Glenn T. Chinery **EPA ENERGY STAR® for Homes** September 2006
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Policy recommendations for the HERS Community to consider regarding HERS scoring credit due to enhanced effective energy factors of water heaters resulting from volumetric hot water savings due to conservation devices/strategies

The following algorithm was developed to enable the translation of volumetric hot water savings due to hot water conservation devices and strategies into an enhanced effective water heater energy factor – which, when plugged into HERS residential energy simulation software, can calculate a corresponding HERS scoring credit, as well as enhanced energy and utility bill savings.

If, for example, a rater is using typical HERS residential energy software (e.g., REM/Rate), then given the DOE water heater test result parameters (energy factor, recovery efficiency), this algorithm takes % of hot water savings due to the hot water conservation measures and calculates an ***energy factor enhancement coefficient*** which is used to multiply the DOE energy factor to obtain an ***enhanced effective energy factor***.

The HERS software then simulates real-world water heater performance based on this ***enhanced effective energy factor***, the number of bedrooms, local water main inlet temperatures, etc. and calculates energy/utility bill savings, and HERS scoring credit.

ALGORITHM

1) Look up a water heater's DOE test performances factors:

- **EFdoe = energy factor**
- **REdoe = recovery efficiency**

(Note: these two parameters are available from the GAMA directory or mfg. literature)

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2) **Estimate S = % volumetric water savings due to the water saving technologies being investigated. This could typically vary from 5% to as much as 50%. This is calculated independently by whatever estimating algorithms and/or test results are being employed by the analyst/tester of the hot water saving device or strategy. Only estimates from national laboratories, national or state energy office-sponsored studies, or approved by RESNET are acceptable.**

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3) Calculate Energy Factor Enhancement Coefficient (EFEC):

--------->EFEC = [REdoe / (REdoe - S*EFdoe)]

where:
EFEC = Energy Factor enhancement coefficient
s = volumetric water savings coefficient (convert this to a decimal fraction of volume of water saved by the hot water conservation devices/strategies (e.g., for a 20% savings this would be 0.2)

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4) Calculate Enhanced Effective Water Heater Energy Factor

--------->EFenhanced = EFEC * EFdoe

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5) Plug EFenhanced into HERS simulation software in place of normal EFdoe

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Example Calculation

A tankless gas water heater has an EFdoe=0.82 and REdoe=0.84. An optimized plumbing layout and demand controlled pumping system are installed. It is estimated (independently of the above EPA algorithm) that these conservation devices/strategies save 20% of the volume of hot water use in this particular installation.

from the algorithm above:
1) EFdoe = 0.82, REdoe = 0.84,
2) Estimate S=20% = 0.2 (volumetric HW water savings due to optimized plumbing layout and demand controlled pumping system)
3) Calculate Energy Factor Enhancement Coefficient
EFEC = [REdoe / (REdoe - S*EFdoe)] = [0.84 / (0.84 - 0.2 * 0.82)] = 1.24
4) Calculate EFenhanced = EFEC * EFdoe = 1.24*0.82 = 1.017
5) Plug EFenhanced into the EFdoe input to HERS software. The HERS software will calculate the correct water heating energy for the number of gallons of hot water usage and the local water main inlet temperature and the resultant energy savings will be used in the HERS analysis/scoring.

Applications

The volumetric hot water savings to which this algorithm may be applied include:
- **low-flow showerheads**
- **horizontal-axis washing machines**
- **optimized plumbing layouts and demand controlled pumping systems that minimize hot water waste (does not include constant recirculation HW systems).**

Example Results

Some example EF enhancements were calculated for a number of typical water heaters, whose properties and enhanced energy factors as a function of volumetric hot water savings are delineated in the table below:

Typical Enhanced Energy Factors

Fuel	**Gas**			**Electric**		
Type	**NAECA**	**High-Efficiency**	**Tankless**	**NAECA**	**High-Efficiency**	**Tankless**
Volume (Gallons)	**40**	**40**	*****	**52**	**52**	*****
Energy Factor	**0.54**	**0.63**	**0.82**	**0.86**	**0.93**	**0.98**
Recovery Efficiency	**0.76**	**0.80**	**0.84**	**0.98**	**0.98**	**0.99**
Water Savings (%)	**Enhanced Energy Factor**					
0%	0.54	0.63	0.82	0.86	0.93	0.98
5%	0.56	0.66	0.86	0.90	0.98	1.03
10%	0.59	0.68	0.91	0.94	1.03	1.09
15%	0.61	0.71	0.96	0.99	1.08	1.15
20%	0.63	0.75	1.02	1.04	1.15	1.22
25%	0.66	0.78	1.08	1.10	1.22	1.30
30%	0.69	0.82	1.16	1.17	1.30	1.39
35%	0.73	0.87	1.25	1.24	1.39	1.50
40%	0.76	0.92	1.35	1.33	1.50	1.62
45%	0.80	0.98	1.46	1.42	1.62	1.77
50%	0.85	1.04	1.60	1.53	1.77	1.94

* Volume of tankless water heaters is small, generally less than 1 gallon.

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Appendix - Industry Estimates of Volumetric Hot Water Savings due to Structured Plumbing and Demand Controlled Pumping

Synopsis: There are two recently-developed technological innovations that can achieve volumetric hot water savings in a residence: Demand Controlled Pumping and Structured Plumbing. To assist home energy raters in identifying and confirming their installation descriptions and diagrams of these innovations are shown below. Following that are estimates of volumetric hot water savings deemed reasonable by EPA for these innovations.

Plumbing System Layouts and Terminology

Conventional Trunk, Branch and Twig Plumbing System (see figure 1 below)

Trunk, branch and twig plumbing can be found in both new and existing homes. There is one (and sometimes two or more) hot water main trunk line(s) that serve(s) multiple fixtures through either branches or individual twigs. A "twig" serves an individual fixture. A "branch" line serves more than one fixture. A "trunk" line serves one or more branches and many fixtures. There are usually always a corresponding number of cold water trunk and branch lines too, as well as additional cold water lines to outdoor spigots.

In these systems, neither the builder nor the plumber has made any special attempt to minimize the volume of water in the branches or the twigs serving individual fixtures or to minimize flow restrictions through standard 90 degree elbows and extra fittings. The hot water piping is generally not insulated. The piping is "one-way" from the water heater (hot water) or the water main (cold water) to the water use (sink, shower, dishwasher, etc.) and then "down the drain."

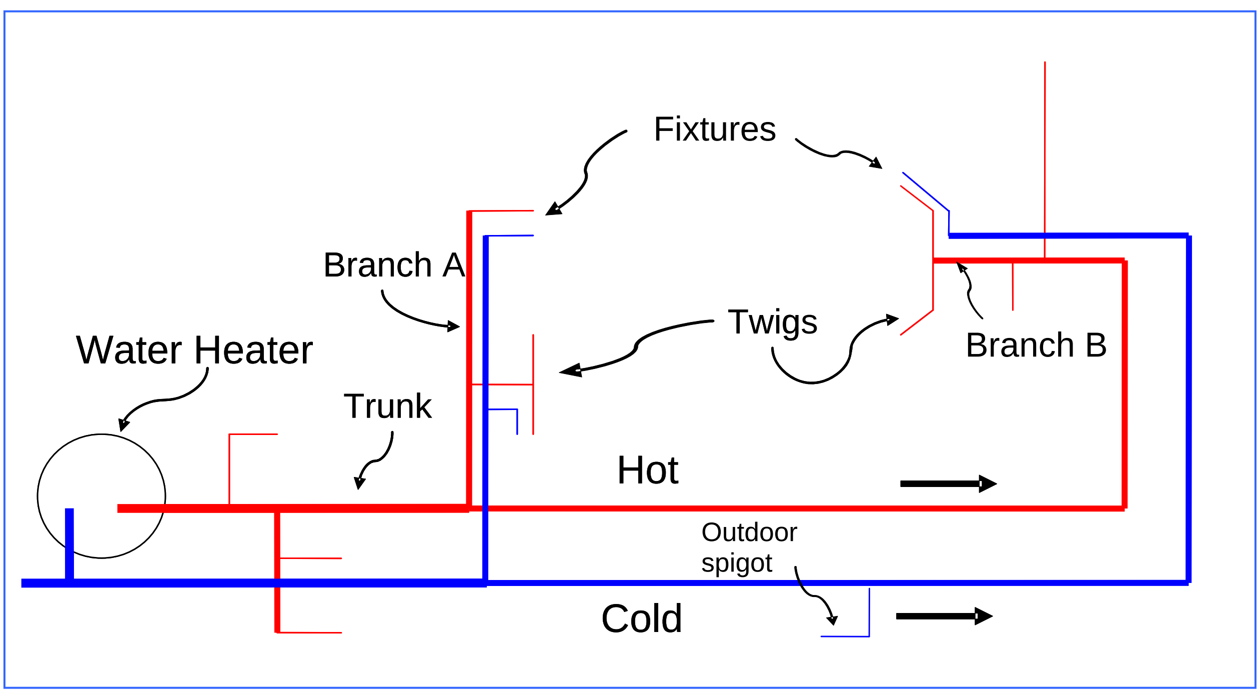


Figure 1: Conventional Single Trunk, Double Branch and Twig Plumbing Layout with Separate Hot and Cold Water Supply Lines to individual fixtures.

Conventional Trunk, Branch and Twig Plumbing System with Demand Controlled Pumping (see figure 2 below)

Below is the same plumbing layout system as in figure 1 but with a Demand Controlled Pumping System installed on Branch B. This would be a typical retrofit in an existing home.

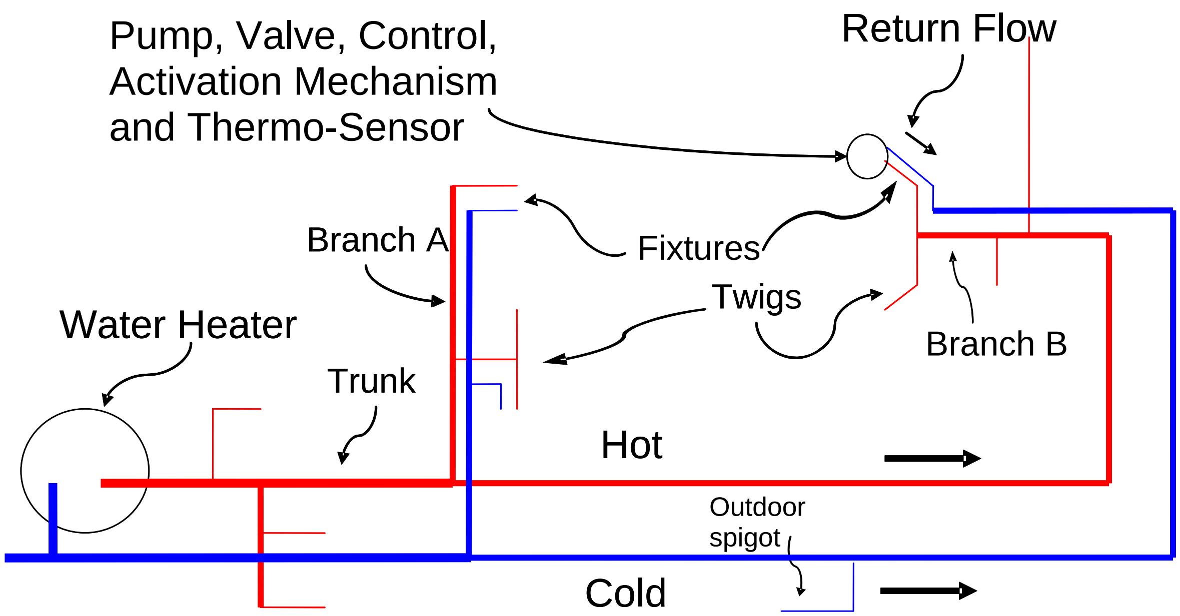


Figure 2 Single Trunk, Double Branch and Twig Plumbing Layout with Demand Controlled Pumping on Branch B, Using the Cold Water Line as the Return

In the layout above the demand controlled pumping system consists of an on-demand pump, valve, control and activation mechanism installed at a heavy-use hot water fixture at the end of Branch B. When hot water is desired at the fixture an activation mechanism (could be a pressure sensor on the hot water faucet, a motion sensor, a pushbutton, etc.) signals the control, which:

a. temporarily closes the valve to prevent hot water from flowing into the drain
b. energizes the pump which begins pumping water quickly on a "round-trip" through a loop starting from the water heater, through the hot water supply line to the fixture, and back to the water heater through the cold water supply line in the direction labeled "reverse flow" shown above.

When hot water from the water heater reaches the fixture the thermo sensor detects it and signals the control, which deactivates the valve and pump, and hot water begins to flow normally from the fixture. The demand plumbing system has effectively speeded hot water delivery to the fixture and prevented water from being wasted into the drain while waiting for the hot water to arrive at the fixture.

In these plumbing layouts, the on-demand pump, control and thermo sensor are generally located under a sink at the hot water location furthest from the water heater. There will be one or more activation mechanisms, generally one activation mechanism per hot water use location. The activation mechanisms are either wired or wireless buttons (motion sensors are not recommended when the cold line is used as the return.)

In an optimized whole house plumbing layout you would expect to find four activation mechanisms – one in the room near the pump (e.g., the master bathroom), one in the second furthest hot water use location (e.g., the kitchen), one in the hot water location with the large branch line serving three fixtures (e.g., an upstairs bathroom) and one in a downstairs bathroom.

Some houses may have more than one trunk line, each serving a group of fixtures. There may be an on-demand pump at the end of each trunk line, depending on the delay in getting hot water to the furthest hot water use location. There may be one water heater for all trunk lines or one water heater for each trunk line.

Structured Plumbing System with Demand Controlled Pumping (see figure 3)

Structured plumbing systems are usually amenable to installation in new construction and gut rehab. Structured Plumbing is a concept that includes:

- A circulation loop as short as practical and with as few hard elbows as possible.
- Fixtures or appliances located within 10 plumbing feet of the circulation loop on branch lines that are no larger than ½ inch diameter.
- All hot water pipes insulated (It is very common to find a 5-10F temperature drop from the water heater to the furthest fixtures in a house. For a given flow rate, R-4 insulation will reduce the temperature drop by half).
- An on-demand pumping system with electronic controls and activation mechanisms placed in key locations throughout the house, generally one per hot water using location.

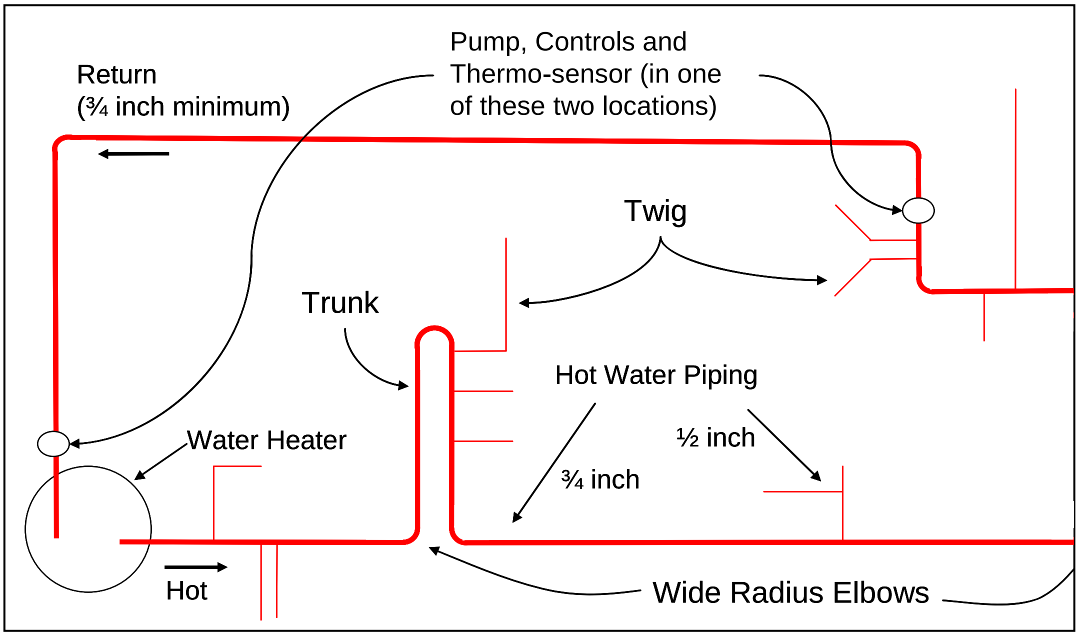
The circulation loop is intentionally located such that it is both as short as possible and within 10 plumbing feet of every fixture. Except for the friction losses due to its length, it has few other restrictions to flow. Ideally, the only fittings in the circulation loop are the tees for the branch lines feeding each fixture.

An on-demand pump, sized to overcome the now reduced losses in the main circulation line will be able to preheat the circulation loop in a relatively short amount of time. The pump is activated shortly before the desired use to “prime the insulated line”, after which the electronic controls automatically shut off the pump when they recognize that the water in the circulation loop is hot. The insulation on the piping keeps the water hot for about an hour between uses. The small volume of cold water in each branch line will be replaced with hot water in just a few seconds. Water waste will be minimized, ideally to less than 2 cups per hot water event. Hot water will arrive at each fixture in less than 5 seconds depending on the flow rate at the fixture. Assuming that the average waste is 0.5 to 1 gallon per hot water event in houses without a circulation system, this represents a 75 – 90 percent reduction in water waste. There is a small additional cost of $1-2 per year to operate the demand controlled pump and associated controls.

Installing Structured Plumbing in new construction or major rehab makes it possible to configure the circulation loop to take advantage of the lessons learned from research. The result will be increased water savings due to the small residual volume of water in the branch lines serving individual fixtures. There will be additional savings due to the insulation on the hot water piping.

There is one (sometimes two or more) main trunk line(s) that serve(s) multiple fixtures. The volumes of water in the lines serving individual fixtures and the flow restrictions (standard 90 degree elbows and extra fittings) in the piping have been minimized. The twig lines serving individual fixtures are small in volume (length times inside diameter); ideally less than 10 feet long and no larger than ½ inch nominal diameter. All hot water piping has been insulated. Usually there is a dedicated return line (¾ inch nominal diameter minimum) to complete the loop back to the water heater, although sometimes the cold water line is used as the return.

Figure 3 Structured Plumbing System with a Dedicated Return Line



In a Structured Plumbing System layout, the on-demand pump is generally located on the return line near the water heater. In some cases it will be located under a sink in the hot water location furthest from the water heater, connecting the hot water supply line with the return line. Both of these options are shown in Figure 3. Sometimes the cold water line is used as the return as shown in the figure for single trunk and branch layouts.

There will generally be one activation mechanism per hot water use location. The activation mechanisms are either wired or wireless buttons or motion sensors (motion sensors are not recommended when the cold line is used as the return.)

Some houses may have more than one Structured Plumbing line, each serving a group of fixtures. There may be one water heater for all Structured Plumbing loops or one water heater for each loop.

The tables immediately below give estimates deemed by EPA to be reasonable for volumetric hot water savings due to these innovations.

Percent Volumetric Hot Water Savings for Trunk, Branch and Twig Plumbing Systems with Demand Controlled Pumping

Plumbing Layout: Trunk/Branch/Twig		Estimated Volumetric Hot Water Savings (%)
Single trunk		15%
Two Trunk	Both with demand controlled pump	15%
	Only one with demand controlled pump	7.5%

Percent Volumetric Water Savings for Structured Plumbing Systems with Demand Controlled Pumping

Plumbing Layout: Structured Plumbing	Small Volume Twig Lines Verified	Small Volume Twig Lines Unverified
	Water Savings (%)	Water Savings (%)
Pipe Insulation Verified	30%	25%
Pipe Insulation Unverified	20%	15%

References

Acker, Larry and Gary Klein, "Benefits of Demand Controlled Pumping," *Home Energy*, September/October, 2006, pp. 18 ff. {attached}

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Acker, Larry, "Estimating Potential Hot Water Savings from Demand Controlled Pumping Systems and Structured Plumbing Layouts", unpublished manuscript, June 2006

Private communication with Larry Acker (Metlund Systems) and Gary Klein (California Energy Commission).