Green Code and the Hot Water System

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- **Indoor**
  - Cold
  - Hot

Water Use Efficiency

- **Outdoor**
  - Landscape
    - Climate appropriate plant selection
    - Watering methods
    - ‘Need-based” controls
  - Hardscape
    - Solid
    - Porous

Water Use Efficiency

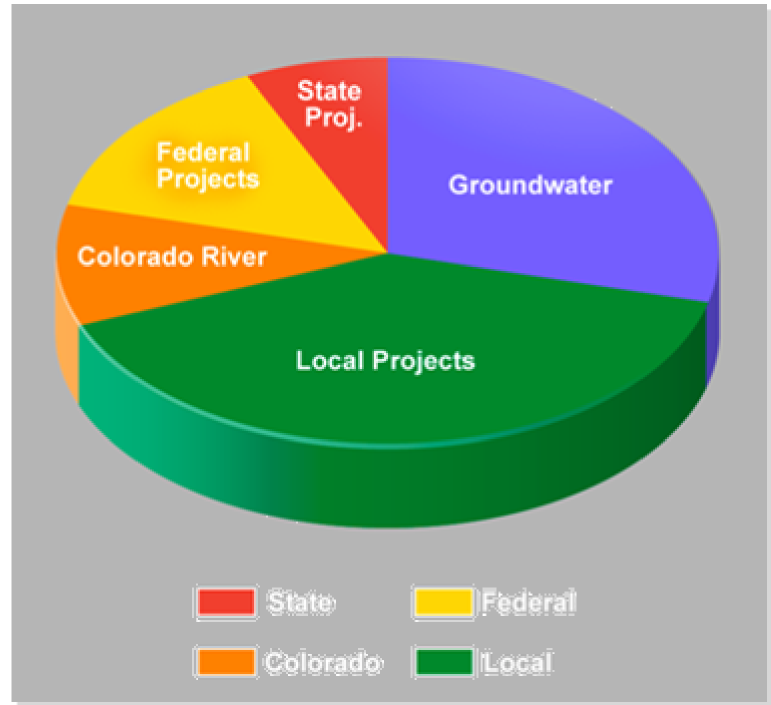
- **Advanced Systems**
  - Graywater
    - On-site collection and reuse
      - Separate drain lines
      - Separate delivery piping
  - Reclaimed water reuse
    - Outdoor or indoor use?
  - Rainwater collection and use
    - Outdoor or indoor use?
  - Mechanical Systems
    - Cooling towers
    - Condensate recovery

Water Use Efficiency

- **Indoor**
  - Cold
    - Toilets, Faucets, Aerators, Showerheads, Dish machines, Clothes washers, Ice machines
  - Hot
    - Wring out the Wastes
      - Improve hot water delivery
      - Capture waste heat running down the drain
      - Insulate hot water piping
    - Install water use efficient hot water devices
    - Select Water Heaters Compatible with WUE

Energy Embedded in Water

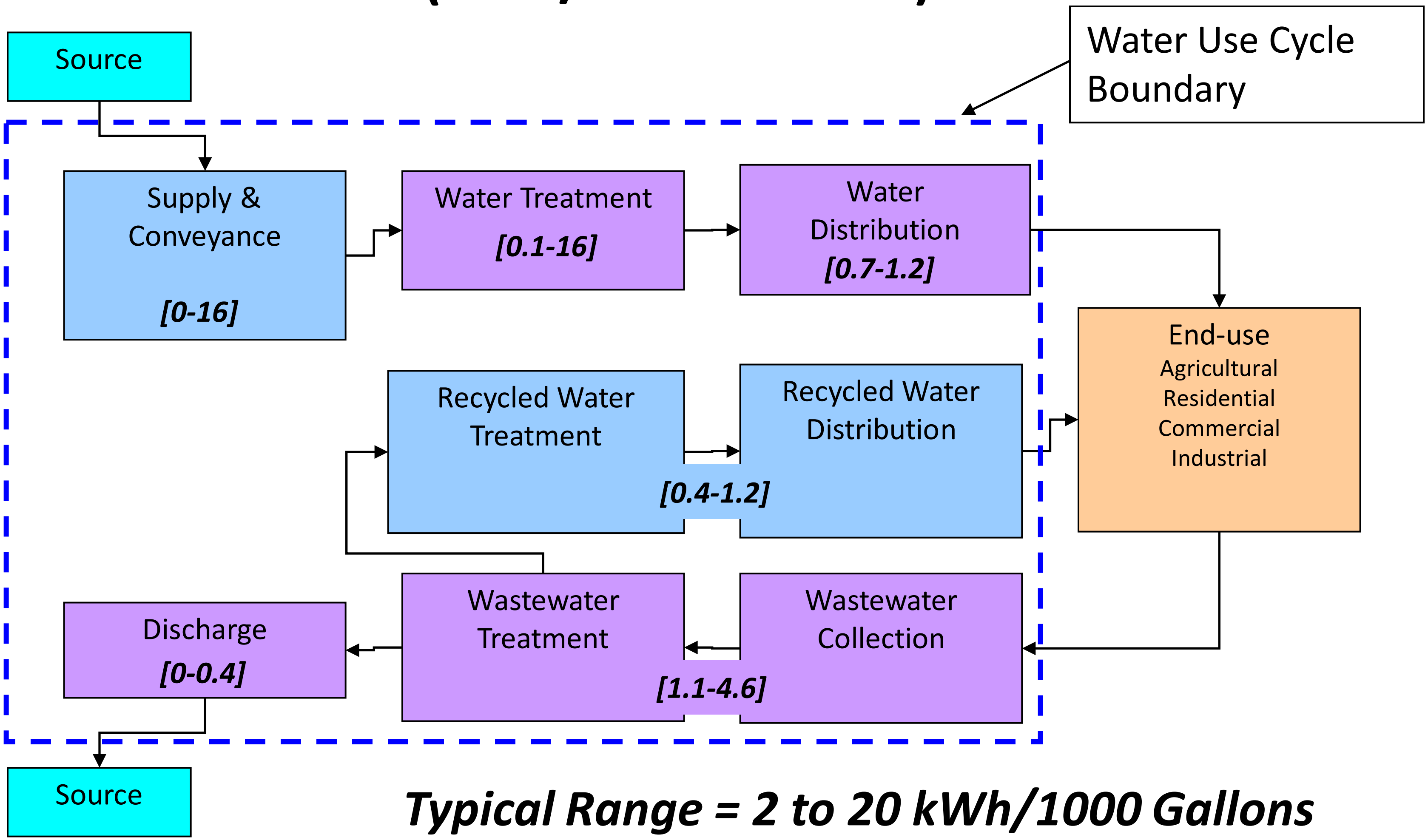
California's Water Supply Systems



Lester Snow, California Department of Water Resources

Water Use Cycle Energy Intensities

(kWh/1000 Gallons)



Typical Range = 2 to 20 kWh/1000 Gallons

Source: California Energy Commission, 2005 Integrated Energy Policy Report

Water-Related Energy Use-CA 2001

	Electricity (GWh)	Natural Gas (Million Therms)	Diesel (Million Gallons)
Urban Water Use Cycle			
Water Supply	7,554	19	?
Including Conveyance, Treatment and Distribution			
Wastewater	2,012	27	?
Including Collection, Treatment, Discharge and Recycled Water			
End Uses of Water			
Agriculture			
Supply to the Farm	3,188		
On-Farm Pumping	7,372	18	88
Residential	13,528	2,055	?
Commercial	8,341	250	?
Industrial	6,017	1,914	?
Totals	**48,012**	**4,283**	**88**
2001 Consumption	**250,494**	**13,571**	?
Percent of Energy Use	**19%**	**32%**	Small
CO_2 e (Million Metric Tons)	**56**	**50**	Small

Approximately 20-25 % of the nation’s stationary energy use goes to water in some form.

Source: California Energy Commission, 2005 Integrated Energy Policy Report

Water-Related Energy Use-CA 2001
Another Perspective

	Electricity (GWh)	Natural Gas (Million Therms)	Diesel (Million Gallons)
Urban Water Use Cycle	9,566	46	
End Uses of Water			
Agriculture	10,560	18	88
Residential, Commercial, Industrial	27,886	4,219	
Totals	**48,012**	**4,283**	**88**
2001 Consumption	**250,494**	**13,571**	?
Percent of Energy Use			
All Water-Related Energy	19%	32%	Small
Urban Water Use Cycle	4%	0.3%	
Agriculture	4%	0.1%	Small
Residential, Commercial, Industrial	11%	31%	

Source: California Energy Commission, 2005 Integrated Energy Policy Report

The Most Energy Intensive Urban Water in the United States?

Lake Arrowhead, California

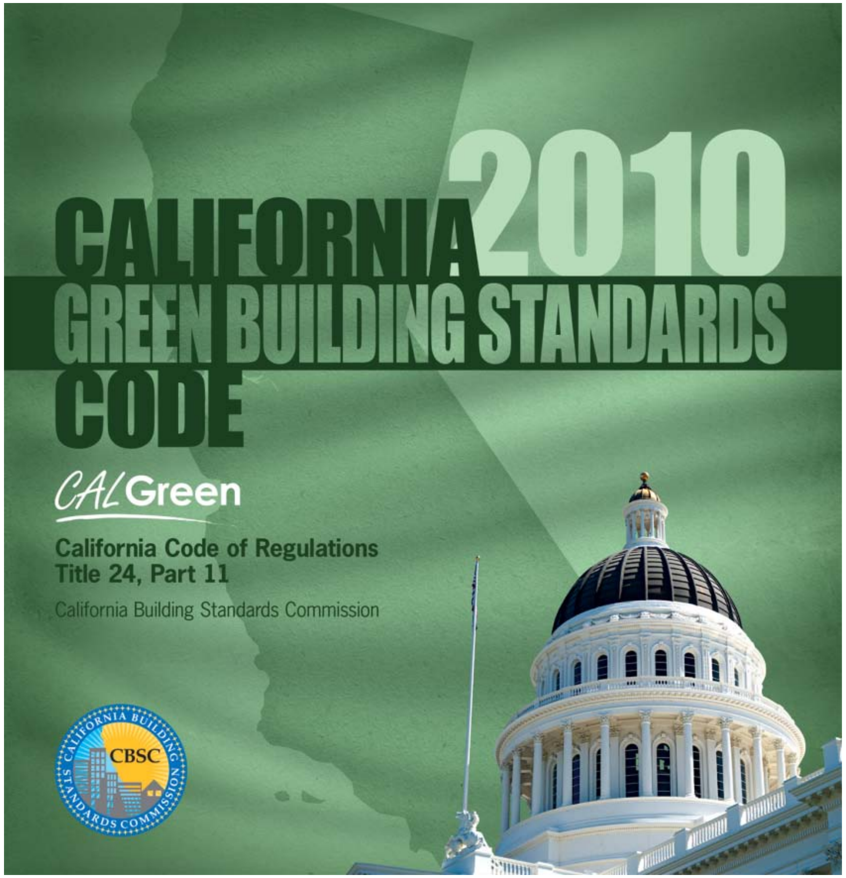
Energy Intensity kWh per 1000 Gallons

	Lake Water	Ground Water	State Water Project
Pumping to Lake Silverwood			10.13
Pumping from Lake Silverwood to Lake Arrowhead Treatment Plant			7.83
Pumping to Treatment Plant	1.95	1.84	
Water Treatment	1.21	1.21	1.21
Wastewater Collection	1.83	1.83	1.83
Wastewater Treatment	3.99	3.99	3.99
Total	8.99	8.87	24.99

Data provided courtesy of: Mary Ann Dickinson, Alliance for Water Efficiency
maryann@aw4e.org (773) 360-5100

CalGreen

1	Administration
2	Planning & Design
3	Water Efficiency
4	Material Conservation & Resource Efficiency
5	Environmental Quality
6	Voluntary Measures Tier 1 & 2



ADMINISTRATION

- Building Standards Commission (BSC)
- Housing and Community Development (HCD)
- Department of State Architect (DSA)
- Office of Statewide Health Planning and Development (OSHPD)

BUILDING STANDARDS COMMISSION (BSC)

PRIVATELY OWNED NON-RESIDENTIAL BUILDINGS

- Groups:
  - A (Assembly), B (Business), E (Educational), F (Factory), H (High Hazard), I (Institutional), L (Laboratory), M (Mercantile), S (Storage) and U (Utility and Miscellaneous)

HOUSING AND COMMUNITY DEVELOPMENT (HCD)

RESIDENTIAL BUILDINGS

- Including hotels, motels, apartments, condominiums, single family and multi-family dwellings, up to three stories.

DIVISION OF THE STATE ARCHITECT (DSA)

PUBLIC SCHOOLS

- Including public elementary, secondary and community college buildings.

OFFICE OF STATEWIDE HEALTH PLANNING AND DEVLELOPMENT (OSPHPD)

MEDICAL BUILDINGS

- Including general acute care hospitals, skilled nursing facilities, intermediate care facilities, and correctional treatment centers.
- Voluntary standards and not mandatory.

WATER EFFICIENCY

SEPARATE METERS – ADOPTED BY BSC

- **For buildings larger than 50,000 square feet**
  - Determine if your leased, rented, or other tenant space is projected to consume more than 100 gallons per day. If so, then provide separate sub-meters to be installed by the owner or contractor after the main meter supplied by the utility.
- **For all buildings**
  - If any occupant of a project or space within a building is projected to consume more than1000 gallons per day then provide a separate sub-meter or metering devices. Examples are car washes and aquariums.
- **Landscaped areas between 1,000 and 5,000 square feet**
  - Owner or contractor shall install a sub-meter after the main meter for outdoor potable water use.

WATER EFFICIENCY

20% SAVINGS IN POTABLE WATER USE – ADOPTED BY BSC, HSC & DSA

- **Prescriptive Method** - Refer to Table 5.303.2.3 and select the plumbing fixtures and fittings that meet the reduced flow rates.
- **Performance Method** - Refer to Table 5.303.2.2 and provide a calculation demonstrating a 20 percent reduction in the building "water use baseline" as established in the table.
- Special Calculations for Multiple Shower Heads.

WATER EFFICIENCY

20% REDUCTION IN WASTEWATER – ADOPTED BY BSC, HSC & DSA

- **Prescriptive Method** - Refer to Table 5.303.2.3 and select the plumbing fixtures and fittings that meet the reduced flow rates.
- **Performance Method** - Refer to Table 5.303.2.2 and provide a calculation demonstrating a 20 percent reduction in the building "water use baseline" as established in the table.
- **Use of Non-potable Water** - Where available and/or permitted by the local jurisdiction, utilize non-potable water systems (captured rainwater, graywater, and municipally treated wastewater [recycled water]).
- **Diversion of graywater** - Irrigate landscape with graywater from fixtures or appliances per CPC Appendix G.

Voluntary Measures

ADOPTED BY BSC, HSC, & DSA FOR JURISDICTIONS THAT WANT TO EXCEED MANDATORY MEASURES

- **Tier 1**
  - Mandatory Measures
  - 30% Water savings
  - Exceed Title-24 by 15%
  - Plus five additional electives – one from Planning and Design, Water Efficiency, Material Conservation and Resource Efficiency, Environmental Quality and One Additional from any Category.
- **Tier 2**
  - Mandatory Measures
  - 35% Water savings
  - Exceed Title-24 by 30%
  - Plus seven additional electives – one from Planning and Design, Water Efficiency, Material Conservation and Resource Efficiency, Environmental Quality and Three Additional from any Category.

SECTION A4.208 WATER HEATING DESIGN, EQUIPMENT AND INSTALLATION

A4.208.1 Tank type water heater efficiency. The Energy Factor (EF) for a gas-fired storage water heater is higher than 0.60.

A4.208.2 Tankless water heater efficiency. The Energy Factor (EF) for a gas-fired tankless water heater is 0.80 or higher.

A4.208.3 Distribution systems. Where the hot water source is more than 10 feet from a fixture, the potable water distribution system shall convey hotwater using one of the following methods:

1. A central manifold plumbing system with parallel piping configuration ("home-run system") is installed using the smallest diameter piping allowed by the *California Plumbing Code or an approved alternate.*
2. The plumbing system design incorporates the use of a demand controlled circulation pump.
3. A gravity-based hot water recirculation system is used.
4. A timer-based hot water recirculation system is used.
5. Other methods approved by the enforcing agency.

Why are these not energy or water efficient options?

CalGreen Pipe Insulation Table

TABLE A5.207.6-A
PIPE INSULATION THICKNESS

FLUID TEMPERATURE RANGE (°F)	CONDUCTIVITY RANGE (in Btu-inch per hour per square foot per °F)	INSULATION MEAN RATING TEMPERATURE (°F)	NOMINAL PIPE DIAMETER (in inches)					
			Runouts up to 2	1 and less	1.25-2	2.50-4	5-6	8 and larger
			INSULATION THICKNESS REQUIRED (in inches)					
Space heating systems (steam, steam condensate and hot water)								
Above 350	0.32-0.34	250	1.5	2.5	2.5	3.0	3.5	3.5
251-350	0.29-0.31	200	1.5	2.0	2.5	2.5	3.5	3.5
201-250	0.27-0.30	150	1.0	1.5	1.5	2.0	2.0	3.5
141-200	0.25-0.29	125	0.5	1.5	1.5	1.5	1.5	1.5
105-140	0.24-0.28	100	0.5	1.0	1.0	1.0	1.5	1.5
Service water-heating systems (recirculating sections, all piping in electric trace tape systems and the first 8 feet of piping from the storage tank for nonrecirculating systems)								
Above 105	0.24-0.28	100	0.5	1.0	1.0	1.5	1.5	1.5
Space cooling systems (chilled water, refrigerant and brine)								
40-60	0.23-0.27	75	0.5	0.5	0.5	1.0	1.0	1.0
Below 40	0.23-0.27	75	1.0	1.0	1.5	1.5	1.5	1.5

Defining the Service of
Hot Water

Why Do I Work on Hot Water?

- Energy Intensity of Indoor Cold Water
  - Range from 5 to 25 kWh per 1000 gallons
- Energy Intensity of Hot Water
  - 85 kWh per 1000 gallons
    - Heat Pump with COP of 2 and 70 F temperature rise
  - 440 kWh per 1000 gallons
    - Gas Water Heater with efficiency of 0.5 and 90 F temperature rise
- Hot Water is 3.4 to 88 times more energy intensive than indoor cold water.

The most valuable water to conserve
is hot water
at the top of the tallest building, with
the highest elevation,
in the highest pressure zone.

Annual Energy Use for Hot Water?

Residential

- Single family or individual units in multi-family
  - 20 gallons per person per day
  - Large variations within and between households
- Annual costs for a US median household of 3:
  - Approximately $150-300 – natural gas
  - Approximately $500-900 – electric resistance or propane
    - Variations depend on temperature rise, water heater or boiler efficiency and fuel price
    - What would operating a heat pump water heater cost?
    - A condensing gas water heater or boiler?
  - Approximately $130 for water and sewer combined

How Big is Residential 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 Hot Water?

Commercial and Institutional

- Aggregated multi-family
- Office Buildings
- Food Service
- Schools
  - Elementary, High School, College or University
- Hospitals
  - Patient rooms, operating, outpatient, public restrooms
- Combinations?
- Others?

How Big is Hot Water in these Applications?

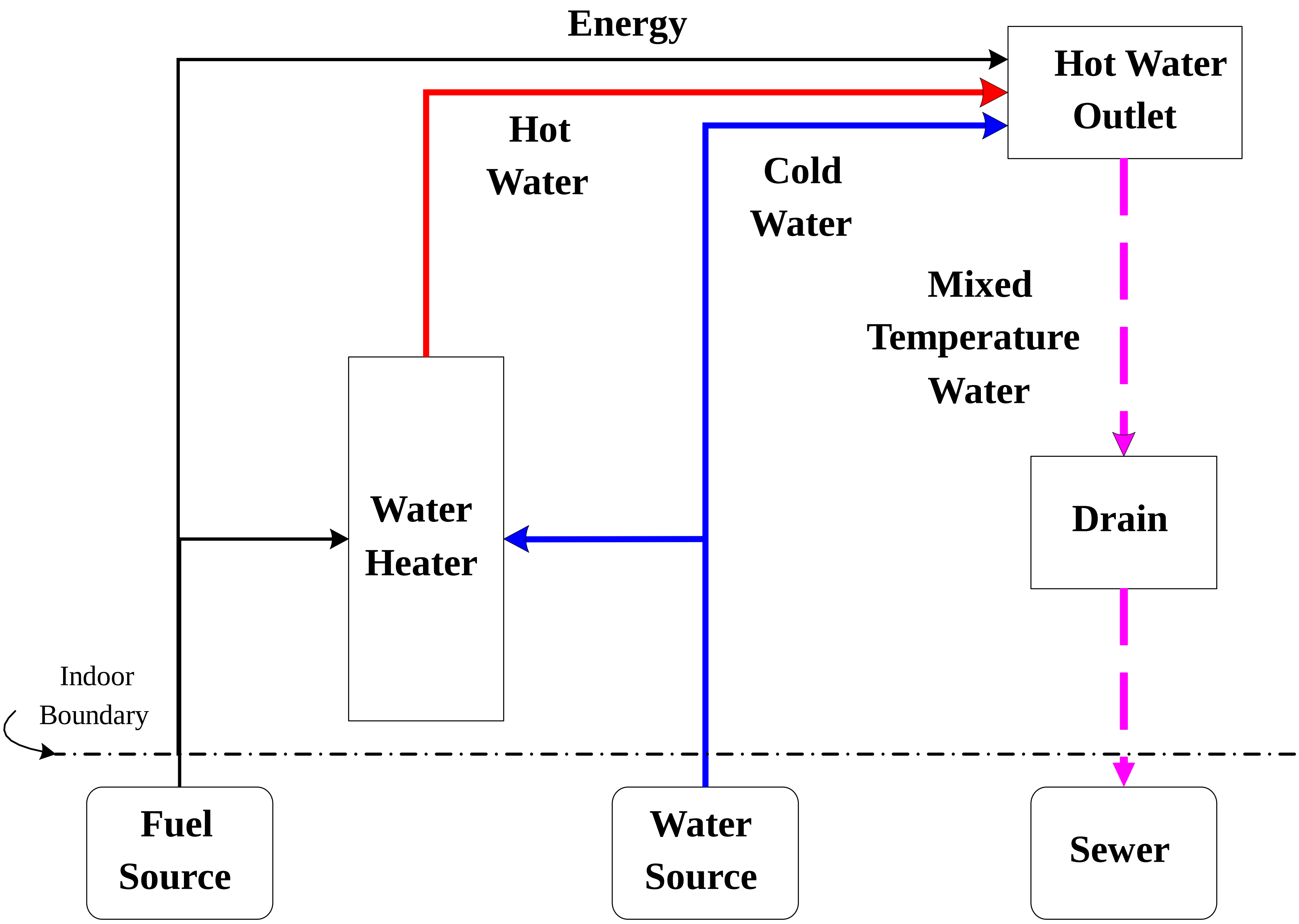
The Hot Water System

- 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

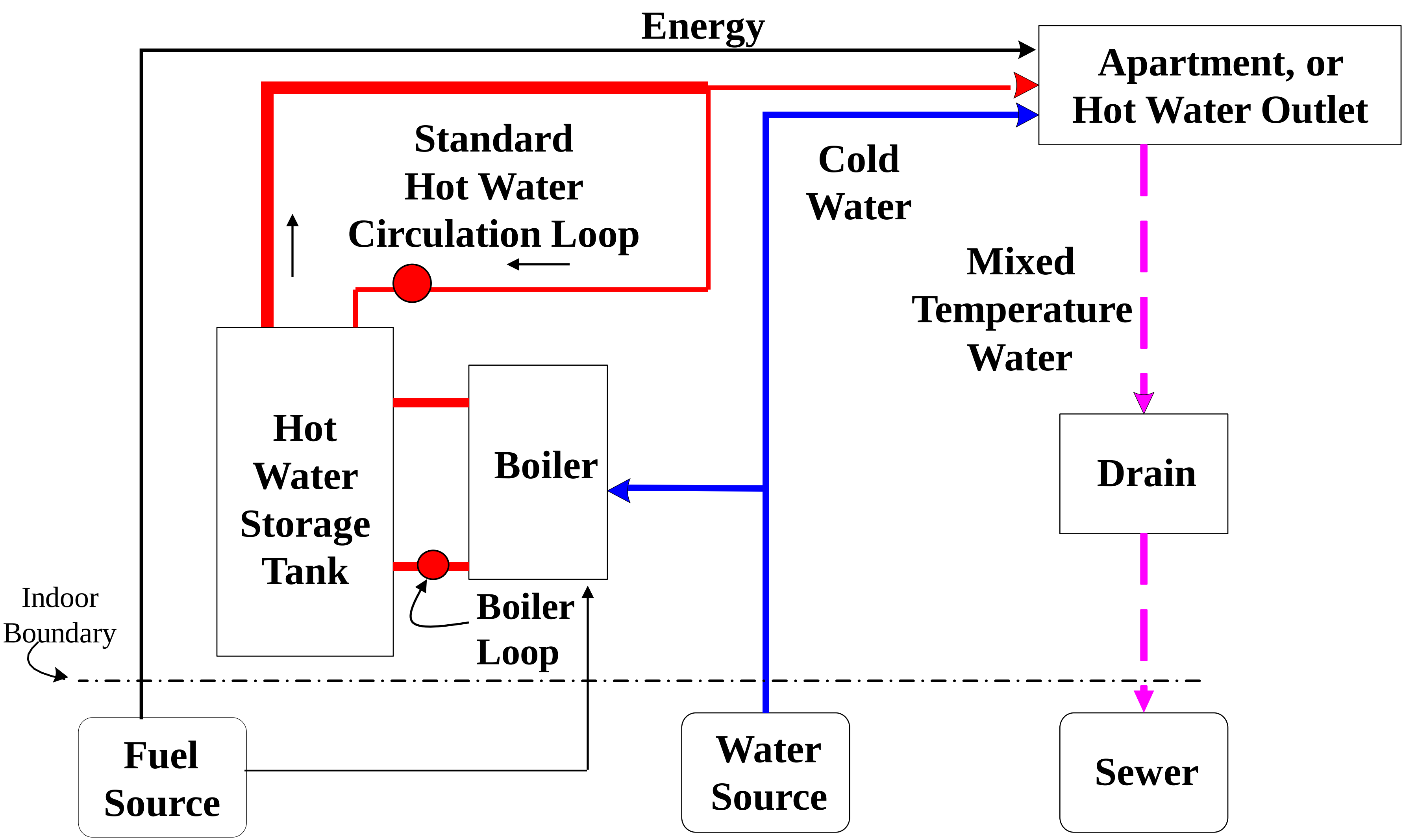
Which is the biggest ***variable*** in determining water and energy use?

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

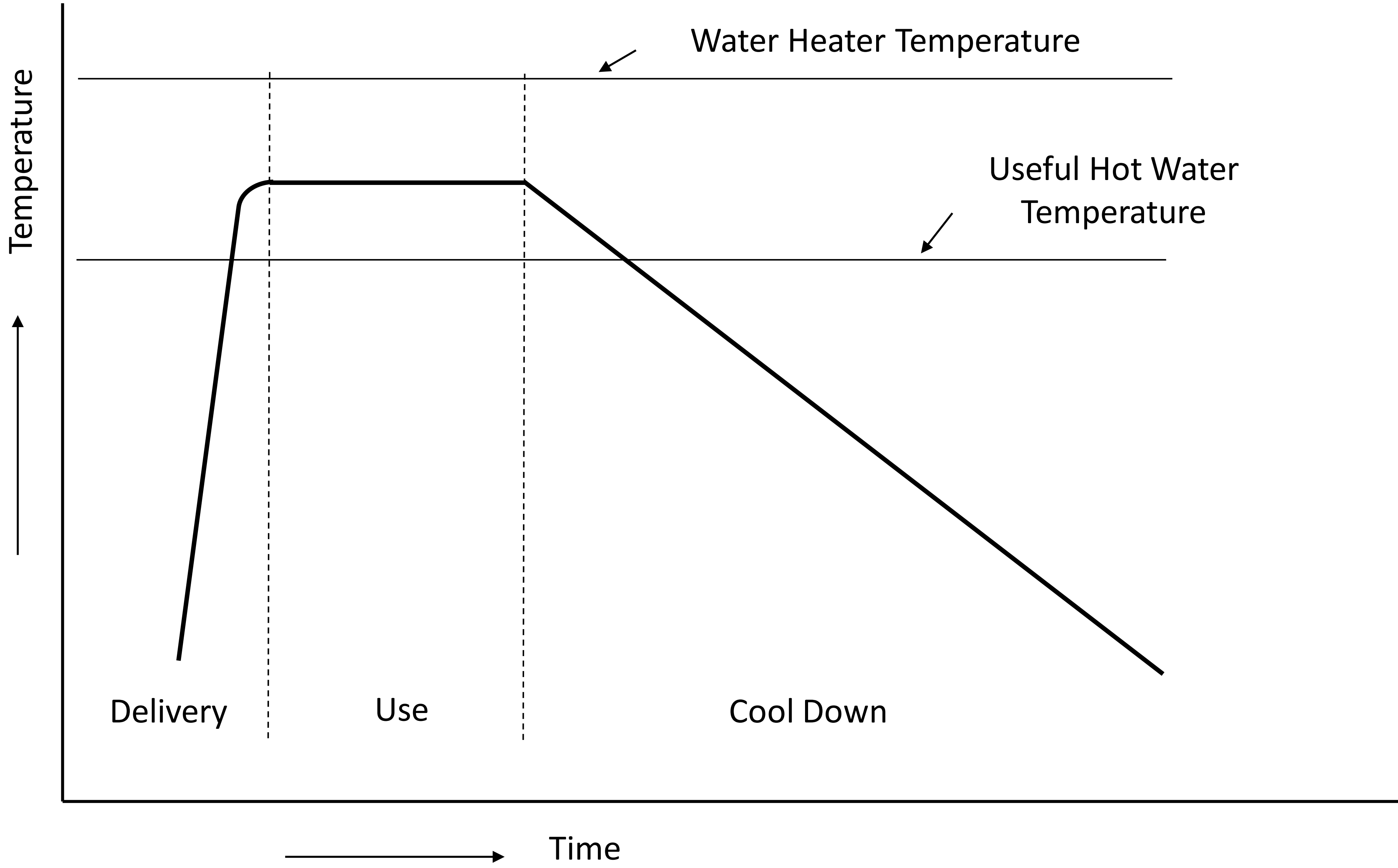
Typical “Simple” Hot Water System



Typical Central Boiler Hot Water System



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

Guiding Principle

Provide people what they want...

The Service of Hot Water

with what they expect...

Safety, Reliability and Convenience

as efficiently as possible

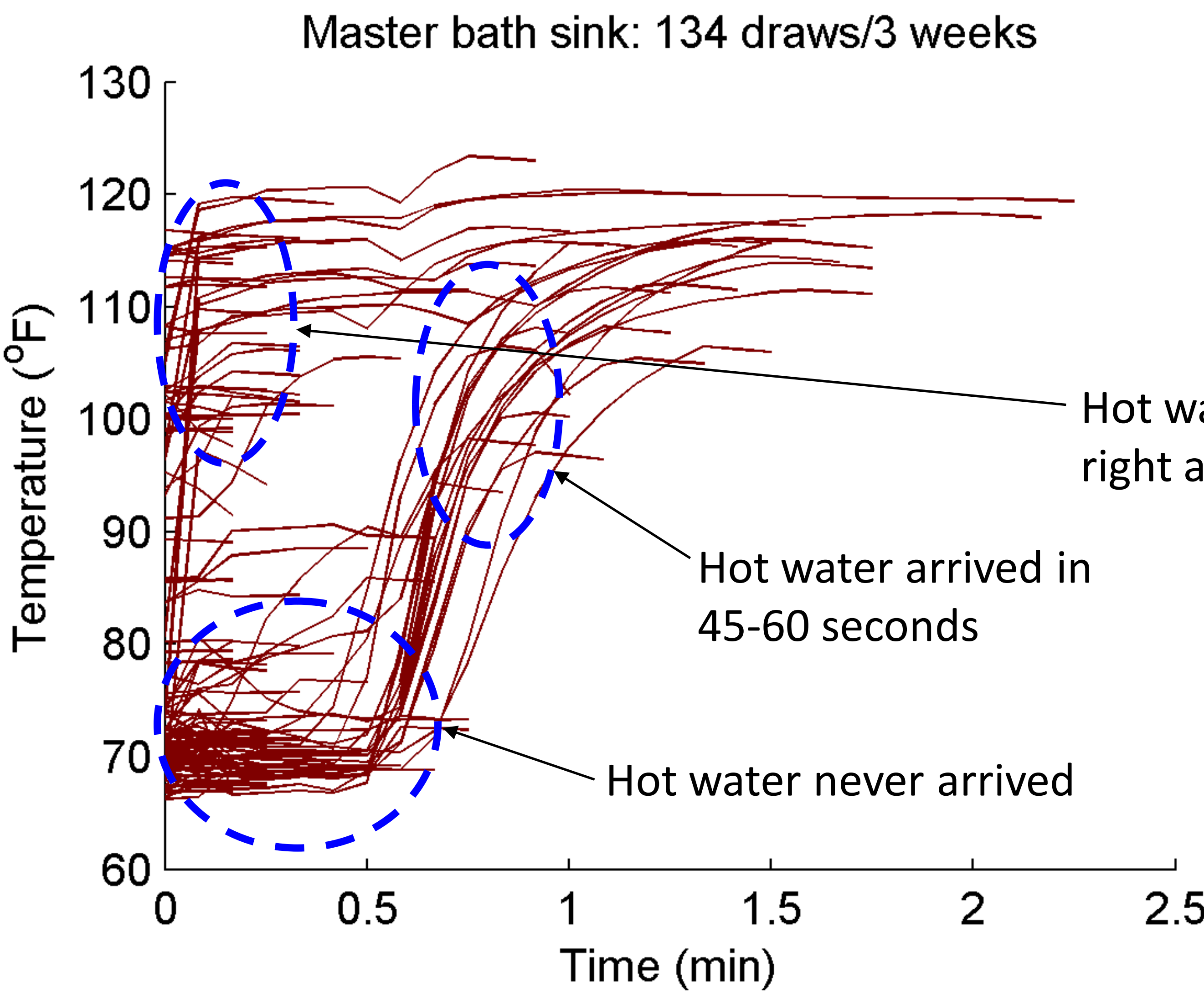
What are Your Hot Water Usage Patterns?

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

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

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

Time and Temperature at a Master Bath Sink



Average draw is 30 ± 29 seconds

Source: National Renewable Energy Laboratory

How do we use hot water?

- Frequent short, low flow-rate draws
- Occasional long draws at low flow-rates
- High flow-rate and high volume draws are rare

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 supply of hot water ends at the fixtures and 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 in My Shower = "Continousness"

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

Waste versus Use

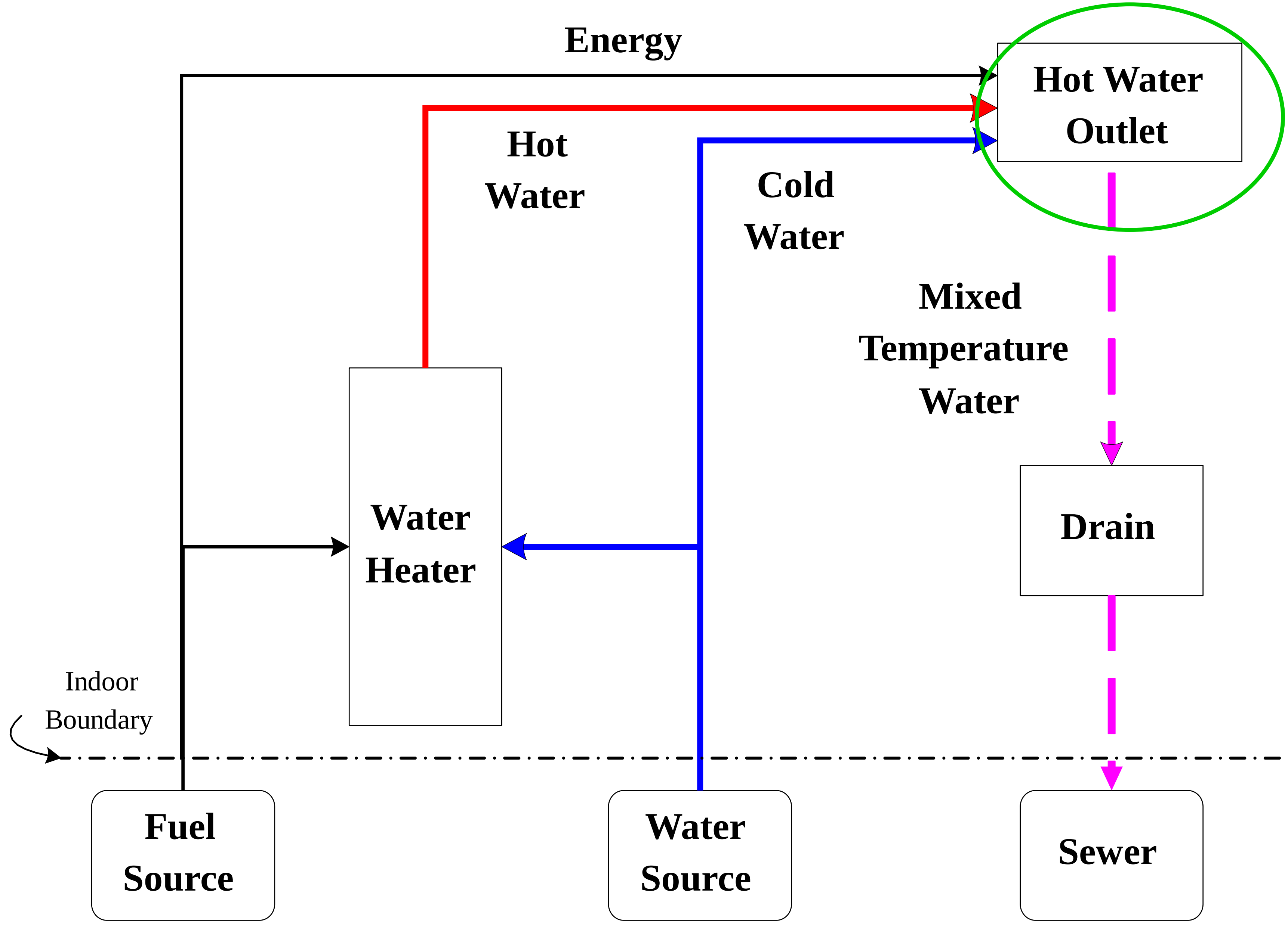
$$\frac{\text{Use + Waste}}{\text{Water Heater Efficiency}} = \text{Purchased Energy}$$

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

Reduce the waste. Improve the use. Increase the efficiency.

Hot Water Outlets:
Flow Rates and Fill Volumes

Typical “Simple” Hot Water System



Hot Water Outlets:
Flow Rates and Fill Volumes

Maximum allowable flow rates allowed by Federal and California regulation:

- Shower heads: 2.5 gpm @ 80 psi
- Lavatory and kitchen faucets:
  - Residential: 2.2 gpm @ 60 psi
  - Replacement aerators: 2.2 gpm @ 60 psi
  - Public Restrooms: 0.5 gpm @ 60 psi
0.25 gallons maximum per event
- Commercial Pre-rinse Spray Valves
  - 1.6 gpm @ 60 psi
  - Capable of cleaning 60 plates at not more than 30 seconds per plate

Appliances

- Dishwashers, Dish Machines and Washing Machines
  - Combine Energy Star and Low Water Use

Other Equipment?

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%
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	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%

What happens to the percentage of hot water:
As the hot water temperature increases? Decreases?
As the cold water temperature increases? Decreases?

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)

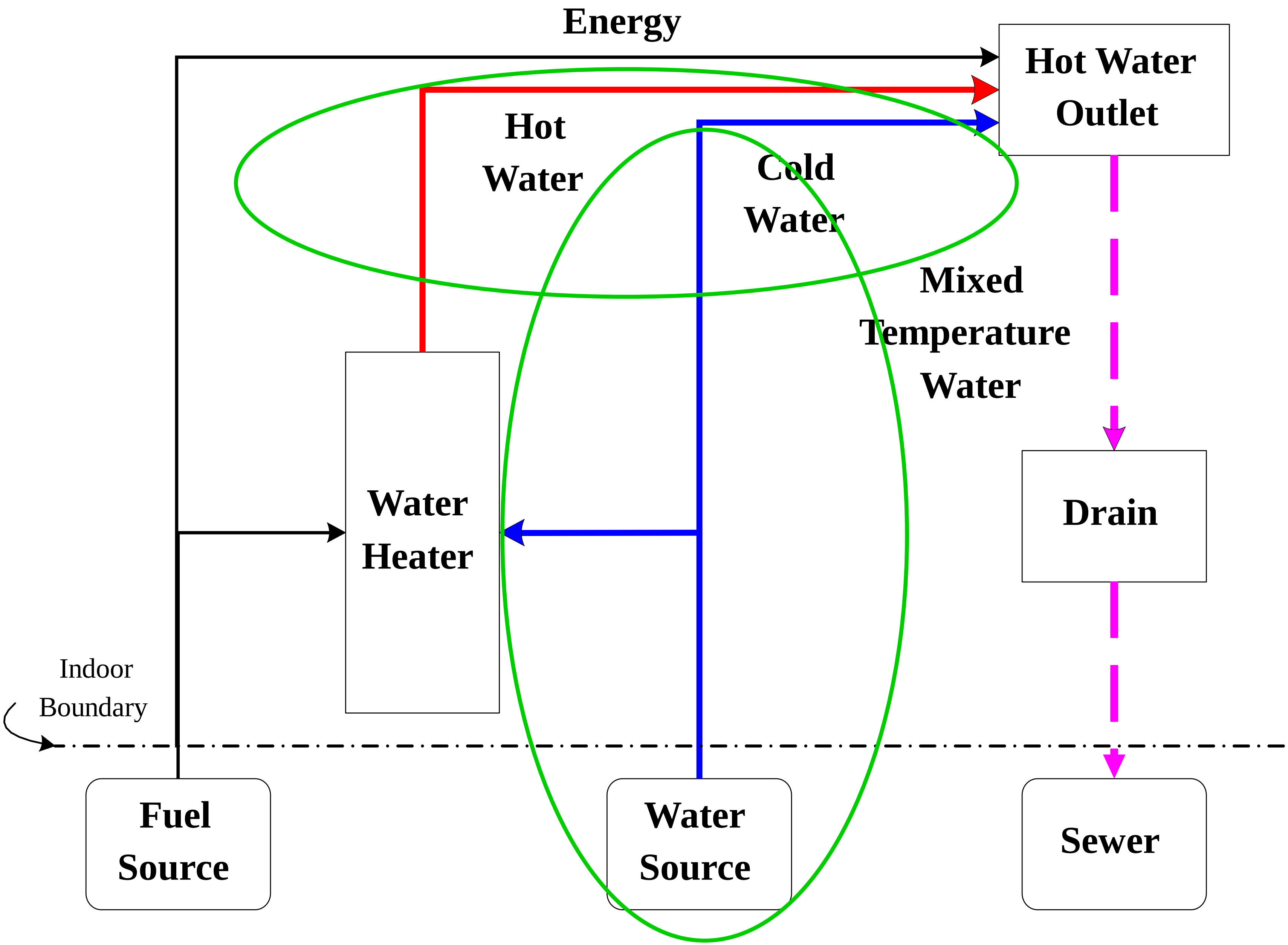
Showers – 15 gallons (maximum volume per event)

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 Hot Water Distribution System

Typical "Simple" Hot Water System



Definitions

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

Four Questions

1. Where is the location of the hot water event in relation to the source of hot water?
2. How long is the time until the next hot water event?
3. What is the temperature of the hot water needed for that subsequent event?
4. What is the volume of water in the pipe that eventually cools down?

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

Flow Rate	¾ inch Nominal Diameter Pipe	
	Relative Water Waste Percent	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	Roughly 400% ????	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

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.
- 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 running water down the drain 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

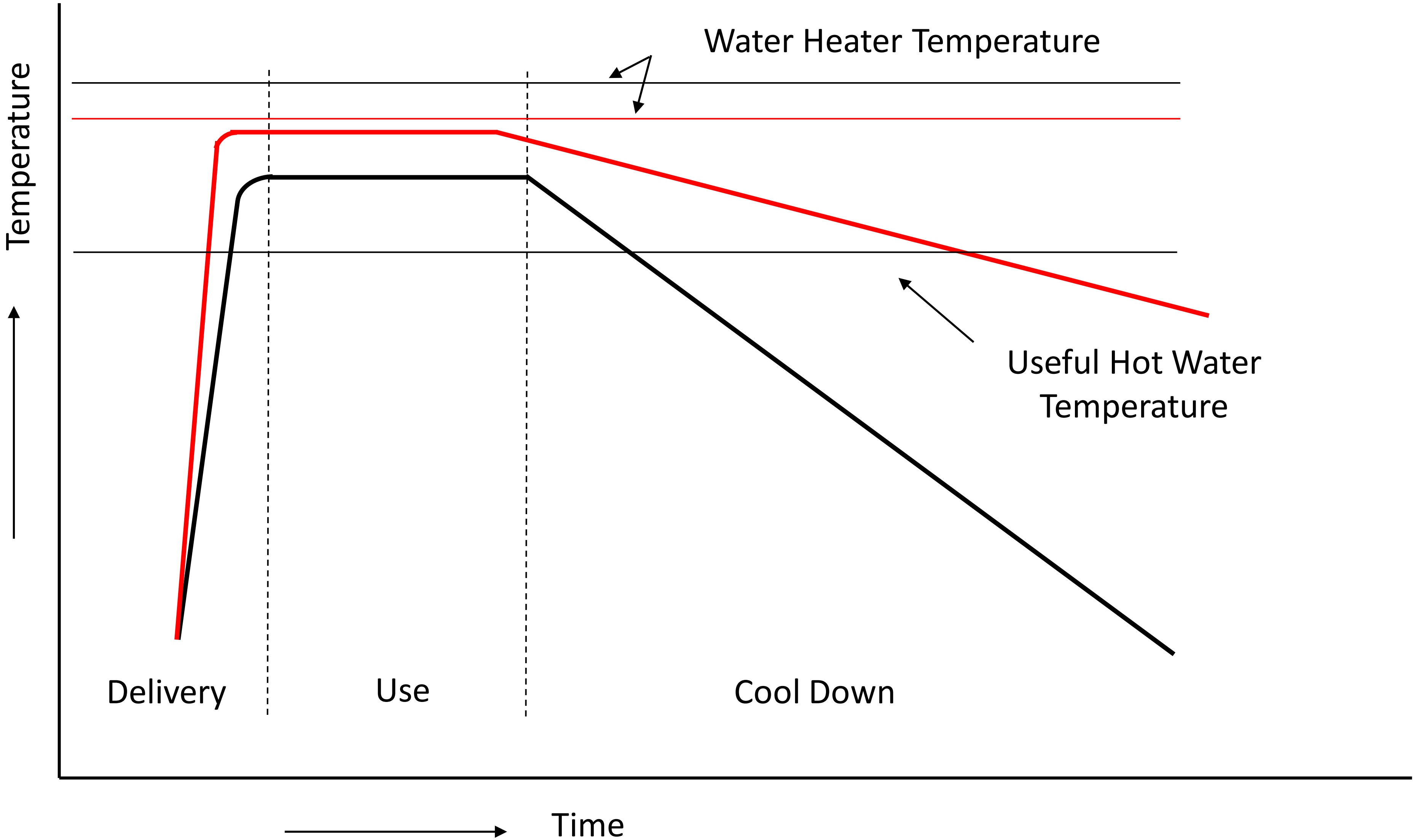
Question:

If you want to waste no more energy than you would have wasted waiting for hot water to arrive while running water down the drain, how much energy can any alternative consume?

Answer:

No more than was originally wasted!

Improved Hot Water Event



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 face-velocity (smaller diameter pipe or 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. This is particularly important for low flow fixtures and appliances.
- 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.
- R-4 insulation doubles cool down time with ½ inch pipe, triples it with ¾ inch pipe.
- Equal heat loss per foot regardless of pipe diameter

Is there a priority to insulating the pipes?

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

What About *Really* Low Flow Rates?

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**

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)

Actual Volume in Piping ≈ 0.38

Measured Volume

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
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)

Increased Time and Volume

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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	[illegible]	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	[illegible]	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	[illegible]	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	[illegible]	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

Volume is Critical when Flow Rates are Low

- For all cold-start hot water events
  - the waste of water and energy goes up as flow rate goes down
  - this is exponential compared to the difference in flow rate.
- At flow rates of 0.5 gpm and less (think the portion of hot water in hands-free lavatory faucets, or about 0.25 gpm)
  - the total volume that runs down the drain before the hot water arrives can be 2-4 times the volume of not-hot-enough water that is in the piping at the start of the draw.

Is Volume or Time the Limiting Factor?

- It may make more sense to base the volume at these low flow rates on the time-to-tap.
  - ASPE says that up to 10 seconds is acceptable. To meet this requirement this means that:
    - At 2 gpm, the volume can be no more than 4 cups
    - At 1 gpm, the volume can be no more than 2 cups
    - At 0.5 gpm, the volume can be no more than 1/2 cup
    - At 0.25 gpm, the volume can be no more than 1/6 cup
  - *Volumes above are approximate.*
  - *These volumes include the volume in the piping and in the fixture itself.*

Cups Wasted as a Function of Time and Fixture Flow Rate

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

Time-to-Tap (Seconds)

Flow Rate (GPM)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.25	0.07	0.13	0.20	0.27	0.33	0.40	0.47	0.53	0.60	0.67	0.73	0.80	0.87	0.93	1.0
0.5	0.13	0.27	0.40	0.53	0.67	0.80	0.93	1.1	1.2	1.3	1.5	1.6	1.7	1.9	2.0
0.75	0.20	0.40	0.60	0.80	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0
1	0.27	0.53	0.80	1.1	1.3	1.6	1.9	2.1	2.4	2.7	2.9	3.2	3.5	3.7	4.0
1.25	0.33	0.67	1.0	1.3	1.7	2.0	2.3	2.7	3.0	3.3	3.7	4.0	4.3	4.7	5.0
1.5	0.40	0.80	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0	4.4	4.8	5.2	5.6	6.0
1.75	0.47	0.93	1.4	1.9	2.3	2.8	3.3	3.7	4.2	4.7	5.1	5.6	6.1	6.5	7.0
2	0.53	1.1	1.6	2.1	2.7	3.2	3.7	4.3	4.8	5.3	5.9	6.4	6.9	7.5	8.0
2.25	0.60	1.2	1.8	2.4	3.0	3.6	4.2	4.8	5.4	6.0	6.6	7.2	7.8	8.4	9.0
2.5	0.67	1.3	2.0	2.7	3.3	4.0	4.7	5.3	6.0	6.7	7.3	8.0	8.7	9.3	10.0

Cups Wasted as a Function of Time and Fixture Flow Rate

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

This much water

This much time

Time-to-Tap (Seconds)

Flow Rate (GPM)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.25	0.07	0.13	0.20	0.27	0.33	0.40	0.47	0.53	0.60	0.67	0.73	0.80	0.87	0.93	1.0
0.5	0.13	0.27	0.40	0.53	0.67	0.80	0.93	1.1	1.2	1.3	1.5	1.6	1.7	1.9	2.0
0.75	0.20	0.40	0.60	0.80	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0
1	0.27	0.53	0.80	1.1	1.3	1.6	1.9	2.1	2.4	2.7	2.9	3.2	3.5	3.7	4.0
1.25	0.33	0.67	1.0	1.3	1.7	2.0	2.3	2.7	3.0	3.3	3.7	4.0	4.3	4.7	5.0
1.5	0.40	0.80	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0	4.4	4.8	5.2	5.6	6.0
1.75	0.47	0.93	1.4	1.9	2.3	2.8	3.3	3.7	4.2	4.7	5.1	5.6	6.1	6.5	7.0
2	0.53	1.1	1.6	2.1	2.7	3.2	3.7	4.3	4.8	5.3	5.9	6.4	6.9	7.5	8.0
2.25	0.60	1.2	1.8	2.4	3.0	3.6	4.2	4.8	5.4	6.0	6.6	7.2	7.8	8.4	9.0
2.5	0.67	1.3	2.0	2.7	3.3	4.0	4.7	5.3	6.0	6.7	7.3	8.0	8.7	9.3	10.0

"Future Proof" the Hot Water Distribution System

<u>Cups</u> Wasted as a Function of Time and Fixture Flow Rate

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

This much water

This much time

Time-to-Tap (Seconds)

Flow Rate (GPM)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.25	0.07	0.13	0.20	0.27	0.33	0.40	0.47	0.53	0.60	0.67	0.73	0.80	0.87	0.93	1.0
0.5	0.13	0.27	0.40	0.53	0.67	0.80	0.93	1.1	1.2	1.3	1.5	1.6	1.7	1.9	2.0
0.75	0.20	0.40	0.60	0.80	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0
1	0.27	0.53	0.80	1.1	1.3	1.6	1.9	2.1	2.4	2.7	2.9	3.2	3.5	3.7	4.0
1.25	0.33	0.67	1.0	1.3	1.7	2.0	2.3	2.7	3.0	3.3	3.7	4.0	4.3	4.7	5.0
1.5	0.40	0.80	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0	4.4	4.8	5.2	5.6	6.0
1.75	0.47	0.93	1.4	1.9	2.3	2.8	3.3	3.7	4.2	4.7	5.1	5.6	6.1	6.5	7.0
2	0.53	1.1	1.6	2.1	2.7	3.2	3.7	4.3	4.8	5.3	5.9	6.4	6.9	7.5	8.0
2.25	0.60	1.2	1.8	2.4	3.0	3.6	4.2	4.8	5.4	6.0	6.6	7.2	7.8	8.4	9.0
2.5	0.67	1.3	2.0	2.7	3.3	4.0	4.7	5.3	6.0	6.7	7.3	8.0	8.7	9.3	10.0

"Future Proof" the Hot Water Distribution System

What Diameter Pipe Can We Use?

- With 1/2 nominal tubing (UPC minimum)
  - 1.5 cups = 9 feet in PEX
  - 1/2 cup = 3 feet in PEX
  - 1/6 cup = 1 feet in PEX
- With 3/8 inch nominal tubing (IPC minimum)
  - 1.5 cups = 18 feet in PEX
  - 1/2 cup = 6 feet in PEX
  - 1/6 cup = 2 feet in PEX
- With 1/4 inch nominal tubing
  - This diameter is used in the exposed piping under sinks today. It is not currently covered in either code for use behind the wall, but could be specified based on physics
    - 1.5 cups = 36 feet in PEX
    - 1/2 cup = 12 feet in PEX
    - 1/6 cup = 4 feet in PEX

The length in copper or CPVC will be less

Options

- It appears to be difficult to expect the use of ¼ inch nominal tubing in the near future.

1. Allow for a longer time-to-tap for these low fixture flow rates.
   - Probably unacceptable because duration of actual use is small and wait time is a large percentage of the total hot water event.
2. Run circulation loops and heat traced lines down the wall behind lavatory sinks.
   - Adds 16-20 feet of large diameter pipe, 4 elbows, insulation and labor costs for every bathroom group

Options – Continued

3. Install water heaters in each bathroom
   - Takes the low flow fixtures off the main system.
     - This saves the cost of the additional piping to provide the desired level of performance.
   - Adds the cost of one or more water heaters per bathroom group.
     - Could be as many as one tankless electric water heater per sink, but this is actually excessive.
     - Could be as few as one water heater for back-to-back banks of lavatory faucets.
     - Water heater must be able to operate with a flow rate of 0.25 gpm
   - Adds the cost of operation and maintenance of these water heaters.
   - In larger bathrooms with many lavatory sinks, could combine one water heater with an on-demand priming system.
     - Reduces the number of water heaters while providing the desired level of performance.

Options – Continued

4. Heat trace all of the run-outs from a circulation loop or heat traced line to just behind the wall near the angle stop.
    - Adds cost for installation and operation of heat trace system. Trades off increased energy use for water savings.
5. Install on-demand pumping systems on the run-outs from a circulation loop or heat traced line
    - Prime the branch line behind the wall with hot water when someone enters the restroom.
    - Adds cost for installation of the on-demand pump, activation mechanism and controls
    - Some small energy cost to prime the line with hot water. Less than would have been spent running the water down the drain. Less than standard recirculation or heat trace.

The Key to Efficient Hot Water Distribution

- Reduce the volume of water between the source of hot water and the hot water outlet.
- Delivery time: consistent and short
- How much do you want to waste?
  - 1 gallon or more?
  - 0.5 gallons?
  - 0.25 gallons (4 cups)?
  - 0.125 gallons (2 cups)?
  - 0.0625 gallons (1 cup)?

Allowable Volume from Source to Use

	System without a Circulation Loop or Heat Traced Line (ounces)	System with a Circulation Loop or Heat Traced Line (ounces)	Comments
IPC	No limit	No limit	2012 maximum of 50 feet. (currently 100 feet)
IECC-Res	No Limit	No Limit	
IECC Non-Res	No Limit	No Limit	
GPMCS	32	16	
IgCC	80	24	Proposed: 2 oz. for Lavatory Faucets 64 oz. for other fixtures

Original IgCC Table702.8

TABLE 702.8.2
INTERNAL VOLUME OF
VARIOUS TYPES OF WATER DISTRIBUTION PIPE AND TUBING

Nominal Pipe or Tube Size (inch)	PIPE OR TUBING MATERIAL								
	COPPER (Type)			CPVC			PE	PEX	
	M	L	K	CTS SDR 11	SCH 40	SCH 80	AL-PE	CTS SDR 9	-AL-PEX
	LIQUID OUNCES PER FOOT OF LENGTH								
3/8	1.06	0.97	0.84	NA	1.17	0.86	0.63	0.64	0.63
1/2	1.69	1.55	1.45	1.25	1.89	1.46	1.31	1.18	1.31
3/4	3.43	3.22	2.90	2.67	3.38	2.74	3.39	2.35	3.39
1	5.81	5.49	5.17	4.43	5.53	4.56	5.56	3.91	5.56
1 1/4	8.70	8.36	8.09	6.61	9.66	8.24	8.49	5.81	8.49
1 1/2	12.18	11.83	11.45	9.22	13.20	11.38	13.88	8.09	13.88
2	21.08	20.58	20.04	15.79	21.88	19.11	21.48	13.86	21.48

Revised IgCC Table 702.8.2

TABLE 702.8.2
MAXIMUM LENGTH OF PIPE OR TUBE

Nominal Pipe or Tube Size (inch)	Liquid Ounces per Foot of Length	Maximum Pipe or Tube Length		
		System without a Circulation Loop or Heat Traced Line (feet)	System with a Circulation Loop or Heat Traced Line (feet)	Lavatory Faucets – Public (metering and non-metering) (feet)
1/4[a]	0.33	50	16	6
5/16[a]	0.5	50	16	4
3/8[a]	0.75	50	16	3
1/2	1.5	43	16	2
5/8	2	32	12	1
3/4	3	21	8	0.5
7/8	4	16	6	0.5
1	5	13	5	0.5
1 1/4	8	8	3	0.5
1 1/2	11	6	2	0.5
2 or larger	18	4	1	0.5

a. The flow rate for 1/4 inch size is limited to 0.5 gpm; for 5/16 inch size is limited to 1 gpm; for 3/8 inch size is limited to 1.5 gpm.