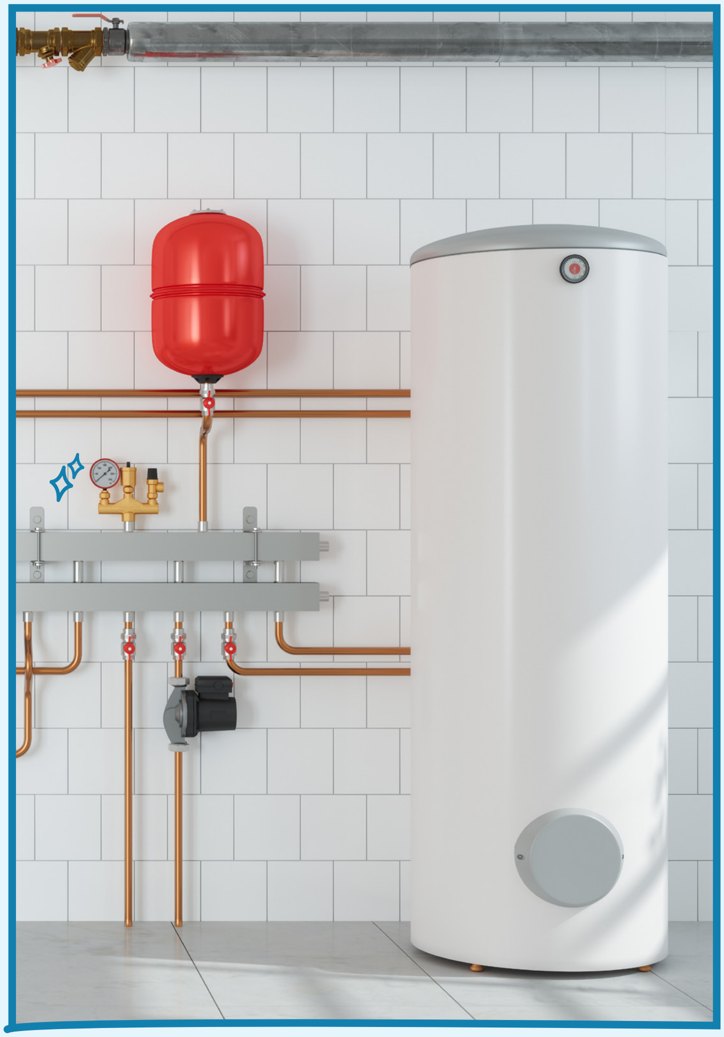
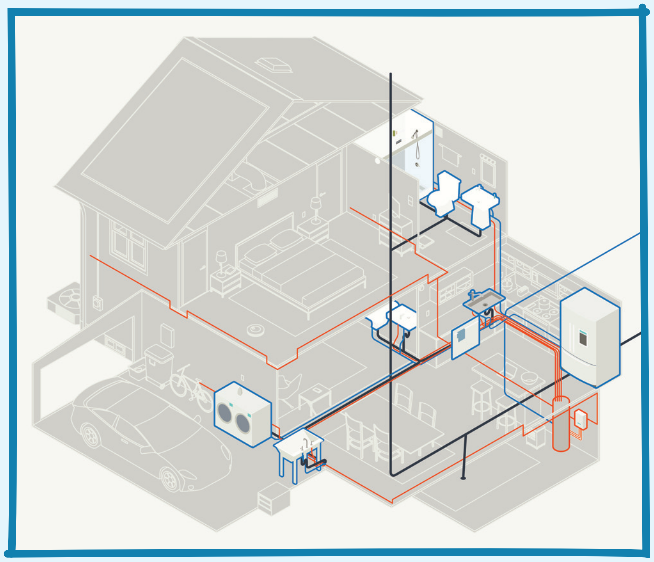
Best Practices for Efficient Hot Water Delivery in Homes





EPA WaterSense

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1.0 Introduction

The design of a hot water delivery system, including home/building layout, water heater location, and piping layout and materials, can greatly impact its efficiency and performance. If not designed intentionally, hot water delivery systems run the risk of sending large volumes of water that has cooled in the pipes down the drain while newly heated water travels through a lengthy piping system to its intended end use. An efficient hot water delivery system will provide heated water throughout a home quickly, minimizing the distance that hot water travels and the amount of water and energy used in the process.

The U.S. Environmental Protection Agency (EPA) developed this guide to help the building community better understand hot water delivery systems and how to design them to maximize water and energy efficiency and enhance performance. It offers a brief overview of hot water delivery systems and the associated benefits of efficient systems. It also explores potential home and hot water delivery system layout and design considerations, available water heating technologies that may impact system design, ways to right-size plumbing systems, and examples of efficient hot water delivery system designs.

Builders are encouraged to use this guide to inform hot water delivery system design, keeping in mind that all new homes are required to meet applicable building codes and regulations. In addition, all plumbing system installers should meet applicable licensing requirements.

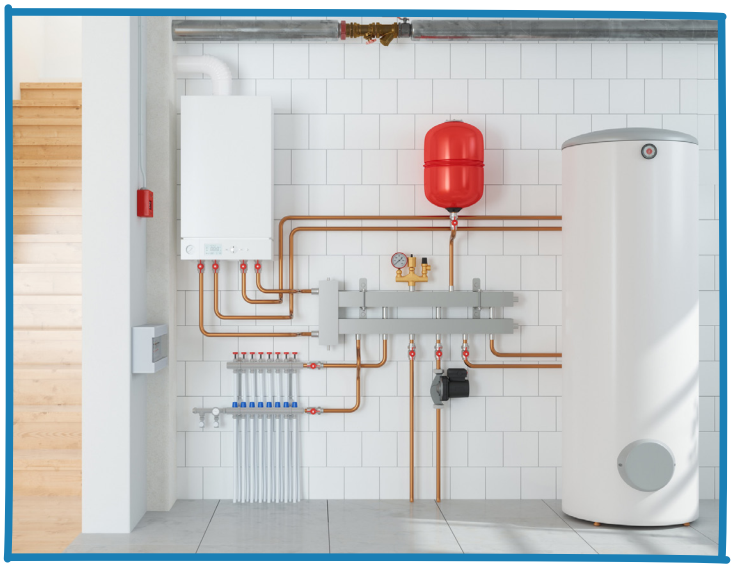
Using the recommendations this guide can contribute to high-performing design and help builders meet the *WaterSense® Specification for Homes*[1] efficiency requirement. However, the recommendations provided in this guide are not required to meet the specification criteria. In a previous version of the specification, EPA had required hot water delivery systems to be designed so that no more than 0.5 gallons of water would be stored between the water heater and any hot water fixture (i.e., in any pipe that carries hot water). While this is no longer a requirement, EPA still recommends using the stored volume of 0.5 gallons as a benchmark for designing efficient hot water delivery systems. Considering the information included in this guide, EPA recommends that builders, designers, and plumbing professionals exercise their own professional judgment to select the most appropriate materials and hot water delivery system design for each new home. For more information about WaterSense labeled homes, including specification requirements and details on how to participate in the program, please visit www.epa.gov/watersense/homes.

[1] U.S. Environmental Protection Agency's (EPA's) WaterSense program. Homes Specification. www.epa.gov/watersense/homes-specification.

1.1 Hot Water Delivery System Overview

Heating water is typically one of the largest uses of energy in a home.[2] Some homes today are built with poorly performing, inefficient hot water delivery systems that take minutes to deliver hot water to the point of use (e.g., shower, kitchen faucet) and waste large amounts of energy and water in the process. Approximately 13 to 29 percent of the energy use associated with a home's hot water delivery system is wasted in distribution losses.[3] Studies have shown that 20 to 30 percent of water used during a shower is not used for actual bathing, but rather goes directly down the drain due to structural and behavioral waste.[4] How quickly and efficiently a hot water system can produce and deliver appropriately heated water to the point of use depends on multiple factors that occur in three distinct—but interrelated—phases:

1. **Generation:** How efficiently a water heater can convert electricity, natural gas, or other fuel source (depending on the type of heater) into useful hot water has a major impact on the overall efficiency of the system. Hot water generation can be made more efficient by selecting a water heater with a higher Uniform Energy Factor (UEF), a ratio that measures how much energy is transferred to useful hot water compared to the total energy consumed by the appliance (including conversions, stand-by losses, etc.).[5]



Boiler room with water heater and pipes carrying hot water to end uses.

2. **Distribution:** Once heated, the hot water must be delivered to the intended point of use in the home. Several factors influence distribution efficiency and can play a role in a more efficient system. They include:

[2] U.S. Energy Information Administration. Residential Energy Consumption Survey (RECS), 2020 RECS Survey Data. www.eia.gov/consumption/residential/data/2020/.
[3] Weitzel, E. and M. Hoeschele. September 2014. *Evaluating Domestic Hot Water Distribution System Options With Validated Analysis Models*. Prepared for U.S. Department of Energy (DOE). https://docs.nrel.gov/docs/fy14osti/62848.pdf.
[4] Lutz, Jim. Lawrence Berkeley National Laboratory. September 2011. *Water and Energy Wasted During Residential Shower Events: Findings from a Pilot Field Study of Hot Water Distribution Systems*. https://eta-publications.lbl.gov/sites/default/files/water_and_energy_wasted_during_residential_shower_events_findings_from_a_pilot_field_study_of_hot_water_distribution_systems_lbnl-5115e.pdf.
[5] DOE. April 2024. "What is Uniform Energy Factor and Why Does it Matter?" www.energystar.gov/products/ask-the-experts/what-uniform-energy-factor-and-why-does-it-matter.

- Length of piping between the water heater and a given fixture.
- Pipe diameter and material.
- Whether the piping is insulated.

3. **Use:** Hot water is used by a variety of fixtures and appliances throughout the home (e.g., faucets, showerheads, clothes washers, and dishwashers). Using products that use less water overall (e.g., WaterSense labeled faucets and showerheads and ENERGY STAR certified clothes washers and dishwashers) will reduce the amount of hot water consumption and therefore reduce the amount of associated energy.

Products to Help Avoid Hot Water Waste

Installing certain fixtures can help reduce behavioral hot water waste, such as unnecessary hot water draws or hot water sent down the drain before the user actually receives it (i.e., washes the dishes, gets in the shower).

Cold-start faucet

- A type of single-handled faucet that only delivers cold water when initially turned on in a neutral position.
- User has to manually adjust the handle to initiate hot water draw.
- Reduces hot water use without impact to the user by eliminating unnecessary hot water draws, which occur when the user turns on a tap without consciously wanting or needing hot water that was unlikely to ever arrive.

Thermostatic shut-off valve

- A device that can be installed between the shower arm and showerhead.
- Monitors water temperature after flow is initiated and reduces water flow to a trickle once water at the desired temperature arrives at the shower.
- User manually resumes regular flow when they are ready to enter the shower and use the hot water.
- Avoids water being sent down the drain after hot water arrives and before the user is ready to get in the shower.

Both generation and use of hot water can be reduced through product solutions. Installing water heaters with higher UEFs reduces the energy needed to serve a home's hot water needs, while using WaterSense labeled products and ENERGY STAR certified appliances (such as dishwashers and clothes washers) reduces both the energy and water use of the home by using less hot water at the point of use.

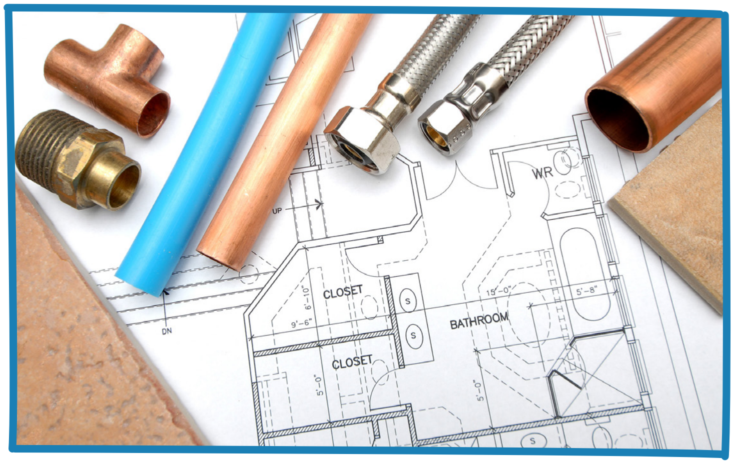
Unlike generation and use, effective and efficient distribution of hot water requires a whole-system approach and can be challenging. However, considering the hot water delivery system early in the design phase and carefully following efficient plumbing design principles can help ensure homeowner satisfaction with reduced installation costs.

The volume of stored water affects how long it takes for hot water to reach each fixture, as well as how the water maintains its temperature in between draws. Systems with the least stored volume of water in the pipes waste the least amount of water and energy. The following factors determine the volume of water stored in the delivery system that must be cleared (i.e., wasted) each time the hot water is drawn:

- Length of piping between the water heater and each fixture.
- Pipe diameter and material from which the pipe is made, which impact the inside diameter.

Although these tips are not required to meet the *WaterSense Specification for Homes*,[6] EPA recommends the following to reduce hot water delivery system water and energy waste:

- Where possible, cluster wet rooms (e.g., bathrooms, kitchens, laundry rooms) close together within the home layout. Refer to Section 2.0: Home Layout.
- Select a water heater model, location, and plumbing/system design that minimizes inside pipe diameter and pipe length. Refer to Section 3.0: Hot Water Delivery System Design and Layout.
- Right-size the pipes based on a home's peak water demand, fixtures, and typical use patterns to avoid oversized pipes; and minimize the volume of stored hot water within a home's piping. Where allowed by local plumbing code, the International Association of Plumbing and Mechanical Officials' (IAMPO's) Water Demand Calculator®[7] can help builders determine a conservative and accurate estimate of a residential home's water demand compared to typical pipe sizing methods. Refer to Section 3.3: Right-Sizing Pipes for Peak Water Demand.



Builders may design home layouts and plumbing systems to maximize the efficiency of the hot water delivery system.

[6] EPA's WaterSense program. May 2026. Hot Water Distribution Volume Calculator. www.epa.gov/watersense/watersense-labeled-homes-hot-water.

[7] International Association of Plumbing and Mechanical Officials' (IAPMO's) Water Efficiency and Sanitation Standard (WE•Stand). *Water Demand Calculator*. https://iapmo.org/we-stand/water-demand-calculator.

- Use EPA's Hot Water Distribution Volume Calculator[8] to determine whether the designed hot water delivery system will minimize the volume of water stored between the hot water source (i.e., water heater or recirculation loop) and each end use. EPA recommends aiming for no more than 0.5 gallons of water stored in each pipe, if possible. Refer to Section 3.4: Pipe Diameter, Length, and Materials for Construction.
- If the calculation indicates water stored within piping and manifolds is not sufficiently minimized in the designed system, consider including a demand-based hot water recirculation system to ensure hot water will reach the affected fixtures sooner. Refer to Section 3.1.4: Demand-Initiated Recirculation Systems.

The following sections discuss these recommendations in more detail to help builders ensure efficient hot water delivery that helps residents save water, energy, and utility costs.

1.2 Benefits of Efficient Hot Water Delivery Systems

The average household sends 6.35 gallons of water down the drain each day while residents wait for showers and faucets to deliver hot water, which is 3.7 percent of the average household's indoor daily water use.[9] Designing an efficient hot water delivery system contributes to water, energy, and cost savings; reduces installation costs; improves occupant satisfaction; and contributes to fewer water quality concerns. Savings can also be achieved beyond the household. Because residents are using less water overall, that results in embedded energy savings in the water drawn from water utilities or sent to wastewater utilities.

- **Reduced hot water consumption.** Optimizing hot water generation, distribution, and use in a home means less water stored in pipes and ensures less water is sent down the drain before hot water arrives at a fixture.
- **Hot water that gets to the tap faster.** Assuming the pipes are sized correctly and insulated properly, a home layout with optimum water heater placement and shorter distances between the water heater and each of the end uses means residents receive hot water more quickly.
- **Decreased energy use from heat loss.** Less heat is lost when a smaller volume of hot water is stored in the piping and eventually cools down.

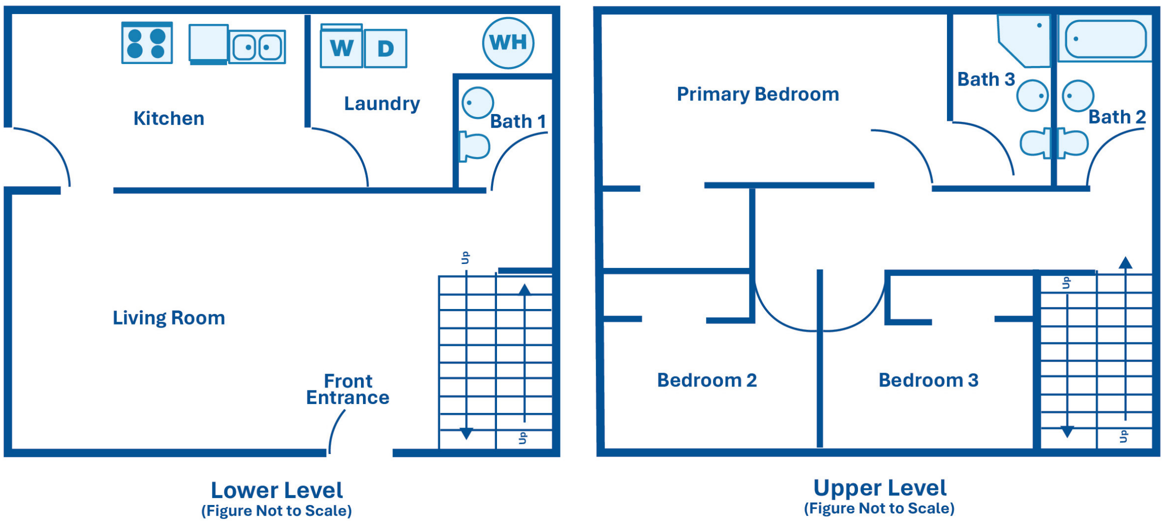
[8] EPA's WaterSense program. March 2026. Hot Water Distribution Volume Calculator. www.epa.gov/watersense/watersense-labeled-homes-hot-water.
[9] Lutz, James. Lawrence Berkeley National Laboratory. February 2005. *Estimating Energy and Water Losses in Residential Hot Water Distribution Systems*. https://www.osti.gov/biblio/861252.

- **Savings on utility, material, and construction costs.** In addition to potential water, wastewater, and energy utility savings, efficient hot water delivery systems in new homes can mean lower material costs, construction costs, and connection fees for builders.
- **Improved resident satisfaction.** Homeowner satisfaction with hot water delivery means fewer call-backs to builders and fewer warranty claims.
- **Enhanced water quality.** Efficient hot water delivery systems that minimize the volume of water stored also minimize the age of water standing in pipes. The water in the system is more frequently and completely flushed through the pipes, which can help address water quality concerns associated with pathogen growth in stagnant water.
- **Green building certification support.** Many green building certification programs have requirements related to hot water systems, and this guide can help you meet them.

2.0 Home Layout

Certain home layouts lend themselves to more efficient hot water delivery systems, depending on the footprint of the hot water service area. Clustering "wet rooms" such as bathrooms, kitchens, and laundry rooms close together and placing the water heater near or within the cluster will reduce the pipe length between the water heater and each of the end uses, reducing water and heat loss. Figure 1 below displays an example of clustering wet rooms in a two-story home. While the exact location of certain fixtures will depend on multiple factors, the rooms with hot water taps can be placed in the same area on each respective level of the home to reduce the piping distance.

Figure 1. A Home Layout With Clustered Wet Rooms



Some home layouts are less favorable for efficient hot water delivery. For example, if a home has multiple bedrooms and adjacent bathrooms on opposite sides of the home, significant volumes of hot water will have to reach both sides of the home. It also may be more difficult to choose an optimal location for the water heater. The center of the home may technically lend itself to the shortest piping runs in this case, but this may not provide adequate space or ventilation or may otherwise disrupt normal home operation. Faucets, dishwashers, and other water-using appliances located in a kitchen island can also pose challenges for efficient

Figure 2. A One-Story Home Layout With Remote Wet Rooms

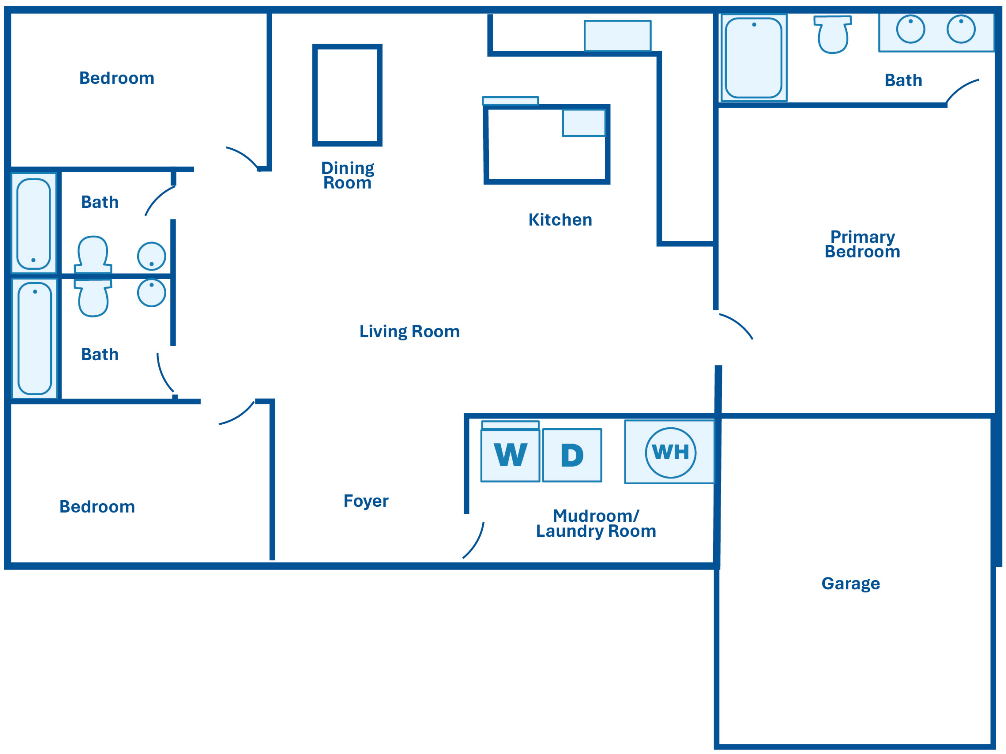
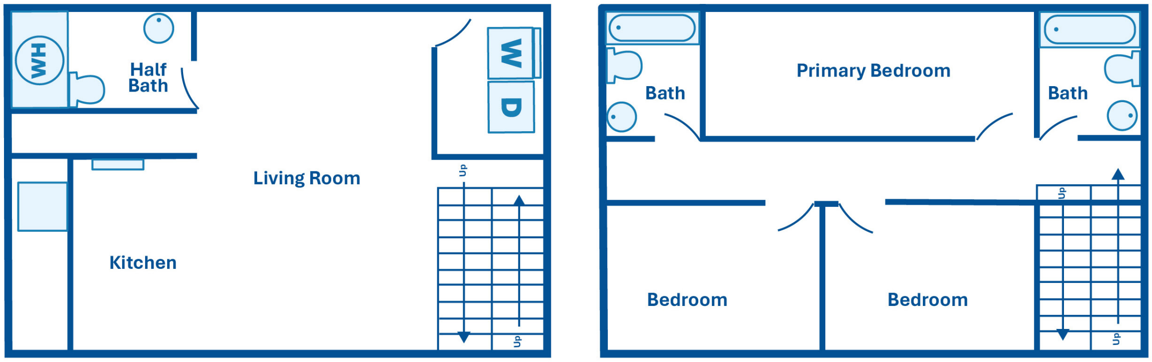


Figure 3. A Two-Story Home Layout With Remote Wet Rooms



hot water delivery. This is particularly true for slab-on-grade homes, where water can cool as it passes through a conduit under the slab to get to the island. Examples of challenging home layouts are displayed in Figure 2 (a one-story home) and Figure 3 (a two-story home) on the previous page.

If a home layout is not conducive to clustering hot water uses, consider installing multiple water heaters and effectively creating smaller clusters. While this could require a higher initial investment for water heating equipment, it could lower costs for pipe materials, in addition to the long-term utility cost savings for the homeowner. Alternatively, a recirculation system can efficiently provide hot water to multiple, more remote locations within the home. See Section 3.1.4: Demand-Initiated Recirculation Systems for more information.

3.0 Hot Water Delivery System Design and Layout

Efficient hot water delivery system design includes planning to minimize pipe run lengths and, to the extent possible, pipe diameters.

3.1 System Design Options

Although individual designs will vary by project-specific needs, there are four basic hot water delivery system types used in single- and multifamily homes:

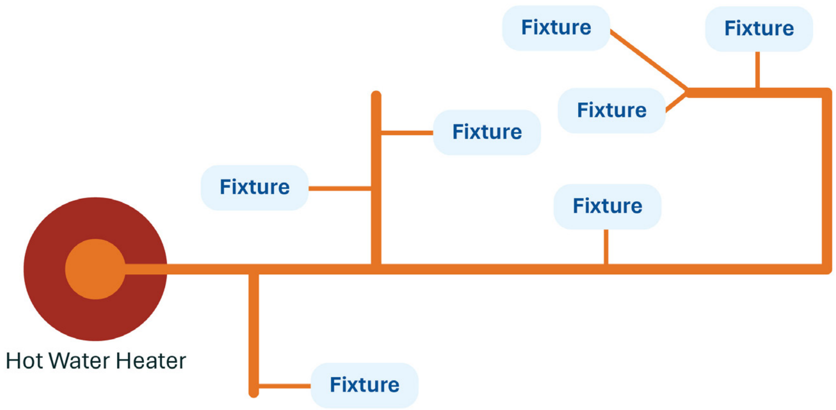
- Trunk and branch systems
- Core systems
- Whole-house manifold systems
- Recirculation systems

The following subsections provide a brief description of each system type, key considerations for system efficiency, and examples and illustrations of how each of the four types of hot water delivery systems can be designed to ensure efficiency. For demonstration purposes, the same floor plan that exhibits clustered wet rooms, as originally shown in Figure 1 on page 8, is used in each sample layout. Only the placement of the fixtures and water heater varies, in order to more easily compare how each system type can be designed.

3.1.1 Trunk and Branch Systems

Trunk and branch systems are characterized by one long, large diameter main line (i.e., the "trunk") that runs from the water heater to the farthest fixture in the house. As illustrated in Figure 4 on the next page, "branches" from the main trunk supply hot water to various areas of the home, and smaller "twigs" branch off to supply hot water to individual fixtures. Typically, the main trunk uses larger diameter piping to ensure adequate flow, with smaller diameter piping branching off to individual fixtures.

Figure 4. A General Configuration Typical of Trunk and Branch Systems



Trunk and branch systems are traditionally the most common type of hot water delivery system. They can be utilized in both single- and multifamily homes. In terms of maximizing hot water delivery system efficiency, trunk and branch systems are most suitable for smaller homes, homes with relatively few fixtures, or in multifamily housing if installed individually in each unit. It may be difficult to design an efficient trunk and branch system in larger homes with spacious layouts and a large number of fixtures. Compared to the other hot water delivery systems presented in this guide, trunk and branch systems have the greatest potential to be inefficient, if care is not taken to centralize fixture placement and minimize pipe run length of the larger diameter trunk.

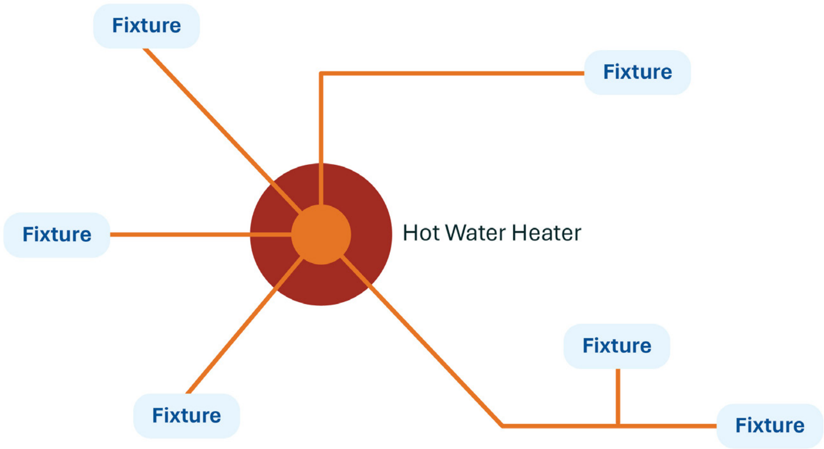
Figure 8 (on page 16) illustrates a typical trunk and branch plumbing system. In this example, the main trunk extends from the water heater and supplies hot water to branches that run to the laundry, kitchen, and lower and upper level bathrooms. To reduce the total length of piping runs throughout the home, the floor plan is configured so that the bathrooms are stacked vertically between the lower and upper levels. Also, the laundry room is co-located with the lower level bathroom, so that the water heater can be placed close to the bathrooms without sacrificing usable space in the lower level.

Note that, for the lower level bathroom, only twig lines run to the sink. Since this area has only one fixture, a larger diameter branch line is not necessary and would be less efficient than using the smaller diameter twig line.

3.1.2 Core Systems

Core systems utilize a central plumbing core, where plumbing areas (i.e., kitchens, bathrooms, laundry rooms) are placed in close proximity to the water heater. Hot water is piped directly to each fixture or group of fixtures using smaller diameter piping, when appropriate, and as direct a path as possible. Figure 5 on the next page illustrates the main design principles of this configuration. As the figure shows, the relative proximity of the fixtures and direct runs minimize the length of piping and the amount of time required for hot water to reach each fixture.

Figure 5. A General Configuration Typical of Core Systems



Because core systems use less—and smaller diameter—piping, they can significantly reduce the amount of water that users waste waiting for hot water to arrive at the fixtures. They can also be made with any type of piping (or multiple types if necessary); copper, CPVC, and cross-lined polyethylene (PEX) are the most commonly used types. As a result, core systems provide greater flexibility and can be less expensive and quicker to install compared to other water delivery systems.

Core systems can be installed in both single- and multifamily homes, though they may not work as well for multifamily building-wide hot water delivery; they are most suitable for smaller homes or homes with relatively few fixtures. Since core systems supply each fixture or point of use with their own line, they can be difficult to retrofit at a later time.

Figure 9 (on page 16) illustrates a plumbing layout with a core system; key factors to keep in mind with core systems include:

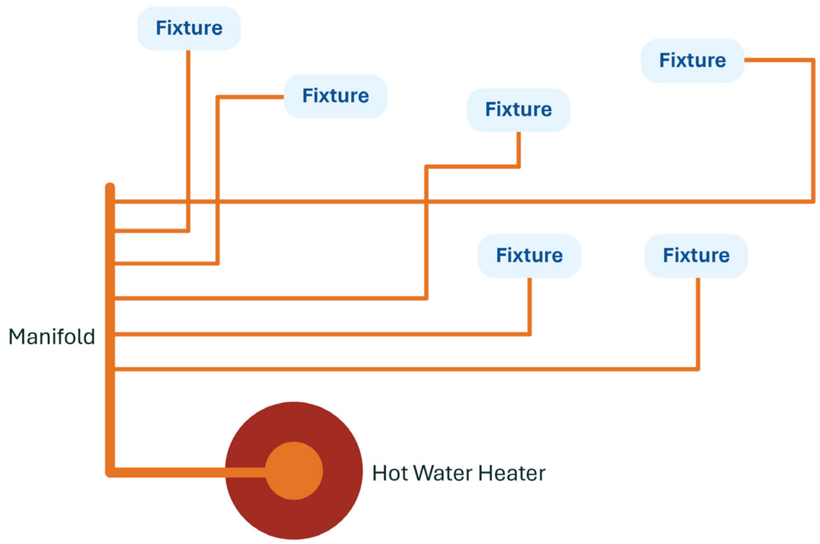
- Try to centralize the water heater relative to the fixtures to minimize long pipe runs.
- Make direct connections from the water heater to fixtures.
- Use smaller diameter piping on direct connections from water heater to fixtures.

In comparing the core system layout to the trunk and branch system layout, note that the locations of the water heater and washer/dryer units are swapped so that the water heater is centrally located between the kitchen, laundry room, and lower and upper level bathrooms. The kitchen fixtures with the core system are also located on the wall closest to the water heater. For the upper level fixtures, the vertical branch line is placed at the center of the upper-level bathrooms to minimize distance from the water heater to the fixtures.

3.1.3 Whole-House Manifold Systems

Whole-house manifold systems, also called parallel pipe or home run systems, use small diameter, flexible piping (such as PEX) that runs directly to each individual fixture from a central manifold. As shown in Figure 6 on the next page, the central manifold is typically kept in close proximity to the water heater. The manifold may be constructed of either plastic or metal.

Figure 6. A General Configuration Typical of Whole-House Manifold Systems



By using flexible piping, these systems can be installed more quickly than rigid, nonflexible plumbing systems. Fewer fittings are necessary during installation, which makes the use of this layout with metal pipe possible, but uncommon in modern building practice. Because the flexible piping is supplied as spools of continuous piping, plumbers can lay out relatively long piping runs without needing to install coupling fittings at regular intervals. Furthermore, by virtue of the piping's flexibility, it can be redirected as needed using continuous sweeping turns, eliminating the need for elbow fittings, which are time-consuming to install and contribute to the loss of pressure and heat as water moves through the system.

Whole-house manifold systems also equalize pressure, and, therefore, several fixtures can be used simultaneously without dramatic changes in pressure or temperature. As noted above, the elimination of inline fittings also reduces pressure and temperature losses, allowing for the use of smaller 3/8 inch diameter piping in certain scenarios. Reduced pipe diameters in turn deliver hot water to fixtures faster and with less water and energy waste than conventional piping systems.

Whole-house manifold systems can be installed in either single- or multifamily homes, and they are an ideal option for larger homes with more spacious layouts and multiple fixtures, where longer piping runs may be necessary. Like core systems, whole-house manifold systems supply each fixture with an independent line and can be difficult to retrofit. In addition, where each fixture has its own line, homeowners cannot rely on each hot water-using fixture to prime the hot water lines for other fixtures; each fixture needs to prime its own line itself for use.

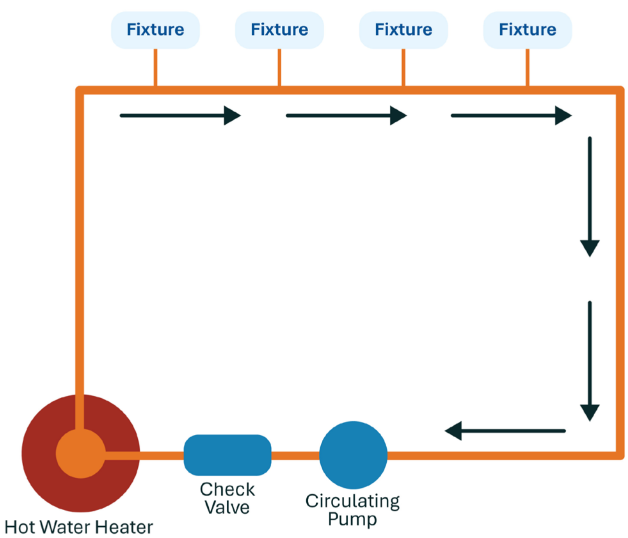
Figure 10 (on page 17) provides a plumbing layout for a whole-house manifold system. In this example, individual runs span from the manifold to each fixture, and the manifold is installed in close proximity to the water heater. The smaller pipe diameter and associated volume reductions compensate for the fact that the water heater is not in a centralized location relative to the fixtures.

3.1.4 Recirculation Systems

Recirculation systems consist of one or more continuous hot water supply loops that recirculate water throughout the home. As shown in Figure 7, a circulating pump draws hot water through the recirculation loop and returns water that is ambient temperature from the loop to the heater. Alternatively, the pump can return this water to the cold water line while simultaneously drawing hot water from the water heater. Utilizing the cold water line as the return is often a convenient solution for inefficient distribution systems that are being retrofitted but may not achieve the same efficiency or performance of dedicated returns. Recirculation pumps can also be included within certain water heaters. These integrated recirculation pumps can either recirculate water within the heater to keep it available for the initial draw or can recirculate water throughout the home.

Recirculation systems save water both because they can significantly reduce the wait time for hot water and by returning ambient-temperature water stored in the piping back to the heater. This decreases energy consumption from the water heater by reducing the work that a water heater must do to reach an acceptable temperature. In addition, the recirculation loop is typically located where it can be kept as short as possible and within 10 feet of every fixture.[10]

Figure 7. A General Configuration Typical of Demand-Initiated Recirculation Systems



It is important to note that timer- and temperature-based recirculation systems can increase energy use due to frequent use of the recirculation pump. Research indicates that these systems can use a large amount of energy to maintain the water temperature in the recirculation loop and are not considered to be energy-efficient. Some timer-based systems will also attempt to curtail this energy use by operating only at specific times of the day. The water and energy efficiency of this approach can be highly variable depending on the settings and the consistency of the residents' routines.

Therefore, demand-initiated recirculation systems tend to be more energy-efficient than timer- or temperature-based recirculation systems, because hot water is only drawn into the recirculation loop when it is needed. Demand-initiated systems use push buttons or motion sensors in conjunction with sensor electronics installed near the fixtures to draw hot water closer via the recirculation

[10] Acker, L., G. Klein. Home Energy. 2006. "Benefits of Demand-Controlled Pumping."

loop. When the resident initiates the demand, a sensor measures temperature changes in the recirculation loop and activates the circulating pump until the water in the loop reaches a specified temperature, at which time the water is delivered to the fixture.

Demand-initiated recirculation systems can offer builders more flexibility than the other types of hot water delivery systems, because they can allow for longer pipe runs and less centralized fixture placement. Although demand-initiated recirculation systems use energy in their operation, they can save energy as well:

- The water in the recirculation loop that is returned to the water heater is generally warmer than water entering into the house; therefore, the water heater requires less energy to keep the water heated.
- Since hot water is distributed at a high flow rate to fixtures, significantly less heat is lost during distribution. The high flow rate also allows hot water to reach the fixtures faster; therefore, less hot water is needed to prime the recirculation loop.[11]

While the cost of recirculation equipment is a deterrent to many, builders should weigh the water efficiency and performance benefits against the costs associated with this type of system. Additionally, long-term operating cost savings by reducing the amount of water that is heated and lost typically far outweighs the energy used to operate the pump.

Figure 11 (on page 17) illustrates a hot water delivery system that is representative of a demand-initiated recirculation system. In this example, a recirculation loop is installed over the kitchen, laundry, and bathrooms between the lower and upper levels and achieves the recommended 10-foot distance to each fixture. Because the recirculation loop is the hot water source, the demand-initiated recirculation system is able to compensate for distances from the water heater that may otherwise result in inefficient or high-volume layouts if implemented within the other three system types.

3.2 Heating Technologies

Different water heating technologies may affect the optimal hot water delivery system design and water heater placement within a home. Table 1 on page 18 summarizes common water heating technologies and how they may affect the placement of the water heater and the overall efficiency of the hot water distribution system.

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[11] *Ibid*.

Figure 8. A Plumbing Layout Representative of a Trunk and Branch System

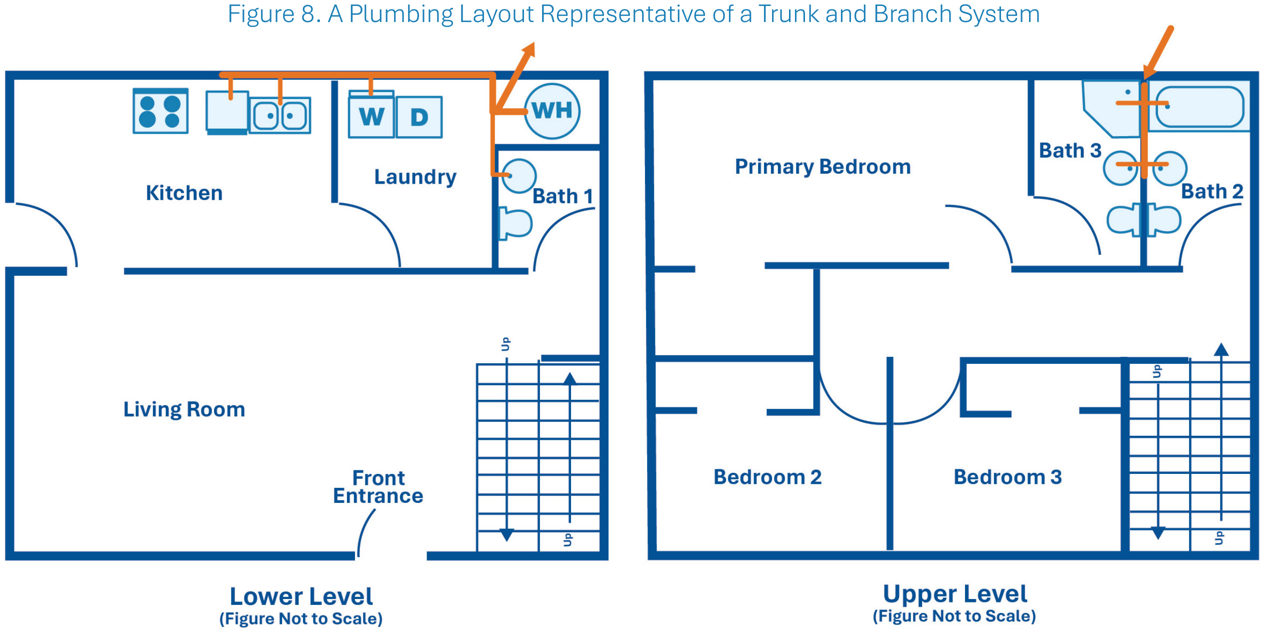
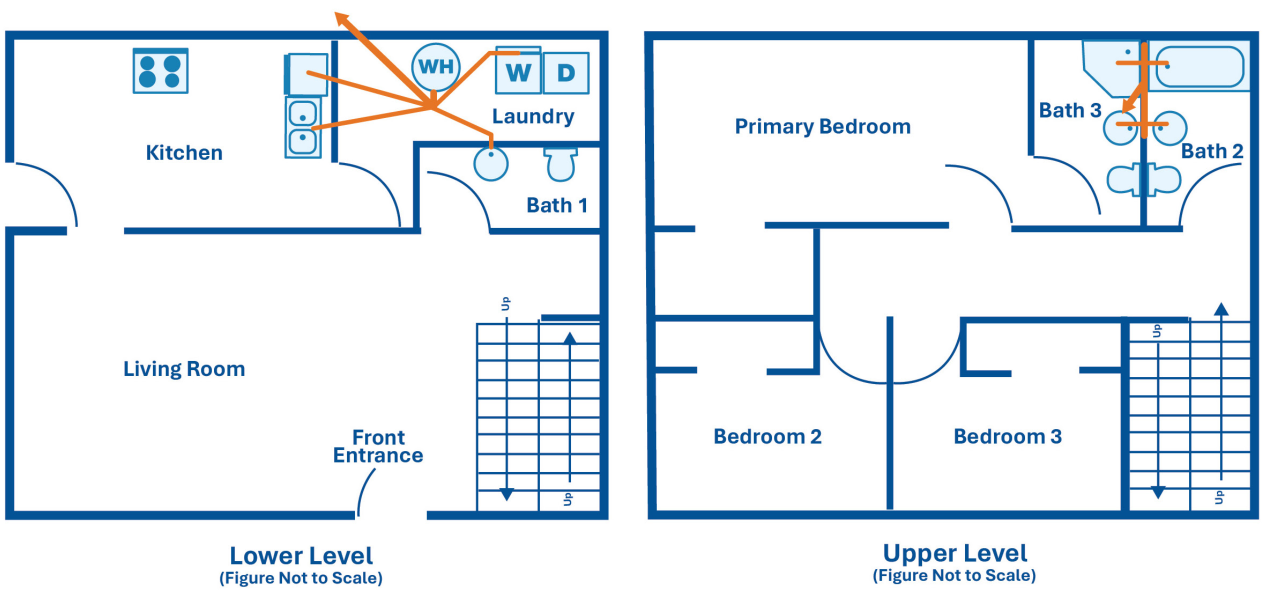


Figure 9. A Plumbing Layout Representative of a Core System



Orange lines represent the potential layout of hot water delivery pipes.

Figure 10. A Plumbing Layout Representative of a Whole-House Manifold System

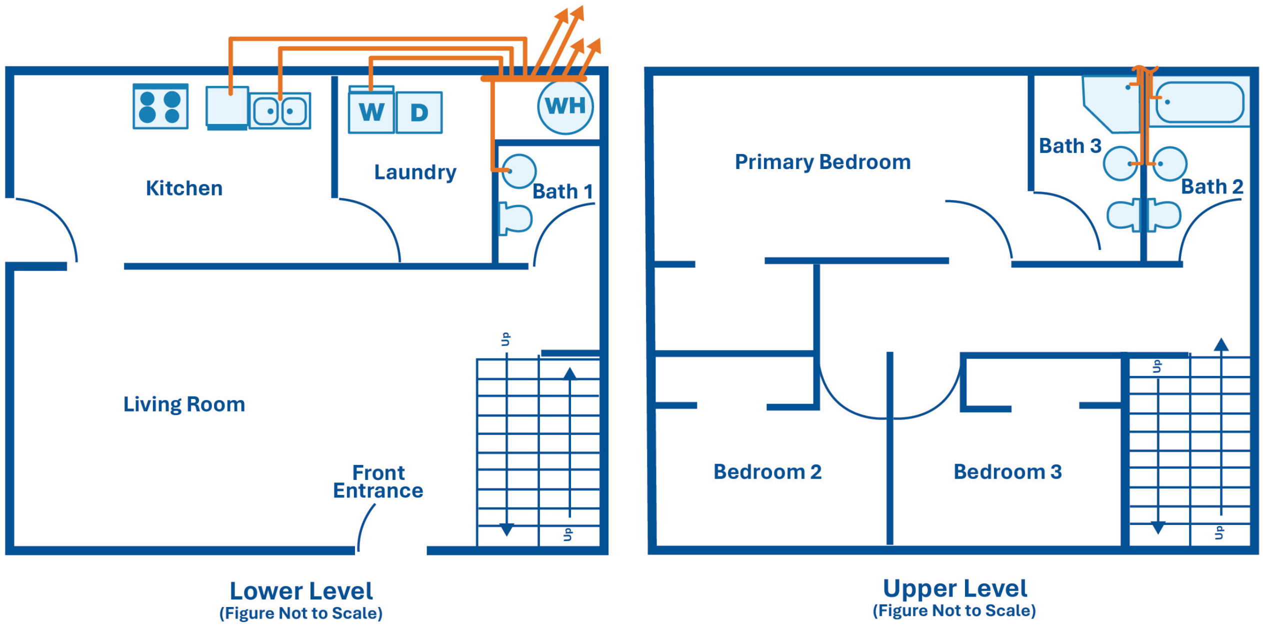
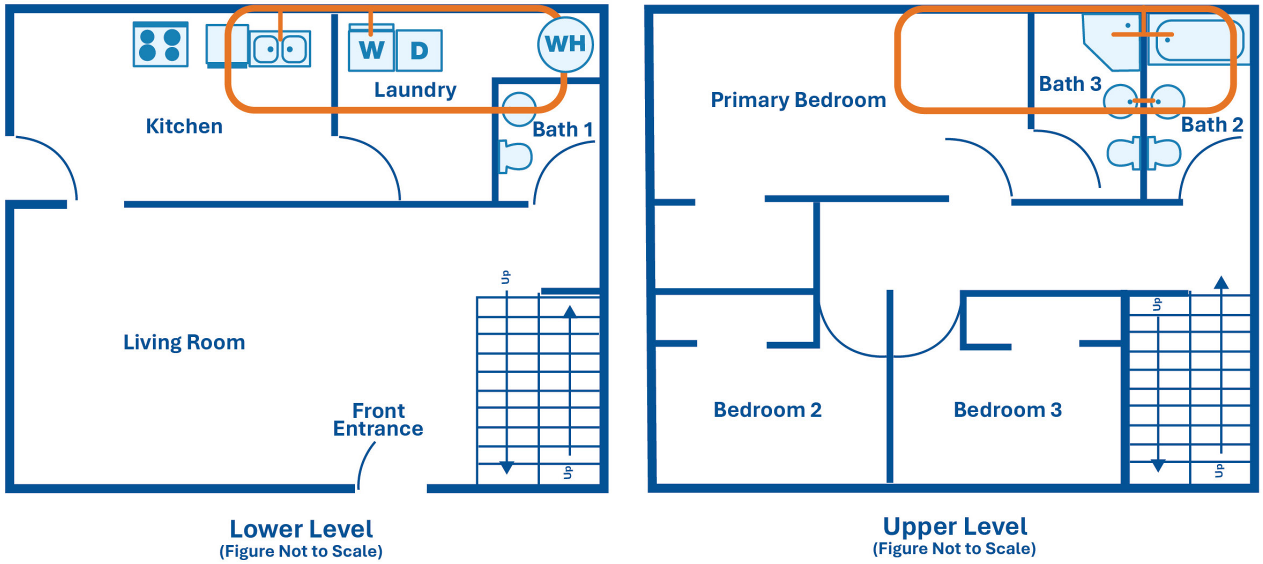


Figure 11. A Plumbing Layout Representative of a Recirculation System



Orange lines represent the potential layout of hot water delivery pipes.

Table 1. Common Types of Water Heaters

Type	Description	Placement Consideration	Impact on Hot Water Delivery and Efficiency
Conventional storage water heater	Heats water in a storage tank or reservoir for ready use. Water is replaced and heated as hot water is used.	Size depends on hot water demand and occupancy of household, but typically requires space for the storage tank and sufficient clearance in the immediate surroundings for maintenance, water/gas lines, and ventilation (as applicable). The water heater should be in a central location near hot water draws for efficiency.	Energy can be wasted due to standby heat loss and reheating cooled water in the tank. Heavy insulation can reduce standby heat losses.[12]
Instantaneous water heater	Only heats water as needed and does not utilize any storage tank.	Smaller water heaters can more easily be optimized in specific locations depending on the fuel source and venting requirements. Smaller units can serve single applications, rooms, or remote uses far from the centralized heater (e.g., kitchens, bathtubs).	Has less standing heat loss but requires greater heat input, since there's no stored energy in heated water waiting to be delivered.[13] Less consistent water demand increases efficiency (if installing a singular heater).[14]
Air-source heat pump water heater	Uses a refrigeration cycle to move heat from the surrounding air to the water.	Install in larger room (e.g., basement, garage) with proper ventilation. Consider the effect of heater noise and cool exhaust air on residents. Locating the heater near equipment that produces waste heat (e.g., furnace, fridge, clothes dryers) can provide additional heat for pump.	This can be a highly energy-efficient option. Central systems in multifamily homes are not as efficient, but it's easier to avoid problems associated with placement.
Point-of-use water heater	Heats water very near the fixture to provide hot water or boost the temperature if located far from the primary water heater.	Locate the water heater at or near end uses. They are often used for hot tubs, additions to existing homes, or otherwise isolated end-use points.	They are not suitable as back-up water heaters because they cannot support an entire household. Assess costs and benefits before deciding to use a decentralized approach.

[12] DOE. Sizing a New Water Heater. www.energy.gov/energysaver/sizing-new-water-heater

[13] Healy, W., Hiller, C., and Lutz, J. *ASHRAE Journal*. "How Residential Water Heating is Changing". www.nist.gov/publications/how-residential-water-heating-changing.

[14] DOE. Tankless or Demand-Type Water Heater. www.energy.gov/energysaver/tankless-or-demand-type-water-heaters.

Storage, instantaneous, and point-of-use water heaters are typically available as either gas-fired or electric heaters; heat pump water heaters are inherently electric (although some heat pumps do have a natural gas backup). If installing a gas-fired heater, builders should consult with gas companies, as well as all pertinent codes for direction on locating the water heater with access to proper ventilation and where gas lines are available. When selecting a water heater, use the UEF to compare the energy efficiency of various water heaters. Additionally, compare the cost of the water heater with the cost of operating it over time. While more efficient options may require a higher initial investment, they may achieve greater operating savings over the lifetime of the heater.

However, the types of water heaters described above do not represent all available heating technologies, and there are hybridized options that may incorporate multiple heating technologies in their design. For example, some instantaneous heaters may also be equipped with a small stand-by storage tank, which can be built as part of the initial system or retrofitted to an existing instantaneous heater. This ensures that the system can continuously supply hot water during periods of high demand, avoiding decreased water pressure or potential lapses in supply to allow for recalibration when multiple hot water taps are turned on. Similarly, heat pump water heaters may also rely on a secondary technology during periods of high hot water demand or ambient temperatures below about 40°F (the lower temperature limit for sole reliance on the heat pump).[15] As needed, hybrid models typically switch to using electric resistance heating elements, which are employed in electric storage water heaters.

Alternative Heating Technology: Solar Water Heaters

Solar water heaters are essentially storage water heaters that rely on solar collectors to heat a tank of water prior to distribution throughout the home. While solar water heaters do not necessarily affect the distribution efficiency of the hot water delivery system, they will reduce utility bills compared to electric or gas-fired heaters. Keep in mind that a backup heating technology (e.g., a storage tank that heats water with resistance elements) ensures performance during increased demand or when sunlight is not available.

For more information on different types of solar water heaters, visit www.energy.gov/energysaver/solar-water-heaters. For more information on energy and cost savings associated with solar water heaters, visit www.energy.gov/energysaver/estimating-cost-and-energy-efficiency-solar-water-heater.

[15] ENERGY STAR. Heat Pump Water Heater Frequently Asked Questions. www.energystar.gov/partner-resources/residential_new/educational_resources/sup_program_guidance/heat_pump_water_heater_guide/frequently_asked_questions.

While it's a best practice to optimize the location of fixtures that use hot water relative to the water heater location, there may be cases where a second water heater or a demand-initiated recirculation system makes more sense. If extended piping runs have large diameters and lengths, a second water heater would help avoid additional plumbing costs and distribution losses, and the money saved in operation would help offset the initial investment of the additional heater.[16] A second water heater in the same location is almost never necessary in a modern home as first-hour ratings of today's water heaters can meet most residential demands. Alternatively, a demand-initiated recirculation system can more efficiently cover larger distances from the water heater, because significantly less heat is lost during distribution. Since the recirculation loop is considered the hot water source, hot water taps should be placed near the recirculation loop; however, they do not need to be clustered as tightly as other delivery system designs.

3.3 Right-Sizing Pipes for Peak Water Demand

In order to right-size plumbing pipes to ensure water and energy efficiency, it's important to understand the building's peak water demand based on the number of fixtures, types of fixtures and their maximum flow rates, and typical use patterns within the home. Studies have shown that historical methods to estimate the peak water demand of a building, such as the Hunter's Curve method currently used as the basis for pipe sizing in U.S. plumbing codes, overestimate the actual peak water demand and result in oversized pipes.[17] To address the discrepancy between expected use and actual use, IAPMO developed the Water Demand Calculator; the current version of the calculator takes into consideration lower consumption rates from more efficient fixtures (e.g., WaterSense labeled products) to more accurately predict the peak water demand of single- and multifamily homes.[18] While previous methods can predict a peak demand five to 27 times greater than observed peak flow rates, the Water Demand Calculator typically estimates a peak demand between two to six times actual flow rates. The calculator relies on more realistic yet still conservative assumptions, to ensure builders and plumbers will not undersize pipes.[19]

When pipes are right-sized, they typically have smaller diameters or lengths compared to traditional pipe sizing methods, which means that hot water is delivered more quickly and the material and installation costs decrease. In addition, the volume of standing water decreases, reducing the amount of energy lost when heated water cools within the pipe and the water lost when the cooled water is cleared during a hot water draw. Right-sizing also can reduce the required water meter size, saving builders money on water connection fees, while also

[16] DOE, Sizing a New Water Heater, *op. cit*.

[17] IAPMO. 2024. *Peak Water Demand Study*. https://iapmo.org/media/42ehgafw/peak-water-demand-full-study.pdf.

[18] IAPMO's WE•Stand, Water Demand Calculator, *op. cit*.

[19] IAPMO. *Fact Sheet: UPC Appendix M Peak Water Demand Calculator*. https://iapmo.org/media/2xvl24k4/fact-sheet_wdc.pdf.

improving performance of meter-based equipment and appliances such as water softeners, if they are calibrated for overestimated flow.[20]

3.4 Pipe Diameter, Length, and Materials of Construction

An efficient hot water delivery system design and layout will address water waste from long pipe runs, but pipe material and pipe diameter also impact system efficiency. For a given nominal diameter of pipe (where diameter is measured on the outside), the inside diameter will vary by material, because the material has differing wall thicknesses. This means that identically designed hot water delivery systems will store different volumes of hot water within the respective systems, depending on the material the pipe is made from.

A plumber installing PEX piping for hot water distribution in a new home.

When designing hot water delivery systems, builders have several available choices regarding pipe material. Table 2 on the next page identifies some common types of pipe used for hot water delivery systems and lists the capacity of water that each type stores per foot of pipe for a given pipe diameter. It is important to note that the pipe material selection will to some extent be dictated by the type of hot water delivery system that will be installed in the home. For example:

- Trunk and branch, core, and demand-initiated recirculation systems can utilize any type of piping, although copper or CPVC is traditionally used.
- Whole-house manifold systems typically utilize flexible piping such as PEX-Al-PEX, PEAL-PE, or PEX CTS SDR 9 piping.

There are three primary types of copper that can be used for piping: Type M, L, or K. Of the three, Type L and M are traditionally used in home plumbing systems, while Type K tubing, which is the thickest type of piping, is used primarily for main and underground water lines.

While builders are encouraged to consider how pipe material and associated diameters affect the efficiency of hot water delivery systems, the diameter should not be minimized to such an extent that it will compromise the system's operability. Pipe diameters should be sized according to the specific needs, design constraints, and applicable plumbing codes or standards. For example, main supply lines require larger pipe diameters to ensure adequate water flow to each of the fixtures connected to that line. Smaller diameter piping may be acceptable to deliver water from the main supply line to the individual fixtures.

[20] IAPMO, *Peak Water Demand Study, op. cit.*

Pipe run length and pipe diameter both contribute to the stored hot water volume that stands in pipes between hot water draws. As previously discussed, the greater the stored volume of water between the water heater and fixtures, the greater the heat loss and water loss will be when standing water goes down the drain while users wait for hot water. While not a requirement to earn the WaterSense label for homes, EPA recommends that no more than 0.5 gallons of water be stored in piping between the water heater and any end use.

Table 2. Internal Volume of Various Water Distribution Piping

	Ounces of Water Per Foot of Hot Water Tubing								
Nominal Diameter in Inches	Copper M	Copper L	Copper K	CPVC CTS SDR 11	CPVC SCH 40	PE-RT SDR 9	PEX-AL-PEX ASTM F 1281	PE-AL-PE	PEX CTS SDR 9
3/8	1.06	0.97	0.84	N/A	1.17	0.64	0.63	0.63	0.64
1/2	1.69	1.55	1.45	1.25	1.89	1.18	1.31	1.31	1.16
3/4	3.43	3.22	2.90	2.67	3.38	2.35	3.39	3.39	2.35
1	5.81	5.49	5.17	4.43	5.53	3.91	5.56	5.56	3.91
1 1/4	8.70	8.36	8.09	6.61	9.66	5.81	8.49	8.49	5.81
1 1/2	12.18	11.83	11.45	9.22	13.20	8.09	13.88	13.88	8.09
2	21.08	20.58	20.04	15.79	21.88	13.86	21.48	21.48	13.86

Source: Modified from 2024 International Plumbing Code Table E105.1. International Code Council.

Conversions: 1 gallon (3.8 liters) = 128 ounces
1 ounce = 0.00781 gallons (0.0296 liters)

To determine whether a planned hot water delivery system will meet this recommendation, EPA has developed a simple, Excel-based calculator to help estimate the volume of water stored in a system.[21] Builders can use this tool to compare how different hot water delivery system designs may affect stored water volumes for a specific home layout, based on the associated piping lengths, diameters, and materials.

The use of pipe insulation can reduce heat loss of water stored in piping and further improve hot water delivery system efficiency, both while the system is in standby mode and as hot water moves through the piping. If the wall thickness of the pipe insulation is equal to or greater than the nominal pipe diameter (up to 2 inches), the temperature drop as water travels from the water heater to the end use is reduced by 50 percent, and the cool down time of stored water within the pipes increases.[22]

[21] EPA's WaterSense program, Hot Water Distribution Volume Calculator, op. cit.

[22] Klein, Gary and Sherman, Troy. ACEEE Summer Study on Energy Efficiency in Buildings. 2016. *Getting Into Hot Water – The New Energy Efficiency Frontier*. www.aceee.org/files/proceedings/2016/data/papers/1_12.pdf.

4.0 Summary and Recommendations

In summary, although not a requirement of the *WaterSense Specification for Homes*,[23] EPA recommends the following to reduce hot water delivery system water and energy waste:

- Select water heaters with a higher UEF than standard models.
- If possible, cluster wet rooms (e.g., bathrooms, kitchens, laundry rooms) close together within the home layout.
- Locate the water heater near hot water use if possible and choose a plumbing design that minimizes pipe diameter and pipe length.
- Right-size pipes to minimize the volume of stored hot water within plumbing piping. Where allowed by local plumbing code, use IAMPO's Water Demand Calculator[24] to determine a conservative and accurate estimate of a residential home's water demand compared to typical pipe sizing methods and contribute to successful right-sizing efforts.
- Use EPA's Hot Water Distribution Volume Calculator[25] to determine whether the designed hot water delivery system will minimize the volume of water stored between the hot water source (i.e., water heater or recirculation loop) and each end use. EPA recommends aiming for no more than 0.5 gallons of water stored in each pipe.
- If the calculation indicates that the amount of water stored within piping and manifolds is not sufficiently minimized in the designed system, consider including a demand-based hot water recirculation system to ensure hot water will reach the affected fixtures sooner.
- Install WaterSense labeled faucets and showerheads and ENERGY STAR certified dishwashers and clothes washers.

For more information on promoting water efficiency in homes, refer to EPA's WaterSense program website at www.epa.gov/watersense.

[23] EPA's WaterSense program, Homes Specification, *op. cit*.
[24] IAPMO's *Water Demand Calculator, op. cit*.
[25] EPA's WaterSense program, Hot Water Distribution Volume Calculator, op. cit.