Residential Water Heating

Energy Design Conference, Duluth

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Center for Energy and Environment

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About CEE

The Center for Energy and Environment (CEE) is a nonprofit organization that promotes energy efficiency to strengthen the economy while improving the environment.

CEE conducts research and develops programs so that:

- Businesses operate more efficiently and profitably;
- Government agencies and nonprofits spend less on facilities and functions;
- Utilities achieve their energy-efficiency goals at least-cost; and
- Households save money and improve comfort.

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.

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

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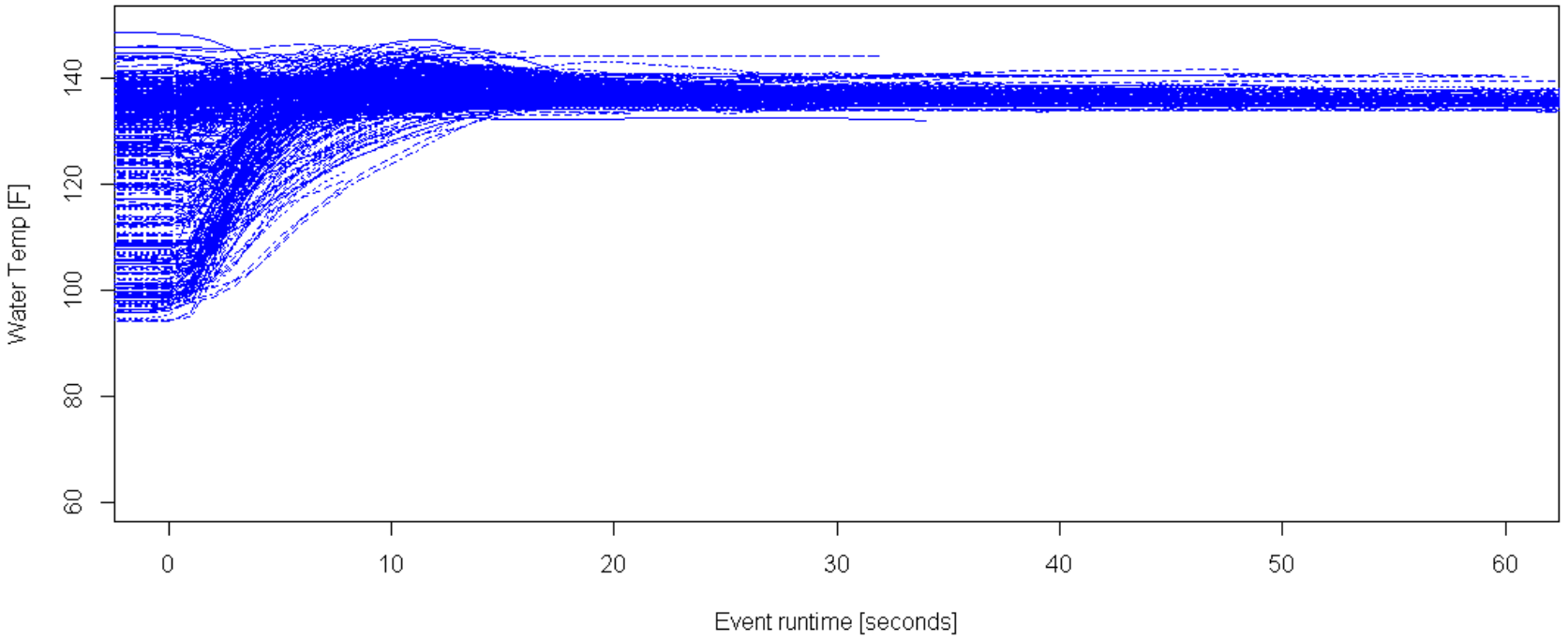
Storage Water Heaters

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

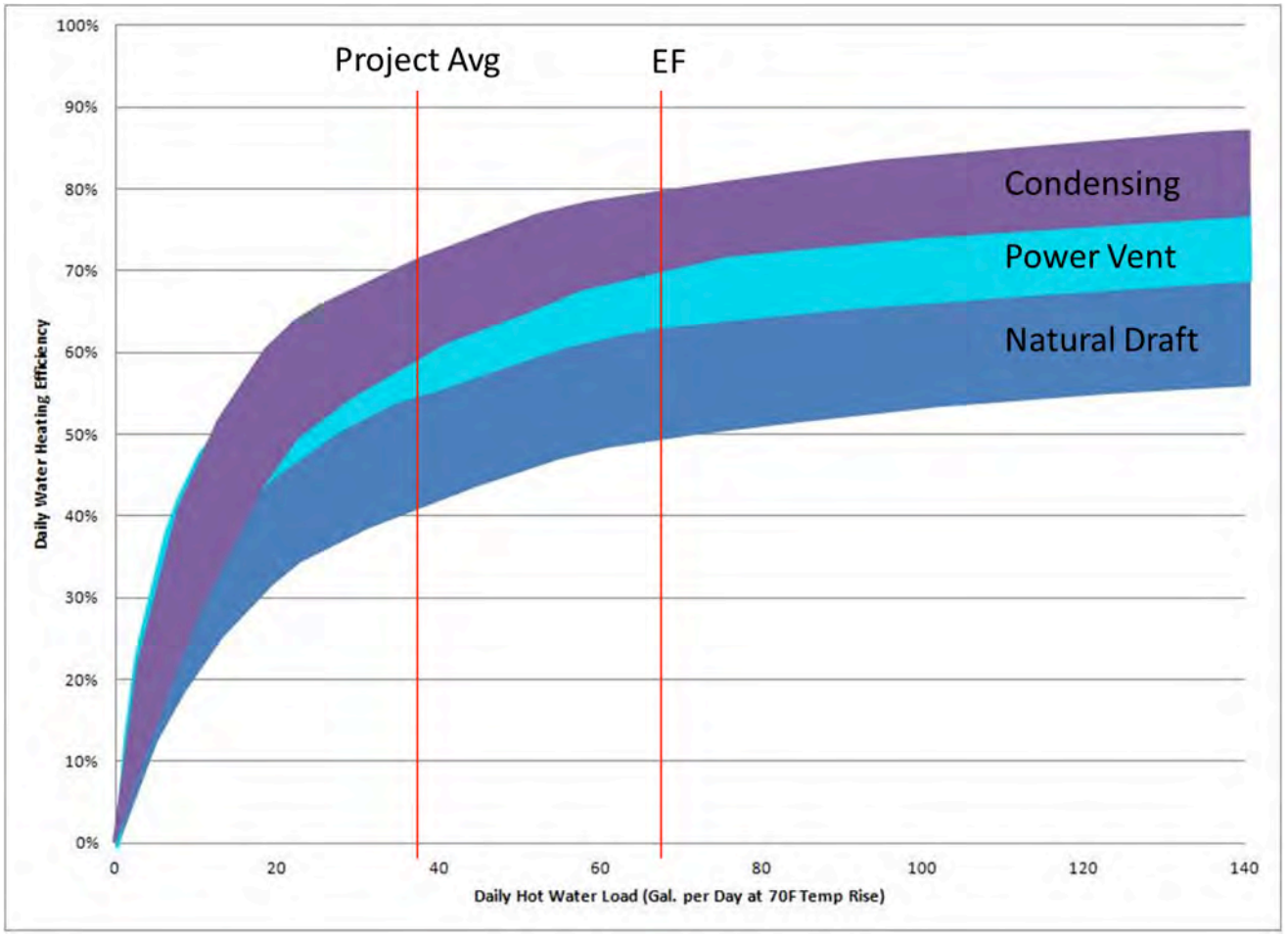
Storage Water Heaters

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

Hot Water Delivery



Efficiency

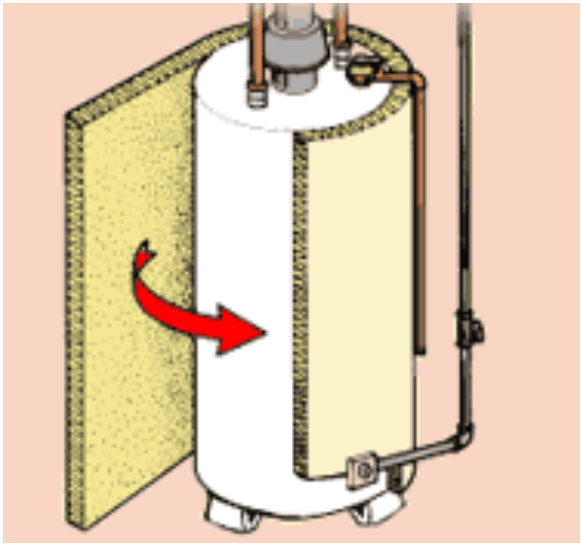

Project Avg
EF
Condensing
Power Vent
Natural Draft
Daily Water Heating Efficiency
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
20
40
60
80
100
120
140
Daily Hot Water Load (Gal. per Day at 70F Temp Rise)

Improving Efficiency

Reducing stand-by loses with an insulation 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



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Improving Efficiency

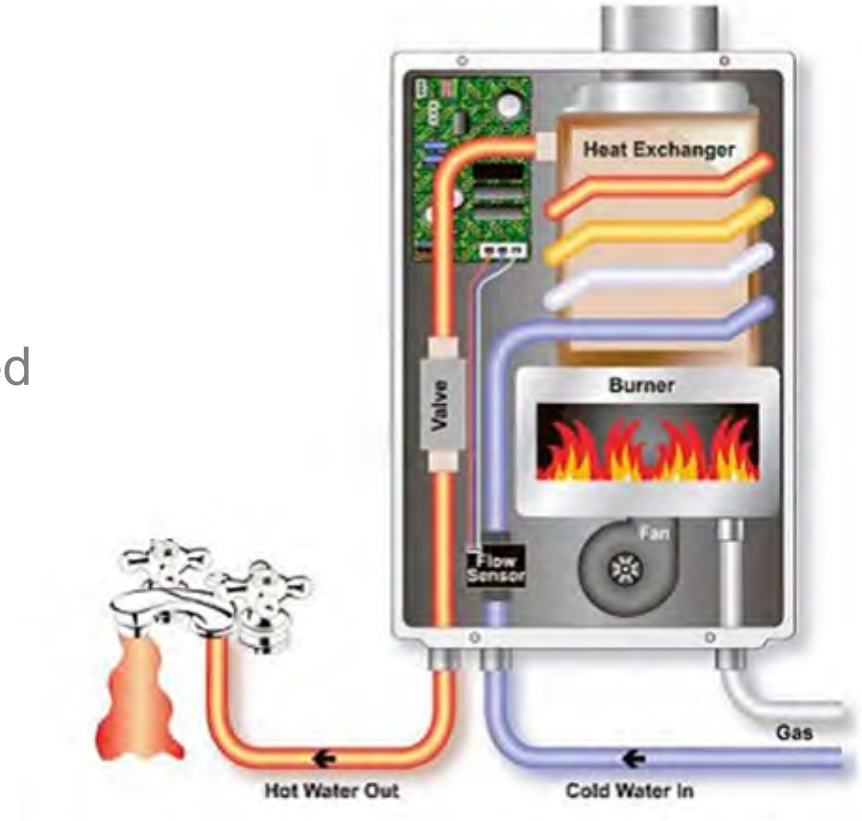
Reducing stand-by loses by reducing temperature

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

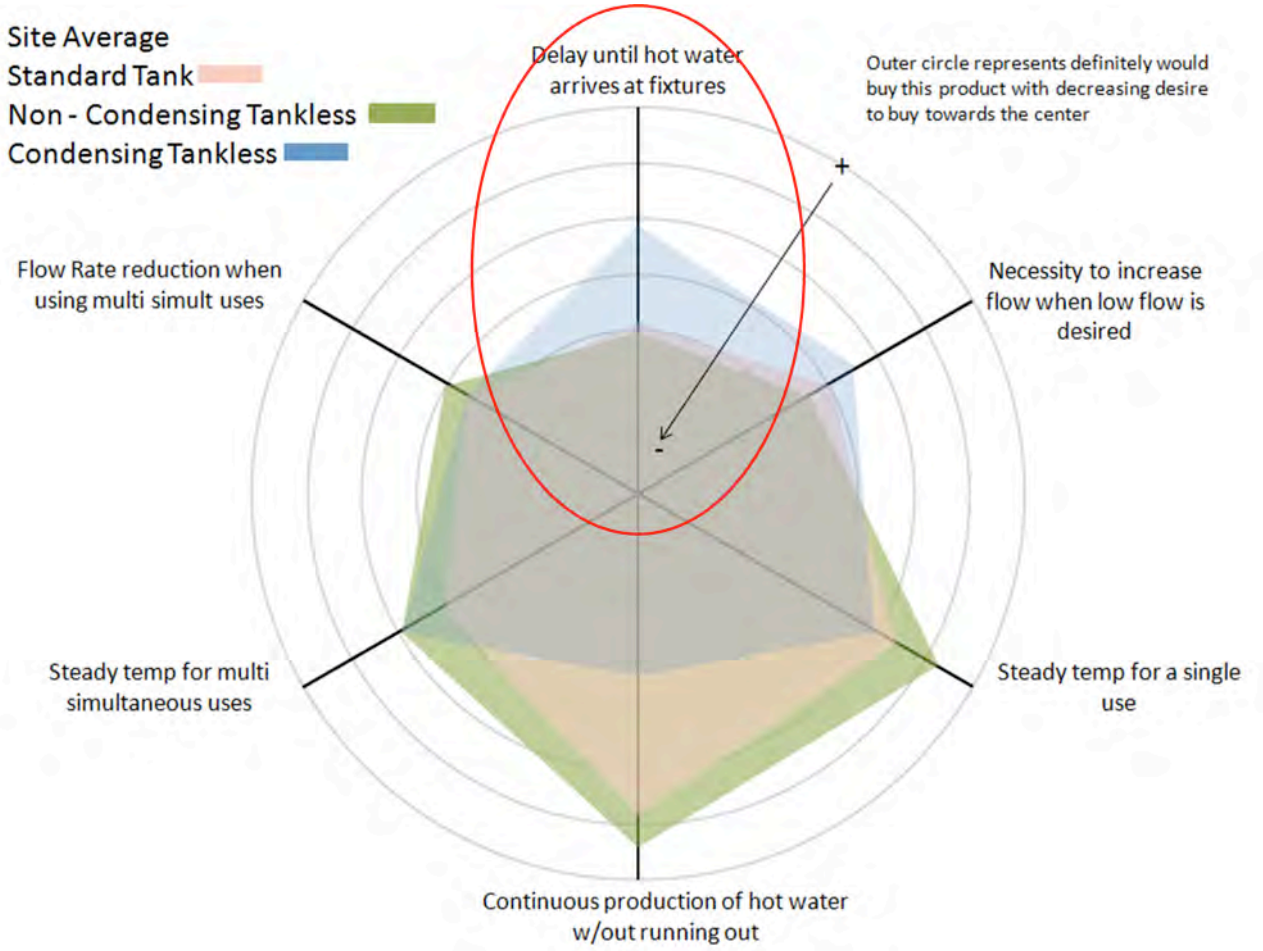
- Types
  - Condensing
  - Non-condensing
- Operation
  - No storage, water is heated as needed
  - Eliminate stand-by loses
  - 80%-95% EF



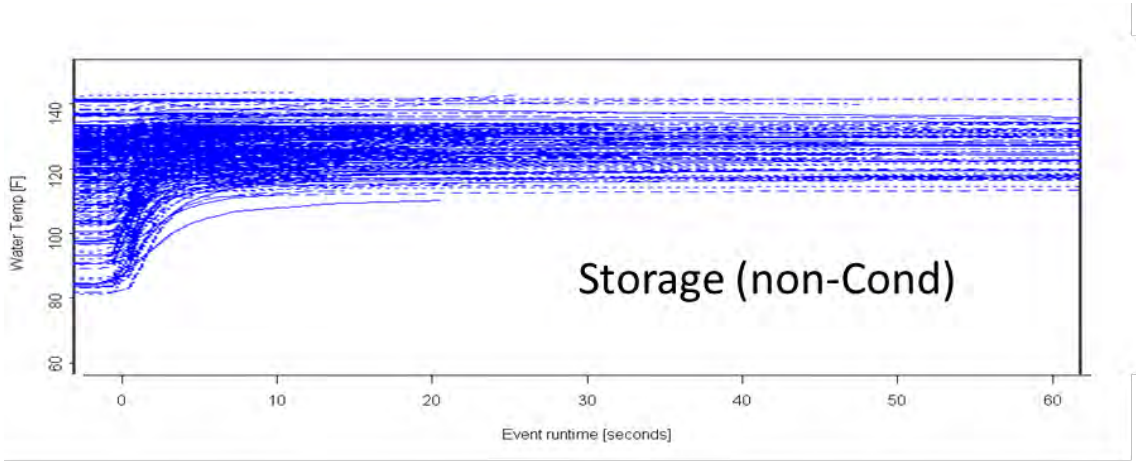
Issues Facing Tankless Water Heaters

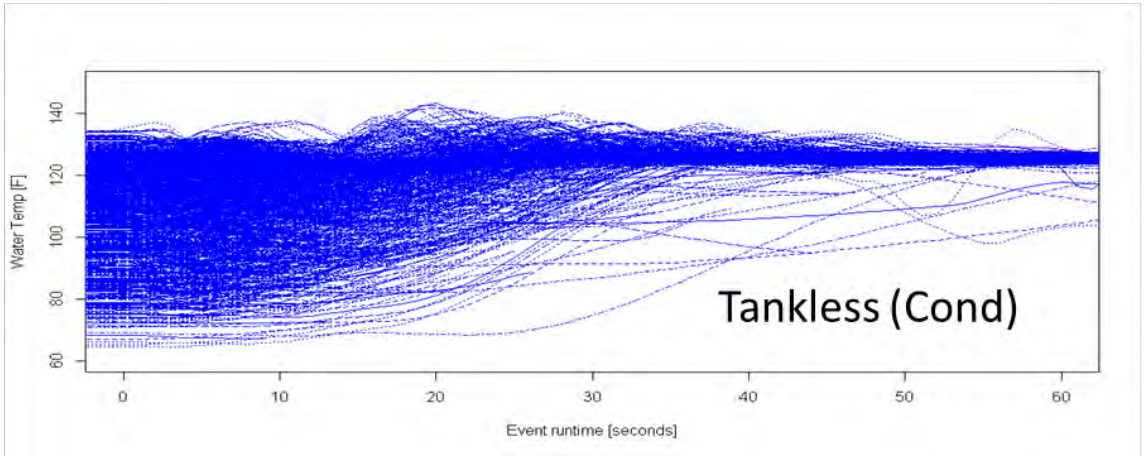
- Hot water quality
  - Delayed delivery time
  - Cold water sandwich
  - Consistent Supply temperature
  - Minimum flow rate for firing
  - Performance for multiple simultaneous uses
- Higher installation costs
- Maintenance costs

Home Owner Survey

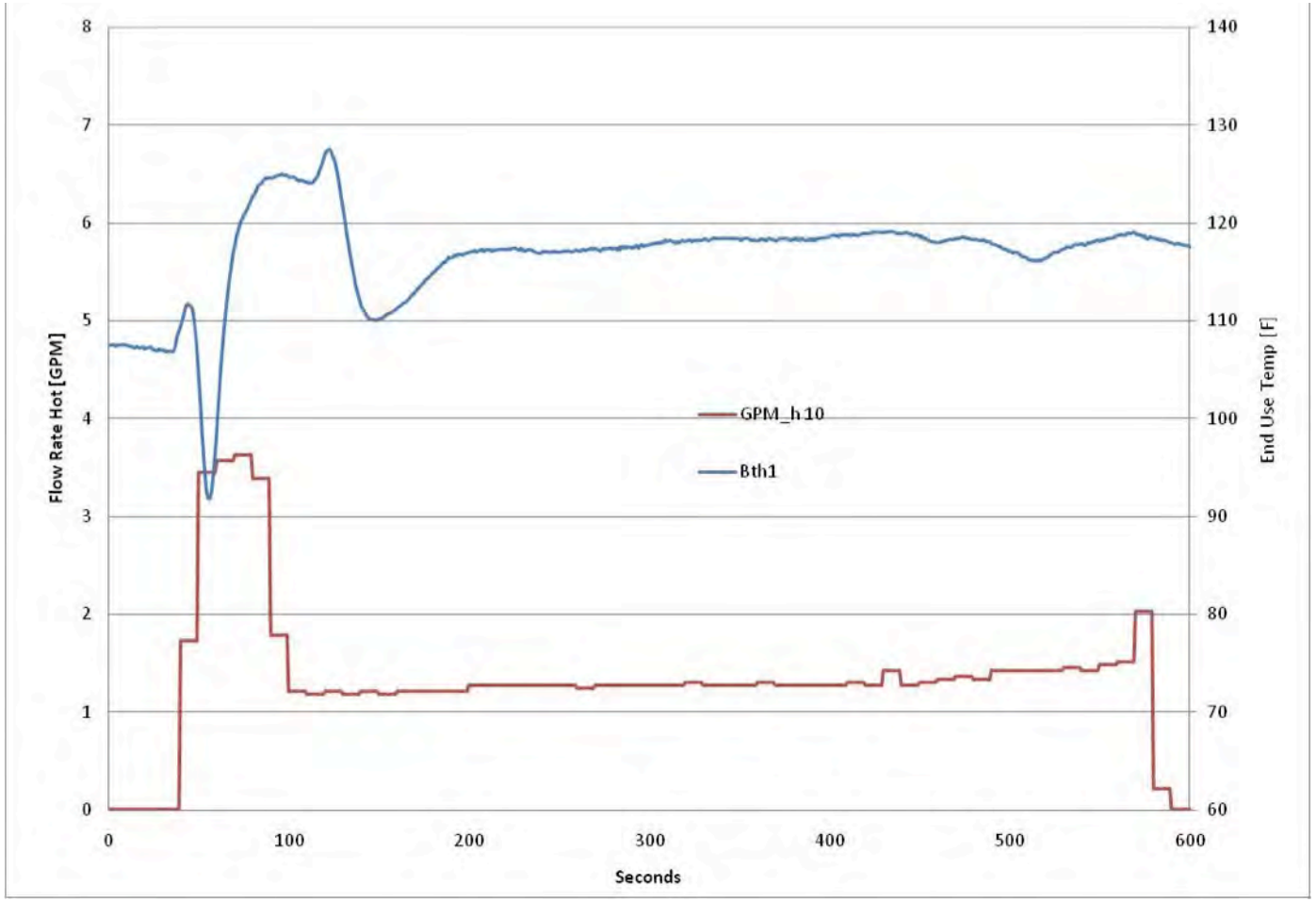


Temperature Profiles

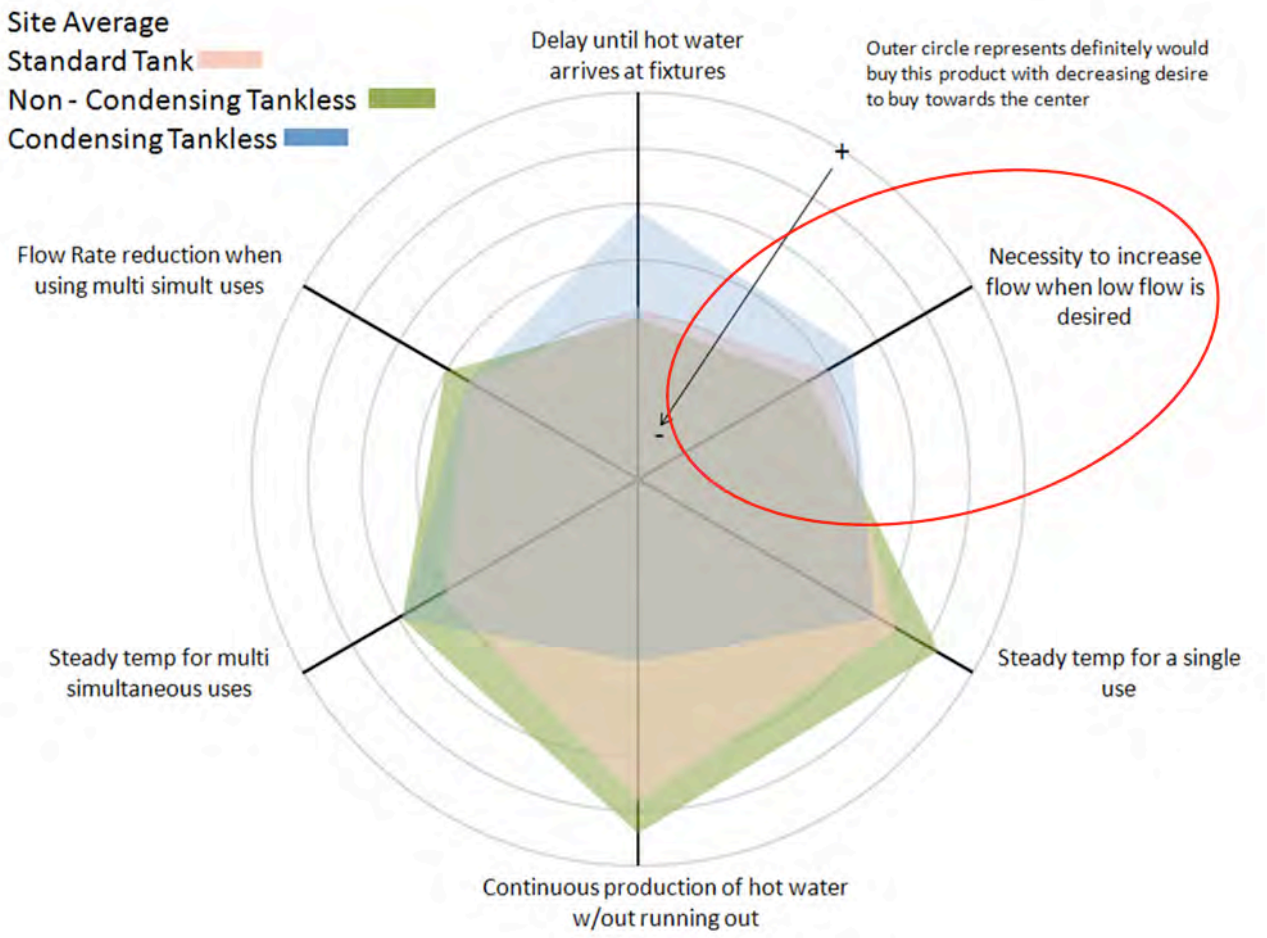




Cold Water Sandwich



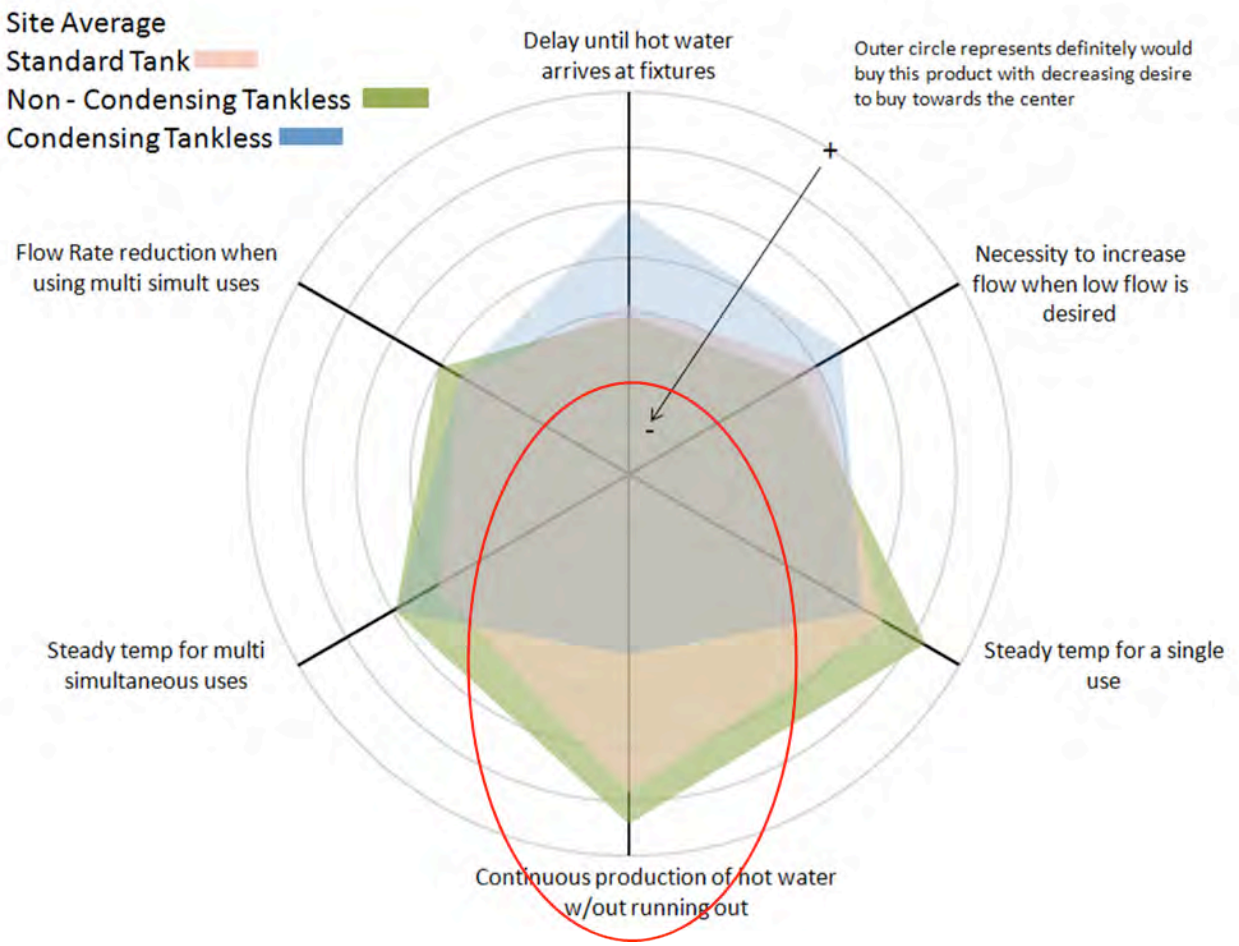
Home Owner Survey



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 loses are increased for these units

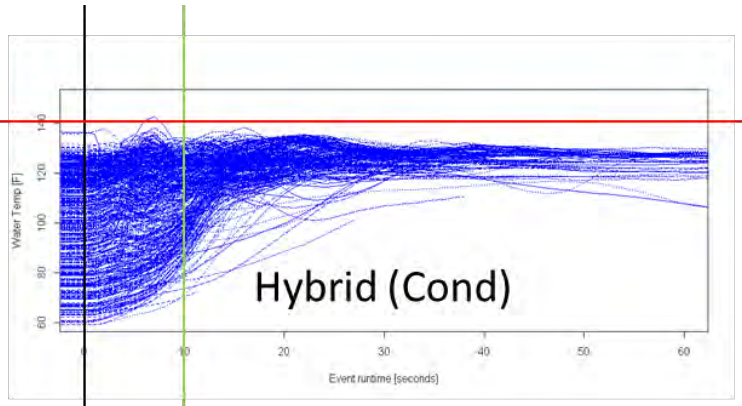
Home Owner Survey

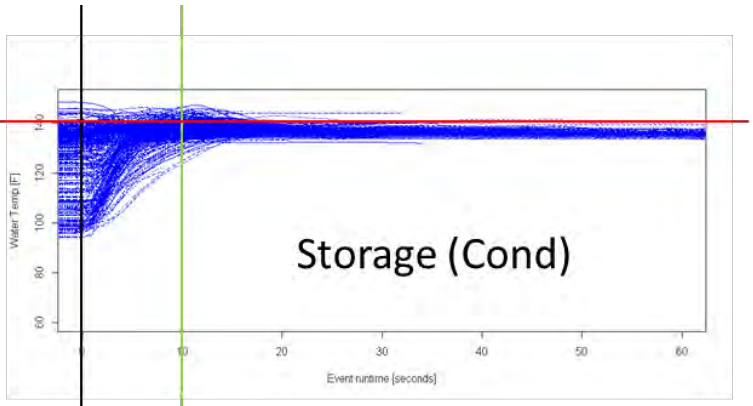


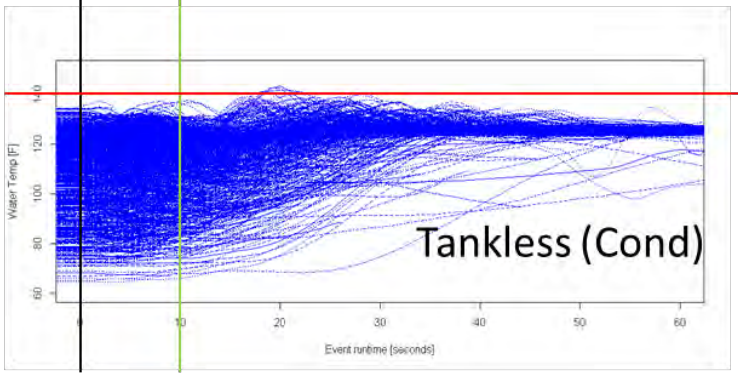
Gas Hybrid Water Heaters

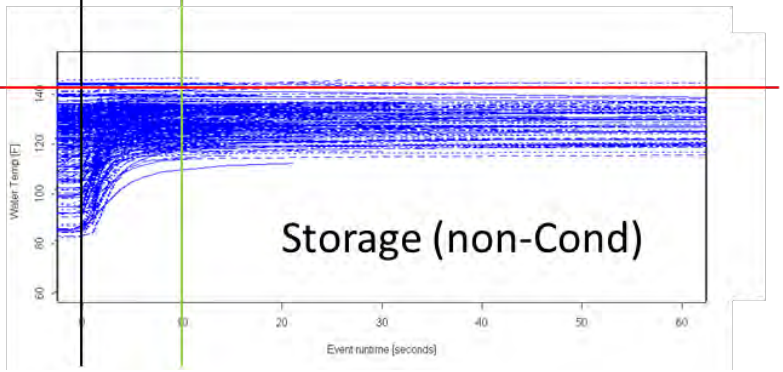
- Types
  - Small tank (0.5 to 2 gallon) and big burner (up to 199,000 Btu/hr)
  - Medium tank (around 20 gallon) and medium burner (100,000 Btu/hr)
- EF 85% to 95%
- Balances benefits and drawbacks of tanks and tankless
  - Water delivery
  - Stand by Loses

Water Delivery Temperature



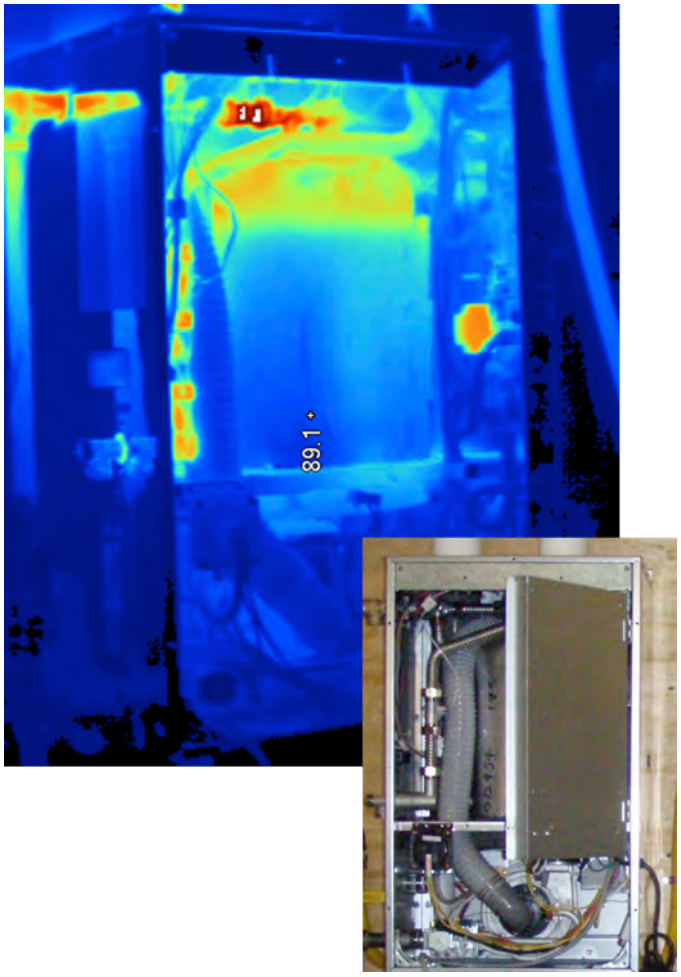






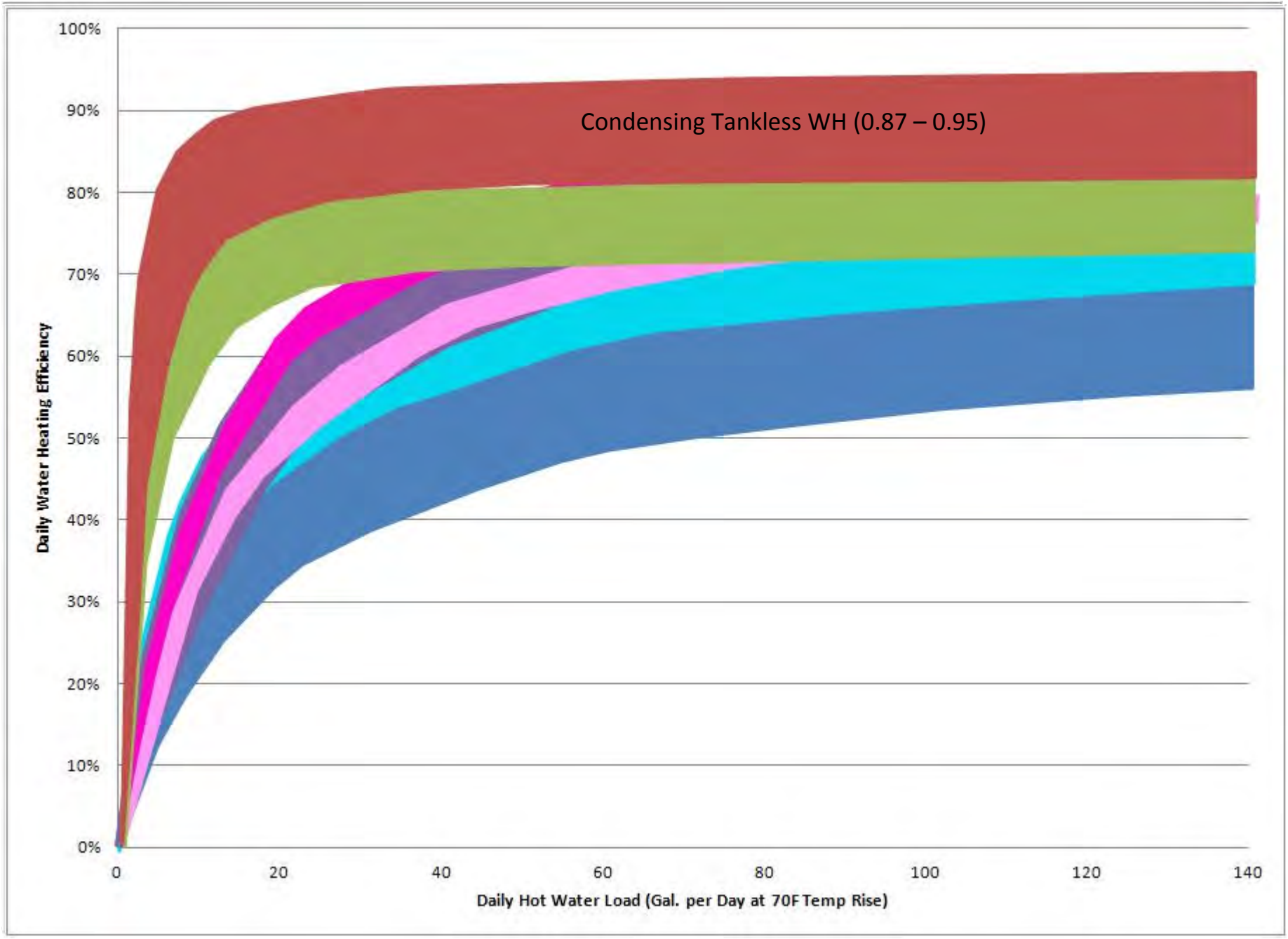
Stand-by Loses

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

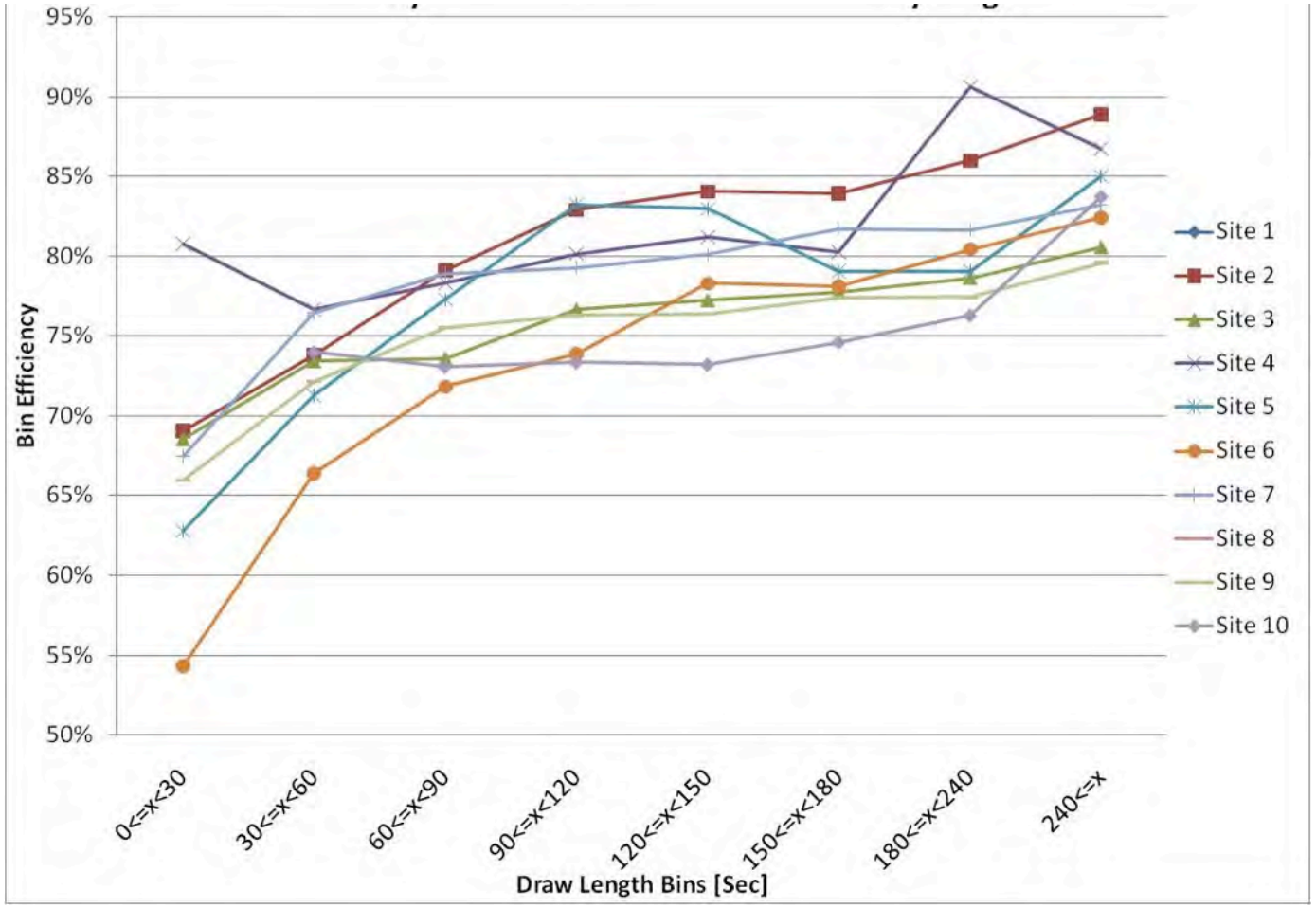


Gas Water Heater Comparison

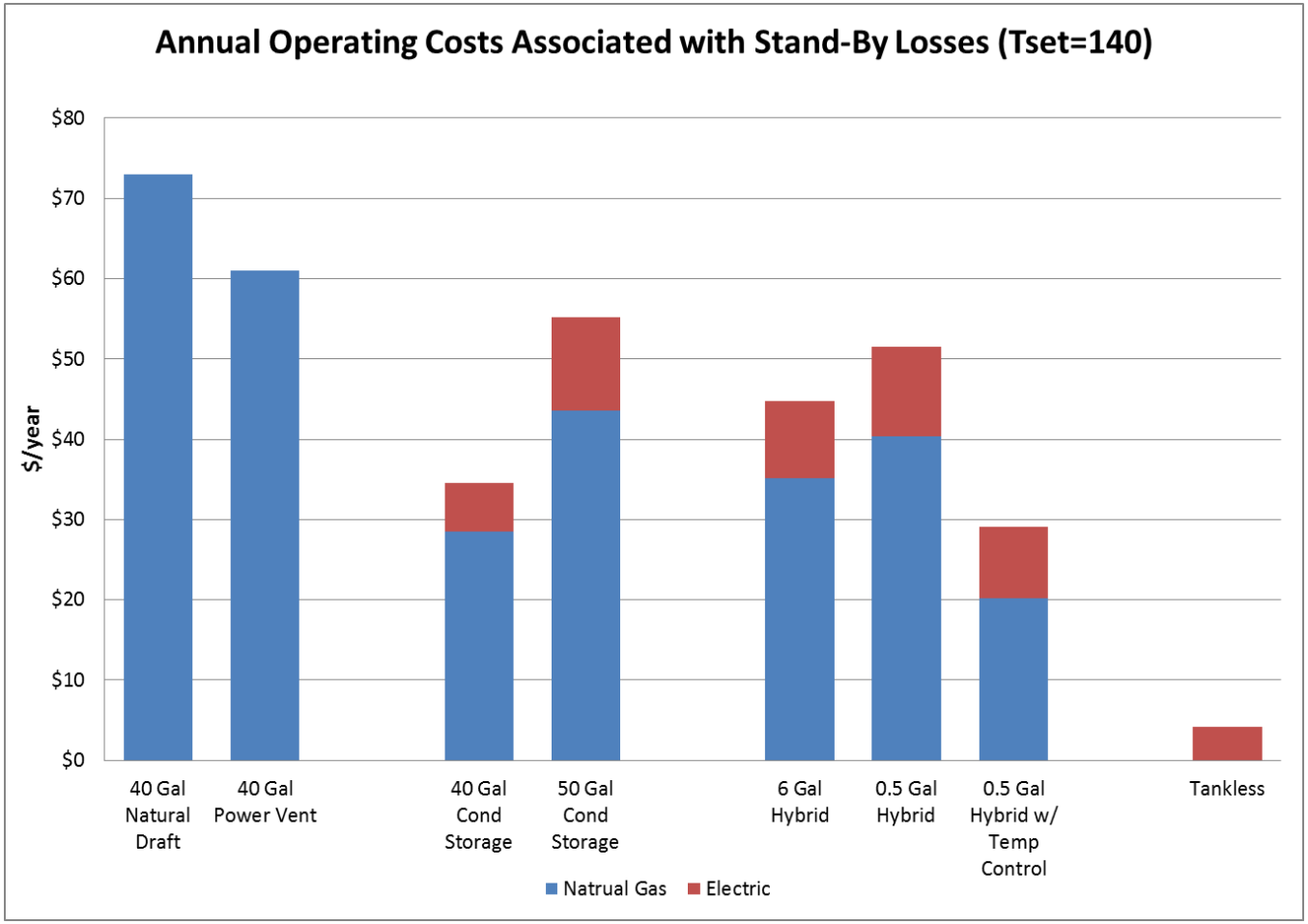
- Efficiency
- Installation
- Safety
- Economics


Condensing Tankless WH (0.87 – 0.95)
Daily Water Heating Efficiency
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
20
40
60
80
100
120
140
Daily Hot Water Load (Gal. per Day at 70F Temp Rise)

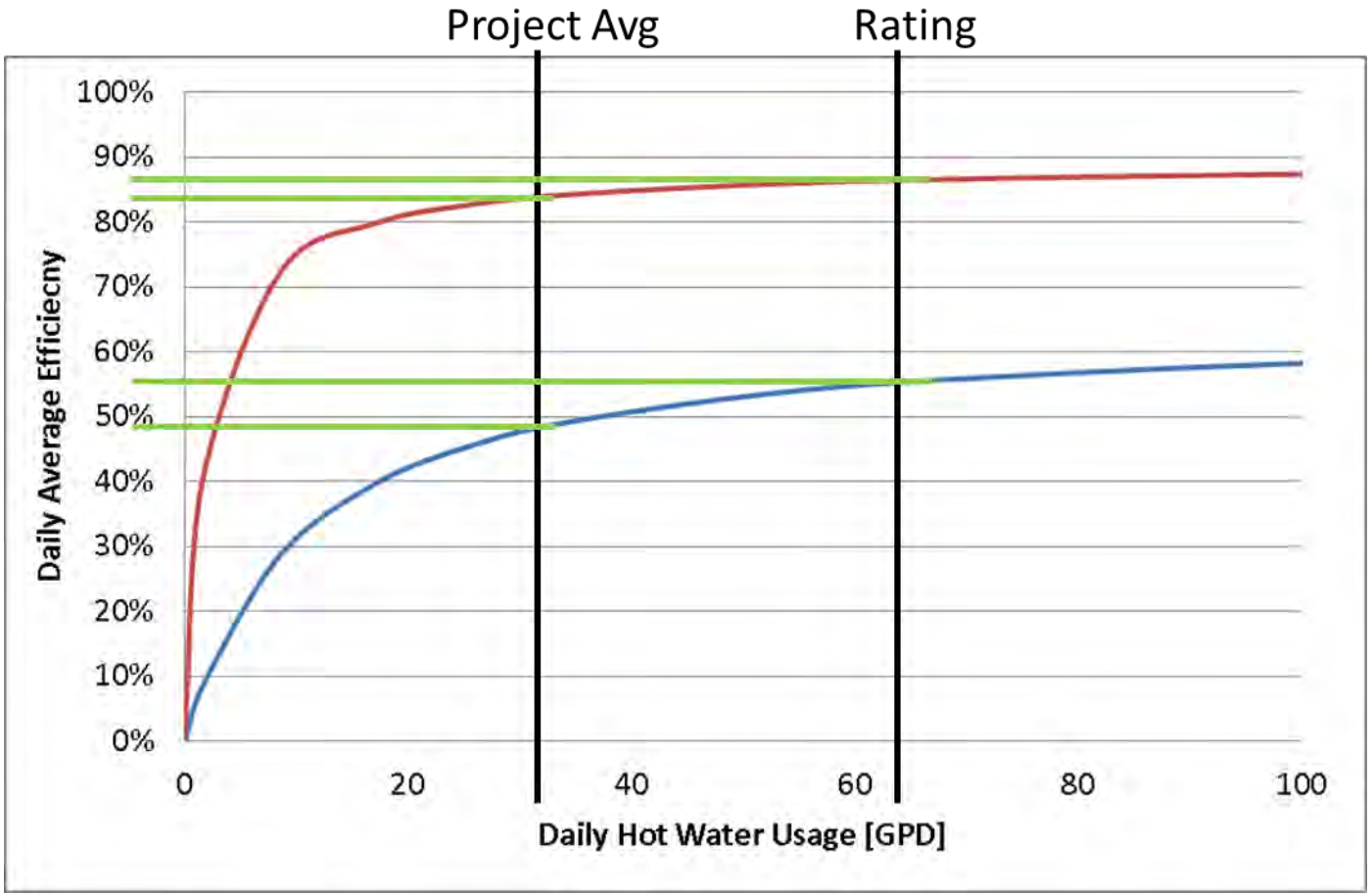
Tankless Efficiency by Draw Length



Impact of Stand-by Loss

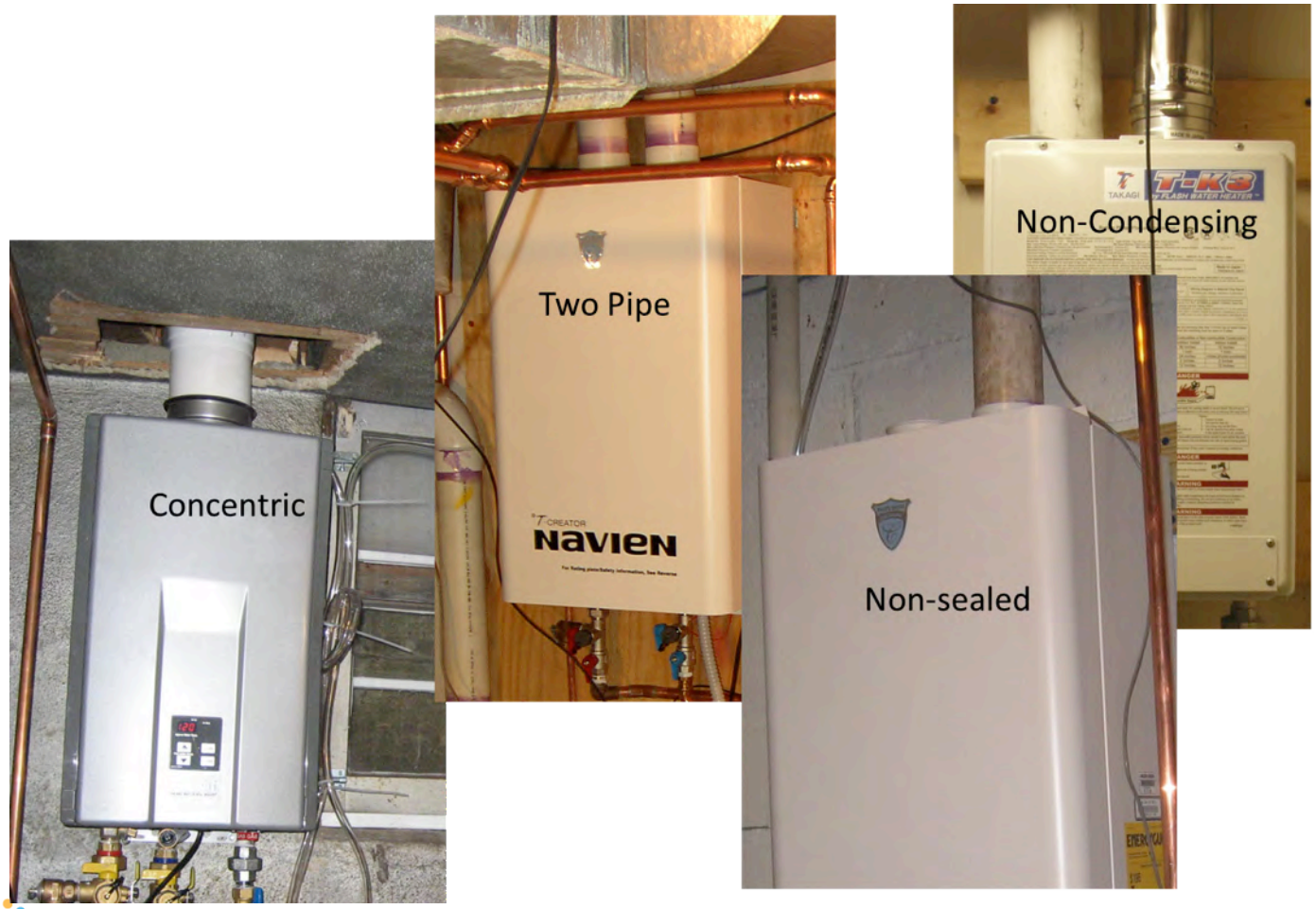


Impact of Stand-by on Efficiency



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

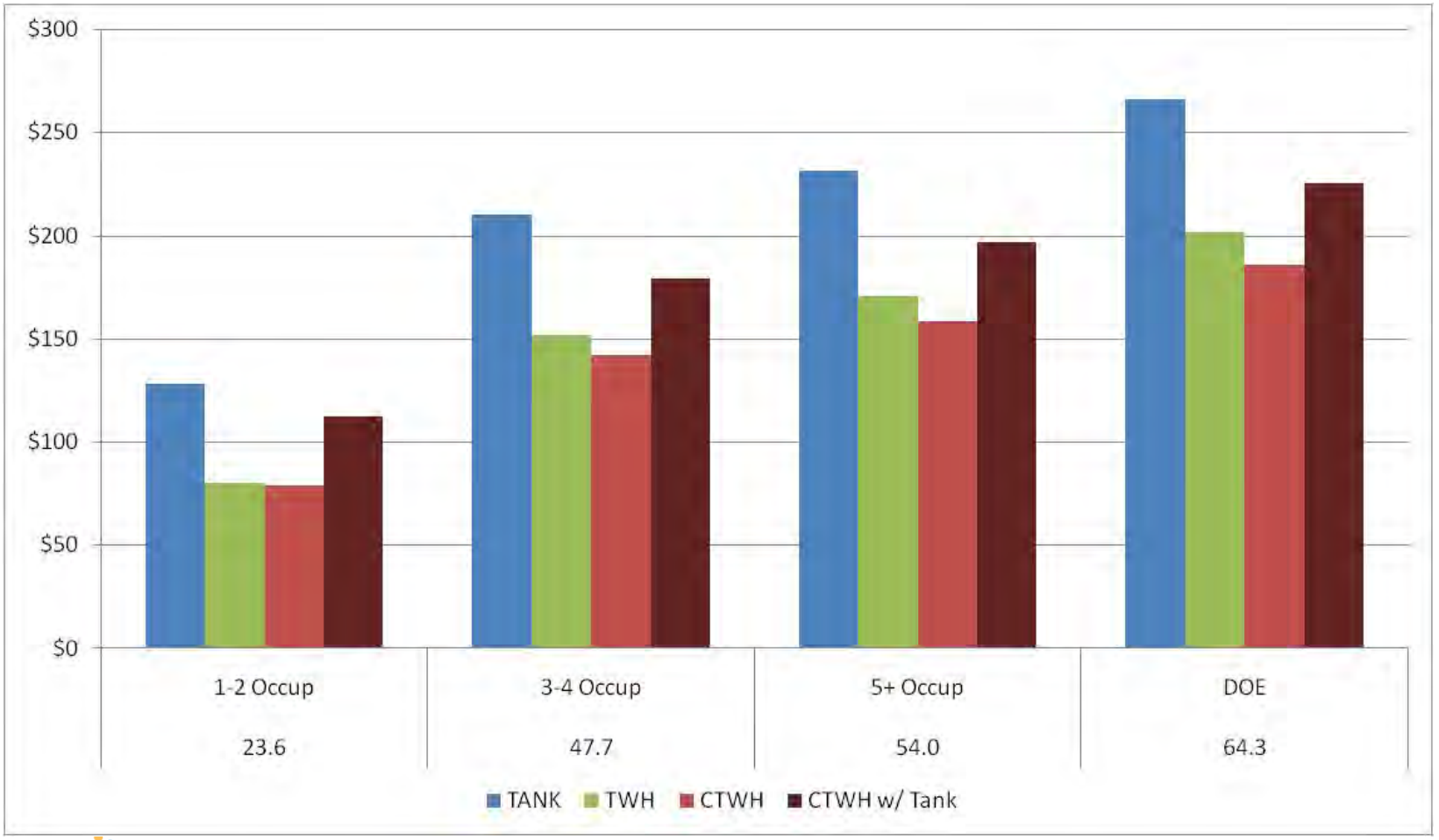
Electrical

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


$300
$250
$200
$150
$100
$50
$0
1-2 Occup
23.6
3-4 Occup
47.7
5+ Occup
54.0
DOE
64.3
TANK
TWH
CTWH
CTWH w/ Tank

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

PV Required | New Construction | Best Case Retrofit

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

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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 loses 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 loses compared to central system
- Whole house units available for small homes
  - Require larger electric hook ups
- Rated EF of 0.90 to 0.95

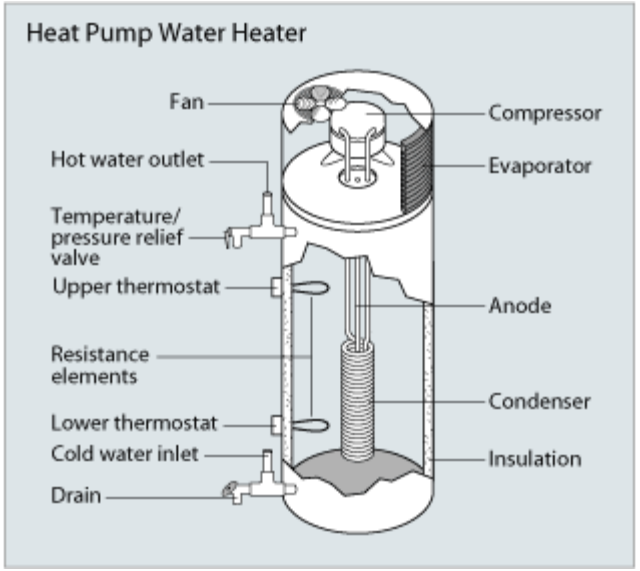
Distribution efficiency

- 5% to 27% of hot water is from draws where fixture is never gets hot (by volume)
- Draws lost 2-8 ºF, 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 loses are very small

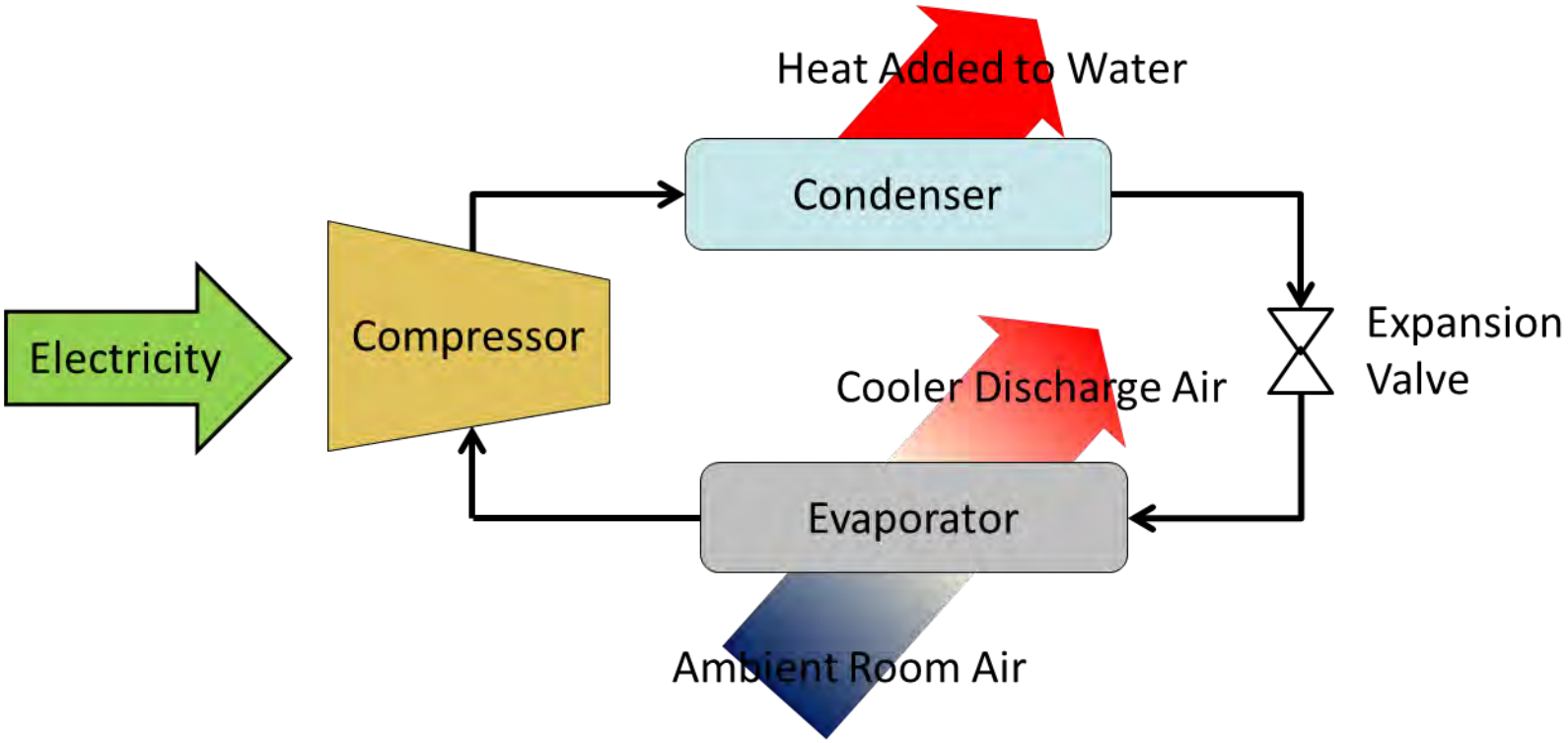
- Point of use heaters can reduces these loses to almost zero

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

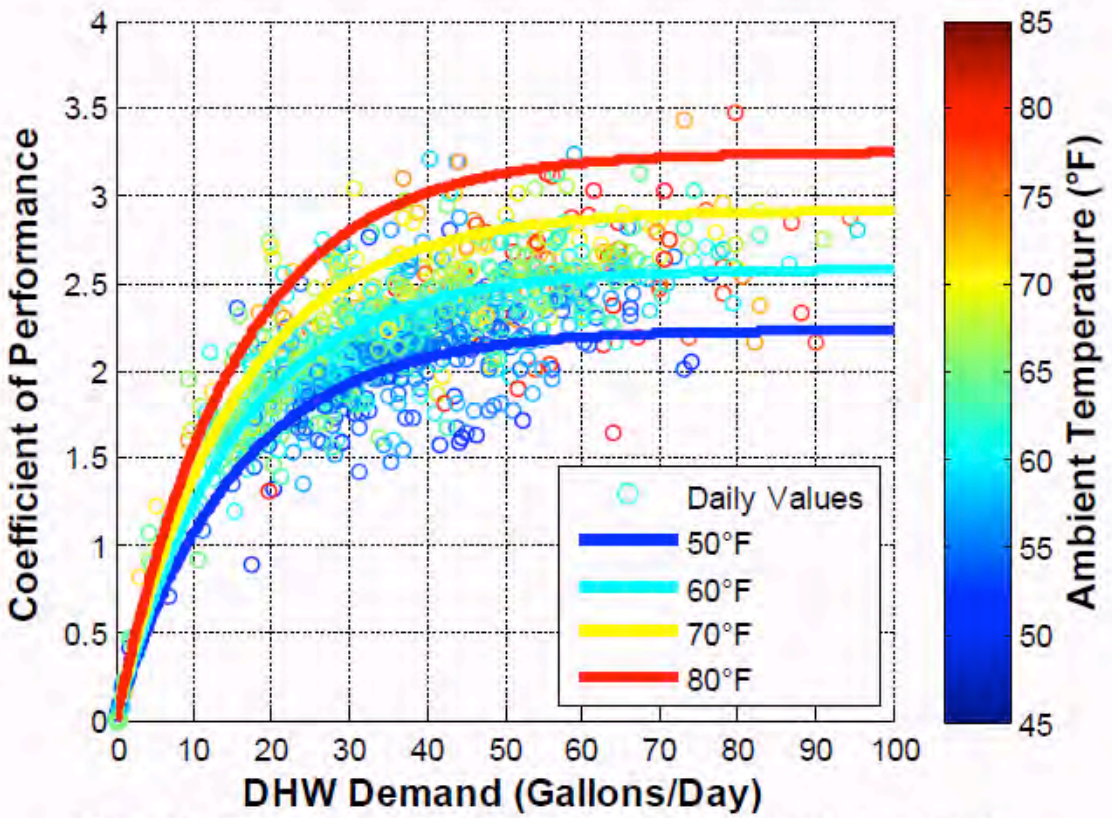


Figure 5. Efficiency of a 50-gal HPWH operating in heat pump mode

From: Steven Winter 2011 Measure Guideline for HPWHs

HPWH Space Conditioning Impact

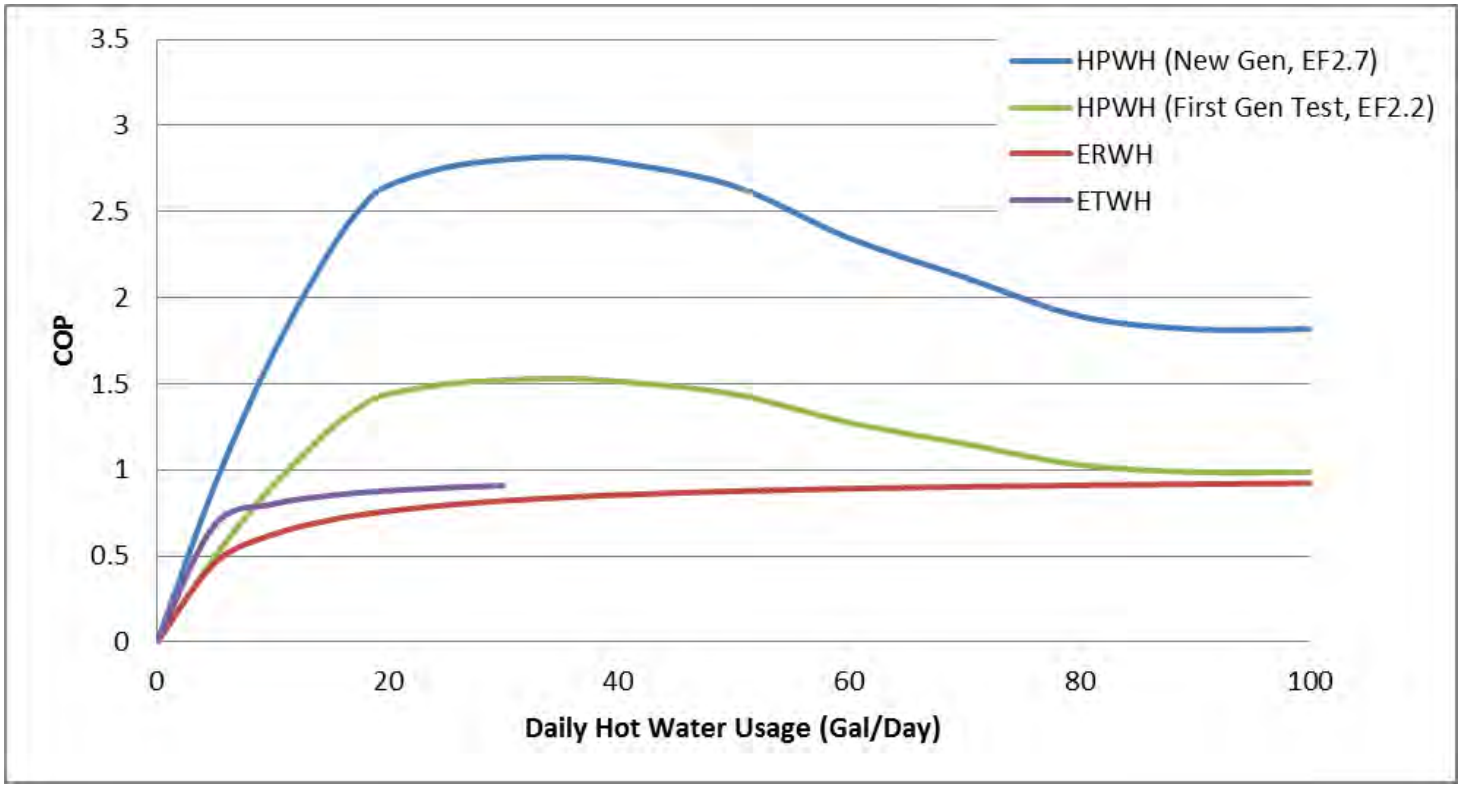
- Lots of modeling around the country still need DATA!!
- Lots of variables:
  - Installation location
    - In conditioned space – Max effect
    - In garage – No effect
    - In semi-conditioned (basement/craw space) – secondary effect
  - Conditioning load of house and heating equipment
    - Efficiency,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

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

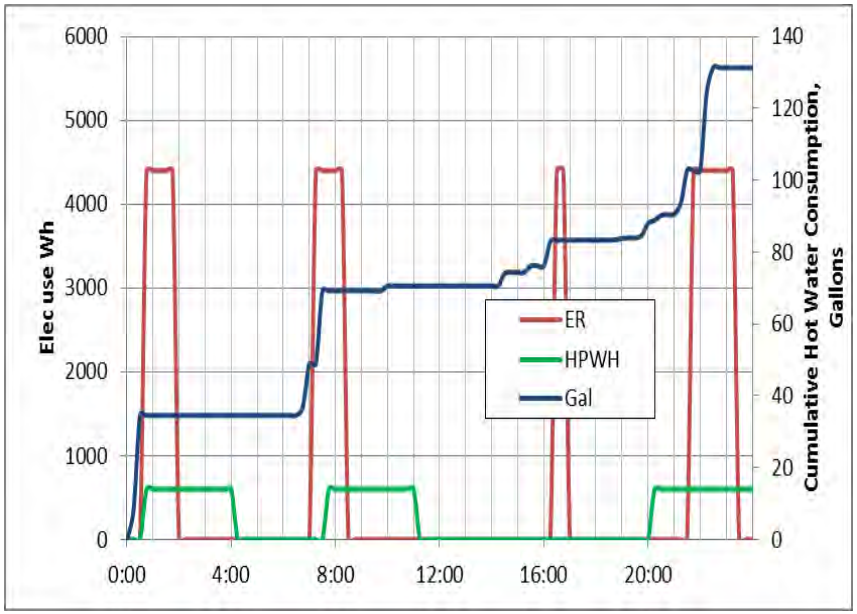
COP for electric water heaters

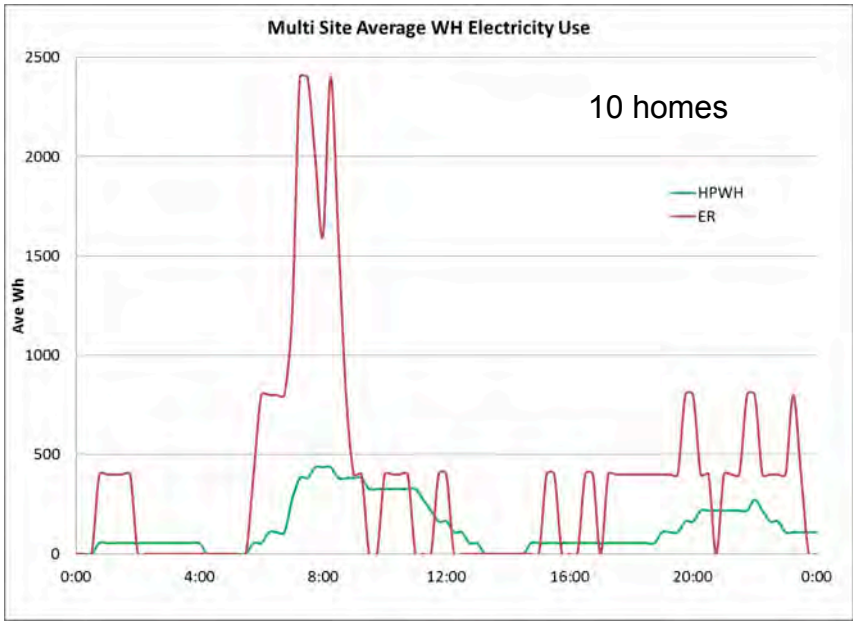


Paybacks

- HPWHs on average save $250 per year
- Simple paybacks in typical homes of about 3 years
- CEE developing savings and payback tools for MN CARD
  - Watch mncee.org for developments
  - Tool will include impacts of
    - Installation location
    - Impact on space heating load
    - Ambient temperatures
    - And more…
- Typical Annual Electric Bill 90% = $650
- Typical Annual Gas Bill 60% = $250

Peak load energy consumption





What to look for in the future

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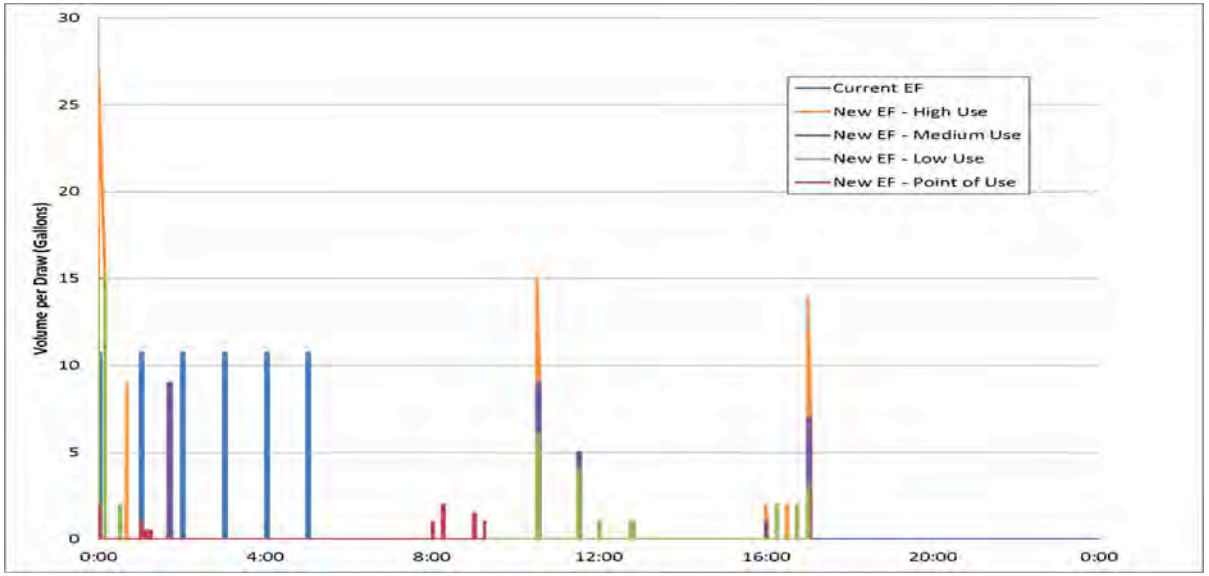
DOE Energy Factor Rating

- Likely changes
  - New hot water usage pattern
  - Multiple daily volume categories by WH size
  - One rating for a larger range of WHs
  - Improved accuracy
  - Controls?



New Products

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

THANK *you!*

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Potential Plumbing Code Changes

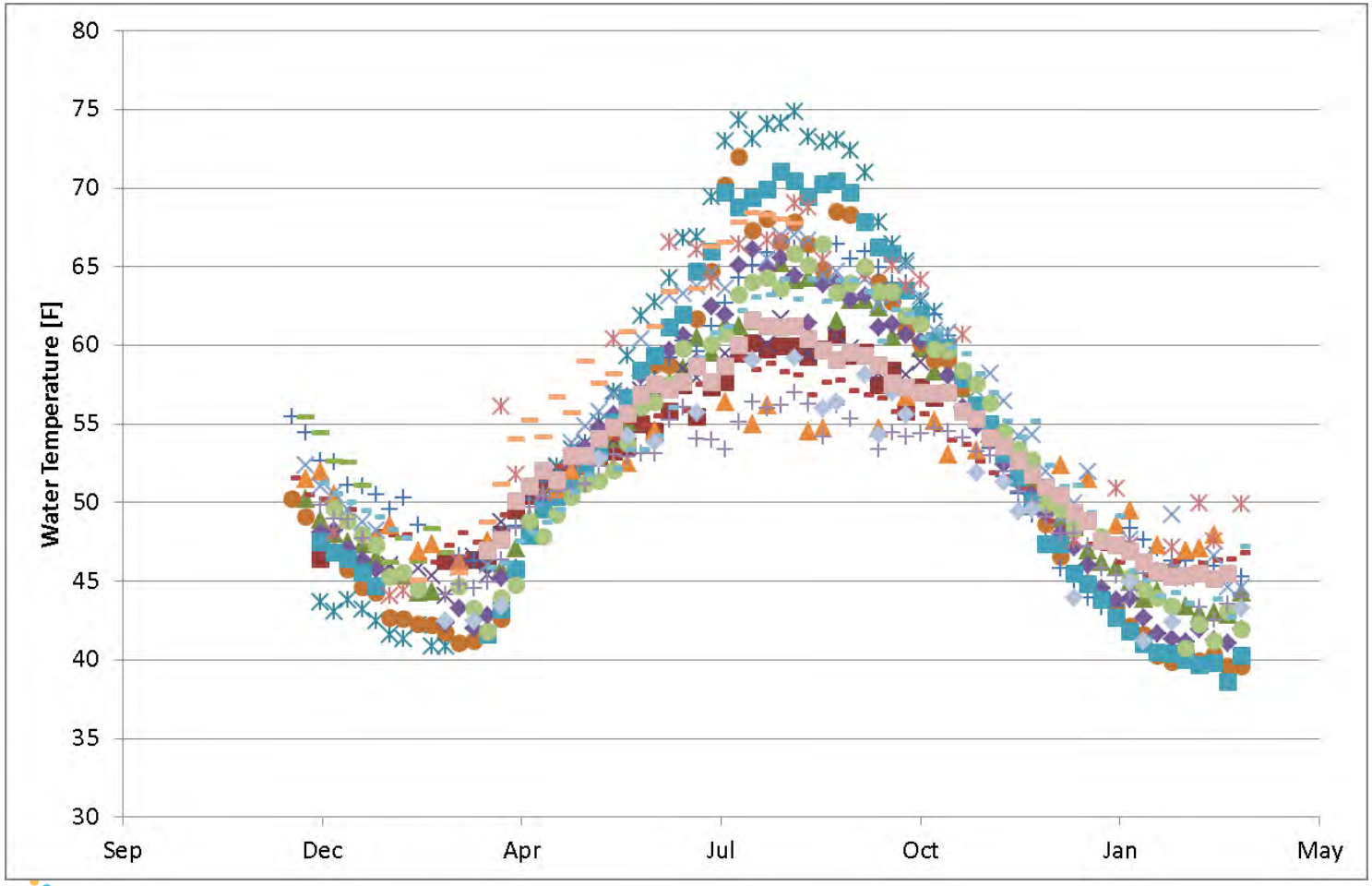
- Allowing smaller pipe diameter
- Requiring low water volume between WH and fixtures
- Pipe insulation guideline/requirements
- Recirculation controls

- 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 costumer 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