IBACOS

Domestic Hot Water Research

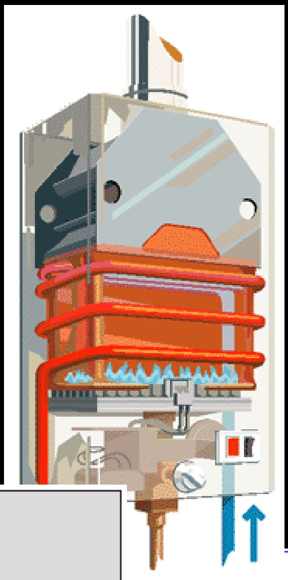
Research conducted by Bill Rittelmann

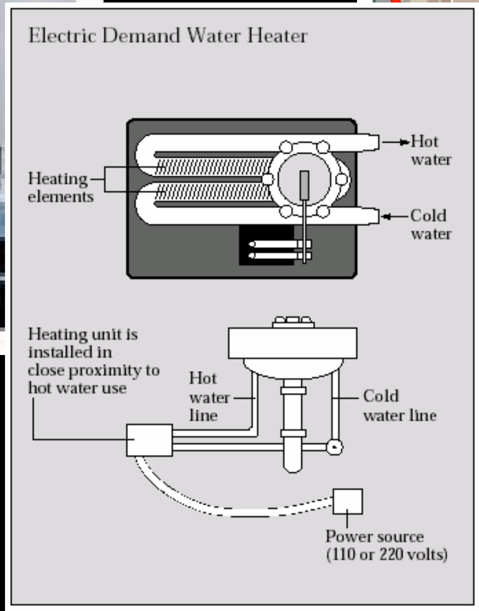
Presented by Duncan Prahl

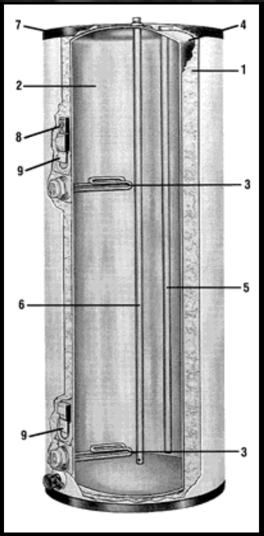
Partners for High Performance Homes Meeting

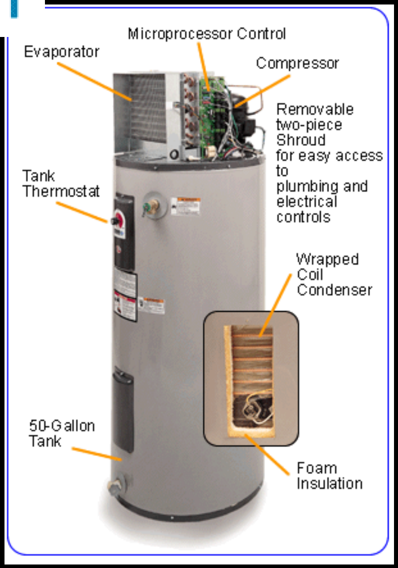
Westminster, CO, June 23, 2005

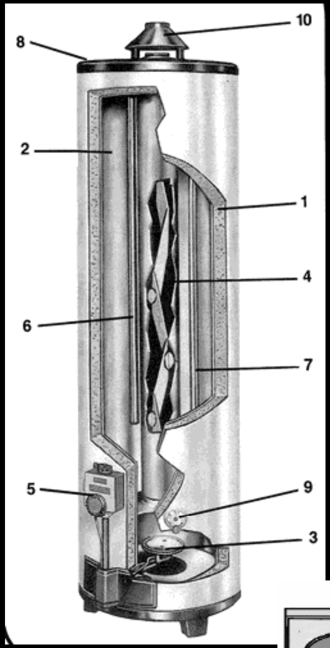
DHW Systems: Current Technologies

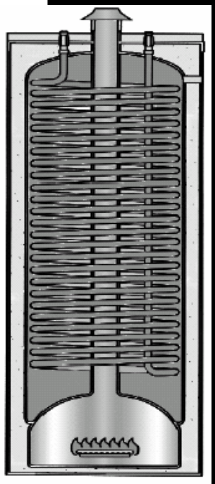












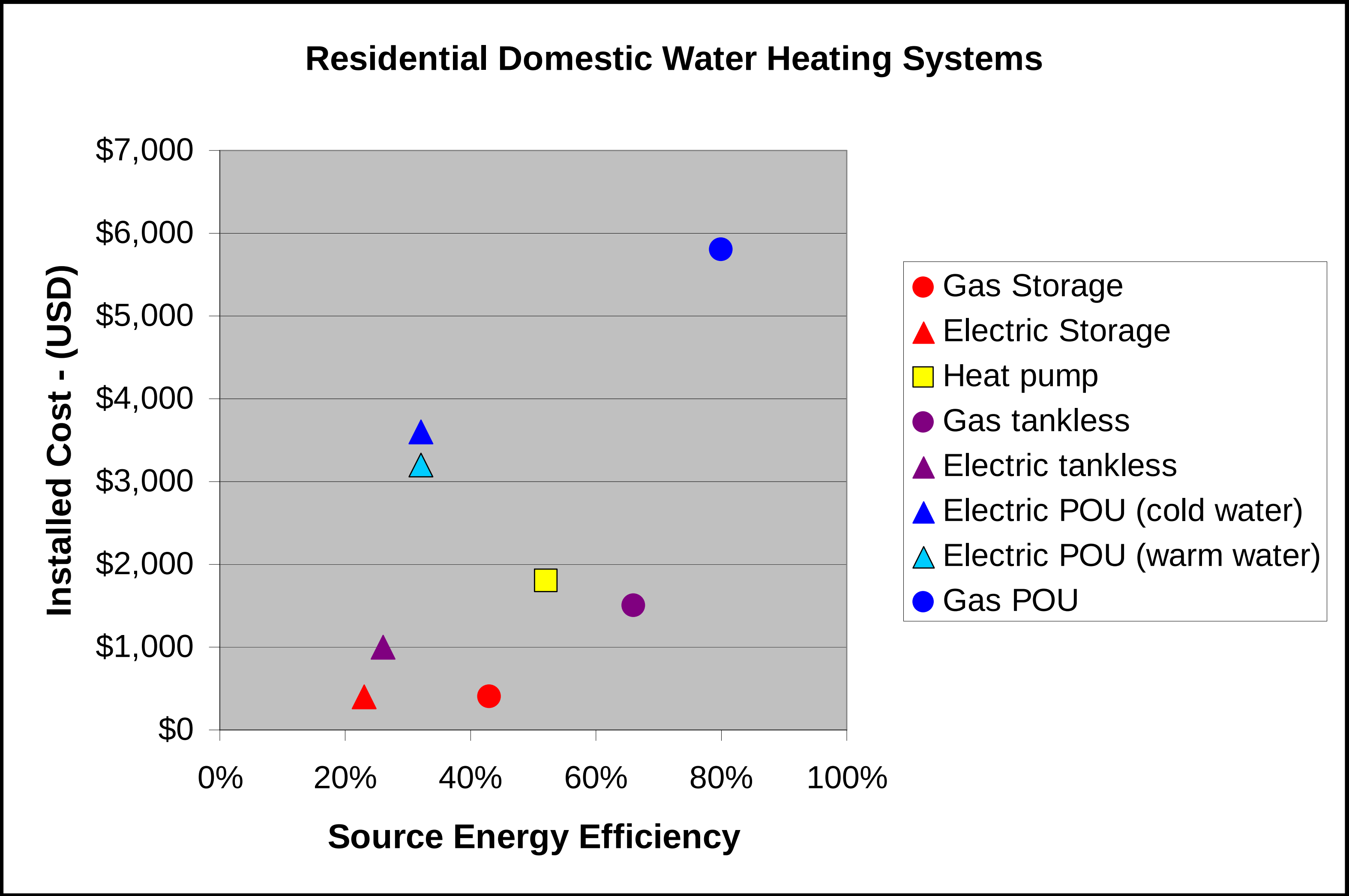
DHW Systems: Current Technologies

Product Class	Efficiency Factor (EF)		
	NAECA 2004 Minimum	GAMA Maximum	DOE* Maximum
Gas-Fired Storage (40 gal.)	0.54	0.64	0.71
Oil-Fired Storage (32 gal.)	0.53	0.68	0.61
Electric Storage (50 gal.)	0.86	0.95	0.91
Heat Pump Storage (50 gal.)	0.86	2.37	N/E
Gas-Fired tankless	0.62	**0.82**	**0.96**
Electric tankless	0.95	**0.98**	**1.00**
Integrated Water/Space (CAef)	0.54	0.86	N/E

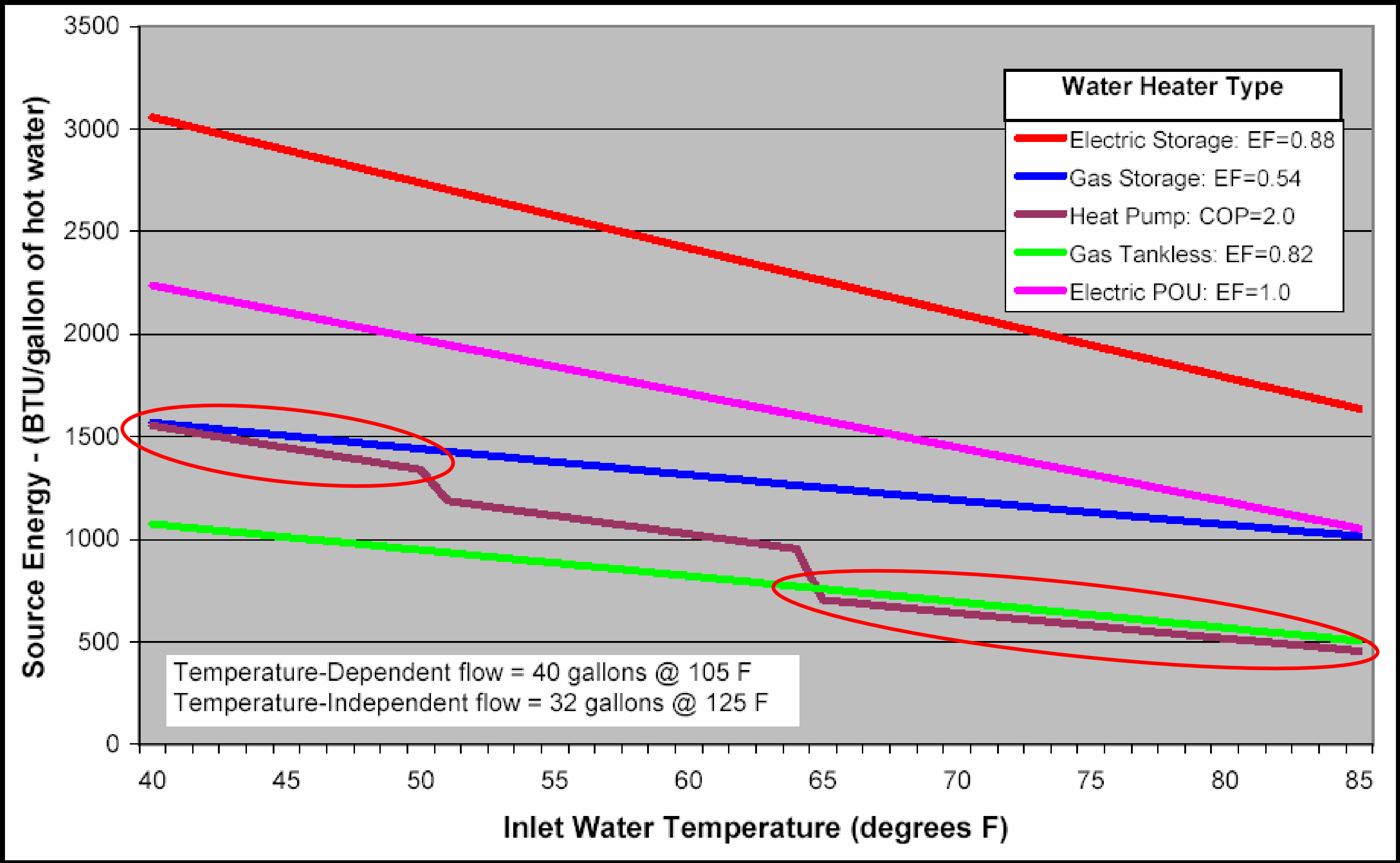
* (DOE, 2000)

N/E – Not Evaluated

DHW Systems: Current Technologies



Efficiency vs Inlet Water Temp



DHW Systems: Sizing Methods

BRADFORD WHITE

RightSpec™ Residential Water Heater Sizing

Cancel / Main Menu Submit

To override a default parameter, select from the dropdown list:

Fuel	Natural Gas	Vent Type	Standard
Cold Water Inlet Temp	40°F	California Installation	No
Number of Bathrooms	2	Customer	IBACOS
Number of People	4	Job Name	
Whirlpool Tub Capacity	None	Comments	
Dishwasher	Yes		
Washing Machine	Yes		

Note: Large homes may require a return circulation system. If your requirements exceed the c... plumbing contractor.

Cancel / Main Menu Submit

What Size Water Heater Do You Need?

Household Size		GAS*	ELECTRIC
5 OR MORE	Regular Demand	50 GAL. (50, 60 or 75kbtu Input)	80 GAL.
	High Demand	75 GAL.	120 GAL.
3 TO 4	Regular Demand	50 GAL.	50 or 65 GAL.
		...L. (...u Input)	80 GAL.
		...L.	40 GAL.
		...L.	50 GAL.

Other sizes are available. This chart is designed to help you select the appropriate water heater capacity. Your use may vary. *Regular Demand* capacities are based on a home with a washing machine and an automatic dishwasher. *High Demand* capacities meet the hot water needs of teenagers, whirlpool tubs, spas, and oversized baths. Always anticipate your family's future needs when selecting your water heater.

Table 2 Minimum Permissible Water Heater Size

Number of Baths	1-1.5			2-2.5				3-3.5		
Number of Bedrooms	1	2	3	2	3	4	5	3	4	5
GAS										
Storage–Gal	20	30	30	30	40	40	50	40	50	50
1,000 Btu Input	27	36	36	36	36	38	47	38	38	47
1-Hr Draw Gal	43	60	60	60	70	72	90	72	82	90
Recovery–Gal/Hr	23	30	30	30	30	32	40	32	32	40
ELECTRIC										
Storage–Gal	20	30	40	40	50	50	66	50	66	66
Kilowatts–Input	2.5	3.5	4.5	4.5	5.5	5.5	5.5	5.5	5.5	5.5
1-Hr Draw Gal	30	44	58	58	72	72	88	72	88	88
Recovery–Gal/Hr	10	14	18	18	22	22	22	22	22	22
OIL										
Storage–Gal	30	30	30	30	30	30	30	30	30	30
1,000 BTU Input	70	70	70	70	70	70	70	70	70	70
1-Hr Draw Gal	89	89	89	89	89	89	89	89	89	89
Recovery–Gal/Hr	59	59	59	59	59	59	59	59	59	59

To estimate your peak hour demand:

1. Determine during what general time of day (morning, noon, evening) there is usually th... use of hot water in your home, keeping in mind the number of people in your home.
2. Using the following table, determine what your maximum usage of hot water in on... could be; this is your peak hour demand:

NOTE: This table does not estimate total daily hot water usage. As an example, an aver... 4 gallons of hot water is used each time dishes are washed by hand but, ... washed by hand are usually done 3 times a day. The average daily hot water... for hand dishwashing, 12 gallons, is about the same as the average hot water... for an automatic dishwasher, used once a day.

Use	Average Gallons of Hot Water per Usage		Times Used During One Hour		Ga... in
Shower	20	x	______	=	___
Bath	20	x	______	=	___
Shaving	2	x	______	=	___
Hands and Face Washing	4	x	______	=	___
Hair Shampoo	4	x	______	=	___
Hand Dishwashing	4	x	______	=	___
Automatic Dishwasher	14	x	______	=	___
Food Preparation	5	x	______	=	___
Wringer Clothes Washer	26	x	______	=	___
Automatic Clothes Washer	32	x	______	=	___
			TOTAL (Peak Hour Demand)		___

RightSpec™ Residential Water Heater Sizing Recommendations

Resize Job Main Menu

Click on Model Number to view spec sheet

...Saver ...endation #1	Energy Saver Recommendation #2	Energy Saver Recommendation #3
	1	1
...BN	M-I-504S6FBN	M-1-XR504T6FBN
...s	50 Gallons	48 Gallons
...TU Each	48,000 BTU Each	65,000 BTU Each
...agram	Piping Diagram	Piping Diagram
...s	92 Gallons	103 Gallons
...@ 90°F Rise	49 GPH @ 90°F Rise	67 GPH @ 90°F Rise
Annual Operating Cost (1): N/A	N/A	N/A
Approx. Storage Recovery: 73 Minutes	59 Minutes	43 Minutes
% of Demand Satisfied (2): 100%	108%	121%
Heater Height: 58 1/2"	58 1/2"	59 1/4"
Heater Diameter: 20"	20"	20"
Heater Vent Diameter: 3"	4"	4"

Notes: (1) % Based on First Hour Deliveries
(2) Sizings Based on ASHRAE 1999 HVAC Applications HUD-FHA Minimum Water Heater Capacities. The Suffix "6" represents Tank Warranty and may be substituted with "10". Most M-I models are equipped with 1" (25mm) non-CFC foam insulation. Other models available with 2" (51mm) non-CFC foam insulation. Ask your plumbing contractor.

DHW Systems: Event-Based Sizing

Key Concepts

- Temperature-dependent flow

  The hot water flow rate depends on the temperature of the cold and hot water. This includes showers, baths, some clothes washers, hand washing, etc.

- Temperature-independent flow

  The hot water flow is constant regardless of cold and hot water temperatures. This is characteristic of most clothes washers & dishwashers

DHW Systems: Event-Based Sizing

Key Concepts

- Energy Factor is not a constant

  The DOE Energy Factor is calculated under one set of laboratory conditions and does not account for different climates and usage.

- Inlet water temperature is not a constant

  Minimum annual inlet water temperatures vary more than 40°F across the country.

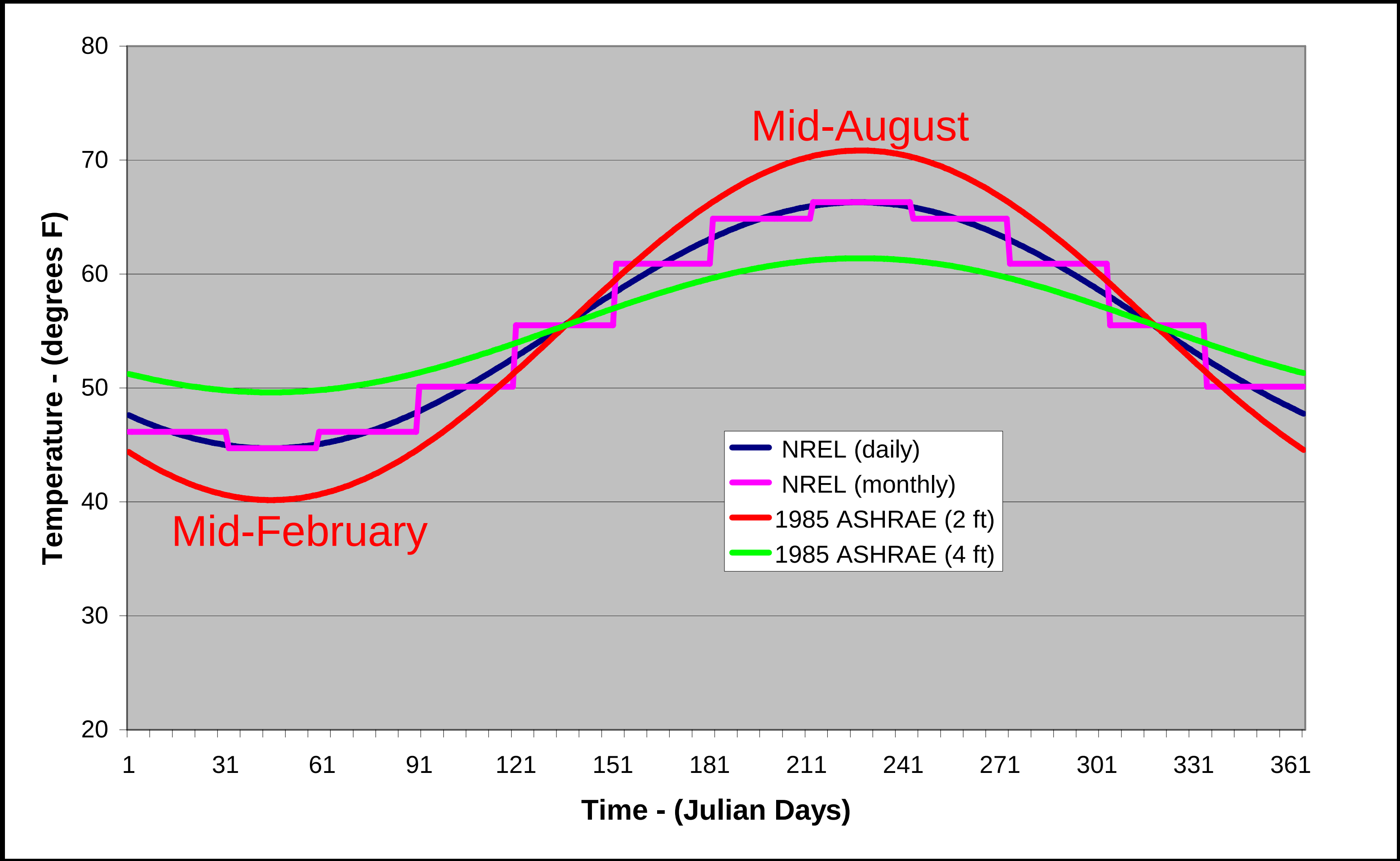
DHW Systems: Event-Based Sizing

Key Concepts

- "Event-based" method is more universal

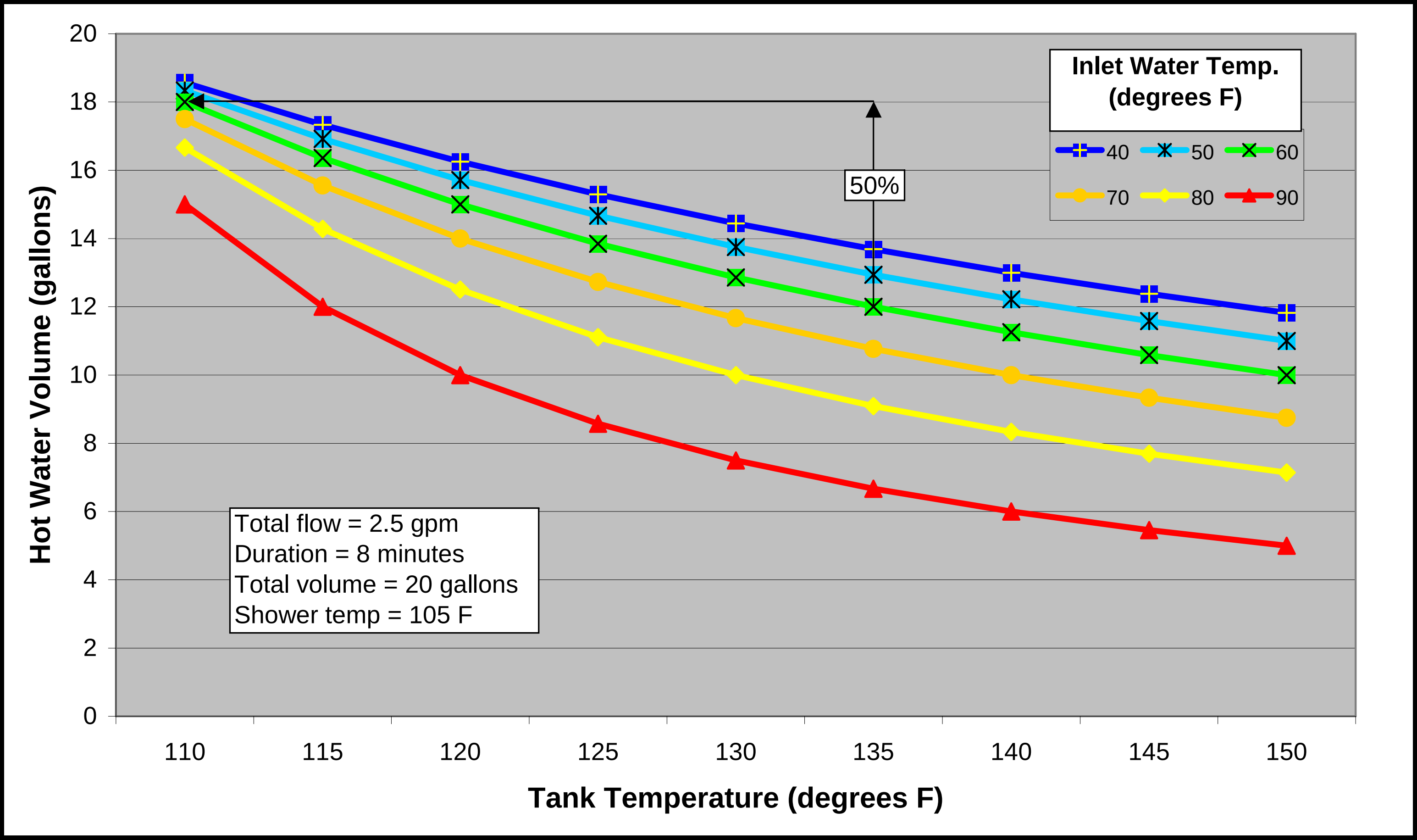
  The same event descriptions can be used to accurately size a water heater in Miami or Minneapolis. Although the resulting hot water demand will be quite different, the margin of error in the estimation is greatly reduced compared to "demand estimation" methods that use the same values regardless of water temperatures and end-use fixture descriptions.

DHW Systems: Event-Based Sizing



Inlet (mains) Water Temperature

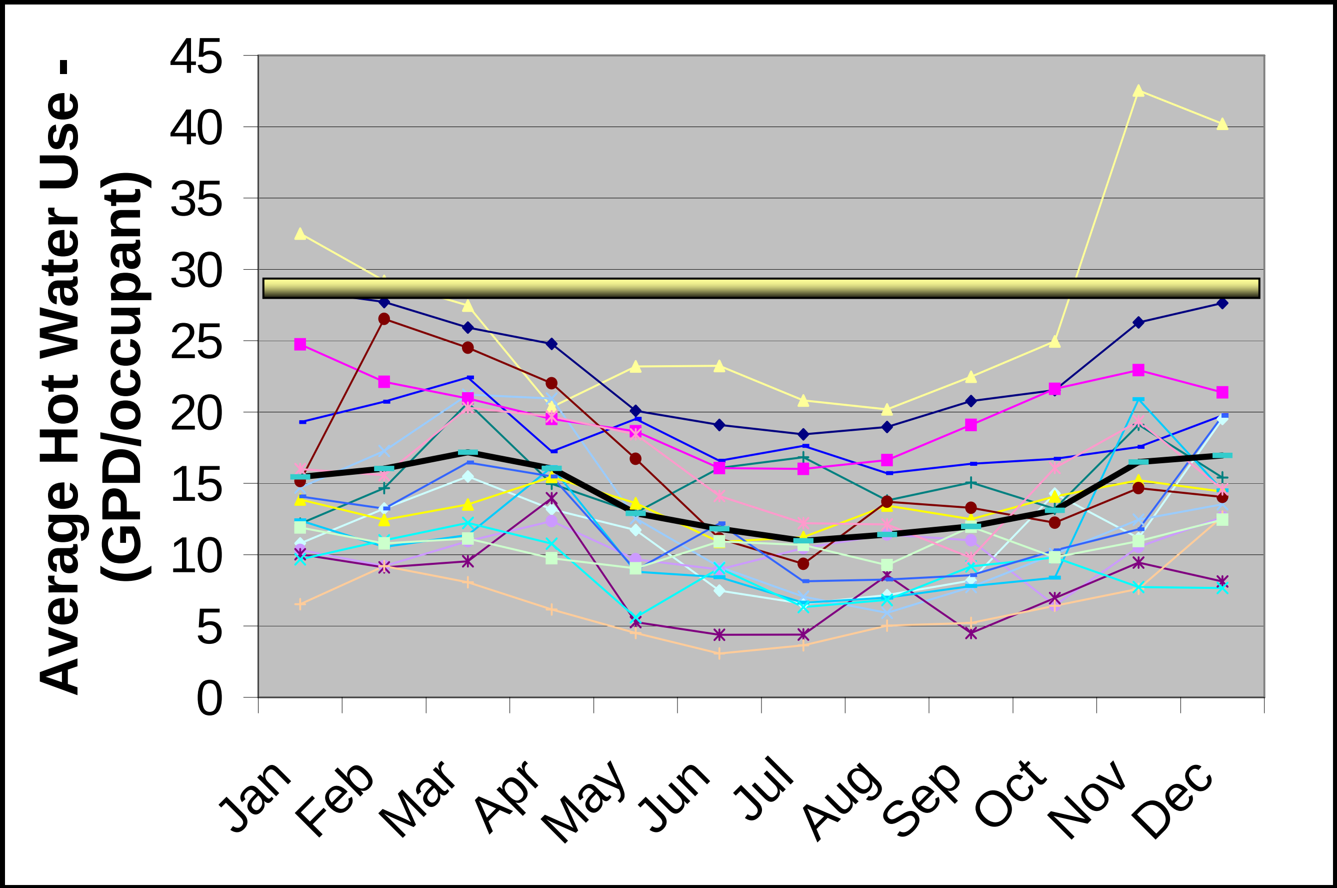
DHW Systems: Event-Based Sizing



Temperature-Dependent Flow

DHW Systems: Event-Based Sizing

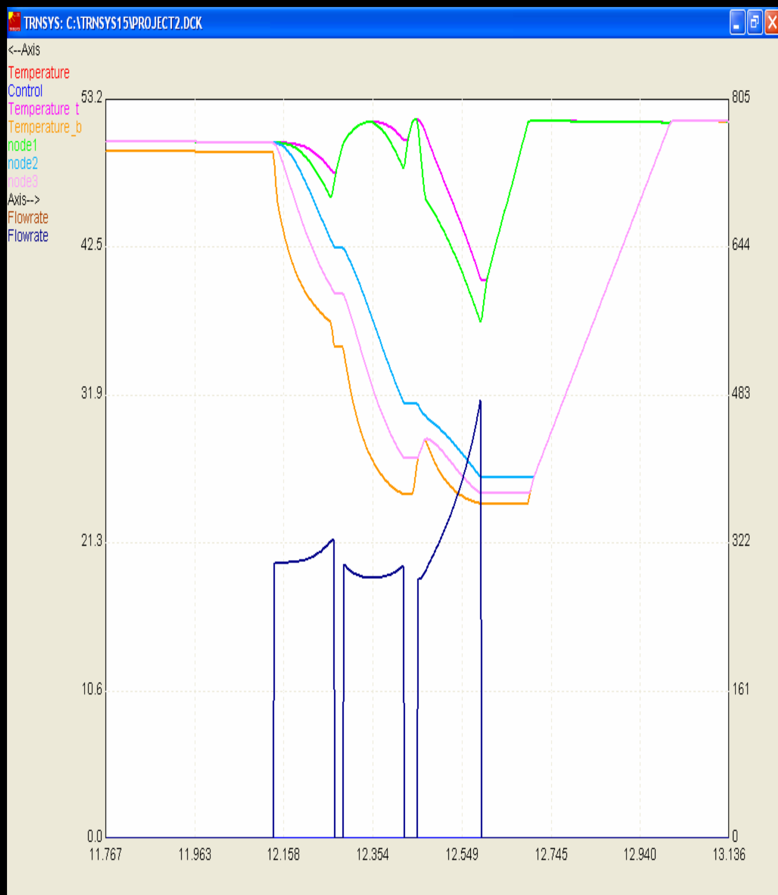
Monthly per Capita Hot Water Use

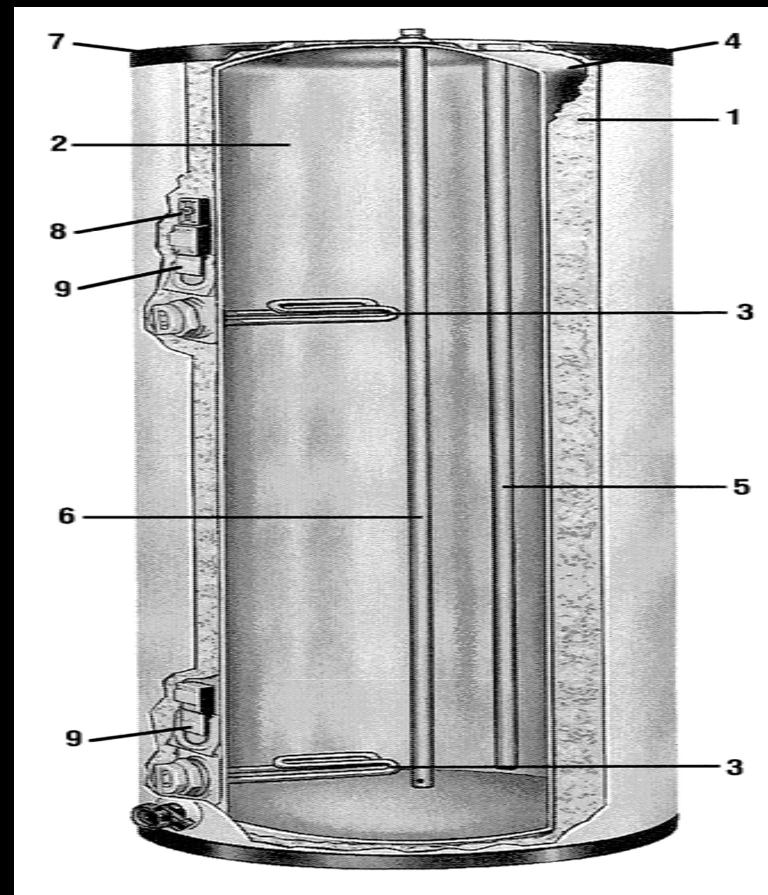


DOE standard usage rate = 28GPD

DHW Systems: Event-Based Sizing

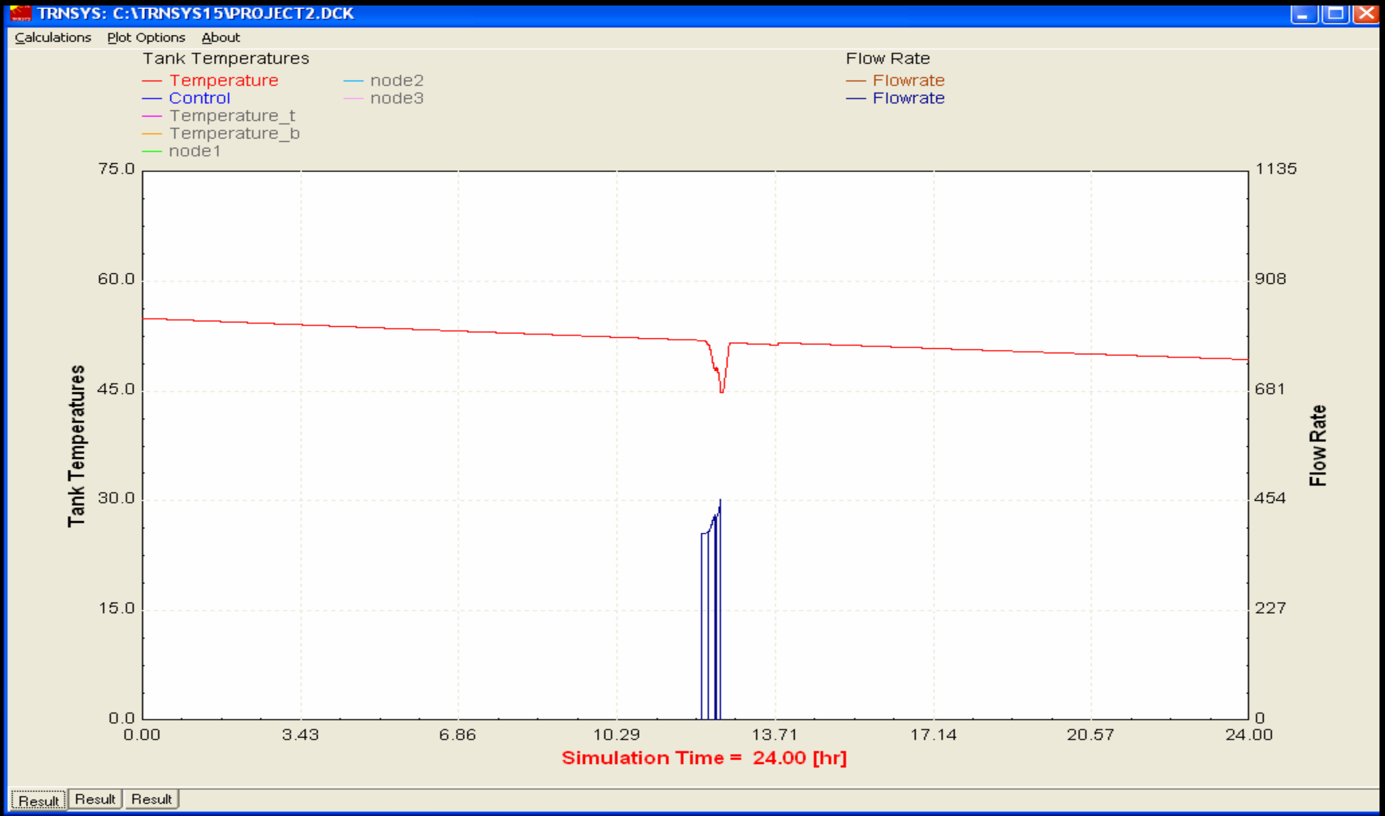
Use TRNSYS program to simulate DWH system





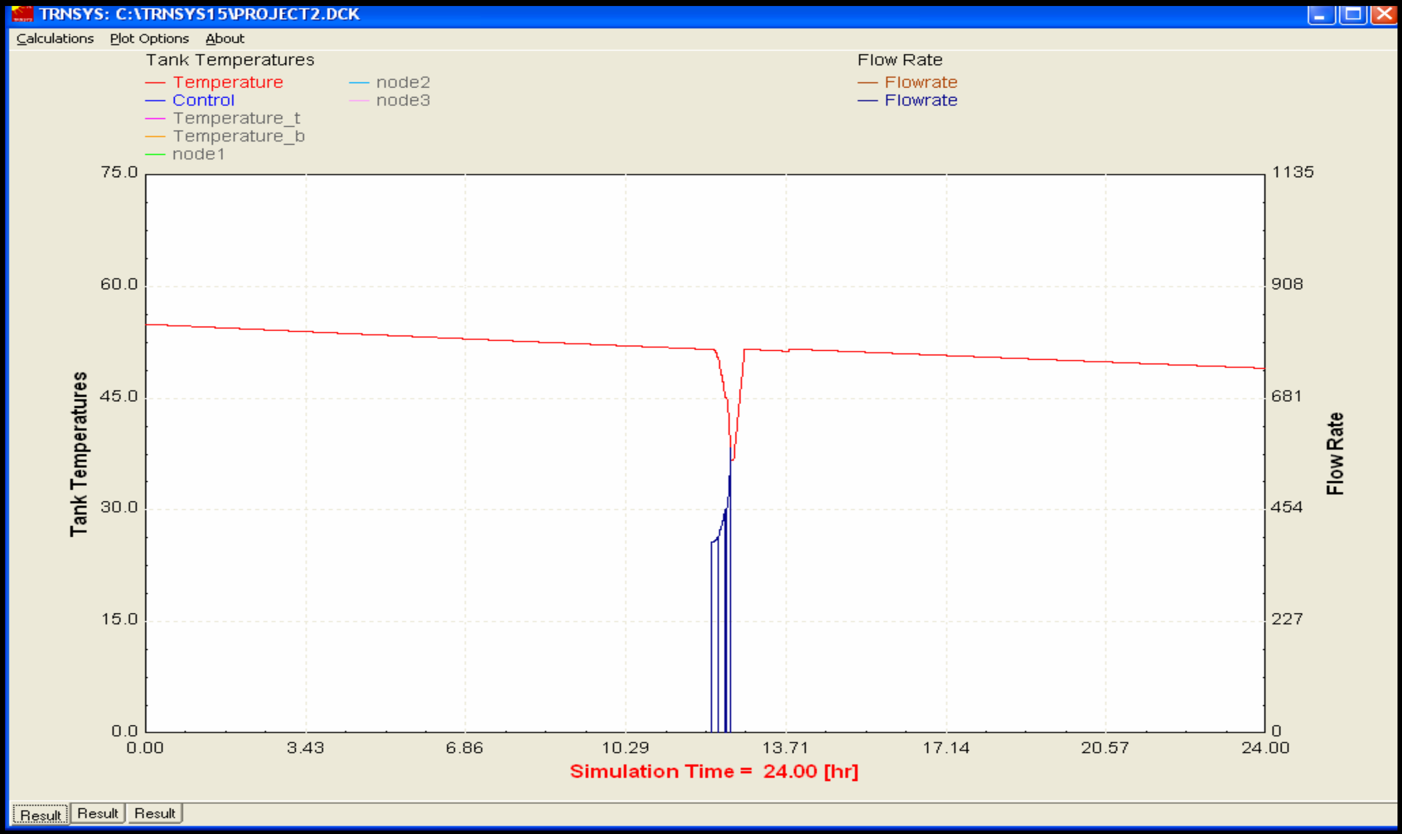
Detailed Temperature Profile and Hot Water Flow Rate

DHW Systems: Event-Based Sizing



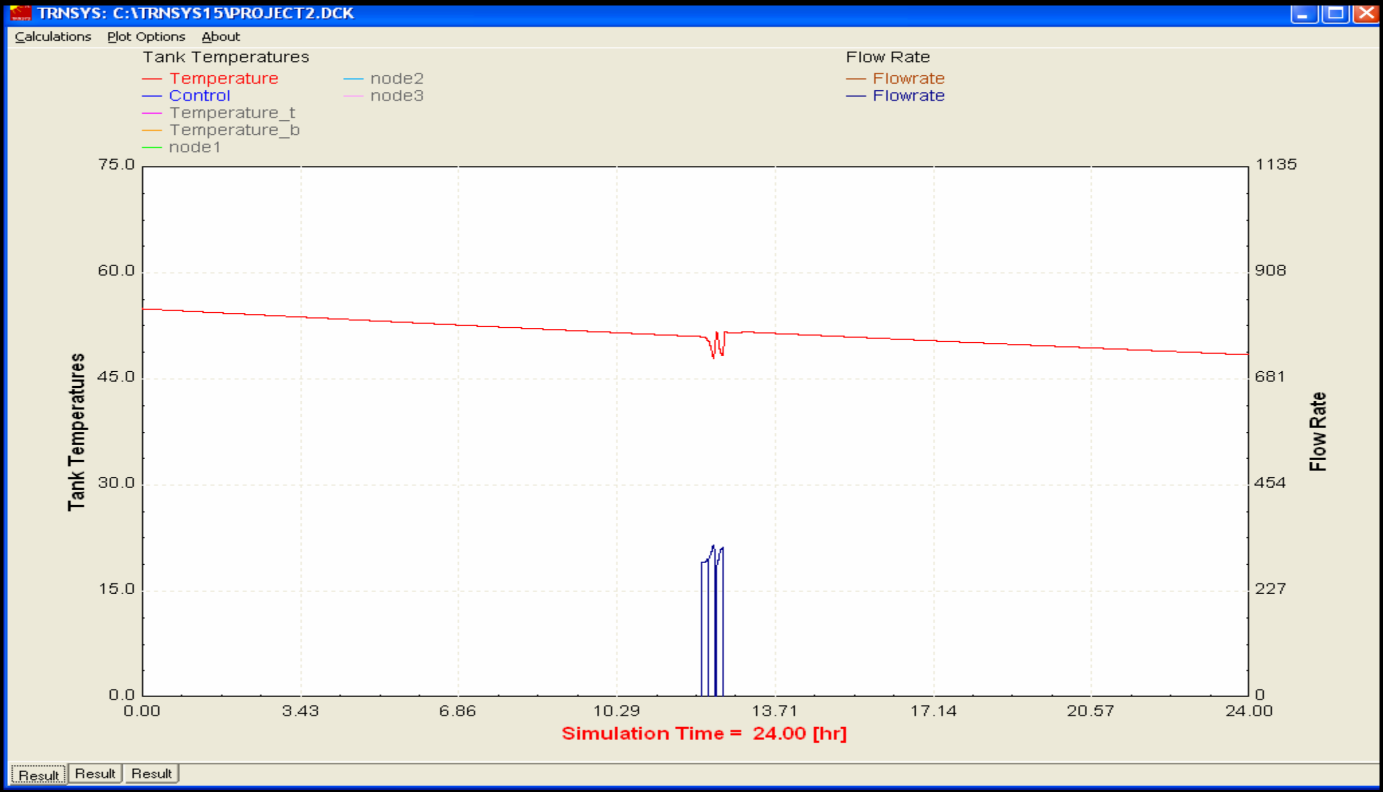
Electric Water Heater
Inlet Water Temp. 45 F, Tank Volume 50 Gallon

DHW Systems: Event-Based Sizing



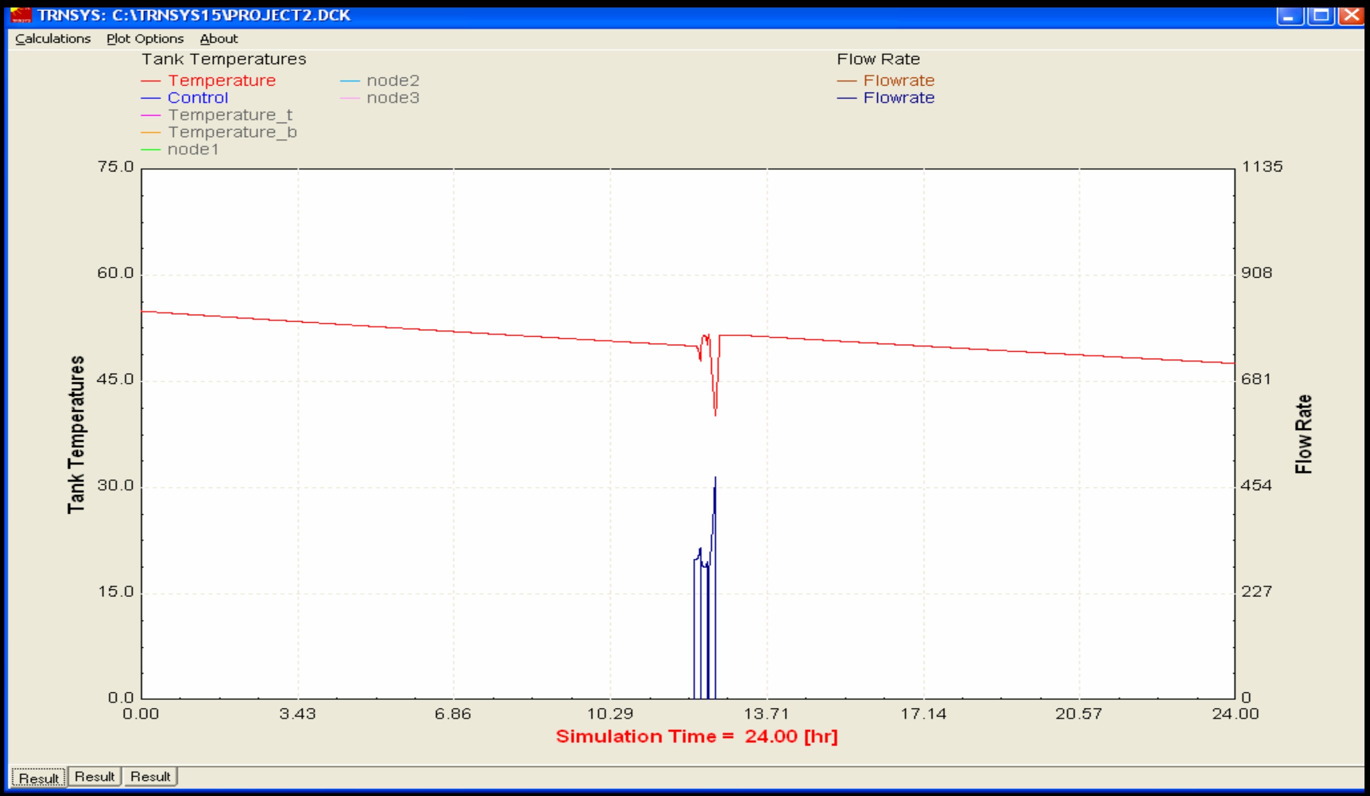
Electric Water Heater
Inlet Water Temp. 45 F, Tank Volume 40 Gallon

DHW Systems: Event-Based Sizing



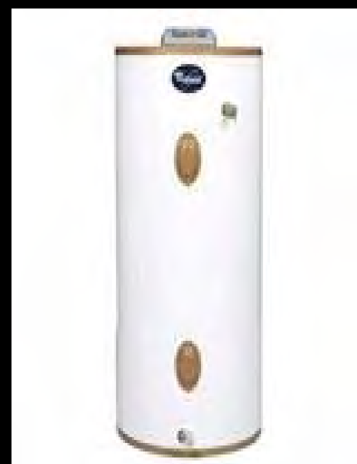
Electric Water Heater
Inlet Water Temp. 75 F, Tank Volume 30 Gallon

DHW Systems: Event-Based Sizing



Electric Water Heater
Inlet Water Temp. 75 F, Tank Volume 20 Gallon

DHW Systems: Event-Based Sizing



- T_inlet=60 F
- V = 30 gallon

T_inlet=45 F
V = 40 gallon

T_inlet=36 F
V = 50 gallon

Summary of the Tank Size vs. Inlet Water Temp. (Electric)

Temperature Variance

Temperature in different US cities

City	Yearly Average		
	Temp. (ºF)	T_min	T_max
Fairbanks, AK	26.9	11.80	51.00
Anchorage, AK	35.9	28.66	52.15
Duluth, MN	38.5	27.04	58.96
Juneau, AK	40.6	36.51	53.69
Fargo, ND	41	27.90	63.10
Saint Cloud, MN	41.5	29.26	62.74
Glasgow, MT	42.4	30.65	63.15
Green Bay, WI	43.8	33.34	63.26
Missoula, MT	44.3	36.89	60.71
Burlington, VT	44.6	34.47	63.73
Great Falls, MT	44.8	36.61	61.99
Minneapolis - St. Paul, MN	44.9	32.71	66.09
Casper, WY	45.1	36.53	62.67
Concord, NH	45.1	35.86	63.34
Madison, WI	45.2	34.85	64.55

DHW Systems: Event-Based Sizing

City	Yearly Average		
	Temp. (ºF)	T_min	T_max
Corpus Christi, TX	71.6	68.24	83.96
Orlando, FL	72.3	70.64	82.96
Tampa, FL	72.3	70.73	82.88
Vero Beach, FL	72.4	71.58	82.22
Phoenix, AZ	72.6	66.33	87.87
Yuma, AZ	74.2	68.63	88.77
Fort Myers, FL	74.4	73.72	84.08
West Palm Beach, FL	74.7	74.50	83.90
Miami, FL	75.9	76.19	84.61
Honolulu, HI	77.2	79.41	84.00
Key West, FL	77.8	78.39	86.22

- **Temperature in different US cities**

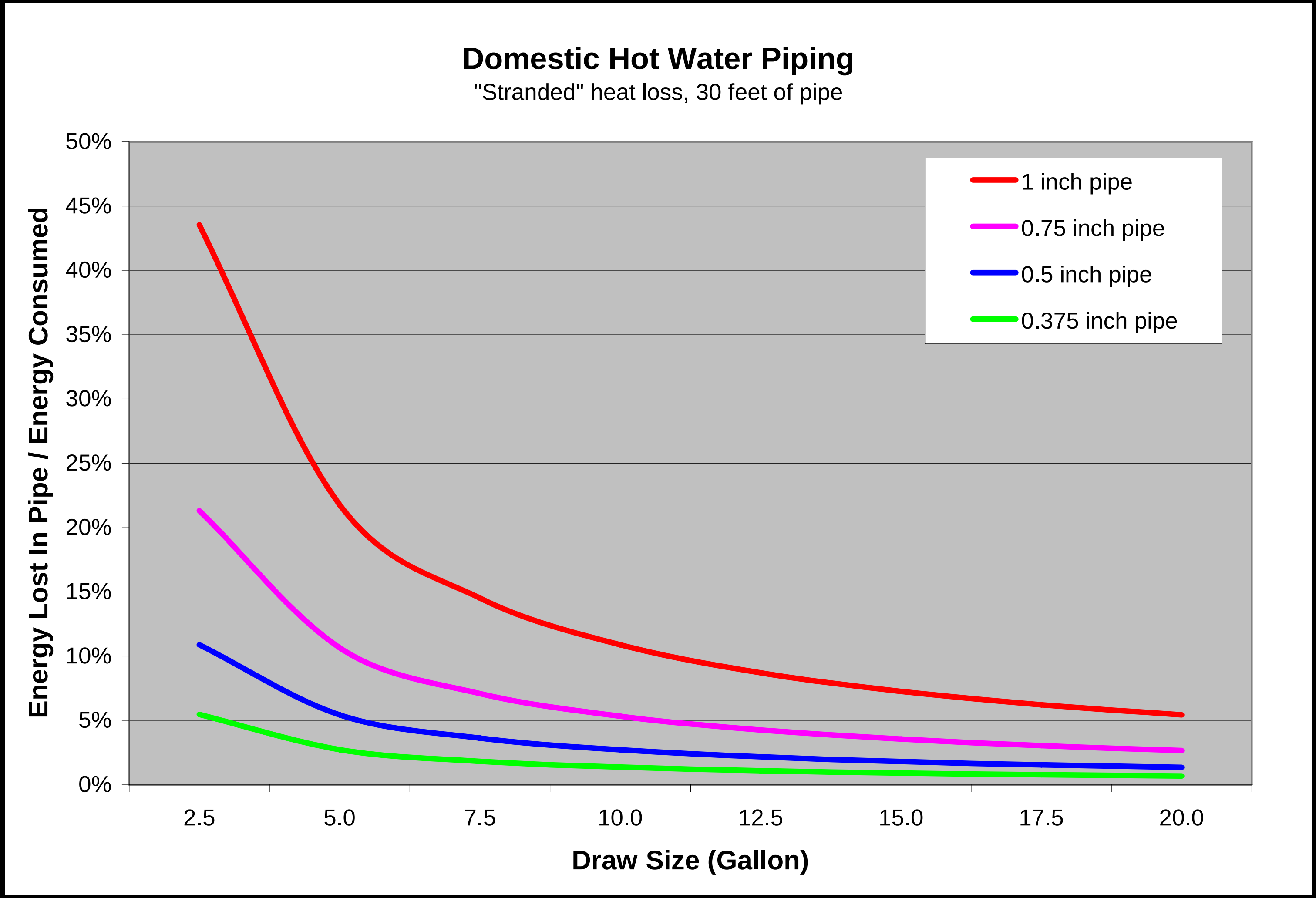
DHW Systems: Event-Based Sizing

Preliminary conclusions from TRNSYS analysis:

- The size of the water heater is closely related to the cold water inlet temperature. Therefore, the sizing method should include climate zone consideration.

- The water usage pattern will influence the size of the water heater. The water schedule profile should be part of the sizing consideration.

DHW Systems: Piping losses



Efficient DHW Systems

- Factors that Impact Water Heater Energy Efficiency

- Fuel Conversion Efficiency
- Inlet (mains) Water Temperature
- Standby Losses (Storage Volume)
  - Tank Set Point Temperature
  - Ambient Air Temperature
  - NAECA Minimum Efficiency Standards

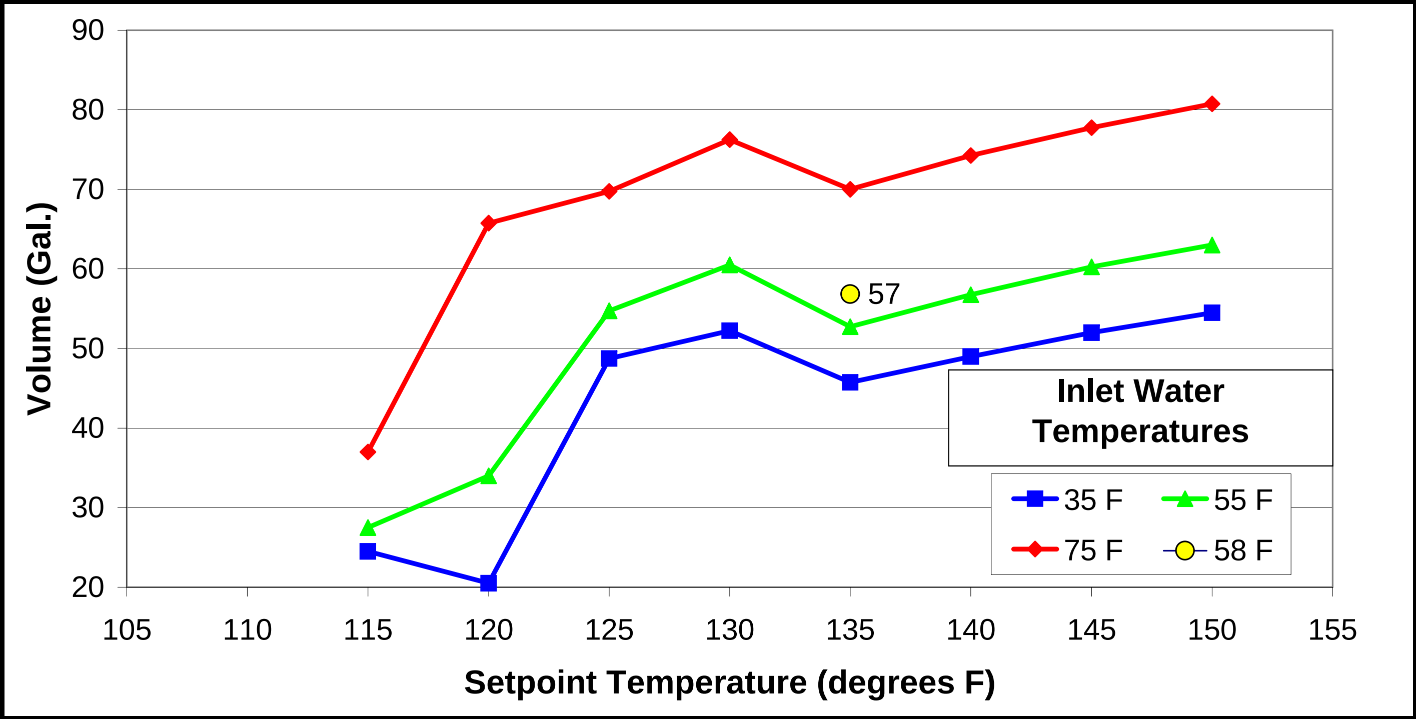
Efficient DHW Systems

DOE Test Procedure First Hour Rating

	DOE Test Procedure	Conventional Controls	Energy Smart Controls
Draw Initiation:	Upper Element OFF	Upper Element OFF or Set Point Temperature Achieved	
Draw Termination:	T_{MAX} - 25°F	105°F	105°F
Initial Tank Temp.:	135°F ± 5°F	T_{SP} - 10°F	T_{SP} - 5°F
Set Point Temp.:	135°F ± 5°F	115°F - 155°F	110°F - 155°F
Upper Element Diff.:	unspecified	20°F	5°F
Lower Element Diff.:	unspecified	10°F	5°F
Supply Water Temp.:	58°F ± 2°F	55°F	55°F
Ambient Air Temp.:	65°F to 70°F	67.5°F	67.5°F
Water Draw Rate:	3.0 ± 0.25 gpm	3.0 gpm	3.0 gpm

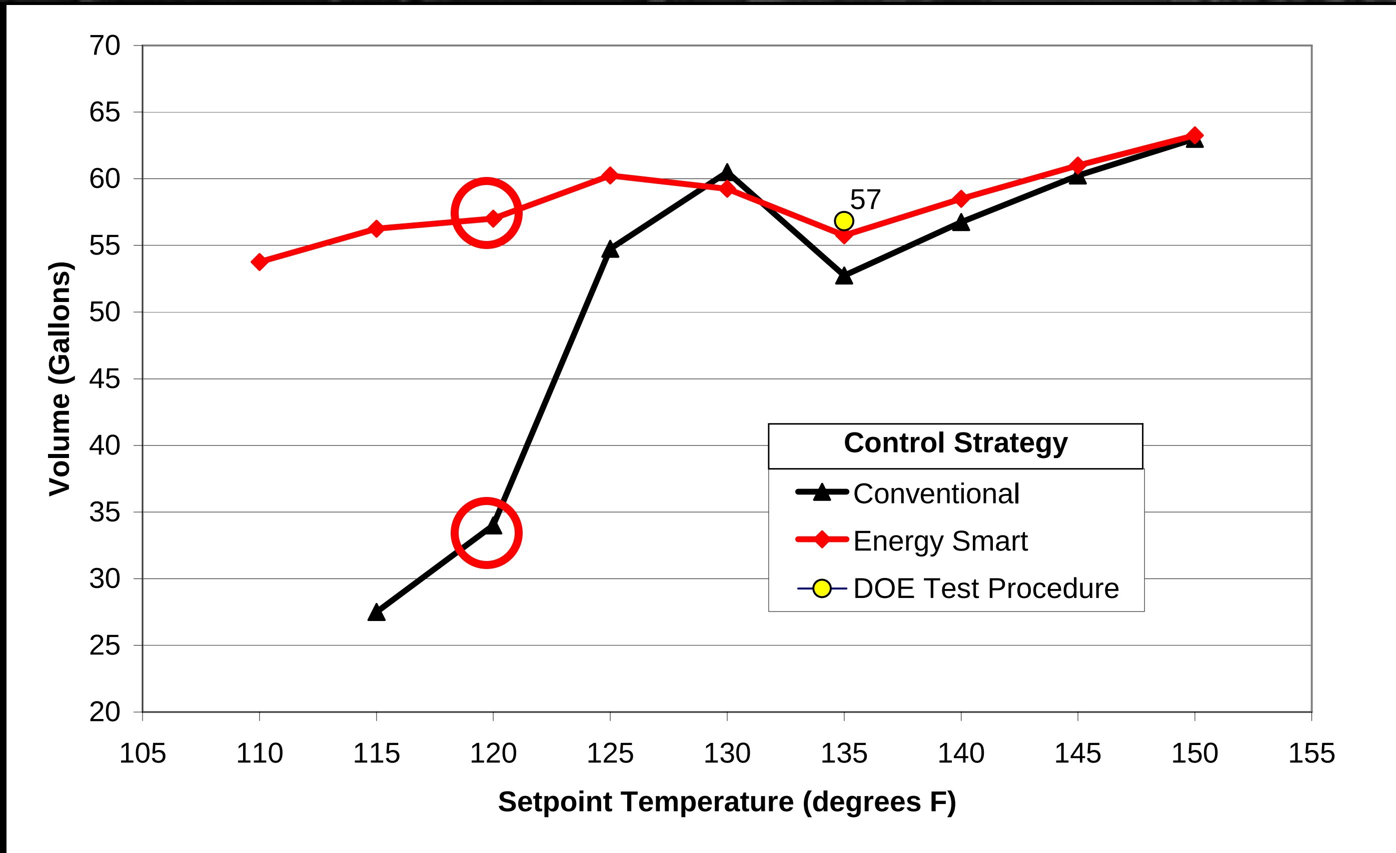
Efficient DHW Systems

Water Heater Performance



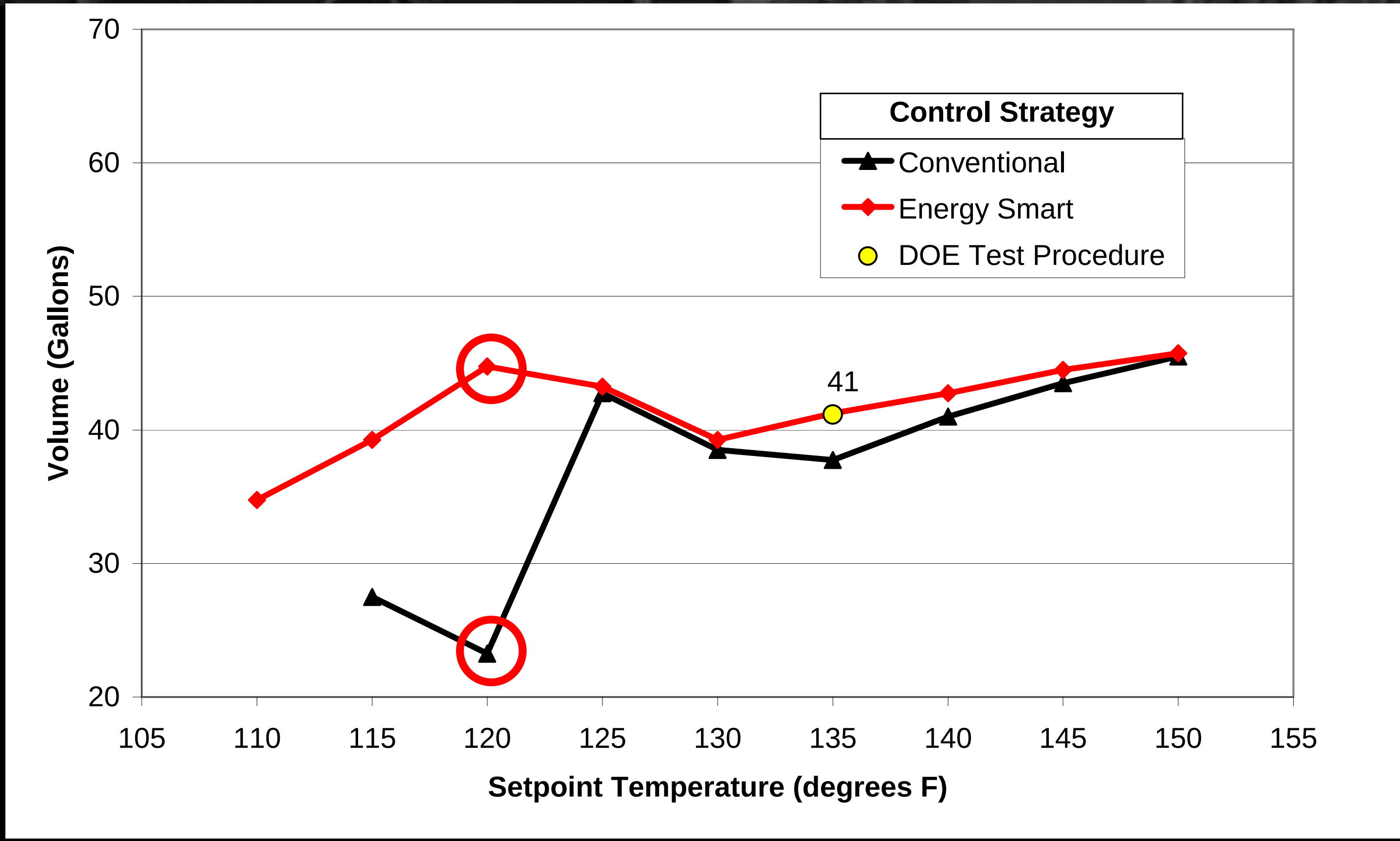
- 50-Gallon Electric Water Heater
  - Conventional Controls

Efficient DHW Systems



- First-Hour Rating – 50-gallon electric water heater

Efficient DHW Systems



- 30-Minute Rating – 50-gallon electric water heater

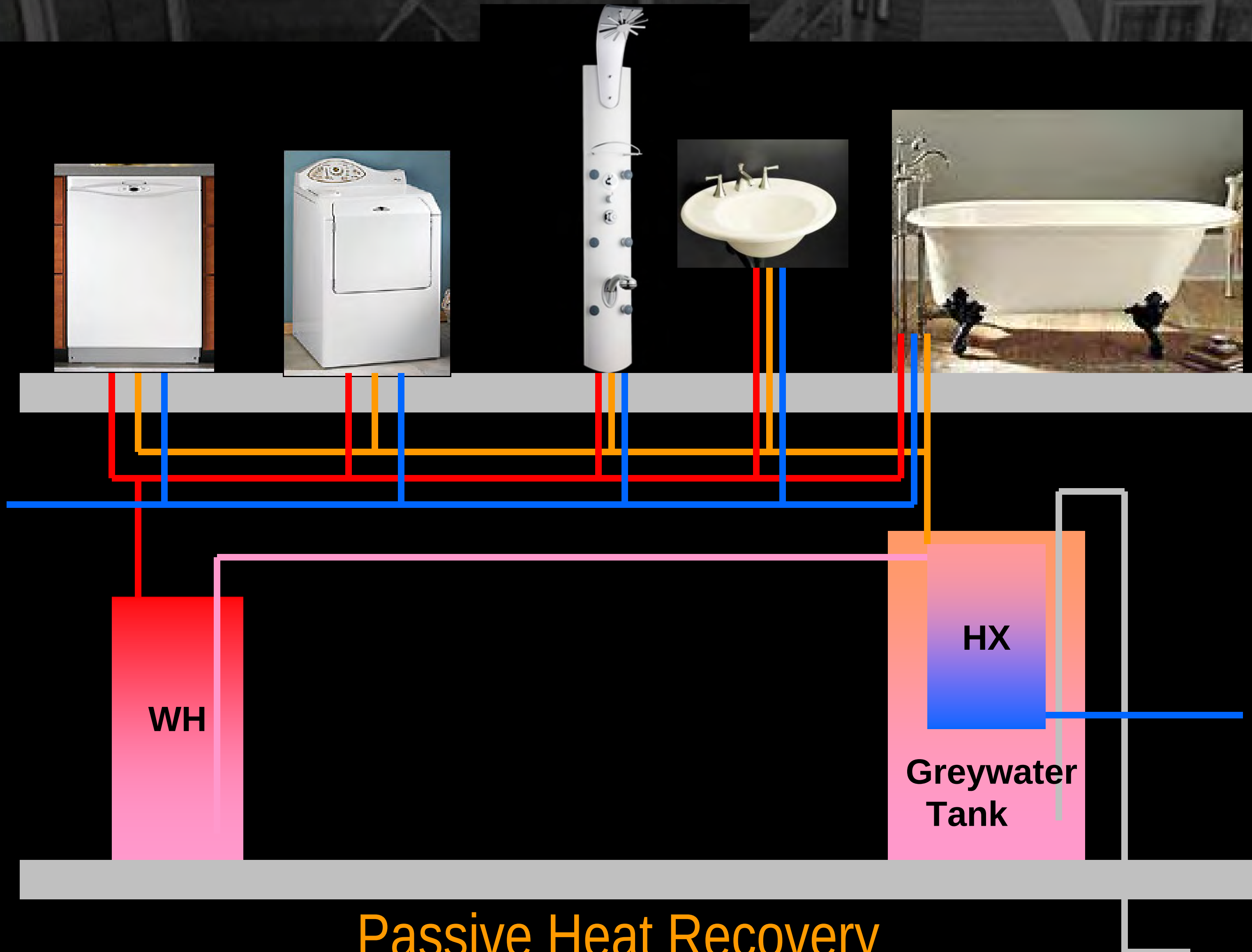
First Hour Ratings….

- Size Matters
- But Technology Matters More

Breaking the Limits of Efficiency

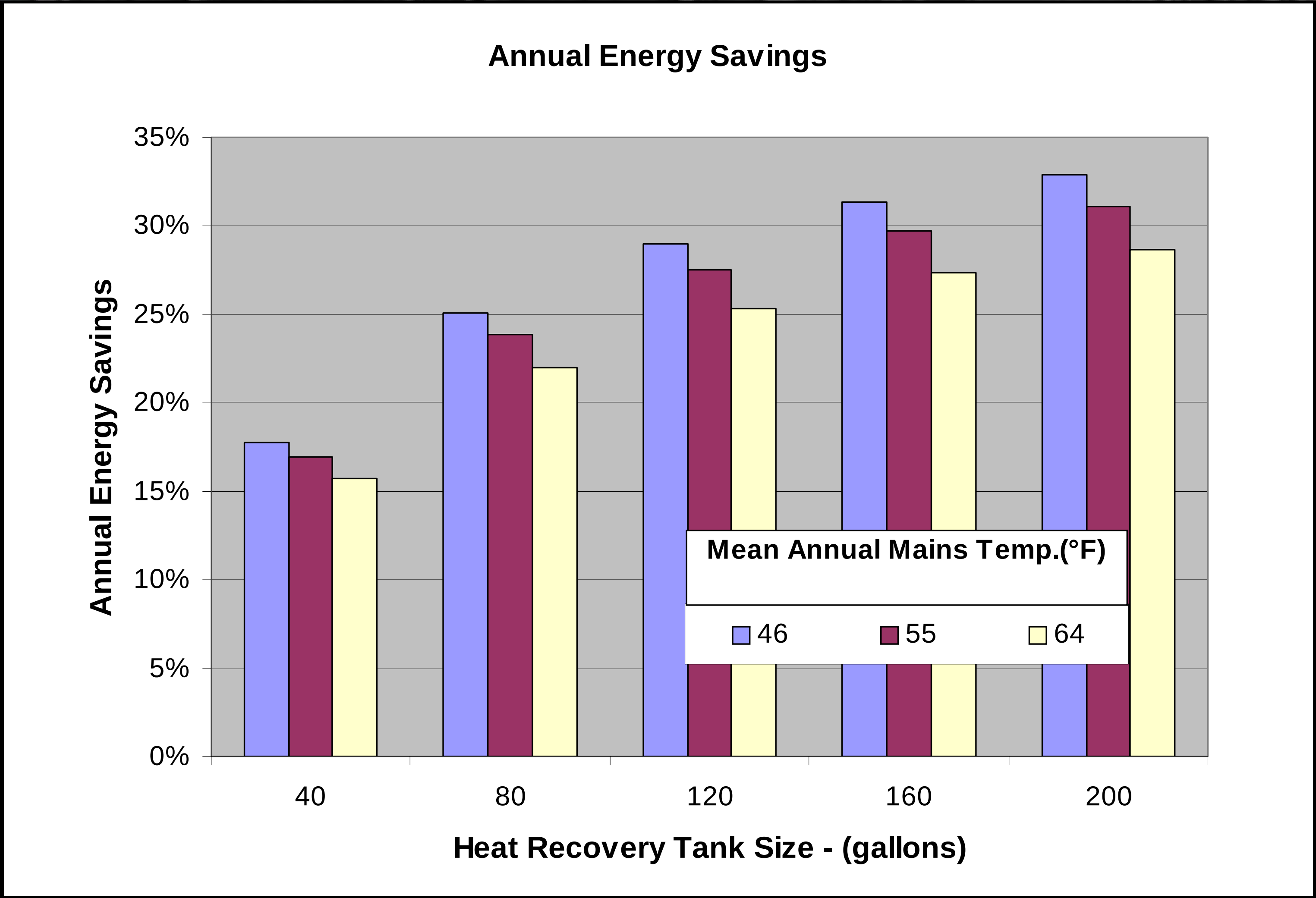
- Develop a non-solar electric DHW system with a source energy efficiency greater than 100%. (site to source multiplier is assumed to be 3.16)
- Identify efficiencies and limitations of earth-coupled heat pump systems adjacent to foundations.
- Quantify displacement of primary energy use relative to thermal storage capacity in a high performance home.

Non-Coincident DHW Heat Recovery



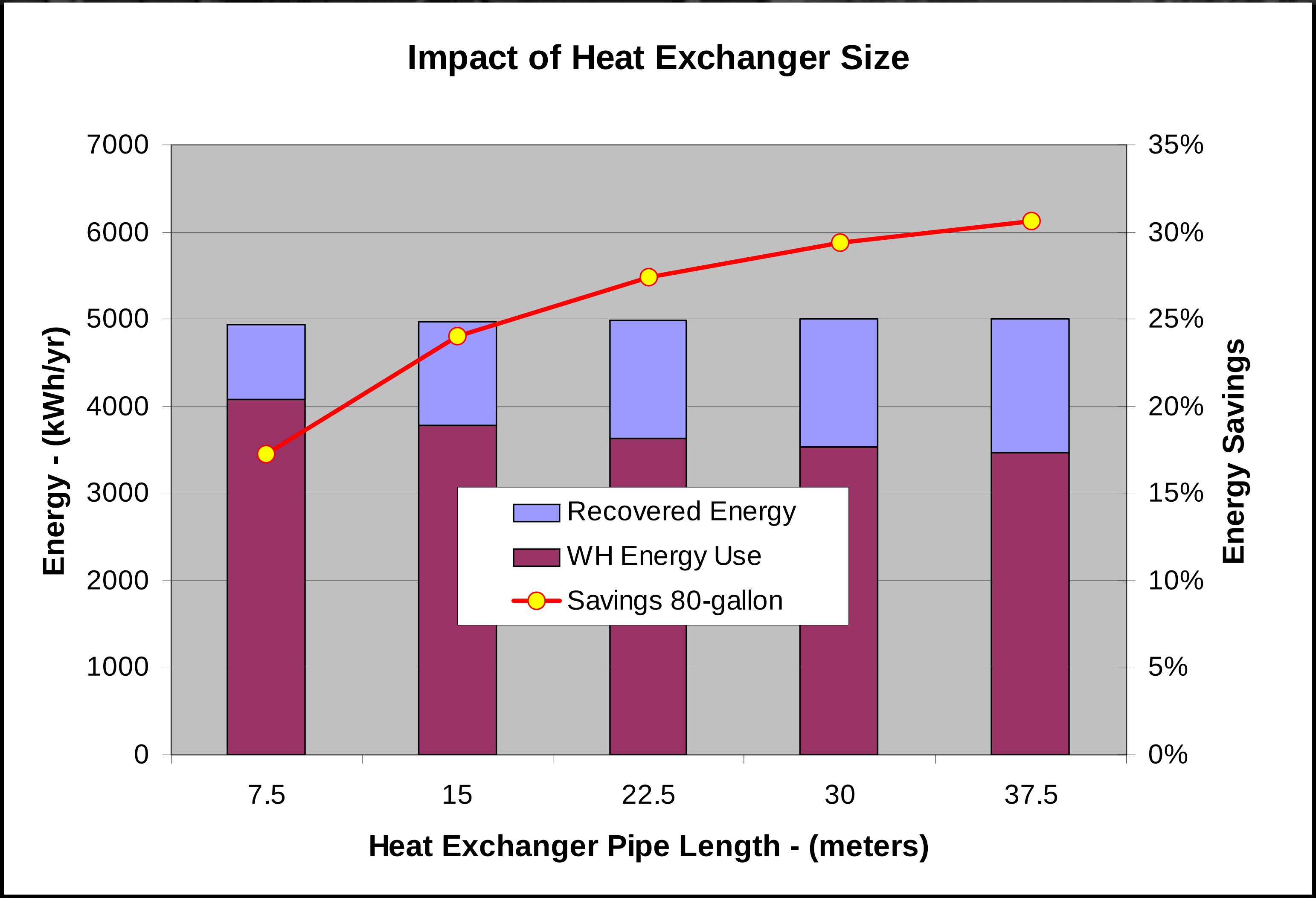
Passive Heat Recovery

Non-Coincident DHW Heat Recovery



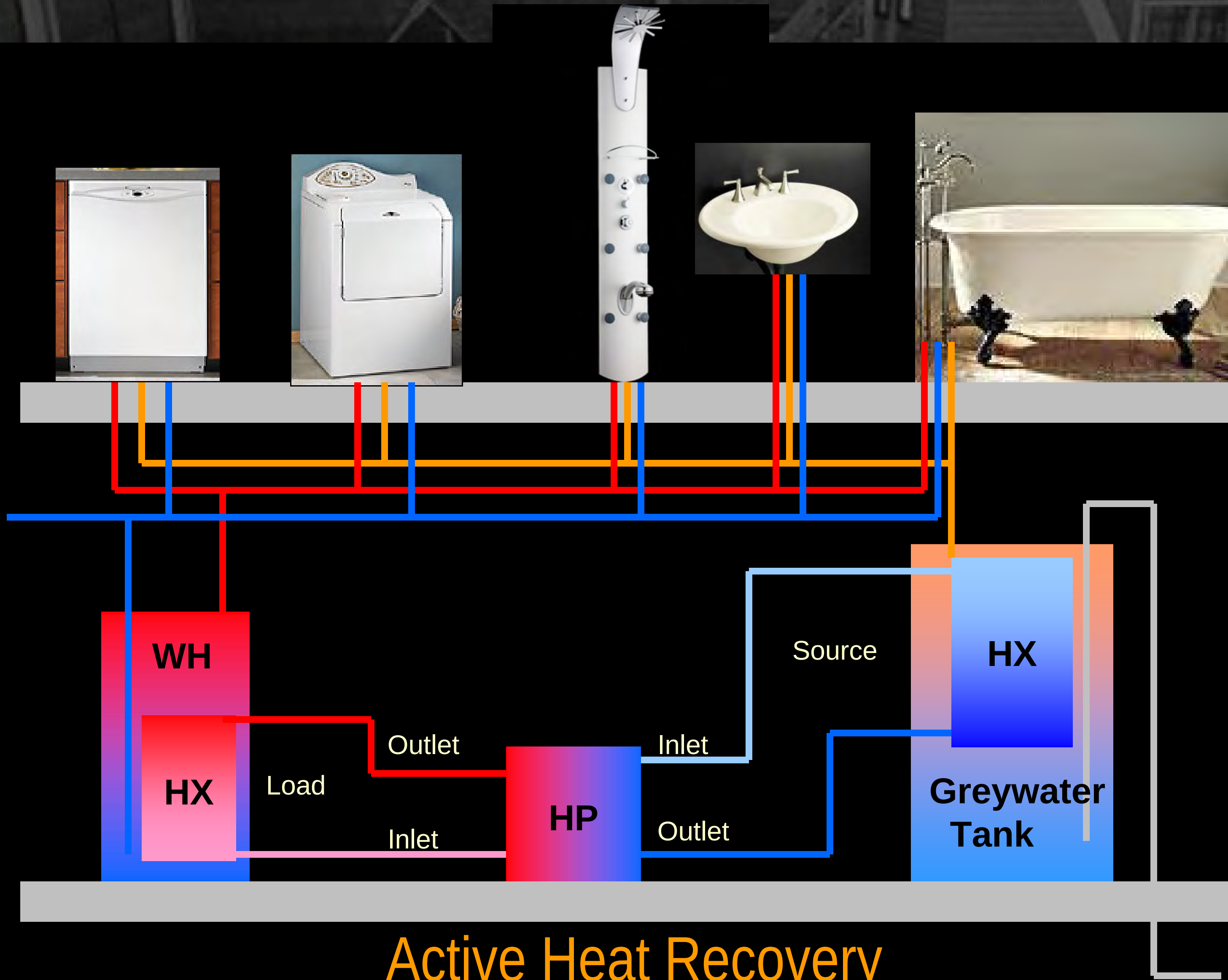
Passive Heat Recovery

Non-Coincident DHW Heat Recovery



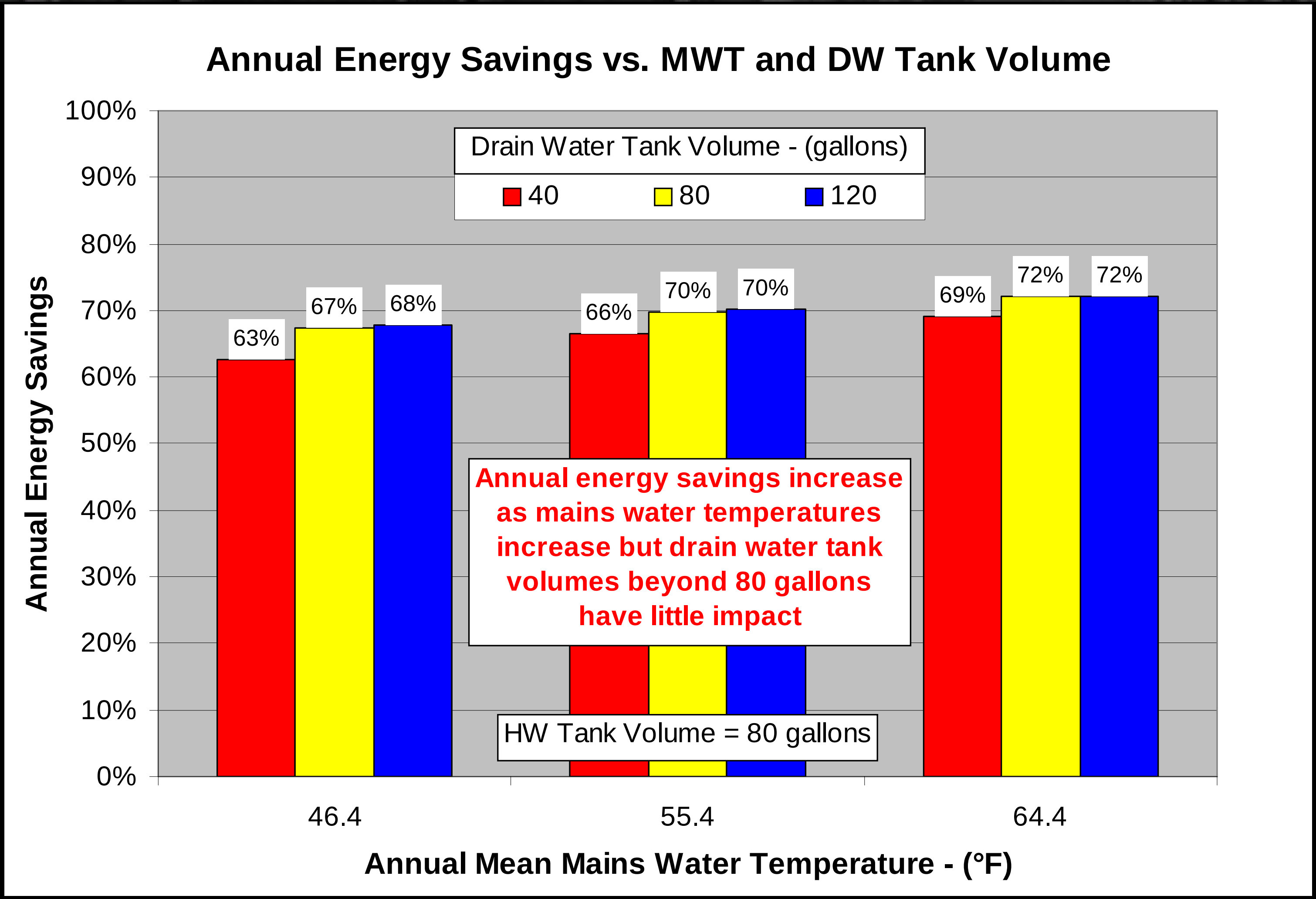
Passive Heat Recovery

Non-Coincident DHW Heat Recovery



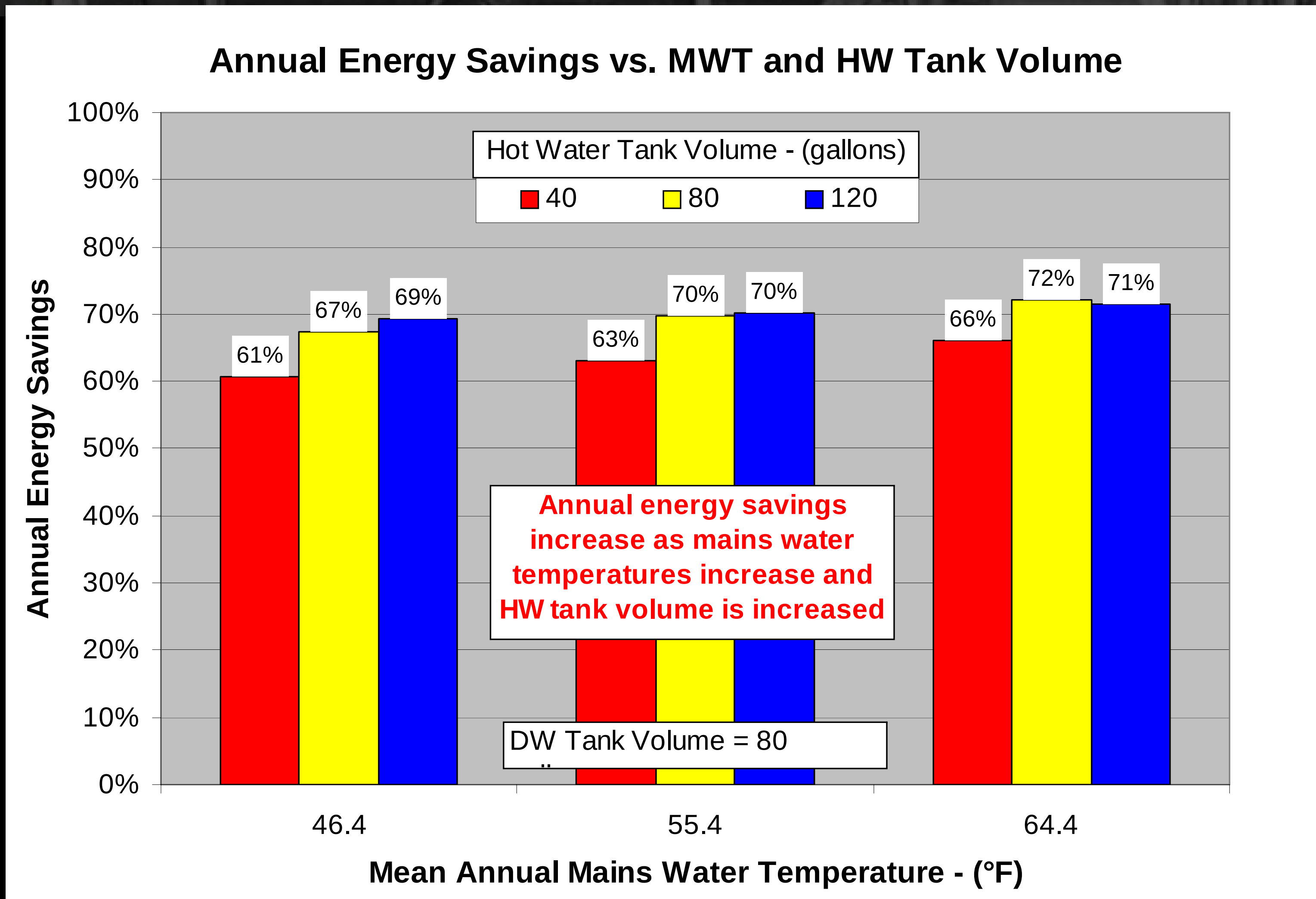
Active Heat Recovery

Non-Coincident DHW Heat Recovery



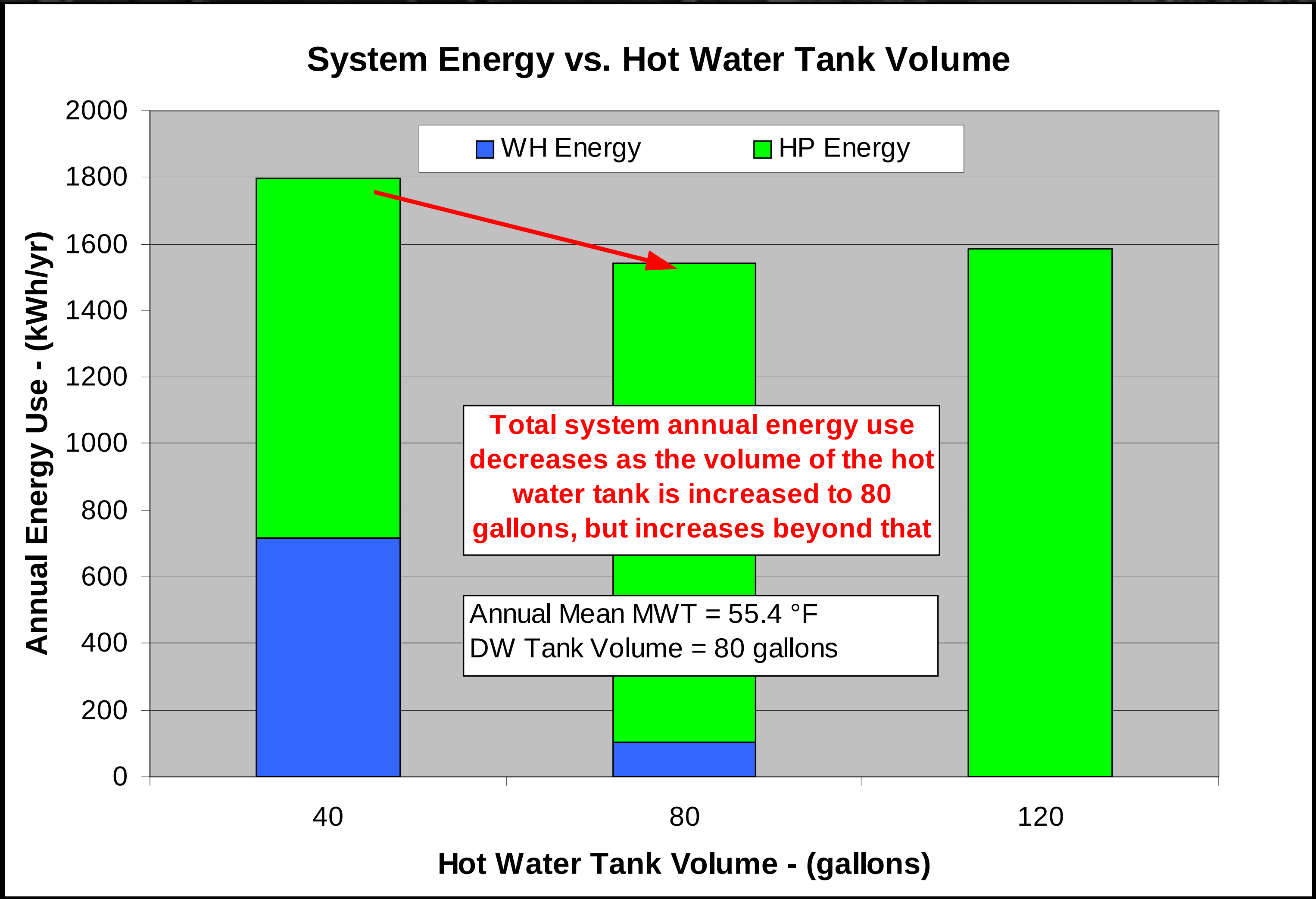
Active Heat Recovery

Non-Coincident DHW Heat Recovery



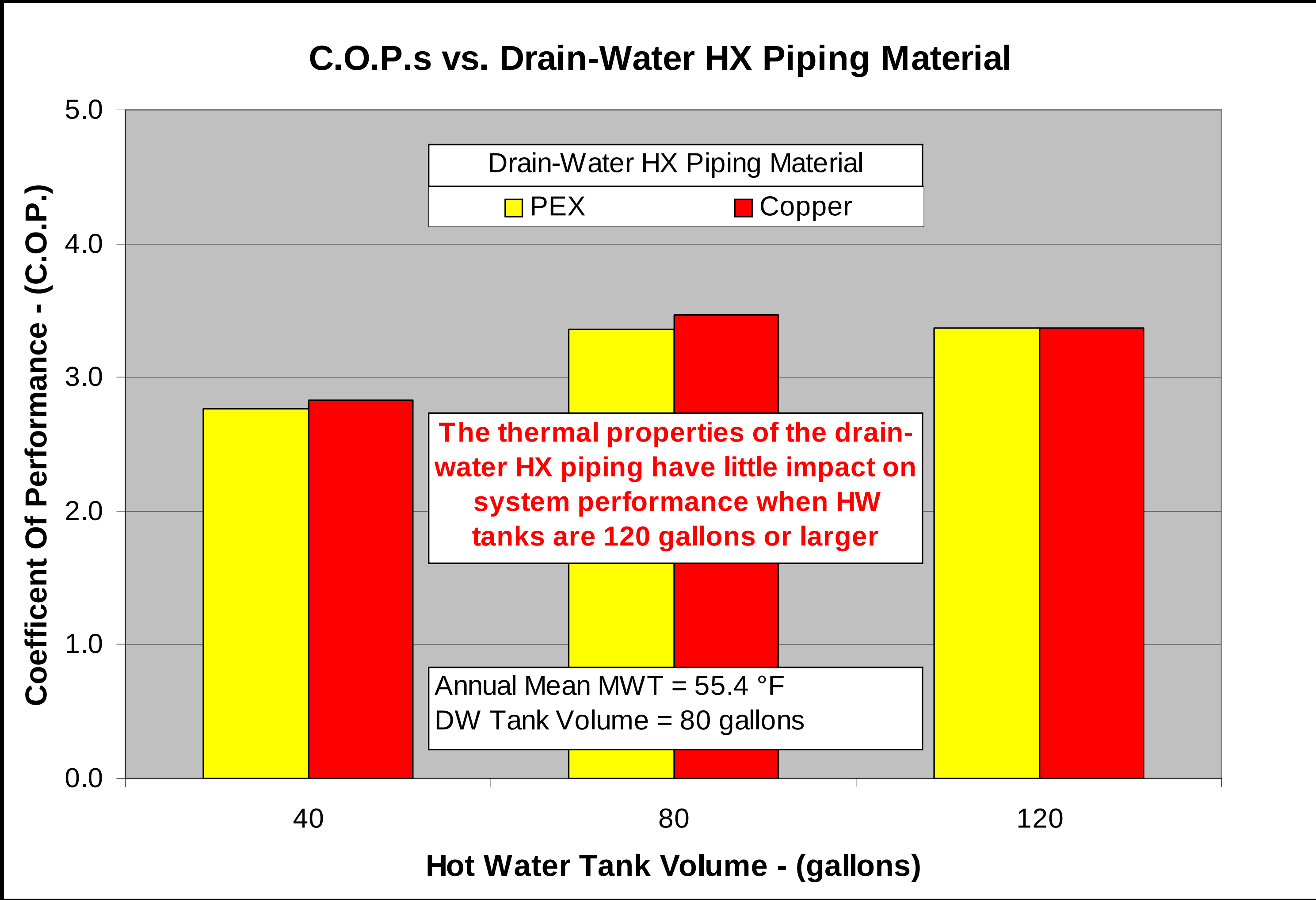
Active Heat Recovery

Non-Coincident DHW Heat Recovery



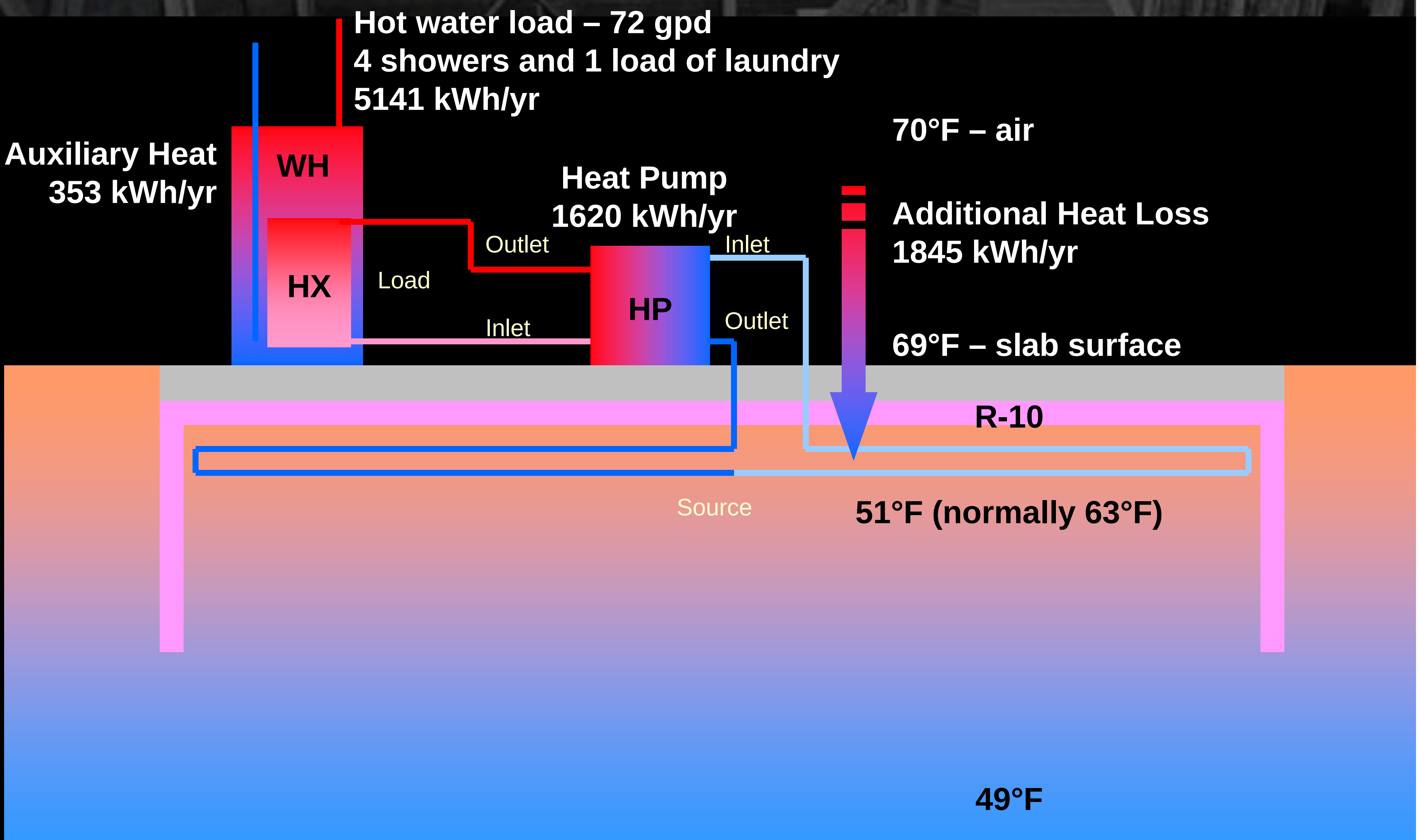
Active Heat Recovery

Non-Coincident DHW Heat Recovery

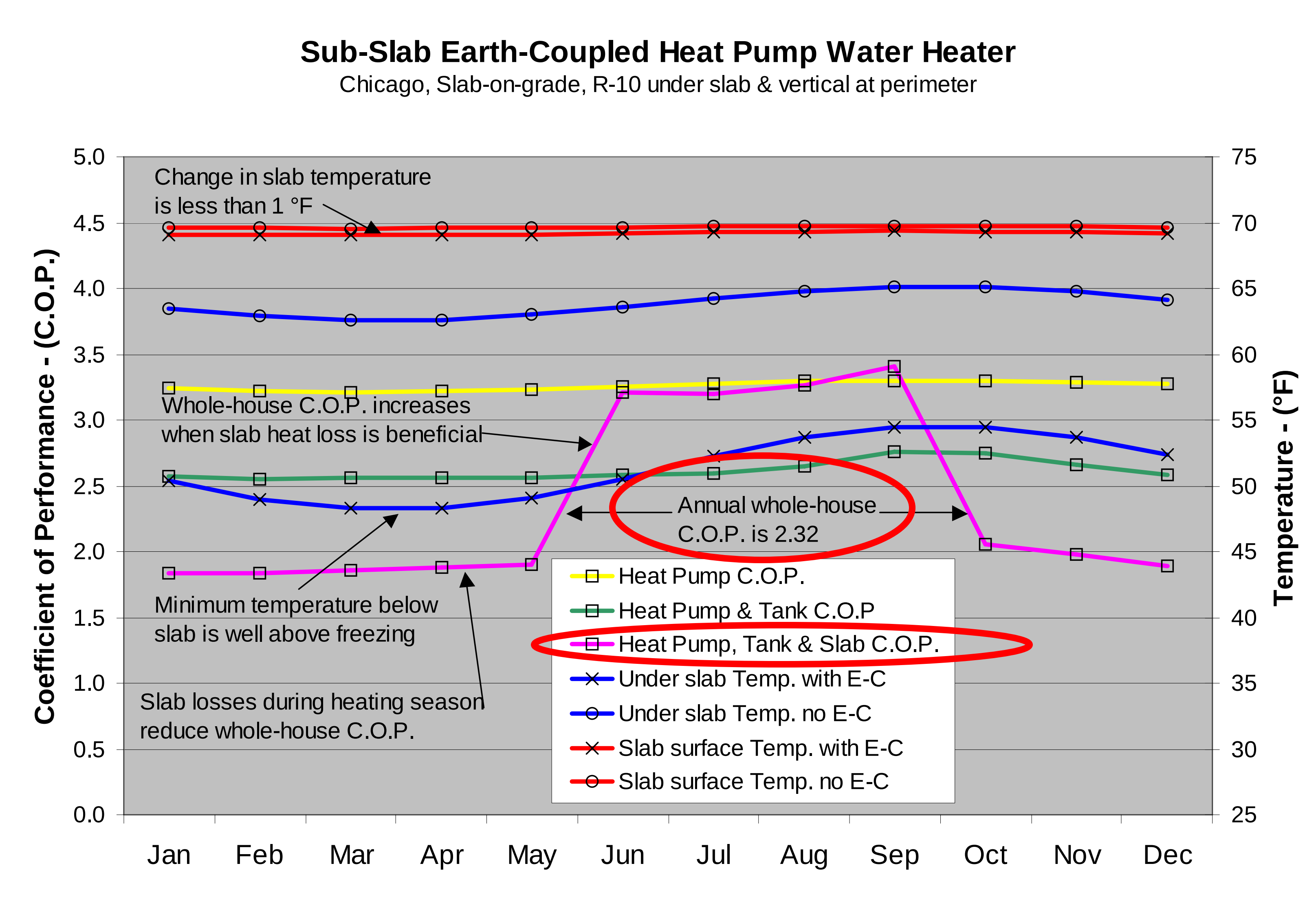


Active Heat Recovery

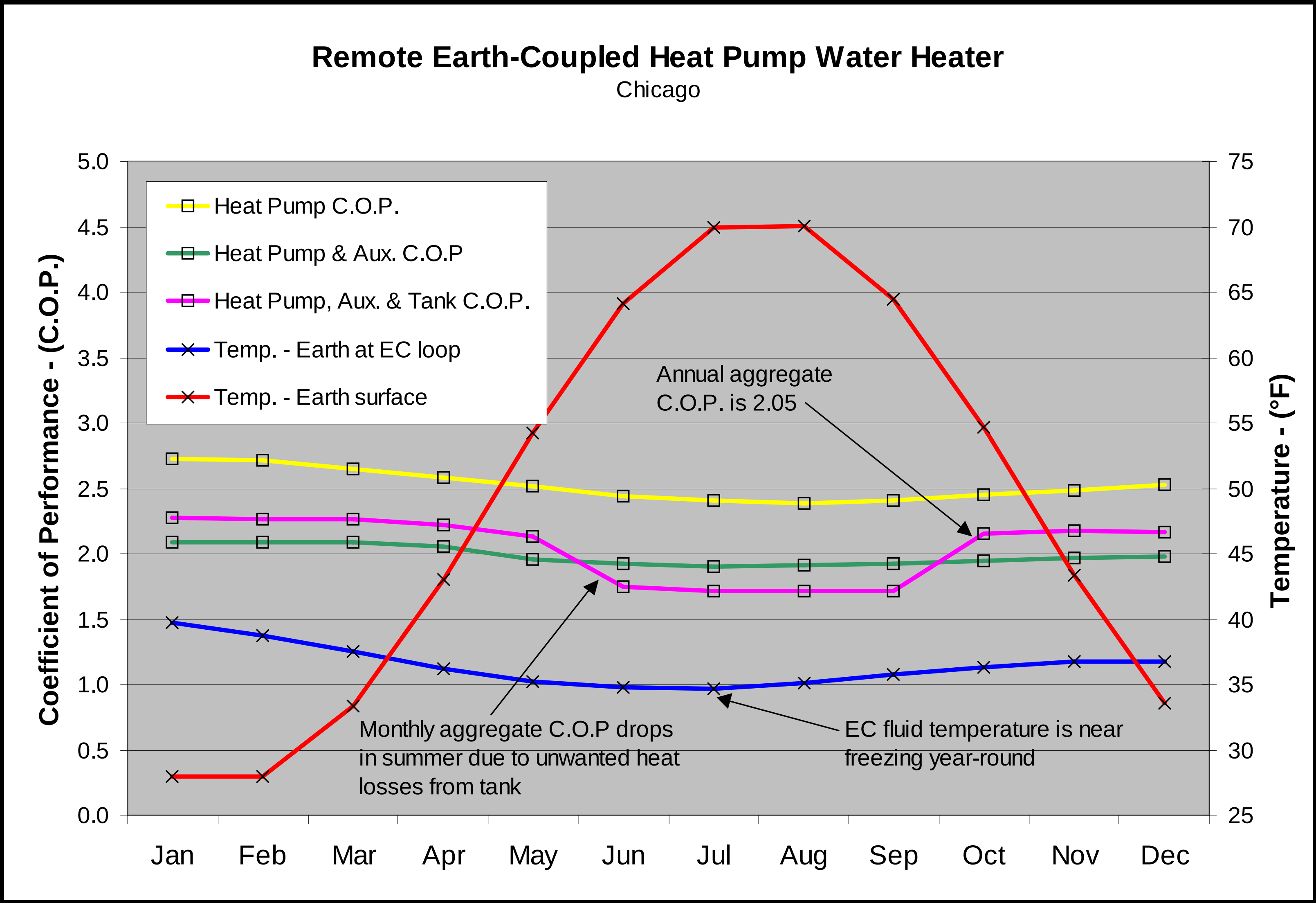
Earth-Coupled Heat Pump Water Heater



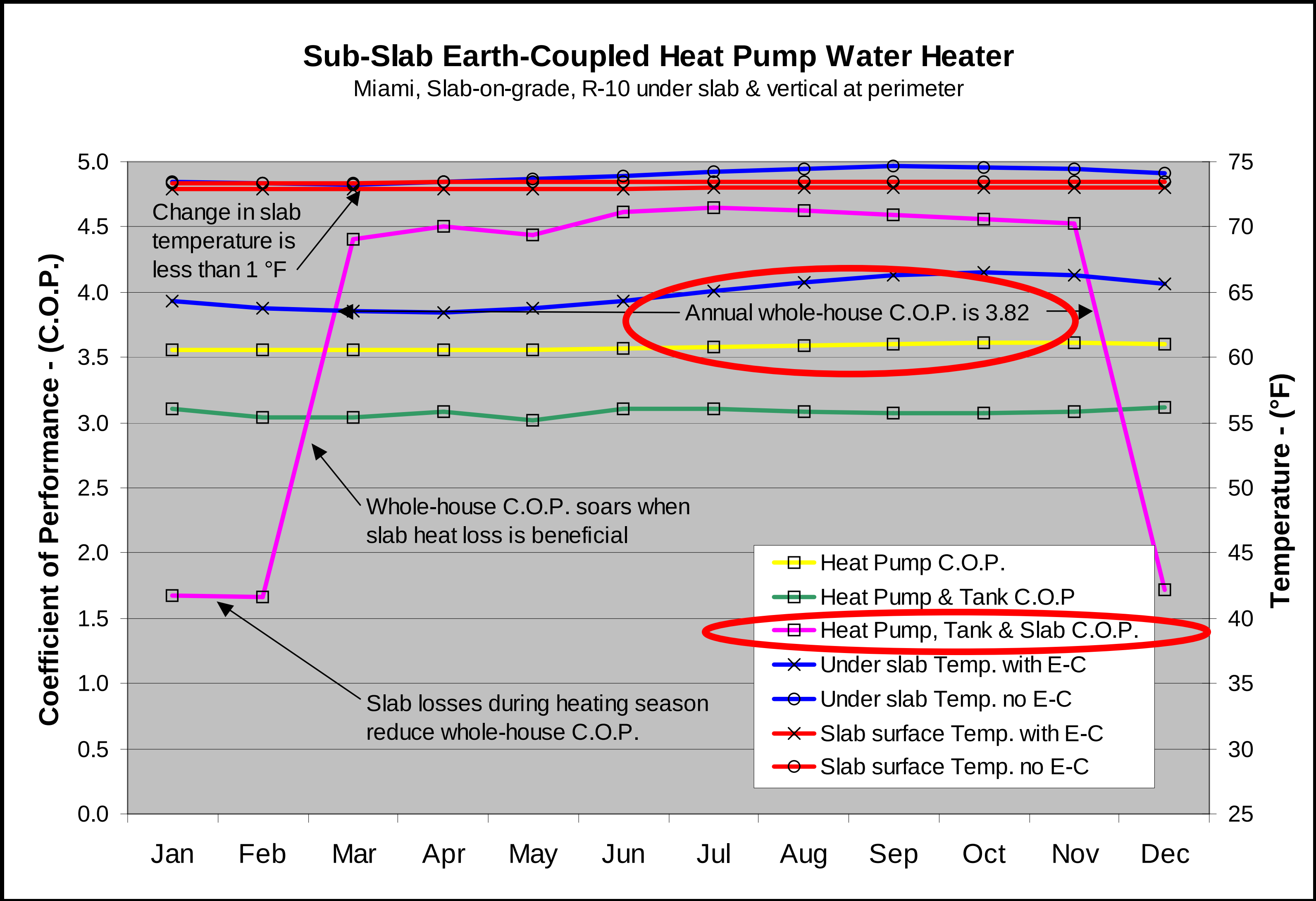
ECHP Water Heater - Chicago



ECHP Water Heater - Chicago



ECHP Water Heater - Miami



Domestic Hot Water Systems

And that's how it works.

Any Questions?