CHAPTER 9 WATER HEATING

This chapter explores types of water-heating systems along with energy-efficiency and maintenance issues related to water heating.

A *domestic hot-water system* consists of: a heat source, a heat exchanger, a piping system, and plumbing fixtures like showers and sinks. Most domestic hot-water systems also have storage tanks. The heat source is a gas or oil burner, electric heating elements, a heat pump, or a solar collector. Heat exchangers usually consist of metal tanks or pipes.

A vast majority of North Americans use storage water heaters consisting of a tank, insulation, and a heating device which uses gas, oil or electricity. Recent improvements in water heaters include more and better tank insulation and improved combustion systems.

Water-heating Energy Use

The average household uses around 3500 kilowatt-hours of electricity or 230 therms of natural gas to heat water annually. Water heating consumes approximately 15% of the electricity and 25% of the natural gas used in residences. Water heating is the most variable class of energy consumption among families and varies according to water-heater capacity, climate, economic status, work schedule, and age.

Water heaters use energy in three ways: demand, standby, and distribution. *Demand* means energy is used for heating incoming cold water up to the temperature setpoint as hot water in the tank is used. Demand energy depends on water heater efficiency, occupant behavior, and consumption of fixtures like shower, clothes washer, and dishwasher.

Standby energy accounts for heat lost through the storage tank's walls. Standby losses amount to 20% to 60% of the total water-heating energy. Households using less hot water have a higher percent of standby losses.

Distribution losses consist of heat escaping through the pipes and fixtures. Pipes near the water heater lose heat even when water isn't flowing because hot water rises out of the tank, cools off in the nearby pipes, then falls back down into the tank.

Typical Consumption According to Family Size

Number of Residents	Annual kWh	Annual Therms	Gallons Per Day
1	2700	180	25
2	3500	230	40
3	4900	320	50
4	5400	350	65
5	6300	410	75
6	7000	750	85

Author's interpretation of single-family house data from Energy Information Administration, Lawrence Berkeley Laboratory, *Home Energy Magazine*, and others.

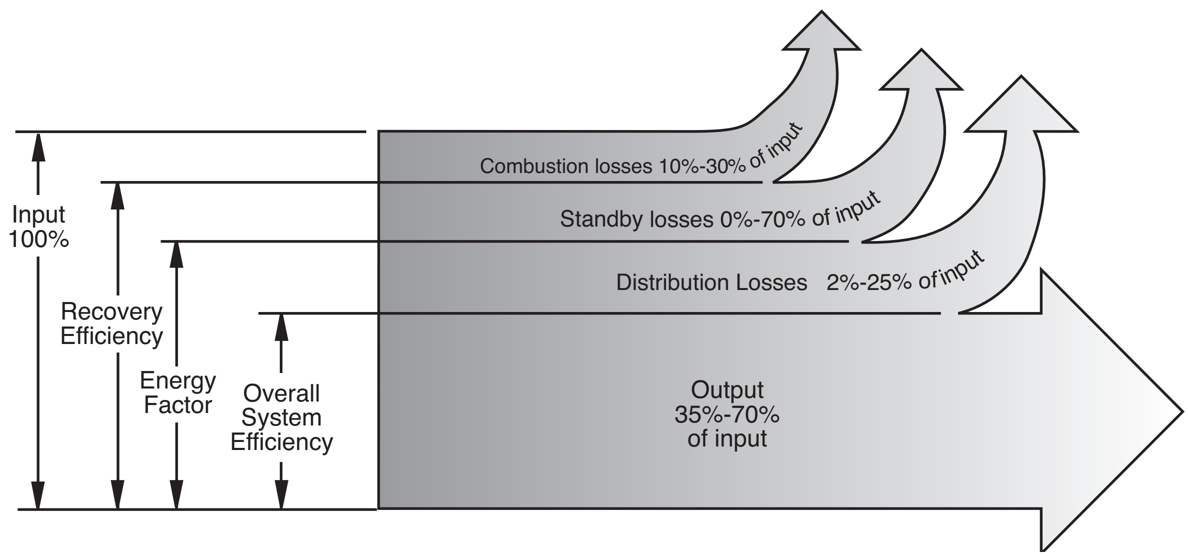
Water-heating Capacity

Americans use 15 to 40 gallons of hot water per day per person. Designing or selecting a water heater involves consideration of the first-hour rating and the storage capacity.

Hourly peak hot-water flow rate in gallons per hour is known as the *first-hour rating* or *recovery capacity*—an important design consideration for water-heating systems. The size of heating equipment, capacity of storage tanks, and design of piping systems is determined by recovery capacity needed by a building.

Water-heating systems are designed for recovery capacities of 3 to 20 gallons per hour per resident. Multifamily buildings—especially large ones—need less recovery capacity per resident or dwell-

Water-Heating Efficiency



The various efficiencies used for rating water-heating systems account for losses in the combustion process, standby losses, and distribution losses.

ing unit because of residents' differing schedules. Suggested recovery capacities for multifamily range from 3 to 10 gallons per hour per resident.

Storage capacity, the amount of water in the storage tank, relates to the number of occupants or number of dwelling units in a building. Storage capacity typically varies from 8 to 20 gallons per person or 30 to 65 gallons per living unit. Most single-family homes have 40-gallon or 50-gallon storage tanks.

Water-heating Efficiency

There are several types of efficiencies used to rate water-heating systems. The DOE ENERGY STAR program sets criteria for residential electric and gas water heaters using several efficiency ratings; *Energy factor* (EF), *First-Hour Rating* (FHR), and *Gallon-per-Minute* (GPM).

Energy Factor—a number between 0.50 and 2.0 or more— is a ratio of useful water heating energy output to the total energy consumed by the water heater. Heat pump water heaters are able to reach higher EFs of 2.0 or more. *First-Hour Rating* estimates the gallons of hot water a storage water heater can deliver once the water heater is fully heated. *Gallons-per-Minute* is how many gallons per minute that an instantaneous water heater can continuously supply.

See "Heat Pumps" on page 182 for information on heat pump operation.

Energy Factor Requirements for ENERGY STAR

Water Heater	EF	FHR/GPM
Electric	≥ 2.0	≥ 50 FHR
Gas Storage	≥ 0.67	≥ 67 FHR
Gas Instantaneous	≥ 0.82	≥ 2.5 GPM

Recovery efficiency accounts for just the losses during the water-heating process. A storage water heater's energy factor is less than its recovery efficiency. For demand water heaters without pilot lights, recovery efficiency is the same as their energy factor because they have no storage losses.

Overall system efficiency includes all losses and measures the efficiency of the water heater and its distribution system in providing heated water to points of use.

The American Council for an Energy Efficient Economy lists the most efficient storage water heaters in their annual guide, The *Consumer Guide to Home Energy Savings*. See "Bibliography" on page 309.

Water-heater Design Types

Design of water-heating systems is based on three interrelated factors: *recovery capacity* (gallons per hour), *energy input* (BTUs per hour), and *storage capacity* (gallons). These are determined by occupancy, number of plumbing fixtures, and per capita use.

Fuels for water heating include: fossil fuel, electricity, solar energy, and waste heat recovery. Each of these fuels can be used directly or indirectly. Direct water heating applies the fuel's heat to only one heat exchanger—a tank or pipes containing domestic hot water. Indirect water heating applies heat collected by water or air in a remote area to heat the domestic hot water. This remote heat comes from a boiler, solar collector, or waste heat exchanger. Indirect water heaters employ two or more heat exchangers.

Storage Water Heaters

Most single-family homes use direct storage water heaters that combine the heating device, heat exchanger, and storage tank into one unit. Single-family storage water heaters hold 30 to 80 gallons of water. Their tanks are insulated with fiberglass or plastic foam insulation and covered with outer jackets of painted sheet metal. Hot water exits the top of the tank, and cold water enters through a tube extending to the tank's bottom.

Older storage water heaters, insulated with fiberglass, have a thermal resistance (R-value) of R-3 to R-6, while newer models have R-7 to R-25. The extra cost of the better insulated water heaters will be returned to the buyer in energy savings in a year or less. Improved insulation is the only significant, recent improvement to electric storage water heaters.

A thin layer of glass, mineral, or plastic coats the steel tank's inside for corrosion resistance. A metal rod attached to the top of the tank, called the sacrificial anode, also protects the tank's steel parts from corrosion.

Storage water heaters with better warranties incorporate features like improved tank coatings, auxiliary sacrificial anodes, and curved dip tubes that make flushing more effective at removing sediment.

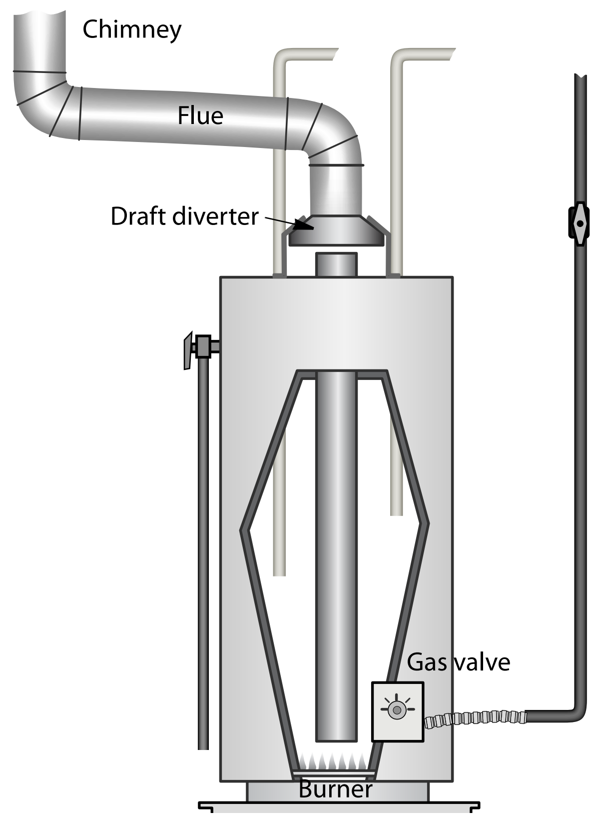
A pressure-and-temperature-relief valve mounted on the tank opens to expel hot water or steam if the pressure or temperature in the tank becomes dangerously high.

Since May 1980, all new storage water heaters sold in the United States must have an Energy Guide Label. The *Energy Guide Label* is intended for comparison shopping and not as a table for actual operating cost and performance. It features an estimated yearly operating cost, a bar scale comparing operating costs for similar models, and a table to allow the buyer to estimate the operating costs.

Gas Storage Water Heaters

A gas water heater and a propane water heater are nearly identical except for burner orifice, gas valve, and pilot orifice. Storage capacities are 30 to 80 gallons for single-family and 40 to 100 gallons for multifamily buildings. Larger multifamily buildings are often zoned and have a water heater for each zone. Or, the water heaters can be staged—one or two units supply hot water for average demand with more heaters coming on at peak demand.

Standard Gas Storage Water Heater

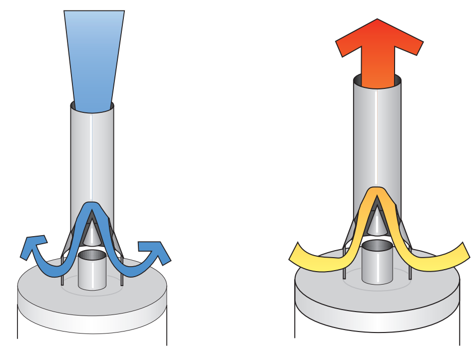


Combustion air enters the bottom, combusts with gas, then rises through the flue which is surrounded by water. The gases heat the water as they rise through the tank. Dilution air enters through the draft diverter.

A gas burner located under the tank heats water. A thermostat opens the gas valve as the water temperature falls, and closes it when the temperature rises to the thermostat's setpoint. A pilot light—a miniature burner and flame—lights the main burner which heats the water in the storage tank.

The metal flue takes the hot combustion gases up through the center of the tank, using them to heat the water further. Multifamily units have multiple flues. The pressure (called draft) drawing the combustion by-products up the flue comes from the difference in temperature between the combustion by-products and the outside air.

Function of a Draft Diverter



This device diverts down-drafts so they do not blow out the pilot light. The draft diverter also lets dilution air into the flue to relieve pressure that would otherwise pull directly on the burner, causing unnecessary excess air.

Where the flue and chimney join is an opening called the draft diverter. The draft diverter moderates strong updrafts by allowing indoor air into the flue, and diverts strong down-drafts so they don't extinguish the pilot light.

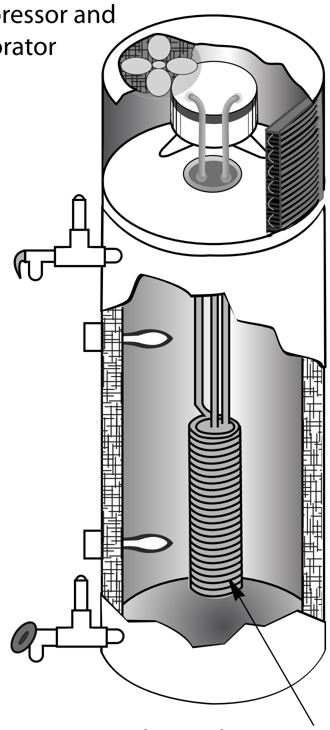
Oil-fired Storage Water Heaters

Oil-fired water heaters are similar to gas and propane water heaters. However, they have power burners that mix oil and air in a vaporizing mist, ignited by an electric spark. The flue has a barometric damper that performs the same function as a draft diverter, but provides more precise draft regulation. For a fairly airtight residential structure, the oil-fired water heater should have a draft inducer to minimize the indoor air it consumes and to provide more reliable draft than the barometric draft control.

Heat-Pump Water Heaters

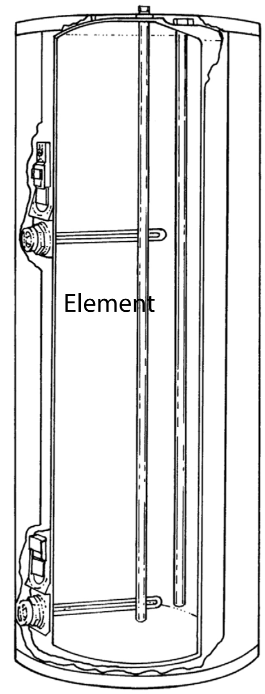
Heat pump water heaters can heat water at up to 2.3 times more efficient than electric-resistance storage water heaters. Heat pump water heaters use heat from surrounding air to heat water stored in the tank. They cost much more than conventional electric water heaters but are far less costly to operate.

Heat-Pump Water Heater



A heat-pump water heater uses a refrigeration system to heat water. The coil in the tank uses heat collected from indoor air.

Electric Water Heater Operation



Electric water heaters have one or two electric elements controlled by adjustable thermostats. The elements can be removed for inspection, cleaning, and service.

Electric Storage Water Heaters

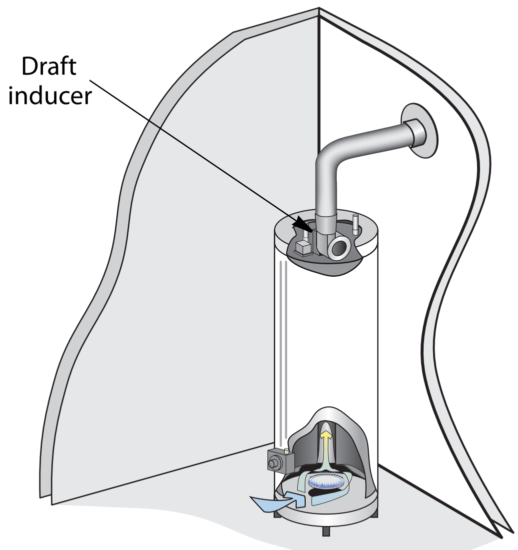
Electric water heaters have lower standby losses and higher energy factors than similar gas, propane, and oil water heaters because they don't have flue pipes running up the center of their tanks like combustion units do. However, electric water heating is typically 1.5 to 2 times more expensive than natural gas, reflecting electricity's generation and distribution losses. Because of the higher cost of electricity, electric water heaters tend to have thicker insulation—3 inches of plastic foam in the best new models.

Electric water heaters don't need a chimney, so they can be easier to install than gas water heaters. However, since electricity is more expensive than gas, propane, or oil, many people choose combustion water heaters over electric.

Electric storage water heaters have higher energy factors and lower recovery capacities than fuel-fired water heaters. They tend to have higher storage capacities to compensate for their slower recovery.

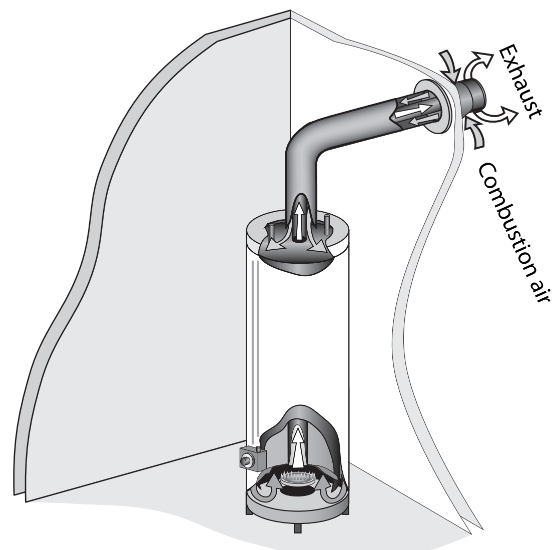
An electric water heater is usually wired for 240 volts and has one or two electric elements, each with its own thermostat. In two-element water heaters, the element at the bottom of the tank is the standby element that maintains the minimum setting on its thermostat. The standby element adds heat to replace the tank's heat losses and maintain the minimum thermostat setting. The upper demand element heats water at the top of the tank to provide quick recovery of usable hot water during times of high demand. The elements are wired so they can't operate simultaneously.

Fan-Assisted Gas Water Heater



The draft-inducer fan controls the draft and reduces excess air to a minimum, increasing efficiency. These improved water heaters are vented through a sidewall.

Sealed-Combustion Water Heater



These water heaters have lower excess air and no dilution air, giving the units a higher recovery efficiency. The sidewall venting eliminates the need for a vertical chimney.

Demand control is an important water-heating issue in multifamily buildings because they may be charged for peak demand by the utility company. Automatic controls should ensure that most of the water heating is done during off-peak hours.

Combustion Water Heater Safety

Most residential combustion water heaters are the open-combustion, atmospheric type. Their combustion efficiency and recovery efficiency haven't improved in decades. The combustion chamber and flue are open to the surrounding indoor air, and the combustion by-products flow up the chimney because they're lighter than surrounding air. This simple combustion system becomes a safety problem if the burner produces carbon monoxide (CO) and the chimney backdrafts—a common occurrence.

See "Combustion By-products" on page 241 and "Combustion-safety Issues" on page 150.

These safety problems are most dangerous when air from the living space has a direct connection with air near the water heater. Testing draft and CO should be part of installation and maintenance of all combustion water heaters. The same testing should accompany all weatherization, heating, and air-conditioning work.

Improved Combustion Water Heaters

Conventional gas water heaters waste a greater percentage of energy than electric water heaters do because of the design of the burner and venting system. Besides standby and distribution losses common to all storage water heaters, the wasted energy specific to gas and oil water heaters can be classified into three different types: excess air, dilution air, and off-cycle air circulation.

About 15 cubic feet of air is required to completely burn a cubic foot of gas. Every molecule of air flowing out the chimney carries wasted heat with it. Some waste is unavoidable, but the more excess air that flows through the burner, the more energy is wasted. Dilution air enters the flue at the draft diverter during combustion. Some or all of this dilution air is heated air from the home.

The third type of waste occurs when the burner is off. Surrounding indoor air circulates through the burner and flue, carrying heat away from the water and up the chimney.

Improved gas and oil water heaters reduce these venting-related losses by restricting the airflow through the flue and chimney and by eliminating the draft diverter or barometric draft control. Restricting airflow through the flue and chimney reduces air circulation, carrying heat away from the tank. Eliminating the atmospheric draft control and closing that hole in the venting system allows far less heated indoor air to pass through the venting system to the outdoors.

An *induced-draft water heater* uses a fan to pull the combustion gases through the flue in the center of the tank. The draft fan regulates the air that passes through the burner—minimizing the amount of excess air during combustion and limiting airflow through the flue during the off cycle.

Draft inducers—small fans for providing a steady and predictable draft—make these water heaters safer. The draft inducer makes the water heater safer by eliminating the draft diverter, using far less indoor air, and providing a more reliable draft.

A *sealed-combustion water heater* uses a combustion and venting system that is totally sealed from the house. Sealed-combustion water heaters draw combustion air from outdoors through pipes connecting to sealed burner compartments. They don't have draft diverters, and they may or may not have draft inducers. Sealed-combustion water heaters are designed for safety in tight homes. They are used routinely in mobile homes when installed in the living space.

Alternatives to Storage Water Heaters

Storage water heaters dominate the market, but indirect water heaters are common in multifamily buildings. Demand water heaters offer an attractive alternative when hot-water use is moderate, space is limited, and fuel is expensive. Solar water-heating equipment is expensive, but its competitive in life-cycle cost with storage water heating in warm climates or where hot-water demand is high.

Integrated space and water heating may be the choice of the future because the combined efficiency of a single heater providing both space and water heating is higher than the efficiency of heaters doing these tasks separately.

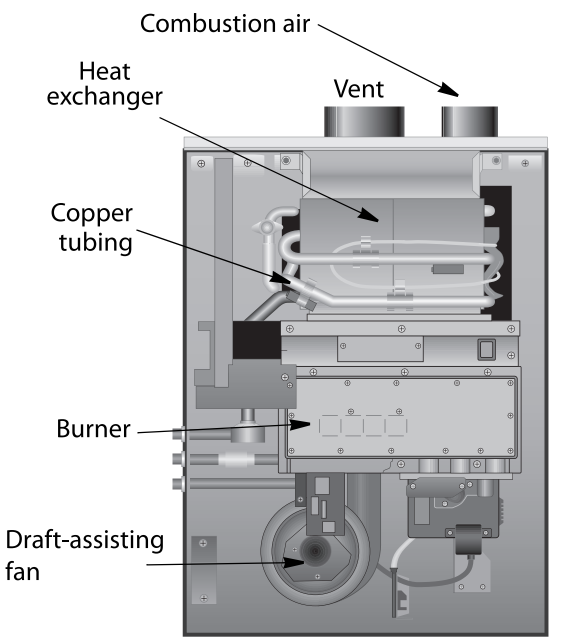
Tankless Water Heaters

Tankless water heaters heat water as it flows through the heater; there is no storage tank. Tankless water heaters are also called demand water heaters or instantaneous water heaters. The absence of a storage tank eliminates standby losses through the walls of the tank. Tankless water heaters can provide a continuous flow of hot water at a specific flow rate and temperature. They are available with recovery efficiencies ranging from 78 to 95 percent.

Tankless heaters are more expensive than conventional water heaters. The largest of them provides about 5 gallons of hot water per minute at 140°F. Taking a hot shower and running the automatic dishwasher at the same time stretches a tankless water heater to its limit.

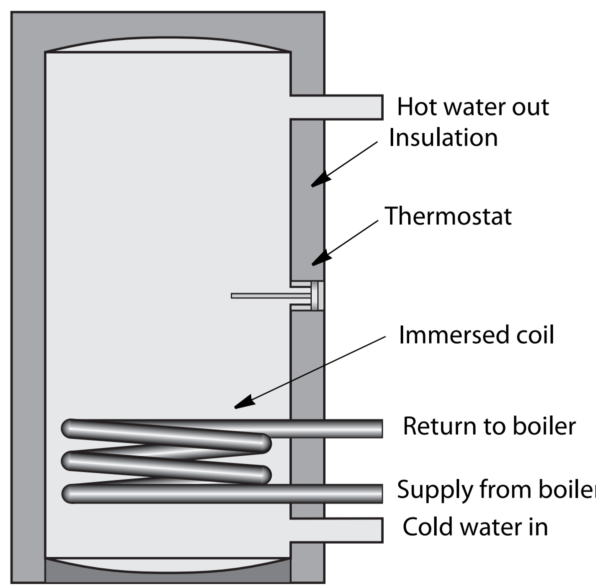
The better gas-fired tankless water heaters have modulating gas valves that vary gas input depending on the demand for hot water. This modulation is necessary if the unit is serving two plumbing fixtures at once.

Sealed-Combustion Tankless Water Heater



A tankless water heater has its own heat source but no storage tank. Water is heated, on demand, as it flows through the heat exchanger.

Immersed Coil with Tank



A coil inside the storage tank heats the tank's water with boiler-heated water or refrigerant carrying heat rejected from a building or refrigerator.

There are a variety of gas tankless water heaters available. Be sure to specify sealed combustion or direct vent (they mean the same thing). The old tankless water heaters are inefficient and unsafe because they have natural draft and open combustion. Don't specify or install a tankless water heater equipped with a draft diverter. The 80+ and 90+ efficiency units have draft-assisting fans which make venting safer. The sealed-combustion or direct-vent units are the best choice for both efficiency and safety.

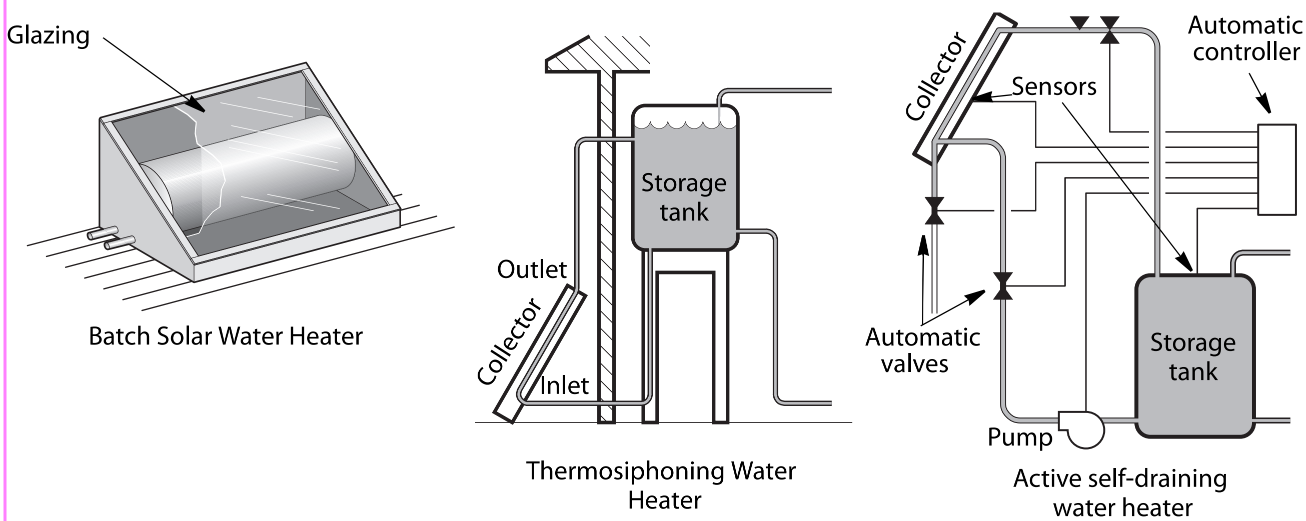
Tankless electric water heaters generally serve just a single fixture like a shower or sink. They are a problem for utility companies because of their very large power draw. The largest electric tankless water heater, which draws up to 20 kW, will produce 2 gallons per minute with a 70°F temperature rise. New, heavily insulated storage electric water heaters have energy factors as high as 0.95, and that doesn't leave much room for improvement by tankless models.

Water Heating Integrated with Space Conditioning

An *indirect water heater* is a heat exchanger that derives its heat from a boiler, a solar collector, a heat pump, or an air conditioner. A boiler is the most common heat source for indirect water-heating systems. Boilers are generally more durable and efficient than combustion storage water heaters. The efficiency of indirect water heaters depends on the boiler's efficiency and how closely the boiler is matched to its water-heating and space-heating loads.

Well-engineered, indirect water heaters may have significant advantages over direct water heaters. First, they eliminate the need for a chimney with its heat losses. They're safer because they don't burn fuel or need combustion air. An indirect water heater can beat a direct water heater's efficiency, if it is well-insulated and coupled to a boiler which also provides space-heating.

Solar Water Heating Systems



The two most common types of indirect water heaters are the immersed coil and the tankless coil. *Immersed-coil water heaters* use coils immersed in a tank of water. Boiler water or solar-heated water circulates through the coil, heating the water in the tank.

Tankless coils are heat exchangers installed inside a large boiler for heating domestic water. Tankless coils usually heat water for a separate storage tank near the boiler. A boiler's tankless coil may waste significant energy when it forces the operation of a large boiler during the summer months. Instead, it is better to install a separate water heater which is matched to the building's water-heating load. This allows the large boiler, which is used in the winter for both space-heating and water-heating, to remain idle during warmer months.

See "Boilers" on page 166 for a thorough discussion of boiler efficiency.

Two types of appliances are designed to heat water with hot refrigerant (waste heat) from a heat pump or air conditioner. They are the heat pump water heater and the de-superheater. A *heat pump water heater* is a small air conditioner attached to a tank with an immersed coil that is the air conditioner's condenser. A *de-superheater* is an exterior heat exchanger that transfers heat from compressed refrigerant to domestic water before it goes to the condenser.

Other indirect water heaters use tanks inside other tanks, tubes inside tubes, or narrow chambers separating the heating water, steam, hot refrigerant, or other hot gases from the water being heated.

See "Integrated Heating Systems" on page 176 for more on integrated space and water-heating systems.

Solar Water Heaters

Solar water heaters are classified as active or passive depending on whether they use a pump to circulate water. *Batch solar water heaters* are just a black painted tank inside a partially glazed and partially reflective box. *Thermosiphoning solar water heaters* are also passive solar water heaters. They move water from the collector to a storage tank on top of the collector using only the buoyancy of hot water.

Active solar water-heating systems circulate water using pumps. They need freeze protection in temperate climates because their collectors become even colder than the outdoor air due to radiation losses into the night sky. Solar water heaters that circulate domestic hot water through the collector employ an automatic valve to drain the water back to the storage tank. Other solar water-heating systems circulate a water-antifreeze mix through the collectors for protection from freezing. Antifreeze systems circulate the water-antifreeze mixture through the collector, then through a heating coil inside a water storage tank—identical to an immersed-coil water heater, as described later.

Solar water heaters are usually connected to backup water heaters in case of cloudy weather.

Increasing Water-Heating Efficiency

Energy-efficient retrofits to water-heating systems follow three strategies:

- Reducing the use or waste of hot water.
- Reducing standby losses from storage tank and pipes.
- Reducing distribution losses through pipes and fittings.

Fixing all leaks, using pressure reducing valves, or installing low-flow shower heads and sink strainers minimizes waste of the hot-water supply. Tank insulation, pipe insulation, heat traps, automatic controls, and reducing water temperature all minimize standby and distribution losses. Designing the system to minimize the length and diameter of piping is the most effective way to minimize distribution losses in new water-heating systems.

Fixing Leaks

Repair leaks in fixtures or pipes before doing any other hot-water energy-conservation measures. If the water heater tank leaks, it needs to be replaced.

Flow Controls

Low-flow shower heads save energy by limiting hot-water use and are one of the most cost-effective energy conservation projects for homes. Shower heads with a maximum flow rate of 2 to 3 gallons per minute will save considerable energy if existing flow rate exceeds 4 gallons per minute.

There are two general types of low-flow shower heads—aerating models and laminar-flow models. The aerating models mix air with water coming out of small holes in the shower head, forming a misty spray.

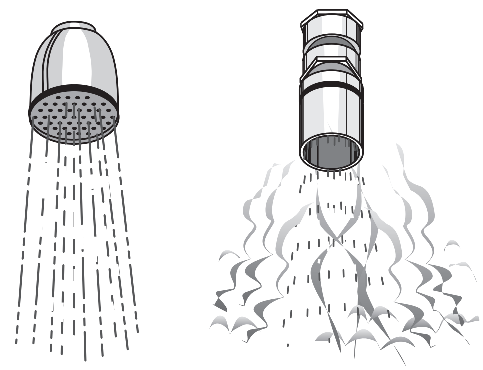
Laminar-flow shower heads do not mix water and air at the nozzle, but instead, form individual streams of water. The laminar-flow models are recommended for damp climates because aerating shower heads create a lot of steam and may put too much moisture in the air. Many bathrooms don't need any additional moisture.

Approximate Savings: Hot-Water Retrofits

Retrofit	Electricity (kWh)	Gas (Therms)
Reduce tank temperature	100–200	4–8
Exterior insulation blanket	150–450	4–16
Water-saving shower head	200–400	8–14
Heat traps	100–250	4–10

Home Energy Magazine, Oak Ridge National Laboratory, Pacific Northwest Laboratory, and others.

Water-Saving Shower Heads



Some water-saving shower heads shoot fine streams of water, while others emit a misty spray.

Low-flow faucet strainers are cost-effective and practical when delivery pressure is high and when the hot water is circulated. Some large homes and many multifamily buildings use pumps to circulate hot water, so it's available at every tap instantly when residents turn on the water. Faucets that are distant from the water heater can take a long time to receive hot water through a low-flow aerator.

In multifamily buildings, *pressure-reducing valves* can reduce hot-water flow rate. Lower water pressure reduces maintenance on valves and plumbing fixtures. Storing hotter water in smaller, highly insulated tanks is often an effective energy-saving strategy. *Mixing valves* combine cold water with the hot water stored at temperatures above 120°F. The skillful application of pressure-reducing valves, mixing valves, low-flow shower heads, and low-flow faucet strainers can provide adequate flow, comfortable temperature, low maintenance, and low energy costs.

Tank Insulation

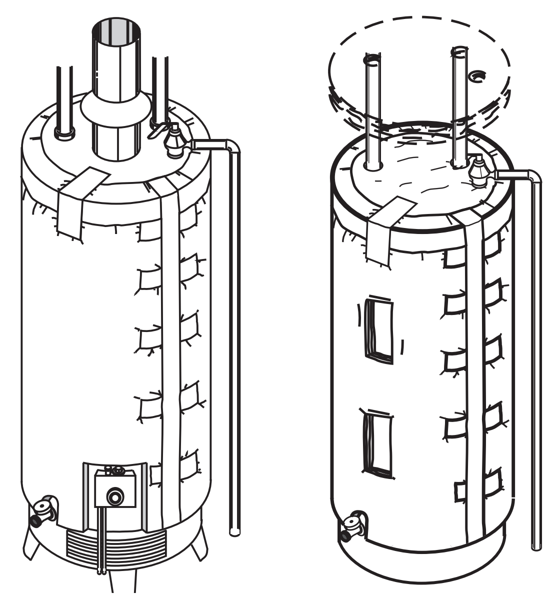
Storage water heaters and other hot-water storage tanks rarely have an economically optimal level of insulation. The total R-value for any type of hot-water storage tank should be R-15 to R-35, depending on the cost of fuel. If possible, the insulation should completely surround the tank. Usually the tank already has some insulation.

Standard storage water heaters have a few inches of fiberglass between the tank and outer steel shell, amounting to R-3 to R-6. New standard models use foam insulation for higher R-values.

Technicians commonly use vinyl-faced fiberglass insulation (3 to 6 inches thick) to insulate storage water heaters. The insulation is often strapped or wired to the outside of the tank, with the seams in the vinyl covering taped. The tape alone may not hold the insulation's weight permanently, so plastic straps are often used for support. Technicians don't insulate the tops of gas-fired storage water heaters, since the vinyl facing is combustible and the insulation might interfere with the draft diverter.

When installing or replacing electric storage water heaters, placing them on top of an insulated platform made of 2-inch foamboard and plywood is especially cost-effective.

Water-Heater Insulation and Temperature



The external insulation of a gas water heater should not cover the top. Leaving the top uncovered avoids interference with the draft diverter and the hot flue. The insulation should have adequate clearance near the controls and the access door to the burner. Insulation for electric water heaters covers the top of the tank. Provide access to the cover plates for the electric elements and thermostats.

Commercial insulation suppliers offer a variety of insulating systems for larger storage tanks in multifamily buildings. Fiberglass or mineral wool are usually chosen because they are heat-resistant. However, many new storage tanks employ polyurethane insulation. Small uninsulated protrusions from the tank create heat loss. Experts in water-heating efficiency recommend covering all pipes and fittings near the water heater with insulation.

Pipe Insulation

Pipe insulation can reduce heat losses in three ways:

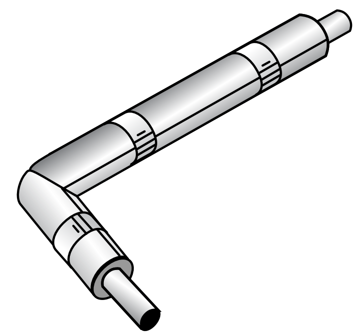
- First, it slows the direct conduction of heat through the distribution pipes.
- Second, it reduces the loss of convected heat through the hot and cold water pipes near the tank.
- And third, insulated pipes deliver water 2°F to 4°F hotter than uninsulated pipes, allowing a lower tank temperature setting.

Insulating exposed water pipes can reduce standby losses 50 to 150 kW-hour per year in single-family homes.

Pipe insulation is particularly cost-effective in larger water-heating systems with pumps that circulate the hot water (so tenants don't have to wait for hot water). In these systems, every exposed foot of pipe should be insulated.

Polyethylene- or neoprene-foam pipe sleeves are most commonly used to insulate pipes. Pipe sleeves should be taped, wired, or clamped with a cable tie every foot or two to secure them to the pipe. Pipe sleeves can be mitered together at 90° bends.

Pipe Sleeves



Polyethylene foam pipe sleeves insulate water pipes and reduce delivery losses. When installed immediately adjacent to a storage water heater they reduce convective standby losses in both hot and cold water lines.

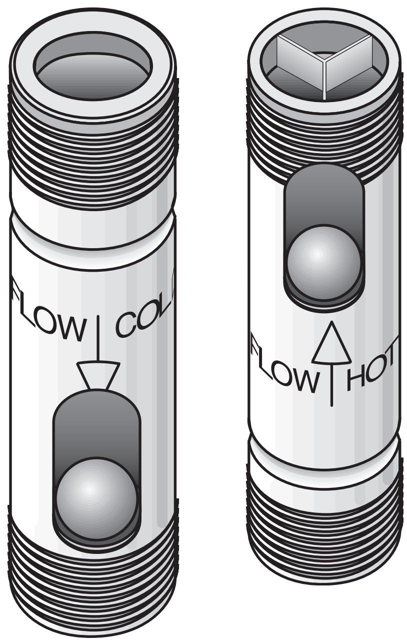
Matching the pipe sleeve's inside diameter to the pipe's outside diameter is important for a snug fit. Most copper pipe is one-eighth of an inch larger in outside diameter than its nominal size. For example, $^1/_2$-inch copper pipe has an outside diameter of $^5/_8$ inch. Galvanized steel pipe is $^1/_4$ inch larger in outside diameter than its nominal size — for example, $^3/_4$-inch galvanized steel pipe has an outside diameter of 1 inch.

If the pipes are within 8 inches of a flue, fiberglass pipe-wrap, without a facing and wired into place, is the safest choice. The thickness of the fiberglass wrap should be at least 1 inch.

Heat Traps

Heat traps are specially designed valves or loops of pipe that stop convection of hot water into the hot and cold water pipes above the storage water heater or external storage tank. The special valves come in pairs and are designed differently for installation in either the hot or the cold water line. Heat traps have floating ball valves or delicate rubber check valves to stop convection.

Heat Traps



Heat traps with gravity-operated check valves prevent most convection heat loss due to circulation of hot water in the pipes above the water heater.

Automatic Controls

Automatic controls for water-heating systems vary from simple mechanical time clocks to sophisticated electronic controls that chart a large system's demand schedule and change water temperature accordingly.

A time clock controller turns the bottom element of a storage electric water heater off during periods when hot water is not used. The time clock controller saves energy by reducing the standby losses from the tank. Time clocks also save energy unintentionally, by reducing the average tap water temperature. Time clocks are most effective on uninsulated water heaters with high water temperatures, and without heat traps or pipe insulation. These inefficient water heaters cool faster to a temperature where standby losses are negligible. The maximum savings for a time clock is less than 4%, without counting the savings from lower delivery temperature, which is more easily achieved by setting back the tank's thermostat. A better solution for reducing standby losses is to insulate the water heater or buy a new one that is insulated with 3 inches of polyurethane.

Time clocks aren't very effective on well-insulated, storage electric water heaters with heat traps because they lose heat so slowly that the temperature of the water remains high for many hours. Well-insulated, storage electric water heaters have few standby losses for the time clock to save.

Electronic controllers typically save 10% to 25% on larger water-heating systems by reducing the storage temperature during periods of light demand. Usually, a multifamily building's heavy hot-water demand occurs during predictable morning and evening hours. The electronic control learns when the high-demand times occur and increases storage temperature to accommodate high demand.

Electric water heating poses a particular challenge to multifamily building operators in avoiding high electric demand charges. The priority to minimize electric demand requires demand controllers, or at least time clocks, that confine water heating to off-peak hours. This often requires increasing storage capacity.

The word *staging* means activating multiple boilers based on the size of the water-heating load. Staging multiple storage or demand water heaters is an effective control strategy for multifamily buildings, but the system's engineering is very critical to avoid scalding and shortages.