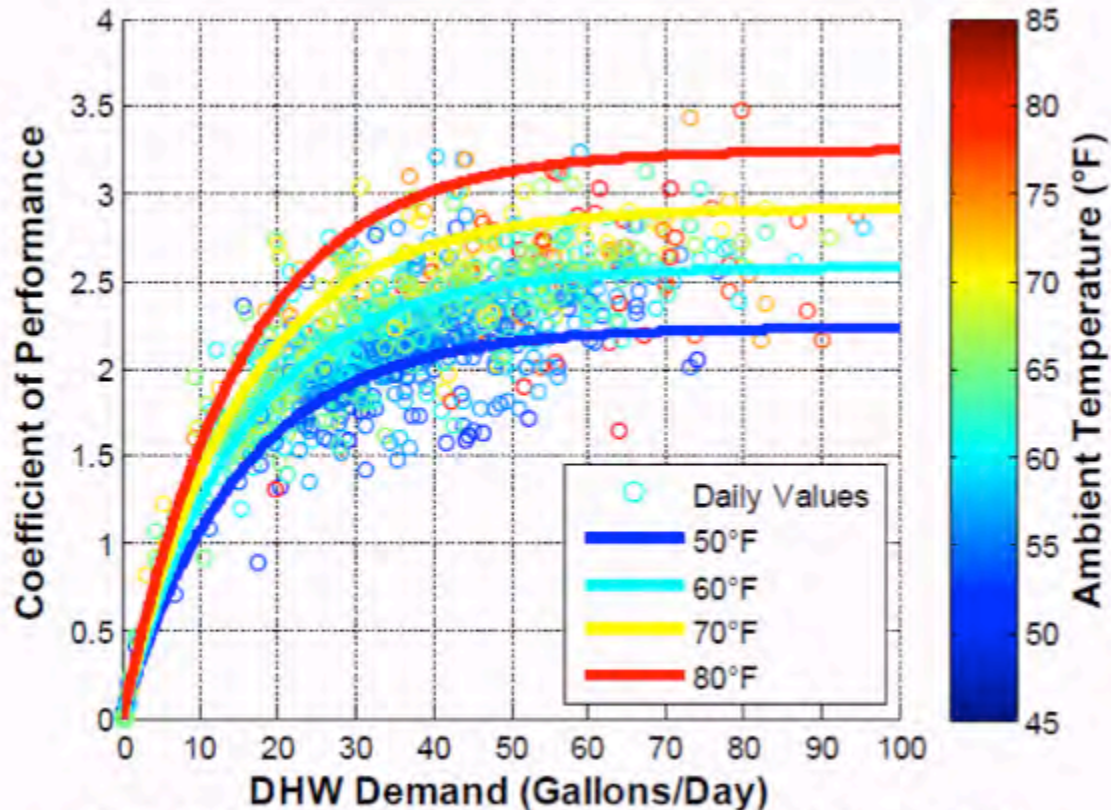


Figure 5. Efficiency of a 50-gal HPWH operating in heat pump mode

• HPWH Space Conditioning Impact

- Lots of modeling around the country still need DATA!!
- Lots of variables:
 - Installation location
 - In conditioned space – Max effect
 - In garage – No effect
 - In semi-conditioned (basement/craw space) – secondary effect
 - Conditioning load of house and heating equipment
 - Efficiency, set points, use, etc
- Limited lab data shows HPWHs deliver ~1 ton of cooling at 50 gallons per day



CEE HPWH Savings Calculator

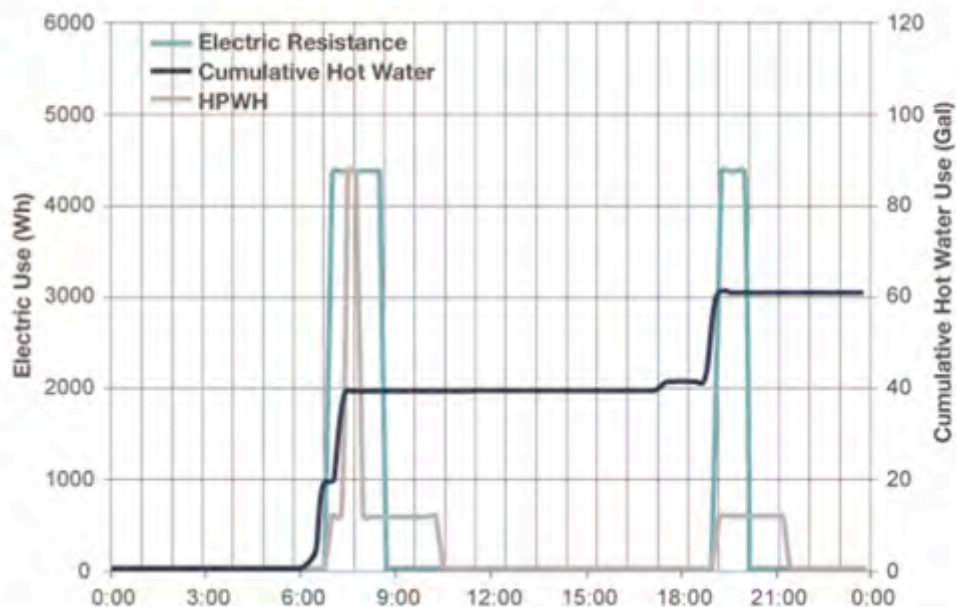
- Inputs:
 - Geographic location
 - Space heating fuel & system type
 - Air conditioner type and typical operation
 - Number occupants
- Installation location
 - In conditioned space – Max effect
 - In garage – No effect
 - In semi-conditioned (basement/craw space) – secondary effect
- <http://www.mncee.org/Innovation-Exchange/Resource-Center/Data-and-Reference/Heat-Pump-Water-Heater-Calculator/>

CEE HPWH Savings Calculator

Heat Pump Water Heater Savings

Water Heater	Installed COP	Hot Water Usage (GPD)	Hot Water Energy Usage (kWh/year)	Cooling Benefit (kWh/year)	Heating Increase (kWh/year)	Annual Operating Cost (\$/year)	Annual Savings (\$/year)	Simple Payback (Years)
Electric Resistance, Baseline	0.89	54	3,770	0	0	452	.	.
Heat Pump Water Heater	1.64	54	2,043	16	362	287	165	6.1

The table above shows the estimated performance of a heat pump water heater in your home. The information you provided was used to estimate the hot water usage both in volume and energy used in your home. This usage information was used to determine the performance and savings expected from the heat pump water heater as well as the impact of the heat pump on the space conditioning use of the home (Cooling Benefit and Heating Increase). The water and energy usage patterns for a sample day are shown below. The graph shows what the electricity use pattern would be for either a heat pump water heater or an electric resistance water heater under the same hot water use.

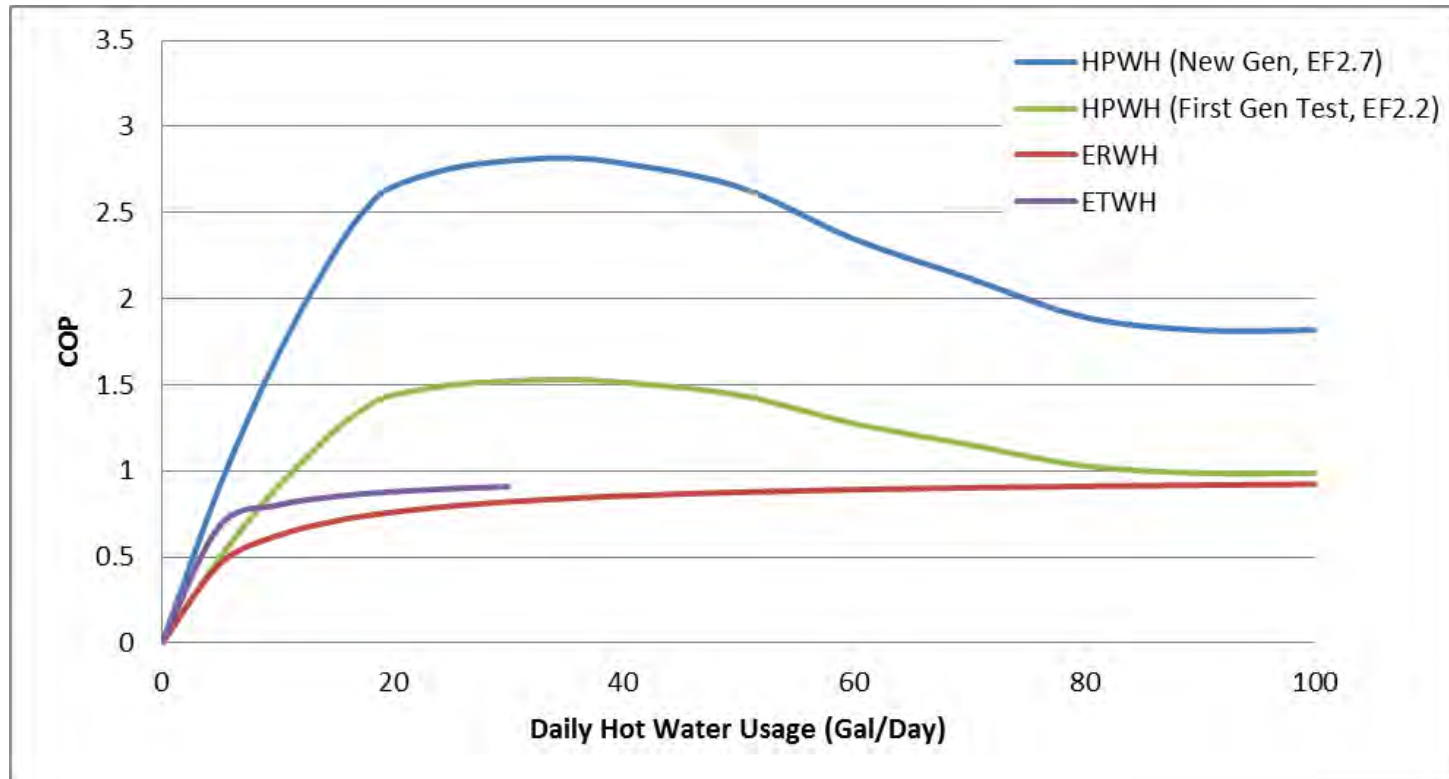




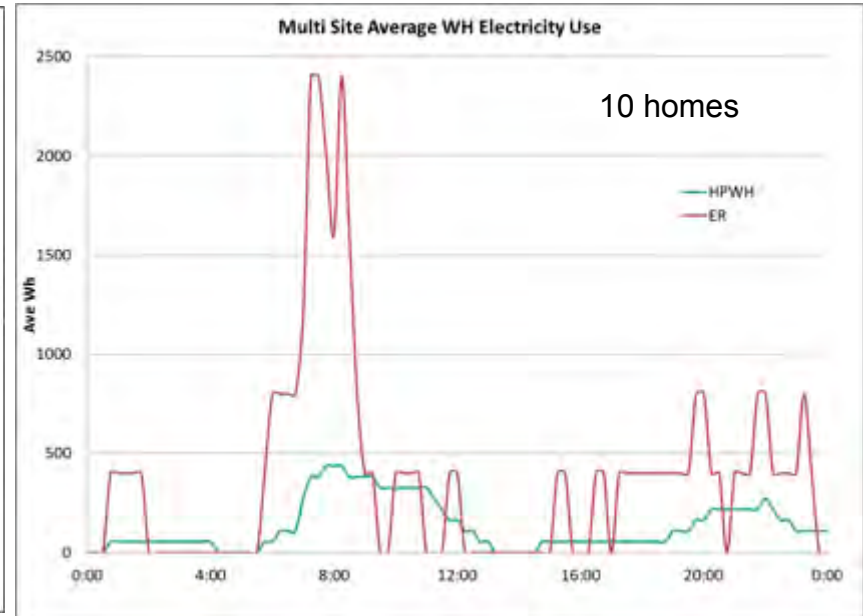
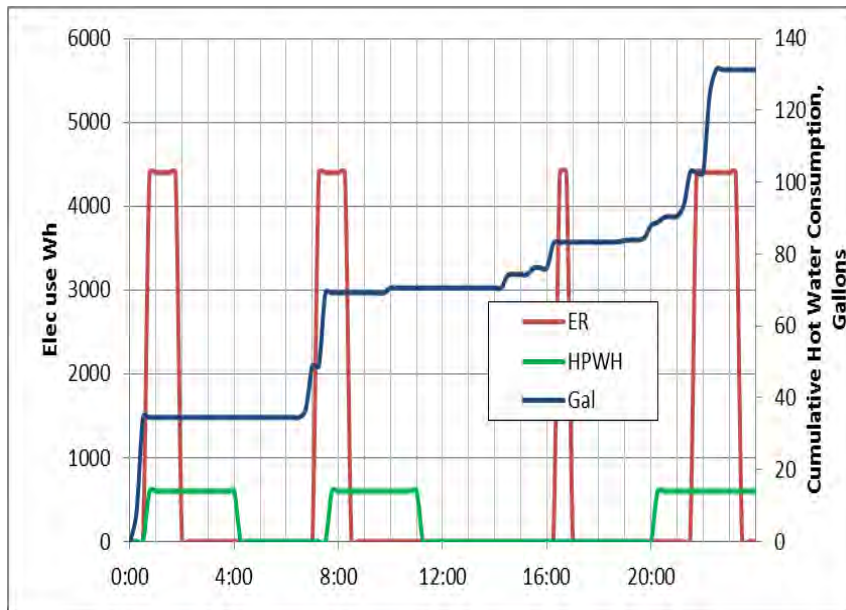
Electric Thermal Storage

- Increases the temperature WH at low electricity use periods (overnight)
- Not an energy savings measure, but reduces peak load
- Units typically have larger storage capacity's, 60 gallons plus
- Some units have increased insulation to prevent increasing stand by loses

COP for electric water heaters



Peak load energy consumption

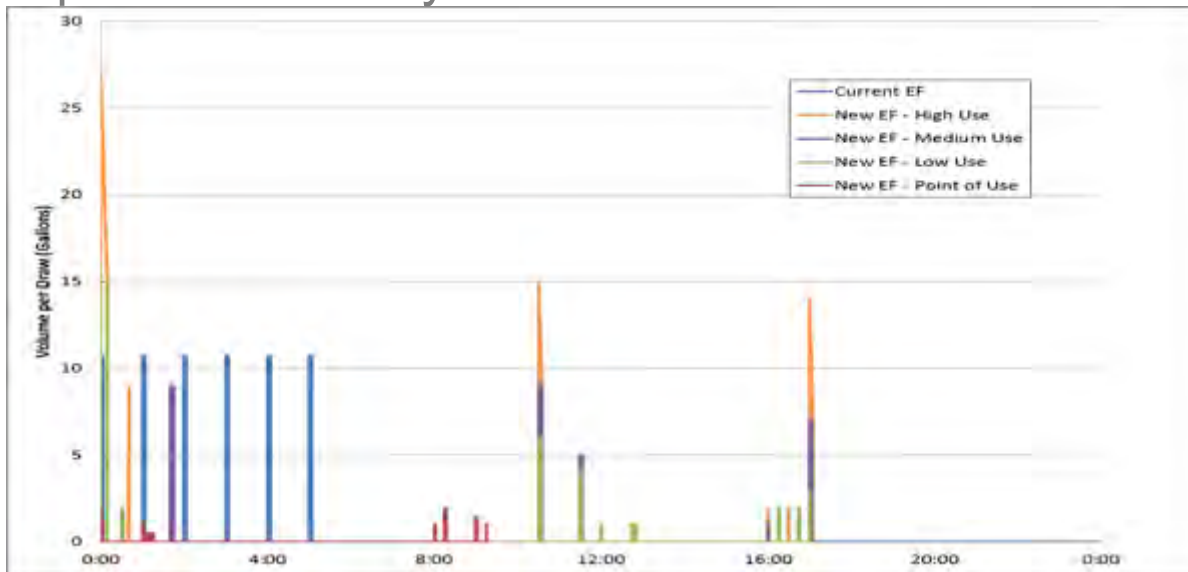


What to look for in the future



DOE Energy Factor Rating

- DOE Passed a new rating method
 - Goes into effect April 2015
 - New hot water usage pattern
 - Multiple daily volume categories by WH size
 - One rating for a larger range of WHs
 - Improved accuracy



DOE Energy Factor Rating

Energy Conservation Standards				
Fuel	Type	Rated Storage Volume	Energy Factor (Effective April 16, 2015)	Energy Factor
Natural Gas	Storage	≥ 20 gal and ≤ 55 gal	0.675 – 0.0015V	0.67 – 0.0019V
Natural Gas	Storage	> 55 gal and ≤ 100 gal	0.8012 – 0.00078V	0.67 – 0.0019V
Fuel Oil	Storage	≤ 50 gal	0.68 – 0.0019V	0.59 – 0.0019V
Electric	Storage	≥ 20 gal and ≤ 55 gal	0.960 – 0.0003V	0.97 – 0.00132V
Electric	Storage	> 55 gal and ≤ 120 gal	2.057 – 0.00113V	0.97 – 0.00132V
Tabletop	Storage	≥ 20 gal and ≤ 100 gal	0.93 – 0.00132V	0.93 – 0.00132V
Natural Gas	Instantaneous	< 2 gal	0.82 – 0.0019V	0.62 – 0.0019V
Electric	Instantaneous	< 2 gal	0.93 – 0.00132V	0.93 – 0.00132V

What to look for in the future





New Products

- Thermal storage HPWH
- Retrofit high efficiency gas tankless and hybrid
- Gas fired heat pump technology

THANK
you!





Potential Plumbing Code Changes

- Allowing smaller pipe diameter
- Requiring low water volume between WH and fixtures
- Pipe insulation guideline/requirements
- Recirculation controls

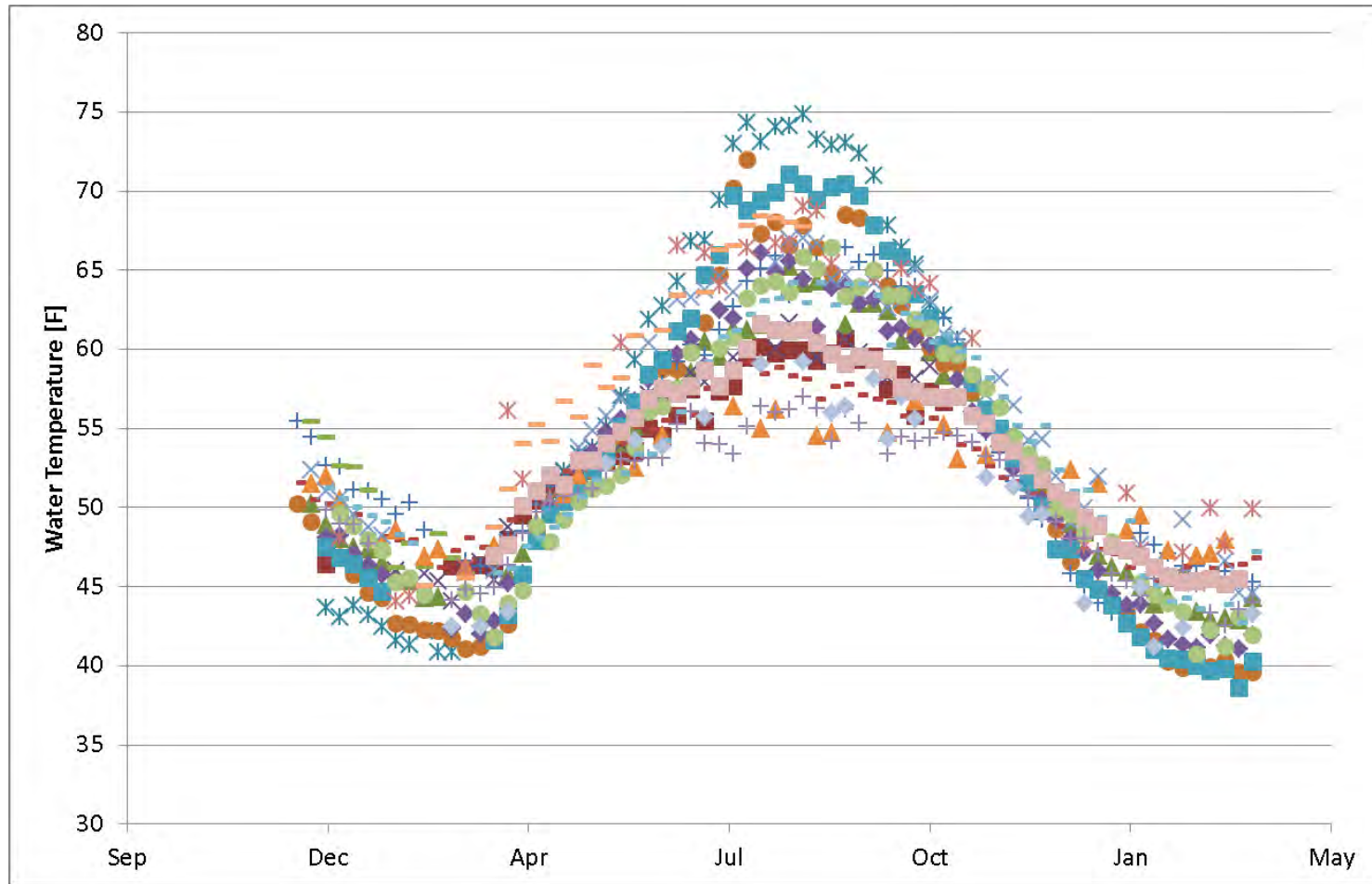
- International Energy Conservation Code (IECC-R and IECC-C)
- International Association of Plumbing and Mechanical Officials (IAPMO) Uniform Plumbing Code (UPC)



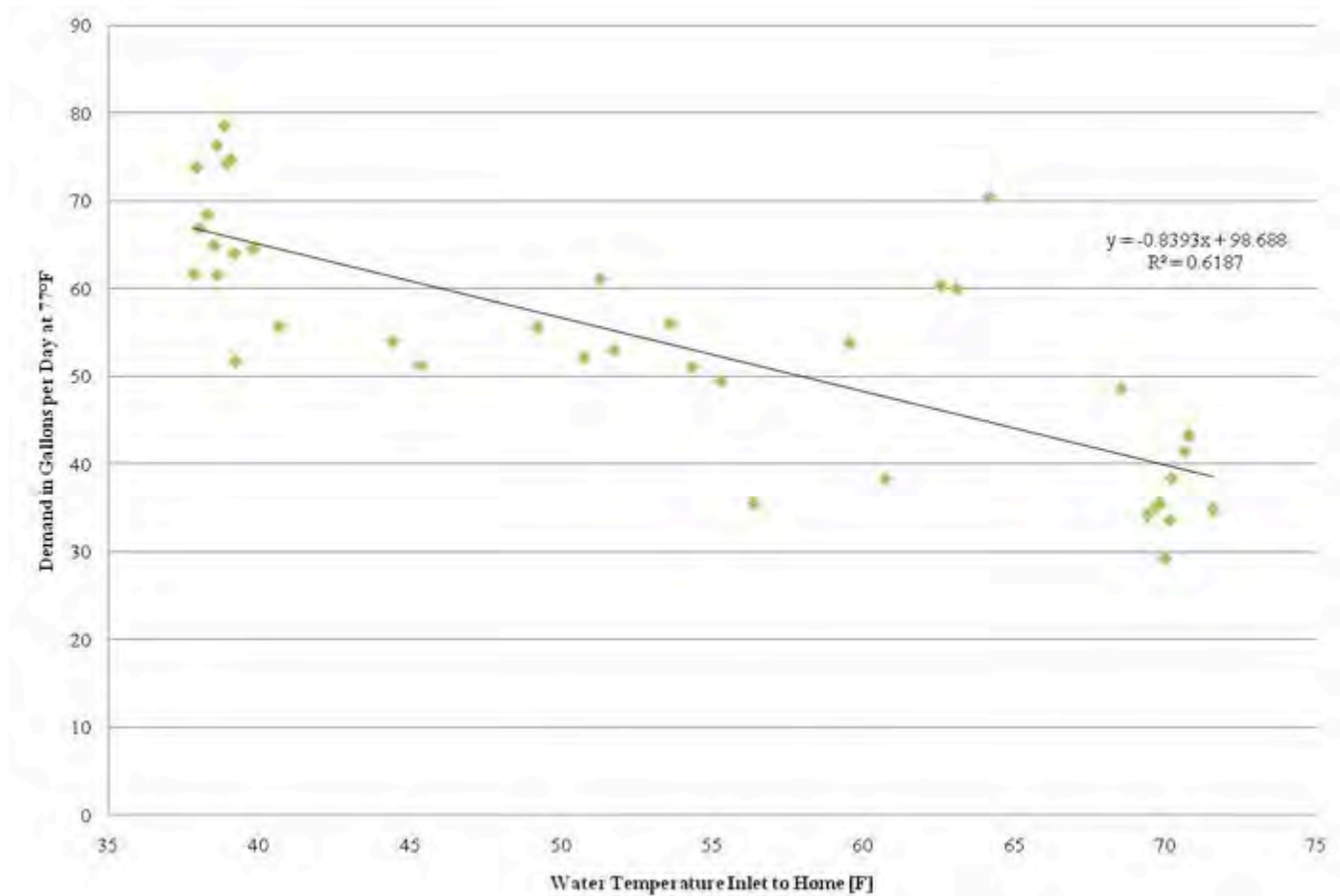
New Regulations April 2015

- Units greater than 55 gallons will be required to be HPWHs or condensing gas water heaters
- Impacts
- 30 year customer savings for \$8.7 billion
 - Are high efficiency units cost effective? Does it matter?
 - Some electric utilities rely on large electric storage water heaters for thermal storage?
 - Potential for a waiver for these programs

Impact on Inlet Water Temperature



Seasonal Change in Load





Support for Water Heating Projects

- Minnesota CARD Grants
 - MN Department of Commerce
 - To identify new technologies or strategies to maximize energy savings, improve the effectiveness of energy conservation programs in order to help utilities to achieve the annual state energy conservation goal of 1.5 percent
- Building America
 - Department of Energy
 - Conducts research to continually develop innovative, cost-effective energy saving solutions—better products, better new homes, better ways to improve older homes, and better buildings in which we work, shop, and lead our everyday lives.