

Battelle Study Findings

Gas Storage Tank Water heaters:

- **With softened water.** Gas storage tank household water heaters operated on softened water maintained the original factory efficiency rating over a 15 year lifetime.
- **With hard water.** Hard water can lead to as much as a 24% loss of efficiency in water heaters.
 - Each 5 grains per gallon of water hardness causes a 4% loss in efficiency and 4% increase in cost for gas storage tank water heaters when using 50 gallons of hot water per day. (On 30 gpg hard water that's 24% less efficient than with softened water.)

Tankless heaters:

- **The economic savings** of softened water with instantaneous tankless water heaters can lead to recovery of the cost of a water softener and operating supplies in a period as short as a year, if the incoming water is sufficiently hard.
- **With softened water.** Indoor instantaneous gas water heaters (tankless heaters) operated on softened water maintained the original factory efficiency rating over a 15 year lifetime.
- **With hard water.** Tank-less water heaters operating on hard water failed after 19 days of testing.
 - The study found that tankless water heaters completely failed to function because of scale plugging in the downstream plumbing after only 1.6 years of equivalent hot water use on 26 gpg hard water.
 - Softened water saves 34% of costs compared to operating on 20 gpg and saves 47% compared to operation on 30 gpg hard water.

Electric Water Heaters

- **30 pounds calcium carbonate rock-like scale deposits** accumulated in electric water heaters operated on hard well water.
- **Each 5 gpg of water hardness causes 0.4 pounds of scale** accumulation each year in electric storage tank household water heaters.
- ***"the life of the heating element can be expected to shorten due to scale buildup increasing the operating temperature of the element"*** in the electric storage water heaters operating on unsoftened water, says Battelle Memorial Institute.

Carbon Footprint

- **The carbon footprint increases 18%** for gas storage tank water heaters when operated on 26 gpg hard water for 15 years as compared to the same operation on 0 gpg softened water.
- **For instantaneous type natural gas water heaters this same carbon footprint increases 4%** when operated on 26 gpg hard water versus 0 gpg softened water.

Showerheads and Fixtures:

- **With softened water.** Shower heads on soft water maintained a brilliant luster and full flow. Faucets on softened water performed well throughout the study; nearly as well as the day they were installed.
- **With hard water.** Shower heads on hard water lost 75% of the flow rate in less than 18 months.
 - Faucets on hard water could not maintain the specified 1.25 gallons per minute flow rate because of scale collection of the strainers. The strainers on the faucets using unsoftened water were almost completely plugged after 19 equivalent days of testing.

Table ES-1. Summary of Results for Water Heaters

| Water Heater Type | Water Supply | Average Thermal Efficiency, (%) | | Equivalent Field Service (Years) | Average Annual Scale Accumulation ¹ (grams/year) | Carbon Footprint ² (kg CO ₂ /gal hot water) |
|-------------------|--------------|---------------------------------|-----------------|----------------------------------|---|---|
| | | Test Start | Test End | | | |
| Instantaneous Gas | Unsoftened | 80 | 72 ³ | 1.6 | NA | 0.052 |
| | Softened | 80 | 80 | 1.6 | NA | 0.050 |
| Gas Storage | Unsoftened | 70.4 | 67.4 | 2.0 | 528 | 0.066 |
| | Softened | 70.4 | 70.4 | 2.25 | 7 | 0.056 |
| Electric Storage | Unsoftened | 99.5 | 99.5 | 1.25 | 907 | Not Determined |
| | Softened | 99.3 | 99.3 | 1.25 | 14 | Not Determined |

Notes: ¹ The submerged heating element in an electric water heater operates at very high temperatures which results in a high rate of scale buildup in electric water heater when compared to a gas water heater.

² Average over 15 years Equivalent Life.

³ Deliming or Cleaning was performed at this point.

Table ES-2. Estimated Savings for Gas-fired Water Heaters using Softened Water Over 15 years Life

| Cost Elements | Water Hardness, grains per gallon | | | | | | |
|---|-----------------------------------|------|------|------|------|------|------|
| | 0 | 5 | 10 | 15 | 20 | 25 | 30 |
| Instantaneous Gas Water Heaters | | | | | | | |
| Percent Life Cycle Energy Cost Savings, % ¹ | NA | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 |
| Percent Total Life Cycle Cost Savings, % ¹ | NA | 14.0 | 22.5 | 31.2 | 39.6 | 48.4 | 57.0 |
| Estimated Usage before Deliming Required, years ² | NA | 8.4 | 4.1 | 2.7 | 2.0 | 1.6 | 1.4 |
| Gas Storage Water Heaters | | | | | | | |
| Life Cycle Operating Efficiency Reduction From Baseline, % ³ | 0.0 | 4.3 | 8.5 | 12.8 | 17.0 | 21.3 | 25.5 |
| Percent Life Cycle Energy Cost Savings, % ⁴ | NA | 3.1 | 6.6 | 10.3 | 14.5 | 19.0 | 24.2 |

- Notes: ¹ Derived from Table 5-2
² Derived from Table 5-1
³ Derived from Table 5-3
⁴ Derived from Table 5-4

Table 5-2. Energy costs as a function of water hardness for instantaneous water heaters.

| Cost of Natural Gas Over The Life of an Instantaneous Gas Water Heater | | | | | | | |
|---|-----------------|--------------------|-----------|-----------|-----------|-----------|-----------|
| Water Hardness, grains/gallon | 0 | 5 | 10 | 15 | 20 | 25 | 30 |
| Water Inlet Temperature, F | 46.6 | 46.6 | 46.6 | 46.6 | 46.6 | 46.6 | 46.6 |
| Set Point Temperature, F | 136.6 | 136.6 | 136.6 | 136.6 | 136.6 | 136.6 | 136.6 |
| Life of Water Heater, Years | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| Efficiency at Beginning | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 |
| Efficiency at Delimiting | NA ¹ | 72.0 | 72.0 | 72.0 | 72.0 | 72.0 | 72.0 |
| Natural Gas Used, mmBtu | 256.5 | 270.3 ² | 270.4 | 270.3 | 270.4 | 270.3 | 270.3 |
| Natural Gas Price, \$/mmBtu | \$10 | \$10 | \$10 | \$10 | \$10 | \$10 | \$10 |
| Cost of Natural Gas, \$ | \$2,565 | \$2,703 | \$2,704 | \$2,703 | \$2,704 | \$2,703 | \$2,703 |
| Added Cost Without Softener | \$0 | \$138 | \$138 | \$138 | \$138 | \$137 | \$138 |
| Delimiting Cost \$120 | \$0 | \$220 | \$439 | \$662 | \$878 | \$1,104 | \$1,324 |
| Additional Operating Costs | \$0 | \$358 | \$577 | \$799 | \$1,016 | \$1,242 | \$1,461 |

Table 5-4. Energy costs for operating a gas storage water heater as a function of water hardness.

| Cost of Natural Gas Over The Life of A Gas Storage Water Heater | | | | | | | |
|--|----------|----------|-----------|-----------|-----------|-----------|-----------|
| Water Hardness, grains/gallon | 0 | 5 | 10 | 15 | 20 | 25 | 30 |
| Water Inlet Temperature, F | 71.8 | 71.8 | 71.8 | 71.8 | 71.8 | 71.8 | 71.8 |
| Set Point Temperature, F | 161.8 | 161.8 | 161.8 | 161.8 | 161.8 | 161.8 | 161.8 |
| Life of Water Heater, Years | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| Efficiency at Beginning | 70.4 | 70.4 | 70.4 | 70.4 | 70.4 | 70.4 | 70.4 |
| Efficiency at End | 70.4 | 66.3 | 62.2 | 58.1 | 54.0 | 49.8 | 45.7 |
| Natural Gas Used, mmBtu | 291.5 | 300.7 | 310.7 | 321.6 | 333.7 | 347.0 | 362.0 |
| Natural Gas Price, \$/mmBtu | \$10 | \$10 | \$10 | \$10 | \$10 | \$10 | \$10 |
| Cost of Natural Gas, \$ | \$2,915 | \$3,007 | \$3,107 | \$3,216 | \$3,337 | \$3,470 | \$3,620 |
| Added Cost Without Softener | \$0 | \$92 | \$192 | \$301 | \$422 | \$555 | \$705 |

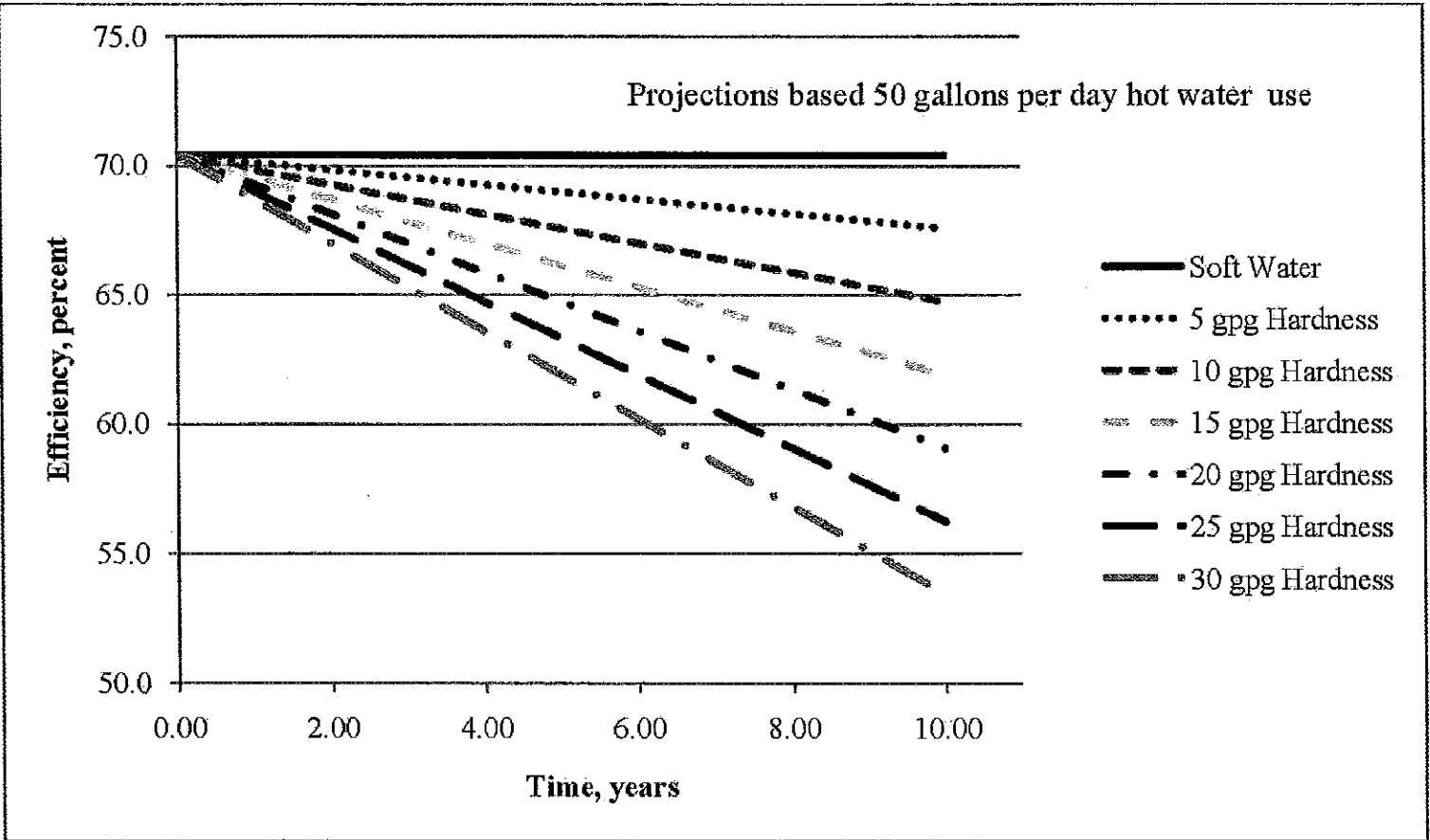


Figure 5-12. Predicted efficiency of a gas storage water heaters operating on soft water (0 grains per gallon) versus one operating on unsoftened water with a hardness of 30 grains per gallon.