Water Heating, Hot Water Distribution and Water Conservation

Gary Klein
Affiliated International Management, LLC
916-549-7080
gary@aim4sustainability.com

Bill Hoover
William R. Hoover LLC
262-388-4489
whoover@wi.rr.com

The Water – Energy Nexus

- Saving energy saves water
- Saving water saves energy

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 and appliances get more efficient

How does this compare to your:

- Cell phone bill?
- Internet bill?
- Cable or Satellite bill?
- Designer coffee bill?

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

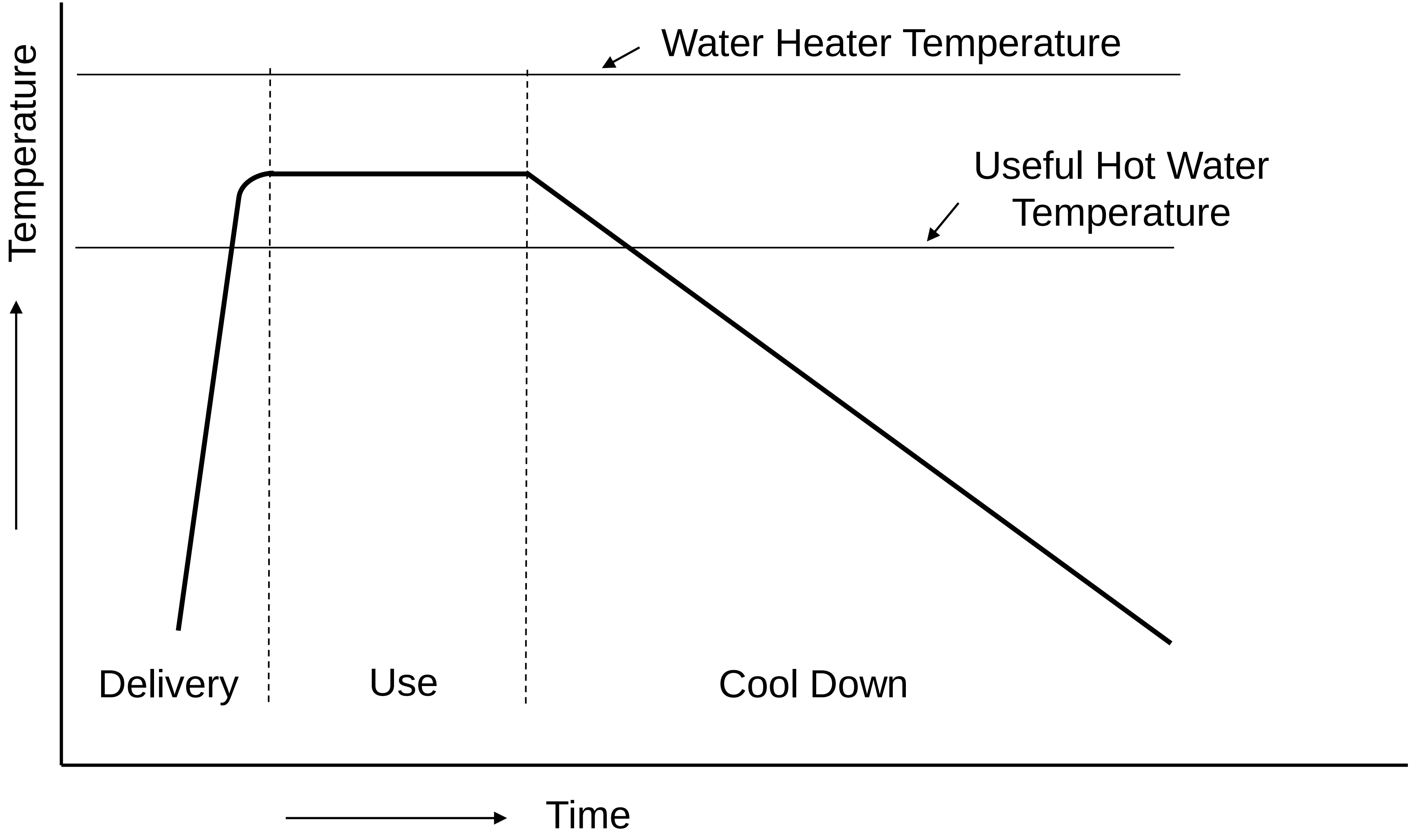
Assumes hot water is 90 degrees F above incoming cold water.
Cost per year has been rounded off.

Add about $130 per year for water and sewer (at $0.006 per gallon combined)

Do You Know:

- *Anyone who waits a long time to get hot water somewhere in their house? At their job? In their favorite restaurant?*
- *Someone who has ever run out of hot water?*
- Anyone who wants instantaneous hot water?
- *Someone who thinks that a tankless water heater is instantaneous?*
- Anyone who thinks that a whole-house manifold plumbing system will save water?
- *Someone who is confused about how to implement the LEED, NAHB, Water Sense, Build-it-Green or other hot water distribution system credits?*
- Anyone who would like to learn how to get hot water to every fixture wasting no more than 1 cup waiting for the hot water to arrive?
- *Someone 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

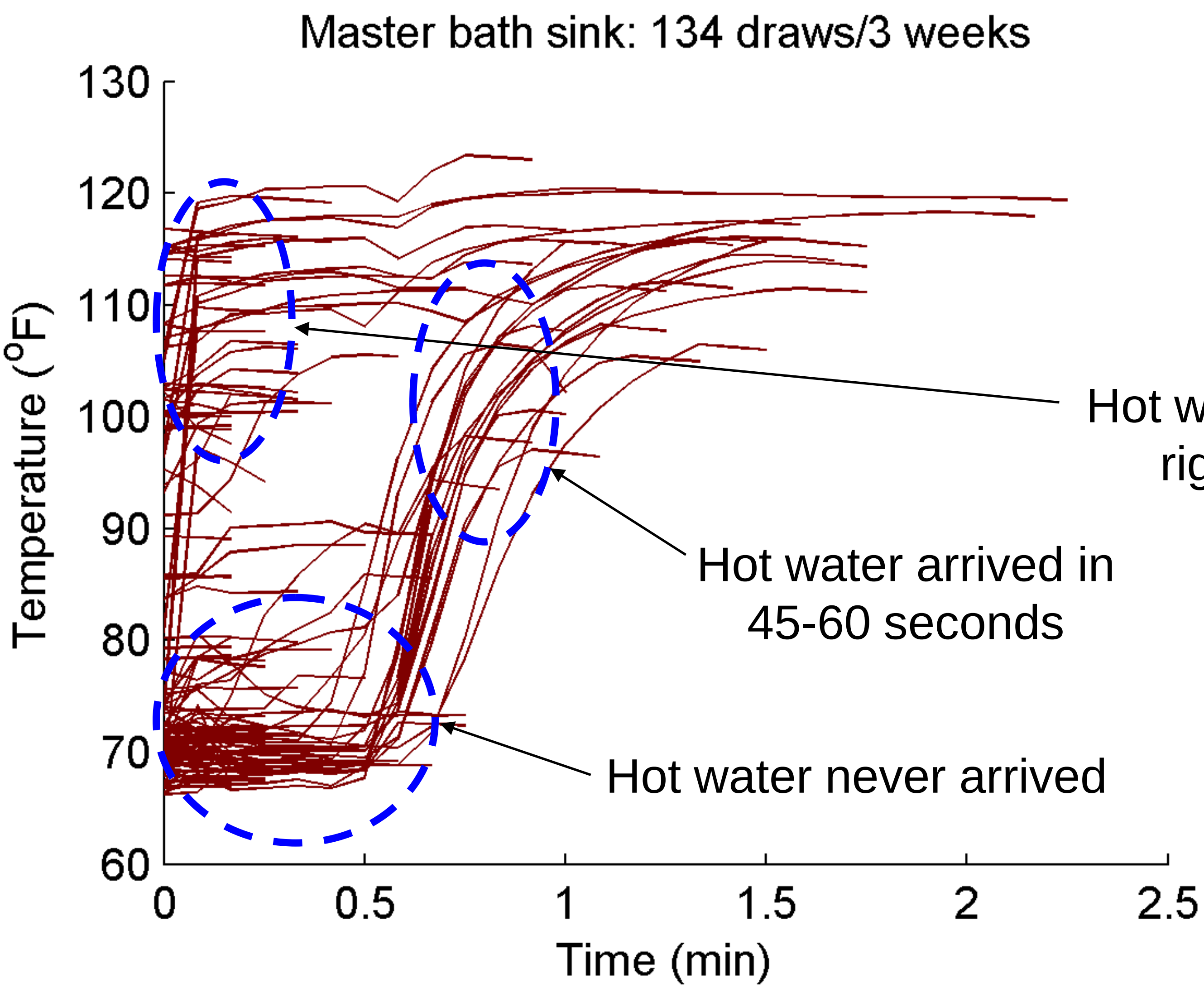
- Adjustable temperature and flow
- Never run out
- Quiet
- Hot water now

What are Your Hot Water Usage Patterns?

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

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

Time and Temperature at the Master Bath Sink



Average draw is 30 ± 29 seconds

Source: National Renewable Energy Laboratory

Guiding Principle

Provide people what they want...

The Service of Hot Water

with what they expect…

Safety, Reliability and Convenience

as efficiently as possible

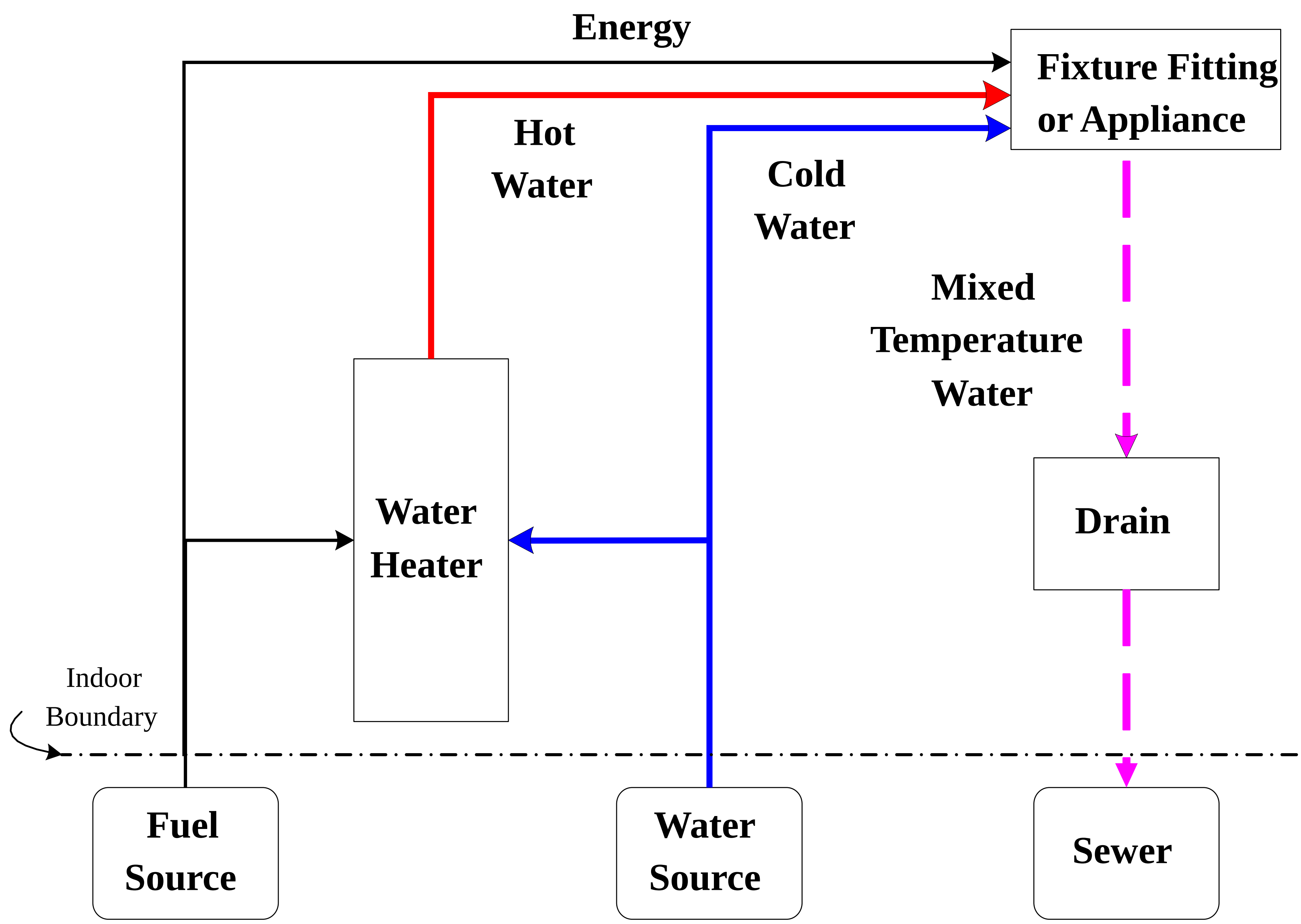
The Hot Water System

- Treatment and Delivery to the Building
- Use in the Building
  - Water Heater
  - Piping
  - Fixtures, Fittings and Appliances
  - Behavior
  - Water Down the Drain
- Waste Water Removal and Treatment

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

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

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 fixture fittings and appliances
- Mixed temperature water runs down the drain
- Total is due to a combination of structural and behavioral considerations.

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

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
- Never Run Out in My Shower = “Continousness”
  - – Need a large enough tank or a large enough burner or element
  - – Or, a modest amount of both

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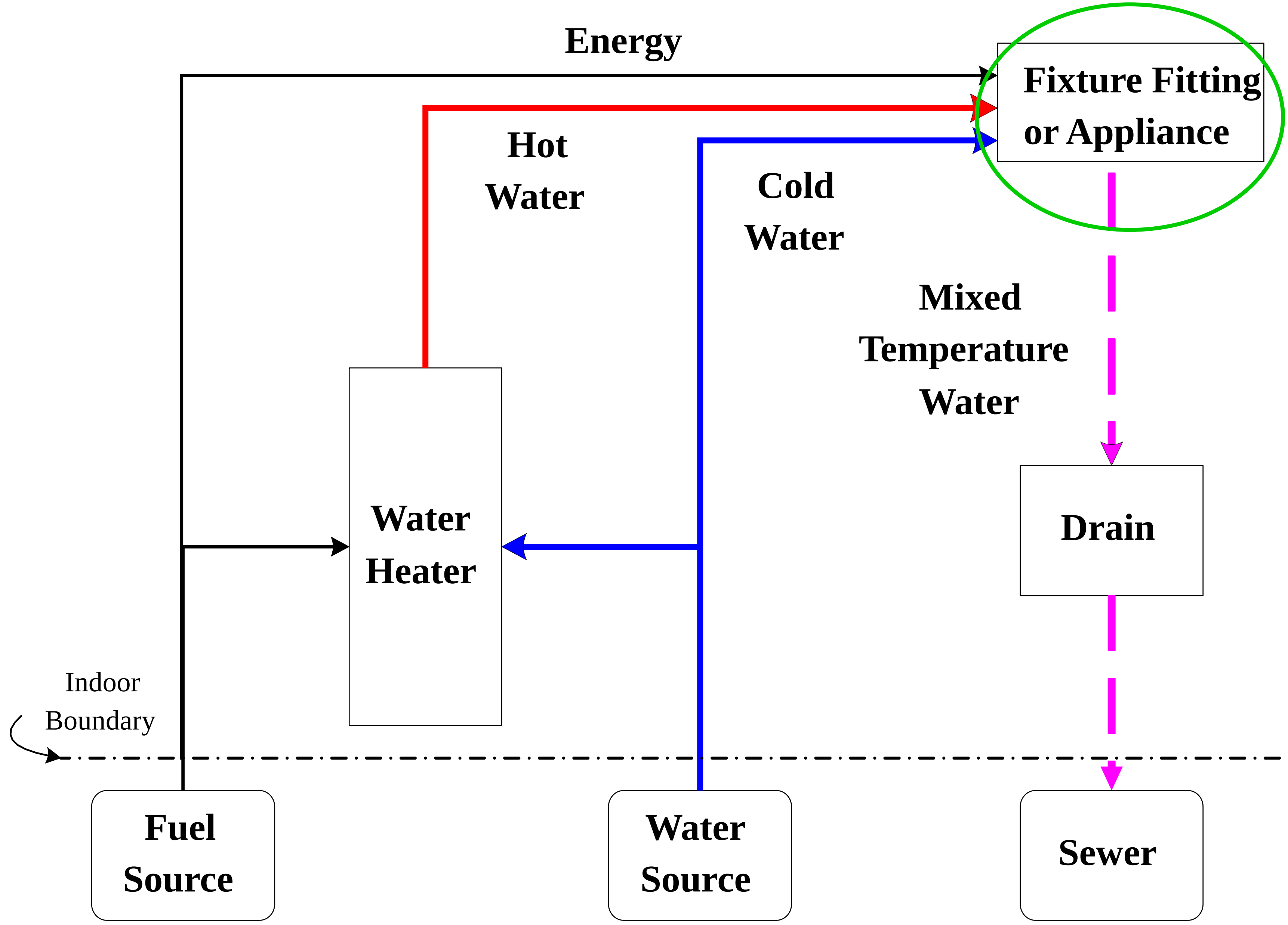


Fixture Fitting Flow Rates

Maximum allowable flow rates allowed by Federal and California regulation:

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

Concerns:

- Single lever versus dual lever fixture fittings
- Temperature regulation
- Cross-over
- Being held responsible for someone else’s problem
- Overbearing and multiple regulations
- Others?

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?

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.

Question:

If you want to waste no more than 1 cup
while waiting for hot water to arrive,
what is the maximum amount of water
that can be in the pipe that is not usefully hot?

Answer:

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

Possible Solutions

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

B. 1 water heater for every hot water fixture
   - 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, and 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 and very intermittent uses.

D. Heat trace on the pipes
   - Long, skinny, under insulated water heater. Expensive to install. Great on water conservation. Competitive in certain applications, otherwise can be very be 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.

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)
- Reduce the number of restrictions to flow (decrease "effective length")
- Increase the flow rate (use a demand controlled pump)
- Insulate the pipe (becomes critical for very low flow rates and adverse environmental conditions)

Length of Pipe that Holds 8 oz of Water

	3/8" CTS	1/2" CTS	3/4" CTS	1" CTS
	ft/cup	**ft/cup**	**ft/cup**	**ft/cup**
"K" copper	9.48	5.52	2.76	1.55
"L" copper	7.92	5.16	2.49	1.46
"M" copper	7.57	4.73	2.33	1.38
CPVC	N/A	6.41	3.00	1.81
PEX	12.09	6.62	3.34	2.02
Ave	**8 feet**	**5 feet**	**2.5 feet**	**1.5 feet**

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 and reduces heat loss during a hot water event. This is particularly important for low flow fittings and appliances.
  - Increases number of “hot starts.”
- Take advantage of the energy savings:
  - Keep the water heater temperature the same and change the mix point
  - Reduce the water heater temperature setting.

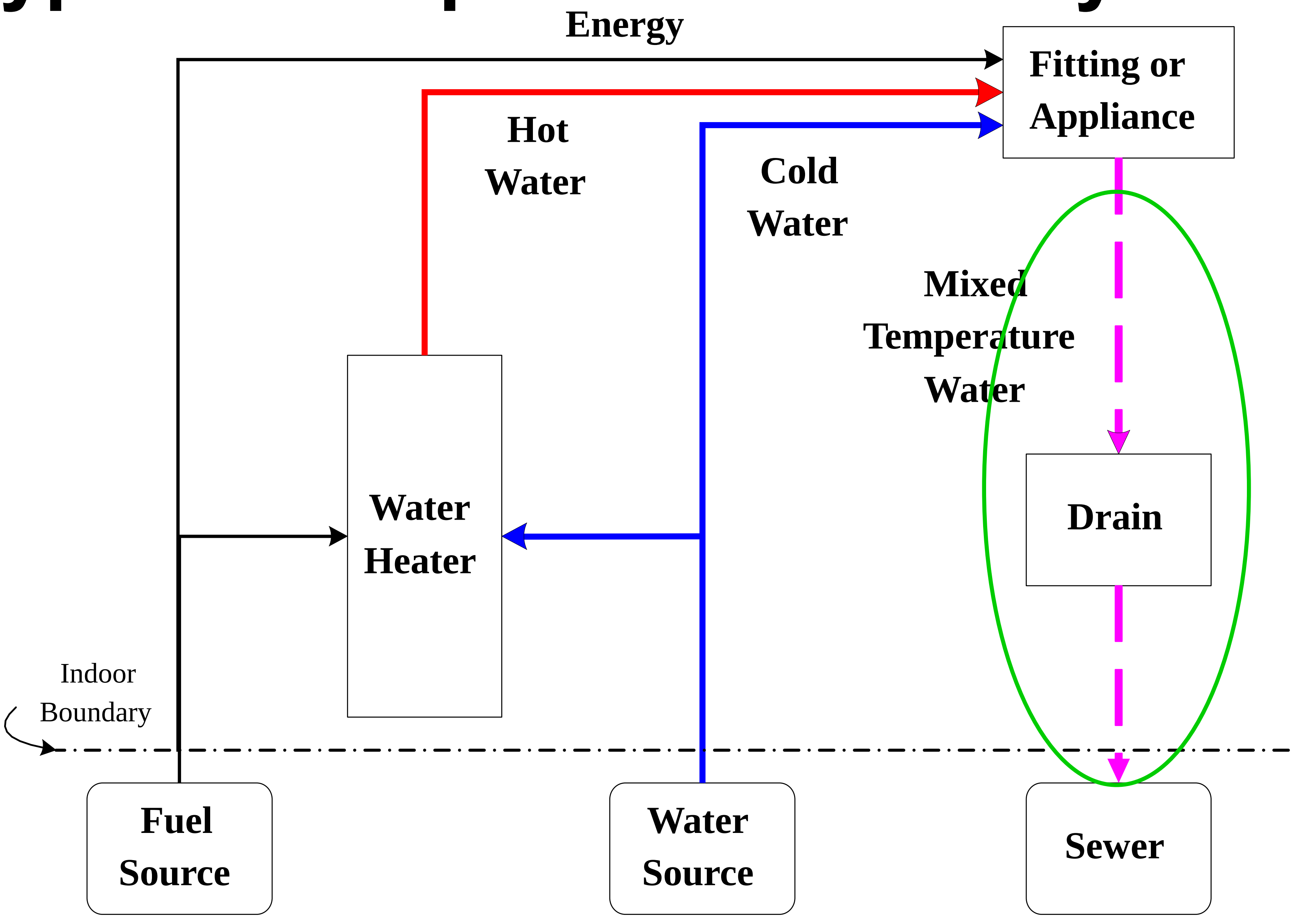
To improve the cool-down phase:

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

Insulate the pipes

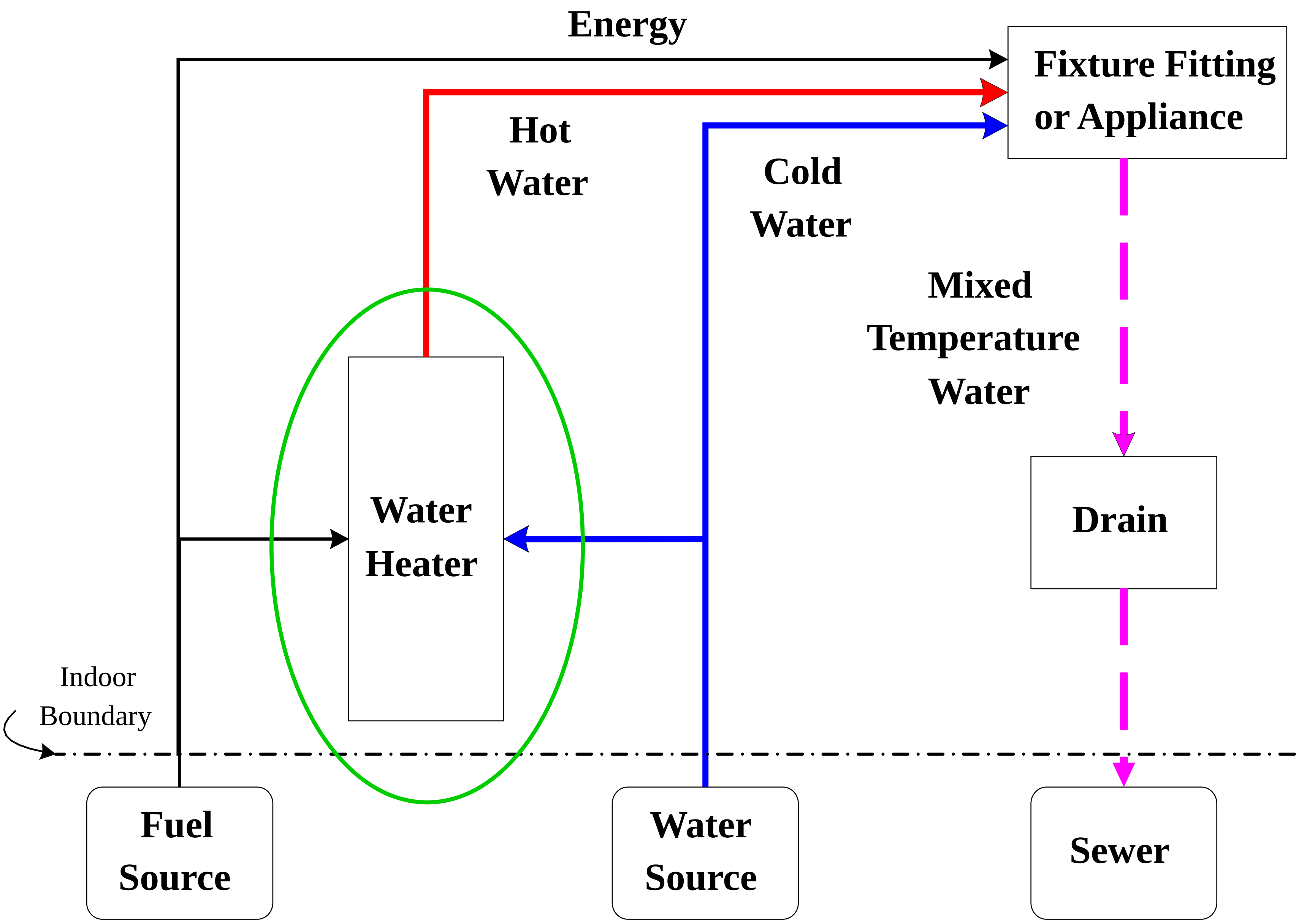
- Increases the time pipes stay hot between events.
- R-4 insulation doubles cool down time with ½ inch pipe, triples it with ¾ inch pipe.

Typical “Simple” Hot Water System



Drain Water Heat Recovery

Typical "Simple" Hot Water System



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

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Neither Tank or Tankless is Necessarily the Answer

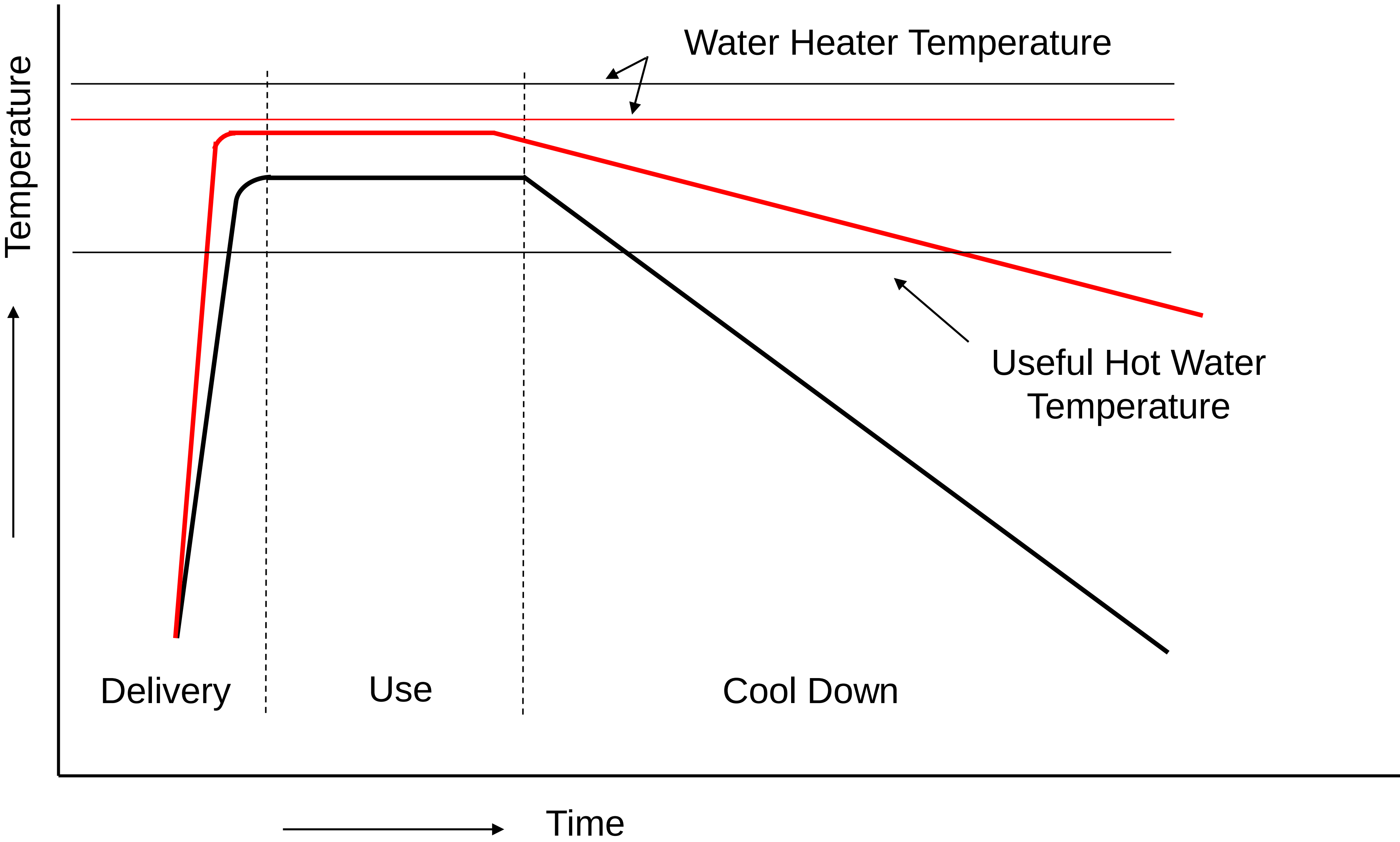
A combination of the two might be better:

- **Burner or element**
  - Sized for some amount of continuous use
    - Approximately 2-3 GPM
    - 80-120,000 Btu Natural Gas, 20-30 kW Electric
- **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 and electric**

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?
- Cost
- Maintenance
- Simple Solar

Improved Hot Water Event



Potentially Conflicting Trends

On one hand:

- Larger houses
- More hot water outlets
- Increased desire for hot water
- Higher expectations of performance
- Desire to be Green

On the other:

- Lower city water pressures
- Lower fitting flow rates
- Greater pressure drop in piping
- Tightening of codes and standards
- New policies to reduce GHG emissions

Result:

Longer wait, less pressure, lower performance, less satisfied customers, increased complaints

The Answer – Long

- Reduce the waste.
  - Decrease the volume between source of hot water and the use – instantaneousness
    - This is a benefit in delivery, use and cool down phases of a hot water event.
  - Utilize the waste heat running down the drain
- Improve the use.
  - Reduce hot water outlet flow rates
  - Reduce the volume of hot water needed for each task
- Increase the efficiency.
  - Preheat – solar, heat pump, off-peak electric
  - Utilize efficient water heatering equipment
  - Combine water and space heating

The Answer – Short

Short, skinny pipe

The Answer – Short