TECHNICAL SUPPORT DOCUMENT: ENERGY EFFICIENCY PROGRAM FOR COMMERCIAL AND INDUSTRIAL EQUIPMENT:

PACKAGED TERMINAL AIR CONDITIONERS AND HEAT PUMPS

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CHAPTER 1. INTRODUCTION

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CHAPTER 1. INTRODUCTION

1.1 PURPOSE OF THE DOCUMENT

This technical support document (TSD) is a stand-alone report that provides the technical analyses and results supporting the information presented in the final rule for packaged terminal air conditioners (PTACs) and packaged terminal heat pumps (PTHPs). This final rule TSD complements the life-cycle cost (LCC), payback period (PBP), and national impact analysis (NIA) spreadsheets posted on the U.S. Department of Energy's (DOE's) website at: http://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/64

1.2 OVERVIEW OF ENERGY CONSERVATION STANDARDS

Title III, Part C[a] of the Energy Policy and Conservation Act of 1975 ("EPCA" or "the Act"), Pub. L. 94-163 (42 U.S.C. 6311-6317, as codified), added by Pub. L. 95-619, Title IV, §441(a), established the Energy Conservation Program for Certain Industrial Equipment, which includes the PTAC and PTHP equipment that are the subject of this TSD.[b] In general, this program addresses the energy efficiency of certain types of commercial and industrial equipment. Relevant provisions of the Act include definitions (42 U.S.C. 6311), energy conservation standards (42 U.S.C. 6313), test procedures (42 U.S.C. 6314), labelling provisions (42 U.S.C. 6315), and the authority to require information and reports from manufacturers (42 U.S.C. 6316). EPCA contains mandatory energy conservation standards for commercial heating, air-conditioning, and water-heating equipment. (42 U.S.C. 6313(a)) Specifically, the statute sets standards for small, large, and very large commercial package air-conditioning and heating equipment, PTACs and PTHPs, warm-air furnaces, packaged boilers, storage water heaters, instantaneous water heaters, and unfired hot water storage tanks. Id.

Section 5(b) of the American Energy Manufacturing Technical Corrections Act of 2012 (Pub. L. No. 112-210 (Dec. 18, 2012) (AEMTCA) amended Section 342(a)(6) of EPCA. Among other things, AEMTCA modified the manner in which DOE must amend the energy efficiency standards for certain types of commercial and industrial equipment. DOE is typically obligated either to adopt those standards developed by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) – or to adopt levels more stringent than the ASHRAE levels if there is clear and convincing evidence in support of doing so (42 U.S.C. 6313(a)(6)(A)). AEMTCA added to this process a requirement that DOE initiate a rulemaking to consider amending the standards for any covered equipment as to which more than 6 years has elapsed since the issuance of the most recent final rule establishing or amending a standard for the equipment as of the date of AEMTCA's enactment, December 18, 2012. (42 U.S.C. 6313(a)(6)(C)(vi))

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[a] For editorial reasons, upon codification in the U.S. Code, Part C was re-designated Part A-1.

[b] All references to EPCA in this document refer to the statute as amended through the American Energy Manufacturing Technical Corrections Act of 2012, Pub. L. 112-210 (Dec. 18, 2012).

Under EPCA, when DOE is studying new or amended standards, it must consider, to the greatest extent practicable, the following seven factors:

1) the economic impact of the standard on the manufacturers and consumers of the equipment subject to the standard;

2) the savings in operating costs throughout the estimated average life of the equipment compared to any increases in the initial cost or maintenance expense;

3) the total projected amount of energy savings likely to result directly from the imposition of the standard;

4) any lessening of the utility or the performance of the covered equipment likely to result from the imposition of the standard;

5) the impact of any lessening of competition, as determined in writing by the Attorney General, that is likely to result from the imposition of the standard;

6) the need for national energy conservation; and

7) other factors the Secretary considers relevant. (42 U.S.C. 6313(a)(6)(B))

Other statutory requirements are set forth in 42 U.S.C. 6313(a)(6)(A)–(C).

DOE considers interested party participation to be a very important part of the process for setting energy conservation standards. Through formal public notifications (*i.e.*, *Federal Register* notices), DOE actively encourages the participation and interaction of all interested parties during the comment period in each stage of the rulemaking. Beginning with the framework document and during subsequent comment periods, interactions among interested parties provide a balanced discussion of the information that is required for the standards rulemaking.

Before DOE determines whether or not to adopt a proposed energy conservation standard, it must first solicit comments on the proposed standard. Any new or amended standard must be designed to achieve significant additional conservation of energy and be technologically feasible and economically justified. To determine whether economic justification exists, DOE must review comments on the proposal and determine that the benefits of the proposed standard exceed its burdens to the greatest extent practicable, weighing the seven factors listed above.

The energy conservation standards rulemaking process involves two formal public notices, which DOE publishes in the *Federal Register*. The first notice is the NOPR, which presents the analyses of the impacts of potential amended energy conservation standards on customers, manufacturers, and the Nation; DOE's weighting of these impacts of amended energy conservation standards; and the proposed energy conservation standards for the equipment. The second notice is the final rule, which presents a discussion of the comments received in response to the NOPR; the revised analyses; DOE's weighting of these impacts; the amended energy conservation standards DOE is adopting for each equipment class; and the effective dates of the amended energy conservation standards.

1.3 OVERVIEW OF PTAC AND PTHP STANDARDS

EPCA sets standards for small, large, and very large commercial package air-conditioning and heating equipment, PTACs and PTHPs, warm-air furnaces, packaged boilers, storage water heaters, instantaneous water heaters, and unfired hot water storage tanks. (42 U.S.C. 6313(a)) Section 340 of EPCA defines a “packaged terminal air conditioner” as “a wall sleeve and a separate unencased combination of heating and cooling assemblies specified by the builder and intended for mounting through the wall. It includes a prime source of refrigeration, separable outdoor louvers, forced ventilation, and heating availability by builder's choice of hot water, steam, or electricity.” (42 U.S.C. 6311(10)(A)) EPCA defines a “packaged terminal heat pump” as “a packaged terminal air conditioner that utilizes reverse cycle refrigeration as its prime heat source and should have supplementary heat source available to builders with the choice of hot water, steam, or electric resistant heat.” (42 U.S.C. 6311(10)(B))

DOE most recently issued amended standards for PTACs and PTHPs on October 7, 2008, which codified amended standards for PTACs and PTHPs and divided PTACs and PTHPs into two equipment classes – standard size and non-standard size. 73 FR 58772 (Oct. 7, 2008) On October 29, 2010, ASHRAE released ASHRAE Standard 90.1-2010 (formally the American National Standards Institute (ANSI)/ASHRAE/Illuminating Engineering Society of North America (IES) Standard 90.1-2010), which increased the efficiency levels for standard size PTACs and PTHPs to be equal to DOE standards, effective as of October 8, 2012. Hence, DOE did not consider revision of PTAC and PTHP standards at that time.

1.3.1 Framework and Analysis Methodology

DOE began this rulemaking by analyzing amended standards consistent with the procedures defined under 42 U.S.C. 6313(a)(6)(C). However, before DOE could finalize the NOPR for this rulemaking, ASHRAE acted on October 9, 2013 to adopt ANSI/ASHRAE/IES Standard 90.1-2013, and this revision contained amended standards PTACs at levels above the current Federal standards, thereby triggering DOE’s statutory obligation under 42 U.S.C. 6313(a)(6)(A) to promulgate an amended uniform national standard at those levels unless DOE determines that there is clear and convincing evidence supporting the adoption of energy conservation standards more stringent than the ASHRAE levels. Consequently, DOE prepared an analysis of the energy savings potential of amended standards at the ANSI/ASHRAE/IES Standard 90.1-2013 levels (as required by 42 U.S.C. 6313(a)(6)(A)(i)) and updated the accompanying analyses to reflect appropriate statutory provision, timelines, and compliance dates.

On February 22, 2013, DOE published a notice of public meeting and availability of the framework document regarding energy conservation standards for packaged terminal air conditioners and heat pumps standards. 78 FR 12252. This notice is available at: http://www.regulations.gov/#!documentDetail;D=EERE-2012-BT-STD-0029-0001.

DOE held a public meeting on March 18, 2013 ("March 2013 framework public meeting") to discuss procedural and analytical approaches to the rulemaking and to inform interested parties and facilitate their involvement in the rulemaking process. The public meeting sought input on DOE's planned analytical approach and identified several issues of particular interest to DOE for this rulemaking proceeding.

Table 1.3.1 lists the analyses conducted throughout the rulemaking process.

Table 1.3.1. PTAC and PTHP Analyses*

Preliminary Analyses	NOPR	Final Rule
Market and technology assessment	Life-cycle cost sub-group analysis	Revised NOPR analyses
Screening analysis	Manufacturer impact analysis	
Engineering analysis	Utility impact analysis	
Energy use determination	Emissions analysis	
Markups for equipment price determination	Employment impact analysis	
Life-cycle cost and payback period analysis	Regulatory impact analysis	
Shipments analysis		
National impact analysis		

* In the current rulemaking, DOE conducted the analyses listed under Preliminary Analyses as part of the NOPR analysis.

After the March 2013 framework public meeting, as part of the information gathering and sharing process for the manufacturer impact analysis (MIA), DOE organized and held interviews with manufacturers of PTACs and PTHPs as part of the engineering analysis. DOE had four objectives for these interviews: (1) solicit manufacturer feedback on the draft inputs to the engineering analysis; (2) solicit feedback on topics related to the manufacturer impact analysis; (3) provide an opportunity to express manufacturers' concerns to DOE; and (4) foster cooperation between manufacturers and DOE. DOE incorporated the information gathered during the engineering interviews with manufacturers into its engineering analysis (Chapter 5 of the final rule TSD) and the manufacturer impact analysis (Chapter 12 of the final rule TSD).

On September 16, 2014, DOE published a notice of public rulemaking ("September 2014 NOPR") in the Federal Register. 79 FR 55538 (September 16, 2014). In the September 2014 NOPR, DOE addressed, in detail, the comments received in earlier stages of rulemaking, and proposed amended energy conservation standards for PTACs and PTHPs that were more stringent that the levels in ASHRAE 90.1-2013. In conjunction with the September 2014 NOPR, DOE also published on its website the complete TSD for the proposed rule, which incorporated the analyses DOE conducted and technical documentation for each analysis. Also published on DOE's website were the engineering analysis spreadsheets, the LCC spreadsheet, and the national impact analysis standard spreadsheet. These materials are available at: http://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/64

In the September 2014 NOPR, DOE identified seven issues on which it was particularly interested in receiving comments and views of interested parties: alternate refrigerants, distribution channels, shipments data, efficiency trends, conversion costs, direct employment levels, and effects on small businesses. 79 FR 55538 at 55599-55600. After the publication of the September 2014 NOPR, DOE received written comments on these and other issues. DOE also held a public meeting in Washington, DC, on October 29, 2014, to discuss and receive comments regarding the tools and methods DOE used in the NOPR analysis, as well as the results of the analysis. DOE also invited written comments and announced the availability of a NOPR analysis technical support document (NOPR TSD). The NOPR TSD is available at: http://www.regulations.gov/#!documentDetail;D=EERE-2012-BT-STD-0029-0021

At the public meeting held on October 29, 2014, DOE presented the methodologies and results of the analyses set forth in the NOPR TSD. Interested parties provided comments. Key issues raised by stakeholders included: (1) the use of the ASHRAE 90.1-2013 levels as the analytical baseline; (2) the proportion of units that would require redesign to meet the standard levels proposed in the September 2014 NOPR; (3) the cumulative burden on manufacturers of redesigning to the amended ASHRAE levels and then redesigning to a more stringent Federal standard; and (4) the assumptions about PTAC and PTHP operations used in the energy use analysis.

DOE refined the NOPR analyses based on stakeholder comments for the final rule TSD.

1.4 STRUCTURE OF THE DOCUMENT

This final rule TSD outlines the analytical approaches used in this rulemaking. The TSD consists of seventeen chapters and appendices.

Chapter 1	Introduction: provides an overview of the appliance standards program and how it applies to the PTAC and PTHP rulemaking, and outlines the structure of the document.
Chapter 2	Analytical Framework: describes the rulemaking process.
Chapter 3	Market and Technology Assessment: characterizes the PTAC and PTHP market and the technologies available for increasing equipment efficiency.
Chapter 4	Screening Analysis: identifies design options that improve efficiency of the covered equipment and determines which technology options are viable for consideration in the engineering analysis.
Chapter 5	Engineering Analysis: discusses the methods used for developing the relationship between increased manufacturer price and increased efficiency.
Chapter 6	Markups Analysis: discusses the methods used for establishing markups for converting manufacturer prices to customer equipment costs.

Chapter 7	Energy Use Analysis: discusses the process used for generating energy-use estimates for the covered equipment as a function of standard levels.
Chapter 8	Life-Cycle Cost and Payback Period Analysis: discusses the methods used to analyze effects of standards on individual customers and users of the equipment and compares the LCC and PBP of equipment with and without higher efficiency standards.
Chapter 9	Shipments Analysis: estimates shipments of the equipment over the 30-year analysis period that is used in performing the national impact analysis (NIA), including how shipments may vary under alternative standard levels.
Chapter 10	National Impact Analysis: assesses the national energy savings, and the national net present value of total customer costs and savings, expected to result from specific, potential energy conservation standards.
Chapter 11	Life-Cycle Cost Subgroup Analysis: discusses the effects of potential standards on different subgroups of customers.
Chapter 12	Manufacturer Impact Analysis: discusses the effects of amended energy conservation standards on the finances and profitability of equipment manufacturers.
Chapter 13	Emissions Impact Analysis: discusses the effects of standards on three pollutants—sulfur dioxide (SO_2), nitrogen oxides (NOx), and mercury—as well as CO_2 emissions.
Chapter 14	Monetization of Emissions Reductions Benefits: discusses the basis for estimated monetary values used for the reduced emissions of CO_2 and NOx that are expected to result from each of the TSLs considered.
Chapter 15	Utility Impact Analysis: discusses selected effects of potential standards on electric utilities.
Chapter 16	Employment Impact Analysis: discusses the effects of amended energy conservation standards on national employment.
Chapter 17	Regulatory Impact Analysis: discusses the impact of non-regulatory alternatives to efficiency standards.
Appendix 6A	Detailed Data for Equipment Price Markups
Appendix 7A	Detailed Unit Energy Consumption Data
Appendix 10A	Full-Fuel-Cycle Multipliers

Appendix 10B	NIA Sensitivity Analysis for Alternative Product Price Trend Scenarios
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CHAPTER 2. ANALYTICAL FRAMEWORK

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CHAPTER 2. ANALYTICAL FRAMEWORK

2.1 INTRODUCTION

Section 6313(a)(6)(A)(ii) of 42 United Standards Code (U.S.C.), requires the U.S. Department of Energy (DOE) to establish energy conservation standards that are technologically feasible and economically justified and will result in significant energy conservation. This chapter describes the general analytical framework that DOE uses in developing such standards, as well as aspects specific to the analysis of standards for packaged terminal air conditioner (PTAC) and packaged terminal heat pump (PTHP) equipment. The analytical framework summarizes the methodologies, analytical tools, and relationships among the various analyses that are part of a standards rulemaking.

Figure 2.1.1 summarizes the analytical components of the standards-setting process. The column labeled *Approaches* lists the methodologies DOE uses to perform the various steps and analyses in the process. The primary focus of the figure is the column labeled *Analyses*. The columns labeled *Key Inputs* and *Key Outputs* show how the analyses fit into the rulemaking process and how they relate to each other. Key inputs are the types of data and information that the analyses require. Some key inputs can be found in public databases; other inputs DOE collects from interested parties or experts having specialized knowledge. Key outputs are the analytical results that feed directly into the standards-setting process. Lines with arrows connecting analyses show the types of information that feed from one analysis to another.

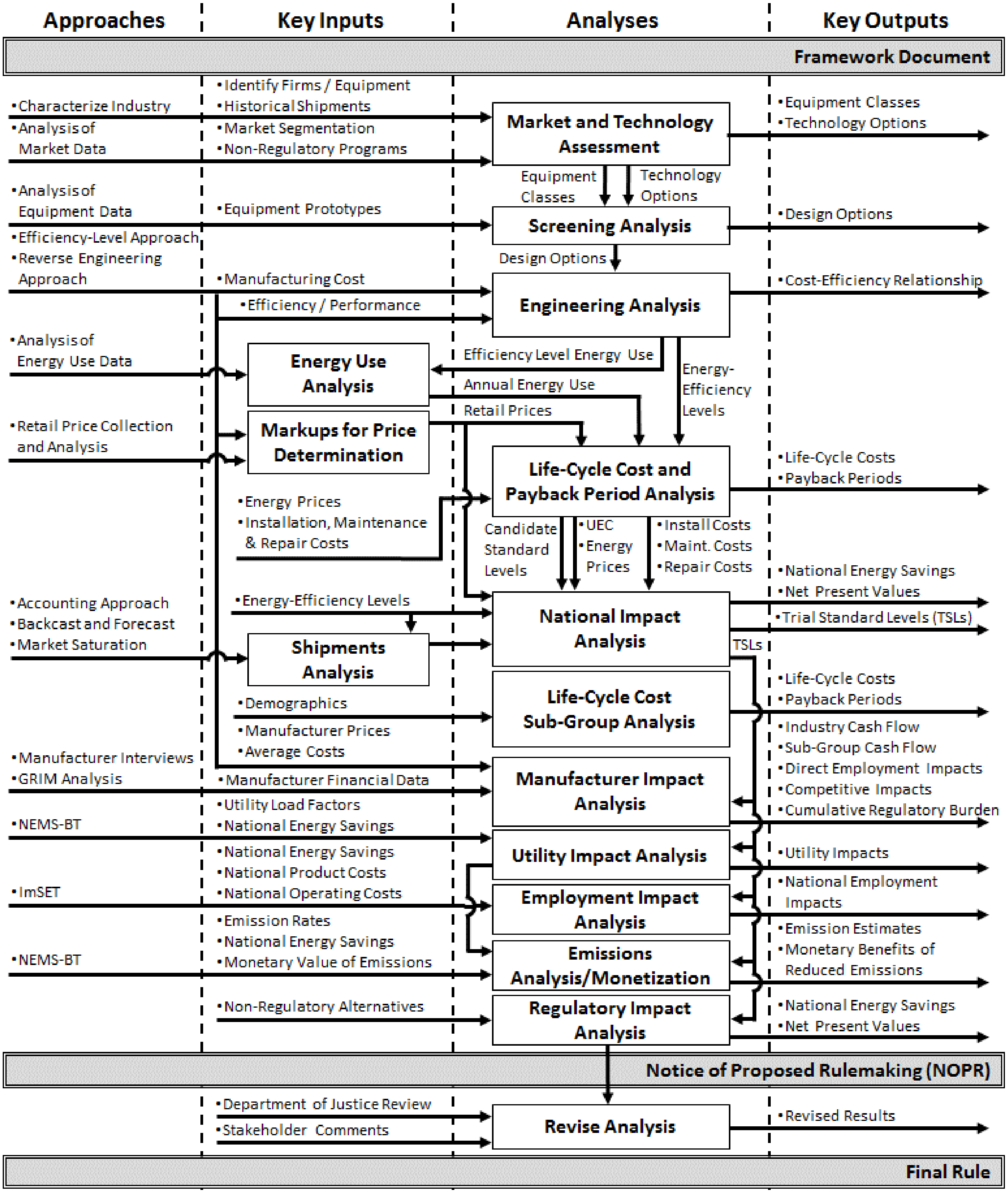

Figure 2.1.1 Analyses for PTAC and PTHP Energy Conservation Standards

The analyses that DOE performed in developing this final rule include:

- A *market and technology assessment* to characterize the relevant equipment markets and technology options, including prototype designs;
- A *screening analysis* to review each technology option and determine whether it is technologically feasible; is practical to manufacture, install, and service; would adversely affect equipment utility or availability; or would have adverse impacts on health and safety;
- An *engineering analysis* to develop cost-efficiency relationships for equipment designs that passed the screening analysis; the manufacturer's production costs (material, labor, and factory overhead) for achieving increased efficiency are evaluated;
- An *energy use* analysis to determine the annual energy use of the considered equipment at specific efficiency levels;
- A *markups analysis* to convert the manufacturer costs estimated from the engineering analysis to customer prices, which are then used in the life-cycle cost (LCC) and payback period analysis (PBP) and in the manufacturer impact analysis.;
- A *life-cycle cost and payback period analysis* to calculate, at the customer level, the discounted savings in operating costs (minus maintenance and repair costs) throughout the estimated average life of the covered equipment, compared to any increase in the installed cost of the equipment likely to result directly from the imposition of the standard;
- A *shipments analysis* to forecast equipment shipments, which then are used to calculate the national impacts of standards on energy consumption and costs, net present value (NPV), and future manufacturer cash flows;
- A *national impact analysis* to assess the aggregate impacts nationwide of the NPV of total customer LCC and national energy savings (NES);
- A *customer sub-group analysis* to evaluate variations in customer characteristics that might cause a standard to affect the LCC for particular customer sub-populations differently than for the overall population;
- A *manufacturer impact analysis* to estimate the financial impacts of standards on manufacturers and to calculate effects on competition, employment, and manufacturing capacity;
- An *employment impact analysis* to assess the aggregate effects of standards on national employment;
- A *utility impact analysis* to estimate the effects of proposed standards on the generation capacity and electricity generation of electric utilities;
- An *emissions analysis* to estimate the effects of amended energy conservation standards on emissions of carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen oxides (NO_X), and mercury (Hg);
- A *monetization of emission reduction benefits* resulting from reduced emissions associated with potential amended standards; and
- A *regulatory impact analysis* to evaluate alternatives to proposed amended energy conservation standards that could achieve substantially the same regulatory goal.

2.2 BACKGROUND

DOE developed the analytical framework pertaining to PTAC and PTHP equipment in the *Rulemaking Framework for Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps* (February 22, 2013). DOE announced the availability of the Framework document in a notice of public meeting and availability of a Framework document published in the *Federal Register* on February 22, 2013. 78 FR 12252

DOE presented the analytical approach to interested parties during a public meeting held on March 18, 2013.[1] DOE used comments gathered during the Framework public meeting as well as additional information to conduct analyses culminating in the publication of a Notice of Proposed Rulemaking for PTAC and PTHP equipment[2] on September 16, 2014. 79 FR 55538. DOE also held an associated public meeting for the NOPR stage in Washington, D.C. on October 29, 2014. After gathering stakeholder comments through the public meeting and open comment period, DOE revised and updated its analysis for today's final rule.

The following sections provide a brief overview of the different analytical approaches of this rulemaking analysis plan. DOE has used the most reliable data available at the time of each analysis in this rulemaking. DOE has also considered the submissions of additional data from interested parties during the rulemaking process.

2.3 MARKET AND TECHNOLOGY ASSESSMENT

The market and technology assessment characterizes the relevant equipment markets and technology options, including prototype designs, for considered equipment. Chapter 3 of this TSD describes in detail the market and technology assessment for PTAC and PTHP equipment.

2.3.1 Market Assessment

When initiating a standards rulemaking, DOE develops information on the present and past industry structure and market characteristics for the equipment being studied. This activity assesses the industry and equipment, both quantitatively and qualitatively, based on publicly available information. As such, for the considered equipment, DOE addressed (1) manufacturer market share and characteristics; (2) current regulatory and non-regulatory initiatives for improving equipment efficiency; and (3) trends in equipment characteristics and retail markets. This information serves as resource material throughout the rulemaking.

DOE reviewed equipment literature and interviewed manufacturers to develop an overall picture of the market for PTAC and PTHP equipment in the United States. Industry publications and trade journals, government agencies, and trade organizations provided the bulk of this information. The appropriate sections of this TSD, particularly chapter 3, describe the resulting information as DOE used it in the analysis.

2.3.2 Technology Assessment

DOE typically uses information relating to current and past technology options and prototype designs to determine what technologies manufacturers use to attain higher performance levels. In consultation with interested parties, DOE develops a list of technologies for consideration. Initially, the list encompasses all the technologies DOE believes are technologically feasible. DOE developed a list of technologically feasible design options through consultation with manufacturers of components and systems, from trade publications and technical papers. Since many options for improving equipment efficiency are available in existing units, equipment literature and direct examination of equipment provided additional information.

2.4 SCREENING ANALYSIS

As described in section 2.3.2, DOE develops an initial list of efficiency enhancement options from the technologies identified as technologically feasible. Then DOE, in consultation with interested parties, reviews the list to determine whether those options (1) are technologically feasible; (2) are practicable to manufacture, install, and service; (3) have an adverse impact on equipment utility or availability; or (4) have adverse impacts on health and safety. In addition, DOE removes from the list any technology options for which energy consumption data are lacking as well as any for which the energy consumption cannot be measured adequately by DOE test procedures. Chapter 4 of this TSD describes the screening analysis. In the engineering analysis, DOE further considers the efficiency-enhancement options that it did not eliminate in the screening analysis.

2.5 ENGINEERING ANALYSIS

In the engineering analysis (chapter 5 of this TSD), DOE evaluates a range of equipment efficiency levels and their associated manufacturing costs in order to establish the relationship between the cost and the efficiency of PTAC and PTHP equipment. This relationship serves as the basis for cost/benefit calculations related to individual customers, manufacturers, and the nation. Chapter 5 discusses the equipment classes DOE analyzed, the representative baseline units, the incremental efficiency levels, and the methodology DOE used to develop manufacturing costs, the methodology it used to develop the energy consumption model, the cost-efficiency curves, and the effect of efficiency improvements on the covered equipment.

The purpose of the engineering analysis is to estimate the incremental manufacturing production costs associated with increasing equipment efficiency above the level of the baseline model in each equipment class. The engineering analysis generally considers technologies not eliminated in the screening analysis, although certain technologies were not analyzed because they offered negligible incremental improvements to efficiency. DOE considers the remaining technologies, designated “design options,” in developing cost-efficiency curves, which are used for the LCC and PBP analysis. For each equipment class, DOE selected efficiency levels and obtained incremental cost data at each level.

DOE typically structures its engineering analysis around one of three methodologies: (1) the design-option approach, which calculates the incremental costs of adding specific design options to a baseline model; (2) the efficiency-level approach, which calculates the relative costs of achieving increases in energy efficiency levels without regard to the particular design options used to achieve such increases; and/or (3) the reverse-engineering or cost-assessment approach, which involves a “bottom-up” manufacturing cost assessment based on a detailed bill of materials derived from teardowns of the equipment being analyzed. A supplementary method called a catalog teardown uses published manufacturer catalogs and supplementary component data to estimate the major physical differences between a piece of equipment that has been physically disassembled and another piece of similar equipment for which catalog data is available to determine the cost of the latter equipment.

DOE conducted the engineering analyses using the efficiency-level approach and the reverse-engineering approach. DOE designated a baseline efficiency level equivalent to the minimum efficiency allowed by energy conservation standards. DOE set the baseline level equivalent to the ANSI/ASHRAE/IES Standard 90.1-2013 minimum for PTAC and PTHP equipment, since DOE is required to, at a minimum, adopt the ASHRAE levels as the Federal standard. (42 U.S.C. (a)(6)(A)(ii)(I)). DOE set efficiency levels at incremental steps above the baseline up to the maximum efficiency level that is technologically feasible using current technologies.

To estimate the manufacturing production costs for equipment at each efficiency level, DOE reverse engineered a set of PTAC and PTHP equipment that was specifically selected to represent the range of efficiency levels. This reverse engineering involved the disassembly of units, analysis of the materials and manufacturing processes, and development of a spreadsheet cost model based on a clear and consistent manufacturing cost assessment methodology. DOE built a detailed cost assessment model that accurately estimates the manufacturing production cost (MPC) associated with producing a specific piece of equipment. The cost model reports those costs in aggregated form to maintain confidentiality of the data.

The reverse engineering analysis provides an estimated MPC for each PTAC and PTHP unit considered in the analysis. DOE used the least squares method to develop cost-efficiency equations for PTAC and PTHP equipment at different capacity levels. These cost-efficiency equations predict the MPC of a given unit based on its capacity and its rated efficiency. DOE used the cost-efficiency equations to estimate the incremental cost increases associated with each efficiency level used in the analysis. This production cost information is an input to the markups analysis.

2.6 MARKUPS ANALYSIS

DOE uses manufacturer-to-customer markups to convert the manufacturer selling price (MSP) estimates from the engineering analysis to customer prices, which are then used in the LCC and PBP analysis and in the manufacturer impact analysis. Retail prices are necessary for the baseline efficiency level and all other efficiency levels under consideration (see chapter 6 of this TSD). To develop markups, DOE identified distribution channels (*i.e.*, how the equipment is distributed from the manufacturer to the customer). After identifying appropriate distribution channels, DOE utilized economic census data from the U.S. Census Bureau and input from the industry to define how equipment is marked up from the manufacturer to the customer.

2.7 ENERGY USE ANALYSIS

The energy use analysis (chapter 7 of this TSD) provides estimates of the annual unit energy consumption (UEC) of PTAC and PTHP equipment at the considered equipment classes and efficiency levels. The annual UECs are used in subsequent analyses including the LCC, PBP, and National Energy Savings (NES). In the 2008 rulemaking for PTAC and PTHP equipment, DOE used whole-building simulations to determine annual UEC data by cooling capacity and efficiency rating.[3] In the current rulemaking, DOE used the data for those equipment classes and efficiency levels that are the same as the 2008 rulemaking, and adjusted the data for those equipment classes and efficiency levels that are different from the 2008 rulemaking. Chapter 7 describes the methodology used to adjust the unit energy consumption of PTAC and PTHP equipment for the current rulemaking. As part of the energy use characterization, DOE made certain engineering assumptions regarding equipment application, including how the equipment is operated and under what conditions, and documented these assumptions in chapter 7 of the TSD.

2.8 LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

New or amended energy conservation standards for equipment result in a change in operating costs—usually a decrease—and a change in customer price—usually an increase. DOE analyzed the net effect of new standards on customers (chapter 8 of this TSD) by evaluating the net LCC using the cost-efficiency relationship derived in the engineering analysis, as well as the energy costs derived from the energy use analysis. Inputs to the LCC calculation include the installed cost to the customer (customer price plus installation cost); operating expenses (energy expenses and maintenance costs); the lifetime of the equipment; and a discount rate.

Equipment with efficiency higher than baseline typically has a higher installed cost and lower operating cost relative to baseline equipment. The payback period is the estimated amount of time (in years) it takes customers to recover the increased total installed cost (including equipment and installation costs) of a more efficient type of equipment through lower operating costs. DOE calculates the PBP by dividing the change in total installed cost (normally higher) due to a standard by the change in annual operating cost (normally lower) that results from the standard.

DOE conducted the LCC and PBP analyses for the PTAC and PTHP equipment classes 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 analyses by incorporating uncertainty and variability considerations in certain of the key parameters as discussed below. Inputs to the LCC and PBP analysis are categorized as: (1) inputs for establishing the total installed cost and (2) inputs for calculating the operating expense. Results of the LCC and PBP analyses were applied to other equipment classes through linear scaling of the results by the cooling capacity of the equipment class.

The equipment costs faced by purchasers of PTAC and PTHP equipment are derived from the MSPs estimated in the markups analysis. To forecast equipment costs into the future, DOE chose to apply a constant price trend (2013 levels) for each efficiency level in each equipment class for the NOPR. DOE reviewed the Energy Information Administration (EIA)'s energy price data to establish electricity prices for commercial consumers. DOE used EIA's *Annual Energy Outlook 2014* (*AEO 2014*) as the default source of projections of future energy prices for its LCC and PBP analysis.[4]

DOE developed discount rates for customers based on the cost of capital, which is commonly used to estimate the present value of cash flows to be derived from a typical company project or investment. DOE estimated the cost of capital of companies that purchase PTAC and PTHP equipment. The types of companies that DOE used are large hotel/motel chains, independent hotel/motel, assisted living/health care, and small office. More details regarding DOE's estimates of customer discount rates are provided in chapter 8 of the TSD.

DOE considered maintenance, repair, and installation costs for the equipment covered in this rulemaking. For PTACs, DOE utilized estimates of annual maintenance cost from the 2008 rulemaking for PTAC and PTHP equipment; the values were adjusted to current material and labor rates. For PTHPs, DOE scaled the adjusted estimate of PTAC maintenance costs with the ratio of PTHP to PTAC annualized maintenance costs. Repair costs are associated with repairing or replacing components that have failed. DOE utilized manufacturer- and vendor-provider extended warranty price data to estimate annual repair costs. DOE assumed that any routine or minor repairs are included in the annualized maintenance costs. Repair costs were linearly scaled by cooling capacity to apply to all equipment classes.

DOE established average equipment lifetimes for use in the LCC and subsequent analyses by using data from the previous rulemaking, stakeholder comments from this current rulemaking, and stakeholder comments from the ASHRAE Standard 90.1-2013 Notice of Data Availability.[5]

2.9 SHIPMENTS ANALYSIS

Forecasts of shipments are required to calculate the national impacts of standards on energy consumption, NPV, and future manufacturer cash flows. DOE used historical data as the basis for projecting future shipments of PTAC and PTHP equipment (Chapter 9 of this TSD). Historical shipments data are used to build up an equipment stock and also to calibrate the shipments model. Based off the equipment stock and calibrated model, DOE calculated shipments intended for new construction and replacement applications. The sum of new construction and replacement shipments is the total shipments.

2.10 NATIONAL IMPACT ANALYSIS

The national impact analysis, described in chapter 10 of this TSD, assesses the NPV of total customer costs and benefits. DOE determined both the NPV and the national energy savings (NES) for the efficiency levels established for PTAC and PTHP equipment. To make the analysis more accessible and transparent to all interested parties, DOE used a spreadsheet model to calculate the energy savings and the national commercial customer costs and savings from each TSL. The NIA calculations are based on the annual energy consumption and total installed cost data from the energy use analysis and the LCC analysis. In the NIA, DOE forecasted the lifetime energy savings, energy cost savings, equipment costs, and NPV of commercial customer benefits for each equipment class over the lifetime of PTAC equipment sold during the 30 year analysis period.

2.10.1 National Energy Savings

The inputs for determining NES are (1) annual energy consumption per unit, (2) shipments, (3) equipment stock, (4) national energy consumption, and (5) site-to-source conversion factors. DOE calculated the national energy consumption by multiplying the number of units, or stock, of equipment (by vintage) by the unit energy consumption (also by vintage).[1] DOE calculated national annual energy savings as the difference between national energy consumption in the base case (without new efficiency standards) and in each higher-efficiency standards case. The analysis included estimated energy savings by fuel type used for generating electricity. DOE estimates energy consumption and savings based on site energy, then converts the electricity consumption and savings into source energy. Cumulative energy savings are the sum of the annual NES throughout the forecast period.

The stock of PTAC and PTHP equipment is dependent on annual shipments and the lifetime of the equipment. DOE conducted shipments projections under the baseline efficiency levels and new standard levels and equipment efficiency trends. DOE's shipments model presumed that shipments of new PTACs and PTHPs were driven by growth in commercial floor space for building types using equipment as well as necessary stock replacements.

2.10.2 Net Present Value

The inputs for determining NPV are (1) total annual installed cost, (2) total annual operating cost savings, (3) discount factor, (4) present value of costs, and (5) present value of savings. DOE calculated NPV as the difference between total operating-cost savings (including electricity, repair, and maintenance cost savings) and increases in total installed costs (including equipment price and installation cost). DOE calculated savings over the life of the equipment, accounting for differences in yearly energy rates, and used a discount factor to discount future costs and savings to the present.

DOE calculated increases in total installed costs as the product of the difference in the total installed cost between the baseline efficiency level and new standard levels (i.e., once the amended energy conservation standard takes effect) and the annual shipments in the standards case. Because costs of the more-efficient equipment bought in the standard cases are higher than those of equipment bought in the base case, price increases appear as negative values in the NPV.

DOE expressed operating cost savings as decreases in operating costs associated with the lower energy consumption of equipment bought under the new standards compared to the

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[1] Vintage represents the age of the equipment.

baseline efficiency level. Total operating-cost savings are the product of savings per unit and the number of units of each vintage surviving in a particular year.

2.10.3 Forecasted Efficiencies

Several of the inputs for determining NES (*e.g.*, annual energy consumption per unit) and NPV (*e.g.*, total annual installed cost and total annual operating cost savings) depend on the efficiency of the equipment. Thus, DOE forecasted efficiencies for the base case and standards cases. The forecasted efficiencies specify the annual average shipment-weighted equipment efficiencies for future years.

DOE based historical shipment-weighted average efficiency trends for PTAC and PTHP equipment on limited PTAC and PTHP efficiency data. Once DOE established historical efficiency trends, it estimated future trends of equipment efficiency, and in turn, annual energy consumption by extrapolating from the historical trend.

DOE based its standards-case forecasts (i.e., forecasts of efficiency trends after standards take effect) on the use of a roll-up efficiency scenario and parallel growth trend. Under a roll-up scenario, all equipment at energy efficiency levels below a prospective standard are moved or rolled-up to the minimum efficiency level allowed under the new standard. The distribution of equipment at new standard levels is unaffected (i.e., this equipment remains at its pre-standard efficiency levels). The roll-up efficiency scenario dictates how DOE determined efficiency distributions in the first year a new standard takes effect, but does not define how equipment efficiency will be distributed in the future. Under the parallel growth trend, DOE assumes that the standards case efficiency trend parallels the base case efficiency trend. In other words, the initial jump in shipment-weighted efficiency that occurs when the standard first becomes effective is maintained throughout the forecast.

2.11 CUSTOMER SUB-GROUP ANALYSIS

The customer sub-group analysis evaluates the potential impacts of new or amended standards on commercial customers, DOE evaluates impacts on identifiable groups (i.e., subgroups) of customers that may be disproportionately affected by a national standard.
DOE evaluated impacts on a subgroup consisting of independently-operating lodging businesses using the LCC and PBP spreadsheet model. To the extent possible, it utilized inputs appropriate for this subgroup. Chapter 11 of this TSD describes the sub-group analysis for customers of PTAC and PTHP equipment.

2.12 MANUFACTURER IMPACT ANALYSIS

The manufacturer impact analysis (MIA) assesses the impacts of new energy efficiency standards on manufacturers of PTAC and PTHP equipment. Potential impacts include financial effects, both quantitative and qualitative, that might lead to changes in the manufacturing practices for the equipment. DOE identifies those potential impacts through interviews with manufacturers and other interested parties.

As described in chapter 12 of this TSD, DOE conducted the MIA for the covered equipment in three phases, and further tailored the analytical framework based on stakeholder comments. In Phase I, DOE conducted structured, detailed interviews with a representative cross-section of manufacturers and prepared a profile of the PTAC and PTHP industry. In Phase II, DOE prepared an industry cash-flow analysis to quantify the potential impacts of an amended energy conservation standard on manufacturers of PTACs and PTHPs. In Phase III, DOE evaluated subgroups of manufacturers that may be disproportionately impacted by amended energy conservation standards or that may not be represented accurately by the average cost assumptions used to develop the industry cash-flow analysis.

2.13 EMISSIONS ANALYSIS

In the emissions analysis, DOE estimated the reduction in power sector emissions of carbon dioxide (CO_2), nitrogen oxides (NOx), sulfur dioxide (SO_2), and mercury (Hg) from potential energy conservation standards for PTAC and PTHP equipment. In addition, DOE estimates emissions impacts in production activities (extracting, processing, and transporting fuels) that provide the energy inputs to power plants. These are referred to as “upstream” emissions. Together, these emissions account for the full-fuel-cycle (FFC).

As described in chapter 13 of this TSD, the primary environmental effects of the standards will be reduced power plant emissions resulting from reduced consumption of electricity. Emissions reductions associated with new standards for PTAC and PTHP equipment pertain primarily to CO_2, NO_X, and Hg. After estimating emissions reductions, DOE monetized the benefits associated with those reductions, as summarized below.

2.14 MONETIZING CARBON DIOXIDE AND OTHER EMISSIONS REDUCTIONS

DOE estimated the monetary benefits likely to result from the reduced emissions of CO_2 and NO_X that are expected to result from each potential standard level. The monetization of the benefits of emissions reductions is described in chapter 14 of this TSD. DOE is aware of multiple agency efforts to determine the range of values appropriate to evaluating the potential economic benefits of reduced Hg emissions, and DOE is evaluating how to appropriately monetize avoided SO_2 and Hg emissions in energy conservation standards rulemakings. For this rulemaking, DOE did not monetize estimated SO_2 and Hg reductions.

To carry out this analysis, DOE used a variant of the EIA’s National Energy Modeling System (NEMS). NEMS is a large, multi-sector, partial-equilibrium model of the U.S. energy sector that EIA has developed throughout the past decade, primarily to help in preparing the *AEO*. NEMS, which is available in the public domain, produces a widely recognized baseline energy forecast for the United States, currently through 2040. Typical NEMS outputs include forecasts of electricity sales, electricity price, and avoided electric generating capacity. DOE uses a variant of NEMS known as NEMS-BT to provide key inputs to its analysis.[2]

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[a] For more information on NEMS, refer to the U.S. Department of Energy, Energy Information Administration documentation. A useful summary is *National Energy Modeling System: An Overview 2000*, DOE/EIA-

Carbon Dioxide

In order to estimate the monetary value of benefits resulting from reduced CO_2 emissions, DOE used the most current values for the social cost of carbon (SCC) developed and/or agreed to by an interagency work group and adjusted to 2014$ using the implicit price deflator for gross domestic product (GDP) from the Bureau of Economic Analysis. The SCC is intended to serve as a monetary measure of the incremental damage resulting from greenhouse gas (GHG) emissions, including, but not limited to, net loss of agricultural productivity, human health effects, property damage from sea level rise, and changes in ecosystem services. With full regard for the limits of both quantification and monetization, the SCC can be used to provide estimates of the social benefits of reductions in GHG emissions.

At the time of this analysis, the most recent interagency estimates of the potential global benefits resulting from reduced CO_2 emissions in 2015, expressed in 2014$, were $12.2, $41.2, $63.4, and $121 per metric ton avoided.[3] Those values increase in real terms over time. Additionally, the interagency group determined that a range of values from 7 percent to 23 percent should be used to adjust the global SCC to calculate domestic effects, although DOE gives preference to consideration of the global benefits of reduced CO_2 emissions. To calculate a present value of the range of monetary values, DOE discounted each of the four SCC values using the discount rate that was used to obtain the SCC value in that case. Those values are subject to change as the scientific and economic knowledge continues to evolve rapidly regarding the contribution of CO_2 and other GHGs to changes in the future global climate and the potential resulting damages to the world economy.

In the absence of any Federal regulation of power plant emissions of CO_2, a DOE standard is likely to result in reductions of these emissions. The CO_2 emission reductions likely to result from a standard were estimated using NEMS-BT and national energy savings estimates drawn from the NIA spreadsheet model. The net benefit of the standard is the difference between emissions estimated by NEMS-BT at each standard level considered and the *AEO* reference case. NEMS-BT tracks CO_2 emissions using a detailed module that provides results that include broad coverage of all sectors and interactive effects.

Nitrogen Oxides

DOE also estimated the cumulative monetary value of the economic benefits associated with NOx emissions reductions anticipated to result from amended standards for PTACs and PTHPs. Estimates of monetary value for reducing NOx from stationary sources range from $483

0581(2000), March 2000. EIA approves use of the name NEMS to describe only an official version of the model without any modification to code or data. Because DOE's analysis entails minor code modifications, and the model is run under various policy scenarios that are variations on EIA assumptions, DOE refers to the model as NEMS-BT (BT stands for DOE’s Building Technologies Program, under whose aegis this work is performed). NEMS-BT previously was called NEMS-BRS.

[3] The interagency group selected four sets of SCC values for use in regulatory analyses. Three sets of values are based on the average SCC from the three IAMs, at discount rates of 2.5, 3, and 5 percent. The fourth set, which represents the 95th percentile SCC estimate across all three models at a 3-percent discount rate, was included to represent higher than expected impacts from temperature change further out in the tails of the SCC distribution.

to $4,969 per ton in 2014$.[4] DOE calculated monetary benefits using a medium value for NOx emissions of $2,727 per short ton (in 2014$), and real discount rates of 3 percent and 7 percent.

DOE has taken into account how amended energy conservation standards would reduce site NOx emissions nationwide and increase power sector NOx emissions in those 22 States not affected by the Clean Air Interstate Rule (CAIR; 70 FR 25162 (May 12, 2005)).[5] DOE estimated the monetized value of net NOx emissions reductions resulting from each of the efficiency levels considered based on estimates found in the relevant scientific literature.

2.15 UTILITY IMPACT ANALYSIS

The utility impact analysis (chapter 15 of this TSD) assesses the effects of higher efficiency standards on electric utility industries. DOE uses NEMS-BT to provide key inputs to its analysis. DOE conducted the utility impact analysis as a scenario departing from the latest *AEO* reference case. In other words, DOE modeled the energy savings from amended energy conservation standards using NEMS-BT to generate forecasts that deviate from the *AEO* reference case. Chapter 15 of the NOPR TSD describes the utility impact analysis in further detail.

2.16 EMPLOYMENT IMPACT ANALYSIS

Energy conservation standards can affect employment both directly and indirectly. Direct employment effects are changes, resulting from the imposition of new standards, in the number of employees at the plants that produce covered equipment and at affiliated distribution and service companies. DOE evaluates direct employment impacts in the MIA. Indirect employment impacts may result if the imposition of standards causes expenditures to shift between goods (the substitution effect) and/or create changes in income and overall expenditure levels (the income effect).

As discussed in chapter 16 of this TSD, DOE investigated indirect employment impacts for PTAC and PTHP energy conservation standards using the Impact of Sector Energy Technologies (ImSET) model developed by Pacific Northwest National Laboratory (PNNL). PNNL developed the ImSET model for DOE's Office of Planning, Budget, and Analysis. The model estimates the employment and income effects of energy-saving technologies in buildings, industry, and transportation. In comparison with simple economic multiplier approaches, ImSET

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[4] For additional information, refer to U.S. Office of Management and Budget (OMB)–Office of Information and Regulatory Affairs. *2006 Report to Congress on the Costs and Benefits of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities*. Washington, D.C.

[5] CAIR established a cap on NOx emissions in 28 eastern States and the District of Columbia. Energy conservation standards are expected to have little effect on NOx emissions in those States covered by CAIR because excess NOx emissions allowances resulting from the lower electricity demand could be used to permit offsetting increases in NOx emissions. However, standards would be expected to reduce NOx emissions in the States not affected by the caps, so DOE estimated NOx emissions reductions from the standards considered in this NOPR for these States.

allows for more complete and automated analysis of the economic effects of energy conservation investments.

2.17 REGULATORY IMPACT ANALYSIS

Pursuant to Executive Order 12866 (“Regulatory Planning and Review,” October 4, 1993. 58 FR 51735), DOE prepared a regulatory impact analysis (RIA), which was subject to review under the Executive Order by the Office of Information and Regulatory Affairs at the Office of Management and Budget. The RIA, described in chapter 17 of this TSD, evaluated the ability of non-regulatory alternatives to standards to achieve significant energy savings at a reasonable cost, and compared the effectiveness of each to the effectiveness of the new standards.

DOE recognizes that voluntary or other non-regulatory efforts by manufacturers, utilities, and other interested parties can result in substantial improvements to energy efficiency or reductions in energy consumption. DOE considered the likely effects of non-regulatory initiatives on equipment energy use, customer utility, and LCC. Although DOE based its assessment on the documented effects of similar initiatives to date, it also considered information regarding the effects current initiatives might have in the future.

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2. U.S. Department of Energy – Office of Energy Efficiency and Renewable Energy. Notice of Proposed Rulemaking and Public Meeting: Energy Conservation Program: Energy Conservation Standards for Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps. September 2014. Washington, D.C. <www.regulations.gov/#!documentDetail;D=EERE-2012-BT-STD-0029-0017>

3. U.S. Department of Energy – Office of Energy Efficiency and Renewable Energy, Energy Conservation Program for Commercial and Industrial Equipment: Packaged Terminal Air Conditioner and Packaged Terminal Heat Pump Energy Conservation Standards., 2007. (Last accessed June, 2014.) <www.regulations.gov/#!docketDetail;D=EERE-2007-BT-STD-0012>

4. U.S. Department of Energy – Energy Information Administration, Annual Energy Outlook 2014 with Projections to 2040, 2014. Washington, DC. <www.eia.gov/forecasts/aeo/pdf/0383%282014%29.pdf>

5. U.S. Department of Energy – Office of Energy Efficiency and Renewable Energy, Energy Conservation Program for Certain Industrial Equipment: Energy Conservation Standards for Commercial Heating, Air-Conditioning, and Water-Heating Equipment: Notice of Data Availability, 2014. Washington, DC. <www.gpo.gov/fdsys/pkg/FR-2014-04-11/html/2014-08214.htm>

CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

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CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

3.1 INTRODUCTION

This chapter details the market and technology assessment that the U.S. Department of Energy (DOE) has conducted in support of the ongoing energy conservation standards rulemaking for packaged terminal air conditioners (PTACs) and packaged terminal heat pumps (PTHPs). The goal of the assessment is to develop a qualitative and quantitative characterization of the PTAC and PTHP industry and market structure based on publicly available information and data and information submitted by manufacturers and other stakeholders. Publicly available information includes the equipment certification directory from the Air-Conditioning, Heating, and Refrigeration Institute[a] (AHRI), as well as Current Industry Reports (CIR) from the U.S. Census Bureau.

This chapter first defines the PTAC and PTHP equipment that is the subject of this rulemaking (section 3.2), divides the equipment into equipment classes (3.3), and describes the metrics and test procedures that are used to characterize PTAC and PTHP equipment (3.4). Next, the chapter defines the equipment producers by discussing trade groups (3.5), manufacturers and market shares (3.6), and the regulatory programs (3.7) and voluntary programs (3.8) to which they may adhere. Then the chapter describes the market by discussing shipment data (3.9) and characterizing the market for different equipment types (3.10). The chapter closes with a technology assessment (3.11) that presents a preliminary list of technologies (referred to as technology options) that may improve the energy efficiency of PTACs and PTHPs.

3.2 EQUIPMENT DEFINITIONS

Section 340 of the Energy Policy and Conservation Act (EPCA) defines a "packaged terminal air conditioner" as "a wall sleeve and a separate unencased combination of heating and cooling assemblies specified by the builder and intended for mounting through the wall. It includes a prime source of refrigeration, separable outdoor louvers, forced ventilation, and heating availability by builder's choice of hot water, steam, or electricity." (42 U.S.C. 6311(10)(A)) EPCA defines a "packaged terminal heat pump" as "a packaged terminal air

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[a] The Air-Conditioning, Heating, and Refrigeration Institute (AHRI), formerly referred to as ARI, is the trade association representing PTAC and PTHP manufacturers.

conditioner that utilizes reverse cycle refrigeration as its prime heat source and should have supplementary heat source available to builders with the choice of hot water, steam, or electric resistant heat.” (42 U.S.C. 6311(10)(B)) DOE codified these definitions in 10 CFR 431.92 in a final rule issued October 21, 2004. 69 FR 61970.

PTACs and PTHPs are self-contained heating and air-conditioning units encased inside a sleeve specifically designed to go through the exterior building wall. The basic design of a PTAC is comprised of a compressor, an evaporator, a condenser, a fan, and an enclosure. Basic PTHPs feature additional items to those found in PTACs, such as more sophisticated metering devices, a reversing valve, and more sophisticated controls. All manufacturers offer PTACs and PTHPs with supplemental heating, with some offering a variety of add-on options. PTACs and PTHPs are installed by insertion into the wall sleeve and connection to an electrical outlet. They are primarily used to provide space conditioning for commercial facilities such as hotels and motels, assisted living facilities, hospitals, apartments, dormitories, schools, and offices.

There is a wide variety of wall sleeve sizes found in different buildings. These wall sleeve sizes are market driven (i.e., the applications or facilities where the PTACs or PTHPs are installed is what determines the “market standard” wall sleeve dimension) and require manufacturers to offer various PTACs and PTHPs that can fit into various wall sleeve dimensions. For new units, the industry has standardized the wall sleeve dimension for PTACs and PTHPs in buildings over the past 25 years to be 16 inches high by 42 inches wide. Units that have a wall sleeve dimension of 16 inches high or greater by 42 inches wide or greater are considered “standard size” equipment and all other units are considered “non-standard size” equipment. In contrast, the industry does not have a common wall sleeve dimension that is typical for all older existing facilities. These facilities, such as high-rise buildings found in large cities, typically use non-standard size equipment. In these installations, altering the existing wall sleeve opening to accommodate the more efficient, standard size equipment could include extensive structural changes to the building, could be very costly, and is therefore rarely done.

3.3 EQUIPMENT CLASSES

When evaluating and establishing energy conservation standards, DOE divides covered equipment into equipment classes by the type of energy used or by capacity or other performance-related features that justify a different standard. In making a determination whether a performance-related feature justifies a different standard, DOE considers such factors as the utility to the customer of the feature and other factors DOE determines are appropriate.

The current equipment classes as established in the final rule issued on October 7, 2008, divide PTAC and PTHP equipment into twelve equipment classes. 73 FR 58772 (October 7, 2008) Equipment classes are based on whether the equipment is an air conditioner or heat pump, the equipment’s cooling capacity, and the equipment’s wall sleeve dimensions. There are two categories of wall sleeve dimensions: “standard size” with wall sleeve dimensions greater than or equal to 16 inches high or greater than or equal to 42 inches wide; and “non-standard size” with wall sleeve dimensions less than 16 inches high or less than 42 inches wide. Table 3.3.1 shows the current equipment class structure.

Table 3.3.1 Existing Federal Equipment Classes for PTACs and PTHPs

Equipment Class		
Equipment	**Category**	**Cooling Capacity**
PTAC	Standard Size*	<7,000 Btu/h
		≥7,000 Btu/h and ≤15,000 Btu/h
		>15,000 Btu/h
	Non-Standard Size**	<7,000 Btu/h
		≥7,000 Btu/h and ≤15,000 Btu/h
		>15,000 Btu/h
PTHP	Standard Size*	<7,000 Btu/h
		≥7,000 Btu/h and ≤15,000 Btu/h
		>15,000 Btu/h
	Non-Standard Size**	<7,000 Btu/h
		≥7,000 Btu/h and ≤15,000 Btu/h
		>15,000 Btu/h

* Standard size refers to PTAC or PTHP equipment with wall sleeve dimensions having an external wall opening greater than or equal to 16 inches high or greater than or equal to 42 inches wide, and a cross-sectional area greater than or equal to 670 square inches.

** Non-standard size refers to PTAC or PTHP equipment with existing wall sleeve dimensions having an external wall opening of less than 16 inches high or less than 42 inches wide, and a cross-sectional area less than 670 square inches.

DOE is not considering amended energy conservation standards for non-standard size PTAC and PTHP equipment in this rulemaking, because the non-standard size equipment classes represent a small and declining portion of the market, and because of a lack of adequate information to analyze non-standard size units. The shipments analysis conducted for the 2008 final rule projected that shipments of non-standard size PTACs and PTHPs would decline from about 30,000 units in 2012 (6.6% of the entire PTAC and PTHP market) to about 16,000 units in 2042 (2.4% of the entire PTAC and PTHP market).[b]

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[b] See DOE’s discussion regarding shipment projections for standard and non-standard PTAC and PTHP equipment and the results of shipment projections in the technical support document for the 2008 PTAC and PTHP energy conservation standard at: *http://www.regulations.gov/#!documentDetail;D=EERE-2007-BT-STD-0012-0032* (Chapter 10, Section 10.5).

Some manufacturers have introduced PTACs on the market that incorporate a ventilation system attachment that takes in make-up air and provides supplemental conditioning for this make-up air: dehumidification when outdoor humidity levels are high and also electric resistance heating when outdoor temperature is low. DOE believes that PTAC and PTHP units with add-on or integrated dehumidification systems currently meet the definition of PTACs and PTHPs, respectively. Thus, models with add-on or integrated dehumidification systems should be tested using the current test procedure and should meet the current energy conservation standards. Currently, the DOE test procedure does not require that the dehumidification module on such models be energized during testing, so the energy use of the dehumidification system would not be measured or accounted for in the EER metric. If DOE considers future amendments to the test procedure to account for energy consumed by the dehumidification systems, then DOE could consider designating a separate equipment class for such equipment at that time.

3.4 ENERGY USE METRIC AND EQUIPMENT TEST PROCEDURES

The energy conservation standards for PTACs and PTHPs are represented in terms of the energy efficiency ratio (EER) and the coefficient of performance (COP) as defined by the AHRI Standard 310/380-2014 *Standard for Packaged Terminal Air-Conditioners and Heat Pumps* (AHRI 310/380-2014) test procedure. EER is defined as “the ratio of the produced cooling effect of an air conditioner or heat pump to its net work input, expressed in Btu/watt-hour.” COP is defined as “the ratio of the produced cooling effect of an air conditioner or heat pump (or its produced heating effect, depending on the mode of operation) to its net work input, when both the cooling (or heating) effect and the net work input are expressed in identical units of measurement.” DOE has incorporated these definitions and test procedures into its regulations at 10 CFR Part 431.92 and 10 CFR Part 431.96, respectively.

3.5 MANUFACTURER TRADE GROUPS

DOE identified the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) as the only trade group that supports, or has an interest in, the PTAC and PTHP industry. Formed in 1953, AHRI, previously known as ARI, is the national trade association representing manufacturers of more than 90 percent of North American produced central air-conditioning and commercial refrigeration equipment. ARI and the Gas Appliance Manufacturers Association (GAMA) merged to become AHRI on January 1, 2008.

AHRI develops and publishes technical standards for residential and commercial air-conditioning, heating, and refrigeration equipment using rating criteria and procedures for measuring and certifying equipment performance. The current Federal test procedure for PTACs and PTHPs incorporates by reference an AHRI standard, AHRI 310/380-2004. AHRI has developed a certification program that a number of manufacturers in the PTAC and PTHP industry have used to certify their equipment. Manufacturers certify their own equipment by providing AHRI with test data. Through the AHRI certification program, AHRI evaluates test data, determines if equipment conforms to AHRI 310/380-2004, and verifies that manufacturer-reported ratings are accurate. AHRI also maintains the Directory of Certified Product Performance, which is a database of equipment ratings for all manufacturers who elect to participate in the program. DOE used AHRI's certification data, retrieved from the 2014 AHRI Directory of Certified Product Performance, in the engineering analysis (chapter 5 of this Technical Support Document (TSD)).

3.6 MANUFACTURER INFORMATION

The following section details information regarding manufacturers of PTAC and PTHP equipment, including estimated market shares (section 3.6.1) and small businesses (section 3.6.2).

3.6.1 Manufacturers and Market Shares

DOE identified three large manufacturers of standard size PTAC and PTHP equipment that hold approximately 80 percent of the standard size market in terms of shipments. Table 3.6.1 shows these manufacturers.

Table 3.6.1 Large Manufacturers of Standard Size PTACs and PTHPs

General Electric (GE) Company
Goodman Manufacturing Company[c]
Friedrich Air Conditioning Company

Ten other manufacturers, listed in Table 3.6.2, hold the remaining 20 percent of the standard size PTAC and PTHP market.

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[c] Goodman Manufacturing Company brands its PTAC and PTHP equipment under the Amana name, a trademark of the Maytag Corporation. More information about the company can be found at http://www.amana-ptac.com.

Table 3.6.2 Other Manufacturers of Standard Size PTACs and PTHPs

Daikin Applied[d]
E-Air, LLC
ECR International[e]
Electrolux Home Products, Inc.
Fedders Islandaire, Inc.
GREE Electric Appliances of Zhuhai
Haier America
Heat Controller, Inc.
LG Electronics
YMGI Group, LLC

DOE estimated market share data for standard size PTAC and PTHP manufacturers using publicly available data including the Securities and Exchange Commission (SEC) 10-K reports filed by publicly owned manufacturers and from stakeholder input. Market share data has been aggregated for this report to avoid disclosing confidential company data.

The standard size PTAC and PTHP market differs from the non-standard size PTAC and PTHP industry in that several of the manufacturers of standard size units are domestically owned with manufacturing facilities located outside of the United States. (In contrast, most non-standard size PTAC and PTHP production occurs in the United States.) Currently there is only one major manufacturer of standard size PTAC and PTHP equipment manufacturing equipment in the United States. Several foreign-owned companies have recently entered the U.S. market for standard-sized PTACs and PTHPs.

DOE identified three major manufacturers of non-standard size PTAC and PTHP equipment: Daikin Applied, ECR International, and Fedders Corporation[f]. These three manufacturers share the majority of the non-standard size PTAC and PTHP market. Other manufacturers of non-standard size units include: Air-Con International, Cold Point Corporation, Comitale National Inc., E-Air LLC, Evergreen LLC, Heat Controller Inc., Ice Air LLC,

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[d] Daikin Applied (formally McQuay International) is a subsidiary of Daikin Industries, Ltd. More information about the company can be found at http://www.daikinapplied.com.

[e] ECR International brands its PTAC and PTHP equipment under the RetroAire brand name. More information about the company can be found at http://www.retroaire.com.

[f] Fedders Corporation brands its non-standard PTAC and PTHP equipment under the Fedders Islandaire brand name. More information about the company can be found at http://www.islandaire.com.

International Refrigeration Products, Prem Sales LLC, Simon-Aire Inc., and YMGI Group LLC. Market share data for non-standard size PTAC and PTHP manufacturers was estimated using publicly available data including the SEC 10-K reports filed by publicly owned manufacturers.

Table 3.6.3 shows current AHRI members that manufacture PTACs and PTHPs, with parent companies shown in parentheses, if applicable. These member companies offer equipment certified under AHRI's PTAC and PTHP certification program.

Table 3.6.3 PTAC and PTHP Manufacturers: AHRI Members

Daikin Applied (Daikin Industries)	EAIR, LLC
ECR International, Inc.	Friedrich Air Conditioning Company
Goodman Manufacturing Company	GREE Electric Appliances of Zhuhai
Haier America	LG Electronics

Source: These PTAC and PTHP manufacturers were listed as of July 2014 at http://www.ahrinet.org/site/661/About-Us/AHRI-Members

Manufacturers are able to certify their equipment under AHRI's PTAC and PTHP certification program without being members of AHRI. The companies that are not AHRI members use AHRI and ASHRAE test procedures and standards to rate the performance of their equipment. Table 3.6.4 shows a list of manufacturers that certify PTACs and PTHPs under AHRI's PTAC and PTHP certification program but are not members of AHRI.

Table 3.6.4 PTAC and PTHP Manufacturers: Non-AHRI Members with AHRI-Certified Equipment

Air-Con International	Cold Point Corporation
Comitale National, Inc.	Electrolux Home Products, Inc.
Evergreen, LLC	Fedders Islandaire, Inc.
General Electric (GE) Company	Heat Controller, Inc.
Ice Air, LLC	YMGI Group, LLC

3.6.2 Small Businesses

DOE considered the possibility that energy conservation standards for PTACs and PTHPs could adversely affect small businesses. For manufacturers of PTACs and PTHPs, the Small Business Administration (SBA) has set a size threshold, which defines those entities classified as "small businesses." DOE used the SBA's small business size standards to determine whether any small entities would be subject to the requirements of the rule. 65 FR 30836, 30848 (May 15, 2000), as amended at 65 FR 53533, 53544 (Sept. 5, 2000) and codified at 13 CFR part 121. The size standards are listed by North American Industry Classification System (NAICS) code and industry description and are published by the SBA. Manufacturing of PTACs and PTHPs is classified under NAICS 333415, "Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing." The SBA sets a threshold of 750 employees or less for an entity to be considered as a small business for this category.

DOE studied the potential impacts on these small businesses in detail during the manufacturer impact analysis, which was conducted as a part of the notice of proposed rulemaking (NOPR) analysis. DOE initially identified 22 companies that sell PTAC and PTHP equipment that would be affected by today's proposal. Of these 22 companies, DOE identified 12 as small businesses. Of the 12 small businesses contacted, DOE was able to reach and discuss potential standards with two. DOE also obtained information about small businesses and potential impacts on small businesses while interviewing large manufacturers.

Within the PTAC and PTHP industry, DOE did not identify any small businesses that are original equipment manufacturers (OEMs) of equipment covered under this rulemaking. Rather, small businesses tend to import, rebrand, and distribute PTACs and PTHPs manufactured overseas, primarily in China. Some small businesses identified are original equipment manufacturers of non-standard size PTACs and PTHPs; however, non-standard equipment are not impacted by this rulemaking and therefore are not considered in this small business subgroup analysis. Chapter 12 of this TSD contains more details regarding the manufacturer impact analysis.

3.7 REGULATORY PROGRAMS

The following section details current regulatory programs mandating energy conservation standards for PTACs and PTHPs. Section 3.7.1 discusses current Federal energy conservation standards; section 3.7.2 discusses ASHRAE's energy conservation standards; and section 3.7.3 provides an overview of existing State standards. Sections 3.7.4 and 3.7.5 review standards in both Canada and Mexico that may affect the companies servicing the North American market.

3.7.1 Current Federal Energy Conservation Standards

For PTAC and PTHP equipment, the last final rule issued by DOE was on October 7, 2008, which codified the amended standards and separated PTAC and PTHP equipment classes into sub-categories of standard size equipment and non-standard size equipment. 73 FR 58772 The current standards are shown in Table 3.7.1.

Table 3.7.1 Current Federal Energy Conservation Standards for PTACS and PTHPs

Equipment Class			Efficiency Level	Compliance Date
Equipment Type	**Sub-Category**	**Cooling Capacity**		
PTAC	Standard Size[*]	<7,000 Btu/h	EER = 11.7	Oct. 8, 2012
		≥7,000 Btu/h and ≤15,000 Btu/h	EER = 13.8 – (0.300 x Cap[†])	Oct. 8, 2012
		>15,000 Btu/h	EER = 9.3	Oct. 8, 2012
	Non-Standard Size[**]	<7,000 Btu/h	EER = 9.4	Oct. 7, 2010
		≥7,000 Btu/h and ≤15,000 Btu/h	EER = 10.9 – (0.213 x Cap[†])	Oct. 7, 2010
		>15,000 Btu/h	EER = 7.7	Oct. 7, 2010
PTHP	Standard Size[*]	<7,000 Btu/h	EER = 11.9 COP = 3.3	Oct. 8, 2012
		≥7,000 Btu/h and ≤15,000 Btu/h	EER = 14.0 – (0.300 x Cap[†]) COP = 3.7 – (0.052 x Cap[†])	Oct. 8, 2012
		>15,000 Btu/h	EER = 9.5 COP = 2.9	Oct. 8, 2012
	Non-Standard Size[**]	<7,000 Btu/h	EER = 9.3 COP = 2.7	Oct. 7, 2010
		≥7,000 Btu/h and ≤15,000 Btu/h	EER = 10.8 – (0.213 x Cap[†]) COP = 2.9 – (0.026 x Cap[†])	Oct. 7, 2010
		>15,000 Btu/h	EER = 7.6 COP = 2.5	Oct. 7, 2010

[*] Standard size refers to PTAC or PTHP equipment with wall sleeve dimensions greater than or equal to 16 inches high, or greater than or equal to 42 inches wide.

[**] Non-standard size refers to PTAC or PTHP equipment with wall sleeve dimensions less than 16 inches high and less than 42 inches wide.

[†] Cap means cooling capacity in kBtu/h at 95°F outdoor dry-bulb temperature.

3.7.2 ASHRAE Energy Conservation Standards for PTACs and PTHPs

On October 9, 2013, ASHRAE adopted ANSI/ASHRAE/IES Standard 90.1-2013, which increased ASHRAE efficiency standards for standard size PTAC equipment to be equal to efficiency standards for standard size PTHP equipment. Table 3.7.2 shows the efficiency levels in ANSI/ASHRAE/IES Standard 90.1-2013 for PTACs and PTHPs.

Table 3.7.2 ANSI/ASHRAE/IES Standard 90.1-2013 Energy Efficiency Levels for PTACs and PTHPs

Equipment Class			Minimum Efficiency
Equipment	**Category**	**Cooling Capacity**	
PTAC	Standard Size[*]	<7,000 Btu/h	EER = 11.9
		≥7,000 Btu/h and ≤15,000 Btu/h	EER = 14.0 – (0.300 x Cap/1000[†])
		>15,000 Btu/h	EER = 9.5
	Non-Standard Size[**]	<7,000 Btu/h	EER = 9.4
		≥7,000 Btu/h and ≤15,000 Btu/h	EER = 10.9 – (0.213 x Cap/1000[†])
		>15,000 Btu/h	EER = 7.7
PTHP	Standard Size[*]	<7,000 Btu/h	EER = 11.9 COP = 3.3
		≥7,000 Btu/h and ≤15,000 Btu/h	EER = 14.0 – (0.300 x Cap/1000[†]) COP = 3.7 – (0.052 x Cap/1000[†])
		>15,000 Btu/h	EER = 9.5 COP = 2.9
	Non-Standard Size[**]	<7,000 Btu/h	EER = 9.3 COP = 2.7
		≥7,000 Btu/h and ≤15,000 Btu/h	EER = 10.8 – (0.213 x Cap/1000[†]) COP = 2.9 – (0.026 x Cap/1000[†])
		>15,000 Btu/h	EER = 7.6 COP = 2.5

[*] Standard size refers to PTAC or PTHP equipment with wall sleeve dimensions greater than or equal to 16 inches high, or greater than or equal to 42 inches wide.

[**] Non-standard size refers to PTAC or PTHP equipment with wall sleeve dimensions less than 16 inches high and less than 42 inches wide.

[†] Cap means cooling capacity in Btu/h at 95°F outdoor dry-bulb temperature.

3.7.3 State Energy Conservation Standards

DOE recognizes that pursuant to EPCA, states may petition to have more stringent energy conservation standards than those codified into law by DOE (see 42 U.S.C. 6297(d)). DOE has not yet granted a petition to any state to establish more stringent energy conservation standards than the levels established by EPCA for PTACs and PTHPs.

3.7.4 Canadian Energy Conservation Standards

The Natural Resources Canada Office of Energy Efficiency regulation mandates minimum energy conservation standards for PTACs and PTHPs. These standards apply to factory-assembled PTACs and PTHPs intended for use in residential, commercial, and industrial heating and cooling systems.[1] The current standards went into effect November 15, 2006, and are shown in Table 3.7.3. The Canadian energy conservation standards for standard size PTACs and PTHPs are less stringent than the current U.S. standards for standard size PTACs and PTHPs. The Canadian energy conservation standards for non-standard size PTACs and PTHPs are identical to the current U.S. standards for non-standard size PTACs and PTHPs.

Table 3.7.3 Canadian Energy Conservation Standards for PTACS and PTHPs

Equipment Type	Minimum Efficiency Ratio
PTAC EER New Construction (cooling)*	12.5 - (0.213 x cap/293.1)† (12.5 - (0.213 x cap/1000))
PTAC EER Replacement (cooling)	10.9 - (0.213 x cap/293.1) (10.9 - (0.213 x cap/1000))
PTHP EER New Construction (cooling)	12.3 - (0.213 x cap/293.1) (12.3 - (0.213 x cap/1000))
PTHP EER Replacement (cooling)	10.8 - (0.213 x cap/293.1) (10.8 - (0.213 x cap/1000))
PTHP COP New Construction (heating)**	3.2 - (0.026 x cap/293.1) (3.2 - (0.026 x cap/1000))
PTHP COP Replacement†† (heating)	2.9 - (0.026 x cap/293.1) (2.9 - (0.026 x cap/1000))

*EER = Energy efficiency ratio – a ratio calculated by dividing the cooling capacity in Btu per hour by the power input in watts at any given set of rating conditions
**COP =Coefficient of performance – a ratio for both the cooling and heating modes calculated by dividing the capacity expressed in watts by the power input in watts, excluding any supplementary heat
†cap = The rated cooling capacity in watts (upper formula) or Btu/h (lower formula).
††Replacement units are to be labeled according to the requirements of CAN/CSA C744-04

3.7.5 Mexican Energy Conservation Standards

Although Mexico has minimum energy conservation standards for air conditioners and heat pumps in general, it currently does not have minimum energy conservation standards for PTACs and PTHPs.

3.8 VOLUNTARY PROGRAMS

3.8.1 ENERGY STAR

ENERGY STAR,[g] a voluntary labeling program backed by the U.S. Environmental Protection Agency (EPA) and DOE, identifies energy-efficient products through a qualification process. To qualify, a product must exceed Federal minimum standards by a specified amount, or, if no Federal standard exists, must exhibit selected energy saving features. The ENERGY STAR program recognizes the top quartile of products on the market, meaning that

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[g] More information regarding the ENERGY STAR program is at www.energystar.gov.

approximately 25 percent of equipment on the market meet or exceed the ENERGY STAR levels. PTACs do not qualify for ENERGY STAR under the room air conditioner criteria, and there are currently no plans to develop ENERGY STAR criteria for PTACs and PTHPs.[2]

3.8.2 Rebate Programs

DOE has identified and reviewed various local utility rebate programs. These include the Platte River Power Authority (PRPA), Xcel Energy Cooling Efficiency Rebate Program, Modesto Irrigation District MPower Business Rebate Program, Shakopee Public Utilities Energy Efficiency Incentive Program, CPS Energy Savers Commercial Rebate Program, and the Southern California Edison (SCE) Multifamily Energy Efficiency Rebate Program.

Platte River Power Authority (PRPA), an organization that generates and delivers electricity to its owner communities of Estes Park, Fort Collins, Longmont and Loveland, Colorado, offers customers cash rebates for upgrading standard and non-standard size PTACs and PTHPs to energy-efficient units through its Efficiency Works Rebate Program. The rebate includes all cooling capacities of PTACs that achieve or exceed 11.0 EER.[3]

Xcel Energy promotes the installation of energy-efficient equipment through the Cooling Efficiency Rebate Program. Rebates are available to the utility's commercial customers. Under this program, commercial business with PTACs can receive a base payment of $65 per ton for units rated at 11.0 EER and $5 per ton for every incremental increase of 0.1 EER above base requirements.[4]

Modesto Irrigation District's MPower Business Rebate Program offers commercial, industrial, and agricultural customers cash rebates for the purchase and installation of energy-efficient standard and non-standard size PTACs and PTHPs. Cash rebates of $75 per unit are available for units that meet minimum efficiency requirements, which vary by capacity. Units with capacity less than or equal to 7,000 Btu/h must meet a minimum 11.29 EER; units with capacity between 7,000 and 24,000 Btu/h must meet a minimum 10.27 EER.[5]

Shakopee Public Utilities promotes installation of energy-efficient equipment through the Commercial and Industrial Energy Efficiency Rebate Program. Rebates are available to the utility's commercial customers. Under this program, commercial and industrial businesses installing PTACs and PTHPs can receive a rebate of $45 per ton of capacity for units that meet or exceed the minimum cooling efficiency, which is calculated using the equation below.[6]

$$\text{Minimum Efficiency (EER)} = 12.8 - \left(0.213 \times \frac{\text{Cooling Capacity }(\frac{\text{Btu}}{\text{h}})}{1000}\right)$$

CPS Energy, the Nation's largest municipally owned energy company, offers rebates for energy-efficient PTACs and PTHPs through the CPS Energy Savers Commercial Rebate Program. Rebates only apply to building improvement or retrofit projects and are not available for new construction projects. The rebate amounts are separated by two tiers of efficiency. A rebate of $65 per ton of cooling capacity is available for PTACs and PTHPs with EER of 11.5 or greater (and COP of 4.9 or greater for PTHPs). A rebate of $150 per ton of cooling capacity is available for PTACs and PTHPs with EER of 12.5 or greater (and COP of 5.9 or greater for PTHPs).[7]

SCE offers rebates to business customers for standard and non-standard size PTAC and PTHP equipment through its Multifamily Energy Efficiency Rebate Program. The program provides a fixed $150 rebate for PTACs and PTHPs that have EER at least 20 percent above California's appliance efficiency regulations, also known as Title 20. The rebate is valid for all units with cooling capacity below 24,000 Btu/h.[8] Under the California Code of Regulations, Title 20, Section 1605.1 b(2), PTACs and PTHPs energy conservation standards are calculated using the equations below, and are less stringent than current Federal PTAC and PTHP energy conservation standards.[9]

$$\text{Minimum Efficiency (EER)} = 10.0 - (0.00016 \times \text{Cooling Capacity (in Btu/h)})$$

$$\text{Minimum Efficiency (COP)} = 1.3 + [0.16(10.0 - 0.00016 \times \text{Cooling Capacity (in Btu/h)}]$$

3.9 SHIPMENTS

Information about annual equipment shipment trends allows DOE to estimate the impacts of energy conservation standards on the PTAC and PTHP industry. Using data from AHRI estimates, DOE examined unit shipments and value of shipments for PTACs and PTHPs. More information about shipments for PTACs and PTHPs can be found in the shipments analysis section (chapter 9) of the TSD.

3.9.1 Unit Shipments

Until 2010, the U.S. Census Bureau published an annual Current Industrial Report (CIR), which provided annual unit shipments and value of shipments for various industries including the PTAC and PTHP industry. However, the CIR has not published shipments data for PTACs or PTHPs since before 2008, due to data disclosure issues and to termination of the CIR series.[10]

Table 3.9.1 presents the total shipments estimated by AHRI of the PTAC and PTHP industry from 2003-2012. The AHRI data shows a decrease in shipments between the 2003-07 period and the 2008-12 period.

Table 3.9.1 AHRI Estimated Shipment Data for PTAC and PTHP Industry (Standard and Non-Standard)

Years	**Total Shipments Over All Years (Thousands of Units)**	
	PTAC	PTHP
2008-2012	1,105.9	986.0
2003-2007	1,352.3	1,068.8

3.9.2 Equipment Lifetime

DOE reviewed available literature and consulted with manufacturers in order to establish typical equipment lifetimes. The literature and experts consulted offered a wide range of typical equipment lifetimes. Individuals with previous experience in manufacturing or distribution of PTACs and PTHPs suggested a typical lifetime of 5 to 10 years. Some experts suggested that the lifetime could be even lower because of the daily or continuous use of the equipment and neglect of maintenance such as cleaning the heat exchangers or replacing the air filters. In addition, the equipment is typically replaced about every 5 years for cosmetic reasons during remodeling in lodging applications. The *2000 Screening Analysis for EPACT-Covered Commercial Heating, Ventilating and Air-Conditioning and Water-Heating Equipment* report (commonly referred to as the 2000 Screening Analysis) used a 15-year lifetime for PTACs and PTHPs based on data from ASHRAE's 1995 *Handbook of HVAC Applications*.[11] In the NOPR analysis for this rulemaking, DOE assumed the equipment lifetime for PTACs and PTHPs to be 10 years. In response to stakeholder input, DOE revised the analysis after the NOPR using an average equipment lifetime of 8 years. More information about PTAC and PTHP equipment lifetime is available in the life-cycle cost and payback period analyses section (chapter 8) of this TSD.

3.10 MARKET CHARACTERIZATION

DOE combined information from the 2013 AHRI *Directory of Certified Product Performance* (2013 AHRI directory) with other publicly available data from manufacturer catalogs of PTACs and PTHPs to develop an understanding of the industry.[12] The database contains information such as manufacturer name, model number, cooling capacity, EER, COP where applicable, heating capacity where applicable, and wall sleeve dimensions. To maintain consistency in the analysis, DOE divided the data into standard and non-standard size classifications in the database based on DOE's equipment classes. Figure 3.2.1 and Figure 3.2.2 show the distribution of standard size PTACs and PTHPs respectively in the 2013 AHRI directory.

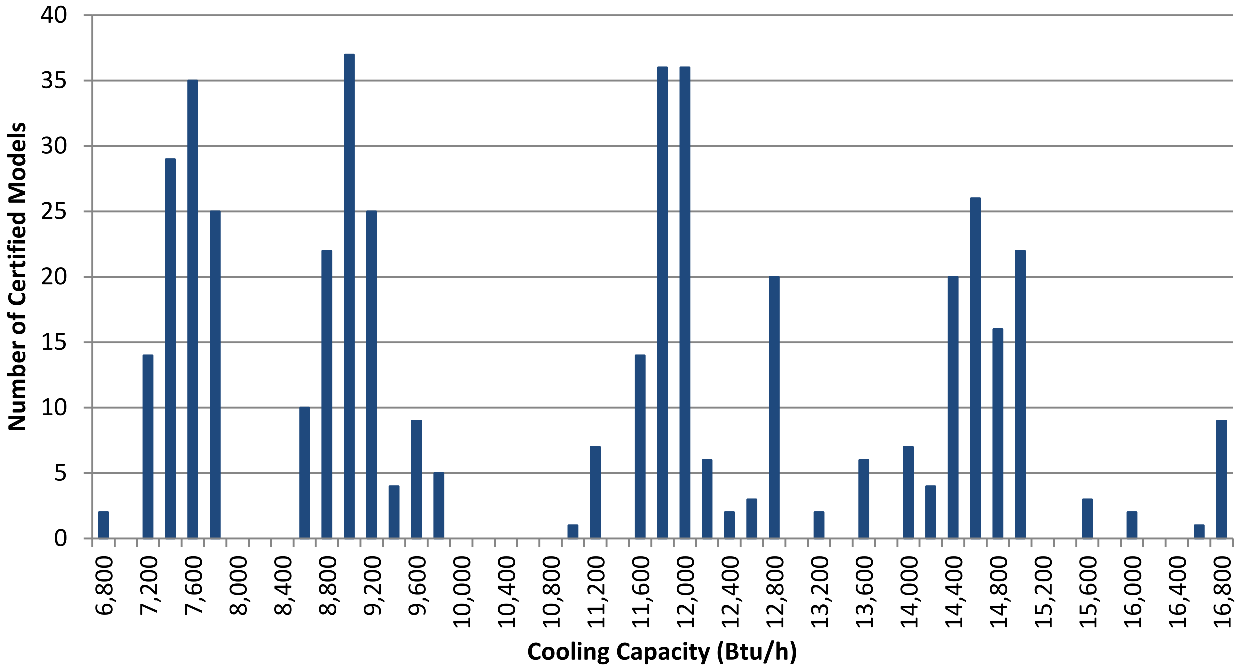

Figure 3.2.1 Number of Certified Standard Size PTAC Models by Cooling Capacity – 2013 AHRI Directory and Manufacturer Catalogs

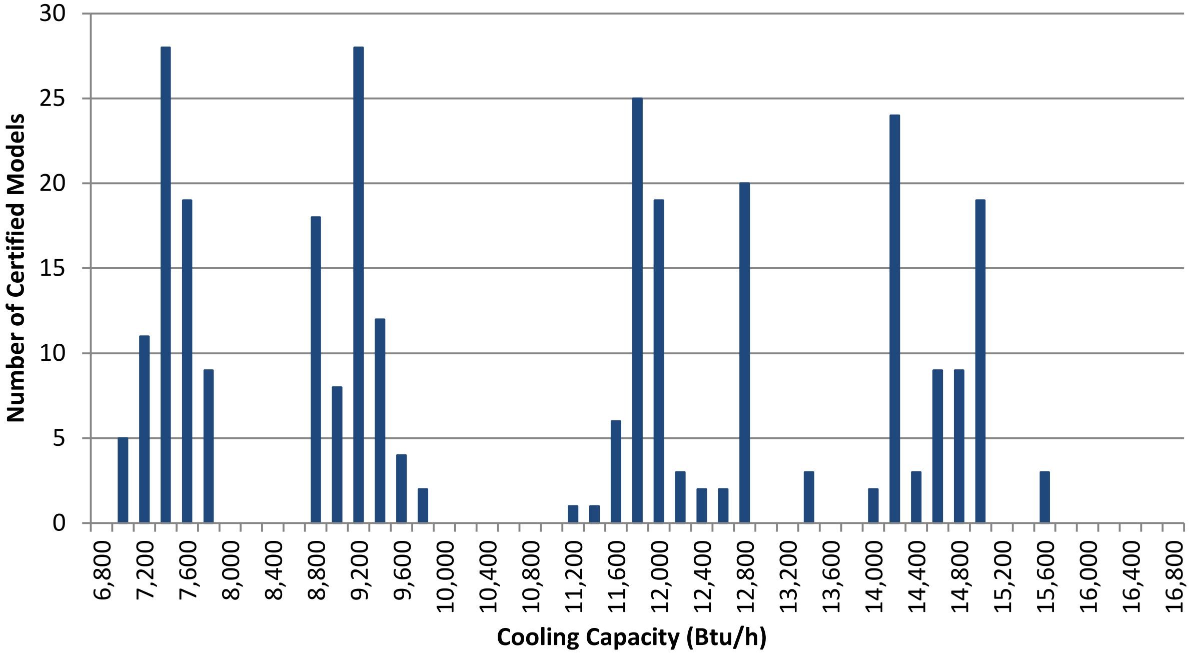

Figure 3.2.2 Number of Certified Standard Size PTHP Models by Cooling Capacity – 2013 AHRI Directory and Manufacturer Catalogs

The standard size PTAC models listed in the 2013 AHRI directory and manufacturers' catalogs may be grouped into several clusters of cooling capacity. These range from 6,800 Btu/h to 7,800 Btu/h; 8,600 Btu/h to 9,800 Btu/h; 11,200 Btu/h to 12,800 Btu/h; and 14,000 Btu/h to 15,100 Btu/h. Standard size PTHPs may be similarly clustered, with cluster ranges from 7,000 Btu/h to 7,800 Btu/h; 8,800 Btu/h to 9,800 Btu/h; 11,200 Btu/h to 12,800 Btu/h; and 14,000 Btu/h to 15,000 Btu/h.

Figure 3.2.3 and Figure 3.2.4 show the distribution of non-standard size PTACs and PTHPs respectively from the 2013 AHRI directory and other manufacturer catalogs.

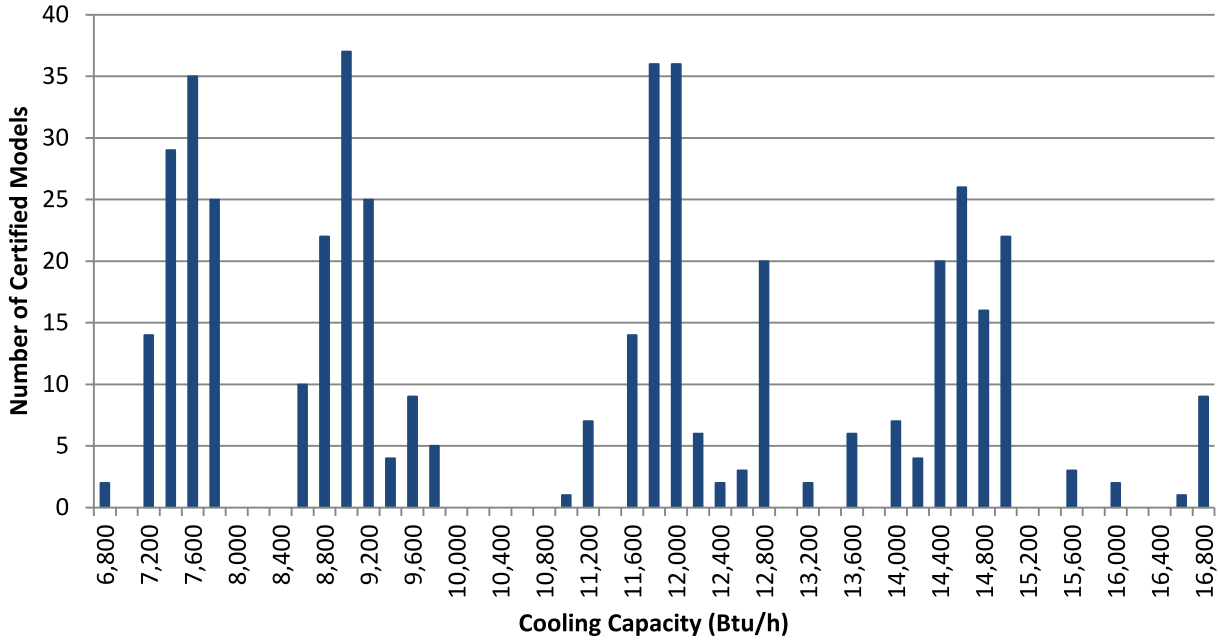

Figure 3.2.3 Non-Standard Size PTAC Models by Cooling Capacity – 2013 AHRI Directory and Manufacturer Catalogs

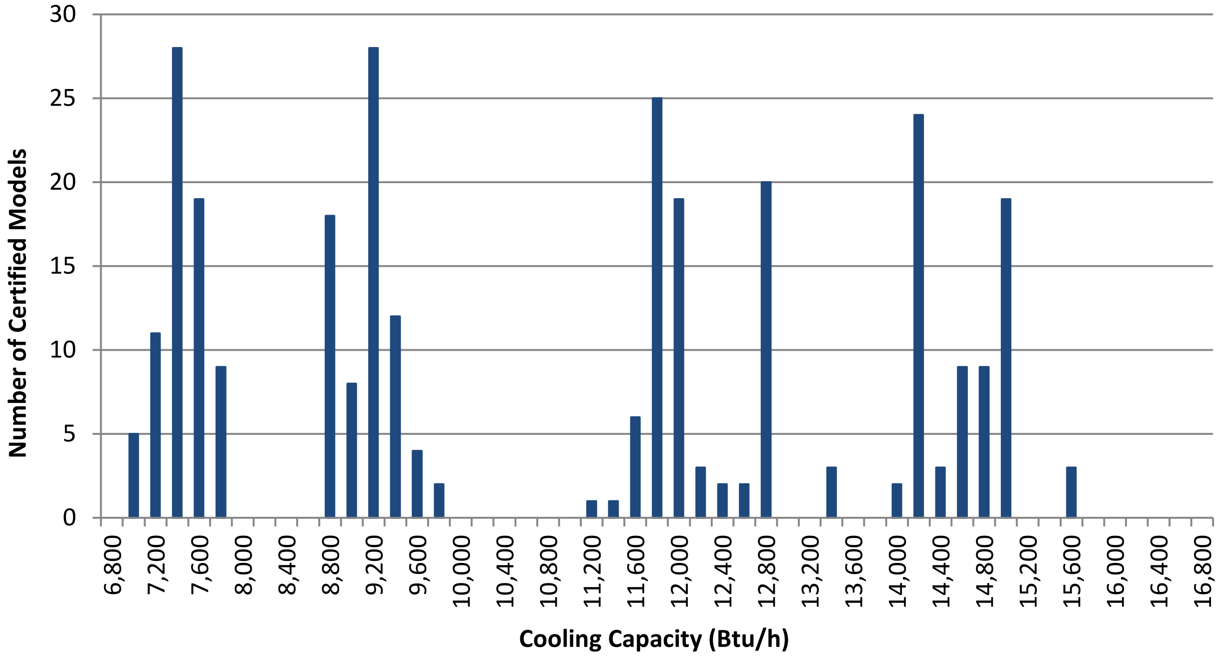

Figure 3.2.4 Non-Standard Size PTHP Models by Cooling Capacity – 2013 AHRI Directory and Manufacturer Catalogs

The non-standard size PTAC models listed in the 2013 AHRI directory and manufacturers' catalogs may be grouped into several clusters of cooling capacity. These range from 7,000 Btu/h to 7,800 Btu/h; 8,800 Btu/h to 9,800 Btu/h; 11,200 Btu/h to 12,800 Btu/h; and 14,000 Btu/h to 15,000 Btu/h.

3.11 TECHNOLOGY ASSESSMENT

This section provides a technology assessment for PTAC and PTHP equipment. The purpose of the technology assessment is to develop a preliminary list of technologies that could potentially be used to improve the efficiency of PTACs and PTHPs. The following assessment provides descriptions of technologies and designs that apply to all equipment classes of PTACs and PTHPs.

Contained in this technology assessment are details about equipment characteristics and operation (section 3.11.1), an examination of possible technological improvements (section 3.11.2), and a characterization of the equipment efficiency levels currently commercially available (section 3.11.3).

3.11.1 Baseline Equipment Components and Operation

The baseline PTAC is an air conditioner that incorporates a complete air-cooled refrigeration and air-handling system in an individual package. Each PTAC has a self-contained, direct-expansion cooling system and packaged control including electromechanical function switches. Models may feature various heating options (electric, hot water, or steam). The basic PTAC cooling system is composed of a compressor (typically a rotary compressor), evaporator, condenser, and motorized fan. Other components of the PTAC include a thermostat, outer casing, and wall sleeve. Manufacturers typically differentiate high-efficiency models from basic models by installing any combination of the following: a higher efficiency compressor, digital controls with energy savings settings, automatic fan controls, higher efficiency fan motors, multiple fans, or a more efficient heat exchanger.

3.11.2 Technology Options

DOE used information about existing and past technology options and prototype designs to help identify technologies that manufacturers could use to improve the efficiency of PTACs and PTHPs. This assessment provides the technical background and structure on which DOE bases its screening analysis (chapter 4 of this TSD) and engineering analyses (chapter 5). In surveying PTAC and PTHP technology options, DOE considered a wide assortment of equipment literature, information derived from the teardown analysis, information derived from the stakeholder interviews, and the previous DOE energy conservation standards rulemaking for air-conditioning products and equipment.

Table 3.11.1 lists all of the potential technology options considered, including options listed in the Framework Document and options suggested in stakeholder comments, for improving energy efficiency of PTACs and PTHPs.

Table 3.11.1 Potential Technology Options for Improving Energy Efficiency of PTACs and PTHPs

Compressor Improvements • Scroll Compressors • Variable-speed Compressors • Higher Efficiency Compressors
Complex Control Boards
Condenser and evaporator fan and fan motor improvements: • Higher Efficiency Fan Motors • Clutched Motor Fans
Microchannel Heat Exchangers
Rifled Interior Heat Exchanger Tube Walls
Increased Heat Exchanger Area
Hydrophobic Material Treatment of Heat Exchangers
Re-circuiting Heat Exchanger Coils
Improved Air Flow and Fan Design
Heat Pipes
Corrosion Protection
Thermostatic Expansion Valve
Alternate Refrigerants (such as HCFC-32)

3.11.3 Equipment Efficiency Levels

Using a list of PTAC and PTHP models assembled from the 2013 AHRI Directory and manufacturer catalogues, DOE examined the relationship between EER and cooling capacity for PTACs and PTHPs of both standard and non-standard size categories. Figure 3.2.5 and Figure 3.2.6 show the relationship between EER and cooling capacity for certified models of standard size PTACs and PTHPs, respectively, listed in the 2013 AHRI Directory. These figures also identify the current Federal energy conservation standards (ECS), and the ANSI/ASHRAE/IES Standard 90.1-2013 efficiency levels.

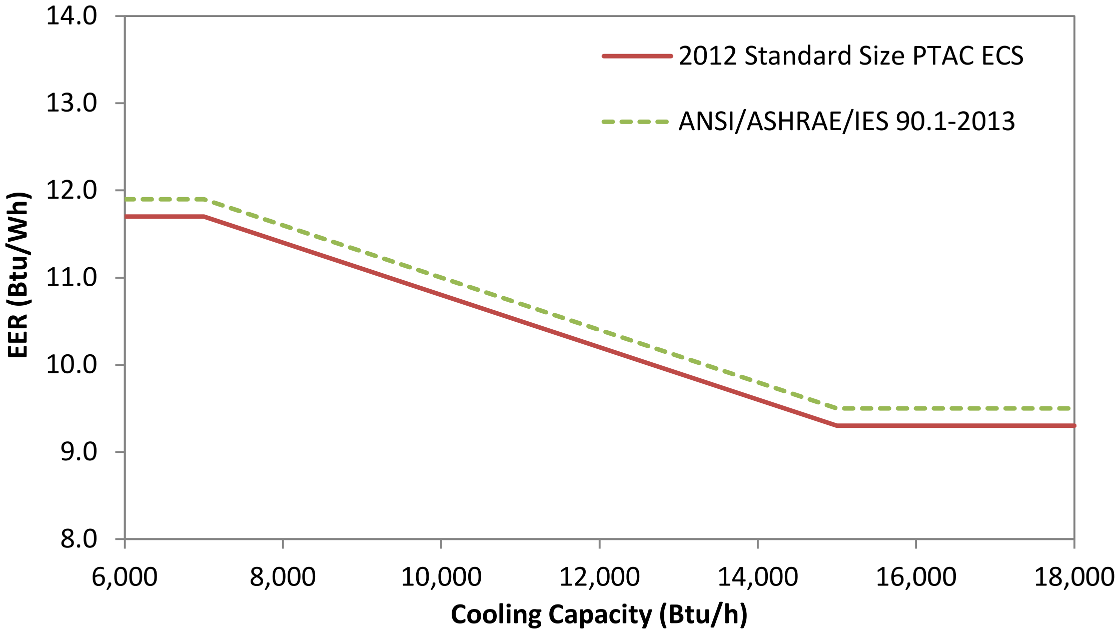

Figure 3.2.5 Standard Size PTAC EER versus Cooling Capacity – 2013 AHRI Directory

As shown in Figure 3.2.5, the EER of standard size PTACs generally decreases as cooling capacity increases. All of the certified standard size PTAC units are above Federal minimum efficiency levels, while close to 80 percent are at or above ANSI/ASHRAE/IES Standard 90.1-2013 efficiency levels.

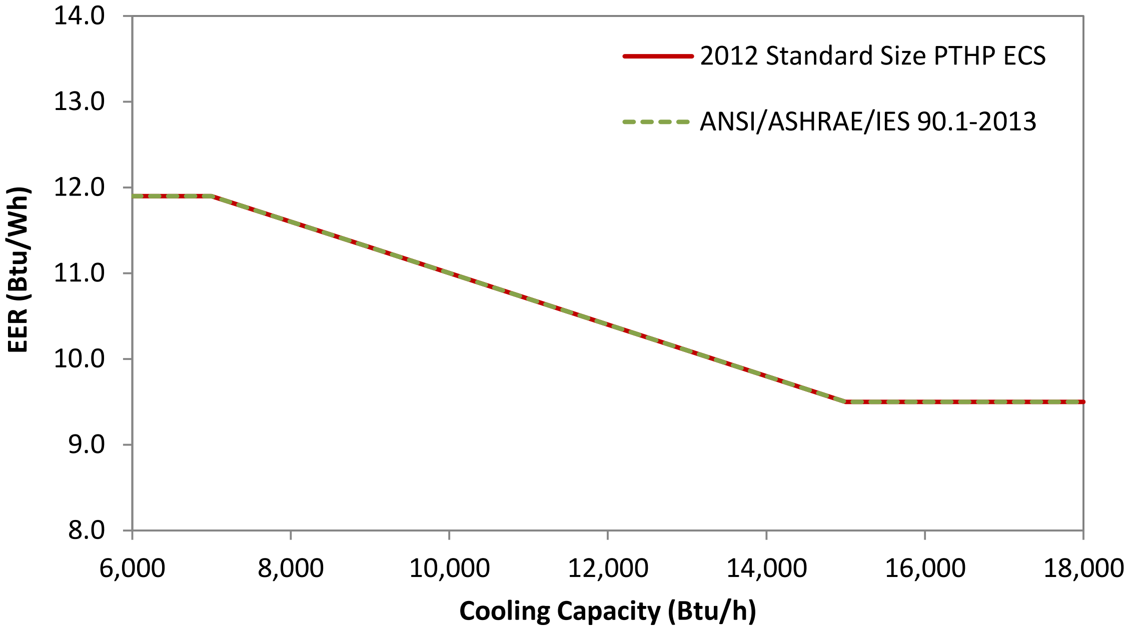

Figure 3.2.6 Standard Size PTHP EER versus Cooling Capacity – 2013 AHRI Directory

As with PTACs, Figure 3.2.6 shows the EER of standard size PTHPs decreases as cooling capacity increases. All of the certified standard size PTHP units are above Federal minimum efficiency levels, which are equivalent to ANSI/ASHRAE/IES 90.1-2013 efficiency levels.

Figure 3.2.7 and Figure 3.2.8 demonstrate the relationship between EER and cooling capacity for non-standard size PTACs and PTHPs respectively. These figures also identify the current Federal ECS and the ANSI/ASHRAE/IES 90.1-2013 efficiency levels for non-standard size equipment.

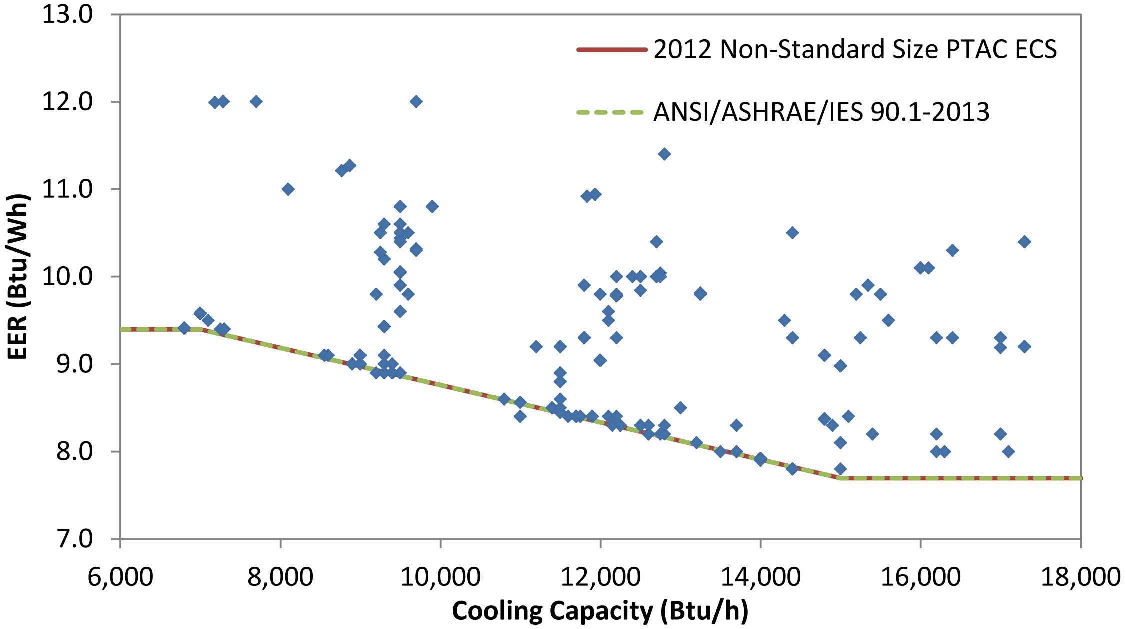

Figure 3.2.7 Non-Standard Size PTAC EER versus Cooling Capacity – 2013 AHRI Directory and Manufacturers' Catalogs

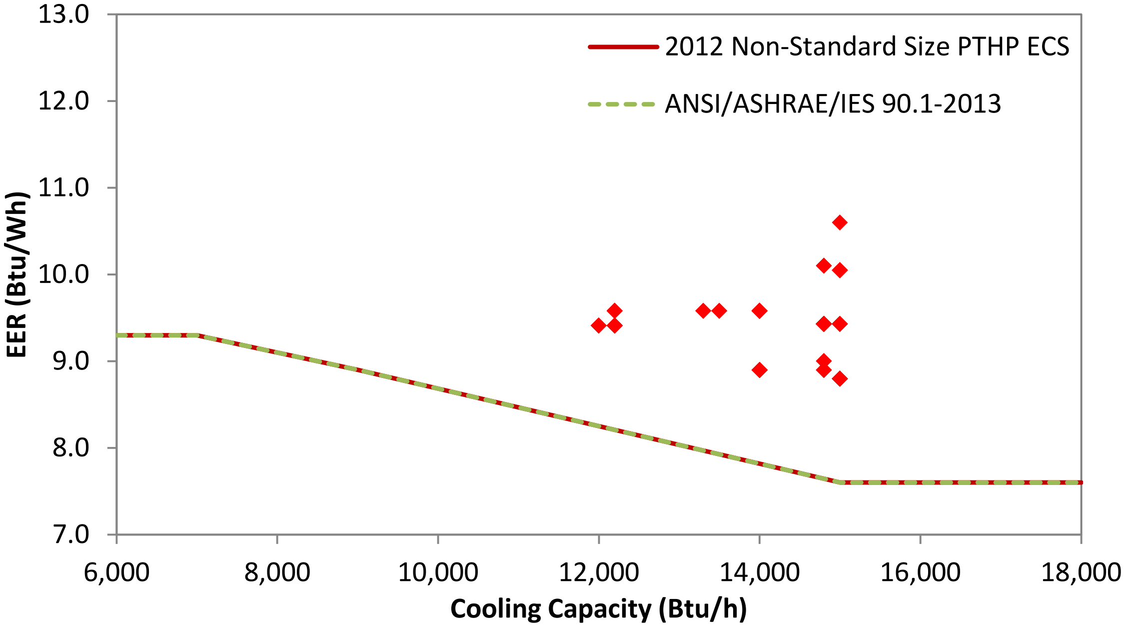

Figure 3.2.8 Non-Standard Size PTHP EER versus Cooling Capacity – 2013 AHRI Directory and Manufacturers' Catalogs

Similar to standard size PTACs, the EER of a non-standard size PTAC decreases as cooling capacity increases. All of the reviewed non-standard size PTAC units excepts one model are rated at or above Federal minimum efficiency levels, which are equivalent to ANSI/ASHRAE/IES 90.1-2013 efficiency levels. All of the reviewed non-standard size PTHP units are rated at or above Federal minimum and ANSI/ASHRAE/IES 90.1-2013 efficiency levels.

DOE also examined the relationship between COP and cooling capacity for standard size and non-standard size PTHPs, shown in Figure 3.2.9 and Figure 3.2.10, respectively. These figures also identify the current Federal ECS and the ANSI/ASHRAE/IES Standard 90.1-2013 efficiency levels for standard size and non-standard size equipment.

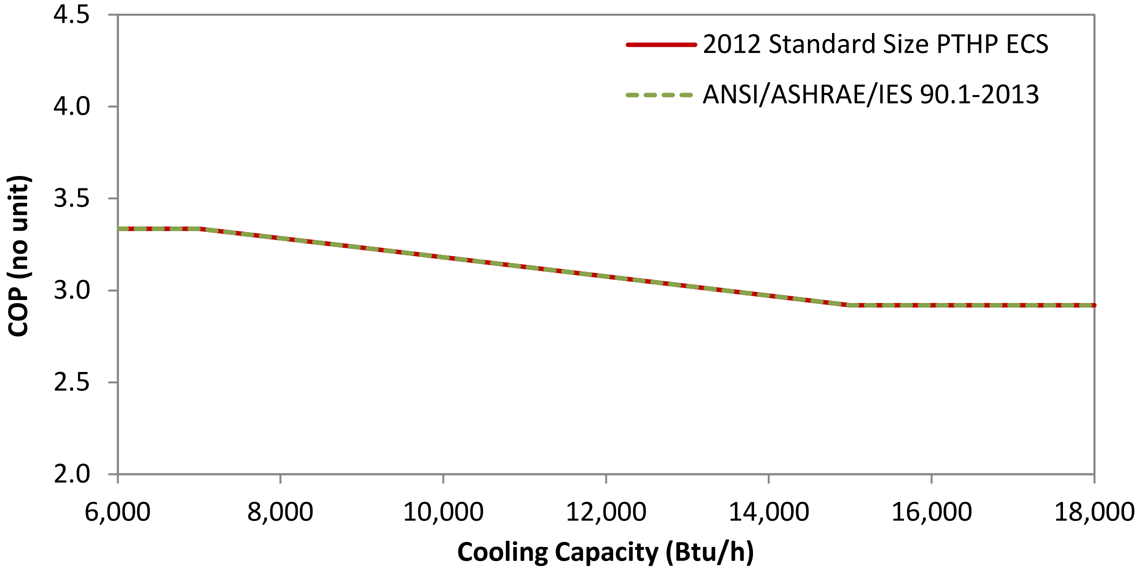

Figure 3.2.9 Standard Size PTHP COP versus Cooling Capacity – 2013 AHRI Directory

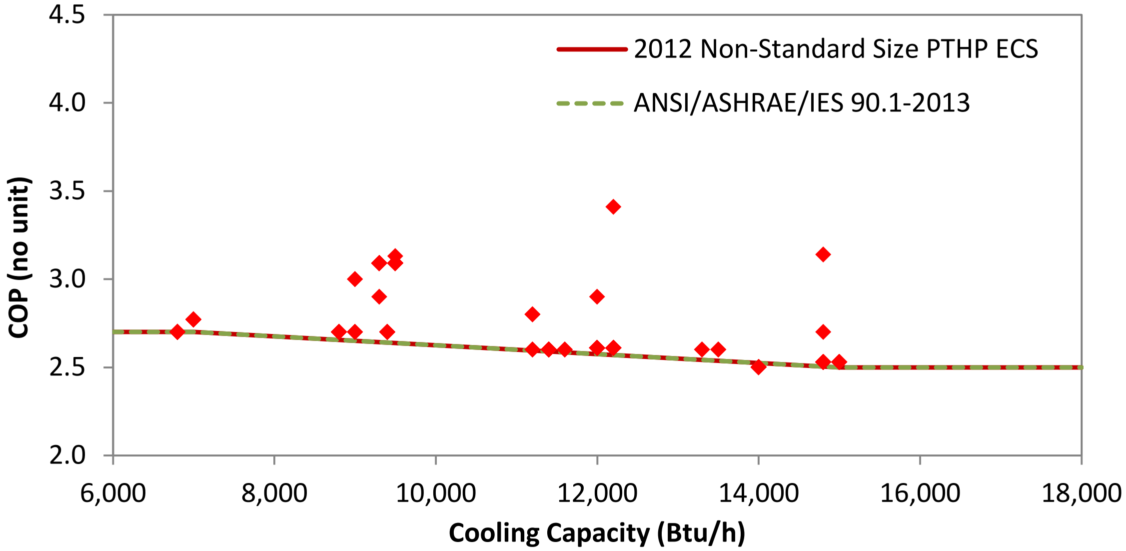

Figure 3.2.10 Non-Standard Size PTHP COP versus Cooling Capacity – 2013 AHRI Directory and Other Publicly Available Data

As with EER, COP tends to decrease with cooling capacity. COP levels for all of the reviewed standard size PTHP units are above Federal efficiency levels, which are equivalent to ANSI/ASHRAE/IES 90.1-2013 efficiency levels. COP levels for all of the reviewed non-standard size PTHP units meet or exceed the Federal minimum and ANSI/ASHRAE/IES 90.1-2013 efficiency levels.

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CHAPTER 4. SCREENING ANALYSIS

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CHAPTER 4. SCREENING ANALYSIS

4.1 INTRODUCTION

This chapter describes the screening analysis that the U.S. Department of Energy (DOE) has performed in support of the energy conservation standards rulemaking for packaged terminal air conditioners (PTACs) and packaged terminal heat pumps (PTHPs).

In the market and technology assessment (chapter 3 of this technical support document (TSD)), DOE presented an initial list of technologies that have the potential to reduce the energy consumption of PTACs and PTHPs. The goal of the screening analysis is to screen out technologies that will not be considered further in the rulemaking analyses. DOE evaluated the technologies identified in the market and technology assessment pursuant to the criteria set out in the Energy Policy and Conservation Act (EPCA). (42 United States Code (U.S.C.) 6291-6317):

(1) Technological feasibility. Technologies incorporated in commercial equipment or in working prototypes will be considered technologically feasible.

(2) Practicability to manufacture, install, and service. If mass production of a technology in commercial equipment and reliable installation and servicing of the technology could be achieved on the scale necessary to serve the relevant market at the time of the effective date of the standard, then that technology will be considered practicable to manufacture, install, and service.

(3) Impacts on equipment utility to customers. If DOE determines that a technology will have significant adverse impact on the utility of the equipment to significant subgroups of consumers, or result in the unavailability of any covered equipment type with performance characteristics (including reliability), features, sizes, capacities, and volumes that are substantially the same as equipment generally available in the United States at the time, DOE will not consider it further.

(4) Adverse impacts on health or safety. If DOE determines that a technology will have significant adverse impacts on health or safety, DOE will not consider it further.

If a particular technology fails to meet one or more of the four criteria, it will be screened out. The rationale for either screening out or retaining each technology option is detailed in the following sections.

4.2 SCREENED-OUT TECHNOLOGY OPTIONS

The following section details the specific technology options that were screened out prior to the engineering analysis, along with the rationale for elimination.

4.2.1 Scroll Compressors

Scroll compressors compress gas between two spirals, one fixed and one rotating. In some capacities and applications, scroll compressors may operate at higher efficiencies than the rotary compressors typically used in PTAC and PTHP applications. Though scroll compressors are less common in the capacity range associated with PTAC and PTHP equipment (6,000 to 15,000 Btu/h), several companies manufacture scroll compressors from 9,000 Btu/h and up. However, DOE is not aware of scroll compressor models at these lower capacities that would fit in a PTAC cabinet and that are more efficient than the same capacity of rotary compressor. The rotary compressors found in reverse engineering of PTACs and PTHPs in the 15,000 Btu/h class had efficiency ratings from 9.8 to 10.6 EER. By comparison, scroll compressors of similar capacity are rated from 7.2 EER to 11.0 EER, but most are too tall to fit in a 16” standard-size PTAC cabinet.

As a result, DOE does not believe at this time that the use of scroll compressors would improve the efficiency of PTAC and PTHP units, given the size and capacity constraints of these units. For this reason, DOE did not consider scroll compressors further in the NOPR analyses.

4.2.2 Heat Pipes

Under humid ambient conditions, using heat pipes to pre-treat the entering air from the conditioned space can improve the evaporator heat exchanger performance. Heat pipes increase the latent cooling capacity (i.e., moisture removal) of an air-conditioner. They do this by transferring heat from the air entering the evaporator to the air leaving the evaporator. This allows the evaporator air exit temperature to be significantly lower. Since the maximum possible moisture content of air increases with increasing temperature, this also means that the reduced-temperature air at the evaporator exit would have lower moisture content. The temperature of the air is then warmed by the post-evaporator portion of the heat pipe. Heat pipes generally shift some of the cooling capacity of the equipment from reduction of air temperature to reduction of humidity, but do not increase the cooling capacity of an evaporator. They impose additional pressure drop that the indoor fan must overcome, thus they do not improve EER of the equipment. Therefore, DOE screened out heat pipes as a design option for improving the energy efficiency of PTACs and PTHPs.

4.2.3 Alternate Refrigerants

Nearly all PTAC and PTHP equipment is designed with R-410A as the refrigerant. The Environmental Protection Agency’s (EPA’s) Significant New Alternatives Policy (SNAP) Program evaluates and regulates substitutes for the ozone-depleting chemicals (such as air conditioning refrigerants) that are being phased out under the stratospheric ozone protection provisions of the Clean Air Act (CAA).[1] (42 U.S.C. 7401 et seq.) The EPA’s SNAP Program currently lists acceptable alternatives for refrigerant used in the Household and Light Commercial Air Conditioning class of equipment (which includes PTAC and PTHP equipment).

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[1] Additional information regarding EPA’s SNAP Program is available online at: http://www.epa.gov/ozone/snap/.

On July 9, 2014, the EPA issued a notice of proposed rulemaking proposing to list three flammable refrigerants (HFC-32 (R-32), Propane (R-290), and R-441A) as new acceptable substitutes, subject to use conditions, for refrigerant in the Household and Light Commercial Air Conditioning class of equipment. 79 FR 38811 (July 9, 2014). On April 10, 2015, the EPA published its final rule that allows the use of R-32, R-290, and R-441A in limited amounts in PTAC and PTHP applications. 80 FR 19454 (April 10, 2015)

DOE considered the possibility of using the alternative refrigerants that EPA approved for limited use in PTAC and PTHP applications. The EPA's final rule limits the maximum design charge amount of the alternative refrigerants in PTAC and PTHP applications. For instance, for a PTAC or PTHP with cooling capacity of 9,000 Btu/h, the EPA rule imposes a maximum design charge of 140 grams of R-290 or 160 grams of R-441A. 80 FR at 19500 (April 10, 2015) In comparison, DOE reverse engineered eleven units with cooling capacities around 9,000 Btu/h and found that these units had refrigerant charges ranging from 600 grams to 950 grams and all units used refrigerant R-410A. The refrigerant charges currently used in current PTAC and PTHP designs far exceed the maximum charges that are allowed for alternative refrigerants under EPA's final rule. DOE acknowledges that it might be possible to incorporate the new refrigerants under consideration into PTAC designs through the use of microchannel heat exchangers or tube and fin heat exchangers with smaller tube diameters than what is currently on the market. However, DOE has not seen evidence that such designs are technologically feasible. Therefore, DOE did not further consider the R-290 and R-441A substitutes proposed by EPA.

DOE is aware of initial research with drop-in applications (where an alternate refrigerant replaces the existing refrigerant in a system that is optimized for the existing refrigerant) using R-32 in place of R-410A in a residential ducted split-system application. Initial research shows that, in this application, R-32 had a higher capacity and similar efficiency as R-410A, but its discharge temperatures and pressures were significantly higher.[2] This suggests that R-32 might show efficiency comparable to R-410A in PTAC and PTHP applications, and the research is inconclusive regarding whether R-32 will reduce energy use and/or by how much. DOE is not aware of test results from the use of alternate refrigerants in PTAC- or PTHP-specific applications that have been optimized for alternate refrigerants.

DOE is not aware of any SNAP-approved refrigerants, or any refrigerants that have been proposed for SNAP approval, that are known to enable better efficiency than R-410A for PTAC and PTHP equipment. Hence, DOE did not consider alternate refrigerants for further analysis.

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[2] This research was published in the journal *ASHRAE* Transactions, at:
Biswas, Auvi; Barve, Atharva; Cremaschi, Lorenzo (2013). "An Experimental Study of the Performance of New Low Global Warming Potential (LGWP) Refrigerants at Extreme High Temperature Ambient Conditions in Residential AC Ducted Split Systems," *ASHRAE Transactions. 119*(1), special section p1.

4.3 OTHER TECHNOLOGIES NOT CONSIDERED IN THE ENGINEERING ANALYSIS

Typically, energy-saving technologies that pass the screening analysis are evaluated in the engineering analysis. However, some technologies are not included in the analysis for other reasons, including: (1) available data suggest that the efficiency benefits of the technology are negligible; (2) data are not available to evaluate the energy efficiency characteristics of the technology; or (3) the test procedure and EER or COP metric would not measure the energy impact of these technologies. Accordingly, DOE eliminated the following technologies from consideration in the engineering analysis based upon these three additional considerations.

4.3.1 Re-Circuiting Heat Exchanger Coils

Manufacturers of PTAC and PTHP heat exchangers may improve the heat transfer efficiency across the heat exchanger by rearranging the refrigerant's path through the various tubes inside the heat exchanger. Manufacturers can rearrange the refrigerant path by "re-circuiting" the heat exchanger, either by splitting the refrigerant path into new circuits or re-routing the existing circuits. One objective of re-circuiting is to optimally pair air and refrigerant at every location in the heat exchanger. DOE believes that PTACs are a very mature industry and that engineers have already optimized the number of circuits for heat transfer. Thus, DOE believes that the efficiency benefits of the technology are negligible and DOE has eliminated heat exchanger re-circuiting as a potential avenue for efficiency improvement.

4.3.2 Rifled Interior Tube Walls

Heat exchangers using rifled interior tube walls (also known as "microgrooves") to enhance energy efficiency by improving heat transfer across the heat exchanger. With this technology, the internal face of heat exchanger tubes is rifled with small grooves that increase the interior surface area of the tube and induce turbulence in the refrigerant flow. Having observed that microgroove technology was used in the majority of baseline units disassembled in the engineering analysis, DOE believes that microgroove technology is currently being used in baseline equipment today. Thus, DOE believes that the efficiency benefits of the technology are negligible and DOE has eliminated rifled interior tube walls as a potential avenue for efficiency improvement.

4.3.3 Microchannel Heat Exchangers

Microchannel heat exchangers in air conditioning applications are heat exchangers in which refrigerant fluid flows in confinements with typical hydraulic diameter of less than one millimeter. Microchannels may improve unit efficiency by improving the efficiency of heat transfer between refrigerant and air across the heat exchanger. However, microchannel heat exchangers are currently in the development stage for PTAC and PTHP applications and are not proven for consistent, field installed equipment performance. DOE notes that the engineering analysis was based on efficiency levels and, because units with microchannels are not commercially available, DOE cannot estimate the increased manufacturing costs associated with whatever efficiency gains such units may offer.

DOE is aware that Zess, Inc. Industries is developing an integrated microchannel refrigeration system for applications in PTAC units. Zess, Inc. Industries has indicated that this application may achieve efficiencies as high as 15 EER in PTACs. DOE requested more information from Zess, Inc. Industries regarding prototype units and test results.

At this point, DOE does not have information regarding these prototype tests that would allow assessment of the efficiency improvements associated with the specific microchannel technology and/or the costs associated with its implementation. DOE eliminated microchannel heat exchanges from the NOPR analysis because data are not available to evaluate the energy efficiency characteristics of the technology.

4.3.4 Complex Control Boards

Digital energy management control interfaces can reduce annual energy consumption of PTACs or PTHPs by optimizing the operation of the equipment under varying operating conditions. For example, they may allow operation managers in hotels to remotely turn off or change temperature set points of units throughout a building. Although this technology can reduce peak energy demand and also reduce overall energy consumption throughout the year, it does not increase the EER under the AHRI 310/380-2014 test procedure. The test procedure requires that units be tested at steady state test conditions and DOE believes that complex control boards do not help steady state performance in PTAC and PTHP applications.

DOE eliminated complex control boards as an efficiency option because the test procedure and EER or COP metric would not measure the energy impact of these technologies.

4.3.5 Corrosion Protection

Corrosion protection materials used in PTACs and PTHPs protect the equipment and prolong its use when it is exposed to chemically harsh operating conditions. DOE believes that corrosion protection has a negative impact on steady state operation to some degree, but that corrosion protection may help improve the overall unit performance over several years of operation. Although it is beneficial for units in harsh environments to be corrosion protected, corrosion protection does not improve the EER as measured by the test procedure. Therefore, DOE did not consider this technology in the engineering analysis.

4.3.6 Hydrophobic Material Treatment of Heat Exchangers

Material treatment of heat exchangers (also known as “plasma treatment”) allows the condensate that forms on the fins to be repelled and drained faster than on non-treated heat exchangers. Hydrophobic treatments are used to reduce mineral build up and corrosion on heat exchanger fins, to improve long-term performance of the unit. Although enhanced long term performance is beneficial, this treatment is not shown to improve the EER as per the test procedure.

4.3.7 Thermal Expansion Valves

Thermal expansion valves (TXVs) control the flow of refrigerant into the evaporator based on a temperature feedback. DOE notes that thermal expansion valves (TXVs) would not improve the energy efficiency of PTACs or PTHPs, because there is only one condition for which the fixed-orifice expansion device can be optimized. DOE has insufficient information to know whether testing at multiple conditions would make sufficient efficiency improvement to justify the increased test time. Therefore, DOE did not consider this technology in the engineering analysis.

4.4 REMAINING TECHNOLOGIES

Table 4.4.1 lists the technologies that were retained by DOE and subsequently designated as design options. Each of these technologies will be evaluated further in the subsequent engineering analysis.

Table 4.4.1 Retained Design Options for PTAC and PTHP

Higher Efficiency Compressors
Higher Efficiency Fan Motors
Increased Heat Exchanger Area
Improved Air Flow and Fan Design

The remaining technology options in Table 4.4.1 are briefly described below.

4.4.1 Higher Efficiency Compressors

Manufacturers can improve the energy efficiency of PTAC and PTHP units by incorporating more efficient components, such as high efficiency compressors, into their designs. DOE observed in reverse engineering analysis that PTAC and PTHP manufacturers use several different compressor models with a wide range of efficiency ratings. During the reverse engineering analysis conducted as part of the engineering analysis, DOE conducted efficiency testing and observed the compressors that were used in nineteen test units. For the representative capacity of 9,000 Btu/h, DOE examined compressors in ten test units and observed that the compressor efficiency ratings ranged from 9.7 EER to 10.9 EER. DOE observed most of the test units at 9,000 Btu/h used a compressor rated at 10.1 EER, but that the test unit with the highest tested efficiency used a compressor rated at 10.9 EER. For the representative capacity of 15,000 Btu/h, DOE examined compressors in nine test units and observed that the compressor efficiency ratings ranged from 9.8 EER to 10.5 EER. DOE observed that the test units at 15,000 Btu/h had an average compressor efficiency rating of 10.1 EER, but that the test unit with the highest tested efficiency used a compressor rated at 10.5 EER. Efficiency test results and compressor observations are included in chapter 5 of this TSD.

4.4.2 Higher Efficiency Fan Motors

Manufacturers of baseline PTACs and PTHPs use permanent split capacitor (PSC) fan motors due to their modest cost, compact design, and durability. More efficient PSC motor designs applicable to PTACs and PTHPs are an ongoing industry challenge, and there been no substantial gain in efficiency in recent years. PSC manufacturers can improve efficiency by increasing the surface area of rotors, although the overall size of the PSC motor would increase in that case. PTACs and PTHPs have size constraints that do not allow an increase in motor size to a level which would have a significant impact on energy efficiency. DOE believes any further gains in PSC fan motor efficiency will be difficult to achieve, and has thus eliminated improvement of PSC fan motors as a potential avenue for efficiency improvement.

Besides PSC-based fan motors, PTAC and PTHP original equipment manufacturers (OEMs) can replace PSC motors with permanent magnet (PM) motors. PM motors typically offer higher efficiencies than PSC-based fan motors, but these improvements come with increased costs for the motor unit and control hardware. Several manufacturers use PM motors in their higher-efficiency PTAC and PTHP models.

4.4.3 Increased Heat Exchanger Area

Manufacturers of PTACs and PTHPs increase unit efficiency by increasing heat exchanger size, either through elongating the face of the heat exchanger or increasing the number of heat exchanger tube rows. Standard-size PTACs are dimensionally constrained and, because of these constraints on unit size, there are limits to the efficiency gains that may be had by increasing heat exchanger size. At least one manufacturer has incorporated bent heat exchanger coils to increase the heat exchanger face area while remaining inside the standard size unit constraints. In its reverse engineering analysis, DOE observed at least three test units that contained a bent heat exchanger. DOE based its analysis on the measured performance of these units (one of which performed at the max-tech efficiency level). The measured performance of these units includes the impact of additional pressure drop associated with the bent heat exchangers.

4.4.4 Improved Air Flow and Fan Design

Manufacturers of PTACs and PTHPs currently use several techniques to shape and direct airflow inside PTAC and PTHP units. Manufacturers may improve unit efficiency by optimizing air paths and fan blade designs, and by selecting appropriate fan and motor combinations so that the fan’s operational efficiency in the unit matches the fan’s peak efficiency exactly.

CHAPTER 5. ENGINEERING ANALYSIS

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CHAPTER 5. ENGINEERING ANALYSIS

5.1 INTRODUCTION

After conducting the screening analysis, the U.S. Department of Energy (DOE) performed an engineering analysis based on the remaining design options. The engineering analysis consists of estimating the energy consumption and costs of producing equipment at various levels of increased efficiency. This section provides an overview of the engineering analysis (section 5.1), discusses equipment classes (section 5.2), describes the efficiency metrics used for this equipment (section 5.3), establishes baseline unit specifications (section 5.4.2), discusses incremental efficiency levels (section 5.4.3), explains the methodology used during data gathering (section 5.5) and discusses the analysis and results (section 5.6).

The primary inputs to the engineering analysis are baseline information from the market and technology assessment (chapter 3 of this technical support document (TSD)) and technology options from the screening analysis (chapter 4). Additional inputs include laboratory testing and reverse-engineering of representative equipment, and manufacturer interviews. The primary output of the engineering analysis is a set of cost-efficiency curves. In the subsequent markups analysis (chapter 6), DOE determined consumer (i.e., equipment purchaser) prices by applying distribution markups, sales tax and contractor markups. After applying these markups and an assumed installation cost, the consumer prices serve as the input to the building energy-use and end-use load characterization (chapter 7) and the life-cycle cost (LCC) and payback period (PBP) analyses (chapter 8).

DOE typically structures its engineering analysis around one of three methodologies. These are: (1) the design-option approach, which calculates the incremental costs of adding specific design options to a baseline model that will improve its efficiency (*i.e.*, lower its energy use); (2) the efficiency-level approach, which calculates the relative costs of achieving increases in energy efficiency levels, without regard to the particular design options used to achieve such increases; and/or (3) the reverse-engineering (or cost-assessment) approach, which provides “bottom-up” manufacturing cost assessments for achieving various levels of increased efficiency, based on teardown analyses (or physical teardowns) providing detailed data on costs for parts and material, labor, shipping/packaging, and investment for models that operate at particular efficiency levels. A supplementary method called a catalog teardown uses published manufacturer catalogs and supplementary component data to estimate the major physical differences between a piece of equipment that has been physically disassembled and another piece of similar equipment for which catalog data are available to determine the cost of the latter equipment. The methodology selected for the engineering analysis depends on the product, the design options under study, and any historical data upon which DOE can draw.

To establish the industry cost-efficiency curves for PTAC and PTHP equipment, the DOE used a combination of the efficiency-level approach and the reverse engineering approach. DOE designated a baseline efficiency level that is equivalent to the minimum efficiency allowed by energy conservation standards.[a] DOE set efficiency levels at incremental steps above the baseline up to the maximum efficiency level that is technologically feasible using current technologies.

To estimate the manufacturing production costs (MPCs) for equipment at each efficiency level, DOE reverse engineered a set of PTAC and PTHP equipment specifically selected to represent the range of efficiency levels. This reverse engineering involved the disassembly of units, analysis of the materials and manufacturing processes, and development of a spreadsheet cost model based on a clear and consistent manufacturing cost assessment methodology. DOE built a detailed cost assessment model that accurately estimates the MPC associated with producing each specific piece of equipment. This chapter reports the cost model results in aggregated form to maintain confidentiality of the data.

DOE notes that the combined efficiency level and cost-assessment approach does not separately evaluate the effects of individual design options and does not prescribe a particular set of design options for manufacturers to improve unit efficiency. Instead, it selects units spanning a range of efficiency levels, estimates MPCs for those units, and constructs a cost curve to define the relationship between energy efficiency and MPC.

5.2 EQUIPMENT CLASSES ANALYZED

The current Federal energy conservation standards (ECS), shown in Table 5 of 10 CFR Part 431.97, divide PTACs and PTHPs into twelve equipment classes based on whether the equipment is an air conditioner or heat pump, the cooling capacity, and the equipment's wall sleeve dimensions, which fall into two categories:

- Standard size (PTAC or PTHP equipment with wall sleeve dimensions greater than or equal to 16 inches high, or greater than or equal to 42 inches wide)
- Non-standard size (PTAC or PTHP equipment with wall sleeve dimensions less than 16 inches high and less than 42 inches wide)

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[a] DOE set the baseline level equivalent to the ANSI/ASHRAE/IES Standard 90.1-2013 minimum for PTAC and PTHP equipment, since DOE is required to, at a minimum, adopt the ASHRAE levels as the Federal standard. (42 U.S.C. (a)(6)(A)(ii)(I)).

The twelve equipment classes for PTACs and PTHPs are listed in Table 5.2.1, and correspond to the classes contained in ANSI/ASHRAE/IES Standard 90.1-2013.

Table 5.2.1 Equipment Classes for PTACs and PTHPs

Equipment Class		
Equipment	**Category**	**Cooling Capacity**
PTAC	Standard Size*	<7,000 Btu/h
		≥7,000 Btu/h and ≤15,000 Btu/h
		>15,000 Btu/h
	Non-Standard Size**	<7,000 Btu/h
		≥7,000 Btu/h and ≤15,000 Btu/h
		>15,000 Btu/h
PTHP	Standard Size*	<7,000 Btu/h
		≥7,000 Btu/h and ≤15,000 Btu/h
		>15,000 Btu/h
	Non-Standard Size**	<7,000 Btu/h
		≥7,000 Btu/h and ≤15,000 Btu/h
		>15,000 Btu/h

* Standard size refers to PTAC or PTHP equipment with wall sleeve dimensions greater than or equal to 16 inches high, or greater than or equal to 42 inches wide.
** Wall sleeve dimensions less than 16 inches high and less than 42 inches wide.

DOE is not considering amended energy conservation standards for non-standard size PTAC and PTHP equipment in this rulemaking, because the non-standard size equipment classes represent a small and declining portion of the market, and because of a lack of adequate information to analyze non-standard size units. The shipments analysis conducted for the 2008 final rule projected that shipments of non-standard size PTACs and PTHPs would decline from about 30,000 units in 2012 (6.6% of the entire PTAC and PTHP market) to about 16,000 units in 2042 (2.4% of the entire PTAC and PTHP market).[b]

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[b] See DOE's discussion regarding shipment projections for standard and non-standard PTAC and PTHP equipment and the results of shipment projections in TSD for the 2008 PTAC and PTHP energy conservation standard rulemaking at: *http://www.regulations.gov/#!documentDetail;D=EERE-2007-BT-STD-0012-0032* (Chapter 10, Section 10.5).

For the purposes of this rulemaking, DOE analyzed the six standard size equipment classes for PTACs and PTHPs, presented in Table 5.2.2.

Table 5.2.2 Equipment Classes Covered by this Rulemaking

Equipment Class		
Equipment	**Category**	**Cooling Capacity**
PTAC	Standard Size*	<7,000 Btu/h
		≥7,000 Btu/h and ≤15,000 Btu/h
		>15,000 Btu/h
PTHP	Standard Size*	<7,000 Btu/h
		≥7,000 Btu/h and ≤15,000 Btu/h
		>15,000 Btu/h

* Standard size refers to PTAC or PTHP equipment with wall sleeve dimensions greater than or equal to 16 inches high, or greater than or equal to 42 inches wide.

The current Federal energy conservation standards and the efficiency levels specified by ANSI/ASHRAE/IES Standard 90.1-2013 for PTAC and PTHP equipment are a function of the equipment's cooling capacity. Both standards have equations to calculate the efficiency levels for PTACs and PTHPs in the cooling capacity range between 7,000 Btu/h and 15,000 Btu/h for each equipment class. For equipment with cooling capacities below 7,000 Btu/h and above 15,000 Btu/h, current Federal energy conservation standards and ANSI/ASHRAE/IES Standard 90.1-2013 maintain a constant efficiency level equal to the value of the efficiency equation at either 7,000 Btu/h or 15,000 Btu/h cooling capacity (e.g., the efficiency level for 6,000 Btu/h cooling capacity equipment equals the efficiency level for 7,000 Btu/h cooling capacity equipment, and the efficiency level for 16,000 Btu/h cooling capacity equipment equals the efficiency level for 15,000 Btu/h cooling capacity equipment).

For the engineering analysis, DOE examined specific cooling capacities for standard size PTACs and PTHPs, which are referred to as "representative cooling capacities." Interviews with manufacturers indicated that the majority of PTAC and PTHP shipments are in the classes with cooling capacity between 7,000 Btu/h to 15,000 Btu/h. According to the certification data provided by the 2013 AHRI Directory of Certified Performance (2013 AHRI Directory), over 90 percent of standard-size PTAC and PTHP models available on the market are within the 7,000 Btu/h to 15,000 Btu/h cooling capacity range.[1] DOE focused its analysis on equipment with cooling capacities in the range between 7,000 Btu/h and 15,000 Btu/h.

5.3 ENERGY EFFICIENCY METRICS

The current energy conservation standards for PTACs and PTHPs are based on energy efficiency ratio (EER) for cooling efficiency and on coefficient of performance (COP) for PTHP heating efficiency. 10 CFR 431.97(c). The current Federal test procedure for PTACs and PTHPs incorporates by reference AHRI 310/380-2014 *Standard for Packaged Terminal Air-Conditioners and Heat Pumps*.[c] This standard defines EER as "the ratio of the produced cooling effect of an air conditioner or heat pump to its net work input, expressed in Btu/watt-hour." COP is defined by AHRI 310/380-2014 as "the ratio of the produced cooling effect of an air conditioner or heat pump (or its produced heating effect, depending on the mode of operation) to its net work input, when both the cooling (or heating) effect and the net work input are expressed in identical units of measurement."

In conducting the engineering analysis, DOE only considered technologies and techniques that improve the EER and COP of PTAC and PTHP equipment. As mentioned in the screening analysis (chapter 4 of this TSD), there are some technology options and techniques that could reduce the annual energy consumption of the system, but that have little effect on EER. DOE did not consider technology options that have negligible effects on EER and COP.

5.4 EFFICIENCY LEVELS

5.4.1 Representative Cooling Capacities

Because there are large variations in equipment cooling capacity and performance in the standard size PTAC and PTHP equipment classes, DOE analyzed some of the cooling capacities individually. DOE selected representative cooling capacities and analyzed specific equipment to provide information representative of the entire equipment class. The representative cooling capacities allowed DOE to establish baseline units that are used throughout the rulemaking analyses.

For standard-size PTAC and PTHP equipment classes, DOE identified two representative cooling capacities: 9,000 Btu/h and 15,000 Btu/h. Both representative cooling capacities fall within the ≥7,000 and ≤15,000 Btu/h cooling capacity range. DOE selected the representative cooling capacity of 9,000 Btu/h because this capacity had the

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[c] DOE has incorporated by reference AHRI Standard 310/380-2014 as the DOE test procedure at 10 CFR 431.97.

highest number of standard-size PTAC and PTHP models listed in the 2013 AHRI Directory. Chapter 3 of this TSD presents the distribution of models in the 2013 AHRI Directory at different capacity levels for standard-size PTAC and PTHP equipment. DOE selected the representative cooling capacity of 15,000 Btu/h because, according to several manufacturers interviewed, the 15,000 Btu/h cooling capacity represents the greatest technical hurdles for efficiency improvement, considering the size constraints of standard-size PTACs and PTHPs. DOE believes that these representative cooling capacities capacities of 9,000 and 15,000 Btu/h accurately represent the markets for PTAC and PTHP equipment.

DOE used the analytical results for the two representative cooling capacities to examine the slope of the energy-efficiency equation (i.e., EER as a function of cooling capacity). Chapter 9 of this TSD contains more details explaining how DOE extrapolates the amended energy conservation standards for the representative cooling capacities to the entire range of cooling capacities.

5.4.2 Baseline Units

DOE selected baseline units as reference points for each equipment class, against which DOE measured changes resulting from potential energy conservation standards. The baseline unit in each equipment class represents the basic characteristics of equipment in that class. Typically, a baseline unit is a unit that just meets current required energy conservation standards and provides basic consumer utility. DOE used the baseline units in the engineering analysis and the life-cycle-cost and payback-period analysis.

The baseline efficiency levels for each equipment class are presented below in Table 5.4.1. These levels represent the ANSI/ASHRAE/IES Standard 90.1-2013 minimums for PTAC and PTHP equipment. These levels are used as the Baselines for PTAC and PTHP equipment since DOE is required to, at a minimum, adopt the ASHRAE levels as the Federal standard. (42 U.S.C. (a)(6)(A)(ii)(I)). The Baseline efficiency level is 1.8% higher than current Federal standard for PTAC equipment, but is equal to current Federal standard for PTHP equipment.

Table 5.4.1 Baseline Efficiency Levels

Equipment Type	Equipment Class	Baseline Efficiency Equation	Cooling Capacity	Baseline Efficiency Level
PTAC	Standard Size	EER = 14.0 – (0.300 x Cap[†])	9,000 Btu/h	11.3 EER
			15,000 Btu/h	9.5 EER
PTHP	Standard Size	EER = 14.0 – (0.300 x Cap[†])	9,000 Btu/h	11.3 EER 3.2 COP
		COP = 3.7 – (0.052 x Cap[†])	15,000 Btu/h	9.5 EER 2.9 COP

[†] Cap means cooling capacity in thousand Btu/h at 95°F outdoor dry-bulb temperature.

5.4.3 Incremental Efficiency Levels

For the equipment classes presented in section 5.2, DOE analyzed several efficiency levels and obtained incremental cost data at each of these levels. DOE considered five efficiency levels beyond the baseline efficiency level for each equipment class. DOE selected these levels based on a review of the efficiency levels of available equipment. DOE indicated in the framework document for this rulemaking that it planned to consider a maximum efficiency level 18.2% higher than the baseline level.[d] The rated efficiencies of PTACs listed in the AHRI Directory extend up to 17.5% above the ANSI/ASHRAE/IES Standard 90.1-2013 baseline efficiency level. However, based on testing of individual units conducted for this rulemaking, DOE only considered efficiencies up to 16.2% above the baseline level. Accordingly, DOE revised the maximum efficiency level for this analysis from 18.2% to 16.2% above the baseline level.

For the PTHP equipment classes, DOE based heating efficiency levels on the variation of COP with EER, as discussed in the framework document for this rulemaking. 78 FR 12252. DOE evaluated AHRI data for PTHP equipment to develop the relationship between COP and EER and used this relationship to establish the COP efficiency levels. Figure 5.4.1 and Figure 5.4.2 below show the COP and EER data and best-fit linear relationships for standard size PTHP units with 9,000 Btu/h or 15,000 Btu/h cooling capacity results.

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[d] Because DOE published the framework document before the publication of ASHRAE 90.1-2013, the framework document described the proposed max tech level as being 20% higher than the current Federal PTAC ECS.

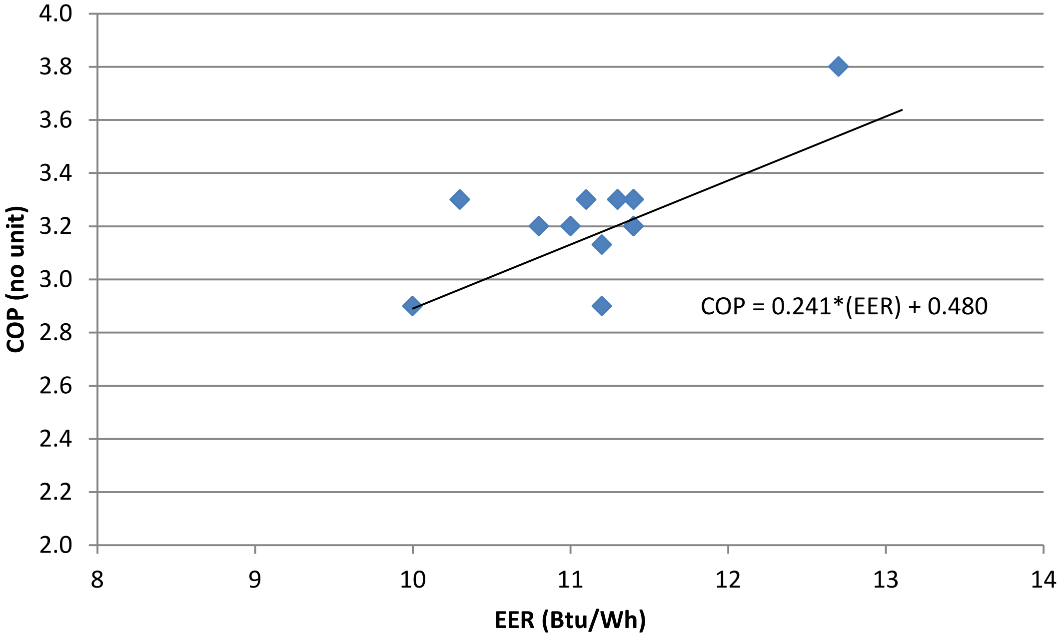

Figure 5.4.1 COP versus EER for Standard Size PTHPs with 9,000 Btu/h Cooling Capacity from 2013 AHRI directory

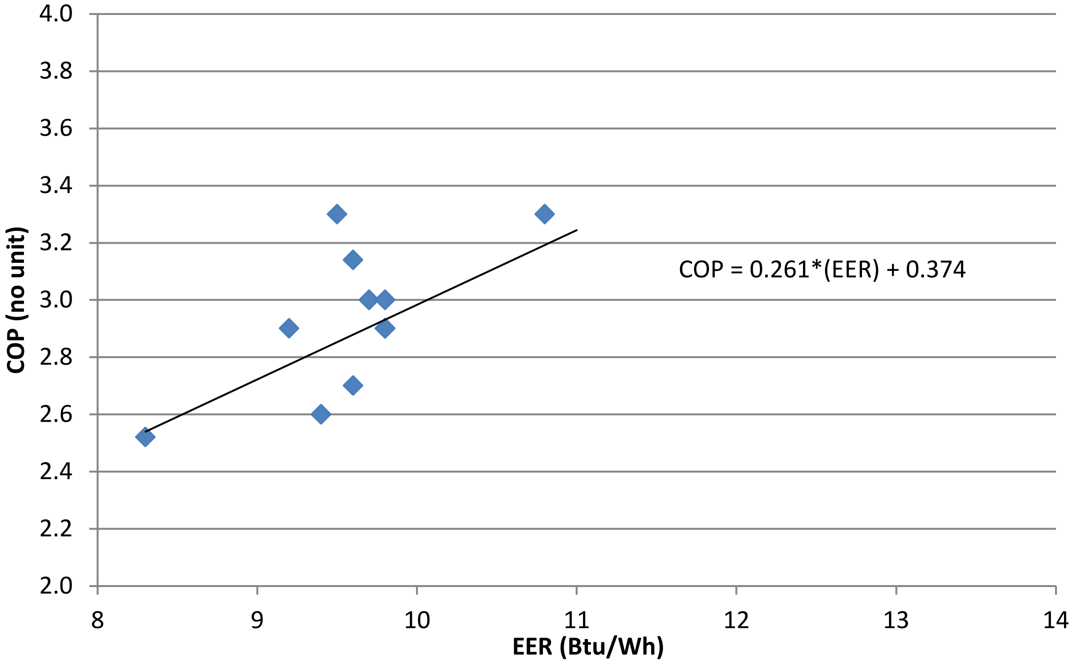

Figure 5.4.2 COP versus EER for Standard Size PTHPs with 15,000 Btu/h Cooling Capacity from 2013 AHRI directory

DOE established COP efficiency levels for PTHPs at 9,000 and 15,000 Btu/h using the EER values corresponding to the incremental cooling performance efficiency levels and the linear equations developed for the COP/EER relationships that are shown in the figures. The resulting incremental COP efficiency levels are shown for PTHP equipment in Table 5.4.2.

Table 5.4.2 presents the efficiency levels for each equipment class.

Table 5.4.2 Incremental Efficiency Levels

			Efficiency Levels (Percentages relative to Baseline)						
Equipment Type	**Cooling Capacity**	**Efficiency Metric**	**Current Federal PTAC ECS***	**EL1, Baseline****	**EL2, 2.2%**	**EL3, 6.2%**	**EL4, 10.2%**	**EL5, 14.2%**	**EL6, 16.2% (MaxTech)**
PTAC, Standard Size	7,000-15,000 Btu/h	EER	13.8 - (0.300 x Cap[†])	14.0 - (0.300 x Cap[†])	14.4 - (0.312 x Cap[†])	14.9 - (0.324 x Cap[†])	15.5 - (0.336 x Cap[†])	16.0 - (0.348 x Cap[†])	16.3 - (0.354 x Cap[†])
	9,000 Btu/h	EER	11.1 EER	11.3 EER	11.5 EER	12.0 EER	12.4 EER	12.9 EER	13.1 EER
	15,000 Btu/h	EER	9.3 EER	9.5 EER	9.7 EER	10.0 EER	10.4 EER	10.8 EER	11.0 EER
Equipment Type	**Cooling Capacity**	**Efficiency Metric**		**Baseline****	**EL1, 2.2%**	**EL2, 6.2%**	**EL3, 10.2%**	**EL4, 14.2%**	**EL5, 16.2% (MaxTech)**
PTHP, Standard Size	7,000-15,000 Btu/h	EER		14.0 - (0.300 x Cap[†])	14.4 - (0.312 x Cap[†])	14.9 - (0.324 x Cap[†])	15.5 - (0.336 x Cap[†])	16.0 - (0.348 x Cap[†])	16.3 - (0.354 x Cap[†])
	7,000-15,000 Btu/h	COP		3.7 - (0.052 x Cap[†])	3.8 - (0.058 x Cap[†])	4.0 - (0.064 x Cap[†])	4.1 - (0.068 x Cap[†])	4.2 - (0.070 x Cap[†])	4.3 - (0.073 x Cap[†])
	9,000 Btu/h	EER COP		11.3 EER 3.2 COP	11.5 EER 3.3 COP	12.0 EER 3.4 COP	12.4 EER 3.5 COP	12.9 EER 3.6 COP	13.1 EER 3.6 COP
	15,000 Btu/h	EER COP		9.5 EER 2.9 COP	9.7 EER 2.9 COP	10.0 EER 3.0 COP	10.4 EER 3.1 COP	10.8 EER 3.2 COP	11.0 EER 3.2 COP

* This level represents the current Federal minimum for PTAC equipment.
** This level represents the ANSI/ASHRAE/IES Standard 90.1-2013 minimum for PTAC and PTHP equipment. This level is used as the Baseline for PTAC and PTHP equipment since DOE is required to, at a minimum, adopt the ASHRAE levels as the Federal standard. (42 U.S.C. (a)(6)(A)(ii)(I)). DOE notes that the Baseline level is 1.8% higher than current Federal ECS for PTAC equipment, but is equivalent to current Federal ECS for PTHP equipment. For PTAC equipment, the Baseline level is also termed EL1.
[†] Cap means cooling capacity in thousand Btu/h at 95ºF outdoor dry-bulb temperature.

5.5 METHODOLOGY OVERVIEW

In order to develop the cost-efficiency relationships for PTACs and PTHPs, DOE conducted testing and performed detailed equipment teardowns and reverse-engineering analyses on a sample of models spanning a range of rated efficiencies. DOE supplemented these analyses by conducting interviews with equipment manufacturers to gain a better understanding of the design options and costs associated with achieving higher efficiency levels.

5.5.1 Manufacturer Interviews

Throughout the rulemaking process, DOE seeks feedback and insight from stakeholders to improve the information used in the analyses. For the engineering analysis, DOE conducted confidential interviews with manufacturers of PTACs and PTHPs to develop a deeper understanding of the various combinations of technologies used to increase equipment efficiency and their associated manufacturing costs. DOE considered all the information manufacturers provided when refining the cost model. DOE incorporated confidential information (*i.e.*, equipment and manufacturing process figures) into the analysis in the form of averages to avoid disclosing sensitive information about individual manufacturers' equipment or manufacturing processes.

Before these interviews, DOE provided manufacturers with an engineering information package that included a spreadsheet with preliminary assumptions, estimates, and cost-efficiency curves, and a list of possible questions to be asked during the interview. DOE asked manufacturers to provide feedback if the data was representative of the market and to supply any data that could improve DOE's estimates and assumptions. DOE's questions included the following:

- Which design features affecting energy use are generally incorporated into "baseline" PTACs and PTHPs?
- What are the costs of attaining the individual efficiency levels selected? How do these efficiency levels correspond to the various design options listed? What other design options do you use to attain the various efficiency levels?
- Do the industry MPCs calculated by DOE represent your firm's costs for manufacturing standard and size PTAC and PTHP?

DOE also requested information on a number of other factors that affect manufacturing cost and the incremental cost associated with attaining higher efficiency levels.

5.5.2 Equipment Teardown

Other than obtaining detailed manufacturing costs directly from a manufacturer, the most accurate method for determining the production cost of a piece of equipment is to disassemble the equipment piece-by-piece and estimate the material and labor cost of each component using a process commonly called a physical teardown.

To calculate the manufacturing costs of PTACs and PTHPs at different efficiency levels, DOE disassembled multiple units into their component parts and used cost modeling techniques to estimate the cost of materials, labor, and capital required to fabricate and assemble the components into a complete piece of equipment. The teardown methodology is described in detail in section 5.5.2.1 through section 5.5.2.3.

5.5.2.1 Selection of Units

DOE selected several standard-size PTAC and PTHP units to represent the market, and used these for teardown in the engineering analysis. The selected equipment exhibited the following five characteristics:

1. The selected equipment, taken together, cover the full range of efficiency levels considered in the analysis.

2. The selected equipment has cooling capacity corresponding to one of the selected representative cooling capacities (9,000 Btu/h or 15,000 Btu/h).

3. When possible, DOE selected one lower-efficiency unit and one higher-efficiency unit from the same manufacturer. When possible, those units shared similar characteristics (e.g., both from the same product line).

4. The equipment tended to be from manufacturers with relatively large shares of the PTAC and PTHP markets, and thus was representative of typical design approaches.

5. The selected equipment included base units with few, if any, equipment features or options that add cost without affecting equipment efficiency.

5.5.2.2 Generation of Bills of Materials

The end result of each teardown is a structured bill of materials (BOM). Structured BOMs describe each equipment part and its relationship to the other parts, in the estimated order of assembly. The BOMs describe each fabrication and assembly operation in detail, including the type of equipment needed (*e.g.*, stamping presses, injection molding machines, spot-welders, etc.) and the process cycle times. The result is a thorough and explicit model of the production process, which includes space, conveyor, and equipment requirements by planned production level.

The BOMs incorporate all materials, components, and fasteners, classified as either raw materials or purchased parts and assemblies. The classification into raw materials or purchased parts is based on DOE's previous industry experience, recent information in trade publications, and discussions with high- and low-volume original equipment manufacturers (OEMs).

For purchased parts, the purchase price is an estimate based on volume-variable price quotations and detailed discussions with suppliers. For fabricated parts, the price of intermediate materials (*e.g.*, tube, sheet metal) and the cost of transforming them into finished parts are an estimate based on current industry pricing. DOE shared major assumptions and estimates with manufacturers during the engineering manufacturer interviews to gain feedback on the analysis, its methodology, and preliminary results.

The cost of raw materials is determined using prices for copper, steel and aluminum from the American Metals Market.[2] Because DOE is using a 5-year average in material prices from 2009–2013, these price increases are normalized, which better represents long-term material prices.

5.5.2.3 Cost Structure of the Spreadsheet Models

The manufacturing cost assessment methodology used is a detailed, component-focused technique for rigorously calculating the manufacturing cost of a product (direct materials, direct labor and some overhead costs.) Figure 5.5.1 shows the three major steps in generating the manufacturing cost.

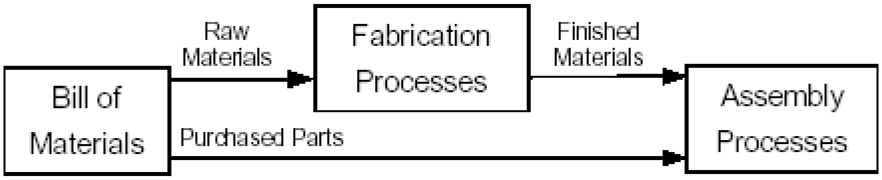

Figure 5.5.1 Manufacturing Cost Assessment Stages

The first step in the manufacturing cost assessment is the creation of a complete and structured BOM from the disassembly of the units selected for teardown. The units are dismantled, and each part is characterized according to weight, manufacturing processes used, dimensions, material, and quantity. The BOM incorporates all materials, components, and fasteners with estimates of raw material costs and purchased part costs. Assumptions on the sourcing of parts and in-house fabrication are based on industry experience, information in trade publications, and discussions with manufacturers. Interviews and plant visits are also conducted with manufacturers to ensure accuracy on methodology and pricing.

Following the development of a detailed BOM, the major manufacturing processes are identified and developed for the spreadsheet model. These processes are listed in Table 5.5.1.

Table 5.5.1 Major Manufacturing Processes

Fabrication	Finishing	Assembly/Joining	Quality Control
Injection Molding	Washing	Adhesive Bonding	Inspecting & Testing
Stamping/Pressing	Powder Coating	Spot Welding	
Turret Punching	De-burring	Seam Welding	
Brake Forming	Polishing	Brazing	
Cutting and Shearing			
Tube Forming			

Fabrication process cycle times are estimated and entered into the BOM. For this analysis, $9.10 per hour was used as the average fully-burdened labor rate based on typical annual wages and benefits of industry employees. Labor rates for manufacturers of standard size PTACs and PTHPs are based on the weighted averages of foreign and domestic manufacturers. Certain large manufacturers of PTACs and PTHPs make their equipment in foreign factories, where labor rates are significantly less than domestic rates. Foreign labor rates are based on engineering manufacturer interviews, internal expertise, and industry literature research. In the final step of the cost assessment, assembly times and associated direct labor costs are estimated. Once the cost estimate for each teardown unit is finalized, a detailed summary is prepared for relevant components, subassemblies and processes. The BOM thus details all aspects of unit costs.

Design options used in units subject to teardown are noted in the summary sheet of each cost model and are cost-estimated individually. Thus, various implementations of design options can be accommodated, ranging from assemblies that are entirely purchased to units that are made entirely from raw materials. Hybrid assemblies, consisting of purchased parts and parts made on site are thus also accommodated.

5.5.3 Shipping Costs

In addition to the MPC, DOE also considered the cost to ship the unit from the manufacturing facility to the first point on the distribution chain. In calculating the shipping costs, DOE first gathered estimates of the cost to ship a standard-size shipping container of manufactured equipment from China to the United States, and the cost to ship the equipment an average distance in the United States. The bulk of PTAC and PTHP shipments originate from factories in China, but one major manufacturer of standard size PTACs and PTHPs produces units in the United States. Using the relative market shares for standard size equipment manufacturers, DOE constructed a weighted average shipping cost to account for units produced domestically and overseas. DOE then used the representative unit sizes to calculate a volume for each unit. Along with the dimensions of a shipping container, DOE used this cost and volume information to develop an average shipping cost for each equipment class analyzed.

5.5.4 Equipment Testing

DOE conducted equipment testing to verify the energy use of equipment and to develop a better understanding of the potential efficiency improvements associated with various design options and to develop disaggregated efficiency data. DOE contracted with qualified third-party test laboratories to test the capacity, EER, and COP of the equipment using the DOE test procedures for PTACs and PTHPs (see 10 CFR 431.96).

5.6 ANALYSIS AND RESULTS

DOE conducted the engineering analysis using the efficiency-level approach and the reverse-engineering approach, analyzing two specific cooling capacities to represent the range of standard-size PTACs and PTHPs available on the market. As discussed in section 5.6.1, DOE selected representative capacities of 9,000 Btu/h and 15,000 Btu/h, ,

5.6.1 Manufacturer Interviews

As discussed in section 5.5.1, DOE conducted confidential interviews with PTAC and PTHP manufacturers. From the manufacturers interviewed, DOE collected a general impression of PTAC and PTHP equipment on the market. Interviewed manufacturers indicated that all of the equipment covered in this rulemaking currently use rotary compressors, round-tube-and-fin heat exchangers, and R-410A refrigerant.

Manufacturers employ different design strategies in terms of compressor selection, indoor and outdoor fan motor selection, and heat exchanger design. Manufacturers interviewed noted that selecting higher efficiency motors and compressors can increase system efficiency. Manufacturers also commented that increasing the size of the heat exchangers in a unit increases efficiency, though this use of this option is limited in larger capacity models (such as 15,000 Btu/h models) because of size constraints. Manufacturers noted that standard-size PTACs and PTHPs are limited in terms of case size because the units are typically installed in wall openings of 16 inches high by 42 inches wide. These wall opening dimensions were standardized in buildings over the past 25 years. DOE understood from manufacturers that altering existing wall sleeve openings could include extensive structural changes to a building, could be very costly, and is therefore rarely done.

5.6.2 Equipment Testing

DOE conducted a market survey of PTAC and PTHP models and their features. DOE selected six 9,000 Btu/h and five 15,000 Btu/h PTAC models for testing and reverse engineering. The models were selected to develop a representative sample of the market at different efficiency levels. DOE selected the units based on the efficiency data available in the AHRI certification database. Where feasible, DOE selected models for reverse engineering with low and high capacities from a given manufacturer that are built on the same platform (i.e., with the same basic design and construction). DOE also selected five 9,000 Btu/h and four 15,000 Btu/h PTHP models to evaluate the differences between PTAC and PTHP units. Details about the key features of the tested units are presented in Table 5.6.1 and Table 5.6.2. DOE notes that the 9,000 Btu/h test unit with the highest tested efficiency (Test Unit 7) used DC fan motors and a compressor rated at 10.9 EER; the 15,000 Btu/h test units with the highest tested efficiency rating (Test Unit 16 & 20) used DC fan motors and a compressor rated at 10.5 EER.

Table 5.6.1 PTAC and PTHP Test Units at 9,000 Btu/h Capacity

Feature		Test Unit Description										
		PTAC						PTHP				
		Test Unit 1	Test Unit 2	Test Unit 3	Test Unit 4	Test Unit 5	Test Unit 6	Test Unit 7	Test Unit 8	Test Unit 9	Test Unit 10	Test Unit 11
Rated Cooling Capacity (Btu/h)		9,000	9,000	9,000	9,700	9,500	9,700	9,500	9,400	9,000	9,000	9,000
Rated EER (Btu/Wh)		11.3	11.5	11.3	12.1	12.7	12.1	12.9	12.7	11.3	11.3	11.5
Rated COP (unitless)		-	-	-	-	-	-	3.6	3.8	3.3	3.3	3.4
Outdoor Coil	Face Area (ft^2)	2.67	2.67	1.85	2.67	2.48	2.67	2.50	2.55	1.85	2.67	2.67
	Fin Pitch	19	23	21	19	21	19	20	19	21	19	23
	Tube Rows	3	2	2	2	3	2	3	3	2	3	2
	Tube OD (in.)	0.200	0.200	0.250	0.250	0.200	0.250	0.250	0.250	0.250	0.200	0.200
Outdoor Fan Motor	Type	PSC	PSC	PSC	PSC	BLDC	PSC	BLDC	BLDC	PSC	PSC	PSC
	Power (hp)	0.054	0.040	0.028	0.037	0.067	0.037	0.067	0.060	0.028	0.054	0.040
Indoor Coil	Face Area (ft^2)	2.08	1.93	2.34	1.87	1.88	1.87	1.88	1.87	2.34	2.08	1.93
	Fin Pitch	18	18	18	19	19	19	19	21	18	18	18
	Tube Rows	2	2	3	2	2	2	2	2	3	2	2
	Tube OD (in.)	0.313	0.375	0.313	0.250	0.375	0.250	0.375	0.250	0.313	0.313	0.375
Indoor Fan Motor	Type	PSC	PSC	PSC	PSC	BLDC	PSC	BLDC	BLDC	PSC	PSC	PSC
	Power (hp)	0.028	0.020	0.054	0.042	0.040	0.042	0.040	0.048	0.028	0.028	0.020
Compressor*	Capacity (Btu/h)	7,438	7,895	7,895	7,895	7,900	7,895	8,700	7,895	Not recorded	7,438	7,895
	Efficiency (EER)	10.1	10.1	10.1	10.1	9.7	10.1	10.9	10.1		10.1	10.1

*All test units were observed to have a single-speed rotary compressor using refrigerant R-410a.

Table 5.6.2 PTAC and PTHP Test Units at 15,000 Btu/h Capacity

Feature		Test Unit Description								
		PTAC					PTHP			
		Test Unit 12	Test Unit 13	Test Unit 14	Test Unit 15	Test Unit 16	Test Unit 17	Test Unit 18	Test Unit 19	Test Unit 20
Rated Cooling Capacity (Btu/h)		15,000	14,400	15,000	15,000	14,200	15,100	14,400	15,000	14,200
Rated EER (Btu/Wh)		10.0	10.5	9.8	10.0	9.7	11.2	10.8	9.8	9.7
Rated COP (unitless)		-	-	-	-	-	3.1	3.3	2.9	3.0
Outdoor Coil	Face Area (ft^2)	2.53	2.44	2.41	2.53	2.56	2.48	2.55	2.41	2.56
	Fin Pitch	24	19	18	24	20	20	19	18	20
	Tube Rows	2	3	3	2	2	3	3	3	2
	Tube OD (in.)	0.200	0.250	0.325	0.200	0.375	0.250	0.250	0.325	0.375
Outdoor Fan Motor	Type	PSC	PSC	PSC	PSC	PSC	BLDC	BLDC	PSC	PSC
	Power (hp)	0.094	0.060	0.088	0.094	0.094	0.067	0.060	0.088	0.094
Indoor Coil	Face Area (ft^2)	2.08	1.87	1.85	2.08	1.79	1.83	1.87	1.85	1.79
	Fin Pitch	18	19	19	18	18	19	21	19	18
	Tube Rows	2	2	3	2	3	2	3	3	3
	Tube OD (in.)	0.375	0.250	0.313	0.375	0.313	0.375	0.250	0.313	0.313
Indoor Fan Motor	Type	PSC	PSC	PSC	PSC	PSC	BLDC	BLDC	PSC	PSC
	Power (hp)	0.034	0.042	0.030	0.034	0.034	0.040	0.048	0.031	0.034
Com-pressor*	Capacity (Btu/h)	14,505	13,529	14,758	14,505	14,481	14,505	13,529	14,758	14,481
	Efficiency (EER)	10.3	9.8	9.9	10.3	10.5	10.3	9.8	9.9	10.5

*All test units were observed to have a single-speed rotary compressor using refrigerant R-410a.

DOE conducted testing on each unit according to the current Federal test procedure for PTACs and PTHPs. Table 5.6.3 shows the test results of selected PTAC and PTHP units. DOE observed that the maximum deviation of tested and rated cooling capacity was +8.9 percent, and the maximum deviation of tested EER and rated EER was -7.1 percent.

Table 5.6.3 Test Results of Selected PTAC and PTHP Units

	Parameter						
Test Unit	Type	Rated Cooling Capacity (Btu/h)	Rated EER (Btu/Wh)	Rated COP (unitless)	Tested Cooling Capacity (Btu/h)	Tested EER (Btu/Wh)	Tested COP (unitless)
1	PTAC	9,000	11.3	-	8,280	10.7	-
2	PTAC	9,000	11.5	-	8,849	10.9	-
3	PTAC	9,000	11.3	-	8,831	11.1	-
4	PTAC	9,700	12.1	-	9,537	12.0	-
5	PTAC	9,500	12.7	-	9,654	12.4	-
6	PTAC	9,700	12.1	-	9,737	12.3	-
7	PTHP	9,500	12.9	3.6	9,691	12.4	3.5
8	PTHP	9,400	12.7	3.8	9,673	12.9	3.6
9	PTHP	9,000	11.3	3.3	9,798	11.6	3.5
10	PTHP	9,000	11.3	3.3	9,298	11.5	3.3
11	PTHP	9,000	11.5	3.4	9,541	11.7	3.5
12	PTAC	15,000	10.0	-	15,037	10.0	-
13	PTAC	14,400	10.5	-	14,450	10.5	-
14	PTAC	15,000	9.8	-	15,635	10.3	-
15	PTAC	15,000	10.0	-	15,088	10.0	-
16	PTAC	15,100	11.2	3.1	14,871	10.4	-
17	PTHP	14,200	9.7	3.0	14,785	9.9	3.0
18	PTHP	14,400	10.8	3.3	14,590	11.0	3.3
19	PTHP	15,000	9.8	2.9	15,394	10.3	2.9
20	PTHP	15,100	11.2	3.1	*	*	*

* Testing on Test Unit 20 failed repeatedly due to frosting on the outdoor heat exchanger. No test data is available for this unit.

5.6.3 Equipment Teardown

As part of the reverse engineering analyses, DOE conducted physical teardowns on each test unit[e] to develop a manufacturing cost model and to evaluate and identify design details of key components (*e.g.*, heat exchangers, compressors, fans and fan motors, control strategies, etc.) and the corresponding manufacturing cost of each unit.

Based upon product teardowns, DOE developed the following baseline production cost distributions and materials cost distributions for typical PTACs, shown in Figure 5.6.1 through Figure 5.6.4. Production cost distributions include raw material, purchased parts, labor (assembly, fabrication, supervision, and indirect labor), depreciation (equipment, tooling, and building depreciation), and other overhead (indirect process, maintenance, utility, property tax, and insurance) costs.

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[e] For test units #6, 9, 11, 12, 15, 17, and 20, DOE conducted a partial teardown, examining key components (heat exchangers, compressors, fans/motors, controls, etc.) and basic design construction without fully disassembling the unit.

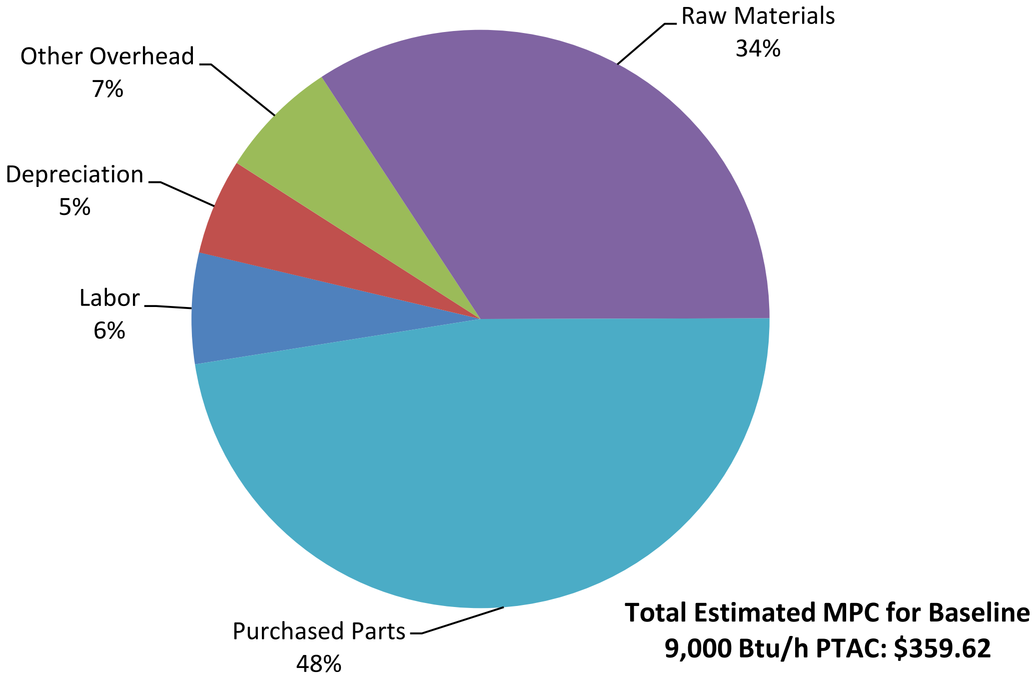

Figure 5.6.1 Baseline 9,000 Btu/h PTAC Full Production Cost Distribution

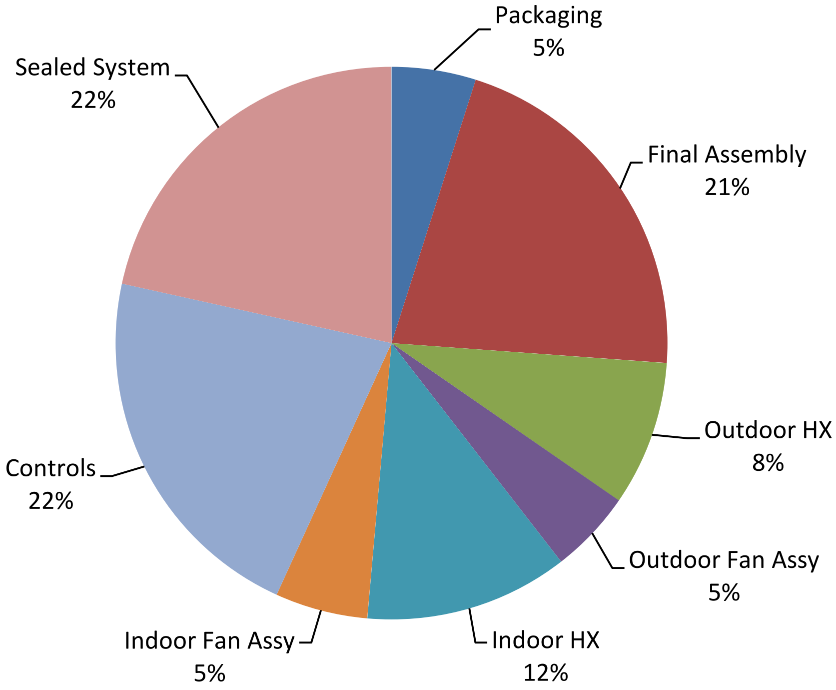

Figure 5.6.2 Baseline 9,000 Btu/h PTAC Materials Cost Distribution

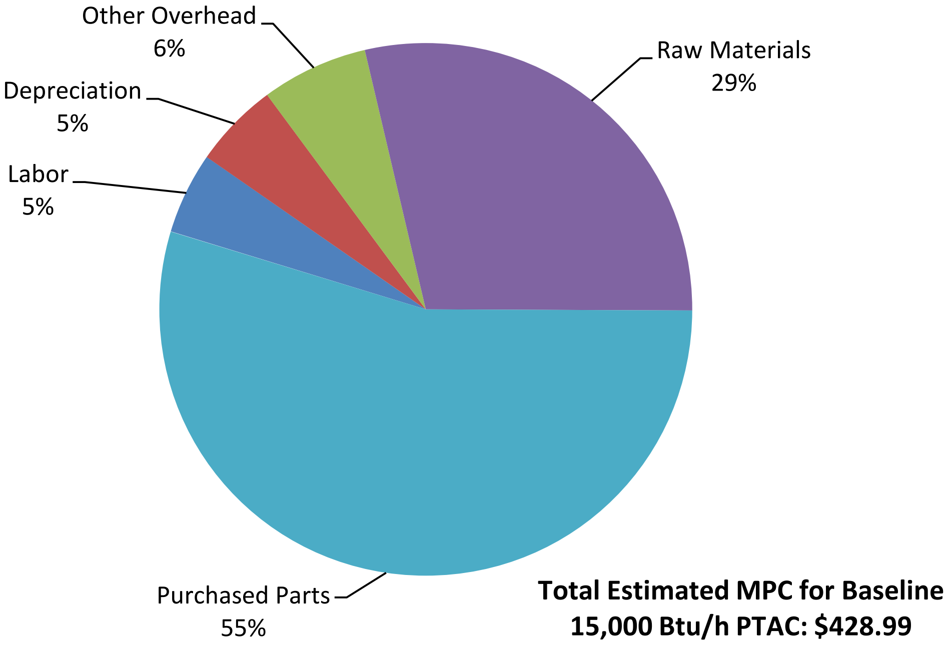

Figure 5.6.3 Baseline 15,000 Btu/h PTAC Full Production Cost Distribution

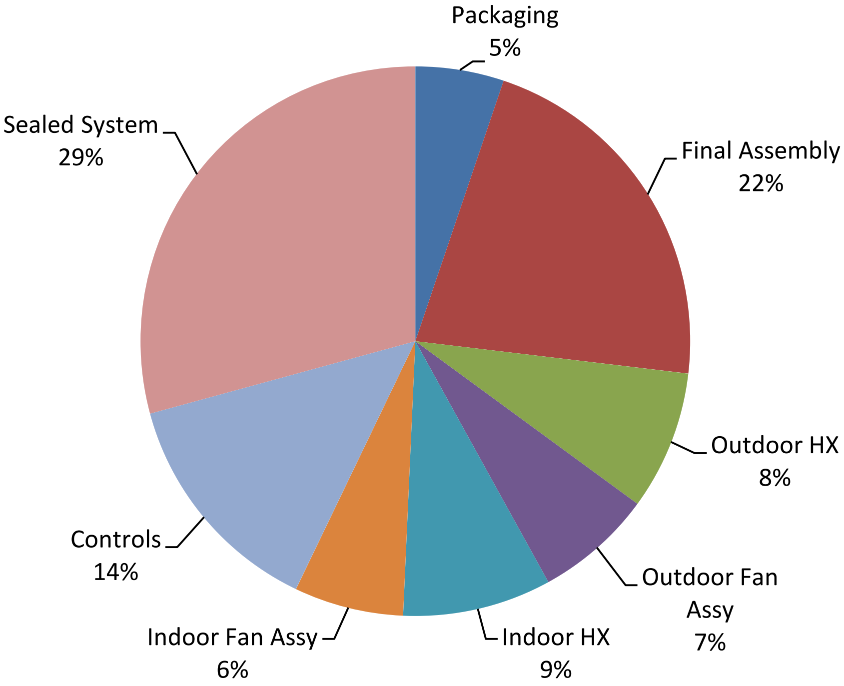

Figure 5.6.4 Baseline 15,000 Btu/h PTAC Materials Cost Distribution

5.6.4 Cost-Efficiency Results

The reverse engineering analysis provides MPC data and tested efficiency data for the selected set of PTAC and PTHP units. DOE assembled this data into four groups, organized by cooling capacity (9,000 Btu/h and 15,000 Btu/h) and equipment type (PTAC and PTHP). DOE used the least squares method to fit second-order polynomial curves to the cost-efficiency data for each group. Figure 5.6.5 through Figure 5.6.8 show the four cost-efficiency curves in the form of EER versus MPC. These four cost curves are pictured together in Figure 5.6.9.

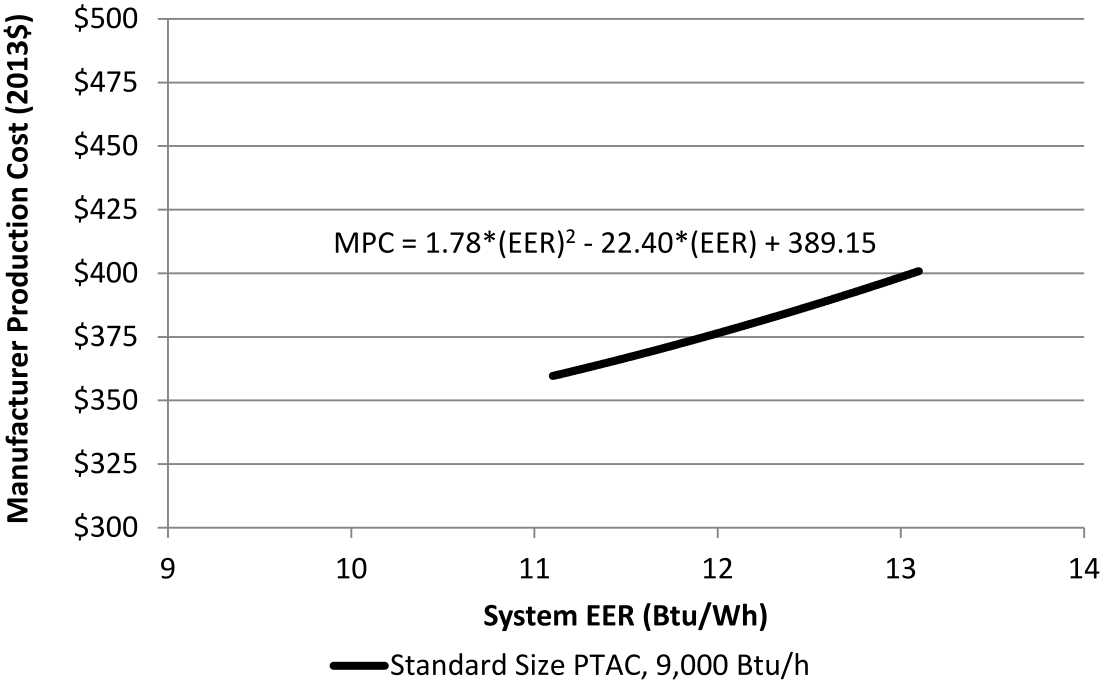

Figure 5.6.5 Manufacturer Production Cost (2013$) versus Efficiency for Standard Size PTACs with a Cooling Capacity of 9,000 Btu/h

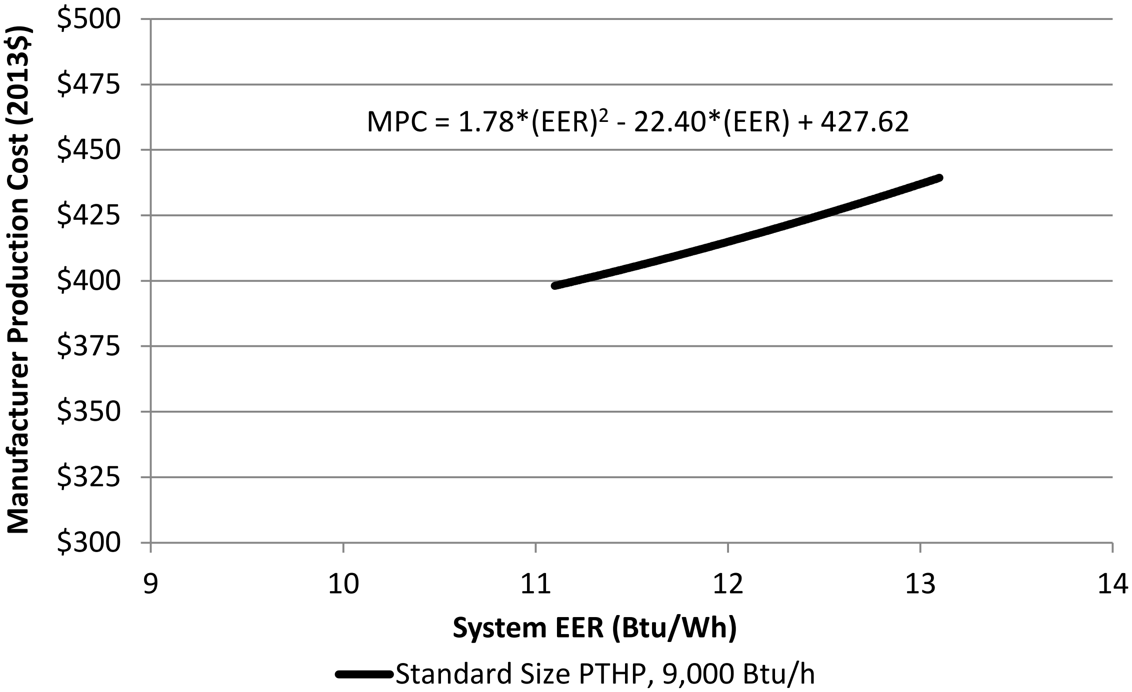

Figure 5.6.6 Manufacturer Production Cost (2013$) versus Efficiency for Standard Size PTHPs with a Cooling Capacity of 9,000 Btu/h

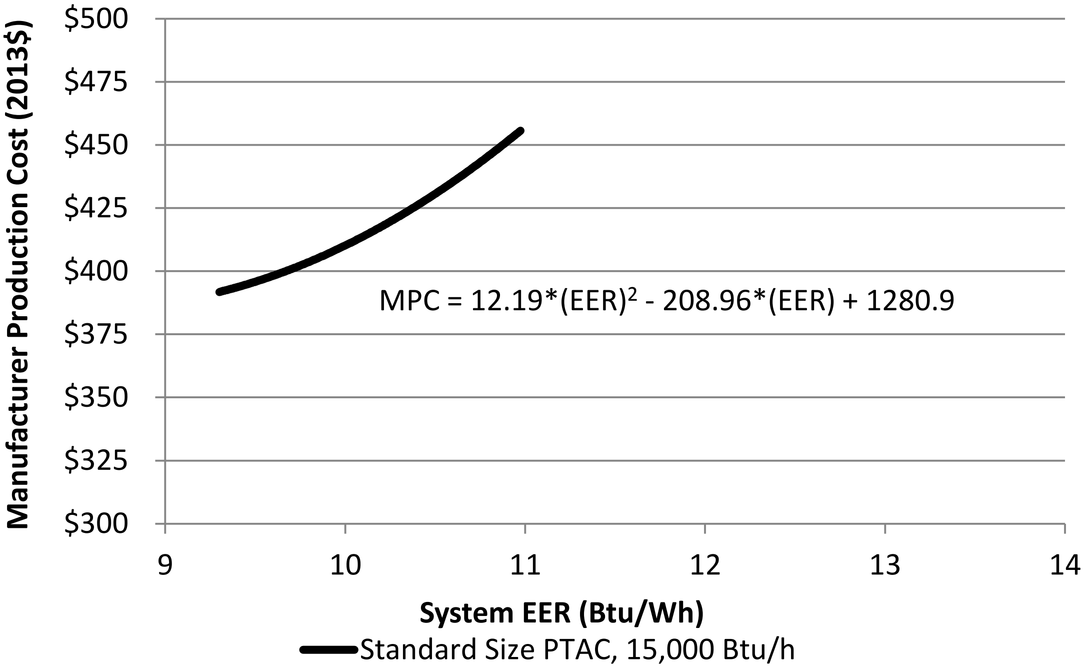

Figure 5.6.7 Manufacturer Production Cost (2013$) versus Efficiency for Standard Size PTACs with a Cooling Capacity of 15,000 Btu/h

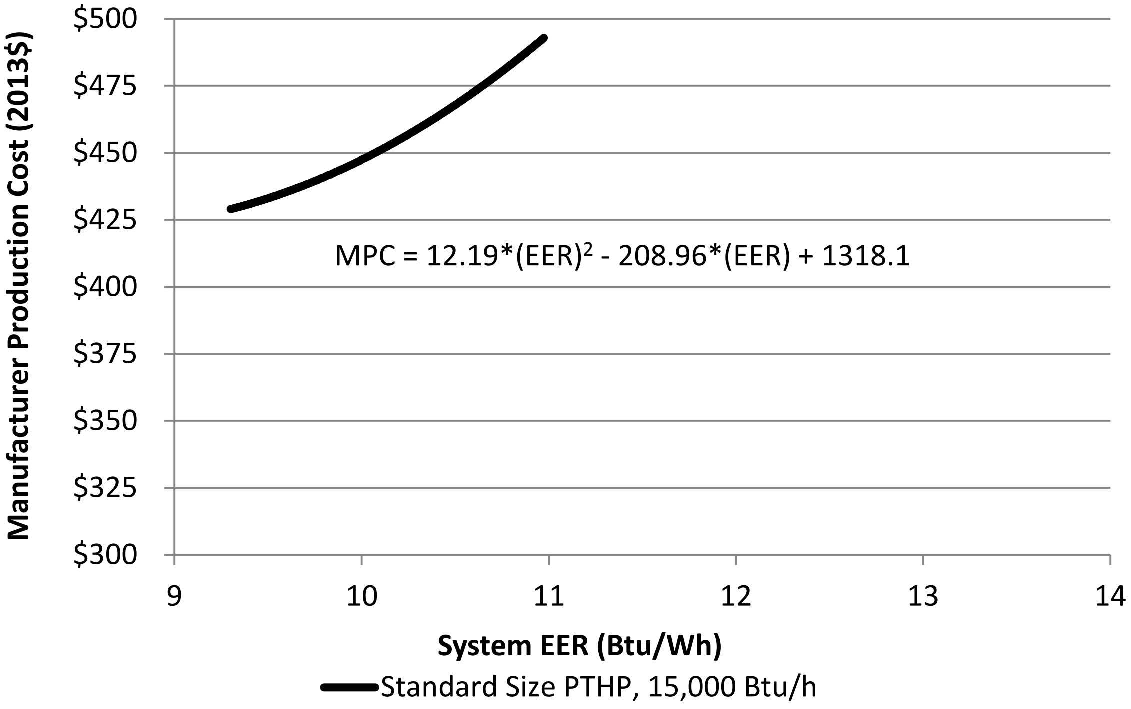

Figure 5.6.8 Manufacturer Production Cost (2013$) versus Efficiency for Standard Size PTHPs with a Cooling Capacity of 15,000 Btu/h

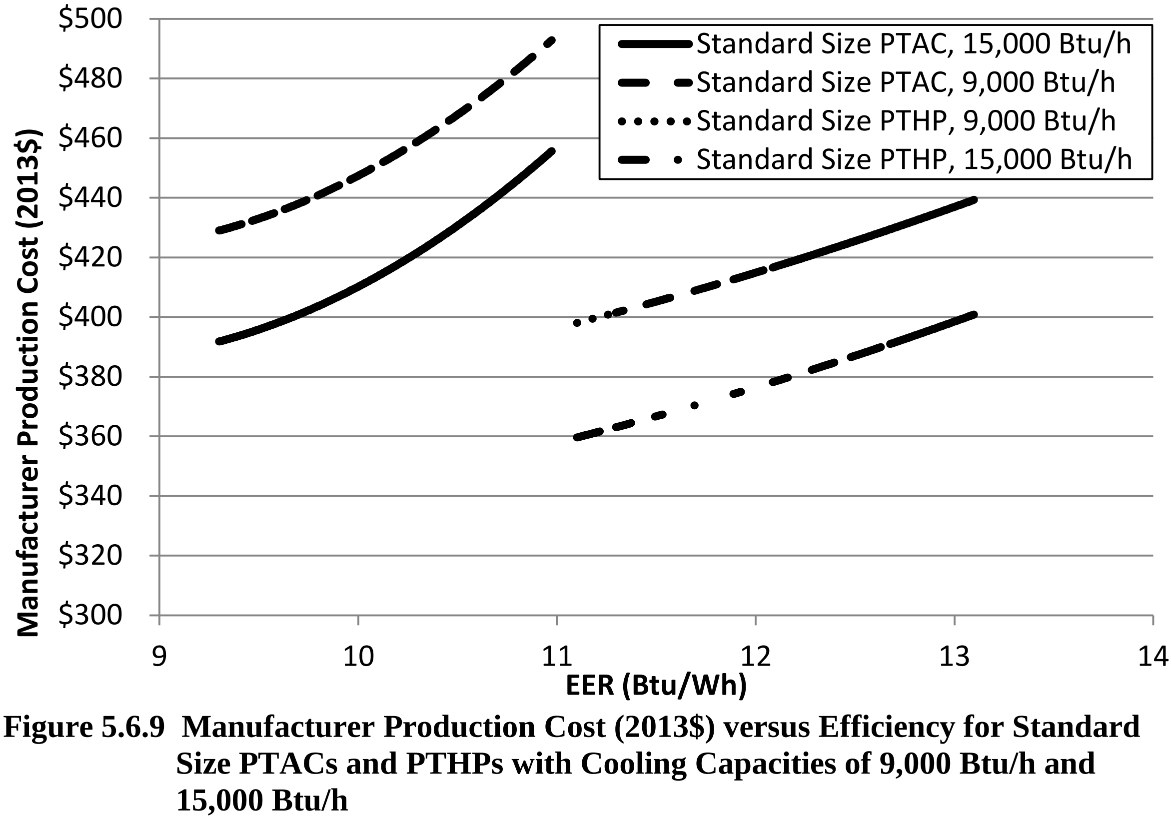

Figure 5.6.9 Manufacturer Production Cost (2013$) versus Efficiency for Standard Size PTACs and PTHPs with Cooling Capacities of 9,000 Btu/h and 15,000 Btu/h

The results show that the cost-efficiency curves are nonlinear. As efficiency increases, manufacturing becomes more difficult and more costly for manufacturers. A faster increase in the curve (i.e., a steeper slope) is evident for the standard size PTACs and PTHPs with 15,000 Btu/h cooling capacity compared to the standard size PTACs and PTHPs with 9,000 Btu/h cooling capacity. The increase in capacity between 9,000 Btu/h and 15,000 Btu/h causes an increase in the baseline unit MPC. Comparing otherwise-identical PTAC and PTHP models (*i.e.*, models with similar casing, controls, and fans, but where the PTHP has reverse cycle capability), DOE estimates that the typical PTHP unit has an additional $37-$38 of production costs compared with an otherwise-identical PTAC unit.

As stated above, the cost efficiency results from the engineering analysis are an input to subsequent LCC analyses that determine the customer price of PTACs and PTHPs (see chapter 8, life-cycle cost and payback period analyses). For these inputs, DOE used the cost-efficiency curves above to calculate the MPCs at each efficiency level considered. DOE used the curve-fit equations presented in Figure 5.6.5 through Figure 5.6.8 to calculate the estimated MPC for each of the efficiency levels for PTACs and PTHPs. These results are shown in Table 5.6.4 through Table 5.6.7.

Table 5.6.4. Cost-Efficiency Relationship for PTACs at 9,000 Btu/h Capacity

Efficiency Level (Percentages relative to 2012 PTAC ECS)	Manufacturer Production Cost (2013$)	Incremental Manufacturer Production Cost (2013$)	Incremental Shipping Cost (2013$)
Baseline, EL1, 1.8%	$359.62	-	-
EL2, 4%	$363.50	$3.88	-
EL3, 8%	$367.55	$7.93	-
EL4, 12%	$376.19	$16.57	-
EL5, 16%	$385.52	$25.91	-
EL6, 18% (Max-Tech)	$395.56	$35.94	-

Table 5.6.5. Cost-Efficiency Relationship for PTHPs at 9,000 Btu/h Capacity

Efficiency Level (Percentages relative to 2012 PTAC ECS)	Manufacturer Production Cost (2013$)	Incremental Manufacturer Production Cost (2013$)	Incremental Shipping Cost (2013$)
Baseline, 1.8%	$398.09	-	-
EL1, 4%	$401.97	$3.88	-
EL2, 8%	$406.02	$7.93	-
EL3, 12%	$414.66	$16.57	-
EL4, 16%	$423.99	$25.91	-
EL5, 18% (Max-Tech)	$434.03	$35.94	-

Table 5.6.6. Cost-Efficiency Relationship for PTACs at 15,000 Btu/h Capacity

Efficiency Level (Percentages relative to 2012 PTAC ECS)	Manufacturer Production Cost (2013$)	Incremental Manufacturer Production Cost (2013$)	Incremental Shipping Cost (2013$)
Baseline, EL1, 1.8%	$391.78	-	-
EL2, 4%	$395.51	$3.73	-
EL3, 8%	$400.08	$8.29	-
EL4, 12%	$411.75	$19.96	-
EL5, 16%	$426.79	$35.00	-
EL6, 18% (Max-Tech)	$445.20	$53.42	-

Table 5.6.7. Cost-Efficiency Relationship for PTHPs at 15,000 Btu/h Capacity

Efficiency Level (Percentages relative to 2012 PTAC ECS)	Manufacturer Production Cost (2013$)	Incremental Manufacturer Production Cost (2013$)	Incremental Shipping Cost (2013$)
Baseline	$428.99	-	-
EL1, 4%	$432.72	$3.73	-
EL2, 8%	$437.29	$8.29	-
EL3, 12%	$448.96	$19.96	-
EL4, 16%	$464.00	$35.00	-
EL5, 18% (Max-Tech)	$482.41	$53.42	-

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[1] Air-Conditioning, Heating, and Refrigeration Institute. *Directory of Certified Product Performance*. Available online at: https://www.ahridirectory.org/ahridirectory/pages/home.aspx (Last accessed July 2014)

[2] American Metals Market. Available online at *http://www.amm.com/*. (Last accessed December 2012)

CHAPTER 6. MARKUPS ANALYSIS

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CHAPTER 6. MARKUPS ANALYSIS

6.1 INTRODUCTION

To carry out the life-cycle cost (LCC) calculations described in Chapter 8 of this technical support document (TSD), the U.S. Department of Energy (DOE) needed to determine the cost to the commercial consumer of a baseline packaged terminal air conditioner (PTAC) or packaged terminal heat pump (PTHP), and the cost of the more-efficient unit the consumer would purchase under the standards. However, the commercial consumer price of such units is not generally known. What is known is the manufacturer's price for both baseline equipment and the more-efficient equipment. By applying a multiplier called a "markup" to the manufacturer's price, DOE was able to estimate the commercial consumer's price. This chapter describes how DOE derived such markups.

The equipment price to the commercial consumer depends on how the consumer purchases the equipment. The Department defines two primary types of distribution channels to describe how the equipment passes from the manufacturer to the consumer: (1) in the first type of distribution channel, the manufacturer sells the equipment to a wholesaler, who in turn may sell it to a mechanical contractor, who in turn may sell it (and its installation) to a general contractor, who in turn sells it to the consumer; (2) in the second type of distribution channel, the manufacturer sells the equipment directly to the consumer through a national account. The Department has further subdivided the distribution channels for new and replacement equipment.

For wholesalers and contractors, DOE estimated a baseline markup and an incremental markup. DOE defined a baseline markup as a multiplier that converts the manufacturing selling price of equipment with baseline efficiency to the consumer purchase price for the equipment at the same baseline efficiency level. An incremental markup is defined as the multiplier to convert the incremental increase in manufacturing selling price of higher efficiency equipment to the consumer purchase price for the same higher efficiency equipment. Because companies mark up the price to cover business cost and profit margin at each step in the distribution channel, both baseline and incremental markups are dependent on the particular distribution channel, as described in section 6.1.1.

6.1.1 Distribution Channels

The appropriate markups for determining consumer equipment prices depend on the type of distribution channels through which equipment moves from manufacturers to purchasers. At each point in the distribution channel, companies mark up the price of the equipment to cover their business costs and profit margin.

There are two primary types of distribution channels describing the way most equipment passes from the manufacturer to the consumer, one involving distributors and contractors and one from manufacturer directly to consumer via national accounts. Within these two primary channels, DOE distinguishes between new and replacement applications; as each application has a different mechanical contractor markup.

Distribution channels for new construction applications are shown in Figure 6.1.1. In the first new construction distribution channel, the manufacturer sells the equipment to a wholesaler, who in turn sells it to a mechanical contractor, who in turn sells it to a general contractor, who in turns sells it to the consumer and performs the installation. In the second new construction distribution channel, the manufacturer sells the equipment to a wholesaler, who in turn sells the equipment to the consumer. In the third new construction distribution channel, the manufacturer sells the equipment directly to the consumer through a national account.

Channel 1	Channel 2	Channel 3
Manufacturer	Manufacturer	Manufacturer (through national accounts)
Wholesaler	Wholesaler	
Mechanical Contractor		
General Contractor		
Consumer	Consumer	Consumer

Figure 6.1.1 Distribution Channels for PTACs and PTHPs in New Construction Applications

Distribution channels for replacement applications are shown in Figure 6.1.2. In the first replacement distribution channel, the manufacturer sells the equipment to a wholesaler, who in turn sells it to a mechanical contractor, who in turn sells it to a general contractor, who in turns sells it to the consumer and performs the installation. In the second, the manufacturer sells the equipment to a wholesaler, who in turn sells the equipment to the consumer. In the third, the manufacturer sells the equipment to a wholesaler, who in turn sells it to a mechanical contractor, who sells it to the consumer and performs the installation.

Channel 1	Channel 2	Channel 3
Manufacturer	Manufacturer	Manufacturer
Wholesaler	Wholesaler	Wholesaler
Mechanical Contractor		Mechanical Contractor
General Contractor		
Consumer	Consumer	Consumer

Figure 6.1.2 Distribution Channels for PTACs and PTHPs in Replacement Applications

Table 6.1.1 lists each distribution channel's share of the full PTAC and PTHP market.

Table 6.1.1 Shares of Market by Distribution Channel

Distribution Channel	New	Replacement
Wholesaler-Consumer	30%	15%
Wholesaler-Mech Contractor-End User	0%	25%
Wholesaler-Mech Contractor-General Contractor-Consumer	38%	60%
National Account	32%	0%
Total	100%	100%

6.2 MARKUP CALCULATION METHODOLOGY

At each point in the distribution channel, companies mark up the price of the equipment to cover their business costs and profit margin. In financial statements, gross margin is the difference between the company revenue and the company cost of sales or cost of goods sold (*CGS*). The gross margin includes company profits and the expenses of companies in the distribution channel, which include overhead costs (sales, general, and administration), research and development (R&D) and interest expenses, depreciation, and taxes. In order for sales of equipment to contribute positively to company cash flow, the equipment's markup must be greater than the corporate gross margin. Equipment commands lower or higher markups, depending on company expenses associated with the equipment and the degree of market competition.

Equipment manufacturers sell most of their equipment directly to wholesalers. Wholesalers sell to contractors or consumers at the wholesale price. Wholesalers absorb short-term imbalances in supply and demand, allowing manufacturers to operate more efficiently and satisfying consumer needs for fast deliveries. In addition, wholesalers are important sources for parts. Most contractors compete at the local level. Many carry more than one brand of equipment, and most install the equipment they sell.

In addition to the wholesaler and mechanical contractor markups, the general contractor adds a markup. In retrofit installations, sales tax applies to the final consumer cost.

6.3 APPROACH FOR CALCULATING OVERALL MARKUP

6.3.1 Baseline Markups: New Construction

DOE used the overall baseline markup to estimate the consumer product price of baseline models, given the manufacturer cost of the baseline models. DOE considers baseline models to be equipment sold under existing market conditions (*i.e.*, without new energy conservation standards). The following equation shows how DOE used baseline markups to determine the product price for baseline models in the first new construction distribution channel.

$$CPP_{BASE} = COST_{MFG} \times \left(MU_{MFG} \times MU_{WHOLE_{BASE}} \times MU_{MCONTRACT_{BASE}} \times MU_{GCONTRACT_{BASE}}\right)$$
$$= COST_{MFG} \times MU_{OVERALL\_BASE\_1}$$

Where:
CPP_{BASE} = consumer product price for baseline models,
$COST_{MFG}$ = manufacturer cost for baseline models,
MU_{MFG} = manufacturer markup,
MU_{WHOLE_BASE} = baseline wholesaler markup,
$MU_{MCONTRACT\_BASE}$ = baseline mechanical contractor markup,
$MU_{MGENERAL\_BASE}$ = baseline general contractor markup, and
$MU_{OVERALL\_BASE\_1}$ = baseline overall markup.

The following equation shows how DOE used baseline markups to determine the product price for baseline models in the second new construction distribution channel.

$$CPP_{BASE} = COST_{MFG} \times \left(MU_{MFG} \times MU_{WHOLE_{BASE}}\right)$$
$$= COST_{MFG} \times MU_{OVERALL\_BASE\_2}$$

Where:

CPP_{BASE} = consumer product price for baseline models,
$COST_{MFG}$ = manufacturer cost for baseline models,
MU_{MFG} = manufacturer markup,
MU_{WHOLE_BASE} = baseline wholesaler markup, and
$MU_{OVERALL\_BASE\_2}$ = baseline overall markup.

6.3.2 Baseline Markups Replacement

The following equation shows how DOE used baseline markups to determine the product price for baseline models in the first replacement distribution channel.

$$CPP_{BASE} = COST_{MFG} \times \left(MU_{MFG} \times MU_{WHOLE_{BASE}} \times MU_{MCONTRACT_{BASE}} \times MU_{GCONTRACT_{BASE}}\right)$$
$$\times TAX_{SALES}$$
$$= COST_{MFG} \times MU_{OVERALL\_BASE\_1} \times TAX_{SALES}$$

Where:

CPP_{BASE} = consumer product price for baseline models,
$COST_{MFG}$ = manufacturer cost for baseline models,
MU_{MFG} = manufacturer markup,
MU_{WHOLE_BASE} = baseline wholesaler markup,
$MU_{MCONTRACT\_BASE}$ = baseline mechanical contractor markup,
$MU_{GCONTRACT\_BASE}$ = baseline general contractor markup,
TAX_{SALES} = sales tax, and
$MU_{OVERALL\_BASE\_1}$ = baseline overall markup.

The following equation shows how DOE used baseline markups to determine the product price for baseline models in the second replacement distribution channel.

$$\begin{aligned} CPP_{BASE} &= COST_{MFG} \times \left(MU_{MFG} \times MU_{WHOLE_{BASE}}\right) \times TAX_{SALES} \\ &= COST_{MFG} \times MU_{OVERALL\_BASE\_2} \times TAX_{SALES} \end{aligned}$$

Where:

CPP_{BASE} = consumer product price for baseline models,
$COST_{MFG}$ = manufacturer cost for baseline models,
MU_{MFG} = manufacturer markup,
MU_{WHOLE_BASE} = baseline wholesaler markup,
TAX_{SALES} = sales tax, and
$MU_{OVERALL\_BASE\_2}$ = baseline overall markup.

The following equation shows how DOE used baseline markups to determine the product price for baseline models in the third replacement distribution channel.

$$\begin{aligned} CPP_{BASE} &= COST_{MFG} \times \left(MU_{MFG} \times MU_{WHOLE_{BASE}} \times MU_{MCONTRACT_{BASE}}\right) \times TAX_{SALES} \\ &= COST_{MFG} \times MU_{OVERALL\_BASE\_3} \times TAX_{SALES} \end{aligned}$$

Where:

CPP_{BASE} = consumer product price for baseline models,
$COST_{MFG}$ = manufacturer cost for baseline models,
MU_{MFG} = manufacturer markup,
MU_{WHOLE_BASE} = baseline wholesaler markup,
$MU_{MCONTRACT\_BASE}$ = baseline mechanical contractor markup,
TAX_{SALES} = sales tax, and
$MU_{OVERALL\_BASE\_3}$ = baseline overall markup.

6.3.3 Incremental Markups: New Construction

Similarly, DOE used the overall incremental markup to estimate changes in the consumer product price, given changes in the manufacturer cost from the baseline model cost resulting from an energy conservation standard to raise equipment energy efficiency. The total consumer product price for more energy-efficient models is composed of two components: the consumer product price of the baseline model and the change in consumer product price associated with the increase in manufacturer cost to meet the new energy conservation standard.

The following equation shows how DOE used the overall incremental markup to determine the product price for more energy-efficient models in the first new construction distribution channel.

$$
\begin{aligned}
CPP_{EFF} = CPP_{BASE} + COST_{MFG\_INCR} \\
\times \left(MU_{MFG} \times MU_{WHOLE\_INCR} \times MU_{MCONTRACT\_INCR} \times MU_{GCONTRACT\_INCR}\right) \\
= COST_{MFG} + COST_{MFG\_INCR} \times MU_{OVERALL\_INCR\_1}
\end{aligned}
$$

Where:

CPP_{EFF} = consumer product price for more-efficient models,
CPP_{BASE} = consumer product price for baseline models,
$COST_{MFG\_INCR}$ = incremental manufacturer cost,
MU_{MFG} = manufacturer markup,
MU_{WHOLE_INCR} = incremental wholesaler markup,
$MU_{MCONTRACT\_INCR}$ = incremental mechanical contractor markup,
$MU_{GCONTRACT\_INCR}$ = incremental general contractor markup, and
$MU_{OVERALL\_INCR\_1}$= incremental overall markup.

The following equation shows how DOE used the overall incremental markup to determine the product price for more energy-efficient models in the second new construction distribution channel.

$$
\begin{aligned}
CPP_{EFF} = CPP_{BASE} + COST_{MFG\_INCR} \times \left(MU_{MFG} \times MU_{WHOLE\_INCR}\right) \\
= CPP_{BASE} + COST_{MFG\_INCR} \times MU_{OVERALL\_INCR\_2}
\end{aligned}
$$

Where:

CPP_{EFF} = consumer product price for more-efficient models,
CPP_{BASE} = consumer product price for baseline models,
$COST_{MFG\_INCR}$ = incremental manufacturer cost,
MU_{MFG} = manufacturer markup,
MU_{WHOLE_INCR} = incremental wholesaler markup, and
$MU_{OVERALL\_INCR\_2}$= incremental overall markup.

6.3.4 Incremental Markups: Replacement

The following equation shows how DOE used the overall incremental markup to determine the product price for more energy-efficient models in the first replacement distribution channel.

$$
\begin{aligned}
CPP_{EFF} = CPP_{BASE} + COST_{MFG\_INCR} \\
\times \left(MU_{MFG} \times MU_{WHOLE\_INCR} \times MU_{MCONTRACT\_INCR} \right. \\
\left. \times MU_{GCONTRACT\_INCR}\right) \times TAX_{SALES} \\
= CPP_{BASE} + COST_{MFG\_INCR} \times MU_{OVERALL\_INCR\_1} \times TAX_{SALES}
\end{aligned}
$$

Where:

CPP_{EFF} = consumer product price for more-efficient models,

CPP_{BASE} = consumer product price for baseline models,
$COST_{MFG\_INCR}$ = incremental manufacturer cost,
MU_{MFG} = manufacturer markup,
MU_{WHOLE_INCR} = incremental wholesaler markup,
$MU_{MCONTRACT\_INCR}$ = incremental mechanical contractor markup,
$MU_{GCONTRACT\_INCR}$ = incremental general contractor markup,
TAX_{SALES} = sales tax, and
$MU_{OVERALL\_INCR\_1}$= incremental overall markup.

The following equation shows how DOE used the overall incremental markup to determine the product price for more energy-efficient models in the second replacement distribution channel.

$$\begin{aligned} CPP_{EFF} &= CPP_{BASE} + COST_{MFG\_INCR} \times \left(MU_{MFG} \times MU_{WHOLE\_INCR}\right) \times TAX_{SALES} \\ &= COST_{MFG\_INCR} \times MU_{OVERALL\_INCR\_2} \times TAX_{SALES} \end{aligned}$$

Where:

CPP_{EFF} = consumer product price for more-efficient models,
CPP_{BASE} = consumer product price for baseline models,
$COST_{MFG\_INCR}$ = incremental manufacturer cost,
MU_{MFG} = manufacturer markup,
MU_{WHOLE_INCR} = incremental wholesaler markup,
TAX_{SALES} = sales tax, and
$MU_{OVERALL\_INCR\_2}$= incremental overall markup.

The following equation shows how DOE used the overall incremental markup to determine the product price for more energy-efficient models in the third replacement distribution channel.

$$\begin{aligned} CPP_{EFF} &= CPP_{BASE} + COST_{MFG\_INCR} \times \left(MU_{MFG} \times MU_{WHOLE\_INCR} \times MU_{MCONTRACT\_INCR}\right) \\ &\qquad \times TAX_{SALES} \\ &= COST_{MFG\_INCR} \times MU_{OVERALL\_INCR\_3} \times TAX_{SALES} \end{aligned}$$

Where:

CPP_{EFF} = consumer product price for more-efficient models,
CPP_{BASE} = consumer product price for baseline models,
$COST_{MFG\_INCR}$ = incremental manufacturer cost,
MU_{MFG} = manufacturer markup,
MU_{WHOLE_INCR} = incremental wholesaler markup,
$MU_{MCONTRACT\_INCR}$ = incremental mechanical contractor markup,
TAX_{SALES} = sales tax, and
$MU_{OVERALL\_INCR\_3}$= incremental overall markup.

6.3.5 Approach for Calculating Overall Markup of the National Accounts Distribution Channel

Equipment purchased through national accounts is an exception to the usual distribution of heating, ventilating, and air conditioning (HVAC) equipment to end users. Large commercial consumers of HVAC equipment use national accounts to circumvent the typical chain of distribution, thereby allowing them to negotiate equipment prices directly with the manufacturer. Due to the large volume of equipment purchased, large commercial consumers, such as national retail chains, are able to purchase equipment directly from the manufacturer at significantly lower prices than could be obtained through the typical distribution chain.

To capture the price savings realized from equipment purchased through national accounts, DOE derived a "national account" markup, assuming that the resulting equipment price increase was one half of that realized from a typical chain of distribution. In other words, if the price increase resulting from the product of the wholesale, mechanical contractor, and general contractor markups is \$100, the "national account" markup is such that the price increase is one-half of that, or \$50. The Department based the use of a "national account" markup that is one-half of that realized from a typical chain of distribution on the assumption that the resulting "national account" equipment price must fall somewhere between the manufacturer price (*i.e.*, a markup of 1.0) and the commercial consumer price under a typical chain of distribution. Because DOE did not know typical values for the actual "national account" equipment price, it chose a value of one-half.

The estimates of national account markups are arrived at through a weighted average of the overall markups for the other new construction distribution channels. Of all PTAC and PTHP equipment used in new construction, 30 percent are sold directly from wholesaler to end user, 38 percent involve mechanical and general contractors, and the remaining 32 percent are sold through national accounts.

The national account baseline markups for new construction are calculated using the following equations:

$$MU_{WTD\_BASE} = \sigma_1 \times MU_{OVERALL\_BASE\_1} + \sigma_2 \times MU_{OVERALL\_BASE\_2}$$

Where:

MU_{WTD_BASE} = weighted average baseline markup of typical distribution channels,
$MU_{OVERALL\_BASE\_1}$ = overall baseline markup for distribution channel 1 (wholesaler to end user),
$MU_{OVERALL\_BASE\_2}$ = overall baseline markup for distribution channel 2 (involving contractors),
σ_1 = share of sales through distribution channel 1, and
σ_2 = share of sales through distribution channel 2.

The half of the overall baseline markup proportion above cost is then calculated as follows:

$$\rho_{NA\_MU\_BASE} = \frac{MU_{WTD\_BASE} - 1}{2}$$

Where:

$\rho_{NA\_MU\_BASE}$ = national account baseline markup proportion above cost.
MU_{WTD_BASE} = weighted average baseline markup of typical distribution channels.

Adding 1 to the national account baseline markup proportion above cost, DOE arrives at the estimated national account baseline markup:

$$MU_{BASE\_NA} = 1 + \rho_{NA\_MU\_BASE}$$

Where:

MU_{BASE_NA}= national account baseline markup, and
$\rho_{NA\_MU\_BASE}$ = national account baseline markup proportion above cost.

The national account incremental markups for new construction are calculated using the following equations:

$$MU_{WTD\_INCR} = \sigma_1 \times MU_{OVERALL\_INCR\_1} + \sigma_2 \times MU_{OVERALL\_INCR\_2}$$

Where:

MU_{WTD_INCR} = weighted average incremental markup of typical distribution channels.
$MU_{OVERALL\_INCR\_1}$ = overall incremental markup for distribution channel 1,
$MU_{OVERALL\_INCR\_2}$ = overall incremental markup for distribution channel 2,
σ_1 = share of sales through distribution channel 1, and
σ_2 = share of sales through distribution channel 2.

$$\rho_{NA\_MU\_INCR} = \frac{MU_{WTD\_INCR} - 1}{2}$$

Where:

$\rho_{NA\_MU\_INCR}$ = national account incremental markup proportion above cost.
MU_{WTD_INCR} = weighted average incremental markup of typical distribution channels.

Adding 1 to the national account incremental markup proportion above cost, DOE arrives at the estimated national account incremental markup:

$$MU_{INCR\_NA} = 1 + \rho_{NA\_MU\_INCR}$$

Where:

MU_{INCR_NA}= national account incremental markup, and
$\rho_{NA\_MU\_INCR}$ = national account incremental markup proportion above cost.

6.4 APPROACH FOR CALCULATING MANUFACTURER MARKUP

DOE uses manufacturer markups to transform a manufacturer's product cost into a manufacturer sales price. Using the *CGS* and gross margin, the manufacturer markup can be calculated as follows:

$$MU_{MFG} = \frac{CGS_{MFG} + GM_{MFG}}{CGS_{MFG}}$$

Where:

MU_{MFG} = manufacturer markup,
CGS_{MFG} = manufacturer cost of goods sold, and
GM_{MFG} = manufacturer gross margin.

6.5 APPROACH FOR CALCULATING WHOLESALER AND CONTRACTOR MARKUPS

DOE examined the manner in which markups change by efficiency level and other factors for wholesalers and contractors. DOE determined that markups are neither fixed-dollar, nor proportional to all direct costs, which means that the selling price of equipment may not be strictly proportional to the purchase price of the equipment. Using the available data, DOE has found measurable differences between *incremental* markups on direct equipment costs and the *average* aggregate markup on direct business costs. Additionally, DOE discovered significant differences between average and incremental markups for heating, ventilation, air-conditioning and refrigeration (HVACR) wholesalers and for HVAC contractors.

The main reason that the selling price of equipment may not be strictly proportional to the purchase price of the equipment is that businesses incur a wide variety of costs. When the purchase price of equipment and materials increases, only a fraction of the business expenses increase, while the remainder of the business' expenses stays relatively constant. Certain business expenses are uncorrelated with the cost of equipment or cost of goods. For example, if the unit price of an air conditioner increases by 30 percent, it is unlikely that the cost of secretarial support in an administrative office will increase by 30 percent also.

6.5.1 Key Data Sources and Assumptions of the Markups Methodology

DOE derived the wholesaler and contractor markups from three key assumptions about the costs associated with PTAC and PTHP equipment. DOE based the wholesaler and mechanical contractor markups on firm-level income statement data, while it based the general contractor markups on U.S. Census Bureau data for the commercial building construction industry. DOE obtained the firm income statements from the Heating, Air-conditioning &

Refrigeration Distributors International (HARDI) 2010 Profit Planning Report and from the Air Conditioning Contractors of America (ACCA).[1, 2] HARDI and ACCA are trade associations representing wholesalers and mechanical contractors, respectively. DOE used the financial data from the 2007 U.S. Economic Census to develop general contractor markups in the same form as the income statement data for wholesalers and mechanical contractors.[3, 4] Additionally, DOE used 2007 Economic Census data to supplement the income statement data obtained from ACCA. These income statements break down the components of all costs incurred by firms that supply and install air conditioning equipment.[a]

The key assumptions used to estimate markups using these financial data are:

1. The firm income statements faithfully represent the industry average for the various costs incurred by firms distributing and installing HVAC equipment including commercial air conditioners.

2. These costs can be divided into two categories: 1) costs that vary in proportion to the manufacturer selling price (MSP) of commercial air conditioners (variant costs); and 2) costs that do not vary with the MSP commercial air conditioners (invariant costs).

3. Overall, commercial air-conditioner wholesaler and contractor prices vary in proportion to commercial air conditioner wholesaler and contractor costs included in the income statements.

In support of the first assumption, the income statements itemize firm costs into a number of expense categories, including direct costs to purchase or install the equipment, operating labor and occupancy costs, and other operating costs and profit. Although wholesalers and contractors tend to handle multiple commodity lines, including room air conditioners, furnaces, central air conditioners and heat pumps, and boilers, the data provide the most accurate available indication of the expenses associated with commercial air conditioners.

Information obtained from the trade literature, and from selected HVAC wholesalers, contractors, and consultants, tends to support the second assumption; this information indicates that wholesale and contractor markups vary according to the quantity of labor and materials used to distribute and install equipment. In its analysis, DOE assumes a division of costs between those that do not scale with the manufacturer price (labor and occupancy expenses), and those that do (operating expenses and profit). This division of costs led to the estimate of wholesale and contractor markups described subsequently.

In support of the third assumption, the HVAC wholesaler and contractor industry is competitive, and consumer demand for commercial heating and air conditioning is inelastic, *i.e.*, the demand is not expected to decrease significantly with an increase in price of equipment. The

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[a] Wholesalers and mechanical contractors to which these reports refer handle multiple commodity lines, including residential and commercial air-conditioners.

large number of HVAC firms listed in the 2007 Census indicates the competitive nature of the market. For example, there are more than 700 HVAC manufacturers,[5] 5,300 wholesalers of heat pumps and air-conditioning equipment,[6] more than 170,000 general residential contractors, 36,000 commercial and institutional building contractors,[7, 8] and 91,000 HVAC contractors listed in the 2007 Census.[9] Additionally, the 2007 Census estimated that the four firm concentration ratio (FFCR) for the HVAC wholesale sector is 29.7%.[10] The FFCR is the market share of the four largest firms in the industry; an FFCR under 40% represents a competitive industry.[11, 12] Following standard economic theory, competitive firms facing inelastic demand either set prices in line with costs or quickly go out of business.[13]

6.5.2 Approach for Wholesaler Markups

Using these assumptions, DOE developed baseline and incremental markups for wholesalers using the firm income statement from the (HARDI 2010 Profit Report). (See Appendix 6-A.) DOE used the baseline markups, which cover all of the wholesaler's costs (both *invariant costs* and *variant costs*), to determine the sales price of baseline models. Here variant costs were defined as costs that vary in proportion to the change in MSP induced by increased efficiency standards; in contrast, invariant costs were defined as costs that do not vary in proportion to the change in MSP due to increased efficiency standards. The baseline markup relates the manufacturer sales price to the wholesaler sales price. DOE calculated the baseline markup for wholesalers using the following equation:

$$MU_{WHOLE\_BASE} = \frac{CGS_{WHOLE} + GM_{WHOLE}}{CGS_{WHOLE}} = \frac{CGS_{WHOLE} + (IVC_{WHOLE} + VC_{WHOLE})}{CGS_{WHOLE}}$$

Where:

MU_{WHOLE_BASE} = baseline wholesaler markup,
CGS_{WHOLE} = wholesaler cost of goods sold,
GM_{WHOLE} = wholesaler gross margin,
IVC_{WHOLE} = wholesaler invariant costs, and
VC_{WHOLE} = wholesaler variant costs.

Incremental markups relate the change in the manufacturer sales price of more energy-efficient models, or those equipment that meet the requirements of new energy conservation standards, to the change in the wholesaler sales price. Incremental markups cover only those costs that scale with a change in the manufacturer sales price (*i.e.*, variant costs, *VC*). DOE calculated the incremental markup for wholesalers using the following equation:

$$MU_{WHOLE\_INCR} = \frac{CGS_{WHOLE} + VC_{WHOLE}}{CGS_{WHOLE}}$$

Where:

MU_{WHOLE_INCR} = incremental wholesaler markup,
CGS_{WHOLE} = wholesaler cost of goods sold, and

VC_{WHOLE}= wholesaler variant costs.

These data are provided for seven regions, which are defined similarly to Census Divisions. Each state is assigned the baseline and incremental wholesaler markup of the region to which it is assigned by HARDI.

6.5.3 Approach for Mechanical Contractor Markups

Similar financial data to that used to estimate wholesaler markups are also available for mechanical contractors and general contractors from ACCA and the 2007 Economic Census.[2, 9] To estimate mechanical contractor markups for commercial air conditioners, DOE collected financial data from ACCA and from the *Plumbing, Heating and Air-Conditioning Contractors* (NAICS 23822) data series of the 2007 Economic Census. This data series provides limited data at the state level and highly detailed national aggregate data. As the Census data is the most recent, DOE relies on it as the primary source for this analysis, using the greater detail of the ACCA data to refine the estimates.

The 2007 Economic Census data include the number of establishments, payroll for construction workers, value of construction, cost of materials, and cost of subcontracted work at both the state and national levels. DOE calculated national average and state-level estimates of the baseline markup for mechanical contractors and general contractors using the following equation:

$$MU_{BASE} = \frac{V_{CONSTRUCT}}{PAY + MATCOST + SUBCOST}$$

Where:

MU_{BASE} = baseline mechanical contractor or general contractor markup,
$V_{CONSTRUCT}$ = value of construction,
PAY = payroll for construction workers,
$MATCOST$ = cost of materials, and
$SUBCOST$ = cost of subcontracted work.

Analogously to the wholesaler markup, DOE estimated the national average incremental mechanical contractor markup by only considering those costs that scale with a change in the manufacturer sales price (variant costs, *VC*) for higher efficiency equipment. Necessary data to perform the incremental markups calculation were not available at the state level. As stated in section 6.5.1, DOE assumes a division of costs between those that do not scale with the manufacturer price (labor and occupancy expenses) and those that do (other operating expenses and profit). Hence, DOE categorized the 2007 Economic Census cost data in each major cost category and estimated incremental contractor markups using the following equation:

$$MU_{CONTRACT\_INCR} = \frac{CGS_{CONTRACT} + VC_{CONTRACT}}{CGS_{CONTRACT}}$$

Where:

$MU_{CONTRACT\_INCR}$ = incremental contractor markup,
$CGS_{CONTRACT}$ = contractor cost of goods sold, and
$VC_{CONTRACT}$= contractor variant costs.

ACCA financial data provide gross margin (GM) as percent of sales for several market subcategories of mechanical contractor (*e.g.*, residential and commercial, new construction and replacement, small and large companies, etc.). In this analysis, DOE distinguishes between replacement and new construction applications. From the ACCA data, baseline mechanical markups are estimated for replacement, new construction, and the overall average of all mechanical contractors. The mechanical contractor markups estimated from the 2007 Economic Census data were scaled by applying the following factors developed from the ACCA data:

$$MU_{MKT\_SEGMENT} = \frac{SALES_{MKT\_SEGMENT}\ (\%)}{SALES_{MKT\_SEGMENT}\ (\%) - GM_{MKT\_SEGMENT}\ (\%)}$$

$$MU_{FULL\_MKT} = \frac{SALES_{FULL\_MKT}\ (\%)}{SALES_{FULL\_MKT}\ (\%) - GM_{FULL\_MKT}\ (\%)}$$

$$MKT\ MODIFIER = \frac{MU_{MKT\_SEGMENT}}{MU_{FULL\_MKT}}$$

Where:

$MKT\_MODIFIER$ = factor used to disaggregate replacement and new construction mechanical contractor applications from the 2007 Economic Census data for the overall market,
$SALES_{MKT\_SEGMENT}$ = sales of the relevant market segment (*i.e.*, replacement or new construction),
$SALES_{FULL\_MKT}$ = sales of the overall mechanical contractor industry,
$GM_{MKT\_SEGMENT}$ = gross margin of the relevant market segment,
GM_{FULL_MKT} = gross margin of the overall mechanical contractor industry,
$MU_{MKT\_SEGMENT}$ = baseline markup of the relevant market segment, and
MU_{FULL_MKT} = baseline markup of the overall mechanical contractor industry.

DOE estimated state-level incremental mechanical contractor markups by calculating the ratio of the national average incremental markup to the national average baseline markup. This ratio was then used to scale the state-level baseline markups, arriving at a state-level estimate of incremental mechanical contractor markups.

6.5.4 Approach for General Contractor Markups

To estimate general contractor markups, DOE collected data from the Commercial and Institutional Building Construction series from the 2007 Economic Census (NAICS 236220). As for mechanical contractors, the 2007 Economic Census data include the number of establishments, payroll for construction workers, value of construction, cost of materials, and cost of subcontracted work at both the state and national levels. DOE estimated the baseline markup for general contractors using the following equation:

$$MU_{BASE} = \frac{V_{CONSTRUCT}}{PAY + MATCOST + SUBCOST}$$

Where:

MU_{BASE} = baseline general contractor markup,
$V_{CONSTRUCT}$ = value of construction,
PAY = payroll for construction workers,
$MATCOST$ = cost of materials, and
$SUBCOST$ = cost of subcontracted work.

DOE estimated the national average incremental general contractor markups by considering only those costs that scale with a change in the manufacturer sales price (variant costs, *VC*) for higher efficiency equipment. Necessary data to perform the incremental markups calculation was not available at the state level. As stated in section 6.5.1, DOE assumes a division of costs between those that do not scale with the manufacturer price (labor and occupancy expenses) and those that do (other operating expenses and profit). Hence, DOE categorized the 2007 Economic Census cost data in each major cost category and estimated incremental general contractor markups using the following equation:

$$MU_{CONTRACT\_INCR} = \frac{CGS_{CONTRACT} + VC_{CONTRACT}}{CGS_{CONTRACT}}$$

Where:

$MU_{CONTRACT\_INCR}$ = incremental contractor markup,
$CGS_{CONTRACT}$ = contractor cost of goods sold, and
$VC_{CONTRACT}$= contractor variant costs.

DOE estimated state-level incremental general contractor markups by calculating the ratio of the national average incremental markup to the national average baseline markup. This ratio was then used to scale the state-level baseline markups, arriving at a state-level estimate of incremental general contractor markups.

6.6 DERIVATION OF MARKUPS

6.6.1 Base Case Manufacturer Markups

DOE developed a set of base case manufacturer markups using data developed as part of the 2008 Final Rule for PTACs and PTHPs (73 FR 58772). DOE then solicited feedback on its markup estimates during confidential manufacturer interviews. Based on this content and manufacturer comments, DOE calculated and applied an average baseline markup of 1.27 for all equipment classes analyzed. This markup includes selling, general and administrative expenses (SG&A), research and development (R&D) expenses, interest, and profit.

Table 6.6.1 Manufacturer Markups by Equipment Type

Equipment Type	Cooling Capacity (Btu/h)	Baseline Markup
PTAC	<7,000 Btu/h	1.27
	≥7,000 Btu/h and ≤15,000 Btu/h	
	>15,000 Btu/h	
PTHP	<7,000 Btu/h	
	≥7,000 Btu/h and ≤15,000 Btu/h	
	>15,000 Btu/h	

6.6.2 Wholesaler Markups

Wholesalers reported median data in a confidential survey that HARDI conducted across its members. In the survey, HARDI itemized revenues and costs into categories, including direct equipment expenses (cost of goods sold), labor expenses, occupancy expenses, other operating expenses, and profit. DOE presents these data in full, by HARDI region, in Appendix 6-A, Detailed Data for Equipment Price Markups. Table 6.6.2 summarizes HARDI wholesaler data, aggregated to the national level, in terms of cost-per-dollar sales revenue in the first data column and in terms of cost-per-dollar of cost of goods sold in the second column.

Table 6.6.2 National Wholesaler Expenses and Markups

Descriptions	Per Dollar Sales Revenue *$*	Per Dollar Cost of Goods *$*
Direct Cost of Equipment Sales: Cost of goods sold	0.737	1.000
Labor Expenses: Salaries and benefits	0.151	0.205
Occupancy Expense: Rent, maintenance, and utilities	0.036	0.049
Other Operating Expenses: Depreciation, advertising, and insurance.	0.055	0.075
Operating Profit	0.020	0.027
Baseline Revenue: Baseline revenue earned per dollar cost of goods sold		**1.357**
Wholesaler Baseline Markup (*$MU_{WHOLE\ BASE}$*)		**1.357**
Incremental Revenue: Increased revenue per dollar increase cost of goods sold		**1.103**
Incremental Markup (*$MU_{WHOLE\ INCR}$*)		**1.103**

Source: Heating, Air Conditioning & Refrigeration Distributors International. 2012. 2012 Profit Report (2010 Data).

In this case, direct equipment expenses (cost of goods sold) represent about $0.74 per dollar sales revenue, so for every $1 wholesalers take in as sales revenue, $0.74 is used to pay the direct equipment costs. Labor expenses represent $0.15 per dollar sales revenue, occupancy expenses represent $0.04, other operating expenses represent $0.06, and profit accounts for $0.02 per dollar sales revenue.

DOE converted the expenses per dollar sales into expenses per dollar cost of goods sold, by dividing each figure in the first data column by $0.74 (*i.e.*, cost of goods sold per dollar of sales revenue). For every $1.00 the wholesaler spends on equipment costs, the wholesaler spends

$0.205 to cover labor costs, $0.049 to cover occupancy expenses, $0.075 for other operating expenses, and $0.027 in profits. This totals to $1.357 in sales revenue earned for every $1.00 spent on equipment costs. Therefore, the wholesaler baseline markup ($MU_{WHOLE\ BASE}$) is 1.357 ($1.357 ÷ $1.00).

DOE also used the data in column two to estimate the incremental markups. The incremental markup depends on which of the costs in Table 6.6.2 are variant or invariant with respect to MSP. For example, for a $1.00 increase in the MSP, if all of the other costs scale with the MSP (*i.e.,* all costs are variant), the increase in wholesale price will be $1.357, implying that the incremental markup is 1.357, or the same as the baseline markup. At the other extreme, if no other costs are variant, then a $1.00 increase in the MSP will lead to a $1.00 increase in the wholesale price, for an incremental markup of 1.0.

As stated in section 6.5, DOE believes that the labor and occupancy costs are invariant with respect to MSP, while other operating costs and profit are variant with respect to MSP. In this case, for a $1.00 increase in the MSP, the wholesale price will increase in line with changes in the categories “other operating costs” and “operating profit”; these approximately amount to $0.067, which when divided by $0.737 cents in cost of goods sold yields an increase of $0.103, giving a wholesaler incremental markup ($MU_{WHOLE\ INCR}$) of 1.103. See Appendix 6-A for cost details.

These data are provided for seven regions, which are defined similarly to Census Divisions. Each state is assigned the baseline and incremental wholesaler markup of the region to which it is assigned by HARDI.

6.6.3 Mechanical Contractor Markups

6.6.3.1 Aggregate Baseline and Incremental Markups for Mechanical Contractors

DOE derived national average markups for mechanical contractors from U.S. Census Bureau data. The 2007 U.S. Census data for mechanical contractors include detailed statistics for establishments with payrolls, similar to the data reported by HARDI for wholesalers. The primary difference is that the U.S. Census Bureau reports itemized revenues and expenses in total dollars for the industry as a whole, rather than in typical values for an average or representative business. Because of this, DOE assumed that the total dollar values that the U.S. Census Bureau reported, once converted to a percentage basis, represented revenues and expenses for an average or typical contracting business. Table 6.6.3 summarizes the national average expenses for general contractors as expenses per dollar sales revenue in the first data column. (Appendix 6-A contains the full set of data.) The process used to calculate markups from the table values is analogous to the process explained in detail in section 6.6.2.

Table 6.6.3 Baseline and Incremental Markups, All Mechanical Contractors (2007 Economic Census data)

Descriptions	Per Dollar Sales Revenue $	Per Dollar Cost of Goods $
Direct Cost of Equipment Sales: Cost of goods sold	0.68	1.00
Labor Expenses: Salaries and benefits	0.18	0.26
Occupancy Expense: Rent, maintenance, and utilities	0.02	0.03
Other Operating Expenses: Depreciation, advertising, and insurance.	0.08	0.12
Operating Profit	0.04	0.06
Wholesaler Baseline Markup ($MU_{WHOLE\ BASE}$)		**1.48**
Incremental Markup ($MU_{WHOLE\ INCR}$)		**1.18**
Incremental Markup as % of Baseline Markup		**80%**

Source: U.S. Census Bureau. 2007 Economic Census, Plumbing, Heating, and Air-Conditioning Contractors. Sector 23: 238220. Construction: Industry Series: Preliminary Detailed Statistics for Establishments: 2007.

The markups derived for mechanical contractors are the national average values for all contractors, including large and small contractors serving the replacement and new construction markets. The results of this calculation are subsequently scaled based on state-level data also obtained from the 2007 U.S. Census *Geographic Area Series* for mechanical contractors.[3] The following section describes how DOE further derived the baseline and incremental markups for two distinct categories of mechanical contractors: (1) contractors in the replacement market and (2) contractors in the new construction market.

6.6.3.2 Baseline Markups for Mechanical Contractors in the Replacement and New Construction Markets

The ACCA *Financial Analysis for the HVACR Contracting Industry* report is used to disaggregate markups for the replacement and new construction markets. ACCA financial data provided only gross margin data, which allows for the determination of only the baseline markup for the two types of contractors, as the gross margin is the sum of all contractor labor and operating expenses plus profit.

Table 6.6.4 summarizes the gross margin and resulting national baseline markup data for mechanical contractors that serve the replacement and new construction markets.

Table 6.6.4 Baseline Markups for the Replacement and New Construction Markets, Mechanical Contractors (ACCA data)

	Contractor Expenses or Revenue by Market Type			
	Replacement		**New Construction**	
Description	**Per Dollar Sales Revenue *$***	**Per Dollar Cost of Goods *$***	**Per Dollar Sales Revenue *$***	**Per Dollar Cost of Goods *$***
Direct Cost of Equipment Sales: Cost of goods sold	0.703	1.000	0.745	1.000
Gross Margin: Labor, occupancy, operating expenses, and profit	0.297	0.422	0.255	0.342
Baseline Markup (*MUMECH CONT BASE*): Revenue per dollar cost of goods	NA	**1.42**	NA	**1.34**
% Difference from Aggregate Mechanical Contractor Baseline MU	NA	**3.6%**	NA	**-2.2%**

Source: Air Conditioning Contractors of America. 2005. Financial Analysis for the HVACR Contracting Industry.

Using the baseline markup data for replacement and new construction contractors from Table 6.6.4, DOE calculated that the baseline markups for the replacement and new markets are 3.6 percent higher and 2.2 percent lower, respectively, than that for all mechanical contractors serving all markets shown in Table 6.6.3. These percentage differences are applied to the previously calculated state-level incremental and baseline markups based on U.S. Census data to estimate separate national and state-level markups for the two categories of mechanical contractor of interest.

6.6.4 Estimation of General Contractor Markups

DOE derived markups for general contractors from U.S. Census Bureau data for the commercial building construction sector. The commercial construction sector includes establishments primarily engaged in the construction of commercial and institutional buildings, including new construction work, additions, alterations, and repairs.

The 2007 U.S. Census data for the commercial construction sector include detailed statistics for establishments with payrolls, similar to the data reported by HARDI for wholesalers. The primary difference is that the U.S. Census Bureau reports itemized revenues and expenses in total dollars for the commercial construction industry as a whole, rather than in typical values for an average or representative business. Because of this, DOE assumed that the total dollar values that the U.S. Census Bureau reported, once converted to a percentage basis, represented revenues and expenses for an average or typical contracting business. The results of this calculation are subsequently scaled based on state-level data also obtained from the 2007 U.S. Census. Similar to the data for wholesalers, Table 6.6.5 summarizes the national average expenses for general contractors as expenses per dollar sales revenue in the first data column.

(Appendix 6-A contains the full set of data.) The process used to calculate markups from the table values is analogous to the process explained in detail in section 6.6.2.

Table 6.6.5 General Contractor Expenses and Markups

Description	Wholesale Firm Expenses or Revenue	
	Per Dollar Sales Revenue ***$***	**Per Dollar Cost of Goods** ***$***
Direct Cost of Equipment Sales: Cost of goods sold	0.76	1.00
Labor Expenses: Salaries (indirect) and benefits	0.08	0.10
Occupancy Expense: Rent, maintenance, and utilities	0.01	0.01
Other Operating Expenses: Depreciation, advertising, and insurance.	0.03	0.04
Net Profit Before Taxes	0.12	0.15
Baseline Markup (*MUGEN CONT BASE*): Revenue per dollar cost of goods		**1.31**
Incremental Markup (*MUGEN CONT INCR*): Increased revenue per dollar increase cost of goods sold		**1.19**

Source: U.S. Census Bureau. 2007. Sector 236220 (Commercial and Institutional Building Construction). Construction: Industry Series: Preliminary Detailed Statistics for Establishments: 2007.

6.7 SALES TAX

The sales tax represents state and local sales taxes that are applied to the consumer price of the equipment. The sales tax is a multiplicative factor that increases the consumer equipment price.

DOE derived state and local taxes from data provided by the Sales Tax Clearinghouse.[14] These data represent weighted averages that include state, county, and city rates. DOE then derived population-weighted average tax values for each Census division and large state, as shown in Table 6.7.1. The average sales tax presented in the bottom row of the table is the weighted average accounting for commercial building floor space with packaged cooling by Census division, calculated using CBECS 2003. Detailed sales tax data by state can be found in Appendix 6-A.

Table 6.7.1 Average Sales Tax Rates by Census Division and Large State

Census Division/State	**Tax Rate (2014)**
New England	5.68%
Mid Atlantic	7.47%
East North Central	6.90%
West North Central	7.09%
South Atlantic	6.47%
East South Central	8.01%
West South Central	8.13%
Mountain	6.44%
Pacific	7.65%
New York	8.40%
California	8.45%
Texas	7.90%
Florida	6.65%
U.S. Average	**7.15%**

Source: The Sales Tax Clearinghouse at https://thestc.com/STRates.stm (Accessed February 2014)

6.8 OVERALL MARKUPS

The overall markup for each distribution channel is the product of the appropriate markups, as well as sales tax in the case of replacement applications (Table 6.8.1).

Table 6.8.1 Summary of Overall Markups

Distribution Channel Segment	**Replacement**		**New Construction**	
	Markup	**Incremental Markup**	**Markup**	**Incremental Markup**
Manufacturer	1.27		1.27	
Wholesaler	1.36	1.10	1.36	1.10
Mechanical Contractor	1.52	1.22	1.43	1.15
General Contractor	1.34	1.22	1.34	1.22
Sales tax (replacements)	1.07		-	
Overall Markup	**3.76**	**1.75**	**3.31**	**1.54**

6.8.1 Estimation of National Account Markups

DOE derived markups for national accounts for new construction through a weighting of the overall markups estimated for the other new construction distribution channels. To capture the price savings realized from equipment purchased through national accounts, DOE applies a national account markup one half of that of a typical chain of distribution, as described in section 6.3.5 (Table 6.8.2).

Table 6.8.2 National Account Markups

Market	Markup	Incremental Markup
New Construction	1.49	1.16

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CHAPTER 7. ENERGY USE ANALYSIS

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CHAPTER 7. ENERGY USE ANALYSIS

7.1 INTRODUCTION

Whole-building simulations from the 2008 packaged terminal air conditioning (PTAC) and packaged terminal heat pump (PTHP) equipment rulemaking provided annual unit energy consumption (UEC) data by cooling capacity and energy efficiency ratio (EER).[1] These data are used for those equipment classes and efficiency levels that are the same in this rulemaking and adjusted for those that are different. This chapter describes the methodology used to adjust the unit energy consumption of PTAC and PTHP equipment for this rulemaking.

7.2 EQUIPMENT ENERGY USE SAVINGS DETERMINATION

Whole-building simulations in the previous rulemaking were performed on PTACs and PTHPs for four equipment classes, six efficiency levels, and 51 locations (the U.S. States and the District of Columbia). The four equipment classes consist of combinations of PTAC and PTHP equipment and of representative cooling capacities, namely 9,000 Btu/h and 12,000 Btu/h. As whole-building simulations are an excellent approach to obtain UEC data, the 1,224 annual UECs data points were leveraged for this rulemaking.

The current rulemaking considers a set of capacities and efficiency levels that differs from that in the previous rulemaking. In order to make relevant the UECs, three transformations were performed: splitting heating and cooling energy, adjusting for climate change, and adjusting for capacity and EER.

7.2.1 Splitting Heating and Cooling Energy

The first transformation prepares the UEC for the following two transformations. As the total annual UECs, UEC_{total}, capture both a cooling and heating energy portion, the UEC was split into $UEC_{cooling}$ and $UEC_{heating}$. The U.S. Department of Energy (DOE) is aware that PTACs and PTHPs have slight differences in function and performance. However, PTACs and PTHPs have a similar functionality other than a reversing valve. In addition, insufficient data exist highlighting substantial differences in cooling energy consumption. For these reasons, DOE assumed that the UEC of a PTAC is equal to the energy expended during a PTHP's operation in cooling mode, assuming that the equipment has the same efficiency level and capacity, as shown in Eq. 7.1. The remaining energy of a PTHP, which is the difference between the total UEC and the cooling energy, as shown in Eq. 7.2 , is the heating energy:

$$UEC_{PTAC} = UEC_{PTHP\_cooling} \quad \textbf{Eq. 7.1}$$

$$UEC_{total} = UEC_{heating} + UEC_{cooling} \quad \textbf{Eq. 7.2}$$

It was assumed that the fan energy during periods of cooling was included with the cooling energy and the fan energy during periods of heating was included with the heating energy. It was also assumed that the fan energy during periods of cooling scaled with the cooling energy and the fan energy during periods of heating scaled with the heating energy.

7.2.2 Adjusting for Climate Change

The second transformation adjusts for the projected impact of global warming on hotter summer days and warmer winter days. An adjustment to the unit cooling energy consumption and unit heating energy consumption was made based on the change in cooling degree days (CDD) and heating degree days (HDD) from an older TMY2 (Typical Meteorological Year) weather dataset to a newer TMY3 weather dataset, which was updated in 2008.[2,3] A comparison of the two datasets showed that total annual CDD have increased by 5 percent and total annual HDD have increased by 2 percent at all locations used in this analysis, as shown in Figure 7.2.1.

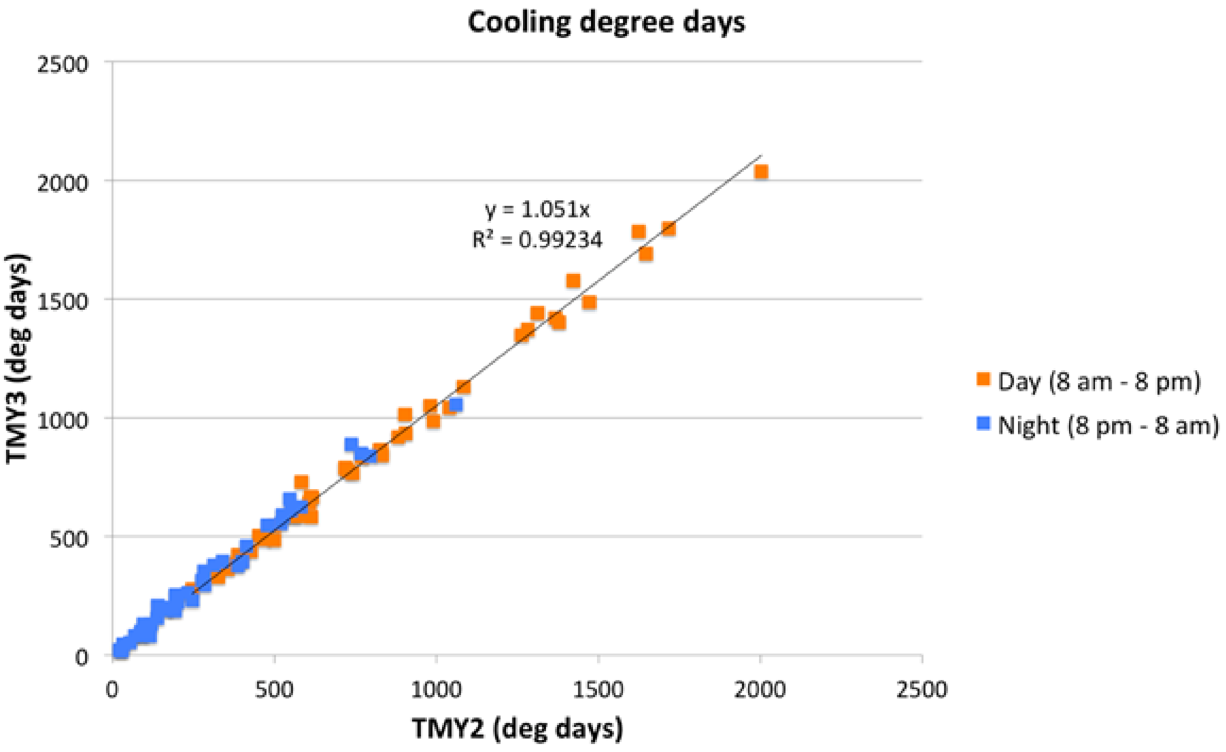

Figure 7.2.1 Comparison of Cooling Degree Days by State for TMY3 and TMY2

The figure shows the cooling degree days (CDD) relative to 65 °F computed from the TMY3 data vs. the CDD for TMY2. The calculation is done separately for day time (8 am to 8pm) and night time hours. Each point corresponds to a state; in cases where there are multiple stations in a single state the data are averaged. As the TMY3 data are considered to be more representative of current weather, the total annual CDD increase and total annual HDD increase were assigned to the weather multipliers, W_c and W_h, for cooling and heating, respectively, and were applied to the separated cooling and heating UECs in the manner as shown in Eq.7.3 and Eq.7.4 :

$$UEC_{\text{cooling\_weather}} = (1 + W_c) \cdot UEC_{\text{cooling}} \qquad \textbf{Eq.7.3}$$

$$UEC_{\text{heating\_weather}} = (1 + W_h) \cdot UEC_{\text{heating}} \qquad \textbf{Eq.7.4}$$

7.2.3 Adjusting for Capacity and Energy Efficiency Ratio

The third transformation adjusts UECs where cooling capacity and/or EER considered in the current rulemaking (target) differ from cooling capacity and/or EER considered in the previous rulemaking (source). Where only cooling capacity differed, DOE performed a linear interpolation on $UEC_{\text{cooling\_weather}}$ across a constant EER value; this operation is highlighted in Eq. 7.5. Where only EER differed, DOE performed a linear interpolation on $UEC_{\text{cooling\_weather}}$ across a constant cooling capacity value; this operation is highlighted in Eq.7.6. Where both cooling capacity and EER differed, DOE performed a linear interpolation on $UEC_{\text{cooling\_weather}}$ across both variables, one at a time, one after another, using the equations as already set forth in Eq. 7.5 and Eq.7.6. The same transformation was performed for heating energy, $UEC_{\text{heating\_weather}}$, as shown in Eq. 7.7, where COP considered in the current rulemaking differ from COP considered in the previous rulemaking.

$$UEC_{\text{target}} = UEC_{\text{source1}} + (UEC_{\text{source2}} - UEC_{\text{source1}})\left(\frac{\text{Capacity}_{\text{target}}\text{-Capacity}_{\text{source1}}}{\text{Capacity}_{\text{source2}}\text{-Capacity}_{\text{source1}}}\right)\Bigg|_{constant\ EER}$$

Eq.7.5

Where:

UEC_{target} =	interpolated unit energy consumption at the target cooling capacity,
UEC_{source1}=	unit energy consumption at the source cooling capacity, for the first point of the interpolation,
$\text{UEC}_{\text{source2}}$=	unit energy consumption at the source cooling capacity, for the second point of the interpolation,
$\text{Capacity}_{\text{target}}$=	target cooling capacity,
$\text{Capacity}_{\text{source1}}$=	source cooling capacity for the first point of the interpolation, and
$\text{Capacity}_{\text{source2}}$=	source cooling capacity for the second point of the interpolation.

$$UEC_{\text{target}} = UEC_{\text{source1}} + (UEC_{\text{source2}} - UEC_{\text{source1}})\left(\frac{EER_{\text{target}} - EER_{\text{source1}}}{EER_{\text{source2}} - EER_{\text{source1}}}\right)\Bigg|_{constant\ cooling\ capacity}$$

Eq.7.6

Where:

UEC_{target} = interpolated unit energy consumption at the target cooling capacity,
UEC_{source1}= unit energy consumption at the source cooling capacity, for the first point of the interpolation,
UEC_{source2}= unit energy consumption at the source cooling capacity, for the second point of the interpolation,
EER_{target}= target EER,
EER_{source1}= source EER for the first point of the interpolation, and
EER_{source2}= source EER for the second point of the interpolation.

$$UEC_{target} = UEC_{source1} + (UEC_{source2} - UEC_{source1})\left(\frac{COP_{target} - COP_{source1}}{COP_{source2} - COP_{source1}}\right)\Bigg|_{constant\ cooling\ capacity}$$

Eq.7.7

Where:

UEC_{target} = interpolated unit energy consumption at the target cooling capacity,
$UEC_{source1}$= unit energy consumption at the source cooling capacity, for the first point of the interpolation,
$UEC_{source2}$= unit energy consumption at the source cooling capacity, for the second point of the interpolation,
COP_{target}= target COP,
$COP_{source1}$= source COP for the first point of the interpolation, and
$COP_{source2}$= source COP for the second point of the interpolation.

7.3 PTAC AND PTHP EQUIPMENT ENERGY USE RESULTS

DOE summed the cooling energy and heating energy, upon completion of the transformations, to give the total UEC for the representative cooling capacities, which are described in Chapter 5. The U.S. average UECs are provided by cooling capacity and EER in Table 7.3.3 for PTACs and Table 7.3.4 for PTHPs and are further disaggregated by location in Appendix 7-A. UECs are inputs into the LCC and PBP analysis as described in Chapter 8.

Table 7.3.1 Annual Unit Energy Use by Representative Cooling Capacity and Efficiency Level for PTACs

Efficiency Level*	**9,000 Btu/h**		**15,000 Btu/h**	
	EER	***UEC (kWh)***	***EER***	***UEC (kWh)***
Federal Minimum	11.1	1078	9.3	1688
Baseline/EL 1	11.3	1066	9.5	1671
EL 2	11.5	1050	9.7	1657
EL 3	12.0	1022	10.0	1625
EL 4	12.4	994	10.4	1594
EL 5	12.9	966	10.8	1563
EL 6	13.1	952	11.0	1547

*The Federal Minimum efficiency level represents the efficiency level of the current federal energy conservation standards for PTAC equipment. Efficiency level 1 is the baseline level for PTAC equipment, and is the ANSI/ASHRAE/IES Standard 90.1-2013 minimum for PTAC equipment.

Table 7.3.2 Annual Unit Energy Use by Representative Cooling Capacity and Efficiency Level for PTHPs

Efficiency Level*	**9,000 Btu/h**		**15,000 Btu/h**	
	EER COP	***UEC (kWh)***	***EER COP***	***UEC (kWh)***
Baseline	11.3 3.2	1985	9.5 2.9	2847
EL 1	11.5 3.3	1956	9.7 2.9	2829
EL 2	12.0 3.4	1918	10.0 3.0	2778
EL 3	12.4 3.5	1879	10.4 3.1	2727
EL 4	12.9 3.6	1841	10.8 3.2	2676
EL 5	13.1 3.6	1822	11.0 3.2	2651

*The baseline efficiency level represents the efficiency level of the current federal energy conservation standards for PTHP equipment, which is the same as the ANSI/ASHRAE/IES Standard 90.1-2013 minimum efficiency for PTHP equipment.

The impact of amended energy efficiency standards also are determined on a national level, as described in the NIA in Chapter 10. As standards are determined with equipment classes instead of representative cooling capacities, DOE calculated UECs for each equipment classes. DOE used the UEC of the 9,000 Btu/h representative cooling capacity unit to represent the ≥7,000 Btu/h and ≤15,000 Btu/h cooling capacity equipment class, and the UEC of the 15,000 Btu/h representative cooling capacity unit to represent the >15,000 Btu/h cooling capacity equipment class. DOE extrapolated UECs from the 9,000 Btu/h and 15,000 Btu/h representative cooling capacity for the UEC of the <7,000 Btu/h cooling capacity equipment class. The U.S. average UECs are provided by cooling capacity and EER in Table 7.3.3 for PTACs and Table 7.3.4 for PTHPs.

Table 7.3.3 Annual Unit Energy Use by Equipment Class and Efficiency Level for PTACs

Efficiency Level*	**<7,000 Btu/h**		**≥7,000 Btu/h and ≤15,000 Btu/h**		**>15,000 Btu/h**	
	EER	***UEC (kWh)***	***EER***	***UEC (kWh)***	***EER***	***UEC (kWh)***
Federal Minimum	11.7	892	11.1	1078	9.3	1688
Baseline/EL 1	11.9	881	11.3	1066	9.5	1671
EL 2	12.2	866	11.5	1050	9.7	1657
EL 3	12.6	839	12.0	1022	10.0	1625
EL 4	13.1	813	12.4	994	10.4	1594
EL 5	13.6	786	12.9	966	10.8	1563
EL 6	13.8	773	13.1	952	11.0	1547

*The Federal Minimum efficiency level represents the efficiency level of the current federal energy conservation standards for PTAC equipment. Efficiency level 1 is the baseline level for PTAC equipment, and is the ANSI/ASHRAE/IES Standard 90.1-2013 minimum for PTAC equipment.

Table 7.3.4 Annual Unit Energy Use by Equipment Class and Efficiency Level for PTHPs

Efficiency Level*	**>7,000 Btu/h**		**≥7,000 Btu/h and ≤15,000 Btu/h**		**>15,000 Btu/h**	
	EER ***COP***	***UEC (kWh)***	***EER*** ***COP***	***UEC (kWh)***	***EER*** ***COP***	***UEC (kWh)***
Baseline	11.9 3.3	1728	11.3 3.2	1985	9.5 2.9	2847
EL 1	12.2 3.5	1708	11.5 3.3	1956	9.7 2.9	2829
EL 2	12.6 3.5	1674	12.0 3.4	1918	10.0 3.0	2778
EL 3	13.1 3.6	1639	12.4 3.5	1879	10.4 3.1	2727
EL 4	13.6 3.7	1605	12.9 3.6	1841	10.8 3.2	2676
EL 5	13.8 3.8	1588	13.1 3.6	1822	11.0 3.2	2651

*The baseline efficiency level represents the efficiency level of the current federal energy conservation standards for PTHP equipment, which is the same as the ANSI/ASHRAE/IES Standard 90.1-2013 minimum efficiency for PTHP equipment.

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1. U.S. Department of Energy – Office of Energy Efficiency and Renewable Energy, *Energy Conservation Program for Commercial and Industrial Equipment: Packaged Terminal Air Conditioner and Packaged Terminal Heat Pump Energy Conservation Standards.*, 2007. (Last accessed June, 2014.) <www.regulations.gov/#!docketDetail;D=EERE-2007-BT-STD-0012>

2. National Renewable Energy Laboratory, *National Solar Radiation Data Base 1961-1990: Typical Meterological Year 2*, (Last accessed June, 2014.) <http://rredc.nrel.gov/solar/old_data/nsrdb/1961-1990/tmy2/>

3. National Renewable Energy Laboratory, *National Solar Radiation Data Base 1991-2005 Update: Typical Meterological Year 3*, (Last accessed June, 2014.) <http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/>

CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

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CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

8.1 INTRODUCTION

The effect of amended standards on individual consumers 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 commercial consumers.

- Life-cycle cost (LCC) is the total consumer 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 consumers 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 further in section 8.1.1.

Inputs to the LCC and PBP analysis of packaged terminal air conditioners (PTACs) and packaged terminal heat pumps (PTHPs) 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 (www1.eere.energy.gov/buildings/appliance_standards/buildings/appliance_standards/product.aspx/productid/77).

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

PTAC and PTHP equipment usage patterns and purchase costs are unique, so variability and uncertainty are analyzed by performing the LCC and PBP calculations detailed here for prototypical commercial buildings across various U.S. locations. The results are expressed as the number of PTAC and PTHP equipment consumers 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 models both the uncertainty and the variability in the model's inputs using Monte Carlo simulation and probability distributions.

These inputs include estimated energy use for each PTAC and PTHP unit, as described in the energy use analysis in Chapter 7. Energy use is sensitive to climate and therefore varies by location within the United States. Aside from energy use, other important inputs influencing the

LCC and PBP analysis include energy prices, installation costs, equipment distribution markups, and sales taxes.

As mentioned previously, 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 consumers 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 base case. The base case efficiency distribution is defined as a mix of efficiency levels reflecting the expected distribution of efficiency levels by equipment class.

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

The LCC is the total consumer cost over the life of the equipment, 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 equipment. The PBP is the increase in purchase cost of a higher efficiency unit divided by the change in annual operating cost of the unit. It represents the number of years that it will take the consumer 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: (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 a wholesaler for equipment 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 equipment 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 consumer price.
- *Installation cost*: Installation cost is the cost to the consumer of installing the equipment. The installation cost represents all costs required to install the equipment but does not

include the marked-up consumer equipment price. The installation cost includes labor, overhead, and any miscellaneous materials and parts.

The primary inputs for calculating the operating cost are:

- *Equipment energy consumption and power demand*: The equipment energy consumption is the site energy use associated with providing space conditioning to the building. The power demand is the maximum power requirement of the equipment (more commonly known as the peak demand) for a specific period of time. Typically, electric utilities measure the peak demand for each month. DOE calculated both the energy consumption and peak demand based on hourly whole-building simulations.
- *Electricity Prices*: Average and marginal electricity prices for commercial buildings are determined using a tariff-based analysis. Marginal prices are used to estimate operating costs for the baseline and value the operating cost savings at higher efficiency levels.
- *Electricity price trends*: The Energy Information Administration's (EIA's) Annual Energy Outlook 2014 (AEO 2014)[1] is used to project electricity prices into the future.
- *Maintenance costs*: The labor and material costs associated with maintaining the operation of the equipment.
- *Repair costs*: The labor and material costs associated with repairing or replacing components that have failed.
- *Lifetime*: The age at which PTAC and PTHP equipment are retired from service.
- *Discount rate*: The rate at which future costs and savings 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.

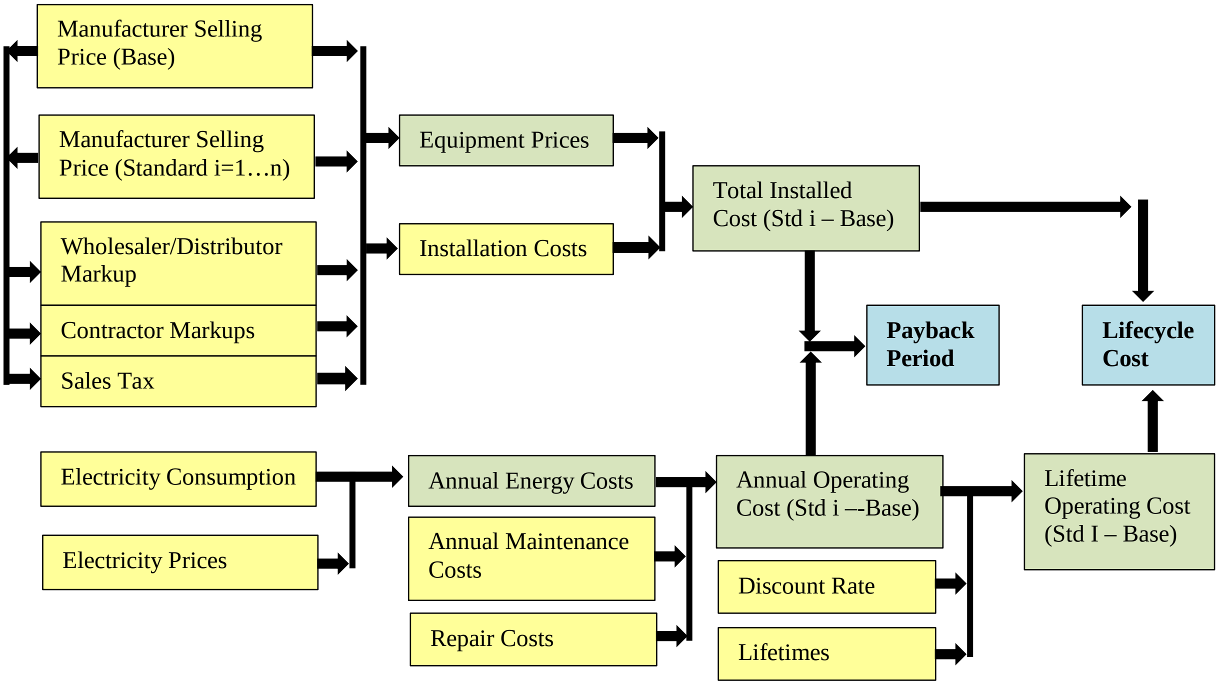

Figure 8.1.1 Flow Diagram of Inputs for the Determination of LCC and PBP

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	
Equipment Price	Derived MSP for PTAC and PTHP equipment at different 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.[2] Overhead and materials costs and profits are assumed to be included in the contractor's markup. Thus, the total installed cost equals the consumer equipment 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 energy efficiency ratio (EER) is the efficiency descriptor for PTAC

Inputs	Description
	and PTHP equipment. Whole-building simulations were used to determine the annual energy consumption associated with a particular standard level.
Electricity Prices	Costs were calculated for generalized buildings from summer and winter marginal and average electricity prices using tariff data and CBECS 1992 and 1995 monthly electricity consumption and demand. Prices were escalated by the AEO 2014 forecasts to update tariff prices to 2014 and to estimate future electricity prices. Escalation was performed at the census division level.
Maintenance Cost	The cost associated with maintaining the operation of the equipment (e.g., cleaning heat exchanger coils) was also obtained from RS Means.[3] Annual maintenance cost does not change as a function of MSP.
Repair Cost	Repair costs for the first five years are calculated assuming the equipment has a standard 5-year warranty, which covers materials and labor for the refrigeration system. After the warranty period, repair costs are calculated using RS Means for labor and materials. DOE annualized the total repair costs over the lifetime of the equipment.
Affecting Present Value of Annual Operating Cost Savings	
Equipment Lifetime	Adjusted the Weibull parameters from the 2014 NOPR to reduce the median lifetime to 8 years. DOE determined that service life was a better measurement of equipment lifetime than “time to failure” because many PTACs and PTHPs are replaced during major renovations at large hotels, which take place approximately every 7 years.
Discount Rate	Mean real discount rates ranging from 4.14 percent to 7.83 percent for various classes of commercial consumers, calculated using financial data from Damodaran Online. Probability distributions are used for the discount rates.

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

8.1.3 Use of Per Unit Annual Energy Consumption Data

As detailed in Chapter 7, DOE used unit energy consumption (UEC) data obtained from the 2008 Energy Conservation Standards Rulemaking for PTAC and PTHP equipment. To account for differences in cooling capacity and/or EER from the previous rulemaking, the UEC (cooling) for each equipment class and each efficiency level were linearly scaled from existing to the considered cooling capacity and/or EER.

8.2 LIFE-CYCLE COST ANALYSIS INPUTS

Life-cycle cost is the total consumer cost over the life of a piece of equipment, 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 equipment. Life-cycle cost is defined by the following equation:

$$LCC = IC + \sum_{t=1}^{N} OC_t / (1 + r)^t$$

Eq. 8.1

Where:

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

DOE expresses all the costs in 2014$. Total installed cost, operating cost, lifetime, and discount rate are discussed in the following sections. In the LCC analysis, the year of equipment purchase is the effective date of the energy conservation standards.

8.2.1 Total Installed Cost Inputs

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

$$IC = EQP + INST$$

Eq. 8.2

Where:

IC = installed cost,
EQP = equipment price ($) (i.e., consumer price for the equipment only), and
INST = installation cost ($) (i.e., the cost for labor and materials).

The equipment price is based on the distribution channel through which the consumer purchases the equipment. As discussed in Chapter 6, DOE defined distribution channels for new and replacement units to describe how the equipment passes from the manufacturer to the consumer.

The remainder of this section provides information about the variables DOE used to calculate the total installed cost for PTACs and PTHPs.

8.2.1.1 Manufacturer Costs

DOE developed the manufacturer costs for PTACs and PTHPs as described in the engineering analysis (Chapter 5). The manufacturer costs at each efficiency level for the representative units in each equipment class are shown in Table 8.2.1 and Table 8.2.2. DOE determined that the shipping costs from the manufacturer is $19.82 per unit and does not vary by equipment class or efficiency level.

Table 8.2.1 Manufacturer Production Costs for PTACs by Efficiency Level (2014$)

	Standard Size PTAC 9,000 Btu/h		Standard Size PTAC (15,000 Btu/h)	
Efficiency Level*	Total Cost	Incremental Cost**	Total Cost	Incremental Cost**
Federal Minimum	$365.00	($3.54)	$397.65	($4.10)
Baseline/EL 1	$368.55	$0.00	$401.75	$0.00
EL 2	$373.05	$4.51	$406.07	$4.32
EL 3	$381.82	$13.27	$417.91	$16.17
EL 4	$391.30	$22.75	$433.18	$31.43
EL 5	$401.48	$32.94	$451.87	$50.12
EL 6	$406.84	$38.30	$462.50	$60.75

*The Federal Minimum efficiency level represents the efficiency level of the current federal energy conservation standards for PTAC equipment. Efficiency level 1 is the baseline level for PTAC equipment, and is the ANSI/ASHRAE/IES Standard 90.1-2013 minimum for PTAC equipment.

**Parenthesis indicate negative values

Table 8.2.2 Manufacturer Production Cost for PTHPs by Efficiency Level (2014$)

	Standard Size PTHP (9,000 Btu/h)		Standard Size PTHP (15,000 Btu/h)	
Efficiency Level*	Total Cost	Incremental Cost	Total Cost	Incremental Cost
Baseline	$404.05	$0.00	$435.41	$0.00
EL 1	$408.56	$4.51	$439.73	$4.32
EL 2	$417.32	$13.27	$451.58	$16.17
EL 3	$426.80	$22.75	$466.84	$31.43
EL 4	$436.99	$32.94	$485.54	$50.12
EL 5	$442.35	$38.30	$496.16	$60.75

*The baseline efficiency level represents the efficiency level of the current federal energy conservation standards for PTHP equipment, which is the same as the ANSI/ASHRAE/IES Standard 90.1-2013 minimum efficiency for PTHP equipment.

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 by the baseline or standard-compliant manufacturer cost to arrive at the price paid by the consumer. Because there are baseline and incremental markups associated with the wholesaler and mechanical and general contractors, the overall markup is also divided into a baseline markup (i.e., a markup used to convert the baseline manufacturer price into a consumer price) and an incremental markup (i.e., a markup used to convert a standard-compliant manufacturer cost increase due to an efficiency increase into an incremental consumer price). Markups can differ depending on whether the equipment is being purchased for a new construction installation or is being purchased to replace existing equipment. DOE developed the overall baseline markups and incremental markups for both new construction and replacement applications as a part of the markups analysis (see Chapter 6 of the technical support document (TSD).

Table 8.2.3 and Table 8.2.4 display baseline and incremental markups used to calculate consumer price from manufacturer cost; Table 8.2.3 presents the values used for the distribution channels involving wholesalers and contractors, while Table 8.2.4 presents the values used for the national accounts distribution channels. Table 8.2.5 presents the resulting overall baseline and incremental markups.

Table 8.2.3 Summary of Average Markups

	Baseline Markup	Incremental Markup
Manufacturer	1.27	
Wholesaler	1.36	1.10
Mechanical Contractor (new construction/replacement)	1.43/1.52	1.15/1.22
General Contractor (new construction only)	1.34	1.22
Sales Tax (replacement only)	1.07	1.07

Table 8.2.4 Summary of National Accounts Markups

Market	Baseline Markup	Incremental Markup
New Construction	1.49	1.16

Table 8.2.5 Overall Markup for Packaged Terminal Air Conditioners and Heat Pumps

Equipment Class	Baseline Markup	Incremental Markup
All Standard Size PTAC and PHTP Equipment and Capacities	2.32	1.46

8.2.1.3 Total Consumer Price

DOE derived the consumer equipment price for the efficiency levels above the baseline by taking the product of the baseline manufacturer cost and the baseline overall markup (including the sales tax for replacement equipment) and adding to it the product of the incremental manufacturer cost and the incremental overall markup (including the sales tax for replacement equipment). DOE followed the same process for shipping costs, but in this case the manufacturer markup was not included in the overall markup. DOE then added the marked-up shipping cost to the consumer equipment price. 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 is represented by a distribution of values.

Table 8.2.6 presents the average consumer equipment price for each PTAC and PTHP equipment class at each efficiency level examined. The EERs and COPs associated with each efficiency level are found in Chapter 5.

Table 8.2.6 Average Consumer Price for Packaged Terminal Air Conditioners and Heat Pumps (2014$)

Equipment Class	**Efficiency Level***						
	Federal Minimum	**Baseline/ EL 1**	**EL 2**	**EL 3**	**EL 4**	**EL 5**	**EL 6**
PTAC Standard Size (9,000 Btu/h)	$1,190	$1,201	$1,210	$1,227	$1,245	$1,265	$1,276
PTAC Standard Size (15,000 Btu/h)	$1,292	$1,304	$1,313	$1,336	$1,366	$1,403	$1,424
Equipment Class		**Baseline**	**EL 1**	**EL 2**	**EL 3**	**EL 4**	**EL 5**
PTHP Standard Size (9,000 Btu/h)		$1,312	$1,320	$1,338	$1,356	$1,376	$1,387
PTHP Standard Size (15,000 Btu/h)		$1,410	$1,418	$1,441	$1,472	$1,508	$1,529

*The Federal Minimum efficiency level represents the efficiency level of the current federal energy conservation standards for PTAC equipment. Efficiency level 1 is the baseline level for PTAC equipment, and is the ANSI/ASHRAE/IES Standard 90.1-2013 minimum for PTAC equipment. The baseline efficiency level represents the efficiency level of the current federal energy conservation standards for PTHP equipment, which is the same as the ANSI/ASHRAE/IES Standard 90.1-2013 minimum efficiency for PTHP equipment.

8.2.1.4 Future Equipment Prices

To derive a price trend for PTACs and PTHPs, DOE obtained historical Producer Price Index (PPI) data for “all other miscellaneous refrigeration and air-conditioning equipment” spanning the time period 1990-2014 from the Bureau of Labor Statistics (BLS).[a] DOE used PPI data for “all other miscellaneous refrigeration and air-conditioning equipment” as representative of PTAC and PTHP equipment because PPI data specific to PTAC and PTHP equipment are not available and this PPI is the closest match. The PPI data reflect nominal prices, adjusted for product quality changes. An inflation-adjusted (deflated) real price index for all other miscellaneous refrigeration and air-conditioning equipment was calculated by dividing the PPI series by the Gross Domestic Product Chained Price Index (see Figure 8.2.1)

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[a] Series ID PCU3334153334159; www.bls.gov/ppi/

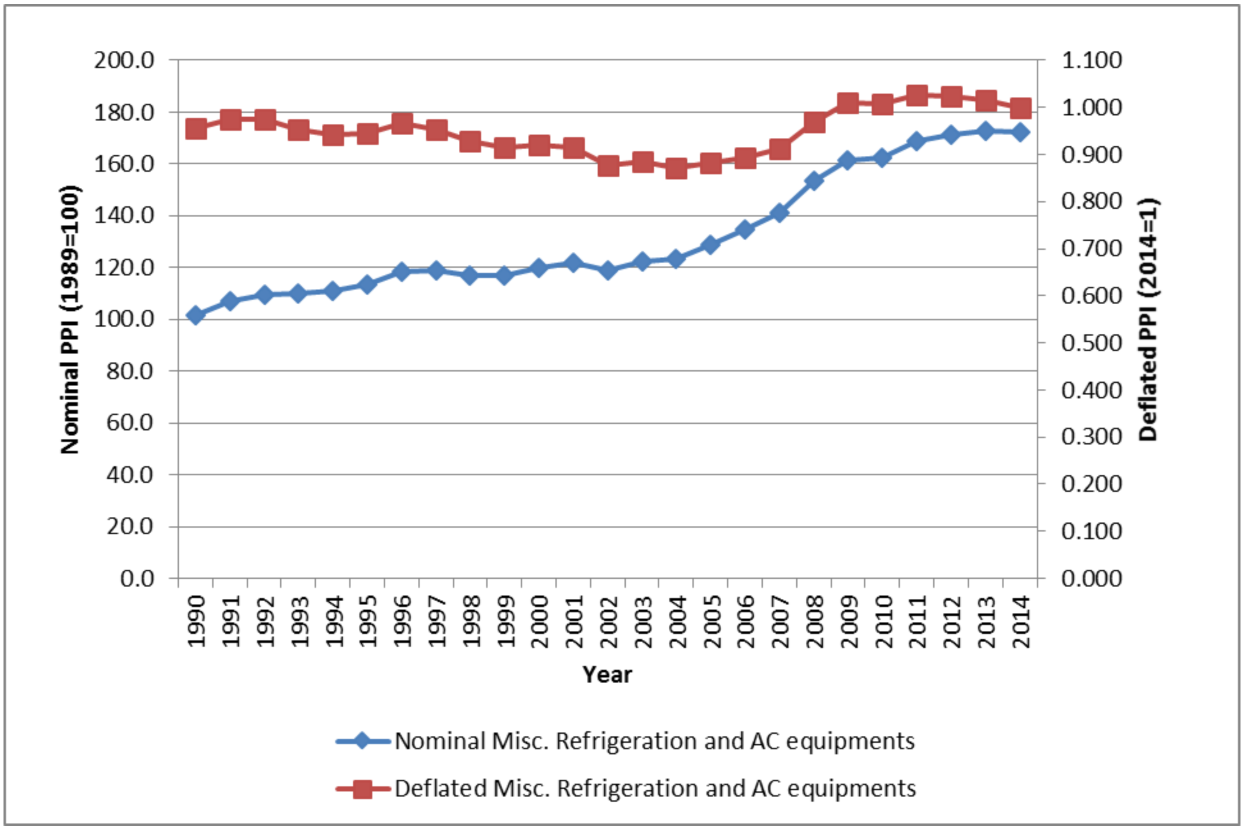

Figure 8.2.1 Historical Nominal and Deflated Producer Price Indexes for Miscellaneous Refrigeration and Air-Conditioning Equipment

From 1990 to 2004, the deflated price index for all other miscellaneous refrigeration and air-conditioning equipment showed a slightly downward trend. Since then, the index has risen sharply, which is highly correlated with the rising prices of copper and steel products that go into PTAC and PTHP equipment (see Figure 8.2.2). 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 global economic activity starting in 2008, DOE believes that the extent to which the trends of the past couple of years will continue is very uncertain.

Given these considerations, DOE decided to use a constant price assumption as the default price factor index to project future PTAC and PTHP equipment prices. . Thus, prices forecast for the LCC and PBP analysis are equal to the 2014 values for each efficiency level in each equipment class.

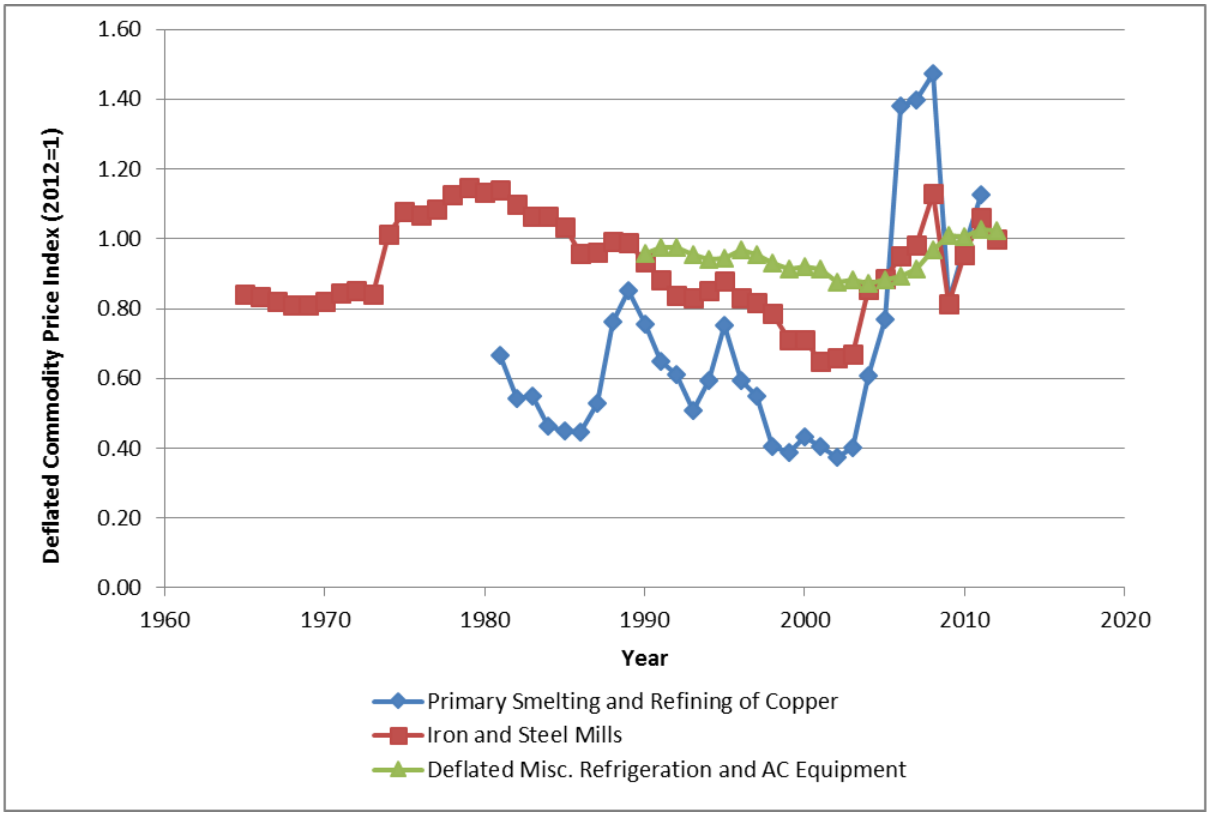

Figure 8.2.2 Historical Deflated Producer Price Indexes for Copper Smelting, Steel Mills Manufacturing and All Other Miscellaneous Refrigeration and Air-Conditioning Equipment

8.2.1.5 Installation Cost

The installation cost is the price to the consumer of labor and materials (other than the actual equipment) needed to install the PTAC and PTHP equipment. DOE derived installation costs from current RS Means data. RS Means provides estimates on the person-hours required to install PTAC and PTHP equipment and the labor rates associated with the type of crew required to install the equipment. DOE calculated the installation cost by multiplying the number of person-hours by the corresponding labor rate. RS Means provides specific person-hour and labor rate data for the installation of packaged cabinet type air conditioners of 9,000 Btu/h and 15,000 Btu/h cooling capacity. DOE decided that these data are also representative of installation costs for equipment of 9,000 Btu/h and 15,000 Btu/h cooling capacity that provides heating in addition to just cooling.

Labor rates vary significantly among regions, and the RS Means data provide the necessary information to capture this regional variability. RS Means provides cost indices that reflect the labor rates for 656 cities in the United States. Several cities in all 50 states of the United States and the District of Columbia are identified in the RS Means data. DOE incorporated these cost indices into the analysis to vary the installation cost depending on the location of the PTAC or PTHP consumer.

Table 8.2.7 summarizes the nationally representative person-hours and labor rates associated with the installation of 9,000 Btu/h and 15,000 Btu/h cooling capacity PTAC and PTHP equipment as presented in RS Means. The table provides both bare installation costs (i.e., costs before overhead and profit (O&P)) and installation costs including O&P. DOE decided that the 9,000 Btu/h and 15,000 Btu/h cooling capacity installation costs that include O&P represent the installation costs for baseline efficient systems (i.e., 11.3 EER for 9,000 Btu/h equipment and 9.5 EER for 15,000 Btu/h equipment). DOE weighted the RS Means cost index by state using 2013 population estimates from the U.S. Census Bureau. The weighted average national installation index was 0.917, which DOE applied to the Total Labor Cost calculation.

Table 8.2.7 Installation Costs for Baseline Packaged Terminal Air Conditioners and Heat Pumps

System Type*	Person-hours	2013 Bare Costs		Labor w/ O&P	
		Cost per Person-hour (2012$)	Total Labor Cost (2012$)	Cost per Person-hour (2012$)	Total Labor Cost (2012$)
PTAC Standard Size (9,000 Btu/h)	3.2	$50.93	$163	$76.75	$225.22
PTAC Standard Size (15,000 Btu/h)	5.3	$51.00	$272	$76.75	$375.34
PTHP Standard Size (9,000 Btu/h)	3.2	$50.93	$163	$76.75	$225.22
PTHP Standard Size (15,000 Btu/h)	5.3	$51.00	$272	$76.75	$375.34

*Description differs in RS Means for Packaged Cabinet Type Air-Conditioners (“9000 BTUH cooling, 13900 BTU heat”; and “15000 BTUH cooling, 13900 BTU heat”).

DOE converted the costs in Table 8.2.8 from 2012$ to 2014$, which are presented in Table 8.2.8: the national average total installation costs by equipment class for PTACs and PTHPs. The average installation costs are constant across all efficiency levels within each equipment class. The total includes O&P, which is calculated using labor markups from RS Means. For efficiency levels above the baseline, the installation costs do not vary with equipment weight.

Table 8.2.8 National Average Installation Cost for Packaged Terminal Air Conditioners and Heat Pumps

Equipment Class	Installation Cost (2014$)
PTAC Standard Size (9,000 Btu/h)	$232.00
PTAC Standard Size (15,000 Btu/h)	$386.64
PTHP Standard Size (9,000 Btu/h)	$232.00
PTHP Standard Size (15,000 Btu/h)	$386.64

Table 8.2.9 summarizes the cost indices for installations in each of the 50 States of the U.S., plus the District of Columbia, used to vary the nationally representative installation costs in Table 8.2.8. To arrive at an average index for each state, DOE weighted the city indices in each state by their population. It used population estimates for the year 2010 from the U.S. Census Bureau to calculate a weighted-average index for each state. DOE then assigned each state to a Census division (with Pacific divided into north and south) and calculated a weighted-average index for each region in the same manner.

Table 8.2.9 Installation Cost Indices by State (National Value = 100.0)

State	Index	State	Index	State	Index
Alabama	50.8	Kentucky	80.9	North Dakota	58.4
Alaska	104.8	Louisiana	59.7	Ohio	91.9
Arizona	79.7	Maine	62.7	Oklahoma	55.6
Arkansas	55.5	Maryland	83.3	Oregon	99.5
California	121.0	Massachusetts	119.0	Pennsylvania	113.9
Colorado	79.0	Michigan	100.7	Rhode Island	108.3
Connecticut	114.7	Minnesota	113.5	South Carolina	37.5
D.C	113.4	Mississippi	51.9	South Dakota	42.0
Delaware	94.2	Missouri	95.8	Tennessee	71.3
Florida	68.7	Montana	70.3	Texas	56.3
Georgia	66.1	Nebraska	77.3	Utah	71.3
Hawaii	109.7	Nevada	100.3	Vermont	70.5
Idaho	68.8	New Hampshire	77.8	Virginia	65.7
Illinois	127.5	New Jersey	125.5	Washington	104.2
Indiana	81.5	New Mexico	68.2	West Virginia	84.8
Iowa	78.8	New York	161.2	Wisconsin	95.2
Kansas	69.8	North Carolina	36.3	Wyoming	54.3

8.2.1.6 Total Installed Cost

The total installed cost is the sum of the equipment price and the installation cost. MSPs, markups, and sales taxes 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 8.2.10 presents the average total installed cost for each equipment class at each efficiency level examined.

Table 8.2.10 Average Total Installed Cost for Packaged Terminal Air Conditioners and Heat Pumps (2014$)

	Efficiency Level*						
Equipment Class	**Federal Minimum**	**Baseline/ EL 1****	**EL 2**	**EL 3**	**EL 4**	**EL 5**	**EL 6**
PTAC Standard Size (9,000 Btu/h)	$1,422	$1,433	$1,442	$1,459	$1,477	$1,497	$1,508
PTAC Standard Size (15,000 Btu/h)	$1,678	$1,691	$1,700	$1,723	$1,753	$1,790	$1,811

Equipment Class		**Baseline**	**EL 1**	**EL 2**	**EL 3**	**EL 4**	**EL 5**
PTHP Standard Size (9,000 Btu/h)		$1,544	$1,552	$1,570	$1,588	$1,608	$1,619
PTHP Standard Size (15,000 Btu/h)		$1,796	$1,805	$1,828	$1,858	$1,895	$1,916

*The Federal Minimum efficiency level represents the efficiency level of the current federal energy conservation standards for PTAC equipment. Efficiency level 1 is the baseline level for PTAC equipment, and is the ANSI/ASHRAE/IES Standard 90.1-2013 minimum for PTAC equipment. The baseline efficiency level represents the efficiency level of the current federal energy conservation standards for PTHP equipment, which is the same as the ANSI/ASHRAE/IES Standard 90.1-2013 minimum efficiency for PTHP equipment.

**Since higher efficiency levels for PTAC equipment are calculated against efficiency level 1 as the baseline, only the baseline markup is applied to efficiency level 1.

8.2.2 Operating Cost Inputs

DOE defined the operating cost by the following equation:

$$OC = EC + MC$$

Eq. 8.3

where:

OC = operating cost ($),
EC = energy cost associated with operating the equipment ($), and
MC = annual maintenance cost for maintaining equipment operation ($).

The remainder of this section provides information about the variables that DOE used to calculate the operating cost for PTACs and PTHPs. The annual energy costs of the equipment are computed from energy consumption per unit for the baseline and standard-compliant cases (efficiency level 2, 3, and so forth), combined with the energy prices. Equipment 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 equipment class, DOE calculated the annual energy use savings for each PTAC and PTHP at each efficiency level by taking the difference between a considered efficiency level and the baseline efficiency level.

8.2.2.2 Energy Prices

Tariff data were used to develop marginal and average prices for each member of a generalized building sample. The approach uses tariff data that have been processed into commercial building marginal and average electricity prices. Tariff data provide a means to calculate the monthly consumer bill given the monthly electricity consumption (kWh) and peak demand (kW). The CBECS 1992 and CBECS 1995 commercial building surveys provide monthly baseline electricity consumption and demand for a large sample of buildings, approximately 5300 in total.[4,5] These monthly values for each building in this generalized building sample were used to (1) calculate monthly bills and (2) calculate monthly marginal consumption and demand prices. The average electricity price is defined as the total electricity bill divided by total electricity consumption. Two marginal prices are defined, one for electricity demand (in $/kW) and one for electricity consumption (in $/kWh). These marginal prices are calculated by applying a 5% decrement to the baseline demand or consumption and recalculating the electricity bill.

This procedure provides an average electricity price, and marginal consumption and demand prices, for each building in the generalized building sample and for each month. The monthly variation was reduced to seasonal variation by taking a simple average of the monthly data for the summer months (defined as May through September) and for the winter months. The average and marginal prices for each building were converted to average prices for the entire building sample using a weighted average across region, vintage, building activity and building size for each of the buildings. The prices defined in this way were converted to 2014 prices and 2014 dollars using scaling factors taken from the AEO.

PTACs and PTHPs are commercial air conditioners and typically consume peak electricity; therefore, electricity costs were calculated using the annual marginal price per kWh, as shown in Table 8.2.11. For each efficiency level, the operating cost savings are calculated by multiplying the electricity consumption savings (relative to the baseline) times the annual marginal consumption price.

Table 8.2.11 Marginal Tariff-Based Prices by Region (2014 Cents)

Region	Marginal Consumption Price (¢/kWh)		
	Annual	Summer	Winter
New England	10.11	10.22	9.93
Mid-Atlantic	9.71	10.04	9.43
ESC	6.58	6.67	6.48
WSC	5.80	6.14	5.54
South Atlantic	7.37	7.34	7.36
ESC	6.00	5.85	6.08
WSC	6.15	6.75	5.45
Mountain	7.46	7.46	7.45
Pacific – WA,OR	5.77	5.76	5.78
Pacific – CA	12.74	12.95	12.34
US Average	7.69	7.86	7.48

8.2.2.3 Energy Price Trends

The tariff-based prices were updated to 2014 using the commercial electricity price series published in the AEO as an index. AEO prices for commercial electricity are presented by region in Table 8.2.12. The table also shows the scaling factor used to convert the tariff data year (2004) to current prices. The national average price increase in constant dollars since the tariff data year is 3.3percent.

Table 8.2.12 Commercial Electricity Prices (2014 Cents/kWh)

Year Region	2009	2010	2011	2012	Scaling Factor
New England	16.50	15.86	15.12	14.50	1.033
Middle Atlantic	14.50	15.01	14.43	14.08	0.964
East North Central	9.97	10.06	10.01	10.16	1.086
West North Central	8.05	8.47	8.70	8.20	1.101
South Atlantic	10.41	10.01	10.01	9.57	1.105
East South Central	10.04	10.06	10.35	8.85	1.046
West South Central	9.68	9.46	9.04	7.66	0.772
Mountain	9.25	9.43	9.37	8.85	1.029
Pacific (North)	12.68	12.48	12.28	12.04	0.957
U.S.	10.99	10.93	10.75	10.21	1.033

Source: AEO 2009 - 2012

DOE projected future electricity prices using trends in average commercial electricity price from EIA's AEO 2014, as shown in Figure 8.2.3. The chart shows constant dollar prices by region for the AEO forecast period, 2011 to 2040. The U.S. average trend is shown as a heavy dashed line. DOE used AEO 2014 Reference Case scenarios[b] for the nine Census divisions. DOE applied the projected energy price for each of the nine Census divisions to each building in the sample based on the building’s location.

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[b] The reference case is a business-as-usual estimate, given known market, demographic, and technological trends.

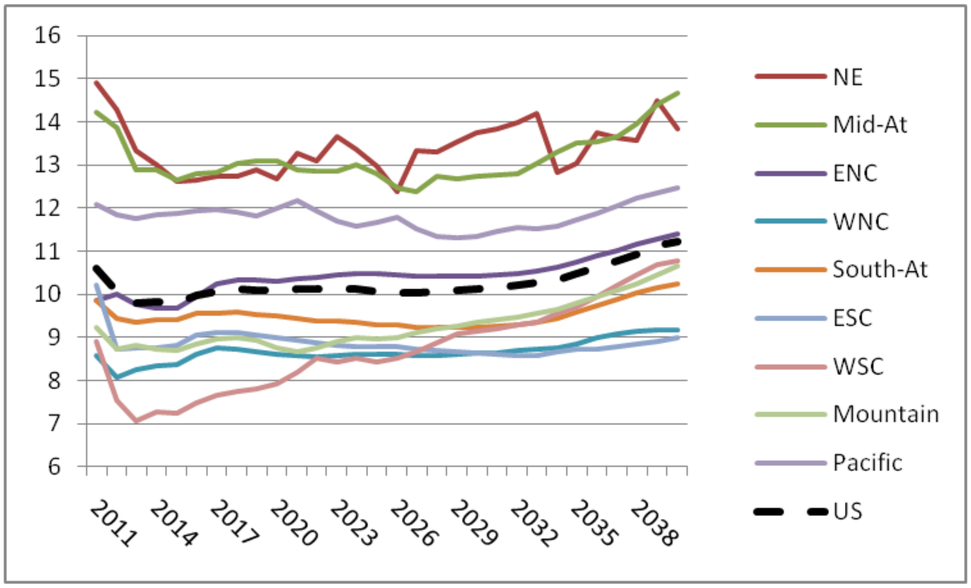

Figure 8.2.3 AEO 2014 electricity price projections by region (2014 cents)

8.2.2.4 Repair Cost

Repair costs are associated with repairing or replacing components that have failed. DOE assumed that all PTAC and PTHP equipment have a one-year warranty which would cover all repairs and a 5 year limited warranty which would cover repairs of the refrigeration system (labor for non-refrigeration system repairs would be paid by the owner in years 2-5). After year 5, the owner bears the full cost of a repair. The total repair cost is the expected value of the sum of the repair cost in the warranty period and in the post-warranty period from different failures rates in each of those periods, which DOE assumed to have a 1 percent chance of failure per year in years 1-5 and a 19 percent chance of failure per year in years 6-10, respectively.[6]

DOE calculated the cost of a repair in the warranty period and the post-warranty period, by multiplying estimated component failure rates with the relevant labor and material costs for each component, which was based on RS Means.[3] The costs in years 2-5 only represent labor costs for non-refrigeration system component repairs, and the costs in years 6-10 represent the total labor and materials cost of a repair for the entire system. DOE then determined the present value of the total repair cost for each year and annualized it. Next, DOE averaged the annualized values to create two annual values, one for the warranty period and another for the post-warranty period. The annual repair costs after year 6 were scaled with equipment price by efficiency level to account for higher material costs for higher efficiency equipment (materials covered under warranty received no scaling in years 1-5). Finally, DOE applied the failure rate associated with each year to determine a weighted average annual repair cost which are shown in Table 8.2.13.

Table 8.2.13 Annual Repair Cost by Efficiency Level (2014$)

Equipment Class	Efficiency Level*						
	Federal Minimum	**Baseline/ EL 1**	**EL 2**	**EL 3**	**EL 4**	**EL 5**	**EL 6**
PTAC Standard Size (9,000 Btu/h)	$69.99	$70.29	$70.67	$71.42	$72.22	$73.09	$73.54
PTAC Standard Size (15,000 Btu/h)	$72.08	$72.39	$72.79	$73.55	$74.38	$75.27	$75.74
Equipment Class		**Baseline**	**EL 1**	**EL 2**	**EL 3**	**EL 4**	**EL 5**
PTHP Standard Size (9,000 Btu/h)		$74.69	$75.06	$75.79	$76.57	$77.41	$77.85
PTHP Standard Size (15,000 Btu/h)		$77.09	$77.47	$78.22	$79.03	$79.90	$80.36

*The Federal Minimum efficiency level represents the efficiency level of the current federal energy conservation standards for PTAC equipment. Efficiency level 1 is the baseline level for PTAC equipment, and is the ANSI/ASHRAE/IES Standard 90.1-2013 minimum for PTAC equipment. The baseline efficiency level represents the efficiency level of the current federal energy conservation standards for PTHP equipment, which is the same as the ANSI/ASHRAE/IES Standard 90.1-2013 minimum efficiency for PTHP equipment.

8.2.2.5 Maintenance Cost

The maintenance cost is the routine cost to the consumer of maintaining equipment operation. DOE calculated the annualized maintenance costs for PTACs based off the figure of $50 that was used in the 2008 PTAC and PTHP rulemaking.[7] The figure was adjusted for inflation to arrive at $55.56 in annual maintenance costs at the baseline efficiency level. The annualized maintenance costs for PTHP were derived from the annualized maintenance costs for PTACs based on RS Means data for both PTACs and PTHPs.[3] The percentage difference in maintenance costs was applied to the PTAC maintenance costs to arrive at the maintenance cost of $62.62 for PTHPs.

8.2.2.6 Lifetime

Equipment lifetime is the age at which the equipment is retired from service. In the September 2014 NOPR, DOE used a median equipment lifetime of 10 years with a maximum lifetime of 20 years. AHRI questioned DOE's use of "time-to-failure" instead of "service life" and thereby urged DOE to recalibrate the Weibull distribution to have a mean of 5 years and a maximum of 12 years.[8] SCS commented that many hotel chains remodel their rooms and replace PTAC/PTHP equipment every seven to ten years.[9] SCS believes that DOE is using a longer equipment lifetime than is applicable in real world use.[9]

Large hotels account for 70 percent of the market for PTAC and PTHP equipment. Given stakeholder comments and data asserting that large hotels undergo major renovations approximately every 7 years[c], DOE revised the Weibull distribution to reflect such an industry practice. DOE assumed that large hotels would replace their PTAC and PTHP equipment every 7 years, and that the other 30 percent of the market (independent hotels, offices, and medical services) would replace their PTAC or PTHP every 10 years. DOE calculated the weighted average median lifetime for the total market for PTACs and PTHPs (7.9 years) and assumed it would represent the median lifetime. DOE rounded the median lifetime up to 8 years and then adjusted the scale and shape factor of the Weibull function so that the mean and median lifetimes would be 8 years. DOE took the same approach for maximum lifetime, using a maximum of 14 years for large hotels (double the median value) and 20 years for independent hotels, offices, and medical services, which provided a weighted average maximum lifetime of 15.8 years. The parameters for the Weibull distribution are provided below.

The Weibull distribution is a probability distribution function commonly used to measure failure rates.[10] Its form is similar to an exponential distribution, which would model a fixed failure rate, except that it allows for a failure rate that changes over time in a particular fashion. The cumulative distribution takes the form:

$$P(x) = e^{-\left(\frac{x-\theta}{\alpha}\right)^{\beta}}$$

Eq. 8.4

for $x > \theta$ and $P(x) = 1$ for $x \leq \theta$,

Where:

$P(x)$ = probability that the equipment is still in use at age x,
x = equipment age,
α = the scale parameter, which is the decay length in an exponential distribution,
β = the shape parameter, which determines the way in which the failure rate changes over time, and
θ = the delay parameter, which allows for a delay before any failures occur.

For the subject analysis, DOE developed a Weibull distribution with an alpha of 9.0 and a beta of 3.0, resulting in a mean lifetime of 8, a median lifetime of 8 and a maximum lifetime of 15 years (15 years is the 99th percentile of the Weibull distribution) years. DOE assumed that the lifetime is the same at different efficiency levels and therefore used the same lifetime distribution for each PTAC and PTHP equipment class.

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[c] McDaniel, K.C., Senie, Stephen R. Why Hotels Will Fail: Source of Distress in the Current Market. *American College of Real Estate Lawyers*. www.acrel.org/Documents/Seminars/a002127.htm#_ftn1

8.2.2.7 Discount Rates

The commercial discount rate is the rate at which future operating costs are discounted to establish their present value in the LCC analysis. The discount rate value is applied in the LCC to future year energy costs and non-energy operations and maintenance costs to calculate the estimated net life-cycle cost of products of various efficiency levels and life-cycle cost savings as compared to the baseline for a representative sample of commercial end users.

DOE's method views the purchase of higher efficiency equipment as an investment that yields a stream of energy cost savings. DOE derived the discount rates for the LCC analysis by estimating the cost of capital for companies that purchase PTACs and PTHPs. The weighted-average cost of capital (WACC) is commonly used to estimate the present value of cash flows to be derived from a typical company project or investment. Most companies use both debt and equity capital to fund investments, so their cost of capital is the weighted average of the cost to the firm of equity and debt financing, as estimated from financial data for publicly traded firms in the sectors that purchase PTACs and PTHPs.[11]

Damodaran Online is a widely used source of information about company debt and equity financing for most types of firms, and was the primary source of data for this analysis.[12] Companies included in the Damodaran Online database were assigned to the aggregate categories listed below:

- Office,
- Hotel,
- Medical Services.

DOE estimated the cost of equity using the capital asset pricing model (CAPM).[13] The CAPM assumes that the cost of equity (ke) for a particular company is proportional to the systematic risk faced by that company, where high risk is associated with a high cost of equity and low risk is associated with a low cost of equity. The systematic risk facing a firm is determined by several variables: the risk coefficient of the firm (β), the expected return on risk-free assets (Rf), and the equity risk premium (ERP). The risk coefficient of the firm indicates the risk associated with that firm relative to the price variability in the stock market. The expected return on risk-free assets is defined by the yield on long-term government bonds. The ERP represents the difference between the expected stock market return and the risk-free rate. The cost of equity financing is estimated using the following equation:

$$k_e = R_f + \left(\beta \times ERP\right)$$

Eq. 8.5

Where:

ke = cost of equity,
Rf = expected return on risk-free assets,
β = risk coefficient of the firm, and

ERP = equity risk premium.

Several parameters of the cost of capital equations can vary substantially over time, and therefore the estimates can vary with the time period over which data is selected and the technical details of the data-averaging method. For guidance on the time period for selecting and averaging data for key parameters and the averaging method, DOE used Federal Reserve methodologies for calculating these parameters. In its use of the CAPM, the Federal Reserve uses a forty-year period for calculating discount rate averages, utilizes the gross domestic product price deflator for estimating inflation, and considers the best method for determining the risk-free rate as one where "the time horizon of the investor is matched with the term of the risk-free security."[14]

By taking a 40-year geometric average of Federal Reserve data on annual nominal returns for 10-year Treasury bills, DOE found for this analysis the following risk-free rates for 2011-2013 (Table 8.2.14).[15] DOE also estimated the ERP by calculating the difference between the risk-free rate and stock market return for the same time period.[12]

Table 8.2.14 Risk-free rate and equity risk premium, 2011-2013

Year	Risk free rate (%)	ERP (%)
2011	6.61%	2.94%
2012	6.41%	3.99%
2013	6.24%	5.30%

The cost of debt financing (k_d) is the interest rate paid on money borrowed by a company. The cost of debt is estimated by adding a risk adjustment factor (Ra) to the risk-free rate. This risk adjustment factor depends on the variability of stock returns represented by standard deviations in stock prices. So for firm i, the cost of debt financing is:

$$\boldsymbol{k_{di} = R_f + R_{ai}}$$

Eq. 8.6

Where:

k_{di} = cost of debt financing for firm, i,
R_f = expected return on risk-free assets, and
R_{ai} = risk adjustment factor to risk-free rate for firm, i.

DOE estimates the WACC using the following equation:

$$WACC = k_e \times w_e + k_d \times w_d$$

Eq. 8.7

Where:

$WACC$ = weighted-average cost of capital,
k_e = cost of equity,
w_e = proportion of equity financing,
k_d = cost of debt financing for firm, and
w_d = proportion of debt financing.

By adjusting for the influence of inflation, DOE estimates the real weighted-average cost of capital, or discount rate, for each company. DOE then aggregates the company real weighted-average costs of capital to estimate the discount rate for each of the eight broader ownership types in the PTAC-PTHP analysis. An overall average is estimated by weighting each ownership type's discount rate by its estimated share of the PTAC and PTHP markets. These values are presented in Table 8.2.15. While WACC values for any category may trend higher or lower over substantial periods of time, these values represent a private sector cost of capital that is averaged over major business cycles.

Table 8.2.15 Weighted-Average Cost of Capital for Analyzed Sectors

Sector	Discount Rate	Standard Deviation	Market Share
Office	4.57%	2.0%	5%
Large Hotel / Motel Chain	6.31%	2.0%	70%
Independent Hotel / Motel	7.83%	3.2%	10%
Medical Services	4.14%	1.5%	15%
Average Discount Rate:	6.05%	-	-

Source: Damodaran Online Data Page: Costs of Capital by Industry Sector, 2011, 2011, 2013.

8.2.2.8 Compliance Year of Standard

DOE calculated the LCC and PBP for all consumers as if each would purchase a new piece of equipment in the year that compliance with amended standards is required. The Energy Policy and Conservation Act (EPCA), as amended, requires DOE to consider amending the existing Federal energy conservation standard for certain types of listed commercial and industrial equipment, including packaged terminal air conditioners and heat pumps, each time the American Society of Heating, Refrigerating and Air- Conditioning Engineers (ASHRAE) Standard 90.1, Energy Standard for Buildings Except Low-Rise Residential Buildings, is amended with respect to such equipment. (42 U.S.C. 6313(a)(6)(A)) If DOE does indeed adopt a uniform national standard more stringent than the amended ASHRAE Standard 90.1, equipment must comply with the efficiency level contained therein if they are manufactured on or after a date which is four years after the date such rule is published in the Federal Register. (42 U.S.C 6313(a)(6)(D)) At the time of preparation of the Final Rule analysis, the expected publication year was 2015.

8.2.2.9 Base Case Distribution of Efficiency Levels

Market share and efficiency level data for PTACs and PTHPs were obtained from a 2013 dataset from the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory of Certified Product Performance. DOE used an efficiency trend to establish the efficiency distribution for 2019. DOE applied the trend from 2012 to 2035 that was used in the commercial unitary air conditioner Advance Notice of Proposed Rulemaking (ANOPR), which estimated an increase of approximately 1 EER every 35 years.[d] Table 8.2.16 presents the estimated base case efficiency market shares for each PTAC and PTHP representative cooling capacity, as described in Chapter 5.

Table 8.2.16 Base Case Efficiency Market Shares in 2019 for Packaged Terminal Air Conditioners and 2018 for Packaged Terminal Heat Pumps

PTAC – 9,000 Btu/h		PTAC – 15,000 Btu/h		PTHP – 9,000 Btu/h		PTHP – 15,000 Btu/h	
IEER	Market Share	IEER	Market Share	IEER	Market Share	IEER	Market Share
11.1	0.0%	9.3	0.0%				
11.3	43.6%	9.5	25.8%	11.3	52.5%	9.5	63.1%
11.5	24.3%	9.7	34.8%	11.5	8.9%	9.7	0.0%
12.0	29.5%	10.0	34.7%	12.0	26.1%	10.0	28.4%
12.4	2.1%	10.4	2.7%	12.4	12.4%	10.4	7.2%
12.9	0.5%	10.8	1.4%	12.9	0.0%	10.8	1.4%
13.1	0.0%	11.0	0.7%	13.1	0.0%	11.0	0.0%

8.3 PAYBACK PERIOD INPUTS

The PBP is the amount of time it takes the consumer 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 first year annual operating expenditures.

The equation for PBP is:

$$PBP = \Delta IC/\Delta OC$$

Eq. 8.8

Where:
PBP = payback period in years,

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[d] See DOE's technical support document underlying DOE's July 29, 2004 ANOPR. 69 FR 45460 (Available at: www.regulations.gov/#!documentDetail;D=EERE-2006-STD-0103-0078).

ΔIC = difference in the total installed cost between the more efficient standard-level equipment (efficiency levels 2, 3, and so on) and the baseline efficiency equipment, and

ΔOC = difference in first year annual operating costs.

Payback periods are expressed in years. Payback periods can be greater than the life of the equipment if 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 based on the DOE test procedure. The calculation excludes maintenance costs.

The data inputs to PBP are the total installed cost of the equipment to the consumer 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 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" payback, the required electricity cost is only for the year in which a new efficiency standard is to take effect.

8.4 LIFE-CYCLE COST AND PAYBACK PERIOD RESULTS

This section presents the results of the LCC and PBP analysis for PTACs and PTHPs. As discussed previously, DOE's approach to the LCC analysis relied on 1,224 unit energy consumption values from the previous rulemaking. DOE also used probability distributions to characterize the uncertainty in many of the inputs to the analysis. DOE used Monte Carlo simulation to perform the LCC calculations for the consumers in the sample.

LCC and PBP calculations were performed 10,000 times on the sample of consumers established for each equipment class. Each LCC and PBP calculation was performed on a single consumer selected from the sample. A consumer was selected based on its weight (i.e., how representative that particular consumer was of other consumers in the distribution). Each LCC and PBP calculation also sampled from the probability distributions that DOE developed to characterize many of the inputs to the analysis.

For each set of sample consumers using the equipment in each equipment class, DOE calculated the average LCC and LCC savings and the median PBP for each trial standard level (TSL). DOE calculated LCC savings and PBPs relative to the base-case products that it assigned to the sample consumers. For some consumers, DOE assigned a base-case product that is more efficient than the baseline. For that reason, the average LCC impacts are not equal to the difference between the LCC of a specific standard level and the LCC of the baseline product. The calculation of average LCC savings includes consumers with zero LCC savings (no impact from a standard). DOE considered a consumer to receive no effect at a given standard level if DOE assigned it base-case equipment having the same or higher efficiency than the standard level. DOE calculated the median PBP values by excluding the consumers that are not impacted by a standard at a given efficiency level.

For each TSL, DOE also calculated the share of consumers experiencing a net LCC benefit, a net LCC cost, and no effect. DOE considered a consumer to receive no effect at a given standard level if DOE assigned it base-case equipment having the same or higher efficiency than the standard level.

For this final rule, DOE also repeated the LCC and PBP calculations for an alternative base case where the mandatory efficiency level is the Federal minimum, for informational purposes.

8.4.1 Packaged Terminal Air Conditioners – 9,000 Btu/h

Table 8.4.1summarizes the LCC and PBP results for PTACs of 9,000 Btu/h cooling capacity.

Table 8.4.1 Packaged Terminal Air Conditioners – 9,000 Btu/h Cooling Capacity: Life-Cycle Cost and Payback Period Results

Efficiency Level	Average Life-Cycle Costs (2014$)*			Life-Cycle Cost Savings**				Median Payback Period (years)†
	Installed Cost	Operating Cost	LCC	Consumers Showing (%)			Avg. Savings (2014$)	
				Net Cost	No Impact	Net Benefit		
EL 1, Baseline	$1,433	$1,314	$2,746	-	-	-	-	-
EL 2	$1,442	$1,308	$2,750	39%	57%	4%	-$1.45	10.4
EL 3	$1,459	$1,298	$2,757	64%	32%	4%	-$6.56	11.1
EL 4	$1,477	$1,289	$2,767	93%	2%	4%	-$15.60	12.1
EL 5	$1,497	$1,280	$2,778	96%	0%	3%	-$26.57	12.9
EL 6	$1,508	$1,276	$2,784	97%	0%	3%	-$32.74	13.3

*The average discounted LCC for each efficiency level is calculated assuming that all purchases are for products only with that efficiency level. This allows the LCCs for each efficiency level to be compared under the same conditions.

**The LCC savings for each efficiency level are calculated relative to the base case efficiency distribution. The calculation includes establishments with zero LCC savings (no impact).

†The median payback period is calculated only for affected establishments. Establishments with no impact have an undefined payback period, and are therefore not included in calculating the median PBP.

Figure 8.4.1 and Figure 8.4.2 show the range of LCC savings and PBPs for all of the efficiency levels considered for PTACs with outputs of 9,000 Btu/h cooling capacity. 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 consumers have LCC savings or PBP above this value. The horizontal lines above and below each box indicate the 95th and 5th percentiles, respectively. The small box shows the average LCC savings or PBP for each standard level.

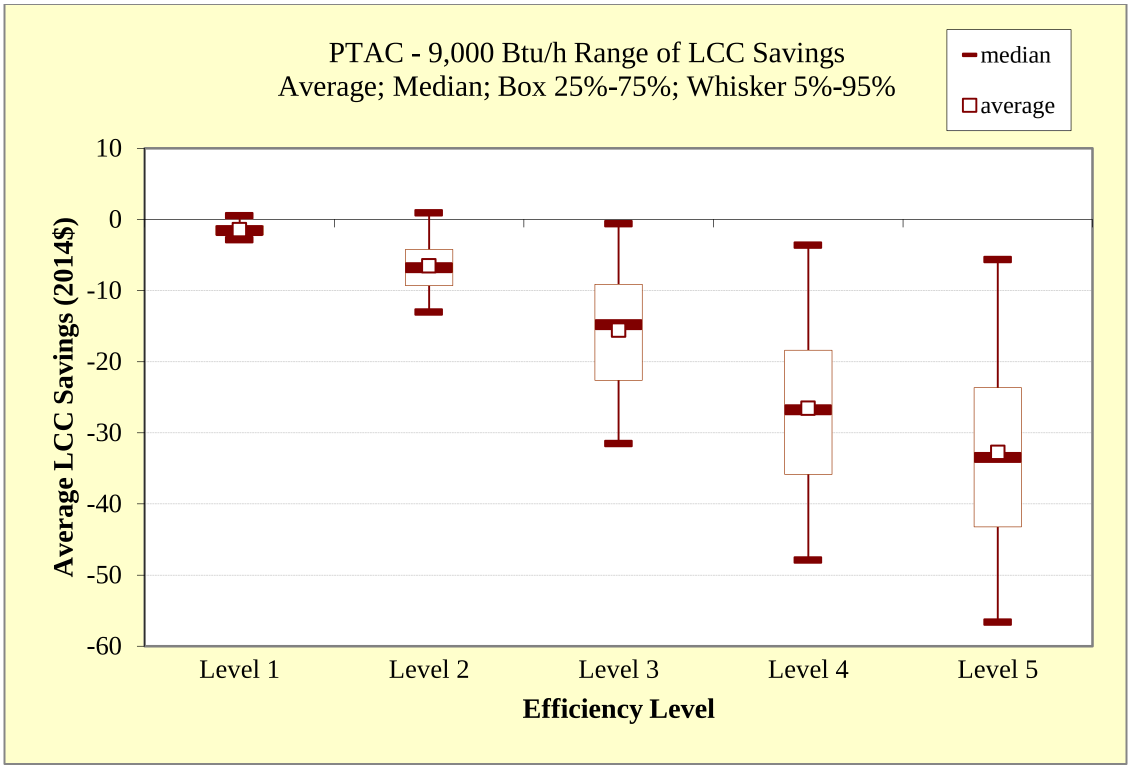

Figure 8.4.1 Range of Life-Cycle Cost Savings for Packaged Terminal Air Conditioners – 9,000 Btu/h Cooling Capacity

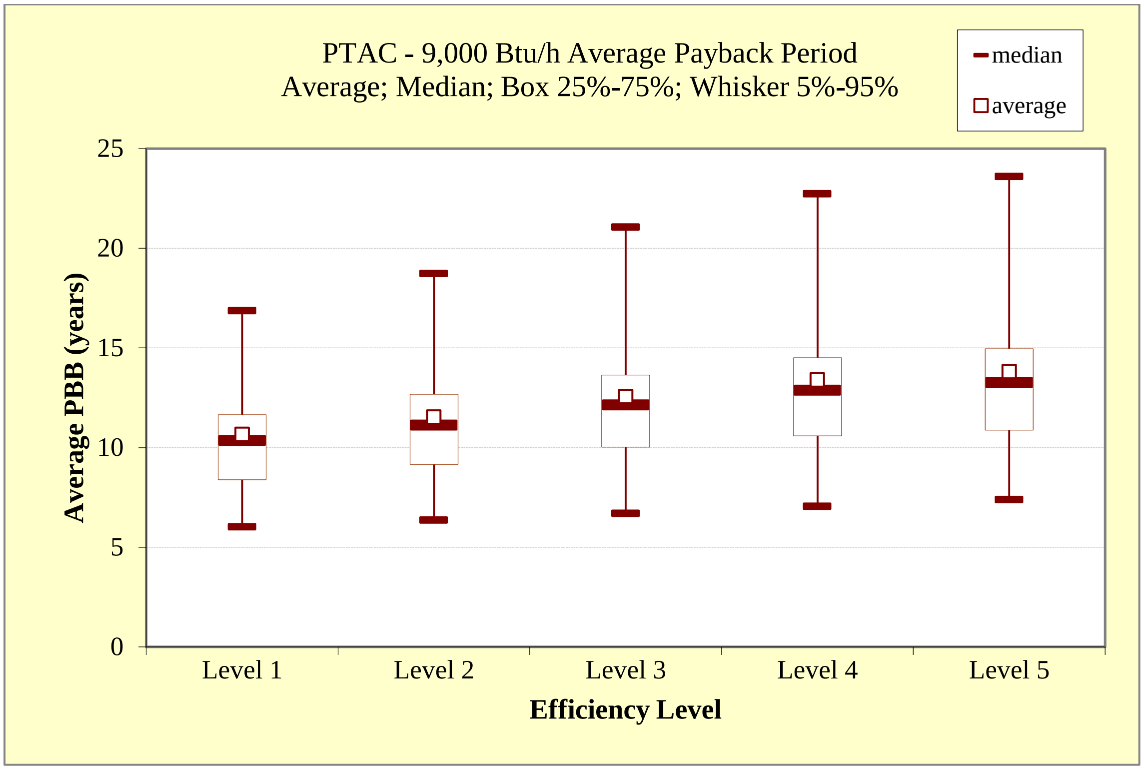

Figure 8.4.2 Range of Payback Periods for Packaged Terminal Air Conditioners – 9,000 Btu/h Cooling Capacity

8.4.2 Packaged Terminal Air Conditioners – 15,000 Btu/h Cooling Capacity

Table 8.4.2 summarizes the LCC and PBP results for PTACs of 15,000 Btu/h cooling capacity.

Table 8.4.2 Packaged Terminal Air Conditioners – 15,000 Btu/h Cooling Capacity: Life-Cycle Cost and Payback Period Results

Efficiency Level	Average Life-Cycle Costs (2014$)*			Life-Cycle Cost Savings**				Median Payback Period (years)†
				Consumers Showing (%)			Avg. Savings (2014$)	
	Installed Cost	Operating Cost	LCC	Net Cost	No Impact	Net Benefit		
EL 1, Baseline	$1,691	$1,635	$3,326	-	-	-	-	-
EL 2	$1,700	$1,630	$3,330	23%	75%	2%	-$0.88	11.1
EL 3	$1,723	$1,619	$3,342	59%	39%	2%	-$8.17	13.2
EL 4	$1,753	$1,608	$3,361	95%	5%	1%	-$26.43	15.7
EL 5	$1,790	$1,597	$3,387	98%	2%	0%	-$52.16	18.0
EL 6	$1,811	$1,592	$3,403	99%	1%	0%	-$67.89	19.2

*The average discounted LCC for each efficiency level is calculated assuming that all purchases are for products only with that efficiency level. This allows the LCCs for each efficiency level to be compared under the same conditions.

**The LCC savings for each efficiency level are calculated relative to the base case efficiency distribution. The calculation includes establishments with zero LCC savings (no impact).

†The median payback period is calculated only for affected consumers. Consumers with no impact have an undefined payback period and are therefore not included in calculating the median PBP.

Figure 8.4.3 and Figure 8.4.4 show the range of LCC savings and PBPs for all of the efficiency levels considered for PTACs with output of 15,000 Btu/h cooling capacity. 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 consumers have LCC savings or PBP above this value. The horizontal lines above and below each box indicate the 95th and 5th percentiles, respectively. The small box shows the average LCC savings or PBP for each standard level.

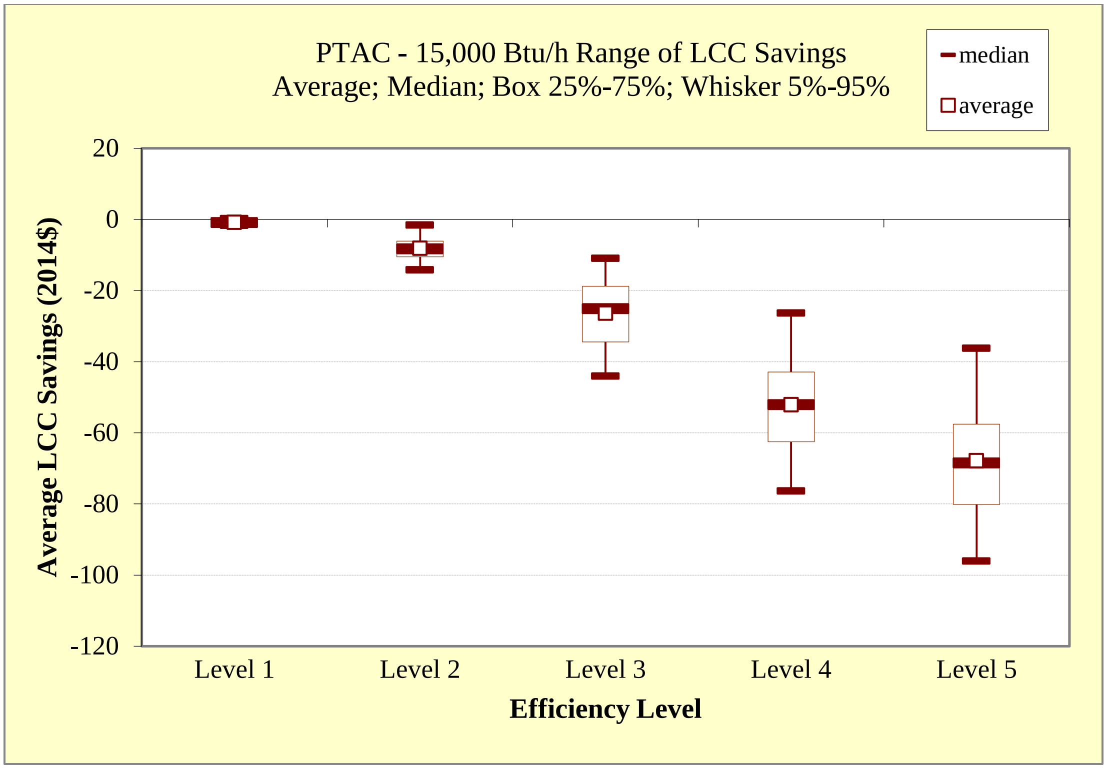

Figure 8.4.3 **Range of Life-Cycle Cost Savings for Packaged Terminal Air Conditioners – 15,000 Btu/h Cooling Capacity**

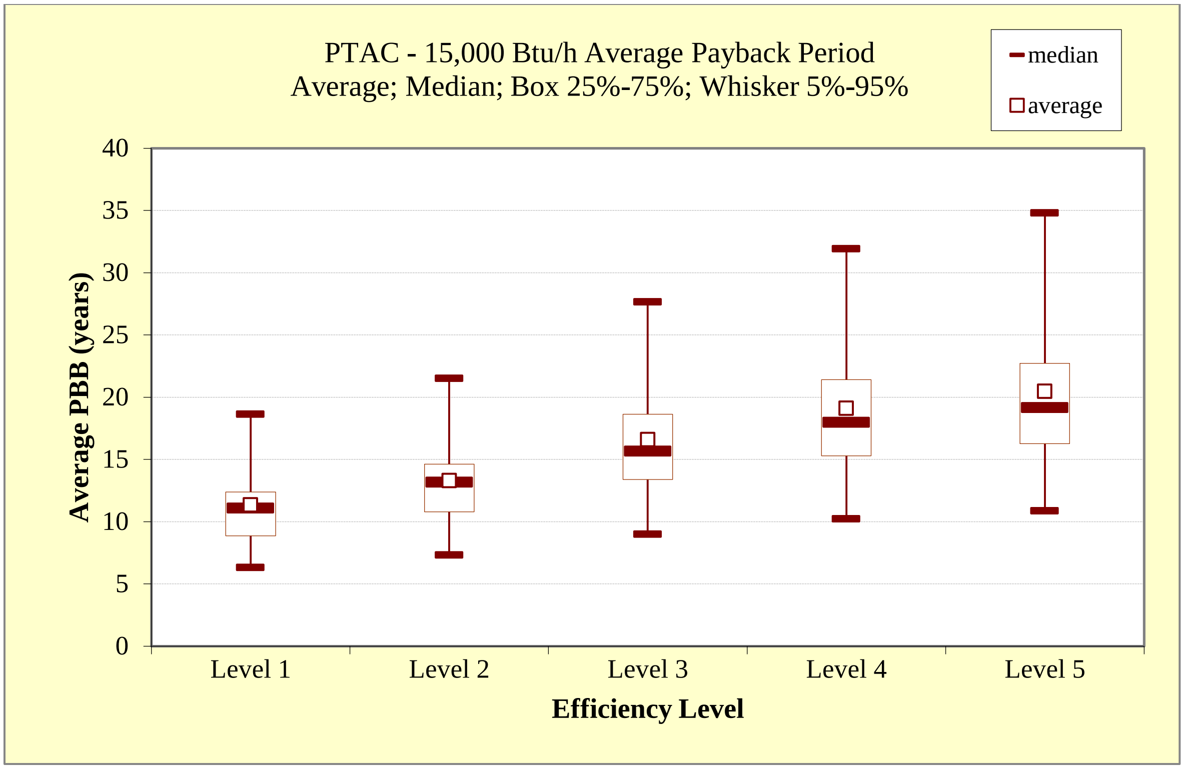

Figure 8.4.4 Range of Payback Periods for Packaged Terminal Air Conditioners – 15,000 Btu/h Cooling Capacity

8.4.3 Packaged Terminal Heat Pumps – 9,000 Btu/h Cooling Capacity

Table 8.4.3 summarizes the LCC and PBP results for PTHPs of 9,000 Btu/h cooling capacity.

Table 8.4.3 Packaged Terminal Heat Pumps – 9,000 Btu/h Cooling Capacity

Efficiency Level	Average Life-Cycle Costs (2014$)*			Life-Cycle Cost Savings**				Median Payback Period (years)†
	Installed Cost	Operating Cost	LCC	Consumers Showing (%)			Avg. Savings (2014$)	
				Net Cost	No Impact	Net Benefit		
EL 1	$1,552	$1,835	$3,388	12%	47%	41%	$2.14	4.5
EL 2	$1,570	$1,820	$3,390	33%	38%	30%	$0.74	6.2
EL 3	$1,588	$1,806	$3,394	60%	12%	28%	-$2.87	7.2
EL 4	$1,608	$1,792	$3,400	75%	0%	25%	-$8.70	7.9
EL 5	$1,619	$1,785	$3,404	77%	0%	23%	-$12.27	8.2

*The average discounted LCC for each efficiency level is calculated assuming that all purchases are for products only with that efficiency level. This allows the LCCs for each efficiency level to be compared under the same conditions.

**The LCC savings for each efficiency level are calculated relative to the base case efficiency distribution. The calculation includes establishments with zero LCC savings (no impact).

†The median payback period is calculated only for affected consumers. Consumers with no impact have an undefined payback period and are therefore not included in calculating the median PBP.

Figure 8.4.5 and Figure 8.4.6 show the range of LCC savings and PBPs for all of the efficiency levels considered for PTHPs with outputs of 9,000 Btu/h cooling capacity. 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 consumers have LCC savings or PBP above this value. The horizontal lines above and below each box indicate the 95th and 5th percentiles, respectively. The small box shows the average LCC savings or PBP for each standard level.

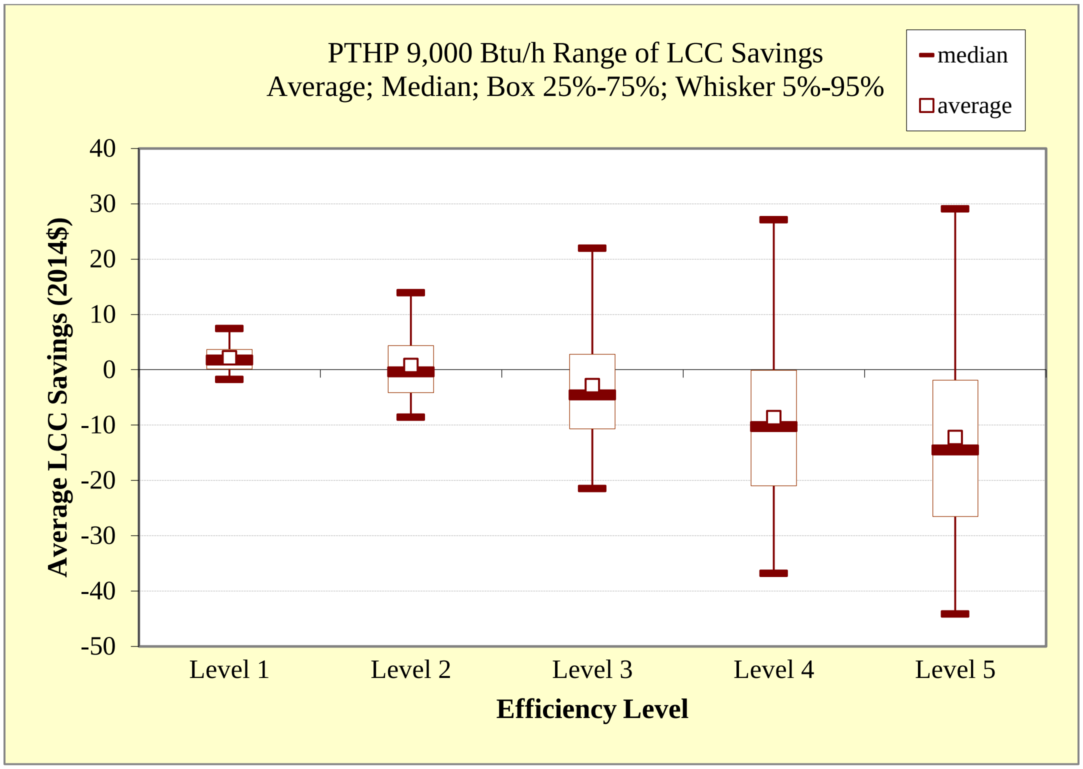

Figure 8.4.5 Range of Life-Cycle Cost Savings for Packaged Terminal Heat Pumps – 9,000 Btu/h Cooling Capacity

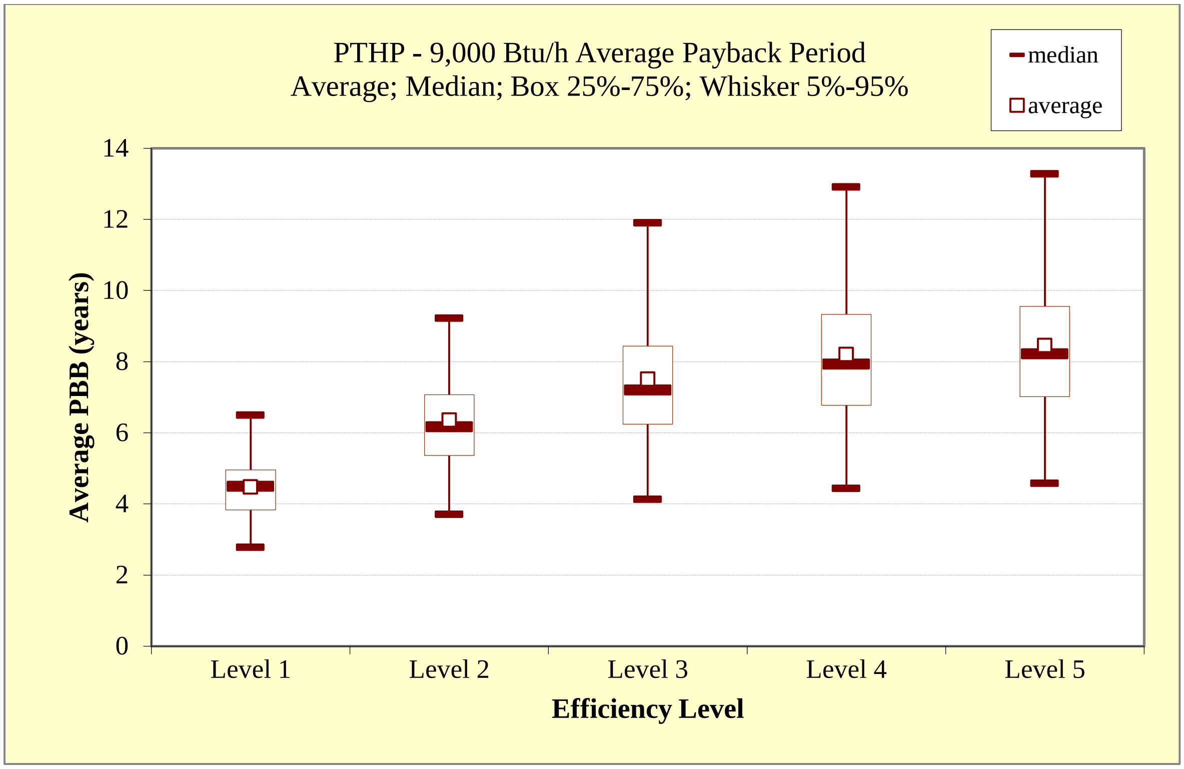

Figure 8.4.6 Range of Payback Periods for Packaged Terminal Heat Pumps – 9,000 Btu/h Cooling Capacity

8.4.4 Packaged Terminal Heat Pumps – 15,000 Btu/h Cooling Capacity

Table 8.4.4 summarizes the LCC and PBP results for PTHPs of 15,000 Btu/h cooling capacity.

Table 8.4.4 Packaged Terminal Heat Pumps – 15,000 Btu/h Cooling Capacity

Efficiency Level	Average Life-Cycle Costs (2014$)*			Life-Cycle Cost Savings**				Median Payback Period (years)†
	Installed Cost	Operating Cost	LCC	Consumers Showing (%)			Avg. Savings (2014$)	
				Net Cost	No Impact	Net Benefit		
EL 1	$1,805	$2,295	$4,100	47%	38%	15%	-$1.04	8.2
EL 2	$1,828	$2,274	$4,102	42%	38%	20%	-$2.27	7.4
EL 3	$1,858	$2,253	$4,111	73%	9%	18%	-$10.50	8.3
EL 4	$1,895	$2,232	$4,127	87%	2%	12%	-$26.41	9.5
EL 5	$1,916	$2,222	$4,138	91%	0%	9%	-$37.17	10.0

*The average discounted LCC for each efficiency level is calculated assuming that all purchases are for products only with that efficiency level. This allows the LCCs for each efficiency level to be compared under the same conditions.

**The LCC savings for each efficiency level are calculated relative to the base case efficiency distribution. The calculation includes establishments with zero LCC savings (no impact).

†The median payback period is calculated only for affected consumers. Consumers with no impact have an undefined payback period and are therefore not included in calculating the median PBP.

Figure 8.4.7 and Figure 8.4.8 show the range of LCC savings and PBPs for all of the efficiency levels considered for PTHPs with output of 15,000 Btu/h cooling capacity. 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 consumers have LCC savings or PBP above this value. The horizontal lines above and below each box indicate the 95th and 5th percentiles, respectively. The small box shows the average LCC savings or PBP for each standard level.

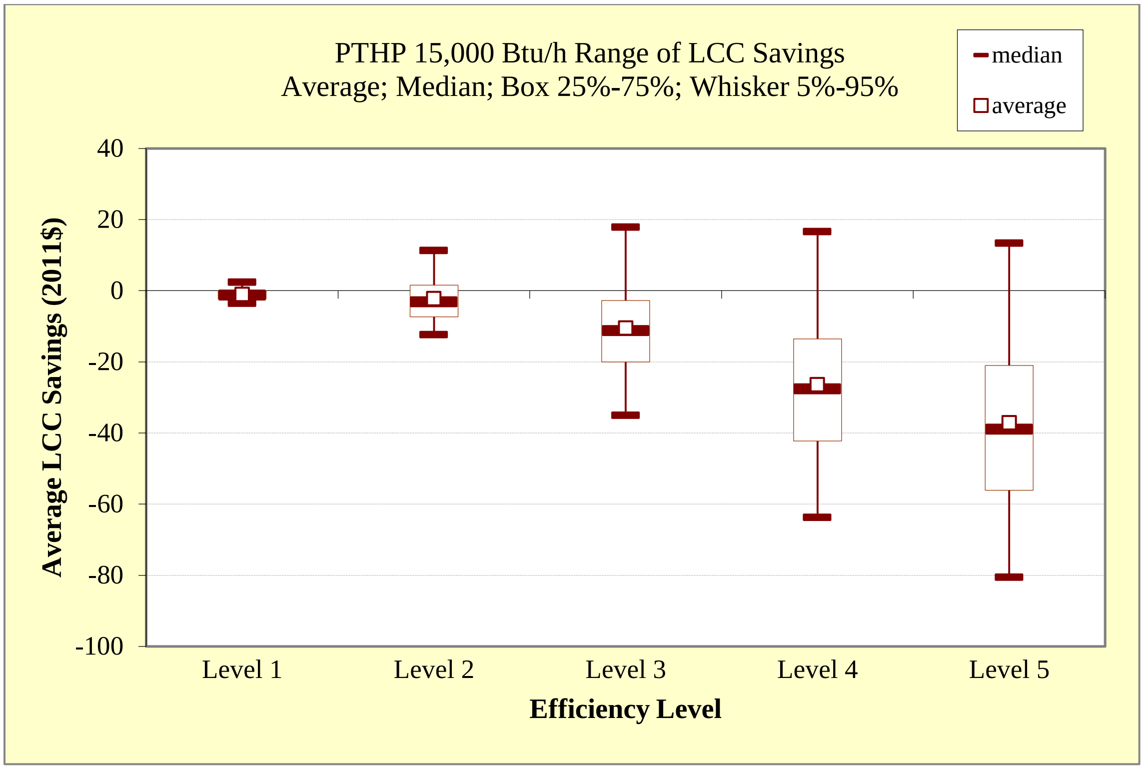

Figure 8.4.7 Range of Life-Cycle Cost Savings for Packaged Terminal Heat Pumps – 15,000 Btu/h Cooling Capacity

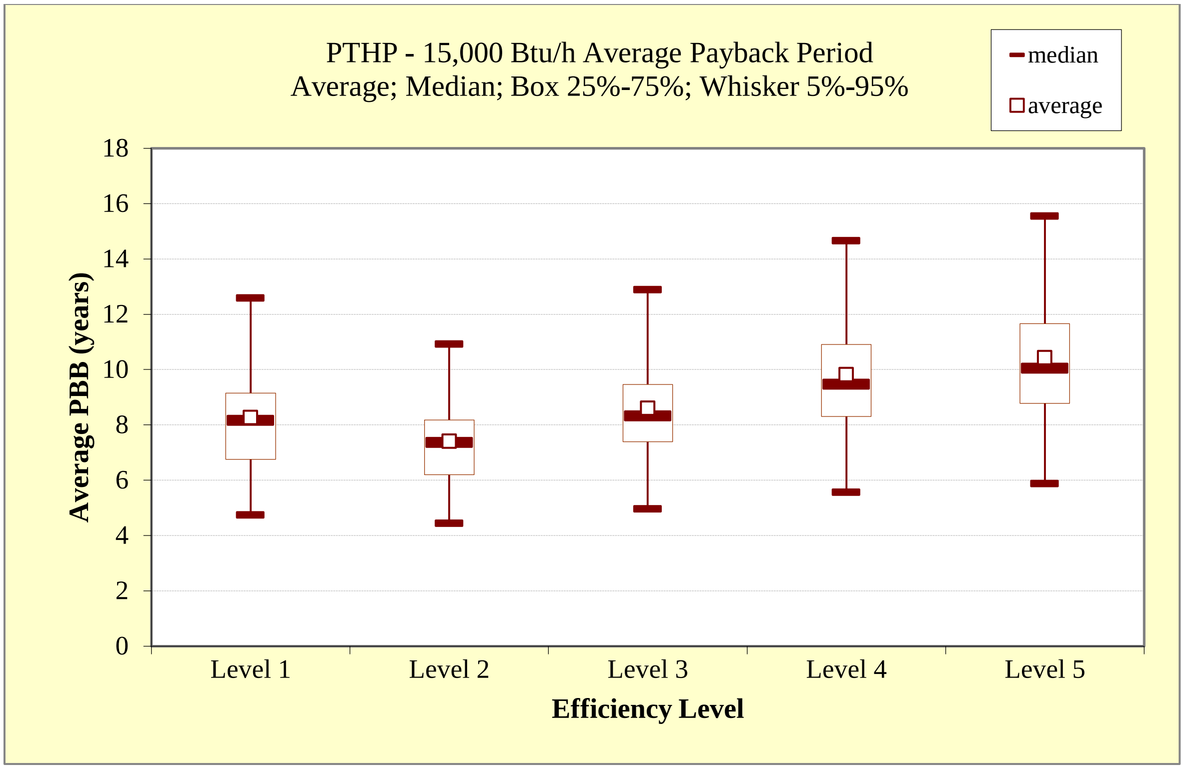

Figure 8.4.8 **Range of Payback Periods for Packaged Terminal Heat Pumps – 15,000 Btu/h Cooling Capacity**

8.4.5 Alternative Base Case Analysis

The alternative base case analysis was based off a scenario where the mandatory efficiency level is the Federal minimum. Table 8.4.5 shows the efficiency distribution against which LCC and PBP results were calculated. The results of these calculations are shown in Table 8.4.6.

Table 8.4.5 **Alternative Base Case Efficiency Market Shares in 2019 for PTACs and 2018 for PTHPs**

PTAC – 9,000 Btu/h		PTAC – 15,000 Btu/h		PTHP – 9,000 Btu/h		PTHP – 15,000 Btu/h	
EER	**Market Share**	**EER**	**Market Share**	**EER**	**Market Share**	**EER**	**Market Share**
11.1	3.4%	9.3	10.9%				
11.3	40.3%	9.5	14.9%	11.3	52.5%	9.5	63.1%
11.5	24.3%	9.7	34.8%	11.5	8.9%	9.7	0.0%
12.0	29.5%	10.0	34.7%	12.0	26.1%	10.0	28.4%
12.4	2.1%	10.4	2.7%	12.4	12.4%	10.4	7.2%
12.9	0.5%	10.8	1.4%	12.9	0.0%	10.8	1.4%
13.1	0.0%	11.0	0.7%	13.1	0.0%	11.0	0.0%

Table 8.4.6 Alternative Base Case Results

	Trial Standard Level	Average Life-Cycle Costs (2014$)[*]			Life-Cycle Cost Savings[**]				Median Payback Period (years)[†]
		Installed Cost	Operating Cost	LCC	Customers Showing (%)			Avg. Savings (2014$)	
					Net Cost	No Impact	Net Benefit		
PTAC <12,000 Btu/h	1	$1,437	$1,308	$2,746	39%	57%	4%	-$2.48	10.1
	2	$1,455	$1,298	$2,753	63%	32%	5%	-$9.01	10.7
	3	$1,473	$1,289	$2,762	92%	2%	6%	-$21.93	11.4
	4	$1,493	$1,280	$2,773	95%	0%	4%	-$33.30	12.1
	5	$1,504	$1,276	$2,780	96%	0%	4%	-$39.63	12.5
PTAC ≥12,000 Btu/h	1	$1,695	$1,630	$3,325	21%	75%	4%	-$1.21	9.1
	2	$1,718	$1,619	$3,337	57%	39%	4%	-$10.24	11.2
	3	$1,748	$1,608	$3,356	93%	5%	2%	-$34.40	13.3
	4	$1,785	$1,597	$3,382	97%	2%	1%	-$61.07	15.5
	5	$1,806	$1,592	$3,398	99%	1%	0%	-$77.77	16.7
PTHP <12,000 Btu/h	1	$1,552	$1,835	$3,388	12%	47%	41%	$2.14	4.5
	2	$1,570	$1,820	$3,390	33%	38%	30%	$0.74	6.2
	3	$1,588	$1,806	$3,394	60%	12%	28%	-$2.87	7.2
	4	$1,608	$1,792	$3,400	75%	0%	25%	-$8.70	7.9
	5	$1,619	$1,785	$3,404	77%	0%	23%	-$12.27	8.2
PTHP ≥12,000 Btu/h	1	$1,805	$2,295	$4,100	47%	38%	15%	-$1.04	8.2
	2	$1,828	$2,274	$4,102	42%	38%	20%	-$2.27	7.4
	3	$1,858	$2,253	$4,111	73%	9%	18%	-$10.50	8.3
	4	$1,895	$2,232	$4,127	87%	2%	12%	-$26.41	9.5
	5	$1,916	$2,222	$4,138	91%	0%	9%	-$37.17	10.0

[*] The average discounted LCC for each TSL is calculated assuming that all purchases are for equipment only with that CSL. This allows the LCCs for each TSL to be compared under the same conditions.

[**] The LCC savings for each TSL are calculated relative to the base case efficiency distribution. The calculation includes customers with zero LCC savings (no impact).

[†] The median payback period is calculated only for affected customers. Customers with no impact have an undefined payback period and are therefore not included in calculating the median PBP.

8.4.6 Rebuttable Payback Period

DOE presents rebuttable PBPs to provide the legally established rebuttable presumption that an energy efficiency standard is economically justified if the additional equipment costs attributed to the standard are less than three times the value of the first-year energy cost savings. (42 U.S.C. §6295(o)(2)(B)(iii))

The basic equation for rebuttable PBP is the same as that shown for the PBP in section 8.3. Unlike the analyses described in section 8.3, however, the rebuttable PBP is not based on the use of probability distributions, but on discrete single-point values. For example, whereas DOE uses a probability distribution of energy prices in the distributional PBP analysis, it uses only the national average energy price to determine the rebuttable PBP.

8.4.6.1 Inputs

Inputs for the rebuttable PBP differ from the distribution PBP in that the calculation uses discrete values, rather than distributions. Note that for the calculation of distribution PBP, because inputs for the determination of total installed cost were based on single-point values, only the variability and/or uncertainty in the inputs for determining operating cost contributed to variability in the distribution PBPs. The following summarizes the single-point values that DOE used in determining the rebuttable PBP:

- Manufacturing costs, markups, sales taxes, and installation costs were all based on the single-point values used in the distributional LCC and PBP analysis.
- Energy prices were based on national average values for the year that new standards will take effect.
- An average discount rate or lifetime is not required in the rebuttable PBP calculation.
- The annual energy consumption uses the single-point per unit values, determined from the whole-building simulations as discussed in Chapter 7.

8.4.6.2 Results

DOE calculated rebuttable PBPs for each standard level relative to the distribution of equipment energy efficiencies estimated for the base case. Table 8.4.7 and Table 8.4.8 present the rebuttable PBPs for PTACs and PTHPs.

Table 8.4.7 Rebuttable-Presumption Payback Periods (years) for Packaged Terminal Air Conditioners

PTACs - 9,000 Btu/h		PTACs - 15,000 Btu/h	
Efficiency Level	PBP (years)	Efficiency Level	PBP (years)
EL 1, Baseline	-	EL 1, Baseline	-
EL 2	6.4	EL 2	6.5
EL 3	6.7	EL 3	7.7
EL 4	6.9	EL 4	8.9
EL 5	7.2	EL 5	10.1
EL 6	7.4	EL 6	10.7

Table 8.4.8 Rebuttable-Presumption Payback Periods (years) for Packaged Terminal Heat Pumps

PTHPs - 9,000 Btu/h		PTHPs - 15,000 Btu/h	
Efficiency Level	PBP (years)	Efficiency Level	PBP (years)
EL 1	3.4	EL 1	5.4
EL 2	4.4	EL 2	5.3
EL 3	4.8	EL 3	5.9
EL 4	5.1	EL 4	6.6
EL 5	5.3	EL 5	6.9

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CHAPTER 9. SHIPMENTS ANALYSIS

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CHAPTER 9. SHIPMENTS ANALYSIS

9.1 INTRODUCTION

The U.S. Department of Energy (DOE) analyzes shipments of affected equipment as part of every rulemaking regarding new or amended energy efficiency standards for appliances or commercial and industrial equipment. Estimates of equipment shipments are a necessary input for calculating national energy savings (NES) and net present value (NPV) of the investment, which are required to justify potential new or amended energy efficiency standards. Shipments also are a necessary input to the manufacturer impact analysis (MIA). This chapter describes DOE's method and results of projecting annual shipments for packaged terminal air conditioners (PTACs) and packaged terminal heat pumps (PTHPs).

To project shipments of PTAC and PTHP equipment, DOE considered specific factors that drive equipment shipments. DOE developed shipments forecasts by accounting for: (1) the growth in the building stock of hotel/motel, healthcare, and small office buildings that are the primary end users of PTACs and PTHPs; (2) market segments; (3) equipment failure; and (4) equipment age.

The shipments models are prepared as Microsoft Excel spreadsheets that are accessible on the Internet (www.eere.energy.gov/buildings/appliance_standards/). The rest of this chapter explains the shipments model in more detail. Section 9.2 describes the methodology that underlies development of the model; section 9.3 describes the input data used to develop the shipments model; and section 9.4 discusses the results in terms of base-case and standards-case shipments.

9.2 METHODOLOGY

This section outlines the methodology used to develop the shipments model that provides projections of shipments for PTAC and PTHP equipment classes defined in Chapter 5. First, a brief summary of the basic framework is provided in the following section.

PTAC and PTHP shipments are driven primarily by two market segments: new construction and replacements. For new construction shipments, DOE combined new construction floor space forecasts with a constant market saturation of the equipment in new construction floor space. DOE estimated replacement shipments using an equipment retirement function that it developed based on equipment lifetimes. DOE designed its shipments model by developing a single shipments model for all PTACs and PTHPs and then disaggregating the shipments into six equipment classes. The shipments model assumes that, in each year, each existing PTAC or PTHP either ages by one year or breaks down, and that equipment that breaks down is replaced. In addition, new equipment can be shipped into new commercial building floor space.

9.2.1 Mathematical Formulation of the Shipments Model

DOE determines the yearly stock based on replacement and new shipments of PTAC and PTHP equipment. The total stock of equipment U of an age a in a given year t is accounted for and is modified by the shipments of new stock in a given year, $Uship(t, a)$, as described below.

$$U(t+1, a) = U(t, a) + Uship(t, 0)|_{\text{for each } t \text{ and for each } a}$$

Eq. 9.1

Where:

$U(t,a)$ = total stock of equipment of an age a in a given year t,
$Uship(t,0)$ = total shipments of new stock,
a = age of stock in years,
t = year.

By definition, the age of the equipment is zero in the year that it is shipped, so $Uship(t, a) = Uship(t, 0)$. The total stock of equipment is initialized for the year 2013 after the initial stock is built up, as described below.

$$U(2013, a) = U0(2013, a)$$

Eq. 9.2

Where:

$U0(2013,a)$ = total stock of equipment for year after based on the build-up of the initial stock.

9.2.2 Historical Shipments

DOE received confidential historical shipments from AHRI for the years 2005-2012. In addition, AHRI provided 1998-2004 data that were published in the 2008 PTAC and PTHP rulemaking.[1] The average of the historical shipments (1998-2012) was used as the constant value for shipments for the years 1993-2012 to build up the initial stock for 2013.

9.2.3 Stock Events

In the transition from year t to year $(t+1)$, two things could happen to the equipment stock:

- existing equipment could break or be removed during a building renovation and be replaced, or
- the stock could simply age by one year.

Such stock events as shipments for replacement equipment and shipments for new equipment are modeled into the shipments of new stock $Uship(t)$:

$$Uship(t) = UR(t) + UN(t)$$

Eq. 9.3

Where:

$Uship(t,0)$ = total shipments of new stock in year t
$UR(t)$ = units replaced in year t
$UN(t)$ = the number of units going into new buildings in year t

In the model, early replacements (*i.e.*, existing equipment that is replaced before the end of its useful life) are not considered, and all broken equipment are assumed to be replaced. The following sections present the equations used to represent each possible event.

9.2.3.1 Replacement Equipment

DOE determined the probability that equipment of average age *a* from the stock of existing units *U* will break, $UB(t)$, and replaced on a one-to-one basis, $UR(t)$ using a function $PB(a)$, based on a Weibull statistical distribution of retirements with a 8-year average life and maximum life of 15 years. The inputs for the Weibull distribution that attains these lifetime characteristics are a scale parameter of 9.0 and shape parameter of 3.0. These probabilities do not depend on the model year *t*. DOE defines the quantities of replaced equipment as

$$UR(t) = UB(t) = \sum_{all\ a}^{a=1} PB(a) \cdot U(t,a)$$

Eq. 9.4

Where:

$UR(t)$ = units replaced,
$UB(t)$ = units broken,
$PB(a)$ = probability that stock of existing units will break,
$U(t, a)$ = total stock of equipment of an age a in a given year t,
a = average age of stock in years,
t = year.

All broken units are assumed to be replaced.

9.2.3.2 New Equipment

New PTAC and PTHP equipment will be purchased to replace the units described above. In addition, new equipment will be purchased to install in newly constructed buildings. Available information suggests that the purchase of new equipment that would go into new buildings is driven by the rate of construction of hotels/motels, health care facilities, and office floor space.

The number of PTAC and PTHP units intended for new buildings is:

$$UN(t) = A0 \text{ x } NFS(t)$$

Eq. 9.5

Where:

$UN(t)$ = the number of units going into new buildings in year t,
$A0$ = the market saturation that accounts for the number of units per new commercial floor space,
$NFS(t)$ = the projected new commercial floor space.

DOE has limited information on the variation in the market saturation of PTAC and PTHP equipment by building type or over time. Therefore, in the model, the purchase of new equipment is driven by the construction of new floor space, and broken or removed equipment is replaced on a one for one basis.

9.3 MODEL INPUTS

As described in Eq. 9.3, the market for PTACs and PTHPs comprises replacement units for equipment that has been retired and units for new construction. The following sections discuss both the new construction and replacement markets in further detail.

9.3.1 New Construction

To develop shipments to new construction, DOE combined new construction floor space forecasts with a constant market saturation of the equipment in new construction. DOE used new construction floor space forecasts for the healthcare, lodging, and small office sectors from the Energy Information Administration (EIA)'s *Annual Energy Outlook 2014* (*AEO2014*) for 2013–2040.[2] Table 9.3.1 presents these forecasts. The data for 2041 through 2048 are based on an extrapolation of the trend from 2030 through 2040.

Table 9.3.1 Historical and Projected New Construction (million sq ft) for the Shipments Model for PTAC and PTHP Equipment*

Year	Healthcare	Lodging	Small Office	Year	Healthcare	Lodging	Small Office
2013	66	147	97	**2031**	71	161	149
2014	66	139	112	**2032**	71	169	160
2015	67	144	137	**2033**	72	184	175
2016	67	149	167	**2034**	72	192	193
2017	68	163	191	**2035**	72	207	211
2018	67	164	209	**2036**	74	215	225
2019	66	171	222	**2037**	74	214	230
2020	65	176	227	**2038**	75	207	228
2021	63	179	228	**2039**	76	198	218
2022	62	182	224	**2040**	76	188	207
2023	61	187	217	**2041**	77	185	198
2024	61	186	209	**2042**	78	183	189
2025	63	181	199	**2043**	78	180	181
2026	65	172	187	**2044**	79	177	173
2027	67	165	173	**2045**	80	174	165
2028	69	155	160	**2046**	80	171	158
2029	70	151	149	**2047**	81	169	151
2030	71	150	146	**2048**	82	166	145

*Source: *AEO2014*; data for 2041-2048 are extrapolated.

To derive the saturation of PTACs and PTHPs (combined) in new construction, DOE used data on shipments to new construction and commercial new construction floor space provided in the 2008 rulemaking, as shown in Table 9.3.2. DOE divided the new construction shipments by the total new construction floor space and used this saturation as the constant saturation for the analysis period.

Table 9.3.2 Historical PTAC and PTHP Shipments with New Construction Floor Space Values Used to Calculate Saturation*

Year	Health care (million s.f.)	Lodging (million s.f.)	Small Office (million s.f.)	Total (million s.f.)	New Construction Shipments	Saturation (units/ million s.f.)
2000	68	172	179	419	66,407	6,315

*Source: DOE 2008 PTAC and PTHP Energy Conservation Standards Rulemaking.

For new commercial buildings acquiring equipment, shipments are estimated by multiplying new construction floor space in each projection year by the saturation value.

9.3.2 Replacements

To determine shipments to the replacement market, DOE used an accounting method that tracks the total stock of units by vintage. DOE estimated a stock of PTACs and PTHPs by using the average of the available historical shipments (1998-2012) as the constant value for shipments for the years 1993-2012. Over time, some units break and are removed from the stock, triggering the one-for-one shipment of a replacement unit. Depending on the vintage, a certain percentage of units will fail and need to be replaced. All PTACs and PTHPs are presumed to be replaced by a unit of the same equipment class and capacity, but of an age of zero. To estimate how long a unit will function before failing, DOE used a survival function based on the distributions of equipment lifetime. The survival function that DOE used had an average lifetime of 8 years and a maximum lifetime of 15 years. Further discussion of equipment lifetime is located in Chapter 8. Figure 9.3.1 shows the survival function DOE used to estimate replacement shipments.

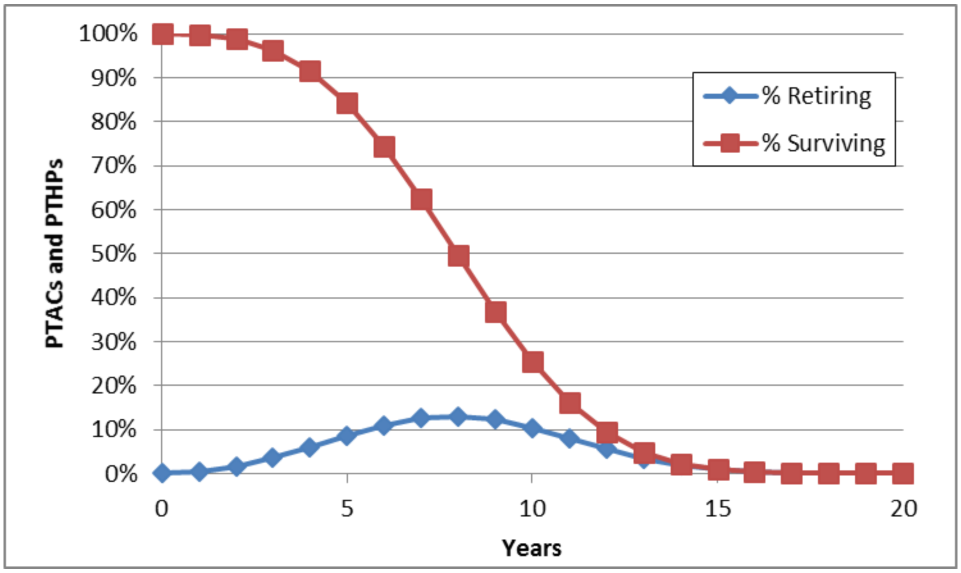

Figure 9.3.1 PTAC and PTHP Equipment Survival Function

9.4 RESULTS

For each year in the analysis period, DOE distributed total PTAC and PTHP shipments into the individual equipment classes using the average shares of the 1998-2004 shipments by equipment class provided by AHRI for the previous rulemaking. Since the data did not perceptibly indicate an increasing or decreasing trend, DOE assumed the distribution to persist throughout the projection years. Table 9.4.1 shows the distribution of PTAC and PTHP shipments by equipment class. Since the market shares are not expected to change with amended standards, the results apply for the base case and standards cases.

Table 9.4.1 PTAC and PTHP Equipment Class Shipment Distribution

	PTAC			**PTHP**			**Total**
	<7,000 Btu/h	**≥7,000 - ≤15,000 Btu/h**	**>15,000 Btu/h**	**<7,000 Btu/h**	**≥7,000 - ≤15,000 Btu/h**	**>15,000 Btu/h**	
1998-2004 Average Shipments	13,340	212,844	16,026	7,945	174,538	14,057	438,750
Percent	3%	48.5%	3.7%	1.8%	39.8%	3.2%	100%

Figure 9.4.1 shows the projected shipments of PTACs and PTHPs by equipment class and the historical shipments (ending in 2048 for PTAC and 2047 for PTHP) DOE used to develop the initial stock that drove the replacement shipment projection.

Figure 9.4.2 shows total shipments (aggregated from individual equipment classes) broken into new construction and replacement shipments. This figure starts in 2013, as historical shipments are not disaggregated into new construction and replacements.

DOE assumed that projected shipments do not change with higher efficiency levels. DOE expects that most consumers would rather replace than repair failed equipment, given the price of repair (as discussed in Chapter 8) and the benefits of new equipment (operating life extension and extended warranty). DOE also assumed that the distribution of the efficiencies of shipments is constant over time.

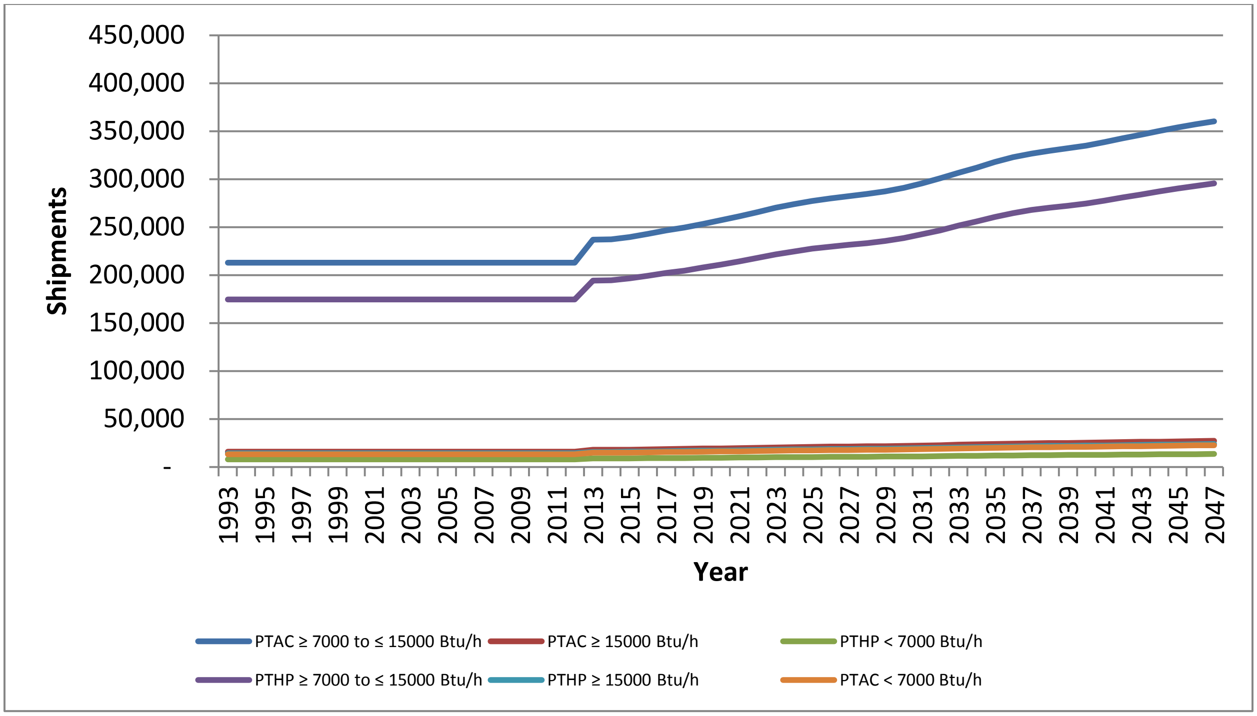

Figure 9.4.1 **Historical and Projected Shipments by Equipment Class**

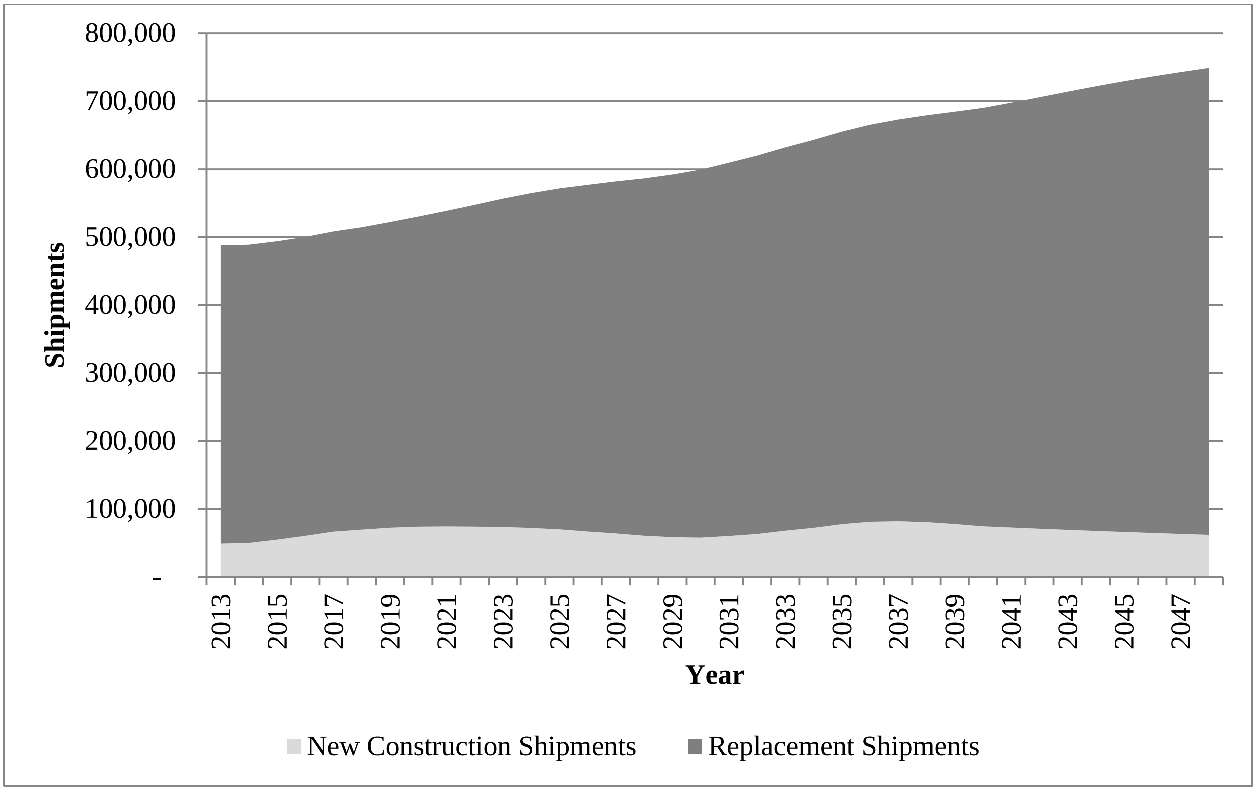

Figure 9.4.2 **Projected New Construction and Replacement Shipments**

For the current year, DOE distributed shipments by efficiency level based on the market availability of models by equipment efficiency. DOE was not able to obtain shipments data of PTAC and PTHP equipment by efficiency as this information was not available, so it used the number of models in a certified model product directory as a proxy for market availability. DOE obtained PTAC and PTHP model and equipment efficiency data from the AHRI Directory of Certified Product Performance[3] and determined and assigned the number of units that fell within a range of efficiencies based on the baseline- and standards-level efficiencies described in Chapter 5. DOE obtained a total of 346 non-discontinued PTAC models and 230 non-discontinued PTHP models; their distribution of efficiencies is reported in Table 9.4.2 and Table 9.4.3.

Table 9.4.2 PTAC Efficiency Distribution in 2014

Equipment class Efficiency level*	<7,000 Btu/h	≥7,000 - ≤15,000 Btu/h	>15,000 Btu/h
Federal Minimum	0%	8%	100%
Baseline/EL 1	0%	46%	0%
EL 2	100%	39%	0%
EL 3	0%	3%	0%
EL 4	0%	2%	0%
EL 5	0%	1%	0%
EL 6	0%	0%	0%

*The Federal Minimum efficiency level represents the efficiency level of the current federal energy conservation standards for PTAC equipment. Efficiency level 1 is the baseline level for PTAC equipment, and is the ANSI/ASHRAE/IES Standard 90.1-2013 minimum for PTAC equipment.

Table 9.4.3 PTHP Efficiency Distribution in 2014

Equipment class Efficiency level*	<7,000 Btu/h	≥7,000 - ≤15,000 Btu/h	>15,000 Btu/h
Baseline	100%	78%	100%
EL 1	0%	6%	0%
EL 2	0%	6%	0%
EL 3	0%	9%	0%
EL 4	0%	1%	0%
EL 5	0%	0%	0%

*The baseline efficiency level represents the efficiency level of the current federal energy conservation standards for PTHP equipment, which is the same as the ANSI/ASHRAE/IES Standard 90.1-2013 minimum efficiency for PTHP equipment.

REFERENCES

1. U.S. Department of Energy – Office of Energy Efficiency and Renewable Energy, *Energy Conservation Program for Commercial and Industrial Equipment: Packaged Terminal Air Conditioner and Packaged Terminal Heat Pump Energy Conservation Standards.*, 2007. (Last accessed June, 2014.) <www.regulations.gov/#!docketDetail;D=EERE-2007-BT-STD-0012>

2. U.S. Department of Energy/Energy Information Administration, *Annual Energy Outlook 2014*, 2013. Washington, D.C. Report No. DOE/EIA0383.

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CHAPTER 10. NATIONAL IMPACT ANALYSIS

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CHAPTER 10. NATIONAL IMPACT ANALYSIS

10.1 INTRODUCTION

This chapter describes the method for estimating the quantity and net value to customers of future national energy savings (NES) from possible trial standard levels (TSLs). Results described here include: (1) national energy consumption and savings, (2) monetary value of operating cost savings to the Nation due to standards, (3) increased total installed costs to the Nation due to standards, and (4) the net present value (NPV) of operating cost savings (the difference between value of operating cost savings and increased total installed costs).

DOE performed all calculations using a Microsoft Excel® spreadsheet, which is accessible on the Internet (www1.eere.energy.gov/buildings/appliance_standards/buildings/appliance_standards/product.aspx/productid/77).

Chapter 9 provides a detailed description of the shipments model that DOE used to project future shipments of PTAC and PTHP equipment. It includes estimates of efficiency market shares in the base case and the considered standards cases, as well as estimates of the impact of standards on the distribution of shipment efficiencies.

10.2 BASE AND STANDARDS CASE EFFICIENCIES

For each equipment class, DOE developed a distribution of base case efficiencies in the compliance year for PTAC and PTHP equipment as described in Chapter 8. In each standards case, DOE assumed a “roll-up” scenario to establish the efficiency distribution. Equipment efficiencies in the base case that did not meet the standard under consideration “roll up” to meet the new standard level. All efficiency shares in the base case that were above the standard under consideration would not be affected.

The tables below present the efficiency distributions for the base case and standards cases for each PTAC and PTHP equipment class. Each standards case refers to a standard at the corresponding efficiency level. For example, standards case 1 refers to the case with a standard at an efficiency level one level above the baseline: for PTAC this represents EL 2, for PTHP this represents EL 1.

Table 10.2.1 Efficiency Distributions for the Base and Standards Cases in 2019 for the PTAC <7,000 Btu/h Equipment Class

Efficiency Level*	Market Share					
	Base Case	Standards Case				
		1	2	3	4	5
Federal Minimum	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Baseline/EL 1	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
EL 2	63.5%	63.5%	0.0%	0.0%	0.0%	0.0%
EL 3	36.5%	36.5%	100.0%	0.0%	0.0%	0.0%
EL 4	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%
EL 5	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%
EL 6	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%

*The Federal Minimum efficiency level represents the efficiency level of the current federal energy conservation standards for PTAC equipment. Efficiency level 1 is the baseline level for PTAC equipment, and is the ANSI/ASHRAE/IES Standard 90.1-2013 minimum for PTAC equipment.

Table 10.2.2 Efficiency Distributions for the Base and Standards Cases in 2019 for the PTAC 7,000 – 15,000 Btu/h Equipment Class

Efficiency Level*	Market Share					
	Base Case	Standards Case				
		1	2	3	4	5
Federal Minimum	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Baseline/EL 1	37.9%	0.0%	0.0%	0.0%	0.0%	0.0%
EL 2	29.0%	68.7%	0.0%	0.0%	0.0%	0.0%
EL 3	29.3%	27.6%	96.3%	0.0%	0.0%	0.0%
EL 4	2.5%	2.5%	2.5%	98.8%	0.0%	0.0%
EL 5	0.9%	0.9%	0.9%	0.9%	99.7%	0.0%
EL 6	0.3%	0.3%	0.3%	0.3%	0.3%	100.0%

*The Federal Minimum efficiency level represents the efficiency level of the current federal energy conservation standards for PTAC equipment. Efficiency level 1 is the baseline level for PTAC equipment, and is the ANSI/ASHRAE/IES Standard 90.1-2013 minimum for PTAC equipment.

Table 10.2.3 Efficiency Distributions for the Base and Standards Cases in 2019 for the PTAC ≥15,000 Btu/h Equipment Class

Efficiency Level*	Market Share					
	Base Case	Standards Case				
		1	2	3	4	5
Federal Minimum	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Baseline/EL 1	65.1%	0.0%	0.0%	0.0%	0.0%	0.0%
EL 2	17.4%	87.4%	0.0%	0.0%	0.0%	0.0%
EL 3	17.5%	12.6%	100.0%	0.0%	0.0%	0.0%
EL 4	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%
EL 5	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%
EL 6	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%

*The Federal Minimum efficiency level represents the efficiency level of the current federal energy conservation standards for PTAC equipment. Efficiency level 1 is the baseline level for PTAC equipment, and is the ANSI/ASHRAE/IES Standard 90.1-2013 minimum for PTAC equipment.

Table 10.2.4 Efficiency Distributions for the Base and Standards Cases in 2018 for the PTHP <7,000 Btu/h Equipment Class

Efficiency Level*	Market Share					
	Base Case	Standards Case				
		1	2	3	4	5
Baseline	71.8%	0.0%	0.0%	0.0%	0.0%	0.0%
EL 1	13.8%	88.3%	0.0%	0.0%	0.0%	0.0%
EL 2	14.4%	11.7%	100.0%	0.0%	0.0%	0.0%
EL 3	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%
EL 4	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%
EL 5	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%

*The baseline efficiency level represents the efficiency level of the current federal energy conservation standards for PTHP equipment, which is the same as the ANSI/ASHRAE/IES Standard 90.1-2013 minimum efficiency for PTHP equipment.

Table 10.2.5 Efficiency Distributions for the Base and Standards Cases in 2018 for the PTHP 7,000 – 15,000 Btu/h Equipment Class

Efficiency Level*	Market Share					
	Base Case	Standards Case				
		1	2	3	4	5
Baseline	55.9%	0.0%	0.0%	0.0%	0.0%	0.0%
EL 1	8.2%	68.0%	0.0%	0.0%	0.0%	0.0%
EL 2	25.9%	22.0%	90.0%	0.0%	0.0%	0.0%
EL 3	9.5%	9.5%	9.5%	99.5%	0.0%	0.0%
EL 4	0.5%	0.5%	0.5%	0.5%	100.0%	0.0%
EL 5	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%

*The baseline efficiency level represents the efficiency level of the current federal energy conservation standards for PTHP equipment, which is the same as the ANSI/ASHRAE/IES Standard 90.1-2013 minimum efficiency for PTHP equipment.

Table 10.2.6 Efficiency Distributions for the Base and Standards Cases in 2018 for the PTHP ≥15,000 Btu/h Equipment Class

Efficiency Level*	Market Share					
	Base Case	Standards Case				
		1	2	3	4	5
Baseline	71.8%	0.0%	0.0%	0.0%	0.0%	0.0%
EL 1	2.8%	79.6%	0.0%	0.0%	0.0%	0.0%
EL 2	25.4%	20.4%	100.0%	0.0%	0.0%	0.0%
EL 3	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%
EL 4	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%
EL 5	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%

*The baseline efficiency level represents the efficiency level of the current federal energy conservation standards for PTHP equipment, which is the same as the ANSI/ASHRAE/IES Standard 90.1-2013 minimum efficiency for PTHP equipment.

Technological improvement in equipment and historical shifts to higher energy efficiency suggest that the distribution of efficiencies do not remain constant. DOE therefore used an efficiency trend to establish the efficiency distribution, as described in chapter 8, and to project the efficiency distribution for the years after the compliance year for the standard case shipments. Figure 10.2.1 illustrates the trend in market-weighted efficiency for the base case and standards cases for the PTAC 7,000 – 15,000 Btu/h cooling capacity equipment class.

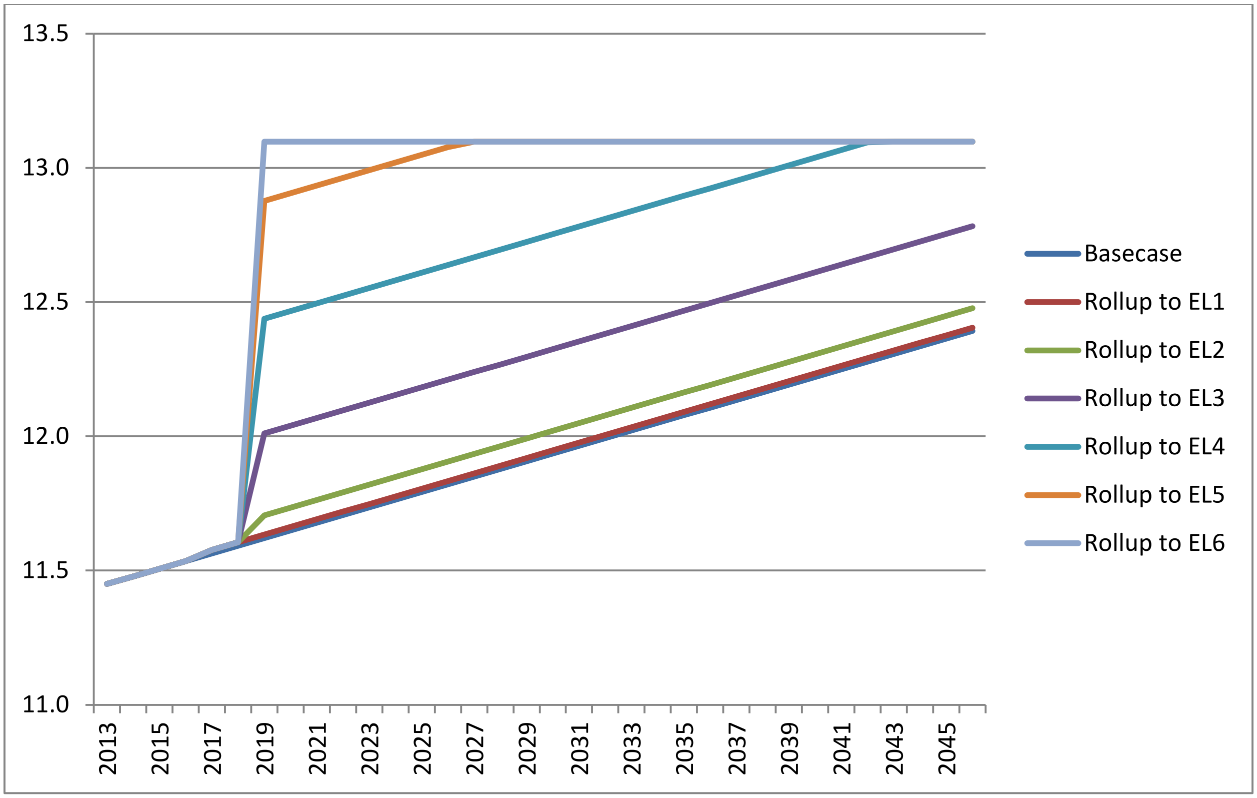

Figure 10.2.1 **Efficiency Trends for the PTAC 7,000 – 15,000 Btu/h Equipment Class**

10.3 NATIONAL ENERGY SAVINGS

10.3.1 Definition

DOE calculates annual NES as the difference between two projections: a base case (without new standards) and a standards case (with new standards). The standards cases also take into account the energy use of units repaired rather than replaced.

The calculation of annual nation energy savings (NES_y) are represented by the following expressions.

$$NES_y = AEC_{natl-base} - AEC_{natl-std}$$

Cumulative energy savings are the sum of each annual *NES* over the lifetime of equipment shipped or repaired in the period that extends from a standard's assumed compliance date for 30 years. This calculation is represented by the following equations for:

$$NES_{cum} = \sum NES_y$$

DOE calculated *AEC* by multiplying the number or stock of a given piece of equipment (by vintage) by its unit energy consumption (also by vintage). The calculation of the national and each regional *AEC* is represented by the following equation:

$$AEC = \sum STOCK_V \times UEC_V$$

Where:

$AEC =$ annual energy consumption each year for the Nation in quadrillion British thermal units (Btus)—quads—summed over vintages of the equipment stock, $STOCK_V$;
$NES_y =$ national annual energy savings (quads);
$NES_{cum} =$ national cumulative energy savings (quads);
$STOCK_V =$ stock of equipment (millions of units) of vintage V that survive in the year for which DOE calculated annual energy consumption;
$UEC_V =$ annual energy consumption per unit in kilowatt-hours (kWh); electricity consumption is converted from site energy to power plant energy (quads) by applying a time-dependent conversion factor;
$natl =$ designates the quantity corresponding to the Nation;
$base =$ designates the quantity corresponding to the base case;
$std =$ designates the quantity corresponding to the standards case;
$y =$ year in the projection; and
$cum =$ cumulative over the projection period; and
$V =$ year in which the equipment was purchased as a new unit.

The stock of PTAC and PTHP equipment is dependent on annual shipments, repairs, and the lifetime of the equipment. As described in Chapter 9, DOE conducted shipments projections under the base case and standards cases. DOE determined that the shipment projections under the standards cases were lower than those in the base case projection, due to the higher installed cost of the more-efficient equipment, which would cause some customers to repair rather than replace equipment. These so-called extended repairs are higher in the standards cases.

10.3.2 NES Inputs

The inputs for calculating national energy savings are:

- average annual energy consumption per unit (*UEC*),
- shipments and extended repairs,
- equipment stock ($STOCK_V$),
- annual energy consumption for the Nation (*AEC*), and
- power plant primary energy use factor (*src_conv*).

10.3.2.1 Annual Energy Consumption per Unit

The annual energy consumption per unit (UEC) is the site energy consumed by a PTAC or PTHP unit per year. The annual energy consumption is directly tied to the efficiency of the unit. Thus, knowing the efficiency of a PTAC or PTHP unit enables a determination of the corresponding annual energy consumption.

For PTACs, as detailed in chapter 7, DOE used unit energy consumption data obtained from the 2008 Energy Conservation Standards Rulemaking for PTAC equipment. To account for differences in cooling capacity and/or EER from the previous rulemaking, the UEC (cooling) for each equipment class and each efficiency level were linearly scaled from source to target cooling capacity and/or EER.

For PTHP, also detailed in chapter 7, DOE used unit energy consumption data obtained from the 2008 Energy Conservation Standards Rulemaking for PHTP equipment. To account for differences in cooling capacity and/or EER from the previous rulemaking, the UECs (cooling potion) for each equipment class and each efficiency level were linearly scaled from source to target cooling capacity and/or EER. To account for differences in COP from the previous rulemaking, the UECs (heating potion) for each equipment class and each efficiency level were linearly scaled from source to target cooling capacity and/or COP.

DOE adjusted UECs to account for changes in climate based on analyses of weather databases. DOE determined annual projected market shares by efficiency level that, in turn, when multiplied by annual energy consumption values by efficiency level, enabled a determination of shipment-weighted annual energy consumption values.

10.3.2.2 Shipments

DOE projected shipments for the base case and all standards cases (see Chapter 9). Several factors, including total installed costs, operating cost, and equipment lifetime, all impact projected shipments. Of the above factors, total installed costs were the primary driver in projecting the impact of standards on shipments. As noted earlier, the increased installed cost of more-efficient equipment causes some customers to forego equipment purchases. Consequently, shipments projected under the standards cases are lower than those projected under the base case. An extensive description of the methodology for conducting and generating the shipments projections can be found in Chapter 9.

10.3.2.3 Equipment Stock

The PTAC and PTHP stock in a given year is the number of PTAC and PTHP units shipped from earlier years that survive in the given year. The NIA model keeps track of the PTAC and PTHP equipment shipped each year. DOE assumed that PTAC and PTHP equipment have an increasing probability of retiring as they age. The probability of survival as a function of years-since-purchase is the survival function. Lifetimes range from 1 to approximately 20 years, with an average lifetime of 10 years (see Chapters 8 and 9 for further details).

10.3.2.4 National Annual Energy Consumption

The national energy consumption is the product of the per-unit PTAC and PTHP annual energy consumption and the number of PTAC and PTHP units of each vintage and efficiency. This approach accounts for differences in unit energy consumption from year to year.

For each equipment class, DOE calculated the total national site (*i.e.*, the energy consumed at the household or establishment) annual energy consumption (AEC). Annual energy consumption is the product of the AEC per unit [also termed the unit energy consumption (UEC)] and the number of units of each vintage and efficiency. This method accounts for differences in UEC from year to year.

In determining national annual energy consumption, DOE initially calculated the annual energy consumption at the site (i.e., electricity in kWh consumed by the PTAC and PTHP unit within the building it is serving). DOE then calculated primary energy consumption from site energy consumption by applying a conversion factor to account for losses associated with the generation, transmission, and distribution of electricity.

10.3.2.5 Site to Primary Energy Conversion Factor

DOE calculates primary energy savings (power plant consumption) from site energy savings by applying a factor to account for losses associated with the generation, transmission, and distribution of electricity. DOE derived annual average site-to-power plant factors based on the version of the National Energy Modeling System (NEMS) that corresponds to Energy Information Administration (EIA) *Annual Energy Outlook 2014* (*AEO 2014*)[1]. The factors change over time in response to projected changes in the types of power plants projected to provide electricity to the country. Figure 10.3.1 shows the site-to-power plant factors from 2019 to the end of the projection period. For years after 2040 (the last year in the *AEO*), DOE held the factors constant at the 2040 value.

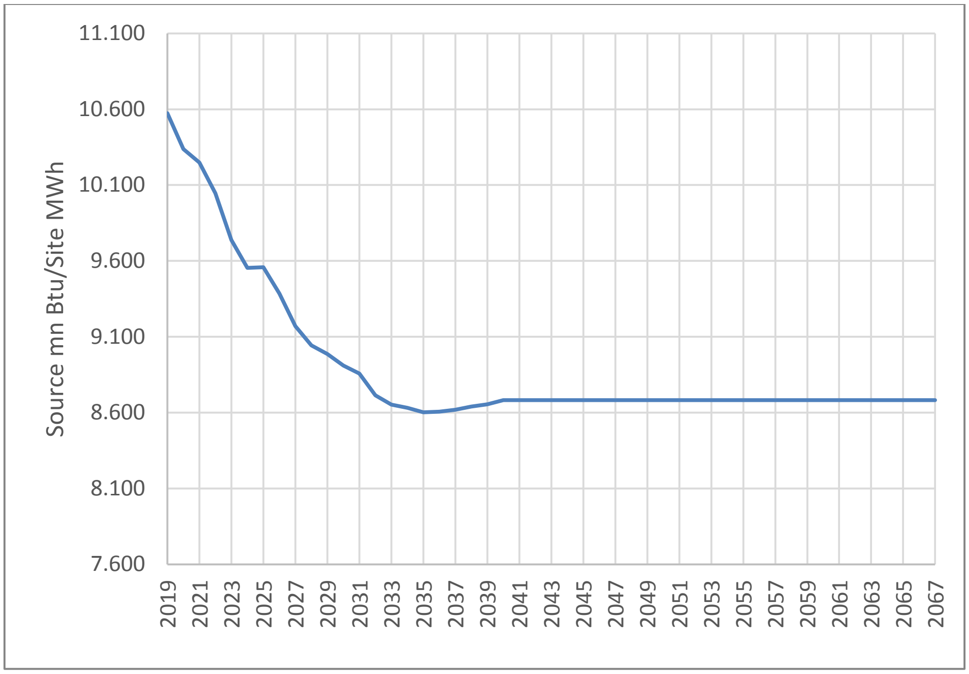

Figure 10.3.1 Site-to-Power Plant Energy Use Factors

10.3.2.6 Full-Fuel-Cycle Energy Factors

The full-fuel-cycle (FFC) measure includes point-of-use (site) energy, the energy losses associated with generation, transmission, and distribution of electricity, and the energy consumed in extracting, processing, and transporting or distributing primary fuels. To complete the full-fuel-cycle by encompassing the energy consumed in extracting, processing, and transporting or distributing primary fuels, which we refer to as “upstream” activities, DOE developed FFC multipliers[a] using the data and projections generated by the NEMS used for *AEO 2014*. The AEO provides extensive information about the energy system, including projections of future oil, natural gas and coal supply, energy use for oil and gas field and refinery operations, and fuel consumption and emissions related to electric power production. This information can be used to define a set of parameters representing the energy intensity of energy production.

Table 10.3.1 shows the FFC energy multipliers used for PTACs and PTHPs for selected years. The method used to calculate FFC energy multipliers is described in appendix 10-A.

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[a] FFC multipliers discussed in this chapter relate to the upstream part of the FFC process.

Table 10.3.1 Full-Fuel-Cycle Energy Multipliers (Based on AEO 2014)

	2019	2020	2025	2030	2035	2040
Electricity (power plant energy use)	1.043	1.044	1.045	1.046	1.047	1.047
Natural Gas (site)	1.108	1.109	1.111	1.113	1.114	1.114
Petroleum Fuels (site)	1.176	1.176	1.176	1.174	1.172	1.170

10.4 NET PRESENT VALUE OF CUSTOMER BENEFITS

10.4.1 Net Present Value Definition

The NPV is the value in the present of a time-series of costs and savings. The NPV is described by the equation:

$$\boldsymbol{NPV = PVS - PVC}$$

Where:

PVS = present value of savings in operating cost (including costs for energy, repair, and maintenance); and
PVC = present value of increase in total installed cost (including costs for equipment, extended repairs, and installation).

DOE determined the *PVS* and *PVC* according to the following expressions.

$$PVS = \sum OCS_y \times DF_y$$

$$PVC = \sum TIC_y \times DF_y$$

DOE calculated the total annual savings in operating cost by multiplying the number or stock of a given equipment (by vintage) by its per-unit operating cost savings (also by vintage). DOE calculated the total annual increase in installed cost by multiplying the number or stock of a given equipment (by vintage) by its per-unit total installed cost increase or extended repair cost (also by vintage). Total annual savings in operating cost and increases in installed cost and extended repair cost are calculated using the following equations.

$$OCS_y = \sum STOCK_V \times UOCS_V$$

$$TIC_y = \sum STOCK_V \times UTIC_V$$

Where:

OCS = total *annual* savings in operating cost each year summed over vintages of the equipment stock, $STOCK_V$;
TIC = total annual increase in installed cost and extended repair cost each year summed over vintages of the equipment stock, $STOCK_V$;
DF = discount factor in each year;
$STOCK_V$ = stock of equipment (millions of units) of vintage V that survive in the year for which DOE calculated annual energy consumption;
$UOCS_V$ = annual per-unit savings in operating cost;
$UTIC_V$ = annual total per-unit increase in installed cost and extended repair cost;
V = year in which the equipment was purchased as a new unit or repaired; and
y = year in the projection.

DOE determined the *PVC* for each year from the compliance date of the standard until the end of the analysis period, which is 2048 for PTAC and 2047 for PTHP. DOE determined the *PVS* for each year from the compliance date of the standard until the year when units purchased or repaired at the end of the analysis period retire. DOE calculated costs and savings as the difference between each standards case and the base case.

DOE calculated a discount factor from the discount rate and the number of years between the "present" (2014, the year to which the sum is being discounted) and the year in which the costs and savings occur. The NPV is the sum over time of the discounted net savings.

10.4.2 Inputs to Calculation

Listed below are the inputs to DOE's calculation of the NPV of costs and savings.

- total annual installed cost,
- total annual operating costs,
- discount factor (*DF*),
- present value of total annual increases in installed cost (*TIC*),
- present value of savings (*PVS*).

The *total annual increase in installed cost* is equal to the annual change in the total per-unit installed cost (difference between base case and standards case) multiplied by the shipments projected for each standards case. As with calculating energy savings, DOE did not use base-case shipments to calculate total annual installed costs for all of the equipment classes. DOE used the projected shipments and stock for each standards case to calculate costs.

The annual operating cost includes energy and maintenance costs. The *total annual savings in operating cost* are equal to the change in the annual operating costs (difference between base case and standards case) per unit multiplied by the shipments projected for each candidate standard level. As with calculating total annual installed costs, DOE did not use base-case shipments to calculate savings in operating cost.

10.4.2.1 Total Annual Installed Cost

The increase in the total annual installed cost is equal to the annual change in the per-unit total installed cost (difference between base case and standards case) multiplied by the shipments projected in the standards case. The total installed cost includes both the equipment cost and the installation cost. Table 10.4.1 provides average total installed cost values by efficiency level for all PTAC and PTHP equipment classes.

Table 10.4.1 Average Total Installed Costs for PTACs in 2019 and PTHPs in 2018 (2014$)

	Efficiency Level*						
Equipment Class	**Federal Minimum**	**Baseline/ EL 1**	**EL 2**	**EL 3**	**EL 4**	**EL 5**	**EL 6**
PTAC <7,000 Btu/h	$1,313	$1,324	$1,333	$1,351	$1,372	$1,395	$1,406
PTAC 7,000 – 15,000 Btu/h	$1,422	$1,433	$1,442	$1,459	$1,477	$1,497	$1,508
PTAC ≥15,000 Btu/h	$1,678	$1,691	$1,700	$1,723	$1,753	$1,790	$1,811
Equipment Class		**Baseline**	**EL 1**	**EL 2**	**EL 3**	**EL 4**	**EL 5**
PTHP <7,000 Btu/h		$1,431	$1,440	$1,458	$1,479	$1,502	$1,514
PTHP 7,000 – 15,000 Btu/h		$1,544	$1,552	$1,570	$1,588	$1,608	$1,619
PTHP ≥15,000 Btu/h		$1,796	$1,805	$1,828	$1,858	$1,895	$1,916

*The Federal Minimum efficiency level represents the efficiency level of the current federal energy conservation standards for PTAC equipment. Efficiency level 1 is the baseline level for PTAC equipment, and is the ANSI/ASHRAE/IES Standard 90.1-2013 minimum for PTAC equipment. The baseline efficiency level represents the efficiency level of the current federal energy conservation standards for PTHP equipment, which is the same as the ANSI/ASHRAE/IES Standard 90.1-2013 minimum efficiency for PTHP equipment.

As discussed in section 10.2, DOE developed base case and standards case projections of market share by efficiency level. DOE multiplied the market share by efficiency level in each year by the values in Table 10.4.1 to calculate annual shipment-weighted average total installed costs.

10.4.2.2 Total Annual Operating Cost

The annual operating cost savings are equal to the change in the annual operating costs (difference between base case and standards case) per unit multiplied by the shipments projected in the standards case. The annual operating cost includes electricity and repair/maintenance costs.

Annual Electricity Cost Savings

As explained in Chapter 7, DOE calculated annual electricity costs using data from the 2008 rulemaking which provided unit energy consumption for PTACs and PTHPs. Chapter 8 describes how DOE calculated annual electricity prices for PTAC and PTHP equipment.

Table 10.4.2 provides weighted-average annual electricity expense values for each efficiency level and each PTAC and PTHP equipment class.

Table 10.4.2 Average Annual Electricity Costs for PTAC in 2019 and for PTHP in 2018 (2014$)

	Efficiency Level*						
Equipment Class	**Federal Minimum**	**Baseline/ EL 1**	**EL 2**	**EL 3**	**EL 4**	**EL 5**	**EL 6**
PTAC <7,000 Btu/h	$80	$79	$77	$75	$73	$70	$69
PTAC 7,000 – 15,000 Btu/h	$96	$95	$94	$91	$89	$86	$85
PTAC ≥15,000 Btu/h	$151	$150	$148	$145	$143	$140	$138
Equipment Class		**Baseline**	**EL 1**	**EL 2**	**EL 3**	**EL 4**	**EL 5**
PTHP <7,000 Btu/h		$152	$150	$147	$144	$141	$139
PTHP 7,000 – 15,000 Btu/h		$174	$172	$168	$165	$162	$160
PTHP ≥15,000 Btu/h		$250	$249	$244	$240	$235	$233

*The Federal Minimum efficiency level represents the efficiency level of the current federal energy conservation standards for PTAC equipment. Efficiency level 1 is the baseline level for PTAC equipment, and is the ANSI/ASHRAE/IES Standard 90.1-2013 minimum for PTAC equipment. The baseline efficiency level represents the efficiency level of the current federal energy conservation standards for PTHP equipment, which is the same as the ANSI/ASHRAE/IES Standard 90.1-2013 minimum efficiency for PTHP equipment.

As with the total installed cost data, DOE developed projected annual electricity expenses based on the annual projections of market share by efficiency level specified in the base case and standards cases. DOE multiplied the market share by efficiency level in each year by the values in Table 10.4.2 to calculate annual shipment-weighted average annual electricity costs. DOE then applied electricity price trends from *AEO 2014* to scale the electricity expenses moving forward.

Annual Maintenance Costs

DOE determined the average annual maintenance costs to be $56 for PTACs and $62 for PTHPs. Because maintenance costs do not change with efficiency, annual maintenance costs do not factor into the determination of the total operating cost savings.

Annual Repair Costs

Since annualized warranty costs offer a proxy price for the price of a repair, DOE determined the average annual repair cost for PTACs and PTHPs by dividing the total cost of various manufacturer- and third-party-provided warranties for a unit by the duration of the warranty. Table 10.4.3 provides repair cost values by efficiency level for the PTAC and PTHP equipment classes.

Table 10.4.3 Average Repair Cost Per Unit for PTACs in 2019 and PTHPs in 2018 (2014$)

	Efficiency Level*						
Equipment Class	**Federal Minimum**	**Baseline/ EL 1**	**EL 2**	**EL 3**	**EL 4**	**EL 5**	**EL 6**
PTAC <7,000 Btu/h	$69	$70	$70	$71	$72	$72	$73
PTAC 7,000 – 15,000 Btu/h	$70	$70	$71	$71	$72	$73	$74
PTAC ≥15,000 Btu/h	$72	$72	$73	$74	$74	$75	$76
Equipment Class		**Baseline**	**EL 1**	**EL 2**	**EL 3**	**EL 4**	**EL 5**
PTHP <7,000 Btu/h		$62	$62	$62	$62	$62	$62
PTHP 7,000 – 15,000 Btu/h		$75	$75	$76	$77	$77	$78
PTHP ≥15,000 Btu/h		$77	$77	$78	$79	$80	$80

*The Federal Minimum efficiency level represents the efficiency level of the current federal energy conservation standards for PTAC equipment. Efficiency level 1 is the baseline level for PTAC equipment, and is the ANSI/ASHRAE/IES Standard 90.1-2013 minimum for PTAC equipment. The baseline efficiency level represents the efficiency level of the current federal energy conservation standards for PTHP equipment, which is the same as the ANSI/ASHRAE/IES Standard 90.1-2013 minimum efficiency for PTHP equipment.

10.4.2.3 Discount Factor

DOE multiplied monetary values in future years by a discount factor to determine the present value. The discount factor (DF) is described by the equation:

$$DF = \frac{1}{(1+r)^{(y-yp)}}$$

Where:

r = discount rate,

y = year of the monetary value, and

y_P = year in which the present value is being determined.

Although DOE used consumer discount rates to determine the life-cycle cost of PTAC equipment (chapter 8), it used national discount rates to calculate national NPV. DOE estimated NPV using both a 3% and a 7% real discount rate, in accordance with the Office of Management and Budget's guidance to Federal agencies on the development of regulatory analysis, particularly section E therein: Identifying and Measuring Benefits and Costs.[2] DOE defined the present year as 2014.

10.4.2.4 Present Value of Increased Installed Costs

The present value of increased installed cost is the difference between installation cost in each standards case and the base case discounted to the present and summed throughout the period over which DOE is considering the installation of units.. DOE calculated annual increases in installed cost as the difference in total installed cost for new equipment purchased each year between the base case and each standards case. DOE also calculated the repair costs for units that are repaired rather than replaced in the standards cases.

10.4.2.5 Present Value of Savings

The present value of annual savings in operating cost is the difference between the base case and each standards case discounted to the present and summed throughout the period from the compliance date, to the time when the last unit is retired from service.

Savings represent decreases in operating cost (including electricity and maintenance) associated with the more energy efficient equipment purchased in each standards case compared to the base case. Savings are reduced by the energy costs associated with units that are repaired rather than replaced in the standards cases. Total annual savings in operating cost are the savings per unit multiplied by the number of units of each vintage that survive in a particular year.

10.5 TRIAL STANDARD LEVELS

DOE developed TSLs that combine efficiency levels for each equipment class. Table 10.5.1 presents the efficiency levels for each equipment class in each TSL.

Table 10.5.1 Trial Standard Levels for PTACs and PTHPs

Equipment Class	**ASHRAE**	**TSL 1**	**TSL 2**	**TSL 3**	**TSL 4**	**TSL 5**
	Efficiency Level					
PTAC <7,000 Btu/h	1	2	3	4	5	6
PTAC 7,000 – 15,000 Btu/h	1	2	3	4	5	6
PTAC ≥15,000 Btu/h	1	2	3	4	5	6
PTHP <7,000 Btu/h	0	1	2	3	4	5
PTHP 7,000 – 15,000 Btu/h	0	1	2	3	4	5
PTHP ≥15,000 Btu/h	0	1	2	3	4	5

10.6 NES AND NPV RESULTS

10.6.1 National Energy Savings

The following section provides NES results for the trial standard levels considered for PTAC and PTHP equipment. DOE based the inputs to the NIA model on weighted-average values, yielding results that are discrete point values rather than a distribution of values as in the LCC analysis.

Table 10.6.1 and Table 10.6.2 show the NES results for the TSLs that DOE analyzed. Each of the standards cases represented by TSLs was compared to the base case represented by the ASHRAE level. NES for the ASHRAE level were determined by comparing to a base case represented by the Federal minimum efficiency levels of current energy conservation standards. To demonstrate the relative share of the energy savings due to each equipment class, DOE disaggregated the results by PTAC and PTHP equipment class.

Table 10.6.1 Cumulative Primary Energy Savings for PTAC and PTHP equipment (quads)

Equipment Class**	ASHRAE*	Trial Standard Level				
		1	2	3	4	5
PTAC <7,000 Btu/h	0.000	0.000	0.001	0.002	0.003	0.003
PTAC 7,000 – 15,000 Btu/h	0.000	0.004	0.020	0.041	0.052	0.053
PTAC ≥15,000 Btu/h	0.001	0.000	0.002	0.004	0.005	0.005
PTHP <7,000 Btu/h	-	0.000	0.001	0.002	0.003	0.003
PTHP 7,000 – 15,000 Btu/h	-	0.007	0.024	0.046	0.058	0.060
PTHP ≥15,000 Btu/h	-	0.001	0.003	0.005	0.006	0.006
Total – All Classes	**0.001**	**0.013**	**0.052**	**0.100**	**0.127**	**0.130**

*Cells that have “-“ have zero energy savings because efficiency remains the same at this level.
**Energy savings of 0.000 have energy savings but cannot be shown due to rounding.

Table 10.6.2 Full-Fuel-Cycle National Energy Savings for PTAC and PTHP (quads)

Equipment Class**	ASHRAE*	Trial Standard Level				
		1	2	3	4	5
PTAC <7,000 Btu/h	0.000	0.000	0.001	0.002	0.003	0.003
PTAC 7,000 – 15,000 Btu/h	0.000	0.004	0.020	0.042	0.053	0.054
PTAC ≥15,000 Btu/h	0.001	0.000	0.002	0.004	0.005	0.005
PTHP <7,000 Btu/h	-	0.000	0.001	0.002	0.003	0.003
PTHP 7,000 – 15,000 Btu/h	-	0.007	0.025	0.047	0.059	0.061
PTHP ≥15,000 Btu/h	-	0.001	0.003	0.005	0.006	0.007
Total – All Classes	**0.001**	**0.014**	**0.052**	**0.102**	**0.129**	**0.133**

*Cells that have “-“ have zero energy savings because efficiency remains the same at this level.
**Energy savings of 0.000 have energy savings but cannot be shown due to rounding.

10.6.2 Annual Costs and Savings

As a prelude to providing the NPVs for each trial standard level in each equipment class, this section presents the annual total installed cost increases and annual operating cost savings for each product class at the national level at TSL 2 as a means to illustrate the inputs for the calculation of NPV.

Figure 10.6.1 to Figure 10.6.5 show the changes over time of the non-discounted annual total equipment cost increases and the non-discounted operating cost savings for each product class at TSL 2.[b] The figures also show the net annual impact, which is the difference between the savings and costs for each year. The annual incremental equipment cost is the increase in the total installed cost for equipment purchased each year. The annual operating cost savings is the savings in operating costs for equipment that has been purchased, and has not been retired, for each year until all purchased equipment has been retired. The NPV is the difference between the cumulative annual discounted savings and the cumulative annual discounted costs.

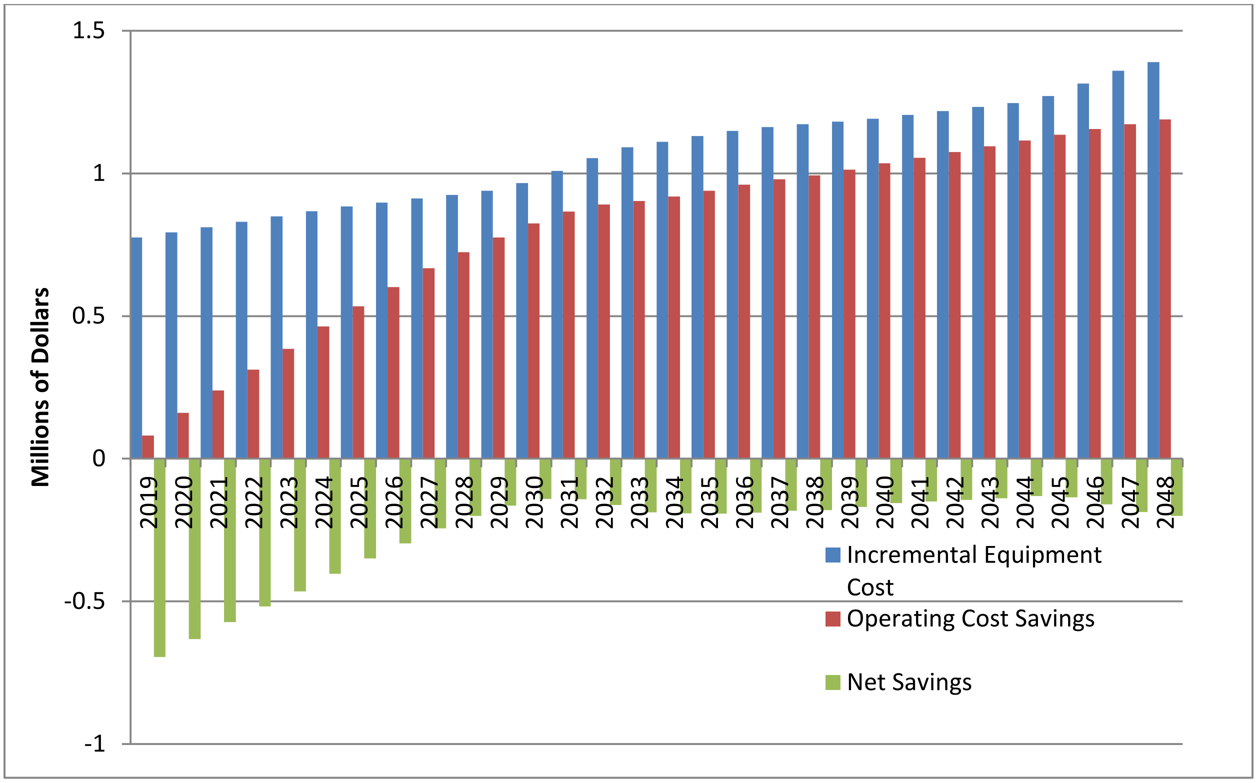

Figure 10.6.1 **Packaged Terminal Air Conditioners 7,000 Btu/h – 15, 000 Btu/h: Incremental Equipment Costs, Operating Cost Savings, and Net Savings; TSL 2**

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[b] Note that the annual costs and savings for the PTAC <7,000 Btu/h cooling capacity equipment class are excluded as they have no market share at TSL 2.

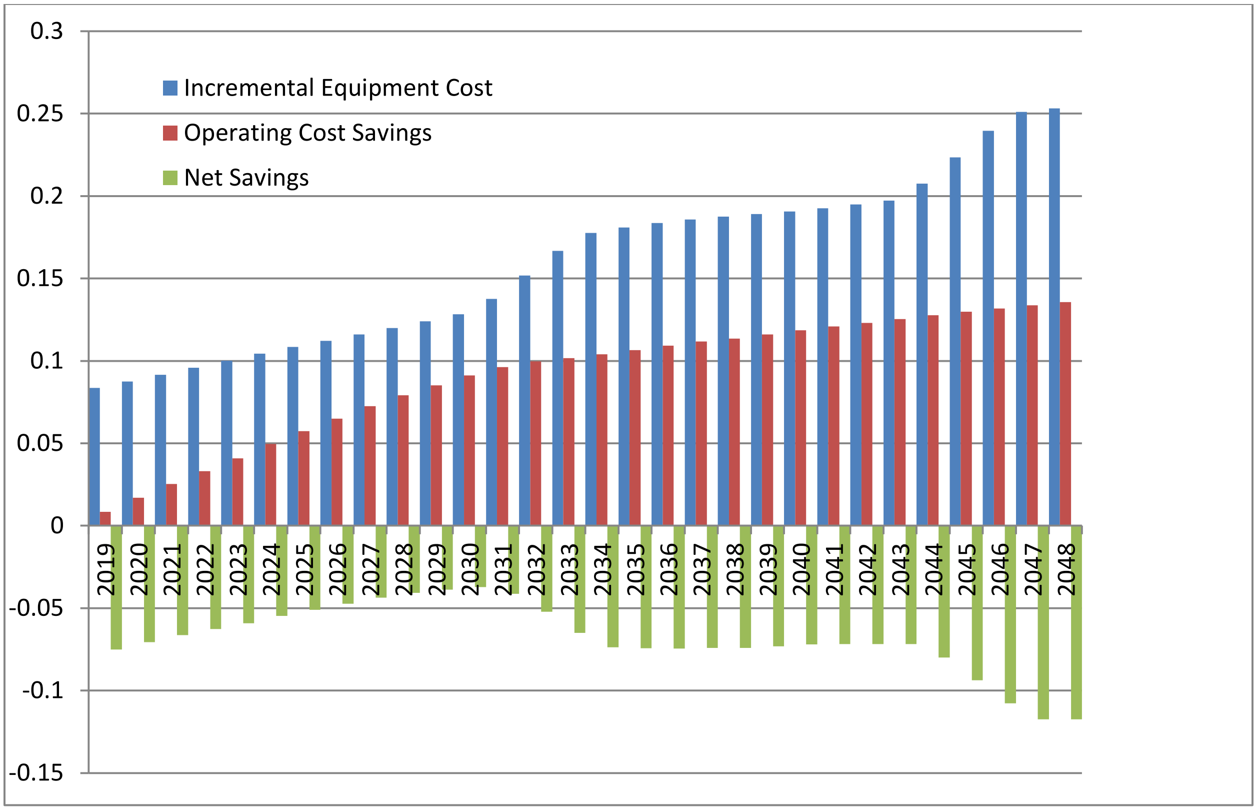

Figure 10.6.2 **Packaged Terminal Air Conditioners ≥15,000 Btu/h: Incremental Equipment Costs, Operating Cost Savings, and Net Savings; TSL 2**

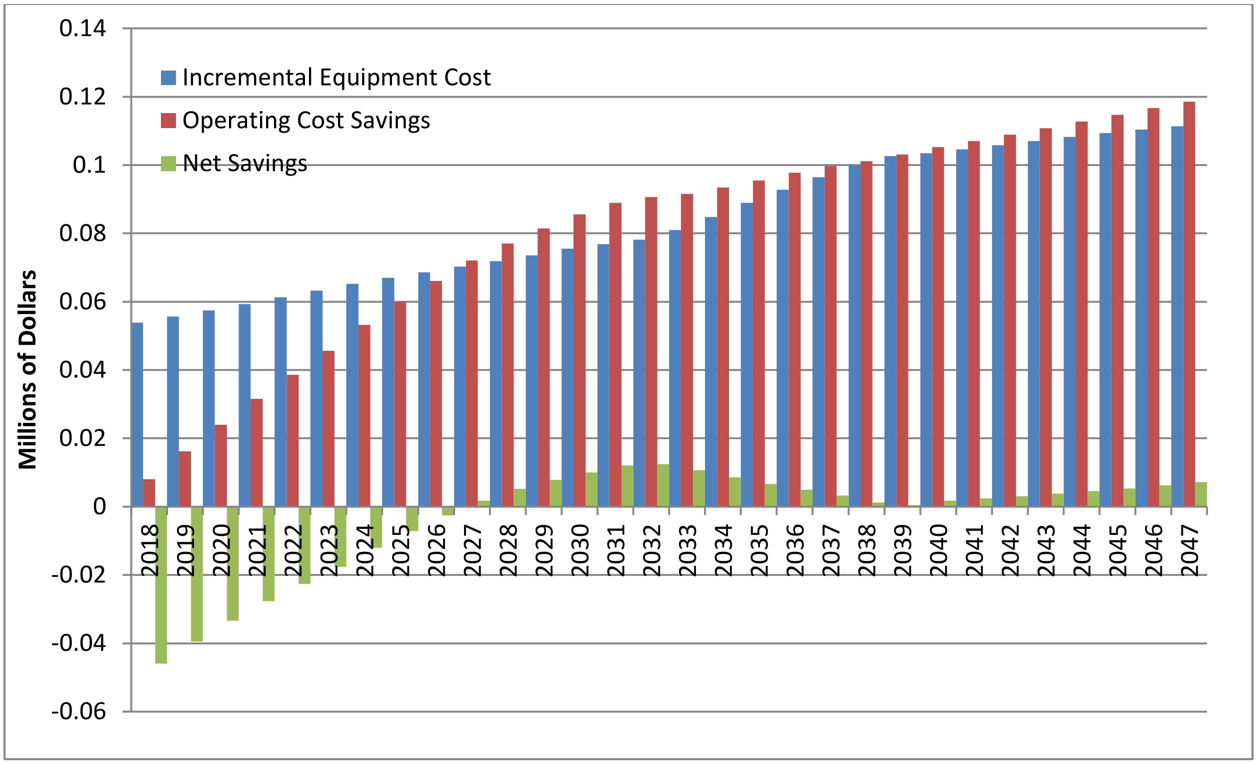

Figure 10.6.3 **Packaged Terminal Heat Pumps <7,000 Btu/h: Incremental Equipment Costs, Operating Cost Savings, and Net Savings; TSL 2**

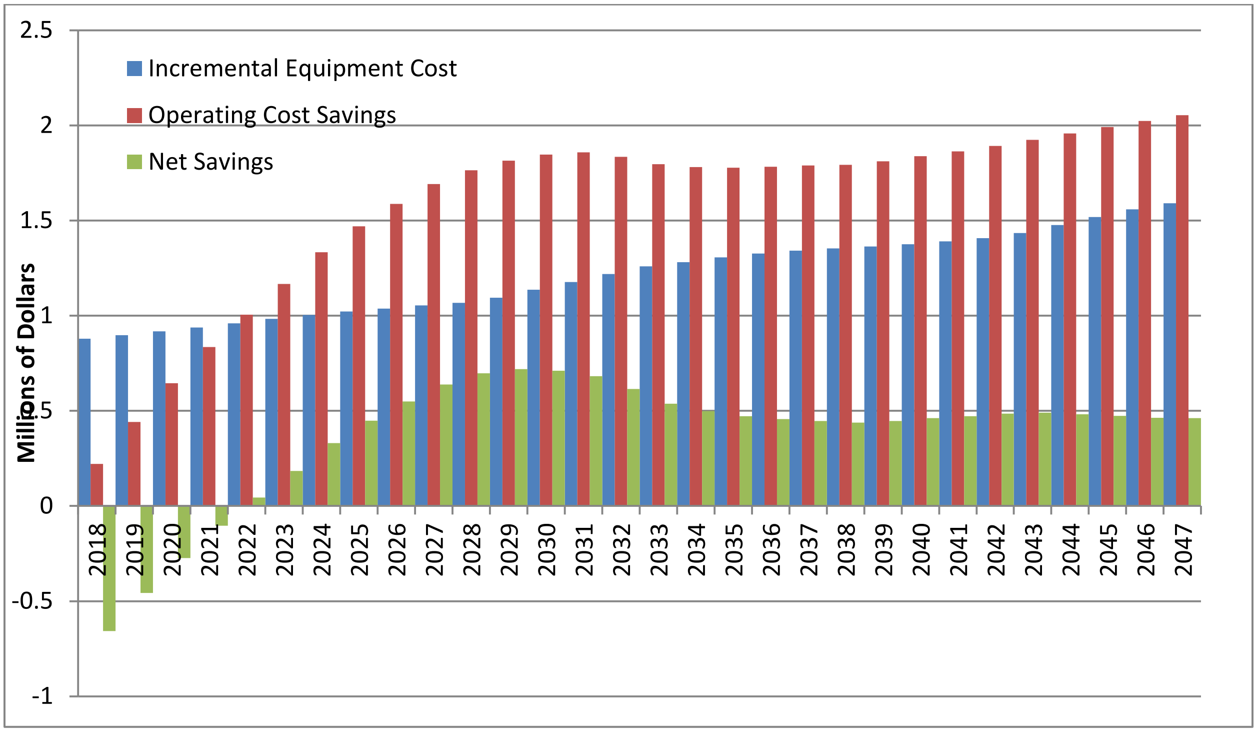

Figure 10.6.4 **Packaged Terminal Heat Pumps 7,000 Btu/h – 15, 000 Btu/h: Installed Costs, Operating Cost Savings, and Net Savings; TSL 2**

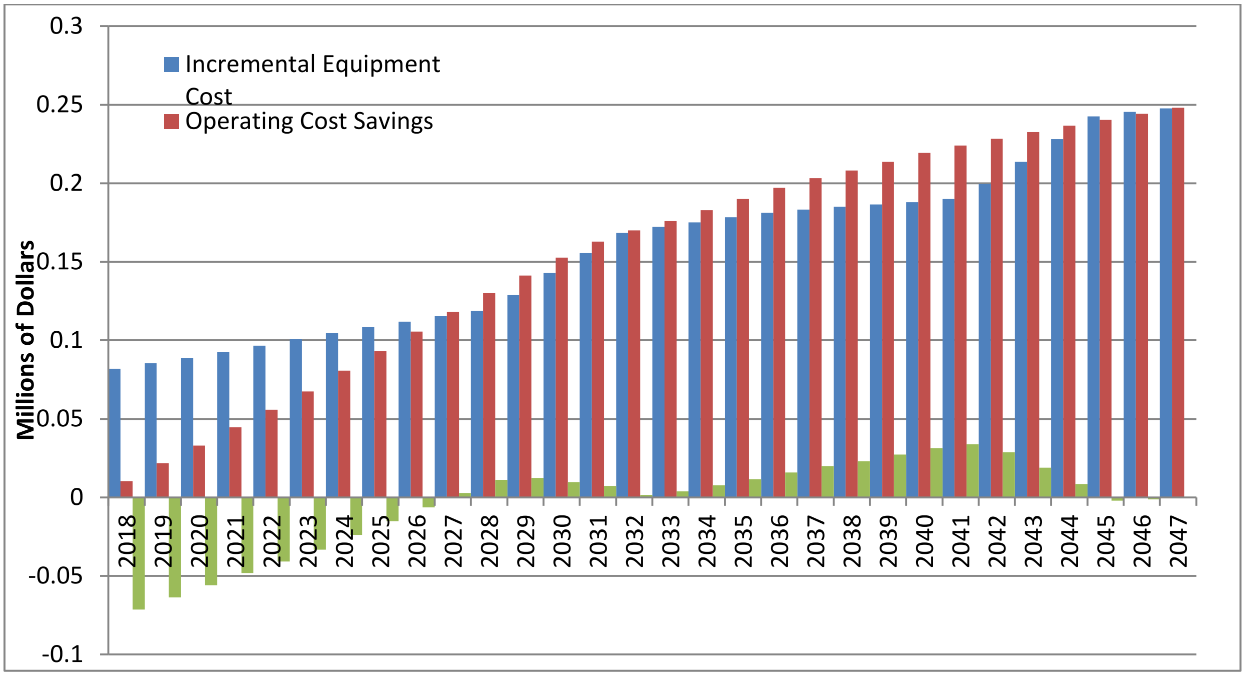

Figure 10.6.5 **Packaged Terminal Heat Pumps ≥15,000 Btu/h: Incremental Equipment Costs, Operating Cost Savings, and Net Savings; TSL 2**

10.6.3 Net Present Value Results

The following section provides NPV results for the trial standard levels considered for PTAC and PTHP equipment. Results are cumulative and are shown as discounted values in dollar terms.

The present value of increased total installed costs is the total installed cost increase (i.e., the difference between the standards case and base case), discounted to the present, and summed over the period of shipments forecasts. The results presented here assume no change in equipment prices during the forecast period. NPV results are not presented for the ASHRAE levels, unlike NES results, because DOE receives no benefit from economic savings when adopting a mandatory efficiency level, which is the efficiency level set forth in ASHRAE Standard 90.1-2013 for PTAC equipment.

Savings are decreases in operating costs associated with the higher energy efficiency of PTAC and PTHP equipment purchased in the standards case compared to the base case. Total operating cost savings are the savings per unit multiplied by the number of units of each vintage (i.e., the year of manufacture) surviving in a particular year. The operating cost includes energy consumed and maintenance and repair costs incurred until the last unit is retired from service.

Table 10.6.3 and Table 10.6.4 show the NPV results for PTAC and PTHP equipment at each TSL, based on a seven-percent discount rate. DOE based all results on electricity price forecasts from the *AEO2014* Reference Case. Table 10.6.4 and Figure 10.6.6 provide the NPV results based on a three-percent discount rate and electricity price forecasts from the *AEO2014* Reference Case.

DOE also developed sensitivity analyses using an increasing product price trend and a decreasing product price trend coupled with *AEO2014* Low Economic Growth and High Economic Growth cases, respectively. These product trends and AEO Economic Growth case are described in appendix 10-B, which also presents NPV results based on these alternative sensitivities.

Table 10.6.3 Cumulative NPV Results for PTAC and PTHP, 7% Discount Rate (millions 2014$)

Equipment Class	**Trial Standard Level**				
	1	**2**	**3**	**4**	**5**
PTAC <7,000 Btu/h	0.0	-1.0	-3.0	-4.6	-5.0
PTAC 7,000 – 15,000 Btu/h	-2.7	-14.9	-35.6	-53.9	-57.6
PTAC ≥15,000 Btu/h	-0.5	-3.3	-7.5	-10.9	-11.6
PTHP <7,000 Btu/h	-0.1	-0.5	-1.1	-1.8	-1.9
PTHP 7,000 – 15,000 Btu/h	3.3	2.9	-0.7	-6.3	-7.7
PTHP ≥15,000 Btu/h	-0.1	-0.6	-2.2	-3.9	-4.3
Total – All Classes	**-0.1**	**-17.3**	**-50.2**	**-81.4**	**-88.1**

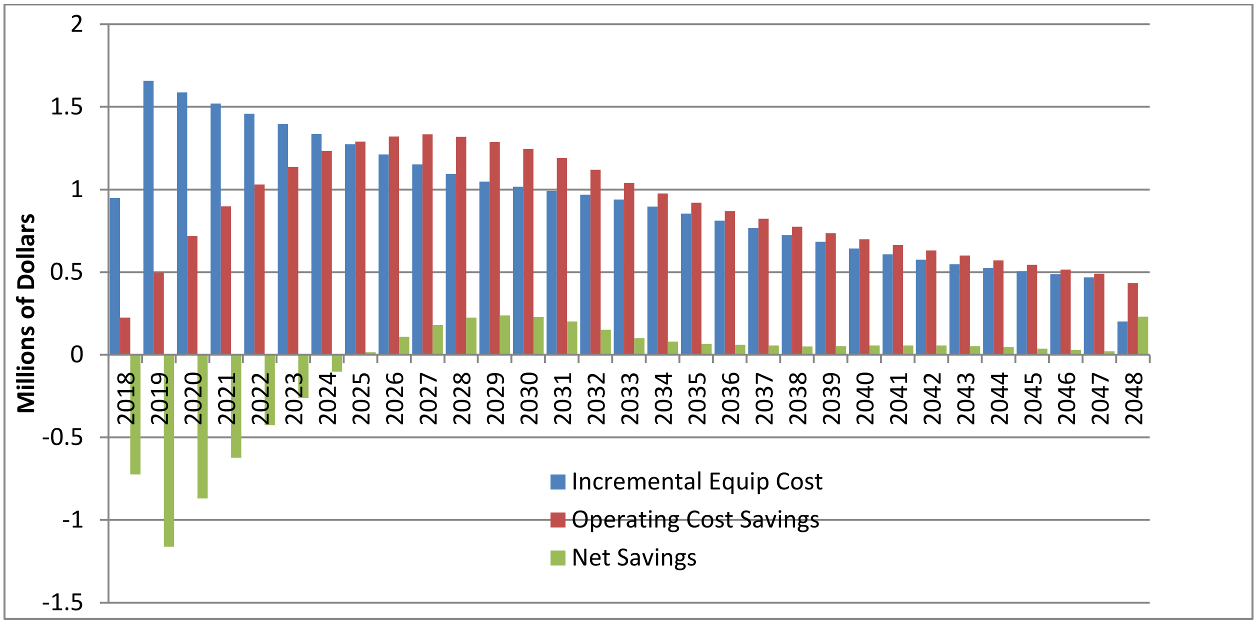

Figure 10.6.6 Present Value of Annual Costs and Benefits for all PTACs and PTHPs, 7% Discount Rate at TSL 2

Table 10.6.4 Cumulative NPV Results for PTAC and PTHP, 3% Discount Rate (millions 2014$)

Product Class	Trial Standard Level				
	1	**2**	**3**	**4**	**5**
PTAC <7,000 Btu/h	0.0	-1.6	-4.6	-6.9	-7.2
PTAC 7,000 – 15,000 Btu/h	-3.0	-18.2	-46.2	-68.7	-72.7
PTAC ≥15,000 Btu/h	-0.9	-5.7	-12.7	-17.5	-18.3
PTHP <7,000 Btu/h	0.1	-0.1	-0.8	-1.4	-1.5
PTHP 7,000 – 15,000 Btu/h	9.4	19.1	25.7	25.7	25.1
PTHP ≥15,000 Btu/h	0.3	0.5	-1.1	-2.8	-3.1
Total – All Classes	**5.9**	**-6.0**	**-39.7**	**-71.5**	**-77.7**

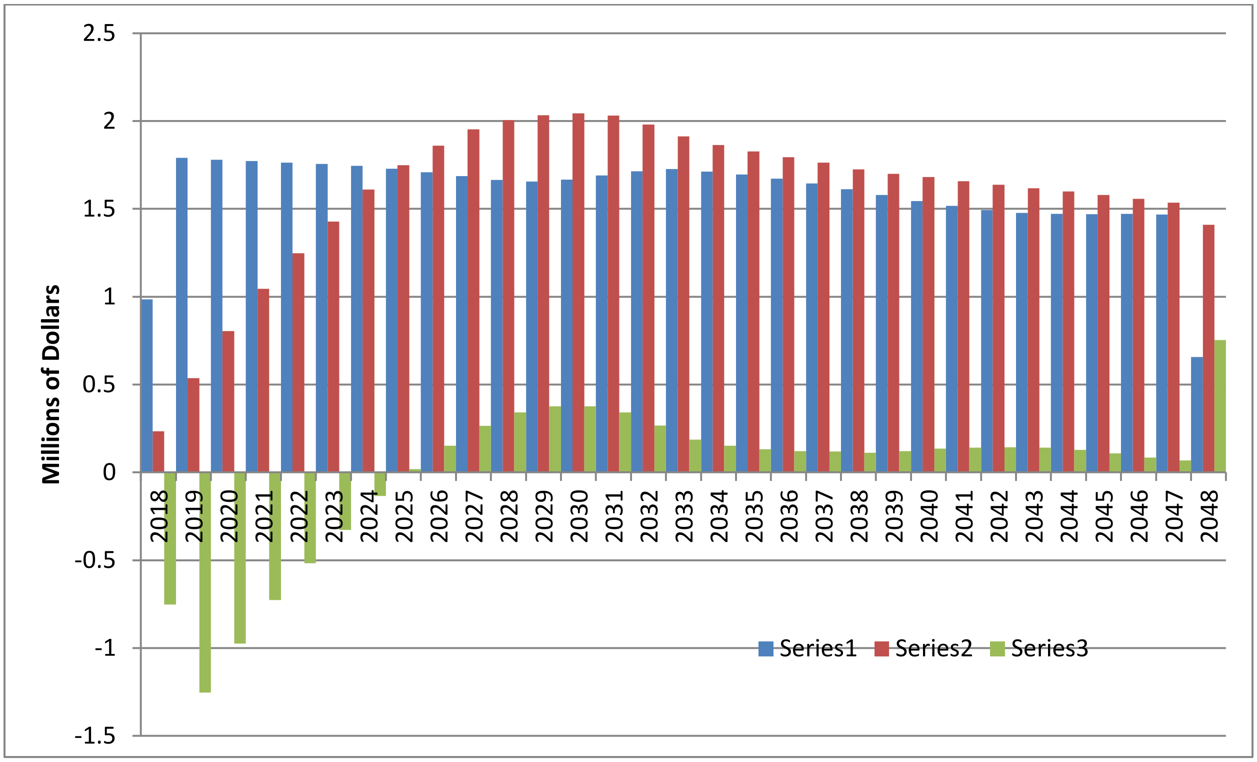

Figure 10.6.7 TSL 2: Present Value of Annual Costs and Benefits for all PTACs and PTHPs, 3% Discount Rate

10.6.4 Alternative Base Case Analysis

The alternative base case analysis was based off a scenario where the mandatory efficiency level is the Federal minimum. Chapter 8 presents the alternative base case efficiency market shares in the compliance year for PTACs and PTHPs. The calculations for NES and NPV were performed against this alternative base case and the cumulative primary energy savings, FFC national energy savings, and NPV results at the 7% and 3% discount rates are shown in Table 10.6.5 to Table 10.6.8, for informational purposes.

Table 10.6.5 Cumulative Primary Energy Savings for PTAC and PTHP Equipment Compared to the Alternative Base Case (quads)

Product Class**	ASHRAE*	Trial Standard Level				
		1	2	3	4	5
PTAC <7,000 Btu/h	0.000	0.000	0.001	0.002	0.003	0.003
PTAC 7,000 – 15,000 Btu/h	0.000	0.004	0.020	0.041	0.052	0.053
PTAC ≥15,000 Btu/h	0.001	0.001	0.003	0.005	0.005	0.006
PTHP <7,000 Btu/h	-	0.000	0.001	0.002	0.003	0.003
PTHP 7,000 – 15,000 Btu/h	-	0.007	0.024	0.046	0.058	0.060
PTHP ≥15,000 Btu/h	-	0.001	0.003	0.005	0.006	0.006
Total – All Classes	**0.001**	**0.014**	**0.052**	**0.101**	**0.128**	**0.131**

*Cells that have "-" have zero energy savings because efficiency remains the same at this level.
**Energy savings of 0.000 have energy savings but cannot be shown due to rounding.

Table 10.6.6 Full-Fuel-Cycle National Energy Savings for PTAC and PTHP Equipment Compared to the Alternative Base Case (quads)

Product Class**	ASHRAE*	Trial Standard Level				
		1	2	3	4	5
PTAC <7,000 Btu/h	0.000	0.000	0.001	0.002	0.003	0.003
PTAC 7,000 – 15,000 Btu/h	0.000	0.004	0.020	0.042	0.053	0.054
PTAC ≥15,000 Btu/h	0.001	0.001	0.003	0.005	0.005	0.006
PTHP <7,000 Btu/h	-	0.000	0.001	0.002	0.003	0.003
PTHP 7,000 – 15,000 Btu/h	-	0.007	0.025	0.047	0.059	0.061
PTHP ≥15,000 Btu/h	-	0.001	0.003	0.005	0.006	0.007
Total – All Classes	**0.001**	**0.014**	**0.053**	**0.103**	**0.130**	**0.133**

*Cells that have "-" have zero energy savings because efficiency remains the same at this level.
**Energy savings of 0.000 have energy savings but cannot be shown due to rounding.

Table 10.6.7 Cumulative NPV Results for PTAC and PTHP Equipment Compared to the Alternative Base Case, 7% Discount Rate (millions 2014$)

Product Class	**Trial Standard Level**				
	1	**2**	**3**	**4**	**5**
PTAC <7,000 Btu/h	0.0	-1.0	-3.0	-4.6	-5.0
PTAC 7,000 – 15,000 Btu/h	-2.9	-15.1	-35.8	-54.0	-57.8
PTAC ≥15,000 Btu/h	-1.5	-4.3	-8.5	-11.9	-12.6
PTHP <7,000 Btu/h	-0.1	-0.5	-1.1	-1.8	-1.9
PTHP 7,000 – 15,000 Btu/h	3.3	2.9	-0.7	-6.3	-7.7
PTHP ≥15,000 Btu/h	-0.1	-0.6	-2.2	-3.9	-4.3
Total – All Classes	**-1.3**	**-18.5**	**-51.3**	**-82.6**	**-89.3**

Table 10.6.8 Cumulative NPV Results for PTAC and PTHP Equipment Compared to the Alternative Base Case, 3% Discount Rate (millions 2014$)

Product Class	**Trial Standard Level**				
	1	**2**	**3**	**4**	**5**
PTAC <7,000 Btu/h	0.0	-1.6	-4.6	-6.9	-7.2
PTAC 7,000 – 15,000 Btu/h	-3.2	-18.4	-46.5	-68.9	-72.9
PTAC ≥15,000 Btu/h	-2.4	-7.2	-14.1	-18.9	-19.7
PTHP <7,000 Btu/h	0.1	-0.1	-0.8	-1.4	-1.5
PTHP 7,000 – 15,000 Btu/h	9.4	19.1	25.7	25.7	25.1
PTHP ≥15,000 Btu/h	0.3	0.5	-1.1	-2.8	-3.1
Total – All Classes	**4.2**	**-7.7**	**-41.3**	**-73.2**	**-79.4**

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CHAPTER 11. CONSUMER SUBGROUP ANALYSIS

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CHAPTER 11. CONSUMER SUBGROUP ANALYSIS

11.1 INTRODUCTION

The subgroup analysis evaluates impacts on any identifiable groups of commercial consumers of packaged terminal air conditioners (PTACs) and packaged terminal heat pumps (PTHPs) who may be disproportionately affected by a national energy-efficiency standard. The U.S. Department of Energy (DOE) accomplished this, in part, by analyzing the LCC and payback period (PBPs) for those commercial consumers that fall into specific subgroup.

DOE determined the impact on commercial consumer subgroup using the LCC spreadsheet model. The standard LCC and PBP analysis (described in Chapter 8) includes various types of commercial buildings that use PTAC equipment. The LCC spreadsheet model allows for the identification of certain subgroup of commercial consumers that can then be analyzed by sampling only that subgroup. (Chapter 8 explains in detail the inputs to the spreadsheet model used in determining the LCC and PBP.)

This chapter describes the subgroup identification in further detail and gives the results of the LCC and PBP analysis for the considered subgroups.

11.2 SUBGROUPS DEFINITION

11.2.1 Commercial Consumer Subgroup

DOE identified small businesses as a subgroup that possibly could be disproportionately affected by PTAC efficiency standards. DOE was concerned that increases in the purchase price of equipment could have negative impacts on small businesses (*i.e.*, those with low annual revenues).

The U.S. Small Business Administration (SBA) established size standards to define small businesses for types of economic activity, or industry, under the North American Industry Classification System (NAICS)[1]. The SBA defines a small business by either its annual receipts (*i.e.*, revenues) or its number of employees. In the case of traveler accommodations, firms with annual revenues of $7 million or less are categorized as small businesses. Generally, chain hotels do not meet this criterion, but a substantial portion of independent hotels do. Based on data reported by Ducker Worldwide, DOE established that independent hotels are the primary small business subgroup, representing approximately 10% of the total building sample.[2]

11.2.2 Small Business Commercial Discount Rate

The capital asset pricing model (CAPM) underestimates the cost of capital for small companies. In CAPM, the risk premium β is used to account for the higher returns associated with greater risk. However, for small companies, particularly very small companies, historic returns have been significantly higher than the CAPM equation predicts. This additional return can be accounted for by adding a size premium to the cost of equity for small firms, as shown in Eq. 11.1:

$$k_e = R_f + (\beta \times ERP) + S$$

Eq. 11.1

Where:

k_e = cost of equity,
R_f = expected return on risk-free assets,
β = risk coefficient of the firm,
ERP = equity risk premium, and
S = size premium.

DOE obtained size premium data from Ibbotson Associates' *Stocks, Bonds, Bills, and Inflation 2009 Yearbook*.[3] For the period of 1926-2008, the average size premium for the smallest companies in all industries is 5.81%, implying that on average, historic performance of small companies has been 5.81% higher than the CAPM estimate of the small company cost of equity.[a]

DOE calculated the real weighted-average cost of capital (as described in Chapter 8) using the cost of equity including a size premium for small companies instead of the CAPM cost of equity.[4] Table 11.2.1 presents DOE's estimates of the discount rates for entire sectors, small companies specifically, and the small company discount rate premium.

To estimate the impact of standards specifically on small businesses, the small company discount rates for each sector were used in the LCC and PBP analysis instead of the sector average discount rates.

Table 11.2.1 Discount Rate Difference between Small Company and Sector Average

Hotels	**Discount Rate**		
	Average	**Standard Deviation**	**Small Company Discount Rate Premium**
Entire Sector	6.05%	2.82%	**1.76%**
Small Companies	7.81%	3.10%	

11.2.3 Life-Cycle Cost and Payback Period Results for Small Business Subgroup

Table 11.2.2 to Table 11.2.5 summarize the LCC results for the small business subgroup for each of the PTAC and PTHP equipment classes, and compare them to the results for the total sample of buildings used in the overall LCC analysis. Table 11.2.6 to Table 11.2.9 summarize

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[a] In this calculation, small companies are defined as companies with market capitalization of less than or equal to $218.53 million, the Ibbotson Associates' definition of Decile 10 companies.

the PBP results. Results are provided by trial standard level (TSL). Note that this is likely an overestimate of the impact on small businesses; not all independent hotels qualify as small businesses.

As is evident from the LCC and PBP results, the effect of higher PTAC and PTHP standards on small businesses is similar to the effect on the full sample of commercial consumers. Thus, small businesses are not substantially disadvantaged by increased PTAC and PTHP equipment standards, as compared to the general population of commercial consumers.

Table 11.2.2 PTAC 9,000 Btu/h Units: LCC Results Comparison between Small Business and Subgroup and All Buildings

Efficiency Level*	Small Businesses			All Buildings		
	Mean LCC	Mean Increase in LCC from Baseline	Percent of Units with LCC Savings	Mean LCC	Mean Increase in LCC from Baseline	Percent of Units with LCC Savings
Baseline/EL 1	$2,651	-	-	$2,746	-	-
EL 2	$2,659	$4	3%	$2,750	$3	4%
EL 3	$2,667	$11	3%	$2,757	$10	4%
EL 4	$2,677	$17	3%	$2,767	$16	4%
EL 5	$2,689	$29	2%	$2,778	$27	3%
EL 6	$2,695	$35	2%	$2,784	$33	3%

*The Federal Minimum efficiency level represents the efficiency level of the current federal energy conservation standards for PTAC equipment. Efficiency level 1 is the baseline level for PTAC equipment, and is the ANSI/ASHRAE/IES Standard 90.1-2013 minimum for PTAC equipment.

Table 11.2.3 PTAC 15,000 Btu/h Units: LCC Results Comparison Between Small Business and Subgroup and All Buildings

Efficiency Level*	Small Businesses			All Buildings		
	Mean LCC	Mean Increase in LCC from Baseline	Percent of Units with LCC Savings	Mean LCC	Mean Increase in LCC from Baseline	Percent of Units with LCC Savings
Baseline/EL 1	$3,207	-	-	$3,326	-	-
EL 2	$3,216	$4	1%	$3,330	$3	2%
EL 3	$3,229	$14	0%	$3,342	$13	2%
EL 4	$3,249	$29	0%	$3,361	$28	1%
EL 5	$3,276	$55	0%	$3,387	$53	0%
EL 6	$3,292	$71	1%	$3,403	$68	0%

*The Federal Minimum efficiency level represents the efficiency level of the current federal energy conservation standards for PTAC equipment. Efficiency level 1 is the baseline level for PTAC equipment, and is the ANSI/ASHRAE/IES Standard 90.1-2013 minimum for PTAC equipment.

Table 11.2.4 PTHP 9,000 Btu/h Units: LCC Results Comparison Between Small Business and Subgroup and All Buildings

Efficiency Level*	Small Businesses			All Buildings		
	Mean LCC	Mean Increase/(Decrease) in LCC from Baseline**	Percent of Units with LCC Savings	Mean LCC	Mean Increase/(Decrease) in LCC from Baseline**	Percent of Units with LCC Savings
Baseline	$3,263	-	-	$3,392	-	-
EL 1	$3,260	($3)	39%	$3,388	($4)	41%
EL 2	$3,264	$1	25%	$3,390	($1)	30%
EL 3	$3,269	$6	22%	$3,394	$3	28%
EL 4	$3,276	$12	19%	$3,400	$9	25%
EL 5	$3,280	$16	17%	$3,403	$12	23%

*The baseline efficiency level represents the efficiency level of the current federal energy conservation standards for PTHP equipment, which is the same as the ANSI/ASHRAE/IES Standard 90.1-2013 minimum efficiency for PTHP equipment.

**Parentheses indicate negative values

Table 11.2.5 PTHP 15,000 Btu/h Units: LCC Results Comparison Between Small Business and Subgroup and All Buildings

Efficiency Level*	Small Businesses			All Buildings		
	Mean LCC	Mean Increase in LCC from Baseline	Percent of Units with LCC Savings	Mean LCC	Mean Increase in LCC from Baseline	Percent of Units with LCC Savings
Baseline	$3,938	-	-	$4,098	-	-
EL 1	$3,940	$2	11%	$4,100	$2	15%
EL 2	$3,944	$6	15%	$4,102	$4	20%
EL 3	$3,954	$14	13%	$4,111	$12	18%
EL 4	$3,972	$31	8%	$4,127	$27	12%
EL 5	$3,983	$42	6%	$4,138	$37	9%

*The baseline efficiency level represents the efficiency level of the current federal energy conservation standards for PTHP equipment, which is the same as the ANSI/ASHRAE/IES Standard 90.1-2013 minimum efficiency for PTHP equipment.

Table 11.2.6 PTAC 9,000 Btu/h Units: PBP Results Comparison Between Small Business Subgroup and All Buildings

Efficiency Level*	Small Businesses		All Buildings	
	Mean PBP (years)	Median PBP (years)	Mean PBP (years)	Median PBP (years)
Baseline/EL 1	-	-	-	-
EL 2	10.7	10.4	10.7	10.4
EL 3	11.5	11.1	11.5	11.1
EL 4	12.6	12.1	12.6	12.1
EL 5	13.4	12.9	13.4	12.9
EL 6	13.8	13.3	13.8	13.3

*The Federal Minimum efficiency level represents the efficiency level of the current federal energy conservation standards for PTAC equipment. Efficiency level 1 is the baseline level for PTAC equipment, and is the ANSI/ASHRAE/IES Standard 90.1-2013 minimum for PTAC equipment.

Table 11.2.7 PTAC 15,000 Btu/h Units: PBP Results Comparison Between Small Business Subgroup and All Buildings

Efficiency Level*	Small Businesses		All Buildings	
	Mean PBP (years)	Median PBP (years)	Mean PBP (years)	Median PBP (years)
Baseline/EL 1	-	-	-	-
EL 2	11.4	11.1	11.4	11.1
EL 3	13.3	13.2	13.3	13.2
EL 4	16.6	15.7	16.6	15.7
EL 5	19.1	18.0	19.1	18.0
EL 6	20.5	19.2	20.5	19.2

*The Federal Minimum efficiency level represents the efficiency level of the current federal energy conservation standards for PTAC equipment. Efficiency level 1 is the baseline level for PTAC equipment, and is the ANSI/ASHRAE/IES Standard 90.1-2013 minimum for PTAC equipment.

Table 11.2.8 PTHP 9,000 Btu/h Units: PBP Results Comparison Between Small Business Subgroup and All Buildings

Efficiency Level*	Small Businesses		All Buildings	
	Mean PBP (years)	Median PBP (years)	Mean PBP (years)	Median PBP (years)
Baseline	-	-	-	-
EL 1	4.4	4.4	4.4	4.4
EL 2	6.3	6.1	6.3	6.1
EL 3	7.4	7.1	7.4	7.1
EL 4	8.1	7.7	8.1	7.7
EL 5	8.3	8.0	8.3	8.0

*The baseline efficiency level represents the efficiency level of the current federal energy conservation standards for PTHP equipment, which is the same as the ANSI/ASHRAE/IES Standard 90.1-2013 minimum efficiency for PTHP equipment.

Table 11.2.9 PTHP 15,000 Btu/h Units: PBP Results Comparison Between Small Business Subgroup and All Buildings

Efficiency Level*	Small Businesses		All Buildings	
	Mean PBP (years)	Median PBP (years)	Mean PBP (years)	Median PBP (years)
Baseline	-	-	-	-
EL 1	8.2	8.0	8.2	8.0
EL 2	7.3	7.2	7.3	7.2
EL 3	8.5	8.2	8.5	8.2
EL 4	9.7	9.3	9.7	9.3
EL 5	10.3	9.9	10.3	9.9

*The baseline efficiency level represents the efficiency level of the current federal energy conservation standards for PTHP equipment, which is the same as the ANSI/ASHRAE/IES Standard 90.1-2013 minimum efficiency for PTHP equipment.

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CHAPTER 12. MANUFACTURER IMPACT ANALYSIS

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12.1 INTRODUCTION

In determining whether a standard is economically justified, the U.S. Department of Energy (DOE) is required to consider "the economic impact of the standard on the manufacturers and on the customers of the products subject to such a standard." (42 U.S.C. 6313(a)(6)(B)(i)) The law also calls for an assessment of the impact of any lessening of competition as determined in writing by the Attorney General. *Id.* DOE conducted a manufacturer impact analysis (MIA) to estimate the financial impact of amended energy conservation standards on manufacturers of packaged terminal air conditioners (PTACs) and packaged terminal heat pumps (PTHPs), and assessed the impact of such standards on direct employment and manufacturing capacity.

The MIA has both quantitative and qualitative aspects. The quantitative part of the MIA primarily relies on the Government Regulatory Impact Model (GRIM), an industry cash-flow model adapted for each equipment type in this rulemaking. The GRIM inputs include information on industry cost structure, shipments, and pricing strategies. The GRIM's key output is the industry net present value (INPV). The model estimates the financial impact of more stringent energy conservation standards for each equipment type by comparing changes in INPV between a base case and the various trial standard levels (TSLs) in the standards case. The qualitative part of the MIA addresses equipment characteristics, manufacturer characteristics, market and equipment trends, as well as the impact of standards on subgroups of manufacturers.

12.2 METHODOLOGY

DOE conducted the MIA in three phases. Phase I, "Industry Profile," consisted of preparing a characterization of the PTAC and PTHP industry, including data on sales volumes, pricing, employment, and financial structure. As part of this phase, DOE conducted interviews with a broad cross-section of PTAC and PTHP manufacturers to gather information on the industry as well as the potential impacts of amended energy conservation standards. In Phase II, "Industry Cash Flow Analysis," DOE used the Government Regulatory Impact Model (GRIM) to assess the potential impacts of amended energy conservation standards on manufacturers. DOE used financial inputs derived from a combination of sources including manufacturer interviews conducted in Phase I as well as public sources of information. In Phase III, "Subgroup Impact Analysis," DOE developed additional analyses for subgroups that required special consideration and incorporated qualitative data from interviews into its analysis.

12.2.1 Phase I: Industry Profile

In Phase I of the MIA, DOE prepared a profile of the PTAC and PTHP industry. DOE developed its industry profile using a combination of sources, including: public information, such as Securities and Exchange Commission (SEC) 10-K reports,[1] Standard & Poor's (S&P) stock reports,[2] market research tools (*e.g.*, Hoovers[3]), corporate annual reports, and the U.S. Census Bureau's 2011 Annual Survey of Manufacturers (ASM)[4]; information obtained through DOE's engineering analysis, life-cycle cost analysis, and market and technology assessment prepared for this rulemaking; financial analysis performed as part of the 2008 energy conservation standards final rule for PTACs and PTHPs; and information obtained directly from manufacturers through interviews.

The industry profile includes: (1) further detail on the overall market and equipment characteristics; (2) estimated manufacturer market shares; (3) financial parameters such as net plant, property, and equipment; selling, general and administrative (SG&A) expenses; cost of goods sold; and (4) trends in the number of firms, market, and equipment characteristics.

12.2.1.1 **Manufacturer Interviews**

During Phase I of the MIA, DOE interviewed manufacturers to gather information on the effects of amended energy conservation standards on revenues and finances, direct employment, capital assets, and industry competitiveness. Before the interviews, DOE distributed an interview guide to interviewees. The interview guide provided a starting point for identifying relevant issues and impacts of amended energy conservation standards on individual manufacturers or subgroups of manufacturers. Most of the information received from these meetings is protected by non-disclosure agreements and resides with DOE's contractors. The MIA interview topics included: (1) key issues to this rulemaking; (2) engineering analysis; (3) company overview and organizational characteristics; (4) manufacturer markups and profitability; (5) shipping costs; (6) industry projections; (7) financial parameters; (8) conversion costs; (9) cumulative regulatory burden; (10) direct employment impact assessment; (11) capacity, exports, foreign competition, and outsourcing; (12) consolidation; and (13) impacts on small businesses.

The interview process provides an opportunity for manufacturers to express their views on important issues privately, allowing confidential or sensitive information to be considered in the rulemaking process. DOE sought to obtain feedback from industry on the approaches used in the GRIM and to isolate key issues and concerns. DOE used these interviews to tailor the GRIM to reflect financial characteristics unique to the PTAC and PTHP industry. Interviews were scheduled well in advance to provide every opportunity for key individuals to be available for comment. Although a written response to the questionnaire was acceptable, DOE sought interactive interviews, which help clarify responses and identify additional issues. The resulting information provides valuable inputs to the GRIM.

12.2.2 Phase II: Industry Cash-Flow Analysis

Phase II focused on the financial impacts of potential amended energy conservation standards on manufacturers of PTAC and PTHP equipment. In general, energy conservation standards can affect manufacturer cash flow in three distinct ways: (1) create a need for increased investment; (2) raise production costs per unit; and (3) alter revenue due to higher per-unit prices and/or possible changes in sales volumes. To quantify these impacts, DOE used the GRIM to perform a cash-flow analysis for the PTAC and PTHP industry. In performing these analyses, DOE used the financial values derived during Phase I and the shipment scenarios used in the national impact analysis (NIA).

The GRIM uses several factors to determine a series of annual cash flows from the announcement year of amended energy conservation standards until 30 years after the standards' compliance date. These factors include annual expected revenues, costs of goods sold, SG&A, taxes, and capital expenditures related to the amended standards. Inputs to the GRIM include manufacturer production costs, markup assumptions, and shipments forecasts developed in other analyses. DOE derived the manufacturing costs from the engineering analysis and information provided by the industry. It estimated typical manufacturer markups from public financial reports and interviews with manufacturers. DOE developed alternative markup scenarios based on discussions with manufacturers. DOE's shipments analysis, presented in Chapter 9 of the technical support document (TSD), provided the basis for the shipment projections in the GRIM. The financial parameters were developed using publicly available manufacturer data and were revised with information submitted confidentially during manufacturer interviews. The GRIM results are compared to base-case projections for the industry. The financial impact of amended energy conservation standards is the difference between the discounted annual cash flows in the base case and standards case at each TSL.

The results of the industry cash-flow analysis are presented in section 12.4.

12.2.3 Phase III: Manufacturer Subgroup Analysis

For its GRIM analysis, DOE presented impacts on the PTAC and PTHP industry as a whole. However, using average cost assumptions to develop an industry cash-flow estimate may not adequately assess differential impacts of amended energy conservation standards among manufacturer subgroups. For example, small manufacturers, niche players, or manufacturers exhibiting a cost structure that largely differs from the industry average could be more negatively affected. To address this possible impact, DOE used the results of the industry characterization analysis in Phase I to group manufacturers that exhibit similar characteristics.

During the interviews, DOE discussed the potential subgroups and subgroup members it identified for the analysis. DOE asked manufacturers and other interested parties to suggest what subgroups or characteristics are the most appropriate to analyze. As described in section 12.4, DOE analyzes the industry impacts on PTAC and PTHP equipment manufacturers as a whole because most of the equipment classes represent the same market served by the same manufacturers. However, as discussed below, DOE identified two manufacturer subgroups that could be disproportionately impacted by amended energy conservation standards and therefore warranted a separate impact analysis: (1) manufacturers with production assets; and (2) small businesses.

12.2.3.1 Manufacturers with Production Assets Subgroup

DOE initially identified 22 companies that sell PTAC and PTHP equipment in the U.S. Among U.S. companies, however, few own production assets; rather, they import and distribute PTACs and PTHPs manufactured overseas, primarily in China. DOE identified a subgroup of three U.S. manufacturers that own production assets. These companies own tooling and manufacturing assets in the US or in foreign countries. Together, these three manufacturers account for approximately 80 percent of the domestic PTAC and PTHP market. Because manufacturers with production assets will incur different costs to comply with amended energy conservation standards compared to their competitors who do not own production assets, DOE conducted a separate subgroup analysis to evaluate the potential impacts of amended energy conservation standards on manufacturers with production assets. DOE reports the potential impact of this rulemaking on the subgroup of manufacturers with production assets in section 12.5.1.

12.2.3.2 Small Business Manufacturer Subgroup

DOE investigated whether small business manufacturers should be analyzed as a manufacturer subgroup. DOE used the Small Business Administration (SBA) small business size standards effective on January 1, 2012, as amended, and the North American Industry Classification System (NAICS) code, presented in Table 12.2.1, to determine whether any small entities would be affected by the rulemaking.[5] For the equipment classes under review, the SBA bases its small business definition on the total number of employees for a business, its subsidiaries, and its parent companies. An aggregated business entity with fewer employees than the listed limit is considered a small business.

Table 12.2.1 SBA and NAICS Classification of Small Businesses Potentially Affected by This Rulemaking

Industry Description	Revenue Limit	Employee Limit	NAICS
Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing	N/A	750	333415

DOE used publicly available and proprietary information to identify potential small businesses. DOE's research involved industry trade association membership directories, product databases (*e.g.*, AHRI Directory), individual company websites, and market research tools (*e.g.*, Hoovers.com) to create a list of companies that manufacture or sell equipment covered by this rulemaking. DOE also asked stakeholders and industry representatives if they were aware of any other small manufacturers during manufacturer interviews. DOE screened out companies that did not offer equipment covered by this rulemaking, did not meet the definition of a "small business," or are foreign owned and operated.

Based on this analysis DOE identified 12 small businesses that sell PTAC and PTHP equipment affected by this rulemaking. DOE reports the potential impact of this rulemaking on small businesses in section 12.5.2.

12.2.4 Manufacturing Capacity Impact

One significant outcome of amended energy conservation standards could be the obsolescence of existing manufacturing assets, including tooling and investment. The manufacturer interview guides have a series of questions to help identify impacts of amended standards on manufacturing capacity, specifically capacity utilization and plant location decisions in the United States, with and without amended standards; the ability of manufacturers to upgrade or remodel existing facilities to accommodate the new requirements; the nature and value of any stranded assets; and estimates for any one-time changes to existing plant, property, and equipment (PPE). DOE's estimates of the one-time capital changes and stranded assets affect the cash flow estimates in the GRIM. These estimates can be found in section 12.3.6. DOE's discussion of the capacity impact can be found in section 12.6.2.

12.2.5 Employment Impact

The impact of amended energy conservation standards on employment is an important consideration in the rulemaking process. To assess how domestic direct employment patterns might be affected, the interviews explored current employment trends in the PTAC and PTHP industry. The interviews also solicited manufacturer views on changes in employment patterns that may result from more stringent standards. The employment impacts section of the interview guide focused on current employment levels associated with manufacturers at each production facility, expected future employment levels with and without amended energy conservation standards, and differences in workforce skills and issues related to the retraining of employees. The employment impacts are reported in section 12.6.1.

12.2.6 Cumulative Regulatory Burden

DOE seeks to mitigate the overlapping effects on manufacturers due to amended energy conservation standards and other regulatory actions affecting the same products. DOE analyzed the impact on manufacturers of multiple, product-specific regulatory actions. Based on research and discussions with manufacturers, DOE identified regulations that impact other products made by manufacturers of PTACs and PTHPs. Discussion of the cumulative regulatory burden can be found in section 12.6.3.

12.3 GRIM INPUTS AND ASSUMPTIONS

The Government Regulatory Impact Model (GRIM) serves as the main tool for assessing the impacts on industry due to amended energy conservation standards. DOE relies on several sources to obtain inputs for the GRIM. Data and assumptions from these sources are then fed into an accounting model that calculates the industry cash flow both with and without amended energy conservation standards.

12.3.1 Overview of the Government Regulatory Impact Model (GRIM)

The basic structure of the GRIM, illustrated in Figure 12.3.1, is an annual cash flow analysis that uses manufacturer production costs, manufacturer selling prices, shipments, and industry financial information as inputs, and accepts a set of regulatory conditions such as changes in costs, investments, and associated margins. The GRIM spreadsheet uses a number of inputs to arrive at a series of annual cash flows, beginning with the base year of the analysis, 2015, and continuing for a 30-year period that begins in the compliance year for each equipment class. The model calculates the INPV by summing the stream of annual discounted cash flows during this period and adding a discounted terminal value.[6]

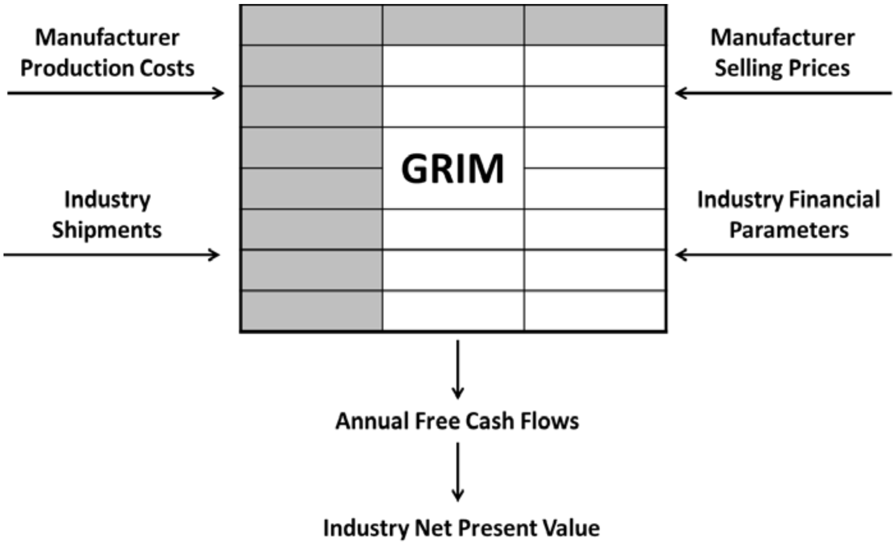


Figure 12.3.1 Using the GRIM to Calculate Cash Flow

The GRIM projects cash flows using standard accounting principles and compares changes in INPV between the base case and the standard-case scenario induced by amended energy conservation standards. The difference in INPV between the base case and the standard case represents the estimated financial impact of the amended energy conservation standard on manufacturers. Appendix 12A provides more technical details and user information for the GRIM.

DOE presents MIA results relative to a base case that uses efficiency levels specified by ASHRAE Standard 90.1-2013 as the baseline efficiencies for PTACs and PTHPs. Consequently, when comparing the INPV impacts of the GRIM model, the baseline efficiency is greater than the current federal minimum efficiency requirements.

For this TSD, DOE also repeats the INPV and cash flow calculations relative to an alternative base case, where the baseline efficiency levels are equal to the current federal minimums, which were set in 2008 (73 FR 58772). This alternative scenario is referred to as the “EPCA Baseline.”

12.3.2 Sources for GRIM Inputs

The GRIM uses several different sources of data to determine industry cash flows. Sources include corporate annual reports, company profiles, census data, credit ratings, the shipments model, the engineering analysis, and manufacturer interviews.

12.1.1.1 2008 Final Rule for PTACs and PTHPs

The 2008 Final Rule for PTACs and PTHPs (73 FR 58772) provided many of the initial financial inputs to the GRIM. As part of the 2008 Final Rule, DOE derived a series of financial parameters for the industry based on a review of corporate annual reports, company profiles, credit ratings, and manufacturer interviews. DOE used these parameters as a starting point for analysis under the current rulemaking. Drawing on feedback obtained during manufacturer interviews conducted in Phase I of this rulemaking, DOE then revised its estimated financial parameters to better reflect the current PTAC and PTHP industry. Table 12.3.1 presents the revised financial parameters used as inputs to the GRIM. The values indicated have been weighted to reflect manufacturers' respective market shares.

Table 12.3.1 GRIM Financial Parameters for PTACs and PTHPs

Parameter	**Revised Estimate**
Tax Rate (% of Taxable Income)	34%
Discount Rate	8.5%
Working Capital (% of Revenue)	7%
Net Property, Plant, and Equipment (% of Revenues)	15%
SG&A (% of Revenue)	15%
R&D (% of Revenues)	3%
Depreciation (% of Revenues)	5%
Capital Expenditures (% of Revenues)	5%

12.3.2.1 **Shipment Model**

The GRIM used shipment projections derived from DOE's shipments model in the national impact analysis (NIA). Chapter 9 of the TSD describes the methodology and analytical model DOE used to forecast shipments.

12.3.2.2 **Engineering Analysis**

During the engineering analysis, DOE used a manufacturing cost model to develop manufacturing production cost (MPC) estimates. The analysis provided the labor, materials, overhead, and total production costs for different design options for PTACs and PTHPs. The engineering analysis also estimated a manufacturer markup and a shipping cost to provide the manufacturer selling price (MSP) for design options.

12.3.2.3 **Manufacturer Interviews**

During the course of the MIA, DOE conducted interviews with a representative cross-section of manufacturers. During these discussions, DOE obtained information to determine and verify GRIM input assumptions. Key topics discussed during the interviews and reflected in the GRIM include:

- Capital conversion costs (one-time investments in PPE);
- Product conversion costs (one-time investments in research, product development, testing, and marketing);
- Equipment cost structure;
- Industry financial parameters;
- Possible profitability impacts.

12.3.3 Trial Standard Levels (TSLs)

DOE developed a number of efficiency levels (ELs) for each equipment class. Trial Standard Levels (TSLs) were then developed by selecting likely groupings of efficiency levels for all equipment classes. Each TSL includes combinations of efficiency levels for PTACs and PTHPs of different cooling capacity.

In this rulemaking, each TSL represents a percentage increase in efficiency relative to the current federal minimum efficiency standard. For both PTACs and PTHPs, TSLs 1, 2, 3, 4, and 5 represent respective increases of 4 percent, 8 percent, 12 percent, 16 percent, and 18 percent above the current federal minimum efficiency standard for PTACs of a specified cooling capacity. Whereas the current federal standard specifies different minimum efficiencies for PTACs and PTHPs of equivalent cooling capacity, DOE has structured TSLs in the present rulemaking to align efficiency standards for PTACs and PTHPs of the same cooling capacity. Table 12.3.2 presents the TSLs used for energy efficiency analysis in the GRIM.

Table 12.3.2 Trial Standard Levels for Analysis of PTACs and PTHPs

Equipment Type	Cooling Capacity (Btu/h)	Baseline	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
PTAC	<7,000 Btu/h	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6
	≥7,000 Btu/h and ≤15,000 Btu/h	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6
	>15,000 Btu/h	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6
PTHP	<7,000 Btu/h	Current Federal Minimum	EL 1	EL 2	EL 3	EL 4	EL 5
	≥7,000 Btu/h and ≤15,000 Btu/h	Current Federal Minimum	EL 1	EL 2	EL 3	EL 4	EL 5
	>15,000 Btu/h	Current Federal Minimum	EL 1	EL 2	EL 3	EL 4	EL 5

The PTAC baseline efficiency level varies from the current federal minimum in order to align with efficiency standards established by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). In October 2013, ASHRAE published ANSI/ASHRAE/IES Standard 90.1-2013, which amended efficiency standards for PTACs, increasing them to 1.8 percent above the current federal minimum. This rulemaking for PTACs is considered an ASHRAE trigger. As such, the baseline for the PTACs analysis is the minimum efficiency level established under the ASHRAE amendment. The baseline analyzed for PTHPs remains the current federal minimum, as PTHP standards were not modified under the ASHRAE amendment. Beyond baseline, as described above, each TSL represents a percentage increase in efficiency for both PTACs and PTHPs relative to the current federal minimum.

12.3.4 NIA Shipments

The GRIM estimates manufacturer revenues based on total-unit-shipment forecasts and the distribution of these values by efficiency level. Changes in the efficiency mix at each standard level are a key driver of manufacturer finances. For this analysis, the GRIM applied the NIA shipments forecasts.

As part of the shipments forecasts, DOE estimated the base-case shipment distribution by efficiency level for each of the six PTAC and PTHP equipment classes. In the standards case, the shipments analysis assumes a roll-up scenario, where all shipments in the base case that do not meet the standard would instead ship at the new standard level. The key assumptions and methodology used to forecast shipments can be found in Chapter 9 of the TSD.

12.3.5 Production Costs

Changes in production costs affect revenues and gross profits. Products that are more efficient typically cost more to produce than baseline products (as shown in Chapter 5 of the TSD). For the MIA, DOE used the MPCs derived in the engineering analysis.

The engineering analysis developed MPCs for representative PTAC units at each of the three capacity categories used to define equipment classes: <7,000 Btu/h; ≥7,000 Btu/h and ≤ 15,000 Btu/h; and >15,000 Btu/h. The NIA shipments estimated the number of PTAC and PTHP units shipped at each equipment class. The GRIM, in turn, used the MPCs from the engineering analysis and the NIA shipments to calculate shipment-weighted average MPCs for each equipment class. Additionally, the GRIM relied on the engineering analysis to determine labor, materials, overhead, and depreciation percentages that constitute the full MPC.

To calculate baseline MSP, DOE followed a two-step process. First, DOE derived MPCs from the engineering and tear down analyses. Second, DOE applied a manufacturer markup, which varies with the markup scenario (discussed in detail in section 12.3.7).

Table 12.3.3 through Table 12.3.5 show the production cost estimates used in the GRIM for each analyzed equipment class. A flat markup of 1.27 was applied to all equipment classes.

Table 12.3.3 Manufacturer Production Cost Breakdown (2014$) for PTACs, < 7,000 Btu/h Capacity

	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	$281.38	$22.61	$19.62	$24.37	$347.98	1.27	$441.94
EL 1	$282.79	$23.35	$20.65	$24.72	$351.52	1.27	$446.44
EL 2	$285.33	$24.04	$21.61	$25.06	$356.03	1.27	$452.16
EL 3	$290.63	$25.21	$23.26	$25.69	$364.80	1.27	$463.29
EL 4	$297.69	$26.13	$24.58	$26.28	$374.68	1.27	$475.84
EL 5	$305.68	$26.80	$25.57	$26.81	$384.87	1.27	$488.78
EL 6	$310.19	$27.04	$25.94	$27.05	$390.23	1.27	$495.59

Table 12.3.4 Manufacturer Production Cost Breakdown (2014$) for PTACs, ≥ 7,000 Btu/h and ≤ 15,000 Btu/h Capacity

	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	$298.40	$22.61	$19.62	$24.37	$365.00	1.27	$463.55
EL 1	$300.21	$23.35	$20.65	$24.72	$368.94	1.27	$468.55
EL 2	$302.35	$24.04	$21.61	$25.06	$373.05	1.27	$473.78
EL 3	$307.65	$25.21	$23.26	$25.69	$381.82	1.27	$484.91
EL 4	$314.30	$26.13	$24.58	$26.28	$391.30	1.27	$496.94
EL 5	$322.30	$26.80	$25.57	$26.81	$401.48	1.27	$509.88
EL 6	$326.81	$27.04	$25.94	$27.05	$406.84	1.27	$516.69

Table 12.3.5 Manufacturer Production Cost Breakdown (2014$) for PTACs, > 15,000 Btu/h Capacity

	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	$331.40	$19.79	$20.70	$25.76	$397.65	1.27	$505.01
EL 1	$332.23	$21.30	$21.23	$26.68	$401.43	1.27	$509.82
EL 2	$334.05	$22.72	$21.82	$27.48	$406.07	1.27	$515.71
EL 3	$340.68	$25.30	$23.17	$28.76	$417.91	1.27	$530.75
EL 4	$351.28	$27.54	$24.75	$29.61	$433.18	1.27	$550.14
EL 5	$365.85	$29.43	$26.58	$30.01	$451.87	1.27	$573.87
EL 6	$374.63	$30.25	$27.58	$30.05	$462.50	1.27	$587.37

12.3.6 Conversion Costs

Amended energy conservation standards typically cause manufacturers to incur one-time conversion costs to bring their production facilities and equipment designs into compliance with new regulations. For the MIA, DOE classified these one-time conversion costs into two major groups: capital conversion costs and product conversion costs. Capital conversion costs are one-time investments in plant, property, and equipment to adapt or change existing production facilities in order to fabricate and assemble new equipment designs that comply with amended energy conservation standards. Product conversion costs are one-time investments in research, development, testing, marketing and other costs to make equipment designs comply with amended energy conservation standards. DOE based its estimates of the conversion costs for each efficiency level on information obtained from manufacturer interviews and the design pathways analyzed in the engineering analysis.

12.3.6.1 Capital Conversion Costs

To estimate the level of capital conversion costs manufacturers would likely incur to comply with amended energy conservation standards, DOE relied on information obtained through manufacturer interviews as well as the engineering analysis. Table 12.3.6 presents estimated capital conversion costs at each TSL. The estimates are cumulative and reflect capital conversion costs anticipated across equipment classes and manufacturers in order to achieve compliance with each TSL analyzed.

Table 12.3.6 Industry Cumulative Capital Conversion Costs (2014$ Millions)

TSL	Capital Conversion Costs (2014$ Millions)
TSL 1	$2.3
TSL 2	$2.9
TSL 3	$7.2
TSL 4	$7.2
TSL 5	$7.5

At TSL 1, manufacturers indicated that converting PTAC equipment lines to comply with amended standards would require minimal capital conversion costs whereas converting PTHPs would require more substantial investment. In particular, converting PTHP lines to meet TSL 1 would require some manufacturers to implement new coil fabrication systems. This accounts for the majority of expected capital conversion costs at TSL 1, which DOE estimates at $2.3 million for all equipment classes.

At TSL 2, manufacturers stated they would need to implement motor and control changes across PTAC and PTHP equipment classes. The additional investment would increase capital conversion costs for the industry to an estimated $2.9 million.

At TSL 3, DOE expects manufacturers to require new tooling and to redesign products to incorporate additional coils and/or formed coils. DOE estimates capital conversion costs at this level to increase to $7.2 million.

At TSL 4, DOE does not expect capital conversion costs beyond those required at TSL 3. Accordingly, capital conversion costs remain level at $7.2 million.

At TSL 5, the engineering analysis suggests manufacturers would have to increase the fin density of the heat exchanger, requiring investment in new jigs to position the fins. Industry capital conversion costs increase to $7.5 million.

12.3.6.2 **Product Conversion Costs**

As with capital conversion costs, DOE relied on manufacturer interviews as well as the engineering analysis to evaluate product conversion costs. For manufacturers with production assets, DOE estimated costs related to R&D (including design engineering, technician salaries, and laboratory costs) as well as costs of testing, certification, etc. DOE assumed R&D costs ranging from $50,000 to $200,000 per platform based on the complexity of the redesign anticipated at each TSL. For all manufacturers (*i.e.*, manufacturers with production assets as well as manufacturers that import and distribute PTACs and PTHPs manufactured overseas) DOE assumed a flat fee per platform required for testing and certification. DOE multiplied this fee by the number of platforms identified for each manufacturer in order to estimate total product conversion costs facing the industry.

Table 12.3.7 presents industry-wide product conversion costs at each TSL. The estimates are cumulative and reflect product conversion costs anticipated across equipment classes and manufacturers in order to achieve compliance with each TSL analyzed.

Table 12.3.7 Industry Cumulative Product Conversion Costs (2014$ Millions)

TSL	Product Conversion Costs (2014$ Millions)
TSL 1	$2.2
TSL 2	$4.8
TSL 3	$7.3
TSL 4	$8.6
TSL 5	$13.7

The increase in product conversion costs, which ranges from a low of $2.2 million at TSL 1 to a high of $13.7 million at TSL 5, reflects a rise in R&D effort required to meet increasingly stringent efficiency standards. As noted, R&D costs will fall disproportionately on manufacturers with production assets. See section 12.5.1 for further analysis of financial impacts facing the subgroup of manufacturers with production assets.

12.3.7 Markup Scenarios

DOE modeled multiple standards-case markup scenarios to represent uncertainty surrounding the potential impacts of energy conservation standards on prices and profitability. In the base case, DOE used the same markups applied in the engineering analysis. In the standards case, DOE modeled two markup scenarios to capture a range of potential impacts on manufacturers following implementation of amended energy conservation standards: (1) a preservation of gross margin percentage scenario; and (2) a preservation of operating profit scenario. These scenarios lead to different markup values, which, when applied to the inputted MPCs, result in varying revenue and cash flow impacts.

12.3.7.1 Preservation of Gross Margin Percentage Scenario

Under the preservation of gross margin percentage scenario, DOE applied a single uniform “gross margin percentage” markup across all efficiency levels, which assumes that manufacturers would be able to maintain the same amount of profit as a percentage of revenues at all efficiency levels within an equipment class. As production costs increase with efficiency, this scenario implies that the absolute dollar markup will increase as well. Based on publicly available financial information for manufacturers of PTACs and PTHPs as well as comments from manufacturer interviews, DOE assumed the average markup—which includes SG&A expenses, R&D expenses, interest, and profit—to be 1.27 for all PTAC and PTHP equipment classes. Because this markup scenario assumes that manufacturers would be able to maintain their gross margin percentage markups as production costs increase in response to an amended energy conservation standard, it represents a high bound to industry profitability.

12.3.7.2 **Preservation of Operating Profit Scenario**

In the preservation of per unit operating profit scenario, manufacturer markups are set so that operating profit one year after the compliance date of the amended energy conservation standard is the same as in the base case on a per unit basis. Under this scenario, as the costs of production increase under a standards case, manufacturers are generally required to reduce their markups to a level that maintains base-case operating profit per unit. The implicit assumption behind this markup scenario is that the industry can only maintain its operating profit in absolute dollars per unit after compliance with the new standard is required. Therefore, operating margin in percentage terms is reduced between the base case and standards case. DOE adjusted the manufacturer markups in the GRIM at each TSL to yield approximately the same earnings before interest and taxes in the standards case as in the base case. This markup scenario represents a low bound to industry profitability under an amended energy conservation standard.

12.4 INDUSTRY FINANCIAL IMPACTS

Using the inputs and scenarios described in the previous sections, the GRIM estimated indicators of financial impacts on the PTAC and PTHP industry. The following sections detail additional inputs and assumptions for the analysis of industry financial impacts. The main results of the MIA are also reported in this section. The MIA consists of two key financial metrics: industry net present value (INPV) and annual cash flows.

12.4.1 Introduction

The INPV measures the industry value and is used in the MIA to compare the economic impacts of different TSLs in the standards case. The INPV is different from DOE’s NPV, which applies to the U.S. economy. The INPV is the sum of annual net cash flows over the 30-year analysis period discounted at the industry’s cost of capital or discount rate. The GRIM for this rulemaking estimates cash flows beginning in the base year of the analysis, 2015, and continuing for a 30-year period that begins in the compliance year for each equipment class.

In the MIA, DOE compares the INPV of the base case to that of each TSL in the standards case. The difference between the base case and a standards case INPV is an estimate of the economic impacts that implementing that particular TSL would have on the industry. In this final rule, DOE presents MIA results relative to a base case that uses efficiency levels specified by ASHRAE Standard 90.1-2013 as the baseline efficiencies for PTACs and PTHPs. Consequently, when comparing the INPV impacts of the GRIM model, the baseline efficiency for PTACs is greater than the current federal minimum efficiency requirements. However, the baseline efficiency for PTHPs is equivalent to the current federal minimum efficiency requirements, as ASHRAE Standard 90.1-2013 did not specify new efficiency levels for PTHPs.

In analyzing the financial impacts in this TSD, DOE also presents the INPV and cash flow calculations relative to an alternative base case, where the baseline efficiency levels are equal to the current federal minimums, which were set in 2008 (73 FR 58772). This alternative scenario is referred to as the “EPCA Baseline”.

While INPV is useful for evaluating the long-term effects of amended energy conservation standards, short-term changes in cash flow are also important indicators of the industry's financial situation. For example, a large investment over one or two years could strain the industry's access to capital. Consequently, the sharp drop in financial performance could cause investors to flee, even though recovery may be possible. Thus, a short-term disturbance can have long-term effects that the INPV cannot capture. To get an idea of the behavior of annual net cash flows, Figure 12.4.1 and Figure 12.4.2 below present the annual net cash flows over the analysis period.

Annual cash flows are discounted to the base year, 2015. After the standards announcement date (*i.e.*, the publication date of the final rule), industry cash flows begin to decline as companies use their financial resources to prepare for the amended energy conservation standard. Cash flows between the announcement date and the compliance date are driven by the level of conversion costs and the proportion of these investments spent every year. The more stringent the amended energy conservation standard, the greater the impact on industry cash flows in the years leading up to the compliance date, as product conversion costs lower cash inflows from operations and capital conversion costs increase cash outflows for capital expenditures.

Free cash flow in the year the amended energy conservation standards take effect is driven by two competing factors. In addition to capital and product conversion costs, amended energy conservation standards could create stranded assets, *i.e.*, tooling and equipment that would have enjoyed longer use if the energy conservation standard had not made them obsolete. In this year, manufacturers write down the remaining book value of existing tooling and equipment whose value is affected by the amended energy conservation standard. This one time write down acts as a tax shield that alleviates decreases in cash flow from operations in the year of the write-down. In this year, there is also an increase in working capital that reduces cash flow from operations. A large increase in working capital is needed due to more costly production components and materials, higher inventory carrying to sell more expensive products, and higher accounts receivable for more expensive products. Depending on these two competing factors, cash flow can either be positively or negatively affected in the year the standard takes effect.

12.4.2 PTAC and PTHP Industry Financial Impacts

Table 12.4.1 and Table 12.4.2 provide INPV estimates for PTACs and PTHPs under the two markup scenarios analyzed. Figure 12.4.1 and Figure 12.4.2 present annual industry net cash flows under the two markup scenarios. As described in section 12.3.7, the preservation of gross margin percentage scenario presents an upper bound to industry profitability under amended standards while the preservation of operating profit scenario presents a lower bound to industry profitability. These results are based on an ASHRAE baseline and are consistent with results presented in the final rule.

Table 12.4.1 ASHRAE Baseline: Preservation of Gross Margin Percentage Scenario Changes in INPV for PTACs and PTHPs

	Units	Base Case	Trial Standard Level				
			1	2	3	4	5

INPV	2014$M	62.2	61.1	63.1	61.9	63.1	60.3
Change in INPV*	2014$M	-	(1.1)	0.8	(0.3)	0.8	(1.9)
	% Change	-	(1.8)	1.3	(0.5)	1.4	(3.1)

* Parentheses indicate negative values.

Table 12.4.2 ASHRAE Baseline: Preservation of Operating Profit Scenario Changes in INPV for PTACs and PTHPs

	Units	Base Case	Trial Standard Level				
			1	**2**	**3**	**4**	**5**
INPV	2014$M	62.2	60.7	61.8	59.3	58.9	55.6
Change in INPV*	2014$M	-	(1.5)	(0.5)	(3.0)	(3.4)	(6.7)
	% Change	-	(2.4)	(0.8)	(4.8)	(5.4)	(10.7)

* Parentheses indicate negative values.

At TSL 1, DOE estimates impacts on INPV to range from -$1.5 million to -$1.1 million, or a change of -2.4 percent to -1.8 percent. At TSL 2, DOE estimates impacts on INPV to range from -$0.5 million to $0.8 million, or a change in INPV of -0.8 percent to 1.3 percent. At TSL 3, DOE estimates impacts on INPV to range from -$3.0 million to -$0.3 million, or a change in INPV of -4.8 percent to -0.5 percent. At TSL 4, DOE estimates impacts on INPV to range from -$3.4 million to $0.8 million, or a change in INPV of -5.4 percent to 1.4 percent. At TSL 5, DOE estimates impacts on INPV to range from -$6.7 million to -$1.9 million, or a change in INPV of -10.7 percent to -3.1 percent. See section 12.7 below for a more detailed discussion of results.

Figure 12.4.1 ASHRAE Baseline: Annual Industry Net Cash Flows under Preservation of Gross Margin Percentage Markup Scenario (in 2014$M)

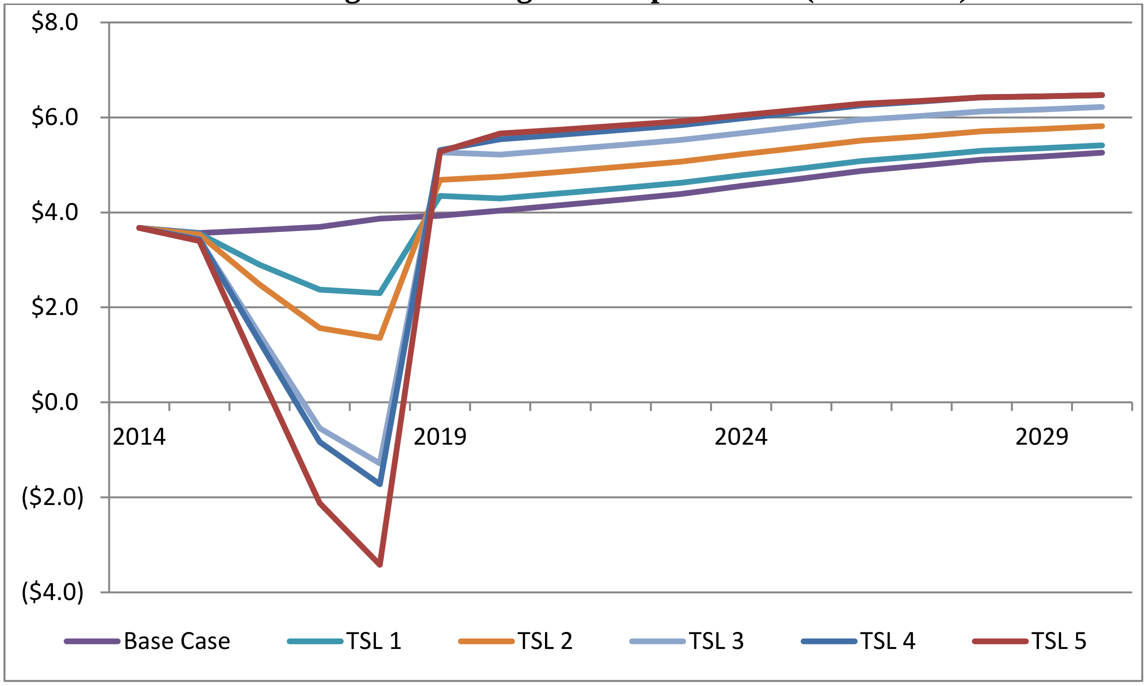
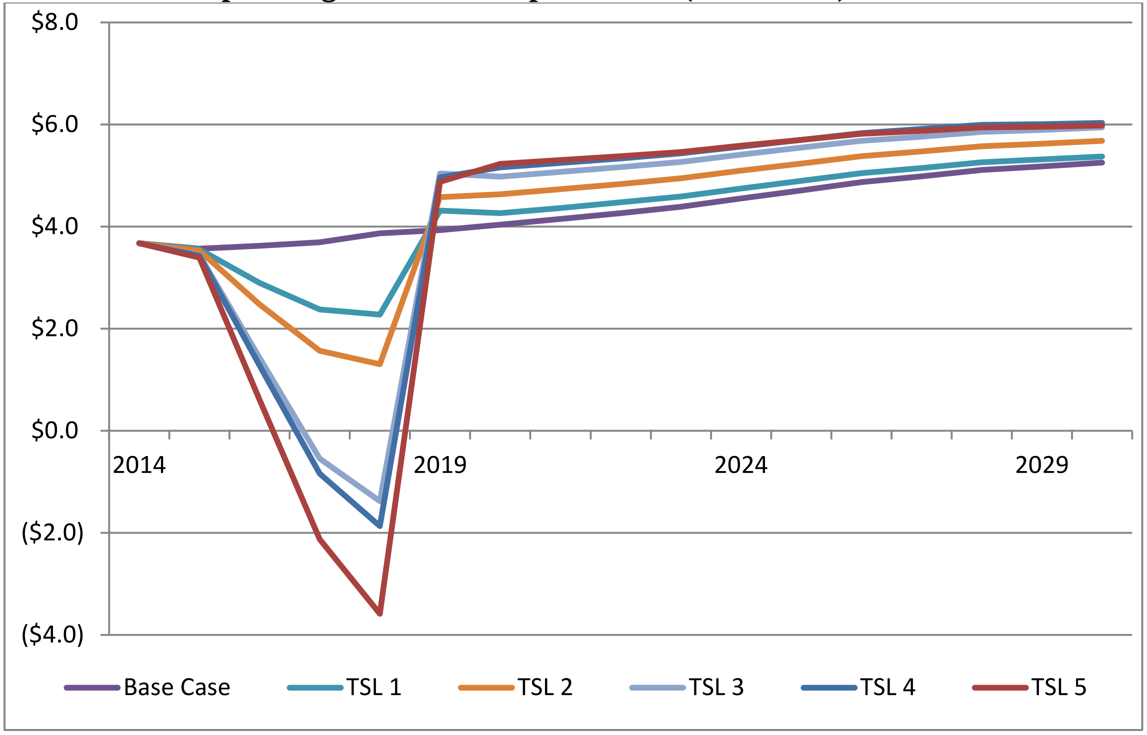


Figure 12.4.2 ASHRAE Baseline: Annual Industry Net Cash Flows under Preservation of Operating Profit Markup Scenario (in 2014$M)



The following tables present alternative results based on the EPCA Baseline. Table 12.4.3 and Table 12.4.4 present the INPV estimates for the two markup scenarios relative to the EPCA Baseline. Figure 12.4.3 and Figure 12.4.4 present the net annual cash flows for the two markup scenarios under the alternative baseline.

Table 12.4.3 EPCA Baseline: Preservation of Gross Margin Percentage Scenario Changes in INPV for PTACs and PTHPs

	Units	Base Case	Trial Standard Level				
			1	2	3	4	5
INPV	2014$M	62.1	60.7	62.5	61.3	62.4	59.5
Change in INPV*	2014$M	-	(1.4)	0.4	(0.8)	0.3	(2.6)
	% Change	-	(2.3)	0.7	(1.3)	0.5%	(4.2)

* Parentheses indicate negative values.

Table 12.4.4 EPCA Baseline: Preservation of Operating Profit Scenario Changes in INPV for PTACs and PTHPs

	Units	Base Case	Trial Standard Level				
			1	2	3	4	5
INPV	2014$M	62.1	60.3	61.2	58.6	58.2	54.7
Change in INPV*	2014$M	-	(1.8)	(0.9)	(3.5)	(3.9)	(7.4)
	% Change	-	(2.9)	(1.4)	(5.6)	(6.3)	(11.9)

* Parentheses indicate negative values.

In the EPCA baseline analysis, DOE estimated an additional set of product conversion costs intended to capture the cost to manufacturers of bringing PTAC equipment into compliance with ASHRAE Standard 90.1-2013. Based on feedback received from manufacturers during interviews, DOE does not expect manufacturers to undertake capital investments in order to comply with efficiency levels established by ASHRAE and therefore did not account for additional capital conversion costs. DOE estimated total industry product conversion costs of $0.48 million to meet amended ASHRAE standards for PTACs. DOE incorporated these costs into its cash flow model as one-time product conversion costs incurred in 2015, the year the ASHRAE standard takes effect.

Figure 12.4.3 EPCA Baseline: Annual Industry Net Cash Flows under Preservation of Gross Margin Percentage Markup Scenario (in 2014$M)

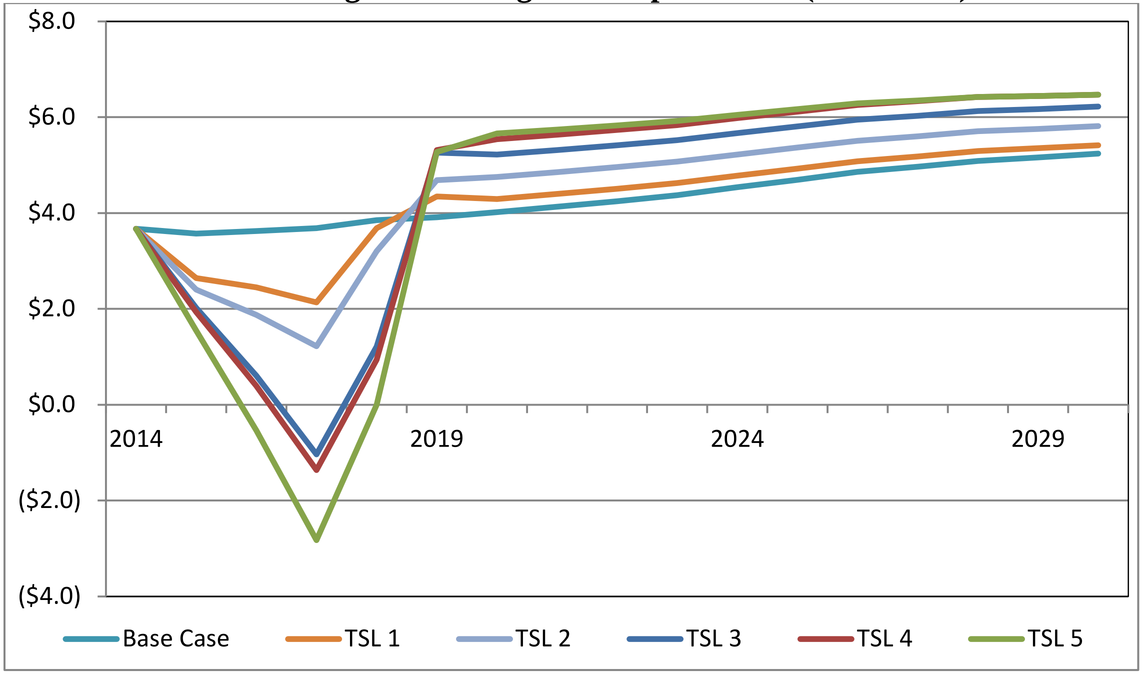
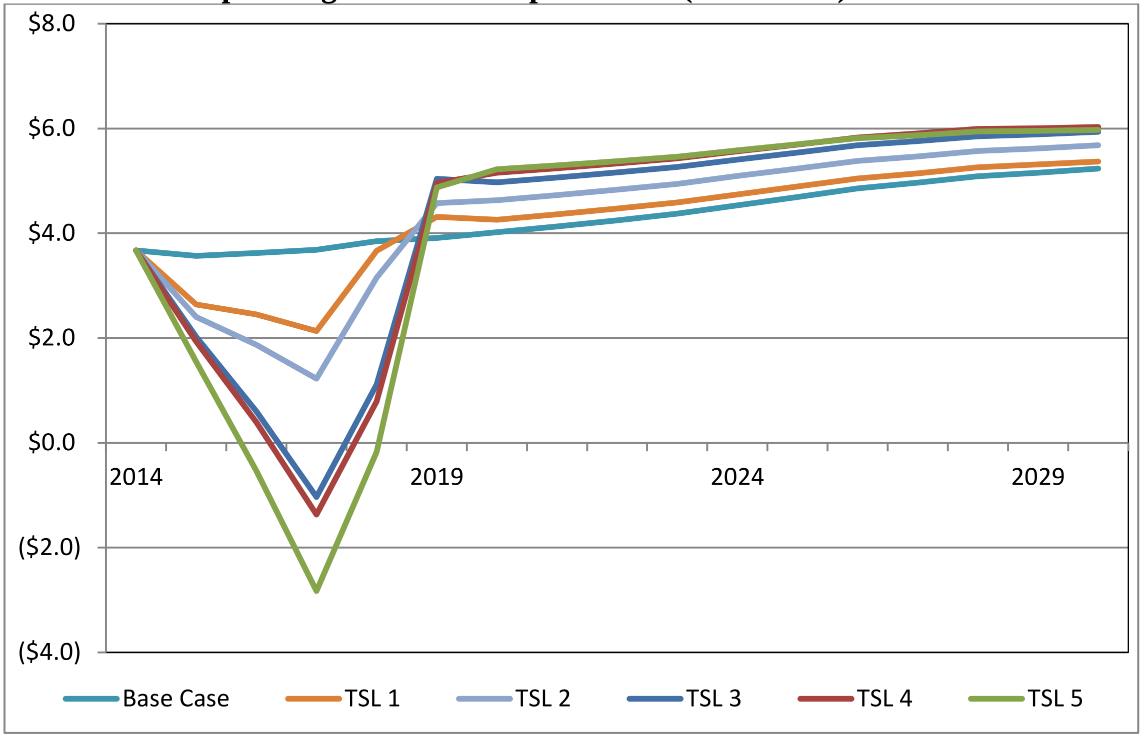


Figure 12.4.4 EPCA Baseline: Annual Industry Net Cash Flows under Preservation of Operating Profit Markup Scenario (in 2014$M)



12.5 IMPACTS ON SUBGROUPS OF MANUFACTURERS

As discussed above, using average cost assumptions to develop an industry cash flow estimate is not adequate for assessing differential impacts among subgroups of manufacturers. Small manufacturers, niche players, or manufacturers exhibiting a cost structure that differs largely from the industry average could be affected differently. DOE used the results of the industry characterization to group manufacturers exhibiting similar characteristics. Specifically, DOE identified two subgroups of manufacturers for separate impact analyses: (1) manufacturers with production assets; and (2) small business manufacturers.

12.5.1 Impacts on Manufacturers with Production Assets

As discussed above, DOE initially identified 22 companies that sell PTAC and PTHP equipment. Most U.S. companies, however, do not own production assets; rather, they import and distribute PTACs and PTHPs manufactured overseas, primarily in China. DOE identified a subgroup of three U.S.-headquartered manufacturers that own production assets. These companies own tooling and manufacturing assets in the U.S. or in foreign countries. Together, these three manufacturers account for approximately 80 percent of the domestic PTAC and PTHP market. Because manufacturers with production assets will incur different costs to comply with an amended energy conservation standard compared to their competitors who do not own production assets, DOE conducted a separate analysis to evaluate the impact of an amended energy conservation standard on the subgroup of manufacturers with production assets.

As with the overall industry analysis, DOE modeled two different markup scenarios to evaluate the range of cash flow impacts on manufacturers with production assets: (1) the preservation of gross margin percentage markup scenario; and (2) the preservation of operating profit markup scenario. See section 12.3.7 for a complete description of markup scenarios.

Each of the modeled scenarios results in a unique set of cash flows and corresponding INPV values at each TSL. In the following discussion, the INPV results refer to the difference in value of manufacturers with production assets between the base case and each TSL in the standards case. As with the overall industry analysis, the INPV for manufacturers with production assets is calculated as the sum of annual net cash flows over the 30-year analysis period, discounted at the industry's cost of capital.

To provide perspective on the short-run cash flow impact, DOE includes in the discussion of results a comparison of free cash flow between the base case and the standards case at each TSL in the year before amended standards would take effect. This figure provides an understanding of the magnitude of required conversion costs relative to the cash flow generated by manufacturers with production assets in the base case.

Table 12.5.1 and Table 12.5.2 present a range of results reflecting both the preservation of gross margin percentage markup scenario and the preservation of operating profit markup scenario. As discussed in section 12.3.7, the preservation of operating profit scenario accounts for the more severe impacts presented.

Table 12.5.1 Manufacturer Impact Analysis Results for the Subgroup of PTAC and PTHP Manufacturers with Production Assets, Gross Margin Percentage Markup Scenario

	Units	Base Case	Trial Standard Level*				
			1	2	3	4	5
INPV	2014$M	49.8	48.7	49.9	48.1	48.9	46.0
Change in INPV	2014$M	-	(1.1)	0.1	(1.7)	(0.9)	(3.8)
	% Change	-	(2.1)	0.3	(3.4)	(1.8)	(7.5)
Product Conversion Costs	2014$M	-	1.4	4.0	6.5	7.8	12.8
Capital Conversion Costs	2014$M	-	2.3	2.9	7.2	7.2	7.5
Total Conversion Costs	2014$M	-	3.7	6.9	13.7	15.0	20.4
Free Cash Flow**	2014$M	3.1	1.7	0.8	(1.9)	(2.3)	(4.0)
	% Change	-	(43.7)	(74.7)	(160.1)	(173.8)	(228.3)

* Parentheses indicate negative values.

Table 12.5.2 Manufacturer Impact Analysis Results for the Subgroup of PTAC and PTHP Manufacturers with Production Assets, Preservation of Operating Profit Markup Scenario

	Units	Base Case	Trial Standard Level*				
			1	2	3	4	5
INPV	2014$M	49.8	48.5	48.9	46.0	45.5	42.3
Change in INPV	2014$M	-	(1.3)	(0.9)	(3.8)	(4.3)	(7.5)
	% Change	-	(2.7)	(1.8)	(7.7)	(8.6)	(15.1)
Product Conversion Costs	2014$M	-	1.4	4.0	6.5	7.8	12.8
Capital Conversion Costs	2014$M	-	2.3	2.9	7.2	7.2	7.5
Total Conversion Costs	2014$M	-	3.7	6.9	13.7	15.0	20.4
Free Cash Flow**	2014$M	3.1	1.7	0.7	(1.9)	(2.4)	(4.1)
	% Change	-	(44.2)	(76.0)	(162.6)	(177.7)	(232.6)

* Parentheses indicate negative values.

In the standards case, manufacturers with production assets would likely experience financial impacts more negative than those facing the industry as a whole (see section 12.4 for industry-wide financial impacts). These differential impacts derive primarily from the conversion costs manufacturers with production assets would incur in order to comply with an amended standard. In particular, manufacturers with production assets would face capital conversion costs not shared by their competitors who import and distribute PTACs and PTHPs and do not require tooling investments. In interviews, manufacturers with production assets indicated that higher standards could require significant investment in new tooling to support new coil designs. In addition, manufacturers with production assets would face product conversion costs in the form of design engineering, product development, testing, certification, marketing, and related costs. See section 12.3.6 for further discussion of conversion costs. However, since this rule maintains the standard at baseline (*i.e.*, ASHRAE), DOE's modeling does not show any negative financial impacts on industry, including manufacturers with production assets, as a direct result of the standard.

12.5.2 Impacts on Small Business Manufacturers

DOE conducted a more focused inquiry of the companies that could be small business manufacturers of products covered by this rulemaking. For "Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing," the Small Business Administration (SBA) has set a size threshold of 750 employees or less for an entity to be considered a small business for this category. During its market survey, DOE used all available public information to identify potential small manufacturers. DOE's research involved industry trade association membership directories (*e.g.*, AHRI), product databases, individual company websites, and market research tools (*e.g.*, Hoovers.com) to create a comprehensive list of companies that manufacture or sell products covered by this rulemaking. DOE also asked stakeholders and industry representatives if they were aware of any other small manufacturers during manufacturer interviews and at previous DOE public meetings. DOE reviewed publicly available data and contacted companies on its list, as necessary, to determine whether they met the SBA's definition of a small business manufacturer of covered PTAC and PTHP products. DOE screened out companies that did not offer products affected by this rulemaking, did not meet the definition of a "small business," or are foreign owned and operated.

DOE identified 22 companies that sell PTAC and PTHP equipment that would be affected by today's proposal. Of these 22 companies, DOE identified 12 as small businesses. DOE contacted the identified small businesses to invite them to take part in a manufacturer impact analysis interview. Of the 12 small businesses contacted, DOE was able to reach and discuss potential standards with two. DOE also obtained information about small businesses and potential impacts on small businesses while interviewing large manufacturers.
Within the PTAC and PTHP industry, no small business identified is an original equipment manufacturer of standard-size equipment affected by this rulemaking. Rather, small businesses tend to import, rebrand, and distribute PTACs and PTHPs manufactured overseas, primarily in China. Some small businesses identified are original equipment manufacturers of non-standard size PTACs and PTHPs; however, non-standard equipment is not impacted by this rulemaking and therefore is not considered in this small business subgroup analysis.

Because small businesses import and distribute, rather than directly manufacture, covered equipment, they would not be expected to incur capital conversion costs in order to comply with amended energy conservation standards nor would they be expected to incur product conversion costs related to engineering and redesign of equipment. Small businesses could potentially incur product conversion costs related to testing and certification of products that undergo redesign by original equipment manufacturers in order to comply with amended standards.

However, in this final rule, DOE is adopting amended energy conservation standards for PTACs equivalent to those set forth in ASHRAE Standard 90.1-2013. In line with ASHRAE Standard 90.1-2013, DOE is not amending energy conservation standards for PTHPs. DOE is required to adopt minimum efficiency standards either equivalent to or more stringent than those set forth by ASHRAE. Therefore, at the proposed level, no regulatory alternatives are available. Since this rule adopts the ASHRAE baseline as the standards level, DOE's modeling does not show any negative financial impacts on industry, including small manufacturers, as a direct result of the standard.

DOE provides additional analysis in section VI.B of the final rule, Review under the Regulatory Flexibility Act.

12.6 OTHER IMPACTS

12.6.1 Employment

12.6.1.1 Methodology

To quantitatively assess the impacts of energy conservation standards on employment, DOE used the GRIM to estimate the domestic labor expenditures and number of employees in the base case and at each TSL from 2015 through the end of the analysis period. DOE used statistical data from the U.S. Census Bureau's 2011 Annual Survey of Manufacturers (ASM), the results of the engineering analysis, and interviews with manufacturers to determine the inputs necessary to calculate industry-wide labor expenditures and domestic employment levels. Labor expenditures related to manufacturing of the equipment are a function of the labor intensity of the product, the sales volume, and an assumption that wages remain fixed in real terms over time. The total labor expenditures in each year are calculated by multiplying the MPCs by the labor percentage of MPCs.

The total labor expenditures in the GRIM were then converted to domestic production employment levels by dividing production labor expenditures by the annual payment per production worker (production worker hours times the labor rate found in the U.S. Census Bureau's 2011 ASM). The production worker estimates in this section cover workers up to the line-supervisor level who are directly involved in fabricating and assembling equipment within the original equipment manufacturer facility. Workers performing services that are closely associated with production operations, such as materials handling tasks using forklifts, are also included as production labor. DOE's estimates only account for production workers who manufacture the specific products covered by this rulemaking.

To estimate an upper bound to employment change, DOE assumes all domestic manufacturers would choose to continue producing products in the U.S. and would not move production to foreign countries. To estimate a lower bound to employment, DOE estimates the maximum portion of the industry that would choose to leave the industry or relocate production overseas rather than make the necessary conversions at domestic production facilities.

12.6.1.2 Direct Employment Impacts

DOE estimates that 50 percent of standard-size PTAC and PTHP units are manufactured domestically. In the absence of amended energy conservation standards, DOE estimates that the PTAC and PTHP industry would employ 175 domestic production workers in 2019.

Table 12.6.1 shows the range of impacts of potential amended energy conservation standards on U.S. production workers of PTACs and PTHPs. The potential changes to direct employment presented suggest that the PTAC and PTHP industry could experience anything from a slight gain in domestic direct employment to a loss of all domestic direct employment. Since this rule maintains the standard at baseline (i.e., ASHRAE), DOE does not expect any loss in domestic direct employment.

Table 12.6.1 Potential Changes in the Total Number of Production Workers in the PTAC and PTHP Industry in 2019

	Trial Standard Level					
	Base Case**	1	2	3	4	5
Potential Changes in Domestic Production Workers in 2019*	-	(175) to 4	(175) to 10	(175) to 17	(175) to 22	(175) to 24

* Parentheses indicate negative values.

**Base Case assumes 175 domestic production workers in the PTAC and PTHP industry in 2019.

The upper end of the range estimates the maximum increase in the number of domestic production workers in the PTAC and PTHP industry after implementation of an amended energy conservation standard. It assumes manufacturers would continue to produce the same scope of covered products within the United States and would require some additional labor to produce more efficient products.

The lower end of the range represents the maximum decrease in total number of U.S. production workers that could result from an amended energy conservation standard. During interviews, manufacturers stated their concerns about increasing offshore competition entering the market. If the cost of complying with amended standards significantly erodes the profitability of domestic manufacturers relative to their competitors who manufacture and/or import PTACs and PTHPs from overseas, manufacturers with domestic production could decide to exit the PTAC and PTHP market and/or shift their production facilities offshore. The lower bound of direct employment impacts therefore assumes domestic production of PTACs and PTHPs ceases, as domestic manufacturers either exit the market or shift production overseas in search of reduced manufacturing costs.

The direct employment impacts discussed here do not include indirect employment impacts on the broader U.S. economy, which are documented in Chapter 16 of the TSD.

12.6.2 Production Capacity

According to PTAC and PTHP manufacturers interviewed, amended energy conservation standards would not significantly constrain manufacturing production capacity. Among manufacturers with production assets, some indicated that higher energy conservation standards could reduce sales volumes, thereby resulting in excess capacity. Among importers and distributors, amended energy conservation standards would not likely impact production capacity. Since this rule maintains the standard at baseline (i.e., ASHRAE), DOE does not expect any change in production capacity.

12.6.3 Cumulative Regulatory Burden

While any one regulation may not impose a significant burden on manufacturers, the combined effects of several impending regulations may have serious consequences for some manufacturers, groups of manufacturers, or an entire industry. Assessing the impact of a single regulation may overlook this cumulative regulatory burden. Multiple regulations affecting the same manufacturer can strain profits and can lead companies to abandon equipment lines or markets with lower expected future returns than competing products. For these reasons, DOE conducts an analysis of cumulative regulatory burden as part of its rulemakings pertaining to equipment efficiency.

Companies that produce a wide range of regulated products may be faced with more capital and product development expenditures than competitors with a narrower scope of products. Regulatory burdens can prompt companies to exit the market or reduce their equipment offerings, potentially reducing competition. Smaller companies in particular can be affected by regulatory costs since these companies have lower sales volumes over which they can amortize the costs of meeting new regulations. A proposed standard is not economically justified if it contributes to an unacceptable level of cumulative regulatory burden.

For the cumulative regulatory burden analysis, DOE looks at other regulations that could affect PTAC and PTHP manufacturers that will take effect approximately three years before or after the 2017 compliance date of this final rule. In interviews, manufacturers cited federal regulations on equipment other than PTACs and PTHPs that contribute to their cumulative regulatory burden. The compliance years and expected industry conversion costs of relevant amended energy conservation standards are presented in Table 12.6.2.

Table 12.6.2 Compliance Dates and Expected Conversion Expenses of Federal Energy Conservation Standards Affecting PTAC and PTHP Manufacturers

Federal Energy Conservation Standards	Approximate Compliance Date	Estimated Total Industry Conversion Expense
2011 Room Air Conditioners 76 FR 22454 (April 21, 2011); 76 FR 52854 (August 24, 2011)	2014	$171M (2009$)
2007 Residential Furnaces & Boilers 72 FR 65136 (Nov. 19, 2007)	2015	$88M (2006$)*
2011 Residential Furnaces 76 FR 37408 (June 27, 2011); 76 FR 67037 (Oct. 31, 2011)	2015	$2.5M (2009$)**
2011 Residential Central Air Conditioners and Heat Pumps 76 FR 37408 (June 27, 2011); 76 FR 67037 (Oct. 31, 2011)	2015	$26.0M (2009$)**
2010 Gas Fired and Electric Storage Water Heaters 75 FR 20112 (April 16, 2010)	2015	$95.4M (2009$)
Dishwashers***	2018	TBD
Commercial Packaged Air-Conditioning and Heating Equipment*** 79 FR 58948 (September 30, 2014)	2018	$226.4M (2013$)
Commercial Warm-Air Furnaces***	2018	$19.9M (2013$)
Furnace Fans 79 FR 38129 (July 3, 2014)	2019	$40.6M (2013$)
Miscellaneous Residential Refrigeration***	2019	TBD
Single Packaged Vertical Units*** 79 FR 78614 (December 30, 2014)	2019	$16.1M (2013$)
Commercial Water Heaters***	2019	TBD
Commercial Packaged Boilers***	2020	TBD

* Conversion expenses for manufacturers of oil-fired furnaces and gas-fired and oil-fired boilers associated with the November 2007 final rule for residential furnaces and boilers are excluded from this figure. The 2011 direct final rule for residential furnaces sets a higher standard and earlier compliance date for oil-fired furnaces than the 2007 final rule. As a result, manufacturers will be required design to the 2011 direct final rule standard. The conversion costs associated with the 2011 direct final rule are listed separately in this table. EISA 2007 legislated higher standards and earlier compliance dates for residential boilers than were in the November 2007 final rule. As a result, gas-fired and oil-fired boiler manufacturers were required to design to the EISA 2007 standard beginning in 2012. The conversion costs listed for residential gas-fired and oil-fired boilers in the November 2007 residential furnaces and boilers final rule analysis are not included in this figure.

**Estimated industry conversion expense and approximate compliance date reflect a court-ordered April 24, 2014 remand of the residential non-weatherized and mobile home gas furnaces standards set in the 2011 Energy Conservation Standards for Residential Furnaces and Residential

Central Air Conditioners and Heat Pumps. The costs associated with this rule reflect implementation of the amended standards for the remaining furnace product classes (i.e., oil-fired furnaces).

***The final rule for this energy conservation standard has not been published. The compliance date and analysis of conversion costs have not been finalized at this time. (If a value is provided for total industry conversion expense, this value represents an estimate from the NOPR.)

Additionally, manufacturers cited increasing ENERGY STAR standards for room air conditioners and ductless heating and cooling systems as a source of regulatory burden. However, DOE does not consider ENERGY STAR in its presentation of cumulative regulatory burden because ENERGY STAR is a voluntary program and is not federally mandated. DOE also notes that it does not consider proposed legislation in its cumulative regulatory burden analysis because the impacts of such legislation would be speculative.

Manufacturers also cited the U.S. EPA Significant New Alternatives Policy (SNAP) Program as a source of regulatory burden. The SNAP Program evaluates and regulates substitutes for ozone-depleting chemicals (such as air conditioning refrigerants) that are being phased out under the stratospheric ozone protection provisions of the Clean Air Act. On July 9, 2014, the EPA issued a notice of proposed rulemaking proposing to list three flammable refrigerants (HFC-32 (R-32), Propane (R-290), and R-441A) as new acceptable substitutes, subject to use conditions, for refrigerant in the Household and Light Commercial Air Conditioning class of equipment. 79 FR 38811 (July 9, 2014). On February 27, 2015, the EPA finalized its proposed rule, and the final rule allows the use of R-32, R-290, and R-441A in limited amounts in PTAC and PTHP applications.[a] DOE notes that the EPA has not proposed delisting R-410A for use in new production in the Household and Light Commercial Air Conditioning class of equipment (which includes PTAC and PTHP equipment). DOE also notes that the use of alternate refrigerants by manufacturers of PTACs and PTHPs would not be required as a direct result of this rule. Furthermore, there is no requirement (nor any proposal to adopt requirements) mandating the use of alternate refrigerants at this time. Hence, alternate refrigerants were not considered in this analysis.

12.7 CONCLUSION

The following section summarizes the range of financial impacts DOE believes PTAC and PTHP manufacturers are likely to experience as a result of amended energy conservation standards. DOE also notes that while these scenarios bound the range of most plausible impacts on manufacturers, there potentially could be circumstances that cause manufacturers to experience impacts outside this range.

Each TSL analyzed in this rulemaking represents a percentage increase in efficiency above current federal minimum efficiency standards. Specifically, TSLs 1, 2, 3, 4, and 5 represent respective increases of 4 percent, 8 percent, 12 percent, 16 percent, and 18 percent

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[a] The pre-publication version of the final rule is available from the EPA at: www.epa.gov/ozone/snap/download/SAN_5745-SNAP_Low_GWP_Refrigerants_FRM_Signature_Version-signed-2-27-2015.pdf

above the current federal minimum efficiency standard for PTACs of a specified cooling capacity. See section 12.3.3 for further discussion of the TSLs.

12.7.1 Conclusions for PTACs and PTHPs MIA

Table 12.7.1 presents a range of results reflecting both the preservation of gross margin percentage markup scenario and the preservation of operating profit markup scenario. As explained in section 12.3.7, the preservation of operating profit scenario accounts for the more severe impacts presented. Estimated conversion costs do not vary with the markup scenario.

Table 12.7.1 Manufacturer Impact Analysis Results for PTACs and PTHPs, Gross Margin Percentage Markup Scenario*

	Units	Base Case	Trial Standard Level*				
			1	**2**	**3**	**4**	**5**
INPV	2014$M	62.2	61.1	63.1	61.9	63.1	60.3
Change in INPV	2014$M	-	(1.1)	0.8	(0.3)	0.8	(1.9)
	% Change	-	(1.8)	1.3	(0.5)	1.4	(3.1)
Product Conversion Costs	2014$M	-	2.2	4.8	7.3	8.6	13.7
Capital Conversion Costs	2014$M	-	2.3	2.9	7.2	7.2	7.5
Total Conversion Costs	2014$M	-	4.5	7.7	14.5	15.8	21.2
Free Cash Flow **	2014$M	3.9	2.3	1.4	(1.3)	(1.7)	(3.4)
	% Change	-	(40.6)	(64.9)	(133.2)	(144.5)	(188.5)

* Parentheses indicate negative values.

Table 12.7.2 Manufacturer Impact Analysis Results for PTACs and PTHPs, Preservation of Operating Profit Markup Scenario*

	Units	Base Case	Trial Standard Level*				
			1	2	3	4	5
INPV	2014$M	62.2	60.7	61.8	59.3	58.9	55.6
Change in INPV	2014$M	-	(1.5)	(0.5)	(3.0)	(3.4)	(6.7)
	% Change	-	(2.4)	(0.8)	(4.8)	(5.4)	(10.7)
Product Conversion Costs	2014$M	-	2.2	4.8	7.3	8.6	13.7
Capital Conversion Costs	2014$M	-	2.3	2.9	7.2	7.2	7.5
Total Conversion Costs	2014$M	-	4.5	7.7	14.5	15.8	21.2
Free Cash Flow **	2014$M	3.9	2.3	1.3	(1.4)	(1.9)	(3.6)
	% Change	-	(41.1)	(66.2)	(135.6)	(148.3)	(192.8)

* Parentheses indicate negative values.

TSL 1 represents a 4 percent increase above current federal minimum efficiency standards for PTACs. At TSL 1, DOE estimates the impacts on INPV to range from -$1.5 million to -$1.1 million, or a change of -2.4 percent to -1.8 percent. Industry free cash flow is estimated to decrease by as much as $1.6 million, in the preservation of operating profit markup scenario, or a change of 41.1 percent compared to the base-case value of $3.9 million in the year before the compliance date (2018). At TSL 1, DOE estimates industry conversion costs of $4.5 million.

TSL 2 represents an 8 percent increase above current federal minimum efficiency standards for PTACs. At TSL 2, DOE estimates impacts on INPV to range from -$0.5 million to $0.8 million, or a change in INPV of -0.8 percent to 1.3 percent. At this level, industry free cash flow is estimated to decrease by as much as $2.6 million, in the preservation of operating profit markup scenario, or a change of 66.2 percent compared to the base-case value of $3.9 million in the year before the compliance date (2018). DOE expects conversion costs at this level to increase to $7.7 million, reflecting the need for additional motor and control changes as well as a more significant R&D and testing burden. The INPV impacts at TSL 2 are slightly less severe than those at TSL 1 due to the interplay of conversion costs, manufacturer selling prices, and shipments. Specifically, the anticipated increase in per-unit purchase price at this level combined with steady shipments is expected to dampen the effects of conversion costs on INPV.

TSL 3 represents a 12 percent increase above current federal minimum efficiency standards for PTACs. At TSL 3, DOE estimates impacts on INPV to range from -$3.0 million to -$0.3 million, or a change in INPV of -4.8 percent to -0.5 percent. At this level, industry free cash flow is estimated to decrease by as much as $5.2 million, in the preservation of operating profit markup scenario, or a change of 135.6 percent compared to the base-case value of $3.9

million in the year before the compliance date (2018). DOE estimates conversion costs at TSL 3 would increase to $14.5 million, nearly double the expected conversion costs at TSL 2. Anticipated conversion costs at this level include investing in new tooling and redesigning equipment to incorporate additional coils and/or formed coils.

TSL 4 represents a 16 percent increase above current federal minimum efficiency standards for PTACs. At TSL 4, DOE estimates impacts on INPV to range from -$3.4 million to $0.8 million, or a change in INPV of -5.4 percent to 1.4 percent. At this level, industry free cash flow is estimated to decrease by as much as $5.7 million, in the preservation of operating profit markup scenario, or a change of 148.3 percent compared to the base-case value of $3.9 million in the year before the compliance date (2018). DOE estimates conversion costs at TSL 4 would increase to $15.8 million. At this level, however, DOE does not anticipate capital conversion costs beyond those required at TSL 3. Rather, product conversion costs account for the full increase. Similar to TSL 2, the INPV impacts at TSL 4 are slightly less severe than those at TSL 3 due to the interplay of conversion costs, manufacturer selling prices, and shipments. The anticipated increase in per-unit purchase price at this level combined with steady shipments is expected to dampen the effects of conversion costs on INPV.

TSL 5 represents the use of max-tech design options for each equipment class. At this level, DOE estimates impacts on INPV to range from -$6.7 million to -$1.9 million, or a change in INPV of -10.7 percent to -3.1 percent. Industry free cash flow is estimated to decrease by as much as $7.5 million, in the preservation of operating profit markup scenario, or a change of 192.8 percent compared to the base-case value of $3.9 million in the year before the compliance date (2018). At this level, DOE estimates conversion costs would increase to $21.2 million.

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CHAPTER 13. EMISSIONS IMPACT ANALYSIS

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CHAPTER 13. EMISSIONS IMPACT ANALYSIS

13.1 INTRODUCTION

The emissions analysis consists of two components. The first component estimates the effect of potential energy conservation standards on power sector and site combustion emissions of carbon dioxide (CO_2), nitrogen oxides (NO_X), sulfur dioxide (SO_2) and mercury (Hg). The second component estimates the impacts of a potential standard on emissions of two additional greenhouse gases, methane (CH_4) and nitrous oxide (N_2O), as well as the reductions to emissions of all species due to “upstream” activities in the fuel production chain. These upstream activities comprise extraction, processing, and transporting fuels to the site of combustion. The associated emissions are referred to as upstream emissions. Together, these emissions account for the full-fuel-cycle (FFC), in accordance with DOE’s FFC Statement of Policy. 76 FR 51282 (Aug. 18, 2011).

The analysis of power sector emissions uses marginal emissions intensity factors calculated by DOE. As of 2014, DOE is using a new methodology based on results published for the *Annual Energy Outlook 2014* (*AEO 2014*) reference case and a set of side cases that implement a variety of efficiency-related policies.[1] The new methodology is described in chapter 15 and in the report “Utility Sector Impacts of Reduced Electricity Demand” (Coughlin, 2014).[2] Site emissions of CO_2 and NO_X are estimated using emissions intensity factors from a publication of the Environmental Protection Agency (EPA).[3]

Combustion emissions of CH_4 and N_2O are estimated using emissions intensity factors published by the EPA, GHG Emissions Factors Hub.[a] The FFC upstream emissions are estimated based on the methodology developed by Coughlin (2013).[4] The upstream emissions include both emissions from fuel combustion during extraction, processing and transportation of fuel, and “fugitive” emissions (direct leakage to the atmosphere) of CH_4 and CO_2.

The emissions intensity factors are expressed in terms of physical units per MWh or MMBtu of site energy savings. Total emissions reductions are estimated using the energy savings calculated in the national impact analysis (chapter 10).

13.2 AIR QUALITY REGULATIONS AND EMISSIONS IMPACTS

Each annual version of the AEO incorporates the projected impacts of existing air quality regulations on emissions. *AEO 2014* generally represents current Federal and State legislation and final implementation regulations in place as of the end of October 2013.

SO_2 emissions from affected electric generating units (EGUs) are subject to nationwide and regional emissions cap and trading programs. Title IV of the Clean Air Act sets an annual

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[a] www.epa.gov/climateleadership/documents/resources/mfgrfg.pdf

emissions cap on SO_2 for affected EGUs in the 48 contiguous states and the District of Columbia (D.C.). SO_2 emissions from 28 eastern states and D.C. were also limited under the Clean Air Interstate Rule (CAIR), which created an allowance-based trading program that that operates along with the Title IV program in those States and D.C. 70 FR 25162 (May 12, 2005). CAIR was remanded to EPA by the U.S. Court of Appeals for the District of Columbia Circuit (D.C. Circuit) but parts of it remained in effect. On July 6, 2011 EPA issued a replacement for CAIR, the Cross-State Air Pollution Rule (CSAPR). 76 FR 48208 (August 8, 2011). On August 21, 2012, the D.C. Circuit issued a decision to vacate CSAPR. See *EME Homer City Generation, LP v. EPA*, 696 F.3d 7, 38 (D.C. Cir. 2012). The court ordered EPA to continue administering CAIR. On April 29, 2014, the U.S. Supreme Court reversed the judgment of the D.C. Circuit and remanded the case for further proceedings consistent with the Supreme Court's opinion.[b] On October 23, 2014, the D.C. Circuit lifted the stay of CSAPR. [c] Pursuant to this action, CSAPR went into effect (and CAIR ceased to be in effect) as of January 1, 2015.

Because *AEO 2014* was prepared prior to the Supreme Court's opinion, it assumed that CAIR remains a binding regulation through 2040. Thus, DOE’s analysis used emissions factors that assume that CAIR, not CSAPR, is the regulation in force. However, the difference between CAIR and CSAPR is not relevant for the purpose of DOE's analysis of emissions impacts from energy conservation standards.

The attainment of emissions caps is typically flexible among affected Electric Generating Units (EGUs) and is enforced through the use of emissions allowances and tradable permits. Under existing EPA regulations, any excess SO_2 emissions allowances resulting from the lower electricity demand caused by the imposition of an efficiency standard could be used to permit offsetting increases in SO_2 emissions by any regulated EGU. In past rulemakings, DOE recognized that there was uncertainty about the effects of efficiency standards on SO_2 emissions covered by the existing cap-and-trade system, but it concluded that no reductions in power sector emissions would occur for SO_2 as a result of standards.

Beginning in 2016, however, SO_2 emissions will fall as a result of the Mercury and Air Toxics Standards (MATS) for power plants. 77 FR 9304 (Feb. 16, 2012). In the final MATS rule, EPA established a standard for hydrogen chloride as a surrogate for acid gas hazardous air pollutants (HAP), and also established a standard for SO_2 (a non-HAP acid gas) as an alternative equivalent surrogate standard for acid gas HAP. The same controls are used to reduce HAP and non-HAP acid gas; thus, SO_2 emissions will be reduced as a result of the control technologies installed on coal-fired power plants to comply with the MATS requirements for acid gas. *AEO 2014* assumes that, in order to continue operating, coal plants must have either flue gas desulfurization or dry sorbent injection systems installed by 2016. Both technologies, which are used to reduce acid gas emissions, also reduce SO_2 emissions. Under the MATS, emissions will

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[b] See EPA v. EME Homer City Generation, 134 S.Ct. 1584, 1610 (U.S. 2014). The Supreme Court held in part that EPA's methodology for quantifying emissions that must be eliminated in certain States due to their impacts in other downwind States was based on a permissible, workable, and equitable interpretation of the Clean Air Act provision that provides statutory authority for CSAPR.

[c] See Georgia v. EPA, Order (D. C. Cir. filed October 23, 2014) (No. 11-1302),

be far below the cap established by CAIR, so it is unlikely that excess SO_2 emissions allowances resulting from the lower electricity demand would be needed or used to permit offsetting increases in SO_2 emissions by any regulated EGU. Therefore, DOE believes that efficiency standards will reduce SO_2 emissions in 2016 and beyond.

CAIR established a cap on NO_x emissions in 28 eastern States and the District of Columbia. Energy conservation standards are expected to have little effect on NO_x emissions in those States covered by CSAPR because excess NO_x emissions allowances resulting from the lower electricity demand could be used to permit offsetting increases in NO_x emissions. However, standards would be expected to reduce NO_x emissions in the States not affected by CAIR, so DOE estimated NOx emissions reductions from potential standards for those States.

The MATS limit mercury emissions from power plants, but they do not include emissions caps and, as such, DOE's energy conservation standards would likely reduce Hg emissions. DOE estimated mercury emissions reductions using emissions factors based on *AEO 2014*, which incorporates the MATS.

13.3 POWER SECTOR AND SITE EMISSIONS FACTORS

The analysis of power sector emissions uses marginal emissions intensity factors derived from analysis of the *AEO 2014* reference and a number of side cases incorporating enhanced equipment efficiencies. To model the impact of a standard, DOE calculates factors that relate a unit reduction to annual site electricity demand for a given end use to corresponding reductions to installed capacity by fuel type, fuel use for generation, and power sector emissions. Details on the approach used may be found in Coughlin (2014).

Table 13.3.1 presents the average power plant emissions factors for selected years. These power plant emissions factors are derived from the emissions factors of the plant types used to supply electricity for space cooling and lighting in commercial buildings. The average factors for each year take into account the projected shares of each of the sources in total electricity generation.

Table 13.3.1 Power Plant Emissions Factors

	Unit*	**2020**	**2025**	**2030**	**2035**	**2040**
CO_2	kg/MWh	708	630	569	521	478
SO_2	g/MWh	679	530	446	374	334
NOx	g/MWh	553	463	405	357	324
Hg	g/MWh	0.00209	0.00164	0.00138	0.00115	0.00103
N_2O	g/MWh	7.2	7.1	6.9	6.6	6.4
CH_4	g/MWh	50	49	48	46	45

* Refers to site electricity savings.

13.4 UPSTREAM EMISSIONS FACTORS

The upstream emissions accounting uses the same approach as the upstream energy accounting described in appendix 10-A. See also Coughlin (2013) and Coughlin (2014). When demand for a particular fuel is reduced, there is a corresponding reduction in the emissions from combustion of that fuel at either the building site or the power plant. The associated reduction in energy use for upstream activities leads to further reductions in emissions. These upstream emissions are defined to include the combustion emissions from the fuel used upstream, the fugitive emissions associated with the fuel used upstream, and the fugitive emissions associated with the fuel used on site.

Fugitive emissions of CO_2 occur during oil and gas production, but are small relative to combustion emissions. They comprise about 2.5 percent of total CO_2 emissions for natural gas and 1.7 percent for petroleum fuels. Fugitive emissions of methane occur during oil, gas and coal production. Combustion emissions of CH_4 are very small, while fugitive emissions (particularly for gas production) may be relatively large. Hence, fugitive emissions make up over 99 percent of total methane emissions for natural gas, about 95 percent for coal, and 93 percent for petroleum fuels.

Upstream emissions factors account for both fugitive emissions and combustion emissions in extraction, processing, and transport of primary fuels. Fugitive emissions factors for methane from coal mining and natural gas production were estimated based on a review of recent studies compiled by Burnham (2011).[6] This review includes estimates of the difference between fugitive emissions factors for conventional production of natural vs. unconventional (shale or tight gas). These estimates rely in turn on data gathered by EPA under new GHG reporting requirements for the petroleum and natural gas industries.[7, 8] As more data are made available, DOE will continue to update these estimated emissions factors.

For ease of application in its analysis, DOE developed all of the emissions factors using site (point of use) energy savings in the denominator. Table 13.4.1 presents the electricity upstream emissions factors for selected years. These were used to estimate the emissions associated with the decreased electricity use. The caps that apply to power sector NO_X emissions do not apply to upstream combustion sources.

Table 13.4.1 Electricity Upstream Emissions Factors

	Unit	2020	2025	2030	2035	2040
CO_2	kg/MWh	29.1	29.4	29.7	29.9	29.8
SO_2	g/MWh	5.0	5.1	4.9	4.7	4.6
NOx	g/MWh	368	375	382	387	387
Hg	g/MWh	0.00001	0.00001	0.00001	0.00001	0.00001
N_2O	g/MWh	0.252	0.247	0.241	0.234	0.228
CH_4	g/MWh	2149	2195	2216	2248	2255

* Refers to site electricity savings.

13.5 EMISSIONS IMPACT RESULTS

Table 13.5.1 presents the estimated cumulative emissions reductions for the lifetime of products sold during the 30 year analysis period at all TSLs.

Table 13.5.1 Cumulative Emissions Reduction for Potential Standard for Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps

	ASHRAE	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
Power Sector and Site Emissions						
CO_2 (million metric tons)	0.049	0.788	3.04	5.90	7.57	7.80
SO_2 (thousand tons)	0.041	0.651	2.50	4.85	6.28	6.50
NO_X (thousand tons)	0.038	0.607	2.34	4.53	5.84	6.03
Hg (tons)	0.000	0.002	0.008	0.015	0.019	0.020
N_2O (thousand tons)	0.001	0.011	0.043	0.082	0.105	0.108
CH_4 (thousand tons)	0.005	0.077	0.297	0.576	0.731	0.752
Upstream Emissions						
CO_2 (million metric tons)	0.003	0.045	0.173	0.336	0.424	0.436
SO_2 (thousand tons)	0.000	0.008	0.031	0.059	0.075	0.077
NO_X (thousand tons)	0.039	0.636	2.47	4.79	6.04	6.20
Hg (tons)	0.000	0.000	0.000	0.000	0.000	0.000
N_2O (thousand tons)	0.000	0.000	0.002	0.003	0.004	0.004
CH_4 (thousand tons)	0.225	3.70	14.4	27.9	35.2	36.1
Total Emissions						
CO_2 (million metric tons)	0.052	0.833	3.21	6.24	7.99	8.24
SO_2 (thousand tons)	0.042	0.658	2.53	4.91	6.36	6.58
NO_X (thousand tons)	0.076	1.24	4.81	9.32	11.9	12.2
Hg (tons)	0.000	0.002	0.008	0.015	0.020	0.020
N_2O (thousand tons)	0.001	0.011	0.044	0.085	0.108	0.111
CH_4 (thousand tons)	0.229	3.78	14.7	28.5	35.9	36.8

Figure 13.5.1 through Figure 13.5.6 show the annual reductions for total emissions for each type of emission from each TSL. The reductions reflect the lifetime impacts of products sold during the 30 year analysis period at all TSLs.

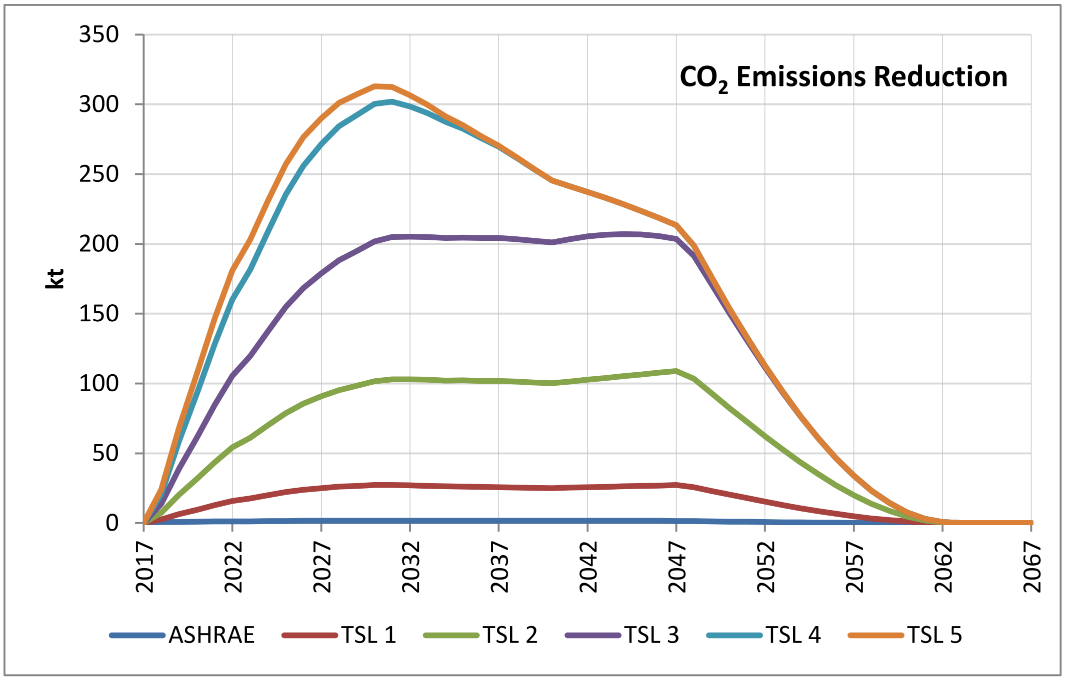

Figure 13.5.1 CO_2 Total Emissions Reduction

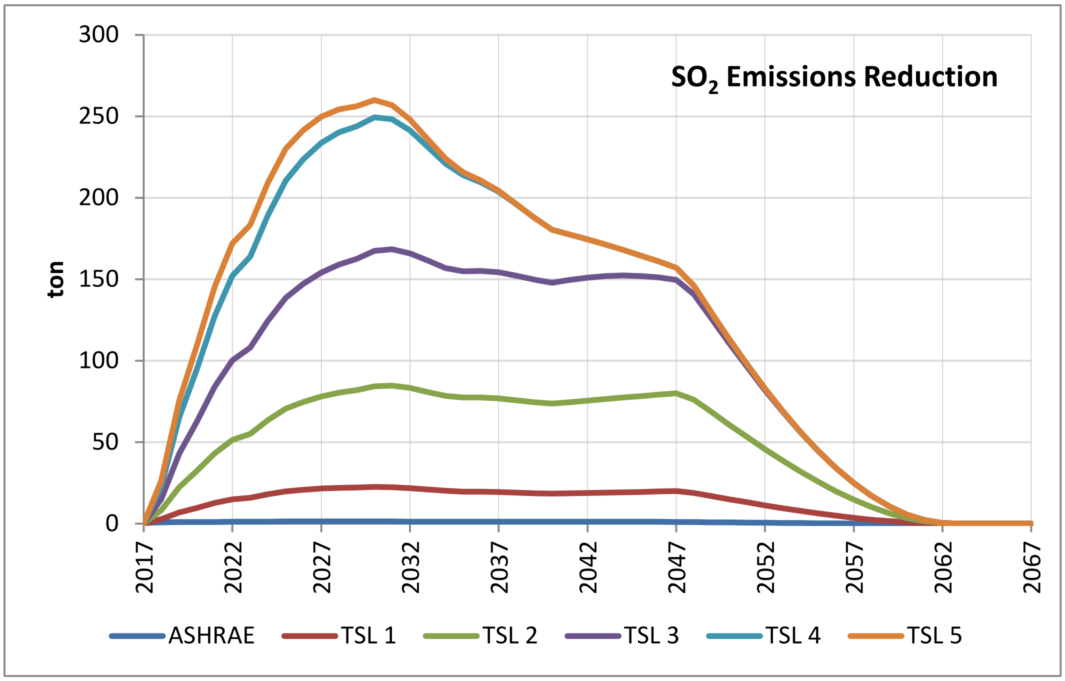

Figure 13.5.2 SO_2 Total Emissions Reduction

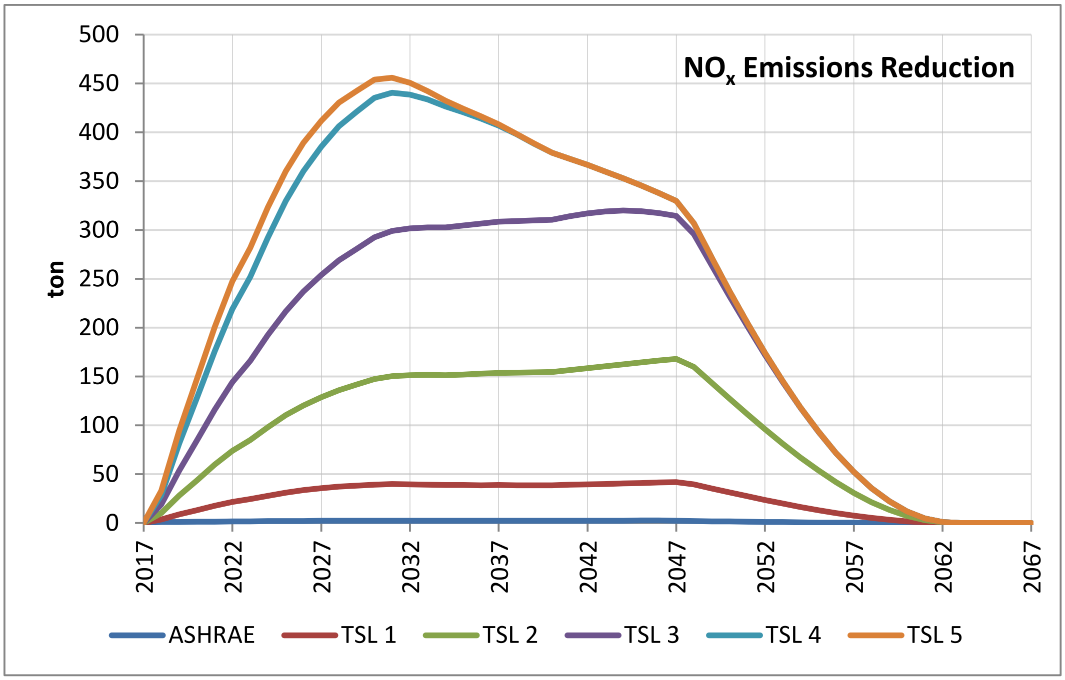

Figure 13.5.3 NO$_x$ Total Emissions Reduction

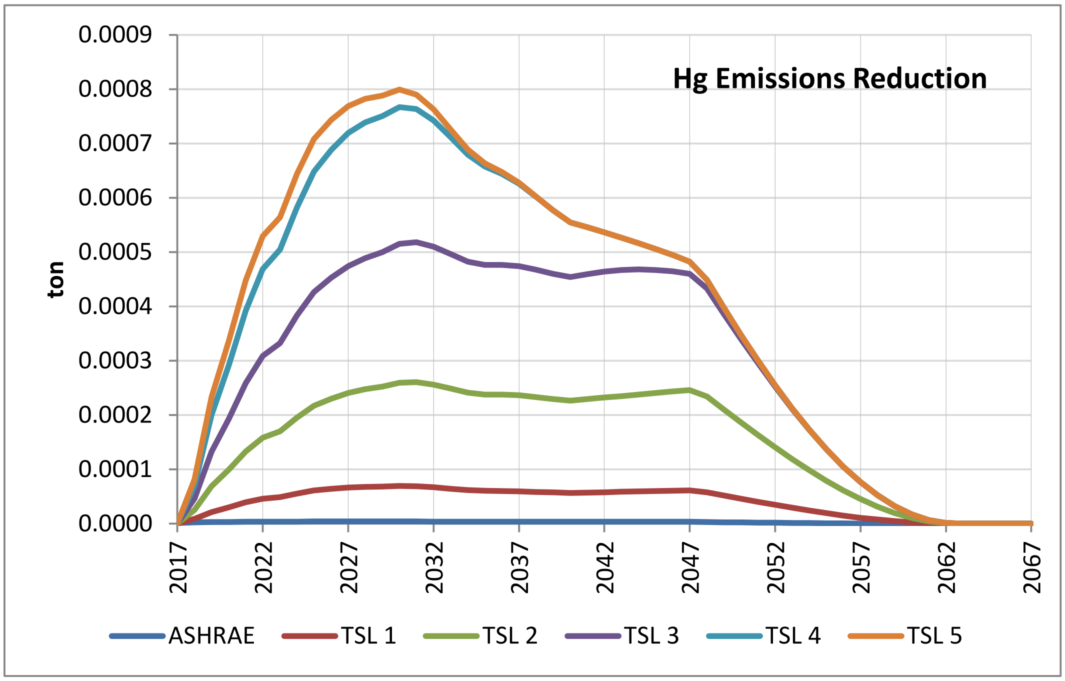

Figure 13.5.4 Hg Total Emissions Reduction

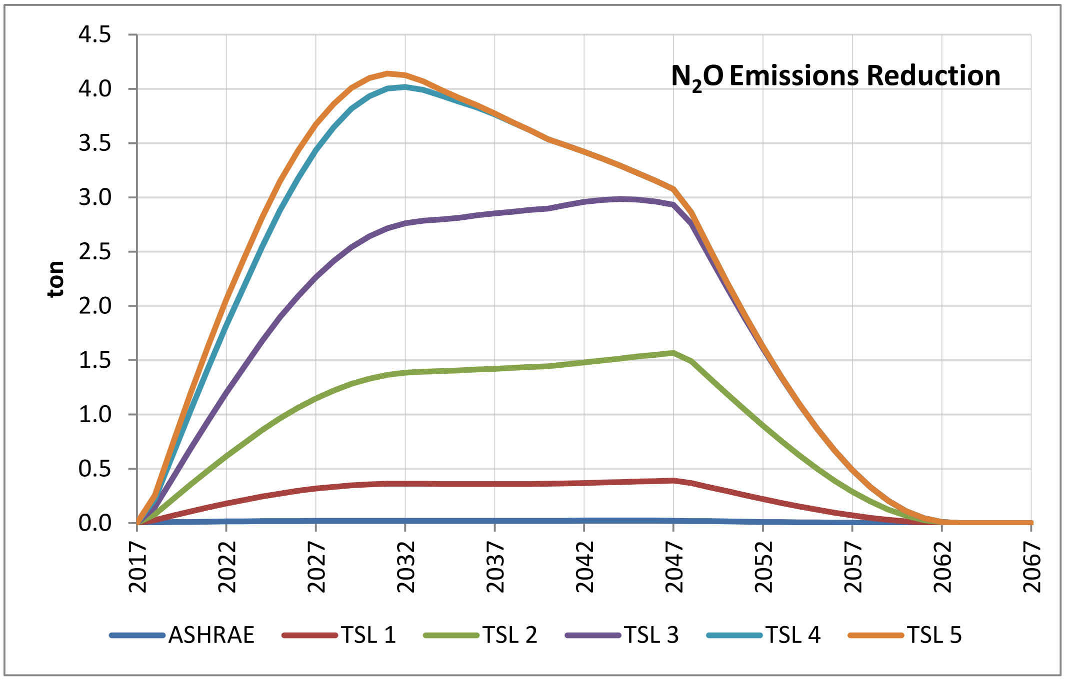

Figure 13.5.5 N_2O Total Emissions Reduction

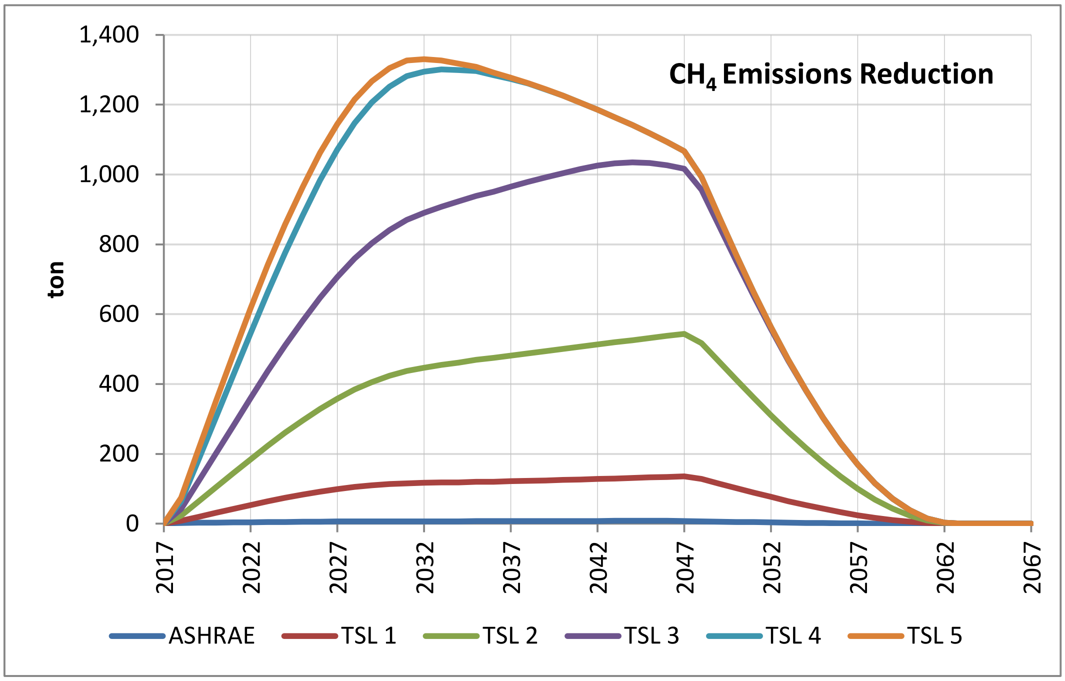

Figure 13.5.6 CH_4 Total Emissions Reduction

As described in Chapter 8, the alternative base case analysis was based off a scenario where the mandatory efficiency level is the Federal minimum, against which DOE determined the impacts on emissions. The estimated cumulative emissions reduction for PTACs and PTHPs are shown in Table 13.5.2, for informational purposes.

Table 13.5.2 Cumulative Emissions Reduction Estimated for Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps Trial Standard Levels Compared to the Alternative Base Case

	ASHRAE	1	2	3	4	5
Primary Emissions						
CO_2 (million metric tons)	0.05	0.84	3.09	5.95	7.62	7.85
SO_2 (thousand tons)	0.04	0.69	2.54	4.89	6.32	6.54
NO_X (thousand tons)	0.04	0.64	2.37	4.57	5.87	6.07
Hg (tons)	0.00	0.00	0.01	0.02	0.02	0.02
N_2O (thousand tons)	0.00	0.01	0.04	0.08	0.11	0.11
CH_4 (thousand tons)	0.00	0.08	0.30	0.58	0.74	0.76
Upstream Emissions						
CO_2 (million metric tons)	0.00	0.05	0.18	0.34	0.43	0.44
SO_2 (thousand tons)	0.00	0.01	0.03	0.06	0.08	0.08
NO_X (thousand tons)	0.04	0.68	2.51	4.83	6.08	6.24
Hg (tons)	0.00	0.00	0.00	0.00	0.00	0.00
N_2O (thousand tons)	0.00	0.00	0.00	0.00	0.00	0.00
CH_4 (thousand tons)	0.22	3.94	14.62	28.11	35.40	36.32
Full Fuel Cycle Emissions						
CO_2 (million metric tons)	0.05	0.89	3.27	6.29	8.04	8.29
SO_2 (thousand tons)	0.04	0.70	2.57	4.95	6.40	6.62
NO_X (thousand tons)	0.08	1.32	4.88	9.40	11.95	12.30
Hg (tons)	0.00	0.00	0.01	0.02	0.02	0.02
N_2O (thousand tons)	0.00	0.01	0.04	0.09	0.11	0.11
CH_4 (thousand tons)	0.23	4.02	14.92	28.70	36.14	37.08

Note: Components may not sum to total due to rounding. Values appear as “0.00” due to rounding.

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CHAPTER 14. MONETIZATION OF EMISSION REDUCTIONS BENEFITS

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CHAPTER 14. MONETIZATION OF EMISSION REDUCTIONS BENEFITS

14.1 INTRODUCTION

As part of its assessment of the effects of potential energy conservation standards for Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps, the U.S. Department of Energy (DOE) estimated the monetary benefits of the reduced emissions of carbon dioxide (CO_2) and nitrogen oxides (NO_X) that would be expected to result from each trial standard level (TSL) considered for this rulemaking. This chapter summarizes the basis for the monetary values assigned to emissions and presents the modeled benefits of estimated reductions.

14.2 MONETIZING CARBON DIOXIDE EMISSIONS

One challenge for anyone attempting to calculate the monetary benefits of reduced emissions of CO_2 is what value to assign to each unit eliminated. The value must encompass a broad range of physical, economic, social, and political effects. Analysts developed the concept of the social cost of carbon (SCC) to represent the broad cost or value associated with producing—or reducing—a quantifiable amount of CO_2 emissions.

14.2.1 Social Cost of Carbon

The SCC is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. The SCC is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services. SCC estimates are provided in dollars per metric ton of carbon dioxide. A value for the domestic SCC is meant to represent the damages in the United States resulting from a unit change in carbon dioxide emissions, whereas a global SCC is meant to reflect the value of damages worldwide.

Under section 1(b)(6) of Executive Order 12866,[1] agencies must, to the extent permitted by law, “assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs.” The purpose of the SCC estimates required by the Executive Order is to enable agencies to incorporate the monetized social benefits of reducing CO_2 emissions into cost-benefit analyses of regulatory actions. The estimates are presented with an acknowledgement of the many uncertainties involved and with a clear understanding that they will need updating in response to increasing knowledge of the science and economics of climate impacts.

As part of the interagency process that developed the SCC estimates, technical experts from numerous agencies met regularly to explore the technical literature in relevant fields, discuss key model inputs and assumptions, and consider public comments. The primary objective of the process was to develop a range of SCC values using a defensible set of assumptions regarding model inputs that was grounded in the scientific and economic literature. In this way, key uncertainties and model differences transparently and consistently inform the range of SCC estimates developed for use in the rulemaking process.

14.2.2 Monetizing Carbon Dioxide Emissions

When attempting to assess the incremental economic impacts of carbon dioxide emissions, the analyst faces several serious challenges. A report from the National Research Council[2] points out that any assessment will suffer from uncertainty, speculation, and lack of information about (1) future emissions of greenhouse gases, (2) the effects of past and future emissions on the climate system, (3) the effects of changes in climate on the physical and biological environment, and (4) the translation of those environmental impacts into economic damages. As a result, any effort to quantify and monetize the harms associated with climate change raises serious questions of science, economics, and ethics and should be viewed as provisional.

Despite the limits of both quantification and monetization, SCC estimates can be useful in estimating the social benefits of reducing CO_2 emissions. An agency can estimate the benefits from reduced (or costs from increased) emissions in any future year by multiplying the change in emissions in that year by the SCC values appropriate for that year. Then the net present value of the benefits can be calculated by multiplying each of the future benefits by an appropriate discount factor and summing across all affected years. This approach assumes that the marginal damages from increased emissions are constant for small departures from the baseline emissions path, an approximation that is reasonable for policies that have effects on emissions that are small relative to cumulative global carbon dioxide emissions.

14.3 DEVELOPMENT OF SOCIAL COST OF CARBON VALUES

In 2009, an interagency process was initiated to develop a preliminary assessment of how best to quantify the benefits from reducing carbon dioxide emissions. To provide consistency in how benefits are evaluated across Federal agencies, the Administration sought to develop a transparent and defensible method, specifically designed for the rulemaking process, to quantify avoided climate change damages from reduced CO_2 emissions. The interagency group did not undertake any original analysis. Instead, it combined SCC estimates from the literature to use as interim values until a more comprehensive analysis could be conducted. The outcome of the preliminary assessment was a set of five interim values: global SCC estimates for 2007 (in 2006$) of $55, $33, $19, $10, and $5 per ton of CO_2.[3] Those interim values represented the first sustained interagency effort within the U.S. government to develop an SCC for use in regulatory analysis. The results of that preliminary effort were presented in several proposed and final rules.

14.3.1 Current Approach and Key Assumptions

After the release of the interim values, the interagency group reconvened regularly to improve the SCC estimates. Specifically, the group considered public comments and further explored the technical literature in relevant fields. The interagency group relied on three integrated assessment models commonly used to estimate the SCC. The models are known by their acronyms of FUND, DICE, and PAGE. Those three models frequently are cited in the peer-reviewed literature and were used in the most recent assessment of the Intergovernmental Panel on Climate Change. Each model was given equal weight in developing SCC values.

Each model takes a slightly different approach to calculating how increases in emissions produce economic damages. A key objective of the interagency process was to enable a consistent exploration of the three models while respecting the different approaches taken by the key modelers in the field. An extensive review of the literature identified three sets of input parameters for the models: climate sensitivity; socioeconomic and emissions trajectories; and discount rates. A probability distribution for climate sensitivity was specified as an input to all three models. In addition, the interagency group used a range of scenarios for the socioeconomic parameters and a range of values for the discount rate. All other model features were left unchanged, relying on the model developers' best estimates and judgments.

The interagency group selected four SCC values for use in regulatory analyses. Three values are based on the average SCC from the three integrated assessment models, at discount rates of 2.5 percent, 3 percent, and 5 percent. The fourth value, which represents the 95th percentile of the SCC estimate across all three models at a 3-percent discount rate, is included to represent larger-than-expected effects from temperature changes farther out in the tails of the SCC distribution. The values increase in real terms over time. Additionally, the interagency group determined that a range of values from 7 percent to 23 percent should be used to adjust the global SCC to calculate domestic effects, although preference is given to consideration of the global benefits of reducing CO_2 emissions. Table 14.3.1 presents the values in the 2010 interagency group report.[4]

Table 14.3.1 Annual SCC Values for 2010-2050 from 2010 Interagency Report (in 2007$ per Metric Ton)

Year	Discount Rate (%)			
	5	3	2.5	3
	Average	Average	Average	95th Percentile
2010	4.7	21.4	35.1	64.9
2015	5.7	23.8	38.4	72.8
2020	6.8	26.3	41.7	80.7
2025	8.2	29.6	45.9	90.4
2030	9.7	32.8	50.0	100.0
2035	11.2	36.0	54.2	109.7
2040	12.7	39.2	58.4	119.3
2045	14.2	42.1	61.7	127.8
2050	15.7	44.9	65.0	136.2

The SCC values used for the analysis of the effects of potential standards for hearth products were generated using the most recent versions of the three integrated assessment models that have been published in the peer-reviewed literature, as described in the 2013 update from the interagency working group (revised November 2013). Table 14.3.2 shows the updated sets of SCC estimates in 5-year increments from 2010 to 2050. The full set of annual SCC estimates for 2010–2050 is presented in appendix 14B of this TSD. The central value that emerges is the average SCC across models at a 3-percent discount rate. To capture the uncertainties involved in regulatory impact analysis, however, the interagency group emphasizes the importance of including all four sets of SCC values.

Table 14.3.2 Annual SCC Values for 2010–2050 from 2013 Interagency Update (in 2007$ per Metric Ton of CO_2)

Year	Discount Rate (%)			
	5	3	2.5	3
	Average	Average	Average	95th Percentile
2010	11	32	51	89
2015	11	37	57	109
2020	12	43	64	128
2025	14	47	69	143
2030	16	52	75	159
2035	19	56	80	175
2040	21	61	86	191
2045	24	66	92	206
2050	26	71	97	220

14.3.2 Limitations of Current Estimates

The interagency group recognizes that current models are imperfect and incomplete. Because key uncertainties remain, current SCC estimates should be treated as provisional and revisable. Estimates doubtless will evolve in response to improved scientific and economic understanding. The 2009 National Research Council report points out the tension between producing quantified estimates of the economic damages from an incremental ton of carbon and the limits of current modeling efforts. Several analytic challenges are being addressed by the research community, some by research programs housed in many of the Federal agencies participating in the interagency process. The interagency group intends to review and reconsider SCC estimates periodically to incorporate expanding knowledge of the science and economics of climate impacts, as well as improvements in modeling.

In summary, in considering the potential global benefits resulting from reduced CO_2 emissions, DOE used the values from the 2013 interagency report, applying the GDP price deflator to adjust the values to 2014$. For the four SCC values, the values of emissions in 2015 were $12.2, $41.2, $63.4, and $121 per metric ton avoided (values expressed in 2014$). DOE derived values after 2050 using the relevant growth rates for 2040–2050 in the interagency update.

DOE multiplied the CO_2 emissions reduction estimated for each year by the SCC value for that year under each discount rate. To calculate a present value of the stream of monetary values, DOE discounted the values in each of the four cases using the same discount rate that had been used to obtain the SCC values in each case.

14.4 VALUATION OF OTHER EMISSIONS REDUCTIONS

DOE considered the potential monetary benefits of reduced NO_X emissions attributable to the TSLs considered for hearth product ignition devices. As noted in chapter 13, new or amended energy conservation standards would reduce NO_X emissions in those States that are not affected by emissions caps. DOE estimated the monetized value of NO_X emissions reductions resulting from each TSL based on estimates of environmental damage found in the scientific literature. Estimates suggest a wide range of monetary values, from $484 to $4,971 per ton (in 2014$).[5] DOE calculated monetary benefits using a median value for NO_X emissions of $2,727 per short ton (in 2014$), at real discount rates of 3 percent and 7 percent.

DOE continues to evaluate appropriate values for monetizing avoided SO_2 and Hg emissions. DOE did not monetize those emissions for this analysis.

14.5 RESULTS

Table 14.5.1 presents the global values of CO_2 emissions reductions for each considered TSL.

Table 14.5.1 Estimates of Global Present Value of CO_2 Emissions Reduction under TSLs for Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps

TSL	SCC Case*			
	5% discount rate, average*	3% discount rate, average*	2.5% discount rate, average*	3% discount rate, 95th percentile*
	Million 2014$			
Primary Energy Emissions				
1	5.60	25.7	40.7	79.3
2	21.4	98.3	156	304
3	41.7	192	304	592
4	55.2	250	396	772
5	57.3	259	409	799
Upstream Emissions				
1	0.310	1.43	2.28	4.44
2	1.19	5.54	8.81	17.1
3	2.32	10.8	17.1	33.3
4	3.02	13.8	22.0	42.8
5	3.12	14.3	22.6	44.1
Full-Fuel-Cycle Emissions				
1	5.91	27.1	43.0	83.7
2	22.5	104	165	321
3	44.0	202	321	626
4	58.2	264	418	815
5	60.5	273	432	843

* For each of the four cases, the corresponding global SCC value for emissions in 2015 is $12.2, $41.2, $63.4, and $121 per metric ton (2014$).

After calculating global values of CO_2 emissions reductions for each considered TSL, DOE calculated domestic values as a range of from 7 percent to 23 percent of the global values. Results for domestic values are presented in Table 14.5.2.

Table 14.5.2 Estimates of Domestic Present Value of CO_2 Emissions Reduction under TSLs for Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps

TSL	SCC Case*			
	5% discount rate, average*	3% discount rate, average*	2.5% discount rate, average*	3% discount rate, 95th percentile*
	Million 2014$			
Primary Energy Emissions				
1	0.4 to 1.3	1.8 to 5.9	2.8 to 9.4	5.5 to 18.2
2	1.5 to 4.9	6.9 to 22.6	10.9 to 35.9	21.3 to 69.9
3	2.9 to 9.6	13.4 to 44.0	21.3 to 69.9	41.5 to 136.2
4	3.9 to 12.7	17.5 to 57.5	27.7 to 91.0	54.0 to 177.6
5	4.0 to 13.2	18.1 to 59.5	28.7 to 94.2	55.9 to 183.8
Upstream Emissions				
1	0.0 to 0.1	0.1 to 0.3	0.2 to 0.5	0.3 to 1.0
2	0.1 to 0.3	0.4 to 1.3	0.6 to 2.0	1.2 to 3.9
3	0.2 to 0.5	0.8 to 2.5	1.2 to 3.9	2.3 to 7.7
4	0.2 to 0.7	1.0 to 3.2	1.5 to 5.0	3.0 to 9.8
5	0.2 to 0.7	1.0 to 3.3	1.6 to 5.2	3.1 to 10.1
Full-Fuel-Cycle Emissions				
1	0.4 to 1.4	1.9 to 6.2	3.0 to 9.9	5.9 to 19.3
2	1.6 to 5.2	7.3 to 23.9	11.6 to 38.0	22.5 to 73.9
3	3.1 to 10.1	14.2 to 46.5	22.5 to 73.9	43.8 to 143.9
4	4.1 to 13.4	18.5 to 60.7	29.2 to 96.1	57.0 to 187.4
5	4.2 to 13.9	19.1 to 62.8	30.2 to 99.4	59.0 to 193.9

* For each of the four cases, the corresponding global SCC value for emissions in 2015 is $12.2, $41.2, $63.4, and $121 per metric ton (2014$).

Table 14.5.3 presents the present value of cumulative NO_X emissions reductions for each TSL. Monetary values are calculated using the average dollar-per-ton values assigned to NO_X emissions at 7-percent and 3-percent discount rates.

Table 14.5.3 Estimates of Present Value of NO_X Emissions Reduction under TSLs for Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps

TSL	3% discount rate	7% discount rate
	Million 2014$	
Primary Energy Emissions		
1	0.871	0.427
2	3.30	1.58
3	6.45	3.11
4	8.63	4.34
5	9.01	4.60
Upstream Emissions		
1	0.873	0.403
2	3.34	1.51
3	6.53	2.97
4	8.56	4.07
5	8.87	4.27
Full-Fuel-Cycle Emissions		
1	1.74	0.830
2	6.64	3.10
3	13.0	6.08
4	17.2	8.42
5	17.9	8.87

As described in Chapter 8, the alternative base case analysis was based off a scenario where the mandatory efficiency level is the Federal minimum, against which DOE determined the impacts on the monetization of emissions reduction. Estimates of the present values of global and domestic CO_2 emissions reduction and of cumulative NO_X emissions reductions are shown in Table 14.5.4 to Table 14.5.6, for informational purposes.

Table 14.5.4 Estimates of Global Present Value of CO_2 Emissions Reduction under Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps Trial Standard Levels Compared to the Alternative Base Case

TSL	SCC Case*			
	5% discount rate, average*	3% discount rate, average*	2.5% discount rate, average*	3% discount rate, 95th percentile*
	Million 2014$			
Primary Energy Emissions				
1	5.95	27.25	43.24	84.21
2	21.70	99.93	158.73	309.02
3	42.04	193.10	306.57	597.15
4	55.52	251.48	398.20	776.89
5	57.68	260.37	412.02	803.97
Upstream Emissions				
1	0.33	1.52	2.42	4.71
2	1.21	5.63	8.95	17.42
3	2.34	10.86	17.27	33.62
4	3.04	13.92	22.09	43.08
5	3.14	14.34	22.75	44.35
Full-Fuel-Cycle Emissions				
1	6.28	28.77	45.66	88.92
2	22.91	105.56	167.69	326.43
3	44.38	203.95	323.85	630.76
4	58.57	265.40	420.30	819.97
5	60.82	274.72	434.76	848.32

* For each of the four cases, the corresponding global SCC value for emissions in 2015 is $12.2, $41.2, $63.4, and $121 per metric ton (2014$).

Table 14.5.5 Estimates of Domestic Present Value of CO_2 Emissions Reduction under Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps Trial Standard Levels Compared to the Alternative Base Case

TSL	SCC Case*			
	5% discount rate, average*	3% discount rate, average*	2.5% discount rate, average*	3% discount rate, 95th percentile*
	Million 2014$			
Primary Energy Emissions				
1	0.4 to 1.4	1.9 to 6.3	3.0 to 9.9	5.9 to 19.4
2	1.5 to 5.0	7.0 to 23.0	11.1 to 36.5	21.6 to 71.1
3	2.9 to 9.7	13.5 to 44.4	21.5 to 70.5	41.8 to 137.3
4	3.9 to 12.8	17.6 to 57.8	27.9 to 91.6	54.4 to 178.7
5	4.0 to 13.3	18.2 to 59.9	28.8 to 94.8	56.3 to 184.9
Upstream Emissions				
1	0.0 to 0.1	0.1 to 0.4	0.2 to 0.6	0.3 to 1.1
2	0.1 to 0.3	0.4 to 1.3	0.6 to 2.1	1.2 to 4.0
3	0.2 to 0.5	0.8 to 2.5	1.2 to 4.0	2.4 to 7.7
4	0.2 to 0.7	1.0 to 3.2	1.5 to 5.1	3.0 to 9.9
5	0.2 to 0.7	1.0 to 3.3	1.6 to 5.2	3.1 to 10.2
Full-Fuel-Cycle Emissions				
1	0.4 to 1.4	2.0 to 6.6	3.2 to 10.5	6.2 to 20.5
2	1.6 to 5.3	7.4 to 24.3	11.7 to 38.6	22.9 to 75.1
3	3.1 to 10.2	14.3 to 46.9	22.7 to 74.5	44.2 to 145.1
4	4.1 to 13.5	18.6 to 61.0	29.4 to 96.7	57.4 to 188.6
5	4.3 to 14.0	19.2 to 63.2	30.4 to 100.0	59.4 to 195.1

* For each of the four cases, the corresponding global SCC value for emissions in 2015 is $12.2, $41.2, $63.4, and $121 per metric ton (2014$).

Table 14.5.6 Estimates of Present Value of NO_X Emissions Reduction under Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps Trial Standard Levels Compared to the Alternative Base Case

TSL	3% discount rate	7% discount rate
	Million 2014$	
Primary Energy Emissions		
1	0.92	0.45
2	3.35	1.61
3	6.50	3.14
4	8.69	4.37
5	9.07	4.62
Upstream Emissions		
1	0.93	0.43
2	3.40	1.54
3	6.58	3.00
4	8.62	4.10
5	8.92	4.30
Full-Fuel-Cycle Emissions		
1	1.85	0.88
2	6.75	3.15
3	13.08	6.13
4	17.30	8.47
5	17.99	8.92

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CHAPTER 15. UTILITY IMPACT ANALYSIS

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15.1 INTRODUCTION

In the utility impact analysis, the U.S. Department of Energy (DOE) analyzes the changes in electric installed capacity and power generation that result for each trial standard level (TSL).

The utility impact analysis is based on output of the DOE/Energy Information Administration (EIA)'s National Energy Modeling System (NEMS).[a] NEMS is a public domain, multi-sectored, partial equilibrium model of the U.S. energy sector. Each year, DOE/EIA uses NEMS to produce an energy forecast for the United States, the Annual Energy Outlook (AEO). The EIA publishes a reference case, which incorporates all existing energy-related policies at the time of publication, and a variety of side cases which analyze the impact of different policies, energy price and market trends. As of 2014, DOE is using a new methodology based on results published for the *Annual Energy Outlook 2014* (*AEO 2014*) Reference case and a set of side cases that implement a variety of efficiency-related policies.[2]

The new approach retains key aspects of DOE's previous methodology, and provides some improvements:

- The assumptions used in the AEO reference case and side cases are fully documented and receive detailed public scrutiny.
- NEMS is updated each year, with each edition of the AEO, to reflect changes in energy prices, supply trends, regulations, *etc.*
- The comprehensiveness of NEMS permits the modeling of interactions among the various energy supply and demand sectors.
- Using EIA published side cases to estimate the utility impacts enhances the transparency of DOE's analysis.
- The variability in impacts estimates from one edition of AEO to the next will be reduced under the new approach.

The methodology is described in more detail in K. Coughlin, "Utility Sector Impacts of Reduced Electricity Demand."[3]

This chapter presents the results for Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps.

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[a] For more information on NEMS, refer to the U.S. Department of Energy, Energy Information Administration documentation. A useful summary is *National Energy Modeling System: An Overview*.[1]

15.2 METHODOLOGY

DOE estimates the marginal impacts of reduction in energy demand on the energy supply sector. In principle, marginal values should provide a better estimate of the actual impact of energy conservation standards. DOE represents these marginal impacts using time series of *impact factors.*

The impact factors are calculated based on output from NEMS for the *AEO 2014*. NEMS uses predicted growth in demand for each end use to build up a projection of the total electric system load growth. The system load shapes are converted internally to load duration curves, which are then used to estimate the most cost-effective additions to capacity. When electricity demand deviates from the AEO reference case, in general there are three inter-related effects: the annual generation (TWh) from the stock of electric generating capacity changes, the total generation capacity itself (GW) may change, and the mix of capacity types and technologies may change. Technology changes lead to a change in the proportion of fuel consumption to electricity generated (referred to as the heat rate). Each of these effects can vary for different types of end use. The change in total generating capacity is sensitive to the degree to which the end-use is peak coincident, while the capacity mix is sensitive to the hourly load shape associated with the end use.

DOE defined impact factors describing the change in installed capacity and fuel consumption per unit reduction of site electricity demand. The impact factors vary by sector and end-use, as well as by year. DOE multiplied the impact factors by the stream of energy savings calculated in the NES (chapter 10) to produce estimates of the utility impacts. For Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps DOE used the impact factors for space cooling and lighting in commercial buildings.

15.3 UTILITY IMPACT RESULTS

This section presents results of the analysis for all of the capacity types.

15.3.1 Installed Capacity

The figures in this section show the changes in U.S. electricity installed capacity that result for each TSL by major plant type for selected years. Units are megawatts of capacity per gigawatt-hour of site electricity use (MW/GWh).[b] Note that a negative number means an increase in capacity under a TSL.

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[b] These units are equivalent to GW/TWh.

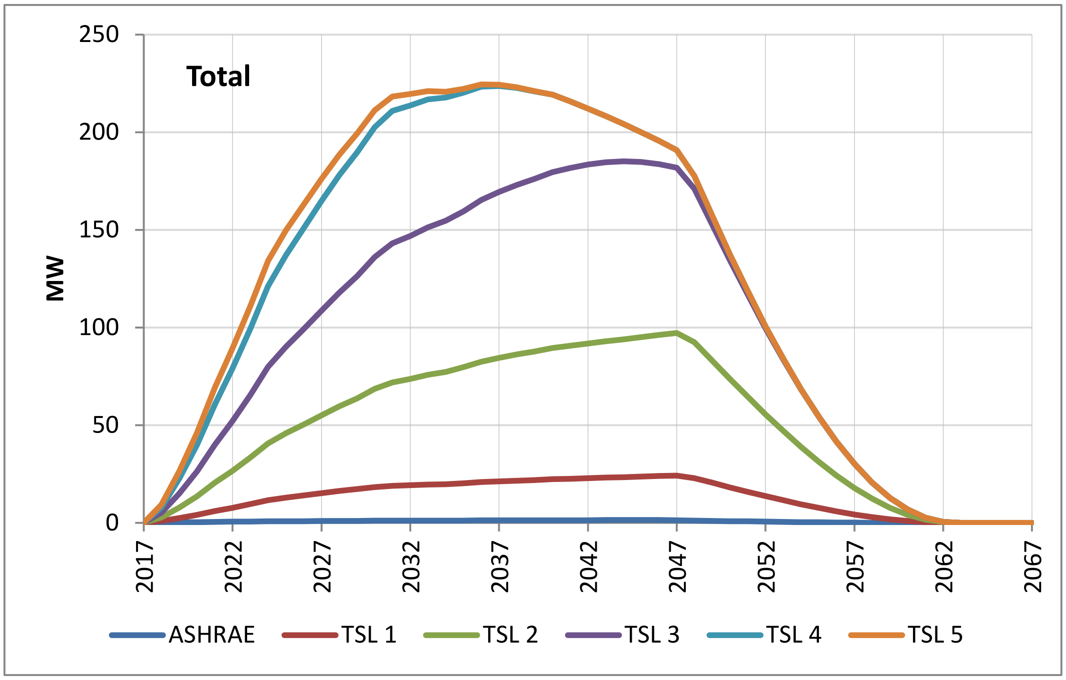

Figure 15.3.1 Total Electric Capacity Reduction

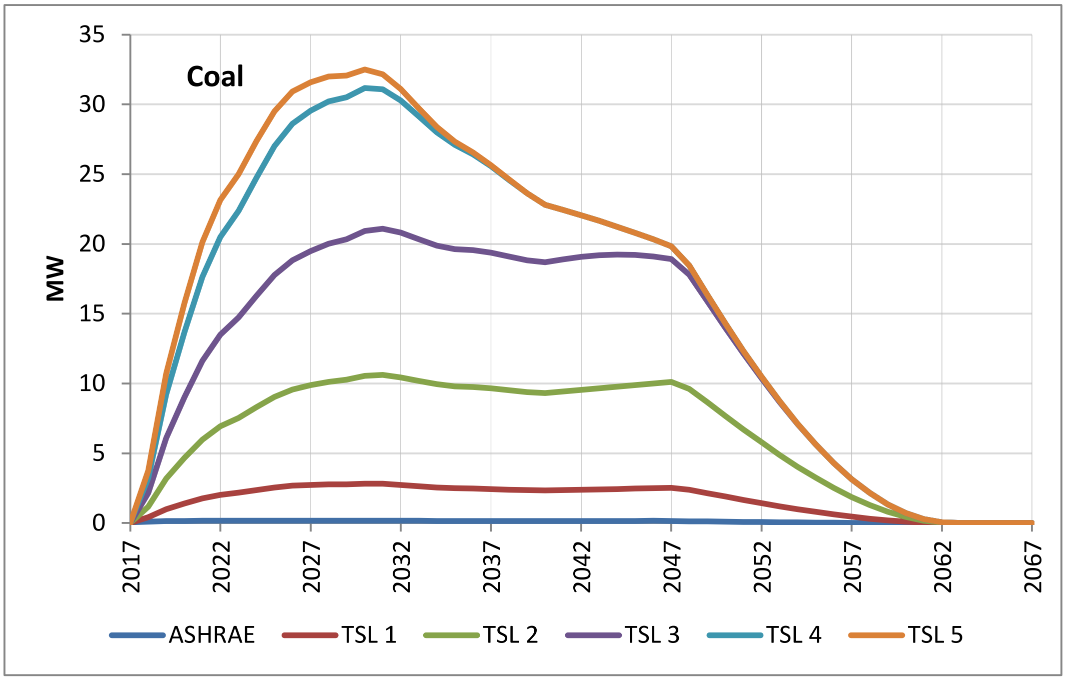

Figure 15.3.2 Coal Capacity Reduction

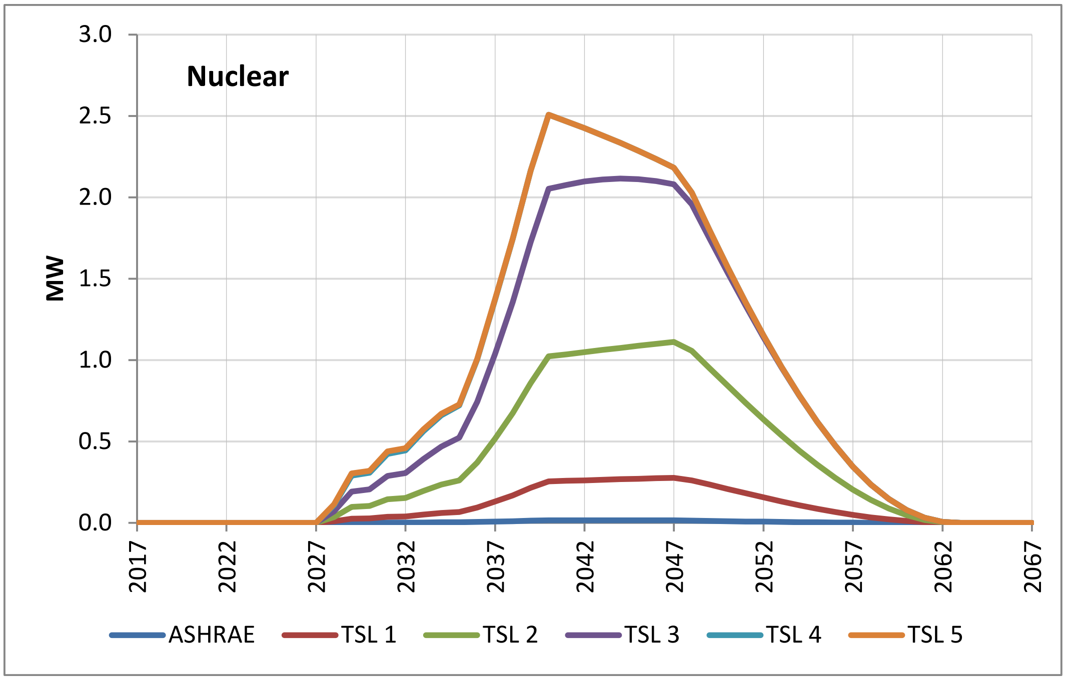

Figure 15.3.3 Nuclear Capacity Reduction

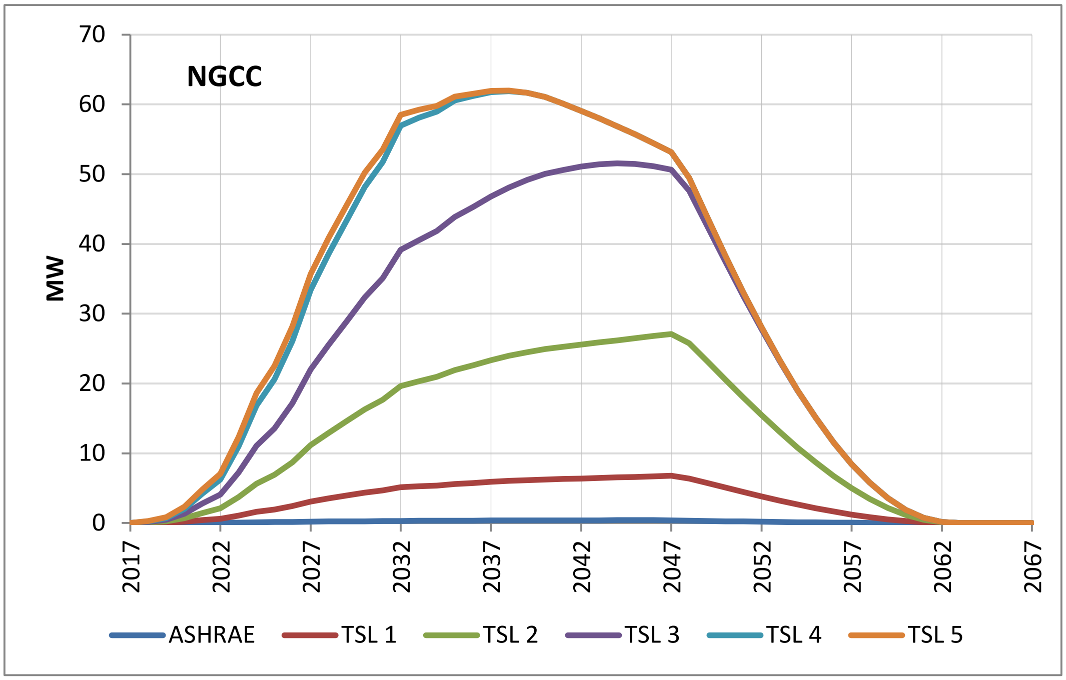

Figure 15.3.4 Gas Combined Cycle Capacity Reduction

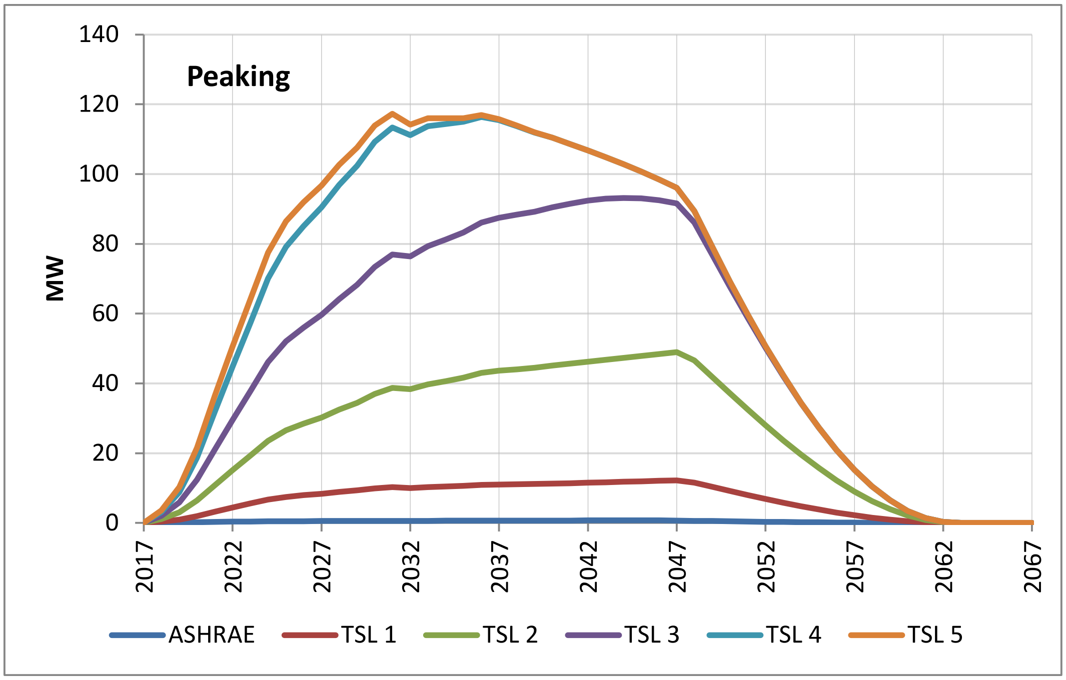

Figure 15.3.5 Peaking Capacity Reduction

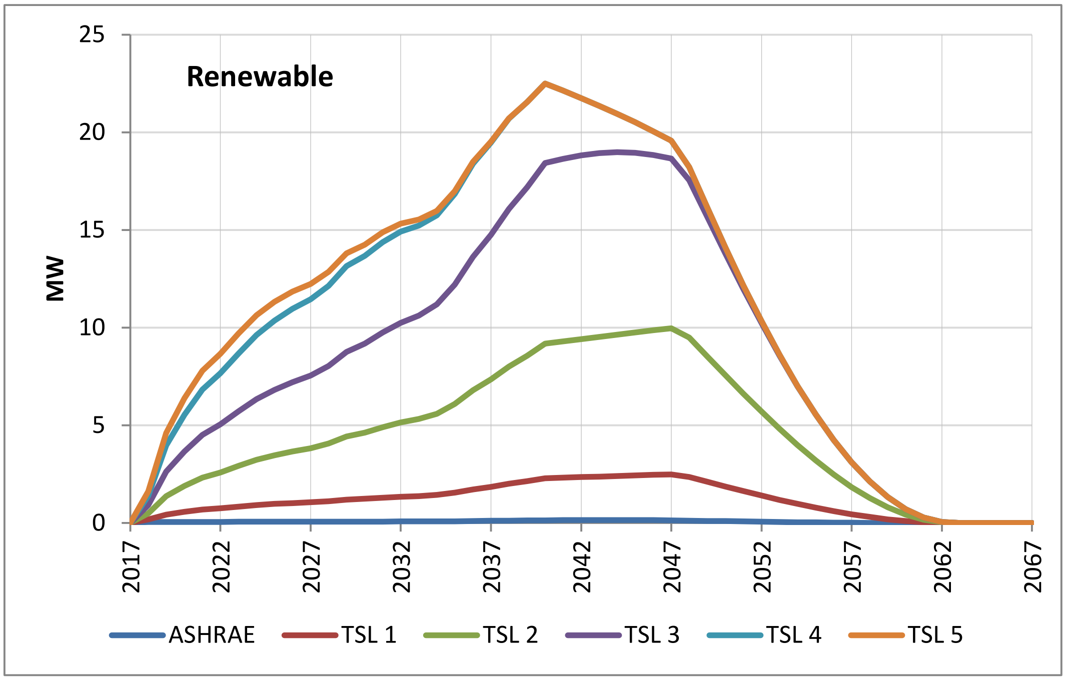

Figure 15.3.6 Renewables Capacity Reduction

15.3.2 Electricity Generation

The figures in this section show the annual change in electricity generation that result for each TSL by fuel type. Note that a negative number means an increase in generation under a TSL.

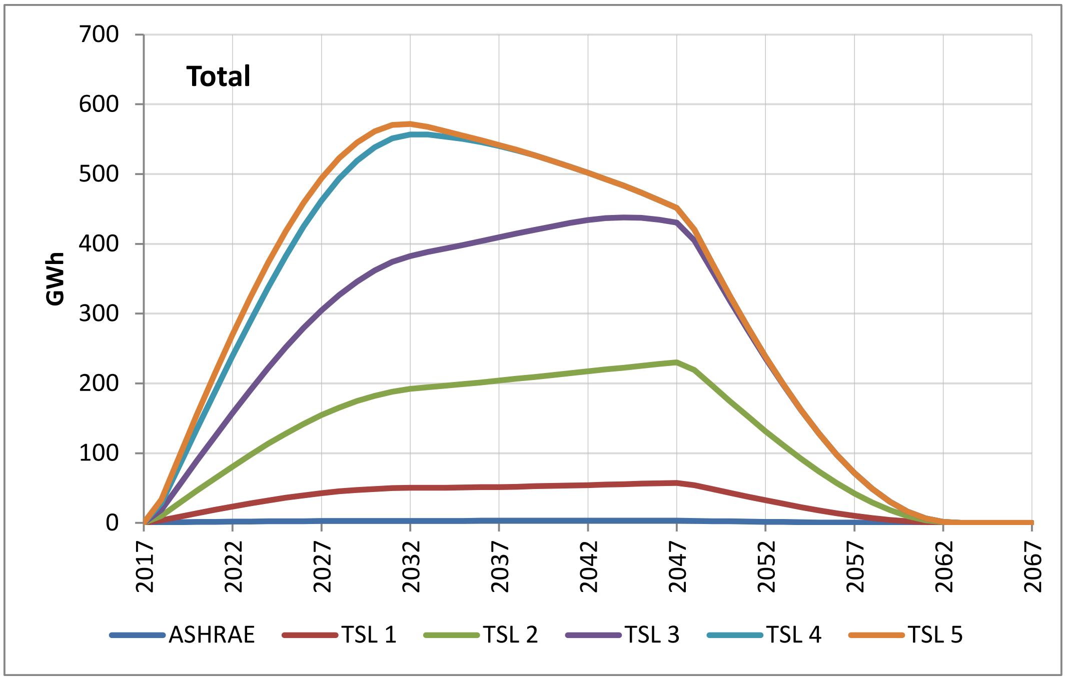

Figure 15.3.7 Total Generation Reduction

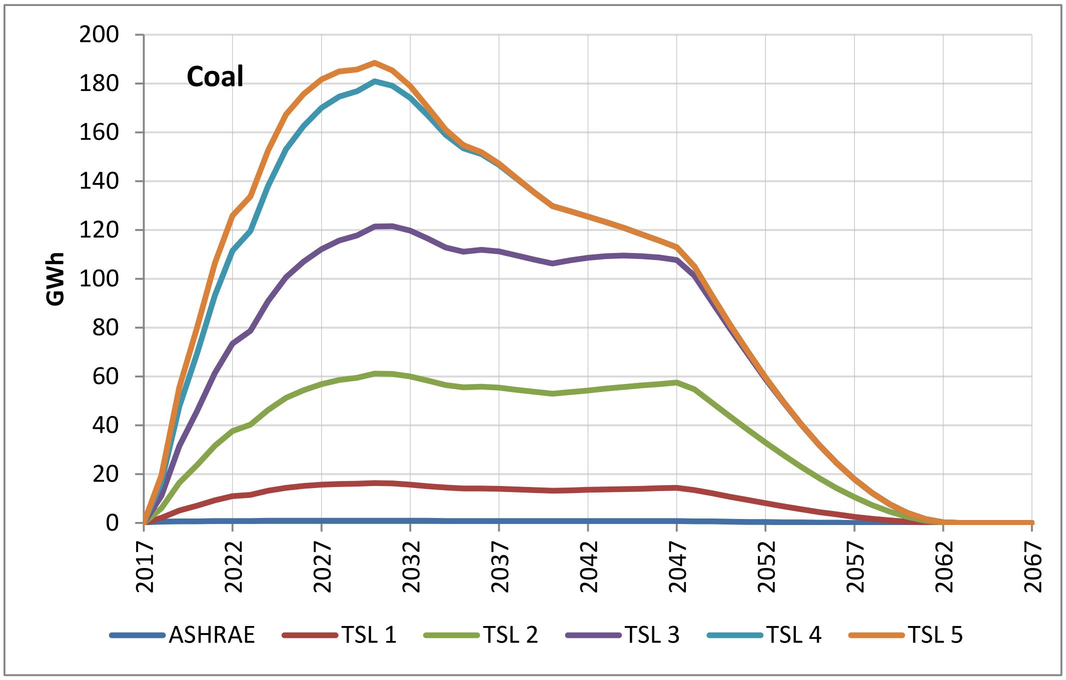

Figure 15.3.8 Coal Generation Reduction

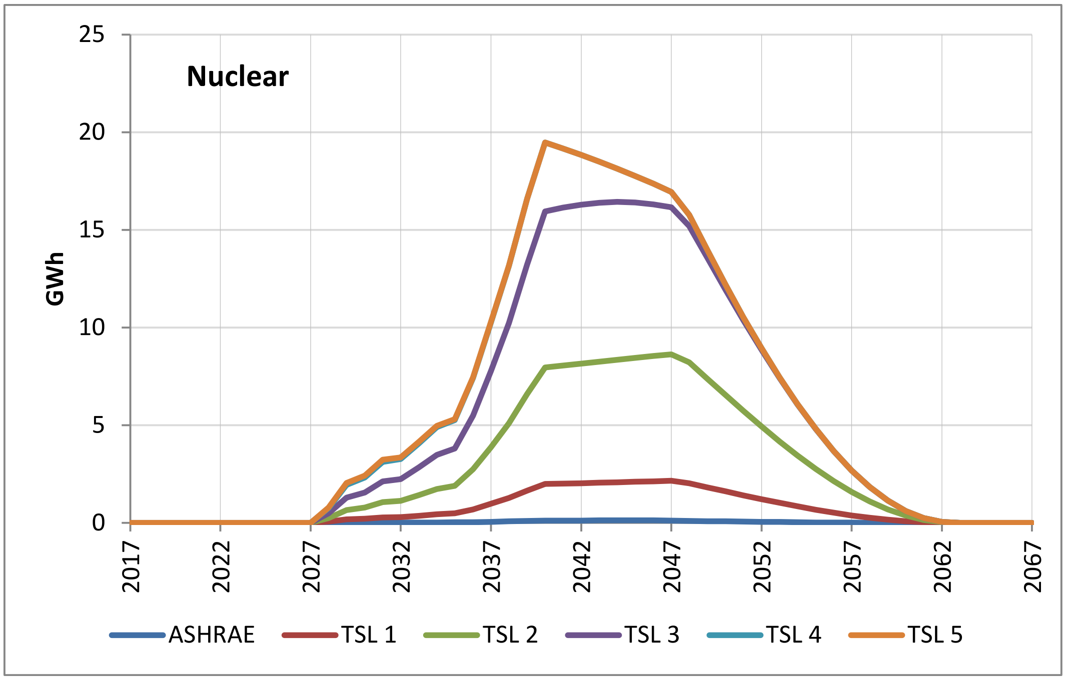

Figure 15.3.9 Nuclear Generation Reduction

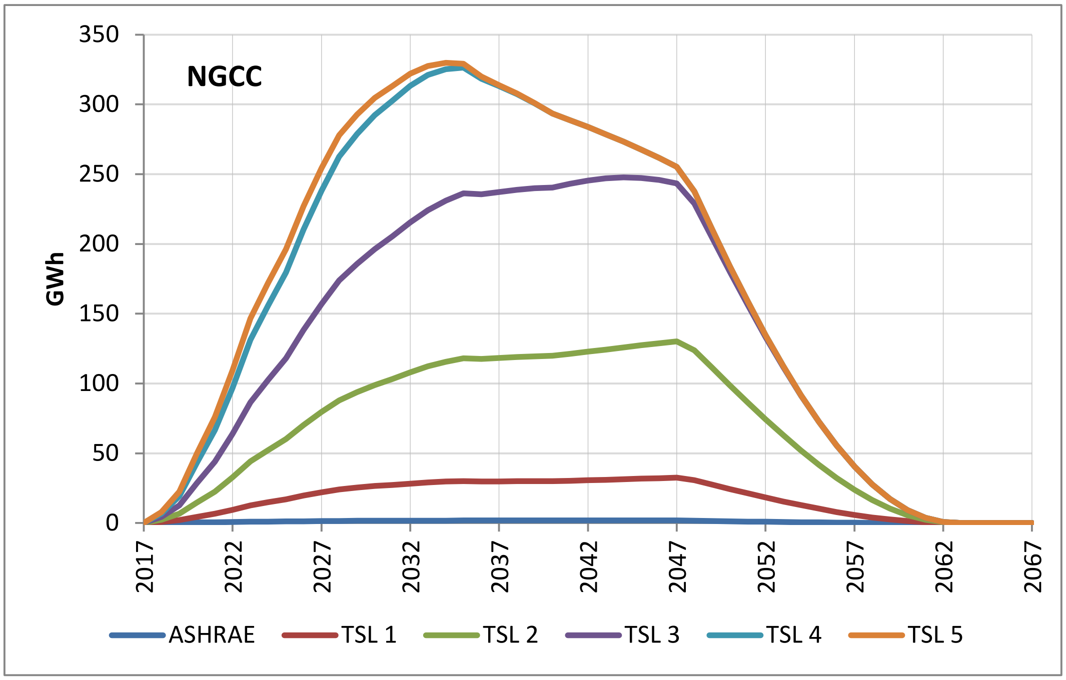

Figure 15.3.10 Gas Combined Cycle Generation Reduction

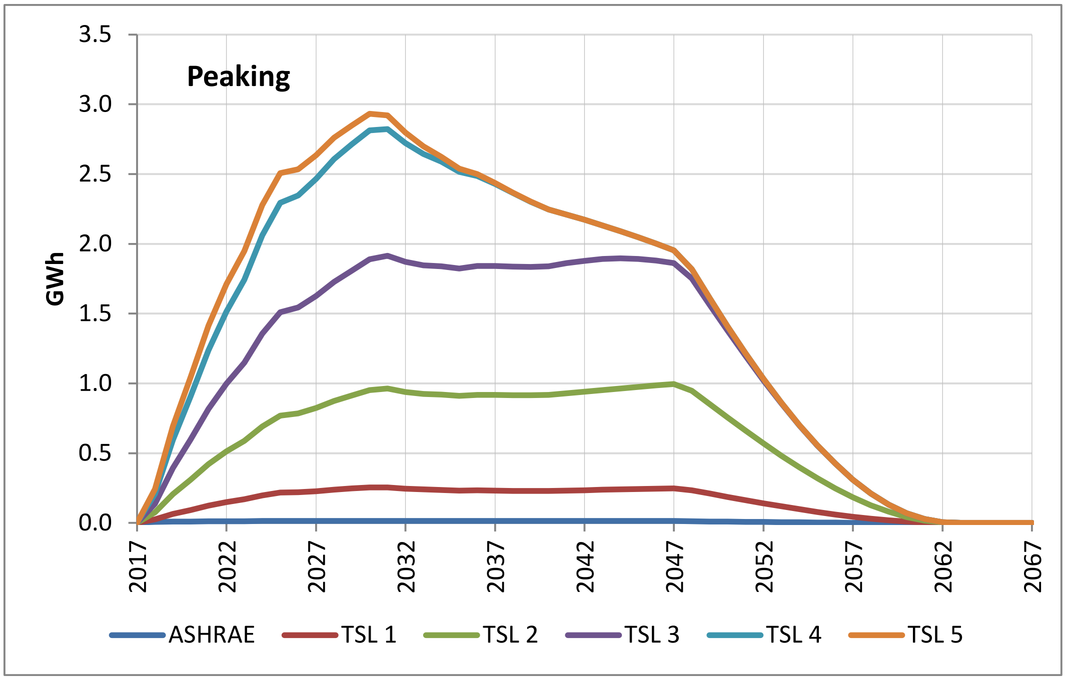

Figure 15.3.11 Peaking Generation Reduction

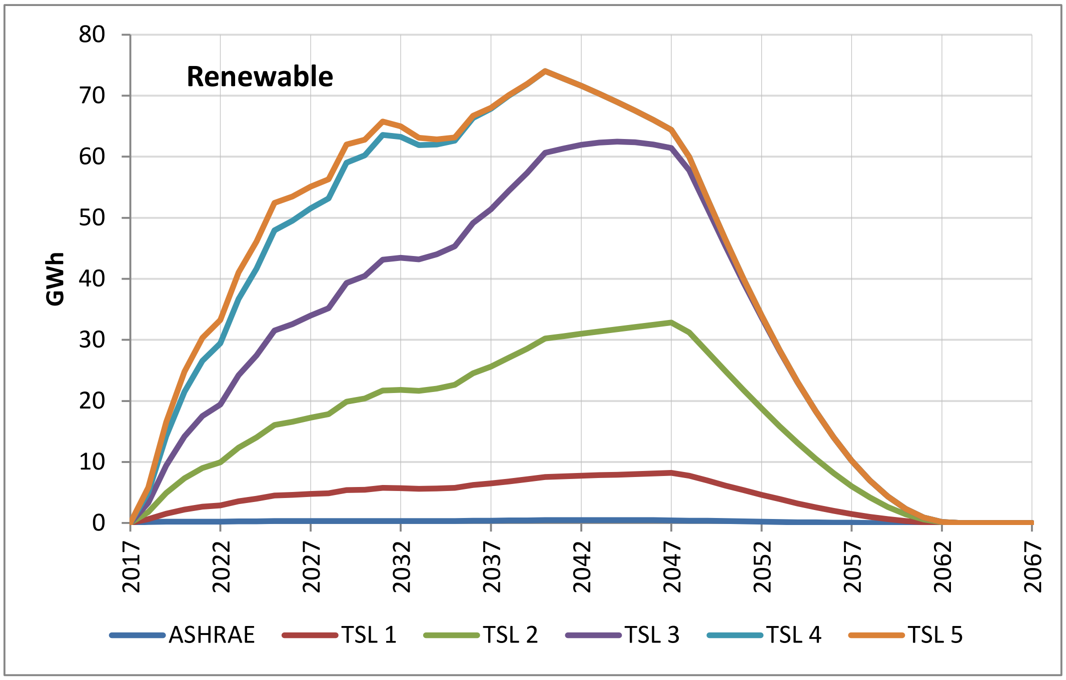

Figure 15.3.12 Renewables Generation Reduction

15.3.3 Results Summary

Table 15.3.1 presents a summary of the utility impact results for Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps.

Table 15.3.1 Summary of Utility Impact Results

	ASHRAE	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
Installed Capacity Reduction (MW)						
2020	0.420	4.10	13.6	26.4	39.9	46.0
2025	0.877	13.0	45.9	90.2	137	150
2030	1.10	18.3	68.6	136	203	211
2035	1.22	20.3	79.7	159	220	222
2040	1.38	22.4	89.5	180	219	219
Electricity Generation Reduction (GWh)						
2020	1.42	13.9	46.1	89.1	135	156
2025	2.45	36.2	128	252	383	418
2030	2.93	48.8	182	362	538	561
2035	3.05	50.8	199	398	550	555
2040	3.27	53.0	212	425	519	519

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16.1 INTRODUCTION

The U.S. Department of Energy's (DOE's) employment impact analysis is designed to estimate indirect national job creation or elimination resulting from possible standards, due to reallocation of the associated expenditures for purchasing and operating PTACs/PTHPs. Job increases or decreases reported in this chapter are separate from the direct manufacturing sector employment impacts reported in chapter 12 and reflect the employment impact of efficiency standards on all other sectors of the economy.

16.2 ASSUMPTIONS

DOE expects energy conservation standards to decrease energy consumption and, therefore, to reduce energy expenditures. The savings in energy expenditures may be spent on new investment or not at all (*i.e.*, they may remain "saved"). The standards may increase the purchase price of appliances, including the retail price plus sales tax, and increase installation costs.

Using an input/output econometric model of the U.S. economy, this analysis estimated the short-term effect of these expenditure impacts on net economic output and employment. DOE intends this analysis to quantify the indirect employment impacts of these expenditure changes. It evaluated direct employment impacts at manufacturers' facilities in the manufacturer impact analysis (see chapter 12).

DOE notes that ImSET is not a general equilibrium forecasting model and understands the uncertainties involved in projecting employment impacts, especially changes in the later years of the analysis.[1] Because ImSET does not incorporate price changes, the employment effects predicted by ImSET would over-estimate the magnitude of actual job impacts over the long run for this rule. As input/output models do not allow prices to bring markets into equilibrium, they are best used for short-run analyses. DOE, therefore, includes a qualitative discussion of how labor markets are likely to respond in the longer term. In future rulemakings, DOE may consider the use of other modeling approaches for examining long-run employment impacts.

16.3 METHODOLOGY

The Department based its analysis on an input/output model of the U.S. economy that estimates the effects of standards on major sectors of the economy related to buildings and the net impact of standards on jobs. The Pacific Northwest National Laboratory developed the model, ImSET 3.1.1[2] (Impact of Sector Energy Technologies), as a successor to ImBuild[3], a special-purpose version of the IMPLAN[4] national input/output model. ImSET estimates the employment and income effects of building energy technologies. In comparison with simple economic multiplier approaches, ImSET allows for a more complete and automated analysis of the economic impacts of energy efficiency investments in buildings.

In an input/output model, the level of employment in an economy is determined by the relationship of different sectors of the economy and the spending flows among them. Different sectors have different levels of labor intensity, and changes in the level of spending (*e.g.,* due to the effects of an efficiency standard) in one sector of the economy will affect flows in other sectors, which affect the overall level of employment.

ImSET uses a 187-sector model of the national economy to predict the economic effects of residential and commercial building technologies. ImSET collects estimates of initial investments, energy savings, and economic activity associated with spending the savings resulting from standards (*e.g.,* changes in final demand in personal consumption, business investment and spending, and government spending). It provides overall estimates of the change in national output for each input-output sector. The model applies estimates of employment and wage income per dollar of economic output for each sector and calculates impacts on national employment and wage income.

Energy efficiency technology primarily affects the U.S. economy along three spending pathways. First, general investment funds are diverted to sectors that manufacture, install, and maintain energy-efficient appliances. The increased cost of appliances leads to higher employment in the appliance manufacturing sectors and lower employment in other economic sectors. Second, commercial firm and residential spending are redirected from utilities toward firms that supply production inputs. Third, electric utility sector investment funds are released for use in other sectors of the economy. When consumers use less energy, electric utilities experience relative reductions in demand, which leads to reductions in utility sector investment and employment.

DOE also notes that the employment impacts estimated with ImSET for the entire economy differ from the employment impacts in the PTAC manufacturing sector estimated in chapter 12 using the Government Regulatory Impact Model (GRIM). The methodologies used and the sectors analyzed in the ImSET and GRIM models are different.

16.4 SHORT-TERM RESULTS

The results in this section refer to impacts of PTAC/PTHP standards relative to the base case. DOE disaggregated the impact of standards on employment into three component effects: increased capital investment costs, decreased energy costs, and changes in operations and maintenance costs. DOE presents the summary impact.

Conceptually, one can consider the impact of the rule in its first year on three aggregate sectors: the PTAC production sector, the energy generation sector, and the general consumer good sector (as mentioned previously, ImSET's calculations are made at a much more disaggregate level). By raising energy efficiency, the rule increases the purchase price of PTACs; this increase in expenditures causes an increase in employment in this sector. At the same time, the improvements in energy efficiency reduce consumer expenditures on electricity. The reduction in electricity demand causes a reduction in employment in that sector. Finally, based on the net impact of increased expenditures on PTACs and reduced expenditures on electricity, consumer expenditures on everything else are either positively or negatively affected, increasing or reducing jobs in that sector accordingly. The model also captures any indirect jobs created or lost by changes in consumption due to changes in employment. (As more workers are hired, they consume more goods, generating more employment; the converse is true for workers who are laid off.)

Table 16.4.1 presents the modeled net employment impact from the rule in 2019, rounded to the nearest ten jobs. Approximately 40% of PTACs are domestically produced and 60% are imported or assembled from imported components. The net employment impact estimate is sensitive to assumptions regarding the return to the U.S. economy of money spent on imported PTACs. The two scenarios bounding the ranges presented in Table 16.4.1 represent situations in which none of the money spent on imported PTACs returns to the U.S. economy and all of the money spent on imported PTACs returns to the U.S. economy. The U.S. trade deficit in recent years suggests that between 50% and 75% of the money spent on imported PTACs is likely to return, with employment impacts falling within the ranges presented below.

Table 16.4.1 Net National Short-Term Change in Employment (Number of Jobs)

Trial Standard Level	2019	2024
ASHRAE	*(ASHRAE level: impact not modeled)*	
1	-10 to 0	-10 to 10
2	-60 to 0	-40 to 30
3	-130 to -10	-90 to 50
4	-220 to -20	-150 to 70
5	-260 to -20	-150 to 80

For context, the Office of Management and Budget (OMB) currently projects that the official unemployment rate may decline to 5.4% in 2019.[5] The unemployment rate in 2019 is projected to be close to "full employment." When an economy is at full employment, any effects on net employment are likely to be transitory as workers change jobs, rather than enter or exit longer-term employment.

16.5 LONG-TERM IMPACTS

Due to the short payback period of energy efficiency improvements mandated by this rule, over the long term DOE expects the energy savings to consumers to increasingly dominate the increase in appliance costs, resulting in increased aggregate savings to consumers. As a result, DOE expects demand for electricity to decline over time and demand for other goods to increase. As the electricity generation sector is relatively capital intensive compared to the consumer goods sector, the net effect will be an increase in labor demand. In equilibrium, this should lead to upward pressure on wages and a shift in employment away from electricity generation towards consumer goods. Note that, in a long-run equilibrium, there is no net effect on total employment, because wages adjust to bring the labor market into equilibrium. Nonetheless, even to the extent that markets are slow to adjust, DOE anticipates that net labor market impacts will be negligible over time due to the small magnitude of the short-term effects presented in Table 16.4.1. The ImSET model projections, assuming no price or wage effects until 2024, are included in the second column of Table 16.4.1.

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CHAPTER 17. REGULATORY IMPACT ANALYSIS: ASSESSMENT OF ALTERNATIVES TO NATIONAL STANDARDS

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CHAPTER 17. REGULATORY IMPACT ANALYSIS: ASSESSMENT OF ALTERNATIVES TO NATIONAL STANDARDS

17.1 INTRODUCTION

The U.S. Department of Energy (DOE) has determined that the regulatory action described in the Federal Register notice associated with this TSD constitutes an "economically significant regulatory action" under Executive Order (E.O.) 12866, Regulatory Planning and Review. 58 FR 51735 (October 4, 1993). For such actions, E.O. 12866 requires Federal agencies to provide "an assessment, including the underlying analysis, of costs and benefits of potentially effective and reasonably feasible alternatives to the planned regulation, identified by the agencies or the public (including improving the current regulation and reasonably viable non-regulatory actions), and an explanation why the planned regulatory action is preferable to the identified potential alternatives." 58 FR 51735, 51741.

To conduct this analysis, DOE used an integrated National Impact Analysis (NIA)-RIA model built on the NIA model discussed in Chapter 10 for its analysis.

DOE identified five non-regulatory policy alternatives that possibly could provide incentives for the same energy efficiency levels as the ones in the trial standard levels (TSL) for packaged terminal air conditioners (PTACs) and packaged terminal heat pumps (PTHPs), which are the subject of this rulemaking. The non-regulatory policy alternatives are listed in Table 17.1.1, which also includes the "no new regulatory action" alternative. DOE evaluated each alternative in terms of its ability to achieve significant energy savings at a reasonable cost, and compared the effectiveness of each to the effectiveness of the selected standard.

Table 17.1.1 Non-Regulatory Alternatives to National Standards

No New Regulatory Action
Consumer Rebates
Consumer Tax Credits
Manufacturer Tax Credits
Voluntary Energy Efficiency Targets
Bulk Government Purchases

Sections 17.2 and 17.3 discuss the analysis of five selected policies listed above (excluding the alternative of no new regulatory action). Section 17.4 presents the results of the policy alternatives.

17.2 NON-REGULATORY POLICIES

This section describes the method DOE used to analyze the energy savings and cost effectiveness of the non-regulatory policy alternatives for PTACs and PTHPs. This section also describes the assumptions underlying the analysis.

17.2.1 Methodology

DOE used its integrated NIA-RIA spreadsheet model to calculate the national energy savings (NES) and net present value (NPV) associated with each non-regulatory policy alternative. Chapter 10 of the technical support document (TSD) describes the NIA spreadsheet model. Appendix 17-A discusses the NIA-RIA integrated model approach.

DOE quantified the effect of each alternative on the purchase of equipment that meet the efficiency levels corresponding to the levels set for each TSL. After establishing the quantitative assumptions underlying each alternative, DOE appropriately revised inputs to the NIA-RIA spreadsheet model. The primary model inputs revised were market shares of equipment meeting the target efficiency levels set for each TSL. The shipments of equipment for any given year reflect a distribution of efficiency levels. DOE assumed, for each TSL, that new energy efficiency standards would affect 100 percent of the shipments of equipment that did not meet the TSL target level in the base case,[a] whereas the non-regulatory policies would affect a smaller percentage of those shipments. DOE made certain assumptions about the percentage of shipments affected by each alternative policy. DOE used those percentages to calculate the shipment-weighted average energy consumption and costs of PTACs and PTHPs attributable to each policy alternative.

Increasing the efficiency of equipment often increases its average installed cost. However, operating costs generally decrease because energy consumption declines. DOE therefore calculated an NPV for each non-regulatory alternative in the same way it did for the selected standards. In some policy scenarios, increases in total installed cost are mitigated by government rebates or tax credits. Because DOE assumed that consumers would re-pay credits and rebates in some way (such as additional taxes), DOE did not include rebates or tax credits as a consumer benefit when calculating national NPV. DOE's analysis also excluded any administrative costs for the non-regulatory policies; including such costs would decrease the NPVs slightly.

The following are key measures for evaluating the impact of each alternative.

- <u>National Energy Savings</u> (NES), given in quadrillion Btus (quads), describes the cumulative national primary energy saved over the lifetime of equipment purchased during the 30-year analysis period..

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[a] The base case for the NIA is a market-weighted average energy efficiency calculated from units at several efficiency levels.

- Net Present Value (NPV), represents the value of net monetary savings in 2015, expressed in 2014$, from equipment purchased during the 30-year analysis period. DOE calculated the NPV as the difference between the present value of installed equipment cost and operating expenditures in the base case and the present value of those costs in each policy case. DOE calculated operating expenses (including energy costs) for the life of equipment.

17.2.2 Assumptions Regarding Non-Regulatory Policies

The effects of non-regulatory policies are by nature uncertain because they depend on program implementation, marketing efforts, and on consumers' responses to a program. Because the projected effects depend on assumptions regarding the rate of consumer participation, they are subject to more uncertainty than are the impacts of mandatory standards, which DOE assumes will be met with full compliance. To increase the robustness of the analysis, DOE conducted a literature review regarding each non-regulatory policy and consulted with recognized experts to gather information on similar incentive programs that have been implemented in the United States. By studying experiences with the various types of programs, DOE sought to make credible assumptions regarding potential market impacts. Section 17.3 presents the sources DOE relied on in developing assumptions about each alternative policy and reports DOE's conclusions as they affected the assumptions that underlie the modeling of each alternative policy.

Each non-regulatory policy that DOE considered would improve the average efficiency of new PTACs and PTHPs relative to their base case efficiency scenario (which involves no new regulatory action), except for PTAC <7,000 Btu/hr at TSL ASHRAE and TSL 1, for which there is no market in the base case at efficiency levels below the corresponding CSLs, and for all PTHPs at TSL ASHRAE for which the selected standards coincide with current baseline efficiency levels. The analysis considered that each alternative policy would induce consumers to purchase units having the same efficiency level as required by the selected standards (the target level) set for each TSL. As opposed to the standards case, however, the policy cases may not lead to 100 percent market penetration of units that meet the target level.

Table 17.2.1 shows the efficiency level stipulated in the selected standards for PTACs and PTHPs.

Table 17.2.1 Efficiency Levels for Trial Standard Levels for Packaged Terminal Air Conditioner and Packaged Terminal Heat Pump Equipment Classes (EER)

Equipment Class	**Trial Standard Levels**					
	ASHRAE	1	2	3	4	5
PTAC						
< 7,000 Btu/h	11.9	12.2	12.6	13.1	13.6	13.8
7,000 – 15,000 Btu/h	11.3	11.5	12.0	12.4	12.9	13.1
> 15,000 Btu/h	9.5	9.7	10.0	10.4	10.8	11.0
PTHP						
< 7,000 Btu/h	11.9	12.2	12.6	13.1	13.6	13.8
7,000 – 15,000 Btu/h	11.3	11.5	12.0	12.4	12.9	13.1
> 15,000 Btu/h	9.5	9.7	10.0	10.4	10.8	11.0

DOE assumed that the effects of non-regulatory policies would last from the effective date of standards through the end of the analysis period.

17.2.3 Policy Interactions

DOE calculated the effects of each non-regulatory policy separately from those of the other policies. In practice, some policies are most effective when implemented in combination, such as voluntary efficiency targets implemented with consumer rebates or tax credits. However, DOE attempted to make conservative assumptions to avoid double-counting policy impacts. The resulting policy impacts are not additive; the combined effect of several or all policies cannot be inferred from summing their results.

Section 17.4 presents graphs that show the market penetration estimated under each non-regulatory policy for the PTAC and PTHP equipment classes.

17.3 NON-REGULATORY POLICY ASSUMPTIONS

The following subsections describe DOE's analysis of the impacts of the five non-regulatory policy alternatives to selected standards for PTACs and PTHPs. (Because the alternative of No New Regulatory Action has no energy or economic impacts, essentially representing the NIA base case, DOE did not perform any additional analysis for that alternative.) DOE developed estimates of the market penetration of high-efficiency equipment both with and without each of the non-regulatory policy alternatives.

17.3.1 No New Regulatory Action

The case in which no new regulatory action is taken with regard to the energy efficiency of PTACs and PTHPs constitutes the base case, as described in Chapter 10, National Impact Analysis. The base case provides the basis of comparison for all other policies. By definition, no new regulatory action yields zero NES and an NPV of zero dollars.

17.3.2 Consumer Rebates

DOE considered the scenario in which the Federal government would provide financial incentives in the form of rebates to consumers for purchasing energy-efficient appliances. This policy provides a consumer rebate for purchasing PTACs and PTHPs that operate at the same efficiency as stipulated in each TSL (target level).

17.3.2.1 Methodology

DOE based its evaluation methodology for consumer rebates on a comprehensive study of California's potential for achieving energy efficiency. The study, performed by XENERGY, Inc.,[b] summarized experiences with various utility rebate programs.[1] XENERGY's analytical method utilized graphs, or penetration curves, that estimate the market penetration of a technology based on its benefit/cost (B/C) ratio. DOE consulted with experts and reviewed other methods of estimating the effect of consumer rebate programs on the market penetration of efficient technologies. The other methods, developed after the referenced XENERGY report was published,[2, 3, 4, 5, 6, 7] used different approaches: other economic parameters (e.g., payback period), expert surveys, or model calibration based on specific utility program data rather than multi-utility data. Some models in use by energy efficiency program evaluation experts were so client-specific that generic relationships between economic parameters and consumer response could not be established.[5] DOE decided that the most appropriate available method for this RIA analysis was the XENERGY approach of penetration curves based on B/C ratio, which incorporates lifetime operating cost savings.

XENERGY's model estimates market impacts induced by financial incentives based on the premise that two types of information diffusion drive the adoption of new technologies. *Internal sources* of information encourage consumers to purchase new equipment primarily through word-of-mouth from early adopters. *External sources* affect consumer purchase decisions through marketing efforts and information from outside the consumer group. Appendix 17-A contains additional details on internal and external information diffusion.

XENERGY's model equation accounts for the influences of both internal and external sources of information by superimposing the two components. Combining the two mechanisms for information diffusion, XENERGY's model generates a set of penetration (or implementation) curves for a policy measure. XENERGY calibrated the curves based on participation data from

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[b] XENERGY is now owned by KEMA, Inc. (www.kema.com)

utility rebate programs. The curves illustrate the increased penetration (i.e., increased market share) of efficient equipment driven by consumer response to changes in B/C ratio induced by rebate programs. The penetration curves depict various diffusion patterns based on perceived market barriers (from no-barriers to extremely-high-barriers) to consumer purchase of high-efficiency equipment. DOE adjusted the XENERGY former penetration curves based on expert advice founded on more recent utility program experience.[5, 8]

DOE modeled the effects of a consumer rebate policy for PTACs and PTHPs by determining, for each TSL, the increase in market penetration of equipment meeting the target level relative to their market penetration in the base case. It used the interpolation method presented in Blum et al (2011)[9] to create customized penetration curves based on relationships between actual base case market penetrations and actual B/C ratios. To inform its estimate of B/C ratios provided by a rebate program DOE performed a thorough nationwide search for existing rebate programs for PTACs and PTHPs. It gathered data on utility or agency rebates throughout the nation for this equipment, and used this data to calibrate the customized penetration curves it developed for each equipment class so they can best reflect the market barrier level faced by each equipment class. Section 17.3.2.2 shows the interpolated curves used in the analysis.

17.3.2.2 Analysis

For the six equipment classes it analyzed, DOE estimated the effect of increasing its B/C ratio via a rebate that would pay all or part of the increased installed cost of a unit that met the target efficiency level compared to one meeting the baseline efficiency level.[c] To inform its estimate of an appropriate rebate amount, DOE performed a thorough nationwide search for existing rebate programs for PTACs and PTHPs. It gathered data from a sample of utility and agency rebate programs that includes 37 rebates for PTACs and PTHPs initiated by 30 utilities or agencies in various States. (Appendix 17-A, identifies the rebate programs.) To represent the rebate level, DOE used the simple average of the rebate amounts in these programs. DOE assumed that rebates would remain in effect at the same levels throughout the forecast period.

For each of the six equipment classes, DOE first calculated the B/C ratio without a rebate using the difference in total installed costs (C) and lifetime operating cost savings (B) between the unit meeting the target level and the baseline unit. It then calculated the B/C ratio given a rebate for the unit meeting the target efficiency level. Because the rebate reduced the incremental cost, the unit receiving the rebate had a larger B/C ratio. Table 17.3.1 shows the effect of consumer rebates on the B/C ratio for each TSL in the first year of its corresponding analysis period.

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[c] The baseline technology for each product class is defined in the engineering analysis, Chapter 5, as the technology that represents the basic characteristics of products in that class. A baseline unit typically is one that just meets current Federal energy conservation standards and provides basic consumer utility.

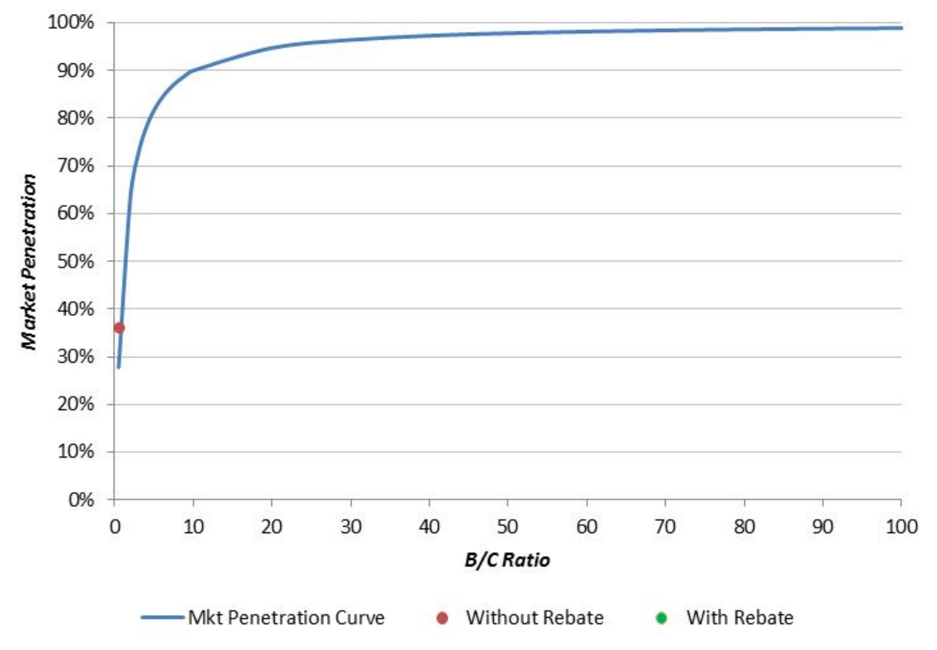
Table 17.3.1 Benefit/Cost Ratios Without and With Rebates for Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps

	Trial Standard Levels					
PTAC	ASHRAE	1	2	3	4	5
< 7,000 Btu/h						
B/C Without Rebate	-	-	0.8	0.8	0.8	0.8
Rebate (2014$)			37.13	39.43	41.74	42.89
B/C With Rebate			4.8	1.8	1.4	1.2
Market Barriers			No-Low	Hg-xHg	Hg-xHg	Hg-xHg
7,000 – 15,000 Btu/h						
B/C Without Rebate	0.7	0.8	0.9	0.9	0.9	0.9
Rebate (2014$)	41.89	43.95	47.70	51.45	55.20	57.08
B/C With Rebate	infinite	infinite	infinite	4.0	2.2	1.9
Market Barriers	No-Low	No-Low	No-Low	Low-Mod	Mod-Hg	Mod-Hg
> 15,000 Btu/h						
B/C Without Rebate	0.8	0.9	0.8	0.7	0.7	0.6
Rebate (2014$)	46.93	48.74	52.67	56.60	60.52	62.49
B/C With Rebate	infinite	infinite	infinite	2.1	1.2	1.1
Market Barriers	Hg-xHg	No	Hg-xHg	Hg-xHg	Hg-xHg	Hg-xHg
PTHP	ASHRAE	1	2	3	4	5
< 7,000 Btu/h						
B/C Without Rebate	-	1.3	1.2	1.1	1.0	1.0
Rebate (2014$)		32.91	33.14	33.37	33.60	33.71
B/C With Rebate		infinite	infinite	2.6	1.7	1.6
Market Barriers		Low-Mod	Low-Mod	xHigh	xHigh	xHigh
7,000 – 15,000 Btu/h						
B/C Without Rebate	-	2.0	1.5	1.4	1.3	1.3
Rebate (2014$)		40.95	41.32	41.70	42.07	42.26
B/C With Rebate		infinite	infinite	6.4	2.9	2.4
Market Barriers		Low-Mod	No-Low	Low-Mod	Mod-Hg	xHigh
> 15,000 Btu/h						
B/C Without Rebate	-	1.3	1.3	1.1	1.0	1.0
Rebate (2014$)		45.71	46.10	46.49	46.88	47.08
B/C With Rebate		infinite	infinite	3.2	1.7	1.5
Market Barriers		Low-Mod	No-Low	xHigh	xHigh	xHigh

* No-Low: No-to-Low market barriers; Mod: Moderate market barriers; Low-Mod: Low-to-Moderate market barriers; Mod-High: Moderate-to-High market barriers; xHigh: Extremely-High market barriers; Hg-xHg: High-to-Extremely-High market barriers

DOE used these B/C ratios, along with the penetration curves it estimated for each equipment class at each TSL, to estimate the percentage of consumers who would purchase PTACs and PTHPs that meet the target level both with and without a rebate incentive. Figure 17.3.1 shows the penetration curves DOE estimated for the two equipment classes affected by the policy at TSL ASHRAE. The market barriers DOE calculated to represent the market behavior for these two equipment classes at TSL ASHRAE are indicated in Table 17.3.1.

PTAC 7,000 – 15,000 Btu/h



PTAC > 15,000 Btu/h

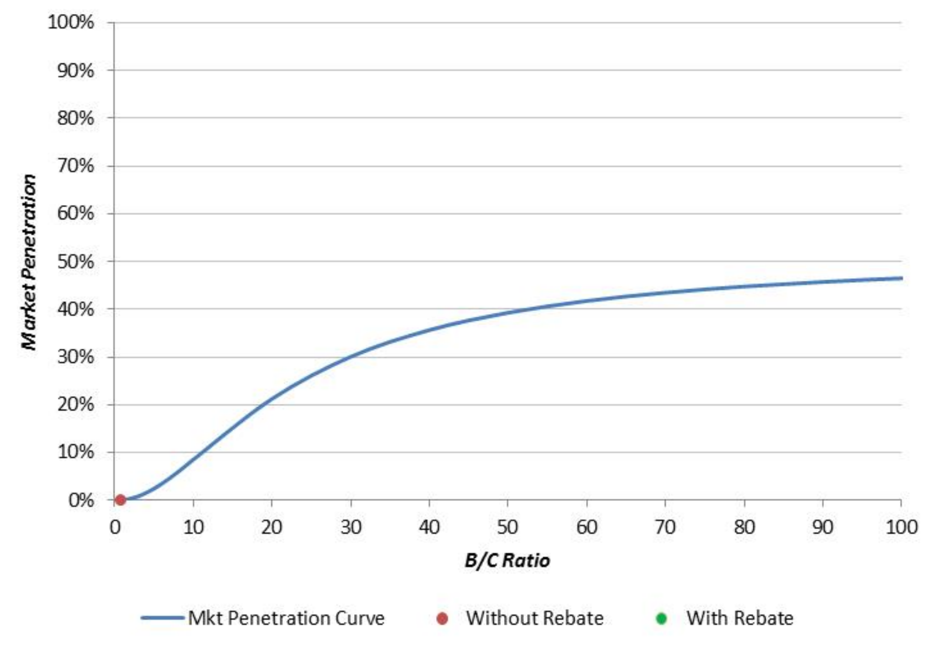


Figure 17.3.1 Market Penetration Curves (TSL ASHRAE)[d]

For each equipment class, DOE next estimated the percent increases represented by the change in penetration rate shown on the corresponding penetration curve. It then added this

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[d] The green dots are not shown in the charts, as the B/C ratio for both equipment classes at TSL ASHRAE is infinite.

percent increase to the market share of units that meet the target level in the base case to obtain the market share of units that meet the target level in the rebate policy case.[e]

Table 17.3.2 summarizes DOE's assumptions for PTACs and PTHPs regarding the market penetration of products in the start year of analysis that meet the target efficiency level at each TSL given a consumer rebate.

Table 17.3.2 Market Penetrations in the First Year of the Analysis Period* Attributable to Consumer Rebates for Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps

	Trial Standard Levels					
PTAC	ASHRAE	1	2	3	4	5
< 7,000 Btu/h						
Base-Case Market Share	0.0%	69.5%	30.5%	0.0%	0.0%	0.0%
Policy Case Market Share	0.0%	69.5%	66.7%	0.2%	0.1%	0.1%
Increased Market Share	0.0%	0.0%	36.2%	0.2%	0.1%	0.1%
7,000 – 15,000 Btu/h						
Base-Case Market Share	36.0%	32.8%	25.3%	2.5%	0.9%	0.3%
Policy Case Market Share	41.6%	71.0%	87.9%	20.6%	5.8%	1.6%
Increased Market Share	5.6%	38.2%	62.6%	18.2%	4.8%	1.3%
> 15,000 Btu/h						
Base-Case Market Share	0.0%	38.5%	0.0%	0.0%	0.0%	0.0%
Policy Case Market Share	51.6%	100.0%	15.0%	0.3%	0.1%	0.1%
Increased Market Share	51.6%	61.5%	15.0%	0.3%	0.1%	0.1%
PTHP	ASHRAE	1	2	3	4	5
< 7,000 Btu/h						
Base-Case Market Share	-	13.8%	14.4%	0.0%	0.0%	0.0%
Policy Case Market Share	-	75.8%	69.4%	0.2%	0.1%	0.1%
Increased Market Share	-	62.0%	55.0%	0.2%	0.1%	0.1%
7,000 – 15,000 Btu/h						
Base-Case Market Share	-	8.2%	25.9%	9.5%	0.5%	0.0%
Policy Case Market Share	-	64.1%	80.6%	36.6%	2.6%	0.2%
Increased Market Share	-	55.9%	54.7%	27.1%	2.1%	0.2%
> 15,000 Btu/h						
Base-Case Market Share	-	2.8%	25.4%	0.0%	0.0%	0.0%
Policy Case Market Share	-	70.9%	82.0%	0.4%	0.1%	0.1%
Increased Market Share	-	68.0%	56.6%	0.4%	0.1%	0.1%

* 2017 for TSL ASHRAE for PTACs; 2019 for the remaining PTAC TSLs; and 2018 for all TSLs for PTHPs.

DOE used the resulting annual increases in market shares as inputs to represent the rebate policy case scenario in its NIA-RIA model. Appendix 17-A shows the annual market share increases due to this policy. Section 17.4 presents the resulting market penetration trends for the policy case of consumer rebates for PTACs and PTHPs.

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[e] Note that the percent increases are upper bounded by the total market share below the target level in the base case.

17.3.3 Consumer Tax Credits

DOE estimated the effects of tax credits on consumer purchases based on its previous analysis of consumer participation in tax credits. DOE supported its approach using data from Oregon State's tax credit program for energy-efficient appliances. DOE also incorporated previous research that disaggregated the effect of rebates and tax credits into a *direct price effect*, which derives from the savings in purchase price, and an *announcement effect*, which is independent of the amount of the incentive.[10, 11] The announcement effect derives from the credibility that a technology receives from being included in an incentive program, as well as changes in product marketing and modifications in markup and pricing. DOE assumed that the rebate and consumer tax credit policies would encompass both direct price effects and announcement effects, and that half the increase in market penetration associated with either policy would be due to the direct price effect and half to the announcement effect.

In estimating the effects of a tax credit on purchases of consumer products that meet new efficiency standards, DOE assumed the amount of the tax credit would be the same as the corresponding rebate amount discussed above.

DOE estimated that fewer consumers would participate in a tax credit program than would take advantage of a rebate. Research has shown that the delay required for a consumer to receive a tax credit, plus the added time and cost in preparing the tax return, make a tax credit incentive less effective than a rebate received at the time of purchase. Based on previous analyses, DOE assumed that only 60 percent of the consumers who would take advantage of a rebate would take advantage of a tax credit.[12]

In preparing its assumptions to estimate the effects of tax credits on consumer purchases of PTACs and PTHPs, DOE also reviewed other tax credit programs that have been offered at both the Federal and State levels for energy-efficient appliances.

The Energy Policy Act of 2005 (EPACT 2005) included Federal tax credits for consumers who purchase energy-efficient products.[13] Those tax credits were in effect in 2006 and 2007, expired in 2008, were reinstated for 2009–2010 by the American Recovery and Reinvestment Act of 2009 (ARRA), extended by Congress for 2011 with some modifications, and expired at the end of 2011.[14, 15] The American Taxpayer Relief Act of 2012 extended, with some modifications, residential tax credits for air conditioners, heat pumps, furnaces, and water heaters placed in service between January 1, 2012 and December 31, 2013.[16] DOE reviewed Internal Revenue Service data on the numbers of taxpayers who claimed the tax credits during tax years 2006 and 2007. DOE also reviewed data from an earlier Federal energy conservation tax credit program in place in the 1980s. However, DOE did not find data specific enough to PTACs and PTHPs to warrant adjusting its analysis method for the Consumer Tax Credits policy case. Appendix 17-A contains more information on Federal consumer tax credits.

DOE also reviewed its previous analysis of Oregon's tax credits for clothes washers to provide support for its assumptions.[17] In that previous analysis, DOE compared the market shares of ultra-high efficiency (UHE) residential clothes washers in Oregon, which offered both State tax credits and utility rebates, with those in Washington State, which offered only utility rebates during the same period. Based on this analysis, DOE estimated that in Oregon the impact of tax credits was 62 percent of the impact of rebates for UHE clothes washers having equivalent efficiency. This finding supports its original assumption that participation in a tax credit program would be about 60 percent of participation in a rebate program. Additional discussion of State tax credits for Oregon and other states is in Appendix 17-A.

DOE applied the assumed 60 percent participation described above to the penetration rates estimated for the rebate policy to estimate penetration rates attributable to consumer tax credits. In doing so, DOE incorporated the assumptions for consumer response to financial incentives from the penetration curves selected for PTACs and PTHPs.

Table 17.3.3 summarizes DOE's assumptions for PTACs and PTHPs regarding the market penetration of units in the start year of analysis that meet the efficiency level at each TSL given a consumer tax credit.

Table 17.3.3 Market Penetrations in the First Year of the Analysis Period* Attributable to Consumer Tax Credits for Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps

	Trial Standard Levels					
PTAC	ASHRAE	1	2	3	4	5
< 7,000 Btu/h						
Base-Case Market Share	0.0%	69.5%	30.5%	0.0%	0.0%	0.0%
Policy Case Market Share	0.0%	69.5%	52.3%	0.1%	0.1%	0.04%
Increased Market Share	0.0%	0.0%	21.7%	0.1%	0.1%	0.04%
7,000 – 15,000 Btu/h						
Base-Case Market Share	36.0%	32.8%	25.3%	2.5%	0.9%	0.3%
Policy Case Market Share	39.3%	55.7%	62.9%	13.4%	3.8%	1.1%
Increased Market Share	3.4%	22.9%	37.5%	10.9%	2.9%	0.8%
> 15,000 Btu/h						
Base-Case Market Share	0.0%	38.5%	0.0%	0.0%	0.0%	0.0%
Policy Case Market Share	30.9%	75.4%	9.0%	0.2%	0.1%	0.1%
Increased Market Share	30.9%	36.9%	9.0%	0.2%	0.1%	0.1%
PTHP	ASHRAE	1	2	3	4	5
< 7,000 Btu/h						
Base-Case Market Share	-	13.8%	14.4%	0.0%	0.0%	0.0%
Policy Case Market Share		51.0%	47.4%	0.1%	0.1%	0.05%
Increased Market Share		37.2%	33.0%	0.1%	0.1%	0.05%
7,000 – 15,000 Btu/h						
Base-Case Market Share	-	8.2%	25.9%	9.5%	0.5%	0.0%
Policy Case Market Share		41.7%	58.7%	25.7%	1.8%	0.1%
Increased Market Share		33.6%	32.8%	16.3%	1.3%	0.1%
> 15,000 Btu/h						
Base-Case Market Share	-	2.8%	25.4%	0.0%	0.0%	0.0%
Policy Case Market Share		43.7%	59.3%	0.2%	0.1%	0.05%
Increased Market Share		40.8%	34.0%	0.2%	0.1%	0.05%

* 2017 for TSL ASHRAE for PTACs; 2019 for the remaining PTAC TSLs; and 2018 for all TSLs for PTHPs.

The increased market shares attributable to consumer tax credits shown in Table 17.3.3 were used as inputs in the NIA-RIA model. Appendix 17-A shows the annual market share increases due to this policy. Section 17.4 presents the resulting market penetration trends for the policy case of consumer tax credits for PTACs and PTHPs that meet the efficiency level for each TSL.

17.3.4 Manufacturer Tax Credits

To analyze the potential effects of a policy that offers tax credits to manufacturers that produce PTACs and PTHPs that meet the target efficiency level at each TSL, DOE assumed that a manufacturer tax credit would lower the consumer's purchase cost by an amount equivalent to that provided by the consumer rebates or tax credits described above. DOE further assumed that manufacturers would pass on some of their reduced costs to consumers, causing a direct price effect. DOE assumed that no announcement effect would occur, because the program would not be visible to consumers.[f] Because the direct price effect is approximately equivalent to the announcement effect,[10] DOE estimated that a manufacturer tax credit would induce half the number of consumers assumed to take advantage of a consumer tax credit to purchase more efficient equipment. Thus the assumed participation rate is equal to 30 percent of the number of consumers who would participate in a rebate program.

DOE attempted to investigate manufacturer response to the Energy Efficient Appliance Credits for manufacturers mandated by EPACT 2005.[18] Those manufacturer tax credits have been in effect for dishwashers, clothes washers and refrigerators produced beginning in 2009. DOE was unable to locate data from the Internal Revenue Service or other sources on manufacturer response to the Federal credits. Appendix 17-A presents details on Federal manufacturer tax credits.

DOE applied the assumption of 30 percent participation to the penetration rates predicted for the rebate policy to estimate the effects of a manufacturer tax credit policy. In doing so, the Department incorporated the assumptions for consumer response to financial incentives from the penetration curves calculated for PTACs and PTHPs.

Table 17.3.4 summarize DOE's assumptions for PTACs and PTHPs regarding the market penetration of units in the start year of analysis that meet the efficiency level at each TSL given a manufacturer tax credit.

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[f] Note that this is a conservative assumption, since it is possible that manufacturers or utility/agency efficiency programs might promote the models for which manufacturers increase production due to the tax credits, which in turn might induce some announcement effect. However, DOE found no data on such programs on which to base an estimate of the magnitude of this possible announcement effect on consumer behavior.

Table 17.3.4 Market Penetrations in the First Year of the Analysis Period* Attributable to Manufacturer Tax Credits for Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps

	Trial Standard Levels					
PTAC	ASHRAE	1	2	3	4	5
< 7,000 Btu/h						
Base-Case Market Share	0.0%	69.5%	30.5%	0.0%	0.0%	0.0%
Policy Case Market Share	0.0%	69.5%	41.4%	0.1%	0.03%	0.02%
Increased Market Share	0.0%	0.0%	10.9%	0.1%	0.03%	0.02%
7,000 – 15,000 Btu/h						
Base-Case Market Share	36.0%	32.8%	25.3%	2.5%	0.9%	0.3%
Policy Case Market Share	37.7%	44.2%	44.1%	7.9%	2.4%	0.7%
Increased Market Share	1.7%	11.5%	18.8%	5.4%	1.5%	0.4%
> 15,000 Btu/h						
Base-Case Market Share	0.0%	38.5%	0.0%	0.0%	0.0%	0.0%
Policy Case Market Share	15.5%	56.9%	4.5%	0.1%	0.03%	0.03%
Increased Market Share	15.5%	18.5%	4.5%	0.1%	0.03%	0.03%
PTHP	ASHRAE	1	2	3	4	5
< 7,000 Btu/h						
Base-Case Market Share	-	13.8%	14.4%	0.0%	0.0%	0.0%
Policy Case Market Share		32.4%	30.9%	0.1%	0.03%	0.02%
Increased Market Share		18.6%	16.5%	0.1%	0.03%	0.02%
7,000 – 15,000 Btu/h						
Base-Case Market Share	-	8.2%	25.9%	9.5%	0.5%	0.0%
Policy Case Market Share		25.0%	42.3%	17.6%	1.2%	0.05%
Increased Market Share		16.8%	16.4%	8.1%	0.6%	0.05%
> 15,000 Btu/h						
Base-Case Market Share	-	2.8%	25.4%	0.0%	0.0%	0.0%
Policy Case Market Share		23.3%	42.3%	0.1%	0.03%	0.02%
Increased Market Share		20.4%	17.0%	0.1%	0.03%	0.02%

* 2017 for TSL ASHRAE for PTACs; 2019 for the remaining PTAC TSLs; and 2018 for all TSLs for PTHPs.

The increased market shares attributable to a manufacturer tax credit shown in Table 17.3.4 were used as inputs in the NIA-RIA model. Appendix 17-A shows the annual market share increases due to this policy. Section 17.4 presents the resulting market penetration trends for the policy case of manufacturer tax credits for PTACs and PTHPs.

17.3.5 Voluntary Energy Efficiency Targets

For each equipment class, DOE assumed that voluntary energy efficiency targets would be achieved as manufacturers gradually stopped producing units that operated below the efficiency level set for each TSL. DOE assumed that the impetus for phasing out production of low-efficiency units would be a program with impacts similar to those of the ENERGY STAR labeling program conducted by the Environmental Protection Agency (EPA) and DOE in conjunction with industry partners. The ENERGY STAR program specifies the minimum energy efficiencies that various products must have to receive the ENERGY STAR label. ENERGY

STAR encourages consumers to purchase efficient products via marketing that promotes consumer label recognition, various incentive programs that adopt the ENERGY STAR specifications, and manufacturers' promotion of their qualifying appliances. ENERGY STAR projects market penetration of compliant appliances and estimates the percentage of sales of compliant appliances that are attributable to the ENERGY STAR program.

Researchers have analyzed the ENERGY STAR program's effects on sales of several consumer products. Program efforts generally involve a combination of information dissemination and utility or agency rebates. The analyses have been based on State-specific data on percentages of shipments of various appliances that meet ENERGY STAR specifications. The analyses generally have concluded that the market penetration of ENERGY STAR-qualifying appliances is higher in regions or States where ancillary promotional programs have been active.[19, 20, 21]

DOE believes that informational incentive programs – like ENERGY STAR, or any other labeling program sponsored by industry or other organizations – are likely to reduce the market barriers to more efficient equipment over time. Table 17.3.5 shows the estimated market barriers to energy efficient PTACs and PTHPs in the base case for each TSL. DOE estimates that voluntary energy efficiency targets could reduce these barriers to lower levels over 10 years. Table 17.3.6 shows the reduced market barriers to energy efficient PTACs and PTHPs for each TSL. DOE followed the methodology presented by Blum et al (2011)[22] to evaluate the effects that such a reduction in market barriers have on the market penetration of each equipment class of PTACs and PTHPs. The methodology relies on interpolated market penetration curves to calculate – given a B/C ratio – how the market penetration of more efficient units increases as the market barrier level to those units decreases.

Table 17.3.5 Estimated Market Barriers to Energy Efficient PTACs and PTHPs

	Trial Standard Levels					
PTAC	ASHRAE	1	2	3	4	5
< 7,000 Btu/h	-	-	No	Hg-xHg	Hg-xHg	Hg-xHg
7,000 – 15,000 Btu/h	No	No	No	Lo-Mod	Lo-Mod	Mod-Hg
> 15,000 Btu/h	Hg-xHg	No	Hg-xHg	Hg-xHg	Hg-xHg	Mod-Hg
PTHP	ASHRAE	1	2	3	4	5
< 7,000 Btu/h	-	Lo-Mod	No	Hg-xHg	Hg-xHg	Hg-xHg
7,000 – 15,000 Btu/h	-	Lo-Mod	No	Lo-Mod	Mod-Hg	Hg-xHg
> 15,000 Btu/h	-	Lo-Mod	No	Hg-xHg	Hg-xHg	Hg-xHg

No-Low: No-to-Low market barriers; Mod: Moderate market barriers; Low-Mod: Low-to-Moderate market barriers; Mod-High: Moderate-to-High market barriers; xHigh: Extremely-High market barriers; Hg-xHg: High-to-Extremely-High market barriers

Table 17.3.6 Reduced Market Barriers to Energy Efficient PTACs and PTHPs

	Trial Standard Levels					
PTAC	ASHRAE	1	2	3	4	5
< 7,000 Btu/h	-	-	No	High	High	High
7,000 – 15,000 Btu/h	No	No	No	Low	Low	Moderate
> 15,000 Btu/h	High	No	High	High	High	Moderate
PTHP	ASHRAE	1	2	3	4	5
< 7,000 Btu/h	-	Low	No	High	High	High
7,000 – 15,000 Btu/h	-	Low	No	Low	Moderate	High
> 15,000 Btu/h	-	Low	No	High	High	High

Table 17.3.7 summarizes DOE's assumptions for PTACs and PTHPs regarding the market penetration of units in the start year of analysis that meet the efficiency level at each TSL given voluntary energy efficiency targets.

Table 17.3.7 Market Penetrations in the First Year of the Analysis Period* Attributable to Voluntary Energy Efficiency Targets for Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps

	Trial Standard Levels					
PTAC	ASHRAE	1	2	3	4	5
< 7,000 Btu/h						
Base-Case Market Share	0.0%	69.5%	30.5%	0.0%	0.0%	0.0%
Policy Case Market Share	0.0%	69.5%	31.4%	0.03%	0.03%	0.03%
Increased Market Share	0.0%	0.0%	0.9%	0.03%	0.03%	0.03%
7,000 – 15,000 Btu/h						
Base-Case Market Share	36.0%	32.8%	25.3%	2.5%	0.9%	0.31%
Policy Case Market Share	36.0%	33.3%	27.9%	4.5%	2.8%	0.36%
Increased Market Share	0.0%	0.6%	2.6%	2.0%	1.9%	0.05%
> 15,000 Btu/h						
Base-Case Market Share	0.0%	38.5%	0.0%	0.0%	0.0%	0.0%
Policy Case Market Share	0.03%	38.5%	0.03%	0.03%	0.03%	0.05%
Increased Market Share	0.03%	0.0%	0.03%	0.03%	0.03%	0.05%
PTHP	ASHRAE	1	2	3	4	5
< 7,000 Btu/h						
Base-Case Market Share	-	13.8%	14.4%	0.0%	0.0%	0.0%
Policy Case Market Share		15.4%	17.6%	0.05%	0.05%	0.04%
Increased Market Share		1.6%	3.2%	0.05%	0.05%	0.04%
7,000 – 15,000 Btu/h						
Base-Case Market Share	-	8.2%	25.9%	9.5%	0.5%	0.0%
Policy Case Market Share		14.2%	32.6%	12.4%	0.7%	0.1%
Increased Market Share		6.0%	6.7%	2.9%	0.2%	0.1%
> 15,000 Btu/h						
Base-Case Market Share	-	2.8%	25.4%	0.0%	0.0%	0.0%
Policy Case Market Share		6.3%	30.9%	0.1%	0.05%	0.04%
Increased Market Share		3.5%	5.5%	0.1%	0.05%	0.04%

* 2017 for TSL ASHRAE for PTACs; 2019 for the remaining PTAC TSLs; and 2018 for all TSLs for PTHPs.

The increased market shares attributable to voluntary energy efficiency targets shown in Table 17.3.7 were used as inputs in the NIA-RIA model. Appendix 17-A shows the annual market share increases due to this policy. Section 17.4 presents the resulting market penetration trends for the policy case of voluntary energy efficiency targets for PTACs and PTHPs that meet the efficiency level for each TSL.

17.3.6 Bulk Government Purchases

Bulk government purchases can lead to Federal, State, and local governments purchasing large quantities of equipment that meet the target efficiency level. Combining the market demands of multiple public sectors also can provide a market signal to manufacturers and vendors that some of their largest customers seek equipment that meet an efficiency target at favorable prices. Such a program also can induce “market pull,” whereby manufacturers and vendors would achieve economies of scale for high efficiency equipment.

Most of the previous bulk government purchase (procurement) initiatives at the Federal, State, and municipal levels have not tracked data on numbers of purchases or degree of compliance with procurement specifications. In many cases, procurement programs are decentralized, being part of larger State or regional initiatives. DOE based its assumptions regarding the effects of this policy on studies the Federal Energy Management Program (FEMP) performed regarding the savings potential of its procurement specifications for appliances and other equipment. FEMP, however, does not track purchasing data, because of the complex range of purchasing systems, large number of vendors, and so on. States, counties, and municipalities have demonstrated increasing interest and activity in “green purchasing." Although many of the programs target office equipment, the growing infrastructure for developing and applying efficient purchasing specifications indicates that bulk government purchase programs are feasible.[23, 24]

DOE assumed that government agencies would administer bulk purchasing programs for PTACs and PTHPs. There are currently no FEMP procurement guidelines in place for PTACs and PTHPs.[25] DOE reviewed its own previous research on the potential for market transformation through bulk government purchases. Its major study analyzed several scenarios based on the assumption that 20 percent of Federal equipment purchases in 2000 already incorporated energy efficiency requirements based on FEMP guidelines. One scenario in the DOE report showed energy efficient purchasing ramping up during 10 years from 20 percent to 80 percent of all Federal purchases.[26] Based on this study, DOE estimated that a bulk government purchase program instituted within a 10-year period would result in at least 80 percent of government-purchased PTACs and PTHPs meeting target efficiency levels.

DOE assumed that bulk government purchases would affect a subset of federal government owned buildings cooled by individual room air conditioners or heat pumps. According to the 2003 Commercial Buildings Energy Consumption Survey (CBECS 2003)[27], most of the cooled floor space of this subset of buildings (61 percent for PTACs, and 82 percent for PTHPs) would consist of public buildings used for education, lodging, offices and non-refrigerated warehouses. They represent about 1.8 percent and 0.3 percent of the floor space of all commercial buildings cooled – respectively – by individual room air conditioners and individual room heat pumps.[27] DOE therefore estimated that these percentages of U.S. commercial buildings constitute the market to which this policy would apply.

DOE estimated that starting in the first policy year, each year of a bulk government purchase policy would result in an increasing percent of shipments of government-purchased units beyond the base case that would meet target efficiency levels. DOE estimated that within 10 years bulk government purchasing programs would result in 80 percent of the PTACs and PTHPs market for federal government owned commercial buildings meeting target levels. DOE modeled the bulk government purchase program assuming that the market share for PTACs and PTHPs achieved in the tenth year would be at least maintained throughout the rest of the forecast period.

Table 17.3.8 summarizes DOE’s assumptions for PTACs and PTHPs regarding the market penetration of units in the start year of analysis that meet the efficiency level at each TSL given bulk government purchasing.

Table 17.3.8 Market Penetrations in the First Year of the Analysis Period* Attributable to Bulk Government Purchasing of Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps

	Trial Standard Levels					
PTAC	ASHRAE	1	2	3	5	5
< 7,000 Btu/h						
Base-Case Market Share	0.0%	69.5%	30.5%	0.0%	0.0%	0.0%
Policy Case Market Share	0.0%	69.5%	31.1%	0.3%	0.3%	0.3%
Increased Market Share	0.0%	0.0%	0.6%	0.3%	0.3%	0.3%
7,000 – 15,000 Btu/h						
Base-Case Market Share	36.0%	32.8%	25.3%	2.5%	0.9%	0.3%
Policy Case Market Share	36.6%	33.4%	25.8%	2.8%	1.2%	0.6%
Increased Market Share	0.7%	0.6%	0.5%	0.3%	0.3%	0.3%
> 15,000 Btu/h						
Base-Case Market Share	0.0%	38.5%	0.0%	0.0%	0.0%	0.0%
Policy Case Market Share	0.0%	39.2%	0.3%	0.3%	0.3%	0.3%
Increased Market Share	0.0%	0.7%	0.3%	0.3%	0.3%	0.3%
PTHP	ASHRAE	1	2	3	4	5
< 7,000 Btu/h						
Base-Case Market Share		13.8%	14.4%	0.0%	0.0%	0.0%
Policy Case Market Share	-	13.9%	14.4%	0.04%	0.04%	0.04%
Increased Market Share		0.0%	0.0%	0.04%	0.04%	0.04%
7,000 – 15,000 Btu/h						
Base-Case Market Share		8.2%	25.9%	9.5%	0.53%	0.0%
Policy Case Market Share	-	8.2%	26.0%	9.5%	0.57%	0.04%
Increased Market Share		0.0%	0.1%	0.0%	0.04%	0.04%
> 15,000 Btu/h						
Base-Case Market Share		2.8%	25.4%	0.0%	0.0%	0.0%
Policy Case Market Share	-	2.9%	25.4%	0.04%	0.04%	0.04%
Increased Market Share		0.0%	0.1%	0.04%	0.04%	0.04%

* 2017 for TSL ASHRAE for PTACs; 2019 for the remaining PTAC TSLs; and 2018 for all TSLs for PTHPs.

The increased market shares attributable to bulk government purchasing shown in Table 17.3.8 were used as inputs in the NIA-RIA model. Appendix 17-A shows the annual market share increases due to this policy that DOE used as inputs to the NIA-RIA model. Section 17.4 below presents the resulting market penetration trends for the policy case of bulk government purchase of PTACs and PTHPs.

17.4 IMPACTS OF NON-REGULATORY ALTERNATIVES

Figure 17.4.1 and Figure 17.4.2 show the effects of TSL ASHRAE on market penetration of each non-regulatory policy for the two PTAC equipment classes affected by that TSL. (Notice that TSL ASHRAE has no effects on market penetration of PTAC <7,000 Btu/hr and all PTHP equipment classes). Relative to the base case, (most of) the policy cases increase the market shares that meet the target level until 2026, when the base case market share reaches 100 percent. Recall the selected standards (not shown in the figures) would result in a 100-percent market penetration of equipment that meets the target efficiency level over the entire analysis period.

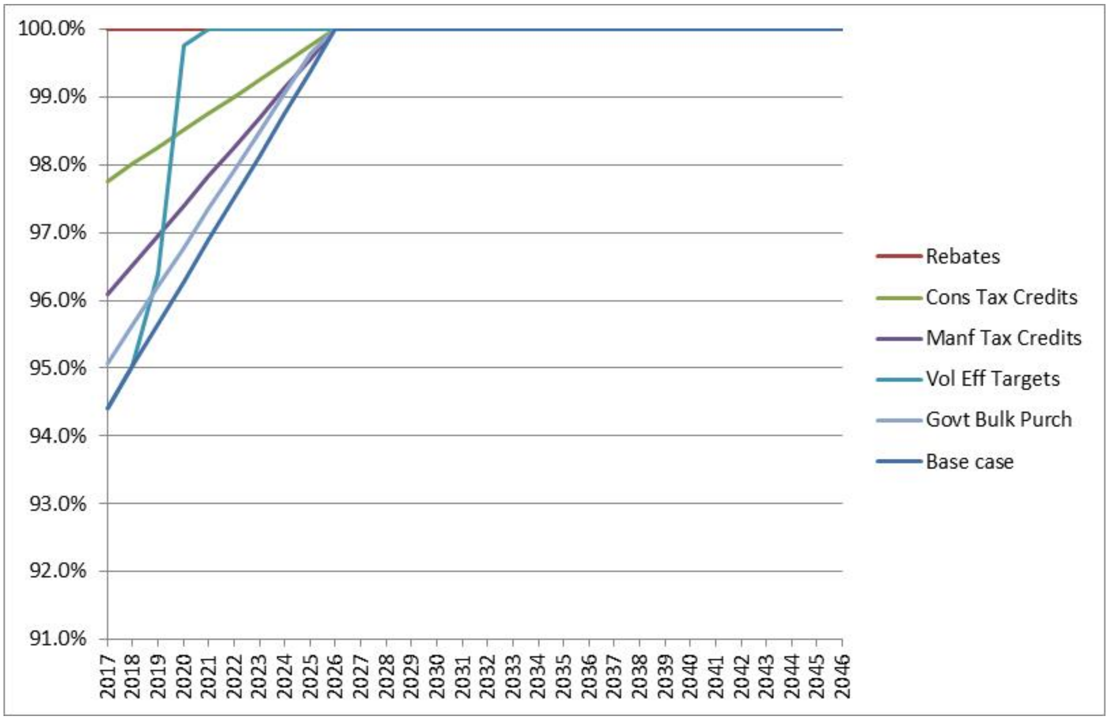

Figure 17.4.1 **Market Penetration of Packaged Terminal Air Conditioners 7,000 – 15,000 Btu/h Meeting the Target Level in Policy Cases (TSL ASHRAE)**

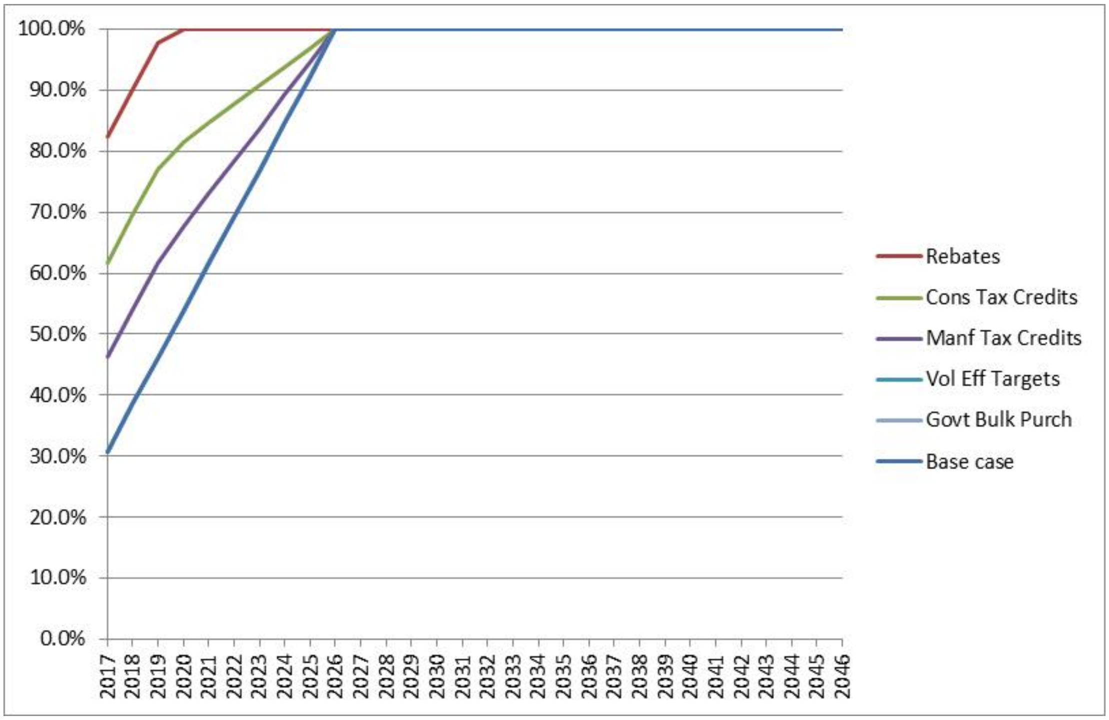

Figure 17.4.2 Market Penetration of Packaged Terminal Air Conditioners >15,000 Btu/h Meeting the Target Level in Policy Cases (TSL ASHRAE)

Table 17.4.1 shows the national energy savings and net present value for five non-regulatory policies analyzed in detail for PTACs. The target level for each policy equals the efficiency levels selected for standards in TSL ASHRAE. The case in which no regulatory action is taken with regard to PTACs constitutes the base case (or "No New Regulatory Action" scenario), in which NES and NPV are zero by definition. For comparison, the table includes the impacts of the selected standards. Energy savings are given in billion British thermal units (quads), and economic savings in million 2014 dollars. The NPVs shown in Table 17.4.1 is based on two discount rates, 7 percent and 3 percent.

The energy benefits from the alternative policies for PTACs range from 1.4 percent to 21.0 percent of those from standards. NPV results for all alternative policies are negative at both 7 and 3 percent discount rates. The policy with the highest projected cumulative energy savings are consumer rebates, followed by consumer tax credits, manufacturer tax credits, and voluntary energy efficiency targets. Bulk government purchases result in very little benefits compared to energy efficiency standards.

Table 17.4.1 Impacts of Non-Regulatory Alternatives for Packaged Terminal Air Conditioners* (TSL ASHRAE)

Policy Alternative	**Primary Energy Savings bi BTU**	**Net Present Value million 2014$** 7% Discount Rate	3% Discount Rate
Consumer Rebates	65.6	-0.476	-0.447
Consumer Tax Credits	39.4	-0.286	-0.268
Manufacturer Tax Credits	19.7	-0.143	-0.134
Voluntary Energy Efficiency Targets	15.4	-0.120	-0.183
Bulk Government Purchases	4.5	-0.039	-0.040
Proposed Standards	311.7	-1.282	-1.715

*For equipment shipped during the analysis period of TSL ASHRAE (2017-2046)

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APPENDIX 6A. DETAILED DATA FOR EQUIPMENT PRICE MARKUPS

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APPENDIX 6A. DETAILED DATA FOR EQUIPMENT PRICE MARKUPS

6A.1 DETAILED WHOLESALER COST DATA

Based on data provided by the Heating Air-conditioning & Refrigeration Distributors International (HARDI), Table 6.6.1 of Chapter 6 shows wholesaler revenues and costs in aggregated form.[1] Table 6-A.1.1 provides the complete breakdown of costs and expenses by HARDI region. These markups are then assigned to each state within a HARDI region. As described in Chapter 6, Section 6.5, only those expenses that scale with both baseline and incremental costs are marked up when there is an incremental change in equipment costs. State level baseline and incremental markups for wholesalers, as well as state populations, are presented in Table 6-A.1.2.[2]

Table 6A.1.1 Disaggregated Costs and Expenses for Wholesalers

	North Eastern	Mid-Atlantic	South Eastern	Great Lakes	Central	South Western	Western
Number of Firms Reporting	8	11	14	18	26	11	9
Typical Sales Volume (million$)	$20.77	$58.34	$34.11	$32.10	$34.27	$22.56	$14.58
Sales Change (2009-2010)	9.3%	4.4%	19.0%	8.6%	9.2%	11.8%	0.6%
Strategic Profit Model Ratios							
Profit Margin	0.2%	2.3%	1.9%	2.4%	2.9%	3.6%	2.9%
Asset Turnover	2.50	3.10	2.40	2.50	2.40	2.50	2.60
Return on Assets	0.5%	7.1%	4.6%	6.0%	7.0%	9.0%	7.5%
Financial Leverage	1.6	2.7	2.3	2.1	1.8	1.7	1.4
Return on Net Worth	0.8%	19.2%	10.6%	12.6%	12.6%	15.3%	10.5%
Income Statement							
Net Sales	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Cost of Goods Sold	73.1%	73.1%	76.4%	73.3%	73.6%	74.5%	71.6%
Gross Margin	**26.9%**	**26.9%**	**23.6%**	**26.7%**	**26.4%**	**25.5%**	**28.4%**
Payroll Expenses							
Executive Salaries & Bonuses	2.0%	1.3%	1.8%	1.4%	2.0%	1.6%	1.8%
Branch Manager Salaries & Bonuses	1.9%	1.2%	1.0%	1.4%	1.5%	1.9%	1.7%
Sales Executive Salaries	0.8%	0.4%	0.5%	0.4%	0.6%	0.3%	0.0%
Outside Sales Salaries	2.3%	1.9%	2.5%	2.0%	2.6%	2.0%	2.1%
Inside/Counter Sales Wages	2.2%	2.8%	2.4%	2.9%	2.6%	2.8%	2.7%
Purchasing Salaries/Wages	0.7%	0.4%	0.3%	0.5%	0.4%	0.4%	0.4%
Credit Salaries/Wages	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
IT Salaries/Wages	0.1%	0.2%	0.0%	0.2%	0.2%	0.0%	0.1%
Warehouse Salaries/Wages	2.0%	1.3%	1.0%	1.3%	1.2%	1.2%	1.6%
Accounting Salaries/Wages	0.6%	0.5%	0.4%	0.5%	0.5%	0.5%	0.4%
Delivery Salaries/Wages	1.2%	1.0%	0.7%	0.8%	0.9%	0.3%	0.5%
All Other Salaries/Wages & Bonuses	0.8%	0.8%	0.4%	1.0%	0.6%	0.4%	0.6%
Total Salaries, Wages, Bonuses	14.8%	12.0%	11.2%	12.6%	13.3%	11.6%	12.1%
Payroll Taxes	1.3%	1.0%	1.0%	1.1%	1.0%	1.0%	1.3%
Group Insurance	0.9%	1.1%	0.8%	1.3%	1.3%	0.9%	1.3%
Benefit Plans	0.6%	0.4%	0.2%	0.3%	0.3%	0.3%	0.5%
Total Payroll Expenses	**17.6%**	**14.5%**	**13.2%**	**15.3%**	**15.9%**	**13.8%**	**15.2%**

Table 6A.1.1 Continued Disaggregated Costs and Expenses for Wholesalers

	North Eastern	Mid-Atlantic	South Eastern	Great Lakes	Central	South Western	Western
Occupancy Expenses							
Utilities (heat, light, power, water)	0.5%	0.5%	0.3%	0.5%	0.4%	0.4%	0.3%
Telephone	0.3%	0.3%	0.3%	0.4%	0.3%	0.4%	0.3%
Building Repairs & Maintenance	0.3%	0.3%	0.1%	0.3%	0.3%	0.2%	0.2%
Rent or Ownership I Real Estate	2.5%	3.1%	2.1%	2.4%	2.5%	2.2%	3.5%
Total Occupancy Expenses	**3.6%**	**4.2%**	**2.8%**	**3.6%**	**3.5%**	**3.2%**	**4.3%**
Other Operating Expenses							
Sales Expenses	0.7%	0.8%	1.1%	1.0%	0.7%	0.6%	0.7%
Insurance	0.1%	0.2%	0.2%	0.2%	0.2%	0.3%	0.2%
Depreciation	0.3%	0.6%	0.4%	0.4%	0.3%	0.2%	0.5%
Vehicle Expenses	1.8%	1.3%	1.0%	1.3%	0.9%	1.0%	1.0%
Personal Property Taxes/Licenses	0.0%	0.1%	0.2%	0.1%	0.0%	0.3%	0.1%
Collection Expenses	0.2%	0.3%	0.2%	0.4%	0.2%	0.4%	0.6%
Bad Debit Losses	0.3%	0.5%	0.3%	0.4%	0.2%	0.3%	0.5%
Data Processing	0.2%	0.1%	0.2%	0.3%	0.3%	0.3%	0.5%
Employee Training	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
All Other Operating Expenses	1.5%	1.8%	1.8%	1.4%	1.3%	1.6%	1.7%
Total Other Operating Expenses	**5.1%**	**5.7%**	**5.5%**	**5.5%**	**4.1%**	**5.0%**	**5.8%**
Total Operating Expenses	**26.3%**	**24.4%**	**21.5%**	**24.4%**	**23.5%**	**22.0%**	**25.3%**
Operating Profit	**0.6%**	**2.5%**	**2.1%**	**2.3%**	**2.9%**	**3.5%**	**3.1%**
Other Income	0.4%	0.3%	0.6%	0.8%	0.4%	0.3%	0.1%
Interest Expense	0.4%	0.4%	0.7%	0.5%	0.4%	0.2%	0.3%
Other Non-operating Expenses	0.1%	0.1%	0.0%	0.2%	0.0%	0.0%	0.0%
Profit Before Taxes & Discretionary Bonuses	**0.5%**	**2.3%**	**2.0%**	**2.4%**	**2.9%**	**3.6%**	**2.9%**
Owners' & Officers' Discretionary Bonus	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
Other Employees' Discretionary Bonus	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Profit Before Taxes	**0.2%**	**2.3%**	**1.9%**	**2.4%**	**2.9%**	**3.6%**	**2.9%**
Wholesaler Baseline Regional Markup	**1.37**	**1.37**	**1.31**	**1.36**	**1.36**	**1.34**	**1.40**
Wholesaler Incremental Regional Markup	**1.08**	**1.11**	**1.10**	**1.11**	**1.10**	**1.11**	**1.12**

Source: Heating, Air-conditioning & Refrigeration Distributors International. 2012. *2012 Profit Report* (2010 data).

Table 6A.1.2 State-Level Baseline and Incremental Markups for Wholesalers

State	Census Division	Baseline	Incremental	Population (2013)
Alabama	East South Central	1.309	1.099	4,833,722
Alaska	Pacific	1.397	1.124	735,132
Arizona	Mountain	1.397	1.124	6,626,624
Arkansas	West South Central	1.342	1.114	2,959,373
California	Pacific	1.397	1.124	38,332,521
Colorado	Mountain	1.359	1.095	5,268,367
Connecticut	New England	1.368	1.078	3,596,080
DC	South Atlantic	1.368	1.112	925,749
Delaware	South Atlantic	1.368	1.112	646,449
Florida	South Atlantic	1.368	1.112	19,552,860
Georgia	South Atlantic	1.309	1.099	9,992,167
Hawaii	Pacific	1.309	1.099	1,404,054
Idaho	Mountain	1.397	1.124	1,612,136
Illinois	East North Central	1.397	1.124	12,882,135
Indiana	East North Central	1.359	1.095	6,570,902
Iowa	West North Central	1.364	1.106	3,090,416
Kansas	West North Central	1.359	1.095	2,893,957
Kentucky	East South Central	1.359	1.095	4,395,295
Louisiana	West South Central	1.364	1.106	4,625,470
Maine	New England	1.342	1.114	1,328,302
Maryland	South Atlantic	1.368	1.078	5,928,814
Massachusetts	New England	1.368	1.112	6,692,824
Michigan	East North Central	1.368	1.078	9,895,622
Minnesota	West North Central	1.364	1.106	5,420,380
Mississippi	East South Central	1.359	1.095	2,991,207
Missouri	West North Central	1.309	1.099	6,044,171
Montana	Mountain	1.359	1.095	1,015,165
Nebraska	West North Central	1.397	1.124	1,868,516
Nevada	Mountain	1.359	1.095	2,790,136
New Hampshire	New England	1.397	1.124	1,323,459
New Jersey	Mid Atlantic	1.368	1.078	8,899,339
New Mexico	Mountain	1.368	1.112	2,085,287
New York	Mid Atlantic	1.342	1.114	19,651,127
North Carolina	South Atlantic	1.368	1.078	9,848,060
North Dakota	West North Central	1.309	1.099	723,393
Ohio	East North Central	1.359	1.095	11,570,808
Oklahoma	West South Central	1.364	1.106	3,850,568
Oregon	Pacific	1.342	1.114	3,930,065
Pennsylvania	Mid Atlantic	1.397	1.124	12,773,801
Rhode Island	New England	1.366	1.109	1,051,511
South Carolina	South Atlantic	1.368	1.078	4,774,839
South Dakota	West North Central	1.309	1.099	844,877
Tennessee	East South Central	1.359	1.095	6,495,978
Texas	West South Central	1.309	1.099	26,448,193
Utah	Mountain	1.342	1.114	2,900,872
Vermont	New England	1.397	1.124	626,630
Virginia	South Atlantic	1.368	1.078	8,260,405
Washington	Pacific	1.368	1.112	6,971,406
West Virginia	South Atlantic	1.397	1.124	1,854,304
Wisconsin	East North Central	1.364	1.106	5,742,713
Wyoming	Mountain	1.359	1.095	582,658

Sources: Heating, Air-conditioning & Refrigeration Distributors International. 2012. 2012 Profit Report (2010 data); U.S. Census Bureau, Population Division, Annual Estimates of the Population for the United States, Regions, States, and Puerto Rico (2013).

6A.2 DETAILED MECHANICAL CONTRACTOR DATA

Section 6.6 of Chapter 6 provides mechanical contractor revenues and costs in aggregated form by ‘Cost of Goods Sold’ and ‘Gross Margin’. The more disaggregated breakdown of costs used to calculate the incremental markups are shown in Table 6-A.2.1, presented in both dollar value and percentage terms from the 2007 Economic Census.[4]

Table 6A.2.1 Detailed National Mechanical Contractor Expenses

Item	**Dollar Value *($1000)***	**Percentage *%***	**Scaling**
Total Cost of Equipment Sales	**107,144,428**	**67.80**	
Cost of materials, components, and supplies	59,023,964	37.35	
Payroll, construction workers	31,373,558	19.85	
Cost of construction work subcontracted out to others	13,646,192	8.64	
Cost of selected power, fuels, and lubricants	3,100,714	1.96	
Gross Margin	**50,895,129**	**32.20**	
Payroll Expenses	**27,626,376**	**17.48**	Baseline
Fringe benefits, all employees	13,585,040	8.60	
Payroll, other employees	14,041,336	8.89	
Occupancy Expenses			
Rental cost for machinery, equipment, and buildings + Cost of repairs to buildings and other structures + Purchased communication services	**3,436,208**	**2.17**	Baseline
Other Operating Expenses	**12,671,194**	**8.02**	Baseline & Incremental
Depreciation charges during year	2,297,550	1.45	
Computers + Insurance and other business services + Advertising and Promotions + Taxes and License Fees	10,373,664	6.56	
Net Profit Before Income Taxes	**6,722,095**	**4.25**	Baseline & Incremental

Source: U.S. Census Bureau. 2007. Plumbing, Heating, and Air-Conditioning Contractors: 2007. Sector 23: 238220. Detailed Statistics for Establishments: 2007.

Note: Mechanical contractor costs and expenses are first presented as *total dollar* values and then converted to *percentage* values.

Table 6A.2.2 State-Level Mechanical Contractor Baseline and Incremental Markups

		Replacement		New Construction		
State	**Census Division**	**Baseline**	**Incremental**	**Baseline**	**Incremental**	**Population (2013)**
Alabama	East South Central	1.476	1.182	1.393	1.116	4,833,722
Alaska	Pacific	1.741	1.394	1.643	1.315	735,132
Arizona	Mountain	1.558	1.247	1.470	1.177	6,626,624
Arkansas	West South Central	1.475	1.181	1.392	1.115	2,959,373
California	Pacific	1.584	1.268	1.495	1.197	38,332,521
Colorado	Mountain	1.509	1.208	1.424	1.140	5,268,367
Connecticut	New England	1.544	1.236	1.457	1.167	3,596,080
DC	South Atlantic	1.486	1.190	1.402	1.123	925,749
Delaware	South Atlantic	1.462	1.171	1.380	1.105	646,449
Florida	South Atlantic	1.491	1.194	1.407	1.126	19,552,860
Georgia	South Atlantic	1.453	1.163	1.371	1.098	9,992,167
Hawaii	Pacific	1.809	1.449	1.707	1.367	1,404,054
Idaho	Mountain	1.502	1.202	1.417	1.135	1,612,136
Illinois	East North Central	1.555	1.245	1.467	1.175	12,882,135
Indiana	East North Central	1.581	1.266	1.492	1.194	6,570,902
Iowa	West North Central	1.472	1.179	1.389	1.113	3,090,416
Kansas	West North Central	1.485	1.189	1.402	1.122	2,893,957
Kentucky	East South Central	1.554	1.244	1.467	1.174	4,395,295
Louisiana	West South Central	1.560	1.249	1.472	1.179	4,625,470
Maine	New England	1.514	1.212	1.428	1.144	1,328,302
Maryland	South Atlantic	1.466	1.174	1.384	1.108	5,928,814
Massachusetts	New England	1.516	1.214	1.431	1.146	6,692,824
Michigan	East North Central	1.508	1.208	1.423	1.140	9,895,622
Minnesota	West North Central	1.512	1.211	1.427	1.143	5,420,380
Mississippi	East South Central	1.475	1.181	1.392	1.114	2,991,207
Missouri	West North Central	1.458	1.167	1.376	1.102	6,044,171
Montana	Mountain	1.440	1.153	1.359	1.088	1,015,165
Nebraska	West North Central	1.368	1.095	1.291	1.034	1,868,516
Nevada	Mountain	1.496	1.198	1.412	1.131	2,790,136
New Hampshire	New England	1.515	1.213	1.429	1.145	1,323,459
New Jersey	Mid Atlantic	1.561	1.250	1.473	1.180	8,899,339
New Mexico	Mountain	1.541	1.234	1.454	1.164	2,085,287
New York	Mid Atlantic	1.578	1.263	1.489	1.192	19,651,127
North Carolina	South Atlantic	1.448	1.160	1.367	1.094	9,848,060
North Dakota	West North Central	1.455	1.165	1.373	1.100	723,393
Ohio	East North Central	1.517	1.215	1.432	1.147	11,570,808
Oklahoma	West South Central	1.506	1.206	1.421	1.138	3,850,568
Oregon	Pacific	1.574	1.260	1.485	1.189	3,930,065
Pennsylvania	Mid Atlantic	1.458	1.167	1.376	1.102	12,773,801
Rhode Island	New England	1.582	1.266	1.493	1.195	1,051,511
South Carolina	South Atlantic	1.544	1.237	1.458	1.167	4,774,839
South Dakota	West North Central	1.662	1.331	1.569	1.256	844,877
Tennessee	East South Central	1.456	1.166	1.374	1.100	6,495,978
Texas	West South Central	1.477	1.182	1.394	1.116	26,448,193
Utah	Mountain	1.455	1.165	1.373	1.099	2,900,872
Vermont	New England	1.515	1.213	1.429	1.145	626,630
Virginia	South Atlantic	1.535	1.229	1.449	1.160	8,260,405
Washington	Pacific	1.547	1.239	1.460	1.169	6,971,406
West Virginia	South Atlantic	1.506	1.206	1.422	1.138	1,854,304
Wisconsin	East North Central	1.488	1.191	1.404	1.124	5,742,713
Wyoming	Mountain	1.503	1.204	1.419	1.136	582,658

Source: U.S. Census Bureau. 2007. Plumbing, Heating, and Air-Conditioning Contractors, Sector 23: EC0723A1: Construction: Geographic Area Series: Detailed Statistics for Establishments: 2007; U.S. Census Bureau, Population Division, Annual Estimates of the Population for the United States, Regions, States, and Puerto Rico (2013).

6A.3 DETAILED GENERAL CONTRACTOR COST DATA

Based on U.S. Department of Census data, Table 6.6.8 of Chapter 6 shows general contractor revenues and costs in aggregated form. Table 6-A.3.1 shows the complete breakdown of costs and expenses provided in the 2007 Economic Census.[5] The column labeled "Scaling" in Detailed sales tax data by state can be found in Table 6-A.4.1.

Table 6-A.4.1 indicates which expenses DOE assumed to scale with only the baseline markup and which scaled with both the baseline and incremental markups. Only those expenses that scale with baseline and incremental costs are marked up when there is an incremental change in equipment costs.

Table 6A.3.1 General Contractor Expenses and Markups

Item	**Dollar Value** ***$1000***	**Percentage** ***%***	**Scaling**
Total Cost of Equipment Sales	**250,657,006**	76.24	
Total payroll, construction workers wages	16,449,830	5.00	
Cost of materials, components, and supplies	74,148,280	22.55	
Cost of construction work subcontracted out to others	157,873,840	48.02	
Total cost of selected power, fuels, and lubricants	2,185,056	0.66	
Gross Margin	**78,113,967**	23.76	
Payroll Expenses	**25,948,454**	7.89	Baseline
Total payroll, other employees' wages	16,652,791	5.07	
Total fringe benefits	8,666,079	2.64	
Temporary staff and leased employee expenses	629,584	0.19	
Occupancy Expenses	**3,301,046**	1.00	Baseline
Rental costs of machinery and equipment	1,403,979	0.43	
Rental costs of buildings	1,045,163	0.32	
Communication services	385,109	0.12	
Cost of repair to machinery and equipment	466,795	0.14	
Other Operating Expenses	**10,770,620**	3.28	Baseline & Incremental
Purchased professional and technical services	1,121,644	0.34	
Data processing and other purchased computer services	127,031	0.04	
Expensed computer hardware and other equipment	219,601	0.07	
Expensed purchases of software	67,977	0.02	
Advertising and promotion services	290,239	0.09	
All other expenses	6,321,197	1.92	
Refuse removal (including hazardous waste) services	233,831	0.07	
Taxes and license fees	807,872	0.25	
Total depreciation ($1,000)	1,581,228	0.48	
Net Profit Before Income Taxes	**38,093,847**	11.59	Baseline & Incremental

Source: U.S. Census Bureau. 2007. Commercial and Institutional Building Construction. Sector 236220. Construction, Industry Series, Preliminary Detailed Statistics for Establishments: 2007.
Note: General contractor costs and expenses are first presented as *total dollar* values and then converted to *percentage* values.

Table 6-A.3.2 shows the state-level general contractor baseline and incremental markups. DOE estimated state-level incremental general contractor markups by calculating the ratio of the national average incremental markup to the national average baseline markup. This ratio was then used to scale the state-level baseline markups, arriving at a state-level estimate of incremental general contractor markups.

Table 6A.3.2 State-Level General Contractor Baseline and Incremental Markups

State	Census Division	Baseline	Incremental	Population (2013)
Alabama	East South Central	1.459	1.329	4,833,722
Alaska	Pacific	1.354	1.233	735,132
Arizona	Mountain	1.358	1.237	6,626,624
Arkansas	West South Central	1.252	1.141	2,959,373
California	Pacific	1.366	1.245	38,332,521
Colorado	Mountain	1.204	1.097	5,268,367
Connecticut	New England	1.499	1.365	3,596,080
DC	South Atlantic	1.334	1.215	925,749
Delaware	South Atlantic	1.334	1.215	646,449
Florida	South Atlantic	1.368	1.246	19,552,860
Georgia	South Atlantic	1.396	1.272	9,992,167
Hawaii	Pacific	1.297	1.181	1,404,054
Idaho	Mountain	1.191	1.085	1,612,136
Illinois	East North Central	1.325	1.207	12,882,135
Indiana	East North Central	1.288	1.174	6,570,902
Iowa	West North Central	1.317	1.200	3,090,416
Kansas	West North Central	1.214	1.106	2,893,957
Kentucky	East South Central	1.326	1.208	4,395,295
Louisiana	West South Central	1.457	1.327	4,625,470
Maine	New England	1.254	1.142	1,328,302
Maryland	South Atlantic	1.259	1.147	5,928,814
Massachusetts	New England	1.349	1.229	6,692,824
Michigan	East North Central	1.410	1.285	9,895,622
Minnesota	West North Central	1.391	1.267	5,420,380
Mississippi	East South Central	1.713	1.560	2,991,207
Missouri	West North Central	1.180	1.075	6,044,171
Montana	Mountain	1.263	1.151	1,015,165
Nebraska	West North Central	1.276	1.162	1,868,516
Nevada	Mountain	1.357	1.236	2,790,136
New Hampshire	New England	1.277	1.163	1,323,459
New Jersey	Mid Atlantic	1.636	1.491	8,899,339
New Mexico	Mountain	1.280	1.166	2,085,287
New York	Mid Atlantic	1.370	1.248	19,651,127
North Carolina	South Atlantic	1.333	1.215	9,848,060
North Dakota	West North Central	1.276	1.162	723,393
Ohio	East North Central	1.247	1.136	11,570,808
Oklahoma	West South Central	1.164	1.060	3,850,568
Oregon	Pacific	1.246	1.135	3,930,065
Pennsylvania	Mid Atlantic	1.345	1.225	12,773,801
Rhode Island	New England	2.097	1.910	1,051,511
South Carolina	South Atlantic	1.232	1.122	4,774,839
South Dakota	West North Central	1.276	1.162	844,877
Tennessee	East South Central	1.231	1.121	6,495,978
Texas	West South Central	1.333	1.214	26,448,193
Utah	Mountain	1.213	1.105	2,900,872
Vermont	New England	1.218	1.109	626,630
Virginia	South Atlantic	1.291	1.176	8,260,405
Washington	Pacific	1.198	1.091	6,971,406
West Virginia	South Atlantic	1.334	1.215	1,854,304
Wisconsin	East North Central	1.263	1.151	5,742,713
Wyoming	Mountain	1.232	1.122	582,658

Source: U.S. Census Bureau. 2007. Commercial and Institutional Building Construction (NAICS 236220): Construction: Summary Series: General Summary: Detailed Statistics for Establishments: 2007; U.S. Census Bureau, Population Division, Annual Estimates of the Population for the United States, Regions, States, and Puerto Rico (2013).

6A.4 STATE SALES TAX RATES

Detailed sales tax data by state can be found in Table 6A.4.1.

Table 6A.4.1 State Sales Tax Rates

State	Combined State and Local Tax Rate	State	Combined State and Local Tax Rate	State	Combined State and Local Tax Rate
Alabama	8.55%	Louisiana	8.75%	Ohio	7.10%
Alaska	1.30%	Maine	5.50%	Oklahoma	8.35%
Arizona	7.15%	Maryland	6.00%	Oregon	0.00%
Arkansas	8.90%	Massachusetts	6.25%	Pennsylvania	6.40%
California	8.45%	Michigan	6.00%	Rhode Island	7.00%
Colorado	6.05%	Minnesota	7.15%	South Carolina	7.20%
Connecticut	6.35%	Mississippi	7.00%	South Dakota	5.40%
Delaware	5.75%	Missouri	7.50%	Tennessee	9.45%
Florida	0.00%	Montana	0.00%	Texas	7.90%
Georgia	6.65%	Nebraska	6.00%	Utah	6.70%
Hawaii	7.05%	Nevada	7.85%	Vermont	6.05%
Idaho	4.40%	New Hampshire	0.00%	Virginia	5.60%
Illinois	6.05%	New Jersey	6.95%	Washington	8.90%
Indiana	8.00%	New Mexico	6.60%	West Virginia	6.10%
Iowa	7.00%	New York	8.40%	Wisconsin	5.45%
Kansas	6.85%	North Carolina	6.90%	Wyoming	5.50%
Kentucky	7.85%	North Dakota	5.90%	**US Average**	**7.15%**

Source: The Sales Tax Clearinghouse at https://thestc.com/STRates.stm (Accessed on February 2014)

REFERENCES

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2. U.S. Census Bureau, *Annual Estimates of the Population for the United States, Regions, States, and Puerto Rico*, Population Division. 2012. www.census.gov/popest/data/state/totals/2012/index.html

3. Air Conditioning Contractors of America, *2005 Financial Analysis for the HVACR Contracting Industry*, 2005.

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5. U.S. Census Bureau, *Construction: Industry Series: Preliminary Detailed Statistics for Establishments: Commercial and Institutional Building Construction*, 2007.

APPENDIX 7A. DETAILED UNIT ENERGY CONSUMPTION DATA

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7A.1 DETAILED UNIT ENERGY CONSUMPTION DATA

Based on the whole-building simulations provided in the previous packaged terminal air conditioning (PTAC) and packaged terminal heat pump (PTHP) equipment rulemaking, unit energy consumption (UEC) data for PTACs and PTHPs on a U.S. average basis are provided in Table 7.3.1 of Chapter 7.[1] For each of the 51 locations (the U.S. States and the District of Columbia) the UECs for the equipment classes and efficiency levels for PTACs and PTHPs are presented in Table 7A.1.1 and Table 7A.1.2.

Table 7A.1.1 Disaggregated PTAC Unit Energy Consumption by Location

State	PTAC Standard Size - 9,000 Btu/h							PTAC Standard Size - 15,000 Btu/h						
	EL0	EL1	EL2	EL3	EL4	EL5	EL6	EL0	EL1	EL2	EL3	EL4	EL5	EL6
Alabama	1344	1326	1304	1264	1224	1185	1165	2043	2019	1998	1953	1909	1864	1841
Alaska	511	510	509	506	504	501	500	971	970	969	966	964	961	960
Arizona	1495	1474	1449	1403	1358	1312	1289	2218	2191	2168	2117	2066	2016	1991
Arkansas	1317	1299	1278	1240	1202	1163	1144	2013	1989	1969	1926	1882	1839	1817
California	901	892	880	859	838	816	806	1423	1411	1401	1378	1356	1333	1322
Colorado	722	716	709	696	683	671	664	1206	1199	1192	1179	1165	1151	1144
Connecticut	852	844	834	815	797	779	770	1393	1382	1373	1353	1332	1312	1302
Delaware	985	974	961	937	913	888	876	1570	1555	1543	1516	1489	1462	1448
Dist. of Col.	992	981	967	943	918	894	881	1574	1560	1547	1520	1493	1466	1452
Florida	1823	1796	1763	1703	1643	1583	1553	2693	2656	2625	2556	2488	2420	2386
Georgia	1317	1300	1278	1240	1201	1162	1143	2005	1981	1961	1918	1874	1831	1809
Hawaii	2115	2082	2042	1969	1897	1824	1788	3062	3018	2980	2898	2816	2734	2693
Idaho	694	689	682	671	659	648	642	1174	1167	1161	1149	1137	1125	1119
Illinois	879	870	860	840	821	802	792	1432	1421	1411	1390	1368	1347	1336
Indiana	804	797	788	772	757	741	733	1340	1331	1323	1305	1288	1270	1262
Iowa	889	880	869	850	830	810	800	1446	1434	1424	1402	1380	1359	1348
Kansas	1094	1081	1065	1036	1008	979	965	1714	1696	1681	1649	1617	1585	1569
Kentucky	1043	1031	1016	989	963	936	923	1641	1626	1612	1582	1552	1523	1508
Louisiana	1604	1581	1553	1503	1452	1401	1376	2399	2368	2341	2283	2225	2168	2139
Maine	700	694	688	676	665	653	647	1192	1185	1179	1166	1154	1141	1135
Maryland	997	986	972	947	923	898	886	1585	1571	1558	1530	1502	1475	1461
Massachusetts	787	780	772	756	741	725	717	1305	1296	1288	1271	1254	1237	1228
Michigan	783	776	768	752	737	722	714	1305	1296	1288	1272	1255	1239	1230
Minnesota	802	795	786	770	755	739	731	1332	1323	1315	1298	1280	1263	1254
Mississippi	1453	1433	1409	1365	1320	1276	1254	2194	2167	2144	2094	2044	1993	1968

State	PTAC Standard Size - 9,000 Btu/h							PTAC Standard Size - 15,000 Btu/h						
	EL0	EL1	EL2	EL3	EL4	EL5	EL6	EL0	EL1	EL2	EL3	EL4	EL5	EL6
Missouri	1111	1098	1082	1052	1023	993	979	1740	1722	1707	1673	1640	1607	1591
Montana	661	656	651	641	631	621	616	1138	1133	1128	1118	1107	1097	1091
Nebraska	946	936	924	902	879	857	846	1521	1507	1496	1471	1447	1422	1410
Nevada	1090	1078	1062	1034	1005	977	962	1682	1665	1651	1620	1589	1558	1543
New Hampshire	751	745	737	723	709	696	689	1259	1251	1244	1228	1213	1198	1190
New Jersey	921	911	900	878	857	835	824	1480	1467	1456	1433	1409	1385	1373
New Mexico	905	896	884	864	843	822	811	1439	1427	1417	1394	1372	1350	1338
New York	869	860	850	830	811	792	783	1411	1399	1389	1368	1347	1326	1316
North Carolina	1148	1134	1116	1085	1054	1022	1007	1779	1760	1744	1709	1674	1639	1621
North Dakota	731	725	718	706	693	681	674	1240	1233	1226	1213	1199	1185	1178
Ohio	991	980	967	942	918	894	881	1575	1561	1548	1521	1494	1467	1453
Oklahoma	1252	1236	1216	1181	1145	1110	1092	1924	1902	1884	1844	1804	1763	1743
Oregon	665	660	654	643	633	622	617	1132	1126	1121	1110	1099	1088	1082
Pennsylvania	888	879	868	848	828	809	799	1440	1428	1418	1396	1374	1352	1341
Rhode Island	794	787	778	762	746	730	722	1316	1307	1299	1281	1264	1246	1238
South Carolina	1284	1267	1247	1209	1172	1135	1117	1962	1939	1920	1878	1836	1794	1773
South Dakota	804	797	788	772	756	740	732	1330	1321	1313	1295	1278	1261	1252
Tennessee	1229	1214	1195	1160	1125	1090	1073	1892	1871	1853	1815	1776	1737	1717
Texas	1547	1525	1499	1450	1402	1354	1330	2319	2289	2264	2209	2154	2100	2072
Utah	816	809	799	782	765	748	740	1327	1317	1309	1291	1273	1256	1247
Vermont	745	739	731	718	704	691	684	1257	1249	1242	1228	1213	1199	1191
Virginia	1069	1056	1041	1013	985	957	943	1675	1659	1644	1613	1582	1551	1535
Washington	617	613	608	600	591	583	579	1074	1069	1065	1056	1048	1039	1034
West Virginia	867	858	847	828	809	790	781	1405	1394	1384	1363	1342	1321	1311
Wisconsin	763	757	749	735	721	707	700	1282	1273	1266	1251	1235	1220	1212
Wyoming	694	689	683	672	660	649	643	1182	1176	1170	1158	1146	1134	1128
US Average	1078	1066	1050	1022	994	966	952	1688	1671	1657	1625	1594	1563	1547

Table 7A.1.2 Disaggregated PTHP Unit Energy Consumption by Location

State	PTHP Standard Size - 9,000 Btu/h						PTHP Standard Size - 15,000 Btu/h					
	EL0	EL1	EL2	EL3	EL4	EL5	EL0	EL1	EL2	EL3	EL4	EL5
Alabama	1729	1697	1653	1608	1563	1541	2576	2554	2494	2433	2373	2343
Alaska	4295	4267	4240	4213	4187	4173	5431	5421	5385	5350	5314	5297
Arizona	1659	1628	1582	1537	1491	1468	2459	2436	2375	2314	2253	2222
Arkansas	1873	1839	1793	1748	1702	1679	2758	2735	2674	2612	2551	2520
California	1091	1072	1047	1022	997	984	1723	1711	1677	1642	1608	1591
Colorado	1902	1879	1854	1829	1804	1791	2718	2707	2673	2639	2605	2588
Connecticut	2184	2152	2116	2080	2044	2026	3098	3082	3034	2986	2938	2914
Delaware	2035	2002	1962	1922	1883	1863	2933	2915	2862	2809	2756	2729
Dist. of Col.	1959	1928	1890	1852	1814	1795	2852	2834	2784	2733	2682	2657
Florida	2066	2027	1969	1911	1853	1824	3004	2975	2896	2818	2739	2700
Georgia	1676	1645	1602	1559	1516	1494	2511	2489	2431	2372	2313	2284
Hawaii	2086	2045	1988	1933	1878	1851	2980	2954	2892	2833	2791	2771
Idaho	1966	1939	1910	1881	1852	1838	2826	2814	2775	2737	2699	2680
Illinois	2595	2564	2527	2491	2454	2436	3549	3532	3484	3436	3388	3364
Indiana	3383	3355	3322	3290	3258	3241	4402	4388	4345	4302	4260	4238
Iowa	2904	2875	2841	2807	2774	2757	3872	3857	3812	3767	3722	3700
Kansas	2194	2163	2123	2084	2044	2025	3112	3093	3040	2987	2934	2908
Kentucky	2024	1994	1956	1917	1879	1860	2904	2886	2835	2784	2733	2707
Louisiana	1781	1746	1695	1643	1592	1566	2661	2634	2564	2494	2425	2390
Maine	2638	2611	2582	2553	2523	2509	3586	3573	3534	3495	3456	3437
Maryland	2017	1984	1945	1906	1866	1847	2913	2895	2842	2790	2738	2711
Massachusetts	2169	2138	2104	2069	2035	2018	3071	3055	3010	2965	2919	2897
Michigan	2625	2594	2560	2526	2491	2474	3581	3566	3521	3476	3432	3409
Minnesota	3390	3365	3336	3308	3279	3264	4398	4385	4346	4308	4270	4251
Mississippi	1756	1722	1674	1626	1578	1554	2631	2607	2542	2477	2412	2379
Missouri	2277	2245	2204	2163	2122	2101	3206	3186	3131	3076	3021	2994
Montana	2593	2568	2542	2515	2488	2475	3508	3497	3462	3426	3391	3374
Nebraska	2802	2772	2737	2701	2666	2648	3756	3740	3693	3646	3599	3575
Nevada	1607	1581	1545	1510	1475	1457	2386	2369	2322	2275	2228	2205
New Hampshire	2728	2701	2672	2642	2612	2597	3689	3676	3636	3596	3556	3536
New Jersey	1927	1896	1859	1822	1786	1767	2806	2789	2740	2691	2642	2617
New Mexico	1642	1617	1586	1555	1524	1509	2425	2411	2370	2329	2288	2267
New York	2028	1998	1963	1928	1893	1875	2913	2897	2850	2804	2757	2734
North Carolina	1741	1710	1670	1629	1589	1568	2585	2565	2510	2456	2401	2374
North Dakota	3580	3557	3531	3506	3480	3467	4603	4591	4557	4522	4487	4470
Ohio	2229	2198	2160	2123	2085	2066	3133	3116	3066	3016	2966	2941
Oklahoma	1962	1930	1886	1843	1799	1778	2850	2829	2770	2712	2653	2624

State	PTHP Standard Size - 9,000 Btu/h						PTHP Standard Size - 15,000 Btu/h					
	EL0	EL1	EL2	EL3	EL4	EL5	EL0	EL1	EL2	EL3	EL4	EL5
Oregon	1328	1303	1276	1250	1223	1209	2079	2067	2031	1994	1957	1939
Pennsylvania	2241	2209	2172	2135	2098	2080	3153	3137	3088	3039	2990	2966
Rhode Island	2172	2141	2106	2071	2037	2019	3074	3059	3013	2967	2921	2898
South Carolina	1679	1648	1605	1562	1519	1497	2518	2497	2438	2380	2322	2293
South Dakota	3020	2995	2967	2938	2909	2894	3989	3976	3938	3899	3860	3841
Tennessee	1857	1825	1783	1740	1697	1676	2733	2712	2654	2596	2539	2510
Texas	1848	1813	1762	1712	1661	1636	2735	2709	2641	2573	2504	2470
Utah	1758	1732	1701	1670	1639	1624	2586	2572	2531	2490	2449	2429
Vermont	3137	3110	3080	3050	3020	3005	4124	4111	4071	4032	3992	3972
Virginia	1802	1771	1732	1693	1654	1634	2660	2642	2589	2536	2484	2458
Washington	1411	1384	1356	1328	1300	1286	2185	2173	2136	2098	2060	2041
West Virginia	2033	2005	1973	1940	1907	1891	2900	2886	2842	2798	2755	2733
Wisconsin	3113	3085	3054	3023	2992	2977	4103	4090	4049	4008	3967	3946
Wyoming	2520	2495	2467	2439	2412	2398	3425	3413	3376	3340	3303	3285

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APPENDIX 10A. FULL-FUEL-CYCLE MULTIPLIERS

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APPENDIX 10A. FULL-FUEL-CYCLE MULTIPLIERS

10A.1 INTRODUCTION

This appendix summarizes the methods used to calculate full-fuel-cycle (FFC) energy savings expected to result from potential standards. The FFC measure includes point-of-use (site) energy, the energy losses associated with generation, transmission, and distribution of electricity, and the energy consumed in extracting, processing, and transporting or distributing primary fuels. The U.S. Department of Energy's (DOE's) traditional approach encompassed only site energy and the energy losses associated with generation, transmission, and distribution of electricity.[1] Per DOE's 2011 *Statement of Policy for Adopting Full Fuel Cycle Analyses*, DOE now uses FFC measures of energy use and emissions in its energy conservation standards analyses. This appendix summarizes the methods used to incorporate the full-fuel-cycle impacts into the analysis.

This analysis uses several different terms to reference energy use. The physical sources of energy are the primary fuels such as coal, natural gas, liquid fuels, *etc*. Primary energy is equal to the heat content (Btu) of the primary fuels used to provide an end-use service. Site energy use is defined as the energy consumed at the point-of-use in a building or industrial process. Where natural gas and petroleum fuels are consumed at the site (for example in a furnace), site energy is identical to primary energy, with both equal to the heat content of the primary fuel consumed. For electricity, site energy is measured in kWh. In this case the primary energy is equal to the quads of primary energy required to generate and deliver the site electricity. This primary energy is calculated by multiplying the site kWh times the site-to-power plant energy use factor, given in Chapter 10. For the FFC analysis, the upstream energy use is defined as the energy consumed in extracting, processing, and transporting or distributing primary fuels. FFC energy use is the sum of primary plus upstream energy use.

Both primary fuels and electricity are used in upstream activities. The treatment of electricity in fuel cycle analysis must distinguish between electricity generated by fossil fuels and uranium, and electricity generated from renewable fluxes (wind, solar and hydro). For the former, the upstream fuel cycle impacts are derived from the amount of fuel consumed at the power plant. For the latter, no fuel *per se* is used, so there is no upstream component.

10A.2 METHODOLOGY

The mathematical approach is discussed in the paper *A Mathematical Analysis of Full Fuel Cycle Energy Use,*[2] and details on the fuel production chain analysis are presented in the paper *Projections of Full Fuel Cycle Energy and Emissions Metrics*.[3] The text below provides a brief summary of the methods used to calculate FFC energy.

When all energy quantities are normalized to the same units, the FFC energy use can be represented as the product of the primary energy use and an *FFC multiplier*. The FFC multiplier is defined mathematically as a function of a set of parameters representing the energy intensity and material losses at each production stage. These parameters depend only on physical data, so the calculations do not require any assumptions about prices or other economic data. While in general these parameter values may vary by geographic region, for this analysis national averages are used.

In the notation below, the indices x and y are used to indicate fuel type, with x=c for coal, x=g for natural gas, x=p for petroleum fuels, x=u for uranium and x=r for renewable fluxes. The fuel cycle parameters are:

- a_x is the quantity of fuel x burned per unit of electricity output, on average, for grid electricity. The calculation of a_x includes a factor to account for transmission and distribution system losses.
- b_y is the amount of grid electricity used in production of fuel y, in MWh per physical unit of fuel y.
- c_{xy} is the amount of fuel x consumed in producing one unit of fuel y.
- q_x is the heat content of fuel x (MBtu/physical unit)
- $z_x(s)$ is the emissions intensity for fuel x (mass of pollutant s per physical unit of x)

The parameters are calculated as a function of time with an annual time step; hence, a time series of annual values is used to estimate the FFC energy and emissions savings in each year of the analysis period. Fossil fuel quantities are converted to energy units using the heat content factors q_x. To convert electricity in kWh to primary energy units, on-site electricity consumption is multiplied by the site-to-power plant energy use factor. The site-to-power plant energy use factor is defined as the ratio of the total primary energy consumption by the electric power sector (in quadrillion Btu's) divided by the total electricity generation in each year.

The FFC multiplier is denoted μ (mu). A separate multiplier is calculated for each fuel used on site. A multiplier is also calculated for electricity reflecting the fuel mix used in its generation. The multipliers are dimensionless numbers that are applied to primary energy savings to obtain the FFC energy savings. The upstream component of the energy savings is proportional to (μ-1). The fuel type is denoted by a subscript on the multiplier μ.

For DOE's appliance standards energy savings estimates, the fuel cycle analysis methodology is designed to make use of data and projections published in the Annual Energy Outlook (AEO). Table 10-A.2.1 provides a summary of the AEO data used as inputs to the different parameter calculations. The AEO does not provide all the information needed to estimate total energy use in the fuel production chain. Reference three describes the additional data sources used to complete the analysis. However, the time dependence in the FFC multipliers arises exclusively from variables taken from the AEO. The FFC analysis for PTAC and PTHP equipment used data from *AEO 2014*.[4]

Table 10A.2.1 Dependence of FFC Parameters on AEO Inputs

Parameter	Fuel	AEO Table	Variables
q_x	all	Conversion Factors	MMBtu per physical unit
a_x	all	Electricity Supply, Disposition, Prices, and Emissions	Generation by fuel type
		Energy Consumption by Sector and Source	Electric power sector energy consumption
b_c, c_{nc}, c_{pc}	coal	Coal Production by Region and Type	Production by coal type and sulfur content
b_p, c_{np}, c_{pp}	petroleum	Refining Industry Energy Consumption	Refining only energy use
		Liquid Fuels Supply and Disposition	Crude supply by source
		International Liquids Supply and Disposition	Crude oil imports
		Oil and Gas Supply	Crude oil domestic production
c_{nn}	natural gas	Oil and Gas Supply	US dry gas production
		Natural Gas Supply, Disposition and Prices	Pipeline, lease and plant fuel
z_x	all	Electricity Supply, Disposition, Prices and Emissions	Power sector emissions

10A.3 FULL-FUEL-CYCLE ENERGY MULTIPLIERS

FFC energy multipliers are presented in Table 10-A.3.1 for selected years. For the analysis period beyond 2040, the last year in the *AEO 2014* projection, the 2040 value was held constant. The multiplier for electricity reflects the shares of various primary fuels in total electricity generation over the forecast period.

Table 10A.3.1 Full-Fuel-Cycle Energy Multipliers (Based on AEO 2014)

	2019	**2020**	**2025**	**2030**	**2035**	**2040**
Electricity	1.043	1.044	1.045	1.046	1.047	1.047
Natural Gas	1.108	1.109	1.111	1.113	1.114	1.114
Petroleum Fuels	1.176	1.176	1.176	1.174	1.172	1.170

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1. United States - Office of the Federal Register, *Federal Register, Volume 76, Number 160, August 18, 2011*. UNT Digital Library. Washington D.C.

2. Coughlin, K., A Mathematical Analysis of Full Fuel Cycle Energy Use. *Energy*, 2012. 37(1): pp. 698-708 <www.sciencedirect.com/science/article/pii/S0360544211006803>

3. Coughlin, K., *Projections of Full-Fuel-Cycle Energy and Emissions Metrics*, 2013. Lawrence Berkeley National Laboratory. Report No. LBNL-6025E.

4. Energy Information Administration, *Annual Energy Outlook 2014 with Projections to 2040*, 2014. Washington, DC. Report No. DOE/EIA-0383. <www.eia.gov/forecasts/aeo/pdf/0383(2014).pdf>

APPENDIX 10B. NIA SENSITIVITY ANALYSIS FOR ALTERNATIVE PRODUCT PRICE TREND SCENARIOS

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APPENDIX 10B. NIA SENSITIVITY ANALYSIS FOR ALTERNATIVE PRODUCT PRICE TREND SCENARIOS

10B.1 INTRODUCTION

The U.S. Department of Energy (DOE) used a constant price assumption for the default forecast in the national impact analysis (NIA) described in Chapter 10. In order to investigate the impact of different product price forecasts on the consumer net present value (NPV) for the considered trial standard levels (TSLs) for packaged terminal air conditioners (PTACs) and packaged terminal heat pumps (PTHPs), DOE also considered two alternative price trends for a sensitivity analysis. This appendix describes the alternative price trends and compares NPV results for these scenarios with the default forecast.

In recent rulemakings for several residential products, DOE has used the experience curve method to derive learning rates to forecast future prices. In the experience curve method, the real cost of production is related to the cumulative production, or experience, with a manufactured product. That experience usually is measured in terms of cumulative production. As experience (production) accumulates, the cost of producing the next unit decreases. The percentage reduction in cost that occurs with each doubling of cumulative production is known as the learning rate. A recent report from Lawrence Berkeley National Laboratory by Taylor and Fujita provides an overview of some of the major findings of the academic literature on learning curves, and describes the application of a component-based learning curve approach (by the Environmental Protection Agency and the National Highway Transportation Safety Administration) and a price-based learning curve approach (by DOE) in regulatory impact assessment.[1]

For some commercial and industrial equipment, there are insufficient data to apply a price-based learning curve approach, particularly with respect to cumulative production. In such cases, DOE used a constant price assumption for the default forecast in the NIA, but made use of price indexes that are relevant for the equipment in question to derive alternative price trends for sensitivity analysis. This approach was used for PTACs and PTHPs.

10B.2 ALTERNATIVE PTAC PRICE TREND SCENARIOS

For PTACs and PTHPs, DOE considered two alternative price trends for sensitivity analysis. One of these used an exponential fit on the deflated Producer Price Index (PPI) for all other miscellaneous refrigeration and air-conditioning equipment, and the other is based on the "deflator— industrial equipment" that was forecasted for the U.S. Energy Information Administration's (EIA's) *Annual Energy Outlook 2014 (AEO2014).*

10B.2.1.1 Exponential Fit (High Price Scenario)

For this scenario, DOE used an inflation-adjusted all other miscellaneous refrigeration and air-conditioning equipment PPI from 2001-2014 to fit an exponential model with year as the explanatory variable. Spanning the time period 2001-2014, DOE obtained historical PPI data, as well as all other miscellaneous refrigeration and air-conditioning equipment from the Bureau of Labor Statistics' (BLS).[a] The PPI data reflect nominal prices, adjusted for product quality changes. An inflation-adjusted (deflated) price index for all other miscellaneous refrigeration and air-conditioning equipment was calculated by dividing the PPI series by the Gross Domestic Product Chained Price Index. The deflated price index is now presented in 2014 dollar values. In this case, the exponential function takes the form of:

$$Y = a \cdot e^{bX}$$

where Y is the all other miscellaneous refrigeration and air-conditioning equipment price index, X is the time variable, a is the constant and b is the slope parameter of the time variable.

To estimate these exponential parameters, a least-square fit was performed on the inflation-adjusted equipment price index versus year from 2001 to 2014. See

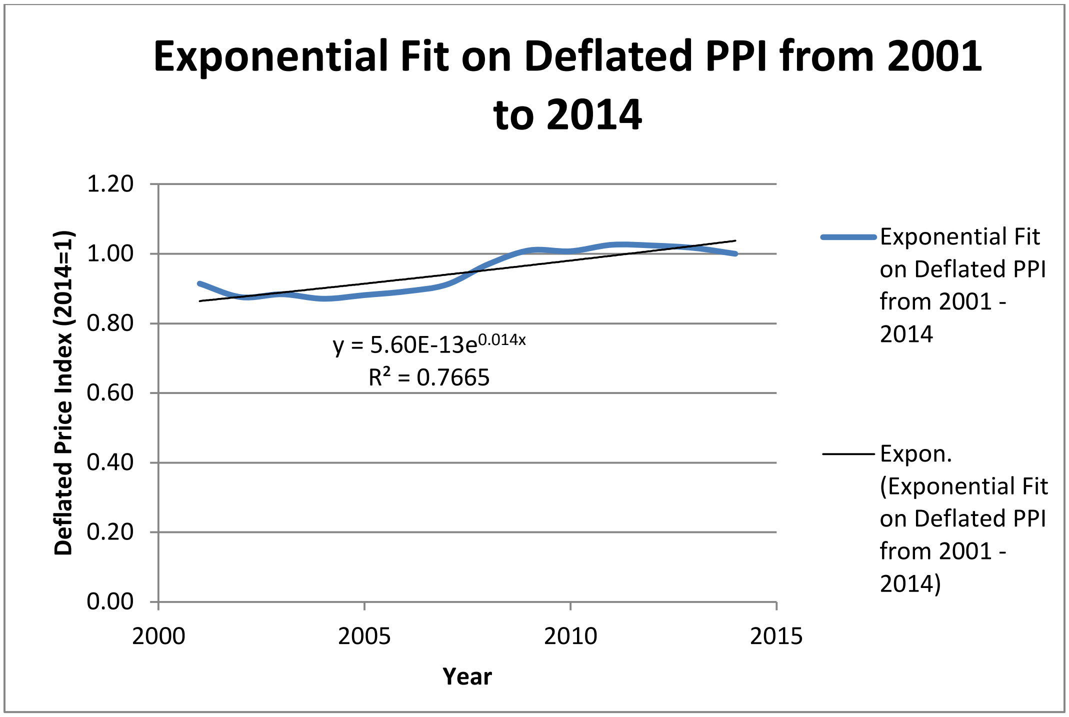

Figure 10B.2.1 Relative Price of PTAC and PTHP Equipment versus Year, with Exponential Fit

The regression performed as an exponential trend line fit results in an R-square of 0.77, which indicates a moderate fit to the data. The final estimated exponential function is:

$$Y = 5.60 \times 10^{(-13)} \cdot e^{0.014X}$$

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[a] Series ID PCU3334153334159; www.bls.gov/ppi/

DOE then derived a price factor index for this scenario, with 2014 equal to 1, to project prices in each future year in the analysis period considered in the NIA. The index value in a given year is a function of the exponential parameter and year.

10B.2.1.2 Annual Energy Outlook 2014 Price Forecast (Low Price Scenario)

DOE also examined a forecast based on the "chained price index—industrial equipment" that was forecasted for AEO 2014 out to 2040. This index is the most disaggregated category that includes PTACs. To develop an inflation-adjusted index, DOE normalized the above index with the "chained price index—gross domestic product" forecasted for AEO 2014. To extend the price index beyond 2040, DOE used the average annual price growth rate in 2031 to 2040.

10B.2.1.3 Summary

Table 10B.2.1 shows the summary of the average annual rates of changes for the product price index in each scenario. Figure 10B.2.2 shows the resulting price trends.

Table 10B.2.1 Price Trend Sensitivites

Sensitivity	Price Trend	Average Annual rate of change %
Medium (Default)	Constant Price Projection	0.00
Low Price Scenario	AEO2014— "chained price index—industrial equipment"	-0.38
High Price Scenario	Exponential Fit using data from 2001 to 2014	1.41

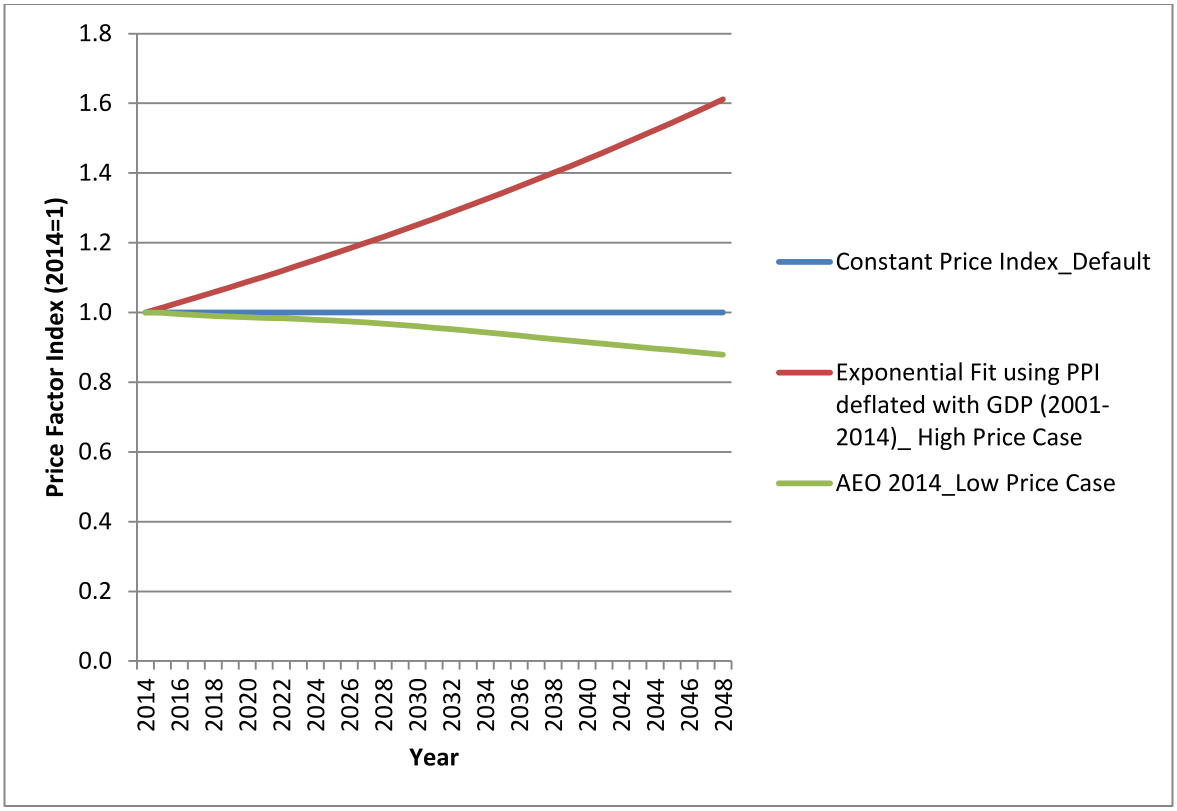

Figure 10B.2.2 PTAC Price Forecast Indexes

10B.3 NPV RESULTS BY ALTERNATIVE PRICE SCENARIO

Table 10B.3.1 Summary of Cumulative Net Present Value for PTAC and PTHP: Decreasing Price Scenario (Seven Percent Discount Rate)

Equipment Class	Net Present Value (Million 2014$)				
	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
PTAC < 7,000 Btu/h	0.0	-1.0	-2.9	-4.5	-4.8
PTAC 7,000 - 15,000 Btu/h	-2.5	-13.8	-33.4	-51.2	-55.0
PTAC > 15,000 Btu/h	-0.5	-3.1	-7.1	-10.5	-11.2
PTHP < 7,000 Btu/h	0.0	-0.4	-1.0	-1.7	-1.8
PTHP 7,000 - 15,000 Btu/h	3.5	3.8	1.0	-4.3	-5.7
PTHP > 15,000 Btu/h	0.0	-0.4	-2.0	-3.6	-4.0
All Classes	**0.5**	**-14.9**	**-45.4**	**-75.8**	**-82.6**

Table 10B.3.2 Summary of Cumulative Net Present Value for PTAC and PTHP: Decreasing Price Scenario (Three Percent Discount Rate)

Equipment Class	Net Present Value (Million 2014$)				
	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
PTAC < 7,000 Btu/h	0.0	-1.5	-4.3	-6.4	-6.8
PTAC 7,000 - 15,000 Btu/h	-2.4	-15.4	-40.5	-62.1	-66.1
PTAC > 15,000 Btu/h	-0.8	-5.2	-11.8	-16.5	-17.3
PTHP < 7,000 Btu/h	0.1	0.0	-0.5	-1.1	-1.2
PTHP 7,000 - 15,000 Btu/h	10.0	21.4	30.1	30.6	30.1
PTHP > 15,000 Btu/h	0.4	0.9	-0.4	-2.1	-2.4
All Classes	**7.4**	**0.2**	**-27.3**	**-57.5**	**-63.8**

Table 10B.3.3 Summary of Cumulative Net Present Value for PTACs and PTHPs: Increasing Price Scenario (Seven Percent Discount Rate)

Equipment Class	Net Present Value (Million 2014$)				
	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
PTAC < 7,000 Btu/h	0.0	-1.7	-4.6	-6.8	-7.2
PTAC 7,000 - 15,000 Btu/h	-5.2	-26.9	-61.0	-86.9	-91.5
PTAC > 15,000 Btu/h	-0.9	-5.2	-11.1	-15.5	-16.3
PTHP < 7,000 Btu/h	-0.3	-1.1	-2.4	-3.4	-3.6
PTHP 7,000 - 15,000 Btu/h	0.4	-7.6	-21.4	-33.0	-35.1
PTHP > 15,000 Btu/h	-0.4	-2.1	-5.3	-7.8	-8.3
All Classes	**-6.4**	**-44.6**	**-105.9**	**-153.4**	**-162.0**

Table 10B.3.4 Summary of Cumulative Net Present Value for PTACs and PTHPs: Increasing Price Scenario (Three Percent Discount Rate)

Equipment Class	Net Present Value (Million 2014$)				
	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
PTAC < 7,000 Btu/h	0.0	-3.0	-8.3	-11.5	-12.0
PTAC 7,000 - 15,000 Btu/h	-8.7	-45.6	-103.3	-139.0	-144.2
PTAC > 15,000 Btu/h	-1.8	-10.1	-20.8	-27.2	-28.1
PTHP < 7,000 Btu/h	-0.3	-1.7	-3.6	-4.8	-5.0
PTHP 7,000 - 15,000 Btu/h	3.0	-4.2	-19.4	-29.7	-31.1
PTHP > 15,000 Btu/h	-0.6	-3.1	-7.9	-10.8	-11.3
All Classes	**-8.4**	**-67.6**	**-163.3**	**-223.0**	**-231.7**

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1. Margaret Taylor and K. Sydny Fujita. Accounting for Technological Change in Regulatory Impact Analyses: The Learning Curve Technique. Lawrence Berkeley National Laboratory, Berkeley, CA. April 2013.

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APPENDIX 12A MANUFACTURER IMPACT ANALYSIS INTERVIEW GUIDE

12A.1 INTRODUCTION

This appendix presents the interview guide that DOE used in 2013 to gather data for the manufacturer impact analysis. When this guide was administered, DOE assumed the baseline in this rulemaking would be equivalent to the PTAC and PTHP energy conservation standards set in the 2008 final rule. 73 FR 58772 (Oct. 7, 2008). ANSI/ASHRAE/IES 90.1-2013 was published after DOE concluded manufacturer interviews, and DOE set the baseline equivalent to ASHRAE levels in the NOPR and final rule analysis.

12A.2 MANUFACTURER IMPACT ANALYSIS INTERVIEW GUIDE

As part of the potential rulemaking process for amending energy conservation standards for packaged terminal air conditioners (PTACs) and packaged terminal heat pumps (PTHPs), the Department of Energy (DOE) is conducting a manufacturer impact analysis (MIA). In this analysis, DOE uses publicly available information and information provided by manufacturers during interviews to assess possible impacts on manufacturers due to amended energy conservation standards.

This questionnaire is a part of the MIA process and is intended to inform the Department's understanding of how changes in the energy conservation standard will affect manufacturers of PTACs and PTHPs. All information provided in response to this questionnaire will be treated as confidential. The questions below range from requests about specific financial figures for use in industry modeling to generic questions intended to solicit qualitative comments. Topics covered include:

1) Key Issues
2) Engineering
3) Company Overview and Organizational Characteristics
4) Markups and Profitability
5) Shipping Costs
6) Industry Projections
7) Financial Parameters
8) Conversion Costs
9) Cumulative Regulatory Burden
10) Direct Employment Impact Assessment
11) Capacity / Exports / Foreign Competition / Outsourcing
12) Consolidation
13) Impacts on Small Business

The questions in this interview guide refer to the equipment classes and potential efficiency levels (ELs) in EER for each equipment class provided in Table 12A.2.1 as well as the design options listed in Table 12A.2.2. The baseline in Table 12A.2.1 refers to current efficiency standards. In the far right column of Table 12A.2.1, please fill out the percentage of your PTAC/PTHP shipments that fall into each equipment class.

Table 12A.2.1. Equipment Classes and Potential Efficiency Levels in EER

	Equipment Type	Size Category	Cooling Capacity	Baseline	EL 1	EL 2	EL 3	EL 4	Max Tech	% of your shipments in this class
1	PTAC	Standard*	<7,000 Btu/h	11.7	12.17	12.64	13.10	13.57	14.04	
2			≥7,000 Btu/h and ≤15,000 Btu/h	13.8 – (0.300 x Cap)	14.35 – (0.312 x Cap)	14.90 – (0.324 x Cap)	15.46 – (0.336 x Cap)	16.01 – (0.348 x Cap)	16.56 – (0.360 x Cap)	
3			>15,000 Btu/h	9.3	9.67	10.04	10.42	10.79	11.16	
4		Non-Standard**	<7,000 Btu/h	9.4	10.15	10.90	11.66	12.41	13.16	
5			≥7,000 Btu/h and ≤15,000 Btu/h	10.9 – (0.213 x Cap)	11.77 – (0.230 x Cap)	12.64 – (0.247 x Cap)	13.52 – (0.264 x Cap)	14.39 – (0.281 x Cap)	15.26 – (0.298 x Cap)	
6			>15,000 Btu/h	7.7	8.32	8.93	9.55	10.16	10.78	
7	PTHP	Standard*	<7,000 Btu/h	11.9	12.17	12.64	13.10	13.57	14.04	
8			≥7,000 Btu/h and ≤15,000 Btu/h	14.0 – (0.300 x Cap)	14.35 – (0.312 x Cap)	14.90 – (0.324 x Cap)	15.46 – (0.336 x Cap)	16.01 – (0.348 x Cap)	16.56 – (0.360 x Cap)	
9			>15,000 Btu/h	9.5	9.67	10.04	10.42	10.79	11.16	
10		Non-Standard**	<7,000 Btu/h	9.3	10.15	10.90	11.66	12.41	13.16	
11			≥7,000 Btu/h and ≤15,000 Btu/h	10.8 - (0.213 x Cap)	11.77- (0.230 x Cap)	12.64 – (0.247 x Cap)	13.52 – (0.264 x Cap)	14.39 – (0.281 x Cap)	15.26 – (0.298 x Cap)	
12			>15,000 Btu/h	7.6	8.32	8.93	9.55	10.16	10.78	

* Standard refers to PTAC or PTHP equipment with wall sleeve dimensions greater than or equal to 16 inches high, or greater than or equal to 42 inches wide.

** Non-Standard refers to PTAC or PTHP equipment with wall sleeve dimensions less than 16 inches high and less than 42 inches wide.

For standard size PTACs, the ELs indicated in Table 12A.2.1 (above) are 4%, 8%, 12%, 16%, and 20% more efficient than the baseline. For non-standard size PTACs, the ELs are 8%, 16%, 24%, 32%, and 40% more efficient than the baseline. The ELs for PTHPs correspond to the ELs for PTACs of equivalent size category and cooling capacity.

Table 12A.2.2. Potential Design Options

Design Options
Heat transfer improvements: • Electro-hydrodynamic enhancement[1]
High-efficiency motors for indoor blower and/or condenser fan • Copper rotor motor • Permanent split-capacitor • Permanent magnet, electronically commutated
Alternative refrigerants
Larger heat exchangers
More efficient condenser/outdoor coil fan • Larger condenser fan diameter • More efficient fan blades
More efficient evaporator/indoor coil fan • Housed backward-curved or airfoil • Plenum fan
Microchannel heat exchangers • Condenser (for Air Conditioners) • Evaporator/Indoor Coil • Outdoor Coil (for heat pumps)
Compressor Improvements • High efficiency compressors • Multiple- or variable-capacity compressors
Thermostatic expansion valves
Electronic expansion valves
Ambient subcoolers[2]
Mechanical subcoolers[3]

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[1] An EHD system uses high-voltage (>1kV), low-current, electricity from integrated electrodes to create an electric field and incite fluid mixing.

[2] Ambient subcoolers reject refrigerant heat to the lower temperature of a surrounding medium (usually air).

[3] Mechanical subcoolers use smaller, secondary vapor-compression circuits.

12A.3 KEY ISSUES

DOE is interested in understanding the impact of amended energy conservation standards on manufacturers. This section provides an opportunity for manufacturers to identify high-priority issues that DOE should take into consideration when conducting the Manufacturer Impact Analysis.

1) In general, what are the key concerns for your company regarding this potential rulemaking for PTACs and PTHPs?

2) For the issues identified, how significant are they for different equipment classes and/or efficiency levels?

12A.4 ENGINEERING

1) Which design features impacting energy use do you generally incorporate into a "baseline" unit in each equipment class? Describe typical key components: compressor, condenser/outdoor coil, evaporator/indoor coil, indoor fan, outdoor fans.

2) Which design features impacting energy use are incorporated into products to reach higher efficiencies—which of these design options provide the greatest EER improvement, and what are their costs? How does the selection of these design options vary by cooling capacity? Would it be possible to obtain detailed design information for key representative products spanning important efficiency levels that would clearly illustrate these trends?

3) How does equipment with "standard sizes" differ from equipment with "non-standard sizes" in terms of design features and energy-efficiency opportunities?

4) How do heat pumps differ from air conditioners in terms of achievable cooling efficiency levels (EER)? Is the 0.2 EER differential of the ASHRAE 90.1-2007 EER levels associated with coil design compromises and reversing valve pressure drop? What unique challenges do heat pumps encounter when trying to improve energy efficiency in terms of EER? Does this vary by capacity? Do design options that increase heating efficiency (COP) positively or negatively impact cooling efficiency (EER)?

5) Are there specific charge imbalance issues associated with heat pumps—what strategies are used to address these issues and do they affect efficiency?

6) Are any of the design options listed in Table 12A.2.2 more effective in air conditioners or heat pumps? Higher or lower capacities? Are there any design options that are not technologically feasible for specific equipment classes? If so, which classes? Are there any important design options for improvement of EER that are not listed in the table?

7) Do you manufacture your own heat exchangers or purchase them from another source? If purchased from another source, please provide cost estimates for the following coil types for 9000 Btu/h, and 15000 Btu/h. In addition, please provide the typical fin spacing for each coil type and unit size. If you manufacture them, do you purchase pre-prepared stock (e.g., tubing and fin stock) and what are the costs for these items?

Table 12A.4.1. Heat Exchanger Cost and Fin Spacing

	Estimated Cost		**Fin Spacing**	
Coil Type	**9000 Btu/h unit**	**15000 Btu/h unit**	**9000 Btu/h unit**	**15000 Btu/h unit**
Fin & Tube				

8) Do any of your units utilize microchannel heat exchangers? If so, do you manufacture them or purchase them from another source? If you purchase them from another source, please provide cost estimates. If you manufacture them, do you purchase pre-prepared stock (e.g., tubing and fin stock), and what are the costs for these items?

9) What is the typical coil depth in number of tube rows for indoor and outdoor coils at baseline and higher efficiency levels for a 9000 Btu/h and 15000 Btu/h AC unit? HP?

10) What factors limit the use of increased coil area to reach higher efficiencies (e.g., aesthetic appeal, cost, sleeve size, etc.)? What efficiency increases can be obtained in terms of EER from increasing coil area before these factors come into play?

11) Does coil efficiency change with the use of different blower motors or compressors? What are typical coil face velocities for indoor and outdoor coils of baseline-efficiency equipment and does this change significantly at higher efficiency levels?

12) Do typical units utilize refrigerant receivers? Does this depend on capacity?

13) What types of compressor are used in PTACs and PTHPs, and does the type of compressor used change based on the nominal capacity of the system? Please list the types and typical efficiency ranges of compressors used for each capacity range (i.e., <7000 Btu/h, between 7000 Btu/h and 15000 Btu/h, and >15000 Btu/h) in Table 12A.4.2. Compressor Type(s) Used by System Cooling Capacity. In cases where multiple compressor types may be used for a given capacity range, what factors affect the decision of which compressor type to use for a given unit?

Table 12A.4.2. Compressor Type(s) Used by System Cooling Capacity

System Cooling Capacity	**Compressor Type(s) Used**	**Typical Efficiency Range**
<7,000 Btu/h		
≥7,000 Btu/h and ≤15,000 Btu/h		
>15,000 Btu/h		

14) How does the cost of a "baseline" compressor vary as a function of compressor type and nominal capacity? Please provide the estimated costs for several "baseline" compressor type and capacity combinations commonly used in your products.

Table 12A.4.3. Baseline Compressor Costs

Compressor Type	**Nominal Capacity**	**"Baseline" Cost**

15) What type(s) of fan motors do you typically use in your products (e.g., TEAO[4], TEFC[5], ODP[6], or EC[7])? What factors affect the decision of which motor type to use for a given unit?

16) When purchasing fans, do you purchase the fan and motor separately or as a single

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[4] Totally Enclosed, Air Over

[5] Totally Enclosed, Fan C

[6] Open Drip Proof

[7] Electronically Commutated

package? If purchased separately, how does shaft power affect motor cost? Please provide estimates of how cost varies based on shaft power for a baseline-efficiency motor of each motor type listed in the previous question. In addition, please provide an estimate of the incremental cost of purchasing a high-efficiency motor of each type.

17) Are installation costs a function of efficiency? Maintenance costs? Repair costs? If yes, please characterize this relationship by providing incremental installation, maintenance, and/or repair cost data.

18) DOE plans to conduct a reverse engineering analysis on units of a representative capacity for each equipment class. DOE plans to use 9000 Btu/h and 15000 Btu/h units to represent medium and large PTAC sizes, respectively. Please comment on the representative sizes.

19) Information gathered from analysis of common industry practices were used to formulate factory parameters for manufacturers. Please comment on the following factory parameter assumptions listed in Table 12A.4.4.

Table 12A.4.4. Factory Parameters

Parameter	Estimate	Manufacturer Feedback
Actual Annual Production Volume (units/year)	100,000	
Work Days Per Year (days)	250	
Assembly Shifts Per Day (shifts)	1	
Fabrication Shifts Per Day (shifts)	2	
Fabrication Labor Wages ($/hr)	7	
Assembly Labor Wages ($/hr)	7	
Assembly Worker Hours Per Year	1687.5	
Fabrication Worker Hours Per Year	3750	
Length of Shift (hrs)	7.5	
Units Per Day	400	
Average Equipment Installation Cost (% of purchase price)	10%	
Fringe Benefits Ratio	15%	
Indirect to Direct Labor Ratio	33%	
Average Scrap Recovery Value	30%	
Building Cost ($/ft^2)	100	
Worker Downtime	10%	
Building Life (in years)	30	
Burdened Assembly Labor Wage ($/hr)	9	
Burdened Fabrication Labor Wage ($/hr)	9	
Supervisor Span (workers/supervisor)	10	
Supervisor Wage Premium (over fabrication and assembly wage)	30%	

12A.5 COMPANY OVERVIEW AND ORGANIZATIONAL CHARACTERISTICS

1) Do you have a parent company and/or subsidiary? If so, please provide their name(s).

2) What is your company's approximate market share of the PTAC/PTHP market? Does this vary significantly for any particular equipment class that you manufacture?

3) Please provide information on your company's shipments of PTAC and PTHP equipment (# of units shipped) for the last five years:

Table 12A.5.1. Shipment Information (total units shipped)

Equipment Type	Size Category	2008	2009	2010	2011	2012
PTAC	Standard					
	Non-Standard					
PTHP	Standard					
	Non-Standard					

4) What percentage of your overall revenue is from PTAC and PTHP sales?

5) Do you manufacturer other products in the same facilities as your PTAC and PTHP equipment?

6) What are your product line niches and relative strengths in the PTAC and PTHP market?

12A.6 MARKUPS AND PROFITABILITY

One of the primary objectives of the Manufacturer Impact Analysis is to assess the impact of amended energy conservation standards on industry profitability. In this section, DOE would like to understand the current markup structure of the industry and how setting an amended energy conservation standard would impact your company's markup structure and profitability. The manufacturer markup is a multiplier applied to manufacturer production cost to cover per-unit research and development, selling, general, and administrative expenses, and profit. It is NOT a profit margin. The manufacturer production cost multiplied by the manufacturer markup plus the shipping costs covers all costs involved in manufacturing and profit for the product.

1) DOE estimated a baseline markup of 1.29 for all equipment classes. Please comment on the accuracy of this figure and whether or not it may vary by equipment class.

2) Within each equipment class, do the per-unit markups vary by efficiency level? Does the markup for more efficient designs differ from the markup for baseline models?

3) What factors besides efficiency affect markups in the same equipment class?

4) Would you expect amended energy conservation standards to affect your profitability? If so, please explain why.

5) Would amended energy conservation standards that eliminate least efficient products impact markups of more efficient products?

12A.7 SHIPPING COSTS

An amended energy conservation standard can change overall shipments by altering product attributes, marketing approaches, product availability, and price. Having an accurate estimate of these changes allows DOE to better examine impacts on profitability due to amended standards. DOE's shipments model includes forecasts for the base case shipments (i.e., total industry shipments absent amended energy conservation standards) and the standards case shipments (i.e., total industry shipments with amended energy conservation standards).

1) In the PTAC and PTHP industry, which party in the supply chain typically pays to ship the product to the distributor warehouse?

2) If the manufacturer pays for shipping costs, is it industry practice to mark-up shipping costs?

3) Do any of the efficiency levels trigger substantial increases in shipping costs? If so, which ones and for which products? Why?

12A.8 INDUSTRY PROJECTIONS

1) Are there any types of equipment that you expect will soon be phased out (in the absence of an amended standard)?

2) How do you think amended energy conservation standards will impact the sales of more efficient products? For example, would customers continue to buy products that exceed the energy conservation standard level? Would your response change for higher mandated efficiency levels?

3) How do you expect shipments to change for the industry as a whole as a result of amended standards? Why?

4) What factors would affect customer decisions to buy new vs. used equipment? What percentage of equipment is purchased used?

12A.9 FINANCIAL PARAMETERS

Navigant Consulting, Inc. (NCI) has developed a “straw man” model of financial performance called the Government Regulatory Impact Model (GRIM) using publicly available data. This section attempts to understand how your company’s financial situation differs from our industry aggregate picture.

Please compare your company’s PTAC and PTHP financial parameters to the GRIM parameters tabulated below.

Table 12A.9.1. Financial Parameters for PTAC and PTHP Manufacturers

GRIM INPUT	DEFINITION	INDUSTRY ESTIMATED VALUE	YOUR ACTUAL
Income Tax Rate	Corporate effective income tax paid (percentage of earnings before taxes, EBT)	35.4%	
Discount Rate	Weighted average cost of capital (inflation-adjusted weighted average of corporate cost of debt and return on equity)	5.0%	
Working Capital	Current assets less current liabilities (percentage of revenues)	3.5%	
SG&A	Selling, general, and administrative expenses (percentage of revenues)	14.1%	
R&D	Research and development expenses (percentage of revenues)	1.6%	
Depreciation	Amortization of fixed assets (percentage of revenues)	1.7%	
Capital Expenditures	Outlay of cash to acquire or improve capital assets (percentage of revenues, not including acquisition or sale of business units)	1.8%	
Net Property, Plant & Equipment	Fixed assets, or long-lived assets, including building, machinery, and equipment less accumulated depreciation (percentage of revenues)	12.8%	

1) Are the figures in Table 12A.9.1 representative of the PTAC / PTHP industry as a whole? If not, why?

2) Do any of the financial parameters in Table 12A.9.1 change for a particular subgroup of manufacturers? Please describe any differences.

12A.10 CONVERSION COSTS

An increase in energy conservation standards may cause the industry to incur capital and product conversion costs to meet the amended energy conservation standard. The MIA considers three types of conversion expenditures:

- **Capital conversion costs**: One-time investments in plant, property, and equipment (PPE) necessitated by an amended energy conservation standard. These may be incremental changes to existing PPE or the replacement of existing PPE. Included are expenditures on buildings, equipment, and tooling.
- **Product conversion costs**: One-time investments in research, product development, testing, marketing and other costs for redesigning products necessitated by an amended energy conservation standard.
- **Stranded assets**: Assets replaced before the end of their useful lives as a direct result of the change in energy conservation standard.

With a detailed understanding of the conversion costs necessitated by different standard levels, DOE can better model the impact of amended energy conservation standards on the PTAC and PTHP industry.

1) At your manufacturing facilities, would potential amended energy conservation standards be difficult to implement? If so, would your company modify existing facilities or develop new facilities?

2) What level of conversion costs do you anticipate incurring at each efficiency level? Please provide dollar amounts as well as descriptions of the investment in the tables below. In the description column, DOE is interested in understanding the kind of changes that would need to be implemented in production lines and production facilities. Where applicable, please quantify the number and cost of new production equipment that would be required to meet the specified efficiency levels.

Table 12A.10.1. Expected Conversion Costs for PTAC and PTHP Equipment, Cooling Capacity: <7,000 Btu/h

Equipment Type	Size Category	Efficiency Level	EER	Capital Conversion Costs	Product Conversion Costs	Description
PTAC	Standard	Baseline	11.70			
		EL 1	12.17			
		EL 2	12.64			
		EL 3	13.10			
		EL 4	13.57			
		Max Tech	14.04			
	Non-Standard	Baseline	9.40			
		EL 1	10.15			
		EL 2	10.90			
		EL 3	11.66			
		EL 4	12.41			
		Max Tech	13.16			
PTHP	Standard	Baseline	11.90			
		EL 1	12.17			
		EL 2	12.64			
		EL 3	13.10			
		EL 4	13.57			
		Max Tech	14.04			
	Non-Standard	Baseline	9.30			
		EL 1	10.15			
		EL 2	10.90			
		EL 3	11.66			
		EL 4	12.41			
		Max Tech	13.16			

Table 12A.10.2. Expected Conversion Costs for PTAC and PTHP Equipment, Cooling Capacity: ≥7,000 Btu/h and ≤15,000 Btu/h

Equipment Type	Size Category	Efficiency Level	EER	Capital Conversion Costs	Product Conversion Costs	Description
PTAC	Standard	Baseline	13.8 - (0.300 x Cap)			
		EL 1	14.35 - (0.312 x Cap)			
		EL 2	14.90 - (0.324 x Cap)			
		EL 3	15.46 - (0.336 x Cap)			
		EL 4	16.01 - (0.348 x Cap)			
		Max Tech	16.56 - (0.360 x Cap)			
	Non-Standard	Baseline	10.9 - (0.213 x Cap)			
		EL 1	11.77 - (0.230 x Cap)			
		EL 2	12.64 - (0.247 x Cap)			
		EL 3	13.52 - (0.264 x Cap)			
		EL 4	14.39 - (0.281 x Cap)			
		Max Tech	15.26 - (0.298 x Cap)			
PTHP	Standard	Baseline	14.0 - (0.300 x Cap)			
		EL 1	14.35 - (0.312 x Cap)			
		EL 2	14.90 - (0.324 x Cap)			
		EL 3	15.46 - (0.336 x Cap)			
		EL 4	16.01 - (0.348 x Cap)			
		Max Tech	16.56 - (0.360 x Cap)			
	Non-Standard	Baseline	10.8 - (0.213 x Cap)			
		EL 1	11.77 - (0.230 x Cap)			
		EL 2	12.64 - (0.247 x Cap)			
		EL 3	13.52 - (0.264 x Cap)			
		EL 4	14.39 - (0.281 x Cap)			
		Max Tech	15.26 - (0.298 x Cap)			

Table 12A.10.3. Expected Conversion Costs for PTAC and PTHP Equipment, Cooling Capacity: >15,000 Btu/h

Equipment Type	Size Category	Efficiency Level	EER	Capital Conversion Costs	Product Conversion Costs	Description
PTAC	Standard	Baseline	9.30			
		EL 1	9.67			
		EL 2	10.04			
		EL 3	10.42			
		EL 4	10.79			
		Max Tech	11.16			
	Non-Standard	Baseline	7.70			
		EL 1	8.32			
		EL 2	8.93			
		EL 3	9.55			
		EL 4	10.16			
		Max Tech	10.78			
PTHP	Standard	Baseline	9.50			
		EL 1	9.67			
		EL 2	10.04			
		EL 3	10.42			
		EL 4	10.79			
		Max Tech	11.16			
	Non-Standard	Baseline	7.60			
		EL 1	8.32			
		EL 2	8.93			
		EL 3	9.55			
		EL 4	10.16			
		Max Tech	10.78			

3) Please comment on any potential stranded assets that may result from an amended energy conservation standard.

4) For any efficiency levels that would require new production equipment, please describe how much downtime would be required. What impact would downtime have on your business?

5) Please provide any additional qualitative information that might help DOE understand the type and nature of your conversion investments, including plant and tooling changes and product development efforts required for different efficiency levels and equipment classes.

12A.11 CUMULATIVE REGULATORY BURDEN

Cumulative regulatory burden refers to the burden that industry faces from overlapping effects of new or revised DOE standards, and/or other regulatory actions affecting the same product or industry.

1) Are there other recent or impending standards that PTAC and PTHP manufacturers face from DOE, other US federal agencies, state regulators, foreign government agencies, or other standard-setting bodies? If so, please identify the regulation and the corresponding possible effective dates for those regulations in the table below.

Table 12A.11.1. Other Regulations Identified

Regulation	Effective Date(s)	Expected Expenses / Comments

2) Under what circumstances would you be able to coordinate expenditures related to these other regulations with an amended energy conservation standard, thereby lessening the cumulative burden?

12A.12 DIRECT EMPLOYMENT IMPACT ASSESSMENT

The impact of amended energy conservation standards on employment is an important consideration in the rulemaking process. This section of the interview guide seeks to explore current trends in PTAC and PTHP equipment employment and solicit manufacturer views on how domestic employment patterns might be affected by amended energy conservation standards.

1) Where are your production facilities located, and what type of product is manufactured at each location? Please provide production figures for your company's manufacturing at each location by product class.

Table 12A.12.1. Manufacturing locations

Location	Product Class	Employees (Production)	Employees (Non-production)	Units/Year Produced

2) Would you expect domestic employment levels to change significantly under amended energy conservation standards?

3) If so, please identify particular standard levels that may trigger changes in employment.

4) Are higher efficiency products built at different plants than lower efficiency products of the same equipment class?

12A.13 CAPACITY/EXPORTS / FOREIGN COMPETITION / OUTSOURCING

Disparity between domestic and foreign energy conservation standards could impact exports or imports. Labor content and material changes resulting from amended energy conservation standards may impact sourcing decisions.

1) How would amended energy conservation standards impact your company's manufacturing capacity, in both the short term and the long term?

2) Absent amended energy conservation standards, are production facilities being relocated to foreign countries?

3) Would amended energy conservation standards impact your domestic vs. foreign manufacturing decision?

4) What percentage of the U.S. market for PTAC and PTHP equipment is imported? Would amended energy conservation standards have an impact on foreign competition?

12A.14 CONSOLIDATION

Amended energy conservation standards can alter the competitive dynamics of the market. This can include prompting companies to enter or exit the market, or to merge. DOE and the Department of Justice are both interested in any potential reduction in competition that would result from an amended energy conservation standard.

1) Please comment on industry consolidation and related trends over the last 10 years.

2) How would industry competition change as a result of amended conservation standards? Due to amended energy conservation standards, do you expect accelerated industry consolidation? Please describe your expectations.

3) How would amended energy conservation standards affect your ability to compete in the marketplace? Would you expect your market share to change?

4) To your knowledge, are there any niche manufacturers for which the adoption of amended energy conservation standards would have a particularly severe impact?

5) To your knowledge, are there any component manufacturers for which the adoption of amended energy conservation standards would have a particularly severe impact?

12A.15 IMPACTS ON SMALL BUSINESS

1) The Small Business Association (SBA) denotes a small business in the PTAC and PTHP industry as having less than 750 employees.[8] By this definition, is your company considered a small business?

2) Below is a list of small business PTAC and PTHP manufacturers compiled by DOE. Are there any small manufacturers that should be added to (or removed from) this list? Are there specific manufacturers on this list that may be more severely impacted by an amended energy conservation standard than others?

   - Air-Con International
   - Cold Point Corporation
   - Comitale National, Inc.
   - EAIR, LLC
   - ECR International
   - Heat Controller, Inc.
   - Ice Air LLC
   - International Refrigeration Products
   - Island Aire, Inc.
   - Prem Sales, LLC
   - Simon-Aire, Inc.
   - YMGI Group, LLC

3) Are there any reasons that a small business might be at a disadvantage relative to a larger business under amended energy conservation standards? Please consider such factors as technical expertise, access to capital, bulk purchasing power for materials/components, engineering resources, and any other relevant issues.

4) To your knowledge, are there any small business manufacturers for which the adoption of amended energy conservation standards would have a particularly severe impact? If so, would small business manufacturers face different incremental impacts from amended energy conservation standards than the rest of the industry?

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[8] DOE uses the SBA small business size standards effective January 1, 2012 to determine whether a company is a small business. To be categorized as a small business, a PTAC/PTHP manufacturer and its affiliates may employ a maximum of 750 employees. The 750 employee threshold includes all employees in a business's parent company and any other subsidiaries.

APPENDIX 12B. GOVERNMENT REGULATORY IMPACT MODEL (GRIM) OVERVIEW

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12B.1 INTRODUCTION AND PURPOSE

The purpose of the Government Regulatory Impact Model (GRIM) is to help quantify the impacts of energy conservation standards and other regulations on manufacturers. The basic mode of analysis is to estimate the change in the value of the industry or manufacturers following a regulation or a series of regulations. The model structure also allows an analysis of multiple equipment types with regulations taking effect over a period of time, and of multiple regulations on the same equipment.

Industry net present value is defined, for the purpose of this analysis, as the discounted sum of industry free cash flows plus a discounted terminal value. The model calculates the actual cash flows by year and then determines the present value of those cash flows both without an energy conservation standard (*i.e.*, the base case) and under different trial standard levels (*i.e.*, the standards case).

Outputs from the model consist of summary financial metrics, graphs of major variables, and, when appropriate, access to the complete cash flow calculation.

12B.2 MODEL DESCRIPTION

The basic structure of the GRIM is a standard annual cash flow analysis that uses manufacturer selling prices, manufacturing costs, a shipments forecast, and financial parameters as inputs and accepts a set of regulatory conditions as changes in costs and investments. The cash flow analysis is separated into two major blocks: income and cash flow. The income calculation determines net operating profit after taxes. The cash flow calculation converts net operating profit after taxes into an annual cash flow by including investment and non-cash items. Below are definitions of listed items on the printout of the output sheet of the GRIM.

(1) ***Revenues:*** Annual revenues – computed by multiplying equipment unit prices at each efficiency level by the appropriate manufacturer markup.

(2) ***Total shipments:*** Total annual shipments for the industry were obtained from the National Impact Analysis Spreadsheet.

(3) ***Material:*** The portion of cost of goods sold (COGS) that includes materials.

(4) ***Labor:*** The portion of COGS that includes direct labor, commissions, dismissal pay, bonuses, vacation, sick leave, social security contributions, fringe, and assembly labor up-time.

(5) ***Depreciation:*** The portion of overhead that includes an allowance for the total amount of fixed assets used to produce that one unit. Annual depreciation is computed as a percentage of ***COGS.*** While included in overhead, the depreciation is shown as a separate line item.

(6) ***Overhead:*** The portion of COGS that includes indirect labor, indirect material, energy use, maintenance, depreciation, property taxes, and insurance related to assets. While included in overhead, the depreciation is shown as a separate line item.

(7) ***Standard SG&A:*** Selling, general, and administrative costs are computed as a percentage of ***Revenues (1)***.

(8) ***R&D:*** GRIM separately accounts for ordinary research and development (R&D) as a percentage of ***Revenues (1)***.

(9) ***Product Conversion Costs:*** Product conversion costs are one-time investments in research, development, testing, marketing, and other costs focused on making equipment designs comply with the new energy conservation standard. The GRIM allocates these costs over the period between the standard's announcement and compliance dates.

(10) ***Stranded Assets:*** In the year the standard becomes effective, a one-time write-off of stranded assets is accounted for.

(11) ***Earnings Before Interest and Taxes (EBIT):*** Includes profits before deductions for interest paid and taxes.

(12) ***EBIT as a Percentage of Sales (EBIT/Revenues):*** GRIM calculates EBIT as a percentage of sales to compare with the industry's average reported in financial statements.

(13) ***Taxes:*** Taxes on ***EBIT (11)*** are calculated by multiplying the tax rate contained in Major Assumptions by ***EBIT (11)***.

(14) ***Net Operating Profits After Taxes (NOPAT):*** Computed by subtracting ***Cost of Goods Sold ((3) to (6))***, ***SG&A (7)***, ***R&D (8)***, ***Product Conversion Costs (9)***, and ***Taxes (13)*** from ***Revenues (1)***.

(15) ***NOPAT repeated***: NOPAT is repeated in the Statement of Cash Flows.

(16) ***Depreciation repeated***: Depreciation and Stranded Assets are added back in the Statement of Cash Flows because they are non-cash expenses.

(17) ***Change in Working Capital***: Change in cash tied up in accounts receivable, inventory, and other cash investments necessary to support operations is calculated by multiplying working capital (as a percentage of revenues) by the change in annual revenues.

(18) ***Cash Flow from Operations***: Calculated by taking ***NOPAT (15)***, adding back non-cash items such as ***Depreciation (16)***, and subtracting the ***Change in Working Capital (17)***.

(19) ***Ordinary Capital Expenditures:*** Ordinary investments in property, plant, and equipment to maintain and replace existing production assets, computed as a percentage of ***Revenues (1)***.

(20) ***Capital Conversion Costs:*** Capital conversion costs are one-time investments in property, plant, and equipment to adapt or change existing production facilities so that new

equipment designs can be fabricated and assembled under the new regulation. The GRIM allocates these costs over the period between the standard's announcement and compliance dates.

(21) ***Capital Investment:*** Total investments in property, plant, and equipment are computed by adding ***Ordinary Capital Expenditures (19)*** and ***Capital Conversion Costs (20)***.

(22) ***Free Cash Flow:*** Annual cash flow from operations and investments; computed by subtracting ***Capital Investment (21)*** from ***Cash Flow from Operations (18)***.

(23) ***Terminal Value:*** Estimate of the continuing value of the industry after the analysis period. Computed by growing the Free Cash Flow at a constant rate in perpetuity.

(24) ***Present Value Factor:*** Factor used to calculate an estimate of the present value of an amount to be received in the future.

(25) ***Discounted Cash Flow: Free Cash Flows (22)*** multiplied by the ***Present Value Factor (24)***. For the end of 2048, the discounted cash flow includes the discounted ***Terminal Value (23)***.

(26) ***Industry Value thru the end of 2048[1]:*** The sum of ***Discounted Cash Flows (25)***.

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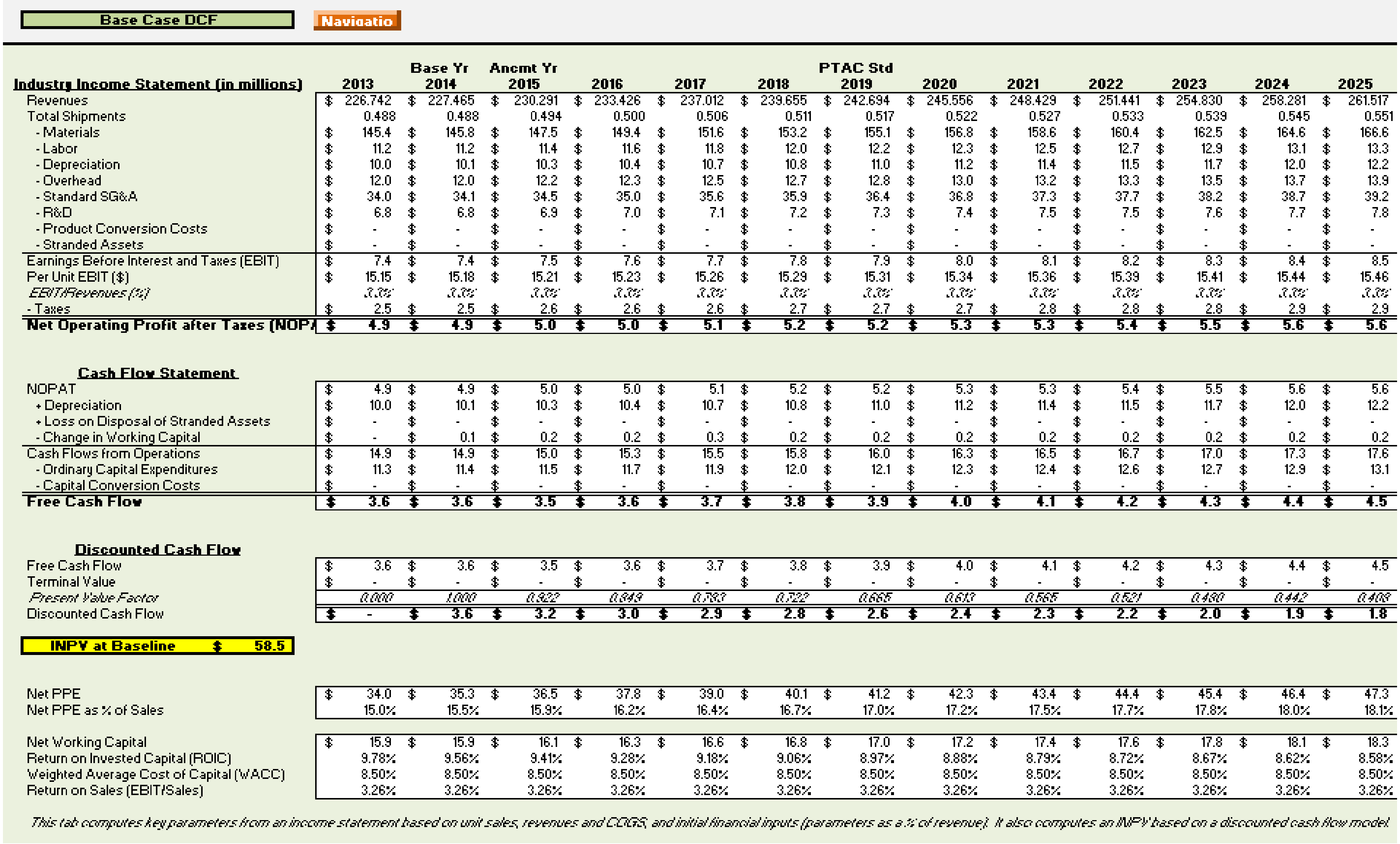
[1] For PTACs and PTHPs, the industry value calculated in the GRIM incorporates three different analysis periods. Since amended standards for PTACs were triggered by ASHRAE Standard 90.1-2013 while amended standards for PTHPs were triggered by EPCA, compliance dates and terminal years differ by case and equipment class.

Table 12B.2.1 Detailed Cash Flow Example



Base Case DCF

Navigatio

		Base Yr	Ancmt Yr				PTAC Std						
Industry Income Statement (in millions)	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
Revenues	$ 226.742	$ 227.465	$ 230.291	$ 233.426	$ 237.012	$ 239.655	$ 242.694	$ 245.556	$ 248.429	$ 251.441	$ 254.830	$ 258.281	$ 261.517
Total Shipments	0.488	0.488	0.494	0.500	0.506	0.511	0.517	0.522	0.527	0.533	0.539	0.545	0.551
- Materials	$ 145.4	$ 145.8	$ 147.5	$ 149.4	$ 151.6	$ 153.2	$ 155.1	$ 156.8	$ 158.6	$ 160.4	$ 162.5	$ 164.6	$ 166.6
- Labor	$ 11.2	$ 11.2	$ 11.4	$ 11.6	$ 11.8	$ 12.0	$ 12.2	$ 12.3	$ 12.5	$ 12.7	$ 12.9	$ 13.1	$ 13.3
- Depreciation	$ 10.0	$ 10.1	$ 10.3	$ 10.4	$ 10.7	$ 10.8	$ 11.0	$ 11.2	$ 11.4	$ 11.5	$ 11.7	$ 12.0	$ 12.2
- Overhead	$ 12.0	$ 12.0	$ 12.2	$ 12.3	$ 12.5	$ 12.7	$ 12.8	$ 13.0	$ 13.2	$ 13.3	$ 13.5	$ 13.7	$ 13.9
- Standard SG&A	$ 34.0	$ 34.1	$ 34.5	$ 35.0	$ 35.6	$ 35.9	$ 36.4	$ 36.8	$ 37.3	$ 37.7	$ 38.2	$ 38.7	$ 39.2
- R&D	$ 6.8	$ 6.8	$ 6.9	$ 7.0	$ 7.1	$ 7.2	$ 7.3	$ 7.4	$ 7.5	$ 7.5	$ 7.6	$ 7.7	$ 7.8
- Product Conversion Costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
- Stranded Assets	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Earnings Before Interest and Taxes (EBIT)	$ 7.4	$ 7.4	$ 7.5	$ 7.6	$ 7.7	$ 7.8	$ 7.9	$ 8.0	$ 8.1	$ 8.2	$ 8.3	$ 8.4	$ 8.5
Per Unit EBIT ($)	$ 15.15	$ 15.18	$ 15.21	$ 15.23	$ 15.26	$ 15.29	$ 15.31	$ 15.34	$ 15.36	$ 15.39	$ 15.41	$ 15.44	$ 15.46
EBIT/Revenues (%)	*3.3%*	*3.3%*	*3.3%*	*3.3%*	*3.3%*	*3.3%*	*3.3%*	*3.3%*	*3.3%*	*3.3%*	*3.3%*	*3.3%*	*3.3%*
- Taxes	$ 2.5	$ 2.5	$ 2.6	$ 2.6	$ 2.6	$ 2.7	$ 2.7	$ 2.7	$ 2.8	$ 2.8	$ 2.8	$ 2.9	$ 2.9
Net Operating Profit after Taxes (NOPA	**$ 4.9**	**$ 4.9**	**$ 5.0**	**$ 5.0**	**$ 5.1**	**$ 5.2**	**$ 5.2**	**$ 5.3**	**$ 5.3**	**$ 5.4**	**$ 5.5**	**$ 5.6**	**$ 5.6**
Cash Flow Statement													
NOPAT	$ 4.9	$ 4.9	$ 5.0	$ 5.0	$ 5.1	$ 5.2	$ 5.2	$ 5.3	$ 5.3	$ 5.4	$ 5.5	$ 5.6	$ 5.6
+ Depreciation	$ 10.0	$ 10.1	$ 10.3	$ 10.4	$ 10.7	$ 10.8	$ 11.0	$ 11.2	$ 11.4	$ 11.5	$ 11.7	$ 12.0	$ 12.2
+ Loss on Disposal of Stranded Assets	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
- Change in Working Capital	$ -	$ 0.1	$ 0.2	$ 0.2	$ 0.3	$ 0.2	$ 0.2	$ 0.2	$ 0.2	$ 0.2	$ 0.2	$ 0.2	$ 0.2
Cash Flows from Operations	$ 14.9	$ 14.9	$ 15.0	$ 15.3	$ 15.5	$ 15.8	$ 16.0	$ 16.3	$ 16.5	$ 16.7	$ 17.0	$ 17.3	$ 17.6
- Ordinary Capital Expenditures	$ 11.3	$ 11.4	$ 11.5	$ 11.7	$ 11.9	$ 12.0	$ 12.1	$ 12.3	$ 12.4	$ 12.6	$ 12.7	$ 12.9	$ 13.1
- Capital Conversion Costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Free Cash Flow	**$ 3.6**	**$ 3.6**	**$ 3.5**	**$ 3.6**	**$ 3.7**	**$ 3.8**	**$ 3.9**	**$ 4.0**	**$ 4.1**	**$ 4.2**	**$ 4.3**	**$ 4.4**	**$ 4.5**
Discounted Cash Flow													
Free Cash Flow	$ 3.6	$ 3.6	$ 3.5	$ 3.6	$ 3.7	$ 3.8	$ 3.9	$ 4.0	$ 4.1	$ 4.2	$ 4.3	$ 4.4	$ 4.5
Terminal Value	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Present Value Factor	*0.000*	*1.000*	*0.922*	*0.849*	*0.783*	*0.722*	*0.665*	*0.613*	*0.565*	*0.521*	*0.480*	*0.442*	*0.408*
Discounted Cash Flow	**$ -**	**$ 3.6**	**$ 3.2**	**$ 3.0**	**$ 2.9**	**$ 2.8**	**$ 2.6**	**$ 2.4**	**$ 2.3**	**$ 2.2**	**$ 2.0**	**$ 1.9**	**$ 1.8**
INPV at Baseline $ 58.5													
Net PPE	$ 34.0	$ 35.3	$ 36.5	$ 37.8	$ 39.0	$ 40.1	$ 41.2	$ 42.3	$ 43.4	$ 44.4	$ 45.4	$ 46.4	$ 47.3
Net PPE as % of Sales	15.0%	15.5%	15.9%	16.2%	16.4%	16.7%	17.0%	17.2%	17.5%	17.7%	17.8%	18.0%	18.1%
Net Working Capital	$ 15.9	$ 15.9	$ 16.1	$ 16.3	$ 16.6	$ 16.8	$ 17.0	$ 17.2	$ 17.4	$ 17.6	$ 17.8	$ 18.1	$ 18.3
Return on Invested Capital (ROIC)	9.78%	9.56%	9.41%	9.28%	9.18%	9.06%	8.97%	8.88%	8.79%	8.72%	8.67%	8.62%	8.58%
Weighted Average Cost of Capital (WACC)	8.50%	8.50%	8.50%	8.50%	8.50%	8.50%	8.50%	8.50%	8.50%	8.50%	8.50%	8.50%	8.50%
Return on Sales (EBIT/Sales)	3.26%	3.26%	3.26%	3.26%	3.26%	3.26%	3.26%	3.26%	3.26%	3.26%	3.26%	3.26%	3.26%

This tab computes key parameters from an income statement based on unit sales, revenues and COGS, and initial financial inputs (parameters as a % of revenue). It also computes an INPV based on a discounted cash flow model.

APPENDIX 14A. SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12866

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APPENDIX 14A. SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12866[a]

14A.1 EXECUTIVE SUMMARY

Under Executive Order 12866, agencies are required, to the extent permitted by law, “to assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs.” The purpose of the “social cost of carbon” (SCC) estimates presented here is to allow agencies to incorporate the social benefits of reducing carbon dioxide (CO_2) emissions into cost-benefit analyses of regulatory actions that have small, or “marginal,” impacts on cumulative global emissions. The estimates are presented with an acknowledgement of the many uncertainties involved and with a clear understanding that they should be updated over time to reflect increasing knowledge of the science and economics of climate impacts.

The SCC is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. It is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services due to climate change.

This document presents a summary of the interagency process that developed these SCC estimates. Technical experts from numerous agencies met on a regular basis to consider public comments, explore the technical literature in relevant fields, and discuss key model inputs and assumptions. The main objective of this process was to develop a range of SCC values using a defensible set of input assumptions grounded in the existing scientific and economic literatures. In this way, key uncertainties and model differences transparently and consistently inform the range of SCC estimates used in the rulemaking process.

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[a] Prepared by Interagency Working Group on Social Cost of Carbon, United States Government.
With participation by:
Council of Economic Advisers
Council on Environmental Quality
Department of Agriculture
Department of Commerce
Department of Energy
Department of Transportation
Environmental Protection Agency
National Economic Council
Office of Energy and Climate Change
Office of Management and Budget
Office of Science and Technology Policy
Department of the Treasury

The interagency group selected four SCC values for use in regulatory analyses. Three values are based on the average SCC from three integrated assessment models, at discount rates of 2.5, 3, and 5 percent. The fourth value, which represents the 95th percentile SCC estimate across all three models at a 3 percent discount rate, is included to represent higher-than-expected impacts from temperature change further out in the tails of the SCC distribution.

Table 14A.1.1 Social Cost of CO_2, 2010 – 2050 (in 2007 dollars)

	Discount Rate			
	5%	3%	2.5%	3%
Year	Avg	Avg	Avg	95th
2010	4.7	21.4	35.1	64.9
2015	5.7	23.8	38.4	72.8
2020	6.8	26.3	41.7	80.7
2025	8.2	29.6	45.9	90.4
2030	9.7	32.8	50.0	100.0
2035	11.2	36.0	54.2	109.7
2040	12.7	39.2	58.4	119.3
2045	14.2	42.1	61.7	127.8
2050	15.7	44.9	65.0	136.2

14A.2 MONETIZING CARBON DIOXIDE EMISSIONS

The SCC is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. We report estimates of the SCC in dollars per metric ton of carbon dioxide throughout this document.[b]

When attempting to assess the incremental economic impacts of carbon dioxide emissions, the analyst faces a number of serious challenges. A recent report from the National Academies of Science (NRC 2009) points out that any assessment will suffer from uncertainty, speculation, and lack of information about (1) future emissions of greenhouse gases, (2) the effects of past and future emissions on the climate system, (3) the impact of changes in climate on the physical and biological environment, and (4) the translation of these environmental impacts into economic damages. As a result, any effort to quantify and monetize the harms associated with climate change will raise serious questions of science, economics, and ethics and should be viewed as provisional.

Despite the serious limits of both quantification and monetization, SCC estimates can be useful in estimating the social benefits of reducing carbon dioxide emissions. Under Executive

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[b] In this document, we present all values of the SCC as the cost per metric ton of CO_2 emissions. Alternatively, one could report the SCC as the cost per metric ton of carbon emissions. The multiplier for translating between mass of CO_2 and the mass of carbon is 3.67 (the molecular weight of CO_2 divided by the molecular weight of carbon = 44/12 = 3.67).

Order 12866, agencies are required, to the extent permitted by law, "to assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs." The purpose of the SCC estimates presented here is to make it possible for agencies to incorporate the social benefits from reducing carbon dioxide emissions into cost-benefit analyses of regulatory actions that have small, or "marginal," impacts on cumulative global emissions. Most federal regulatory actions can be expected to have marginal impacts on global emissions.

For such policies, the benefits from reduced (or costs from increased) emissions in any future year can be estimated by multiplying the change in emissions in that year by the SCC value appropriate for that year. The net present value of the benefits can then be calculated by multiplying each of these future benefits by an appropriate discount factor and summing across all affected years. This approach assumes that the marginal damages from increased emissions are constant for small departures from the baseline emissions path, an approximation that is reasonable for policies that have effects on emissions that are small relative to cumulative global carbon dioxide emissions. For policies that have a large (non-marginal) impact on global cumulative emissions, there is a separate question of whether the SCC is an appropriate tool for calculating the benefits of reduced emissions; we do not attempt to answer that question here.

An interagency group convened on a regular basis to consider public comments, explore the technical literature in relevant fields, and discuss key inputs and assumptions in order to generate SCC estimates. Agencies that actively participated in the interagency process include the Environmental Protection Agency, and the Departments of Agriculture, Commerce, Energy, Transportation, and Treasury. This process was convened by the Council of Economic Advisers and the Office of Management and Budget, with active participation and regular input from the Council on Environmental Quality, National Economic Council, Office of Energy and Climate Change, and Office of Science and Technology Policy. The main objective of this process was to develop a range of SCC values using a defensible set of input assumptions that are grounded in the existing literature. In this way, key uncertainties and model differences can more transparently and consistently inform the range of SCC estimates used in the rulemaking process.

The interagency group selected four SCC estimates for use in regulatory analyses. For 2010, these estimates are $5, $21, $35, and $65 (in 2007 dollars). The first three estimates are based on the average SCC across models and socioeconomic and emissions scenarios at the 5, 3, and 2.5 percent discount rates, respectively. The fourth value is included to represent the higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. For this purpose, we use the SCC value for the 95th percentile at a 3 percent discount rate. The central value is the average SCC across models at the 3 percent discount rate. For purposes of capturing the uncertainties involved in regulatory impact analysis, we emphasize the importance and value of considering the full range. These SCC estimates also grow over time. For instance, the central value increases to $24 per ton of CO_2 in 2015 and $26 per ton of CO_2 in 2020. See section 14-A.9 for the full range of annual SCC estimates from 2010 to 2050.

It is important to emphasize that the interagency process is committed to updating these estimates as the science and economic understanding of climate change and its impacts on society improves over time. Specifically, we have set a preliminary goal of revisiting the SCC values within two years or at such time as substantially updated models become available, and to continue to support research in this area. In the meantime, we will continue to explore the issues raised in this document and consider public comments as part of the ongoing interagency process.

14A.3 SOCIAL COST OF CARBON VALUES USED IN PAST REGULATORY ANALYSES

To date, economic analyses for Federal regulations have used a wide range of values to estimate the benefits associated with reducing carbon dioxide emissions. In the final model year 2011 CAFE rule, the Department of Transportation (DOT) used both a "domestic" SCC value of \$2 per ton of CO_2 and a "global" SCC value of \$33 per ton of CO_2 for 2007 emission reductions (in 2007 dollars), increasing both values at 2.4 percent per year. It also included a sensitivity analysis at \$80 per ton of CO_2. A domestic SCC value is meant to reflect the value of damages in the United States resulting from a unit change in carbon dioxide emissions, while a global SCC value is meant to reflect the value of damages worldwide.

A 2008 regulation proposed by DOT assumed a domestic SCC value of \$7 per ton CO_2 (in 2006 dollars) for 2011 emission reductions (with a range of \$0-\$14 for sensitivity analysis), also increasing at 2.4 percent per year. A regulation finalized by DOE in October of 2008 used a domestic SCC range of \$0 to \$20 per ton CO_2 for 2007 emission reductions (in 2007 dollars). In addition, EPA's 2008 Advance Notice of Proposed Rulemaking for Greenhouse Gases identified what it described as "very preliminary" SCC estimates subject to revision. EPA's global mean values were \$68 and \$40 per ton CO_2 for discount rates of approximately 2 percent and 3 percent, respectively (in 2006 dollars for 2007 emissions).

In 2009, an interagency process was initiated to offer a preliminary assessment of how best to quantify the benefits from reducing carbon dioxide emissions. To ensure consistency in how benefits are evaluated across agencies, the Administration sought to develop a transparent and defensible method, specifically designed for the rulemaking process, to quantify avoided climate change damages from reduced CO_2 emissions. The interagency group did not undertake any original analysis. Instead, it combined SCC estimates from the existing literature to use as interim values until a more comprehensive analysis could be conducted.

The outcome of the preliminary assessment by the interagency group was a set of five interim values: global SCC estimates for 2007 (in 2006 dollars) of \$55, \$33, \$19, \$10, and \$5 per ton of $CO_{2.}$ The \$33 and \$5 values represented model-weighted means of the published estimates produced from the most recently available versions of three integrated assessment models—DICE, PAGE, and FUND—at approximately 3 and 5 percent discount rates. The \$55 and \$10 values were derived by adjusting the published estimates for uncertainty in the discount rate (using factors developed by Newell and Pizer (2003)) at 3 and 5 percent discount rates, respectively. The \$19 value was chosen as a central value between the \$5 and \$33 per ton estimates. All of these values were assumed to increase at 3 percent annually to represent growth in incremental damages over time as the magnitude of climate change increases.

These interim values represent the first sustained interagency effort within the U.S. government to develop an SCC for use in regulatory analysis. The results of this preliminary effort were presented in several proposed and final rules and were offered for public comment in connection with proposed rules, including the joint EPA-DOT fuel economy and CO_2 tailpipe emission proposed rules.

14A.4 APPROACH AND KEY ASSUMPTIONS

Since the release of the interim values, the interagency group has reconvened on a regular basis to generate improved SCC estimates. Specifically, the group has considered public comments and further explored the technical literature in relevant fields. This section details the several choices and assumptions that underlie the resulting estimates of the SCC.

It is important to recognize that a number of key uncertainties remain, and that current SCC estimates should be treated as provisional and revisable, since they will evolve with improved scientific and economic understanding. The interagency group also recognizes that the existing models are imperfect and incomplete. The National Academy of Science (2009) points out that there is tension between the goal of producing quantified estimates of the economic damages from an incremental ton of carbon and the limits of existing efforts to model these effects. Throughout this document, we highlight a number of concerns and problems that should be addressed by the research community, including research programs housed in many of the agencies participating in the interagency process to estimate the SCC.

The U.S. Government will periodically review and reconsider estimates of the SCC used for cost-benefit analyses to reflect increasing knowledge of the science and economics of climate impacts, as well as improvements in modeling. In this context, statements recognizing the limitations of the analysis and calling for further research take on exceptional significance. The interagency group offers the new SCC values with all due humility about the uncertainties embedded in them and with a sincere promise to continue work to improve them.

14A.4.1 Integrated Assessment Models

We rely on three integrated assessment models (IAMs) commonly used to estimate the SCC: the FUND, DICE, and PAGE models.[c] These models are frequently cited in the peer-reviewed literature and used in the IPCC assessment. Each model is given equal weight in the SCC values developed through this process, bearing in mind their different limitations (discussed below).

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[c] The DICE (Dynamic Integrated Climate and Economy) model by William Nordhaus evolved from a series of energy models and was first presented in 1990 (Nordhaus and Boyer 2000, Nordhaus 2008). The PAGE (Policy Analysis of the Greenhouse Effect) model was developed by Chris Hope in 1991 for use by European decision-makers in assessing the marginal impact of carbon emissions (Hope 2006, Hope 2008). The FUND (Climate Framework for Uncertainty, Negotiation, and Distribution) model, developed by Richard Tol in the early 1990s, originally to study international capital transfers in climate policy. is now widely used to study climate impacts (*e.g.*, Tol 2002a, Tol 2002b, Anthoff et al. 2009, Tol 2009).

These models are useful because they combine climate processes, economic growth, and feedbacks between the climate and the global economy into a single modeling framework. At the same time, they gain this advantage at the expense of a more detailed representation of the underlying climatic and economic systems. DICE, PAGE, and FUND all take stylized, reduced-form approaches (see NRC 2009 for a more detailed discussion; see Nordhaus 2008 on the possible advantages of this approach). Other IAMs may better reflect the complexity of the science in their modeling frameworks but do not link physical impacts to economic damages. There is currently a limited amount of research linking climate impacts to economic damages, which makes this exercise even more difficult. Underlying the three IAMs selected for this exercise are a number of simplifying assumptions and judgments reflecting the various modelers' best attempts to synthesize the available scientific and economic research characterizing these relationships.

The three IAMs translate emissions into changes in atmospheric greenhouse concentrations, atmospheric concentrations into changes in temperature, and changes in temperature into economic damages. The emissions projections used in the models are based on specified socioeconomic (GDP and population) pathways. These emissions are translated into concentrations using the carbon cycle built into each model, and concentrations are translated into warming based on each model's simplified representation of the climate and a key parameter, climate sensitivity. Each model uses a different approach to translate warming into damages. Finally, transforming the stream of economic damages over time into a single value requires judgments about how to discount them.

Each model takes a slightly different approach to model how changes in emissions result in changes in economic damages. In PAGE, for example, the consumption-equivalent damages in each period are calculated as a fraction of GDP, depending on the temperature in that period relative to the pre-industrial average temperature in each region. In FUND, damages in each period also depend on the rate of temperature change from the prior period. In DICE, temperature affects both consumption and investment. We describe each model in greater detail here. In a later section, we discuss key gaps in how the models account for various scientific and economic processes (*e.g.* the probability of catastrophe, and the ability to adapt to climate change and the physical changes it causes).

The parameters and assumptions embedded in the three models vary widely. A key objective of the interagency process was to enable a consistent exploration of the three models while respecting the different approaches to quantifying damages taken by the key modelers in the field. An extensive review of the literature was conducted to select three sets of input parameters for these models: climate sensitivity, socioeconomic and emissions trajectories, and discount rates. A probability distribution for climate sensitivity was specified as an input into all three models. In addition, the interagency group used a range of scenarios for the socioeconomic parameters and a range of values for the discount rate. All other model features were left unchanged, relying on the model developers' best estimates and judgments. In DICE, these parameters are handled deterministically and represented by fixed constants; in PAGE, most parameters are represented by probability distributions. FUND was also run in a mode in which parameters were treated probabilistically.

The sensitivity of the results to other aspects of the models (*e.g.* the carbon cycle or damage function) is also important to explore in the context of future revisions to the SCC but has not been incorporated into these estimates. Areas for future research are highlighted at the end of this document.

The DICE Model

The DICE model is an optimal growth model based on a global production function with an extra stock variable (atmospheric carbon dioxide concentrations). Emission reductions are treated as analogous to investment in "natural capital." By investing in natural capital today through reductions in emissions—implying reduced consumption—harmful effects of climate change can be avoided and future consumption thereby increased.

For purposes of estimating the SCC, carbon dioxide emissions are a function of global GDP and the carbon intensity of economic output, with the latter declining over time due to technological progress. The DICE damage function links global average temperature to the overall impact on the world economy. It varies quadratically with temperature change to capture the more rapid increase in damages expected to occur under more extreme climate change, and is calibrated to include the effects of warming on the production of market and nonmarket goods and services. It incorporates impacts on agriculture, coastal areas (due to sea level rise), "other vulnerable market sectors" (based primarily on changes in energy use), human health (based on climate-related diseases, such as malaria and dengue fever, and pollution), non-market amenities (based on outdoor recreation), and human settlements and ecosystems. The DICE damage function also includes the expected value of damages associated with low probability, high impact "catastrophic" climate change. This last component is calibrated based on a survey of experts (Nordhaus 1994). The expected value of these impacts is then added to the other market and non-market impacts mentioned above.

No structural components of the DICE model represent adaptation explicitly, though it is included implicitly through the choice of studies used to calibrate the aggregate damage function. For example, its agricultural impact estimates assume that farmers can adjust land use decisions in response to changing climate conditions, and its health impact estimates assume improvements in healthcare over time. In addition, the small impacts on forestry, water systems, construction, fisheries, and outdoor recreation imply optimistic and costless adaptation in these sectors (Nordhaus and Boyer, 2000; Warren et al., 2006). Costs of resettlement due to sea level rise are incorporated into damage estimates, but their magnitude is not clearly reported. Mastrandrea's (2009) review concludes that "in general, DICE assumes very effective adaptation, and largely ignores adaptation costs."

Note that the damage function in DICE has a somewhat different meaning from the damage functions in FUND and PAGE. Because GDP is endogenous in DICE and because damages in a given year reduce investment in that year, damages propagate forward in time and reduce GDP in future years. In contrast, GDP is exogenous in FUND and PAGE, so damages in any given year do not propagate forward.[d]

The PAGE Model

PAGE2002 (version 1.4epm) treats GDP growth as exogenous. It divides impacts into economic, non-economic, and catastrophic categories and calculates these impacts separately for eight geographic regions. Damages in each region are expressed as a fraction of output, where the fraction lost depends on the temperature change in each region. Damages are expressed as power functions of temperature change. The exponents of the damage function are the same in all regions but are treated as uncertain, with values ranging from 1 to 3 (instead of being fixed at 2 as in DICE).

PAGE2002 includes the consequences of catastrophic events in a separate damage sub-function. Unlike DICE, PAGE2002 models these events probabilistically. The probability of a "discontinuity" (*i.e.*, a catastrophic event) is assumed to increase with temperature above a specified threshold. The threshold temperature, the rate at which the probability of experiencing a discontinuity increases above the threshold, and the magnitude of the resulting catastrophe are all modeled probabilistically.

Adaptation is explicitly included in PAGE. Impacts are assumed to occur for temperature increases above some tolerable level (2°C for developed countries and 0°C for developing countries for economic impacts, and 0°C for all regions for non-economic impacts), but adaptation is assumed to reduce these impacts. Default values in PAGE2002 assume that the developed countries can ultimately eliminate up to 90 percent of all economic impacts beyond the tolerable 2°C increase and that developing countries can eventually eliminate 50 percent of their economic impacts. All regions are assumed to be able to mitigate 25 percent of the non-economic impacts through adaptation (Hope 2006).

The FUND Model

Like PAGE, the FUND model treats GDP growth as exogenous. It includes separately calibrated damage functions for eight market and nonmarket sectors: agriculture, forestry, water, energy (based on heating and cooling demand), sea level rise (based on the value of land lost and the cost of protection), ecosystems, human health (diarrhea, vector-borne diseases, and cardiovascular and respiratory mortality), and extreme weather. Each impact sector has a different functional form, and is calculated separately for sixteen geographic regions. In some impact sectors, the fraction of output lost or gained due to climate change depends not only on

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[d] Using the default assumptions in DICE 2007, this effect generates an approximately 25 percent increase in the SCC relative to damages calculated by fixing GDP. In DICE2007, the time path of GDP is endogenous. Specifically, the path of GDP depends on the rate of saving and level of abatement in each period chosen by the optimizing representative agent in the model. We made two modifications to DICE to make it consistent with EMF GDP trajectories (see next section): we assumed a fixed rate of savings of 20%, and we re-calibrated the exogenous path of total factor productivity so that DICE would produce GDP projections in the absence of warming that exactly matched the EMF scenarios.

the absolute temperature change but also on the rate of temperature change and level of regional income.[e] In the forestry and agricultural sectors, economic damages also depend on CO_2 concentrations.

Tol (2009) discusses impacts not included in FUND, noting that many are likely to have a relatively small effect on damage estimates (both positive and negative). However, he characterizes several omitted impacts as "big unknowns": for instance, extreme climate scenarios, biodiversity loss, and effects on economic development and political violence. With regard to potentially catastrophic events, he notes, "Exactly what would cause these sorts of changes or what effects they would have are not well-understood, although the chance of any one of them happening seems low. But they do have the potential to happen relatively quickly, and if they did, the costs could be substantial. Only a few studies of climate change have examined these issues."

Adaptation is included both implicitly and explicitly in FUND. Explicit adaptation is seen in the agriculture and sea level rise sectors. Implicit adaptation is included in sectors such as energy and human health, where wealthier populations are assumed to be less vulnerable to climate impacts. For example, the damages to agriculture are the sum of three effects: (1) those due to the rate of temperature change (damages are always positive); (2) those due to the level of temperature change (damages can be positive or negative depending on region and temperature); and (3) those from CO_2 fertilization (damages are generally negative but diminishing to zero).

Adaptation is incorporated into FUND by allowing damages to be smaller if climate change happens more slowly. The combined effect of CO_2 fertilization in the agricultural sector, positive impacts to some regions from higher temperatures, and sufficiently slow increases in temperature across these sectors can result in negative economic damages from climate change.

Damage Functions

To generate revised SCC values, we rely on the IAM modelers' current best judgments of how to represent the effects of climate change (represented by the increase in global-average surface temperature) on the consumption-equivalent value of both market and non-market goods (represented as a fraction of global GDP). We recognize that these representations are incomplete and highly uncertain. But given the paucity of data linking the physical impacts to economic damages, we were not able to identify a better way to translate changes in climate into net economic damages, short of launching our own research program.

The damage functions for the three IAMs are presented in Figure 14A.4.1 and Figure 14A.4.2, using the modeler's default scenarios and mean input assumptions. There are significant differences between the three models both at lower (Figure 14A.4.2) and higher (Figure 14A.4.1) increases in global-average temperature.

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[e] In the deterministic version of FUND, the majority of damages are attributable to increased air conditioning demand, while reduced cold stress in Europe, North America, and Central and East Asia results in health benefits in those regions at low to moderate levels of warming (Warren et al., 2006).

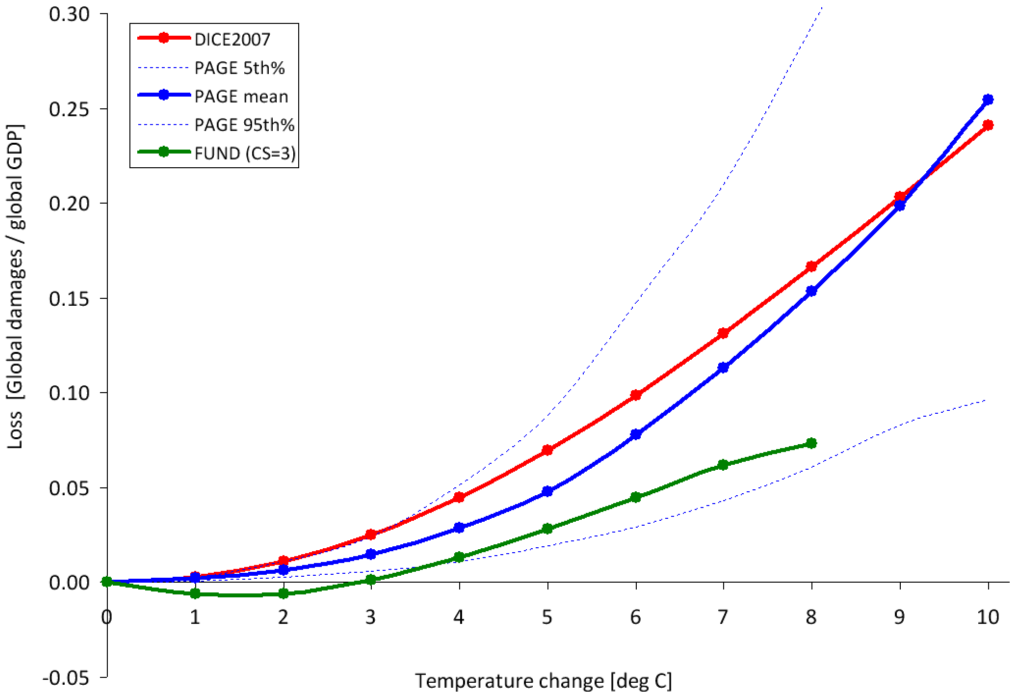

Figure 14A.4.1 Annual Consumption Loss as a Fraction of Global GDP in 2100 Due to an Increase in Annual Global Temperature in the DICE, FUND, and PAGE models[f]

The lack of agreement among the models at lower temperature increases is underscored by the fact that the damages from FUND are well below the 5th percentile estimated by PAGE, while the damages estimated by DICE are roughly equal to the 95th percentile estimated by PAGE. This is significant because at higher discount rates we expect that a greater proportion of the SCC value is due to damages in years with lower temperature increases. For example, when the discount rate is 2.5 percent, about 45 percent of the 2010 SCC value in DICE is due to damages that occur in years when the temperature is less than or equal to 3 °C. This increases to approximately 55 percent and 80 percent at discount rates of 3 and 5 percent, respectively.

These differences underscore the need for a thorough review of damage functions—in particular, how the models incorporate adaptation, technological change, and catastrophic damages. Gaps in the literature make modifying these aspects of the models challenging, which highlights the need for additional research. As knowledge improves, the Federal government is committed to exploring how these (and other) models can be modified to incorporate more accurate estimates of damages.

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[f] The x-axis represents increases in annual, rather than equilibrium, temperature, while the y-axis represents the annual stream of benefits as a share of global GDP. Each specific combination of climate sensitivity, socioeconomic, and emissions parameters will produce a different realization of damages for each IAM. The damage functions represented in Figures 1A and 1B are the outcome of default assumptions. For instance, under alternate assumptions, the damages from FUND may cross from negative to positive at less than or greater than 3 °C.

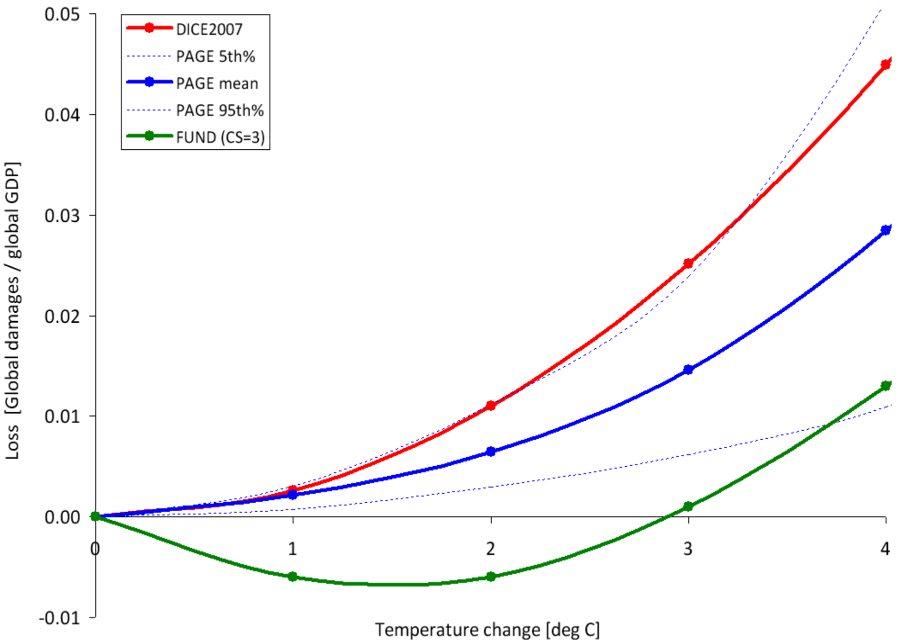

Figure 14A.4.2 Annual Consumption Loss for Lower Temperature Changes in DICE, FUND, and PAGE

14A.4.2 Global versus Domestic Measures of SCC

Because of the distinctive nature of the climate change problem, we center our current attention on a global measure of SCC. This approach is the same as that taken for the interim values, but it otherwise represents a departure from past practices, which tended to put greater emphasis on a domestic measure of SCC (limited to impacts of climate change experienced within U.S. borders). As a matter of law, consideration of both global and domestic values is generally permissible; the relevant statutory provisions are usually ambiguous and allow selection of either measure.[g]

Global SCC

Under current OMB guidance contained in Circular A-4, analysis of economically significant proposed and final regulations from the domestic perspective is required, while analysis from the international perspective is optional. However, the climate change problem is highly unusual in at least two respects. First, it involves a global externality: emissions of most greenhouse gases contribute to damages around the world even when they are emitted in the United States. Consequently, to address the global nature of the problem, the SCC must incorporate the full (global) damages caused by GHG emissions. Second, climate change

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[g] It is true that federal statutes are presumed not to have extraterritorial effect, in part to ensure that the laws of the United States respect the interests of foreign sovereigns. But use of a global measure for the SCC does not give extraterritorial effect to federal law and hence does not intrude on such interests.

presents a problem that the United States alone cannot solve. Even if the United States were to reduce its greenhouse gas emissions to zero, that step would be far from enough to avoid substantial climate change. Other countries would also need to take action to reduce emissions if significant changes in the global climate are to be avoided. Emphasizing the need for a global solution to a global problem, the United States has been actively involved in seeking international agreements to reduce emissions and in encouraging other nations, including emerging major economies, to take significant steps to reduce emissions. When these considerations are taken as a whole, the interagency group concluded that a global measure of the benefits from reducing U.S. emissions is preferable.

When quantifying the damages associated with a change in emissions, a number of analysts (*e.g.*, Anthoff, et al. 2009a) employ "equity weighting" to aggregate changes in consumption across regions. This weighting takes into account the relative reductions in wealth in different regions of the world. A per-capita loss of $500 in GDP, for instance, is weighted more heavily in a country with a per-capita GDP of $2,000 than in one with a per-capita GDP of $40,000. The main argument for this approach is that a loss of $500 in a poor country causes a greater reduction in utility or welfare than does the same loss in a wealthy nation. Notwithstanding the theoretical claims on behalf of equity weighting, the interagency group concluded that this approach would not be appropriate for estimating a SCC value used in domestic regulatory analysis.[h] For this reason, the group concluded that using the global (rather than domestic) value, without equity weighting, is the appropriate approach.

Domestic SCC

As an empirical matter, the development of a domestic SCC is greatly complicated by the relatively few region- or country-specific estimates of the SCC in the literature. One potential source of estimates comes from the FUND model. The resulting estimates suggest that the ratio of domestic to global benefits of emission reductions varies with key parameter assumptions. For example, with a 2.5 or 3 percent discount rate, the U.S. benefit is about 7-10 percent of the global benefit, on average, across the scenarios analyzed. Alternatively, if the fraction of GDP lost due to climate change is assumed to be similar across countries, the domestic benefit would be proportional to the U.S. share of global GDP, which is currently about 23 percent.[i]

On the basis of this evidence, the interagency workgroup determined that a range of values from 7 to 23 percent should be used to adjust the global SCC to calculate domestic effects. Reported domestic values should use this range. It is recognized that these values are approximate, provisional, and highly speculative. There is no a priori reason why domestic benefits should be a constant fraction of net global damages over time. Further, FUND does not

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[h] It is plausible that a loss of $X inflicts more serious harm on a poor nation than on a wealthy one, but development of the appropriate "equity weight" is challenging. Emissions reductions also impose costs, and hence a full account would have to consider that a given cost of emissions reductions imposes a greater utility or welfare loss on a poor nation than on a wealthy one. Even if equity weighting—for both the costs and benefits of emissions reductions—is appropriate when considering the utility or welfare effects of international action, the interagency group concluded that it should not be used in developing an SCC for use in regulatory policy at this time.

[i] Based on 2008 GDP (in current US dollars) from the *World Bank Development Indicators Report*.

account for how damages in other regions could affect the United States (*e.g.*, global migration, economic and political destabilization). If more accurate methods for calculating the domestic SCC become available, the Federal government will examine these to determine whether to update its approach.

14A.4.3 Valuing Non-CO_2 Emissions

While CO_2 is the most prevalent greenhouse gas emitted into the atmosphere, the U.S. included five other greenhouse gases in its recent endangerment finding: methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. The climate impact of these gases is commonly discussed in terms of their 100-year global warming potential (GWP). GWP measures the ability of different gases to trap heat in the atmosphere (*i.e.*, radiative forcing per unit of mass) over a particular timeframe relative to CO_2. However, because these gases differ in both radiative forcing and atmospheric lifetimes, their relative damages are not constant over time. For example, because methane has a short lifetime, its impacts occur primarily in the near term and thus are not discounted as heavily as those caused by longer-lived gases. Impacts other than temperature change also vary across gases in ways that are not captured by GWP. For instance, CO_2 emissions, unlike methane and other greenhouse gases, contribute to ocean acidification. Likewise, damages from methane emissions are not offset by the positive effect of CO_2 fertilization. Thus, transforming gases into CO_2-equivalents using GWP, and then multiplying the carbon-equivalents by the SCC, would not result in accurate estimates of the social costs of non-CO_2 gases.

In light of these limitations, and the significant contributions of non-CO_2 emissions to climate change, further research is required to link non-CO_2 emissions to economic impacts. Such work would feed into efforts to develop a monetized value of reductions in non-CO_2 greenhouse gas emissions. As part of ongoing work to further improve the SCC estimates, the interagency group hopes to develop methods to value these other greenhouse gases. The goal is to develop these estimates by the time we issue revised SCC estimates for carbon dioxide emissions.

14A.4.4 Equilibrium Climate Sensitivity

Equilibrium climate sensitivity (ECS) is a key input parameter for the DICE, PAGE, and FUND models.[j] It is defined as the long-term increase in the annual global-average surface temperature from a doubling of atmospheric CO_2 concentration relative to pre-industrial levels (or stabilization at a concentration of approximately 550 parts per million (ppm)). Uncertainties in this important parameter have received substantial attention in the peer-reviewed literature.

The most authoritative statement about equilibrium climate sensitivity appears in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC):

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[j] The equilibrium climate sensitivity includes the response of the climate system to increased greenhouse gas concentrations over the short to medium term (up to 100-200 years), but it does not include long-term feedback effects due to possible large-scale changes in ice sheets or the biosphere, which occur on a time scale of many hundreds to thousands of years (*e.g.* Hansen et al. 2007).

> *Basing our assessment on a combination of several independent lines of evidence…including observed climate change and the strength of known feedbacks simulated in [global climate models], we conclude that the global mean equilibrium warming for doubling CO_2, or 'equilibrium climate sensitivity', is likely to lie in the range 2 °C to 4.5 °C, with a most likely value of about 3 °C. Equilibrium climate sensitivity is very likely larger than 1.5 °C.* [k]
>
> *For fundamental physical reasons as well as data limitations, values substantially higher than 4.5 °C still cannot be excluded, but agreement with observations and proxy data is generally worse for those high values than for values in the 2 °C to 4.5 °C range.* (Meehl et al., 2007, p 799)

After consulting with several lead authors of this chapter of the IPCC report, the interagency workgroup selected four candidate probability distributions and calibrated them to be consistent with the above statement: Roe and Baker (2007), log-normal, gamma, and Weibull. Table 14A.4.1 included below gives summary statistics for the four calibrated distributions.

Table 14A.4.1 Summary Statistics for Four Calibrated Climate Sensitivity Distributions

	Roe & Baker	Log-normal	Gamma	Weibull
Pr(ECS < 1.5°C)	0.013	0.050	0.070	0.102
Pr(2°C < ECS < 4.5°C)	0.667	0.667	0.667	0.667
5th percentile	1.72	1.49	1.37	1.13
10th percentile	1.91	1.74	1.65	1.48
Mode	2.34	2.52	2.65	2.90
Median (50th percentile)	3.00	3.00	3.00	3.00
Mean	3.50	3.28	3.19	3.07
90th percentile	5.86	5.14	4.93	4.69
95th percentile	7.14	5.97	5.59	5.17

Each distribution was calibrated by applying three constraints from the IPCC:

(1) a median equal to 3°C, to reflect the judgment of "a most likely value of about 3 °C";[l]

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[k] This is in accord with the judgment that it "is likely to lie in the range 2 °C to 4.5 °C" and the IPCC definition of "likely" as greater than 66 percent probability (Le Treut et al.2007). "Very likely" indicates a greater than 90 percent probability.

[l] Strictly speaking, "most likely" refers to the mode of a distribution rather than the median, but common usage would allow the mode, median, or mean to serve as candidates for the central or "most likely" value and the IPCC report is not specific on this point. For the distributions we considered, the median was between the mode and the mean. For the Roe and Baker distribution, setting the median equal to 3°C, rather than the mode or mean, gave a 95th percentile that is more consistent with IPCC judgments and the literature. For example, setting the mean and mode equal to 3°C produced 95th percentiles of 5.6 and 8.6 °C, respectively, which are in the lower and upper end of the range in the literature. Finally, the median is closer to 3°C than is the mode for the truncated distributions selected by the IPCC (Hegerl, et al., 2006); the average median is 3.1 °C and the average mode is 2.3 °C, which is most consistent with a Roe and Baker distribution with the median set equal to 3 °C.

(2) two-thirds probability that the equilibrium climate sensitivity lies between 2 and 4.5 °C; and
(3) zero probability that it is less than 0°C or greater than 10°C (see Hegerl et al. 2006, p. 721).

We selected the calibrated Roe and Baker distribution from the four candidates for two reasons. First, the Roe and Baker distribution is the only one of the four that is based on a theoretical understanding of the response of the climate system to increased greenhouse gas concentrations (Roe and Baker 2007, Roe 2008). In contrast, the other three distributions are mathematical functions that are arbitrarily chosen based on simplicity, convenience, and general shape. The Roe and Baker distribution results from three assumptions about climate response: (1) absent feedback effects, the equilibrium climate sensitivity is equal to 1.2 °C; (2) feedback factors are proportional to the change in surface temperature; and (3) uncertainties in feedback factors are normally distributed. There is widespread agreement on the first point and the second and third points are common assumptions.

Second, the calibrated Roe and Baker distribution better reflects the IPCC judgment that "values substantially higher than 4.5°C still cannot be excluded." Although the IPCC made no quantitative judgment, the 95th percentile of the calibrated Roe & Baker distribution (7.1 °C) is much closer to the mean and the median (7.2 °C) of the 95th percentiles of 21 previous studies summarized by Newbold and Daigneault (2009). It is also closer to the mean (7.5 °C) and median (7.9 °C) of the nine truncated distributions examined by the IPCC (Hegerl, et al., 2006) than are the 95th percentiles of the three other calibrated distributions (5.2-6.0 °C).

Finally, we note the IPCC judgment that the equilibrium climate sensitivity "is very likely larger than 1.5°C." Although the calibrated Roe & Baker distribution, for which the probability of equilibrium climate sensitivity being greater than 1.5 °C is almost 99 percent, is not inconsistent with the IPCC definition of "very likely" as "greater than 90 percent probability," it reflects a greater degree of certainty about very low values of ECS than was expressed by the IPCC.

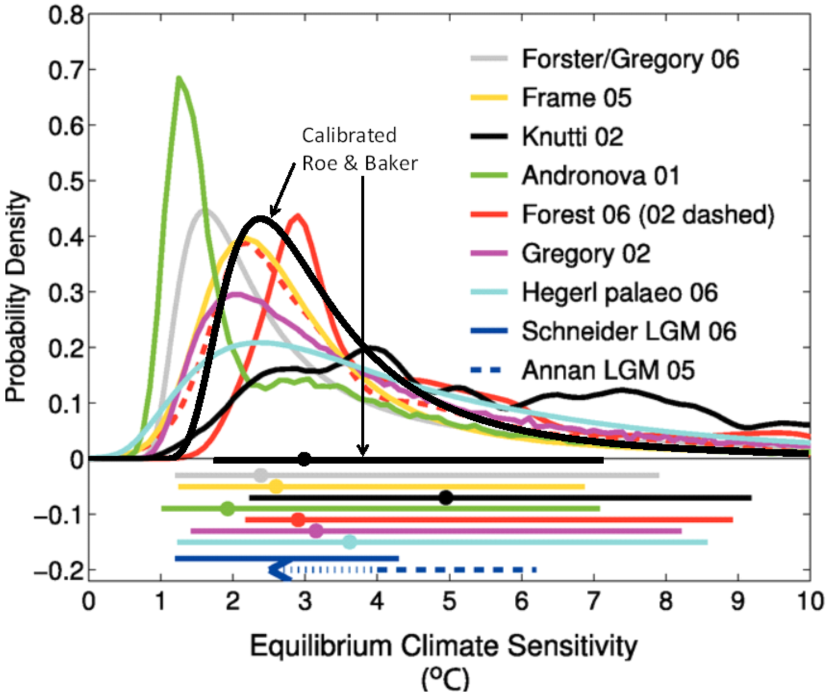

Figure 14A.4.3 Estimates of the Probability Density Function for Equilibrium Climate Sensitivity (°C)

To show how the calibrated Roe and Baker distribution compares to different estimates of the probability distribution function of equilibrium climate sensitivity in the empirical literature, Figure 14A.4.3 (above) overlays it on Figure 9.20 from the IPCC Fourth Assessment Report. These functions are scaled to integrate to unity between 0 °C and 10 °C. The horizontal bars show the respective 5 percent to 95 percent ranges; dots indicate the median estimate.[m]

14A.4.5 Socioeconomic and Emissions Trajectories

Another key issue considered by the interagency group is how to select the set of socioeconomic and emissions parameters for use in PAGE, DICE, and FUND. Socioeconomic pathways are closely tied to climate damages because, all else equal, more and wealthier people tend to emit more greenhouse gases and also have a higher (absolute) willingness to pay to avoid climate disruptions. For this reason, we consider how to model several input parameters in tandem: GDP, population, CO_2 emissions, and non-CO_2 radiative forcing. A wide variety of scenarios have been developed and used for climate change policy simulations (*e.g.*, SRES 2000, CCSP 2007, EMF 2009). In determining which scenarios are appropriate for inclusion, we aimed to select scenarios that span most of the plausible ranges of outcomes for these variables.

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[m] The estimates based on instrumental data are from Andronova and Schlesinger (2001), Forest et al. (2002; dashed line, anthropogenic forcings only), Forest et al. (2006; solid line, anthropogenic and natural forcings), Gregory et al. (2002a), Knutti et al. (2002), Frame et al. (2005), and Forster and Gregory (2006). Hegerl et al. (2006) are based on multiple palaeoclimatic reconstructions of north hemisphere mean temperatures over the last 700 years. Also shown are the 5-95 percent approximate ranges for two estimates from the last glacial maximum (dashed, Annan et al. 2005; solid, Schneider von Deimling et al. 2006), which are based on models with different structural properties.

To accomplish this task in a transparent way, we decided to rely on the recent Stanford Energy Modeling Forum exercise, EMF-22. EMF-22 uses ten well-recognized models to evaluate substantial, coordinated global action to meet specific stabilization targets. A key advantage of relying on these data is that GDP, population, and emission trajectories are internally consistent for each model and scenario evaluated. The EMF-22 modeling effort also is preferable to the IPCC SRES due to their age (SRES were developed in 1997) and the fact that 3 of 4 of the SRES scenarios are now extreme outliers in one or more variables. Although the EMF-22 scenarios have not undergone the same level of scrutiny as the SRES scenarios, they are recent, peer-reviewed, published, and publicly available.

To estimate the SCC for use in evaluating domestic policies that will have a small effect on global cumulative emissions, we use socioeconomic and emission trajectories that span a range of plausible scenarios. Five trajectories were selected from EMF-22 (see Table 14A.4.2 below). Four of these represent potential business-as-usual (BAU) growth in population, wealth, and emissions and are associated with CO_2 (only) concentrations ranging from 612 to 889 ppm in 2100. One represents an emissions pathway that achieves stabilization at 550 ppm CO_2e (i*i.e.*, CO_2-only concentrations of 425 – 484 ppm or a radiative forcing of 3.7 W/m^2) in 2100, a lower-than-BAU trajectory.[n] Out of the 10 models included in the EMF-22 exercise, we selected the trajectories used by MiniCAM, MESSAGE, IMAGE, and the optimistic scenario from MERGE. For the BAU pathways, we used the GDP, population, and emission trajectories from each of these four models. For the 550 ppm CO_2e scenario, we averaged the GDP, population, and emission trajectories implied by these same four models.

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[n] Such an emissions path would be consistent with widespread action by countries to mitigate GHG emissions, though it could also result from technological advances. It was chosen because it represents the most stringent case analyzed by the EMF-22 where all the models converge: a 550 ppm, not to exceed, full participation scenario.

Table 14A.4.2 Socioeconomic and Emissions Projections from Select EMF-22 Reference Scenarios

Reference Fossil and Industrial CO_2 Emissions ($GtCO_2$/yr)

EMF – 22 Based Scenarios	2000	2010	2020	2030	2050	2100
IMAGE	26.6	31.9	36.9	40.0	45.3	60.1
MERGE Optimistic	24.6	31.5	37.6	45.1	66.5	117.9
MESSAGE	26.8	29.2	37.6	42.1	43.5	42.7
MiniCAM	26.5	31.8	38.0	45.1	57.8	80.5
550 ppm average	26.2	31.1	33.2	32.4	20.0	12.8

Reference GDP (using market exchange rates in trillion 2005\$)[o]

EMF – 22 Based Scenarios	2000	2010	2020	2030	2050	2100
IMAGE	38.6	53.0	73.5	97.2	156.3	396.6
MERGE Optimistic	36.3	45.9	59.7	76.8	122.7	268.0
MESSAGE	38.1	52.3	69.4	91.4	153.7	334.9
MiniCAM	36.1	47.4	60.8	78.9	125.7	369.5
550 ppm average	37.1	49.6	65.6	85.5	137.4	337.9

Global Population (billions)

EMF – 22 Based Scenarios	2000	2010	2020	2030	2050	2100
IMAGE	6.1	6.9	7.6	8.2	9.0	9.1
MERGE Optimistic	6.0	6.8	7.5	8.2	9.0	9.7
MESSAGE	6.1	6.9	7.7	8.4	9.4	10.4
MiniCAM	6.0	6.8	7.5	8.1	8.8	8.7
550 ppm average	6.1	6.8	7.6	8.2	8.7	9.1

We explore how sensitive the SCC is to various assumptions about how the future will evolve without prejudging what is likely to occur. The interagency group considered formally assigning probability weights to different states of the world, but this proved challenging to do in an analytically rigorous way given the dearth of information on the likelihood of a full range of future socioeconomic pathways.

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[o] While the EMF-22 models used market exchange rates (MER) to calculate global GDP, it is also possible to use purchasing power parity (PPP). PPP takes into account the different price levels across countries, so it more accurately describes relative standards of living across countries. MERs tend to make low-income countries appear poorer than they actually are. Because many models assume convergence in per capita income over time, use of MER-adjusted GDP gives rise to projections of higher economic growth in low income countries. There is an ongoing debate about how much this will affect estimated climate impacts. Critics of the use of MER argue that it leads to overstated economic growth and hence a significant upward bias in projections of greenhouse gas emissions, and unrealistically high future temperatures (*e.g.*, Castles and Henderson 2003). Others argue that convergence of the emissions-intensity gap across countries at least partially offset the overstated income gap so that differences in exchange rates have less of an effect on emissions (Holtsmark and Alfsen, 2005; Tol, 2006). Nordhaus (2007b) argues that the ideal approach is to use superlative PPP accounts (i.e., using cross-sectional PPP measures for relative incomes and outputs and national accounts price and quantity indexes for time-series extrapolations). However, he notes that it important to keep this debate in perspective; it is by no means clear that exchange-rate-conversion issues are as important as uncertainties about population, technological change, or the many geophysical uncertainties.

There are a number of caveats. First, EMF BAU scenarios represent the modelers' judgment of the most likely pathway absent mitigation policies to reduce greenhouse gas emissions, rather than the wider range of possible outcomes. Nevertheless, these views of the most likely outcome span a wide range, from the more optimistic (*e.g.*, abundant low-cost, low-carbon energy) to more pessimistic (*e.g.*, constraints on the availability of nuclear and renewables).[p] Second, the socioeconomic trajectories associated with a 550 ppm CO_2e concentration scenario are not derived from an assessment of what policy is optimal from a benefit-cost standpoint. Rather, it is indicative of one possible future outcome. The emission trajectories underlying some BAU scenarios (*e.g.*, MESSAGE's 612 ppm) also are consistent with some modest policy action to address climate change.[q] We chose not to include socioeconomic trajectories that achieve even lower GHG concentrations at this time, given the difficulty many models had in converging to meet these targets.

For comparison purposes, the Energy Information Agency in its 2009 Annual Energy Outlook projected that global carbon dioxide emissions will grow to 30.8, 35.6, and 40.4 gigatons in 2010, 2020, and 2030, respectively, while world GDP is projected to be $51.8, $71.0 and $93.9 trillion (in 2005 dollars using market exchange rates) in 2010, 2020, and 2030, respectively. These projections are consistent with one or more EMF-22 scenarios. Likewise, the United Nations' 2008 Population Prospect projects population will grow from 6.1 billion people in 2000 to 9.1 billion people in 2050, which is close to the population trajectories for the IMAGE, MiniCAM, and MERGE models.

In addition to fossil and industrial CO_2 emissions, each EMF scenario provides projections of methane, nitrous oxide, fluorinated greenhouse gases, and net land use CO_2 emissions out to 2100. These assumptions also are used in the three models while retaining the default radiative forcings due to other factors (*e.g.*, aerosols and other gases). See the Annex for greater detail.

14A.4.6 Discount Rate

The choice of a discount rate, especially over long periods of time, raises highly contested and exceedingly difficult questions of science, economics, philosophy, and law. Although it is well understood that the discount rate has a large influence on the current value of future damages, there is no consensus about what rates to use in this context. Because carbon dioxide emissions are long-lived, subsequent damages occur over many years. In calculating the SCC, we first estimate the future damages to agriculture, human health, and other market and non-market sectors from an additional unit of carbon dioxide emitted in a particular year in terms of reduced consumption (or consumption equivalents) due to the impacts of elevated temperatures, as represented in each of the three IAMs. Then we discount the stream of future damages to its present value in the year when the additional unit of emissions was released using

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[p] For instance, in the MESSAGE model's reference case total primary energy production from nuclear, biomass, and non-biomass renewables is projected to increase from about 15 percent of total primary energy in 2000 to 54 percent in 2100. In comparison, the MiniCAM reference case shows 10 percent in 2000 and 21 percent in 2100.

[q] For example, MiniCAM projects if all non-US OECD countries reduce CO_2 emissions to 83 percent below 2005 levels by 2050 (per the G-8 agreement) but all other countries continue along a BAU path CO_2 concentrations in 2100 would drop from 794 ppmv in its reference case to 762 ppmv.

the selected discount rate, which is intended to reflect society's marginal rate of substitution between consumption in different time periods.

For rules with both intra- and intergenerational effects, agencies traditionally employ constant discount rates of both 3 percent and 7 percent in accordance with OMB Circular A-4. As Circular A-4 acknowledges, however, the choice of discount rate for intergenerational problems raises distinctive problems and presents considerable challenges. After reviewing those challenges, Circular A-4 states, "If your rule will have important intergenerational benefits or costs you might consider a further sensitivity analysis using a lower but positive discount rate in addition to calculating net benefits using discount rates of 3 and 7 percent." For the specific purpose of developing the SCC, we adapt and revise that approach here.

Arrow et al. (1996) outlined two main approaches to determine the discount rate for climate change analysis, which they labeled "descriptive" and "prescriptive." The descriptive approach reflects a positive (non-normative) perspective based on observations of people's actual choices—*e.g.,* savings versus consumption decisions over time, and allocations of savings among more and less risky investments. Advocates of this approach generally call for inferring the discount rate from market rates of return "because of a lack of justification for choosing a social welfare function that is any different than what decision makers [individuals] actually use" (Arrow et al. 1996).

One theoretical foundation for the cost-benefit analyses in which the social cost of carbon will be used—the Kaldor-Hicks potential-compensation test—also suggests that market rates should be used to discount future benefits and costs, because it is the market interest rate that would govern the returns potentially set aside today to compensate future individuals for climate damages that they bear (*e.g.,* Just et al. 2004). As some have noted, the word "potentially" is an important qualification; there is no assurance that such returns will actually be set aside to provide compensation, and the very idea of compensation is difficult to define in the intergenerational context. On the other hand, societies provide compensation to future generations through investments in human capital and the resulting increase in knowledge, as well as infrastructure and other physical capital.

The prescriptive approach specifies a social welfare function that formalizes the normative judgments that the decision-maker wants explicitly to incorporate into the policy evaluation—*e.g.*, how inter-personal comparisons of utility should be made, and how the welfare of future generations should be weighed against that of the present generation. Ramsey (1928), for example, has argued that it is "ethically indefensible" to apply a positive pure rate of time preference to discount values across generations, and many agree with this view.

Other concerns also motivate making adjustments to descriptive discount rates. In particular, it has been noted that the preferences of future generations with regard to consumption versus environmental amenities may not be the same as those today, making the current market rate on consumption an inappropriate metric by which to discount future climate-related damages. Others argue that the discount rate should be below market rates to correct for market distortions and uncertainties or inefficiencies in intergenerational transfers of wealth, which in the Kaldor-Hicks logic are presumed to compensate future generations for damage (a potentially controversial assumption, as noted above) (Arrow et al. 1996, Weitzman 1999).

Further, a legitimate concern about both descriptive and prescriptive approaches is that they tend to obscure important heterogeneity in the population. The utility function that underlies the prescriptive approach assumes a representative agent with perfect foresight and no credit constraints. This is an artificial rendering of the real world that misses many of the frictions that characterize individuals' lives and indeed the available descriptive evidence supports this. For instance, many individuals smooth consumption by borrowing with credit cards that have relatively high rates. Some are unable to access traditional credit markets and rely on payday lending operations or other high-cost forms of smoothing consumption. Whether one puts greater weight on the prescriptive or descriptive approach, the high interest rates that credit-constrained individuals accept suggest that some account should be given to the discount rates revealed by their behavior.

We draw on both approaches but rely primarily on the descriptive approach to inform the choice of discount rate. With recognition of its limitations, we find this approach to be the most defensible and transparent given its consistency with the standard contemporary theoretical foundations of benefit-cost analysis and with the approach required by OMB's existing guidance. The logic of this framework also suggests that market rates should be used for discounting future consumption-equivalent damages. Regardless of the theoretical approach used to derive the appropriate discount rate(s), we note the inherent conceptual and practical difficulties of adequately capturing consumption trade-offs over many decades or even centuries. While relying primarily on the descriptive approach in selecting specific discount rates, the interagency group has been keenly aware of the deeply normative dimensions of both the debate over discounting in the intergenerational context and the consequences of selecting one discount rate over another.

Historically Observed Interest Rates

In a market with no distortions, the return to savings would equal the private return on investment, and the market rate of interest would be the appropriate choice for the social discount rate. In the real world risk, taxes, and other market imperfections drive a wedge between the risk-free rate of return on capital and the consumption rate of interest. Thus, the literature recognizes two conceptual discount concepts—the consumption rate of interest and the opportunity cost of capital.

According to OMB's Circular A-4, it is appropriate to use the rate of return on capital when a regulation is expected to displace or alter the use of capital in the private sector. In this case, OMB recommends Agencies use a discount rate of 7 percent. When regulation is expected to primarily affect private consumption—for instance, via higher prices for goods and services—a lower discount rate of 3 percent is appropriate to reflect how private individuals trade-off current and future consumption.

The interagency group examined the economics literature and concluded that the consumption rate of interest is the correct concept to use in evaluating the benefits and costs of a marginal change in carbon emissions (see Lind 1990, Arrow et al 1996, and Arrow 2000). The consumption rate of interest also is appropriate when the impacts of a regulation are measured in consumption (-equivalent) units, as is done in the three integrated assessment models used for estimating the SCC.

Individuals use a variety of savings instruments that vary with risk level, time horizon, and tax characteristics. The standard analytic framework used to develop intuition about the discount rate typically assumes a representative agent with perfect foresight and no credit constraints. The risk-free rate is appropriate for discounting certain future benefits or costs, but the benefits calculated by IAMs are uncertain. To use the risk-free rate to discount uncertain benefits, these benefits first must be transformed into "certainty equivalents," that is the maximum certain amount that we would exchange for the uncertain amount. However, the calculation of the certainty-equivalent requires first estimating the correlation between the benefits of the policy and baseline consumption.

If the IAM projections of future impacts represent expected values (not certainty-equivalent values), then the appropriate discount rate generally does not equal the risk-free rate. If the benefits of the policy tend to be high in those states of the world in which consumption is low, then the certainty-equivalent benefits will be higher than the expected benefits (and vice versa). Since many (though not necessarily all) of the important impacts of climate change will flow through market sectors such as agriculture and energy, and since willingness to pay for environmental protections typically increases with income, we might expect a positive (though not necessarily perfect) correlation between the net benefits from climate policies and market returns. This line of reasoning suggests that the proper discount rate would exceed the riskless rate. Alternatively, a negative correlation between the returns to climate policies and market returns would imply that a discount rate below the riskless rate is appropriate.

This discussion suggests that both the post-tax riskless and risky rates can be used to capture individuals' consumption-equivalent interest rate. As a measure of the post-tax riskless rate, we calculate the average real return from Treasury notes over the longest time period available (those from Newell and Pizer 2003) and adjust for Federal taxes (the average marginal rate from tax years 2003 through 2006 is around 27 percent).[r] This calculation produces a real interest rate of about 2.7 percent, which is roughly consistent with Circular A-4's recommendation to use 3 percent to represent the consumption rate of interest.[s] A measure of the post-tax risky rate for investments whose returns are positively correlated with overall equity market returns can be obtained by adjusting pre-tax rates of household returns to risky investments (approximately 7 percent) for taxes, which yields a real rate of roughly 5 percent.[t]

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[r] The literature argues for a risk-free rate on government bonds as an appropriate measure of the consumption rate of interest. Arrow (2000) suggests that it is roughly 3-4 percent. OMB cites evidence of a 3.1 percent pre-tax rate for 10-year Treasury notes in the A-4 guidance. Newell and Pizer (2003) find real interest rates between 3.5 and 4 percent for 30-year Treasury securities.

[s] The positive approach reflects how individuals make allocation choices across time, but it is important to keep in mind that we wish to reflect preferences for society as a whole, which generally has a longer planning horizon.

[t] Cambell et al (2001) estimates that the annual real return from stocks for 1900-1995 was about 7 percent. The annual real rate of return for the S&P 500 from 1950 – 2008 was about 6.8 percent. In the absence of a better way to population-weight the tax rates, we use the middle of the 20 – 40 percent range to derive a post-tax interest rate (Kotlikoff and Rapson 2006).

The Ramsey Equation

Ramsey discounting also provides a useful framework to inform the choice of a discount rate. Under this approach, the analyst applies either positive or normative judgments in selecting values for the key parameters of the Ramsey equation: η (coefficient of relative risk aversion or elasticity of the marginal utility of consumption) and ρ (pure rate of time preference).[u] These are then combined with g (growth rate of per-capita consumption) to equal the interest rate at which future monetized damages are discounted: $\rho + \eta \cdot g$.[v] In the simplest version of the Ramsey model, with an optimizing representative agent with perfect foresight, what we are calling the "Ramsey discount rate," $\rho + \eta \cdot g$, will be equal to the rate of return to capital, *i.e.*, the market interest rate.

A review of the literature provides some guidance on reasonable parameter values for the Ramsey discounting equation, based on both prescriptive and descriptive approaches.

- η. Most papers in the climate change literature adopt values for η in the range of 0.5 to 3 (Weitzman cites plausible values as those ranging from 1 to 4), although not all authors articulate whether their choice is based on prescriptive or descriptive reasoning.[w] Dasgupta (2008) argues that η should be greater than 1 and may be as high as 3, because η equal to 1 suggests savings rates that do not conform to observed behavior.

- ρ. With respect to the pure rate of time preference, most papers in the climate change literature adopt values for ρ in the range of 0 to 3 percent per year. The very low rates tend to follow from moral judgments involving intergenerational neutrality. Some have argued that to use any value other than $\rho = 0$ would unjustly discriminate against future generations (*e.g.*, Arrow et al. 1996, Stern et al. 2006). However, even in an inter-

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[u] The parameter ρ □measures the *pure rate of time preference*: people's behavior reveals a preference for an increase in utility today versus the future. Consequently, it is standard to place a lower weight on utility in the future. The parameter η captures *diminishing marginal utility*: consumption in the future is likely to be higher than consumption today, so diminishing marginal utility of consumption implies that the same monetary damage will cause a smaller reduction of utility for wealthier individuals, either in the future or in current generations. If $\eta = 0$, then a one dollar increase in income is equally valuable regardless of level of income; if $\eta = 1$, then a one percent increase in income is equally valuable no matter the level of income; and if $\eta > 1$, then a one percent increase in income is less valuable to wealthier individuals.

[v] In this case, g could be taken from the selected EMF socioeconomic scenarios or alternative assumptions about the rate of consumption growth.

[w] Empirical estimates of η span a wide range of values. A benchmark value of 2 is near the middle of the range of values estimated or used by Szpiro (1986), Hall and Jones (2007), Arrow (2007), Dasgupta (2006, 2008), Weitzman (2007, 2009), and Nordhaus (2008). However, Chetty (2006) developed a method of estimating η using data on labor supply behavior. He shows that existing evidence of the effects of wage changes on labor supply imposes a tight upper bound on the curvature of utility over wealth (CRRA < 2) with the mean implied value of 0.71 and concludes that the standard expected utility model cannot generate high levels of risk aversion without contradicting established facts about labor supply. Recent work has jointly estimated the components of the Ramsey equation. Evans and Sezer (2005) estimate $\eta = 1.49$ for 22 OECD countries. They also estimate $\rho = 1.08$ percent per year using data on mortality rates. Anthoff, et al. (2009b) estimate $\eta = 1.18$, and $\rho = 1.4$ percent. When they multiply the bivariate probability distributions from their work and Evans and Sezer (2005) together, they find $\eta = 1.47$, and $\rho = 1.07$.

generational setting, it may make sense to use a small positive pure rate of time preference because of the small probability of unforeseen cataclysmic events (Stern et al. 2006).

- g. A commonly accepted approximation is around 2 percent per year. For the socioeconomic scenarios used for this exercise, the EMF models assume that g is about 1.5-2 percent to 2100.

Some economists and non-economists have argued for constant discount rates below 2 percent based on the prescriptive approach. When grounded in the Ramsey framework, proponents of this approach have argued that a ρ of zero avoids giving preferential treatment to one generation over another. The choice of η has also been posed as an ethical choice linked to the value of an additional dollar in poorer countries compared to wealthier ones. Stern et al. (2006) applies this perspective through his choice of $\rho = 0.1$ percent per year, $\eta = 1$ and $g = 1.3$ percent per year, which yields an annual discount rate of 1.4 percent. In the context of permanent income savings behavior, however, Stern's assumptions suggest that individuals would save 93 percent of their income.[x]

Recently, Stern (2008) revisited the values used in Stern et al. (2006), stating that there is a case to be made for raising η due to the amount of weight lower values place on damages far in the future (over 90 percent of expected damages occur after 2200 with $\eta = 1$). Using Stern's assumption that $\rho = 0.1$ percent, combined with a η of 1.5 to 2 and his original growth rate, yields a discount rate of greater than 2 percent.

We conclude that arguments made under the prescriptive approach can be used to justify discount rates between roughly 1.4 and 3.1 percent. In light of concerns about the most appropriate value for η, we find it difficult to justify rates at the lower end of this range under the Ramsey framework.

Accounting for Uncertainty in the Discount Rate

While the consumption rate of interest is an important driver of the benefits estimate, it is uncertain over time. Ideally, we would formally model this uncertainty, just as we do for climate sensitivity. Weitzman (1998, 2001) showed theoretically and Newell and Pizer (2003) and Groom et al. (2006) confirm empirically that discount rate uncertainty can have a large effect on net present values. A main result from these studies is that if there is a persistent element to the uncertainty in the discount rate (*e.g.,* the rate follows a random walk), then it will result in an effective (or certainty-equivalent) discount rate that declines over time. Consequently, lower discount rates tend to dominate over the very long term (see Weitzman 1998, 1999, 2001; Newell and Pizer 2003; Groom et al. 2006; Gollier 2008; Summers and Zeckhauser 2008; and Gollier and Weitzman 2009).

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[x] Stern (2008) argues that building in a positive rate of exogenous technical change over time reduces the implied savings rate and that η at or above 2 are inconsistent with observed behavior with regard to equity. (At the same time, adding exogenous technical change—all else equal—would increase g as well.)

The proper way to model discount rate uncertainty remains an active area of research. Newell and Pizer (2003) employ a model of how long-term interest rates change over time to forecast future discount rates. Their model incorporates some of the basic features of how interest rates move over time, and its parameters are estimated based on historical observations of long-term rates. Subsequent work on this topic, most notably Groom et al. (2006), uses more general models of interest rate dynamics to allow for better forecasts. Specifically, the volatility of interest rates depends on whether rates are currently low or high and the variation in the level of persistence over time.

While Newell and Pizer (2003) and Groom et al (2006) attempt formally to model uncertainty in the discount rate, others argue for a declining scale of discount rates applied over time (*e.g.*, Weitzman 2001, and the UK's "Green Book" for regulatory analysis). This approach uses a higher discount rate initially, but applies a graduated scale of lower discount rates further out in time.[y] A key question that has emerged with regard to both of these approaches is the trade-off between potential time inconsistency and giving greater weight to far future outcomes (see the EPA Science Advisory Board's recent comments on this topic as part of its review of their *Guidelines for Economic Analysis*).[z]

The Discount Rates Selected for Estimating SCC

In light of disagreement in the literature on the appropriate market interest rate to use in this context and uncertainty about how interest rates may change over time, we use three discount rates to span a plausible range of certainty-equivalent constant discount rates: 2.5, 3, and 5 percent per year. Based on the review in the previous sections, the interagency workgroup determined that these three rates reflect reasonable judgments under both descriptive and prescriptive approaches.

The central value, 3 percent, is consistent with estimates provided in the economics literature and OMB's Circular A-4 guidance for the consumption rate of interest. As previously mentioned, the consumption rate of interest is the correct discounting concept to use when future damages from elevated temperatures are estimated in consumption-equivalent units. Further, 3 percent roughly corresponds to the after-tax riskless interest rate. The upper value of 5 percent is included to represent the possibility that climate damages are positively correlated with market returns. Additionally, this discount rate may be justified by the high interest rates that many consumers use to smooth consumption across periods.

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[y] For instance, the UK applies a discount rate of 3.5 percent to the first 30 years; 3 percent for years 31 - 75; 2.5 percent for years 76 - 125; 2 percent for years 126 - 200; 1.5 percent for years 201 - 300; and 1 percent after 300 years. As a sensitivity, it recommends a discount rate of 3 percent for the first 30 years, also decreasing over time.

[z] Uncertainty in future damages is distinct from uncertainty in the discount rate. Weitzman (2008) argues that Stern's choice of a low discount rate was "right for the wrong reasons." He demonstrates how the damages from a low probability, catastrophic event far in the future dominate the effect of the discount rate in a present value calculation and result in an infinite willingness-to-pay for mitigation today. Newbold and Daigneault, (2009) and Nordhaus (2009) find that Weitzman's result is sensitive to the functional forms chosen for climate sensitivity, utility, and consumption. Summers and Zeckhauser (2008) argue that uncertainty in future damages can also work in the other direction by increasing the benefits of waiting to learn the appropriate level of mitigation required.

The low value, 2.5 percent, is included to incorporate the concern that interest rates are highly uncertain over time. It represents the average certainty-equivalent rate using the mean-reverting and random walk approaches from Newell and Pizer (2003) starting at a discount rate of 3 percent. Using this approach, the certainty equivalent is about 2.2 percent using the random walk model and 2.8 percent using the mean reverting approach.[aa] Without giving preference to a particular model, the average of the two rates is 2.5 percent. Further, a rate below the riskless rate would be justified if climate investments are negatively correlated with the overall market rate of return. Use of this lower value also responds to certain judgments using the prescriptive or normative approach and to ethical objections that have been raised about rates of 3 percent or higher.

14A.5 REVISED SCC ESTIMATES

Our general approach to estimating SCC values is to run the three integrated assessment models (FUND, DICE, and PAGE) using the following inputs agreed upon by the interagency group:

- A Roe and Baker distribution for the climate sensitivity parameter bounded between 0 and 10 with a median of 3 °C and a cumulative probability between 2 and 4.5 °C of two-thirds.
- Five sets of GDP, population, and carbon emissions trajectories based on EMF-22.
- Constant annual discount rates of 2.5, 3, and 5 percent.

Because the climate sensitivity parameter is modeled probabilistically, and because PAGE and FUND incorporate uncertainty in other model parameters, the final output from each model run is a distribution over the SCC in year *t*.

For each of the IAMs, the basic computational steps for calculating the SCC in a particular year *t* are:

1. Input the path of emissions, GDP, and population from the selected EMF-22 scenarios, and the extrapolations based on these scenarios for post-2100 years.

2. Calculate the temperature effects and (consumption-equivalent) damages in each year resulting from the baseline path of emissions.

    a. In PAGE, the consumption-equivalent damages in each period are calculated as a fraction of the EMF GDP forecast, depending on the temperature in that period relative to the pre-industrial average temperature in each region.
    b. In FUND, damages in each period depend on both the level and the rate of temperature change in that period.

[aa] Calculations done by Pizer et al. using the original simulation program from Newell and Pizer (2003).

    c. In DICE, temperature affects both consumption and investment, so we first adjust the EMF GDP paths as follows: Using the Cobb-Douglas production function with the DICE2007 parameters, we extract the path of exogenous technical change implied by the EMF GDP and population paths, then we recalculate the baseline GDP path taking into account climate damages resulting from the baseline emissions path.

3. Add an additional unit of carbon emissions in year *t.* (The exact unit varies by model.)

4. Recalculate the temperature effects and damages expected in all years beyond *t* resulting from this adjusted path of emissions, as in step 2.

5. Subtract the damages computed in step 2 from those in step 4 in each year. (DICE is run in 10-year time steps, FUND in annual time steps, while the time steps in PAGE vary.)

6. Discount the resulting path of marginal damages back to the year of emissions using the agreed upon fixed discount rates.

7. Calculate the SCC as the net present value of the discounted path of damages computed in step 6, divided by the unit of carbon emissions used to shock the models in step 3.

8. Multiply by 12/44 to convert from dollars per ton of carbon to dollars per ton of CO_2 (2007 dollars) in DICE and FUND. (All calculations are done in tons of CO_2 in PAGE).

The steps above were repeated in each model for multiple future years to cover the time horizons anticipated for upcoming rulemaking analysis. To maintain consistency across the three IAMs, climate damages are calculated as lost consumption in each future year.

It is important to note that each of the three models has a different default end year. The default time horizon is 2200 for PAGE, 2595 for DICE, and 3000 for the latest version of FUND. This is an issue for the multi-model approach because differences in SCC estimates may arise simply due to the model time horizon. Many consider 2200 too short a time horizon because it could miss a significant fraction of damages under certain assumptions about the growth of marginal damages and discounting, so each model is run here through 2300. This step required a small adjustment in the PAGE model only. This step also required assumptions about GDP, population, and greenhouse gas emission trajectories after 2100, the last year for which these data are available from the EMF-22 models. (A more detailed discussion of these assumptions is included in the Annex.)

This exercise produces 45 separate distributions of the SCC for a given year, the product of 3 models, 3 discount rates, and 5 socioeconomic scenarios. This is clearly too many separate distributions for consideration in a regulatory impact analysis.

To produce a range of plausible estimates that still reflects the uncertainty in the estimation exercise, the distributions from each of the models and scenarios are equally weighed and combined to produce three separate probability distributions for SCC in a given year, one for each assumed discount rate. These distributions are then used to define a range of point estimates for the global SCC. In this way, no IAM or socioeconomic scenario is given greater weight than another. Because the literature shows that the SCC is quite sensitive to assumptions about the discount rate, and because no consensus exists on the appropriate rate to use in an intergenerational context, we present SCCs based on the average values across models and socioeconomic scenarios for each discount rate.

The interagency group selected four SCC values for use in regulatory analyses. Three values are based on the average SCC across models and socioeconomic and emissions scenarios at the 2.5, 3, and 5 percent discount rates. The fourth value is included to represent the higher-than-expected economic impacts from climate change further out in the tails of the SCC distribution. For this purpose, we use the SCC value for the 95th percentile at a 3 percent discount rate. (The full set of distributions by model and scenario combination is included in the Annex.) As noted above, the 3 percent discount rate is the central value, and so the central value that emerges is the average SCC across models at the 3 percent discount rate. For purposes of capturing the uncertainties involved in regulatory impact analysis, we emphasize the importance and value of considering the full range.

As previously discussed, low probability, high impact events are incorporated into the SCC values through explicit consideration of their effects in two of the three models as well as the use of a probability density function for equilibrium climate sensitivity. Treating climate sensitivity probabilistically results in more high-temperature outcomes, which in turn lead to higher projections of damages. Although FUND does not include catastrophic damages (in contrast to the other two models), its probabilistic treatment of the equilibrium climate sensitivity parameter will directly affect the non-catastrophic damages that are a function of the rate of temperature change.

In Table 14A.5.1, we begin by presenting SCC estimates for 2010 by model, scenario, and discount rate to illustrate the variability in the SCC across each of these input parameters. As expected, higher discount rates consistently result in lower SCC values, while lower discount rates result in higher SCC values for each socioeconomic trajectory. It is also evident that there are differences in the SCC estimated across the three main models. For these estimates, FUND produces the lowest estimates, while PAGE generally produces the highest estimates.

Table 14A.5.1 Disaggregated Social Cost of CO_2 Values by Model, Socioeconomic Trajectory, and Discount Rate for 2010 (in 2007 dollars)

	Discount rate:	**5%**	**3%**	**2.5%**	**3%**
Model	*Scenario*	Avg	Avg	Avg	95th
DICE	IMAGE	10.8	35.8	54.2	70.8
	MERGE	7.5	22.0	31.6	42.1
	Message	9.8	29.8	43.5	58.6
	MiniCAM	8.6	28.8	44.4	57.9
	550 Average	8.2	24.9	37.4	50.8
PAGE	IMAGE	8.3	39.5	65.5	142.4
	MERGE	5.2	22.3	34.6	82.4
	Message	7.2	30.3	49.2	115.6
	MiniCAM	6.4	31.8	54.7	115.4
	550 Average	5.5	25.4	42.9	104.7
FUND	IMAGE	-1.3	8.2	19.3	39.7
	MERGE	-0.3	8.0	14.8	41.3
	Message	-1.9	3.6	8.8	32.1
	MiniCAM	-0.6	10.2	22.2	42.6
	550 Average	-2.7	-0.2	3.0	19.4

These results are not surprising when compared to the estimates in the literature for the latest versions of each model. For example, adjusting the values from the literature that were used to develop interim SCC values to 2007 dollars for the year 2010 (assuming, as we did for the interim process, that SCC grows at 3 percent per year), FUND yields SCC estimates at or near zero for a 5 percent discount rate and around $9 per ton for a 3 percent discount rate. There are far fewer estimates using the latest versions of DICE and PAGE in the literature: Using similar adjustments to generate 2010 estimates, we calculate a SCC from DICE (based on Nordhaus 2008) of around $9 per ton for a 5 percent discount rate, and a SCC from PAGE (based on Hope 2006, 2008) close to $8 per ton for a 4 percent discount rate. Note that these comparisons are only approximate since the literature generally relies on Ramsey discounting, while we have assumed constant discount rates.[bb]

[bb] Nordhaus (2008) runs DICE2007 with $\rho = 1.5$ and $\eta = 2$. The default approach in PAGE2002 (version 1.4epm) treats ρ and η as random parameters, specified using a triangular distribution such that the min, mode, and max = 0.1, 1, and 2 for ρ, and 0.5, 1, and 2 for η, respectively. The FUND default value for η is 1, and Tol generates SCC estimates for values of ρ = 0, 1, and 3 in many recent papers (*e.g.* Anthoff et al. 2009). The path of per-capita consumption growth, g, varies over time but is treated deterministically in two of the three models. In DICE, g is

The SCC estimates from FUND are sensitive to differences in emissions paths but relatively insensitive to differences in GDP paths across scenarios, while the reverse is true for DICE and PAGE. This likely occurs because of several structural differences among the models. Specifically in DICE and PAGE, the fraction of economic output lost due to climate damages increases with the level of temperature alone, whereas in FUND the fractional loss also increases with the rate of temperature change. Furthermore, in FUND increases in income over time decrease vulnerability to climate change (a form of adaptation), whereas this does not occur in DICE and PAGE. These structural differences among the models make FUND more sensitive to the path of emissions and less sensitive to GDP compared to DICE and PAGE.

Figure 14A.5.1 shows that IMAGE has the highest GDP in 2100 while MERGE Optimistic has the lowest. The ordering of global GDP levels in 2100 directly corresponds to the rank ordering of SCC for PAGE and DICE. For FUND, the correspondence is less clear, a result that is to be expected given its less direct relationship between its damage function and GDP.

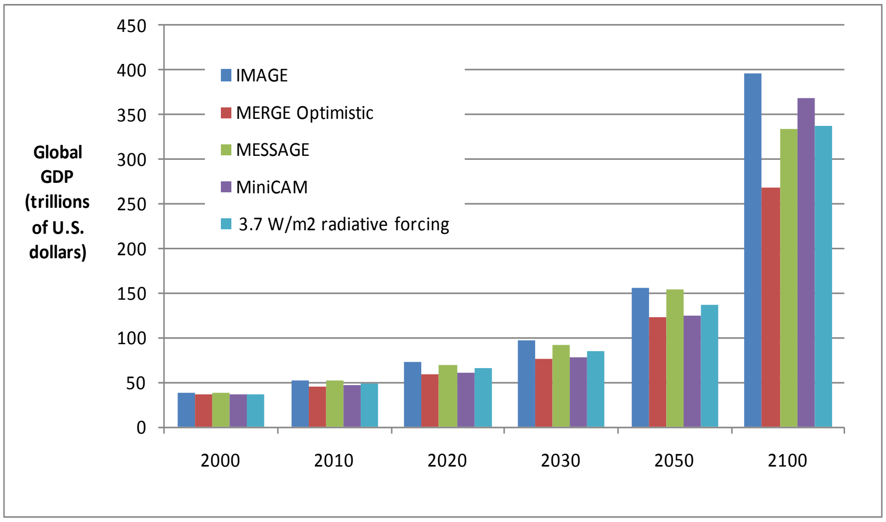

Figure 14A.5.1 Level of Global GDP across EMF Scenarios

Table 14A.5.2 shows the four selected SCC values in five-year increments from 2010 to 2050. Values for 2010, 2020, 2040, and 2050 are calculated by first combining all outputs (10,000 estimates per model run) from all scenarios and models for a given discount rate. Values for the years in between are calculated using a simple linear interpolation.

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endogenous. Under Ramsey discounting, as economic growth slows in the future, the large damages from climate change that occur far out in the future are discounted at a lower rate than impacts that occur in the nearer term.

Table 14A.5.2 Social Cost of CO_2, 2010 – 2050 (in 2007 dollars)

Discount Year	5% Avg	3% Avg	2.5% Avg	3% 95th
2010	4.7	21.4	35.1	64.9
2015	5.7	23.8	38.4	72.8
2020	6.8	26.3	41.7	80.7
2025	8.2	29.6	45.9	90.4
2030	9.7	32.8	50.0	100.0
2035	11.2	36.0	54.2	109.7
2040	12.7	39.2	58.4	119.3
2045	14.2	42.1	61.7	127.8
2050	15.7	44.9	65.0	136.2

The SCC increases over time because future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change. Note that this approach allows us to estimate the growth rate of the SCC directly using DICE, PAGE, and FUND rather than assuming a constant annual growth rate as was done for the interim estimates (using 3 percent). This helps to ensure that the estimates are internally consistent with other modeling assumptions. Table 14A.5.3 illustrates how the growth rate for these four SCC estimates varies over time. The full set of annual SCC estimates between 2010 and 2050 is reported in the Annex.

Table 14A.5.3 Changes in the Average Annual Growth Rates of SCC Estimates between 2010 and 2050

Average Annual Growth Rate (%)	**5%** Avg	**3%** Avg	**2.5%** Avg	**3.0%** 95th
2010-2020	3.6%	2.1%	1.7%	2.2%
2020-2030	3.7%	2.2%	1.8%	2.2%
2030-2040	2.7%	1.8%	1.6%	1.8%
2040-2050	2.1%	1.4%	1.1%	1.3%

While the SCC estimate grows over time, the future monetized value of emissions reductions in each year (the SCC in year *t* multiplied by the change in emissions in year *t*) must be discounted to the present to determine its total net present value for use in regulatory analysis. Damages from future emissions should be discounted at the same rate as that used to calculate the SCC estimates themselves to ensure internal consistency—*i.e.*, future damages from climate change, whether they result from emissions today or emissions in a later year, should be discounted using the same rate. For example, climate damages in the year 2020 that are calculated using a SCC based on a 5 percent discount rate also should be discounted back to the analysis year using a 5 percent discount rate.[cc]

14A.6 LIMITATIONS OF THE ANALYSIS

As noted, any estimate of the SCC must be taken as provisional and subject to further refinement (and possibly significant change) in accordance with evolving scientific, economic, and ethical understandings. During the course of our modeling, it became apparent that there are several areas in particular need of additional exploration and research. These caveats, and additional observations in the following section, are necessary to consider when interpreting and applying the SCC estimates.

Incomplete treatment of non-catastrophic damages. The impacts of climate change are expected to be widespread, diverse, and heterogeneous. In addition, the exact magnitude of these impacts is uncertain because of the inherent complexity of climate processes, the economic behavior of current and future populations, and our inability to accurately forecast technological change and adaptation. Current IAMs do not assign value to all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature (some of which are discussed above) because of lack of precise information on the nature of damages and because the science incorporated into these models understandably lags behind the most recent research. Our ability to quantify and monetize impacts will undoubtedly improve with time. But it is also likely that even in future applications, a number of potentially significant damage categories will remain non-monetized. (Ocean acidification is one example of a potentially large damage from CO_2 emissions not quantified by any of the three models. Species and wildlife loss is another example that is exceedingly difficult to monetize.)

Incomplete treatment of potential catastrophic damages. There has been considerable recent discussion of the risk of catastrophic impacts and how best to account for extreme scenarios, such as the collapse of the Atlantic Meridional Overturning Circulation or the West Antarctic Ice Sheet, or large releases of methane from melting permafrost and warming oceans. Weitzman (2009) suggests that catastrophic damages are extremely large—so large, in fact, that the damages from a low probability, catastrophic event far in the future dominate the effect of the discount rate in a present value calculation and result in an infinite willingness-to-pay for mitigation today. However, Nordhaus (2009) concluded that the conditions under which Weitzman's results hold “are limited and do not apply to a wide range of potential uncertain scenarios."

Using a simplified IAM, Newbold and Daigneault (2009) confirmed the potential for large catastrophe risk premiums but also showed that the aggregate benefit estimates can be highly sensitive to the shapes of both the climate sensitivity distribution and the damage function at high temperature changes. Pindyck (2009) also used a simplified IAM to examine high-

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[cc] However, it is possible that other benefits or costs of proposed regulations unrelated to CO_2 emissions will be discounted at rates that differ from those used to develop the SCC estimates.

impact, low-probability risks, using a right-skewed gamma distribution for climate sensitivity as well as an uncertain damage coefficient, but in most cases found only a modest risk premium. Given this difference in opinion, further research in this area is needed before its practical significance can be fully understood and a reasonable approach developed to account for such risks in regulatory analysis. (The next section discusses the scientific evidence on catastrophic impacts in greater detail.)

Uncertainty in extrapolation of damages to high temperatures: The damage functions in these IAMs are typically calibrated by estimating damages at moderate temperature increases (*e.g.*, DICE was calibrated at 2.5 °C) and extrapolated to far higher temperatures by assuming that damages increase as some power of the temperature change. Hence, estimated damages are far more uncertain under more extreme climate change scenarios.

Incomplete treatment of adaptation and technological change: Each of the three integrated assessment models used here assumes a certain degree of low- or no-cost adaptation. For instance, Tol assumes a great deal of adaptation in FUND, including widespread reliance on air conditioning; so much so, that the largest single benefit category in FUND is the reduced electricity costs from not having to run air conditioning as intensively (NRC 2009).

Climate change also will increase returns on investment to develop technologies that allow individuals to cope with adverse climate conditions, and IAMs to do not adequately account for this directed technological change.[dd] For example, scientists may develop crops that are better able to withstand higher and more variable temperatures. Although DICE and FUND have both calibrated their agricultural sectors under the assumption that farmers will change land use practices in response to climate change (Mastrandrea, 2009), they do not take into account technological changes that lower the cost of this adaptation over time. On the other hand, the calibrations do not account for increases in climate variability, pests, or diseases, which could make adaptation more difficult than assumed by the IAMs for a given temperature change. Hence, models do not adequately account for potential adaptation or technical change that might alter the emissions pathway and resulting damages. In this respect, it is difficult to determine whether the incomplete treatment of adaptation and technological change in these IAMs understate or overstate the likely damages.

Risk aversion: A key question unanswered during this interagency process is what to assume about relative risk aversion with regard to high-impact outcomes. These calculations do not take into account the possibility that individuals may have a higher willingness to pay to reduce the likelihood of low-probability, high-impact damages than they do to reduce the likelihood of higher-probability, but lower-impact, damages with the same expected cost. (The inclusion of the 95th percentile estimate in the final set of SCC values was largely motivated by this concern.) If individuals do show such a higher willingness to pay, a further question is whether that fact should be taken into account for regulatory policy. Even if individuals are not risk-averse for such scenarios, it is possible that regulatory policy should include a degree of risk-aversion.

[dd] However these research dollars will be diverted from whatever their next best use would have been in the absence of climate change (so productivity/GDP would have been still higher).

Assuming a risk-neutral representative agent is consistent with OMB's Circular A-4, which advises that the estimates of benefits and costs used in regulatory analysis are usually based on the average or the expected value and that "emphasis on these expected values is appropriate as long as society is 'risk neutral' with respect to the regulatory alternatives. While this may not always be the case, [analysts] should in general assume 'risk neutrality' in [their] analysis."

Nordhaus (2008) points to the need to explore the relationship between risk and income in the context of climate change across models and to explore the role of uncertainty regarding various parameters in the results. Using FUND, Anthoff et al (2009) explored the sensitivity of the SCC to Ramsey equation parameter assumptions based on observed behavior. They conclude that "the assumed rate of risk aversion is at least as important as the assumed rate of time preference in determining the social cost of carbon." Since Circular A-4 allows for a different assumption on risk preference in regulatory analysis if it is adequately justified, we plan to continue investigating this issue.

14A.7 A FURTHER DISCUSSION OF CATASTROPHIC IMPACTS AND DAMAGE FUNCTIONS

As noted above, the damage functions underlying the three IAMs used to estimate the SCC may not capture the economic effects of all possible adverse consequences of climate change and may therefore lead to underestimates of the SCC (Mastrandrea 2009). In particular, the models' functional forms may not adequately capture: (1) potentially discontinuous "tipping point" behavior in Earth systems, (2) inter-sectoral and inter-regional interactions, including global security impacts of high-end warming, and (3) limited near-term substitutability between damage to natural systems and increased consumption.

It is the hope of the interagency group that over time researchers and modelers will work to fill these gaps and that the SCC estimates used for regulatory analysis by the Federal government will continue to evolve with improvements in modeling. In the meantime, we discuss some of the available evidence.

Extrapolation of climate damages to high levels of warming

The damage functions in the models are calibrated at moderate levels of warming and should therefore be viewed cautiously when extrapolated to the high temperatures found in the upper end of the distribution. Recent science suggests that there are a number of potential climatic "tipping points" at which the Earth system may exhibit discontinuous behavior with potentially severe social and economic consequences (*e.g.*, Lenton et al, 2008, Kriegler et al., 2009). These tipping points include the disruption of the Indian Summer Monsoon, dieback of the Amazon Rainforest and boreal forests, collapse of the Greenland Ice Sheet and the West Antarctic Ice Sheet, reorganization of the Atlantic Meridional Overturning Circulation, strengthening of El Niño-Southern Oscillation, and the release of methane from melting permafrost. Many of these tipping points are estimated to have thresholds between about 3 °C and 5 °C (Lenton et al., 2008). Probabilities of several of these tipping points were assessed through expert elicitation in 2005–2006 by Kriegler et al. (2009); results from this study are highlighted in Table 14A.7.1. Ranges of probability are averaged across core experts on each topic.

As previously mentioned, FUND does not include potentially catastrophic effects. DICE assumes a small probability of catastrophic damages that increases with increased warming, but the damages from these risks are incorporated as expected values (*i.e.*, ignoring potential risk aversion). PAGE models catastrophic impacts in a probabilistic framework (see Figure 14A.4.1), so the high-end output from PAGE potentially offers the best insight into the SCC if the world were to experience catastrophic climate change. For instance, at the 95th percentile and a 3 percent discount rate, the SCC estimated by PAGE across the five socioeconomic and emission trajectories of $113 per ton of CO_2 is almost double the value estimated by DICE, $58 per ton in 2010. We cannot evaluate how well the three models account for catastrophic or non-catastrophic impacts, but this estimate highlights the sensitivity of SCC values in the tails of the distribution to the assumptions made about catastrophic impacts.

Table 14A.7.1 Probabilities of Various Tipping Points from Expert Elicitation

Possible Tipping Points	**Duration before effect is fully realized (in years)**	**Additional Warming by 2100**		
		0.5-1.5 C	**1.5-3.0 C**	**3-5 C**
Reorganization of Atlantic Meridional Overturning Circulation	about 100	0-18%	6-39%	18-67%
Greenland Ice Sheet collapse	at least 300	8-39%	33-73%	67-96%
West Antarctic Ice Sheet collapse	at least 300	5-41%	10-63%	33-88%
Dieback of Amazon rainforest	about 50	2-46%	14-84%	41-94%
Strengthening of El Niño-Southern Oscillation	about 100	1-13%	6-32%	19-49%
Dieback of boreal forests	about 50	13-43%	20-81%	34-91%
Shift in Indian Summer Monsoon	about 1	Not formally assessed		
Release of methane from melting permafrost	Less than 100	Not formally assessed.		

PAGE treats the possibility of a catastrophic event probabilistically, while DICE treats it deterministically (that is, by adding the expected value of the damage from a catastrophe to the aggregate damage function). In part, this results in different probabilities being assigned to a catastrophic event across the two models. For instance, PAGE places a probability near zero on a catastrophe at 2.5 °C warming, while DICE assumes a 4 percent probability of a catastrophe at 2.5 °C. By comparison, Kriegler et al. (2009) estimate a probability of at least 16-36 percent of crossing at least one of their primary climatic tipping points in a scenario with temperatures about 2-4 °C warmer than pre-Industrial levels in 2100.

It is important to note that crossing a climatic tipping point will not necessarily lead to an economic catastrophe in the sense used in the IAMs. A tipping point is a critical threshold across which some aspect of the Earth system starts to shifts into a qualitatively different state (for instance, one with dramatically reduced ice sheet volumes and higher sea levels). In the IAMs, a catastrophe is a low-probability environmental change with high economic impact.

Failure to incorporate inter-sectoral and inter-regional interactions

The damage functions do not fully incorporate either inter-sectoral or inter-regional interactions. For instance, while damages to the agricultural sector are incorporated, the effects of changes in food supply on human health are not fully captured and depend on the modeler's choice of studies used to calibrate the IAM. Likewise, the effects of climate damages in one region of the world on another region are not included in some of the models (FUND includes the effects of migration from sea level rise). These inter-regional interactions, though difficult to quantify, are the basis for climate-induced national and economic security concerns (*e.g.*, Campbell et al., 2007; U.S. Department of Defense 2010) and are particularly worrisome at higher levels of warming. High-end warming scenarios, for instance, project water scarcity affecting 4.3-6.9 billion people by 2050, food scarcity affecting about 120 million additional people by 2080, and the creation of millions of climate refugees (Easterling et al., 2007; Campbell et al., 2007).

Imperfect substitutability of environmental amenities

Data from the geological record of past climate changes suggests that 6 °C of warming may have severe consequences for natural systems. For instance, during the Paleocene-Eocene Thermal Maximum about 55.5 million years ago, when the Earth experienced a geologically rapid release of carbon associated with an approximately 5 °C increase in global mean temperatures, the effects included shifts of about 400-900 miles in the range of plants (Wing et al., 2005), and dwarfing of both land mammals (Gingerich, 2006) and soil fauna (Smith et al., 2009).

The three IAMs used here assume that it is possible to compensate for the economic consequences of damages to natural systems through increased consumption of non-climate goods, a common assumption in many economic models. In the context of climate change, however, it is possible that the damages to natural systems could become so great that no increase in consumption of non-climate goods would provide complete compensation (Levy et al., 2005). For instance, as water supplies become scarcer or ecosystems become more fragile and less bio-diverse, the services they provide may become increasingly more costly to replace. Uncalibrated attempts to incorporate the imperfect substitutability of such amenities into IAMs (Sterner and Persson, 2008) indicate that the optimal degree of emissions abatement can be considerably greater than is commonly recognized.

14A.8 CONCLUSION

The interagency group selected four SCC estimates for use in regulatory analyses. For 2010, these estimates are \$5, \$21, \$35, and \$65 (in 2007 dollars). The first three estimates are based on the average SCC across models and socioeconomic and emissions scenarios at the 5, 3, and 2.5 percent discount rates, respectively. The fourth value is included to represent the higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. For this purpose, we use the SCC value for the 95th percentile at a 3 percent discount rate. The central value is the average SCC across models at the 3 percent discount rate. For purposes of capturing the uncertainties involved in regulatory impact analysis, we emphasize the importance and value of considering the full range. These SCC estimates also grow over time. For instance, the central value increases to \$24 per ton of CO_2 in 2015 and \$26 per ton of CO_2 in 2020.

We noted a number of limitations to this analysis, including the incomplete way in which the integrated assessment models capture catastrophic and non-catastrophic impacts, their incomplete treatment of adaptation and technological change, uncertainty in the extrapolation of damages to high temperatures, and assumptions regarding risk aversion. The limited amount of research linking climate impacts to economic damages makes this modeling exercise even more difficult. It is the hope of the interagency group that over time researchers and modelers will work to fill these gaps and that the SCC estimates used for regulatory analysis by the Federal government will continue to evolve with improvements in modeling.

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14A.9 ANNEX

Table 14A.9.1 Annual SCC Values: 2010–2050 (in 2007 dollars)

Discount Rate	5%	3%	2.5%	3%
Year	Avg	Avg	Avg	95th
2010	4.7	21.4	35.1	64.9
2011	4.9	21.9	35.7	66.5
2012	5.1	22.4	36.4	68.1
2013	5.3	22.8	37.0	69.6
2014	5.5	23.3	37.7	71.2
2015	5.7	23.8	38.4	72.8
2016	5.9	24.3	39.0	74.4
2017	6.1	24.8	39.7	76.0
2018	6.3	25.3	40.4	77.5
2019	6.5	25.8	41.0	79.1
2020	6.8	26.3	41.7	80.7
2021	7.1	27.0	42.5	82.6
2022	7.4	27.6	43.4	84.6
2023	7.7	28.3	44.2	86.5
2024	7.9	28.9	45.0	88.4
2025	8.2	29.6	45.9	90.4
2026	8.5	30.2	46.7	92.3
2027	8.8	30.9	47.5	94.2
2028	9.1	31.5	48.4	96.2
2029	9.4	32.1	49.2	98.1
2030	9.7	32.8	50.0	100.0
2031	10.0	33.4	50.9	102.0
2032	10.3	34.1	51.7	103.9
2033	10.6	34.7	52.5	105.8
2034	10.9	35.4	53.4	107.8
2035	11.2	36.0	54.2	109.7
2036	11.5	36.7	55.0	111.6
2037	11.8	37.3	55.9	113.6
2038	12.1	37.9	56.7	115.5
2039	12.4	38.6	57.5	117.4
2040	12.7	39.2	58.4	119.3
2041	13.0	39.8	59.0	121.0
2042	13.3	40.4	59.7	122.7
2043	13.6	40.9	60.4	124.4
2044	13.9	41.5	61.0	126.1
2045	14.2	42.1	61.7	127.8
2046	14.5	42.6	62.4	129.4
2047	14.8	43.2	63.0	131.1
2048	15.1	43.8	63.7	132.8
2049	15.4	44.4	64.4	134.5
2050	15.7	44.9	65.0	136.2

This Annex provides additional technical information about the non-CO_2 emission projections used in the modeling and the method for extrapolating emissions forecasts through 2300 and shows the full distribution of 2010 SCC estimates by model and scenario combination.

14A.9.1 Other (non-CO_2) gases

In addition to fossil and industrial CO_2 emissions, each EMF scenario provides projections of methane (CH_4), nitrous oxide (N_2O), fluorinated gases, and net land use CO_2 emissions to 2100. These assumptions are used in all three IAMs while retaining each model's default radiative forcings (RF) due to other factors (*e.g.*, aerosols and other gases). Specifically, to obtain the RF associated with the non-CO_2 EMF emissions only, we calculated the RF associated with the EMF atmospheric CO_2 concentrations and subtracted them from the EMF total RF.[ee] This approach respects the EMF scenarios as much as possible and at the same time takes account of those components not included in the EMF projections. Since each model treats non-CO_2 gases differently (*e.g.*, DICE lumps all other gases into one composite exogenous input), this approach was applied slightly differently in each of the models.

FUND: Rather than relying on RF for these gases, the actual emissions from each scenario were used in FUND. The model default trajectories for CH_4, N_20, SF_6, and the CO_2 emissions from land were replaced with the EMF values.

PAGE: PAGE models CO_2, CH_4, sulfur hexafluoride (SF_6), and aerosols and contains an "excess forcing" vector that includes the RF for everything else. To include the EMF values, we removed the default CH_4 and SF_6 factors[ff], decomposed the excess forcing vector, and constructed a new excess forcing vector that includes the EMF RF for CH_4, N_20, and fluorinated gases, as well as the model default values for aerosols and other factors. Net land use CO_2 emissions were added to the fossil and industrial CO_2 emissions pathway.

DICE: DICE presents the greatest challenge because all forcing due to factors other than industrial CO_2 emissions is embedded in an exogenous non-CO_2 RF vector. To decompose this exogenous forcing path into EMF non-CO_2 gases and other gases, we relied on the references in DICE2007 to the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report (AR4) and the discussion of aerosol forecasts in the IPCC's Third Assessment Report (TAR) and in AR4, as explained below. In DICE2007, Nordhaus assumes that exogenous forcing from all non-CO_2 sources is -0.06 W/m^2 in 2005, as reported in AR4, and increases linearly to 0.3 W/m^2 in 2105, based on GISS projections, and then stays constant after that time.

According to AR4, the RF in 2005 from CH_4, N_20, and halocarbons (approximately similar to the F-gases in the EMF-22 scenarios) was $0.48 + 0.16 + 0.34 = 0.98$ W/m^2 and RF from total aerosols was -1.2 W/m^2. Thus, the -.06 W/m^2 non-CO_2 forcing in DICE can be

---

[ee] Note EMF did not provide CO_2 concentrations for the IMAGE reference scenario. Thus, for this scenario, we fed the fossil, industrial, and land CO_2 emissions into MAGICC (considered a "neutral arbiter" model, which is tuned to emulate the major global climate models) and the resulting CO_2 concentrations were used. Note also that MERGE assumes a neutral biosphere so net land CO_2 emissions are set to zero for all years for the MERGE Optimistic reference scenario, and for the MERGE component of the average 550 scenario (i.e., we add up the land use emissions from the other three models and divide by 4).

[ff] Both the model default CH_4 emissions and the initial atmospheric CH_4 is set to zero to avoid double counting the effect of past CH_4 emissions.

decomposed into: 0.98 W/m^2 due to the EMF non-CO_2 gases, -1.2 W/m^2 due to aerosols, and the remainder, 0.16 W/m^2, due to other residual forcing.

For subsequent years, we calculated the DICE default RF from aerosols and other non-CO_2 gases based on the following two assumptions:

> (1) RF from aerosols declines linearly from 2005 to 2100 at the rate projected by the TAR and then stays constant thereafter; and
> (2) With respect to RF from non-CO_2 gases not included in the EMF-22 scenarios, the share of non-aerosol RF matches the share implicit in the AR4 summary statistics cited above and remains constant over time.

Assumption (1) means that the RF from aerosols in 2100 equals 66 percent of that in 2000, which is the fraction of the TAR projection of total RF from aerosols (including sulfates, black carbon, and organic carbon) in 2100 vs. 2000 under the A1B SRES emissions scenario. Since the SRES marker scenarios were not updated for the AR4, the TAR provides the most recent IPCC projection of aerosol forcing. We rely on the A1B projection from the TAR because it provides one of the lower aerosol forecasts among the SRES marker scenarios and is more consistent with the AR4 discussion of the post-SRES literature on aerosols:

> *Aerosols have a net cooling effect and the representation of aerosol and aerosol precursor emissions, including sulfur dioxide, black carbon and organic carbon, has improved in the post-SRES scenarios. Generally, these emissions are projected to be lower than reported in SRES. {WGIII 3.2, TS.3, SPM}.*[gg]

Assuming a simple linear decline in aerosols from 2000 to 2100 also is more consistent with the recent literature on these emissions. For example, the figure below shows that the sulfur dioxide emissions peak over the short term of some SRES scenarios above the upper bound estimates of the more recent scenarios.[hh] Recent scenarios project sulfur emissions to peak earlier and at lower levels compared to the SRES in part because of new information about present and planned sulfur legislation in some developing countries, such as India and China.[ii] The lower-bound projections of the recent literature have also shifted downward slightly compared to the SRES scenario (IPCC 2007).

[gg] AR4 Synthesis Report, p. 44, www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf

[hh] See Smith, S.J., R. Andres, E. Conception, and J. Lurz, 2004: Historical sulfur dioxide emissions, 1850-2000: methods and results. Joint Global Research Institute, College Park, 14 pp.

[ii] See Carmichael, G., D. Streets, G. Calori, M. Amann, M. Jacobson, J. Hansen, and H. Ueda, 2002: Changing trends in sulphur emissions in Asia: implications for acid deposition, air pollution, and climate. Environmental Science and Technology, 36(22):4707- 4713; Streets, D., K. Jiang, X. Hu, J. Sinton, X.-Q. Zhang, D. Xu, M. Jacobson, and J. Hansen, 2001: Recent reductions in China's greenhouse gas emissions. Science, 294(5548): 1835-1837.

With these assumptions, the DICE aerosol forcing changes from -1.2 in 2005 to -0.792 in 2105 W/m^2; forcing due to other non-CO_2 gases not included in the EMF scenarios declines from 0.160 to 0.153 W/m^2.

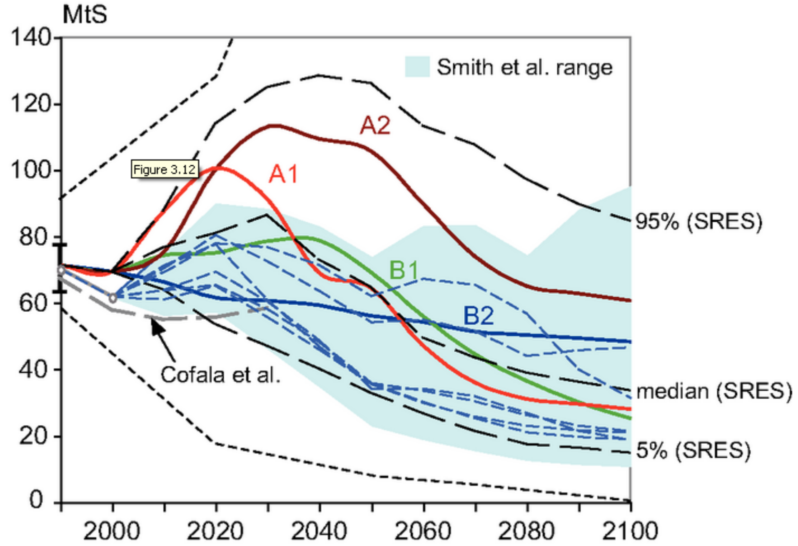

Figure 14A.9.2 Sulfur Dioxide Emission Scenarios

Notes: Thick colored lines depict the four SRES marker scenarios and black dashed lines show the median, 5th, and 95th percentile of the frequency distribution for the full ensemble of 40 SRES scenarios. The blue area (and the thin dashed lines in blue) illustrates individual scenarios and the range of Smith et al. (2004). Dotted lines indicate the minimum and maximum of SO_2 emissions scenarios developed pre-SRES.
Source: IPCC (2007), AR4 WGIII 3.2,
www.ipcc.ch/publications_and_data/ar4/wg3/en/ch3-ens3-2-2-4.html.

Although other approaches to decomposing the DICE exogenous forcing vector are possible, initial sensitivity analysis suggests that the differences among reasonable alternative approaches are likely to be minor. For example, adjusting the TAR aerosol projection above to assume that aerosols will be maintained at 2000 levels through 2100 reduces average SCC values (for 2010) by approximately 3 percent (or less than $2); assuming all aerosols are phased out by 2100 increases average 2010 SCC values by 6-7 percent (or $0.50-$3)–depending on the discount rate. These differences increase slightly for SCC values in later years but are still well within 10 percent of each other as far out as 2050.

Finally, as in PAGE, the EMF net land use CO_2 emissions are added to the fossil and industrial CO_2 emissions pathway.

14A.9.2 Extrapolating Emissions Projections to 2300

To run each model through 2300 requires assumptions about GDP, population, greenhouse gas emissions, and radiative forcing trajectories after 2100, the last year for which these projections are available from the EMF-22 models. These inputs were extrapolated from 2100 to 2300 as follows:

1. Population growth rate declines linearly, reaching zero in the year 2200.
2. GDP/per capita growth rate declines linearly, reaching zero in the year 2300.
3. The decline in the fossil and industrial carbon intensity (CO_2/GDP) growth rate over 2090-2100 is maintained from 2100 through 2300.
4. Net land use CO_2 emissions decline linearly, reaching zero in the year 2200.
5. Non-CO_2 radiative forcing remains constant after 2100.

Long run stabilization of GDP per capita was viewed as a more realistic simplifying assumption than a linear or exponential extrapolation of the pre-2100 economic growth rate of each EMF scenario. This is based on the idea that increasing scarcity of natural resources and the degradation of environmental sinks available for assimilating pollution from economic production activities may eventually overtake the rate of technological progress. Thus, the overall rate of economic growth may slow over the very long run. The interagency group also considered allowing an exponential decline in the growth rate of GDP per capita. However, since this would require an additional assumption about how close to zero the growth rate would get by 2300, the group opted for the simpler and more transparent linear extrapolation to zero by 2300.

The population growth rate is also assumed to decline linearly, reaching zero by 2200. This assumption is reasonably consistent with the United Nations long run population forecast, which estimates global population to be fairly stable after 2150 in the medium scenario (UN 2004).[jj] The resulting range of EMF population trajectories (figure below) also encompass the UN medium scenario forecasts through 2300—global population of 8.5 billion by 2200, and 9 billion by 2300.

Maintaining the decline in the 2090-2100 carbon intensity growth rate (*i.e.*, CO_2 per dollar of GDP) through 2300 assumes that technological improvements and innovations in the areas of energy efficiency and other carbon reducing technologies (possibly including currently unavailable methods) will continue to proceed at roughly the same pace that is projected to occur towards the end of the forecast period for each EMF scenario. This assumption implies that total cumulative emissions in 2300 will be between 5,000 and 12,000 GtC, which is within the range of the total potential global carbon stock estimated in the literature.

Net land use CO_2 emissions are expected to stabilize in the long run, so in the absence of any post 2100 projections, the group assumed a linear decline to zero by 2200. Given no a priori reasons for assuming a long run increase or decline in non-CO_2 radiative forcing, it is assumed to remain at the 2100 levels for each EMF scenario through 2300.

[jj] United Nations. 2004. *World Population to 2300*. www.un.org/esa/population/publications/longrange2/WorldPop2300final.pdf

Figures below show the paths of global population, GDP, fossil and industrial CO_2 emissions, net land CO_2 emissions, non-CO_2 radiative forcing, and CO_2 intensity (fossil and industrial CO_2 emissions/GDP) resulting from these assumptions.

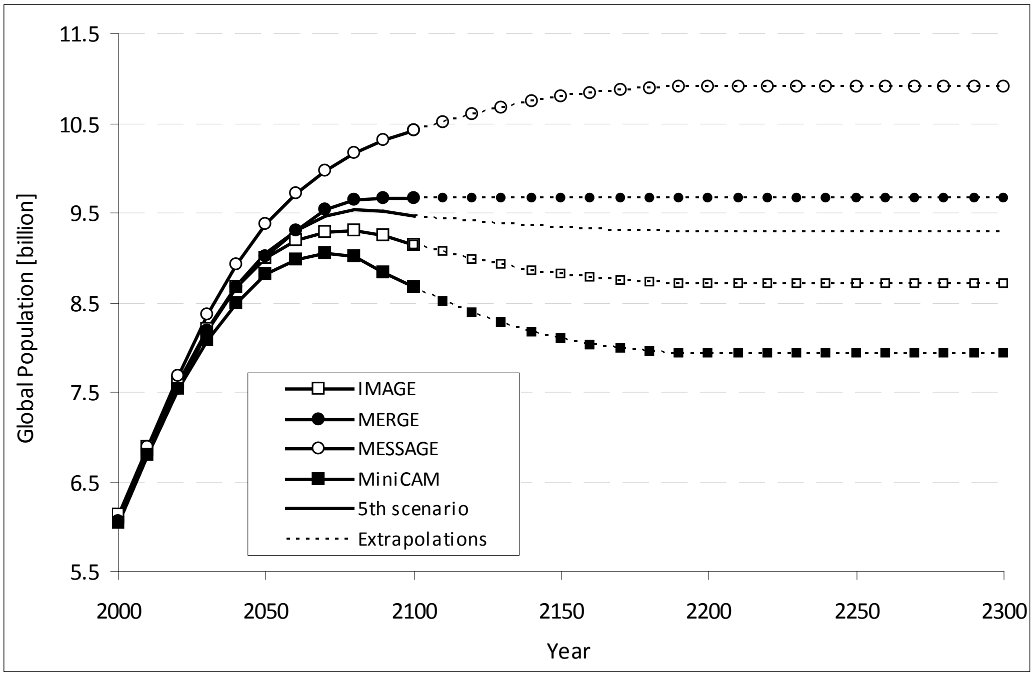

Figure 14A.9.3 Global Population, 2000-2300 (Post-2100 extrapolations assume the population growth rate changes linearly to reach a zero growth rate by 2200.)

Note: In the fifth scenario, 2000-2100 population is equal to the average of the population under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

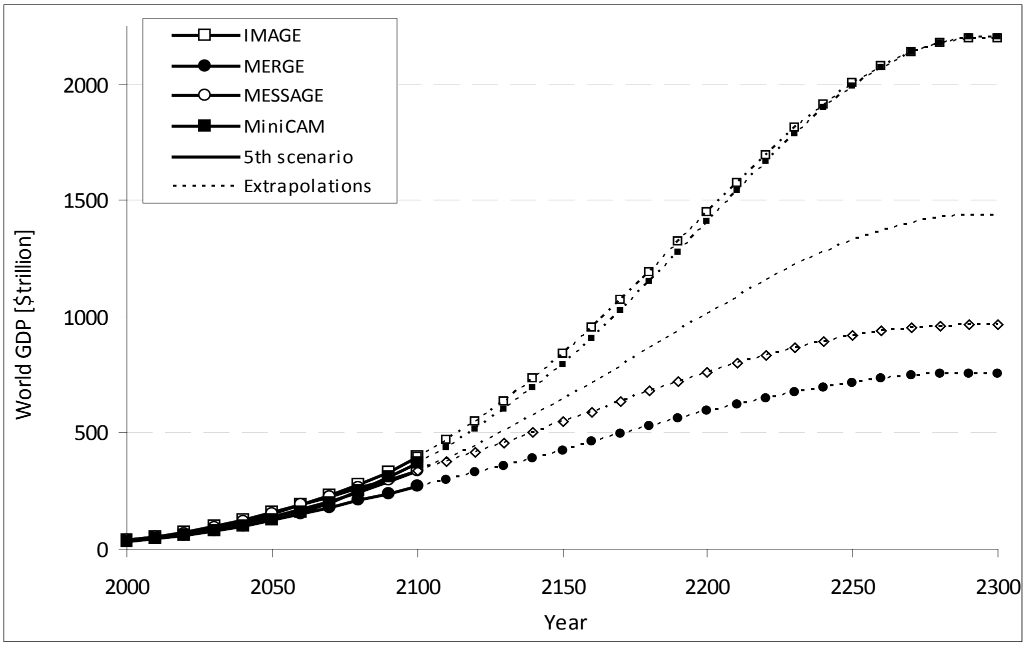

Figure 14A.9.4 World GDP, 2000-2300 (Post-2100 extrapolations assume GDP per capita growth declines linearly, reaching zero in the year 2300)

Note: In the fifth scenario, 2000-2100 GDP is equal to the average of the GDP under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

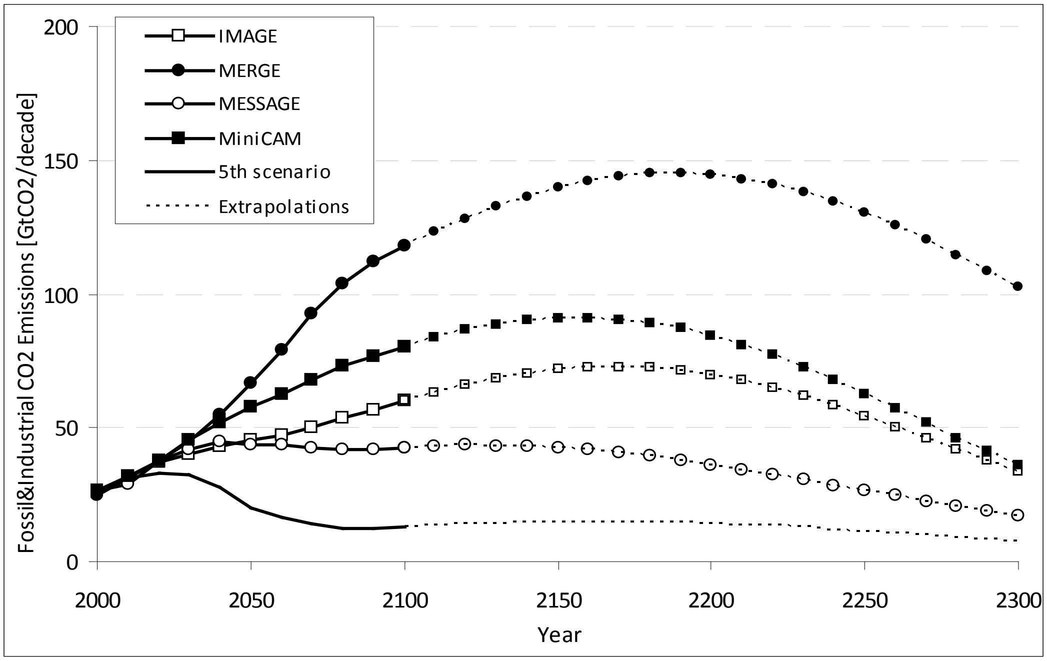

Figure 14A.9.5 Global Fossil and Industrial CO_2 Emissions, 2000-2300 (Post-2100 extrapolations assume growth rate of CO_2 intensity (CO_2/GDP) over 2090-2100 is maintained through 2300)

Note: In the fifth scenario, 2000-2100 emissions are equal to the average of the emissions under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

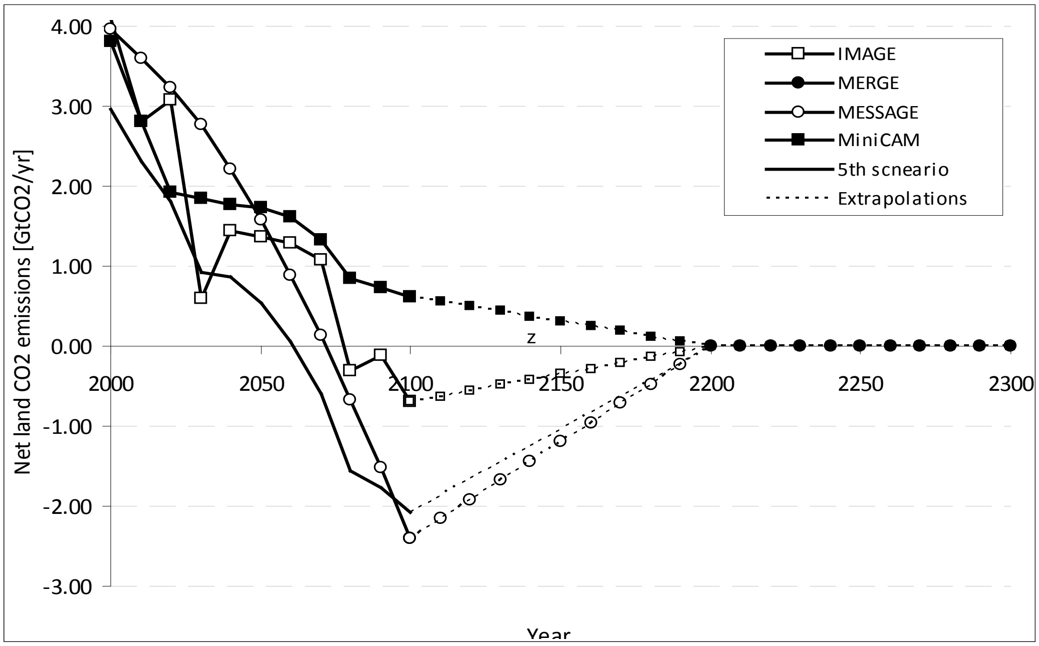

Figure 14A.9.6 Global Net Land Use CO_2 Emissions, 2000-2300 (Post-2100 extrapolations assume emissions decline linearly, reaching zero in the year 2200)[kk]

Note: In the fifth scenario, 2000-2100 emissions are equal to the average of the emissions under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

[kk] MERGE assumes a neutral biosphere so net land CO_2 emissions are set to zero for all years for the MERGE Optimistic reference scenario, and for the MERGE component of the average 550 scenario (i.e., we add up the land use emissions from the other three models and divide by 4).

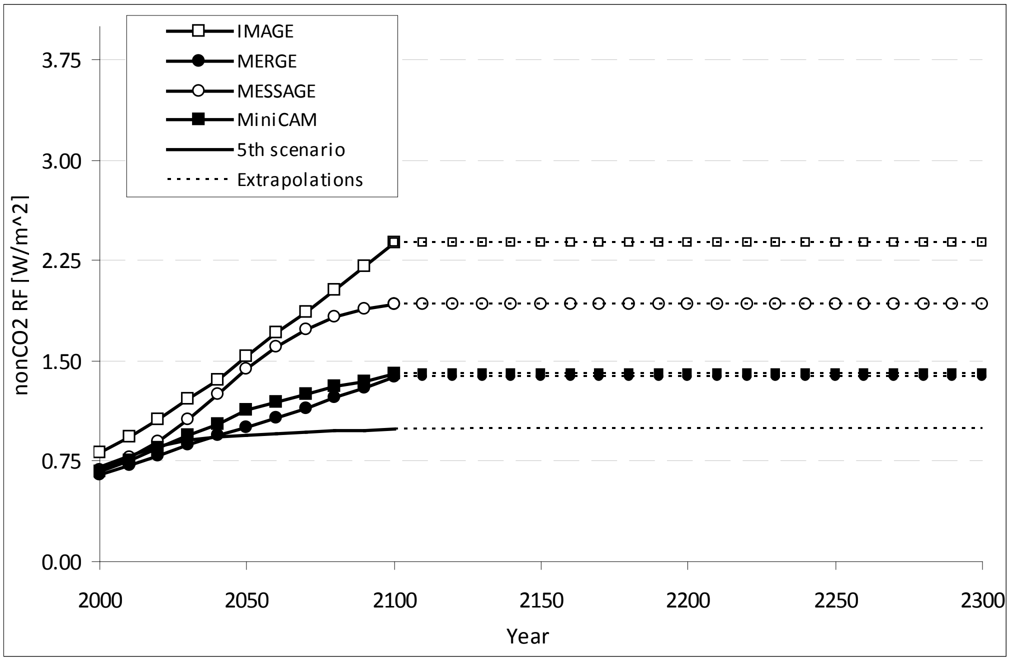

Figure 14A.9.7 Global Non-CO$_2$ Radiative Forcing, 2000-2300 (Post-2100 extrapolations assume constant non-CO$_2$ radiative forcing after 2100)

Note: In the fifth scenario, 2000-2100 emissions are equal to the average of the emissions under the 550 ppm CO$_2$e, full-participation, not-to-exceed scenarios considered by each of the four models.

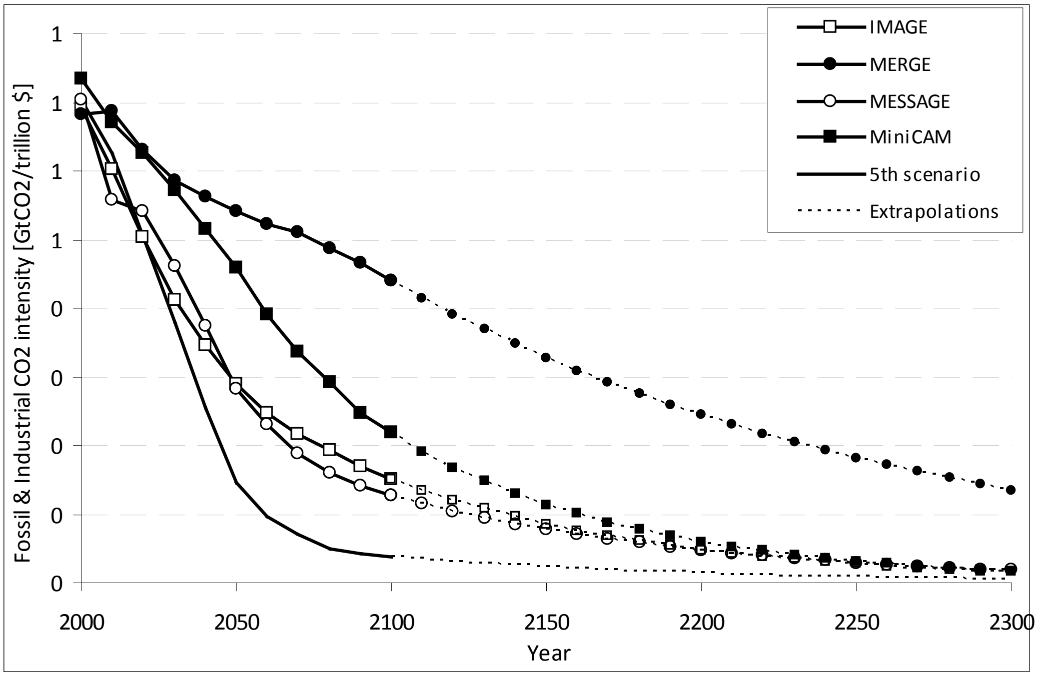

Figure 14A.9.8 **Global CO_2 Intensity (fossil & industrial CO_2 emissions/GDP), 2000-2300 (Post-2100 extrapolations assume decline in CO_2/GDP growth rate over 2090-2100 is maintained through 2300)**

Note: In the fifth scenario, 2000-2100 emissions are equal to the average of the emissions under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

Table 14A.9.2 2010 Global SCC Estimates at 2.5 Percent Discount Rate (2007$/ton CO_2)

Percentile	1st	5th	10th	25th	50th	Avg	75th	90th	95th	99th
Scenario	**PAGE**									
IMAGE	3.3	5.9	8.1	13.9	28.8	65.5	68.2	147.9	239.6	563.8
MERGE optimistic	1.9	3.2	4.3	7.2	14.6	34.6	36.2	79.8	124.8	288.3
Message	2.4	4.3	5.8	9.8	20.3	49.2	50.7	114.9	181.7	428.4
MiniCAM base	2.7	4.6	6.4	11.2	22.8	54.7	55.7	120.5	195.3	482.3
5th scenario	2.0	3.5	4.7	8.1	16.3	42.9	41.5	103.9	176.3	371.9

Scenario	**DICE**									
IMAGE	16.4	21.4	25	33.3	46.8	54.2	69.7	96.3	111.1	130.0
MERGE optimistic	9.7	12.6	14.9	19.7	27.9	31.6	40.7	54.5	63.5	73.3
Message	13.5	17.2	20.1	27	38.5	43.5	55.1	75.8	87.9	103.0
MiniCAM base	13.1	16.7	19.8	26.7	38.6	44.4	56.8	79.5	92.8	109.3
5th scenario	10.8	14	16.7	22.2	32	37.4	47.7	67.8	80.2	96.8

Scenario	**FUND**									
IMAGE	-33.1	-18.9	-13.3	-5.5	4.1	19.3	18.7	43.5	67.1	150.7
MERGE optimistic	-33.1	-14.8	-10	-3	5.9	14.8	20.4	43.9	65.4	132.9
Message	-32.5	-19.8	-14.6	-7.2	1.5	8.8	13.8	33.7	52.3	119.2
MiniCAM base	-31.0	-15.9	-10.7	-3.4	6	22.2	21	46.4	70.4	152.9
5th scenario	-32.2	-21.6	-16.7	-9.7	-2.3	3	6.7	20.5	34.2	96.8

Table 14A.9.3 2010 Global SCC Estimates at 3 Percent Discount Rate (2007$/ton CO_2)

Percentile	1st	5th	10th	25th	50th	Avg	75th	90th	95th	99th
Scenario	**PAGE**									
IMAGE	2.0	3.5	4.8	8.1	16.5	39.5	41.6	90.3	142.4	327.4
MERGE optimistic	1.2	2.1	2.8	4.6	9.3	22.3	22.8	51.3	82.4	190.0
Message	1.6	2.7	3.6	6.2	12.5	30.3	31	71.4	115.6	263.0
MiniCAM base	1.7	2.8	3.8	6.5	13.2	31.8	32.4	72.6	115.4	287.0
5th scenario	1.3	2.3	3.1	5	9.6	25.4	23.6	62.1	104.7	222.5

Scenario	**DICE**									
IMAGE	11.0	14.5	17.2	22.8	31.6	35.8	45.4	61.9	70.8	82.1
MERGE optimistic	7.1	9.2	10.8	14.3	19.9	22	27.9	36.9	42.1	48.8
Message	9.7	12.5	14.7	19	26.6	29.8	37.8	51.1	58.6	67.4
MiniCAM base	8.8	11.5	13.6	18	25.2	28.8	36.9	50.4	57.9	67.8
5th scenario	7.9	10.1	11.8	15.6	21.6	24.9	31.8	43.7	50.8	60.6

Scenario	**FUND**									
IMAGE	-25.2	-15.3	-11.2	-5.6	0.9	8.2	10.4	25.4	39.7	90.3
MERGE optimistic	-24.0	-12.4	-8.7	-3.6	2.6	8	12.2	27	41.3	85.3
Message	-25.3	-16.2	-12.2	-6.8	-0.5	3.6	7.7	20.1	32.1	72.5
MiniCAM base	-23.1	-12.9	-9.3	-4	2.4	10.2	12.2	27.7	42.6	93.0
5th scenario	-24.1	-16.6	-13.2	-8.3	-3	-0.2	2.9	11.2	19.4	53.6

Table 14A.9.4 2010 Global SCC Estimates at 5 Percent Discount Rate (2007$/ton CO_2)

Percentile	1st	5th	10th	25th	50th	Avg	75th	90th	95th	99th
Scenario	**PAGE**									
IMAGE	0.5	0.8	1.1	1.8	3.5	8.3	8.5	19.5	31.4	67.2
MERGE optimistic	0.3	0.5	0.7	1.2	2.3	5.2	5.4	12.3	19.5	42.4
Message	0.4	0.7	0.9	1.6	3	7.2	7.2	17	28.2	60.8
MiniCAM base	0.3	0.6	0.8	1.4	2.7	6.4	6.6	15.9	24.9	52.6
5th scenario	0.3	0.6	0.8	1.3	2.3	5.5	5	12.9	22	48.7

Scenario	**DICE**									
IMAGE	4.2	5.4	6.2	7.6	10	10.8	13.4	16.8	18.7	21.1
MERGE optimistic	2.9	3.7	4.2	5.3	7	7.5	9.3	11.7	12.9	14.4
Message	3.9	4.9	5.5	7	9.2	9.8	12.2	15.4	17.1	18.8
MiniCAM base	3.4	4.2	4.7	6	7.9	8.6	10.7	13.5	15.1	16.9
5th scenario	3.2	4	4.6	5.7	7.6	8.2	10.2	12.8	14.3	16.0

Scenario	**FUND**									
IMAGE	-11.7	-8.4	-6.9	-4.6	-2.2	-1.3	0.7	4.1	7.4	17.4
MERGE optimistic	-10.6	-7.1	-5.6	-3.6	-1.3	-0.3	1.6	5.4	9.1	19.0
Message	-12.2	-8.9	-7.3	-4.9	-2.5	-1.9	0.3	3.5	6.5	15.6
MiniCAM base	-10.4	-7.2	-5.8	-3.8	-1.5	-0.6	1.3	4.8	8.2	18.0
5th scenario	-10.9	-8.3	-7	-5	-2.9	-2.7	-0.8	1.4	3.2	9.2

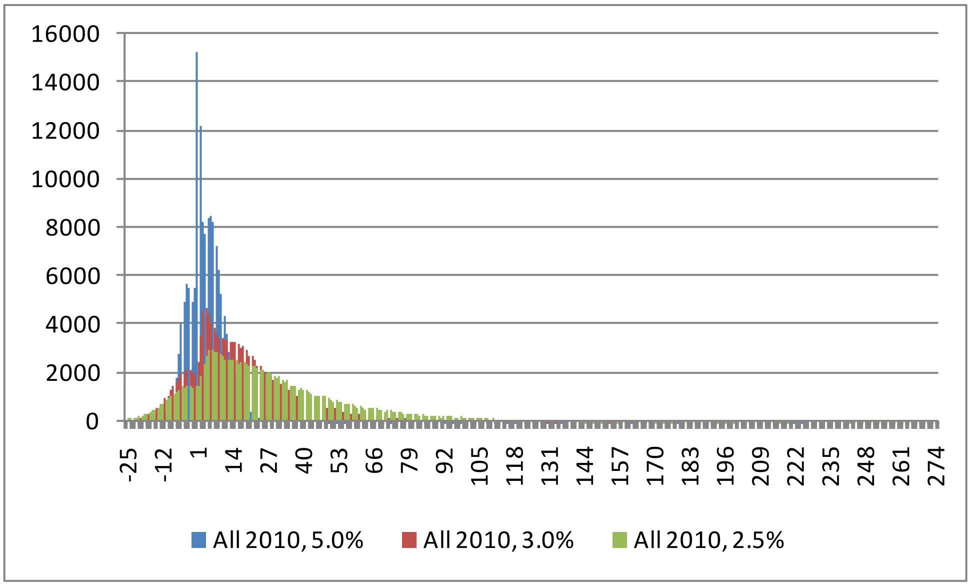

Figure 14A.9.9 Histogram of Global SCC Estimates in 2010 (2007$/ton CO_2), by discount rate

* The distribution of SCC values ranges from -$5,192 to $66,116, but the X-axis has been truncated at approximately the 1st and 99th percentiles to better show the data.

Table 14A.9.5 Additional Summary Statistics of 2010 Global SCC Estimates

Discount Rate		Scenario		
		DICE	PAGE	FUND
5%	Mean	9	6.5	-1.3
	Variance	13.1	136	70.1
	Skewness	0.8	6.3	28.2
	Kurtosis	0.2	72.4	1,479.00
3%	Mean	28.3	29.8	6
	Variance	209.8	3,383.70	16,382.50
	Skewness	1.1	8.6	128
	Kurtosis	0.9	151	18,976.50
2.50%	Mean	42.2	49.3	13.6
	Variance	534.9	9,546.00	#######
	Skewness	1.2	8.7	149
	Kurtosis	1.1	143.8	23,558.30

APPENDIX 14B. TECHNICAL UPDATE OF SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12866

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APPENDIX 14B. TECHNICAL UPDATE OF SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12866

14B.1 PREFACE

The following text is reproduced almost verbatim from the May 2013 report of the Interagency Working Group on the Social Cost of Carbon of the United States Government. Minor changes were made to the working group's report to make it more consistent with the rest of this technical support document.

14B.2 PURPOSE

The purpose of this document is to update the schedule of social cost of carbon (SCC) [a] estimates from the 2010 interagency technical support document (TSD) (Interagency Working Group on Social Cost of Carbon 2010).[1] E.O. 13563 commits the Administration to regulatory decision making "based on the best available science."[b] Additionally, the interagency group recommended in 2010 that the SCC estimates be revisited on a regular basis or as model updates that reflect the growing body of scientific and economic knowledge become available.[c] New versions of the three integrated assessment models used by the U.S. government to estimate the SCC (DICE, FUND, and PAGE), are now available and have been published in the peer reviewed literature. While acknowledging the continued limitations of the approach taken by the interagency group in 2010 (documented in the original 2010 TSD), this document provides an update of the SCC estimates based solely on the latest peer-reviewed version of the models, replacing model versions that were developed up to ten years ago in a rapidly evolving field. It does not revisit other assumptions with regard to the discount rate, reference case socioeconomic and emission scenarios, or equilibrium climate sensitivity. Improvements in the way damages are modeled are confined to those that have been incorporated into the latest versions of the models by the developers themselves in the peer-reviewed literature. The Environmental Protection Agency (EPA), in collaboration with other Federal agencies such as the Department of Energy (DOE), continues to investigate potential improvements to the way in which economic damages associated with changes in CO_2 emissions are quantified.

Section 14B.3 summarizes the major updates relevant to SCC estimation that are contained in the new versions of the integrated assessment models released since the 2010 interagency report. Section 14B.4 presents the updated schedule of SCC estimates for 2010 – 2050 based on these versions of the models.

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[a] In this document, we present all values of the SCC as the cost per metric ton of CO_2 emissions. Alternatively, one could report the SCC as the cost per metric ton of carbon emissions. The multiplier for translating between mass of CO_2 and the mass of carbon is 3.67.

[b] www.whitehouse.gov/sites/default/files/omb/inforeg/eo12866/eo13563_01182011.pdf

[c] See p. 1, 3, 4, 29, and 33 (Interagency Working Group on Social Cost of Carbon 2010).[1]

14B.3 SUMMARY OF MODEL UPDATES

This section briefly summarizes changes integrated into the most recent versions of the three integrated assessment models (IAMs) used by the interagency group in 2010. We focus on describing those model updates that are relevant to estimating the social cost of carbon. For example, both the DICE and PAGE models now include an explicit representation of sea level rise damages. Other revisions to PAGE include: updated adaptation assumptions, revisions to ensure damages are constrained GDP, updated regional scaling of damages, and a revised treatment of potentially abrupt shifts in climate damages. In the most recent version of DICE, the model's simple carbon cycle has been updated to be more consistent with a relatively more complex climate model. The FUND model includes updated damage functions for sea level rise impacts, the agricultural sector, and reduced space heating requirements, as well as changes to the response of temperature to the buildup of GHG concentrations and the inclusion of indirect effects of methane emissions. Changes made to parts of the models that are superseded by the interagency working group's modeling assumptions – regarding climate sensitivity, discounting, and socioeconomic variables – are not discussed.

14B.3.1 DICE

Changes in the DICE model relevant for the SCC estimates developed by the interagency working group include: 1) updated parameter values for the carbon cycle model, 2) an explicit representation of sea level dynamics, and 3) a re-calibrated damage function that includes an explicit representation of economic damages from sea level rise. Changes were also made to other parts of the DICE model—including the equilibrium climate sensitivity parameter, the rate of change of total factor productivity, and the elasticity of the marginal utility of consumption—but these components of DICE are superseded by the interagency working group's assumptions and so will not be discussed here. More details on DICE2007 can be found in Nordhaus (2008)[2] and on DICE2010 in Nordhaus (2010)[3] and the associated on-line appendix containing supplemental information.

Carbon Cycle Parameters

DICE uses a three-box model of carbon stocks and flows to represent the accumulation and transfer of carbon among the atmosphere, the shallow ocean and terrestrial biosphere, and the deep ocean. These parameters are "calibrated to match the carbon cycle in the Model for the Assessment of Greenhouse Gas Induced Climate Change (MAGICC)" (Nordhaus 2008 p 44).[2d] Carbon cycle transfer coefficient values in DICE2010 are based on re-calibration of the model to match the newer version of MAGICC (Nordhaus 2010 p 2).[3] For example, in DICE2010 in each decade, 12 percent of the carbon in the atmosphere is transferred to the shallow ocean, 4.7 percent of the carbon in the shallow ocean is transferred to the atmosphere, 94.8 percent remains in the shallow ocean, and 0.5 percent is transferred to the deep ocean. For comparison, in DICE 2007, 18.9 percent of the carbon in the atmosphere is transferred to the shallow ocean each decade, 9.7 percent of the carbon in the shallow ocean is transferred to the atmosphere, 85.3 percent remains in the shallow ocean, and 5 percent is transferred to the deep ocean.

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[d] MAGICC is a simple climate model initially developed within the U.S. National Center for Atmospheric Research that has been used heavily by the Intergovernmental Panel on Climate Change (IPCC) to emulate projections from much more sophisticated state of the art earth system simulation models (Randall et al. 2007).[4]

The implication of these changes for DICE2010 is in general a weakening of the ocean as a carbon sink and therefore a higher concentration of carbon in the atmosphere than in DICE2007, for a given path of emissions. All else equal, these changes will generally increase the level of warming and therefore the SCC estimates in DICE2010 relative to those from DICE2007.

14B.3.1.1 Sea Level Dynamics

A new feature of DICE2010 is an explicit representation of the dynamics of the global average sea level anomaly to be used in the updated damage function (discussed below). This section contains a brief description of the sea level rise (SLR) module; a more detailed description can be found on the model developer's website.[e] The average global sea level anomaly is modeled as the sum of four terms that represent contributions from: 1) thermal expansion of the oceans, 2) melting of glaciers and small ice caps, 3) melting of the Greenland ice sheet, and 4) melting of the Antarctic ice sheet.

The parameters of the four components of the SLR module are calibrated to match consensus results from the IPCC's Fourth Assessment Report.[4,f] The rise in sea level from thermal expansion in each time period (decade) is 2 percent of the difference between the sea level in the previous period and the long run equilibrium sea level, which is 0.5 meters per degree Celsius (°C) above the average global temperature in 1900. The rise in sea level from the melting of glaciers and small ice caps occurs at a rate of 0.008 meters per decade per °C above the average global temperature in 1900.

The contribution to sea level rise from melting of the Greenland ice sheet is more complex. The equilibrium contribution to SLR is 0 meters for temperature anomalies less than 1 ^{o}C and increases linearly from 0 meters to a maximum of 7.3 meters. The contribution to SLR in each period is proportional to the difference between the previous period's sea level anomaly and the equilibrium sea level anomaly, where the constant of proportionality increases with the temperature anomaly in the current period.

The contribution to SLR from the melting of the Antarctic ice sheet is -0.001 meters per decade when the temperature anomaly is below 3 °C and increases linearly to a maximum rate of 0.025 meters per decade at a temperature anomaly of 6 °C.

14B.3.1.2 Re-calibrated Damage Function

Economic damages from climate change in the DICE model are represented by a fractional loss of gross economic output in each period. A portion of the remaining economic output in each period (net of climate change damages) is consumed and the remainder is invested in the physical capital stock to support future production, so each period's climate damages will

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[e] Documentation on the new sea level rise module of DICE is available on William Nordhaus' website at: http://aida.econ.yale.edu/~nordhaus/homepage/documents/SLR_021910.pdf.

[f] For a review of post-IPCC AR4 research on sea level rise, see Nicholls et al. (2011)[5] and NAS (2011).[6]

reduce consumption in that period and in all future periods due to the lost investment. The fraction of output in each period that is lost due to climate change impacts is represented as one minus a fraction, which is one divided by a quadratic function of the temperature anomaly, producing a sigmoid ("S"-shaped) function. The loss function in DICE2010 has been expanded by adding a quadratic function of SLR to the quadratic function of temperature. In DICE2010 the temperature anomaly coefficients have been recalibrated to avoid double-counting damages from sea level rise that were implicitly included in these parameters in DICE2007.

The aggregate damages in DICE2010 are illustrated by Nordhaus (2010 p 3),[3] who notes that "…damages in the uncontrolled (baseline) (*i.e.*, reference) case … in 2095 are $12 trillion, or 2.8 percent of global output, for a global temperature increase of 3.4 ^{o}C above 1900 levels." This compares to a loss of 3.2 percent of global output at 3.4 ^{o}C in DICE2007. However, in DICE2010 (as downloaded from the homepage of William Nordhaus), annual damages are lower in most of the early periods but higher in later periods of the time horizon than would be calculated using the DICE2007 damage function. Specifically, the percent difference between damages in the base run of DICE2010 and those that would be calculated using the DICE2007 damage function starts at +7 percent in 2005, decreases to a low of -14 percent in 2065, then continuously increases to +20 percent by 2300 (the end of the interagency analysis time horizon), and to +160 percent by the end of the model time horizon in 2595. The large increases in the far future years of the time horizon are due to the permanence associated with damages from sea level rise, along with the assumption that the sea level is projected to continue to rise long after the global average temperature begins to decrease. The changes to the loss function generally decrease the interagency working group SCC estimates slightly, all else equal.

14B.3.2 FUND

FUND version 3.8 includes a number of changes over the previous version 3.5 used in the interagency report. Documentation supporting FUND and the model's source code for all versions of the model is available from the model authors.[g] Notable changes, due to their impact on the estimates of expected SCC, are adjustments to the space heating, agriculture, and sea level rise damage functions in addition to changes to the temperature response function and the inclusion of indirect effects from methane emissions.[h] We discuss each of these in turn.

14B.3.2.1 Space Heating

In FUND, the damages associated with the change in energy needs for space heating are based on the estimated impact due to one degree of warming. These baseline damages are scaled based on the forecasted temperature anomaly's deviation from the one degree benchmark and adjusted for changes in vulnerability due to economic and energy efficiency growth. In FUND

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[g] www.fund-model.org/. This report uses version 3.8 of the FUND model, which represents a modest update to the most recent version of the model to appear in the literature (version 3.7) (Anthoff and Tol, 2013).[7] For the purpose of computing the SCC, the relevant changes are associated with improving consistency with IPCC AR4 by adjusting the atmospheric lifetimes of CH4 and N2O and incorporating the indirect forcing effects of CH4, along with making minor stability improvements in the sea wall construction algorithm.

[h] The other damage sectors (water resources, space cooling, land loss, migration, ecosystems, human health, and extreme weather) were not the subject of significant updates.

3.5, the function that scales the base year damages adjusted for vulnerability allows for the possibility that in some simulations the benefits associated with reduced heating needs may be an unbounded convex function of the temperature anomaly. In FUND 3.8, the form of the scaling has been modified to ensure that the function is everywhere concave, meaning that for every simulation there will exist an upper bound on the benefits a region may receive from reduced space heating needs. The new formulation approaches a value of two in the limit as the temperature anomaly increases, or in other words, assuming no decrease in vulnerability, the reduced expenditures on space heating at any level of warming will not exceed two times the reductions experienced at one degree of warming. Since the reduced need for space heating represents a benefit of climate change in the model, or a negative damage, this change will increase the estimated SCC. This update accounts for a significant portion of the difference in the expected SCC estimates reported by the two versions of the model when run probabilistically.

14B.3.2.2 Sea Level Rise and Land Loss

The FUND model explicitly includes damages associated with the inundation of dry land due to sea level rise. The amount of land lost within a region is dependent upon the proportion of the coastline being protected by adequate sea walls and the amount of sea level rise. In FUND 3.5 the function defining the potential land lost in a given year due to sea level rise is linear in the rate of sea level rise for that year. This assumption implicitly assumes that all regions are well represented by a homogeneous coastline in length and a constant uniform slope moving inland. In FUND 3.8 the function defining the potential land lost has been changed to be a non-linear function of sea level rise, thereby assuming that the slope of the shore line is not constant moving inland, with a positive first derivative. The effect of this change is to typically reduce the vulnerability of some regions to sea level rise based land loss, therefore having an effect of lowering the expected SCC estimate. The model has also been updated to assume that the value of dry land at risk of inundation is not uniform across a region but will be a decreasing function of protection measure, thereby implicitly assuming that the most valuable land will be protected first.

14B.3.2.3 Agriculture

In FUND, the damages associated with the agricultural sector are measured as proportional to the sector’s value. The fraction is made up of three additively separable components that represent the effects from carbon fertilization, the rate of temperature change, and the level of the temperature anomaly. In both FUND 3.5 and FUND 3.8, the fraction of the sector’s value lost due to the level of the temperature anomaly is modeled as a quadratic function with an intercept of zero. In FUND 3.5, the linear and quadratic coefficients are modeled as the ratio of two normal distributions. Within this specification, as draws from the distribution in the denominator approached zero the share of the sector’s value “lost” approaches (+/-) infinity independent of the temperature anomaly itself. In FUND 3.8, the linear and quadratic coefficients are drawn directly from truncated normal distributions so that they remain in the range $[0,\infty)$ and $(-\infty,0]$, respectively, where the means for the new distributions are set equal to the ratio of the means from the normal distributions used in the previous version. In general the impact of this change has been to increase the likelihood that increases in the temperature level will have either larger positive or negative effects on the agricultural sector relative to the previous version (through eliminating simulations in which the “lost” value approached (+/-) infinity). The net effect of this change on the SCC estimates is difficult to predict.

14B.3.2.4 Temperature Response Model

The temperature response model translates changes in global levels of radiative forcing into the current expected temperature anomaly. In FUND, a given year’s increase in the cumulative temperature anomaly is based on a mean reverting function where the mean equals the equilibrium temperature anomaly that would eventually be reached if that year’s level of radiative forcing were sustained. The rate of mean reversion defines the rate at which the transient temperature approaches the equilibrium. In FUND 3.5, the rate of temperature response is defined as a decreasing linear function of equilibrium climate sensitivity to capture the fact that the progressive heat uptake of the deep ocean causes the rate to slow at higher values of the equilibrium climate sensitivity. In FUND 3.8, the rate of temperature response has been updated to a quadratic function of the equilibrium climate sensitivity. This change reduces the sensitivity of the rate of temperature response to the level of the equilibrium climate sensitivity. Therefore in FUND 3.8, the temperature response will typically be faster than in the previous version. The overall effect of this change is likely to increase estimates of the SCC as higher temperatures are reached during the timeframe analyzed and as the same damages experienced in the previous version of the model are now experienced earlier and therefore discounted less.

14B.3.2.5 Methane

The IPCC notes a series of indirect effects of methane emissions, and has developed methods for proxying such effects when computing the global warming potential of methane (Forster et al. 2007).[8] FUND 3.8 now includes the same methods for incorporating the indirect effects of methane emissions. Specifically, the average atmospheric lifetime of methane has been set to 12 years to account for the feedback of CH4 emissions on its own lifetime. The radiative forcing associated with atmospheric methane has also been increase by 40% to account for its net impact on ozone production and increase in stratospheric water vapor. The general effect of this increased radiative forcing will be to increase the estimated SCC values, where the degree to which this occurs will be dependent upon the relative curvature of the damage functions with respect to the temperature anomaly.

14B.3.3 PAGE

PAGE09 (Hope 2012)[9] includes a number of changes from PAGE2002, the version used in the 2009 SCC interagency report. The changes that most directly affect the SCC estimates include: explicitly modeling the impacts from sea level rise, revisions to the damage function to ensure damages are constrained by GDP, a change in the regional scaling of damages, a revised treatment for the probability of a discontinuity within the damage function, and revised assumptions on adaptation. The model also includes revisions to the carbon cycle feedback and the calculation of regional temperatures. More details on PAGE2009 can be found in three working papers (Hope 2011a, 2011b, 2011c).[10, 11, 12] A description of PAGE2002 can be found in Hope (2006).[13]

14B.3.3.1 Sea Level Rise

While PAGE2002 aggregates all damages into two categories – economic and non-economic impacts - PAGE2009 adds a third explicit category: damages from sea level rise. In the previous version of the model, damages from sea level rise were subsumed by the other damage categories. PAGE09 models damages from sea level rise as increasing less than linearly with sea level based on the assumption that low-lying shoreline areas will be associated with higher damages than current inland areas. Damages from the economic and non-economic sector were adjusted to account for the introduction of this new category.

14B.3.3.2 Revised Damage Function to Account for Saturation

In PAGE09, small initial economic and non-economic benefits (negative damages) are modeled for small temperature increases, but all regions eventually experience positive economic damages from climate change, where damages are the sum of additively separable polynomial functions of temperature and sea level rise. Damages transition from this polynomial function to a logistic path once they exceed a certain proportion of remaining Gross Domestic Product (GDP) to ensure that damages do not exceed 100 percent of GDP. This differs from PAGE2002, which allowed Eastern Europe to potentially experience large benefits from temperature increases, and which also did not bound the possible damages that could be experienced.

14B.3.3.3 Regional Scaling Factors

As in the previous version of PAGE, the PAGE09 model calculates the damages for the European Union (EU) and then, assumes that damages for other regions are proportional based on a given scaling factor. The scaling factor in PAGE09 is based on the length of a region's coastline relative to the EU (Hope 2011b).[11] Because of the long coastline in the EU, other regions are, on average, less vulnerable than the EU for the same sea level and temperature increase, but all regions have a positive scaling factor. PAGE2002 based its scaling factors on four studies reported in the IPCC's third assessment report, and allowed for benefits from temperature increase in Eastern Europe, smaller impacts in developing countries, and higher damages in developing countries.

14B.3.3.4 Probability of a Discontinuity

In PAGE2002, the damages associated with a "discontinuity" were modeled as an expected value. That is, additional damages from an extreme event, such as extreme melting of the Greenland ice sheet, were multiplied by the probability of the event occurring and added to the damage estimate. In PAGE09, the probability of "discontinuity" is treated as a discrete event for each year in the model. The damages for each model run are estimated with or without a discontinuity occurring, rather than as an expected value. A large-scale discontinuity becomes possible when the temperature rises beyond some threshold value between 2 and 4°C. The probability that a discontinuity will occur beyond this threshold then increases by between 10 and 30 percent for every 1°C rise in temperature beyond the threshold. If a discontinuity occurs, the EU loses an additional 5 to 25 percent of its GDP (drawn from a triangular distribution with a mean of 15 percent) in addition to other damages, and other regions lose an amount determined by the regional scaling factor. The threshold value for a possible discontinuity is lower than in PAGE2002, while the rate at which the probability of a discontinuity increases with the temperature anomaly and the damages that result from a discontinuity are both higher than in PAGE2002. The model assumes that only one discontinuity can occur and that the impact is phased in over a period of time, but once it occurs, its effect is permanent.

14B.3.3.5 Adaptation

As in PAGE2002, adaptation is available to increase the tolerable level of temperature change and can help mitigate any climate change impacts that still occur. In PAGE this adaptation is the same regardless of the temperature change or sea level rise and is therefore akin to what is more commonly considered a reduction in vulnerability. It is modeled by modifying the temperature change and sea level rise used in the damage function or by reducing the damages by some percentage. PAGE09 assumes a smaller decrease in vulnerability than the previous version of the model and assumes that it will take longer for this change in vulnerability to be realized. In the aggregated economic sector, at the time of full implementation, this adaptation will mitigate all damages up to a temperature increase of 1°C, and for temperature anomalies between 1°C and 3°C, it will reduce damages by 15-30 percent (depending on the region). However, it takes 20 years to fully implement this adaptation. In PAGE2002, adaptation was assumed to reduce economic sector damages up to 3°C by 50-90 percent after 20 years. Beyond 3°C, no adaptation is assumed to be available to mitigate the impacts of climate change. For the non-economic sector, in PAGE09 adaptation is available to reduce 15 percent of the damages due to a temperature increase between 0°C and 2°C and is assumed to take 40 years to fully implement, instead of 25 percent of the damages over 20 years assumed in PAGE2002. Similarly, adaptation is assumed to alleviate 25-50 percent of the damages from the first 0.20 to 0.25 meters of sea level rise but is assumed to be ineffective thereafter. Hope (2011c)[12] estimates that the less optimistic assumptions regarding the ability to offset impacts of temperature and sea level rise via adaptation increase the SCC by approximately 30 percent.

14B.3.3.6 Other Noteworthy Changes

Two other changes in the model are worth noting. A revised carbon cycle feedback is introduced to simulate decreased CO_2 absorption by the terrestrial biosphere and ocean as the temperature rises. This feedback is linear in the average global and annual temperature anomaly but is capped at a maximum value. In the previous version of PAGE, an additional amount was added to the CO_2 emissions each period to account for a decrease in ocean absorption and a loss of soil carbon. Also updated is the method by which the average global and annual temperature anomaly is downscaled to determine annual average regional temperature anomalies to be used in the regional damage functions. In the previous version of PAGE, the scaling was determined solely based on regional difference in emissions of sulfate aerosols. In PAGE09, this regional temperature anomaly is further adjusted using an additive factor that is based on the average absolute latitude of a region relative to the area weighted average absolute latitude of the Earth's landmass.

14B.4 REVISED SCC ESTIMATES

The updated versions of the three integrated assessment models were run using the same methodology detailed in the 2010 TSD.[1] The approach along with the inputs for the socioeconomic emissions scenarios, equilibrium climate sensitivity distribution, and discount rate remains the same. This includes the five reference scenarios based on the EMF-22 modeling exercise, the Roe and Baker equilibrium climate sensitivity distribution calibrated to the Fourth Assessment Report of the IPCC, and three constant discount rates of 2.5, 3, and 5 percent.

As was previously the case, the use of three models, three discount rates, and five scenarios produces 45 separate distributions for the SCC. The approach laid out in the TSD applied equal weight to each model and socioeconomic scenario in order to reduce the dimensionality down to three separate distributions representative of the three discount rates. The interagency group selected four values from these distributions for use in regulatory analysis. Three values are based on the average SCC across models and socio-economic-emissions scenarios at the 2.5, 3, and 5 percent discount rates, respectively. The fourth value was chosen to represent the higher-than-expected economic impacts from climate change further out in the tails of the SCC distribution. For this purpose, the 95th percentile of the SCC estimates at a 3 percent discount rate was chosen. (A detailed set of percentiles by model and scenario combination is available in the Annex.) As noted in the original TSD, “the 3 percent discount rate is the central value, and so the central value that emerges is the average SCC across models at the 3 percent discount rate” (TSD, p. 25). However, for purposes of capturing the uncertainties involved in regulatory impact analysis, the interagency group emphasizes the importance and value of including all four SCC values.

Table 14B.4.1 shows the four selected SCC estimates in five year increments from 2010 to 2050. Values for 2010, 2020, 2030, 2040, and 2050 are calculated by first combining all outputs (10,000 estimates per model run) from all scenarios and models for a given discount rate. Values for the years in between are calculated using basic linear interpolation. The full set of annual SCC estimates between 2010 and 2050 is reported in the Annex.

Table 14B.4.1 Revised Social Cost of CO_2, 2010 – 2050 (in 2007 dollars per ton of CO_2)

Discount Rate Year	5.0% Avg	3.0% Avg	2.5% Avg	3.0% 95th
2010	11	32	51	89
2015	11	37	57	109
2020	12	43	64	128
2025	14	47	69	143
2030	16	52	75	159
2035	19	56	80	175
2040	21	61	86	191
2045	24	66	92	206
2050	26	71	97	220

The SCC estimates using the updated versions of the models are higher than those reported in the TSD due to the changes to the models outlined in the previous section. Figure 14B.4.1 illustrates where the four SCC values for 2020 fall within the full distribution for each discount rate based on the combined set of runs for each model and scenario (150,000 estimates in total for each discount rate). In general, the distributions are skewed to the right and have long tails. The Figure also shows that the lower the discount rate, the longer the right tail of the distribution.

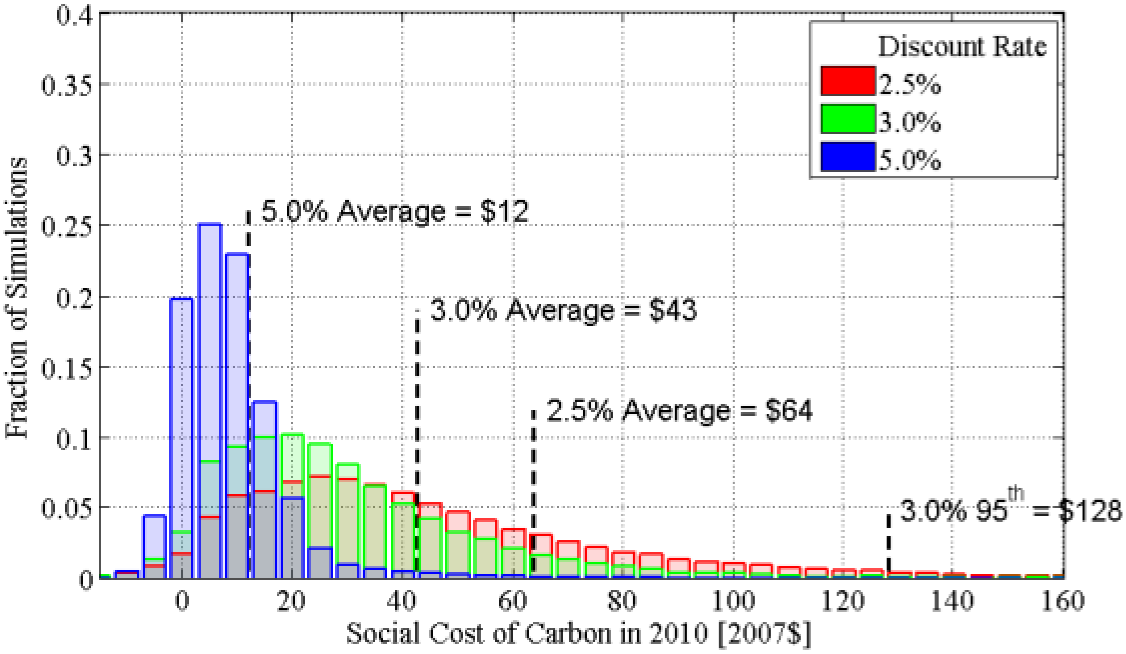

Figure 14B.4.1 Distribution of SCC Estimates for 2010 (in 2007$ per ton CO_2)

As was the case in the original TSD, the SCC increases over time because future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change. The approach taken by the interagency group is to allow the growth rate to be determined endogenously by the models through running them for a set of perturbation years out to 2050. Table 14B.4.2 illustrates how the growth rate for these four SCC estimates varies over time.

Table 14B.4.2 Average Annual Growth Rates of SCC Estimates between 2010 and 2050

Average Annual Rate (%)	5.0% Avg	3.0% Avg	2.5% Avg	3.0% 95th
2010-2020	1.2%	3.3%	2.4%	4.4%
2020-2030	3.4%	2.1%	1.7%	2.4%
2030-2040	3.0%	1.9%	1.5%	2.1%
2040-2050	2.6%	1.6%	1.3%	1.5%

The future monetized value of emission reductions in each year (the SCC in year t multiplied by the change in emissions in year t) must be discounted to the present to determine its total net present value for use in regulatory analysis. As previously discussed in the original TSD, damages from future emissions should be discounted at the same rate as that used to calculate the SCC estimates themselves to ensure internal consistency – *i.e.*, future damages from climate change, whether they result from emissions today or emissions in a later year, should be discounted using the same rate.

14B.5 OTHER MODEL LIMITATIONS OR RESEARCH GAPS

The 2010 interagency SCC technical support report discusses a number of important limitations for which additional research is needed. In particular, the document highlights the need to improve the quantification of both non-catastrophic and catastrophic damages, the treatment of adaptation and technological change, and the way in which inter-regional and inter-sectoral linkages are modeled. It also discusses the need to more carefully assess the implications of risk aversion for SCC estimation as well as the inability to perfectly substitute between climate and non-climate goods at higher temperature increases, both of which have implications for the discount rate used. EPA, DOE, and other agencies continue to engage in long-term research work on modeling and valuation of climate impacts that we expect will inform improvements in SCC estimation in the future.

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14B.6 ANNEX

Table 14B.6.1 Annual SCC Values: 2010-2050 (2007\$/ton CO_2)

Discount Rate	5.0%	3.0%	2.5%	3.0%
Year	Avg	Avg	Avg	95th
2010	11	32	51	89
2011	11	33	52	93
2012	11	34	54	97
2013	11	35	55	101
2014	11	36	56	105
2015	11	37	57	109
2016	12	38	59	112
2017	12	39	60	116
2018	12	40	61	120
2019	12	42	62	124
2020	12	43	64	128
2021	12	43	65	131
2022	13	44	66	134
2023	13	45	67	137
2024	14	46	68	140
2025	14	47	69	143
2026	15	48	70	146
2027	15	49	71	149
2028	15	50	72	152
2029	16	51	73	155
2030	16	52	75	159
2031	17	52	76	162
2032	17	53	77	165
2033	18	54	78	168
2034	18	55	79	172
2035	19	56	80	175
2036	19	57	81	178
2037	20	58	83	181
2038	20	59	84	185
2039	21	60	85	188
2040	21	61	86	191
2041	22	62	87	194
2042	22	63	88	197
2043	23	64	89	200
2044	23	65	90	203
2045	24	66	92	206
2046	24	67	93	209
2047	25	68	94	211
2048	25	69	95	214
2049	26	70	96	217
2050	26	71	97	220

Table 14B.6.2 202 Global SCC Estimates at 2.5 Percent Discount Rate (2007$/ton CO_2)

Percentile	1st	5th	10th	25th	50th	Avg	75th	90th	95th	99th
Scenario	PAGE									
IMAGE	6	11	15	27	58	129	139	327	515	991
MERGE	4	6	9	16	34	78	82	196	317	649
MESSAGE	4	8	11	20	42	108	107	278	483	918
MiniCAM Base	5	9	12	22	47	107	113	266	431	872
5th Scenario	2	4	6	11	25	85	68	200	387	955
Scenario	DICE									
IMAGE	25	31	37	47	64	72	92	123	139	161
MERGE	14	18	20	26	36	40	50	65	74	85
MESSAGE	20	24	28	37	51	58	71	95	109	221
MiniCAM Base	20	25	29	38	53	61	76	102	117	135
5th Scenario	17	22	25	33	45	52	65	91	106	126
Scenario	FUND									
IMAGE	-14	-2	4	15	31	39	55	86	107	157
MERGE	-6	1	6	14	27	35	46	70	87	141
MESSAGE	-16	-5	1	11	24	31	43	67	83	126
MiniCAM Base	-7	2	7	16	32	39	55	83	103	158
5th Scenario	-29	-13	-6	4	16	21	32	53	69	103

Table 14B.6.3 SCC Estimates at 3 Percent Discount Rate (2007$/ton CO2)

Percentile	1st	5th	10th	25th	50th	Avg	75th	90th	95th	99th
Scenario	PAGE									
IMAGE	4	7	10	18	38	91	95	238	385	727
MERGE	2	4	6	11	23	56	58	142	232	481
MESSAGE	3	5	7	13	29	75	74	197	330	641
MiniCAM Base	3	5	8	14	30	73	75	184	300	623
5th Scenario	1	3	4	7	17	58	48	136	264	660
Scenario	DICE									
IMAGE	16	21	24	32	43	48	60	79	90	102
MERGE	10	13	15	19	25	28	35	44	50	58
MESSAGE	14	18	20	26	35	40	49	64	73	83
MiniCAM Base	13	17	20	26	35	39	49	65	73	85
5th Scenario	12	15	17	22	30	34	43	58	67	79
Scenario	FUND									
IMAGE	-13	-4	0	8	18	23	33	51	65	99
MERGE	-7	-1	2	8	17	21	29	45	57	95
MESSAGE	-14	-6	-2	5	14	18	26	41	52	82
MiniCAM Base	-7	-1	3	9	19	23	33	50	63	101
5th Scenario	-22	-11	-6	1	8	11	18	31	40	62

Table 14B.6.4 2020 Global SCC Estimates at 5 Percent Discount Rate (2007$/ton CO$_2$)

Percentile	1st	5th	10th	25th	50th	Avg	75th	90th	95th	99th
Scenario	PAGE									
IMAGE	1	2	2	5	10	28	27	71	123	244
MERGE	1	1	2	3	7	17	17	45	75	153
MESSAGE	1	1	2	4	9	24	22	60	106	216
MiniCAM Base	1	1	2	3	8	21	21	54	94	190
5th Scenario	0	1	1	2	5	18	14	41	78	208
Scenario	DICE									
IMAGE	6	8	9	11	14	15	18	22	25	27
MERGE	4	5	6	7	9	10	12	15	16	18
MESSAGE	6	7	8	10	12	13	16	20	22	25
MiniCAM Base	5	6	7	8	11	12	14	18	20	22
5th Scenario	5	6	6	8	10	11	14	17	19	21
Scenario	FUND									
IMAGE	-9	-5	-4	-1	2	3	6	10	14	24
MERGE	-6	-4	-2	0	3	4	6	11	15	26
MESSAGE	-10	-6	-4	-1	1	2	5	9	12	21
MiniCAM Base	-7	-4	-2	0	3	4	6	11	14	25
5th Scenario	-11	-7	-5	-3	0	0	3	5	7	13

APPENDIX 17A. REGULATORY IMPACT ANALYSIS: SUPPORTING MATERIALS

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APPENDIX 17A. REGULATORY IMPACT ANALYSIS: SUPPORTING MATERIALS

17A.1 INTRODUCTION

This appendix contains sections discussing the following topics:

- Projections of annual market share increases for the alternative policies;
- NIA-RIA Integrated Model;
- XENERGY penetration curves used to analyze consumer rebates, including:
    - Background material,
    - DOE’s adjustment of these curves for this analysis, and
    - The method DOE used for interpolating the curves;
- Detailed tables of rebates offered for the considered products; and
- Background material on Federal and state tax credits for appliances.

17A.2 MARKET SHARE ANNUAL INCREASES BY POLICY

Table 17-A.2.1 and Table 17-A.2.2 show the annual increases in market shares of the two packaged terminal air conditioner (PTAC) equipment classes meeting the target efficiency levels for the selected TSL (TSL ASHRAE). DOE used these market share increases as inputs to the NIA-RIA spreadsheet model. The remaining PTAC and PTHP equipment classes are not affected by the selected TSL.

Table 17A.2.1 Annual Increases in Market Shares Attributable to Alternative Policy Measures for Packaged Terminal Air Conditioners (7,000 – 15,000 Btu/h)

Year	Consumer Rebates	Consumer Tax Credits	Manufacturer Tax Credits	Voluntary Energy Efficiency Targets	Bulk Government Purchases
2017	4.3%	2.6%	1.3%	0.7%	0.6%
2018	3.7%	2.2%	1.1%	3.5%	0.5%
2019	3.1%	1.9%	0.9%	3.1%	0.5%
2020	2.5%	1.5%	0.7%	2.5%	0.4%
2021	1.9%	1.1%	0.6%	1.9%	0.4%
2022	1.2%	0.7%	0.4%	1.2%	0.3%
2023	0.6%	0.4%	0.2%	0.6%	0.3%
2024	0.0%	0.0%	0.0%	0.0%	0.0%
2025	0.0%	0.0%	0.0%	0.0%	0.0%
2026	0.0%	0.0%	0.0%	0.0%	0.0%
2027	0.0%	0.0%	0.0%	0.0%	0.0%
2028	0.0%	0.0%	0.0%	0.0%	0.0%
2029	0.0%	0.0%	0.0%	0.0%	0.0%
2030	0.0%	0.0%	0.0%	0.0%	0.0%
2031	0.0%	0.0%	0.0%	0.0%	0.0%
2032	0.0%	0.0%	0.0%	0.0%	0.0%
2033	0.0%	0.0%	0.0%	0.0%	0.0%
2034	0.0%	0.0%	0.0%	0.0%	0.0%
2035	0.0%	0.0%	0.0%	0.0%	0.0%
2036	0.0%	0.0%	0.0%	0.0%	0.0%
2037	0.0%	0.0%	0.0%	0.0%	0.0%
2038	0.0%	0.0%	0.0%	0.0%	0.0%
2039	0.0%	0.0%	0.0%	0.0%	0.0%
2040	0.0%	0.0%	0.0%	0.0%	0.0%
2041	0.0%	0.0%	0.0%	0.0%	0.0%
2042	0.0%	0.0%	0.0%	0.0%	0.0%
2043	0.0%	0.0%	0.0%	0.0%	0.0%
2044	0.0%	0.0%	0.0%	0.0%	0.0%
2045	0.0%	0.0%	0.0%	0.0%	0.0%
2046	0.0%	0.0%	0.0%	0.0%	0.0%

Table 17A.2.2 Annual Increases in Market Shares Attributable to Alternative Policy Measures for Packaged Terminal Air Conditioners (> 15,000 Btu/h)

Year	Consumer Rebates	Consumer Tax Credits	Manufacturer Tax Credits	Voluntary Energy Efficiency Targets	Bulk Government Purchases
2017	51.6%	30.9%	15.5%	0.0%	0.0%
2018	46.2%	27.7%	13.8%	0.0%	0.0%
2019	38.5%	23.1%	11.5%	0.1%	0.0%
2020	30.8%	18.5%	9.2%	0.1%	0.0%
2021	23.1%	13.8%	6.9%	0.1%	0.0%
2022	15.4%	9.2%	4.6%	0.1%	0.0%
2023	7.7%	4.6%	2.3%	0.1%	0.0%
2024	0.0%	0.0%	0.0%	0.0%	0.0%
2025	0.0%	0.0%	0.0%	0.0%	0.0%
2026	0.0%	0.0%	0.0%	0.0%	0.0%
2027	0.0%	0.0%	0.0%	0.0%	0.0%
2028	0.0%	0.0%	0.0%	0.0%	0.0%
2029	0.0%	0.0%	0.0%	0.0%	0.0%
2030	0.0%	0.0%	0.0%	0.0%	0.0%
2031	0.0%	0.0%	0.0%	0.0%	0.0%
2032	0.0%	0.0%	0.0%	0.0%	0.0%
2033	0.0%	0.0%	0.0%	0.0%	0.0%
2034	0.0%	0.0%	0.0%	0.0%	0.0%
2035	0.0%	0.0%	0.0%	0.0%	0.0%
2036	0.0%	0.0%	0.0%	0.0%	0.0%
2037	0.0%	0.0%	0.0%	0.0%	0.0%
2038	0.0%	0.0%	0.0%	0.0%	0.0%
2039	0.0%	0.0%	0.0%	0.0%	0.0%
2040	0.0%	0.0%	0.0%	0.0%	0.0%
2041	0.0%	0.0%	0.0%	0.0%	0.0%
2042	0.0%	0.0%	0.0%	0.0%	0.0%
2043	0.0%	0.0%	0.0%	0.0%	0.0%
2044	0.0%	0.0%	0.0%	0.0%	0.0%
2045	0.0%	0.0%	0.0%	0.0%	0.0%
2046	0.0%	0.0%	0.0%	0.0%	0.0%

17A.3 NIA-RIA INTEGRATED MODEL

For this analysis, DOE used its integrated NIA-RIA[a] model approach that built on the NIA model discussed in Chapter 10. The resulting integrated NIA-RIA model featured both the NIA analysis inputs and results and the RIA inputs and had the capability to generate results for each of the RIA policies. A separate module produced results summaries for the tables and figures in the RIA document. For the RIA methodology documentation in Chapter 17, the module created summaries of parameters calculated by the model for the consumer rebates policy, generated its penetration curves (discussed in Section 17-A.4.3 below), and reported market share impacts for the rebate and tax credit policies by equipment class. For the RIA results reported in Chapter 17, the module produced graphs of the market share increases resulting from each of the policies analyzed and created summary tables for the national energy savings (NES) and net present value (NPV) results. This module also generated tables of market share increases for each policy reported in Section 17-A.2 of this Appendix.

17A.4 CONSUMER REBATE POLICY MARKET PENETRATION CURVES

This section first discusses the theoretical basis for the market penetration curves that DOE used to analyze the Consumer Rebates policy. Next it discusses the adjustments it made to the maximum penetration rates. It then refers to the method it used to develop interpolated penetration curves for each specific equipment class and efficiency level in the analysis. The resulting curves for the PTAC and PTHP equipment classes are in Chapter 17.

17A.4.1 Introduction

XENERGY, Inc.[b], developed a re-parameterized, mixed-source information diffusion model to estimate market impacts induced by financial incentives for purchasing energy efficient appliances.[1] The basic premise of the mixed-source model is that information diffusion drives the adoption of technology.

Extensive economic literature describes the diffusion of new products as technologies evolve. Some research focuses primarily on developing analytical models of diffusion patterns applicable to individual consumers or to technologies from competing firms.[2, 3, 4] One study records researchers' attempts to investigate the factors that drive diffusion processes.[5] Because a new product generally has its own distinct characteristics, few studies have been able to conclusively develop a universally applicable model. Some key findings, however, generally are accepted in academia and industry.

One accepted finding is that, regardless of their economic benefits and technological merits, new technologies are unlikely to be adopted by all potential users. For many products, a

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[a] NIA = national impact analysis; RIA = regulatory impact analysis

[b] XENERGY is now owned by KEMA, Inc. (www.kema.com)

ceiling must be placed on the adoption rate. A second conclusion is that not all adopters purchase new products at the same time: some act quickly after a new product is introduced; others wait for the product to mature. Third, diffusion processes can be characterized approximately by asymmetric S-curves that depict three stages of diffusion: starting, accelerating, and decreasing (as the adoption ceiling is approached).

A so-called epidemic model of diffusion is used widely in marketing and social studies. The epidemic model assumes that (1) all consumers place identical value on the benefits of a new product, and (2) the cost of a new product is constant or declines monotonically over time. What induces a consumer to purchase a new product is information about the availability and benefits of the product. In other words, information diffusion drives consumers' adoption of a new product.[3] The model incorporates information diffusion from both internal sources (spread by word of mouth from early adopters to prospective adopters) and external sources (the "announcement effect" produced by government agencies, institutions, or commercial advertising). The model incorporates both internal and external sources by combining a logistic function with an exponential function.[4,5]

The relative degree of influence from the internal and external sources determines the general shape of the diffusion curve for a specific product.[4,5] If adoption of a product is influenced primarily by external sources of information (the announcement effect), for instance, a high rate of diffusion occurs at the beginning of the process. In this scenario, external sources provide immediate information exposure to a significant number of prospective adopters. In contrast, internal sources (such as a network of prospective adopters) are relatively small in size and reach, producing a more gradual exposure to prospective adopters. Graphically speaking, information diffusion dominated by external sources is represented by a concave curve (the exponential curve in Figure 17A.4.1). If adoption of a new product is influenced most strongly by internal sources of information, the number of adopters increases gradually, forming a convex curve (the logistic curve in Figure 17A.4.1).

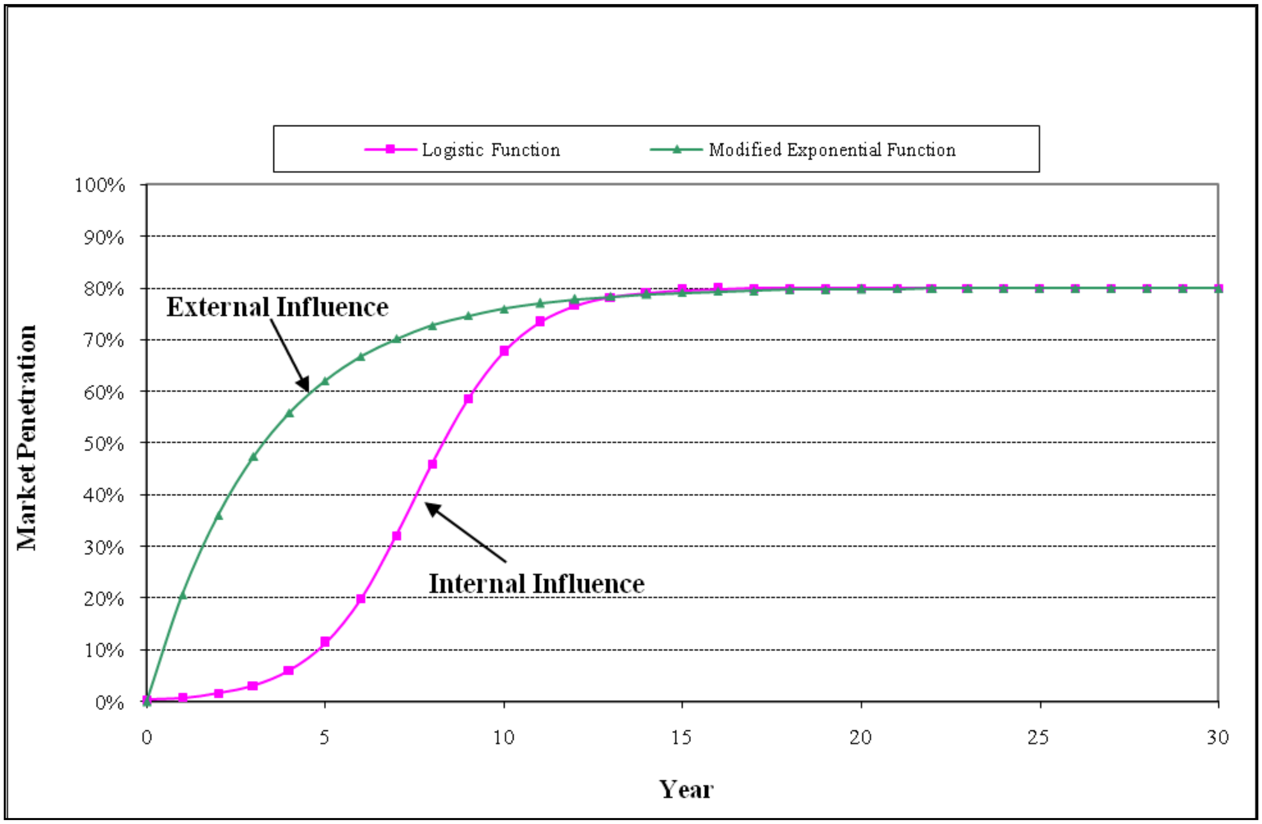

Figure 17A.4.1 S-Curves Showing Effects of External and Internal Sources on Adoption of New Technologies

17A.4.2 Adjustment of Energy Penetration Curves

In consultation with the primary authors of the 2002 XENERGY study who later conducted similar California studies, DOE made some adjustments to XENERGY's original implementation (penetration) curves.[6] The experiences with utility programs since the XENERGY study indicate that incentive programs have difficulty achieving penetration rates as high as 80 percent. Consumer response is limited by barriers created by consumer utility issues and other non-economic factors. DOE therefore adjusted the maximum penetration parameters for some of the curves from 80 percent to the following levels:

Moderate Barriers:	70%
High Barriers:	60%
Extremely High Barriers:	50%

The *low barriers* and *no barriers* curves (the latter used only when a product has a very high base-case-market share) remained, respectively, with 80 percent and 100 percent as their maximum penetration rates. For the interpolated penetration curves (discussed below), DOE set the *no barriers* and *extremely high barriers* curves as the upper and lower bounds, respectively, for any benefit/cost ratio points higher or lower than the curves. It set another constraint such that the policy case market share cannot be greater than 100 percent, as might occur for products with high base case market shares of the target-level technology.

17A.4.3 Interpolation of Penetration Curves

As discussed above, the XENERGY penetration (implementation) curves followed a functional form to estimate the market implementation rate caused by energy efficiency measures such as consumer rebates.[c] The XENERGY report presents five reference market implementation curves that vary according to the level of market barriers to technology penetration.[1] Such curves have been used by DOE in the Regulatory Impact Analyses for rulemakings for appliance energy efficiency standards to estimate market share increases in response to rebate programs.[d] They provide a framework for evaluating technology penetration, yet require matching the studied market to the curve that best represents it. This approximate matching can introduce some inaccuracy to the analysis.

Blum et al (2011, Appendix A)[7]presents an alternative approach to such evaluation: a method to estimate market implementation rates more accurately by performing interpolations of the reference curves. The referred report describes the market implementation rate function and the reference curves, the method to calibrate the function to a given market, and the limitations of the method.

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[c] The RIA chapter refers to these curves as *penetration curves*. This section, in references to the original source, uses the term *implementation curve*.

[d] DOE has also used this method to estimate market share increases resulting from consumer tax credit and manufacturer tax credit programs, since the effects of tax credits on markets can be considered proportional to the rebate impacts.

17A.5 CONSUMER REBATE PROGRAMS

DOE performed a search during the second quarter of 2014 for rebate programs that offered incentives for PTACs and PTHPs. Some organizations nationwide, comprising electric utilities and regional agencies, offered rebate programs for this equipment. Table 17-A.5.3 provides the organizations' names, states, rebate amounts, and program websites. If there is more than one entry for an organization, it offered different rebates in different states. When an organization offered rebates through several utilities, it is represented only once in the table.

Rebates were offered either on per unit or per ton basis. Most of the rebate programs offered a fixed amount rebate. However, some of them included an incremental rebate amount proportional to the equipment cooling capacity and energy efficiency. DOE calculated a representative rebate amount for each equipment class and TSL. The representative amount accounts for the equipment class cooling capacity and the efficiency level corresponding to each TSL. Table 17-A.5.1 shows the cooling capacities (in tons) and efficiencies (in EER) that DOE used to calculate specific rebate amounts for each equipment class and TSL.

Table 17A.5.1 Representative Cooling Capacities and Energy Efficiencies Used to Calculate the Rebate Amounts for each Rebate Program

Equipment Class	**Energy Efficiency (EER) per Trial Standard Levels**						**Representative Cooling Capacity (tons)**
	ASHRAE	1	2	3	4	5	
Packaged Terminal Air Conditioners							
< 7,000 Btu/h	11.9	12.2	12.6	13.1	13.6	13.8	7
7,000 – 15,000 Btu/h	11.3	11.5	12.0	12.4	12.9	13.1	12
> 15,000 Btu/h	9.5	9.7	10.0	10.4	10.8	11.0	15
Packaged Terminal Heat Pumps							
< 7,000 Btu/h	11.9	12.2	12.6	13.1	13.6	13.8	7
7,000 – 15,000 Btu/h	11.3	11.5	12.0	12.4	12.9	13.1	12
> 15,000 Btu/h	9.5	9.7	10.0	10.4	10.8	11.0	15

After calculating a rebate amount for each rebate program, DOE calculated the representative rebate amount for each equipment class and TSL taking the simple average of the rebate amounts that DOE calculated for each rebate program. Table 17-A.5.2 shows the representative rebate amounts DOE used for each equipment class and TSL in its analysis of the benefits from consumer rebates.

Table 17A.5.2 Representative Rebate Amounts (2014$)

Equipment Class	Trial Standard Levels					
	ASHRAE	1	2	3	4	5
Packaged Terminal Air Conditioners						
< 7,000 Btu/h	33.50	41.89	46.93	32.78	40.74	45.52
7,000 – 15,000 Btu/h	34.82	43.95	48.74	32.91	40.95	45.71
> 15,000 Btu/h	37.13	47.70	52.67	33.14	41.32	46.10
Packaged Terminal Heat Pumps						
< 7,000 Btu/h	39.43	51.45	56.60	33.37	41.70	46.49
7,000 – 15,000 Btu/h	41.74	55.20	60.52	33.60	42.07	46.88
> 15,000 Btu/h	42.89	57.08	62.49	33.71	42.26	47.08

Table 17A.5.3 Rebates for Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps[e]

Organization	State	Rebate		Website
		PTAC	PTHP	
SRP	AZ	$20/ton	$20/ton	www.savewithsrpbiz.com/rebates.aspx
Imperial Irrigation District	CA	$50/ton	$50/ton	www.iid.com/index.aspx?page=293
Modesto Irrigation District	CA	$75/unit	$75/unit	www.mid.org/rebates/commercial/default.html
Pacific Power	CA	$25/ton	$50/ton	www.pacificpower.net/bus/se/california/sc/hc.html
City of Roseville California	CA	$125/unit	$125/unit	www.roseville.ca.us/electric/business/rebates/hvac.asp
Southern California Edison	CA	$100/unit	$100/unit	www.sce.com/wps/portal/home/business/savings-incentives/express-solutions/how-to-apply/!ut/p/b1
Silicon Valley Power	CA	$100/ton	$100/ton	http:/siliconvalleypower.com/index.aspx?page=1931
SMUD	CA	$100/unit	$100/unit	www.smud.org/en/business/save-energy/rebates-incentives-financing/incentives-for-heating-and-cooling/express-incentives-air-conditioning.htm
City of Fort Collins	CO	$50/ton[*]	$50/ton[*]	www.fcgov.com/utilities/business/improve-efficiency/rebates-incentives/electric-efficiency/cooling-rebates
JEA	FL	$50/ton	$50/ton	www.jea.com/Manage_My_Account/Ways_to_Save/Rebate_Programs/InvestSmart/Heating,_Cooling_and_Air_Handling_Rebates.aspx
TECO	FL	$37.50/ton	$37.50/ton	www.tampaelectric.com/business/saveenergy/cooling/
Cedar Falls Utilities	IA	$50/unit	$50/unit	www.cfu.net/save-energy/business-rebates.aspx
Illinois Municipal Electric Agency	IL	$50/ton	$50/ton	www.imea.org/EEProjects.aspx
Duke Energy	IN	$20/ton	$20/ton	www.duke-energy.com/indiana-business/energy-management/cooling-incentive.asp
Kentucky Utilities Company	KY	$10/ton	$10/ton	http://lge-ku.com/saving-energy-money/commercial-rebates
Louisville Gas & Electric	KY	$10/ton	$10/ton	http://lge-ku.com/saving-energy-money/commercial-rebates
Baltimore Gas & Electric Company	MD	$30/unit	$30/unit	www.bgesmartenergy.com/business/energy-solutions-business/application-forms
Baltimore Gas & Electric Company	MD	$40/unit	$40/unit	www.bgesmartenergy.com/business/energy-solutions-business/application-forms

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[e] This table is based on rebate programs DOE found to be available through an extensive internet search during the second quarter of 2014. Some of the programs referenced—and consequently their websites—may no longer be available by the time this document is published.

Organization	State	Rebate		Website
Baltimore Gas & Electric Company	MD	$50/unit	$50/unit	www.bgesmartenergy.com/business/energy-solutions-business/application-forms
CONNEXUS ENERGY	MN	$10/ton[**]	$10/ton[**]	www.connexusenergy.com/business/rebates/cooling-and-heat-pumps/
CONNEXUS ENERGY	MN	$10/ton[†]	$10/ton[†]	www.connexusenergy.com/business/rebates/cooling-and-heat-pumps/
Dakota Electric Association	MN	$10/ton[**]	$10/ton[**]	www.dakotaelectric.com/business/programs/rebates_grants_and_loans/heating_cooling_ventilation_rebates
Dakota Electric Association	MN	$10/ton[†]	$10/ton[†]	www.dakotaelectric.com/business/programs/rebates_grants_and_loans/heating_cooling_ventilation_rebates
East Central Energy	MN	$10/ton[**]	$10/ton[**]	www.eastcentralenergy.com/rebatesbusiness.aspx
East Central Energy	MN	$10/ton[†]	$10/ton[†]	www.eastcentralenergy.com/rebatesbusiness.aspx
Elk River Municipal Utilities	MN	$10/ton[**]	$10/ton[**]	www.elkriverutilities.com/pages/rebate-forms
Elk River Municipal Utilities	MN	$10/ton[†]	$10/ton[†]	www.elkriverutilities.com/pages/rebate-forms
Minnesota Valley Electric Cooperative	MN	$10/ton[**]	$10/ton[**]	www.mvec.net/business/efficiency-rebates/
Minnesota Valley Electric Cooperative	MN	$10/ton[†]	$10/ton[†]	www.mvec.net/business/efficiency-rebates/
Moorhead Public Service Utility	MN	$35/room[††]	$30/room[††]	www.brightenergysolutions.org/municipalities/?category=business&state=mn&municipality=28&program=4
El Paso Electric Company	NM	$30/ton	$30/ton	www.epesaver.com/index.php/component/content/article/105-commercial-cooling
PNM	NM	$20/ton	$20/ton	www.pnmenergyefficiency.com/Projects/Default.aspx?tabid=908
conEdison	NY	$50/ton	$50/ton	www.conedci.com/HVAC.aspx#electric
Dayton Power & Light	OH	$50/unit	$50/unit	www.dpandl.com/save-money/business-government/rapid-rebates/hvac-rebates/#pack
AEP Ohio	OH	$30/ton	$30/ton	www.aepohio.com/save/programs/PrescriptiveProgram.aspx
FirstEnergy (MetEdison, Penelec, Penn Power)	PA	$150/unit	$150/unit	www.energysavepa-business.com/index.php
AEP Appalachian Power	WV	$30/ton	$30/ton	http://aeprebates.com/commercial-program/

[*] incremental rebate ($5/ton per 0.1 EER above base)

[**] incremental rebate ($1.75/ton per 0.1 EER above base)

[†] incremental rebate ($3.50/ton per 0.1 EER above base)

[††] DOE assumed a per unit rebate amount

17A.6 FEDERAL AND STATE TAX CREDITS

This section summarizes the Federal and State tax credits available to consumers who purchase energy efficient appliances. This section also describes tax credits available to manufacturers who produce certain energy efficient appliances.

17A.6.1 Federal Tax Credits for Consumers

EPACT 2005 included Federal tax credits for consumers who installed efficient air conditioners or heat pumps; gas, oil and propane furnaces and boilers; furnace fans; and/or gas, oil, or electric heat pump water heaters in new or existing homes.[8, 9] These tax credits were in effect in 2006 and 2007, expired in 2008, and were reinstated for 2009–2010 by the American Recovery and Reinvestment Act (ARRA).[10] There was a $1,500 cap on the credit per home, including the amount received for insulation, windows, and air and duct sealing. Congress extended this provision for 2011, with some modifications to eligibility requirements, and reductions in the cap to $500 per home. The American Taxpayer Relief Act of 2012 extended, with some modifications, residential tax credits for air conditioners, heat pumps, furnaces, and water heaters placed in service between January 1, 2012 and December 31, 2013.[8, 11]
The tax credit for furnace fans was $50 in 2011, after which it expired.

The importance of the Federal tax credits has been emphasized in research in the residential heating industry on the impacts of the relatively large credits that were available for HVAC (heating, ventilating, and air conditioning) equipment. In a survey of HVAC distributors conducted by Vermont Energy Investment Corporation, respondents indicated that the ample credit had had a notable impact on sales of higher-efficiency heating and cooling equipment. Some distributors combined the Federal tax credits with manufacturer rebates and utility program rebates for a greater consumer incentive. However, when the amount of the Federal tax credit was reduced, smaller utility rebate incentives had not induced the same levels of equipment sales increases. The decrease in incentive size from a $1,500 cap in 2009-2010 to a $500 cap in 2011, during a period when the economy continued to be sluggish, resulted in a decline in total sales of residential HVAC products. Distributors stated that an incentive needed to cover 25 to 75 percent of the incremental cost of the efficient equipment to influence consumer choice. The industry publication "2011 HVAC Review and Outlook" noted a decline in sales of air conditioning units with >14 SEER in 2011 and a return in sales of units with >16 SEER to 2009 levels (after an increase in 2010). The large majority of distributor observed no impacts from the utility programs with their lower rebate amounts available in 2011. Distributors also commented on the advantages of the Federal tax credit being nationwide in contrast to utility rebate programs that target regional markets.[12, 13]

In an effort to evaluate the potential impact of a Federal appliance tax credit program, DOE reviewed Internal Revenue Service (IRS) data on the numbers of taxpayers who claimed the tax credits during tax years 2006 and 2007. It estimated the percentage of taxpayers who filed Form 5695, *Residential Energy Credits.*[14] It also estimated the percentage of taxpayers with entries under Form 5695's section 3, *Residential energy property costs*, line 3b, *qualified natural gas, propane, or oil furnace or hot water boiler*. DOE reasoned that the percentage of taxpayers with an entry on Line 3b could serve as a rough indication of the potential of taxpayer participation in a Federal tax credit program for furnaces during the initial program years. DOE found that of all residential taxpayers filing tax returns, 0.8 percent in 2006 and 0.6 percent in 2007, claimed a credit for a furnace or boiler. DOE further found that the percentages of those filing Form 5695 for any qualifying energy property expenditure (which also included installation of efficient windows, doors and roofs) were 3.1 and 3.2 percent in 2006 and 2007 respectively.

DOE also reviewed data from an earlier Federal energy conservation tax credit program in place in the 1980s. While this tax credit was available from 1979 through 1985, DOE located data for only the first three years of the program.[15, 16, 17] For those three years - 1979, 1980, and 1981 - the percentages of taxpayers filing Form 5695 were 6.4 percent, 5.2 percent, and 4.9 percent. Given that the data from this earlier tax credit program were not disaggregated by type of energy property, this data series served only to indicate a possible trend of greater participation in the initial program year, followed by slightly smaller participation in subsequent years. However, DOE did not find detailed analysis of this program to indicate the possible reasons for such a trend. Also, this trend varies from the more stable trend shown in the EPAct 2005 energy tax credit program data for its first two program years.

As discussed in Chapter 17, DOE analyzed the percentage of participation in consumer tax credit programs using its estimates of consumer participation in rebate programs that was based on benefit/cost data specific to each equipment class. Hence it was difficult to compare these detailed estimates to the more general data analysis described above from the existing Federal tax credit program, or to use the IRS data analysis in its consumer tax credit analysis.

17A.6.2 Federal Tax Credits for Manufacturers

EPACT 2005 provided Federal Energy Efficient Appliance Credits to manufacturers that produced high-efficiency refrigerators, clothes washers, and dishwashers in 2006 and 2007.[18] The Emergency Economic Stabilization Act of 2008[19] amended the credits and extended them through 2010. The credits were extended again to 2011 with modifications in the eligibility requirements. Manufacturer tax credits were extended again, by the American Taxpayer Relief Act of 2012, for clothes washers, refrigerators, and dishwashers manufactured between January 1, 2012 and December 31, 2013.

Manufacturers who produce these appliances receive the credits for increasing their production of qualifying appliances. These credits had several efficiency tiers in 2011. For 2012-2013, credits for the higher tiers remain but were eliminated for the lowest (least efficient) tiers for clothes washers and dishwashers.[11] The credit amounts applied to each unit manufactured. The credit to manufacturers of qualifying clothes washers, refrigerators and dishwashers was capped at $75 million for the period of 2008-2010. However, the most efficient refrigerator (30%) and clothes washer (2.2 MEF/4.5 wcf) models was not subject to the cap. The credit to manufacturers was capped at $25 million for 2011, with the most efficient refrigerators (35%) and clothes washers (2.8 MEF/3.5 WCF) exempted from this cap.[20]

17A.6.3 State Tax Credits

The states of Oregon and Montana have offered consumer tax credits for efficient appliances for several years, and the states of Kentucky, Michigan and Indiana began offering such credits in 2009. The Oregon Department of Energy (ODOE) has disaggregated data on taxpayer participation in credits for eligible products. (See the discussion in Chapter 17, Section 17.3.3, on tax credit data for clothes washers). Montana’s Department of Revenue does not disaggregate participation data by appliance, although DOE reviewed Montana's overall participation trends and found them congruent with its analysis of Oregon's clothes washer tax credits.

Oregon’s Residential Energy Tax Credit (RETC) was created in 1977. The Oregon legislature expanded the RETC program in 1997 to include residential refrigerators, clothes washers, and dishwashers, which significantly increased participation in the program. The program subsequently added credits for high-efficiency heat pump systems, air conditioners, and water heaters (2001); furnaces and boilers (2002); and duct/air sealing, fuel cells, heat recovery, and renewable energy equipment. Beginning in 2012 a Tax Credit Extension Bill (HB3672) eliminated refrigerators, clothes washers, dishwashers, air conditioners, and boilers from the RETC program, leaving credits for water heaters, furnaces, heat pumps, tankless water heaters, and heat pump water heaters.[21, 22] Those technologies recognized by the Oregon Department of Energy as “premium efficiency” are eligible for tax credit of $0.60 per kWh saved in the first year (up to $1,500).[21, 23]

Montana has had an Energy Conservation Tax Credit for residential measures since 1998.[24] The tax credit covers various residential energy and water efficient products, including split system central air conditioning; package system central air conditioning; split system air source heat pumps; package system heat pumps; natural gas, propane, or oil furnaces; hot water boilers; advanced main air circulating fans; heat recovery ventilators; gas, oil, or propane water heaters; electric heat pump water heaters; low-flow showerheads and faucets; light fixtures; and controls. In 2002 the amount of the credit was increased from 5 percent of product costs (up to $150) to 25 percent (up to $500) per taxpayer. The credit can be used for products installed in new construction or remodeling projects. The tax credit covers only that part of the cost and materials that exceed established standards of construction.

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