Rocky Mountain Institute's

Home Energy Briefs

#5 WATER HEATING

The 2004 edition of this Brief is made possible with generous support by Stonyfield Farm (www.stonyfield.com), the National Association of Realtors (www.realtor.org), the Durst Organization Inc. (www.durst.org), and Deborah Reich.

After space heating and cooling, water heating is typically the second largest user of energy in the home, accounting for approximately 19 percent of total home energy use and costing an average household over $300 a year.[1] While most homes in the United States have gas water heaters, approximately 38 percent have electric water heaters.[2] Heating water with electricity can cost more than twice as much as heating water with natural gas. However, besides replacing your water heater, there are many things you can do to cut your water heating costs. Using hot water more efficiently, for example, is one of the quickest and easiest ways to save energy and water in the home. Switching to water-efficient shower and faucet fixtures and making a few simple adjustments to your existing heater are great ways to start.

This Brief will cover the following topics:

- Start with **efficiency**;
- **Storage tank** heaters or **demand** water heaters;
- **Solar thermal** water heating;
- **Heat pump** water heaters;
- **Drain-water heat recovery**; and
- **Economics** of buying a new water heater.

WATER EFFICIENT FIXTURES AND APPLIANCES

The U.S. Environmental Protection Agency (EPA) has calculated that a household of four can reduce water use by one-third just by installing efficient fixtures and appliances (dishwashers and clothes washers). Though efficient appliances can cost a little more than conventional appliances, you will get your money back (and then some) via lower water heating bills.

Fixtures

Federal Regulations enacted in 1994 set low-flow standards for water fixtures. All showerheads manufactured after January 1, 1994 cannot have flowrates greater than 2.5 gallons per minute (gpm) at a pressure of 80 pounds per square inch (psi) and faucets cannot have flows greater than 2.2 gpm. While the standards have not changed since then, it is still possible to find fixtures in older homes that don't meet these requirements. If you have fixtures that are ten years old or older, consider replacing them. Typically they can be replaced for less than $10 apiece, and the new devices can achieve water savings of 25–60 percent. In older buildings, showerheads that exceed current minimum standards at 1.6 gpm maximum rate of flow are also common. And today's flow controls for sinks, such as **aerators** and **laminar flow fixtures**, can reduce faucet flow to between 0.5 and 1 gpm. After ten years on the market these efficient water fixtures have advanced considerably. So although they use less water, they do not significantly compromise your showering or washing experience.

Your water pressure should be set at 20–80 psi or else your low-flow fixtures will not work properly. You will likely already be experiencing problems if your water pressure is too high or too low, but a low-cost water pressure gauge—available at most hardware stores—will allow you to check your home's actual water pressure. Low pressure could be a sign of leaks in the plumbing system, which can waste large amounts of water.

For additional information, as well as a downloadable version of this document, please see our website: www.rmi.org

This document was last updated: 04/17/06

Appliances

Efficient appliances—ones that consume less hot water than conventional appliances—can generate large savings for homeowners. Efficient dishwashers can save over 50 percent of the energy used by older and less efficient models because they use much less hot water. In addition, efficient dishwashers are just as or more effective at cleaning than conventional dishwashers. A standard clothes washing machine, even if fairly new, can use 30–50 percent more energy than a modern efficient machine. About 80 percent of the energy used in a clothes washer is used to heat the water. Efficient clothes washers also spin-dry your clothes more effectively, so your clothes dryer doesn't have to run as long, thus saving energy during drying as well.

Whatever type of washing appliance you have, you can save a lot of energy and money by just using cold water instead of warm or hot water; if you use a cold water detergent, cold water cleans as well as hot water and makes clothes last longer. (For more information on saving energy and water with these appliances, see *Home Energy Brief No. 6: Cleaning Appliances*).

Some utilities offer demand management programs that use radio signals to remotely shut off the water heaters of participating customers during periods of high electricity demand, rewarding those customers with lower rates or incentive payments for their participation. The shut-off periods are generally brief enough that customers experience no reduction in service. Check if your local utility offers such a program.

EXISTING WATER HEATERS

Besides purchasing a new, efficient water heater, there are many simple, inexpensive things a homeowner can do to reduce energy bills:

- **Insulate the tank.** Unless your water heater tank is already insulated to at least R-24 (and only a few are), adding an insulating jacket to your water heater is one of the most cost-effective do-it-yourself energy saving projects. Choose a jacket with an insulating value of at least R-8, or use two R-5 jackets if that's all you can find. Follow directions carefully and leave thermostats uncovered. On gas water heaters, keep the jacket away from the drain at the bottom and away from the flue at the top, and make sure the airflow to the burner is not obstructed. The jacket should reduce heat loss through the walls of the tank by 25–45 percent, saving about 4–9 percent of your water heating costs. Jackets cost $10–20 and can pay for themselves via lower energy bills in less than one year.
- **Insulate hot water pipes.** Insulate hot water pipes wherever they are accessible, especially within three feet of the water heater (insulate the cold water (inlet) pipes for the first three feet, too). On gas water heaters, keep insulation at least six inches from the flue. The split foam rubber type is effective and easy to use; be sure to choose the right size so it closes fully around the pipe, put it on crack downward and tape the seams with acrylic tape (duct tape won't last). Insulating hot water pipes reduces heat losses at the tank and along pipes leading to faucets. You also won't have to wait as long for the water to get hot when you turn on the faucet again, which means less water goes down the drain. Note that smaller diameter pipes hold less water and therefore lose less energy while the water is not in use.
- **Turn heater off when on vacation.** For electric water heaters, simply switch off the breaker at the main panel. For gas units, get instructions from your gas supplier about putting out and relighting the pilot.
- **Install bottom boards.** A simple piece of rigid insulation under the tank of an electric water heater prevents heat from leaking into the floor, saving 4–9 percent of water heating energy. This is best done when installing a new water heater.
- **Install timer controls.** You can save an additional 5–12 percent of water heating energy by turning water heaters off for certain periods.[3] For example, during the night, when no hot water is being used, and during a utility's peak demand times are both good times to shut off water heaters. You can control your own water heater with a timer that automatically turns the heater off for preset periods. The $60-plus investment can pay for itself in lower bills in about fourteen months. (Note: timers are not useful on gas water heaters as they require a pilot light.)
- **Anti-convection valves and loops.** A $10–30 pair of these heat traps can save $15–30 a year on your water heating bill by preventing convective heat losses through the inlet and outlet pipes.[4] Some new models of water heaters have heat traps built in or available as an option; existing heaters are easily retrofitted by your plumber or by yourself (if you can solder a pipe joint).
- **Turn down the water temperature.** If you have to mix hot and cold water to get the desired temperature, your water heater temperature is set too high and you're wasting energy and money. Many heaters are set to 140°F or higher. For most

households, 120–130°F is sufficient. For each 10-degree reduction, you can save up to 5 percent on your water heating costs. If you have an electric water heater, be sure to first turn off the electricity to the heater at the circuit breaker in the main electrical panel. Then, open the thermostat access panels (some models have one, some two) and turn the indicators to 120–130°F or halfway between low and medium. Check the temperature with a thermometer at the tap since the dials are often inaccurate. After living with the new setting for a while, re-adjust it, if necessary, to a temperature that suits your needs. In addition to saving energy, you'll increase the life of the water heater and reduce the risk of scalding. If you have installed efficient showerheads and faucet controls, your hot water will last even longer.

- **The whole package.** To make your hot water system truly energy efficient, consider doing all the things described above. You'll save enough energy and money so that the total investment could pay for itself in energy savings in just the first year or two, and you'll continue to collect dividends for many years to come.

Choosing a new water heater

There's a good chance that you didn't choose your current water heater. Most water heaters are selected and paid for by building contractors, plumbers, or landlords, and since they don't pay your water heating bills, they have no incentive to choose the most efficient models. Your chance to select a water heater will come when your existing one fails (they generally last ten to fifteen years). Unfortunately, when that happens, you'll want it replaced immediately with whatever is available. Take the time to do some research now, so when the time comes you can choose a model that will save energy and money, and you'll know where to get it. Again, more efficient water heaters generally cost more and might be harder to find than the moderately efficient to inefficient models that are readily available. Remember, however, that the energy savings make the higher initial investment cost irrelevant. For example, a more efficient gas water heater can initially cost $350 more than a standard electric model, but it can save you $130 per year in energy bills. In less than three years, this small investment will pay for itself. In addition, efficient models that are well built can last longer than the typical low-cost models found in stores. Well-built water heaters can last up to twenty years or more, again offsetting their higher initial price.

Storage tank water heaters

Most houses have gas or electric storage tanks, and they are usually sized from 40 to 80 gallons. You can reduce water heating energy consumption by choosing one of the more efficient tanks on the market. The efficiency of a water heater is presented as its energy factor (EF), generally found in product literature from the manufacturer. All things being equal, the smaller the tank size, the more efficient the water heater. Smaller storage tanks have less surface area exposed, thus they lose less heat than a larger tank. A revision of the 1990 federal standards for storage tank water heaters took effect January 20, 2004, and electric tanks are now required to achieve an EF of at least 0.90–0.93, depending on the size of the tank. The 2004 Federal Standards require minimum gas tank EFs of 0.56–0.61. Yet the most efficient new gas tanks are available with EFs as high as 0.68. Also, gas tanks that offer electric pilot lights instead of gas pilots save more energy.

Demand or tankless water heaters

Demand or tankless heaters are becoming more common. The National Renewable Energy Laboratory (NREL) found that even in high-water-use homes (e.g., about 86 gallons per day), demand heaters are at least 8–14 percent more efficient than storage tanks.[5] For low-water-use homes (e.g., about 41 gallons per day and less), demand heaters were 24–34 percent more efficient than storage tanks. Further research by NREL showed that even greater savings (of 27–50 percent) could be achieved using on-demand heaters at each water outlet (e.g., dishwashers, washing machine, showers, etc.).

Solar water heating systems

There are many different solar water-heating systems to consider. The climate where you live will generally determine which system you should use. In general, solar water-heating systems should be considered as substitutes for traditional electric storage tank water-heating systems when your electricity rates are high enough to justify the capital cost of a solar system, and when you live in an area with adequate solar exposure year-round. All solar water-heating systems consist of a collector, piping, valves, a storage tank, and sometimes, pumps. Flat plate solar panels are the most common type of solar collectors and can heat water up to 160°F. Flat plate solar panels are weatherproof, highly insulated boxes that contain absorber plates under glass or plastic covers.

Evacuated-tube solar collectors—made of rows of vacuumed glass tubes and containing an inner absorber tube—are also used for heating water. These collectors have higher efficiencies than flat-plate panels and can reach temperatures of 170–350°F. Yet, they are more expensive so they are generally used in cold climates and for commercial applications.

Passive solar

Thermosiphon systems, also known as passive solar systems, use natural convection (i.e., the fact that heated water rises) to move water. This system can be simple to build and can either provide all your hot water needs or act as a preheater to reduce the heating work required of your main tank. A disadvantage of thermosiphon systems is that the weight of a full storage tank is often 1,000 pounds or more, meaning you need a sturdy roof. Also, the efficiency of thermosiphon systems drops as the temperature of the water in the storage tank rises. This is because the strength of natural convection flow is based on temperature differences so, as the incoming water and exiting water become closer in temperature, the water flow slows.

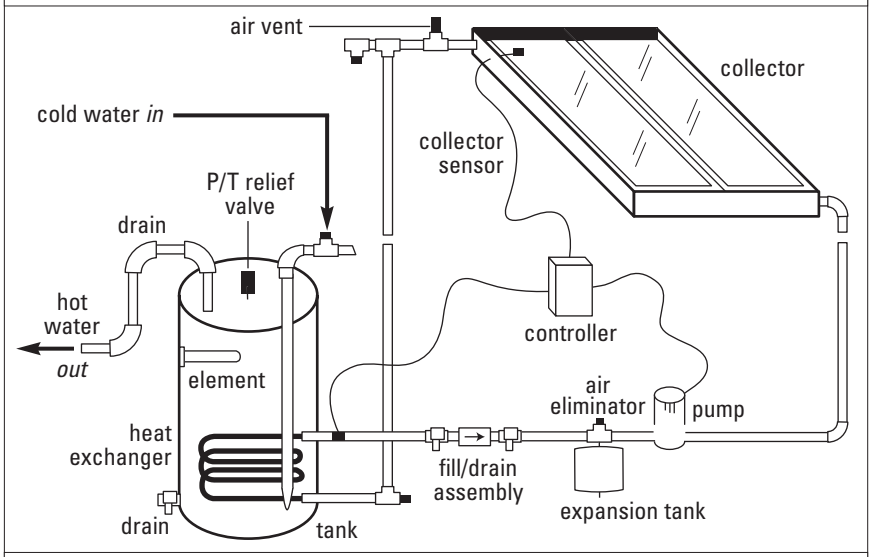
Active solar

Active solar systems differ from passive ones in that they use pumps, sensors, and heat exchangers to control and move air, water, or water/anti-freeze solutions. A thermal exchange fluid is pumped through the solar collectors absorbing solar energy; then the heat is transferred to household water. Air systems use the solar collectors to heat air, which then runs through an air-to-water heat exchanger. This type of system is less efficient than a liquid-to-water system, but it also requires less maintenance and freezing temperatures won't damage it. *Direct-circulation active systems* pump water directly through the collector to the hot water storage tank. In cold climates, the water must be drained out of the collectors when freezing is likely (such as at nights and during the winter), to protect them from damage. Hence, they are often known as "drain-down" systems. The overall efficiency of these systems is generally less than in other solar water-heating systems, so they are typically used in areas where freezing temperatures are infrequent. *Indirect active systems* use freeze-protected heat-exchange fluids, such as antifreeze, in the solar collectors. The fluid is then run through a heat exchanger inside the hot water storage tank. This system is preferred in cold climates as there is less chance of freezing damage than in a drain-down system.
When sizing a solar water-heating system for your home, keep in mind that there are differences between it and your conventional water heating system. An electric water-heating tank is usually sized around 40–80 gallons, whereas a solar system will typically need a 80–120 gallon tank for the same home. Unlike the electrical system, which can run at night, the solar system has to be capable of storing hot water for an entire day and it cannot heat water until the sun comes out again. Solar systems' storage tanks might have heating elements for back up heating requirements (conventional electric storage tanks contain two heating elements, which are its only source of heat). In some instances you can still use a smaller tank for your active solar heater as a preheater for the main electric water tank.

Integrated water heater/home heating system: heat pumps

There are two types of heat pumps: air-source and geothermal. Using a heat-pump water heater alone is 33–50 percent more efficient than using an electric water heater because heat-pump water heaters use electricity to move heat from the air or ground to the water instead of heating water directly. You can purchase a heat-

Figure 1: Indirect active solar system with one tank



Source: Adapted from U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy

pump water heater as an integrated unit (with the water tank attached) or as an accessory for an existing water tank. If you live in a hot climate, integrating your space cooling and water heating with a heat pump can save 25—70 percent of the amount of energy that a typical electric water heater would use. If you're building a new house or upgrading your heating system, there are now a number of advanced, high-efficiency boilers for space heating that include water heaters available. Heat-pump heating and cooling systems that have water-heating components are also available. Some units are even plumbed for easy integration with solar systems. For additional information about heat pumps, see our *Home Energy Briefs No. 3: Space Cooling* and *No. 4: Space Heating*.

Drain-water heat recovery

Typically, 80–90 percent of the energy used to heat water in the home goes down the drain. Heat exchangers capture some of the heat in drain-water, allowing it to be reused by incoming water. One type, called a gravity film exchange drain-water heat recovery system, has been found to save 25–30 percent of total water-heating energy needed.[6] This technology is compatible with all types of water heating systems, but it is especially suitable with on-demand water heaters and solar thermal systems. Prices range from $300–400 and paybacks are in the range of 2.5 to 7 years, depending on how often it is used. For more information on this technology, visit www.gfxtechnology.com.

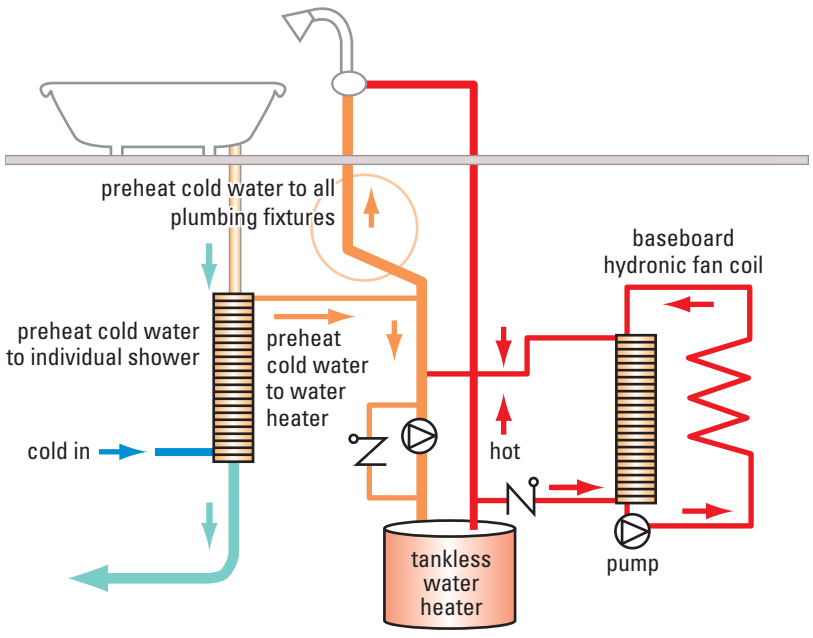
Economics of buying a new water heater

If your water heater is nearing the end of its life and you've already employed the hot-water saving methods described in the first section of this Brief, it may be time to buy a new water heater. When investigating a water heater for your home, consider the entire life-cycle costs of the equipment, not just the price tag. Table 1 (see next page) shows how different types of water heaters compare with a standard electric water heater in terms of initial price, annual savings, and payback periods. It also shows how combining a new water heater with a drain-water heat recovery system can typically increase savings and shorten payback periods.

If you own a gas water heater and you're considering replacing it with one of the water heaters listed in Table 1, you may find that the savings are smaller and the payback periods are longer than if you were to replace an old electric water heater. For example, replacing a standard electric tank with a high efficiency gas tank saves $167 per year but costs around $350 more, which results in a simple payback of slightly more than two years. Replacing a standard gas water heater with a high efficiency gas water heater only saves $25 and costs $300 more, which results in a payback period of about twelve years.

If you have access to gas but are using an electric water heater, your best bet is to switch to a gas water heater. Even just buying a standard gas water heater may save you about $142 dollars per year with only a small increase in cost (around $50), because natural gas is generally a much more cost-effective energy source (the fuel (gas) is burned directly at the house for heating rather than being first converted to electricity at the power plant). Further savings can be achieved with a drain-water recovery system.

Figure 2: Drain-water heat recovery system



Source: Adapted from WaterFilm Energy Inc. 2004

SUMMARY

You can save money immediately by changing how you use your hot water, for example, by lowering the temperature on your hot water tank, using cold water to wash your clothes, and/or insulating your hot water heater and pipes. Installing new and more efficient technologies and devices can also help save money. Such technologies and devices range from efficient showerheads and aerators to the installation of new efficient water heaters, heat pumps, solar water heaters, or drain-water heat recovery systems. Just remember, before going out and investing in a new water heater, make sure you investigate what is right for your home. Some technologies that might be right for one home might not be right for another.

ADDITIONAL RESOURCES

DOE's Energy Efficiency and Renewable Energy Network (EREN) — A comprehensive resource for information from solar thermal systems to geothermal systems (www.eren.doe.gov).

Geothermal Heat Pump Consortium — Also known as Geoexchange, provides general information on GHP systems to more detailed state-to-state information (www.geoexchange.org).

Database of State Incentives for Renewable Energy — DSIRE contains information on what state tax credits or rebates are available for using renewable energy technology (www.dsireusa.org).

WaterFilm Energy Inc — Sells the Gravity Film Exchange Drain-water Heat Recovery System. They also offer a lot of information on their website about the technology (www.gfxtechnology.com).

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy (EERE) — *Geothermal Heat Pumps; Using the Earth to Heat and Cool Building:* An excellent resource for general heat pump information (www.eere.energy.gov/femp/pdfs/26014.pdf).

NOTES

1. EPA (Environmental Protection Agency), *Using Water Wisely in the Home*, (Washington, DC: EPA, June 2002).

2. EIA (Energy Information Administration), *A Look at Residential Energy Consumption in 2001*, Water-Heating Consumption Tables, (Washington, DC: EIA, 2001), www.eia.doe.gov/emeu/consumption.

3. EERE (Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy) A Consumer's Guide to Energy Efficiency and Renewable Energy, www.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=13110.

4–5. J.L. Sikora & J. Wiehagen, "Performance Comparison of Residential Hot Water Systems," (Golden, CO: National Renewable Energy Laboratory, March 2003), NREL/SR-550-32922.

6. J.J. Tomlinson, *GFX Evaluation*, (Oak Ridge, TN: Oak Ridge National Laboratory, August 2000), www.eere.energy.gov/buildings/emergingtech/printable/page2d.html.

Table 1: The economics of replacing an electric water heater

Type of water heater	Avg. installed cost ($)	*Annual savings ($/yr)	Percent savings	Payback (yr)	Installed cost with drain-water recovery system ($)	Annual savings ($/yr)	Percent savings	Payback (yr)
BASELINE: standard electric tank	250	–	–	–	550	117	–	2.6
high efficiency electric tank	600	39	10	9.0	900	144	37	4.5
standard gas tank	300	142	36	0.4	600	216	55	1.6
high efficiency gas tank	600	167	43	2.1	900	234	60	2.8
demand gas tank	650	179	46	2.2	950	242	62	2.9
point-of-use gas tank	1,935	216	55	7.8	2,235	268	69	7.4
solar	2,500	303	78	7.4	2,800	329	84	7.7
air-source heat pump	1,250	229	59	4.4	1,550	277	71	4.7
geothermal heat pump	2,500	291	75	7.7	2,800	321	82	8.0

* Savings calculations based on electricity costs of $0.083/kWh and natural gas costs of $0.92/therm

Source: RMI analysis

Contact your local utility or energy office for information on rebates that may be available in your area on the purchase of new energy-efficient appliances. This publication is intended to help you improve the resource efficiency of your home. You should use your best judgment about your home, and seek expert advice when appropriate. Rocky Mountain Institute does not endorse any products mentioned and does not assume any responsibility for the accuracy or completeness of the information in this Brief. Written by Sarah Goorskey, Andy Smith, and Katherine Wang.

Briefs Nos. 1–9 in the Home Energy series are funded by Stonyfield Farm, the Durst Organization Inc., the National Association of Realtors, and Deborah Reich.

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