Water Heating Technologies and Ratings

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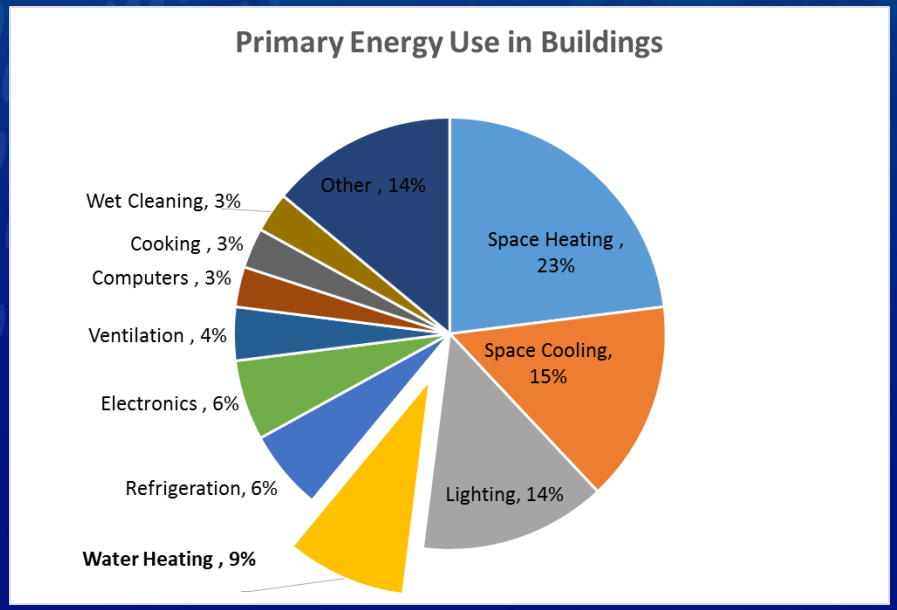
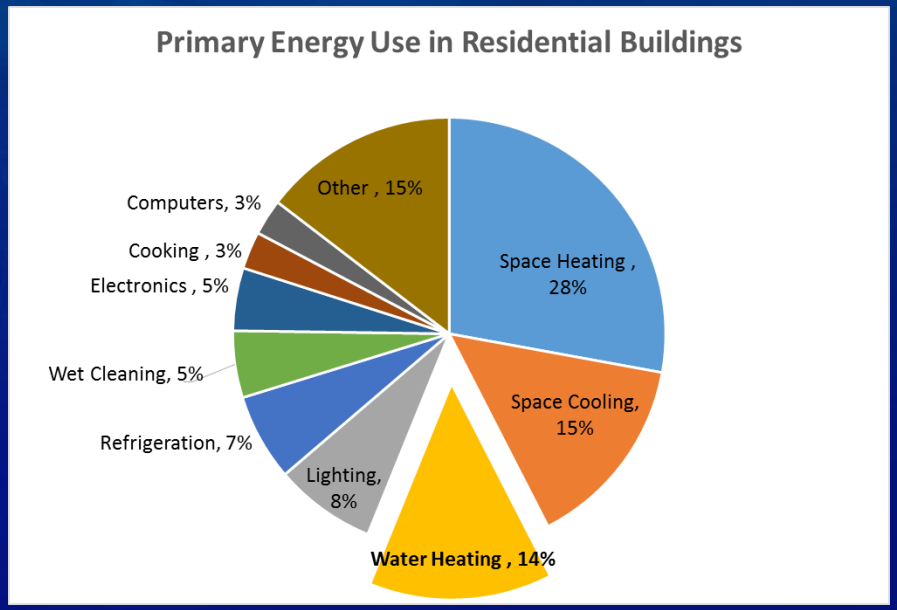
Outline

- Water Heating Energy Use
- Water Heater Technologies
- U.S. Market
- U.S. Test Method Overview
- U.S. Minimum Efficiency Standards
- Equipment and Facilities
- Summary

Water Heating Energy Consumption in United States

- 3.8 x 10^{18} J (3.6 quads) of primary energy use
- 9 % of energy consumption in all buildings
- 14 % of energy consumption in residential buildings





Water Heating Energy Efficiency

Three ways to increase efficiency of Water Heating systems:

1) Use less hot water
    1) Regulations on flow rates of faucets and showerheads
    2) Voluntary programs such as WaterSense
2) Make hot water efficiently
3) Distribute hot water efficiently
    1) Place end uses close to water heaters
    2) Use appropriate sized pipes
    3) Insulate hot water pipes

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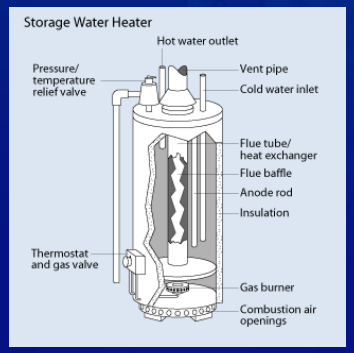
Water Heater Categorization

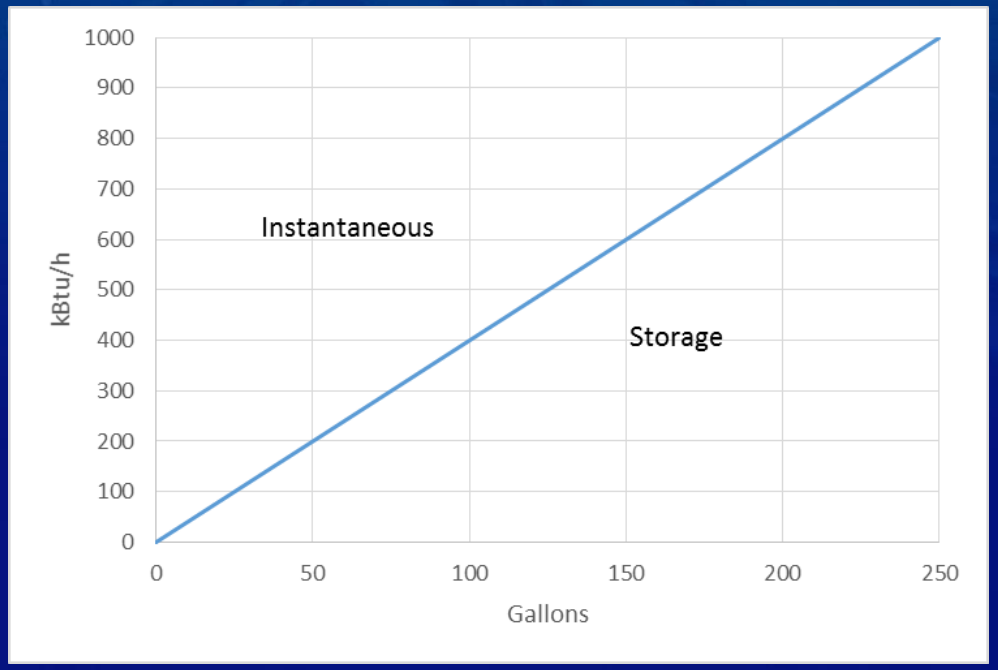
- Focus here is on non-solar options
- Residential versus Commercial
  - Residential: serves a single household
  - Commercial: serves other buildings such as offices, restaurants, hotels, hospitals, multi-family dwellings, schools, etc.
- Fuel Type: Electric, Natural Gas, Propane, Oil
- Storage versus Instantaneous (i.e., Tankless, On-Demand)



- Whole Building versus Point-of-Use

U.S. Classifications for Water Heaters: Storage vs. Instantaneous

- As specified by the Department of Energy (DOE)
- A function of storage volume and heating input rate
  - Instantaneous < [1 gallon per 4000 Btu/h of input (1 L / 310 W)]
  - Storage ≥ [1 gallon per 4000 Btu/h of input (1 L / 310 W)]



U.S. Classifications for Water Heaters: Residential vs. Commercial

- As specified by DOE for applying test procedure (note: different breakpoints for applying minimum efficiency standards)
- A Commercial Water Heater meets *any* of the following criteria:
  - Electric: does not use single phase power
  - Designed to provide outlet hot water at T > 180 °F (82 °C)

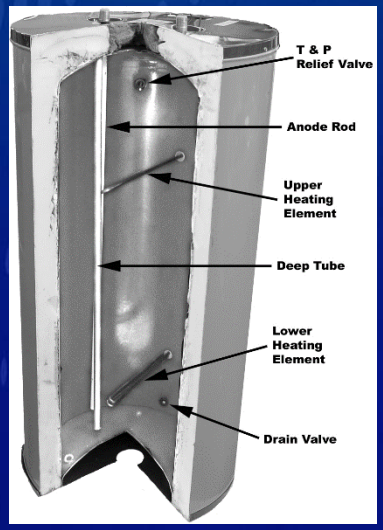
	Storage Volume Greater Than…	Input Rate Greater Than…
Storage: Gas	120 gallons (454 L)	105 kBtu/h (30.8 kW)
Storage: Electric	120 gallons (454 L)	12 kW
Storage: Oil	120 gallons (454 L)	140 kBtu/h (41 kW)
Instantaneous: Gas	2 gallons (7.6 L)	200 kBtu/h (58.6 kW)
Instantaneous: Electric	2 gallons (7.6 L)	200 kBtu/h (58.6 kW)
Instantaneous: Oil	2 gallons (7.6 L)	210 kBtu/h (61.5 kW)

All other water heaters are considered “Residential” or “Consumer.”

Electric Water Heating Technologies

Electric Resistance Storage

- Maximum Efficiency of 1
- Typical input ~ 4000 W
- Typical residential size ~ 50 gal. (190 L)



Electric Resistance Instantaneous

- Maximum Efficiency of 1
- Requires Large Inputs: 12 kW to 60 kW
- Eliminates standby loss

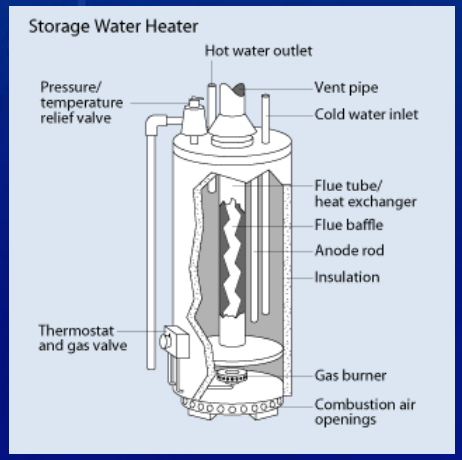
Heat Pump Water Heater

- Coefficients of Performance of 3+
- Provides space cooling
- More expensive

Gas Water Heating Technologies

Gas Storage

- Standard Burner Efficiency ~ 80 %
- Condensing Burner Efficiency ~ 95 %
- Relatively high standby heat losses
- Typical input ~ 40 000 Btu/h (12 kW)
- Typical residential size ~ 40 gal (151 L)



Gas Instantaneous

- Standard Burner Efficiency ~ 80 %
- Condensing Burner Efficiency ~ 95 %
- Minimizes standby heat losses
- Typical input ~ 150 000 Btu/h (44 kW)
- Typically require electric connection

U.S. Residential Water Heater Market

Main Water Heater Type	Number of Households (Percent)
Storage	110.6 Million (98 %)
Instantaneous	2.6 Million (2 %)

Fuel Source of Main Water Heater	Number of Households (Percent)
Natural Gas	58.3 Million (51.4 %)
Electricity	46.8 Million (41.3 %)
Propane	4.2 Million (3.7 %)
Fuel Oil	3.6 Million (3.2 %)
Other	0.4 Million (0.4 %)

Source: DOE Residential Energy Consumption Survey 2009

- Approximately 8 Million water heaters sold in 2009
- Historically, 18 % of sales are for new construction, 82 % as replacements
- Water Heaters replaced on average every 13 years

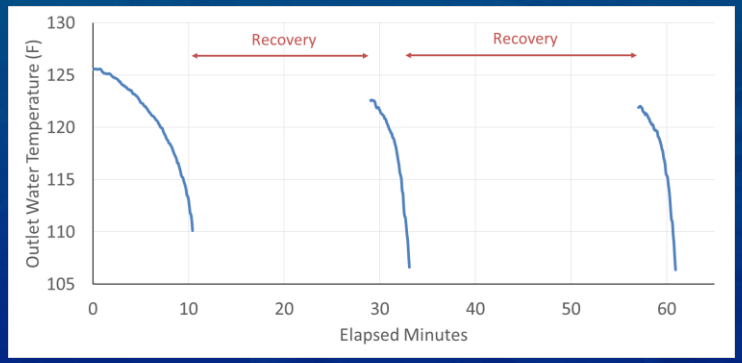
Source: DOE Energy Star Water Heater Market Profile, September 2010

U.S. Test Procedure - Residential

- Specified by the Department of Energy (*a similar test method is maintained by ASHRAE [Standard 118.2], but it is not officially used in the U.S.*)
- Significant revision in 2014
- Prescribed Test Conditions:
  - Ambient Temperature: 65 °F to 70 °F (18 °C to 21 °C)
  - Inlet Water Temperature: 56 °F to 60 °F (13.3 °C to 15.6 °C)
  - Water Delivery Temperature: 125 °F (52 °C)
  - For Heat Pump Water Heaters: Relative Humidity at 50 % ± 2 %
- Two tests
  1) Delivery Capacity
  2) Energy Efficiency

Delivery Capacity Tests

- Storage Water Heaters: First Hour Rating
  - An estimate of how much hot water the unit can provide in one hour



Example of delivered water temperature during a test

- Flow Activated (e.g., instantaneous): Maximum Gallons Per Minute
  - Full input rate
  - Measure the amount of hot water delivered over a 10 minute period
  - Adjust for deviations from prescribed inlet and outlet temperatures

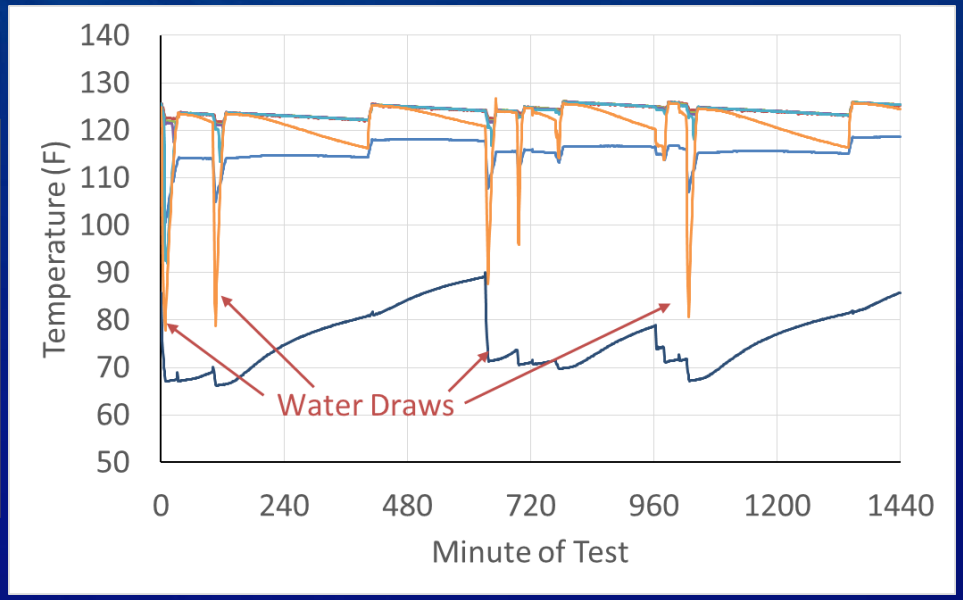
Energy Efficiency Test

- 24-hour Simulated Use Test
- Depending upon delivery capacity, impose one of four draw patterns: Very Small, Low, Medium, High Use
- Draw Patterns attempt to mimic typical amount of water used per day and the timing of usage over the course of a day.
- Measure all energy input to unit over 24 hours and all thermal energy delivered

Uniform Energy Factor (UEF) =

$$\frac{Energy\ Delivered}{Normalized\ Energy\ Consumption}$$

over 24 hour period



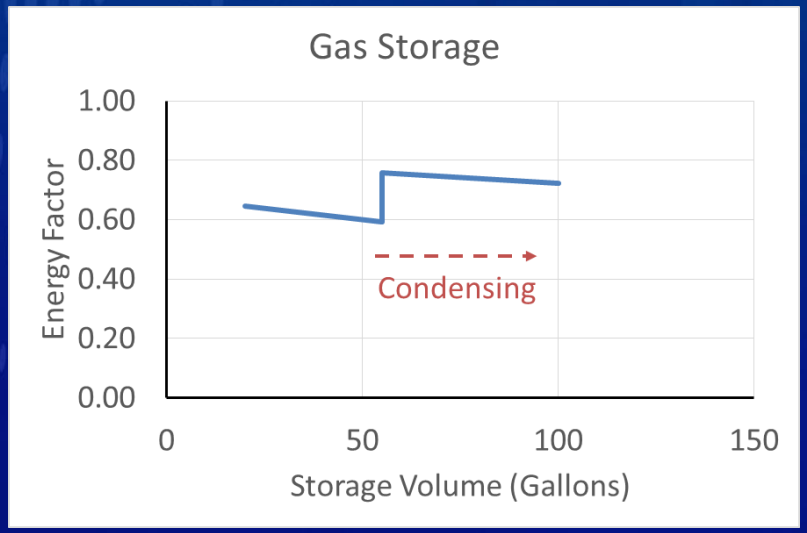
Example of T at 6 locations within tank during test

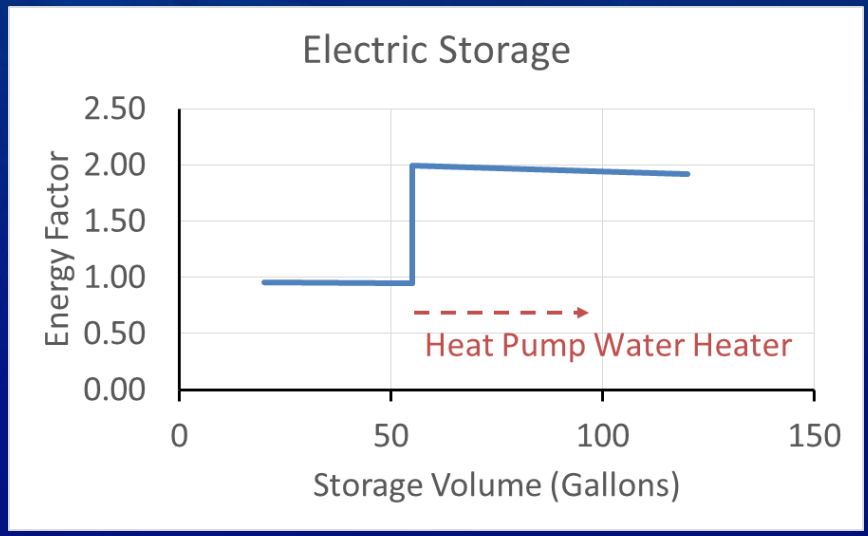
U.S. Test Procedure - Commercial

- Test Conditions:
  - Delivery temperature = 140 °F (60 °C)
  - Ambient temperature = 70 °F (21 °C)
  - Inlet Water Temperature = 70 °F (21 °C)
- **Thermal Efficiency Test** (Fossil Fuel Only)
  - Steady State
  - Flow water through water heater for 30 minutes
  - Measure hot water delivered, energy consumption
  - TE = (Energy Delivered) / (Energy Consumed)
- **Standby Loss Test** (Storage Water Heaters Only)
  - Unit sits at temperature for 24 to 48 hours
  - Measure temperature of water in tank and energy consumption
  - SL = Energy consumed per hour to maintain water temperature

Current U.S. Minimum Efficiency Standards – Residential

- Updated in April 2015 (still based on old test procedure, with Energy Factor as regulating metric)
  - Instantaneous Gas: Energy Factor ≥ 0.82
  - Instantaneous Electric: Energy Factor ≥ 0.93
  - Storage:





Current U.S. Minimum Efficiency Standards – Commercial

- Electric Storage:
  - Standby Loss ≤ (0.30 + 27/V) %/h
- Gas Storage and Instantaneous:
  - Thermal Efficiency ≥ 0.80
  - Standby Loss ≤ [(Input Rate)/800 + 110*V] Btu/h

** only for instantaneous above 10 gallons

Laboratory Requirements

- Temperature controlled room
- For Heat Pump Water Heaters (HPWH): Temperature and humidity control in room
- Supply of inlet water at a controlled temperature
- Instrumentation
  - 10 temperature sensors
  - Electric power meter
  - Gas meter
  - Scale or water flow meter
  - Relative Humidity sensor (for HPWH)
  - Data acquisition system

Summary

- U.S. market currently dominated by conventional gas and electric storage water heaters
- Test methods and standards distinguished by application (residential vs. commercial) and partly by technology but are meant to be technology neutral
- Residential test method determines efficiency over a simulated 24 hour use cycle
- Commercial test method estimates both the burner efficiency and the insulation level of the water heater