Payback Analysis of Design Options for Residential Water Heaters

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ABSTRACT

This paper describes the results of an analysis to determine the costs of increased energy efficiency for residential water heaters. In this study, cost and efficiency data were developed for a total of 23 design options for typical tank sizes applied to one or more of three water heater product classes, i.e., electric, gas-fired, and oil-fired.

This analysis used computer simulation models and other analytical methods to investigate the efficiency improvements due to design options and combinations of designs. The calculations were based on the U.S. Department of Energy (DOE) test procedure for residential water heaters. The analysis included two insulation blowing agents based on non-ozone-depleting substances - HFC-245fa and water-blown. The analysis used average manufacturer, distributor, and installer costs to calculate the costs of different water heater designs. Consumer operating expenses were calculated based on modeled energy consumption and U.S. average energy prices. With this information, a cost-efficiency relationship was developed to show the average manufacturer and consumer cost to achieve increased efficiency. The results provided the engineering basis for DOE's proposed efficiency standard for residential water heaters. These data were subsequently used in the Life-Cycle Cost and National Energy Savings components of the appliance standards rulemaking process.

Introduction

The National Appliance Energy Conservation Act of 1987 (NAECA) requires the U.S. Department of Energy (DOE) to consider amendments to the energy conservation standards to increase efficiency in residential water heaters. Residential water heating represents a large opportunity for savings because it uses about 2.6 quads of the total of 19 quads per year primary energy (year 1997) used in residential buildings at an annual cost of $26.4 billion. Two additional driving forces affecting water heater energy efficiency are the issue of flammable vapors in gas-fired water heaters and ozone-depletion regulations regarding blowing agents for insulation in all water heater fuel types.

For the analysis, the following steps were applied: 1) identify design options that are expected to increase energy efficiency, 2) quantify the expected improvements in energy efficiency, and 3) estimate consumer costs to purchase, install, operate, and maintain the higher efficiency water heaters. This method was applied to residential electric, gas-fired, and oil-fired water heaters of a typical size, i.e., 50-gal (190-l) electric, 40-gal (150-l) gas-fired, and 32-gal (190-l) oil-fired.

"Price efficiency results" were presented to demonstrate increased cost and efficiency due to design options and combinations of design options within each product class of residential water heaters. The analysis used computer simulation models for electric and gas-fired water heaters and a spreadsheet model for oil-fired water heaters to investigate the efficiency improvements of design options and combinations of design options. All calculations were based on DOE's test procedure for measuring the energy factor of residential water heaters (CFR 1998).

The studied design options were ranked by payback period. Payback period measures the amount of time needed to recover the additional consumer investment in increased efficiency through lower operating costs. National average energy prices (in 1998$), $0.0788/kWh for electricity and $6.42/MMBtu for natural gas, taken from Annual Energy Outlook 1999 (EIA 1999), were used for the payback calculations. Manufacturers' cost data for the design options were obtained from Gas Appliance Manufacturers Association (GAMA 1998) and an industry consultant (Minnier. M.,1998). Additionally, retailers and installers around the country provided retail prices and installation costs of water heaters. The retail price of the water heater equipment and the installation cost are detailed in the Water Heater Price Database (DOE 1999). The total installed cost was developed by adding sales tax and manufacturer, distributor, and installer markups on to factory costs.

The analysis' results showed a cost-efficiency relationship between manufacturer and consumer costs and increased efficiency. Results of this analysis were used to select and rank order the combination of design options for the Life-Cycle Cost Analysis in the standards rulemaking process (DOE 2000).

Overall Analytical Approach

Existing water heater efficiency standards have been in effect since 1991. Overall energy efficiency is measured in terms of an energy factor (EF) and is determined by the DOE test procedure. Current standards call for an EF = 0.93 - (0.00132 x rated volume) for electric; an EF = 0.62 - (0.0019 x rated volume) for gas-fired; and EF = 0.59 - (0.0019 x rated volume) for oil-fired water heaters.

The starting point for analyzing design options for energy efficiency improvements were baseline units. For each product class, the baseline unit was one that just meets the existing standard. Table 1 shows characteristics of the baseline unit for each of the three primary product classes.

Table 1. General Characteristics of Water Heaters Baseline Units

Characteristics	Electric	Gas	Oil
Rated Volume	50-gallon (190-l)	40-gallon (150-l)	32 gallon (120-l)
Insulation Blowing Agent	HCFC-141b	HCFC-141b	HCFC-141b
Insulation Thickness (nom.)	1.5 in. (3.8 cm)	1 in. (2.5 cm)	1 in. (2.5 cm)
Rated Input	4,500 W	40,000 Btu/hr (11,700 W)	90,000 Btu/hr (26,000 W)
Ignition System	N/A	Pilot at 450 Btu/hr (120W)	Interrupted Ignition
Energy Factor (EF)	0.86	0.54	0.53
Recovery Efficiency (RE)	98%	76%	75%

Two actions by Federal agencies outside of the efficiency standards process affected these analyses. First, manufacturers reached an agreement with the Consumer Product Safety Commission (CPSC) to produce gas-fired water heaters resistant to igniting flammable vapors. This design was assumed to have no impact on efficiency, but would increase the price of all gas-fired water heaters. Second, the U.S. Environmental Protection Agency (EPA) required a phase-out by January 1, 2003 of the ozone-depleting hydrochlorofluorocarbon (HCFC-141b) blowing agent currently used by the water heater industry for polyurethane insulation. This requirement will affect the efficiency of all water heaters because of the different physical properties of the new insulation. Two alternative blowing agents, water and hydrofluorocarbon 245fa (HFC-245fa), were considered in this analysis. Published laboratory measurements (see Table 2) of the properties of water heater insulation blown with water or HFC-245fa were used (Fanney,Zarr, Ketay-Paprocki,1999).

Table 2. Water Heater Insulation Characteristics w/ Different Blowing Agents

	w/ HCFC-141b	w/ HFC-245fa	w/ Water
Insulation conductivity	0.000233 Btu/ft·min·°F (0.02420 W/m·K)	0.000240 Btu/ft·min·°F (0.024922 W/m·K)	0.000331 Btu/ft·min·°F (0.034327 W/m·K)

A distinction was made between baseline models containing current technologies and future baseline models that were expected to incorporate the two new mandated features. The current technologies were referred to as "existing" baseline models and the future technologies as "2003" baseline models (the year when new efficiency standards are proposed to take effect).

The energy performance for each of the three classes of water heaters were modeled with either a computer simulation program or a simplified calculation method. The computer simulations were used to determine the energy-efficiency characteristics of the water heater (e.g., EF, Recovery Efficiency (RE), and standby heat loss coefficient, (UA)), based on the DOE test procedure. For the electric water heater analysis, the analysis used WATSIM, a electric water heater simulation program (Hiller 1992). For the gas-fired water heater analysis, the procedure used the TANK simulation tool (Paul 1993). A simplified water heater analysis model (WHAM) was used for the analysis for oil-fired water heaters (Lutz 1999).

Computer simulations of existing baseline models for all three fuel types used characteristics of water heaters recently available on the market and included specifications described for baseline models (see Table 1). The 2003 baseline models used foam insulation blown with water or HFC-245fa. Although the cost of water-blown insulation was lower than the cost of HFC-245fa, it was also 42% less effective as an insulation compared to HCFC-141b as a blowing agent. By comparison, HFC-245fa was projected to be 2.5 times more costly than HCFC-141b, but it was only 3% less effective as insulation blown with HCFC-141b. To model the 2003 baseline electric water heater with the alternative blowing agents so that they still meet current efficiency standards, the foam insulation thickness was increased to 2.12 in. for water and 1.55 in. for HFC-245fa. To keep the energy characteristics of the new baselines for gas-fired water heaters equivalent to the HCFC-141b baseline, the foam insulation thickness was increased from 0.981 in. to 1.31 in. for water and 1.0 in. for HFC-245fa. For the oil-fired water heater baseline for the alternative blowing agents, the foam insulation thickness was increased from 0.981 in. to 1.41 in. for water and 1.01 in. for HFC-245fa.

Design Option Selection and Modeling Methodology

Table 3 shows the design options analyzed for each water heater class. Only design options already in use or that have been tested as prototypes were analyzed.

Table 3. Water Heater Design Options

Design Option	Electric	Gas	Oil
Heat Trap	Yes	Yes	Yes
Insulation Thickness	2", 2.5", 3"	2", 2.5", 3"	2", 2.5", 3"
Insulated Tank Bottom	Foamed disk/bottom	N/A	N/A
Plastic Tank	Steel Shell & Plastic Liner	Only with Side Arm Heater	N/A
Increased HX Area	N/A	N/A	82% RE
Improved Flue Baffle	N/A	78% RE & 80% RE	78% RE
Electromech Flue Damper	N/A	Yes	N/A
Electronic Ignition, IID	N/A	Yes	N/A
Side Arm Heater	N/A	Yes	N/A
Interrupted Ignition	N/A	N/A	Yes

Design options that improve the efficiency of water heaters were grouped into two categories: 1) those that reduce standby losses and 2) those that improve combustion efficiency.

Designs Option for All Water Heaters

Designs that reduce standby losses—heat traps and increased jacket insulation—are frequently applicable to all fuel types. A heat trap prevents losses associated with the circulation of hot water into the water heater plumbing when hot water is not being drawn and thus minimizing standby heat loss. To model the impacts of heat traps for water heaters, the natural convection heat transfer losses at the supply and draw lines were reduced.

Manufacturers insulate water heaters by filling the cavity between the jacket and the tank with polyurethane foam insulation. Most water heaters on the market today have at least 1-inch thick foam insulation, while some models have 2- or 3-inch thick insulation. Although increasing the insulation thickness reduced standby heat loss, the increased overall diameter of the water heater could pose shipping cost increases and installation problems.

Other design options reduce standby losses, but are usually unique to a given water heater class.

Designs Option for Electric Water Heaters

Plastic water heater tanks reduce conducted heat. There are several methods for constructing plastic water heater tanks. This analysis models a thin steel shell with an internal plastic tank. The lower heat conductivity of the plastic compared to steel reduces the heat conducted through the tank wall to the insulation. (Plastic tanks cannot be used with center-flue gas-fired water heaters because they cannot withstand the high temperatures produced by the flames.)

The bottom of the tank can be insulated but only in electric (or indirect gas-fired, e.g., side arm) water heaters. Insulating the bottom of electric water heater tanks reduces standby loss. A foamed "disk/bottom insulation" assembly is used for the tank bottom insulation. The bottom insulation portion of the disk/bottom insulation assembly reduces the heat losses from the bottom of the tank, and the disk portion reduces conductive heat losses through the perimeter rim of the tank bottom.

Designs Option for Gas- or Oil-Fired Water Heaters

A damper installed on the flue of gas-fired water heaters minimizes off-cycle heat losses. During off-cycle, a gas-fired water heater loses heat by natural convection up the flue. A damper can minimize off-cycle heat losses. A flue damper was modeled by adjusting the off-cycle pressure loss coefficient. Electromechanical flue dampers were considered only in conjunction with electronic ignition systems.

Unlike standing pilots that consume gas continuously, electric ignition devices operate only at the beginning of each on-cycle. Although no increase exists in steady-state efficiency with use of electronic ignition devices, overall fuel consumption may be reduced. Burner on-time may increase to make up for the heat the standing pilot would have supplied during standby periods. Total on-cycle power consumption includes the power draw of the gas valve, control module, and electronic thermostat. The only off-cycle power consumption is the electronic thermostat.

The side arm heater design on gas-fired water heaters uses a separate heat exchanger to heat water and a small circulation pump. This design avoids large flue losses by removing the flue from the center of the tank. Water is withdrawn from the bottom of the tank, heated by a burner in a small, separate heat exchanger, and returned to the top of the tank. A small circulation pump moves water through the heat exchanger when the burner is on. The basic design incorporates an intermittent pilot ignition device and 1 in. (2.56 cm) of HFC-245fa or 1.31 in (3.33 cm) of water-blown insulation and were analyzed with three REs: 76%, 78%, and 80%. The calculation was based on the WHAM energy calculation method.

Two design options were considered that improve combustion efficiency. The first was increased heat exchange from a flue baffle. A flue baffle is a twisted strip of metal inserted into the flue of a gas or oil water heater that improves heat transfer to the flue wall. Flue, in this context, refers to the "internal gas passageway" inside fuel-fired water heaters. A flue baffle with optimized geometry can increase RE from 76% to as much as 85%, depending on the specific geometry. This analysis considered REs of 78% and 80%. In the case of oil-fired water heaters, the flue losses were reduced during on-time only. Existing oil-fired water heaters have REs ranging from 75% to 83%.

The second design, increased heat exchanger surface area using multiple flues, improves heat transfer from the flue gas to the water. This design option was applied to oil-fired water heaters only. It is based on a design which uses small fins on the inner flue surface to increase the heat-transfer area and turbulence. Its energy performance was modeled by increasing the RE of the 2003 baseline model from 0.75 to 0.82.

Manufacturer Costs

Once the design options and the combinations of design options were selected, the costs to manufacturers and consumers were determined, then the design options were rank ordered according to least cost per unit of energy savings. These analyses used the incremental costs of adding design options to a baseline model. Manufacturer cost estimates were for a 50-gallon electric water heater, a 40-gallon gas-fired water heater and a 32-gallon oil-fired water heater and were expressed on a per-unit basis as an incremental cost over the existing baseline design.

Cost estimates for existing baseline models—an electric water heater with 1.5 in. (3.8 cm) of jacket insulation and a gas-fired water heater with 1 in. (2.5 cm) of jacket insulation, both using HCFC-141b as a blowing agent—were supplied by GAMA. The cost of an existing baseline oil-fired water heater was provided by industry consultants.

To convert the baseline manufacturer costs associated with foam insulation blown with HCFC-141b to insulation blown with HFC-245fa or with water, the amount and cost of materials associated with varying thicknesses of insulation were estimated. Material costs for the HCFC-141b foam insulation is $1/lb ($2.2/kg) and for the sheet metal, $0.30/lb ($0.66/kg). It was assumed manufacturers will maintain the thermal resistance of their baseline model when switching from HCFC-141b to an alternative insulation. In Table 4, it can be seen that the actual thickness level for 1.5 in. or 1 in. of HFC-245fa and water-blown insulation are greater than for HCFC-141b because of the higher conductivity.

Table 4. Baseline Model Manufacturer Costs

Design	Total Mfg Cost *($)*
Electric Water Heater	
Existing Baseline w/ 141b - 1.5 in (3.81 cm)	121.73
2003 Baseline w/ 245fa - 1.55 in (3.94 cm)	123.87
2003 Baseline w/ water - 2.12 in (5.38 cm)	131.54
Gas-fired Water Heater	
Existing Baseline w/ 141b - 0.981 in (2.49 cm)	133.78
2003 Baseline w/ 245fa - 1.00 in (2.54 cm)	169.89
2003 Baseline w/ water - 1.31 in (3.33 cm)	172.98
Oil-fired Water Heater	
Existing Baseline w/ 141b - 0.981 in (2.49 cm)	139.25
2003 Baseline w/ 245fa - 1.01 in (2.57 cm)	140.27
2003 Baseline w/ water - 1.41 in (3.54 cm)	144.16

Table 4 presents manufacturer cost estimates for the baseline water heaters with HCFC-141b, HFC-245fa, and water-blown insulation. The material costs for the 2003 baseline models include the difference in material costs between HCFC-141b and HFC-245fa and between HCFC-141b and water-blown models. In addition, in order to resist the ignition of flammable vapors, the manufacturing cost of gas-fired water heaters includes a $35 charge.

Tables 5a and 5b summarize manufacturers cost for incorporating different design options into baseline water heaters. GAMA provided most of the design option manufacturer costs with the exception of those associated with oil-fired water heaters, plastic tanks, and side-arm heaters, which were provided by industry consultants.

Manufacturer costs for heat traps for electric and gas-fired water heaters differed slightly due to the differences in production volume. Higher manufacturer cost for heat traps used in oil-fired water heaters reflected the smaller production volume and design differences. Costs included heat traps on both the supply and draw lines.

Manufacturer cost data provided for jacket insulation included increases from a baseline level to a thickness of 2.0 in. only. This costs, modified for both HFC-245fa and water-blown foam, was used to approximate the costs for 2.5-in. (6.4-cm) and 3-in. (7.6-cm) of insulation. In the case of water- blown insulation for electric water heaters, no cost was estimated for 2.0-in. insulation, because the 2003 baseline model already had an insulation thicker than 2.0 in.

Manufacturer costs for the insulated tank bottom and plastic tank electric water heater designs were based on data provided by industry consultants. The plastic tank design costs included an amount required to convert baseline production to the new design and was based on an assumed baseline model production volume of 40,000 units per year.

The cost provided for the improved flue baffle design for gas-fired water heaters was only for increasing the RE to 78%. It was assumed that the cost to increase RE to 80% was the same as the cost to increase the RE to 78%. The largest component of the manufacturing cost increase was product design.

Manufacturer costs for electronic ignition were based on replacing a standing pilot with an intermittent pilot ignition device. The cost of the electronic ignition system was based entirely on data from GAMA. In the case of oil-fired water heaters, the reported cost reflected the change from intermittent ignition to an interrupted ignition system. The electromechanical flue dampers were only analyzed with electronic ignition systems.

The manufacturer costs for six types of side arm heater designs are also summarized in Table 5b; 76%, 78%, and 80% RE designs that use a metal tank and 76%, 78% and 80% RE designs using a plastic tank. It was assumed that the cost difference between the 76% and 78% RE designs and between the 76% and 80% RE designs are the same as the cost of the improved flue baffle design. This assumption meant heat exchanger costs for a 78% RE design would be higher than those for a 76% RE design. It was also assumed that the cost to switch from a 76% RE design to an 80% RE design was equivalent to the cost to switch to a 78% RE design. The incremental manufacturer costs associated with all six side arm design options included electronic ignition.

Table 5a. Incremental Manufacturer Costs for Water Heater Design Options

Design		Total Incremental Mfg Costs (per unit) ($) Electric	Gas-fired	Oil-fired
Heat Traps		4.01	3.32	4.67
HFC-245fa:	Incr. Insulation - 2.0 in	17.40	16.59	15.31
	Incr. Insulation - 2.5 in	29.73	28.09	20.38
	Incr. Insulation - 3.0 in	44.50	42.63	25.60
Water-blown:	Incr. Insulation - 2.0 in	-	11.72	4.85
	Incr. Insulation - 2.5 in	13.60	24.33	14.04
	Incr. Insulation - 3.0 in	27.15	38.14	18.71

Table 5b. Incremental Manufacturer Costs for Water Heater Design Options

Design		Total Incremental Mfg Costs (per unit) ($) Electric	Gas-fired	Oil-fired
Insulated Tank Bottom		3.91	-	-
Plastic Tank		27.25	-	-
Improved Flue Baffle		-	6.44	62.90
Electronic Ignition (IID)		-	62.26	80.40
Metal Tank:	76% RE Side Arm Heater	-	105.13	-
	78% RE Side Arm Heater	-	111.57	-
	80% RE Side Arm Heater	-	111.57	-
Plastic Tank:	76% RE Side Arm Heater	-	118.98	-
	78% RE Side Arm Heater	-	125.42	-
	80% RE Side Arm Heater	-	125.42	-
Increased HX Area		-	-	146.35

Retail Price, Installation, and Maintenance Costs

Retail price was defined as the cost to the consumer of the water heating equipment only. Retail price of a baseline water heater was a function of the length of the manufacturer's warranty. Baseline models had up to six-year warranties. All price data came from the Water Heater Price Database, which contains information from more than 130 retail stores, wholesale distributors, and plumbing contractors on more than 1100 water heater models.

The median retail price for a baseline 50-gallon (190-liter) electric storage water heater was $181.58. The manufacturer cost of an existing electric baseline water heater was $121.73. Dividing the median retail price ($181.58) by the manufacturer cost ($121.73) yielded a manufacturer cost-to-retail price markup of 1.49. The median retail price for a baseline 40-gallon (150-liter) gas-fired storage water heater was $163.00. The manufacturer cost of an existing gas-fired baseline water heater was $133.78. Dividing the median retail price ($163.00) by the manufacturer cost ($133.78) yielded a manufacturer cost-to-retail price markup of 1.22. The estimated consumer cost for a baseline 32-gal (120-l) oil-fired water heater, without a burner, was $446. The estimated manufacturing cost was $139.25. The typical manufacturer-to-retail markup was 3.2. National average sales tax was assumed to be 5%.

A constant baseline manufacturer cost-to-retail price markup was assumed for all of design options considered here. The retail price for any modified design was determined by multiplying the manufacturer cost by the derived markup and adding a 5% sales tax.

The installation and maintenance costs were part of the total installed cost. The median installation cost for the 50-gallon baseline electric water heater was $155, for the 40-gallon baseline gas-fired water heater, $159, and for 32-gallon oil-fired water heater, $491. No extra maintenance costs were associated with baseline electric and gas-fired water heaters with the exception of the side-arm design, which was estimated at $14.73 per year for the circulation pump failures. Typical annual maintenance cost for a baseline oil-fired water heater was $97.14.

Efficiency Potentials and Payback Periods

The goal of this analysis was to estimate the energy savings potential and costs of individual design options and combinations of design options. The approach used was to add individual design options or combinations of design options to the baseline unit. First, a set of design combinations for all three fuel types and for the two "2003" insulations was established. The analysis then developed a cost-efficiency relationship to show the manufacturer and consumer cost to achieve increased efficiency. The following describe the combinations of design options which were found by the analysis to be the most technologically feasible and economically justified.

For electric water heaters using the blowing agent HFC-245fa, the highest EF attainable was 0.912, achieved using heat traps, 3-in. (7.6-cm) jacket insulation, an insulated tank bottom, and a plastic tank. The payback period for this design was 8.21 years compared to a baseline unit (EF 0.86). Energy savings were 250 kWh/yr (a 5% savings compared to a baseline unit). Models incorporating heat traps, 2.5 in. insulation, and an insulated tank bottom had an EF of 0.901 and a payback of 3.69 years. This design saved 203 kWh/yr (4.1%) in electricity. For water-blown insulation, the highest EF attainable was 0.894, achieved with heat traps, 3-in. (7.6-cm) jacket insulation, an insulated tank bottom, and a plastic tank. The payback period for this design was 9.86 years and energy savings were173 kWh/yr (3.5%). Models incorporating heat traps, 2.5-in. insulation, and an insulated tank bottom had an EF of 0.883 and a payback of 3.67 years. This design saved 117 kWh/yr (2.4%).

For gas-fired water-heaters using HFC-245fa as the blowing agent, the highest EF attainable was 0.715, achieved by using a side arm design, electronic ignition, an improved flue baffle (80% RE), a plastic tank, 3-in. (7.6-cm) jacket insulation, and heat traps. The payback period for this design was 10.3 years compared to a baseline unit (EF 0.54). Energy savings were 7.70 million Btu/year (27.5%). Models incorporating heat traps, 2 in. insulation, and 78% RE had an EF of 0.592 and a payback of 3.27 years. This design saved 1.93 million Btu/year (6.7%). For water-blown insulation, the highest EF attainable was 0.706, achieved with a side arm design, electronic ignition, 80% RE, a plastic tank, 3-in. (7.6-cm) jacket insulation, and heat traps. The payback period for this design was 10.7 years and energy savings were 7.42 million Btu/year (26.6%). Models incorporating heat traps, 2 in. insulation, and 78% RE had an EF of 0.583 and a payback of 3.26 years. This design saved 1.63 million Btu/year (5.7%).

For oil-fired water heaters using HFC-245fa as the blowing agent, the highest EF attainable was 0.614, achieved by using intermittent ignition, 82% RE, 3-in. (7.6-cm) jacket insulation, and heat traps. The payback period for this design was 15.5 years compared to a baseline unit (EF 0.53). Energy savings were 3.6 million Btu/year (12.9%). Models using heat traps only had the shortest payback period of 6.1 years and an EF of 0.535. This design saved 0.31 million Btu/year (1.1%). For water-blown insulation, the highest EF attainable was 0.6058, achieved with an intermittent ignition, 82% RE, 3-in. (7.6-cm) jacket insulation, and heat traps. The payback period for this design was 15.1 years with energy savings of 3.4 million Btu/year (12.1%). The design option using 2 in. insulation had an EF of 0.537 and a payback of 4.62 years. This design saved 0.43 million Btu/year (1.5%).

The results showed that energy efficiency measurements could be increased by 6 EF points for electric, 17 EF points for gas-fired, and 9 EF points for oil-fired water heaters. Figures 1, 2, and 3 depict a simple payback period and EF for the selected design options. The two curves present the payback in years vs. the energy factor for water heaters with HFC-245fa and water-blown insulation. For purposes of comparison, lifetimes of water heater average 12 years for electric and 9 years for both gas-fired and oil-fired water heaters.

Conclusions

This study determined the costs of increased energy efficiency for residential water heaters by developing price and efficiency data for design options and combinations of design options for each type of water heater. It rank ordered design options based on the shortest payback period.

The results show that in the case of electric and gas-fired water heaters, the HFC-245fa based insulation shows an overall higher efficiency and lower payback period compared to water-blown insulation for the same design options. Even though the water-blown insulation is less expensive, its impact on the energy efficiency of the water heater is lower due to its higher conductivity. A payback of less than 4 years is considered an acceptable criteria for a cost-effective design option.

For electric water heaters with HFC-245fa insulation, it was possible to achieve energy factors as high as 0.90 with an energy savings of about 5% and a payback of about 4 years. For water-blown insulation, the energy factor could reach 0.88 with an energy savings of about 2.4% and a 4-year payback. For gas-fired water heaters with HFC-245fa insulation, it was possible to achieve an energy factor of 0.59, with an energy savings of about 6.7% and a payback of about 3.3 years. For water blown insulation, the energy factor could reach 0.58 with energy savings of about 5.7% and a 3.3-year payback. For oil-fired water heaters with HFC-245fa insulation, the efficiency level with an energy factor of 0.54 would have an energy savings of about 1.1 % and a payback of more than 6 years. For water blown insulation, an energy factor of 0.54 would have an energy savings of about 1.5 % and a 4.6-year payback.

From these results, it can be concluded that significant improvements in energy efficiency can be achieved for electric and gas-fired water heaters with economic benefits to consumers.

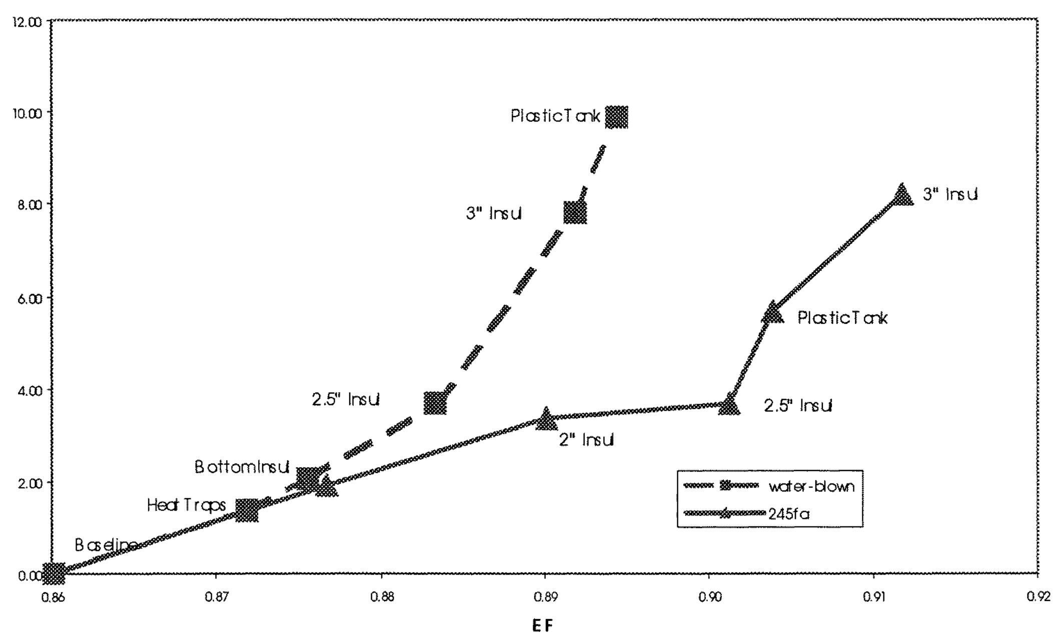

Figure 1. Payback vs. Energy Factor: Electric Water Heaters, 50-gal (190 l)

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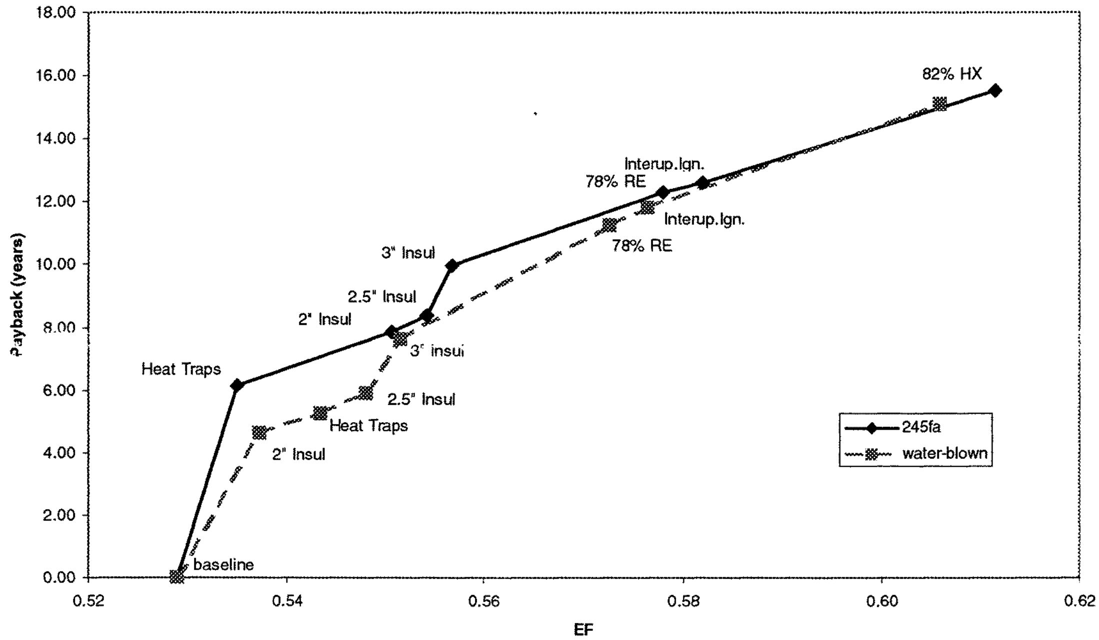

Figure 2. Payback vs. Energy Factor: Oil-Fired Water Heaters, 32-gal (120 l)

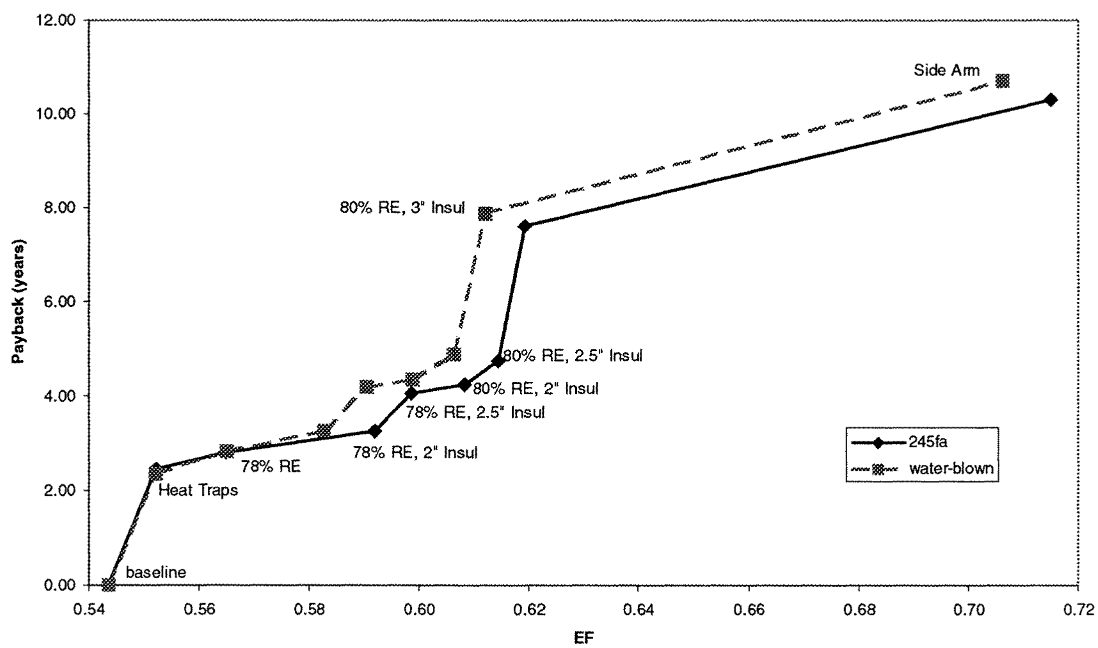

Figure 3. Payback vs. Energy Factor: Gas-Fired Water Heaters, 40-gal (150 l)

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