CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

8.1 INTRODUCTION

The effect of amended standards on individual customers usually includes a reduction in operating cost and an increase in purchase cost. This chapter describes two metrics used in the analysis to determine the economic impact of standards on individual residential consumers.

- Life-cycle cost (LCC) is the total customer cost over the life of an appliance or product, including purchase costs and operating costs (which in turn include maintenance, repair, and energy costs). Future operating costs are discounted to the time of purchase and summed over the lifetime of the appliance or product.
- Payback period (PBP) measures the amount of time it takes customers to recover the assumed higher purchase price of more energy-efficient products through reduced operating costs.

The U.S. Department of Energy (DOE) conducted the LCC and PBP analysis using a spreadsheet model developed in Microsoft Excel. When combined with Crystal Ball (a commercially available software program), the LCC and PBP model generates a Monte Carlo simulation to perform the analysis by incorporating uncertainty and variability considerations in certain of the key parameters as discussed below.

Inputs to the LCC and PBP analysis of furnace fan products are discussed in sections 8.2 and 8.3 respectively. Results for each metric are presented in section 8.4. Key variables and calculations are presented for each metric. The calculations discussed here were performed with a series of Microsoft Excel spreadsheets that are accessible over the Internet (http://www1.eere.energy.gov/buildings/appliance_standards/residential/furnace_fans.html).

Details of the spreadsheets and instructions for using them are discussed in appendix 8-A.

8.1.1 General Approach for Life-Cycle Cost and Payback Period Analyses

In recognition of the fact that each building using furnace fans is unique, variability and uncertainty are analyzed by performing the LCC and PBP calculations detailed here for a representative sample of individual households and commercial buildings. The results are expressed as the number of buildings experiencing economic impacts of different magnitudes. The LCC and PBP model was developed using Microsoft Excel spreadsheets combined with Crystal Ball. The LCC and PBP analysis explicitly model both the uncertainty and the variability in the model's inputs using Monte Carlo simulation and probability distributions.

The LCC analysis used the estimated energy use for each furnace fan unit as described in the energy use characterization analysis in chapter 7 of the preliminary technical support document (TSD). Energy use of furnace fans is sensitive to climate and therefore varies by location within the United States. An important feature of the LCC and PBP analysis is that it has been conducted at both the regional and national level. Aside from energy use, other important factors influencing the LCC and PBP analysis include energy prices, installation costs, product distribution markups, and sales taxes. At both the national and the regional level, the LCC spreadsheets explicitly modeled both the uncertainty and the variability in the model's inputs, using probability distributions based on the shipment of products to different regions of the country.

As mentioned above, DOE generated LCC and PBP results as probability distributions using a simulation based on Monte Carlo analysis methods, in which certain key inputs to the analysis consist of probability distributions rather than single-point values. Therefore, the outcomes of the Monte Carlo analysis can also be expressed as probability distributions. As a result, the Monte Carlo analysis produces a range of LCC and PBP results. A distinct advantage of this type of approach is that DOE can identify the percentage of customers achieving LCC savings or attaining certain PBP values due to an increased efficiency level, in addition to the average LCC savings or average PBP for that efficiency level.

The LCC and PBP results are displayed as distributions of impacts compared to a market baseline. As described in chapter 7, the market baseline efficiency level is for 2018 and is defined as a mix of furnace fan efficiency levels reflecting the current distribution of efficiency levels purchased by product class. Results are presented at the end of this chapter. A variety of graphic displays can be created to illustrate the implications of the analysis. Examples of graphic displays are (1) a cumulative probability distribution showing the percentage of furnace fan product in U.S. residential and commercial buildings that would experience a net LCC savings, and (2) a cumulative frequency chart depicting variation in PBP for each furnace fan efficiency level considered.

8.1.2 Overview of Life-Cycle Cost and Payback Period Analyses Inputs

The LCC is the total customer cost over the life of the product, including purchase price (including retail markups, sales taxes, and installation costs), and operating cost (including repair costs, maintenance costs, and energy cost). Future operating costs are discounted to the time of purchase and summed over the lifetime of the product. The PBP is the increase in purchase cost of a higher efficiency product divided by the change in annual operating cost (as a result of lower energy consumption) of the product. It represents the number of years that it will take the customer to recover the increased purchase cost through decreased operating costs. In the calculation of PBP, future costs are not discounted.

Inputs to the LCC and PBP analysis are categorized as follows: (1) inputs for establishing the purchase cost, otherwise known as the total installed cost; and (2) inputs for calculating the operating cost (*i.e.*, energy, maintenance, and repair costs).

The primary inputs for establishing the total installed cost are:

- *Baseline manufacturer selling price*: The baseline manufacturer selling price (MSP) is the price charged by the manufacturer to either a wholesaler or customer for product meeting existing minimum efficiency (or baseline) standards. The MSP includes a markup that converts the cost of production (*i.e.*, the manufacturer cost) to a MSP.

- *Standard-level manufacturer selling price increase*: The standard-level MSP is the incremental change in MSP associated with producing product at each of the higher standard levels.
- *Markups and sales tax*: Markups and sales tax are the wholesaler and contractor margins and state and local retail sales taxes associated with converting the MSP to a customer price.
- *Installation cost*: Installation cost is the cost to the customer of installing the product. The installation cost represents all costs required to install the product but does not include the marked-up customer product price. The installation cost includes labor, overhead, and any miscellaneous materials and parts. Thus, the total installed cost equals the customer product price plus the installation price.

The primary inputs for calculating the operating cost are:

- *Product energy consumption*: The product energy consumption is the site energy use associated with the use of the furnace fan units to provide space conditioning to the building.
- *Energy Prices*: Electricity, natural gas, liquid petroleum gas (LPG), and fuel oil prices are determined using average monthly energy prices.
- *Electricity, natural gas, and fuel oil price trends*: The Energy Information Administration's (EIA's) *Annual Energy Outlook 2012* (*AEO 2012*) is used to forecast electricity prices into the future.[1] For the results presented in this chapter, DOE used the *AEO 2012* reference case to forecast future energy prices.
- *Maintenance costs*: The labor and material costs associated with maintaining the operation of the product (*e.g.*, cleaning heat exchanger coils and drain pans, changing air filters).
- *Repair costs*: The labor and material costs associated with repairing or replacing components that have failed.
- *Lifetime*: The age at which the central air conditioner and furnace product is retired from service.
- *Discount rate*: The rate at which future costs are discounted to establish their present value. Figure 8.1.1 graphically depicts the relationships between the installed cost and operating cost inputs for the calculation of the LCC and PBP.

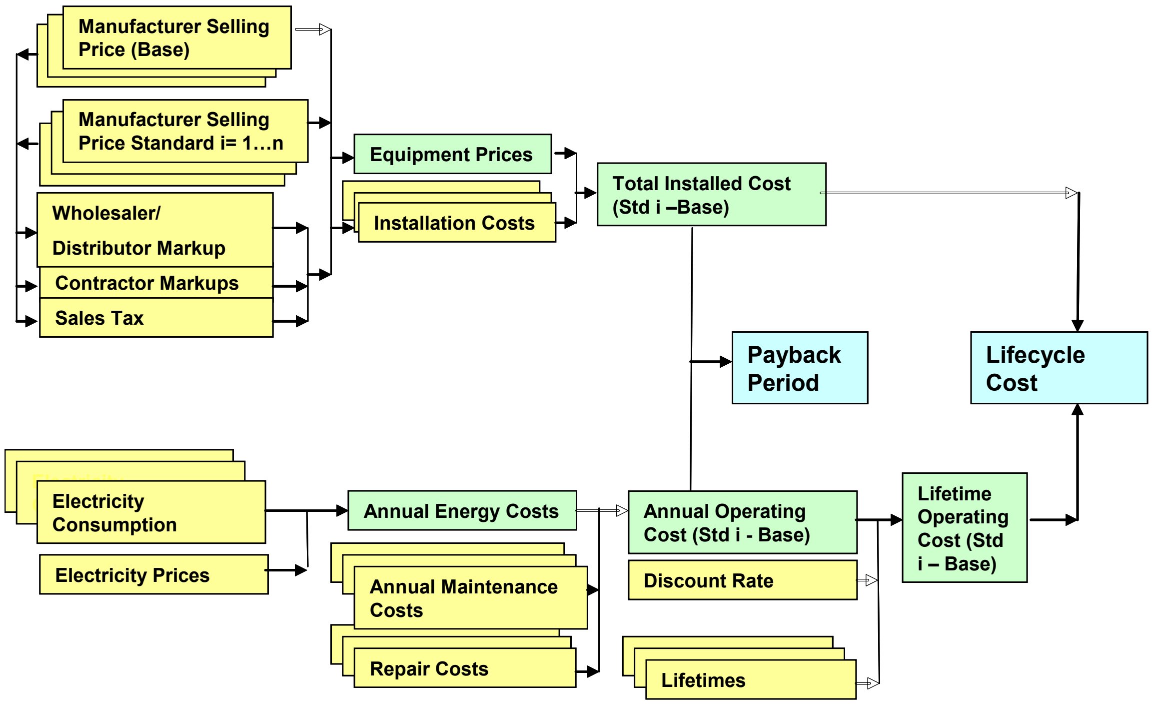

Figure 8.1.1 Flow Diagram of Inputs for the Determination of LCC and PBP

Table 8.1.1 provides descriptions of the various inputs to the calculation of the LCC and PBP. As noted earlier, most of the inputs are characterized by probability distributions that capture variability in the input variables.

Table 8.1.1 Summary of Inputs and Key Assumptions Used in the LCC and PBP Analysis

Inputs	Description
Affecting Installed Costs	
Product Price	Derived MSP for furnace fan units at different heating and air conditioning input capacities (from the engineering analysis) and multiplied by wholesaler markups and contractor markups plus sales tax (from markups analysis). Used the probability distribution for the different markups to describe their variability.
Installation Cost	Includes installation labor derived from *RS Means CostWorks 2012* and *RS Means Residential Cost Data 2012*. Overhead and materials costs and profits are assumed to be included in the contractor's markup. Thus, the total installed cost equals the consumer product price (manufacturer cost multiplied by the various markups plus sales tax) plus the installation cost.
Affecting Operating Costs	
Annual Energy Use	See chapter 7.
Energy Efficiency	The fan efficiency ratio (FER) is the efficiency descriptor for furnaces fan. Furnace and air conditioning test procedure algorithms as well as furnace fan performance characteristics are used to determine the annual energy consumption associated with a particular standard level.
Energy Prices	For residential furnace fan equipment customers, costs were calculated for

	RECS 2005 households from monthly marginal average electricity and natural gas, LPG, or fuel oil prices in each 27 states and groups of states in RECS 2009. Residential prices were escalated by the *AEO 2012* forecasts to estimate the future electricity prices. Escalation was performed at the census division level and aggregated to the regions used in the study.
Maintenance Cost	The cost associated with maintaining the operation of the product (*e.g.*, checking blower). Annual maintenance cost does not change as a function of MSP.
Repair Cost	Estimated the annualized repair cost for baseline efficiency furnace product, based on costs of major repair (motor replacement), from a variety of published sources. It is assumed that repair costs would vary in direct proportion with the MSP at higher efficiency levels, because it generally costs more to replace components that are more efficient.
Affecting Present Value of Annual Operating Cost Savings	
Product Lifetime	Used the probability distribution of lifetimes developed for furnaces.
Discount Rate	Mean real discount rates ranging from 0 percent to 10.7 percent for various classes of residential customers based on Federal Reserve Board's *Survey of Consumer Finances*. Probability distributions are assumed for the discount rates.
Date Standards Become Effective	2018 (5 years after expected publication of the final rule)

All of the inputs depicted in Figure 8.1.1 and summarized in Table 8.1.1 are discussed in sections 8.2 and 8.3.

8.1.3 Use of Residential Energy Consumption Survey in Life-Cycle Cost and Payback Period Analysis

The LCC and PBP calculations detailed here are for a representative sample of individual households and commercial buildings. All furnace equipment is assumed to be for residential buildings.

The 2005 RECS[2] serves as the basis for determining the representative sample. The 2005 RECS is based on a sample of 4,382 households that were surveyed for information on their housing units, energy consumption and expenditures, stock of energy-consuming appliances, and energy-related behavior. Information was also collected on certain demographic and economic characteristics of household members. The information collected represents all households nationwide—approximately 111 million. RECS is conducted every 3 years with data collected directly from energy end users. The RECS consists of three parts:

- Personal interviews with households for information about energy used, how it is used, energy-using appliances, structural features, energy efficiency measures, and demographic characteristics of the household.
- Telephone interviews with rental agents for households that have any of their energy use included in their rent. This information augments information collected from those

households that may not be knowledgeable about the fuels used for space heating or water heating.

- Mail questionnaires sent to energy suppliers (after obtaining permission from households) to collect the actual billing data on energy consumption and expenditures.

Of the 4,382 households surveyed in the 2005 RECS, 1,726 households representing 41.0% of the housing population have a gas furnace (non-weatherized or weatherized), 576 representing 16.1% of the housing population have an electric furnace, 109 representing 2.3% of the housing population have a manufactured home gas furnace, 150 representing 2.5% of the housing population have an oil-fired furnace, and 68 representing 1.9% of the housing population have a manufactured home electric furnace[a]. Using the households in RECS that utilize each type of furnace, LCC and PBP analysis are performed on a household-by-household basis to determine whether an increase in the minimum efficiency standard is economically justified. Each RECS household has an associated household weight representing the number of similar households in the nation.

Of the inputs necessary for the LCC and PBP analysis, there are three inputs that are based on data from the 2005 RECS: (1) space-conditioning annual energy consumption (RECS-based), (2) product efficiency, and (3) average electricity price. All of these inputs are used in determining the operating cost. With the exception of product efficiency, each household in RECS with a furnace has a unique value for the space-conditioning annual energy consumption, the average electricity price, and the marginal electricity price. In other words, the annual energy consumption and average electricity price associated with a particular RECS household are not uncertain and are, therefore, not expressed with probability distributions. Although those three input variables are not uncertain, they are extremely variable. Due to the large number of households considered in the LCC and PBP analysis (almost 2,000 for furnaces), the range of annual energy use, average electricity price, and marginal electricity price is quite large. Thus, although the above three input variables are not uncertain for any particular household, their variability across all households contributes significantly to the range of LCCs and PBPs calculated for any particular standard level.

8.2 LIFE-CYCLE COST ANALYSIS INPUTS

Life-cycle cost is the total customer cost over the life of a product, including purchase cost and operating costs (which are composed of energy costs, maintenance costs, and repair costs). Future operating costs are discounted to the time of purchase and summed over the lifetime of the product. Life-cycle cost is defined by the following equation:

$$LCC = IC + \sum_{t=1}^{N} OC_t / (1+r)^t \qquad \textbf{Eq. 8.2.1}$$

Where:

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[a] RECS does not provide a direct way of determining which households are using hydronic air handlers.

LCC = life-cycle cost ($),
IC = total installed cost ($),
$\sum$ = sum over the lifetime, from year 1 to year N, where N = lifetime of product (years),
OC = operating cost ($),
r = discount rate, and
t = year for which operating cost is being determined.

DOE expresses all the costs in 2011$. Total installed cost, operating cost, lifetime, and discount rate are discussed in the following sections. In the LCC analysis, the year of product purchase is assumed to be 2018, the effective date of the energy conservation standards for furnace fans.

8.2.1 Total Installed Cost Inputs

The total installed cost to the customer is defined by the following equation:

$$IC = EQP + INST \qquad \textbf{Eq. 8.2.2}$$

Where:

EQP = product price ($) (*i.e.*, customer price for the product only), and
$INST$ = installation cost or the customer price to install product ($) (*i.e.*, the cost for labor and materials).

The product price is based on the distribution channel through which the customer purchases the product. As discussed in chapter 6, Markups for Product Price Determination, DOE defined one major distribution channel for new units to describe how the product passes from the manufacturer to the customer: the manufacturer sells the product to a wholesaler or distributor, who sells to a mechanical contractor hired by a general contractor. The general contractor purchases and installs the product on behalf of the customer and adds its markup to the mechanical contractor's price. Replacement products follow the same distribution channel, except that there is no general contractor. Instead, the mechanical contractor takes on the general contractor's function.

The remainder of this section provides information about the variables DOE used to calculate the total installed cost for furnace fan products.

8.2.1.1 Manufacturer Costs

DOE developed the manufacturer costs for furnace fans as described in chapter 5, Engineering Analysis. The manufacturer costs at each efficiency level are shown in Table 8.2.1 and Table 8.2.2.

Table 8.2.1 Manufacturer Production Cost for Non-Hydronic Furnace Fans by Efficiency Level

Efficiency Level		Total Cost (2011$)	Incremental Cost (2011$)
0	Baseline PSC	$69	N/A
1	Improved PSC	$71	$3
2	PSC w/controls	$80	$16
3	X13	$92	$31
4	Electronically commutated motor (ECM) + Multi-Stage	$161	$124
5	ECM w/ backward-curved (BC) Impeller	$176	$144

Table 8.2.2 Manufacturer Production Cost for Hydronic Furnace Fans by Efficiency Level

Efficiency Level		Total Cost (2011$)	Incremental Cost (2011$)
0	Baseline PSC	$84	N/A
1	Improved PSC	$91	$9
2	PSC w/controls	$101	$22
3	X13	$122	$50
4	ECM + Multi-Stage	$191	$144
5	ECM w/BC Impeller	$206	$165
6	Switching mode power supply	$213	$175
7	Toroidal Transformer	$225	$189

8.2.1.2 Markups

For a given distribution channel, the overall markup is the value determined by multiplying all the associated markups and the applicable sales tax together to arrive at a single overall distribution chain markup value. The overall markup is multiplied times the baseline or standard-compliant MSP (including transportation) to arrive at the price paid by the customer. Because there are baseline and incremental markups associated with the wholesaler and mechanical contractor, the overall markup is also divided into a baseline markup (*i.e.*, a markup used to convert the baseline manufacturer price into a customer price) and an incremental markup (*i.e.*, a markup used to convert a standard-compliant MSP increase due to an efficiency increase into an incremental customer price). Markups can differ depending on whether the product is being purchased for a new construction installation or is being purchased to replace an existing product. DOE developed the overall baseline markups and incremental markups for both new construction and replacement applications as a part of the markups analysis (chapter 6 of the TSD).

Based on the percentages of the market attributed to each distribution channel, Table 8.2.3 and Table 8.2.4 display the weighted-average overall markups and their associated components for the baseline and incremental markups, respectively.

Table 8.2.3 National Average Baseline Markups

Factor	New Construction Application	Replacement Application
Wholesale Markup	1.362	1.362
Mechanical Contractor Markup	1.280	1.380
General Contractor Markup	1.480	N/A*
Sales Tax	1.073	1.073
Total Markup	2.767	2.016

* General contractors do not appear in the replacements distribution channel

Table 8.2.4 National Average Incremental Markups

Factor	New Construction Application	Replacement Application
Wholesale Markup	1.091	1.091
Mechanical Contractor Markup	1.024	1.104
General Contractor Markup	1.347	N/A*
Sales Tax	1.073	1.073
Total Markup	1.614	1.292

* General contractors do not appear in the replacements distribution channel

Because the relative importance of new construction and replacements in total shipments varies among the product classes, the total markup varies as well (Table 8.2.5).

Table 8.2.5 Overall Markup for Furnace Fans by Product Class

Product Class	Baseline Markup	Incremental Markup
Non-Weatherized, Non-Condensing Gas Furnaces	2.49	1.59
Non-Weatherized, Condensing Gas Furnaces	2.45	1.54
Weatherized Gas Furnace	2.46	1.57
Oil Furnace	2.30	1.46
Electric Furnace / Modular Blower	2.41	1.54
Manufactured Home Non-Weatherized, Non-Condensing Gas Furnaces	3.04	2.35
Manufactured Home Non-Weatherized, Condensing Gas Furnaces	2.96	2.29
Manufactured Home Electric Furnace /Modular Blower	2.95	2.28
Hydronic Air Handler (Heat/Cool)	2.62	1.65

8.2.1.3 Total Consumer Price

DOE derived the consumer product price for the efficiency levels above the baseline by taking the product of the baseline manufacturer cost and the baseline markup index (including the sales tax) and adding to it the product of the incremental manufacturer cost and the incremental markup index (including the sales tax). Markups and the sales tax all can take on a variety of values, depending on location, so the resulting total installed cost for a particular efficiency level will not be a single-point value, but rather a distribution of values.

Table 8.2.6 and Table 8.2.7 present the consumer product price for each furnace product class at each efficiency level examined.

Table 8.2.6 Total Consumer Price for Furnace Fans Used in HVAC Products Other than Hydronic Air Handlers (2011$)

	Efficiency Level					
Key Product Class	**0**	**1**	**2**	**3**	**4**	**5**
	Baseline PSC	Improved PSC	PSC w/ Controls	X13	ECM + Multi-Stage	ECM + Backward -curved Impeller
Non-weatherized, Non-condensing Gas Furnace Fan	$236	$240	$261	$290	$437	$470
Non-weatherized, Condensing Gas Furnace Fan	$241	$246	$265	$303	$447	$478
Weatherized Gas Furnace Fan	$237	$241	$261	$295	$441	$473
Oil Furnace Fan	$313	$327	$345	$433	$560	$590
Electric Furnace / Modular Blower Fan	$207	$211	$231	$232	$379	$411
Manufactured Home Non-weatherized, Non-condensing Gas Furnace Fan	$218	$224	$278	$313	$524	$554
Manufactured Home Non-weatherized, Condensing Gas Furnace Fan	$237	$243	$284	$317	$523	$564
Manufactured Home Electric Furnace / Modular Blower Fan	$177	$183	$253	$286	$491	$495

Table 8.2.7 Total Consumer Price for Furnace Fans Used in Hydronic Air Handlers (2011$)

	Efficiency Level							
Key Product Class	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
	Baseline PSC	Improved PSC	PSC w/ Controls	X13	ECM + Multi - Stage	ECM + Backward -curved Impeller	Switching Mode Power Supply	Toroidal Transformer
Hydronic Air Handler Fan (Heat/Cool)	$230	$246	$291	$338	$492	$513	$518	$543

8.2.1.4 Future Product Prices

In DOE's 2011 heating, ventilating, and air conditioning (HVAC) standards rulemaking, it derived a forecast of future furnace prices based on an analysis of the historic trend in the producer price index (PPI) for furnaces. DOE believes that using the same trend for furnace fans would not be appropriate, however, as the fan does not make up a major part of the total cost of a furnace. Because the fan motor is the most important component of the furnace fan, DOE believes that historic prices of electric motors provide a more reasonable basis for considering trends in the price of furnace fans.

DOE developed data on historic prices of electric motors in its preliminary analysis of standards for electric motors. DOE obtained historical PPI data for integral horsepower motors and generators manufacturing spanning the time period 1969-2010 from the Bureau of Labor Statistics' (BLS).[b] The PPI data reflect nominal prices, adjusted for product quality changes. An inflation-adjusted (deflated) price index for integral horsepower motors and generators manufacturing was calculated by dividing the PPI series by the Gross Domestic Product Chained Price Index (see Figure 8.2.1).

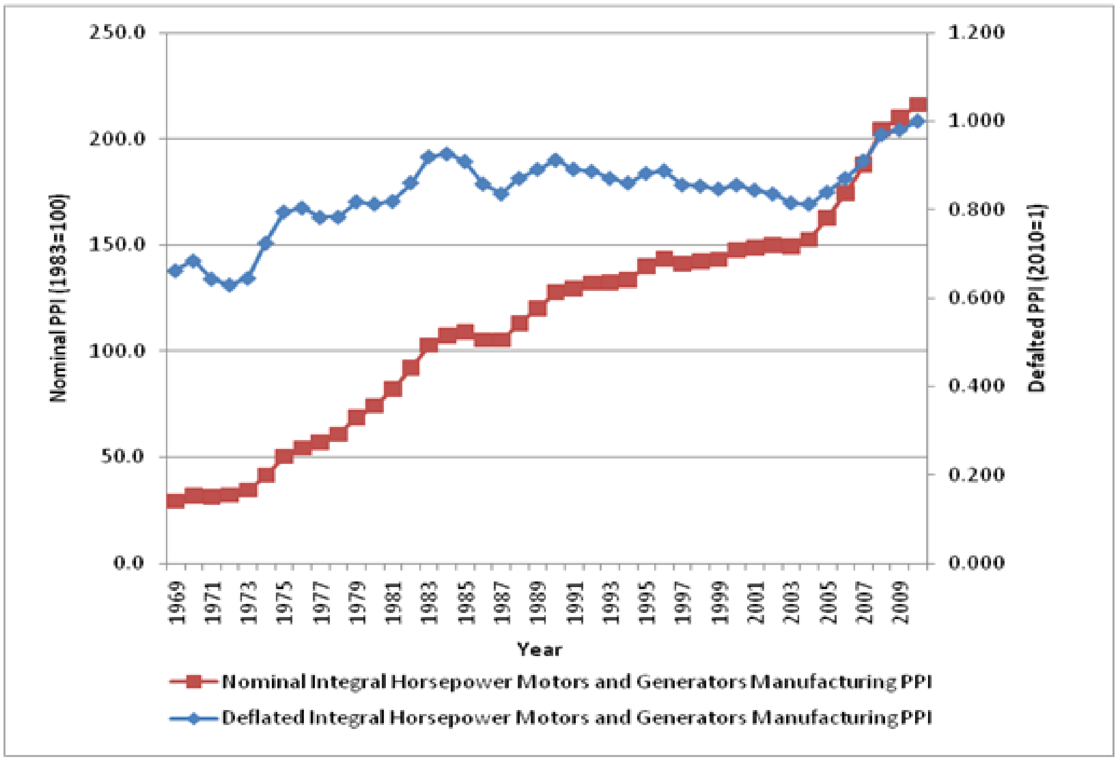

Figure 8.2.1 Historical Nominal and Deflated Producer Price Indexes for Integral Horsepower Motors and Generators Manufacturing

From the mid-1970s to 2005, the deflated price index for electric motors was roughly flat. Since then, the index has risen sharply, primarily due to rising prices of copper and steel products that are used in motors. The rising prices for copper and steel products were primarily a result of strong demand from China and other emerging economies. Given the slowdown in

[b] Series ID PCU3353123353123; http://www.bls.gov/ppi/

global economic activity in 2011, DOE believes that the extent to which the trends of the past five years will continue is very uncertain. DOE performed an exponential fit on the deflated price index for electric motors, but the R^2 was relatively low (0.5). DOE also considered the experience curve approach, in which an experience rate parameter is derived using two historical data series on price and cumulative production, but the time series for historical shipments was not long enough for a robust analysis.

Given the above considerations, DOE decided to use constant prices as the default price assumption to project future motor prices. DOE used the same assumption in its preliminary analysis for furnace fans. Thus, prices forecast for the LCC and PBP analysis are equal to the 2011 values for each efficiency level in each product class.

8.2.1.5 Installation Cost

Because the furnace fan is installed in the furnace in the factory, there is generally no additional installation cost at the home. However, ECM furnace fan design may require additional installation costs. DOE assumed that a fraction of the ECM furnace fan installations will require up to an hour of extra labor at startup to check and adjust airflow.

DOE's analysis of installation costs accounts for regional differences in labor costs. DOE estimated the installation costs using a variety of sources, including RS Means CostWorks 2012, manufacturer literature, and information from expert consultants. For a detailed discussion of the development of installation costs, see appendix 8-D, Installation, Repair, and Maintenance Cost Calculations.

8.2.1.6 Total Installed Cost

The total installed cost is the sum of the product price and the installation cost. DOE derived the consumer product price for any given efficiency level by taking the product of the baseline MSP and the baseline markup index (including the sales tax) and adding to it the product of the incremental MSP and the incremental markup index (including the sales tax). MSPs, markups, and the sales tax all can take on a variety of values, depending on location, so the resulting total installed cost for a particular efficiency level will not be a single-point value, but rather a distribution of values

Table 8.2.8 and Table 8.2.9 present the consumer product price for each furnace product class at each efficiency level examined.

Table 8.2.8 Total Installed Cost for Furnace Fans Used in HVAC Products Other than Hydronic Air Handlers (2011$)

	Efficiency Level					
Key Product Class	**0**	**1**	**2**	**3**	**4**	**5**
	Baseline PSC	Improved PSC	PSC w/ Controls	X13	ECM + Multi-Stage	ECM + Backward -curved Impeller
Non-weatherized, Non-condensing Gas Furnace Fan	$236	$240	$261	$293	$448	$480
Non-weatherized, Condensing Gas Furnace Fan	$241	$246	$265	$306	$459	$491
Weatherized Gas Furnace Fan	$237	$241	$261	$297	$451	$483
Oil Furnace Fan	$313	$327	$345	$437	$577	$607
Electric Furnace / Modular Blower Fan	$207	$211	$231	$235	$388	$420
Manufactured Home Non-weatherized, Non-condensing Gas Furnace Fan	$218	$224	$278	$314	$531	$561
Manufactured Home Non-weatherized, Condensing Gas Furnace Fan	$237	$243	$284	$319	$531	$572
Manufactured Home Electric Furnace / Modular Blower Fan	$177	$183	$253	$287	$497	$501

Table 8.2.9 Total Installed Cost for Furnace Fans Used in Hydronic Air Handlers (2011$)

	Efficiency Level							
Key Product Class	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
	Baseline PSC	Improved PSC	PSC w/ Controls	X13	ECM + Multi - Stage	ECM + Backward-curved Impeller	Switching Mode Power Supply	Toroidal Transformer
Hydronic Air Handler Fan (Heat/Cool)	$230	$246	$291	$341	$504	$525	$531	$555

8.2.2 Operating Cost Inputs

DOE defined the operating cost by the following equation:

$OC = EC + RC + MC$ **Eq. 8.2.3**

Where:

OC = operating cost ($),
EC = energy cost associated with operating the product ($),
RC = repair cost associated with component failure ($), and
MC = annual maintenance cost for maintaining product operation ($).

The remainder of this section provides information about the variables that DOE used to calculate the operating cost for furnace products. The annual energy costs of the product are computed from energy consumption per unit for the baseline and standard-compliant cases (efficiency level 2, 3, etc.), combined with the energy prices. Product lifetime, discount rate, and compliance date of the standard are required for determining the operating cost and for establishing the operating cost present value.

8.2.2.1 Annual Energy Use Savings

For each key product class, DOE calculated the annual energy use savings for each sample household at each efficiency level as described in chapter 7. DOE accounted for additional energy use required for space heating due to more-efficient furnace fans, as well as reduction in energy use required for air conditioning.

DOE considered the possibility that some consumers may use a higher-efficiency furnace fan more than a baseline furnace fan, thereby negating some or all of the energy savings from the more-efficient fan. Such change in behavior when operating costs decline is known as a rebound effect.

DOE reviewed an evaluation report from Wisconsin[c] that indicates that a considerable number of homeowners who purchase ECM furnaces significantly increase the frequency with which they operate their furnace fan subsequent to the installation of the ECM furnace. To estimate a rebound effect that would apply to the national household sample, DOE calculated a separate rebound effect for the north and for the south regions based on the expected increase of constant circulation fan use that can be expected for ECM furnaces.

The take-back in energy consumption associated with the rebound effect provides consumers with increased value (e.g., enhanced comfort associated with use of constant circulation). DOE believes that, if it were able to monetize the increased value to consumers of the rebound effect, this value would be similar in value to the foregone energy savings. Therefore, the economic impacts on consumers with or without the rebound effect, as measured in the LCC analysis, are the same.

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[c] State of Wisconsin, Public Service Commission of Wisconsin, Focus on Energy Evaluation Semiannual Report, Final: April 8, 2009.
http://www.focusonenergy.com/files/Document_Management_System/Evaluation/semiannualreport18monthcontractperiodfinalrevisedoctober192009_evaluationreport.pdf

8.2.2.2 Energy Prices

DOE derived average monthly energy prices for a number of geographic areas in the United States using the latest data from EIA and monthly energy price factors that it developed. DOE assigned an appropriate price to each household in the sample, depending on its location.

EIA Data. DOE derived 2010 annual electricity prices from EIA Form 826 data.[3] The EIA Form 826 data include energy prices by State. DOE calculated annual electricity prices for each geographical area by averaging monthly energy prices by State to get State electricity prices. For areas with more than one State, DOE weighted each State's average price by its number of households. Table 8.2.10 shows the average prices for each geographic area.

DOE obtained the data for natural gas prices from EIA's Natural Gas Navigator,[4] which includes monthly natural gas prices by State for residential, commercial, and industrial customers. For areas with more than one State, DOE weighted each State's average price by its number of households. Table 8.2.11 displays the 2010 annual natural gas prices.

Table 8.2.10 Average Residential Electricity Prices in 2010

Geographic Area	2011$/kWh
Connecticut, Maine, New Hampshire, Rhode Island, Vermont	$0.178
Massachusetts	$0.151
New York	$0.193
New Jersey	$0.170
Pennsylvania	$0.131
Illinois	$0.119
Indiana, Ohio	$0.111
Michigan	$0.128
Wisconsin	$0.131
Iowa, Minnesota, North Dakota, South Dakota	$0.106
Kansas, Nebraska	$0.099
Missouri	$0.094
Virginia	$0.108
Delaware, District of Columbia, Maryland, West Virginia	$0.135
Georgia	$0.103
North Carolina, South Carolina	$0.106
Florida	$0.118
Alabama, Kentucky, Mississippi	$0.101
Tennessee	$0.096
Arkansas, Louisiana, Oklahoma	$0.093
Texas	$0.120
Colorado	$0.114
Idaho, Montana, Utah, Wyoming	$0.089
Arizona	$0.111
Nevada, New Mexico	$0.120
California	$0.152
Oregon, Washington	$0.086
Alaska	$0.168
Hawaii	$0.290

Table 8.2.11 Average Residential Natural Gas Prices in 2010

Geographic Area	2011$/MMBtu
Connecticut, Maine, New Hampshire, Rhode Island, Vermont	$16.94
Massachusetts	$14.96
New York	$15.94
New Jersey	$13.71
Pennsylvania	$15.11
Illinois	$11.68
Indiana, Ohio	$13.42
Michigan	$12.58
Wisconsin	$11.28
Iowa, Minnesota, North Dakota, South Dakota	$10.24
Kansas, Nebraska	$12.66
Missouri	$16.78
Virginia	$15.96
Delaware, District of Columbia, Maryland, West Virginia	$15.57
Georgia	$19.63
North Carolina, South Carolina	$18.14
Florida	$19.67
Alabama, Kentucky, Mississippi	$14.93
Tennessee	$13.69
Arkansas, Louisiana, Oklahoma	$15.07
Texas	$13.16
Colorado	$9.07
Idaho, Montana, Utah, Wyoming	$9.12
Arizona	$18.03
Nevada, New Mexico	$12.37
California	$10.06
Oregon, Washington	$13.09
Alaska	$9.27
Hawaii	$44.90

DOE collected 2010 average LPG prices from EIA's 2010 State Energy Consumption, Price, and Expenditures Estimates (SEDS).[5] SEDS includes annual LPG prices for residential, commercial, industrial, and transportation consumers by state. For areas with more than one State, DOE weighted each State's average price by its number of households. See Table 8.2.12.

Table 8.2.12 Average Residential LPG Prices in 2010

Geographic Area	2011$/MMBtu
Connecticut, Maine, New Hampshire, Rhode Island, Vermont	$32.51
Massachusetts	$35.63
New York	$31.92
New Jersey	$35.37
Pennsylvania	$31.09
Illinois	$21.42
Indiana, Ohio	$24.96
Michigan	$23.66
Wisconsin	$20.47
Iowa, Minnesota, North Dakota, South Dakota	$20.28
Kansas, Nebraska	$20.14
Missouri	$21.04
Virginia	$31.30
Delaware, District of Columbia, Maryland, West Virginia	$32.38
Georgia	$26.71
North Carolina, South Carolina	$30.42
Florida	$37.29
Alabama, Kentucky, Mississippi	$26.86
Tennessee	$28.03
Arkansas, Louisiana, Oklahoma	$26.38
Texas	$28.75
Colorado	$23.16
Idaho, Montana, Utah, Wyoming	$23.92
Arizona	$32.40
Nevada, New Mexico	$29.65
California	$31.42
Oregon, Washington	$26.77
Alaska	$35.37
Hawaii	$58.88

DOE collected 2010 average fuel oil prices from EIA's SEDS.[5] SEDS includes annual fuel oil prices for residential, commercial, industrial, and transportation consumers by state. For areas with more than one State, DOE weighted each State's average price by its number of households. See Table 8.2.13.

Table 8.2.13 Average Residential Fuel Oil Prices in 2010

Geographic Area	2011$/MMBtu
Connecticut, Maine, New Hampshire, Rhode Island, Vermont	$21.67
Massachusetts	$22.52
New York	$23.00
New Jersey	$23.66
Pennsylvania	$21.92
Illinois	$21.72
Indiana, Ohio	$20.97
Michigan	$20.95
Wisconsin	$20.38
Iowa, Minnesota, North Dakota, South Dakota	$19.79
Kansas, Nebraska	$20.09
Missouri	$19.75
Virginia	$20.47
Delaware, District of Columbia, Maryland, West Virginia	$22.59
Georgia	$20.55
North Carolina, South Carolina	$20.91
Florida	$20.94
Alabama, Kentucky, Mississippi	$18.67
Tennessee	$20.28
Arkansas, Louisiana, Oklahoma	$18.46
Texas	$18.06
Colorado	$19.89
Idaho, Montana, Utah, Wyoming	$20.50
Arizona	$23.42
Nevada, New Mexico	$20.90
California	$23.78
Oregon, Washington	$22.81
Alaska	$21.95
Hawaii	$22.85

Monthly Prices. To determine monthly prices for use in the analysis, DOE developed monthly energy price factors for each fuel based on long-term price data. See appendix 8-B, Monthly Energy Price Factor Calculations for description of the method. DOE multiplied the annual prices shown in the above tables by the monthly price factors for each fuel to derive prices for each month.

Electricity and Natural Gas Marginal Prices. Electricity and natural gas prices were adjusted using seasonal marginal price factors to come up with monthly marginal electricity and natural gas prices. For a detailed discussion of the development of marginal energy price factors, see appendix 8-C, Seasonal Marginal Energy Price Factor Calculations.

8.2.2.3 Energy Price Trends

DOE used price forecasts by the EIA to estimate future trends in energy prices. To arrive at prices in future years, it multiplied the prices described in the preceding section by the forecast of annual average price changes in EIA's *AEO 2012 Early Release.*[6] Figure 8.2.2 shows the national residential electricity price trend. To estimate the trend after 2035, DOE followed past guidelines provided to the Federal Energy Management Program (FEMP) by EIA and used the average rate of change during 2020–2035 for electricity, natural gas, and LPG.

DOE used *AEO 2012* Reference Case scenarios for the nine census divisions. DOE applied the applied the energy price forecast for each of the nine census divisions to each household in the sample based on the household's location.

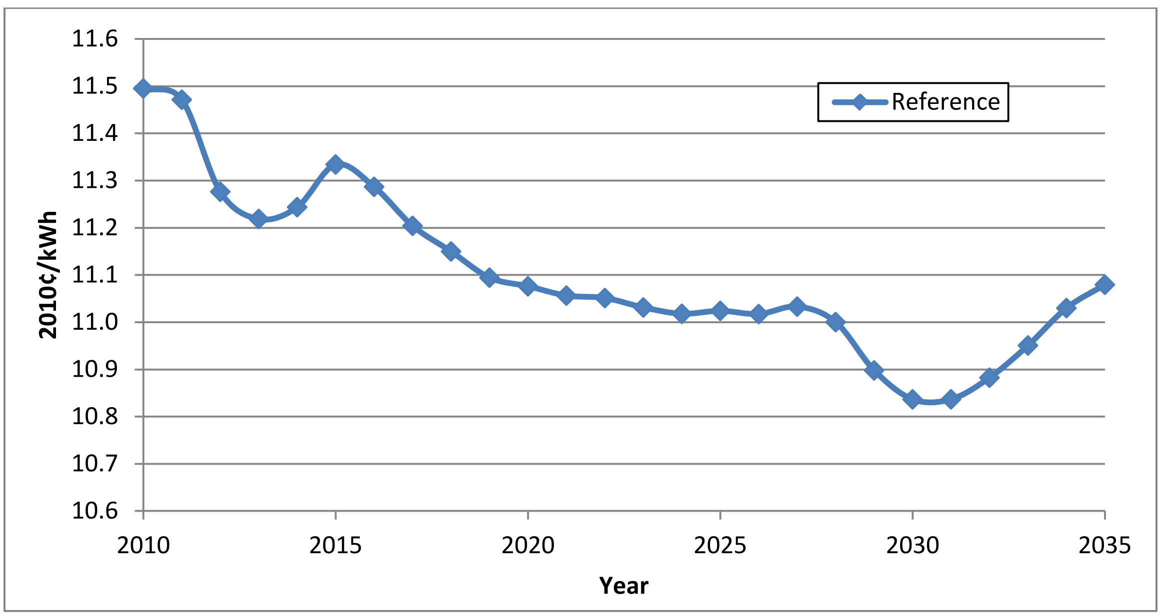

Figure 8.2.2 Electricity Price Forecast

8.2.2.4 Repair Cost

The repair cost is the cost to the consumer for replacing or repairing components in the furnace fan that have failed. DOE included motor replacement as a repair cost for a fraction of furnace fans. To estimate rates of motor failure, DOE developed a distribution of fan motor lifetime (expressed in operating hours) by motor size using data from DOE's analysis for small electric motors.[d] DOE then paired these data with the calculated number of annual operating hours for each sample furnace. Motor costs were based on costs developed in the engineering

[d] http://www1.eere.energy.gov/buildings/appliance_standards/commercial/sem_finalrule_tsd.html

analysis and the replacement markups developed in the markup analysis. DOE assumed that the motor cost does not apply if motor failure occurs during the furnace warranty period.

The repair costs at each considered efficiency level were based on *2010 RS Means Facility Repair and Maintenance Data*. DOE accounts for regional differences in labor costs. For a detailed discussion of the development of repair costs, see appendix 8-D, Installation, Repair, and Maintenance Cost Calculations.

Table 8.2.14 and Table 8.2.15 show the annualized repair cost estimates for each product class.

Table 8.2.14 Annualized Repair Cost for Furnace Fans Used in HVAC Products Other than Hydronic Air Handlers (2011$)

Key Product Class	Efficiency Level					
	0	1	2	3	4	5
	Baseline PSC	Improved PSC	PSC w/ Controls	X13	ECM + Multi-Stage	ECM + Backward -curved Impeller
Non-weatherized, Non-condensing Gas Furnace Fan	$13	$13	$14	$15	$20	$21
Non-weatherized, Condensing Gas Furnace Fan	$13	$13	$14	$15	$20	$20
Weatherized Gas Furnace Fan	$15	$16	$16	$18	$23	$25
Oil Furnace Fan	$15	$16	$16	$18	$23	$24
Electric Furnace / Modular Blower Fan	$14	$14	$15	$15	$21	$22
Manufactured Home Non-weatherized, Non-condensing Gas Furnace Fan	$12	$12	$13	$14	$19	$20
Manufactured Home Non-weatherized, Condensing Gas Furnace Fan	$13	$13	$14	$15	$20	$20
Manufactured Home Electric Furnace / Modular Blower Fan	$12	$12	$14	$15	$21	$21

Table 8.2.15 Annualized Repair Cost for Furnace Fans Used in Hydronic Air Handlers (2011$)

	Efficiency Level							
Key Product Class	0	1	2	3	4	5	6	7
	Baseline PSC	Improved PSC	PSC w/ Controls	X13	ECM + Multi - Stage	ECM + Backward -curved Impeller	Switching Mode Power Supply	Toroidal Transformer
Hydronic Air Handler Fan (Heat/Cool)	$17	$17	$19	$20	$26	$27	$27	$28

8.2.2.5 Maintenance Cost

The maintenance cost is the routine cost to the consumer of maintaining equipment operation. The regular furnace maintenance generally includes checking the furnace fan. DOE assumes that this maintenance cost is the same at all efficiency levels.

Labor hours and costs for annual maintenance was estimated using RS Means data. The frequency with which the maintenance occurs was derived from a consumer survey[7] on the frequency with which owners of different types of furnaces perform maintenance. For a detailed discussion of the development of maintenance costs, see appendix 8-D.

8.2.2.6 Lifetime

DOE defines lifetime as the age when a product is retired from service. Furnace fan lifetimes are considered to be equivalent to furnace lifetimes, so DOE modeled furnace fan lifetime based on estimated furnace lifetimes, which were developed for the recent furnace standards rulemaking.[e] In that analysis, DOE used national survey data, along with manufacturer shipment data, to calculate the distribution of furnace lifetimes. For a detailed discussion of the development of furnace fan lifetime, see appendix 8-E, Furnace Fan Lifetime Determination.

Table 8.2.16 shows the minimum, median, and average lifetime, as well as the Weibull distribution parameters alpha and beta for each product class. DOE assumed that the lifetime of a fan is the same at different efficiency levels.

Table 8.2.16 Lifetime Parameters for Furnace Fans

Product Class	Weibull Parameters				
	Minimum *years*	**Median** *years*	**Average** *years*	**Alpha (scale)**	**Beta (shape)**
Non-Weatherized Gas Furnace Fans (Condensing and Non-Condensing)	1	22.6	23.6	26.7	2.218
Manufactured Home Gas Furnace Fans (Condensing and Non-Condensing)	1	16.9	18.7	21.0	1.682
Oil-Fired Furnace Fans	1	26.3	26.5	29.7	3.019
Weatherized Gas Furnace Fans; Electric Furnace/Modular Blower Fans; Manufactured Home Electric Furnace/Modular Blower Fans; Hydronic Air Handlers	1	17.3	18.0	20.3	2.255

[e] http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_furnaces_cac_hp_direct_final_rule.html

8.2.2.7 Discount Rate

The discount rate is the rate at which future expenditures are discounted to establish their present value. DOE derived the discount rates for the LCC analysis by estimating the cost of capital for individuals and companies that purchase furnace fan products.

In the case of individual households, the financing of purchasing products installed in new homes is different from the financing of appliances bought directly by consumers *(i.e.*, as a replacement for a failed unit or as a new purchase for an existing household that does not already own the appliance). Thus, DOE used different discount rates for these residential purchases.

Discount Rates for Replacement Products Purchased by Existing Households

Households use various methods to finance the purchase of major appliances. In principle, one could estimate the interest rates on the actual financing vehicles used to purchase appliances. However, the frequency with which each financing vehicle is used to purchase an appliance is unknown.

DOE's approach involved identifying all possible debt or asset classes that might be used to purchase the considered appliances, including household assets that might be affected indirectly.[f] DOE excluded debt from primary mortgages and the equity of assets considered non-liquid (such as retirement accounts), because those financing methods are unlikely to be used by households in existing housing to purchase appliances. DOE estimated the average percentage shares of the various types of debt and equity in the average U.S. household using data from the Federal Reserve Board's *Survey of Consumer Finances (SCF)* for 1989, 1992, 1995, 1998, 2001, 2004, and 2007.[8] Table 8.2.17 shows the average percentages of each considered type of debt or equity. DOE derived the mean percentages of each source of financing for the 7 years surveyed.

[f] An indirect effect would arise if a household sold assets in order to pay off a loan or credit card debt that might have been used to finance the appliance purchase.

Table 8.2.17 Types of Household Debt and Equity by Percentage Shares

Type of Debt or Equity	Distribution %							
	1989	1992	1995	1998	2001	2004	2007	Mean
Home equity loan	4.3	4.5	2.7	2.8	2.8	4.4	4.6	3.7
Credit card	1.6	2.1	2.6	2.2	1.7	2.0	2.4	2.1
Other installment loan	2.8	1.7	1.4	1.7	1.1	1.3	1.1	1.6
Other residential loan	4.4	6.9	5.2	4.3	3.1	5.8	7.1	5.3
Other line of credit	1.1	0.6	0.4	0.2	0.3	0.5	0.3	0.5
Checking account	5.8	4.7	4.9	3.9	3.6	4.2	3.4	4.4
Savings or money market account	19.2	18.8	14.0	12.8	14.2	15.1	13.0	15.3
Certificate of deposit	14.5	11.7	9.4	7.0	5.4	5.9	6.5	8.6
Savings bond	2.2	1.7	2.2	1.1	1.2	0.9	0.7	1.4
Bonds	13.8	12.3	10.5	7.0	7.9	8.4	6.7	9.5
Stocks	22.4	24.0	25.9	36.9	37.5	28.0	28.6	29.0
Mutual funds	8.0	11.1	20.9	20.1	21.3	23.4	25.5	18.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Sources: Federal Reserve Board. *Survey of Consumer Finances (SCF)* for 1989, 1992, 1995, 1998, 2001, 2004, and 2007.

DOE also estimated interest or return rates associated with each type of equity and debt. The source for interest rates for loans, credit cards, and lines of credit was the Federal Reserve Board's Survey of Consumer Finances (SCF) for 1989, 1992, 1995, 1998, 2001, 2004, and 2007. Table 8.2.18 shows the average nominal rates in each year and the inflation factors used to calculate real rates. DOE calculated effective interest rates for home equity loans in a similar manner as for mortgage rates, because interest on both such loans is tax deductible. Table 8.2.19 shows the average effective real rates in each year and the mean rate across years. Because the interest rates for each type of household debt reflect economic conditions throughout numerous years, they are expected to be representative of rates that may be in effect in 2018.

Table 8.2.18 Average Nominal Interest Rates for Household Debt

Type of Debt	Average Nominal Interest Rate %							
	1989	1992	1995	1998	2001	2004	2007	Mean
Home equity loan	11.5	9.6	9.6	9.8	8.7	5.7	6.3	7.9
Credit card*	-	-	14.2	14.5	14.2	11.7	7.9	9.0
Other installment loan	9.0	7.8	9.3	7.8	8.7	7.4	12.6	13.4
Other residential loan	8.8	7.6	7.7	7.7	7.5	6.0	10.4	8.6
Other line of credit	14.8	12.7	12.4	11.9	14.7	8.8	6.3	7.4
Inflation rate	4.82	3.01	2.83	1.56	2.85	2.66	2.85	--

Sources: Federal Reserve Board. *Survey of Consumer Finances (SCF)* for 1989, 1992, 1995, 1998, 2001, 2004, and 2007.
* No data on interest rates available for credit cards in 1989 or 1992.

Table 8.2.19 Average Real Effective Interest Rates for Household Debt

Type of Debt	Average Real Effective Interest Rate %							
	1989	**1992**	**1995**	**1998**	**2001**	**2004**	**2007**	**Mean**
Home equity loan	3.8	4.3	4.4	5.8	3.8	1.9	2.1	3.0
Credit card*	-	-	11.0	12.7	11.1	9.1	3.3	3.9
Other installment loan	4.9	5.8	7.0	6.6	6.1	5.4	9.7	10.7
Other residential loan	4.0	4.7	4.8	6.0	4.6	3.3	5.8	6.0
Other line of credit	9.6	9.4	9.3	10.2	7.3	6.0	3.4	4.4

Sources: Federal Reserve Board. *Survey of Consumer Finances (SCF)* for 1989, 1992, 1995, 1998, 2001, 2004, and 2007.
* No data on interest rates available for credit cards in 1989 or 1992.

No similar rate data are available from the *SCF* for classes of assets, so the Department derived that information from national historical data. The interest rates associated with certificates of deposit,[9] savings bonds,[10] and bonds (AAA corporate bonds)[11] were collected from Federal Reserve Board time-series data for 1977–2011. DOE assumed rates on checking accounts to be zero. Rates on savings and money market accounts came from Cost of Savings Index data covering 1984–2011.[12] The rates for stocks are the annual returns on the Standard and Poor's 500 for 1977–20011.[13] Rates for mutual funds are a weighted average of the stock rates (two-thirds weight) and the bond rates (one-third weight) in each year for 1977–2011. DOE adjusted the nominal rates to real rates using the annual inflation rate for each year. Average nominal and real interest rates for the classes of household assets are listed in Table 8.2.20. Because the interest and return rates for each type of asset reflect economic conditions throughout numerous years, they are expected to be representative of rates that may be in effect in 2018.

Table 8.2.20 Average Nominal and Real Interest Rates for Household Equity

Type of Equity	Average Nominal Rate %	Average Real Rate %
Checking account	-	0.0
Savings and money market accounts	5.1	2.1
Certificate of deposit	6.1	2.0
Savings bond	7.4	3.3
Bonds	8.2	4.0
Stocks	11.8	7.6
Mutual funds	10.4	6.1

Table 8.2.21 summarizes the mean real effective rates of each type of equity or debt. DOE determined the average percentage of each type of debt and asset using SCF data for 1989, 1992, 1995, 1998, 2001, 2004, and 2007. Each year of SCF data provides the percentages of debts and assets for U.S. households. DOE averaged those percentages for the 7 years of survey

data to arrive at the percentages shown in Table 8.2.21. The average rate across all types of household debt and equity, weighted by the percentages of each type, is 5.0 percent.

Table 8.2.21 Average Interest on Household Debt and Equity

Type of Debt or Equity	Average Percentage of Household Debt plus Equity %*	Mean Effective Real Rate %**
Home equity loan	3.7	3.9
Credit card	2.1	10.7
Other installment loan	1.6	6.0
Other residential loan	5.3	4.4
Other line of credit	0.5	8.8
Checking account	4.4	0.0
Savings and money market account	15.3	2.1
Certificate of deposit	8.6	2.0
Savings bond	1.4	3.3
Bonds	9.5	4.0
Stocks	29.0	7.6
Mutual funds	18.6	6.1
Total/weighted-average discount rate	100.0	5.0

* Not including primary mortgage or retirement accounts.

** Adjusted for inflation and, for home equity loans, tax deduction of interest.

DOE developed a normal probability distribution of interest rates for each asset type by using the mean value and standard deviation from the distribution. To account for variation among households, DOE sampled a rate for each household from the distributions for the appropriate asset class. Appendix 8-F presents the probability distributions for each class that DOE used in the LCC and PBP analysis.

Discount Rates for Products Installed in New Housing

Appliances installed in new homes ("new-housing appliances") are purchased as part of the home, which is almost always financed with a mortgage loan. DOE estimated discount rates for new-housing appliances using the effective real (after-inflation) mortgage rate for homebuyers. This rate corresponds to the interest rate after deduction of mortgage interest for income tax purposes and after adjusting for inflation (using the Fisher formula).[g] For example, a 6% nominal mortgage rate has an effective nominal rate of 4.5% for a household at the 25% marginal tax rate. When adjusted for an inflation rate of 2%, the effective real rate becomes 2.45%.

The data sources DOE used for mortgage interest rates were the SCF in 1989, 1992, 1995, 1998, 2001, 2004, and 2007. Using the appropriate SCF data for each year, DOE adjusted

[g] Fisher formula is given by: Real Interest Rate = [(1 + Nominal Interest Rate) / (1 + Inflation Rate)] – 1.

the mortgage interest rate for each relevant household in the SCF for mortgage tax deduction and inflation (see Table 8.2.22). In cases where the effective interest rate is equal to or below the inflation rate (resulting in a negative real interest rate), DOE set the real effective interest rate to zero.

The average nominal mortgage rate carried by homeowners in these 6 years was 7.9%. As the mortgage rates carried by households in these years were established over a range of time, DOE believes they are representative of rates that may apply when amended standards take effect. After adjusting for inflation and interest tax deduction, effective real interest rates on mortgages across the six surveys averaged 3.0%.

Table 8.2.22 Data Used to Calculate Real Effective Mortgage Rates

Year	Mortgage Interest Rates in Selected Years %			
	Average Nominal Interest Rate	**Inflation Rate[14]**	**Marginal Tax Rate Applicable to Mortgage Interest[15]**	**Average Real Effective Interest Rate**
1989	9.7	4.82	24.3	2.4
1992	9.1	3.01	23.4	3.8
1995	8.2	2.83	24.1	3.3
1998	7.9	1.56	23.9	4.4
2001	7.6	2.85	22.9	2.9
2004	6.2	2.66	20.6	2.2
2007	6.3	2.85	21.6	2.1
Average	7.9			**3.0**

To account for variation among households, DOE sampled a rate for each household in the RECS samples from a distribution of mortgage rates. DOE developed the distribution based on the SCF data. Appendix 8-F presents the probability distribution that DOE used in the LCC and PBP analysis.

8.2.2.8 Compliance Date of Standard

Pursuant to 42 U.S.C. 6295(m), the compliance date of any new energy efficiency standard for furnace fans is 5 years after the final rule is published. Consistent with its published regulatory agenda, DOE assumed that the final rule would be issued in 2013 and that, therefore, the new standards would require compliance in 2018. DOE calculated the LCC and PBP for all consumers as if they each would purchase a new furnace fan in 2018.

8.2.2.9 Base Case Distribution of Efficiency Levels

DOE did not have access to sales data describing the actual distribution of efficiencies in current sales of furnaces, nor was specific information provided by industry for this analysis. DOE found very limited historical data upon which to estimate either current shares or recent trends. To start, DOE used Rheem's comment, stating that the market share for ECM motors has increased from 10 percent to 30 percent within the last five years.[16] To estimate the market share for ECM motors in 2018, DOE developed data on the share of models in each product class that are ECM design.[h] DOE believes that the current number of models is a reasonable indication of where the market may be in several years. The resulting estimate for 2018 is a 45 percent share for ECM fans out of the overall market for furnace fans. This level is consistent with the historical trend.

The market shares of each of the three ECM fan efficiency levels were derived from data on number of models. No such data were available for the PSC fan efficiency levels, so DOE assumed that half of shipments are at the baseline level and half are improved PSC fans. There are currently no models of PSC with controls design, so DOE assumed zero market share.

DOE made separate estimates of the ECM fan market shares in replacements and new homes using data from a Canadian survey in 2003.[17] The survey indicated that the market share of ECM fans in replacement applications was 3.7 times higher than the share in new homes.

Table 8.2.23 shows the market shares that were used in the LCC and PBP analysis for non-weatherized gas furnaces. The market shares used for the other key product classes may be found in the sheet "Base Case Fan Efficiency" in the furnace fan LCC spreadsheet posted on the DOE web site.

Table 8.2.23 Base Case Market Shares (2018) by Efficiency Level for Fans in Non-Weatherized Gas Furnaces

Efficiency Level	Non-Condensing		Condensing	
	Replacements (%)	New Homes (%)	Replacements (%)	New Homes (%)
Baseline PSC	34	46	18	41
Improved PSC	34	46	18	41
PSC w/controls	0	0	0	0
X13	14	4	26	7
ECM, variable speed	18	5	39	11
ECM w/BC impeller	0	0	0	0

8.2.2.10 Avoiding Double-Counting Savings Accounted for in Air Conditioner Standards Rulemaking

The fan electricity used for cooling operation or heat pump heating operation is part of the SEER and HSPF ratings for air conditioners and heat pumps. In the recent HVAC rulemaking,[i] the standard adopted by DOE accounted for savings from higher-efficiency central

[h] DOE used the AHRI Directory of Certified Furnace Equipment as well as manufacturer product literature.

[i] http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_furnaces_central_ac_hp_direct_final_rule_tsd.html

air conditioners (CAC) and heat pumps (HP) (above SEER 14) that incorporate an ECM fan. DOE has taken steps to avoid also counting those energy savings in this rulemaking for furnace fans.

DOE used the same base case efficiency distribution of CAC and HP efficiencies in this analysis as it used in the HVAC rulemaking. In the household sample, those households assigned a CAC or HP at 15 SEER or above would already have an ECM fan. This situation is reflected in the base case efficiency distribution used for furnace fans. Since the energy savings from the considered fan efficiency levels are measured relative to the base case efficiencies, any savings reported here are over and above those counted in the CAC and HP rulemaking.

8.3 PAYBACK PERIOD INPUTS

The PBP is the amount of time it takes the customer to recover the assumed higher purchase cost of more energy-efficient equipment as a result of lower operating costs. Numerically, the PBP is the ratio of the increase in purchase cost (*i.e.*, from a less efficient design to a more efficient design) to the decrease in annual operating expenditures. This type of calculation is known as a "simple" payback period, because it does not take into account changes in the operating cost value of money.

The equation for PBP is:

$$PBP = \Delta IC / \Delta OC \qquad \textbf{Eq. 8.3.1}$$

Where:

PBP = payback period in years,
Δ IC = difference in the total installed cost between the more efficient standard-level equipment (efficiency levels 2, 3, etc.) and the baseline efficiency equipment, and
ΔOC = difference in first year annual operating costs.

Payback periods are expressed in years. Payback periods greater than the life of the equipment mean that the increased total installed cost of the more efficient equipment is not recovered fast enough in reduced operating costs.

DOE also calculates a rebuttable PBP, which is the time it takes the consumer to recover the assumed higher purchase cost of more energy-efficient equipment as a result of lower energy costs. Numerically, the rebuttable PBP is the ratio of the increase in purchase cost (i.e., from a less efficient design to a more efficient design) to the decrease in annual energy expenditures; that is, the difference in first year annual energy cost as calculated from the DOE test procedure. The calculation excludes repair costs and maintenance costs.

The data inputs to PBP are the total installed cost of the equipment to the customer for each efficiency level and the annual (first year) operating costs for each efficiency level. The inputs to the total installed cost are the equipment price and the installation cost. The inputs to the operating costs are the annual energy cost, the annual repair cost, and the annual maintenance cost (or, in the case of rebuttable PBP, only the annual energy cost). The PBP uses the same inputs as the LCC analysis, except that electricity price trends and discount rates are not required. Since the PBP is a "simple" (undiscounted) payback, the required electricity cost is only for the year in which a new efficient standard is to take effect—in this case, 2018. The electricity price used in the PBP calculation was the price projected for 2018. Discount rates are not used in the PBP calculation.

8.4 LCC AND PBP RESULTS

As discussed previously, DOE's approach for conducting the LCC and PBP analysis relied on developing samples of households that use each of the products. DOE also characterized the uncertainty of many of the inputs to the analysis with probability distributions. DOE used a Monte Carlo simulation technique to perform the LCC and PBP calculations on the households in the sample. For each set of sample households using the equipment in each product class, DOE calculated the average LCC and LCC savings and the median and average PBP for each of the efficiency levels. These efficiency levels are also referred to as candidate standard levels (CSLs).

DOE calculated LCC savings and PBPs relative to the base case equipment that it assigned to the households. In some cases, DOE assigned base case equipment that is more efficient than the baseline and some of the CSLs. For that reason, in those cases the average LCC impacts are not equal to the difference between the LCC of a specific CSL and the LCC of the baseline product. DOE calculated the average LCC savings and the median PBP values by excluding the households that are not impacted by a standard at a given efficiency level.

LCC and PBP calculations were performed 10,000 times on the sample of households established for each residential product. Each LCC and PBP calculation was performed on a single household that was selected from the sample of the residential users. The selection of a household was based on its sample weight (*i.e.*, how representative a particular household is of other households in the distribution—either regionally or nationally) in the 2005 RECS Public Use Sample, as described in chapter 7 of the TSD. Each LCC and PBP calculation also sampled from the probability distributions that DOE developed to characterize many of the inputs to the analysis.

Based on the Monte Carlo simulations that DOE performed, for each standard level, DOE calculated the share of households receiving a net LCC benefit, a net LCC cost, and no impact. DOE considered a household to receive no impact at a given standard level if DOE assigned it base case equipment whose efficiency is the same as, or is more than, the CSL.

8.4.1 Non-Weatherized, Non-Condensing Gas Furnace Fans

Table 8.4.1 shows the LCC and PBP results for non-weatherized, non-condensing gas furnace fans.

Table 8.4.1 Non-Weatherized, Non-Condensing Gas Furnace Fans: LCC and PBP Results

		Life-Cycle Cost (2011$)			Life-Cycle Cost Savings				Payback Period (years)
						% Households with			
CSL	Technology Option	Average Installed Cost	Average Lifetime Operating Cost	Average LCC	Average Savings (2011$)	Net Cost	No Impact	Net Benefit	Median
0	Baseline (PSC)	236	1,354	1,590	N/A	0	100	0	N/A
1	Improved PSC	240	1,333	1,573	6	33	63	4	1.2
2	PSC w/ Controls	261	1,312	1,573	7	61	26	13	8.8
3	X13	293	967	1,260	240	24	26	50	3.7
4	ECM + Multi-Stage	448	1,056	1,503	31	64	15	21	20.5
5	ECM + Backward-Curved Impeller	480	984	1,463	71	67	0	33	15.9

Figure 8.4.1 shows the range of LCC savings for the efficiency levels considered for non-weatherized, non-condensing gas furnace fans. For each standard level, the top and the bottom of the box indicate the 75^{th} and 25^{th} percentiles, respectively. The bar at the middle of the box indicates the median; 50 percent of the households have lifecycle cost savings above this value. The 'whiskers' at the bottom and the top of the box indicate the 5^{th} and 95^{th} percentiles. The small box shows the average LCC savings for each standard level.

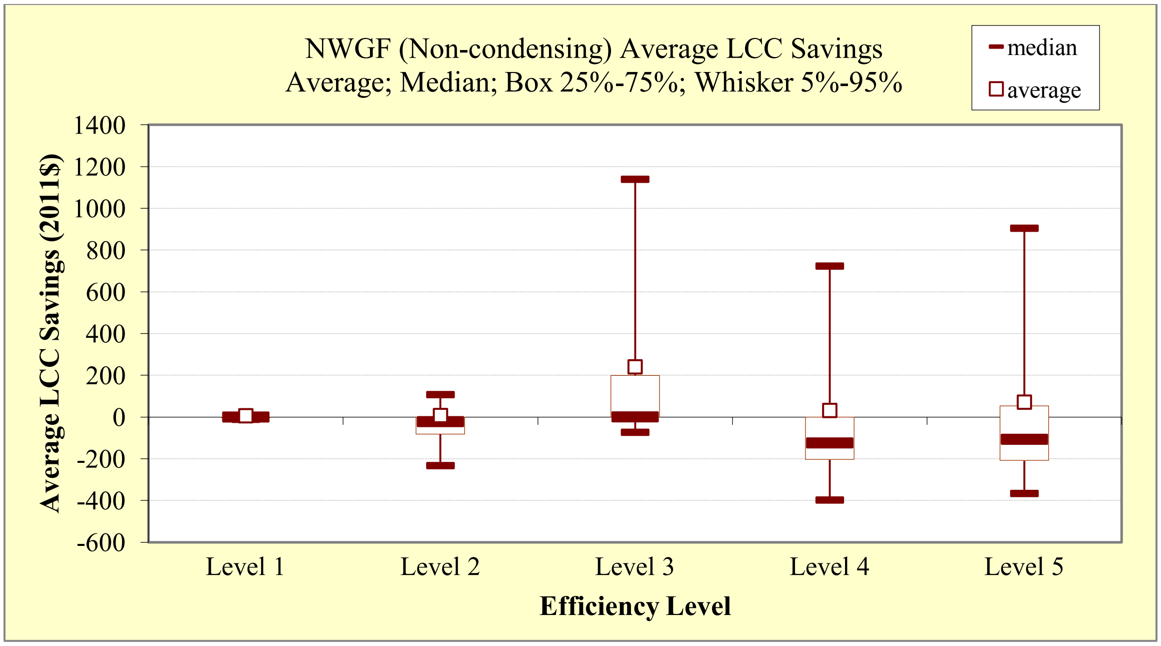

Figure 8.4.1 Distribution of LCC Savings for Non-Weatherized, Non-Condensing Gas Furnace Fans

Figure 8.4.2 show the range of PBPs for all efficiency levels considered for non-weatherized, non-condensing gas furnace fans.

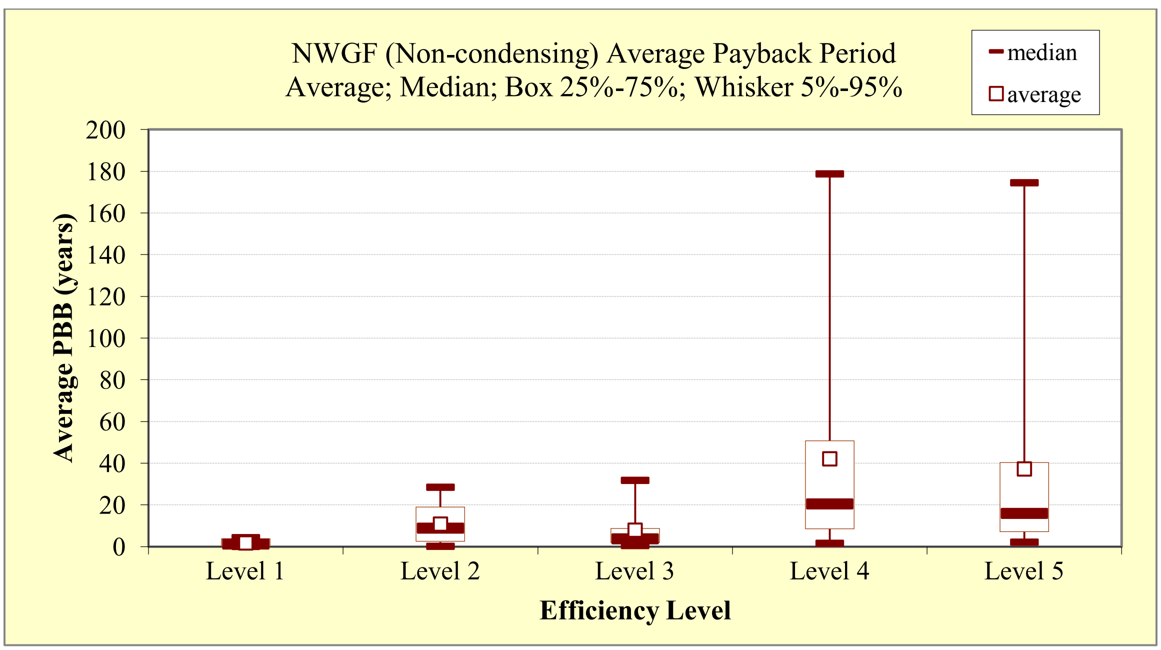

Figure 8.4.2 Distributions of PBP for Non-Weatherized, Non-Condensing Gas Furnace Fans

The rebuttable PBP for each efficiency level is shown in Table 8.4.2.

Table 8.4.2 Rebuttable Payback Period for Non-Weatherized, Non-Condensing Gas Furnace Fans

Efficiency Level	Technology Option	Rebuttable Payback Period *years*
1	Improved PSC	2.2
2	PSC w/ Controls	3.2
3	X13	1.3
4	ECM (Variable Speed)	4.8
5	ECM + Backward-curved Impeller	5.1

8.4.2 Non-Weatherized, Condensing Gas Furnace Fans

Table 8.4.3 shows the LCC and PBP results for non-weatherized, condensing gas furnace fans.

Table 8.4.3 Non-Weatherized, Condensing Gas Furnace Fan: LCC and PBP Results

		Life-Cycle Cost (2011$)			Life-Cycle Cost Savings				Payback Period (years)
						% Households with			
CSL	Technology Option	Average Installed Cost	Average Lifetime Operating Cost	Average LCC	Average Savings (2011$)	Net Cost	No Impact	Net Benefit	Median
0	Baseline (PSC)	241	1,292	1,533	N/A	0	100	0	N/A
1	Improved PSC	246	1,242	1,488	10	20	76	4	0.8
2	PSC w/ Controls	265	1,095	1,361	65	35	53	12	5.3
3	X13	306	840	1,146	169	13	53	33	5.2
4	ECM + Multi-Stage	459	884	1,344	34	54	33	13	22.8
5	ECM + Backward-Curved Impeller	491	836	1,327	51	71	0	29	17.3

Figure 8.4.3 shows the range of LCC savings for the efficiency levels considered for non-weatherized, condensing gas furnace fans. For each standard level, the top and the bottom of the box indicate the 75th and 25th percentiles, respectively. The bar at the middle of the box indicates the median; 50 percent of the households have life-cycle cost savings above this value. The 'whiskers' at the bottom and the top of the box indicate the 5th and 95th percentiles. The small box shows the average LCC savings for each standard level.

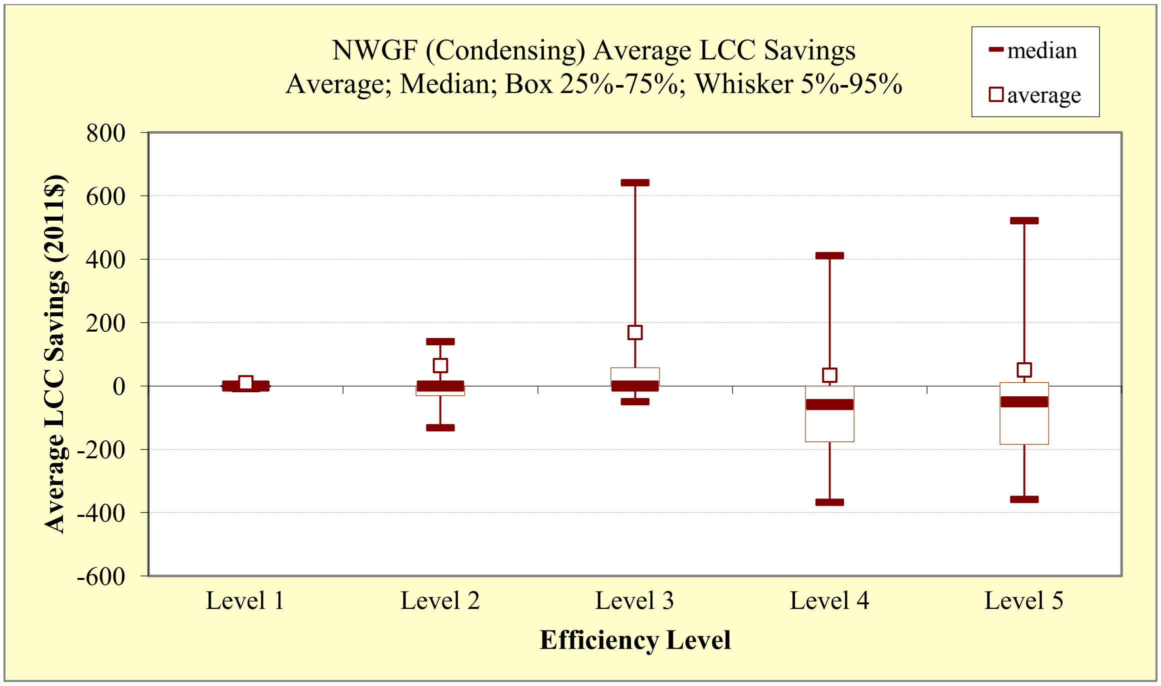

Figure 8.4.3 Distribution of LCC Savings for Non-Weatherized, Condensing Gas Furnace Fans

Figure 8.4.4 show the range of PBPs for all efficiency levels considered for non-weatherized, condensing gas furnace fans.

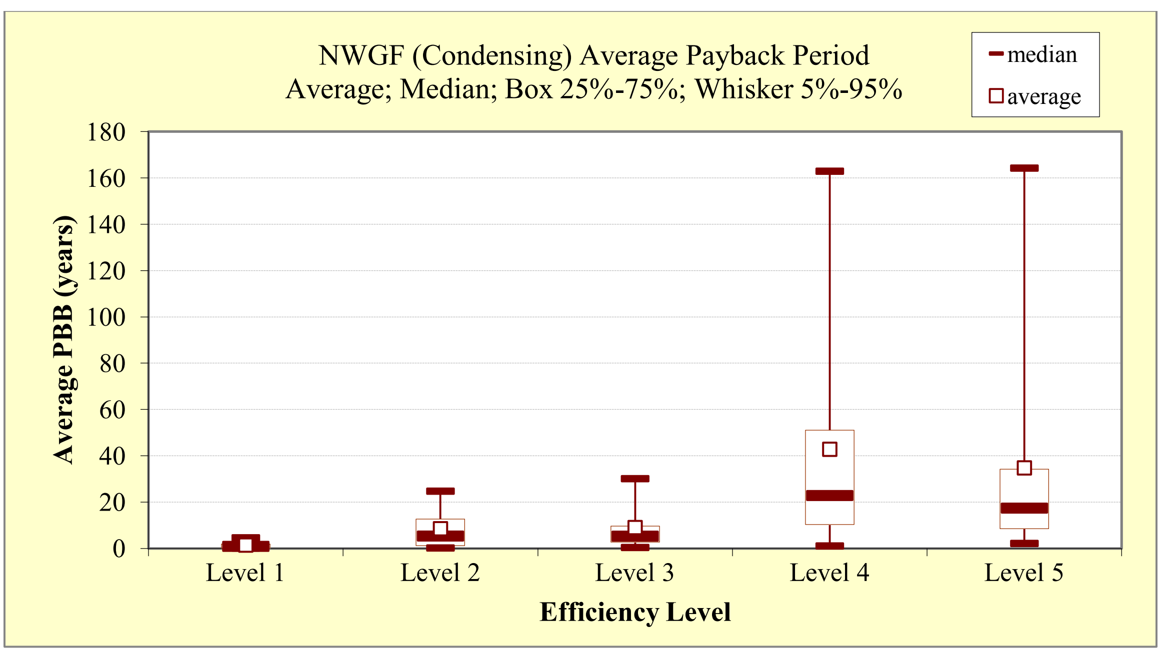

Figure 8.4.4 Distributions of PBP for Non-Weatherized, Condensing Gas Furnace Fans

The rebuttable PBP for each efficiency level is shown in Table 8.4.4.

Table 8.4.4 Rebuttable Payback Period for Non-Weatherized, Condensing Gas Furnace Fans

Efficiency Level	Technology Option	Rebuttable Payback Period *years*
1	Improved PSC	2.1
2	PSC w/ Controls	3.0
3	X13	1.2
4	ECM (Variable Speed)	4.5
5	ECM + Backward-curved Impeller	4.7

8.4.3 Weatherized Gas Furnace Fans

Table 8.4.5 shows the LCC and PBP results for weatherized gas furnace fans.

Table 8.4.5 Weatherized Gas Furnace Fan: LCC and PBP Results

		Life-Cycle Cost (2011$)			Life-Cycle Cost Savings				Payback Period (years)
						% Households with			
CSL	Technology Option	Average Installed Cost	Average Lifetime Operating Cost	Average LCC	Average Savings (2011$)	Net Cost	No Impact	Net Benefit	Median
0	Baseline (PSC)	237	1,243	1,480	N/A	0	100	0	N/A
1	Improved PSC	241	1,233	1,474	1	25	72	3	1.9
2	PSC w/ Controls	261	1,180	1,441	18	37	44	19	4.0
3	X13	297	820	1,117	203	7	44	49	2.6
4	ECM + Multi-Stage	451	814	1,264	102	37	32	30	10.1
5	ECM + Backward-Curved Impeller	483	751	1,234	133	48	0	51	9.4

Figure 8.4.5 shows the range of LCC savings for the efficiency levels considered for weatherized gas furnace fans. For each standard level, the top and the bottom of the box indicate the 75th and 25th percentiles, respectively. The bar at the middle of the box indicates the median; 50 percent of the households have life-cycle cost savings above this value. The 'whiskers' at the

bottom and the top of the box indicate the 5th and 95th percentiles. The small box shows the average LCC savings for each standard level.

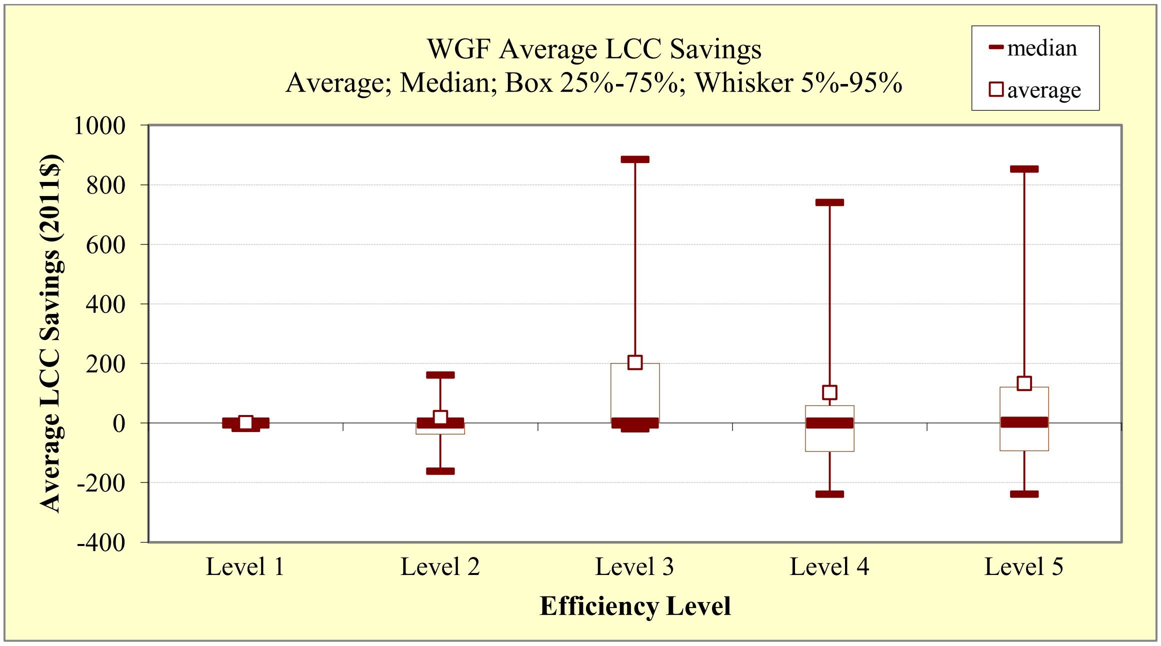

Figure 8.4.5 Distribution of LCC Savings for Weatherized Gas Furnace Fans

Figure 8.4.6 shows the range of PBPs for all efficiency levels considered for weatherized gas furnace fans.

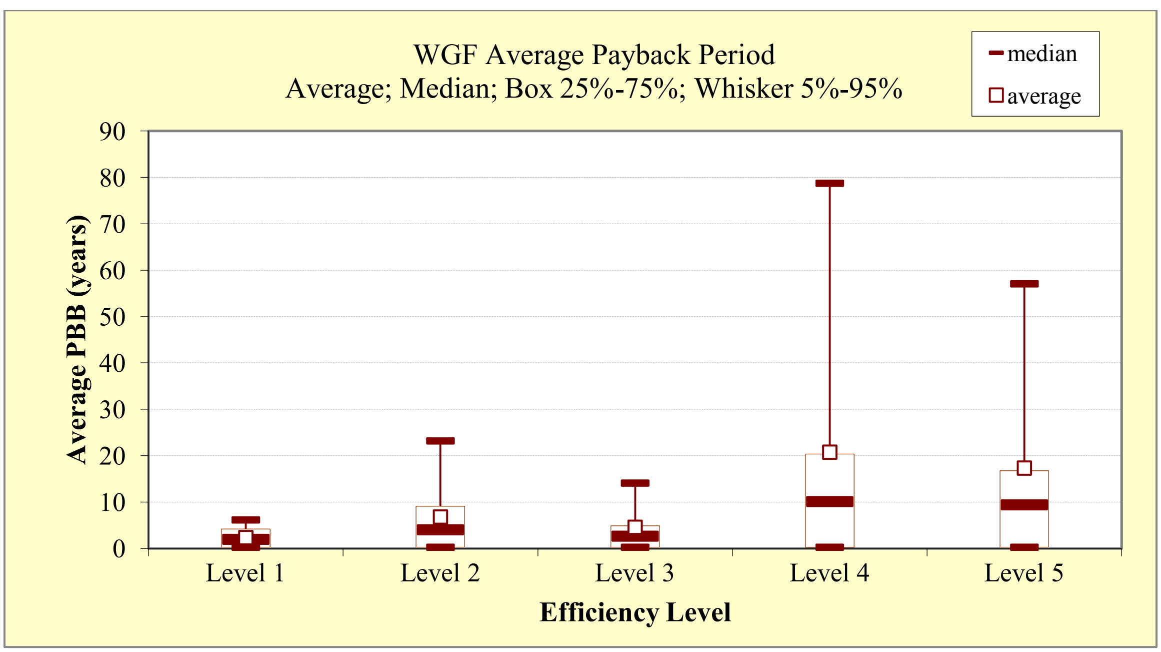

Figure 8.4.6 Distributions of PBP for Weatherized Gas Furnace Fans

The rebuttable PBP for each efficiency level is shown in Table 8.4.6.

Table 8.4.6 Rebuttable Payback Period for Weatherized Gas Furnace Fans

Efficiency Level	Technology Option	Rebuttable Payback Period *years*
1	Improved PSC	2.8
2	PSC w/ Controls	3.5
3	X13	1.5
4	ECM (Variable Speed)	5.4
5	ECM + Backward-curved Impeller	5.7

8.4.4 Oil Furnace Fans

Table 8.4.7 shows the LCC and PBP results for oil furnace fans.

Table 8.4.7 Oil Furnace Fan: LCC and PBP Results

		Life-Cycle Cost (2011$)			Life-Cycle Cost Savings				Payback Period (years)
						% Households with			
CSL	Technology Option	Average Installed Cost	Average Lifetime Operating Cost	Average LCC	Average Savings (2011$)	Net Cost	No Impact	Net Benefit	Median
0	Baseline (PSC)	313	1,327	1,640	N/A	0	100	0	N/A
1	Improved PSC	327	1,261	1,588	19	30	65	5	1.5
2	PSC w/ Controls	345	1,037	1,382	156	59	29	11	2.5
3	X13	437	1,005	1,442	111	56	29	15	9.6
4	ECM + Multi-Stage	577	1,059	1,636	-29	63	29	8	19.1
5	ECM + Backward-Curved Impeller	607	1,040	1,647	-40	85	0	15	15.4

Figure 8.4.7 show the range of LCC savings for the efficiency levels considered for oil furnace fans. For each standard level, the top and the bottom of the box indicate the 75th and 25th percentiles, respectively. The bar at the middle of the box indicates the median; 50 percent of the households have life-cycle cost savings above this value. The 'whiskers' at the bottom and the

top of the box indicate the 5th and 95th percentiles. The small box shows the average LCC savings for each standard level.

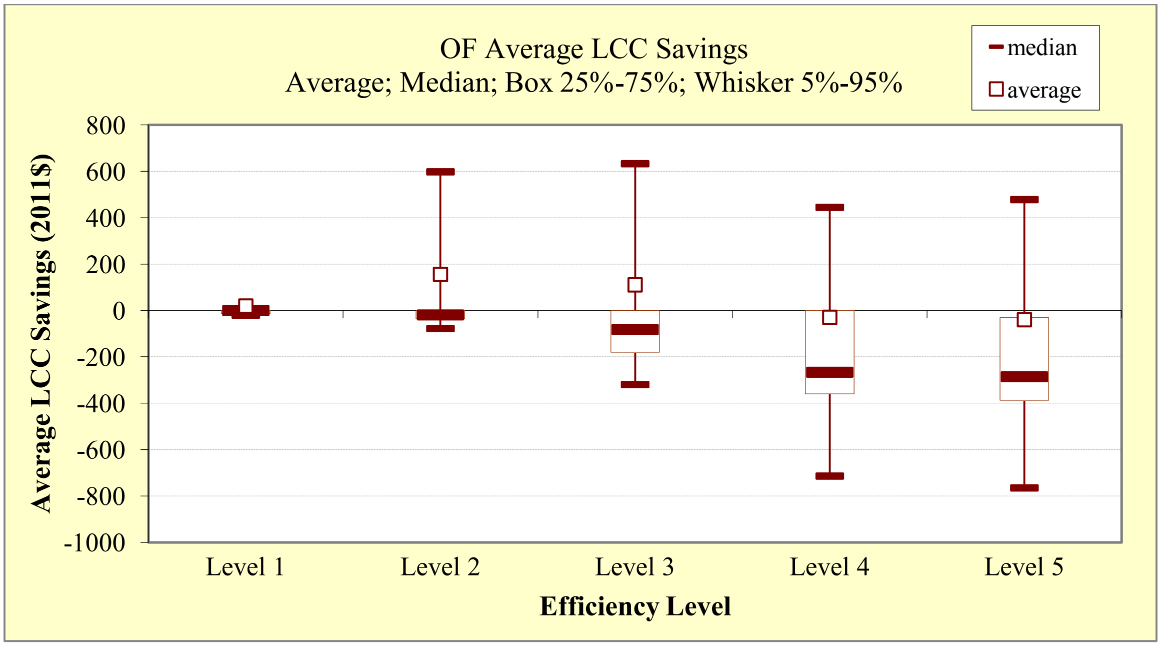

Figure 8.4.7 Distribution of LCC Savings for Oil Furnace Fans

Figure 8.4.8 show the range of PBPs for all efficiency levels considered for oil furnace fans.

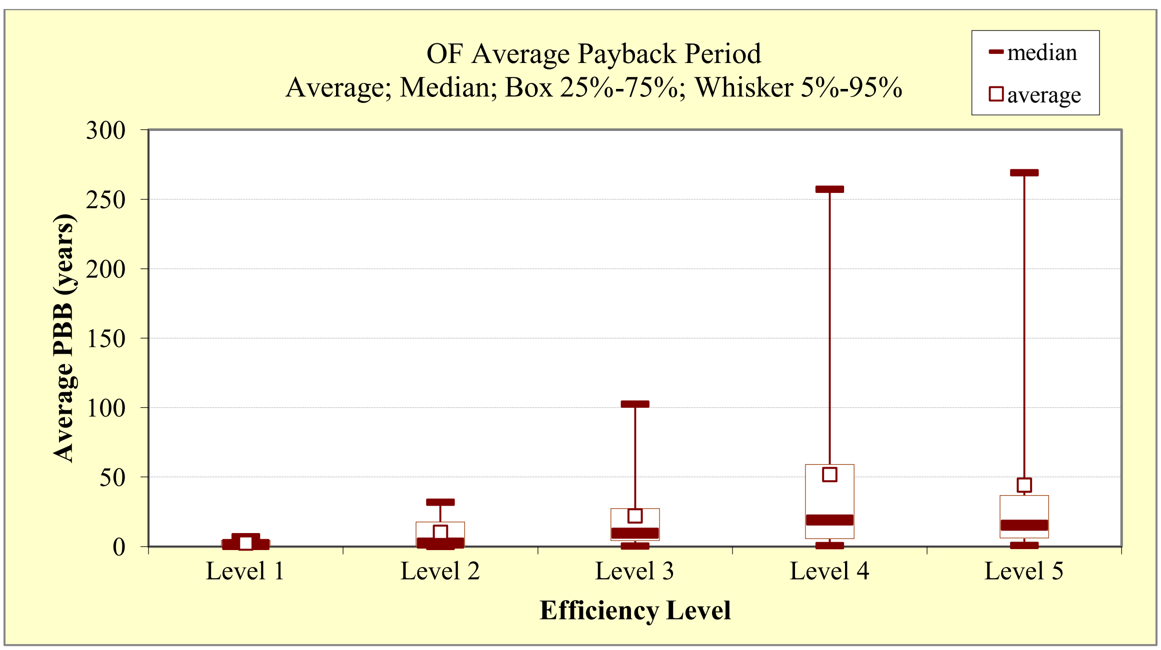

Figure 8.4.8 Distributions of PBP for Oil Furnace Fans

The rebuttable PBP for each efficiency level is shown in Table 8.4.8.

Table 8.4.8 Rebuttable Payback Period for Oil Furnace Fan

Efficiency Level	Technology Option	Rebuttable Payback Period *years*
1	Improved PSC	9.1
2	PSC w/ Controls	4.6
3	X13	2.3
4	ECM (Variable Speed)	5.8
5	ECM + Backward-curved Impeller	6.0

8.4.5 Electric Furnace Fans

Table 8.4.9 shows the LCC and PBP results for electric furnace/modular blower fans.

Table 8.4.9 Electric Furnace/Modular Blower Fan: LCC and PBP Results

CSL	Technology Option	Life-Cycle Cost (2011$)			Life-Cycle Cost Savings				Payback Period (years)
		Average Installed Cost	Average Lifetime Operating Cost	Average LCC	Average Savings (2011$)	% Households with Net Cost	% Households with No Impact	% Households with Net Benefit	Median
0	Baseline (PSC)	207	827	1,034	N/A	0	100	0	N/A
1	Improved PSC	211	817	1,028	1	23	74	3	3.8
2	PSC w/ Controls	231	829	1,060	-17	44	48	7	4.5
3	X13	235	629	864	88	16	48	35	1.9
4	ECM + Multi-Stage	388	680	1,069	-53	56	33	11	18.5
5	ECM + Backward-Curved Impeller	420	635	1,054	-38	71	0	29	14.3

Figure 8.4.9 show the range of LCC savings for the efficiency levels considered for electric furnace fans. For each standard level, the top and the bottom of the box indicate the 75th and 25th percentiles, respectively. The bar at the middle of the box indicates the median; 50 percent of the households have lifecycle cost savings above this value. The 'whiskers' at the bottom and the top of the box indicate the 5th and 95th percentiles. The small box shows the average LCC savings for each standard level.

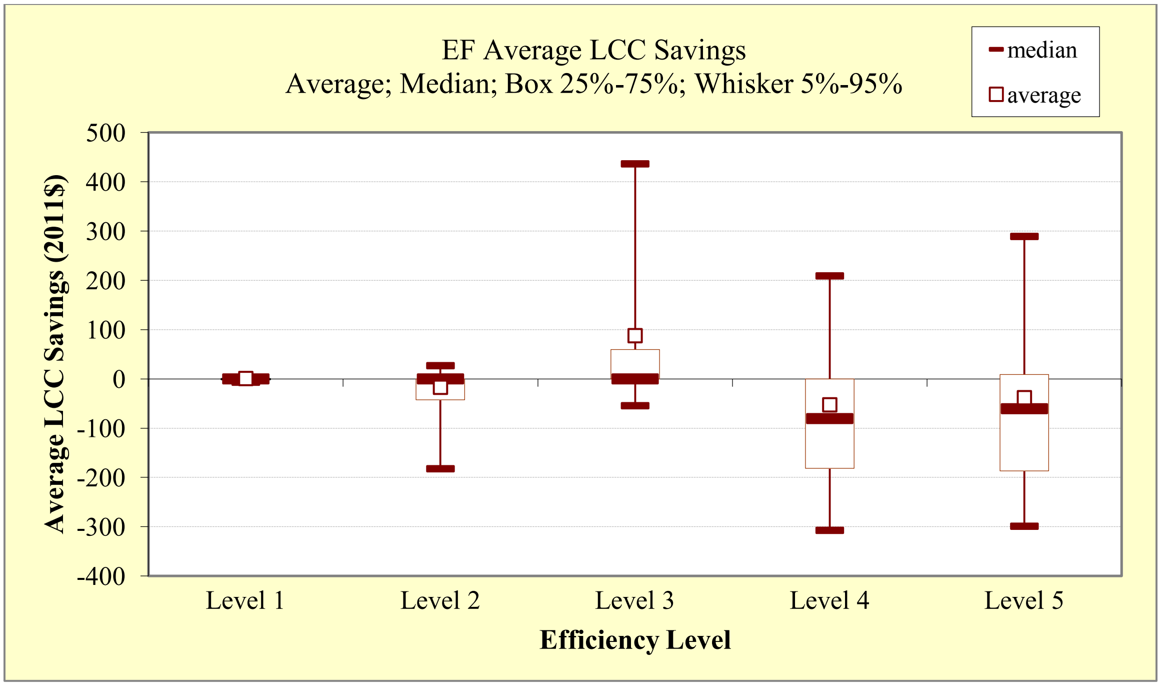

Figure 8.4.9 Distribution of LCC Savings for Electric Furnace Fans

Figure 8.4.10 shows the range of PBPs for all efficiency levels considered for electric furnace fans.

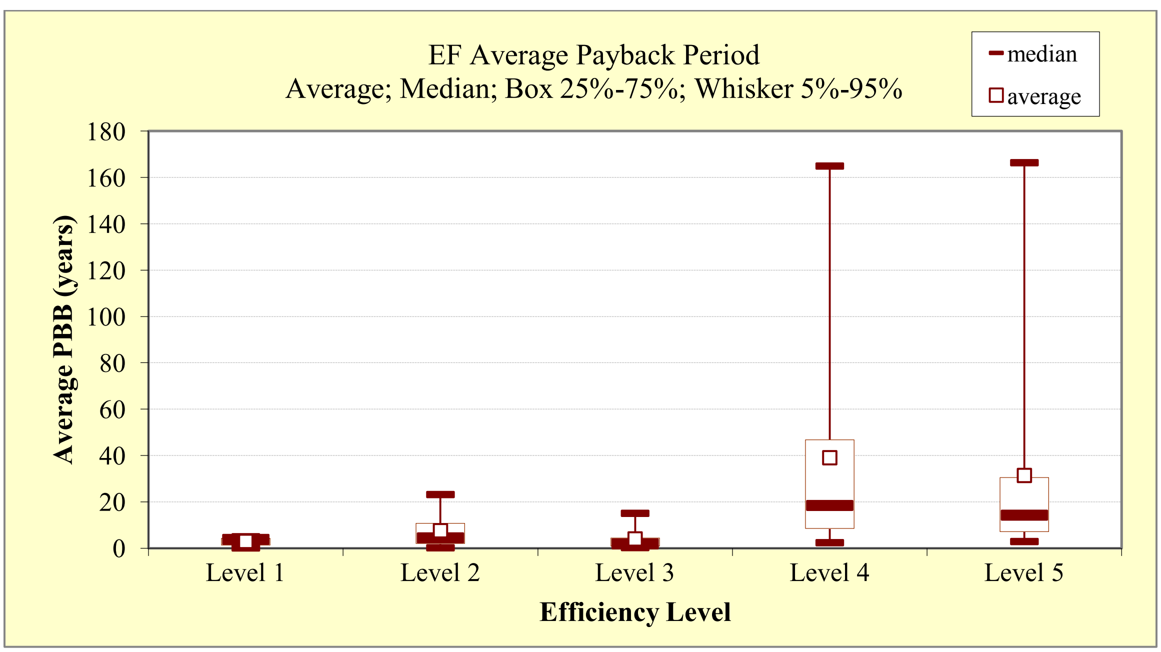

Figure 8.4.10 Distributions of PBP for Electric Furnace Fans

The rebuttable PBP for each efficiency level is shown in Table 8.4.10.

Table 8.4.10 Rebuttable Payback Period for Electric Furnace/Modular Blower Fan

Efficiency Level	Technology Option	Rebuttable Payback Period *years*
1	Improved PSC	2.8
2	PSC w/ Controls	3.7
3	X13	1.6
4	ECM (Variable Speed)	5.6
5	ECM + Backward-curved Impeller	6.0

8.4.6 Manufactured Home Non-Weatherized, Non-Condensing Gas Furnace Fans

Table 8.4.11 shows the LCC and PBP results for manufactured home non-weatherized, non-condensing gas furnace fans.

Table 8.4.11 Manufactured Home Non-Weatherized, Non-Condensing Gas Furnace Fans: LCC and PBP Results

		Life-Cycle Cost (2011$)			Life-Cycle Cost Savings				Payback Period (years)
						% Households with			
CSL	Technology Option	Average Installed Cost	Average Lifetime Operating Cost	Average LCC	Average Savings (2011$)	Net Cost	No Impact	Net Benefit	Median
0	Baseline (PSC)	218	742	961	N/A	0	100	0	N/A
1	Improved PSC	224	724	948	6	44	50	5	1.6
2	PSC w/ Controls	278	637	915	39	71	0	28	13.5
3	X13	314	567	881	74	60	0	39	9.3
4	ECM + Multi-Stage	531	536	1,067	-112	85	0	15	24.4
5	ECM + Backward-Curved Impeller	561	518	1,079	-124	84	0	16	23.7

Figure 8.4.11 shows the range of LCC savings for the efficiency levels considered for manufactured home non-weatherized, non-condensing gas furnace fans. For each standard level, the top and the bottom of the box indicate the 75th and 25th percentiles, respectively. The bar at the middle of the box indicates the median; 50 percent of the households have life-cycle cost savings above this value. The 'whiskers' at the bottom and the top of the box indicate the 5th and 95th percentiles. The small box shows the average LCC savings for each standard level.

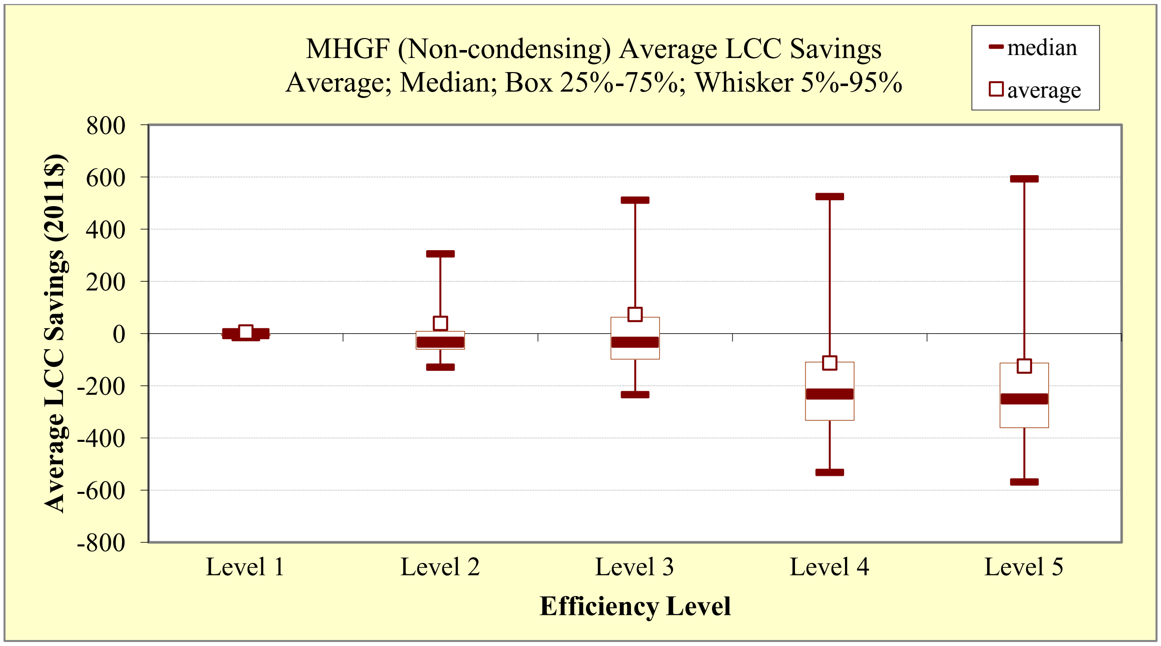

Figure 8.4.11 Distribution of LCC Savings for Manufactured Home Non-Weatherized, Non-Condensing Gas Furnace Fans

Figure 8.4.12 shows the range of PBPs for all efficiency levels considered for manufactured home non-weatherized, non-condensing gas furnace fans.

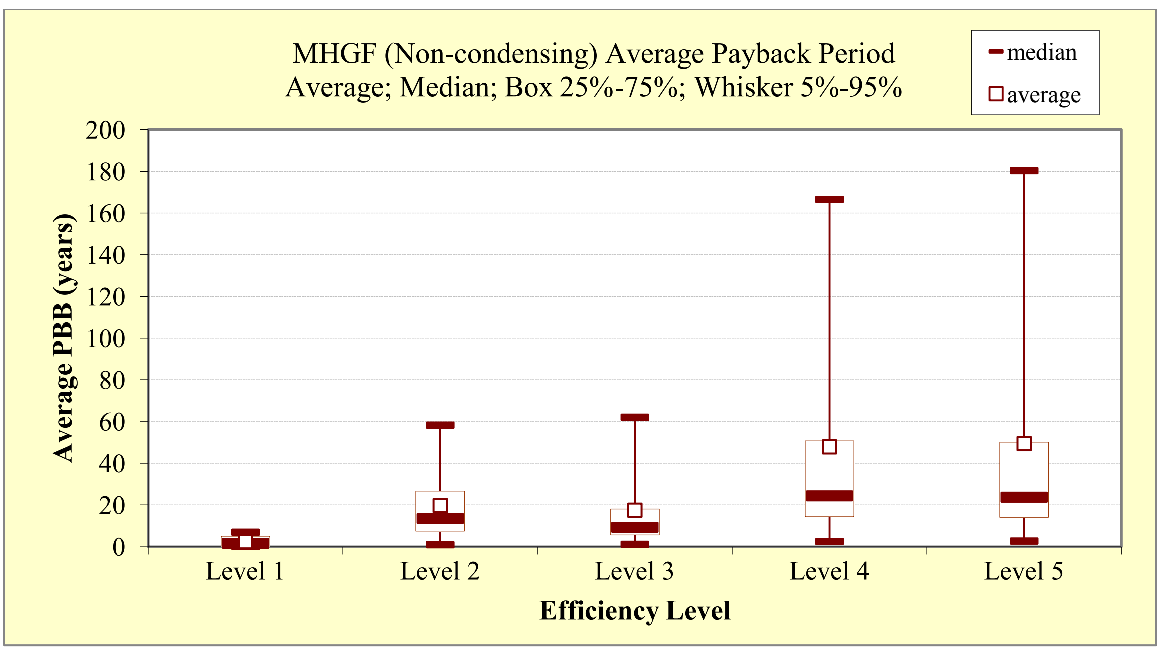

Figure 8.4.12 Distributions of PBP for Manufactured Home, Non-Weatherized, Non-Condensing Gas Furnace Fans

The rebuttable PBP for each efficiency level is shown in Table 8.4.12.

Table 8.4.12 Rebuttable Payback Period for Manufactured Home Non-Weatherized, Non-Condensing Gas Furnace Fans

Efficiency Level	Technology Option	Rebuttable Payback Period *years*
1	Improved PSC	4.1
2	PSC w/ Controls	5.8
3	X13	2.4
4	ECM (Variable Speed)	8.7
5	ECM + Backward-curved Impeller	9.3

8.4.7 Manufactured Home Non-Weatherized, Condensing Gas Furnace Fans

Table 8.4.13 shows the LCC and PBP results for manufactured home non-weatherized, condensing gas furnace fans.

Table 8.4.13 Manufactured Home Non-Weatherized, Condensing Gas Furnace Fans: LCC and PBP Results

		Life-Cycle Cost (2011$)			Life-Cycle Cost Savings				Payback Period (years)
						% Households with			
CSL	Technology Option	Average Installed Cost	Average Lifetime Operating Cost	Average LCC	Average Savings (2011$)	Net Cost	No Impact	Net Benefit	Median
0	Baseline (PSC)	237	778	1,015	N/A	0	100	0	N/A
1	Improved PSC	243	743	985	10	28	67	5	1.0
2	PSC w/ Controls	284	616	900	66	43	34	24	10.2
3	X13	319	554	873	85	38	34	28	8.3
4	ECM + Multi-Stage	531	537	1,068	-110	89	0	11	35.0
5	ECM + Backward-Curved Impeller	572	525	1,098	-140	89	0	11	36.3

Figure 8.4.13 shows the range of LCC savings for the efficiency levels considered for manufactured home non-weatherized, condensing gas furnace fans. For each standard level, the top and the bottom of the box indicate the 75^{th} and 25^{th} percentiles, respectively. The bar at the

middle of the box indicates the median; 50 percent of the households have life-cycle cost savings above this value. The 'whiskers' at the bottom and the top of the box indicate the 5th and 95th percentiles. The small box shows the average LCC savings for each standard level.

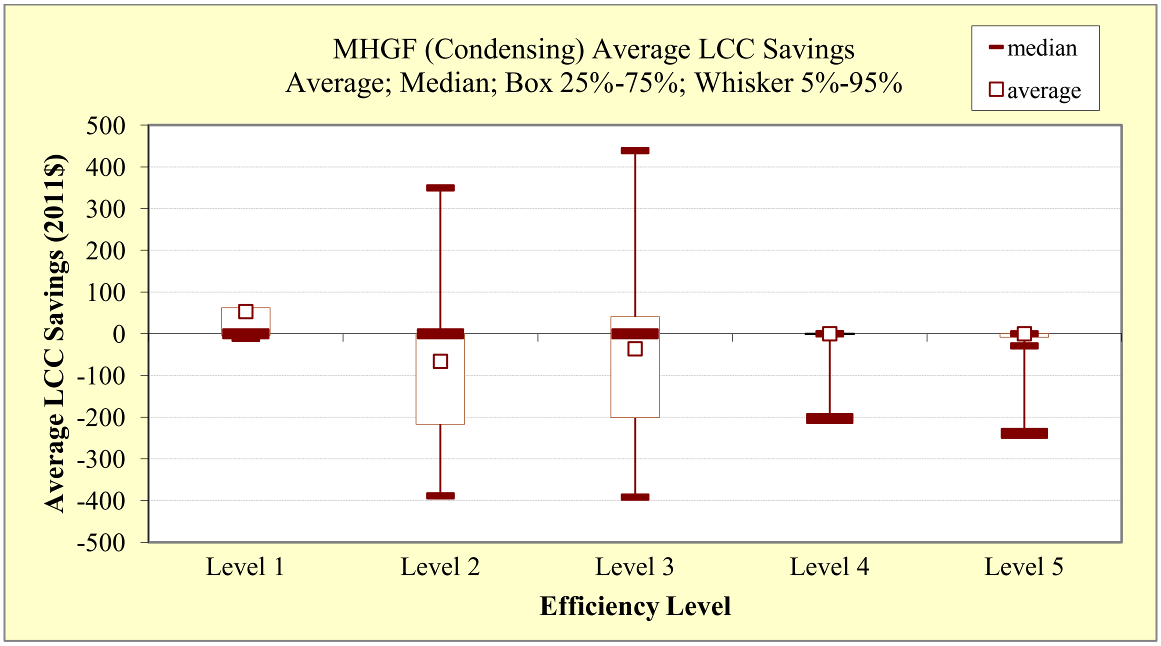

Figure 8.4.13 Distribution of LCC Savings for Manufactured Home Non-Weatherized, Condensing Gas Furnace Fans

Figure 8.4.14 shows the range of PBPs for all efficiency levels considered for manufactured home non-weatherized, condensing gas furnace fans.

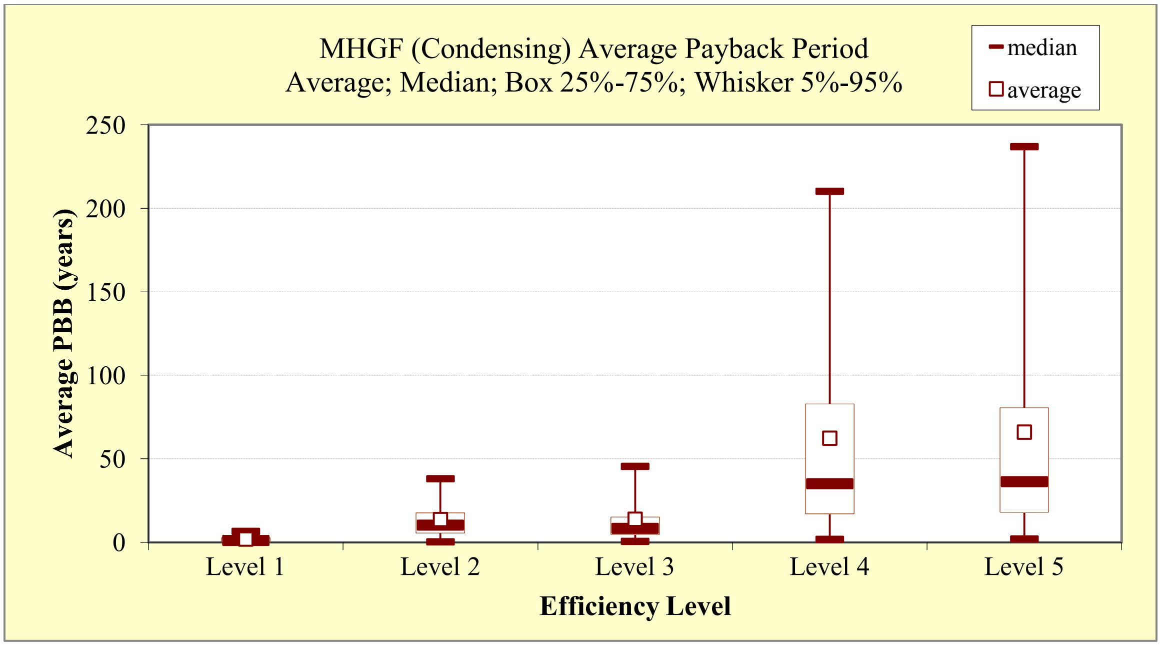

Figure 8.4.14 Distributions of PBP for Manufactured Home Non-Weatherized, Condensing Gas Furnace Fans

The rebuttable PBP for each efficiency level is shown in Table 8.4.14.

Table 8.4.14 Rebuttable Payback Period for Manufactured Home Non-Weatherized, Condensing Gas Furnace Fans

Efficiency Level	Technology Option	Rebuttable Payback Period *years*
1	Improved PSC	4.0
2	PSC w/ Controls	5.3
3	X13	2.2
4	ECM (Variable Speed)	7.9
5	ECM + Backward-curved Impeller	8.4

8.4.8 Manufactured Home Electric Furnace/Modular Blower Fans

Table 8.4.15 shows the LCC and PBP results for manufactured home electric furnace/modular blower fans.

Table 8.4.15 Manufactured Home Electric Furnace/Module Blower Fans: LCC and PBP Results

CSL	Technology Option	Life-Cycle Cost (2011$)			Life-Cycle Cost Savings				Payback Period (years)
		Average Installed Cost	Average Lifetime Operating Cost	Average LCC	Average Savings (2011$)	% Households with Net Cost	% Households with No Impact	% Households with Net Benefit	Median
0	Baseline (PSC)	177	733	910	N/A	0	100	0	N/A
1	Improved PSC	183	731	914	-2	29	69	2	5.1
2	PSC w/ Controls	253	643	896	8	39	37	24	9.7
3	X13	287	541	829	53	27	37	35	7.4
4	ECM + Multi-Stage	497	489	986	-66	57	25	17	17.1
5	ECM + Backward-Curved Impeller	501	454	956	-36	59	0	40	11.3

Figure 8.4.15 shows the range of LCC savings for the efficiency levels considered for manufactured home electric furnace/modular blower fans. For each standard level, the top and the bottom of the box indicate the 75^{th} and 25^{th} percentiles, respectively. The bar at the middle of the box indicates the median; 50 percent of the households have life-cycle cost savings above this value. The ‘whiskers’ at the bottom and the top of the box indicate the 5^{th} and 95^{th} percentiles. The small box shows the average LCC savings for each standard level.

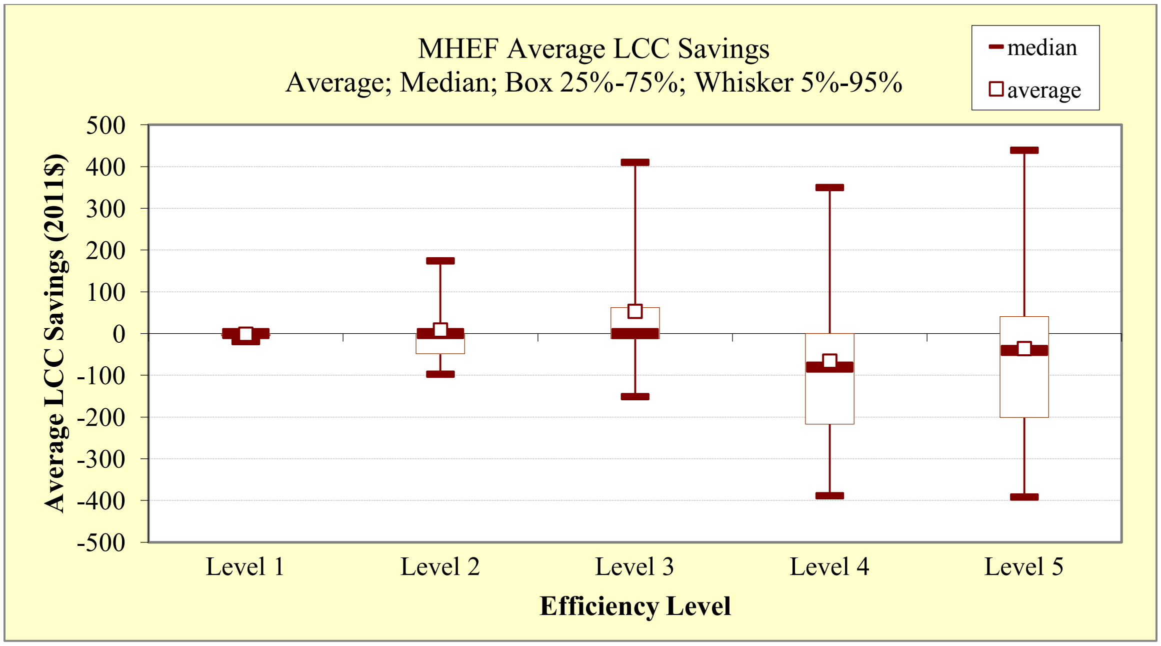

Figure 8.4.15 Distribution of LCC Savings for Manufactured Home Electric Furnace/Modular Blower Fans

Figure 8.4.16 shows the range of PBPs for all efficiency levels considered for manufactured home electric furnace/modular blower fans.

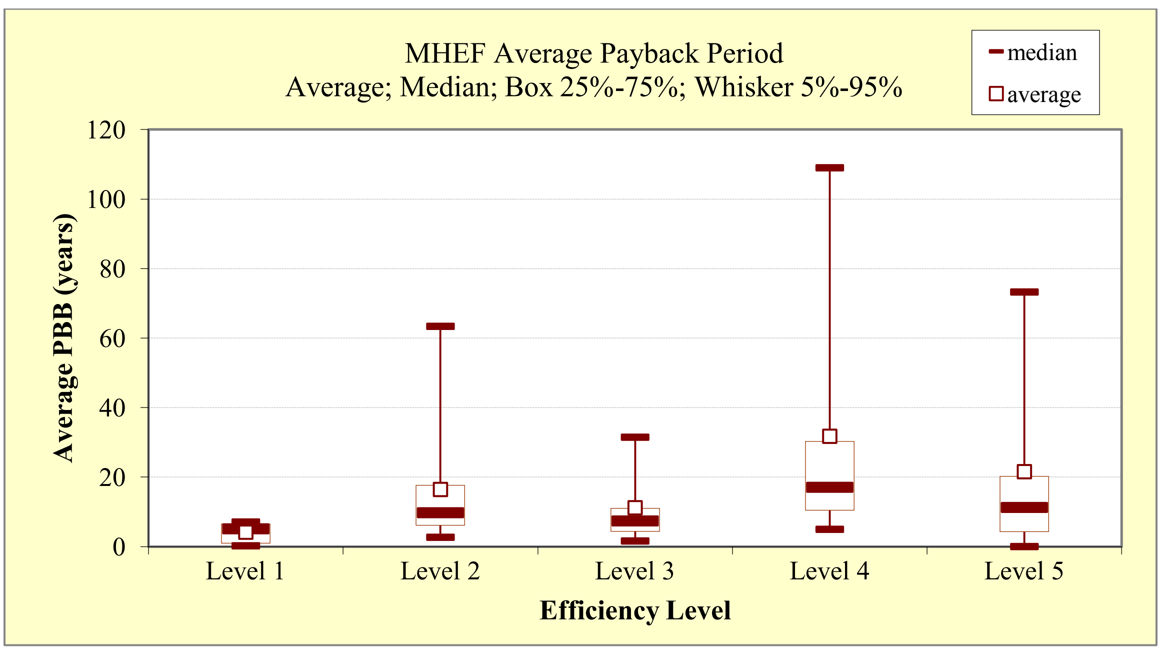

Figure 8.4.16 Distributions of PBP for Manufactured Home Electric Furnace/Modular Blower Fans

The rebuttable PBP for each efficiency level is shown in Table 8.4.16.

Table 8.4.16 Rebuttable Payback Period for Manufactured Home Electric Furnace/Modular Blower Fans

Efficiency Level	Technology Option	Rebuttable Payback Period *years*
1	Improved PSC	5.5
2	PSC w/ Controls	6.9
3	X13	2.8
4	ECM (Variable Speed)	10.3
5	ECM + Backward-curved Impeller	10.9

8.4.9 Hydronic Air Handler Fans

Table 8.4.17 shows the LCC and PBP results for hydronic air handler fans.

Table 8.4.17 Hydronic Air Handler Fan (Heat/Cool): LCC and PBP Results

		Life-Cycle Cost (2011$)			Life-Cycle Cost Savings				Payback Period (years)
						% Households with			
CSL	Technology Option	Average Installed Cost	Average Lifetime Operating Cost	Average LCC	Average Savings (2011$)	Net Cost	No Impact	Net Benefit	Median
0	Baseline (PSC)	230	1,284	1,515	N/A	0	100	0	N/A
1	Improved PSC	246	1,268	1,514	0	28	69	3	14.7
2	PSC w/ Controls	291	1,288	1,579	-39	53	38	8	11.4
3	X13	341	897	1,237	176	21	38	40	5.2
4	ECM + Multi-Stage	504	704	1,208	200	37	22	40	9.1
5	ECM + Backward-Curved Impeller	525	658	1,183	225	47	0	53	8.1
6	Switching mode Power Supply	531	629	1,160	249	35	0	65	6.8
7	Toroidal Transformer	555	613	1,168	240	39	0	61	7.8

Figure 8.4.17 shows the range of LCC savings for the efficiency levels considered for hydronic air handler fans. For each standard level, the top and the bottom of the box indicate the 75th and 25th percentiles, respectively. The bar at the middle of the box indicates the median; 50

percent of the households have life-cycle cost savings above this value. The 'whiskers' at the bottom and the top of the box indicate the 5th and 95th percentiles. The small box shows the average LCC savings for each standard level.

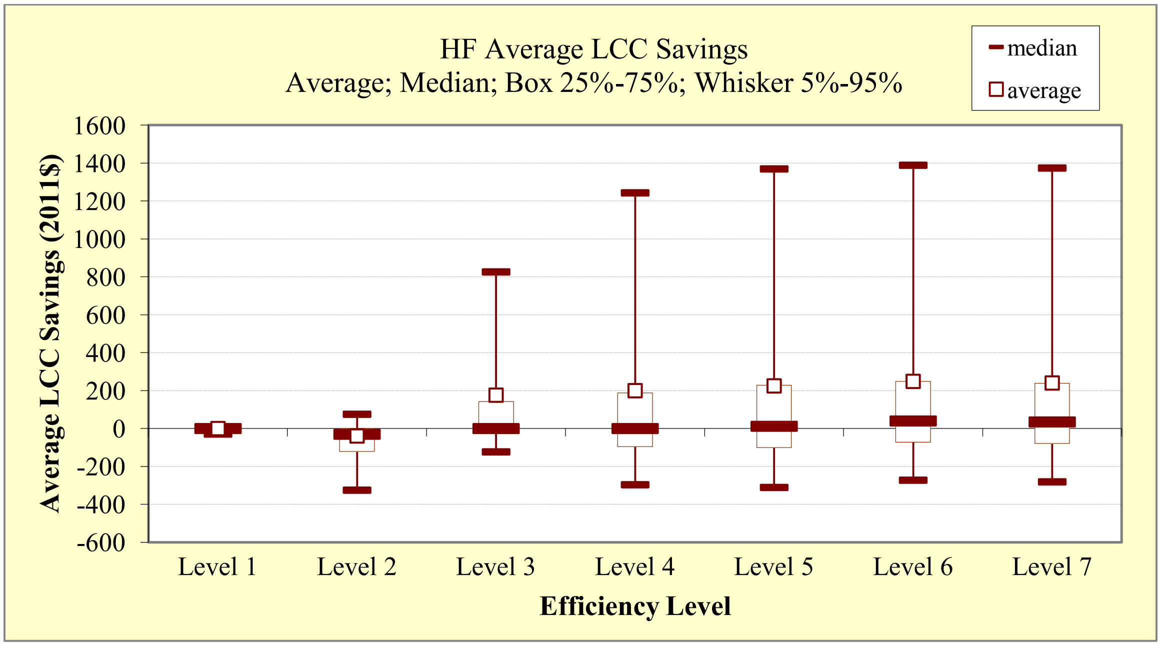

Figure 8.4.17 Distribution of LCC Savings for Hydronic Air Handler Fans

Figure 8.4.18 shows the range of PBPs for all efficiency levels considered for hydronic air handler fans.

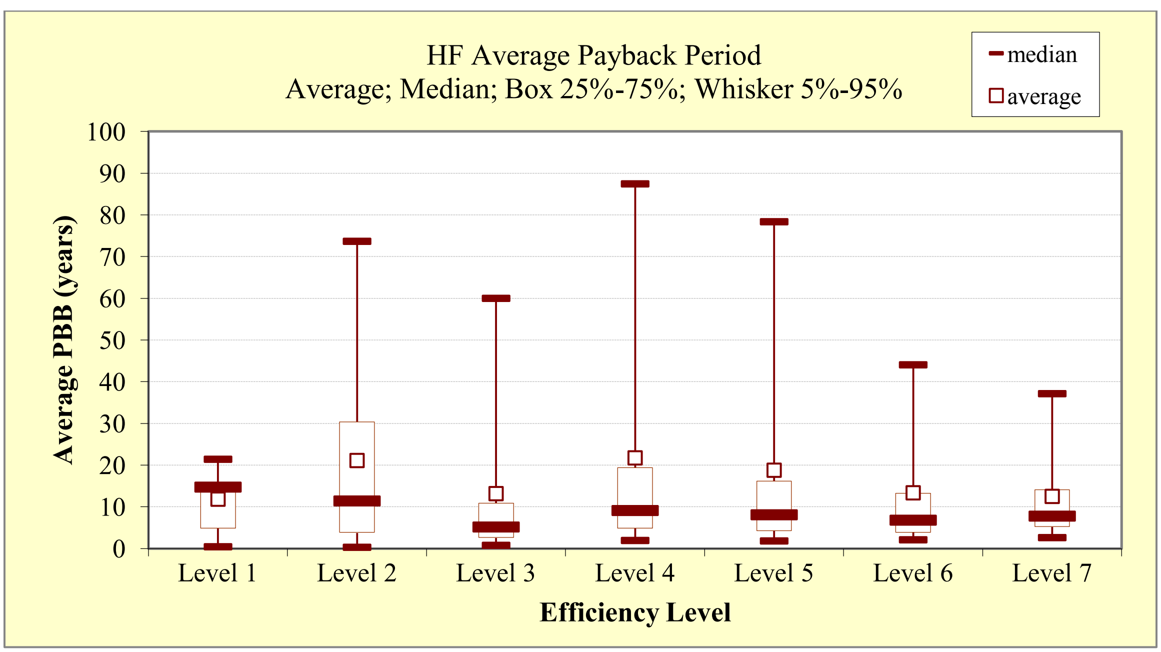

Figure 8.4.18 Distributions of PBP for Hydronic Air Handler Fans

The rebuttable PBP for each efficiency level is shown in Table 8.4.18.

Table 8.4.18 Rebuttable Payback Period for Hydronic Air Handler Fan (Heat/Cool)

Efficiency Level	Technology Option	Rebuttable Payback Period *years*
1	Improved PSC	7.7
2	PSC w/ Controls	3.6
3	X13	1.7
4	ECM (Variable Speed)	3.5
5	ECM + Backward-curved Impeller	3.8
6	Switching Mode Power Supply	4.0
7	Toroidal Transformer	4.3

REFERENCES

1. Energy Information Administration, *Annual Energy Outlook 2010 with Projections to 2035*, 2010. Washington, DC. Report No. DOE/EIA-0383(2010). <http://www.eia.doe.gov/oiaf/aeo/>

2. U.S. Department of Energy: Energy Information Administration, *Residential Energy Consumption Survey: 2005 Public Use Data Files,* 2009. (Last accessed May, 2011.) <http://www.eia.doe.gov/emeu/recs/recspubuse05/pubuse05.html>

3. U.S. Department of Energy - Energy Information Administration, *Form EIA-826 Database Monthly Electric Utility Sales and Revenue Data,* 2012. <http://www.eia.doe.gov/cneaf/electricity/page/eia826.html>

4. U.S. Department of Energy - Energy Information Administration, *Natural Gas Navigator*. 2010. http://tonto.eia.doe.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm

5. Energy Information Administration, *2008 State Energy Consumption, Price, and Expenditure Estimates (SEDS)*, 2008. Washington, DC. <http://www.eia.doe.gov/emeu/states/_seds.html>

6. Energy Information Administration, *Annual Energy Outlook 2012 (Early Release) with Projections to 2035*, 2012. Washington, DC. Report No. DOE/EIA-0383(2012). <http://www.eia.doe.gov/oiaf/aeo/>

7. Decision Analysts, *2008 American Home Comfort Study: Online Database Tool*, 2009. Arlington, Texas. <http://www.decisionanalyst.com/Syndicated/HomeComfort.dai>

8. The Federal Reserve Board, *Survey of Consumer Finances 1989, 1992, 1995, 1998, 2001, 2004, 2007*. <http://www.federalreserve.gov/pubs/oss/oss2/scfindex.html>

9. The Federal Reserve Board, *Federal Reserve Statistical Release, Selected Interest Rates, Historical Data, Instrument: CDs (secondary market), Maturity: 6-month, Frequency: Annual, Description: Average rate on 6-month negotiable certificates of deposit (secondary market), quoted on an investment basis*, 2011. Washington, D.C. <ww.federalreserve.gov/releases/H15/data.htm>

10. The Federal Reserve Board, *Federal Reserve Statistical Release, Selected Interest Rates, Historical Data, Instrument: State and local bonds, Maturity: 20-year, Frequency: Monthly, Description: Bond buyer go 20-bond municipal bond index*, 2011. Washington, D.C. <www.federalreserve.gov/releases/H15/data.htm>

11. The Federal Reserve Board, *Federal Reserve Statistical Release, Selected Interest Rates, Historical Data, Instrument: Corporate bonds/Moody's Seasoned AAA, Frequency:*

Annual, Description: Moody's yield on seasoned corporate bonds—all industries, AAA, 2011. Washington, D.C. <www.federalreserve.gov/releases/H15/data.htm>

12. Mortgage-X - Mortgage Information Service, *Cost of Savings Index (COSI) Index History,* 2011. (Last accessed February 25, 2009.) <http://mortgage-x.com/general/indexes/default.asp>

13. Damodaran Online Data Page, *The Data Page: Historical Returns on Stocks, Bonds and Bills - United States,* 2011. Damodaran. (Last accessed February 25, 2009.) <http://pages.stern.nyu.edu/~adamodar/>

14. U.S. Department of Labor - Bureau of Labor Statistics, *Bureau of Labor Statistics Data, Prices & Living Conditions,* 2011. (Last accessed February 25, 2011.) <http://data.bls.gov>

15. National Bureau of Economic Research, *U.S. Federal and State Average Marginal Income Tax Rates,* 2010. (Last accessed February 25, 2011.) <http://www.nber.org/~taxsim/marginal-tax-rates/plusstate.html>

16. Rheem Heating and Cooling, *Comments from Rheem On Framework Document for Energy Conservation Program for Consumer Products: Energy Conservation Standards for Residential Furnace Fans (Docket number EERE-2010-BT-STD-0011, RIN 1904-AC22),* July 27, 2010.

17. Innes Hood, *High Efficiency Furnace Blower Motors: Market Baseline Assessment*, 2004. The Sheltair Group. Vancouver, BC. <http://www.cee1.org/eval/db_pdf/416.pdf>