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High Performance Hot Water: *On the Path to* Deep Energy Reductions - Part 1

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Presented by: Gary Klein

Affiliated International Management, LLC

916-549-7080   gary@aim4sustainability.com

www.1000HomeChallenge.org   www.affordablecomfort.org

Your Instructor

Gary Klein, Affiliated International Management, LLC, provides consulting on sustainability through an international team of affiliates. He has been intimately involved in energy efficiency & renewable energy since 1973. Gary has a passion for hot water: getting into it, getting out of it, & efficiently delivering it to meet customers' needs. In addition to presenting seminars to audiences throughout the United States, Gary has been working to develop better language for codes & standards with the goal of getting all new hot water systems to be "good" by 2015.

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Learning Objectives

1. Understand typical residential water heating loads & the levels of reduction needed to meet the Thousand Home Challenge

2. Learn how to evaluate existing hot water systems for energy & water reduction opportunities

3. Recognize the characteristics of, & equipment available for, high performance water heating systems

Thousand Home Challenge

Overview – Deep Reductions

- 70 – 90% reduction
- Identify performance threshold
- One year of measured verifiable use
- Includes efficiency, behavioral choices, community solutions, & renewables

Thousand Home Challenge

Summary of Goal for “Hot Water”

- OPTION A
  - 75% reduction
  - Determine baseline from energy bills
- OPTION B
  - 10 gal/person hot water @ 100% efficiency
  - 7 gal 3 or more occupants
  - Consideration of incoming water temp
- Hot Water Budget
  - Gallons/day & system efficiency
- Do We
  - Redeem what exists?
  - Start from scratch?
  - Develop creative solutions?
  - Blend all 3?

Overview

Annual Energy Use for Heating Water

	Natural Gas	Electricity
Gallons per Day	60	
Gallons per Year	21,900	
Energy into Water	16.4 Million Btu	
Efficiency	0.6	0.9
Cost per Unit	$1.00/therm	$0.10/kWh
Cost per Year	$275	$535

Assumes hot water is 90º F above incoming cold water. Cost per year has been rounded off.

Add ~ $130 per year for water & sewer (at $0.006 per gallon combined)

Proportion costs to your fuel & water rates

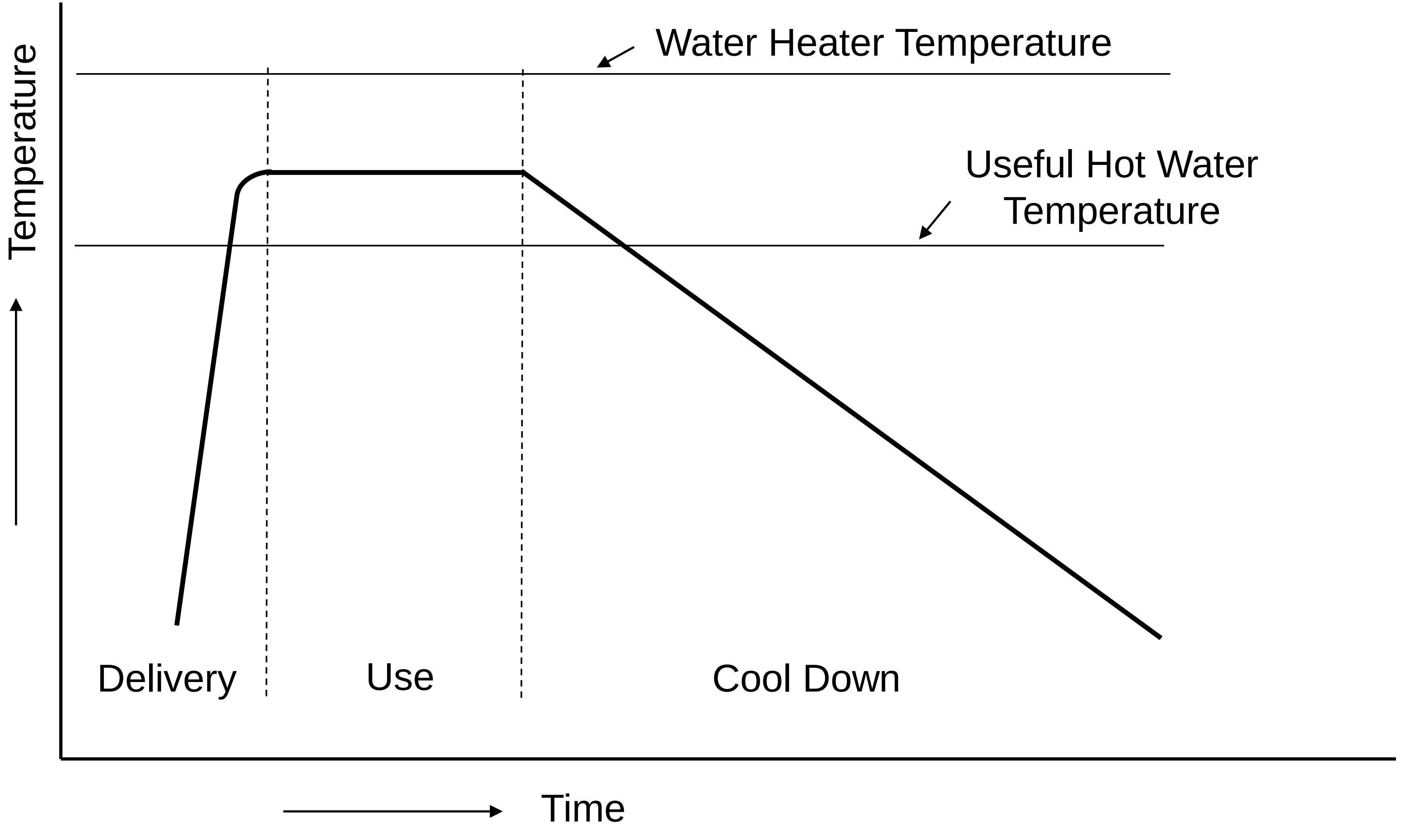
How Big is Hot Water?

- Water heating is the 1st or 2nd largest residential energy end-use (15 – 30% of a house's total energy pie)
  - What is number 1? Number 3?
  - Percentage grows as houses & appliances get more efficient
- How does this compare to your
  - Cell phone bill?
  - Internet bill?
  - Cable or satellite bill?
  - Designer coffee bill?

Do You Know

- *Anyone who waits a long time to get hot water somewhere in their house? At their job? In their favorite restaurant?*
- Any communities that have building or appliance energy standards or incentive programs? Green building programs?
- *Someone who has ever run out of hot water?*
- *Any communities that have a "you can't build unless you can guarantee a long term supply of water" ordinance?*
- Anyone who wants instantaneous hot water?
- *Someone who thinks that a tankless water heater is instantaneous?*
- Anyone *who wants to know "the answer"?*

Typical Hot Water Event



What Do You Want from your Hot Water System?

- Clean clothes
- Clean dishes
- Clean hands
- Clean body
- Relaxation
- Enjoyment

The Service of Hot Water

What Do You Expect from your Hot Water System?

Safety

- Not too hot
- Not too cold
- No harmful bacteria or particulates
- Sanitation

Reliability

- Little or no maintenance
- Last forever
- Low cost

Convenience

- Adjustable temperature & flow
- Never run out
- Quiet
- Hot water now

Analyzing a
Water Heating System

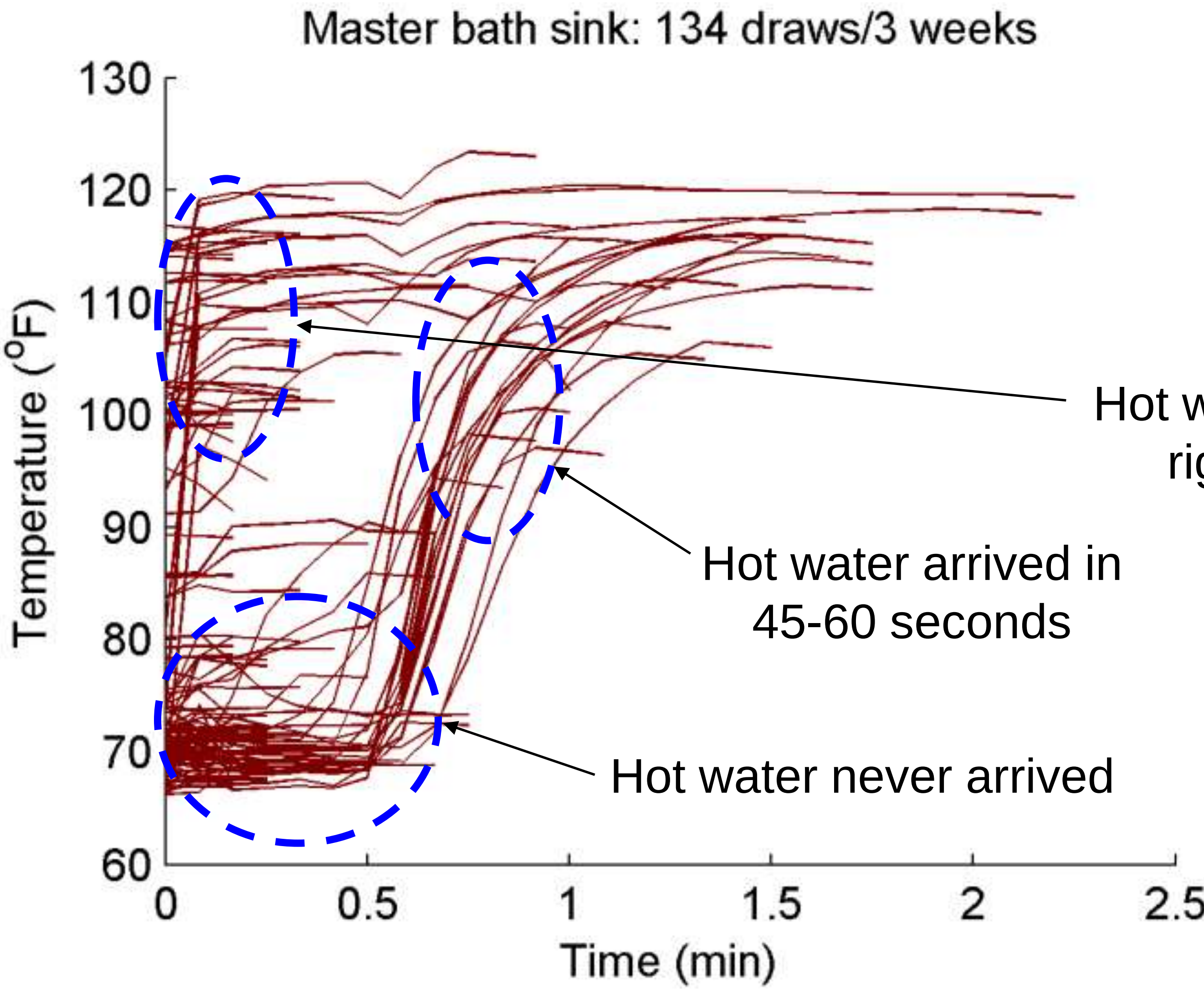
What are Your Hot Water Usage Patterns?

- Volume
- Flow Rate
- Duration
- Frequency of Use
- Number of Occupants
- Hot Water Fittings & Appliances
  - Number
  - Location

Have you ***measured*** the ***hot water*** demand in the buildings you are designing for lately?

How many hours a day do you ***use*** hot water?

Time & Temperature at the Master Bath Sink



Average draw is 30 ± 29 seconds

Source: National Renewable Energy Laboratory

Waste Versus Use

$$\frac{\text{Use + Waste}}{\text{Water Heater Efficiency}} = \text{Purchased Energy}$$

1. You cannot waste more than you purchase
2. But you can waste more than you use
3. Structural waste
4. Behavioral waste

Guiding Principle

Provide people what they want...

The Service of Hot Water

with what they expect…

Safety, Reliability, & Convenience

as efficiently as possible

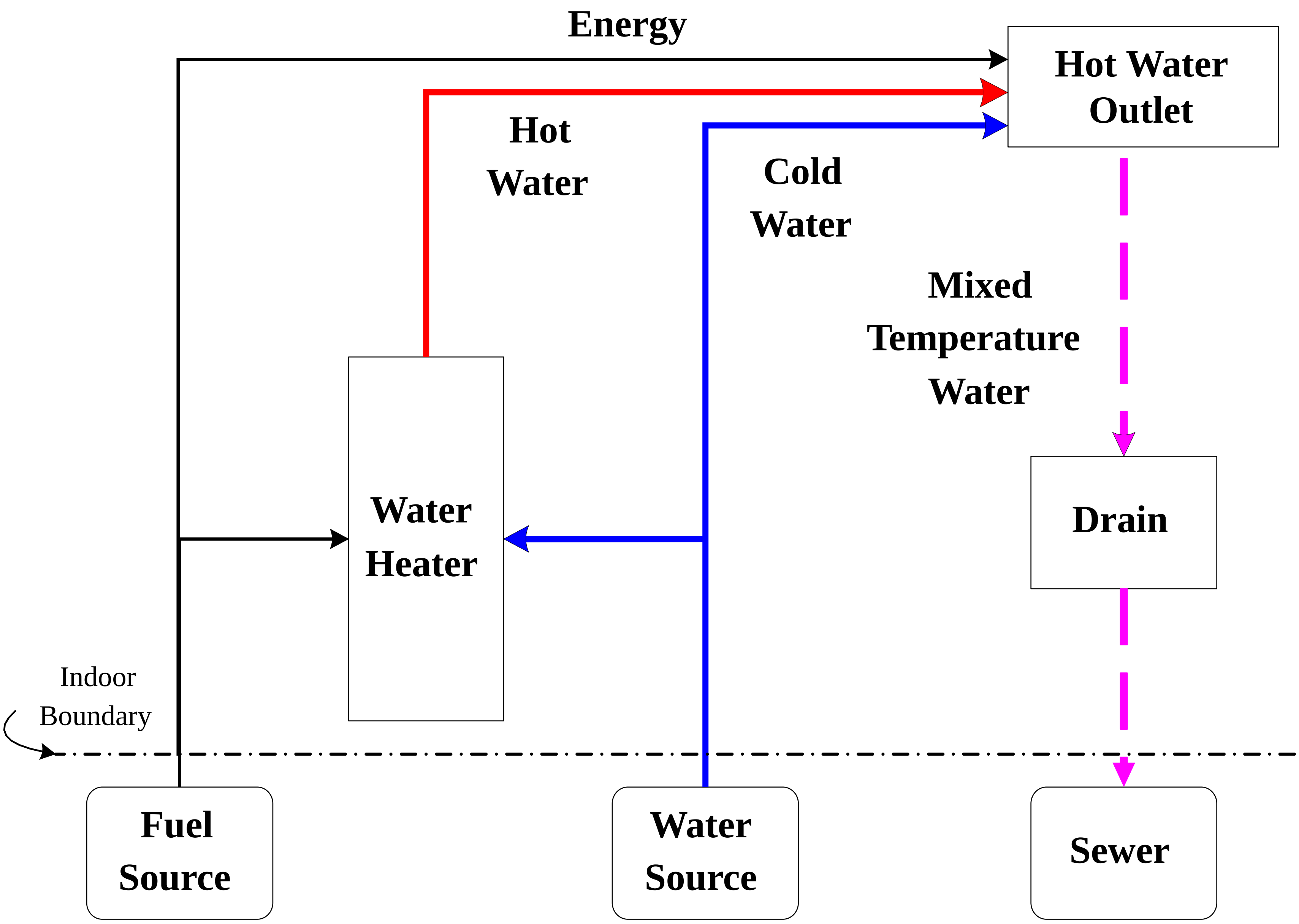
The Hot Water System

- Treatment & Delivery to the Building
- Use in the Building
  - Water heater
  - Piping
  - Fixtures, fittings & appliances
  - Behavior
  - Water down the drain
- Waste Water Removal & Treatment

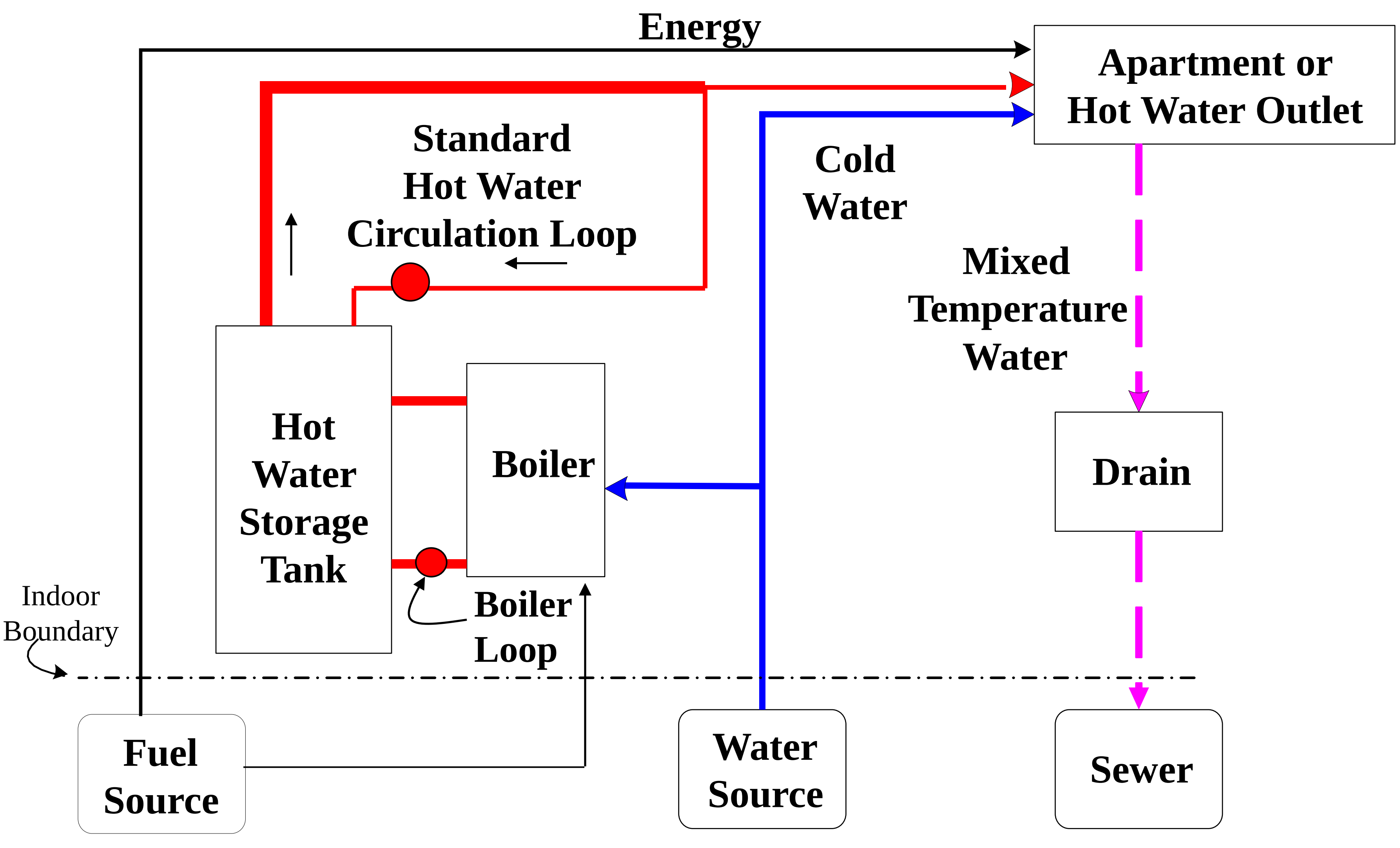
Which is the biggest ***variable*** in determining water & energy use?

How do the ***interactions*** among these components affect ***system*** performance?

Typical “Simple” Hot Water System

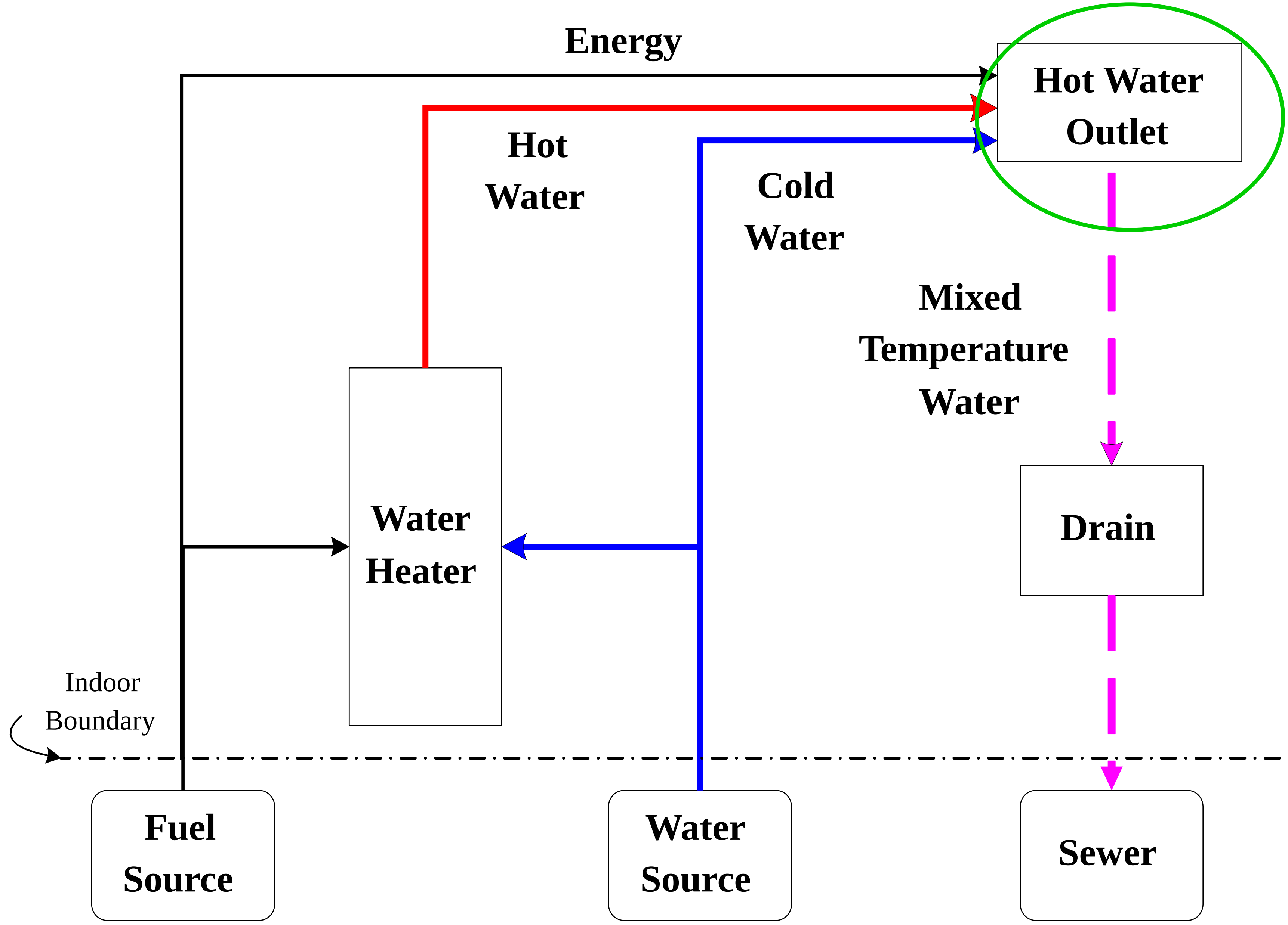


Typical Central Boiler Hot Water System



Existing Hot Water Outlets

Typical “Simple” Hot Water System



Hot Water Outlet Flow Rates

Maximum allowable flow rates allowed by Federal regulations

- Shower heads: 2.5 gpm @ 80 psi
- Lavatory & kitchen faucets: 2.2 gpm @ 60 psi
- Replacement aerators: 2.2 gpm @ 60 psi

How Much is Hot? How Much is Cold?

- $gpm_{mix} = gpm_{cold} + gpm_{hot}$
- $gpm_{cold} = gpm_{mix} * (T_{hot} - T_{mix})/(T_{hot} - T_{cold})$
- $gpm_{hot} = gpm_{mix} * (T_{mix} - T_{cold})/T_{hot} - T_{cold})$

Example:

- $gpm_{mix} = 2.0$
- $T_{cold} = 50F$
- $T_{hot} = 120F$
- $T_{mix} = 105F$
- $gpm_{hot} = 2*(105-50)/(120-50) = 2*(55)/(70)$
  $= 1.57$ gpm
- $gpm_{cold} = 2.0 – 1.57 = 0.43$

How Much is Hot? How Much is Cold?

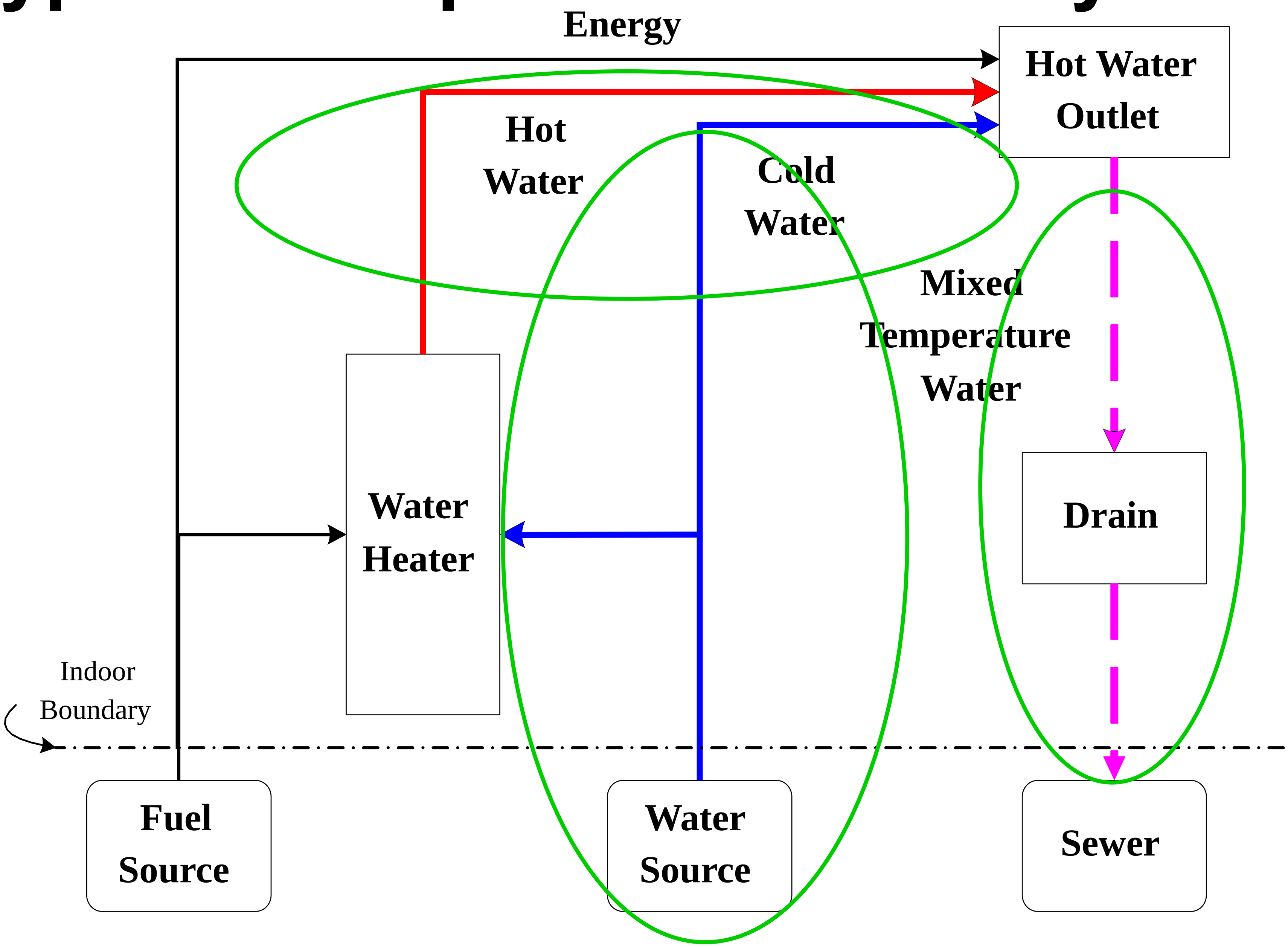
		Percent of Mixed Temperature Water (105F) that is Hot										
		Hot Water Temperature (F)										
		110	**115**	**120**	**125**	**130**	**135**	**140**	**145**	**150**	**155**	**160**
Cold Water Temperature (F)	**35**	93%	88%	82%	78%	74%	70%	67%	64%	61%	58%	56%
	40	93%	87%	81%	76%	72%	68%	65%	62%	59%	57%	54%
	45	92%	86%	80%	75%	71%	67%	63%	60%	57%	55%	52%
	50	92%	85%	79%	73%	69%	65%	61%	58%	55%	52%	50%
	55	91%	83%	77%	71%	67%	63%	59%	56%	53%	50%	48%
	60	90%	82%	75%	69%	64%	60%	56%	53%	50%	47%	45%
	65	89%	80%	73%	67%	62%	57%	53%	50%	47%	44%	42%
	70	88%	78%	70%	64%	58%	54%	50%	47%	44%	41%	39%
	75	86%	75%	67%	60%	55%	50%	46%	43%	40%	38%	35%
	80	83%	71%	63%	56%	50%	45%	42%	38%	36%	33%	31%

How Much is Hot? How Much is Cold?

		Percent of Mixed Temperature Water (105F) that is Hot										
		Hot Water Temperature (F)										
		110	115	120	125	130	135	140	145	150	155	160
Cold Water Temperature (F)	35	93%	88%	82%	78%	74%	70%	67%	64%	61%	58%	56%
	40	93%	87%	81%	76%	72%	68%	65%	62%	59%	57%	54%
	45	92%	86%	80%	75%	71%	67%	63%	60%	57%	55%	52%
	50	92%	85%	79%	73%	69%	65%	61%	58%	55%	52%	50%
	55	91%	83%	77%	71%	67%	63%	59%	56%	53%	50%	48%
	60	90%	82%	75%	69%	64%	60%	56%	53%	50%	47%	45%
	65	89%	80%	73%	67%	62%	57%	53%	50%	47%	44%	42%
	70	88%	78%	70%	64%	58%	54%	50%	47%	44%	41%	39%
	75	86%	75%	67%	60%	55%	50%	46%	43%	40%	38%	35%
	80	83%	71%	63%	56%	50%	45%	42%	38%	36%	33%	31%

Existing Hot Water Distribution Systems

Typical "Simple" Hot Water System



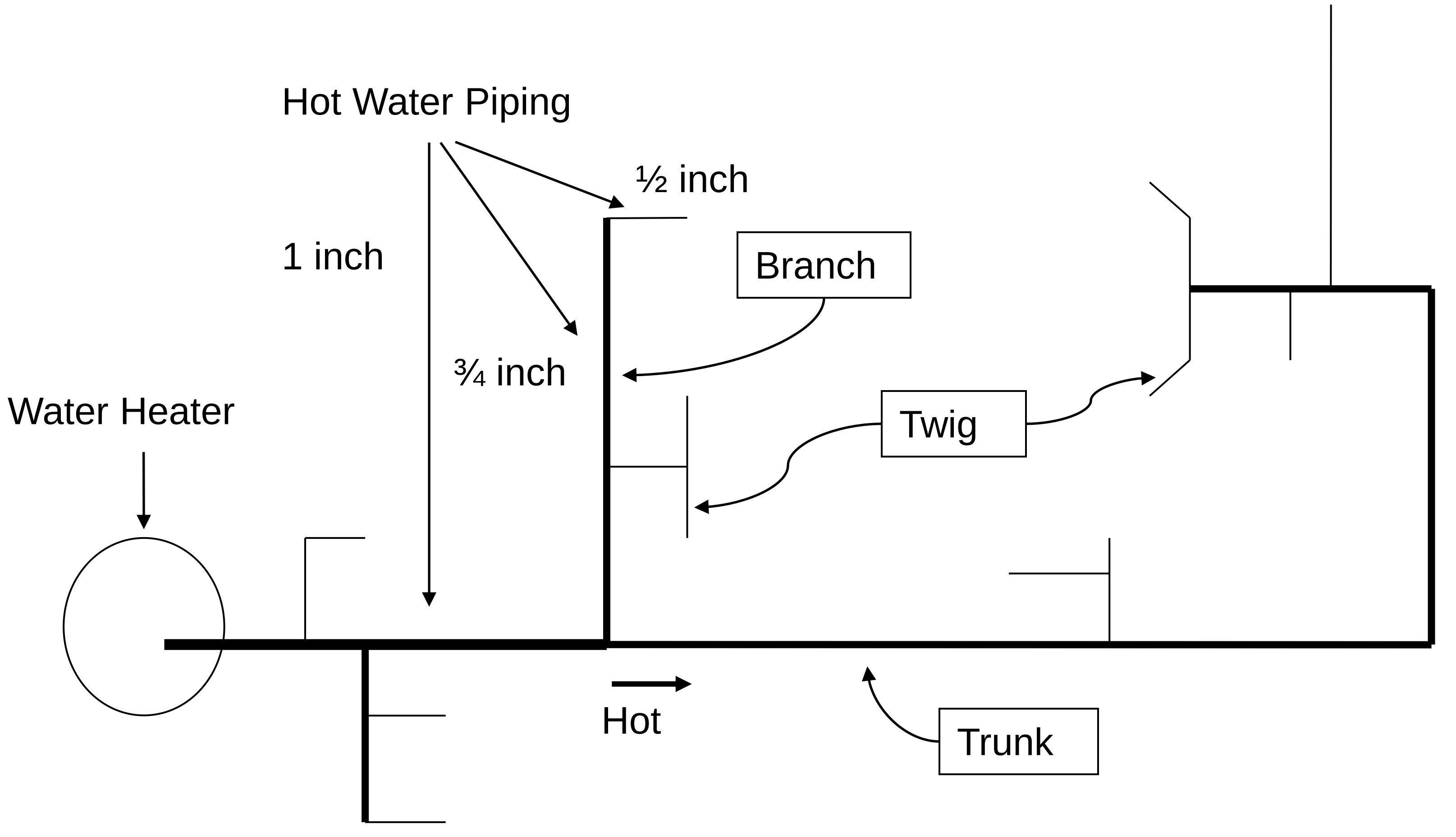
Definitions

1. A **Twig** line serves one outlet or appliance
   - The diameter of the twig should be determined by the flow rate of the outlet or appliance it serves & the pressure drop that will occur due to length, velocity, & restrictions to flow (e.g. elbows & tees)
2. A **Branch** line serves more than one twig
3. A **Trunk** line serves branches & twigs
4. A **Main** line serves the building
5. A **Hot Water Location** contains one or more hot water outlets & some cold ones, too

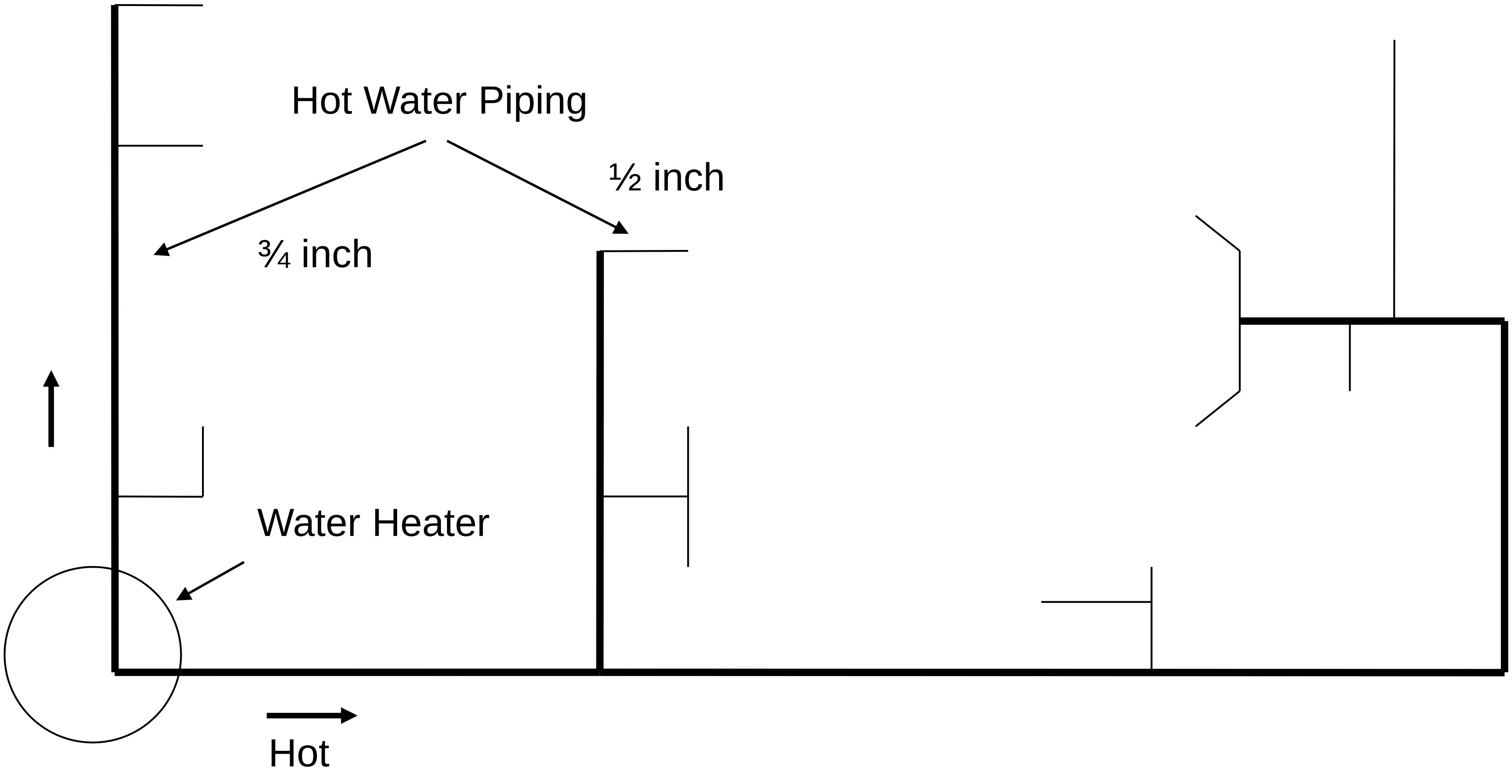
Which Distribution System is

In Your House?
At Your Job?
In Your Favorite Restaurant?

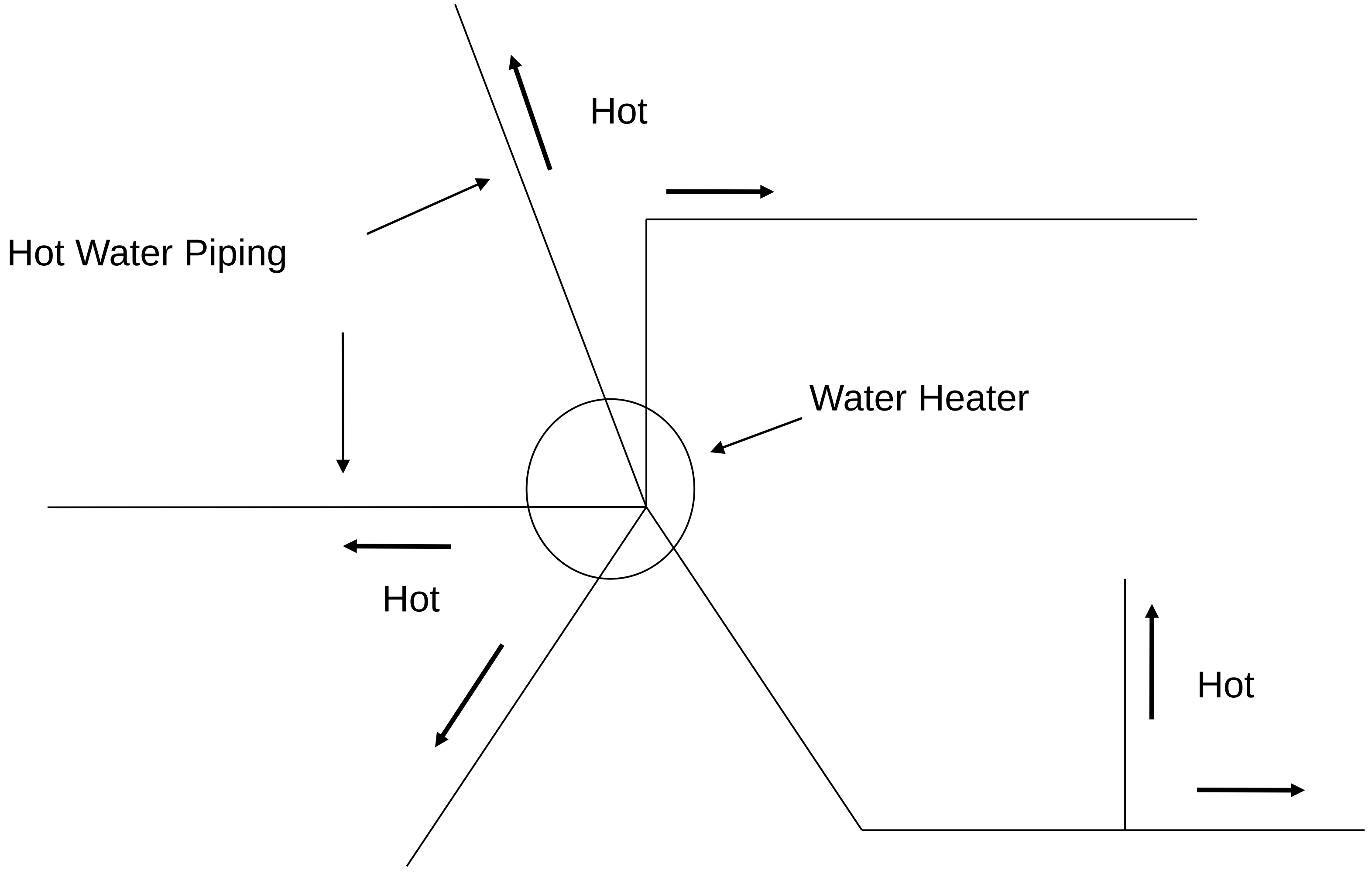
Single Trunk, Branch, & Twig



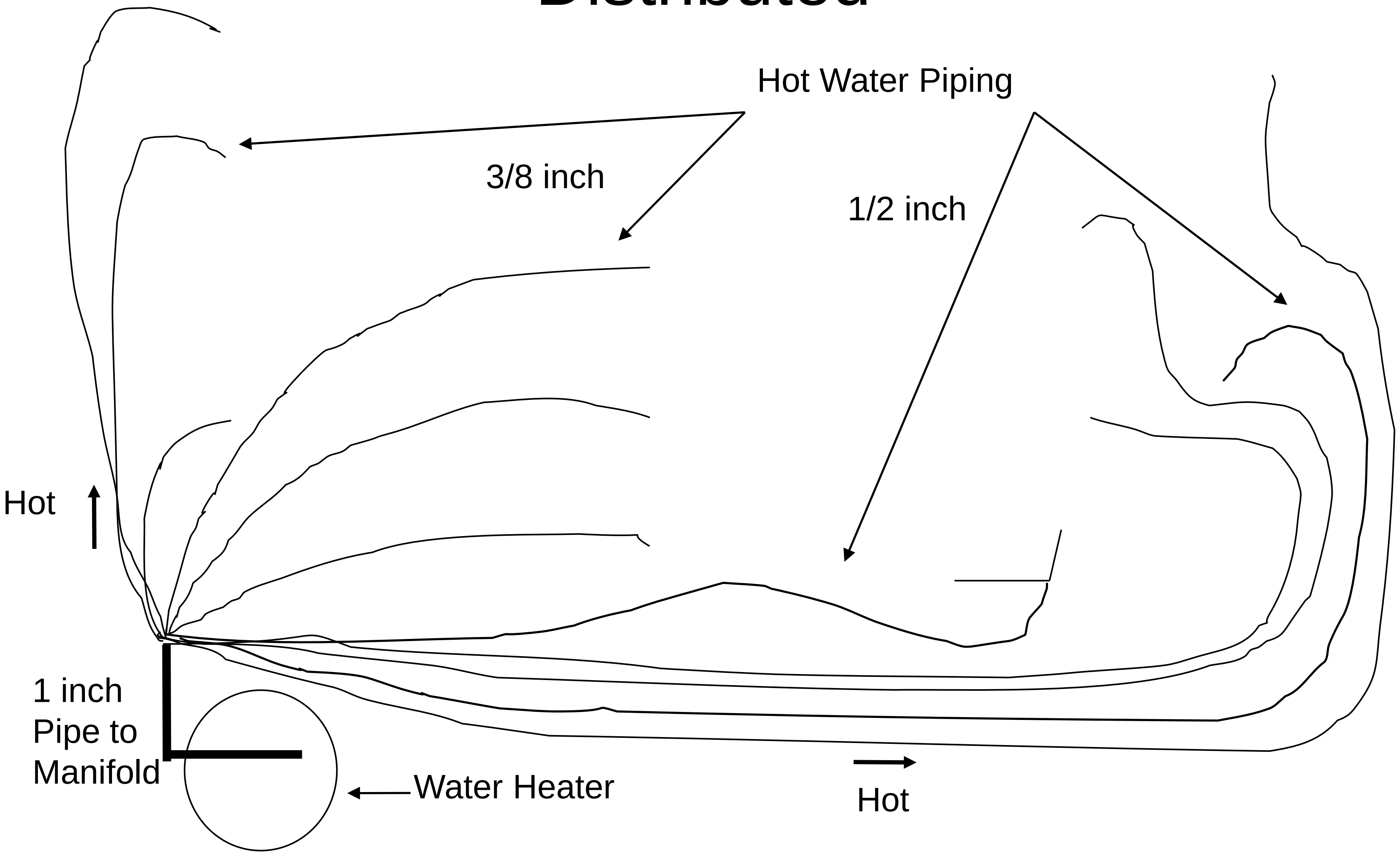
Multiple Trunk, Branch, & Twig



Radial, Manifold, Parallel Pipe- Central Core

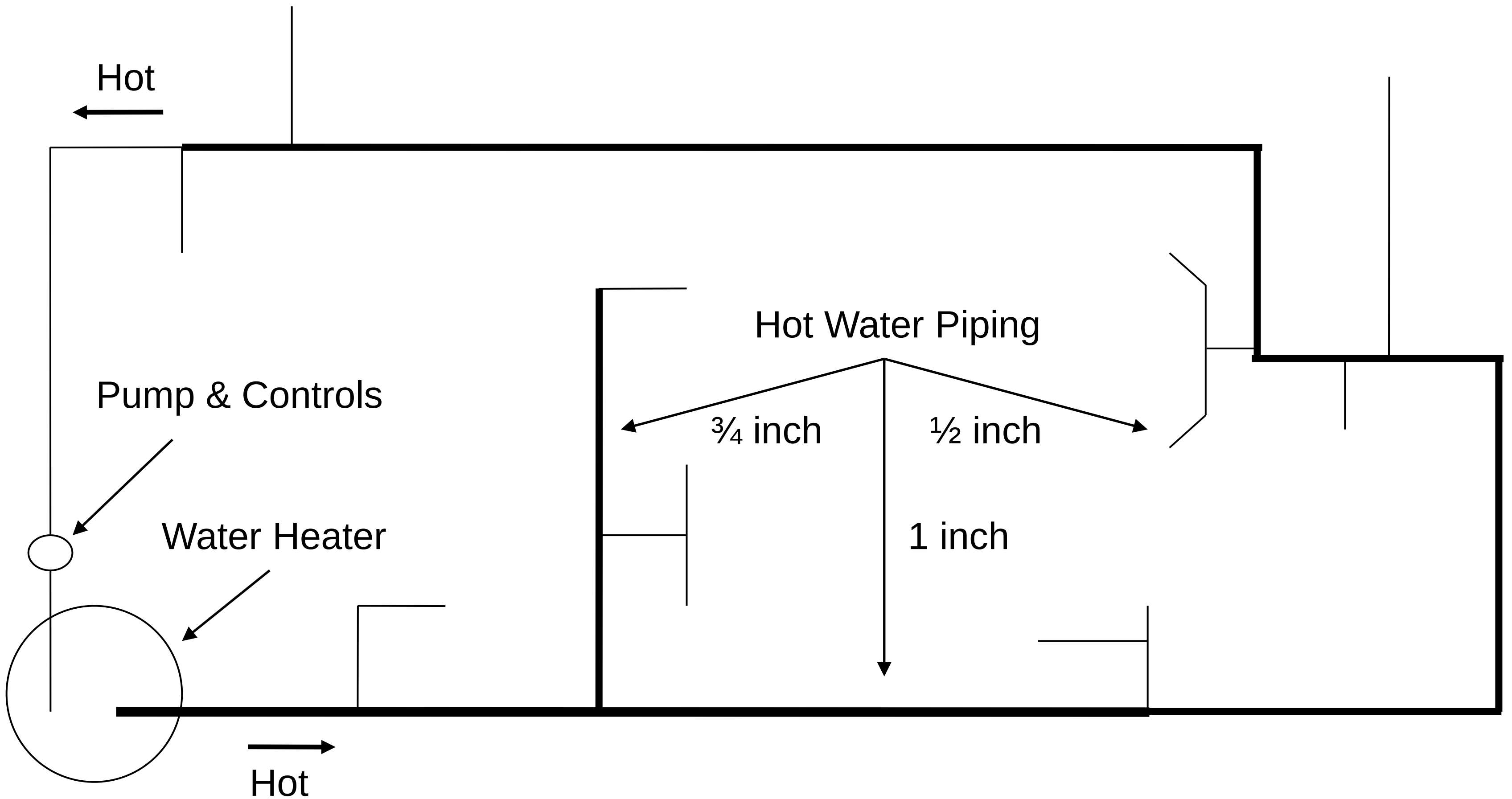


Radial, Manifold, Parallel Pipe- Distributed



Standard Recirculation

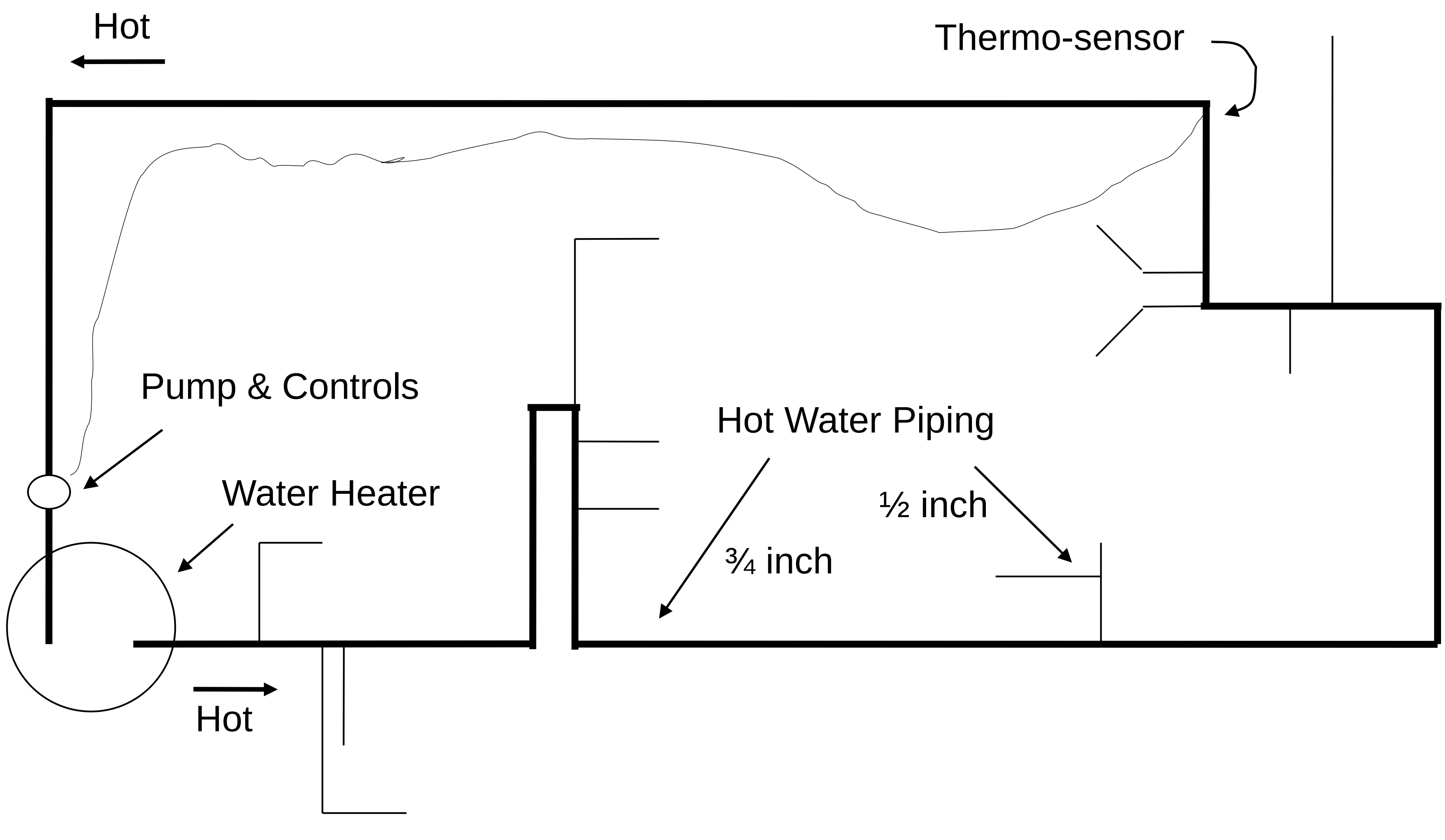
Fully Heated Loop



Standard Recirculation

Half-heated Loop

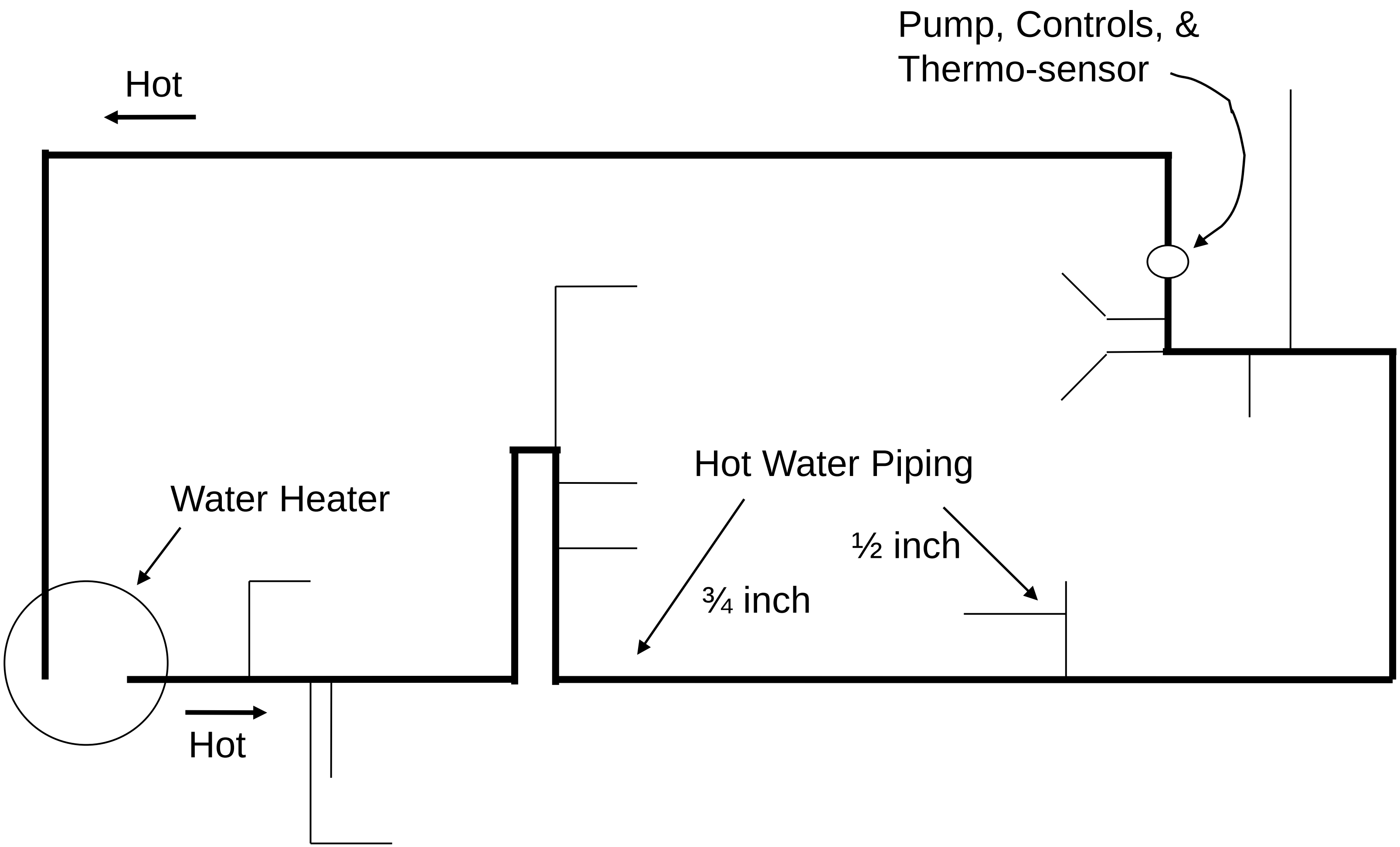
Pump Separated from Thermo-sensor



Standard Recirculation

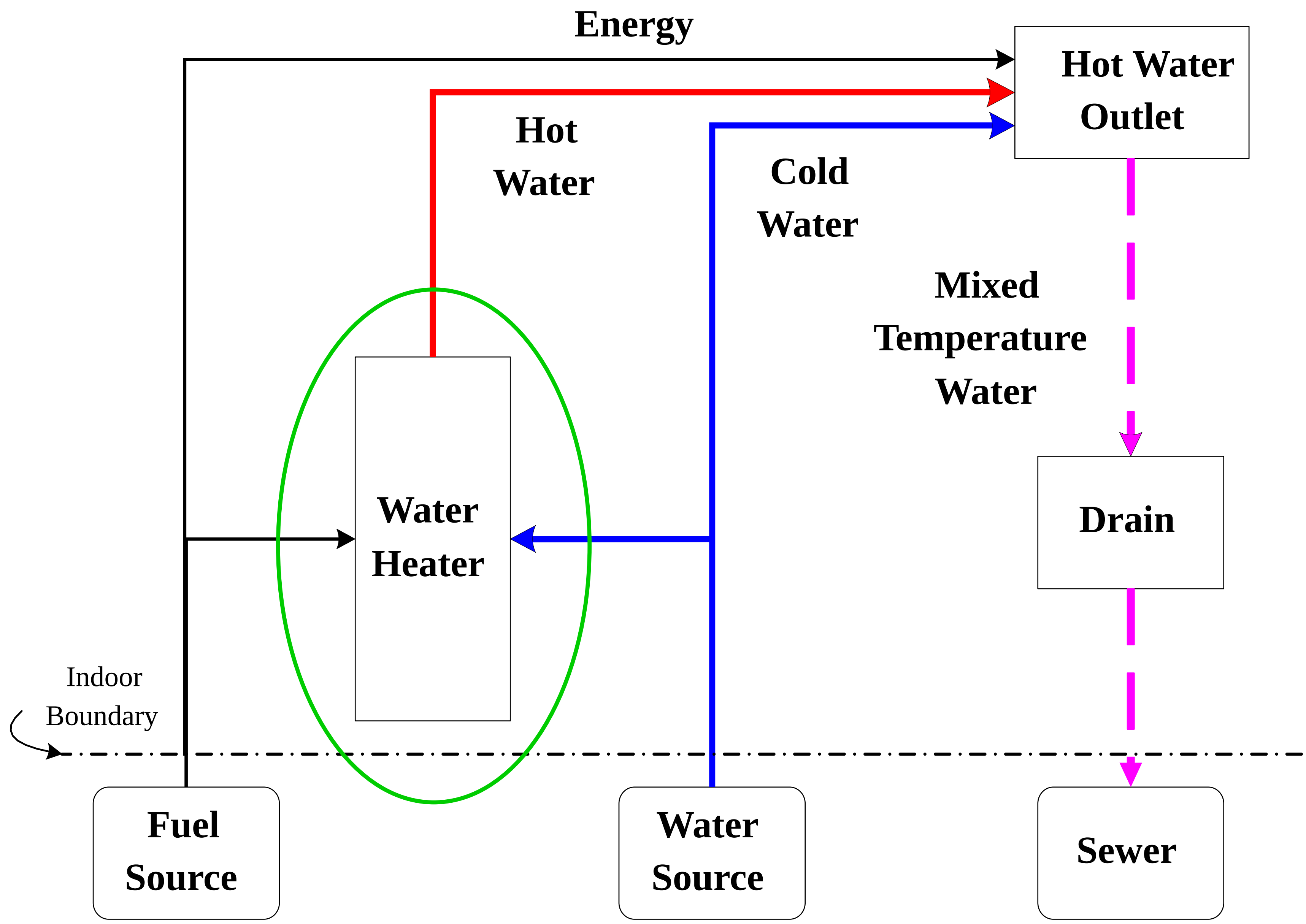
Half-heated Loop

Pump Located with Thermo-sensor



What About the
Existing Water Heater?

Typical “Simple” Hot Water System

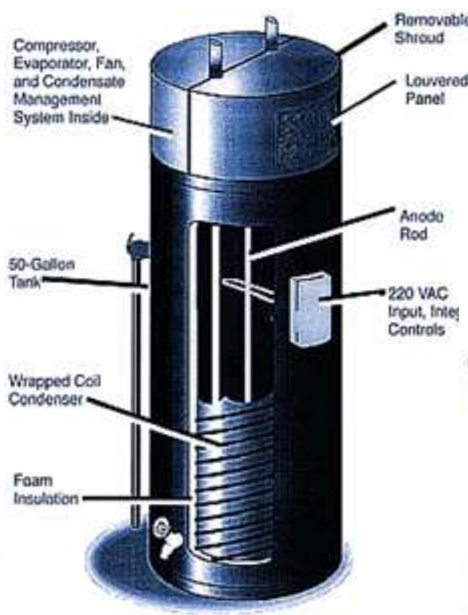


Water Heating Technologies

Electric





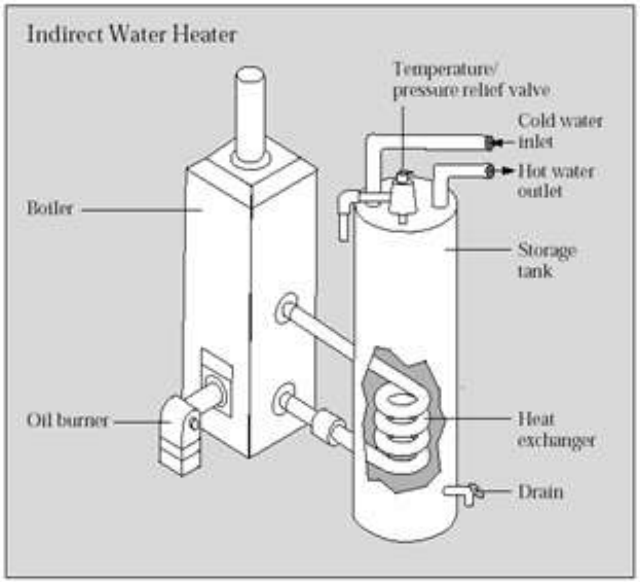


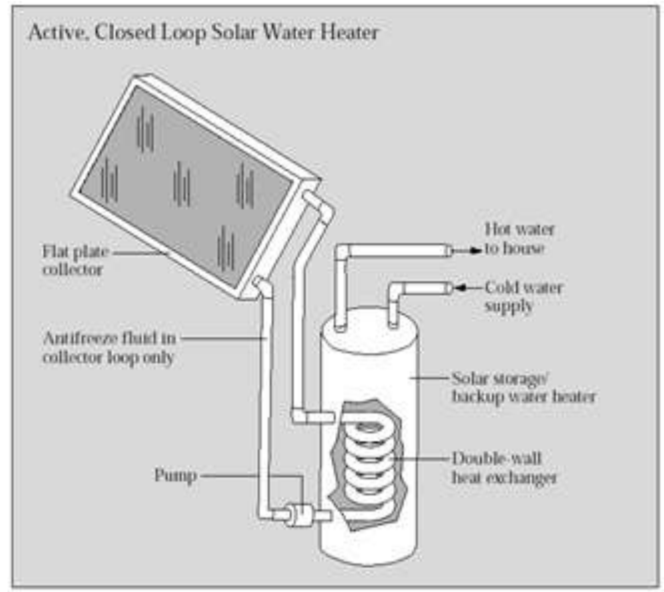
Gas



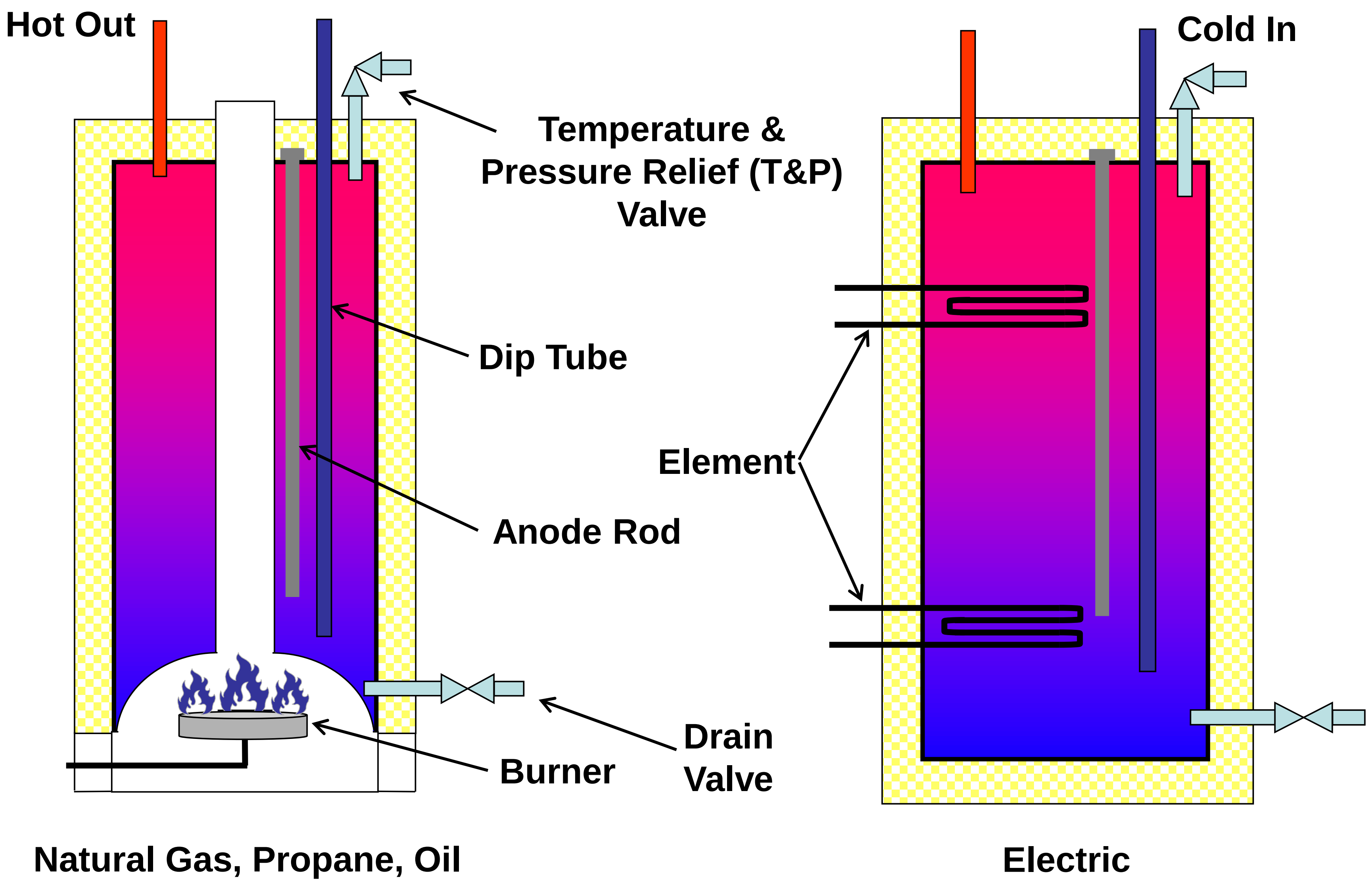



Still More Ways to Heat Water





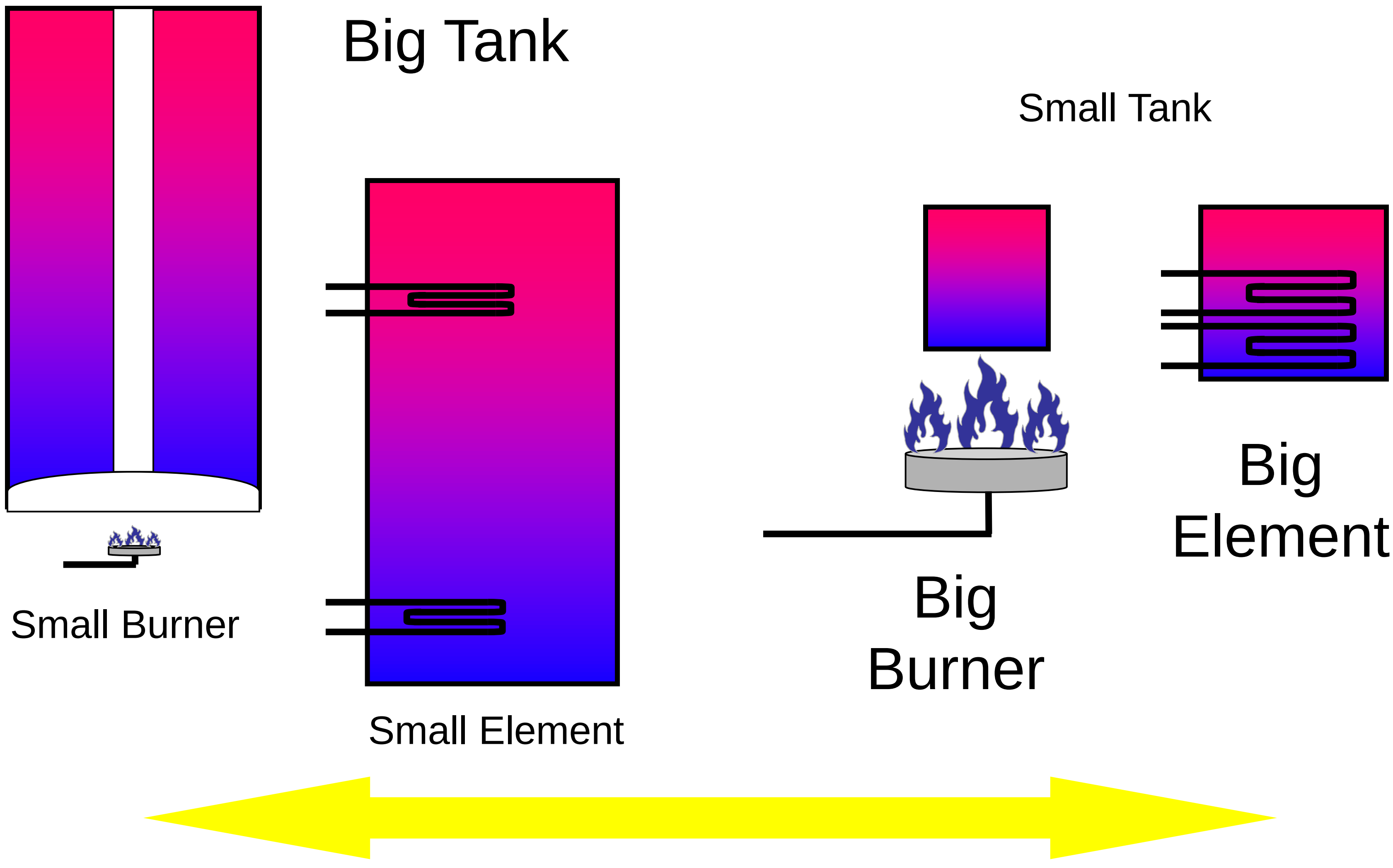
Inside a Storage Water Heater



Comparing Tank & Tankless Water Heaters

1. Efficiency
   - Energy factor or thermal efficiency
   - As compared to use pattern
2. Performance Characteristics
   - How does the water heater interact with the fixtures?
3. Ability to Meet Loads
   - Minimum, normal, & maximum
   - Volume & flow rate
4. Installation
   - Size
   - Location
   - Bring in gas or electricity
   - Venting
   - Cost
5. Life Expectancy
6. Warranties

The Essential Differences



Small Water Heaters “NAECA”

	Tank **(Storage)** <4000 Btu/hr/gal	**Tankless** **(On Demand)** < 2 gallons
Natural Gas	≤ 75,000 Btu	≤ 200,000 Btu
Oil	≤ 105,000 Btu	≤ 210,000 Btu
Electric		
•**Resistance** •**Heat Pump**	≤ 12 kW ≤ 24 amps	≤ 12 kW NA
Measure of Efficiency	Energy Factor (EF)	

Minimum Energy Factor

Storage Water Heaters

Natural Gas	min. EF = 0.67 - (0.0019*V)
Electric	min. EF = 0.97 - (0.00132*V)

Tankless Water Heaters

Natural Gas	min. EF = 0.62 – (0.0019*V)
Electric	min. EF = 0.93 – (0.00132*V)

Where V = volume

Note: Since the maximum volume for small tankless is 2 gallons, the minimum EF for gas tankless becomes 0.62 & the minimum EF for electric tankless is 0.93.

Range of Energy Factors

Volume (gallons)	Minimum EF	Maximum EF available
Natural Gas Storage Water Heater		
30	0.61	0.64
40	0.59	0.65
50	0.58	0.65
75	0.53	0.59
Electric Storage Water Heater		
40	0.92	0.95
50	0.90	0.95
66	0.88	0.95
80	0.86	0.95

Large Water Heaters "EPAct"

	Tank (Storage)	**Tankless (On demand)** < 2 gallons
Natural Gas	> 75,000 Btu	> 200,000 Btu
Oil	> 105,000 Btu	> 210,000 Btu
Electric	> 12 kW	> 12 kW
Measure of Efficiency	Thermal Efficiency (TE) and standby loss	

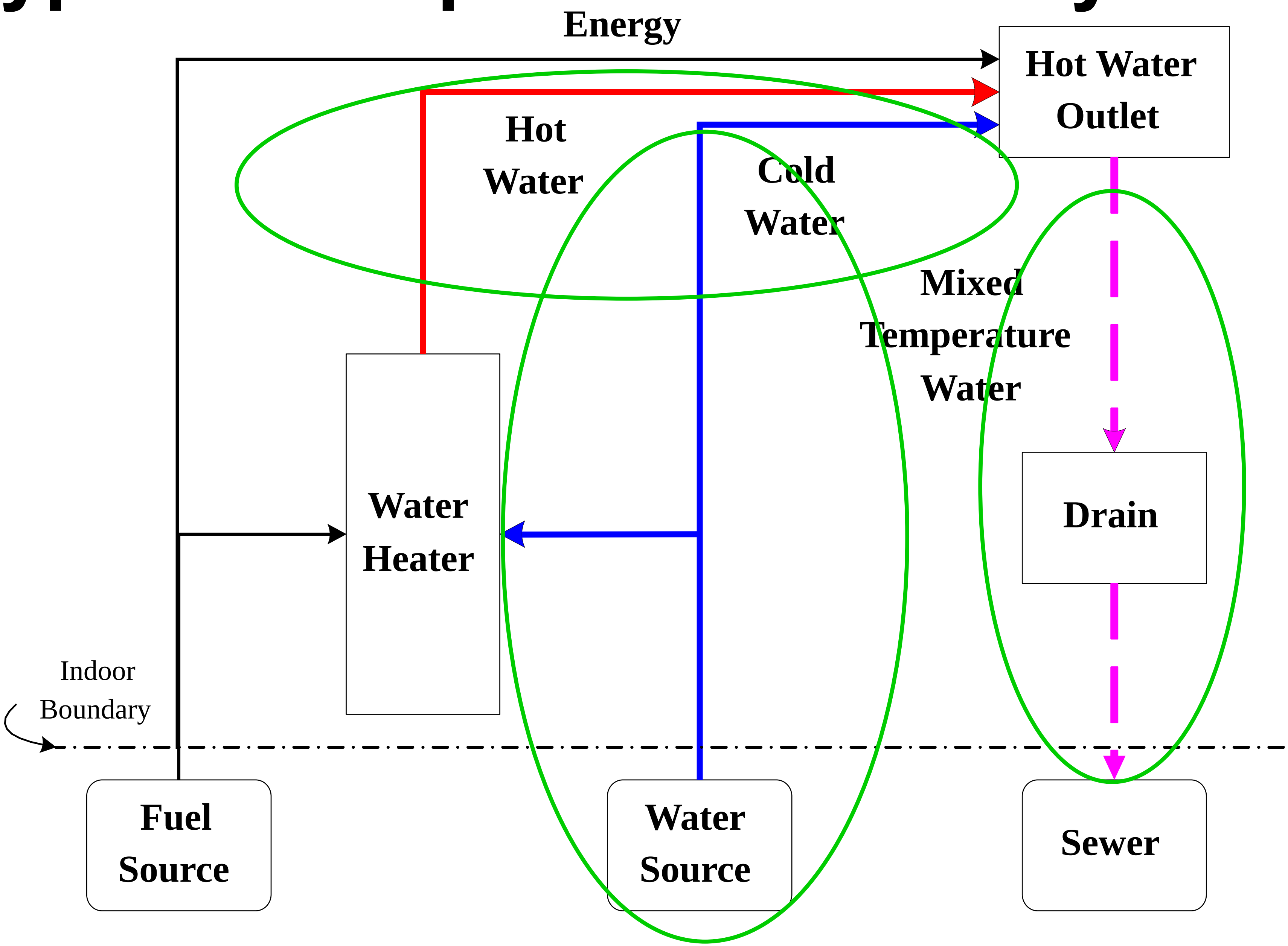
Achieving Deep Reductions in Water Heating

- Apply behavioral choices to change hot water-using behavior
- Consider community solutions

High Efficiency Water Heating Systems

Step 1:
Improve the Hot Water Distribution System

Typical “Simple” Hot Water System



How Do We Conserve Hot Water?

Use less hot water (volume) per event

- Begins with the water heater
- Passes through the hot water distribution system
- Discharges through the hot water outlets
- Mixed temperature water runs down the drain
- Total is due to a combination of structural & behavioral considerations.

The supply of hot water ends at the fixtures & appliances, not at the customer’s meter

The future of water conservation programs depends on getting the structural considerations correct today

Begin with the end in mind…

How much do you want to waste?

Remember What People Want

- Hot Water Now = “Instantaneousness”
  - – Need hot water available before the start of each draw
    - A tank with hot water
    - Heated pipes
  - – Need the source of hot water close to each fixture or appliance
  - – Point of use is not about water heater size, its about location
- Never Run Out = “Continuousness”
  - – Need a large enough tank or a large enough burner or element
  - – Or, a modest amount of both

The Ideal Hot Water Distribution System

- Has the smallest volume (length & smallest "possible" diameter) of pipe from the source of hot water to the hot water outlet
- Sometimes the source of hot water is the water heater, sometimes a trunk line
- For a given layout (floor plan) of hot water locations the system will have
  - The shortest buildable trunk line
  - Few or no branches
  - The shortest buildable twigs
  - The fewest plumbing restrictions
  - Insulation on all hot water pipes, minimum R-4

The Challenge

Deliver hot water

to every hot water outlet

wasting no more energy

than we currently waste and

wasting no more than 1 cup

waiting for the hot water to arrive

Possible Solutions

A. Central plumbing core
   - Only if all fittings are within 1 cup of one water heater. Unlikely without shift in perceptions of floor plans

B. 1 water heater for every hot water fitting
   - More expensive to bring energy to the water heaters than it is to bring plumbing. Then you have the additional cost for the heaters, flues, & space. Not to mention the future maintenance.

C. 2-3 water heaters per home
   - Same as above. Might make sense in buildings with distant hot water locations & very intermittent uses.

D. Heat trace on the pipes
   - Long, skinny, under insulated water heater. Expensive to install. Great on water conservation. Very expensive on energy.

E. Circulation loop 1 cup from every hot water fixture
   - Most buildable option. All circulation systems can save water, only one can save energy.

How Tall Are You?

Courtesy of Florida PHCC

To Improve the Delivery Phase

Get hotter water sooner by minimizing
the waste of water, energy, & time

- Reduce the volume of water in the pipe
  - Smaller diameter, shorter length
  - As flow rates go down, water waste goes up
- Reduce the number of restrictions to flow
  - Decrease “effective length”
- Increase the flow rate
  - Prime the hot water trunk just prior to use with a demand-controlled pump
- Insulate the pipe
  - Becomes critical for very low flow rates & adverse environmental conditions

To Improve the Use Phase

Minimize the thermal losses the water heater needs to overcome in the piping during a hot water event

- Insulate the pipes
  - Increases pipe temperature & reduces heat loss during a hot water event.
    - Particularly important for low flow rate outlets.
  - Temperature drop over a given distance for a given flow rate is cut roughly in half (**pipes in air**)
    - Uninsulated: ≈ 6^{o}F in 100 ft of ¾ inch pipe
    - Insulated: ≈ 3^{o}F in 100 ft of ¾ inch pipe
  - Much larger reductions for buried pipe
- Take advantage of the energy savings
  - Keep the water heater temperature the same & change the mix point
  - Reduce the water heater temperature setting.
  - Combine both strategies.

To Improve the Cool-Down Phase

Increase the availability of hot water &
minimize the waste of water, energy, & time

Insulate the pipes

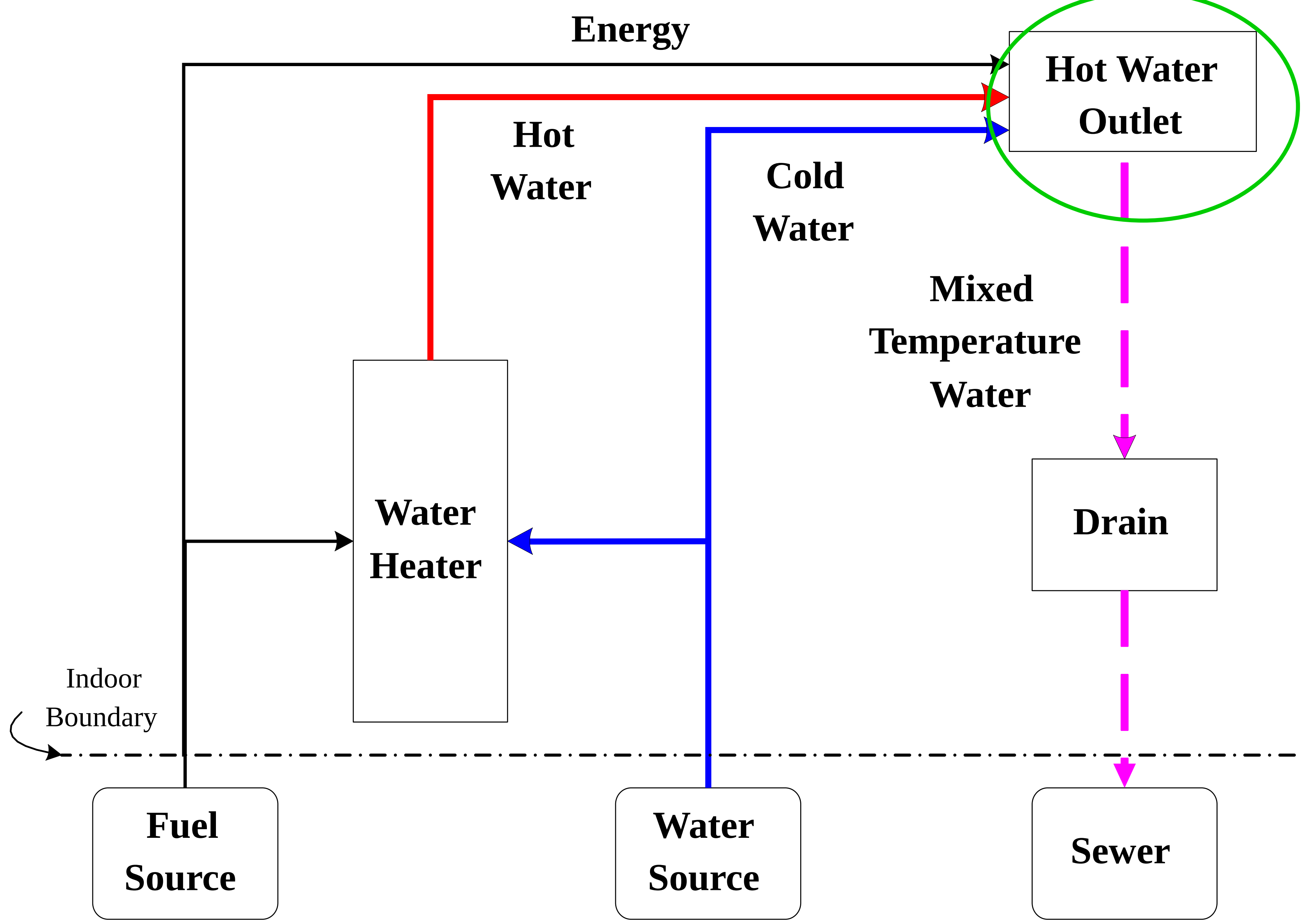
- Increases the time pipes stay hot between events
  - On ½ inch pipe in room temperature air R-4 insulation
    - Doubles cool down time
    - ≈ 10 minutes (uninsulated) to 20 min (insulated)
  - On ¾ inch pipe in room temperature air R-4 insulation
    - Triples cool down time
    - ≈ 15 minutes (uninsulated) to 20 min (insulated)
  - What will it be with 3/8 inch? 1 inch? 2 inch?
  - Buried piping – cool down is 8 times longer (5 to 40 min)

Is there a priority to insulating the pipes?

- Trunks, branches, twigs?
- Duration of hot water events?
- Time between hot water events?

Step 2:
Improve the Water Use Efficiency of the Hot Water Outlets

Typical "Simple" Hot Water System



What is the Future of Flow Rates?

Kitchen sinks – 0.5 to 2 gpm (hot only to left, pot fill)

Lavatory sinks – 0.5 gpm (hot only to left)

Showers – 1.5 gpm (water down drain)

Showers – 15 gallons (maximum volume per event)

What impact will these flow rates have on system performance?

Given these flow rates, what impact will the interactions with the rest of the system have on customer satisfaction?

Water Waste as a Function of Flow Rate (Really Velocity)

Flow Rate	¾ inch Nominal Diameter Pipe	
	% Relative Water Waste	Approximate Velocity Feet per Second
Greater than 4 gpm	Just over 100%	Greater than 3
4 gpm	110%	2.65
3 gpm	120%	1.99
2 gpm	130%	1.33
1 gpm	150%	0.66
0.5 gpm	Roughly 200%	0.33
0.25 gpm	????	0.17

The velocity of 0.5 gpm in ¾ inch nominal pipe
is roughly equivalent to the velocity of
2 gpm in 1.5 inch nominal pipe

Gallons Wasted as a Function of Time and Fixture Flow Rate

(Green < 2 cups), Red >1/2 Gallon)

Flow Rate (GPM)	Time Until Hot Water Arrives (Seconds)															
	1	2	3	4	5	10	15	20	25	30	35	40	45	50	55	60
0.5	0.01	0.02	0.03	0.03	0.04	0.08	0.13	0.17	0.21	0.25	0.29	0.33	0.38	0.42	0.46	0.50
1	0.02	0.03	0.05	0.07	0.08	0.17	0.25	0.33	0.42	0.50	0.58	0.67	0.75	0.83	0.92	1.00
1.5	0.03	0.05	0.08	0.10	0.13	0.25	0.38	0.50	0.63	0.75	0.88	1.00	1.13	1.25	1.38	1.50
2	0.03	0.07	0.10	0.13	0.17	0.33	0.50	0.67	0.83	1.00	1.17	1.33	1.50	1.67	1.83	2.00
2.5	0.04	0.08	0.13	0.17	0.21	0.42	0.63	0.83	1.04	1.25	1.46	1.67	1.88	2.08	2.29	2.50
3	0.05	0.10	0.15	0.20	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
3.5	0.06	0.12	0.18	0.23	0.29	0.58	0.88	1.17	1.46	1.75	2.04	2.33	2.63	2.92	3.21	3.50
4	0.07	0.13	0.20	0.27	0.33	0.67	1.00	1.33	1.67	2.00	2.33	2.67	3.00	3.33	3.67	4.00
4.5	0.08	0.15	0.23	0.30	0.38	0.75	1.13	1.50	1.88	2.25	2.63	3.00	3.38	3.75	4.13	4.50
5	0.08	0.17	0.25	0.33	0.42	0.83	1.25	1.67	2.08	2.50	2.92	3.33	3.75	4.17	4.58	5.00
5.5	0.09	0.18	0.28	0.37	0.46	0.92	1.38	1.83	2.29	2.75	3.21	3.67	4.13	4.58	5.04	5.50
6	0.10	0.20	0.30	0.40	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00
6.5	0.11	0.22	0.33	0.43	0.54	1.08	1.63	2.17	2.71	3.25	3.79	4.33	4.88	5.42	5.96	6.50
7	0.12	0.23	0.35	0.47	0.58	1.17	1.75	2.33	2.92	3.50	4.08	4.67	5.25	5.83	6.42	7.00
7.5	0.13	0.25	0.38	0.50	0.63	1.25	1.88	2.50	3.13	3.75	4.38	5.00	5.63	6.25	6.88	7.50
8	0.13	0.27	0.40	0.53	0.67	1.33	2.00	2.67	3.33	4.00	4.67	5.33	6.00	6.67	7.33	8.00
8.5	0.14	0.28	0.43	0.57	0.71	1.42	2.13	2.83	3.54	4.25	4.96	5.67	6.38	7.08	7.79	8.50
9	0.15	0.30	0.45	0.60	0.75	1.50	2.25	3.00	3.75	4.50	5.25	6.00	6.75	7.50	8.25	9.00
9.5	0.16	0.32	0.48	0.63	0.79	1.58	2.38	3.17	3.96	4.75	5.54	6.33	7.13	7.92	8.71	9.50
10	0.17	0.33	0.50	0.67	0.83	1.67	2.50	3.33	4.17	5.00	5.83	6.67	7.50	8.33	9.17	10.00

1 cup = 8 ounces = 1/16th gallon = 0.0625 gallon

Gallons Wasted as a Function of Time and Fixture Flow Rate

(Green < 2 cups), Red >1/2 Gallon)

Time Until Hot Water Arrives (Seconds)

Flow Rate (GPM)	1	2	3	4	5	10	15	20	25	30	35	40	45	50	55	60
0.5	0.01	0.02	0.03	0.03	0.04	0.08	0.13	0.17	0.21	0.25	0.29	0.33	0.38	0.42	0.46	0.50
1	0.02	0.03	0.05	0.07	0.08	0.17	0.25	0.33	0.42	0.50	0.58	0.67	0.75	0.83	0.92	1.00
1.5	0.03	0.05	0.08	0.10	0.13	0.25	0.38	0.50	0.63	0.75	0.88	1.00	1.13	1.25	1.38	1.50
2	0.03	0.07	0.10	0.13	0.17	0.33	0.50	0.67	0.83	1.00	1.17	1.33	1.50	1.67	1.83	2.00
2.5	0.04	0.08	0.13	0.17	0.21	0.42	0.63	[illegible]	1.04	1.25	1.46	1.67	1.88	2.08	2.29	2.50
3	0.05	0.10	0.15	0.20	0.25	0.50	0.75	[illegible]	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
3.5	0.06	0.12	0.18	0.23	0.29	0.58	0.88	1.17	[illegible]	1.75	2.04	2.33	2.63	2.92	3.21	3.50
4	0.07	0.13	0.20	0.27	0.33	0.67	1.00	1.33	[illegible]	2.00	2.33	2.67	3.00	3.33	3.67	4.00
4.5	0.08	0.15	0.23	0.30	0.38	0.75	1.13	1.50	1.88	2.25	2.63	3.00	3.38	3.75	4.13	4.50
5	0.08	0.17	0.25	0.33	0.42	0.83	1.25	1.67	2.08	2.50	2.92	3.33	3.75	4.17	4.58	5.00
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6.5	0.11	0.22	0.33	0.43	0.54	1.08	1.63	2.17	2.71	3.25	3.79	4.33	4.88	5.42	5.96	6.50
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8.5	0.14	0.28	0.43	0.57	0.71	1.42	2.13	2.83	3.54	4.25	4.96	5.67	6.38	7.08	7.79	8.50
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Gallons Wasted as a Function of Time and Fixture Flow Rate

(Green < 2 cups), Red >1/2 Gallon)

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1	0.02	0.03	0.05	0.07	0.08	0.17	0.25	0.33	0.42	0.50	0.58	0.67	0.75	0.83	0.92	1.00
1.5	0.03	0.05	0.08	0.10	0.13	0.25	0.38	0.50	0.63	0.75	[illegible]	1.00	1.13	1.25	1.38	1.50
2	0.03	0.07	0.10	0.13	0.17	0.33	0.50	0.67	0.83	1.00	[illegible]	1.33	1.50	1.67	1.83	2.00
2.5	0.04	0.08	0.13	0.17	0.21	0.42	0.63	0.83	1.04	1.25	1.46	[illegible]	1.88	2.08	2.29	2.50
3	0.05	0.10	0.15	0.20	0.25	0.50	0.75	1.00	1.25	1.50	1.75	[illegible]	2.25	2.50	2.75	3.00
3.5	0.06	0.12	0.18	0.23	0.29	0.58	0.88	1.17	1.46	1.75	2.04	2.33	2.63	2.92	3.21	3.50
4	0.07	0.13	0.20	0.27	0.33	0.67	1.00	1.33	1.67	2.00	2.33	2.67	3.00	3.33	3.67	4.00
4.5	0.08	0.15	0.23	0.30	0.38	0.75	1.13	1.50	1.88	2.25	2.63	3.00	3.38	3.75	4.13	4.50
5	0.08	0.17	0.25	0.33	0.42	0.83	1.25	1.67	2.08	2.50	2.92	3.33	3.75	4.17	4.58	5.00
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6.5	0.11	0.22	0.33	0.43	0.54	1.08	1.63	2.17	2.71	3.25	3.79	4.33	4.88	5.42	5.96	6.50
7	0.12	0.23	0.35	0.47	0.58	1.17	1.75	2.33	2.92	3.50	4.08	4.67	5.25	5.83	6.42	7.00
7.5	0.13	0.25	0.38	0.50	0.63	1.25	1.88	2.50	3.13	3.75	4.38	5.00	5.63	6.25	6.88	7.50
8	0.13	0.27	0.40	0.53	0.67	1.33	2.00	2.67	3.33	4.00	4.67	5.33	6.00	6.67	7.33	8.00
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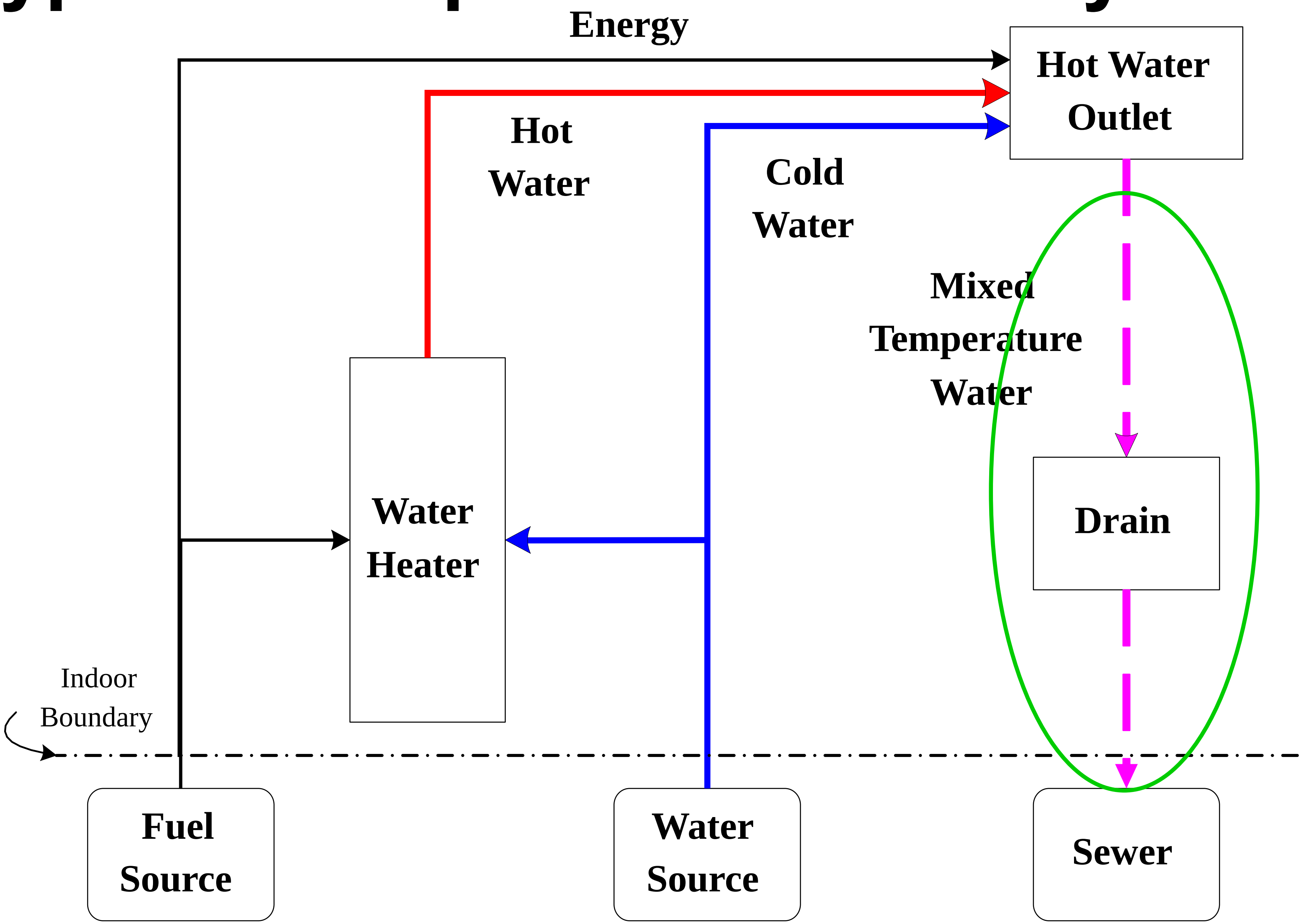
9.5	0.16	0.32	0.48	0.63	0.79	1.58	2.38	3.17	3.96	4.75	5.54	6.33	7.13	7.92	8.71	9.50
10	0.17	0.33	0.50	0.67	0.83	1.67	2.50	3.33	4.17	5.00	5.83	6.67	7.50	8.33	9.17	10.00

1 cup = 8 ounces = 1/16th gallon = 0.0625 gallon

Step 3:
Capture Waste Heat from the Drains

Typical "Simple" Hot Water System



Drain Water Heat Recovery

Drain Water Heat Recovery (DWHR)

- **Potential Savings**
  - Roughly 50% of the needed temperature rise
- **Impacts**
  - Reduce hot water portion of outlet flow rate
  - How does this affect the operation of the water heater?
    - Tank versus tankless
  - How does it impact temperature drop in the piping?

How Much is Hot? How Much is Cold?

		Percent of Mixed Temperature Water (105F) that is Hot										
		Hot Water Temperature (F)										
		110	115	120	125	130	135	140	145	150	155	160
Cold Water Temperature (F)	35	93%	88%	82%	78%	74%	70%	67%	64%	61%	58%	56%
	40	93%	87%	81%	76%	72%	68%	65%	62%	59%	57%	54%
	45	92%	86%	80%	75%	71%	67%	63%	60%	57%	55%	52%
	50	92%	85%	79%	73%	69%	65%	61%	58%	55%	52%	50%
	55	91%	83%	77%	71%	67%	63%	59%	56%	53%	50%	48%
	60	90%	82%	75%	69%	64%	60%	56%	53%	50%	47%	45%
	65	89%	80%	73%	67%	62%	57%	53%	50%	47%	44%	42%
	70	88%	78%	70%	64%	58%	54%	50%	47%	44%	41%	39%
	75	86%	75%	67%	60%	55%	50%	46%	43%	40%	38%	35%
	80	83%	71%	63%	56%	50%	45%	42%	38%	36%	33%	31%

Step 4:
Increase Water Heater Efficiency

Energy Star for Water Heaters

Effective January 1, 2009, there is an Energy Star program for NAECA (residential) water heaters.

- 0.62 EF for standard gas storage water heaters
- 0.80 EF for condensing storage water heaters
- 0.82 EF for gas tankless water heaters
- 2.0 EF for heat pump water heaters
- Solar Water Heaters
  - Solar Fraction ≥ 0.5, OG-300 Certification from SRCC
  - Warranty ≥ 10 yrs. collector, 6 yrs. storage tank, 2 yrs. controls, 1 yr. piping & parts

Energy Star for Water Heaters

- Facts to note
  - No Energy Star for resistance electric water heaters – storage & tankless
  - No Energy Star for EPAct water heaters
  - EF level for standard gas storage water heaters will increase to 0.67 in 2010
- Opportunity!
  - This program should facilitate the sale of more efficient water heaters.

Effex^{TM} 2010 Energy Star

AO Smith Gas Water Heater

- 0.70 EF
- No standing pilot
- Standard venting & gas lines

1. Advanced electronic control
2. Tighter baffling
3. Patented air intake

A “Good” Water Heater

Residential

- Does not have to be large enough for extreme peak periods, but it must have a large enough burner or element to keep up with the hot water needed for one standard shower.
- Must be able to serve an infinite number of hot water use patterns
- Typical pattern: morning rush hour, evening plateau, weekends are spread out, lots of small draws

Commercial

- Serves the intended loads
- Meets the requirements of the applicable codes:
  - Health & Safety, Plumbing, Energy, Building, Green

Effective Capacity of Storage Water Heaters

50 gallon tank with 70% available volume (35 gal)

1 gpm =	35	minute shower
2 gpm =	17.5	minute shower
2.5 gpm =	14	minute shower
5 gpm =	7	minute shower
10 gpm =	3.5	minute shower
20 gpm =	1.5	minute shower

Typical burner or element:

- Natural gas – 40,000 Btu, 75% thermal efficiency
- Electric – 4,500 watts in each of 2 elements, 98% thermal efficiency

Effective Capacity of Tankless Water Heaters

Incoming cold water 50F. Hot output 120F.

Natural Gas		Electric
20,000 Btu =	0.5 gpm =	5 kW
40,000 Btu =	1 gpm =	10 kW
100,000 Btu =	2.5 gpm =	25 kW
200,000 Btu =	5 gpm =	50 kW
400,000 Btu =	10 gpm =	100 kW
800,000 Btu =	20 gpm =	200 kW

Natural Gas – nominal 85% thermal efficiency

Electric – nominal 98% thermal efficiency

Neither Tank or Tankless is Necessarily the Answer

A combination of the two might be better:

- **Burner or element**
  - Sized for some amount of continuous use
  - Residential
    - Approximately 1.5-3 GPM
    - 60-120,000 Btu Natural Gas, 15-30 kW Electric
  - Commercial
- **Modest tank**
  - Hot water available at the beginning of every draw
  - Some volume for peak conditions
  - Enables a simpler burner control strategy
- **Possible in both gas & electric**

How does the water heater interact with the fixtures?

Several Options in Natural Gas

Navien (www.navienamerica.com)

- 98% thermal efficiency (condensing)
- Power direct vent (sealed combustion)
- 15-150,000 or 17-199,000 Btu input (modulating)
- ½ gallon storage tank

Grand Hall-Eternal (www.eternalwaterheater.com)

- 98% thermal efficiency (condensing) (0.96 EF)
- Power direct vent (sealed combustion)
- 31-145,000 or 199,000 Btu input (modulating)
- < 2 gallon storage tank

Several Options in Natural Gas

AO Smith (www.hotwater.com)

Vertex

- 50 gallon storage tank
- 100,000 Btu input, power direct vent
    - 96% thermal efficiency (condensing)

NEXT Hybrid

- 90% thermal efficiency (condensing)
- Same water & gas connections as standard gas storage

Several Options in Natural Gas

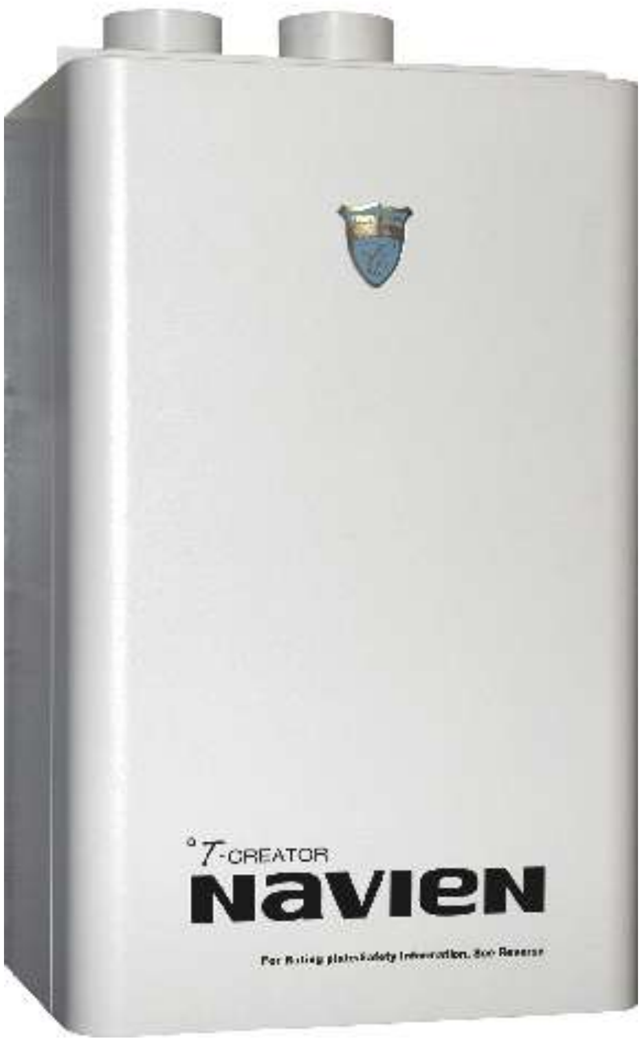
American Water Heater-Polaris (www.americanwaterheater.com)

- 95% thermal efficiency (condensing)
- Power direct vent (sealed combustion)
- 100, 130, 150, 175, 199,000 Btu input
- 34, 50 or 100 gallon storage tank

Heat Transfer Products-Phoenix (www.htproducts.com)

- 96% thermal efficiency (condensing)
- Power direct vent (sealed combustion)
- 100, 130 or 199,00 Btu input
  - Modulating (3:1 turndown)
- 55, 80 or 199 gallon storage tank

Navien
What is actual efficiency?



?

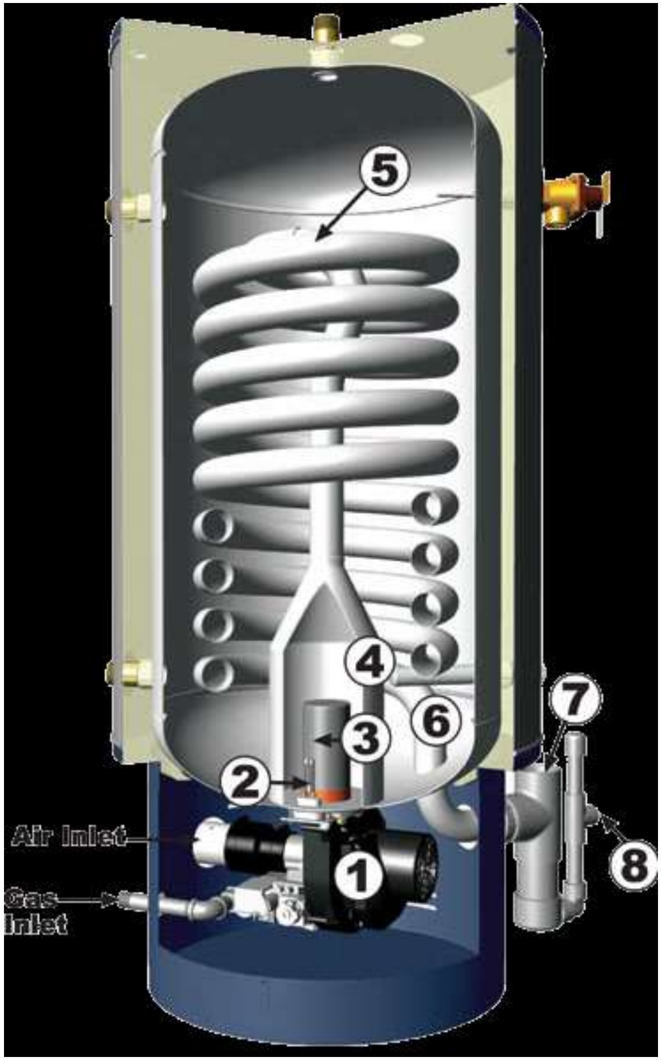
Grandhall-Eternal

A.O. Smith-Vertex

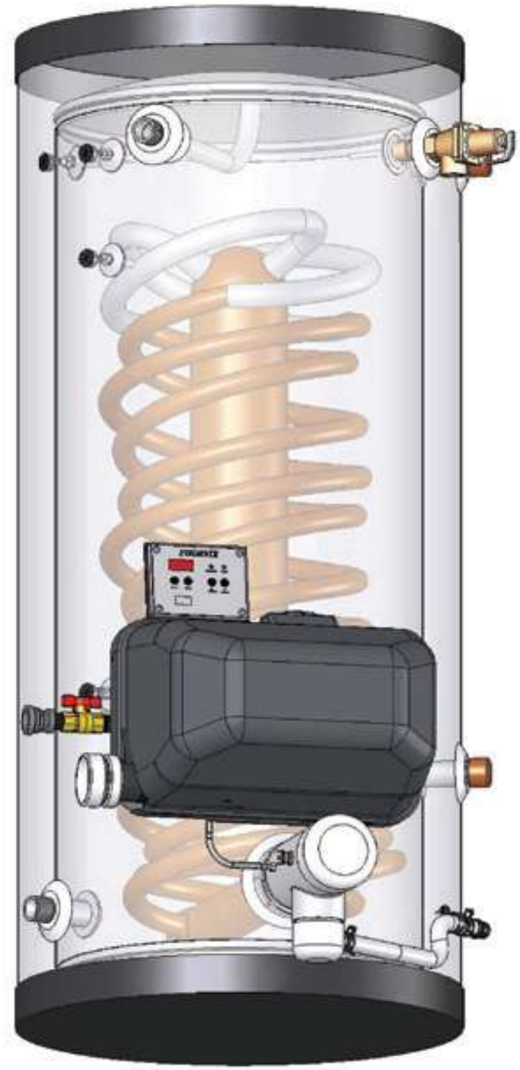
A.O. Smith-NEXT Hybrid

- Small foot-print
  - 24”W * 48”H * 32”D
- Combines tankless & storage features

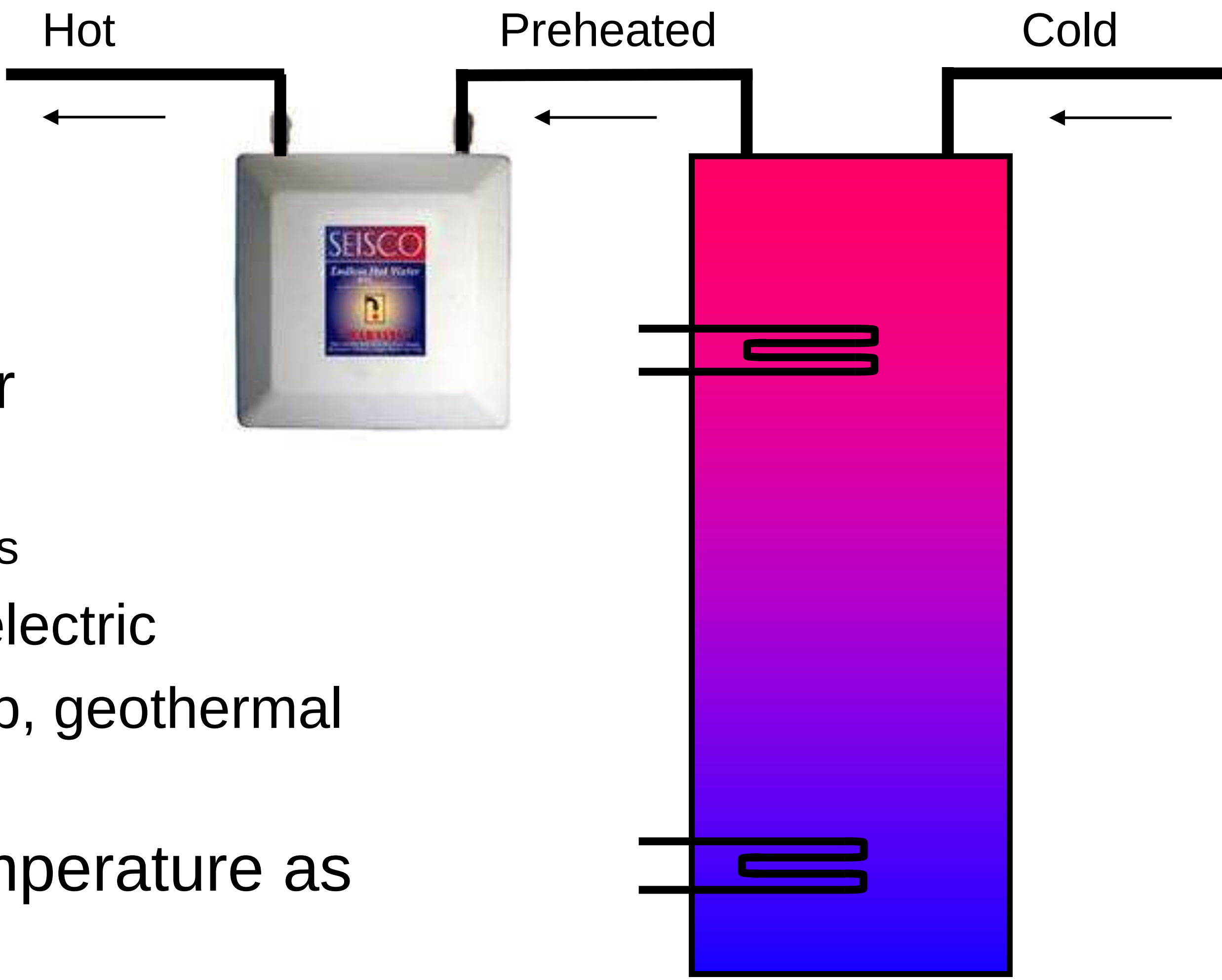
American Water Heater-Polaris



Heat Transfer Products-Phoenix



A Few Electric Alternatives



- Tank preheats water
  - Usually to 70-90º F
    - small standby losses
  - Could be off-peak electric
  - Could be heat pump, geothermal or solar
- Tankless boosts temperature as needed
- Adjust tank temperature upward for peak events

Unique Electric Storage Water Heaters

- Marathon
  - Manufactured by Water Heater Innovations (Rheem)
  - Seamless blow-molded polybutene tank
  - EF = 0.90-0.94
  - Warrantee
    - Tank – as long as you own it
    - Parts – 6 years

Unique Electric Storage Water Heaters

- Marathon

Unique Electric Storage Water Heaters

Heat Pump Water Heaters

Integrated

1. GE
2. Rheem
3. A.O. Smith

Add-on

1. AirTap™

Voltex™ Hybrid Electric

A.O. Smith integrated heat pump water heater

2.3 EF

80 gallons capacity

Three modes of operation
Tax credit eligible

Effective throughout the US

Can save about 60% of water heating

Voltex^{TM} Hybrid Electric

1. A fan brings air through the top air filter
2. Heat in the air is absorbed by the refrigerant inside the evaporator coil
3. The refrigerant is pumped through a compressor, which raises the temperature
4. Hot refrigerant is circulated through the copper coil & transfers heat to the water

Unique Electric Storage Water Heaters

- AirTap™
  - A HPWH by Airgenerate
  - Attachable to gas or electric storage water heaters
  - Can be vented to make use of the cool, dry air generated
  - EF = 2.11 @ 68˚F
    110v
    50 db

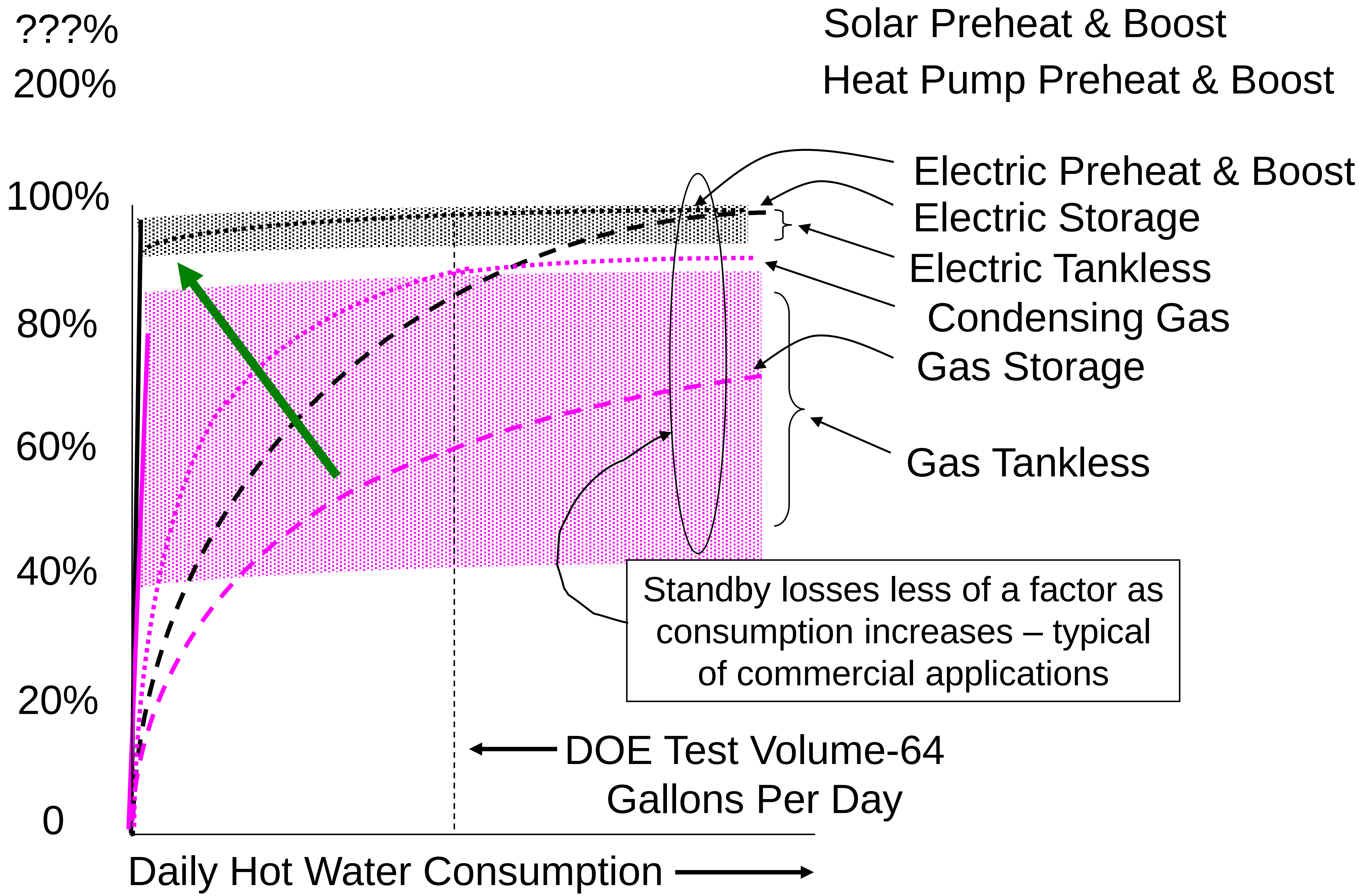
Unique Electric Storage Water Heaters

- AirTap™
- Dissimilar metals in the tank?

What About Solar Water Heating?

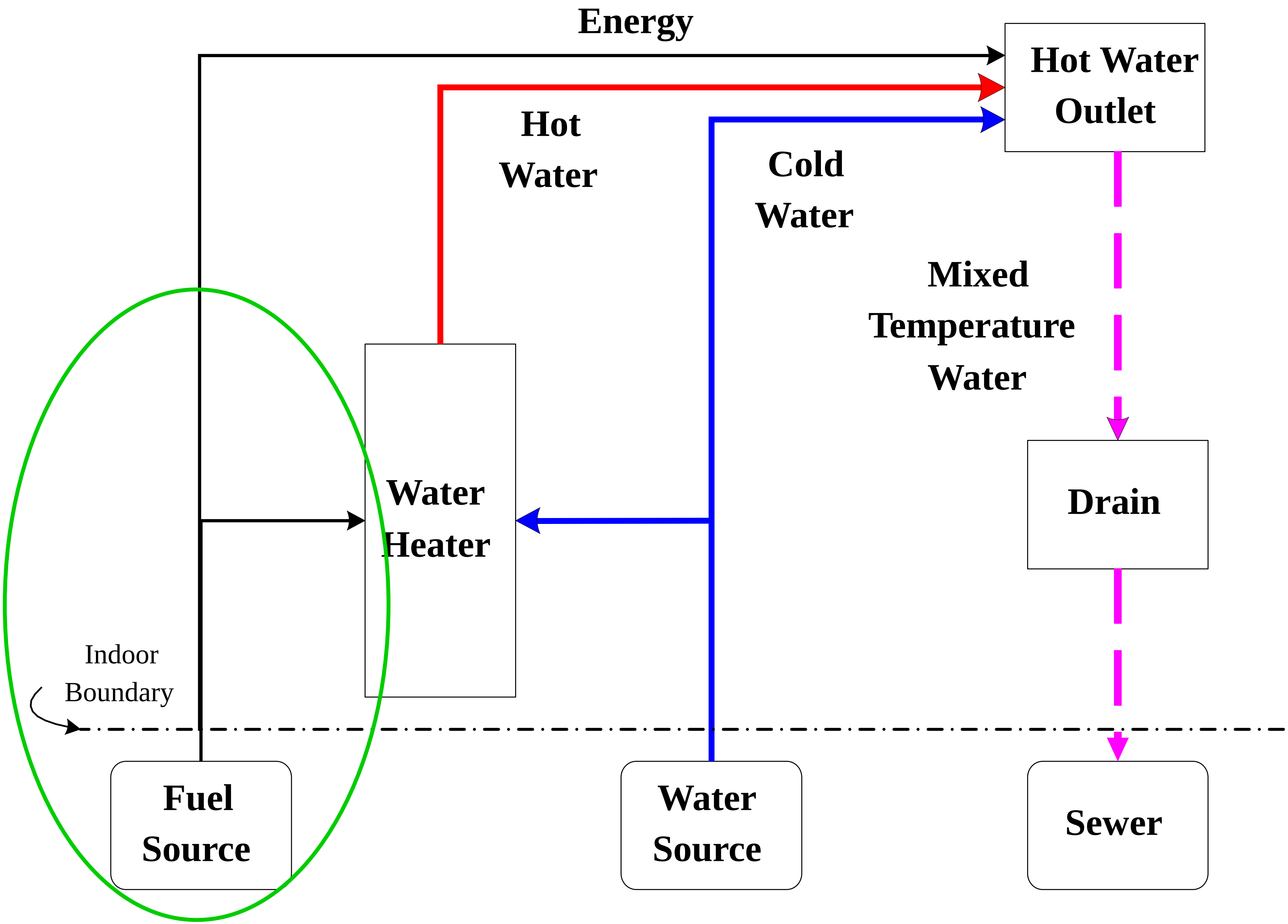
- Back-Up
  - Will you have a back-up?
  - What is your expectations for cloudy days?
  - How does the back-up handle almost-hot-enough pre-heated water?
    - 0.25 gpm, 1ºF temperature rise = 125 Btu
- Solar Fraction
  - Combined Water & Space Heating
- Cost
- Maintenance
- Simple Solar

Relative Efficiency of Water Heaters



Match the Input of Energy to the Capacity of the Water Heater

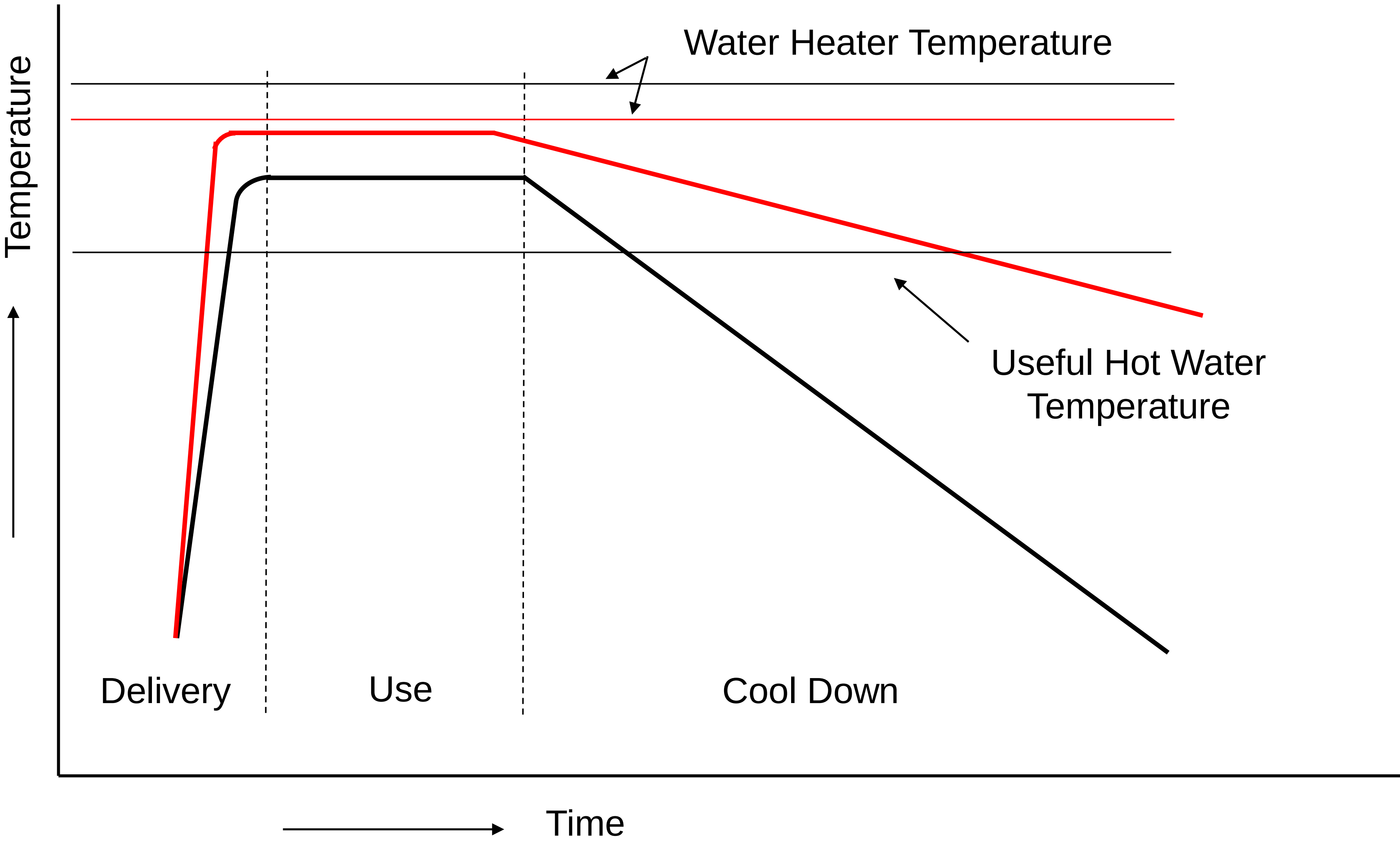
Typical "Simple" Hot Water System



What goes out must come in:

The guhzintahs must match the guhzoutahs!

Improved Hot Water Event



The Answer – Part 1

- Wring out the wastes
  - Decrease the volume between source of hot water & the use – instantaneousness
  - Insulate the hot water piping
  - Utilize the waste heat running down the drain
- Improve the water efficiency of the uses
  - Reduce hot water outlet flow rates
  - Reduce the volume of hot water needed for each task
- Combine water & space heating
- Increase the efficiency making hot water
  - Preheat – solar, heat pump, off-peak electric
  - Select one or more very efficient supplemental heaters that work with preheated water to reach the desired temperature & for continuousness

The Answer – Part 2

SHORT, Right-sized pipe

Summary

Questions or topics that you want to address on Day 2?

Additional Resources

Information about the Thousand Home Challenge:

www.ThousandHomeChallenge.org

Select “Resources” for:

Gary Klein’s articles on high performance hot water

Information about upcoming ACI events:

www.affordablecomfort.org

Thanks for Participating!

Thanks to Pacific Gas & Electric Company's Energy Training Center - Stockton

NEXT WEBINAR IN THIS SERIES:

High Performance Hot Water Part 2

Thursday, July 29, 2010 – 9 AM Pacific Time

To register:

http://www.affordablecomfort.org/thc/thcwebinar1.html

www.ThousandHomeChallenge.org