High Performance Hot Water Systems

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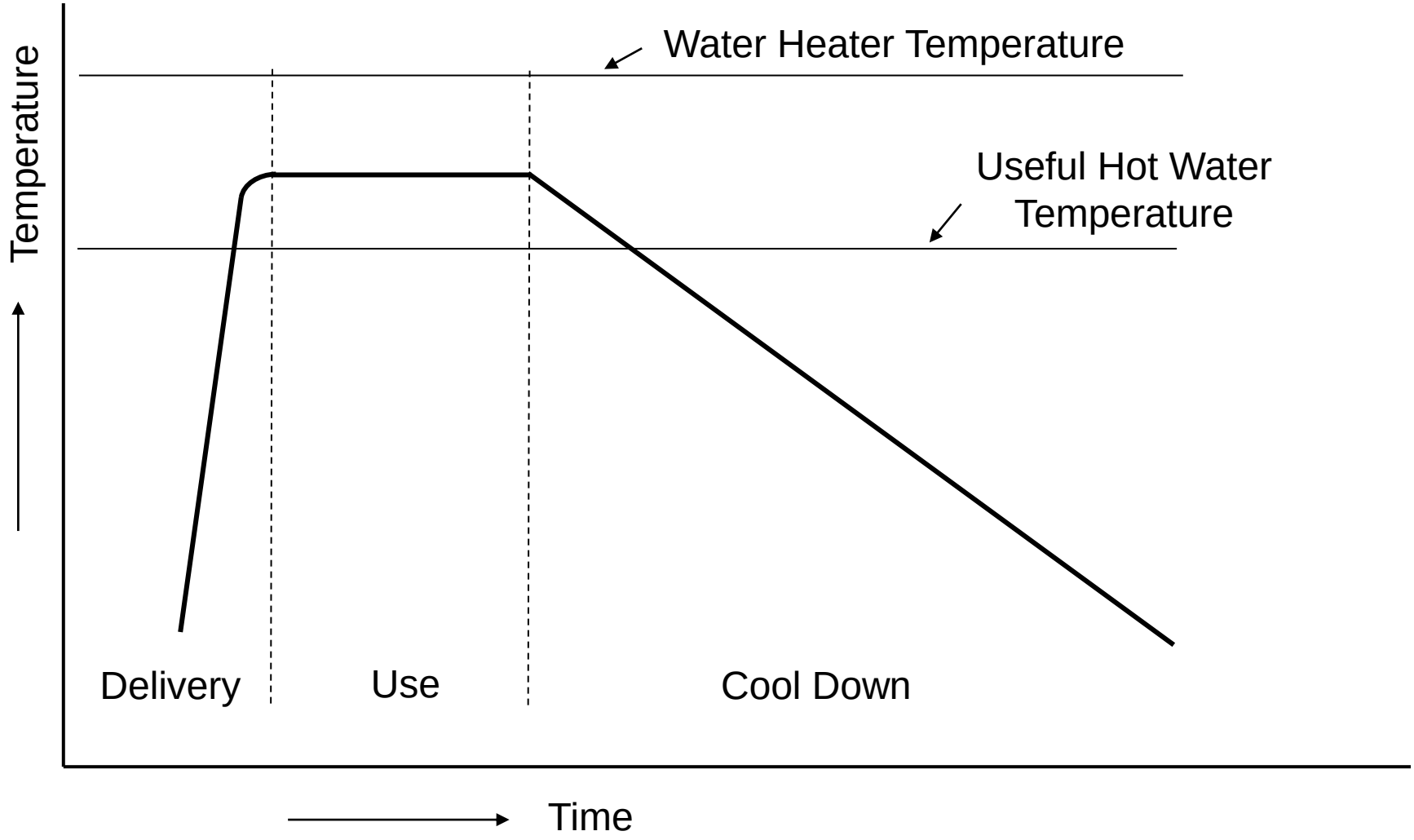
Gaps

- Hot water is a system –
  - We need systemic thinking so that the components work together to get high performance
- This is primarily a design, engineering and implementation challenge
- We need one thermal engine for water heating and space conditioning
  - Water heating takes the lead
  - Space heating systems are needed for peak loads of 10 Btu/hour/square foot or less

Typical Hot Water Event



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 wants to utilize solar energy for water heating?
- Someone *who wants to know “the answer”?*

Key Strategies

- Wring out the wastes.
  - Decrease the volume between source of hot water and 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
- 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 and for continuousness
  - Combine water and space heating

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 in My Shower = “Continousness”

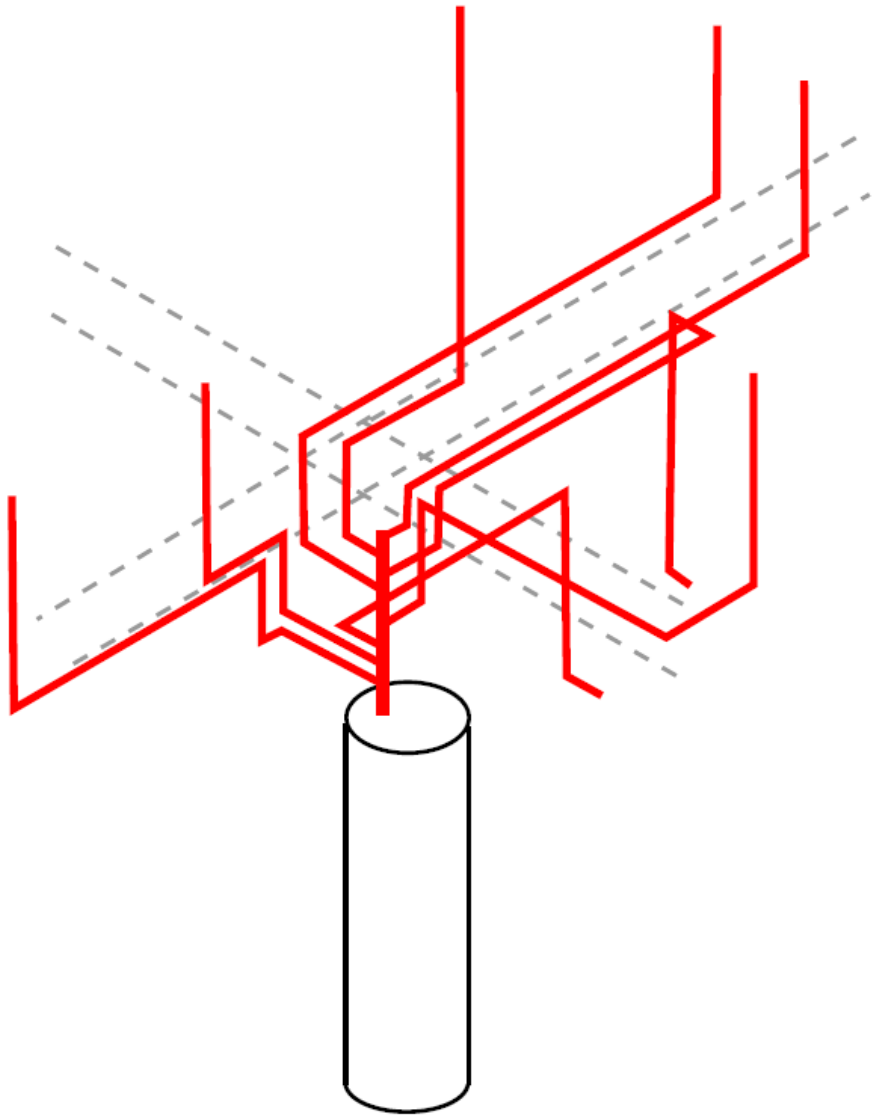
- Need a large enough tank or a large enough burner or element
- Or, a modest amount of both

The Ideal
Hot Water Distribution System

- Has the smallest volume (length and 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.
- How many water heaters does a building need?

1- Quart Hot Water Distribution System

Short Trunk – Long Twig



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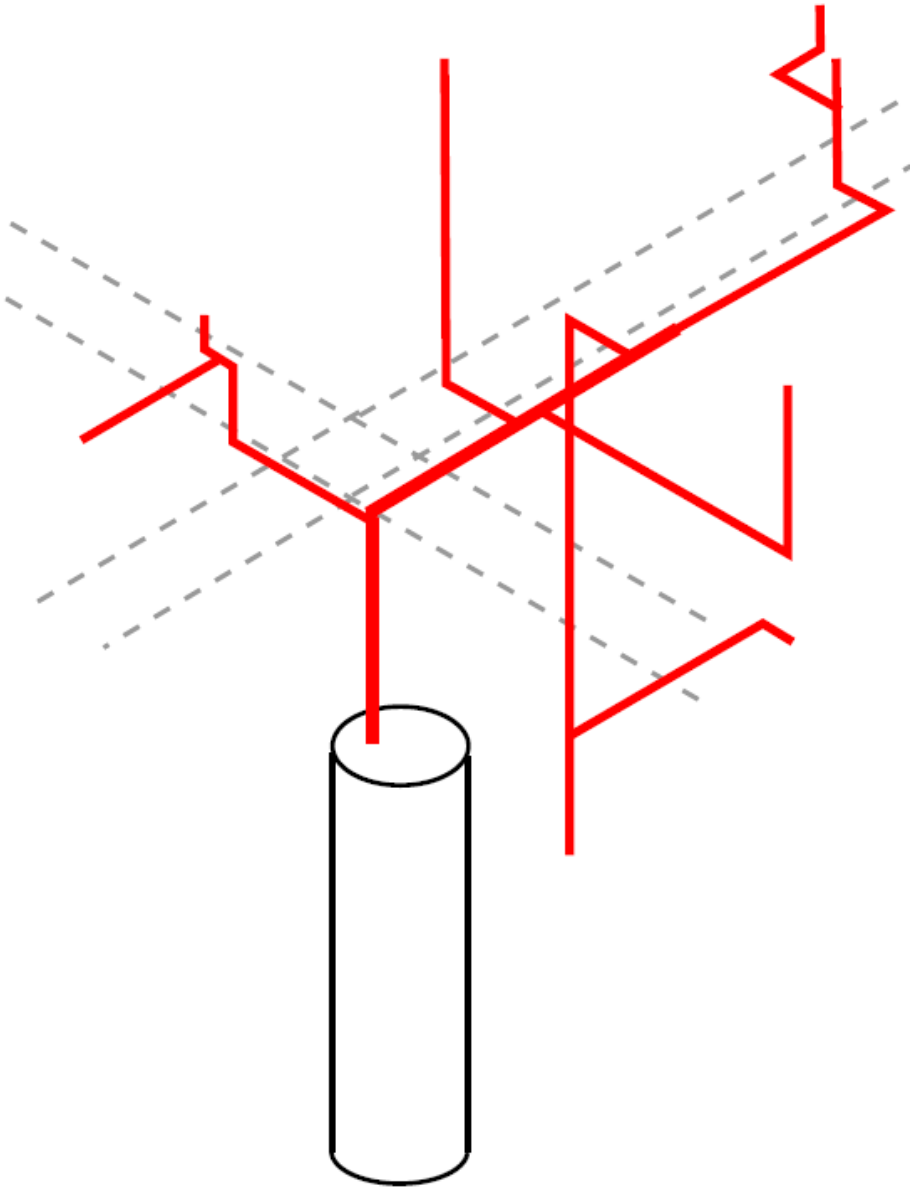


The Challenge

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, 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. 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.

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 and 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 and 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: ≈ 6F in 100 feet of ¾ inch pipe
    - Insulated: ≈ 3F in 100 feet of ¾ inch pipe
  - Much larger reductions for buried pipe
- Take advantage of the energy savings
  - Keep the water heater temperature the same and 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 and minimize the waste of water, energy and 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?

Comparing Volumetric Heat Loss to Storage Tank Standby Heat Loss

- How many times per day does the water in the pipes cool down?
  - Trunks? Branches? Twigs?
- How does this compare to standby loss of a water heater?
- When does it make sense to install another water heater?
  - Energy
  - Water
  - Cost (installation and maintenance)

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 and Safety, Plumbing, Energy, Building, Green

Neither Tank or Tankless is Necessarily the Answer

A combination of the two might be better:

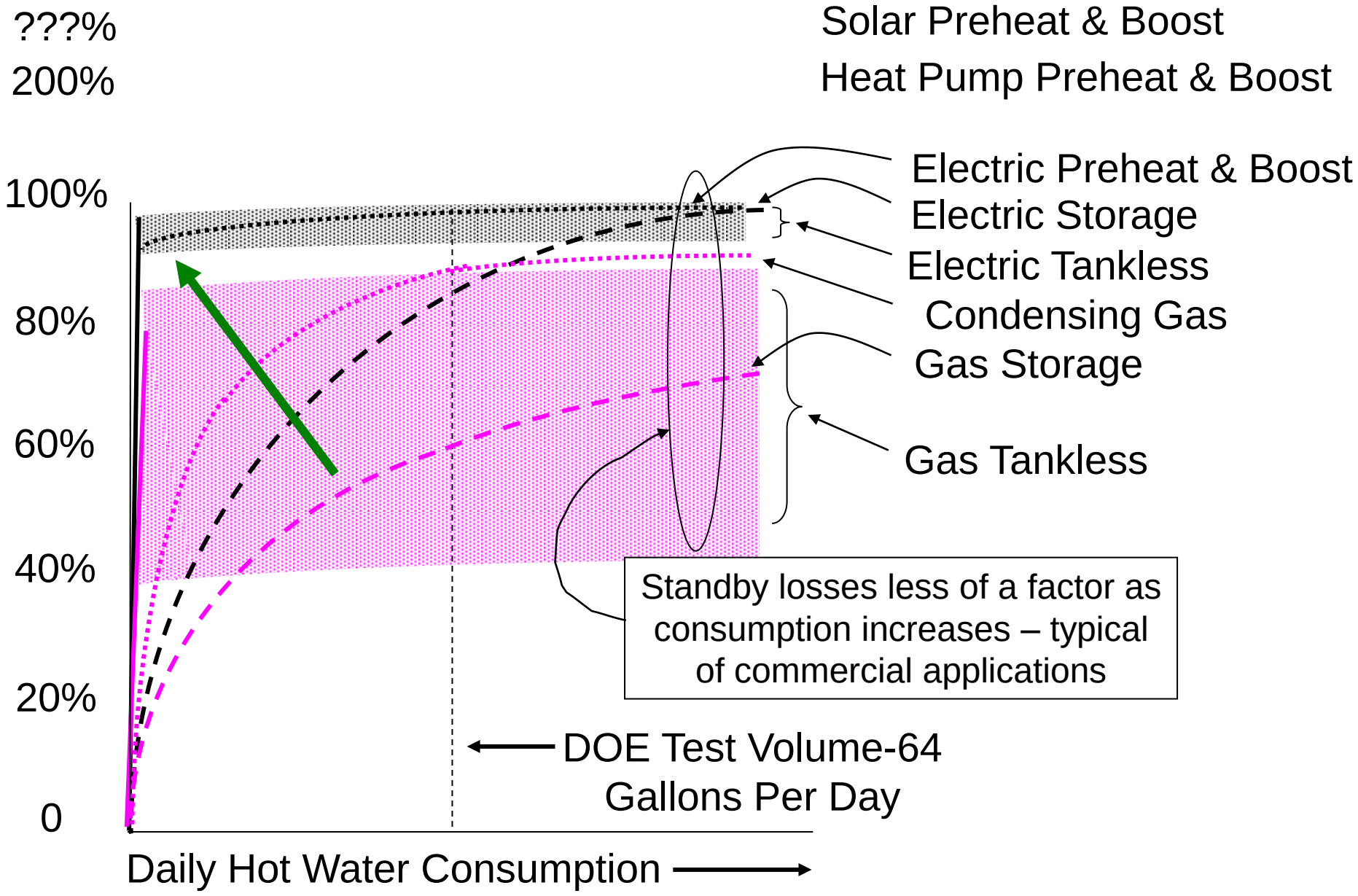
- **Burner or element**
  - Sized for some amount of continuous use
  - Residential
    - Approximately 1.5-3 GPM
    - 60-120,000 Btu Natural Gas, 15-30 kW Electric
  - Commercial
- **Modest tank**
  - Hot water available at the beginning of every draw
  - Some volume for peak conditions
  - Enables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

How does the water heater interact with the fixtures?

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, 1F temperature rise = 125 Btu
- Solar Fraction
  - Combined Water and Space Heating
- Cost
- Maintenance
- Simple Solar

Relative Efficiency of Water Heaters



The Answer

Short, Right-sized pipe