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

Dedicated-Purpose Pool Pumps

December 2016

U.S. Department of Energy
Assistant Secretary
Office of Energy Efficiency and Renewable Energy
Building Technologies Program
Appliances and Commercial Equipment Standards
Washington, DC 20585

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CHAPTER 1. INTRODUCTION

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CHAPTER 1. INTRODUCTION

1.1 DOCUMENT PURPOSE

This technical support document (TSD) is a standalone document that presents the technical analyses that the U.S. Department of Energy (DOE) conducted for evaluating new energy conservation standards for dedicated-purpose pool pumps.

1.2 SUMMARY OF NATIONAL BENEFITS

DOE's analyses indicate that the adopted standards would save a significant amount of energy. The lifetime savings for dedicated-purpose pool pumps purchased in the 30-year period that begins in the first full year of compliance with new standards (2021-2050) amount to 3.8 quadrillion Btu (quads).[a]

The cumulative net present value (NPV) of total customer costs and savings of the adopted standards for dedicated-purpose pool pumps ranges from $11 billion (at a 7-percent discount rate) to $24 billion (at a 3-percent discount rate). This NPV expresses the estimated total value of future operating-cost savings minus the estimated increased equipment costs for equipment purchased in 2021–2050.

In addition, the adopted standards would have significant environmental benefits. The energy savings would result in cumulative emission reductions of 202 million metric tons (Mt)[b] of carbon dioxide (CO_2), 968 thousand tons of methane, 147 thousand tons of sulfur dioxide (SO_2), 257 thousand tons of nitrogen oxides (NO_X), 3.0 thousand tons of nitrous oxide (N_2O), and 0.50 tons of mercury (Hg).[c] The cumulative reduction in CO_2 emissions through 2030 amounts to 48 Mt, which is equivalent to the emissions associated with the annual electricity use of 7.1 million homes.

The value of the CO_2 reductions is calculated using a range of values per metric ton of CO_2 (otherwise known as the Social Cost of Carbon, or SCC) developed by a recent Federal interagency process.[d] Using discount rates appropriate for each set of SCC values, DOE estimates the present monetary value of the CO_2 emissions reduction is between $1.5 billion and

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[a] A quad is equal to 10^{15} British thermal units (Btu).
[b] A metric ton is equivalent to 1.1 short tons. Results for emissions other than CO_2 are presented in short tons.
[c] DOE calculated emissions reductions relative to the Annual Energy Outlook 2014 (AEO 2014) Reference case, which generally represents current legislation and environmental regulations for which implementing regulations were available as of October 31, 2013.
[d] Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. Interagency Working Group on Social Cost of Carbon, United States Government. May 2013; revised November 2013. http://www.whitehouse.gov/sites/default/files/omb/assets/inforeg/technical-update-social-cost-of-carbon-for-regulator-impact-analysis.pdf.

$21 billion. DOE also estimates the present monetary value of the NO_X emissions reduction, is $0.21 billion at a 7-percent discount rate and $0.48 billion at a 3-percent discount rate.[e]

Table 1.2.1 summarizes the national economic costs and benefits expected to result from the adopted standards for dedicated-purpose pool pumps.

Table 1.2.1 Summary of National Economic Benefits and Costs of Adopted Energy Conservation Standards for Dedicated-Purpose Pool Pumps*

Category	Present Value Billion 2013$	Discount Rate
Benefits		
Consumer Operating Cost Savings	13	7%
	26	3%
GHG Reduction (using avg. social costs at 5% discount rate)*	1.9	5%
GHG Reduction (using avg. social costs at 3% discount rate)*	7.8	3%
GHG Reduction (using avg. social costs at 2.5% discount rate)*	12	2.5%
GHG Reduction (using 95th percentile social costs at 3% discount rate)*	23	3%
NO_X Reduction**	0.21	7%
	0.48	3%
Total Benefits†	21	7%
	35	3%
Costs		
Consumer Incremental Installed Costs	1.3	7%
	2.6	3%
Total Net Benefits		
Including GHG and NO_X Reduction Monetized Value	19	7%
	32	3%

Note: This table presents the costs and benefits associated with dedicated-purpose pool pumps shipped in 2021−2050. These results include benefits to consumers which accrue after 2050 from the equipment purchased in 2021−2050. The incremental installed costs include incremental equipment cost as well as installation costs. The costs account for the incremental variable and fixed costs incurred by manufacturers due to the adopted standards, some of which may be incurred in preparation for the rule. The CO_2 reduction benefits are global benefits due to actions that occur domestically.
* The interagency group selected four sets of SC-CO_2 SC-CH_4, and SC-N_2O values for use in regulatory analyses. Three sets of values are based on the average social costs from the integrated assessment models, at discount rates of 5 percent, 3 percent, and 2.5 percent. The fourth set, which represents the 95th percentile of the social cost distributions calculated using a 3-percent discount rate, is included to represent higher-than-expected impacts from climate change further out in the tails of the social cost distributions. The social cost values are emission year specific.
** DOE estimated the monetized value of NO_X emissions reductions associated with electricity savings using benefit per ton estimates from the Regulatory Impact Analysis for the Clean Power Plan Final Rule, published in August 2015 by EPA's Office

[e] DOE is currently investigating valuation of avoided Hg and SO_2 emissions.

of Air Quality Planning and Standards. (Available at www.epa.gov/cleanpowerplan/clean-power-plan-final-rule-regulatory-impact-analysis.) See section IV.L.3 for further discussion. DOE is primarily using a national benefit-per-ton estimate for NO_X emitted from the electricity generating unit sector based on an estimate of premature mortality derived from the ACS study (Krewski et al. 2009). If the benefit-per-ton estimates were based on the Six Cities study (Lepuele et al. 2011), the values would be nearly two-and-a-half times larger.
† Total Benefits for both the 3-percent and 7-percent cases are presented using only the average social costs with 3-percent discount rate.

1.3 OVERVIEW OF STANDARDS

Title III, Part C[f] of the Energy Policy and Conservation Act of 1975 (EPCA), (42 U.S.C. 6311–6317, as codified) established the Energy Conservation Program for Certain Industrial Equipment, a program covering certain industrial equipment.[g] "Pumps" are listed as a type of covered industrial equipment. (42 U.S.C. 6311(1)(A))

While pumps are listed as a type of covered equipment, EPCA does not define the term "pump." To address this, in January 2016, DOE published a test procedure final rule (January 2016 general pumps test procedure final rule) that established a definition for the term "pump." 81 FR 4086, 4147 (January 25, 2016). In the December, 2016 test procedure final rule ("test procedure final rule"),[h] DOE noted the applicability of the definition of "pump" and associated terms to dedicated-purpose pool pumps.

Currently, no Federal energy conservation standards exist for dedicated-purpose pool pumps. DOE excluded this category of pumps from its recent consensus-based energy conservation standard final rule for general pumps. 81 FR 4368 (January 26, 2016). That final rule, which was the product of a pumps working group that had been created through the ASRAC, examined a variety of pump categories. While dedicated-purpose pool pumps were one of the pump categories that were considered during the working group's discussions, the working group ultimately recommended that DOE initiate a separate rulemaking for dedicated-purpose pool pumps. (Docket No. EERE-2013-BT-NOC-0039, No. 0092 at p. 2)

DOE began the separate rulemaking for dedicated-purpose pool pumps on May 8, 2015, when it issued a Request for Information (RFI) (May 2015 DPPP RFI). 80 FR 26475. The May 2015 DPPP RFI presented information and requested public comment about definitions, metrics, test procedures, equipment characteristics, and typical applications relevant to DPPP equipment. DOE received six written comments in response to the May 2015 DPPP RFI.

Consistent with feedback from these interested parties to the RFI, DOE began a process through the ASRAC to charter a working group to recommend energy conservation standards and a test procedure for dedicated-purpose pool pumps rather than continuing down the traditional notice and comment route that DOE had already begun. (Docket No. EERE-2015-BT-STD-0008) On August 25, 2015, DOE published a notice of intent to establish a working group for dedicated-purpose pool pumps (the DPPP Working Group) 80 FR 51483. The initial DPPP

[f] For editorial reasons, upon codification in the U.S. Code, Part C was re-designated Part A-1.
[g] All references to EPCA refer to the statute as amended through the Energy Efficiency Improvement Act of 2015, Public Law 114-11 (April 30, 2015).
[h] See https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=41

Working Group charter allowed for 3 months of DPPP Working Group meetings to establish the scope, metric, definitions, and test procedure for dedicated-purpose pool pumps. The charter reserved the discussion of standards for a later set of meetings, after the working group produced a term sheet recommending a scope, metric, definitions, and test procedure for DPPPs. (Docket No. EERE-2013-BT-NOC-0005, No. 56 at p. 27) On October 15, 2015, DOE published a notice of public open meetings of the DPPP Working Group to establish three additional meetings under the initial charter. 80 FR 61996. DOE selected the members of the DPPP Working Group to ensure a broad and balanced array of interested parties and expertise, including representatives from efficiency advocacy organizations and manufacturers, as well as one representative from a state government organization.

The DPPP Working Group commenced negotiations at an open meeting between September 30 and October 1, 2015, and then held three additional meetings to discuss scope, metrics, and the test procedure.[i] The DPPP Working Group completed its initial charter on December 8, 2015, with a consensus vote to approve a term sheet containing recommendations to DOE on scope, metric, and the basis of test procedure ("December 2015 DPPP Working Group recommendations").[j] The term sheet containing these recommendations is available in the DPPP Working Group docket. (Docket No. EERE-2015-BT-STD-0008, No. 51) ASRAC subsequently voted unanimously to approve the December 2015 DPPP Working Group recommendations during its January 20, 2016 meeting. (Docket No. EERE-2015-BT-STD-0008, No. 0052)

The second phase of meetings commenced on March 21, 2016 (81 FR 10152, 10153) and concluded on June 23, 2016, with approval of a second term sheet (June 2016 DPPP Working Group recommendations). This term sheet contained DPPP Working Group recommendations on performance-based energy conservation standard levels, scope of such standards, certain prescriptive requirements, certain labeling requirements, certain definitions, and certain amendments to its previous test procedure recommendations. (Docket No. EERE-2015-BT-STD-0008, No. 82) ASRAC subsequently voted unanimously to approve the June 2016 DPPP Working Group recommendations during a July 29, 2016 meeting. (Docket No. EERE-2013-BT-NOC-0005, No. 87)

After carefully considering the recommendations submitted by the DPPP Working Group and adopted by ASRAC related to energy conservation standards for pool pumps, DOE has determined that these recommendations comprise a statement submitted by interested persons who represent relevant points of view on this matter, and which, if compliant with certain statutory requirements, could result in issuance of a direct final rule.

Consequently, DOE is adopting new energy conservation standards for certain dedicated-purpose pool pumps. The adopted standards are shown in Table 1.3.1 and Table 1.3.2. Standards for the equipment classes in Table 1.3.1 are performance based, expressed in terms of weighted

[i] Details of the negotiations sessions can be found in the public meeting transcripts that are posted to the docket for the Working Group (www.regulations.gov/#!docketDetail;D=EERE-2015-BT-STD-0008).

[j] The ground rules of the DPPP Working Group define consensus as no more than three negative votes. (Docket No. EERE-2015-BT-0008-0016 at p. 3) Abstention was not construed as a negative vote.

energy factor (WEF); standards in Table 1.3.2 are prescriptive. These standards apply to all equipment listed in Table 1.3.1 and Table 1.3.2 and manufactured in or imported into the United States starting on 54 months after date of publication in the *Federal Register*.

Table 1.3.1 Performance-Based Energy Conservation Standards for Dedicated-Purpose Pool Pumps

Equipment Class			Minimum Allowable WEF** Score
Dedicated-Purpose Pool Pump Variety	**Hydraulic Horsepower Applicability***	**Motor Phase**	
Standard-Size Self-Priming Pool Filter Pumps	<2.5 hhp and >=0.711	Single	WEF = - 2.30 * ln (hhp) + 6.59
Small-Size Self-Priming Pool Filter Pumps	hhp < 0.711 hp	Single	WEF = 5.55 for hhp ≤ 0.13 hp, -1.30 * ln (hhp) + 2.90 for hhp > 0.13 hp
Non-Self-Priming Pool Filter Pumps	hhp < 2.5 hp	Any	WEF = 4.60 for hhp ≤ 0.13 hp, -0.85 * ln (hhp) + 2.87 for hhp > 0.13 hp
Pressure Cleaner Booster Pumps	Any	Any	WEF = 0.42

*All instances of hhp refer to rated hydraulic horsepower determined in accordance with the DOE test procedure at 10 CFR 431.464 and applicable sampling plans.
** WEF is measured by kgal/kWh.

Table 1.3.2 Prescriptive Energy Conservation Standards for Dedicated-Purpose Pool Pumps

Equipment Class			Prescriptive Standard
Dedicated-Purpose Pool Pump Variety	**Hydraulic Horsepower Applicability**	**Motor Phase**	
Integral Sand Filter Pool Pump	Any	Any	Must be distributed in commerce with a pool pump timer that is either integral to the pump or a separate component that is shipped with the pump.
Integral Cartridge Filter Pool Pump	Any	Any	Must be distributed in commerce with a pool pump timer that is either integral to the pump or a separate component that is shipped with the pump.
All Dedicated-Purpose Pool Pumps Distributed in Commerce with Freeze Protection Controls	Any	Any	The pump must be shipped with freeze protection disabled or with the following default, user-adjustable settings: • The default dry-bulb air temperature setting is no greater than 40 °F; • The default run time setting shall be no greater than 1 hour (before the temperature is rechecked); and • The default motor speed shall not be more than

			½ of the maximum available speed.

1.4 PROCESS FOR SETTING ENERGY CONSERVATION STANDARDS

Under EPCA, when DOE evaluates new or amended standards, it must consider, to the greatest extent practicable, the following seven factors. (42 U.S.C. 6295(o)(2)(B)(i) and 6316(a))

1. the economic impact of the standard on the manufacturers and consumers of the affected products;

2. the savings in operating costs throughout the estimated average life of the product compared to any increases in the initial cost or maintenance expense for the products that are likely to result from the imposition of the standard;

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 products 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.

Other statutory requirements are set forth in 42 U.S.C. 6295(o)(1)–(2)(A), (2)(B)(ii)–(iii), and (3)–(4).

With particular regard to direct final rules, the Energy Independence and Security Act of 2007 (EISA 2007), Pub. Law 110-140 (December 19, 2007), amended EPCA, in relevant part, to grant DOE authority to issue a type of final rule (i.e., a “direct final rule”) establishing an energy conservation standard for a product or equipment (including dedicated-purpose pool pumps) on receipt of a statement submitted jointly by interested persons that are fairly representative of relevant points of view (including representatives of manufacturers of covered equipment, States, and efficiency advocates), as determined by the Secretary. (42 U.S.C. 6295(p)(4)(A)) and 6316(a)) That statement must contain recommendations with respect to an energy or water conservation standard that are in accordance with the provisions of 42 U.S.C. 6295(o). (42 U.S.C. 6295(p)(4)(A)(i)) A notice of proposed rulemaking (NOPR) that proposes an identical energy efficiency standard must be published simultaneously with the direct final rule and a public comment period of at least 110 days provided. (42 U.S.C. 6295(p)(4)(A)-(B)) Not later than 120 days after issuance of the direct final rule, if DOE receives one or more adverse comments or an alternative joint recommendation relating to the direct final rule, the Secretary must determine whether the comments or alternative joint recommendation may provide a reasonable basis for withdrawal under 42 U.S.C. 6295(o) or other applicable law. (42 U.S.C. 6295(p)(4)(C)(i)) If the Secretary makes such a determination, DOE must withdraw the direct final rule and proceed with the simultaneously published NOPR, and publish in the Federal Register the reason why the direct final rule was withdrawn. (42 U.S.C. 6295(p)(4)(C)(ii))

This TSD describes the various analyses DOE performed in developing the direct final rule, such as the engineering analysis and the consumer economic analyses (e.g., the life-cycle cost [LCC] and payback period [PBP] analyses); the methods used for conducting the analyses, and the relationships among the various analyses. Table 1.4.1 lists the analyses DOE conducted for the direct final rule.

Table 1.4.1 Direct Final Rule Analyses

Analyses Performed for this Direct Final Rule
Market and technology assessment
Screening analysis
Engineering analysis
Energy use characterization
Product price determination
Life-cycle cost and payback period analyses
Life-cycle cost subgroup analysis
Shipments analysis
National impact analysis
Manufacturer impact analysis
Utility impact analysis
Employment impact analysis
Emissions Analysis
Regulatory impact analysis

DOE developed spreadsheets for the LCC, PBP, and national impact analyses (NIA) for dedicated-purpose pool pumps. The LCC workbook calculates the LCC and PBP at various energy efficiency levels. The NIA workbook does the same for national energy savings and national net present values (NPVs). All of the spreadsheets are available on the DOE website for dedicated-purpose pool pumps at https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=67.

As part of the information gathering and sharing process, DOE interviewed dedicated-purpose pool pumps manufacturers. DOE selected companies that represent production of all types of equipment. DOE had five objectives for these interviews: (1) solicit manufacturer feedback on the draft inputs to the engineering analysis; (2) solicit manufacturer data for use in the analysis and downstream analyses; (3) solicit feedback on topics related to the manufacturer impact analysis; (4) provide an opportunity for manufacturers to express their concerns to DOE; and (5) foster cooperation between manufacturers and DOE. DOE incorporated the information gathered during these interviews into its engineering analysis (chapter 5) and its manufacturer impact analysis (chapter 12).

1.5 STRUCTURE OF THE DOCUMENT

This TSD describes the analytical approaches and data sources that DOE used in the rulemaking for dedicated-purpose pool pumps. The TSD consists of the following chapters and appendices.

Chapter 1	Introduction: provides an overview of DOE's standards program for equipment and how it applies to the rulemaking for dedicated-purpose pool pumps; outlines the structure of the document.
Chapter 2	Analytical Framework: describes the methods, analytical tools, and relationships among the various analyses.
Chapter 3	Market and Technology Assessment: establishes equipment classes and identifies industry trends in shipments and technology. This chapter also provides an overview of dedicated-purpose pool pump technology, including techniques employed to reduce the energy consumption of dedicated-purpose pool pumps.
Chapter 4	Screening Analysis: after identifying and evaluating design options for improving pump efficiency, determines which of those DOE screened out of further analysis.
Chapter 5	Engineering Analysis: discusses the methods used for developing the relationship between increased manufacturer price and increased efficiency. Presents detailed cost and efficiency information for equipment classes analyzed.
Appendix 5A	Engineering Analysis: Variable-Speed Pump Performance at Low Speeds
Chapter 6	Markups Analysis: discusses the methods used to establish price markups for converting manufacturer prices to consumer equipment prices.
Appendix 6A	Detailed Data for Product Price Markups
Appendix 6B	Incremental Markups: Theory and Evidence
Chapter 7	Energy Use Analysis: discusses the process used for estimating energy use of the considered equipment as a function of efficiency level.
Appendix 7A	Household Variables

Chapter 8	Life-Cycle Cost and Payback Period Analysis: discusses the effects of standards on individual consumers and users of the equipment and compares the LCC and PBP of equipment with and without higher energy conservation standards.
Appendix 8A	User Instructions for Life-Cycle Cost and Payback Period Spreadsheet
Appendix 8B	Uncertainty and Variability in LCC Analysis for Dedicated-Purpose Pool Pumps
Appendix 8C	Energy Price Calculations for Dedicated-Purpose Pool Pumps
Appendix 8D	Dedicated-Purpose Pool Pump Lifetime Determination
Appendix 8E	Distributions used for Discount Rates
Chapter 9	Shipments Analysis: discusses the methods used for projecting the total number of dedicated-purpose pool pumps that would be affected by standards.
Chapter 10	National Impact Analysis: discusses the methods used for projecting national energy consumption and consumer economic impacts in the absence and presence of standards.
Appendix 10A	User Instructions for Shipments and NIA Spreadsheet
Appendix 10B	Full-Fuel-Cycle Analysis
Appendix 10C	Net Present Value Under Alternative Scenarios
Chapter 11	Consumer Subgroup Analysis: discusses the effects of standards on any identifiable subgroups of consumers who may be disproportionately affected by the adopted standard level.
Chapter 12	Manufacturer Impact Analysis: discusses the effects of standards on the finances and profitability of manufacturers of dedicated-purpose pool pumps.
Appendix 12A	Manufacturer Impact Analysis Interview Guide
Appendix 12B	Government Regulatory Impact Model Overview
Chapter 13	Emissions Impact Analysis: discusses the effects of standards on pollutants, including sulfur dioxide, nitrogen oxides (NOX), and mercury, as well as carbon emissions.
Appendix 13A	Emissions Analysis Methodology

Chapter 14	Monetization of Emission Reductions Benefits: Assigns monetary values to the benefits likely to result from the reduced emissions of carbon dioxide (CO2) and nitrogen oxides (NOX) resulting from standards.
Appendix 14A	Social Cost of Greenhouse Gases
Appendix 14B	Benefit-per-ton Values for NO_x Emissions from Electricity Generation
Chapter 15	Utility Impact Analysis: discusses selected effects of standards on the electric utility industry.
Appendix 15A	Utility Impact Analysis Methodology
Chapter 16	Employment Impact Analysis: discusses the effects of standards on national employment.
Chapter 17	Regulatory Impact Analysis: discusses the effects of non-regulatory alternatives to efficiency standards.
Appendix 17A	Regulatory Impact Analysis: Supporting Materials

CHAPTER 2. ANALYTICAL FRAMEWORK

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CHAPTER 2. ANALYTICAL FRAMEWORK

2.1 INTRODUCTION

Section 6295(o)(2)(A) of the Energy Policy and Conservation Act (EPCA), as amended, 42 USC 6291 *et. seq.*, requires that when prescribing new or amended energy conservation standards for covered products, the U.S. Department of Energy (DOE) promulgate standards that achieve the maximum improvements in energy efficiency that are technologically feasible and economically justified. This chapter provides a description of the analytical framework that DOE is using to evaluate amended energy conservation standards for dedicated-purpose pool pumps. This chapter sets forth the methodology, analytical tools, and relationships among the various analyses that are part of this rulemaking.

Figure 2.1.1 summarizes the analytical components of the standards-setting process. The focus of this figure is the center column, identified as “Analyses.” The columns labeled “Key Inputs” and “Key Outputs” show how the analyses fit into the rulemaking process, and how the analyses relate to each other. Key inputs are the types of data and information that the analyses require. Some key inputs exist in public databases; DOE collects other inputs from stakeholders or persons with special knowledge. Key outputs are analytical results that feed directly into the standards-setting process. Arrows connecting analyses show types of information that feed from one analysis to another. While Figure 2.1.1 summarizes the inputs, outputs, and analytical stages of a typical standards rulemaking, individual inputs, outputs, and stages may vary by rulemaking.

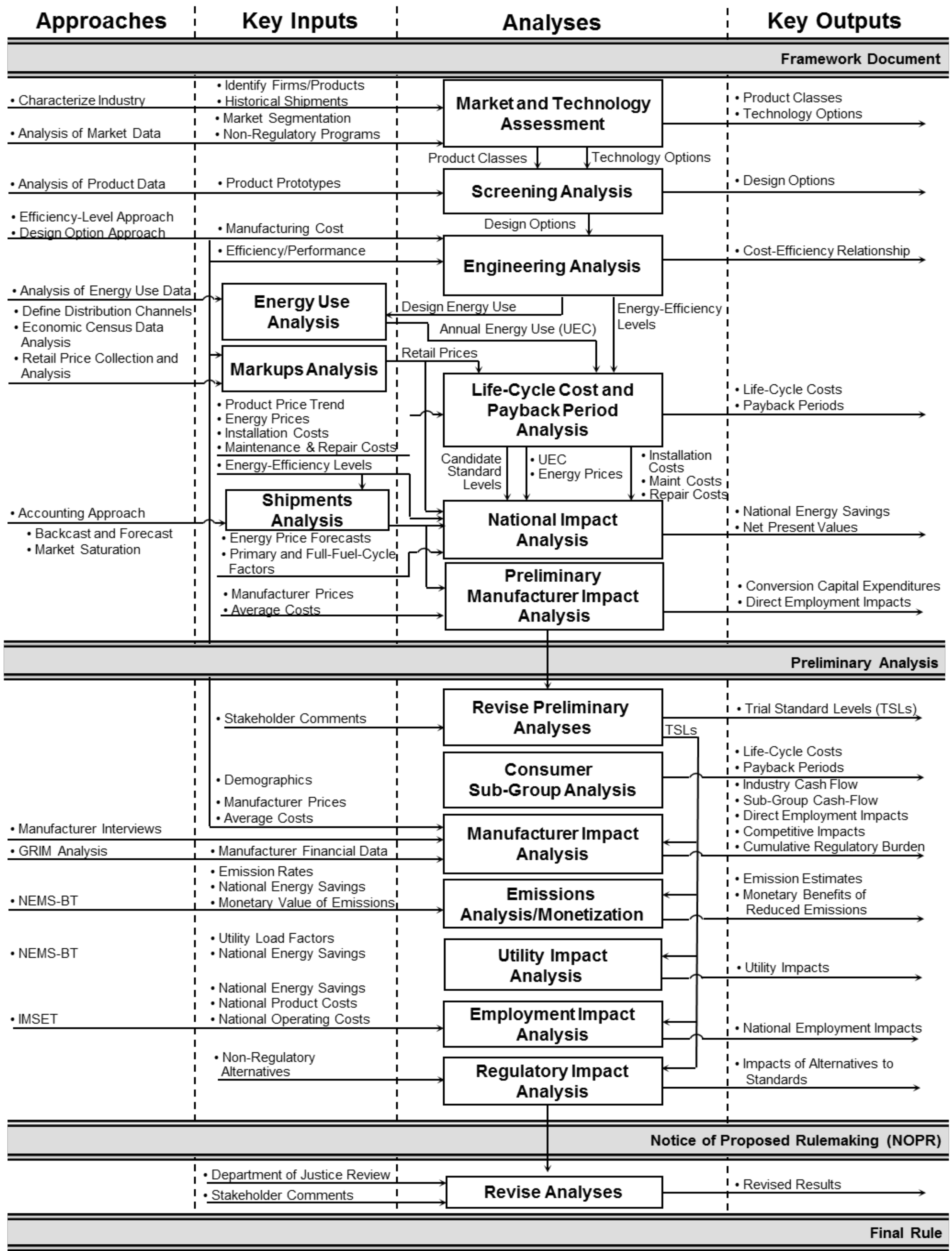

Figure 2.1.1 Flow Diagram of Analyses for the Rulemaking Process

In this technical support document (TSD), DOE presents results of the following analyses that were performed for this direct final rule:

- A market and technology assessment to characterize the relevant equipment, its market presence, and any technology options that may improve its energy efficiency, including prototype designs.
- A screening analysis to review each technology option and determine if it is technologically feasible; is practicable to manufacture, install, and service; would adversely affect equipment utility or equipment availability; or would have adverse impacts on health and safety.
- An engineering analysis to develop relationships that show the manufacturer's cost of achieving increased efficiency.
- A markups analysis to develop distribution channel markups that relate the manufacturer production cost (MPC) to the cost to the consumer.
- An energy use analysis to determine the annual energy use of the considered equipment in a representative set of end users.
- Life-cycle cost (LCC) and payback period (PBP) analysis to calculate the savings in operating costs to the end user throughout the life of the covered equipment compared with any increase in the installed cost for the equipment likely to result directly from a standard.
- A shipments analysis to project equipment shipments and to assess the impact of potential standards on shipments.
- A national impact analysis (NIA) to assess the aggregate impacts at the national level of potential energy conservation standards for the considered equipment, as measured by the NPV of total consumer economic impacts and the national energy savings (NES).
- A customer subgroup analysis to evaluate variations in consumer characteristics that might cause a standard to disproportionately affect particular consumer subpopulations.
- A manufacturer impact analysis (MIA) to estimate the financial impact of standards on manufacturers and calculated impacts on competition, employment, and manufacturing capacity.
- An emissions analysis to assess the impacts of amended energy conservation standards on CO_2 and other air emissions.
- An emissions monetization to assess the benefits associated with emissions reductions.
- A utility impact analysis to estimate key effects of potential standards on electric utilities.
- An employment impact analysis to assess the aggregate impacts on national employment.

- A regulatory impact analysis to examine major alternatives to amended energy conservation standards that potentially could achieve substantially the same regulatory goal at a lower cost.

2.2 BACKGROUND

Title III, Part C[a] of the Energy Policy and Conservation Act of 1975 (EPCA), (42 U.S.C. 6311–6317, as codified) established the Energy Conservation Program for Certain Industrial Equipment, a program covering certain industrial equipment.[b] "Pumps" are listed as a type of covered industrial equipment. (42 U.S.C. 6311(1)(A))

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The second phase of meetings commenced on March 21, 2016 (81 FR 10152, 10153) and concluded on June 23, 2016, with approval of a second term sheet (June 2016 DPPP Working Group recommendations). This term sheet contained DPPP Working Group recommendations on performance-based energy conservation standard levels, scope of such standards, certain prescriptive requirements, certain labeling requirements, certain definitions, and certain amendments to its previous test procedure recommendations. (Docket No. EERE-2015-BT-STD-0008, No. 82) ASRAC subsequently voted unanimously to approve the June 2016 DPPP Working Group recommendations during a July 29, 2016 meeting. (Docket No. EERE-2013-BT-NOC-0005, No. 87)

After carefully considering the recommendations submitted by the DPPP Working Group and adopted by ASRAC related to energy conservation standards for dedicated-purpose pool pumps, DOE has determined that these recommendations comprise a statement submitted by interested persons who represent relevant points of view on this matter, and which, if compliant with certain statutory requirements, could result in issuance of a direct final rule.

Consequently, DOE is adopting new energy conservation standards for certain dedicated-purpose pool pumps. The adopted standards are shown in Table 2.2.1 and Table 2.2.2. Standards for the equipment classes in Table 2.2.1 are performance based, expressed in terms of weighted energy factor (WEF); standards in Table 2.2.2 are prescriptive. These standards apply to all equipment listed in Table 2.2.1 and Table 2.2.2 and manufactured in or imported into the United States starting on 54 months after date of publication in the *Federal Register*.

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[d] Details of the negotiations sessions can be found in the public meeting transcripts that are posted to the docket for the Working Group (www.regulations.gov/#!docketDetail;D=EERE-2015-BT-STD-0008).

[e] The ground rules of the DPPP Working Group define consensus as no more than three negative votes. (Docket No. EERE-2015-BT-0008-0016 at p. 3) Abstention was not construed as a negative vote.

Table 2.2.1 Performance-Based Energy Conservation Standards for Dedicated-Purpose Pool Pumps

Equipment Class			Minimum Allowable WEF** Score
Dedicated-Purpose Pool Pump Variety	**Hydraulic Horsepower Applicability***	**Motor Phase**	
Standard-Size Self-Priming Pool Filter Pumps	<2.5 hhp and >=0.711	Single	WEF = - 2.30 * ln (hhp) + 6.59
Small-Size Self-Priming Pool Filter Pumps	hhp < 0.711 hp	Single	WEF = 5.55 for hhp ≤ 0.13 hp, -1.30 * ln (hhp) + 2.90 for hhp > 0.13 hp
Non-Self-Priming Pool Filter Pumps	hhp < 2.5 hp	Any	WEF = 4.60 for hhp ≤ 0.13 hp, -0.85 * ln (hhp) + 2.87 for hhp > 0.13 hp
Pressure Cleaner Booster Pumps	Any	Any	WEF = 0.42

*All instances of hhp refer to rated hydraulic horsepower determined in accordance with the DOE test procedure at 10 CFR 431.464 and applicable sampling plans.
** WEF is measured by kgal/kWh.

Table 2.2.2 Prescriptive Energy Conservation Standards for Dedicated-Purpose Pool Pumps

Equipment Class			Prescriptive Standard
Dedicated-Purpose Pool Pump Variety	**Hydraulic Horsepower Applicability***	**Motor Phase**	
Integral Sand Filter Pool Pump	Any	Any	Must be distributed in commerce with a pool pump timer that is either integral to the pump or a separate component that is shipped with the pump.*
Integral Cartridge Filter Pool Pump	Any	Any	Must be distributed in commerce with a pool pump timer that is either integral to the pump or a separate component that is shipped with the pump.*
All Dedicated-Purpose Pool Pumps Distributed in Commerce with Freeze Protection Controls	Any	Any	The pump must be shipped with freeze protection disabled or with the following default, user-adjustable settings: • The default dry-bulb air temperature setting is no greater than 40 °F; • The default run time setting shall be no greater than 1 hour (before the temperature is rechecked); and • The default motor speed shall not be more than ½ of the maximum available speed.

* Pool pump timer means a pool pump control that automatically turns off a dedicated-purpose pool pump after a run-time of no longer than 10 hours.

The following sections provide a brief overview of the different analytical approaches used for analyzing standards for dedicated-purpose pool pumps. DOE used the most reliable data available at the time of each analysis in this rulemaking.

2.3 MARKET AND TECHNOLOGY ASSESSMENT

The market and technology assessment characterizes the relevant markets for the considered equipment and technology options for improving efficiency, including prototype designs.

2.3.1 Market Assessment

When DOE begins an energy conservation standards rulemaking, it develops information that provides an overall picture of the market for the equipment considered, including the nature of the equipment, the market characteristics, and the industry structure. This activity consists of both quantitative and qualitative efforts based primarily on publicly-available information. The market assessment examined manufacturers, trade associations, and the quantities and types of products sold and offered for sale.

DOE reviewed relevant literature and interviewed manufacturers to develop an overall picture of the DPPP industry in the United States. Industry publications, data aggregated by industry consultants, and trade organizations provided the bulk of the information, including (1) manufacturers and their market shares, (2) shipments (3) equipment information, and (4) industry trends. The analyses developed as part of the market and technology assessment are described in chapter 3 of this TSD.

2.3.2 Technology Assessment

As part of the market and technology assessment, DOE developed a list of technologies to consider for improving the weighted energy factor (WEF) of pool filter pump varieties and pressure cleaner booster pumps. DOE also considered a prescriptive technology that could reduce the energy consumption of integrated cartridge filter and integrated sand filter pool pumps. Chapter 3 of this TSD includes the detailed list of all technology options DOE identified for this rulemaking.

2.4 SCREENING ANALYSIS

The purpose of the screening analysis is to evaluate the technologies identified in the technology assessment to determine which options to consider further in the analysis and which options to screen out. The screening analysis examines whether various technologies (1) are technologically feasible; (2) are practicable to manufacture, install, and service; (3) have an adverse impact on product utility or availability; and (4) have adverse impacts on health and safety. In consultation with interested parties, DOE reviewed the list of DPPP technologies according to these criteria.

DOE applied the screening criteria and determined that none of the technologies identified in the technology assessment should be screened out from futher consideration. This means that all of the technology options identified in the technology assessment are considered in the engineering analysis. Chapter 4 of this TSD contains details about DOE's screening analysis.

2.5 ENGINEERING ANALYSIS

The engineering analysis establishes the relationship between the manufacturing production cost and the efficiency for each DPPP equipment class. This relationship serves as the basis for cost-benefit calculations in terms of individual end users, manufacturers, and the nation. Chapter 5 of this TSD discusses the equipment classes analyzed, the representative baseline units, the incremental efficiency levels, the methodology used to develop manufacturing production costs, and the cost-efficiency relationships for the considered equipment. The cost-efficiency relationship describes how manufacturing costs increase with each efficiency level above the baseline. To determine the costs for end users to purchase dedicated-purpose pool pumps, chapters 6 and 8 of this TSD estimate the markups in the distribution chain and the costs associated with installation and maintenance.

2.5.1 Baseline Models

To analyze the different options available for improving energy efficiency, DOE first defined a baseline model unit each DPPP equipment class. DOE defined these baseline models as pumps that represent the lowest efficiencies (in terms of WEF) in the market. DOE calculated the efficiency of dedicated-purpose pool pumps in terms of WEF according to the DOE test procedure established in the DPPP test procedure final rule. In selecting baseline models, DOE considered technical descriptions of the covered equipment, definitions of the equipment classes, results of the market assessment, and input from the DPPP Working Group.

2.5.2 Manufacturing Cost Analysis

There are several ways to develop the relationship between cost and efficiency. DOE chose to use a design option approach that identifies specific design options manufacturers might use and the efficiency improvements that would result from applying the different design options. The design options that DOE considered including pump motor improvements and hydraulic design improvements. DOE determined the manufacturing cost of applying these design options based on data gathered from pump and motor manufacturers and retailers. DOE estimated the efficiency improvements associated with these design options based on publicly available certification data for motors and pumps. DOE estimated the manufacturing costs of finished pumps using a combination of virtual teardown analysis, manufacturer-supplied estimates, and retail price analysis.

Chapter 5 of this TSD contains complete details regarding DOE's engineering analysis.

2.6 MARKUPS ANALYSIS

DOE performed a markups analysis to convert the manufacturer costs estimated in the engineering analysis to consumer prices, which then were used in the LCC and PBP analysis and the MIA. DOE calculated markups for baseline equipment (baseline markups) and for more efficient equipment (incremental markups). The incremental markup relates the change in the MPC of higher efficiency models (the incremental cost increase) to the change in the retailer or distributor sales price.

To develop markups, DOE identified how the equipment is distributed from the manufacturer to the consumer. After establishing appropriate distribution channels, DOE relied on economic data from the U.S. Census Bureau and other sources to determine how prices are marked up as the equipment passes from the manufacturer to the consumer. Chapter 6 of the direct final rule TSD provides details on DOE's development of markups for dedicated-purpose pool pumps.

2.7 ENERGY USE ANALYSIS

The purpose of the energy use analysis is to determine the annual energy consumption of pool pumps at different efficiencies in representative U.S. applications, and to assess the energy savings potential of increased dedicated-purpose pool pump efficiency. The energy use analysis estimates the range of energy use of dedicated-purpose pool pumps in the field (i.e., as they are actually used by consumers). The energy use analysis provides the basis for other analyses DOE performed, particularly assessments of the energy savings and the savings in consumer operating costs that could result from adoption of standards.

DOE used Residential Energy Consumption Survey (RECS 2009),[1] Commercial Building Energy Consumption Survey (CBECS 2012),[2] and energy and weather data from the National Oceanic and Atmospheric Administration [3] to estimate weather-normalized energy use.

DOE calculated the annual unit energy consumption (UEC) of dedicated-purpose pool pumps at the considered efficiency levels by multiplying the average daily UEC by the annual days of operation. For single-speed pool pumps, the daily UEC is simply the input power to the motor or controls (if present) multiplied by the daily operating hours. For two-speed and variable-speed pool pumps, the daily UEC is the sum of low-speed mode power multiplied by the low-speed daily operating hours and the high-speed mode power multiplied by the corresponding daily operating hours.

Chapter 7 of the TSD describes the details of the energy use analysis methodology.

2.8 LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSES

In determining whether an energy conservation standard is economically justified, DOE considers the economic impact of potential standards on consumers. The effect of new standards on individual consumers usually includes a reduction in operating cost and an increase in purchase cost. DOE used the following two metrics to measure consumer impacts:

- The LCC (life-cycle cost) is the total consumer expense of equipment over the life of that equipment, consisting of total installed cost (MSP, distribution chain markups, sales tax, and installation costs) plus operating costs (expenses for energy use, maintenance, and repair). To compute the operating costs, DOE discounts future operating costs to the time of purchase and sums them over the lifetime of the equipment.
- The PBP is the estimated amount of time it takes consumers to recover the increased purchase cost (including installation) of more-efficient equipment through lower operating costs. DOE calculates the PBP by dividing the change in purchase cost at higher efficiency levels by the change in annual operating cost for the year that amended or new standards are assumed to take effect.

DOE analyzed the net effect of potential new dedicated-purpose pool pump standards on consumers by determining the LCC and PBP using the engineering performance data, the energy use data, and the markups. Inputs to the LCC calculation include the installed cost to the consumer (purchase price plus installation cost), operating expenses (energy expenses, repair costs, and maintenance costs), the lifetime of the equipment, and a discount rate. Inputs to the payback period calculation include the installed cost to the consumer and first-year operating costs.

DOE generated LCC and PBP results as probability distributions using a simulation approach 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 analysis produces a range of LCC and PBP results, which allows DOE to identify the fraction of customers achieving LCC savings or incurring net cost at the considered efficiency levels.

Chapter 8 of the direct final rule TSD describes the LCC and PBP analyses.

2.9 SHIPMENTS ANALYSIS

Projections of equipment shipments are needed to calculate the national impacts of standards on energy use, NPV, and future manufacturer cash flows. DOE developed shipment projections based on an analysis of key market drivers for dedicated-purpose pool pumps.

The shipments models take an accounting approach, tracking market shares of each equipment class and the vintage of units in the existing stock. Stock accounting uses equipment shipments as inputs to estimate the age distribution of in-service equipment stocks for all years. The age distribution of in-service equipment stocks is a key input to calculations of both the NES and NPV, because operating costs for any year depend on the age distribution of the stock.

Chapter 9 of the DFR TSD provides additional details on the shipments analysis.

2.10 NATIONAL IMPACT ANALYSIS

The national impact analysis assesses the net present value, to the nation, of total consumer life-cycle cost and net energy savings. DOE determined both the NPV and NES for the efficiency levels considered for the equipment classes analyzed. To make the analysis more accessible and transparent to all interested parties, DOE prepared a Microsoft® Excel spreadsheet model to project NES and the national consumer economic costs and savings resulting from new standards. The spreadsheet model uses as inputs typical values (as opposed to probability distributions). Chapter 10 of the DFR TSD provides additional details regarding the national impact analysis.

Several of the inputs for determining NES and NPV depend on the projected trends in equipment energy efficiency. For the case without new standards ("no-new-standards case"), DOE uses the efficiency distributions developed for the LCC analysis, and assumed some rate of change over the projection period. In this analysis, DOE used a roll-up scenario in developing its projections of efficiency trends after compliance is required with standards. Under a roll-up scenario, all equipment that perform at levels below a prospective standard are moved, or rolled-up, to the minimum performance level allowed under the standard. Equipment efficiencies above the standard level under consideration would remain the same as before the revised standard takes effect.

2.10.1 National Energy Savings Analysis

The inputs for determining the national energy savings for each equipment class are: (1) annual energy consumption per unit, (2) shipments, (3) equipment stock, (4) national energy consumption, and (5) site-to-source conversion factors for energy. DOE calculated national energy consumption by multiplying the number of units, or stock, of each equipment class (by vintage, or age) by the unit energy consumption (also by vintage). DOE calculated annual NES based on the difference in national energy consumption for the no-standards case and for each energy conservation standard being considered. DOE estimated energy consumption and savings based on site energy consumption, which it then converted to source energy. DOE also calculates full-fuel-cycle energy savings using factors discussed in appendix 10B. Cumulative energy savings are the sum of the NES for each year.

2.10.2 Net Present Value Analysis

The inputs for determining NPV are: (1) total annual installed cost, (2) total annual savings in operating costs, and (3) a discount factor to calculate the present value of costs and savings. DOE determined the net savings for each year as the difference between the no-standards case and each standards case in terms of total savings in operating costs versus total increases in installed costs. DOE calculated savings over the lifetime of equipment shipped in the projection period. DOE calculated NPV as the difference between the present value of operating cost savings and the present value of total installed costs. DOE used a discount factor based on real discount rates of 3 and 7 percent to discount future costs and savings to present values.

For the NPV analysis, DOE calculates increases in total installed costs as the difference in total installed cost between the no-standards case and standards case (*i.e.*, once the standards take effect). Because the more efficient equipment bought in the standards case usually cost more than equipment bought in the no-new-standards case, cost increases appear as negative values in the NPV.

DOE expresses savings in operating costs as decreases associated with the lower energy consumption of equipment bought in the standards case compared to the no-standards case. Total savings in operating costs are the product of savings per unit and the number of units of each vintage that survive in a given year. DOE used the Energy Information Administration's (EIA's) *Annual Energy Outlook 2016* (*AEO 2016*)[4] as the source of projections for future energy prices.

DOE estimates the NPV of consumer benefits using both a 3-percent and a 7-percent real discount rate. DOE uses these discount rates in accordance with guidance provided by the Office of Management and Budget (OMB) to federal agencies on the development of regulatory analysis. (OMB Circular A-4 (Sept. 17, 2003), section E, "Identifying and Measuring Benefits and Costs")

2.11 CONSUMER SUBGROUP ANALYSIS

In analyzing the potential impacts of new standards on consumers, DOE evaluates the potential impact of new standards on identifiable groups of consumers (*i.e.*, subgroups), such as senior citizens (*e.g.*, senior-only households), that may be disproportionately affected by a national energy conservation standard. Accordingly, DOE evaluated impacts on senior-only households using the LCC and payback period spreadsheet model, using inputs appropriate to these subgroups to the extent possible. The subgroup analysis is discussed in detail in chapter 11 of this TSD.

2.12 MANUFACTURER IMPACT ANALYSIS

DOE performed an MIA to determine the potential financial impact of higher energy conservation standards on DPPP manufacturers, as well as to estimate the impact of such standards on employment and manufacturing capacity. The MIA has both quantitative and qualitative aspects. The quantitative part of the MIA relies on the government regulatory impact model (GRIM), an industry cash-flow model customized for the DPPP industry. The GRIM inputs include manufacturer production costs, manufacturer selling prices, industry shipments, and industry financial parameters. This includes information from many of the analyses described above, such as manufacturing production costs and manufacturer selling prices from the engineering analysis and shipments forecasts from the shipments analysis. The key GRIM output is the industry net present value (INPV). Different sets of assumptions (scenarios) will produce different results. The qualitative part of the MIA includes factors such as impacts on industry competition, impacts on manufacturing capacity, industry consolidation, employment, and identification of manufacturer key issues.

DOE conducts the MIA in three phases. In Phase I, DOE creates an industry profile to characterize the industry and identify important issues that require consideration. In Phase II, DOE prepares an industry cash-flow model and interview questionnaire to guide subsequent discussions. In Phase III, DOE interviews manufacturers and assesses the impacts of standards quantitatively and qualitatively. DOE assesses industry and subgroup cash flow and NPV using the GRIM. DOE then assesses impacts on competition, manufacturing capacity, employment, and regulatory burden based on manufacturer interview feedback and discussions. Chapter 12 of this TSD describes the complete MIA.

2.13 EMISSIONS IMPACT ANALYSIS

The emissions impact analysis consists of two components. The first component estimates the effect of potential energy conservation standards on power sector and site (where applicable) combustion emissions of CO_2, NO_X, SO_2, and Hg. The second component estimates the impacts of potential standards on emissions of two additional greenhouse gases, CH_4 and 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.

The analysis of power sector emissions uses marginal emissions factors that were derived from data in *AEO 2016*. The methodology is described in chapter 13 and 15 of the TSD.

Combustion emissions of CH_4 and N_2O are estimated using emissions intensity factors published by the EPA: GHG Emissions Factors Hub.[f] The FFC upstream emissions are estimated based on the methodology described in chapter 15 of the TSD. 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.

2.14 MONETIZATION OF EMISSIONS REDUCTION BENEFITS

To estimate the monetary value of benefits resulting from reduced emissions of CO_2, DOE plans to use the most current Social Cost of Carbon (SCC) values developed and/or agreed to by an interagency process. The SCC is intended to be a monetary measure of the incremental damage resulting from greenhouse gas (GHG) emissions, including, but not limited to, net agricultural productivity loss, human health effects, property damage from sea level rise, and

[f] Available at: http://www2.epa.gov/climateleadership/center-corporate-climate-leadership-ghg-emission-factors-hub.

changes in ecosystem services. Any effort to quantify and to monetize the harms associated with climate change will raise serious questions of science, economics, and ethics. But 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.

The Interagency Working Group on Social Cost of Carbon released an update of its previous report in 2013.[g] For each of the four sets of SCC cases specified, the values for emissions in 2015 were $12.4, $40.6, $63.2, and $118 per metric ton avoided (values expressed in 2015$. For emissions reductions that occur in later years, these values grow 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 will give preference to consideration of the global benefits of reducing CO_2 emissions. To calculate a present value of the stream of monetary values, DOE discounts the values in each of the four cases using the discount rates that had been used to obtain the SCC values in each case.

DOE recognizes that scientific and economic knowledge continues to evolve rapidly as to the contribution of CO_2 and other GHGs to changes in the future global climate and the potential resulting damages to the world economy. Thus, these values are subject to change.

DOE also estimated monetary benefits likely to result from the reduced emissions of methane and N_2O that DOE estimated for each of the considered TSLs for dedicated-purpose pool pumps. DOE used the recent values for the social cost of CH_4 and social cost of N_2O developed by the interagency working group. See chapter 14 of the TSD for further discussion.

DOE also considers the potential monetary benefits of reduced NO_X emissions attributable to the standard levels it considers. DOE estimated the monetized value of NO_X emissions reductions using benefit per ton estimates from the *Regulatory Impact Analysis for the Clean Power Plan Final Rule*, published in August 2015 by EPA's Office of Air Quality Planning and Standards.[h] The report includes high and low values for NO_X (as $PM_{2.5}$) for 2020, 2025, and 2030 discounted at 3 percent and 7 percent. DOE developed values for dedicated-purpose pool pumps using a method described in appendix 14B of the TSD.

2.15 UTILITY IMPACT ANALYSIS

To estimate the impacts of potential energy conservation standards on the electric utility industry, DOE used published output from the NEMS associated with *AEO 2016*. NEMS is a large, multi-sectoral, partial-equilibrium model of the U.S. energy sector that EIA has developed over several years, primarily for the purpose of preparing the *AEO*. NEMS produces a widely recognized forecast for the United States through 2040 and is available to the public.

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[g] Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866, Interagency Working Group on Social Cost of Carbon, United States Government (May 2013; revised July 2015) (Available at: http://www.whitehouse.gov/sites/default/files/omb/inforeg/scc-tsd-final-july-2015.pdf).

[h] Available at www.epa.gov/cleanpowerplan/clean-power-plan-final-rule-regulatory-impact-analysis. See Tables 4A-3, 4A-4, and 4A-5 in the report.

DOE's methodology is based on results published for the *Annual Energy Outlook (AEO)* Reference case, as well as a number of side cases that estimate the economy-wide impacts of changes to energy supply and demand. 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 uses the side cases to estimate the marginal impacts of reduced energy demand on the utility sector. These marginal factors are estimated based on the changes to electricity sector generation, installed capacity, fuel consumption and emissions in the *AEO* Reference case and various side cases. The methodology is described in more detail in chapter 15 of the TSD.

The output of this analysis is a set of time-dependent coefficients that capture the change in electricity generation, primary fuel consumption, installed capacity and power sector emissions due to a unit reduction in demand for a given end use. These coefficients are multiplied by the stream of electricity savings calculated in the NIA to provide estimates of selected utility impacts of new energy conservation standards.

2.16 EMPLOYMENT IMPACT ANALYSIS

The adoption of energy conservation standards can affect employment both directly and indirectly. Direct employment impacts are changes in the number of employees at the plants that produce the covered products. DOE evaluates direct employment impacts in the MIA.

Indirect employment impacts may result from expenditures shifting between goods (the substitution effect) and changes in income and overall expenditure levels (the income effect) that occur due to standards. DOE defines indirect employment impacts from standards as net jobs eliminated or created in the general economy as a result of increased spending driven by increased product prices and reduced spending on energy.

The indirect employment impacts are investigated in the employment impact analysis using the Pacific Northwest National Laboratory's "Impact of Sector Energy Technologies" (ImSET) model.[8] The ImSET model was developed for DOE's Office of Planning, Budget, and Analysis to estimate the employment and income effects of energy-saving technologies in buildings, industry, and transportation. Compared with simple economic multiplier approaches, ImSET allows for more complete and automated analysis of the economic impacts of energy conservation investments.

2.17 REGULATORY IMPACT ANALYSIS

DOE prepares a regulatory impact analysis (RIA) pursuant to Executive Order 12866, "Regulatory Planning and Review," 58 FR 51735 (Oct. 4, 1993). The RIA evaluates potential non-regulatory policy alternatives, comparing the costs and benefits of each to those of the proposed standards. The RIA is subject to review under the Executive Order by the Office of Information and Regulatory Affairs (OIRA) at the Office of Management and Budget (OMB).

DOE recognizes that non-regulatory policy alternatives can substantially affect energy efficiency or reduce energy consumption. DOE will base its assessment on the actual impacts of any such initiatives to date, but also will consider information presented by interested parties regarding the potential future impacts of current initiatives.

REFERENCES

1 U.S. Department of Energy: Energy Information Administration, Residential Energy Consumption Survey: 2009 RECS Survey Data (2013) (Available at: www.eia.gov/consumption/residential/data/2009/) (Last accessed April 20, 2016).

2 U.S. Department of Energy: Energy Information Administration, Commercial Buildings Energy Consumption Survey (2012) (Available at: www.eia.gov/consumption/commercial/data/2012/index.cfm?view=microdata) (Last accessed April 20, 2016).

3 National Oceanic and Atmospheric Administration, NNDC Climate Data Online (Available at: http://www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp) (Last accessed April 20, 2016).

4 U.S. Energy Information Administration. *Annual Energy Outlook 2016 with Projections to 2040*. 2016. Washington, D.C. Report No. DOE/EIA-0383(2016). (Last accessed September 21, 2016.) http://www.eia.gov/forecasts/aeo/pdf/0383(2016).pdf.

CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

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CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

3.1 INTRODUCTION

This chapter provides a profile of the dedicated-purpose pool pump (DPPP) industry in the United States. The information that the U.S. Department of Energy (DOE) gathers for a market and technology assessment serves as resource material throughout the rulemaking. DOE considers both quantitative and qualitative information from publicly-available sources and interested parties. DOE consulted publicly-available information and hired a consultant team to collect data under non-disclosure agreement (NDA) to develop the assessment described in this chapter.

In this chapter, section 3.2 defines different varieties of dedicated-purpose pool pump equipment and defines the scope of this rulemaking. Section 3.3 discusses the specific features that distinguish different DPPP equipment classes, and then it uses these features to define the DPPP equipment classes. Section 3.4 describes the test procedure and the energy use metric that DOE established for DPPP equipment. The market assessment in section 3.5 provides an overall picture of the market for the equipment considered, including the industry structure; manufacturer market shares; regulatory and non-regulatory programs for improving efficiency of the equipment; market trends; and quantities of equipment sold. Finally, section 3.6 identifies a preliminary list of technology options that a manufacturer could use to increase the efficiency of dedicated-purpose pool pumps.

3.2 DEFINITIONS AND SCOPE OF COVERAGE

3.2.1 Definition of Covered Equipment

Although pumps are listed as covered equipment under 42 U.S.C. 6311(1)(A), the term "pump" is not defined in the Energy Policy and Conservation Act (42 U.S.C. 6311–6316; EPCA). In the general pumps test procedure final rule, DOE established a definition for *pump* based on discussions of the working group that DOE established under the Appliance Standards and Rulemaking Federal Advisory Committee (ASRAC) to develop energy conservation standards for general pumps. 78 FR 44036 (July 23, 2013). *Pump* means a device that moves liquids (which may include entrained gases, free solids, and totally dissolved solids) by physical or mechanical action and includes a bare pump and, if included by the manufacturer, mechanical equipment, driver and controls. In the December, 2016, test procedure final rule for dedicated-purpose pool pumps ("test procedure final rule"), DOE noted the applicability of the definition of "pump" and associated terms to dedicated-purpose pool pumps.[1]

DOE excluded dedicated-purpose pool pumps from its recent consensus-based energy conservation standard final rule for general pumps. 81 FR 4368 (January 26, 2016). That final rule, which was the product of a general pumps ASRAC working group, examined a variety of pump categories. While dedicated-purpose pool pumps were one of the pump categories considered, the general pumps working group did not define what a dedicated-purpose pool pump is, and the group ultimately recommended that DOE initiate a separate rulemaking for dedicated-purpose pool pumps. (Docket No. EERE-2013-BT-NOC-0039, No. 92, Recommendation #5B at p. 2)

In December, 2015, DOE established a new working group to negotiate a test procedure and energy conservation standards for dedicated-purpose pool pumps. 80 FR 51483 (Aug. 25, 2015). On June 23, 2016, the DPPP Working Group reached unanimous consensus on a term sheet related to performance-based energy conservation standards, the scope of such standards, certain definitions, certain prescriptive requirements, certain labeling requirements, and certain test procedure aspects for dedicated-purpose pool pumps. (Docket No. EERE-2015-BT-STD-0008, No. 82) DOE issued a test procedure final rule in which DOE defined dedicated-purpose pool pumps and different varieties of DPPP equipment.[1] Those definitions are reproduced below.

Dedicated-purpose pool pump means a self-priming pool filter pump, a non-self-priming pool filter pump, a waterfall pump, a pressure cleaner booster pump, an integral sand filter pool pump, an integral cartridge filter pool pump, a storable electric spa pump, or a rigid electric spa pump.

Pool filter pump means an end suction pump that either: (1) includes an integrated basket strainer, or (2) does not include an integrated basket strainer, but requires a basket strainer for operation, as stated in manufacturer literature provided with the pump; and may be distributed in commerce connected to, or packaged with, a sand filter, removable cartridge filter, or other filtration accessory, as long as the bare pump and filtration accessory are connected with consumer-removable connections that allow the pump to be plumbed to bypass the filtration accessory for testing.

Self-priming pool filter pump means a pool filter pump that is certified under NSF/ANSI 50–2015 to be self-priming or is capable of re-priming to a vertical lift of at least 5 feet with a true priming time less than or equal to 10 minutes, when tested in accordance with NSF/ANSI 50–2015, “Equipment for Swimming Pools, Spas, Hot Tubs and Other Recreational Water Facilities.”

Non-self-priming pool filter pump means a pool filter pump that is not certified under NSF/ANSI 50-2015 to be self-priming and is not capable of re-priming to a vertical lift of at least 5 feet with a true priming time less than or equal to 10 minutes, when tested in accordance with NSF/ANSI 50–2015.

Pressure cleaner booster pump means an end suction, dry rotor pump designed and marketed for pressure-side pool cleaner applications, and which may be UL listed under ANSI/UL 1081–2014, “Standard for Swimming Pool Pumps, Filters, and Chlorinators.”

Waterfall pump means a pool filter pump with maximum head less than or equal to 30 feet, and a maximum speed less than or equal to 1,800 rpm.

Integral cartridge filter pool pump means a pump that requires a removable cartridge filter, installed in a housing on the suction side of the pump, for operation; and the pump cannot be plumbed to bypass the cartridge filter for testing.

Integral sand filter pool pump means a pump distributed in commerce with a sand filter that cannot be bypassed for testing.[1]

3.2.2 Scope of this Rulemaking

The test procedure final rule specifically defines several varieties of dedicated-purpose pool pumps, some of which are included in the scope of energy conservation standards. The following sections describe the scope for the adopted performance-based and prescriptive energy conservation standards, respectively, for dedicated-purpose pool pumps.

3.2.2.1 Performance-Based Energy Conservation Standards

DOE is establishing energy conservation standards for a subset of dedicated-purpose pool pumps to which the test procedure applies. Specifically, while the test procedure applies to self-priming pool filter pumps, non-self-priming pool filter pumps, pressure cleaner booster pumps, and waterfall pumps, DOE is establishing energy conservation standards only for the first of these three DPPP varieties. DOE is not establishing standards for waterfall pumps, as DOE concluded that standards were not economically justified. In this direct final rule, DOE is establishing energy conservation standards for only those pump varieties recommended by the DPPP Working Group. Further detail on the economic benefits and burdens for all dedicated-purpose pool pump varieties analyzed, including waterfall pumps, can be found in chapter 8 of this technical support document (TSD). The scope of the performance-based energy conservation standards established in this direct final rule is summarized in Table 3.2.1.

Table 3.2.1 Scope of Performance-Based Standards for DPPPs

Pump Variety	Hydraulic Horsepower (hhp) Range	Power that Pump is Served By
Self-priming pool filter pump	All pumps less than 2.5 hhp	Single-phase
Non-self-priming pool filter pumps	All pumps less than 2.5 hhp	No restriction
Pressure cleaner booster pumps	No restriction	No restriction

As shown in Table 3.2.1, the scope of the standards DOE is establishing is limited to self-priming and non-self-priming pool filter pumps with a hydraulic output power less than 2.5 hydraulic horsepower[a] (hhp). This is consistent with the scope of self-priming and non-self-priming pool filter pumps established in the test procedure final rule.[1] This restriction is based on the combination of three key limitations associated with pool filter pumps larger than 2.5 hhp: (1) low shipments volume, (2) low potential for energy savings (due to the prevalence of motors

[a] The test procedure final rule defines "hydraulic horsepower" as "the mechanical power transferred to the liquid as it passes through the pump," and notes that hydraulic horsepower is synonymous with "pump hydraulic power."

already regulated by DOE), and (3) lack of performance data. This is consistent with the scope recommended by the DPPP Working Group. (Docket No. EERE-2015-BT-STD-0008, No. 82, Recommendation #1 at p. 1)

As also shown in Table 3.2.1, DOE is establishing that the scope of the standards for self-priming pool filter pumps only be applicable to self-priming pool filter pumps served by single-phase power. The DPPP Working Group clarified that the recommended test procedure and reporting requirements would still be applicable to all self-priming pool filter pumps - both those served by single-phase power and those served by three-phase power. Regardless of whether the pump is supplied by single- or three-phase power, the recommended hydraulic horsepower limitation of 2.5 rated hydraulic horsepower would still apply to such self-priming pool filter pumps. DOE is establishing this restriction based on low shipments volume and low potential for energy savings (due to the prevalence of motors already regulated by DOE) associated with three-phase dedicated-purpose pool pumps. This is consistent with the DPPP Working Group recommendations. (Docket No. EERE-2015-BT-STD-0008, No. 82, Recommendation #3 at p. 2)

Finally, consistent with the test procedure scope, standards do not apply to any dedicated-purpose pool pumps that are submersible. In the test procedure final rule, DOE defined a submersible pump as a pump that is designed to be operated with the motor and bare pump fully submerged in the pumped liquid.

3.2.2.2 Prescriptive Energy Conservation Standards

Consistent with the DPPP Working Group recommendations, DOE is setting prescriptive energy conservation standards for integral cartridge filter pool pumps and integral sand filter pool pumps.

3.3 EQUIPMENT CLASSES AND DISTINGUISHING FEATURES

When evaluating and establishing energy conservation standards, DOE divides covered equipment into equipment classes by the type of energy used, by capacity, or by other performance-related features that justify differing standards. In making a determination whether a performance-related feature justifies a different standard, DOE must consider such factors as the utility of the feature to the consumer and other factors DOE determines are appropriate. (42 U.S.C. 6295(q) and 6316(a))

The DPPP varieties defined in section 3.2.1 serve as the basis for the DPPP equipment classes that DOE is establishing. Further, the self-priming pool filter pump variety is being subdivided into two equipment classes based on pump capacity, or more specifically, hydraulic horsepower at maximum speed on curve C (which is also referred to as rated hydraulic horsepower in the test procedure final rule). DOE is dividing DPPP equipment classes based on the following performance-related features:

- strainer or filtration accessory
- self-priming ability

- pump capacity (flow, head, and horsepower)
- rotational speed
- end user safety

The following sections describe these features in more detail.

3.3.1 Strainer or Filtration Accessory

Dedicated-purpose pool pumps employ several different varieties of strainer and filtration accessories, each providing a different utility to the end user. As defined in the test procedure final rule, a pool filter pump either includes a basket strainer or requires a basket strainer for operation. A basket strainer is a specific component that the test procedure final rule defines as "a perforated or otherwise porous receptacle that prevents solid debris from entering a pump, when mounted within a housing on the suction side of a pump. The basket strainer receptacle is capable of passing spherical solids of 1 mm in diameter, and can be removed by hand or with simple tools. Simple tools include but are not limited to a screwdriver, pliers, and an open-ended wrench." The basket strainer provides a direct utility to the pool filter pump end user, as it protects the pump from debris that would otherwise enter the impeller and cause damage to the pump. However, this utility comes at the cost of pump efficiency. The basket strainer has head-loss associated with it, which means a measurable amount of hydraulic power is lost as water traverses the basket strainer and the basket strainer housing. Ultimately, this reduces efficiency for pumps that include or require a basket strainer, compared to those that do not. Based on this relationship between end-user utility and achievable efficiency, DOE concluded that the presence of or requirement for a basket strainer is an appropriate feature to differentiate and establish pool filter pump equipment classes (including standard-size and small-size self-priming pool filter pumps, non-self-priming pool filter pumps, and waterfall pumps).

Typically, if a pool utilizes a pool filter pump, the filtration of particulates less than 1mm in diameter takes place in a separate filtration device, which is either installed separately from the pump, or is attached to the pump and may be removed using simple tools. Alternatively, integral cartridge filter and integral sand filter pump varieties include a filtration accessory, designed to remove particulates less than 1 mm in diameter, which is integrally and permanently mounted to the pump. These integral filter pump varieties are typically distributed in commerce with a storable pool (e.g., inflatable or collapsible pools) or as a replacement pump for such a pool. These storable pools are intended for temporary or seasonal use, and their application and usage profile are unique from other dedicated-purpose pool pump varieties. The end user of a storable pool is required to assemble the pump and pool at the beginning of the season and disassemble the pump and pool for storage at the end of the season. Combining the pump and filtration equipment into one integral piece of equipment enables the user to assemble, disassemble, and store the equipment more easily than if the pump and filter were separate components. Thus, the integral nature of the filtration accessory provides utility to the end user.

Similar to the basket strainer, the integral filtration accessory has head-loss associated with it, which means a measurable amount of hydraulic power is lost as water traverses the integral filtration accessory. However, due to the finer filtering capability of the integral filtration accessory (designed to remove particulates less than 1 mm in diameter), the integral filtration accessory will experience a larger head-loss than a comparably-sized strainer basket. Ultimately, this translates to a reduced efficiency for integral cartridge filter and integral sand filter pool pumps, as compared to similarly sized pool filter pumps and other pumps not requiring a basket strainer. Based on this relationship between end-user utility and achievable efficiency, DOE concluded that the presence of an integral filtration accessory is an appropriate feature to differentiate and establish integral pump equipment classes (including integral cartridge filter and integral sand filter pumps).

The two specific varieties of integral filter pumps (integral cartridge and integral sand) offer different utility to end users. Sand filter pumps typically weigh more (when filled with sand media), but require less ongoing intervention and attention by the end user than cartridge filters. However, integral sand filter pool pumps typically have a greater head-loss across the filtration accessory than integral cartridge filter pool pumps. Ultimately, this translates to a reduced efficiency for integral sand filter pumps, compared to integral cartridge filter pumps. Based on this relationship between end-user utility and achievable efficiency, DOE concluded that the variety of integral filtration accessory (sand filter versus cartridge filter) is an appropriate feature to differentiate integral pumps into two equipment classes, integral cartridge and integral sand filter pumps.

3.3.2 Self-Priming Ability

All pool filter pumps on the market are either self-priming or non-self-priming. The test procedure final rule defines a self-priming pool filter pump as, “a pool filter pump that is certified under NSF/ANSI 50–2015 to be self-priming or is capable of re-priming to a vertical lift of at least 5 feet with a true priming time less than or equal to 10 minutes, when tested in accordance with NSF/ANSI 50–2015.”[1] Self-priming pumps are able to lift liquid that originates below the centerline of the pump inlet and, after initial manual priming, are able to subsequently re-prime without the use of external vacuum sources, manual filling, or a foot valve. In contrast, non-self-priming pumps must be re-primed in order to operate after an idle period. This re-priming may be achieved by manually filling the pump with water, or re-priming may be induced by placing the pump at a lower vertical height than the surface of the water it will pump. The self-priming capability of a pool filter pump affects typical applications for which the pump is appropriate, and thus the utility to the end user. For example, typical inground pool constructions consist of a pump at ground level (above the water level), and main and skimmer drains below the water level. In this configuration, when the pump is cycled off (which will typically happen at least once during a 24-hour period), prime is lost. A self-priming pump provides the end user with the ability to restart the pump (typically using a timer) without any need for manual intervention. Alternatively, a non-self-priming pump would require the end user to manually refill the pump casing (re-prime) the pump, each time the end user wanted to restart the pump.

To achieve self-priming capability, self-priming pumps are constructed in a different manner than non-self-priming pumps. Specifically, self-priming pool filter pumps typically incorporate diffusers and reservoirs that work together to remove air from the suction side of the pump and regain the prime after an idle period. Prime is achieved by recirculating water that is trapped in the reservoir. The water in the pump mixes with air entering the pump from the suction line, and that mixture is discharged back into the reservoir, where air is released out of the pump discharge. Once all of the air is removed from the suction line, the pump is primed. However, once the self-priming pump is primed and running, the diffuser and reservoir configuration, by design, results in significant water recirculation within the bare pump, compared to a non-self-priming pump, where there is less internal recirculation. Internal water recirculation means that a portion of the hydraulic output of the pump is recirculated back to the reservoir of the pump, and is not immediately discharged out of the pump; as such, recirculation reduces the efficiency of the pump. Based on this relationship between end-user utility and achievable efficiency, DOE concluded that self-priming capability is an appropriate feature to differentiate equipment classes (self-priming versus non-self-priming pool filter pumps).[b]

3.3.3 Pump Capacity (Flow, Head, and Power)

The capacity of a dedicated-purpose pool pump can be expressed using measurements of head, flow, and hydraulic power. These three parameters define the useful output to the end user and are interrelated and bound by the Equation 3.1:

$$P_{hydro} = \frac{Q * H}{3956}$$

Equation 3.1

Where:

P_{hydro} = hydraulic power, in horsepower (hp),
Q = volumetric flow, in gallons per minute (gpm), and
H = total dynamic head, in feet of water.

[b] More information on the construction and capabilities of self-priming and non-self-priming pumps is available at Hayward Industries' web page of frequently asked questions. In particular, the descriptions of inground pumps and aboveground pumps discuss priming. These descriptions are available at: www.hayward-pool.com/shop/en/pools/faqs#q188, and at www.hayward-pool.com/shop/en/pools/faqs#q192.

The requirements of a pool (or any water system), can be expressed in terms of a system curve. When a pump is tested on a system curve (such as curve C),[c] any one of these three measurements can be used to calculate the other two measurements. Equation 3.2 and Equation 3.3 illustrate this relationship for system curve C.

$$H_{CurveC} = 0.0082 * Q_{CurveC}{}^{2}$$

Equation 3.2

Where:

Q_{CurveC} = flow rate on system curve C, in gpm, and
H_{CurveC} = head on system curve C, in feet of water.

$$P_{hydro,CurveC} = \frac{0.0082 * Q_{CurveC}{}^{3}}{3956}$$

Equation 3.3

Where:

$P_{hydro,CurveC}$ = hydraulic power on system curve C in hp.

In agreement with DPPP Working Group recommendations, DOE is subdividing self-priming pool filter pumps into two equipment classes based on hydraulic horsepower at maximum speed, on curve C. The DPPP Working Group recommended a breakpoint of 0.711 hhp to divide the self-priming pool filter pump variety into two equipment classes: standard-size and small-size. Equation 3.3 dictates that 0.711 hhp corresponds to a flow rate of 70 gpm on curve C.

As discussed earlier in this subsection, pump capacity may also be considered in terms of pump head (or total dynamic pressure). In this direct final rule, DOE distinguishes waterfall

[c] The test procedure final rule contains a detailed discussion of the system curves used in pump testing.

pump equipment from other pool filter pump varieties using head limitations. Specifically, as discussed by the DPPP Working Group, pumps used in waterfall applications do not need to produce high heads because waterfall pumps are typically not connected to pool circulation plumbing or to ancillary pool components like heaters and chlorinators. Therefore, the DPPP Working Group recommended distinguishing the waterfall pump equipment class by establishing a maximum pump head of 30 feet (inclusive) for the waterfall pump equipment class.

DOE is distinguishing pressure cleaner booster pumps from other pumps based on their unique flow and head output. As discussed by the DPPP Working Group, pressure cleaner booster pumps must provide a high amount of head at a low flow rate to propel pressure-side pool cleaners along the bottom of the pool and to remove debris as the cleaner moves. Specifically, pressure-side pool cleaners (and associated piping and hoses) require a pump that provides at least 60 feet of head at approximately 10 gpm of flow; noting that the actual head requirements vary with each specific system, but will not typically be lower than 60 feet of head. Figure 3.3.1 illustrates the performance of four pressure cleaner booster pump models from the three largest manufacturers (representing the majority of the pressure cleaner booster pump market) and highlights the range of head and flow rates for which these pumps are currently designed.

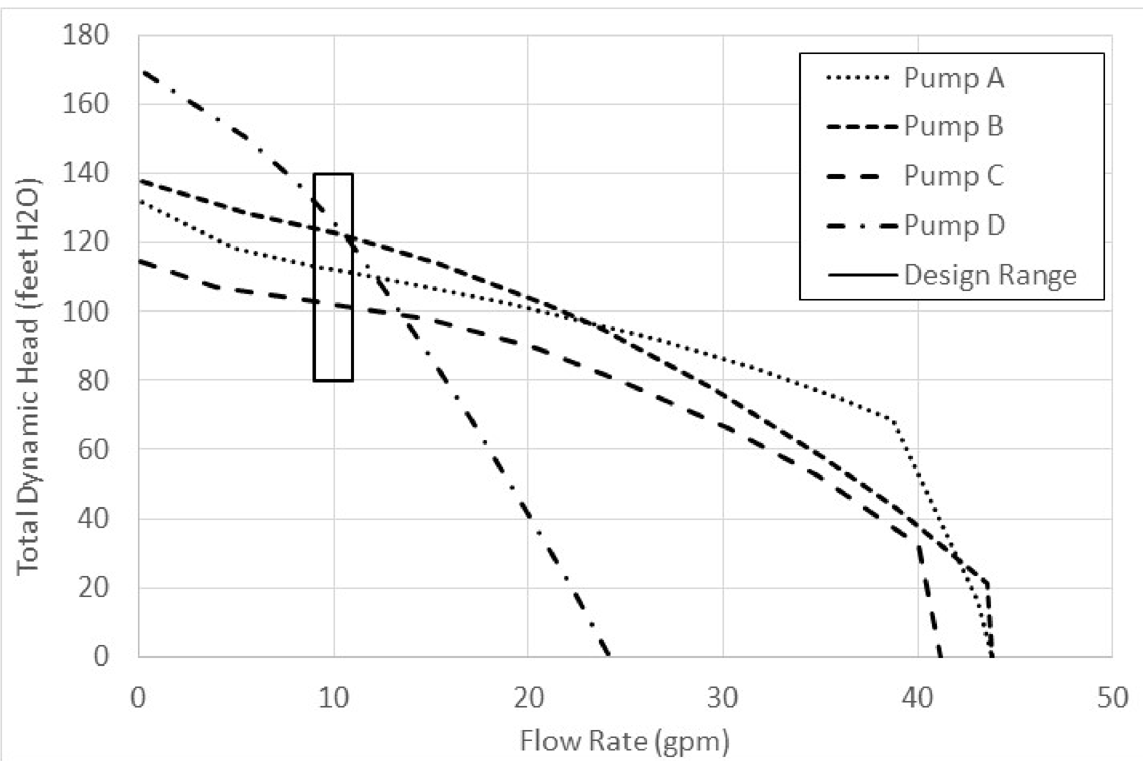

Figure 3.3.1 Head-Flow Chart for Four Pressure Cleaner Booster Pumps, Highlighting Design Range

Although the pumps in Figure 3.3.1 all provide between 100 and 127 feet of head at 10 gpm, the DPPP Working Group concluded that certain systems require less head (down to 60 feet of head). DPPP Working Group members expressed a desire that the test procedure allow better ratings for variable-speed pressure cleaner pumps that are able to reduce speed and energy consumption to avoid supplying (and wasting) excess pressure beyond what is required to drive the cleaner. (Docket No. EERE-2015-BT-STD-0008, May 19 Working Group Meeting, at pp. 49) The DPPP Working Group recommended that, for the test procedure, pressure cleaner booster pumps be evaluated at the lowest speed that can achieve 60 feet of head at a flow rate of 10 gpm. (Docket No. EERE-2015-BT-STD-0008, No. 82 Recommendation #8 at pp. 4) Consequently, DOE concludes that the aforementioned capacity range provides a specific utility to the end user and is appropriate to use as the basis for distinguishing pressure cleaner booster pumps from other pump equipment classes.

3.3.4 Rotational Speed

For dedicated-purpose pool pumps, DOE has determined that rotational speed is not a sufficient differentiator to establish an equipment class without adding specific utility. However, the DPPP Working Group recommended DOE define waterfall pumps as “a pool filter pump with maximum head less than or equal to 30 feet, and a maximum speed less than or equal to 1,800 rpm” and to establish an equipment class for this variety of pool filter pump. Waterfall pumps are used in applications with low head and high flow requirements; i.e., applications that require “flat” head-versus-flow performance curves. This is because waterfall pumps are not typically plumbed through a filter or other auxiliary equipment, and thus do not have a large amount of head to overcome.

Pumps running at 1,800 rpm typically exhibit the fairly flat head-versus-flow operating curve that is usually required by waterfall applications. Figure 3.3.2 illustrates this property in contrast to the steeper head-versus-flow curves that are typical for self-priming pool filter pumps.

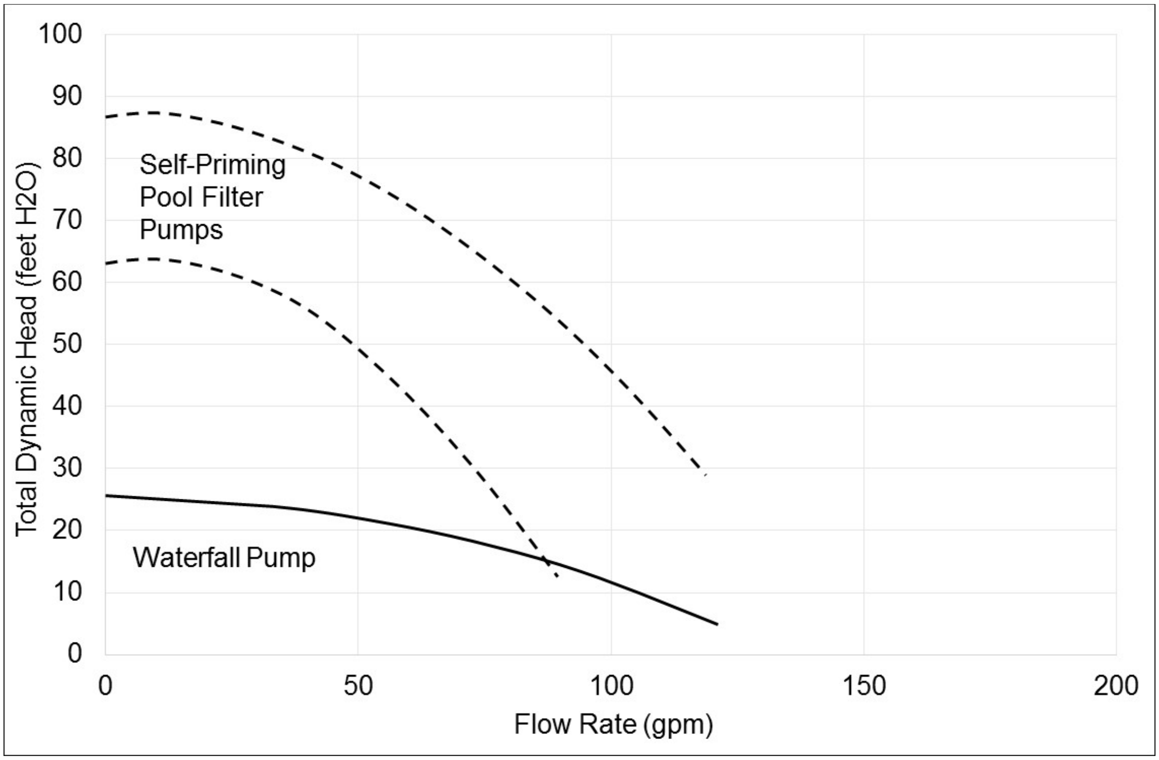

Figure 3.3.2 Head-Flow Curves of a Waterfall Pump and Self-Priming Pool Filter Pumps

Due to the inherent curve shape of 1,800 rpm pumps, this rotational speed limitation in conjunction with the 30-foot head limitation serves to establish a capacity differentiation. The limitations recommended by the DPPP Working Group effectively categorize a set of pumps with similar performance curves (heads, flows, and hydraulic horsepowers) into one equipment class–waterfall pumps. Figure 3.3.3 illustrates this phenomenon.

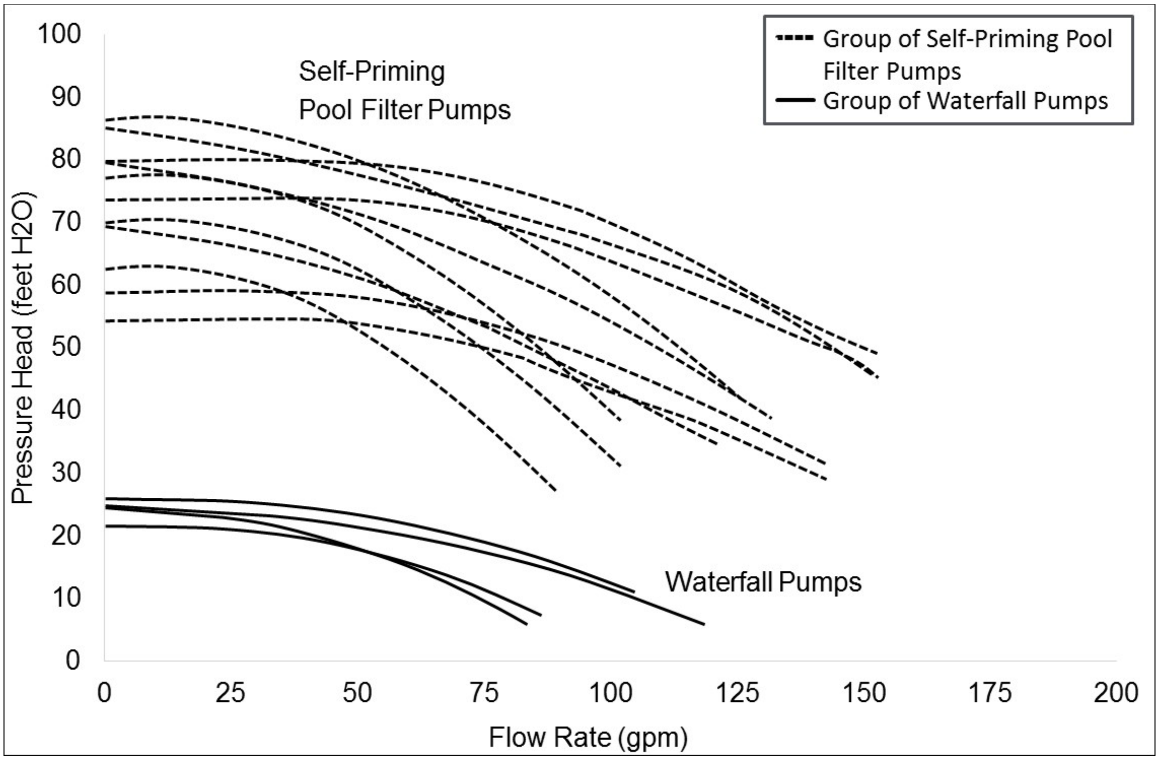

Figure 3.3.3 Head-Flow Curves of Multiple Waterfall Pumps and Self-Priming Pool Filter Pumps

3.3.5 End User Safety

Pressure cleaner booster pumps share many similar design features with end suction close-coupled pumps. However, dedicated-purpose pool pumps (including pressure cleaner booster pumps) must specifically consider the safety of the pool operator (typically a homeowner or renter) in their design (e.g., reduced electrocution or injury risk). To do so, the dedicated-purpose pool pump industry relies on the safety requirements established in the voluntary standard ANSI/UL 1081–2014, "Standard for Swimming Pool Pumps, Filters, and Chlorinators."[2] Based on DPPP Working Group discussion, DOE concluded that most pool filter pumps and all pressure cleaner booster pumps comply with and are currently listed to ANSI/UL 1081-2014. Conversely, general purpose end suction close-coupled pumps are typically installed in commercial and industrial applications and do not need to account for the same specific safety concerns. Differences in safety consideration result in differences in design choices that ultimately affect the performance of the pump. Consequently, DOE concluded that safety considerations are appropriate features to differentiate pressure cleaner booster pumps from end suction close-coupled pumps.

3.3.6 List of Equipment Classes

Based on the performance-related features and distinguishing characteristics described from section 3.3.1 to section 3.3.5, DOE is establishing the following equipment classes, listed in Table 3.3.1 and Table 3.3.2:

Table 3.3.1 DOE Equipment Classes for Pool Filter Pumps

Strainer or Filtration Accessory	Priming Capability	Pump Capacity		Rotational Speed	Equipment Class Designation
		Pump Power	Pump Head		
Basket strainer	Self-priming	<2.5 hhp, >0.711 hhp	n/s*	n/s*	Self-priming pool filter pump, standard-size
		≤0.711 hhp	n/s*	n/s*	Self-priming pool filter pump, small-size
	Non-self-priming	<2.5 hhp	n/s*	n/s*	Non-self-priming pool filter pump**
	n/s*	n/s*	≤30 ft.	≤1800 rpm	Waterfall pump

*n/s indicates not specified.
** DOE analyzed non-self-priming pool filter pumps as two equipment classes: extra-small (less than 0.13 hhp) and standard-size (less than 2.5 hhp and greater than 0.13 hhp). These two equipment classes were ultimately merged into one after DOE selected the same efficiency level for both extra-small and standard-size non-self-priming pool filter pumps.

Table 3.3.2 DOE Equipment Classes for Other Dedicated-Purpose Pool Pumps

Distinguishing Feature(s)	Equipment Class Designation
Integrated cartridge filter	Integral cartridge filter pool pump
Integrated sand filter	Integral sand filter pool pump
Capacity (designed and marketed for pressure-side pool cleaner applications) End-user safety (UL listed under ANSI/UL 1081–2014)	Pressure cleaner booster pump

3.4 TEST PROCEDURES AND ENERGY USE METRIC

DOE recently concluded a rulemaking to establish a uniform test procedure for determining the energy efficiency of dedicated-purpose pool pumps. The test procedure final rule prescribed test methods based on HI 40.6-2014, “Methods for Rotodynamic Pump Efficiency Testing,” with certain exceptions. The prescribed test methods measure the delivered flow rate (in terms of gallons per minute) and the input power to the motor or controls (in terms of watts). The test procedure final rule prescribes a test method for calculating the weighted energy factor[d] (WEF), which is a weighted average of the delivered flow rate divided by input power at one or two different load points. The number and definition of load points depends on the variety of dedicated-purpose pool pump being tested and the number of operating speeds with which it is distributed in commerce. The equation for WEF is shown in Equation 3.4 and the individual load points and weights for different DPPP varieties are described in Table 3.4.1:

[d] The WEF metric requires measurement of gallons per minute and Watts. The DPPP Working Group requested that the units for WEF be in thousands of gallons per minute (kgal/min) and kilowatt-hours (kWh) to make the WEF metric more intuitive to the DPPP industry.

$$\mathrm{WEF} = \frac{\sum_{i=1}^{n}\left(w_i \times \frac{Q_i}{1000} \times 60\right)}{\sum_{i=1}^{n}\left(w_i \times \frac{P_i}{1000}\right)}$$

Equation 3.4

Where:

WEF = weighted energy factor, in kgal/kWh,
w_i = weighting factor at each load point i,
Q_i = flow at each load point i, in gpm,
P_i = input power to the motor (or controls, if present) at each load point i, in watts,
i = load point(s), defined uniquely for each DPPP variety (see Table 3.4.1), and
n = number of load point(s), defined uniquely for each speed configuration.

Table 3.4.1 Load Points and Weights for Each DPPP Variety and Speed Configuration

<table>
<tr><th rowspan="2">DPPP Varieties</th><th rowspan="2">Speed Type</th><th colspan="4">Test Points</th><th rowspan="2">Weight
w_i</th></tr>
<tr><th>No. of Points</th><th>Load Point
i</th><th>Flow Rate
Q</th><th>Head
H</th></tr>
<tr><td rowspan="5">Self-Priming Pool Filter Pumps

and

Non-Self-Priming Pool Filter Pumps (with hhp ≤2.5 hp)</td><td>Single</td><td>1</td><td>High</td><td>Q_{high}(gpm) = $Q_{max\_speed@C}$ = flow at maximum speed on curve C</td><td>H = 0.0082 × Q_{high}^2</td><td>1.0</td></tr>
<tr><td rowspan="2">Two-Speed</td><td rowspan="2">2</td><td>Low</td><td>Q_{low}(gpm) = Flow rate associated with specified head and speed that is not below:
• 31.1 gpm if pump hhp at max speed on curve C is >0.75 or
• 24.7 gpm if pump hydraulic hp at max speed on curve C is ≤0.75
(a pump may vary speed to achieve this load point)</td><td>H ≥ 0.0082 × Q_{low}^2</td><td>0.8</td></tr>
<tr><td>High</td><td>Q_{high}(gpm) = $Q_{max\_speed@C}$ = flow at max speed on curve C</td><td>H = 0.0082 × Q_{high}^2</td><td>0.2</td></tr>
<tr><td rowspan="2">Multi- and Variable-Speed</td><td rowspan="2">2</td><td>Low</td><td>Q_{low}(gpm)=
• If pump hhp at max speed on curve C is >0.75, then Q_{low} = 31.1 gpm
• If pump hydraulic hp at max speed on curve C is ≤0.75, then Q_{low} = 24.7 gpm
(a pump may vary speed to achieve this load point)</td><td>H ≥ 0.0082 × Q_{low}^2</td><td>0.8</td></tr>
<tr><td>High</td><td>Q_{high}(gpm) = 0.8 × $Q_{max\_speed@C}$ = 80% of flow at maximum speed on curve C
(a pump may vary speed to achieve this load point)</td><td>H = 0.0082 × Q_{high}^2</td><td>0.2</td></tr>
<tr><td>Waterfall Pumps</td><td>Single</td><td>1</td><td>High</td><td>Flow corresponding to specified head (on max speed pump curve)</td><td>17.0 ft.</td><td>1.0</td></tr>
<tr><td>Pressure Cleaner Booster Pumps</td><td>All</td><td>1</td><td>High</td><td>10.0 gpm (a pump may vary speed to achieve this load point)</td><td>≥60.0 ft.</td><td>1.0</td></tr>
</table>

The calculated WEF value will be compared to DOE's energy conservation standard. A value greater than the energy conservation standard indicates that the dedicated-purpose pool pump exceeds the requirements of the efficiency standard, while a value lower than the standard indicates that the dedicated-purpose pool pump fails to meet the standard. In this direct final rule, DOE is establishing minimum WEF requirements for the self-priming pool filter pump, non-self-priming pool filter pump, and pressure cleaner booster pump equipment classes described in section 3.3.6. For the pool filter pump classes, DOE uses the pump hydraulic power on curve C to parameterize its standard levels because a pump's attainable WEF score generally decreases as pump capacity increases. Chapter 5 of this TSD provides more details regarding the relationship between pump capacity and efficiency.

3.5 MARKET ASSESSMENT

The market assessment provides a summary of the market for DPPP equipment, including a description of trade associations, existing regulatory and volunteer programs, manufacturer market shares; and market trends and quantities of equipment sold. The market assessment is helpful in identifying the major manufacturers and the characteristics of the equipment they produce, which will be examined further in the engineering and life-cycle cost analyses (chapters 5 and 8 of this TSD, respectively).

3.5.1 Trade Association

The Association of Pool and Spa Professionals (APSP; www.apsp.org) represents the manufacturers of the pool and spa industry in developing legislation and regulations as an advocate. APSP provides product standards for the pool pump industry and a forum for exchanging industry information. APSP provides access to statistical data and economic reports, educational materials, and industry news, and offers courses for installers and designers to become certified in various aspects of installing and repairing pools and spas. APSP maintains a database of pool pumps that meet the ANSI/APSP/ICC-15a-2013 "Standard for Residential Swimming Pool and Spa Energy Efficiency." Section 3.5.4.1 of this chapter provides details on this standard.

3.5.2 Manufacturers and Industry Structure

Manufacturers of dedicated-purpose pool pumps can be categorized into two distinct segments: (1) those that primarily offer pool filter pumps greater than 0.40 hhp and varieties of auxiliary pumps such as waterfall and pressure cleaner booster pumps, (the pool filter pump industry) and (2) those that offer integral filter pumps and pool filter pumps smaller than 0.40 hhp, but not other auxiliary pumps (the integral filter pump industry). The former typically offers larger self-priming pool filter pumps, non-self-priming pool filter pumps, waterfall pumps, and pressure cleaner booster pumps. The latter typically offers very small pool filter pumps, as well as integral cartridge and sand filter pumps that are sold as a package with a seasonal pool, or as a replacement for a pump sold with a seasonal pool. DOE is unaware of any manufacturers that participate in both segments. Consequently, the two categories are discussed separately.

In the pool filter pump industry, DOE identified 17 manufacturers. Of the 17, DOE found that three large manufacturers hold approximately 90 percent of the market in terms of equipment shipments: Hayward Industries, Inc.; Pentair Aquatic Systems; and Zodiac Pool Systems, Inc. These manufacturers primarily produce equipment at manufacturing facilities in the United States. The remaining 10 percent of the market is held by AquaPro Systems; Aquatech Corp.; Asia Connection, LLC; Bridging China International, Ltd.; Carvin Pool Equipment, Inc.; ECO H2O Tech, Inc.; Fluidra USA, LLC; Hoffinger Industries; Raypak; Speck

Pumps; SpectraLight Technologies; Waterway Plastics, Inc.; Waterco Ltd.; and Wayne Water Systems.

DOE identified four manufacturers in the integral filter pump industry: Bestway (USA), Inc.; Great American Merchandise and Events (GAME); Intex Recreation Corp.; and Polygroup. Based on public records found in Hoovers,[3] DOE determined that all four manufacturers are U.S.-based entities. In the DPPP Working Group meeting on April 19, 2016, DOE presented the assumption that none of the integral cartridge and integral sand filter pumps are manufactured domestically. When this information was presented to the DPPP Working Group, there were no objections to this assumption. DOE therefore concluded that all manufacturers in the integral filter pump industry produce equipment abroad and import it for sale in the United States.

3.5.3 Regulatory Programs

DOE reviewed several existing and proposed regulatory energy conservation programs for pool pumps. These programs are described in the following sections.

3.5.3.1 U.S. State-Level Programs

The California Energy Commission (CEC) first issued standards for residential pool pumps under the California Code of Regulations (CCR) 2006.[4] [5] The CEC standards (or similar variations) were subsequently adopted by a number of other states.[6] The CEC's regulations cover all residential pool pump and motor combinations, replacement residential pool pump motors, and portable electric spas.

The CEC's current standard (amended in 2008) has prescriptive design requirements, rather than performance-based regulations for residential pool pump and motor combinations.[7] The CEC defines "residential pool pump and motor combination" as a residential pool pump motor coupled to a residential pool pump. "Residential pool pump" is defined as an impeller attached to a motor that is used to circulate and filter pool water in order to maintain clarity and sanitation. "Residential pool pump motor" refers to a motor that is used as a replacement residential pool pump motor or as part of a residential pool pump and motor combination. (Motors used in these applications are electrically driven.) The CEC imposes a design standard that prohibits the use of split-phase start[e] and capacitor-start-induction-run[f] motor designs in

[e] Defined as: A motor that employs a main winding with a starting winding to start the motor. After the motor has attained approximately 75 percent of rated speed, the starting winding is automatically disconnected by means of a centrifugal switch or by a relay. 20 CCR1602 (g).

residential pool pump motors manufactured on or after January 1, 2006. The CEC also requires that residential pool pump motors with a motor capacity[g] of 1 hp or greater manufactured on or after January 1, 2010, are capable of operating at two or more speeds. The low speed must have a rotation rate that is no more than one-half of the motor's maximum rotation rate, and must be operated with an applicable multi-speed pump control.

The CEC also prescribes design requirements for pump controls. Pool pump motor controls that are manufactured on or after January 1, 2008, and are sold for use with a pump that has two or more speeds are required to be capable of operating the pool pump at a minimum of two speeds. The default circulation speed setting shall be no more than one half of the motor's maximum rotation rate, and high speed overrides should be temporary and not for a period exceeding 24 hours.[8]

In addition to these prescriptive design requirements, the CEC also requires manufacturers of residential pool pump and motor combinations and manufacturers of replacement residential pool pump motors[h] to report certain data regarding the characteristics of their certified equipment. This includes information necessary to verify compliance with the requirements of Section 1605.3(g)(5), as well as the tested flow rate and input power of the equipment at several specific load points. Manufacturers must also submit the pool pump and motor combinations' energy factor (EF) in gallons per watt-hour (gal/Wh) when tested in accordance with the specified test procedure for residential pool pumps.

The CEC is considering revising its pool pump regulations. A recent CEC report[9] proposes updated regulations for all single-phase dedicated-purpose pool pump motors under 5 total horsepower[i] (thp). This report recommends that pool pump motors be covered regardless of whether they are sold with a new pump, or sold as replacement for use with an existing pump wet-end. The report recommends a timer requirement for integral filter pool pumps, and a requirement for freeze protection for pool filter pumps. Additionally, the report recommends that the CEC move to performance-based standards, rather than prescriptive design standards. The prescriptive standards that exist under the 2008 rule prohibit the use of certain motor

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[f] Defined as: A motor that uses a capacitor via the starting winding to start an induction motor, where the capacitor is switched out by a centrifugal switch once the motor is up to speed. 20 CCR1602(g).
[g] Defined as a value equal to the product of motor's nameplate hp and service factor and also referred to a "total hp," where "service factor (of an AC motor)" means a multiplier which, when applied to the rated hp, indicates a permissible hp loading which can be carried under the conditions specified for the service factor. 20 CCR 1602(g).
[h] Defined as a replacement motor intended to be coupled to an existing residential pool pump that is used to circulate and filter pool water in order to maintain clarity and sanitation. Cal. Code Regs., tit. 20, § 1602, subd. (g).
[i] Total hp is the product of motor service factor and motor nameplate (rated) hp.

technologies, and the 2016 proposal would allow these previously-prohibited technologies as long as they meet minimum efficiency standards. Using the modified CSA C747-09 test procedure, the CEC recommends that single-speed motors less than 0.5 thp be at least 70 percent efficient. Single-speed pumps greater than or equal to 0.5 thp and less than 1 thp must use motors that are at least 75 percent efficient. Variable-, multi-, and two-speed pumps greater than or equal to 1 thp and less than or equal to 5 thp must use motors that are at least 80 percent efficient at full speed and 65 percent efficient at half speed.[9]

3.5.3.2 European Union U.S.

The European Union is considering regulations for private and public pool pumps. In 2014, the European Commission completed a study on pumps for private and public swimming pools, along with other pump products under the Ecodesign Directive.[j] The goal of the study was to assess the energy savings potential and feasibility of different types of performance-based or design standards for such equipment. The study considered input from various stakeholders, including representatives from manufacturing companies, energy efficiency advocates, and government agencies. The Ecodesign Directive published the study results March 28, 2014.[10] DOE has reviewed the available information and will continue to monitor these efforts.

3.5.4 Voluntary Programs

DOE reviewed several voluntary energy conservation programs for pool pumps. These programs are described in the following sections.

3.5.4.1 Association of Pool and Spa Professionals

In 2013, the American National Standards Institute (ANSI), APSP, and the International Code Council (ICC) published standard ANSI/APSP/ICC-15a-2013, “American National Standard for Residential Swimming Pool and Spa Energy Efficiency.” This voluntary standard recommends against split-phase, shaded-pole, or capacitor start-induction run motors in dedicated-purpose pool pumps, with the exception of motors that are powered exclusively by onsite electricity generation from renewable energy sources. The standard also recommends that pool pump motors with a capacity of 1.0 total horsepower or greater be capable of operating at

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[j] The Ecodesign Directive provides consistent EU-wide rules for improving the environmental performance of products, such as household appliances. The Directive sets out minimum mandatory requirements for the energy efficiency of these products. Available at http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32009L0125

two or more speeds, with the low speed having a rotation rate that is no more than one-half of the motor's maximum rotation rate.

3.5.4.2 ENERGY STAR

The ENERGY STAR®[k] specification for pool pumps[11] provides criteria for how a product can earn the ENERGY STAR label. The specification is applicable to single-phase residential inground pool pumps that are single-speed, multi-speed,[l] variable-speed, or variable-flow, and have a horsepower rating of greater than 0.5 thp and less than or equal to 4 thp. ENERGY STAR defines a residential inground pool pump as a primary filter pump intended for installation with a permanently installed residential inground swimming pool with dimensions as defined in ANSI/NSPI–5 2003, "Standard for Residential Inground Swimming Pools." Further, ENERGY STAR specifically excludes residential aboveground pool pumps,[m] residential auxiliary pool pumps,[n] and residential portable spa pumps[o] from ENERGY STAR certification. The ENERGY STAR specifications for residential pool pumps establish an energy factor (EF) for the equipment. EF is defined as the volume of water pumped in gallons, divided by the electrical energy consumed by the pump motor while pumping that water. The EF rating is established separately for single-speed and multi-speed pumps, as shown in Table 3.5.1.

Regarding multi-speed pumps, ENERGY STAR specifically excludes multi-speed pumps with manual pump controls that are not sold ready to connect to external pump controls. ENERGY STAR also differentiates between variable-speed pumps that can operate at continuously variable speeds and variable-flow pumps that are equipped with controls that can continuously vary speed to control flow.

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[k] ENERGY STAR is a joint program of the U.S. Environmental Protection Agency and DOE that establishes a voluntary rating, certification, and labeling program for highly energy efficient consumer products and commercial equipment. Information on the program is available at www.energystar.gov/index.cfm?c=home.index

[l] The ENERGY STAR definition of multi-speed pumps includes "pool pumps capable of operating on at least two speeds." This definition includes dual-speed pumps as defined by DOE in the DPPP TP final rule.

[m] Defined as a primary filter pump intended for installation with a permanently installed Residential Aboveground/Onground Swimming Pool as defined in ANSI/APSP- 4 2007, "Standard for Aboveground/Onground Residential Swimming Pools."

[n] Defined as a pump intended for purposes other than a primary pool filter pump, i.e. such as a pool cleaner booster pump or water feature pumps.

[o] Defined as a pump intended for installation with a non-permanently installed residential spa as defined in ANSI/NSPI–6 (ANSI/NSPI–6 1999), "Standard for Portable Spas." Sometimes referred to as a hot tub pump, but not a jetted bathtub pump.

Table 3.5.1 DPPP Energy Factor Criteria at DPPP Performance Curve A

Pump Sub-Type	**Speed Setting**	**Energy Efficiency Level gal/Wh**
Single-speed pump	Single	EF ≥ 3.80
Multi-speed, variable-speed, and variable-flow pump	Most efficient	EF ≥ 3.80

Note: ENERGY STAR specifies that residential inground pool pumps be tested in accordance with their Final Test Method, which is established as part of the ENERGY STAR specification. The ENERGY STAR final test method defines three curves – curve A, curve B, and curve C – that are applicable to the testing of pool pumps.[11]

3.5.4.3 Australia / New Zealand Energy Labelling Program

The Australia state and territory governments and the New Zealand government operate the Equipment Energy Efficiency (E3) Program. The E3 Program established the Voluntary Energy Rating Labelling Program for Pool Pumps (VERLP) in April 2010.[12] This program establishes testing, labeling, and minimum efficiency guidelines for swimming pool pumps for suppliers who choose to participate.[13] The program relies on Australian Standard (AS) 5102–2009, "Performance of household electrical appliances—Swimming pool pump— units, Parts 1 and 2" as the basis for the efficiency levels and testing requirements for residential pool pumps. The AS 5102–2009 standard:

(1) applies to pumps intended to be used in swimming pools and spa pools;

(2) covers all single-phase pumps that are capable of a flow rate equal to or greater than 120 L/min (32 gpm);

(3) applies to single-speed, dual-speed, multi-speed, and variable-speed pumps with an input power of less than or equal to 2,500 W for any of the available speeds;

(4) covers pumps used for circulation of water through pool filters, sanitization devices, cleaning devices, water heaters (including solar), and pumps used for circulation of water through spa or jet outlets or other features forming part of the pool;

(5) covers newly manufactured pumps that form part of a complete new pool installation or intended for sale as replacements for existing pools; and

(6) covers all water-retaining structures designed for human use—

(i) that are capable of holding more than 680 liters of water[p] (179.6 gallons), and

(ii) that incorporate, or are connected to, equipment that is capable of filtering and heating any water contained in it and injecting air bubbles or water into it under pressure so as to cause water turbulence.

The minimum energy performance standard (MEPS) in AS 5102– 2009 part 2 is stated in terms of a minimum EF. Specifically, the current MEPS is 8 liters/watt-hour (2.09 gallons/Wh) measured on system curve D, defined in Table 3.5.2.

Table 3.5.2 DPPP Performance Curve D Definition

Metric Equivalent	Imperial Unit Equivalent*
Head (m) = 0.00018 $Flow^2$ (L/min)	Head (ft.) = 0.00847 x $Flow^2$ (gpm)

* 1 liter/minute = 0.264 gallons/minute; 1 meter of water = 3.28 feet of water

3.5.4.4 Consortium for Energy Efficiency

Effective January 1, 2013, the Consortium for Energy Efficiency (CEE) established voluntary testing, rating, and labeling requirements to encourage market penetration of high-efficiency swimming pool pumps and pool pump controllers.[14] [15] CEE's testing and performance recommendations for pool pumps feature two tiers, which are specified in terms of EF. These recommendations are shown in Table 3.5.3. CEE's performance recommendations for pool pump controls feature two tiers, similar to the requirements adopted by the CEC. Under the CEE program, a pool pump control is recommended to: (1) have the ability to operate the pool pump at either two (for tier 1) or more than two (for tier 2) speeds; (2) contain a default filtration speed that is no more than one-half of the motor's maximum rotation speed; and (3) contain a default setting that returns the pool pump to the lowest user preset speed within one cycle, or 24 hours.

[p] Standard AS 5102–2009 explicitly excludes residential pool pumps designed for use in spa baths (i.e., water retaining structures less than or equal to 680 liters (180 gallons)).

Table 3.5.3 CEE Tier 1 and Tier 2 EF Requirements

Efficiency Level	Lower Speed EF* gal/Wh	Low Speed EF** gal/Wh	High Speed EF† gal/Wh
CEE Tier 1	No requirements	≥3.8	≥1.6
CEE Tier 2	≥12.0	≥5.5	≥1.7

* Where "lower speed" is the optimal or most efficient speed for the pool pump, likely ranging from 600 to 1,200 rpm.
** Where "low speed" is either the minimum speed for two-speed pumps or half the maximum speed for variable-speed pumps, usually 1,725 rpm.
† Where "high speed" is the maximum operating speed of the pump, usually 3,450 rpm.

3.5.5 Dedicated-Purpose Pool Pump Shipments

DOE gathered annual DPPP shipment data from two general sources: (1) Veris Consulting and PK Data; and (2) interviews with individual manufacturers that were conducted under non-disclosure agreements with DOE's contractors.[q] The Veris Consulting and PK Data information included industrywide shipment information for certain dedicated-purpose pool pump varieties. This data was previously aggregated by Veris Consulting and PK Data for use within the industry, DOE gathered and aggregated shipments information for all varieties of dedicated-purpose pool pumps, specifically for this rulemaking. DOE used both sources to shape its initial shipments estimates. These shipments estimates were presented to the DPPP Working Group throughout the negotiation process and were revised based on the group's feedback.

DOE's final estimates of historical shipments by equipment class are shown in Table 3.5.4. The estimates show that the shipments of all classes of dedicated-purpose pool pumps have increased over the past 5 years. In 2015, the shipments of self-priming pool filter pumps were nearly double the shipments of non-self-priming pool filter pumps. Waterfall pumps made up a small portion of the industry, with less than 0.5 percent of total shipments in 2015. Since 2013, the integral cartridge filter and integral sand filter pump classes have totaled over one million shipments per year.

[q] In developing standards, DOE may choose to contract with third party organizations who specialize in various functions.

Table 3.5.4 Estimates of Historical DPPP Shipments, by Equipment Class (Thousands)

Equipment Class	2011	2012	2013	2014	2015
Self-Priming Pool Filter Pump, standard-size	545.4	562.7	580.6	599.0	618.1
Self-Priming Pool Filter Pump, small-size	70.6	72.8	75.1	77.5	80.0
Non-Self-Priming Pool Filter Pump	329.0	339.5	350.2	361.4	372.9
Waterfall Pump	8.8	9.1	9.4	9.7	10.0
Pressure Cleaner Booster Pump	121.6	123.3	125.0	126.8	128.6
Integral Cartridge Filter Pool Pump	843.2	860.4	878.0	895.9	914.2
Integral Sand Filter Pool Pump	130.3	133.0	135.7	138.4	141.3

3.5.6 Market and Industry Trends

DOE gathered data on DPPP market and industry trends. Several of DOE's observations and conclusions are noted in the following sections.

3.5.6.1 Equipment Efficiency

DOE assembled a Pool Pump Performance Database that describes the capacity, speed configuration, and estimated efficiency of the majority of dedicated-purpose pool pumps that are available on the market.[r] Using data from the database, Table 3.5.5 lists the ranges of efficiency that are available for the different speed configurations of standard-size self-priming pool filter pumps. In terms of total annual energy consumption, standard-size self-priming pool filter pumps are the largest equipment class covered by this rulemaking.

Table 3.5.5 Ranges of DPPP Efficiency Available for Standard-Size Self-Priming Pool Filter Pumps

Speed Configuration of Self-Priming Pool Filter Pump, Standard-Size (0.711 to 2.5 hydro hp)	Efficiency Range Available in the Pool Pump Performance Database WEF
Single-Speed	1.81 to 3.73 kgal/kWh
Two-speed	3.41 to 5.45 kgal/kWh
Variable-Speed	5.81 to 10.25 kgal/kWh

[r] See chapter 5 of this TSD for more information regarding the Pool Pump Performance Database.

The engineering analysis, found in chapter 5 of this TSD, provides a full discussion of DPPP efficiency data for all of the equipment classes, from the lowest performing pump available on the market to the highest performing pump that is technologically feasible.

3.5.6.2 Pump Sizing

Based on manufacturer interviews, DOE concluded that approximately 76 percent of the installed base of pool filter pumps are single-speed and two-speed pumps that use single-phase induction motors. These pumps come in a wide range of nominal horsepower ratings. Single-phase induction motor pumps are typically available in a wide variety of nominal horsepower ratings, such as 0.5 hp, 0.75 hp, 1 hp, 1.5 hp, 2 hp, 2.5 hp, and 3 hp, as well as other ratings above, below, and in between. This variety gives a pump installation contractor the ability to select a pump that is appropriately sized for the application. The contractor can make this decision based on the volume of water the pump needs to circulate (related to the pool volume) and the head that the pump needs to overcome (related to the piping and ancillary pool equipment such as heaters and chlorinators).

The remainder of the installed base of pool filter pumps are variable-speed pumps that use electronically commutating motors (ECMs) or other variable-speed motor technologies. These variable-speed pumps are typically only available in a small number of nominal horsepower ratings, such as 1.65 hp, 2.40 hp, 2.70 hp, and 3.45 hp. Due to the limited number of nominal horsepower ratings available, it is common for variable-speed dedicated-purpose pool pumps to be oversized for their application, when evaluated at maximum speed capability. A variable-speed pump can be programmed by the installer or end user to operate at an application-appropriate speed that is less than 100 percent.

3.6 TECHNOLOGY OPTIONS

The purpose of the technology assessment is to develop a preliminary list of technologies that could improve the efficiency of dedicated-purpose pool pumps. This section describes the technology options that can be used to reduce the energy consumption of DPPP equipment. The technology options are divided into two categories: options relevant to DPPP equipment classes that are analyzed for performance standards (e.g., self-priming pool filter pumps, non-self-priming pool filter pumps, pressure cleaner booster pumps, and waterfall pumps) and options relevant to DPPP equipment classes that are analyzed for prescriptive standards (e.g., integral cartridge filter pool pumps and integral sand filter pool pumps).

DOE identified three technology options that can be used to reduce the energy consumption of the DPPP equipment classes for which performance standards were analyzed (i.e., self-priming pool filter pumps, non-self-priming pool filter pumps, pressure cleaner booster pumps, and waterfall pumps). Specifically, those technology options are:

- improved motor efficiency;
- ability to operate at reduced speeds; and

- improved hydraulic design.

DOE identified one technology option, a pool pump timer, which could be used to reduce the energy consumption of the DPPP equipment classes for which prescriptive standards were analyzed (i.e., integral cartridge filter pool pumps and integral sand filter pool pumps).

The DPPP Working Group reviewed both sets of technology options and offered no objections to DOE's approach. The DPPP Working Group ultimately evaluated standards based on efficiency levels determined by these options.

Each technology option is addressed separately in the sections that follow.

3.6.1 Improved Motor Efficiency

Different varieties (or constructions) of motors have different achievable efficiencies. Two general motor constructions are present in dedicated-purpose pool pump market: single-phase induction motors and ECMs.[s] Single-phase induction motors may be further differentiated and include split phase, capacitor-start induction-run (CSIR), capacitor-start capacitor-run (CSCR), and permanent split capacitor (PSC) motors.

The majority of pool filter pumps available on the market come equipped with single-phase induction motors. According to manufacturer interviews, very few pool filter pumps on the market use split phase or CSIR motors. This is partly due to the regulatory prohibition of these motor constructions in California and other states. Most pool filter pumps on the market use CSCR or PSC motors; both have similar attainable efficiencies, although CSCR motors are typically able to provide greater starting torque.

ECMs are typically used in variable-speed pool filter pump applications. However, induction motors, coupled to a proper variable speed drive, can also be used in variable-speed pool filter pump applications. ECMs are inherently more efficient than single-phase induction motors because their construction minimizes slip losses between the motor's rotor and stator components. Unlike single-phase induction motors, ECMs require an electronic drive to function. This electronic drive consumes electricity, and the variations in drive losses and mechanical designs lead to a range of ECM efficiencies.

[s] Three-phase induction motors also are found on certain self-priming pool filter pumps; however this motor construction is specifically excluded from the scope of this rulemaking for self-priming pool filter pumps (as described in section 1.2.2).

As part of the engineering analysis (presented in chapter 5 of this TSD), DOE assessed the range of attainable motor efficiency for certain representative motor capacities and constructions. As motor capacity increases, the attainable efficiency of the motor at full load also increases. Table 3.6.2 presents these ranges of attainable efficiency, based on nameplate (or nominal) motor efficiencies listed in the Pool Pump Performance Database. Motor efficiency data submitted by pump and motor manufacturers to DOE confirms the ranges reported in this table.

Table 3.6.1 Ranges of Nameplate Motor Efficiencies Reported for Three Capacities of Self-Priming Pool Filter Pumps

Motor Total Horsepower thp*	Hydraulic Horsepower on Curve C of a Typical Dedicated-Purpose Pool Pump with This Motor Size	Range of Full Speed Motor Nameplate Efficiencies Reported in the Pool Pump Performance Database, by Motor Construction* %*		
		CSCR†	PSC†	ECM†
0.75	0.44	64 - 79	51 - 75	77
1.65	0.95	65 - 81	61- 78	78 - 86
3.45	1.88	75 - 81	74 - 82	77 - 92

* The three pump capacities described in this table align with the representative unit capacities that are defined and used in the engineering analysis described in chapter 5 of this TSD.

** Neither split phase nor CSIR motors are listed in this table because no self-priming pool filter pumps in the Pool Pump Performance Database utilize these motor types.

† Members of the DPPP Working Group stated that there may be small errors in the motor nameplate efficiency data reported for pumps in the CEC database that DOE incorporated into the Pool Pump Performance Database.

DPPP manufacturers do not typically manufacture motors in-house. Instead, they purchase complete or partial motors from motor manufacturers and/or distributors. As such, improving the nameplate motor efficiency of the pump is typically achieved by substituting a more efficient purchased motor component for a less efficient one.

3.6.2 Ability to operate at reduced speeds

3.6.2.1 Self-priming and non-self-priming pool filter pumps

Self-priming and non-self-priming pool filter pumps that provide 49.4 gpm of flow or more at maximum flow on curve C can achieve a higher (more favorable) WEF value if they have the ability to operate at reduced speeds. As discussed previously in section 3.4, the WEF metric is a weighted average of energy factors, measured at one or two test points. The DPPP test procedure allows WEF values for two-, multi-, and variable-speed pumps to be calculated as the weighted average of performance at both high and low speeds, while WEF for single-speed pumps is calculated based only on performance at high speed. Due to pump affinity laws, most pumps will achieve higher energy factors at lower rotational speeds, compared to higher rotational speeds. As such, the WEF efficiency metric confers benefits on pool filter pumps that are able to operate at reduced rotational speeds.

Specifically, pump affinity laws describe the relationship of pump operating speed, flow rate, head, and hydraulic power. According to the affinity laws, speed is proportional to flow such that a relative change in speed will result in a commensurate change in flow, as described in Equation 3.5. The affinity laws also establish that pump total head is proportional to speed squared, as described in Equation 3.6, and pump hydraulic power is proportional to speed cubed, as described in Equation 3.7.

$$\frac{Q_1}{Q_2} = \frac{N_1}{N_2}$$

Equation 3.5

$$\frac{H_1}{H_2} = \left(\frac{N_1}{N_2}\right)^2$$

Equation 3.6

$$\frac{P_1}{P_2} = \left(\frac{N_1}{N_2}\right)^3$$

Equation 3.7

Where:

Q_1 and Q_2 = flow rate at two operating points,
H_1 and H_2 = pump total head at two operating points,
N_1 and N_2 = pump rotational speed at two operating points, and
P_1 and P_2 = pump hydraulic power at two operating points.

This means that a pump operating at half speed will provide one half of the pump's full-speed flow and one eighth of the pump's full-speed power.[16] However, pump affinity laws do not account for changes in hydraulic and motor efficiency that may occur as a pump's rotational speed is reduced. Typically, hydraulic efficiency and motor efficiency will be reduced at lower operating speeds. Consequently, at reduced speeds, input power is not reduced as drastically as hydraulic output power. Even so, the efficiency losses at low-speed operation are typically outweighed by the exponential reduction in hydraulic output power at low-speed operation; this results in a higher (more beneficial) energy factor at low-speed operation.

Self-priming and non-self-priming pool filter pumps with a two-speed motor configuration that produce less than 49.4 gpm maximum flow on curve C cannot achieve higher WEF score through reduced speed operation. This is because the test procedure final rule specifies two load points for two-speed self-priming and non-self-priming pool filter pumps—one at 100 percent of maximum speed and one 50 percent of maximum speed. Further, the test procedure final rule specifies that the lower of the two load points cannot be below 24.7 gpm, and that the pump will be tested at the "lowest speed capable of meeting the specified flow and head values." A two-speed pump that delivers less than 49.4 gpm of flow at maximum speed on curve C would deliver less than 24.7 gpm of flow at half of the maximum, and the half-speed setting would not be considered in the calculation of the pump's WEF.[t] Such a two-speed pump would effectively be tested as a single-speed pump.

Self-priming and non-self-priming pool filter pumps with a variable- or multi-speed motor configuration that produce less than 49.4 gpm max flow on curve C could conceivably achieve a higher WEF score through reduced speed operation. However, DOE did not apply the "ability to operate at reduced speeds" technology option to pumps that provide less than 49.4 gpm at maximum speed on curve C. A flow of 49.4 gpm at maximum speed on curve C is equivalent to a hydraulic power of 0.25 hhp; such a pump would typically require a motor shaft power of approximately 0.60 horsepower. Comparatively, the smallest currently available variable-speed pool pump motor is 1.65 thp. Due to the mismatch in physical size and performance of such a wet end and motor combination, DOE concluded that it is not technologically feasible to pair a 1.65-thp motor with a pump wet end that provides only 49.4 gpm at maximum speed on curve C. For this reason, DOE's analysis assumes that that the design option described as "ability to operate at reduced speeds" does not apply to self-priming or non-self-priming pool filter pumps that produce less than 49.4 gpm at maximum speed on curve C.

3.6.2.2 Pressure cleaner booster pumps

In the field, pressure cleaner booster pumps are only operated at one speed and thus the test procedure final rule specifies only one load point for testing pressure cleaner booster pumps. However, the test procedure final rule does not specify that pressure cleaner booster pumps are tested at maximum speed. Instead, it specifies that pressure cleaner booster pumps are tested at the lowest speed that can achieve 60 feet of head at the 10 gpm test condition. Depending on its capacity, a pressure cleaner booster pump may be able to achieve a higher (more beneficial) WEF score if it has the ability to operate at reduced speeds. For instance, a variable-speed pressure cleaner booster pump that produces more than 60 feet of head when operated at maximum speed at the 10 gpm test point could be tested at a reduced speed that produces close to 60 feet of head at 10 gpm, while requiring less input power than it would require at maximum speed. In this case, testing at a reduced speed would result in a higher (more beneficial) WEF value compared to testing at the pump's maximum speed. Noting the potential benefits of reduced speed operation, the DPPP Working Group requested that DOE examine variable-speed pumps as a design option for pressure cleaner booster pumps.

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[t] The DOE DPPP test procedure final rule specifies that flow be measured to the nearest tenth of a gpm.

The DPPP Working Group discussed that the pressure cleaners powered by pressure cleaner booster pumps need to be supplied with a minimum amount of head in order to work properly. Cleaner requirements vary, but the group discussed that a typical cleaner requires pressure between 50 and 70 feet of head to operate properly. Pressure cleaner booster pumps on the market supply between 100 and 125 feet of head at the pump outlet at the test condition of 10 gpm. The DPPP Working Group discussed that these pumps provide more pressure that than the cleaner requires because the pump must overcome head losses imposed by piping, couplings, and hoses between the pump and the cleaner. In pool installations with high head loss (due to small-diameter pipes, long hoses, or other causes), these pumps may deliver the recommended amount of head to the cleaner when operating at maximum speed with no flow restrictions. However, in pool installations with low head loss, these pumps may supply more head than is needed to drive the pressure cleaner. Supplying excessive head to the pressure cleaner can result in low cleaner performance or damage to the cleaner. To prevent damage to the cleaner, pressure cleaner instructions typically recommend that the pressure be reduced or relieved.[u] [17] [18] The DPPP Working Group discussed how, in installations with low head loss, energy could be conserved by operating the pressure cleaner booster pump at a reduced speed rather than by releasing pressure that was supplied unnecessarily.

3.6.2.3 Waterfall pumps

The test procedure final rule specifies that waterfall pumps are only tested at 100 percent speed. Waterfall pumps cannot achieve a higher (more beneficial) WEF value if they have the ability to operate at reduced speeds. Consequently, DOE did not consider the “ability to operate at reduced speeds” as a technology option for the waterfall pump equipment class.

3.6.3 Improved hydraulic design

The performance characteristics of a pump, such as flow, head, and efficiency, are a direct result of the pump’s hydraulic design. For purposes of the DOE analysis, “hydraulic design” is a broad term DOE used to describe the system design of the wetted components of a pump. Although hydraulic design focuses on the specific hydraulic characteristics of the impeller and the volute/casing, it also includes design choices related to bearings, seals, and other ancillary components.

[u] For installations where the pressure cleaner booster pump supplies more pressure than is recommended for the cleaner, pressure may be reduced using a throttling valve or restrictor rings, or excess pressure may be relieved using a pressure relief valve. The pressure relief valve is attached to the hose line that connects the pump outlet to the pressure cleaner, and the valve bypasses the cleaner and releases pressure into the pool being serviced.

The hydraulic efficiency, η_{hydro}, of a pump is a ratio of the hydraulic horsepower delivered by the pump to the brake power supplied to the pump and can be found using Equation 3.8.

$$\eta_{hydro} = \frac{P_{brake}}{P_{hydro}} = \frac{P_i \times \eta_{motor}}{P_{hydro}}$$

Equation 3.8

Where:

η_{hydro} = hydraulic efficiency, in percent,
P_{brake} = brake power provided from the motor shaft to the pump, in hp, and
P_{hydro} = hydraulic power output of the pump, in hp.
P_i = input power, in watts, and
η_{motor} = motor efficiency, in percent.

Impeller and volute/casing geometries, clearances, and associated components can be redesigned to a higher hydraulic efficiency (at the same flow and head) using a combination of historical best practices and modern computer-aided design (CAD) and analysis methods. The wide availability of modern CAD packages and techniques now enables pump designers to more quickly reach designs with improved vane shapes, flow paths, and cutwater designs, all of which work to improve the efficiency of the pump as a whole.

3.6.3.1 Self-priming pool filter pumps

For self-priming pool filter pumps, DOE used empirical data from the Pool Pump Performance Database to estimate the potential efficiency gains available from improved hydraulic design. Specifically, DOE used hydraulic power (see Equation 3.9), input power, and nameplate motor efficiency to estimate the hydraulic efficiency of self-priming pool filter pumps and observed the range of hydraulic efficiencies available for self-priming pool filter pumps at various pump capacities less than 2.5 hhp. Table 3.6.2 illustrates the lowest and highest hydraulic efficiencies observed in the Pool Pump Performance Database for three capacities of self-priming pool filter pumps. See chapter 5 of the TSD for more detailed information about estimating hydraulic efficiency.

$$\boldsymbol{P_{hydro} = \frac{Q \times H}{3956}}$$

Equation 3.9

Where:

P_{hydro} = hydraulic power, in hp,
Q = flow rate, in gpm, and

H = total dynamic head, in feet of water.

Table 3.6.2 Ranges of Hydraulic Efficiency for Self-Priming Pool Filter Pumps

Hydraulic power (hp)*	For pump records in the Pool Pump Performance Database that are within 5% of the hydraulic power stated in the leftmost column		
	Lowest hydraulic efficiency observed (%)	Highest hydraulic efficiency observed (%)	Improvement from lowest to highest hydraulic efficiency (%)
0.44	39.0	49.0	125
0.95	48.9	70.9	144
1.88	56.4	78.8	139

* The capacities in this table correspond to the representative pump capacities analyzed in the engineering analysis presented in chapter 5 of this TSD.

In addition to the three capacities in Table 3.6.2, DOE also examined the hydraulic efficiency ranges available for pumps with capacities ranging from 0.1 hhp to 2.5 hhp. DOE found that for any given capacity less than 2.5 hhp, the best hydraulic efficiency of self-priming pool filter pumps at maximum speed on curve C could be at least 116 percent of the baseline hydraulic efficiency. In other words, if a baseline pump were subjected to a hydraulic redesign, the redesigned pump would at a minimum be expected to achieve hydraulic efficiency that is 116 percent of the original baseline hydraulic efficiency, regardless of the pump capacity.

3.6.3.2 Non-self-priming pool filter pumps

For non-self-priming pool filter pumps, DOE attempted to follow a similar methodology to self-priming pumps. While DOE's Pool Pump Performance Database contains few records of non-self-priming pool filter pumps, these records were sufficient to establish a baseline hydraulic efficiency, which DOE identified as 51.5 percent. However, with limited data, DOE was not able to use this database to empirically identify the maximum hydraulic efficiency that is technologically feasible, nor estimate the range of hydraulic efficiency improvements that are available to non-self-priming pool filter pumps.

Instead, DOE referred to empirical data gathered during the 2016 general pumps[v] rulemaking. During the general pumps rulemaking, DOE estimated the maximum

[v] The pumps energy conservation standard rulemaking docket EERE-2011-BT-STD-0031 contains all notices, public comments, public meeting transcripts, and supporting documents pertaining to this rulemaking.

technologically feasible hydraulic efficiency for end suction, close-coupled pumps as a function of flow and specific speed.[w] For this dedicated-purpose pool pumps direct final rule, DOE evaluated a 0.52-hhp, end suction, close-coupled pump that is optimized for curve-C flow and head using equations from the general pumps rulemaking analysis, and found that such a pump can achieve a hydraulic efficiency of up to 69.7 percent.[x] In particular, DOE calculated the standard pump efficiency η_{STD} of 69.7% for the max-tech level of the ESCC.3600 equipment class at a flow rate Q of 63 GPM, a constant C of 125.3, and a specific speed, N_S, of 2,760. This pump has a configuration that is nearly identical to a non-self-priming pool filter pump, with the exception that non-self-priming pool filter pumps are defined by the presence (or requirement of) a basket strainer. As discussed in section 3.3.1, the addition of a basket strainer and strainer housing reduce a pump's hydraulic efficiency by a measurable amount. Based on discussions with pump industry professionals, the impact of adding a strainer basket may be in the range of 1 to 3 points of hydraulic efficiency. Consequently, DOE conservatively estimates a maximum hydraulic efficiency of 67 percent for non-self-priming pool filter pumps. This represents an improvement of 30 percent over the baseline hydraulic efficiency.

3.6.3.3 Pressure cleaner booster pumps

DOE's contractor received motor specifications and test data for pressure cleaner booster pumps from manufacturers, which DOE used to calculate the total pump efficiency and the hydraulic efficiency for several pumps at the pressure cleaner booster pump test point of 10 gpm flow. The hydraulic efficiencies of pressure cleaner booster pumps at the 10 gpm test point ranged from 25.5 percent to 28.6 percent (an improvement of 12.2 percent over the lower 25.5 percent hydraulic efficiency). Based on this information, DOE concluded that the best available hydraulic efficiency of pressure cleaner booster pumps at the test point of 10 gpm, could be 112.2 percent of the baseline hydraulic efficiency.

[w] Specific speed is a dimensionless index describing the geometry of a pump impeller and provides an indication of the pump's pressure/flow ratio at the pump's best efficiency point. For more details, see chapter 3 of the general pumps rulemaking final rule TSD, at www.regulations.gov/document?D=EERE-2011-BT-STD-0031-0056.
[x] See the discussion of efficiency levels for general pumps equipment in the general pumps final rule TSD, available at www.regulations.gov/document?D=EERE-2011-BT-STD-0031-0056. In particular, equation 5.1 in chapter 5 of the general pumps final rule TSD describes an estimation of hydraulic efficiency based on various pump parameters.

3.6.3.4 Waterfall pumps

DOE's contractor used manufacturer-supplied motor specifications and test data for waterfall pumps to calculate the total pump efficiency and the pump hydraulic efficiency for several waterfall pumps at the waterfall pump test point of 17 feet of head. The hydraulic efficiencies of waterfall pumps at the waterfall pump test point ranged from 54.8 percent to 61.1 percent (an improvement of 11.5 percent over the lower 54.8 percent hydraulic efficiency). Based on this information, DOE concluded that the best available hydraulic efficiency of waterfall pumps at this test point could be equal to 111.5 percent of the baseline hydraulic efficiency.

3.6.4 Pool Pump Timer

Pool pump timers can reduce the energy consumed by dedicated-purpose pool pumps by reducing the number of hours that the pump is operated unnecessarily.

Many smaller-size pools do not require a dedicated-purpose pool pump to operate 24 hours per day to achieve the desired turnover of pool water. Several members of the DPPP Working Group commented that the pool industry recommends one turnover per day for residential applications. DOE only considered the pool pump timer design option for the integral cartridge filter pump and integral sand filter pump equipment classes, and these equipment classes are marketed exclusively to residential end users. Therefore, DOE concluded that the pool pump timer design option applies only to pumps that must provide a minimum of one turnover per day. In support of the DPPP Working Group, DOE reviewed the integral filter pump products on the market and the pool volumes that they are recommended to service. DOE concluded that, when paired with the appropriate size pool, integral filter pumps should achieve one turnover in 8 hours or less. If a pool pump timer turns off the pump after 10 hours, it will have allowed at least one full turnover to occur (thus meeting the industry recommendation for daily turnovers and maintaining end user utility), and it will prevent the pump from running unnecessarily for the remainder of the day.

DOE initially suggested that a pool pump timer be defined as a pool pump control that automatically turns a dedicated-purpose pool pump on and off based on a pre-programmed user-selectable schedule. A DPPP Working Group member requested that the pool pump timer be defined instead as a type of countdown timer, where the end user turns on the pump, the pump runs for a preset amount of time, and then the pump shuts off automatically and remains off until the end user starts the pump again. This style of timer is what currently exists in the market for integrated cartridge and integrated sand filter pumps.

The DPPP Working Group discussed whether end users should be able to program the run time of the pool pump timer or whether the pool pump timer should ship with a preprogrammed run-time that cannot be adjusted by the end user. The DPPP Working Group clarified that integrated cartridge filter pumps and integrated sand filter pumps are typically sold in a package with the pool that they are meant to service, so the run-time necessary for the pump to achieve one turnover may be determined prior to sale based upon the relative sizes of the pump and the pool. Therefore, there is little benefit to allowing end users to modify the pump run-time that the pool pump timer allows.

The DPPP Working Group also discussed whether end users might be burdened by a pool pump timer that cannot automatically turn on a pump, since end users would be required to initiate the pump operation on a daily basis to maintain sanitary pool conditions. A major manufacturer of pumps that incorporate the timers under discussion commented that it is not too burdensome to ask the end user to activate their pump on a daily basis.

The DPPP Working Group voted, and did not reach consensus on a pool pump timer definition that included automatic on-off functionality and user-selectable scheduling. Instead, the DPPP Working Group recommended defining a pool pump timer to mean a pool pump control that automatically turns off a dedicated-purpose pool pump after a run-time of no longer than 10 hours. In this final rule, DOE adopts this definition as recommended by the DPPP Working Group.

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CHAPTER 4. SCREENING ANALYSIS

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CHAPTER 4. SCREENING ANALYSIS

4.1 INTRODUCTION

This chapter details the screening analysis that the U.S. Department of Energy (DOE) conducted in support of the energy conservation standards rulemaking for dedicated-purpose pool pumps.

In chapter 3, the market and technology assessment (MTA), DOE presented an initial list of technologies that can improve the energy efficiency of dedicated-purpose pool pumps. The purpose of the screening analysis is to evaluate the technologies that improve equipment efficiency to determine which technologies to consider further and which to screen out. DOE consulted with a range of parties, including industry, technical experts, and others to develop a list of technologies for consideration. DOE evaluated the technologies pursuant to the criteria set out in the Energy Policy and Conservation Act (EPCA), as amended. (42 U.S.C. 6311-6317)

Section 325(o) of EPCA establishes criteria for prescribing new or amended standards designed to achieve the maximum improvement in energy efficiency. Further, EPCA directs the Secretary of Energy to determine whether a standard is technologically feasible and economically justified. (42 U.S.C. 6295(o)(2)(A), as directed by 42 U.S.C. 6316(a)(1)-(3)). EPCA also establishes guidelines for determining whether a standard is economically justified. (42 U.S.C. 6295(o)(2)(B)) Appendix A to subpart C of Title 10, Code of Federal Regulations, Part 430 (10 CFR Part 430), “Procedures, Interpretations and Policies for Consideration of New or Revised Energy Conservation Standards for Consumer Products” (the Process Rule), sets forth procedures to guide DOE in its consideration and promulgation of new or revised equipment energy conservation standards. These procedures elaborate on the statutory criteria provided in 42 U.S.C. 6295(o) and, in part, eliminate problematic technologies early in the process of prescribing or amending an energy efficiency standard. In particular, sections 4(b)(4) and 5(b) of the Process Rule guide DOE in determining whether to eliminate from consideration any technology that presents unacceptable problems with respect to the following criteria:

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

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.

Impacts on equipment utility or equipment availability. If a technology is determined to 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, it will not be considered further.

Adverse impacts on health or safety. If it is determined that a technology will have significant adverse impacts on health or safety, it will not be considered further.

In sum, if DOE determines that a technology, or a combination of technologies, has unacceptable impacts on the policies stated in section 5(b) of the Process Rule, it will be eliminated from consideration. If a particular technology fails to meet one or more of the four criteria, it will be screened out. Section 4.2 documents the reasons for eliminating any technology.

4.2 SCREENED-OUT TECHNOLOGIES

Normally, this section describes the technologies that DOE eliminated for failure to meet one of the following four factors: (1) technological feasibility; (2) practicability to manufacture, install, and service; (3) impacts on equipment utility or equipment availability; and (4) adverse impacts on health or safety.

However, of the identified technology options, DOE was not able to identify any that fail the screening criteria.

4.3 REMAINING TECHNOLOGIES

After reviewing each technology, DOE concluded that all of the identified technologies listed in chapter 3 of the technical support document met all four screening criteria to be examined further as design options in DOE's analysis. In summary, DOE continued its analysis for the following technology options:

- improved motor efficiency
- ability to operate at reduced speeds
- improved hydraulic design
- pool pump timers

DOE determined that these technology options are technologically feasible because they are used or have been used in commercially-available products or working prototypes. DOE also found that these technology options met the other screening criteria (i.e., practicable to manufacture, install, and service and do not result in adverse impacts on consumer utility, equipment availability, health, or safety).

CHAPTER 5. ENGINEERING ANALYSIS

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5.1 INTRODUCTION

The engineering analysis establishes the relationship between manufacturer production cost (MPC) and energy efficiency for the dedicated-purpose pool pumps examined in this rulemaking. This "cost-efficiency" relationship serves as the basis for downstream cost-benefit calculations with respect to individual end users, manufacturers, and the Nation.

5.2 METHODOLOGY OVERVIEW

This section describes the analytical methods the U.S. Department of Energy (DOE) used for the engineering analysis. DOE first collected, organized, and validated data regarding the performance and manufacturing costs of different dedicated-purpose pool pump (DPPP) varieties. DOE then used shipment information and counts of the pump models available at various capacities to identify the most common capacities sold in the market. DOE selected representative units that exemplify these most common capacities, for each DPPP variety, and used these representative units to examine the relationship between energy efficiency and manufacturing production cost. DOE determined a baseline configuration of each representative unit by identifying the least efficient units on the market that have a similar capacity to the representative units. DOE determined the efficiency levels (ELs) that would result from improving the baseline configuration by applying the design options discussed in the technology assessment and screening analysis (found in chapters 3 and 4 of this TSD, respectively). Using a variety of data sources, DOE estimated the MPC associated with manufacturing the representative units at each efficiency level to determine the cost-efficiency relationships. To determine the manufacturer selling price (MSP), DOE applied markups to the MPCs. The engineering analysis resulted in other analytical outputs, which are discussed in section 5.8.

5.3 SUMMARY OF DATA SOURCES

For the engineering analysis, DOE used two principal data sources: (1) the Pool Pump Performance Database; and (2) the manufacturer production cost dataset. The following subsections describe each data source.

5.3.1 Pool Pump Performance Database.

DOE assembled a Pool Pump Performance Database by collecting current and archived records of pool pump performance from current public databases maintained by the California Energy Commission (CEC),[1] the Association of Pool and Spa Professionals (APSP),[2] and the ENERGY STAR® program.[3] The Pool Pump Performance Database also includes historic records from previous CEC database versions that stakeholders provided to DOE. These historic records include pumps that met previous CEC efficiency standards but do not meet the current CEC standards.

The CEC, APSP, and ENERGY STAR databases contain third-party test data that manufacturers submit as a means of certifying their pump equipment to the relevant entity's standards. The database records contain pump performance information such as motor horsepower, pump speed configuration, and flow and head on system curves A, B, and C. DOE also added records to the database using data published in manufacturer specification sheets. These specification sheets typically publish motor horsepower and head-versus-flow performance curves but they do not typically provide information regarding energy consumption or efficiency.

DOE filtered the collected data to remove duplicate entries, entries that only represented a replacement motor (but no pump), and entries with incomplete data. To allow for easier analysis, DOE combined and reformatted the databases into a user-friendly format. DOE performed a regression analysis to estimate the part-load efficiencies of variable-speed pumps at the load points specified in the test procedure final rule. DOE then calculated the weighted energy factor (WEF) value of each pump record in the database, according to the calculation method specified by the test procedure final rule. Section 5.3.1.5 and section 5.3.1.6 contain more detail regarding the regression analysis and the calculation of WEF values.

5.3.1.1 Sources of Pump Performance Data

CEC Appliance Efficiency Database. To sell a pump in California, a manufacturer or test lab must certify that the pump complies with California Title 20 and the manufacturer must register the pump in the CEC's Appliance Efficiency Database.[1] The CEC database contains information about pump performance on system curves A, B, and C. Some, but not all, of the records in the CEC database report motor frame size, motor service factor, and nameplate motor efficiency.

California Title 20 stipulates that, as of January 1, 2006,[4] pool pumps sold in California may not use a split-phase or capacitor start-induction run type motor and, as of January 1, 2010, pumps greater than 1 total horsepower (thp)[a] must be able to operate at two or more speeds with a controller that automatically lowers the pump to the low speed within 24 hours of high-speed operation. The current version of the CEC database no longer lists pumps that meet the 2006 requirements, but not the 2010 requirements; however, some of these pumps are still sold in other states. To gather information on these particular pumps, DOE obtained historical versions of the CEC database from industry stakeholders. Some of the records in the historical CEC databases do not contain curve C data because California did not always require manufacturers to report curve C data. Section 5.3.1.4 explains how DOE estimated curve C data where it was not reported.

ENERGY STAR Data Sheets. DOE and the U.S. Environmental Protection Agency conduct the voluntary ENERGY STAR program to promote energy efficient products and appliances. The ENERGY STAR program specifies the minimum energy efficiencies that various products must meet to receive the ENERGY STAR label. For a dedicated-purpose pool pump to carry the ENERGY STAR label, the ENERGY STAR program requires the pump to have an energy factor (EF) greater than or equal to 3.8 on system curve A at the pump's most efficient speed. For pump equipment, the EF is defined as gallons pumped per watt-hour of energy consumed, and is represented by Equation 5.1.

[a] Total horsepower is the product of motor service factor and motor nameplate (rated) hp.

$$EF = \frac{60 \times Q}{P_i}$$

Equation 5.1

Where:
EF = energy factor, in gallons per watt-hour,
Q = flow rate, in gallons per minute (gpm, and
P_i = input power, in watts.

The ENERGY STAR database contains information about pump performance on system curves A, B, and C at the pump's high speed and, if available, a lower speed and a middle speed. ENERGY STAR reports data including the manufacturer name, brand name, model number, number of available speeds, motor frame size, motor construction, the date the pump was added to ENERGY STAR database, pump nameplate horsepower, pump speeds and for each speed, the flow, input power, and EF.

APSP Database. The APSP maintains the voluntary standard American National Standards Institute (ANSI)/APSP/International Code Council (ICC)-15 2011, "Standard for Residential Swimming Pool and Spa Energy Efficiency" ("ANSI/APSP/ICC-15 2011"). ANSI/APSP/ICC-15 2011 provides minimum energy efficiency guidelines for permanently-installed residential swimming pools. The APSP lists pool pumps that meet the standard in its Approved Energy Efficient Pool Pumps database. This database includes information about anufacturer name, brand name, model number, number of available speeds, pump speeds, nameplate horsepower, total horsepower, motor service factor, nameplate motor efficiency, motor construction, motor frame size, date added to database, and the flow rate, input power, and EF on system curves A, B, and C.

Manufacturer Test Data. DOE's contractor collected test data across a range of DPPP capacities from manufacturers of DPPP equipment for all of the equipment classes in the scope of this rulemaking, including: self-priming pool filter pumps, non-self-priming pool filter pumps, pressure cleaner booster pumps, waterfall pumps, integral cartridge filter pumps, and integrated sand filter pumps. This data is confidential and covered under non-disclosure agreements between DOE's contractor and the individual manufacturers. This manufacturer-provided data typically included input power, total dynamic head, and flow across a range of flow rates and (for pumps with more than one speed) across a range of pump speeds.

Online Performance Data. DOE collected specification data for dedicated-purpose pool pumps from manufacturer and vendor web sites. Specification data sheets frequently but not always report the pump's maximum speed, the number of available speeds, input power, nameplate horsepower, total horsepower, and pump performance curves showing total dynamic head in relation to flow rate.

5.3.1.2 Database Assembly

The CEC, APSP, and ENERGY STAR databases report data using one database record for each pump speed reported. As a result, these databases contain multiple records for pumps that have more than one speed. For instance, the source databases contain three records for most variable-speed pumps: a record for the maximum speed, a record for a lower speed, and a record for a middle speed (usually the most efficient speed for the pump or a midpoint speed).

For two-speed, multi-speed, and variable-speed pumps, the WEF metric is calculated using pump performance information at multiple speeds.[b] To facilitate the calculation of WEF scores, DOE reorganized the data to consolidate multiple database records for individual pump models into a single entry for each pump model, containing performance data for multiple speeds. After compiling the source data from the sources, DOE removed records that were inconsistent or erroneous. DOE filtered out:

- Duplicate values – Some pump models were listed in several databases. After combining records from different sources, DOE removed any duplicate records to ensure that individual pump models were only represented once in the database.

- Motor-only data – DOE removed records containing data for replacement motors sold without a pump because these entries did not meet the definition of a dedicated-purpose pool pump.

- Incomplete data – DOE removed records for two-, multi- or variable- speed pumps that report only maximum-speed data and do not report performance at any speeds below the maximum speed. These records did not contain sufficient information for DOE to calculate a WEF score using the methodology described in sections 5.3.1.4, 5.3.1.5, and 5.3.1.6.

- Entries with erroneous data – DOE identified several pump records with data that was clearly erroneous. For instance, some pump records reported a maximum-speed flow rate and head that correspond to a hydraulic power greater than the total horsepower reported for the pump. It is not possible for a pump to have a hydraulic power output greater than the available motor input power. DOE removed records with erroneous data.

The completed database contains one entry for each pump with information for input power, flow, head, speed, motor efficiency, and hydraulic power output on curves A, B and C at each reported speed.

5.3.1.3 Calculating Total Dynamic Head and Hydraulic Power

The CEC, ENERGY STAR, and APSP databases report flow rates on system curves A, B, and C. These source databases do not report total dynamic head or hydraulic power. To facilitate downstream calculations, DOE calculated total dynamic pump head at each reported speed for each pump record in the Pool Pump Performance Database. DOE calculated total dynamic pump head using the system curve equations, which are reproduced in Equation 5.2 through Equation 5.4.[5] Each system curve defines a relationship between flow (*Q*) and head (*H*).

$$\boldsymbol{H_{curve\ A} = 0.0167 \times (Q_{curve\ A})^2}$$

[b] The WEF metric is discussed further in chapter 3 of this TSD and in the DPPP test procedure final rule.

Equation 5.2

$$H_{curve\ B} = 0.050 \times (Q_{curve\ B})^2$$

Equation 5.3

$$H_{curve\ C} = 0.0082 \times (Q_{curve\ C})^2$$

Equation 5.4

Where:

H = total dynamic head on curve A, B, or C, as noted, in feet of water, and
Q = flow rate on curve A, B, or C, as noted, in gpm.

For each record in the Pool Pump Performance Database, DOE calculated the hydraulic power (P_{hydro}) of each pump speed reported on every system curve for which flow was reported. DOE calculated hydraulic power using Equation 5.5.[6]

$$P_{hydro} = \frac{Q \times H}{3956}$$

Equation 5.5

Where:

P_{hydro} = hydraulic power in hp,
Q = flow rate in gpm, and
H = total dynamic head in feet of water.

5.3.1.4 Estimating Curve C Capacity and Performance Where Curve C Data is Unreported

For the self-priming and non-self-priming pool filter pump equipment classes, this rule specifies standard levels that are a function of hydraulic power on curve C (P_{CurveC}). However, the Pool Pump Performance Database contains records of single-speed pumps sourced from historical versions of the CEC Appliance Efficiency Database, and these records report data on curves A and B but not on curve C (section 5.3.1.1 includes a discussion of data sources). Where possible, DOE used pump specification sheets to complete the curve C data that was not reported in the database. This involved observing the intersection of pump curves and system curves to determine pump performance on a system curve. When DOE was not able to complete the curve C data using pump curves, DOE estimated curve C data based on curve A data using the method below.

The single-speed pool filter pump models in the Pool Pump Performance Database have similar design characteristics; by definition, they are all end suction pumps with basket strainers. Because of these similarities, DOE assumed that the single-speed pool filter pumps in the database all have a similar relationship between performance on system curve A and performance on system curve C. In particular, DOE assumed that at maximum speed, single-speed pool filter pumps have a similar ratio of hydraulic power delivered on curve C, P_{CurveC}, to hydraulic power delivered on curve A, P_{CurveA}. DOE calculated this ratio of (P_{CurveC}/P_{CurveA}) at maximum speed for each of the pool filter pump records in the Pool Pump Performance Database that reports both P_{CurveA} and P_{CurveC}. These calculated ratios have an arithmetic mean of 1.10 and 95 percent of data points fall within a range of 0.87 to 1.30.

DOE calculated a power conversion factor, PCF_{AtoC}, that is equal to the average of the ratio (P_{CurveC}/P_{CurveA}) for all pool filter pumps in the Pool Pump Performance Database that report both P_{CurveA} and P_{CurveC}. The value of PCF_{AtoC} calculated using Equation 5.6 is equal to 1.10. DOE used this power conversion factor to estimate the hydraulic power of pumps that were missing curve C data. As illustrated in Equation 5.7, the power conversion factor is multiplied by P_{CurveA} to estimate P_{CurveC}.

$$\boldsymbol{PCF_{AtoC}} = \frac{\sum_{k=1}^{n}\left(\frac{\boldsymbol{P_{CurveC,k}}}{\boldsymbol{P_{CurveA,k}}}\right)}{n}$$

Equation 5.6

Where:

PCF_{AtoC} = power conversion factor that is calculated using pump records that report both curve A and curve C data, and is used to estimate hydraulic power on curve C based on hydraulic power on curve A, unitless,
n = the number of pumps in the database that report hydraulic power on curve C,
$P_{CurveA,k}$ = hydraulic power at maximum speed on curve A for a pump k in the database, in hp, and
$P_{CurveC,k}$ = hydraulic power at maximum speed on curve C for a pump k in the database, in hp.

$$\boldsymbol{P_{CurveC}} = \boldsymbol{P_{CurveA}} \times \boldsymbol{PCF_{AtoC}}$$

Equation 5.7

Where:

P_{CurveC} = the hydraulic power on curve C for pump records that do not report hydraulic power on curve C, in hp, and
P_{CurveA} = the hydraulic power on curve A, in hp.

DOE also assumed that pool filter pumps in the Pool Pump Performance Database have a similar ratio of energy factor on curve C (EF_{CurveC}) to energy factor on curve A (EF_{CurveA}) at maximum speed. DOE calculated the ratio of (EF_{CurveC} /EF_{CurveA}) at maximum speed for each pool filter pump record in the Pool Pump Performance Database that reports both EF_{CurveA} and EF_{CurveC}. The calculated ratios have an arithmetic mean of 1.23 and 95 percent of data points fall within a range of 1.16 to 1.32.

DOE calculated an efficiency conversion factor, ECF_{AtoC}, that is equal to the average of the ratio (EF_{CurveC} /EF_{CurveA}) for all pool filter pumps in the Pool Pump Performance Database that report both EF_{CurveA} and EF_{CurveC}. The value of ECF_{AtoC} calculated using Equation 5.8 is equal to 1.23. DOE used this efficiency conversion factor to estimate the energy factor of pumps that were missing curve C data, as illustrated in Equation 5.9. The efficiency conversion factor is multiplied by EF_{CurveA} to estimate EF_{CurveC}.

$$\boldsymbol{ECF_{AtoC}} = \frac{\sum_{k=1}^{n}\left(\frac{\boldsymbol{EF_{Curve\mathrm{C}}}}{\boldsymbol{EF_{Curve\mathrm{A}}}}\right)}{n}$$

Equation 5.8

Where:

ECF_{AtoC} = efficiency conversion factor that is calculated using pump records that report both curve A and curve C data, and is used to estimate EF on curve C based on EF on curve A, unitless,
n = the number of pumps in the database that report EF on curve C,
$EF_{CurveA,k}$ = energy factor at maximum speed on curve A for a pump k in the database, in gallons per watt-hour, and
$EF_{CurveC,k}$ = energy factor at maximum speed on curve C for a pump k in the database, in gallons per watt-hour.

$$\boldsymbol{EF_{CurveC}} = \boldsymbol{EF_{CurveA}} \times \boldsymbol{ECF_{AtoC}}$$

Equation 5.9

Where:

EF_{CurveC} = energy factor at maximum speed on curve C for pump records that do not report energy factor on curve C, in gallons per watt-hour, and
EF_{CurveA} = energy factor at maximum speed on curve A, in gallons per watt-hour.

5.3.1.5 Estimation of Part Load Data for Variable Speed Pumps

The DPPP test procedure final rule specifies that input power and flow be measured at two load points for variable-speed pool filter pumps.[7] The high-speed load point is at 80 percent of the maximum flow rate of the pump. The low-speed load point is at one of two possible flow rates; the low-speed load point is either at 24.7 gpm for pumps that deliver hydraulic power less than 0.75 hhp[c] or at 31.1 gpm for pumps that deliver hydraulic power greater than or equal to 0.75 hhp.

Most variable-speed pump records in the Pool Pump Performance Database contain pump performance data at three speeds: (1) a maximum-speed, (2) a lower speed, and (3) a middle speed between the maximum speed and the lower speed. The variable-speed data points reported in the database do not directly align with the low-speed and high-speed load points specified in the test procedure final rule. As a result, DOE could not directly calculate the WEF of variable-speed pumps using the performance data reported in the database. Instead, DOE used the reported data to estimate pump performance at each of the test procedure load points, for each variable-speed pump in the database, and then used the estimated performance of each pump to calculate the WEF of each pump.

The remainder of this subsection describes the methods DOE used to estimate variable-speed pump performance at the low-speed and high-speed test procedure load points. Following this discussion, section 5.3.1.6 explains how DOE used these estimates to calculate an estimated WEF value for variable-speed pumps. Section 5.3.1.7 explains how DOE used test data submitted by manufacturers to verify that these estimation methods produce accurate results.

Throughout this analysis, DOE refers to a set of equations known as the pump affinity laws. The pump affinity laws are a set of formulas that describe the operational characteristics of centrifugal pumps. These formulas are reproduced below and show that changes in pump rotational speed have a linear relationship to changes in flow rate (Equation 5.10), a squared relationship to changes in pump total head (Equation 5.11), and a cubic relationship to changes in pump hydraulic power (Equation 5.12).

$$\frac{Q_1}{Q_2} = \frac{N_1}{N_2}$$

Equation 5.10

$$\frac{H_1}{H_2} = \left(\frac{N_1}{N_2}\right)^2$$

Equation 5.11

$$\frac{P_1}{P_2} = \left(\frac{N_1}{N_2}\right)^3$$

Equation 5.12

[c] The term hhp refers to hydraulic horsepower at maximum speed on system curve C (which is also referred to as rated hydraulic horsepower in the test procedure final rule).

Where:

N_1 and N_2 = pump rotational speed at two operating points,
H_1 and H_2 = pump total head at pump rotational speed one and two,
Q_1 and Q_2 = flow rate at pump rotational speed one and two, and
P_1 and P_2 = pump hydraulic power at pump rotational speed one and two.

Pump and motor manufacturers provided DOE with performance data for several different models of variable-speed pool filter pumps and stand-alone variable-speed motors. The manufacturer-provided pump data included performance test curves, with input power, flow rate, and total dynamic head at load points across a range of pump speeds from 600 RPM to 3,450 RPM on system curves A, B, and C. The manufacturer-provided motor data included performance test curves, with input power, output torque, power factor, and the combined motor and drive efficiency across a range of motor speeds and torques. Using this data, DOE examined how pump wire-to-water efficiency changes as pump speed decreases. Specifically, for each available operating point in the manufacturer-submitted pump data, DOE used Equation 5.5 to calculate the hydraulic power and used Equation 5.13 to calculate the wire-to-water efficiency, η_{WtW}. As Equation 5.13 illustrates, the wire-to-water efficiency is equal to the pump's output hydraulic power, P_{hydro}, divided by the input power to the pump's motor, P_i, and is expressed as a percentage. Equation 5.13 also illustrates that the wire-to-water efficiency of a pump is equal to the product of the pump's hydraulic efficiency, η_{hydro}, and the efficiency of the pump motor, η_{motor}.

$$\eta_{WtW} = \frac{P_{hydro}}{P_i} = \eta_{hydro} \times \eta_{motor}$$

Equation 5.13

Where:

η_{WtW} = wire-to-water efficiency, in percent,
P_{hydro} = hydraulic power, in watts,
P_i = input power, in watts,
η_{hydro} = hydraulic efficiency, in percent, and
η_{motor} = motor efficiency, in percent.

After DOE calculated the wire-to-water efficiency for each operating point in the manufacturer-submitted pump data, DOE plotted wire-to-water efficiency versus pump rotational speed. Figure 5.3.1 shows the speed-efficiency plot of a hypothetical pool filter pump. The horizontal axis in Figure 5.3.1 represents pump rotational speed and is oriented such that the maximum pump speed of 3,450 RPM is at the left of the plot, and speed decreases in the rightward direction. The solid line in Figure 5.3.1 indicates the wire-to-water efficiency at different speeds, and the dashed line indicates the relative decrease in wire-to-water efficiency at each speed compared to the efficiency at maximum speed.

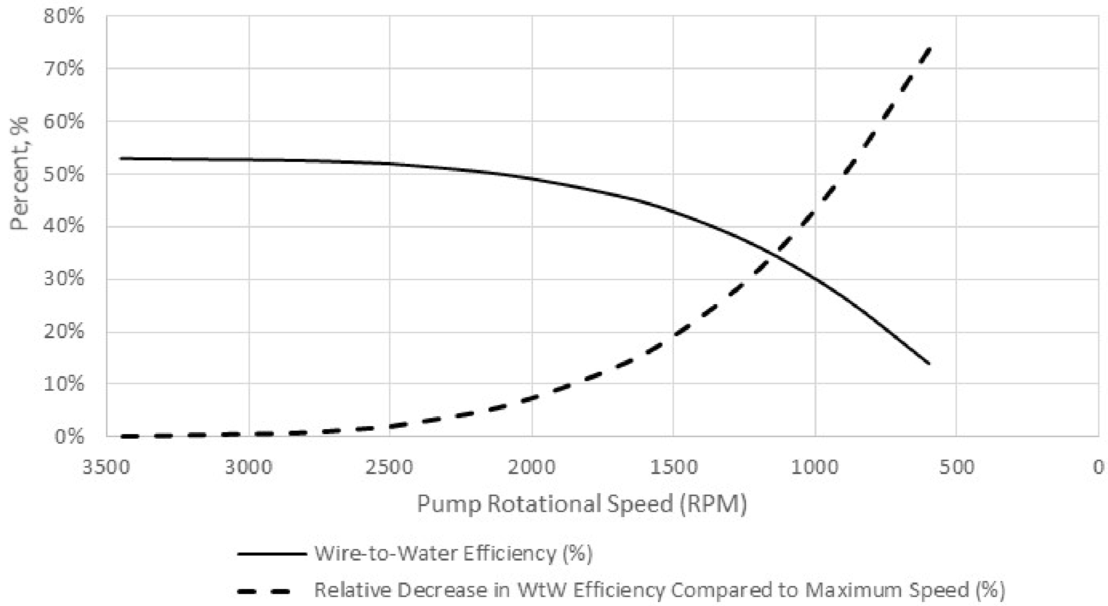

Figure 5.3.1 Wire-to-Water Efficiency Versus Pump Rotational Speed for a Hypothetical Variable-Speed Self-Priming Pool Filter Pump Less than 2.5 Hydraulic Horsepower

Figure 5.3.1 shows that the wire-to-water efficiency for the depicted pump decreases from 53.0 percent at maximum speed to 52.0 percent at 2,500 RPM. This represents a decrease of one percentage point, or a relative decrease of 1.8 percent from the efficiency at maximum speed. Below 2,500 RPM, the efficiency-speed curve becomes steeper as the wire-to-water efficiency decreases more rapidly. This same trend was present in all of the pool filter pump and pump motor test data that DOE examined: efficiency drops by a very small amount from maximum speed to 2,500 RPM, and then efficiency drops more sharply below 2,500 RPM. Furthermore, DOE examined data that showed some pool filter pumps exhibit increased wire-to-water efficiency at certain speeds between 3,450 RPM and 2,500 RPM, relative to their wire-to-water efficiency at the maximum speed of 3,450 RPM.

After looking at all available data, DOE concludes that for pool filter pumps that provide less than 2.5 hhp at maximum speed on curve C, there is no significant reduction in wire-to-water efficiency as pump speed is reduced from 3,450 RPM to 2,500 RPM (equivalent to 72 percent of maximum speed). Thus, DOE concludes that wire-to-water efficiency at the high-speed load point (*i.e.*, at 80 percent of maximum flow) is equivalent to wire-to-water efficiency at maximum speed (Equation 5.14).

DOE used the pump affinity laws to estimate the flow rate and hydraulic power at the high-speed load point based on the maximum speed (Equation 5.15 and Equation 5.16). DOE then divided the hydraulic power at the high-speed load point ($P_{hydro.80\%}$) by the (unchanged) wire-to-water efficiency at the high-speed load point ($\eta_{WtW.80\%}$) to estimate the input power at the high-speed load point ($P_{i.80\%}$). DOE presented this methodology to the DPPP Working Group, and the DPPP Working Group offered no objections to this methodology.

$$\eta_{\mathrm{WtW}.80\%} = \eta_{WtW.max}$$

Equation 5.14

Where:

$\eta_{WtW.80\%}$ = wire-to-water efficiency at 80 percent of maximum flow rate, in percent, and
$\eta_{WtW.max}$ = wire-to-water efficiency at maximum speed, in percent.

$$Q_{80\%} = 0.8 \times Q_{max}$$

Equation 5.15

Where:

$Q_{80\%}$ = flow rate at 80 percent of maximum flow rate, in gpm, and
Q_{max} = flow rate at maximum speed on curve C, in gpm.

$$P_{hydro.80\%} = P_{hydro.max} \times \left(\frac{80}{100}\right)^3$$

Equation 5.16

Where:

$P_{hydro.80\%}$ = hydraulic power at 80 percent of maximum flow rate, in watts,[d] and
$P_{hydro.max}$ = hydraulic power at maximum speed, in watts.

$$P_{i.80\%} = \frac{P_{hydro.80\%}}{\eta_{\mathrm{WtW}.80\%}}$$

Equation 5.17

Where:

$P_{i.80\%}$ = input power at 80 percent of maximum flow rate, in watts.

For the low-speed load point, DOE used the pump affinity laws to calculate the flow rate and hydraulic power. As discussed above, the wire-to-water efficiency of a typical pool filter pump declines sharply when the pump rotational speed is reduced to a speed below 2,500 RPM.

[d] Hydraulic power is typically reported in units of hp. For the purpose of comparing input power and hydraulic power, the units are converted here from hp to watts. 1 hp = 745.7 watts.

Consequently, it is not accurate to assume that wire-to-water efficiency at the low-speed load point is equivalent to the wire-to-water efficiency at the high-speed load point. To calculate the input power at the low-speed load point, DOE first estimated the wire-to water efficiency at the low-speed load point using the following regression methodology.

Using Equation 5.13, DOE calculated the wire-to-water efficiency, η_{WtW}, of all pumps at each speed reported on curve C in the Pool Pump Performance Database. For variable-speed pumps, DOE used Equation 5.18 to calculate the relative decrease in wire-to-water efficiency between 2,500 RPM and the middle and lower speeds (N) reported in the Pool Pump Performance Database, and defined this relative decrease as the efficiency reduction factor, ERF_N. The ERF_N accounts for the difference in wire-to-water efficiency between a speed of 2,500 RPM and a reported speed of the pump that is lower than 2,500 RPM.[e]

$$ERF_N = \frac{\eta_{WtW.2500} - \eta_{WtW.N}}{\eta_{WtW.2500}}$$

Equation 5.18

Where:

N = pump speed reported in the Pool Pump Performance Database, in RPM,
ERF_N = efficiency reduction factor of wire-to-water efficiency associated with the reported speed N, in percent,
$\eta_{WtW.2500}$ = wire-to-water efficiency at 2,500 RPM, which DOE assumes to be equal to the wire-to-water efficiency at the maximum speed, $\eta_{WtW.max}$, in percent, and
$\eta_{WtW.N}$ = wire-to-water efficiency at reported rotational speed N, in percent.

Of the variable-speed pump records in the Pool Pump Performance Database, some records report pump performance at three unique speeds (*i.e.*, a maximum speed, a middle speed, and a lower speed) and some records report pump performance at only two speeds (*i.e.*, a maximum speed and one other speed).

For each variable-speed pump that reports three unique speeds, DOE developed a logarithmic regression of ERF_N versus rotational speed and used this regression to estimate performance at the low-speed load point. The regression applied to each pump with three data points took the form of Equation 5.19.

$$\boldsymbol{ERF(N) = \mathrm{C}_{1.\mathrm{Ind}} \times ln(N) + C_{2.\mathrm{Ind}}}$$

Equation 5.19

[e] The regression approach in this methodology is used to estimate the decrease in wire-to-water efficiency at pump speeds less than 2,500 RPM. For the purpose of this analysis, DOE assumes that wire-to-water efficiency is constant from 3,450 RPM to 2,500 RPM and that that wire-to-water efficiency at speeds below 2,500 RPM may be estimated by regression.

Where:

ERF = efficiency reduction factor at a speed, N, less than 2,500 RPM, in percent,
$C_{1.Ind}$ = regression coefficient of ERF for an individual variable-speed pump, and
$C_{2.Ind}$ = regression constant of ERF for an individual variable-speed pump.

Figure 5.3.2 provides an illustrative example of the regression for a hypothetical pump. The horizontal axis of Figure 5.3.2 represents the rotational speed of a pump, and it decreases from left to right. The vertical axis represents the relative decrease in wire-to-water efficiency from 2,500 RPM (also called the efficiency reduction factor, ERF_N). The top of the vertical axis is zero percent, and a pump speed with an ERF_N value of zero percent has a wire-to-water efficiency equivalent to the wire-to-water efficiency at 2,500 RPM. A pump speed with an ERF_N value of 90 percent has wire-to-water efficiency equivalent to one tenth of the wire-to-water efficiency at 2,500 RPM.

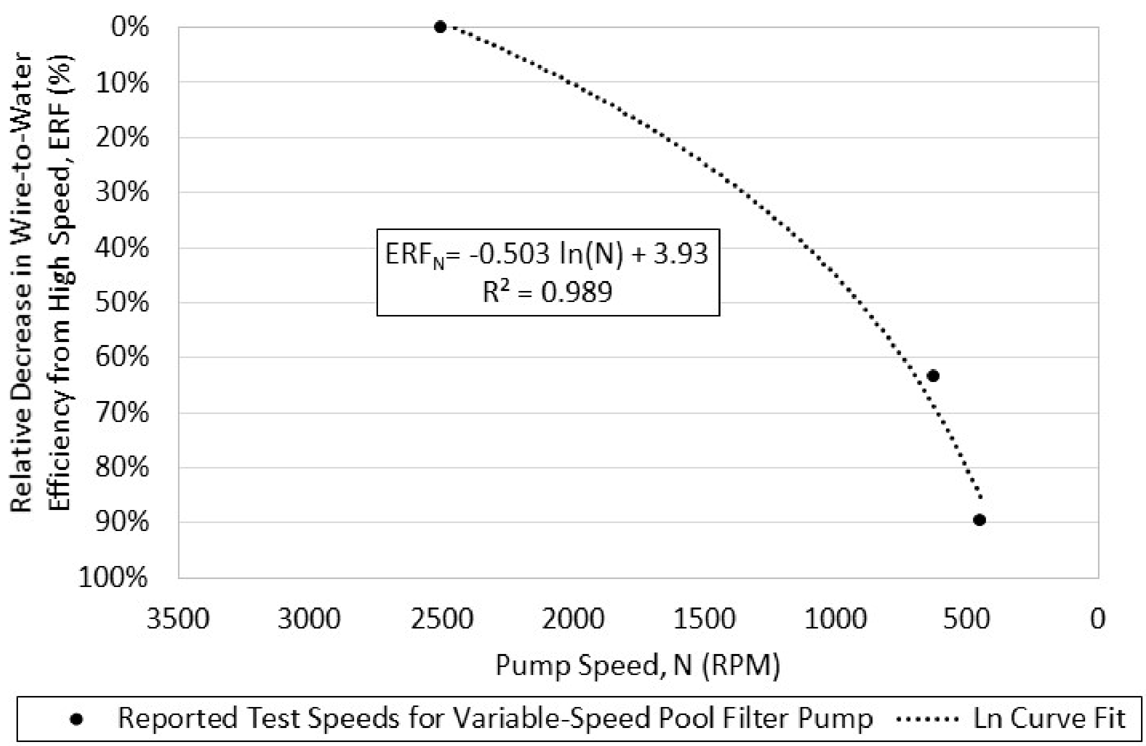

Figure 5.3.2 Relative Decrease in Wire-to-Water Efficiency Versus Pump Speed for One Variable-Speed Pump

For pumps in the database that report fewer than three speeds, DOE was unable to develop individual logarithmic regressions. Instead, DOE developed a group regression, based on the complete set of variable-speed pump data reported in the database. DOE used that group regression to predict the low-speed performance for pump records with fewer than three speeds.

Specifically, DOE plotted efficiency reduction factors (ERF_N) versus the pump speed (N) for all of the reported middle and lower load points. DOE performed a logarithmic least squares regression on this data to fit a natural logarithmic curve to all of the variable speed data points. To be consistent with the approach taken for the high-speed load point, DOE bound the upper (high-speed) end of this regression to a point representing a speed of 2,500 RPM and an ERF_N of zero. The result of this regression is presented mathematically in Equation 5.20 and graphically in Figure 5.3.3. Figure 5.3.3 follows the same format and conventions as described above for Figure 5.3.2.

$$\boldsymbol{ERF}(\boldsymbol{N}) = -0.513 \times \boldsymbol{ln}(\boldsymbol{N}) + 4.02$$

Equation 5.20

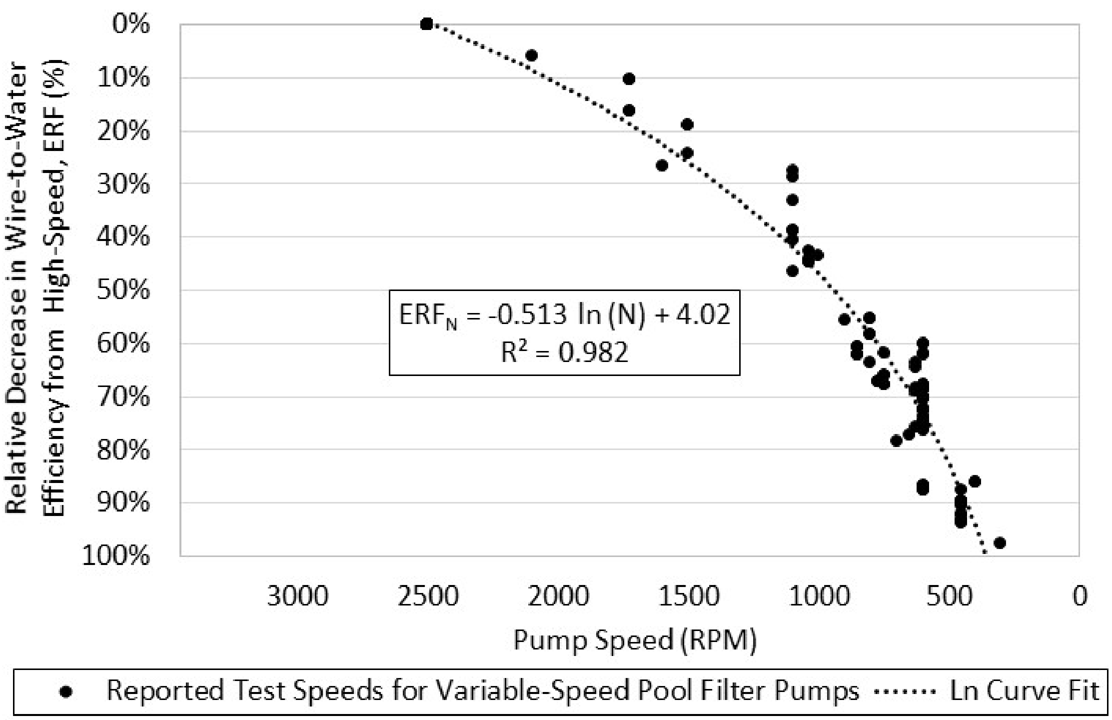

Figure 5.3.3 Relative Decrease in Wire-to-Water Efficiency Versus Pump Speed for All Variable-Speed Pumps

Next, DOE used the individual regressions and the group regression to estimate the performance of variable-speed pumps at the low-speed test point. First, for each variable-speed pump in the database, DOE calculated the pump rotational speed at the low-speed load point (N_{low}) using Equation 5.21, which is derived from the pump affinity law presented in Equation 5.10.

$$N_{low} = N_{max} \times \frac{Q_{low}}{Q_{max}}$$

Equation 5.21

Where:

N_{low} = pump rotation speed at the low-speed load point, in RPM,
N_{max} = the pump's maximum rotation speed, in RPM,
Q_{low} = flow rate at low-speed load point, in gpm, and
Q_{max} = flow rate at the pump's maximum speed, in gpm.

Then, DOE used either an individual regression curve shown in Equation 5.22 (for pump records that report three unique speeds) or the group regression curve shown in Equation 5.23 (for pump records that report fewer than three speeds) to estimate the relative decrease in wire-to-water efficiency at the low-speed load point (ERF_{low}) based on the pump rotational speed at the low-speed load point (N_{low}).

$$\boldsymbol{ERF_{low}} = \boldsymbol{ln}(\boldsymbol{N_{low}}) \times \mathbf{C_{1.Ind}} + \mathbf{C_{2.Ind}}$$

Equation 5.22

$$\boldsymbol{ERF_{low}} = \boldsymbol{ln}(\boldsymbol{N_{low}}) \times -0.513 + 4.02$$

Equation 5.23

Where:

ERF_{low} = efficiency reduction factor at the low-speed test point, in percent.

After calculating the ERF_{low} for each variable-speed pump, DOE used the ERF_{low} values to estimate each pump's wire-to-water efficiency at the low-speed load point, $\eta_{WtW.low}$. DOE estimated $\eta_{WtW.low}$ using equation Equation 5.24, which is derived from Equation 5.18. DOE calculated each pump's hydraulic output power at the low-speed load point ($P_{hydro.low}$) using Equation 5.25, which is derived from the pump affinity laws presented in Equation 5.10 and Equation 5.12. Then, DOE divided the hydraulic power by the wire-to-water efficiency to estimate the input power at the low-speed load point, $P_{i.low}$, using Equation 5.26. This value for $P_{i.low}$ is a key input used to calculate WEF.

$$\boldsymbol{\eta_{WtW.low}} = \boldsymbol{\eta_{\mathbf{WtW.max}}} \times (1 - \mathbf{ERF}_{\boldsymbol{low}})$$

Equation 5.24

$$\boldsymbol{P_{hydro.low}} = \boldsymbol{P_{hydro.max}} \times \left(\frac{\mathbf{Q}_{\boldsymbol{low}}}{\boldsymbol{Q_{max}}}\right)^{\mathbf{3}}$$

Equation 5.25

$$P_{i.low} = \frac{P_{hydro.low}}{\eta_{WtW.low}}$$

Equation 5.26

Where:

ERF_{low} = efficiency reduction factor at the low-speed load point, in percent,
$\eta_{WtW.low}$ = wire-to-water efficiency at the low-speed load point, in percent,
$\eta_{WtW.max}$ = wire-to-water efficiency at maximum speed, in percent,
$P_{hydro.low}$ = hydraulic power on curve C at the low-speed load point, in watts,
$P_{hydro.max}$ = hydraulic power on curve C at maximum speed, in watts, and
$P_{i.low}$ = input power at the low-speed load point, in watts.

The following subsection describes how DOE used these estimates of high-speed and low-speed performance to calculate the WEF of variable-speed pumps.

5.3.1.6 Calculation of WEF Scores for Pool Pump Performance Database Records

DOE calculated WEF values in accordance with the methods prescribed in the test procedure final rule.[7] This section describes how DOE calculated WEF for ifferent varieties and speed configurations of dedicated-purpose pool pumps.

Single-Speed Pumps. For single-speed self-priming and non-self-priming pool filter pumps, DOE used maximum-speed performance data available in the Pool Pump Performance Database and Equation 5.27 to calculate WEF.

$$WEF_{SS} = \frac{\frac{Q_{high}}{1000} \times 60}{\frac{P_{high}}{1000}}$$

Equation 5.27

Where:

WEF_{SS} = WEF of a single-speed pump, in thousands of gallons per kilowatt-hour (kgal/kWh),[f]
Q_{high} = flow rate at high-speed load point, in gpm, and
P_{high} = input power at high-speed load point, in watts.

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[f] For the purposes of this TSD, thousands of gallons is represented as kilogallons, or kgal. Thousands of watt-hours is represented as kilowatt-hours, or kWh.

DOE calculated WEF for pressure cleaner booster pumps using data gathered from manufacturers and Equation 5.27. The test procedure final rule specifies that pressure cleaner booster pumps be tested at one load point where the flow rate, Q_{high}, is 10 gpm and the pump is operating at a speed that achieves a total dynamic head of at least 60 feet of water.

DOE calculated WEF for waterfall pumps using data gathered from manufacturers and Equation 5.27. The test procedure final rule specifies that waterfall pumps be tested at a single load point at the maximum speed of the pump where total dynamic head is 17 feet of water.

Two-Speed Pumps. DOE calculated WEF for two-speed pumps using data reported in the Pool Pump Performance Database and Equation 5.28.

$$\boldsymbol{WEF_{DS} = \frac{\mathbf{w}_{high} \times \frac{Q_{high}}{1000} \times 60 + \mathbf{w}_{low} \times \frac{Q_{low}}{1000} \times 60}{\mathbf{w}_{high} \times \frac{P_{high}}{1000} + \mathbf{w}_{low} \times \frac{P_{low}}{1000}}}$$

Equation 5.28

Where:

WEF_{DS} = WEF of a two-speed pump, in kgal/kWh,
w_{high} = high-speed weighting factor, equal to 0.2,
w_{low} = low-speed weighting factor, equal to 0.8,
Q_{low} = flow rate at the low-speed load point, in gpm, and
P_{low} = input power at the low-speed load point, in watts.

Variable-Speed and Multi-Speed Pumps. For variable speed pumps, the test procedure final rule specifies that flow rate and input power be measured at a high-speed load point and a low-speed load point. The flow rate at the low-speed load point, Q_{low}, is equal to either 24.7 gpm or 31.1 gpm, depending on the capacity of the pump. Section 5.3.1.5 describes how DOE estimated the flow rates and input powers at the exact load points specified by the test procedure final rule. The flow rates and input powers at the low-speed and high-speed load points are used to calculate the WEF of variable-speed pumps as illustrated in Equation 5.29.

$$WEF_{VS} = \frac{w_{low} \times \frac{Q_{low}}{1000} \times 60 + w_{high} \times \frac{Q_{high}}{1000} \times 60}{w_{low} \times \frac{P_{low}}{1000} + w_{high} \times \frac{P_{high}}{1000}}$$

Equation 5.29

Where:

WEF_{VS} = WEF of a variable-speed pump, in kgal/kWh.

The test procedure final rule specifies that the WEF of a multi-speed pump is calculated using the same method described above for variable-speed pumps. However, the Pool Pump Performance Database does not contain records of multi-speed pumps, so DOE did not perform this calculation.

5.3.1.7 Verification of Variable-Speed WEF Estimates

DPPP manufacturers provided DOE with performance data for six different models of variable-speed pool filter pumps in the Pool Pump Performance Database. DOE used this data to validate the method used to estimate low-speed performance, described in section 5.3.1.5. The manufacturer-provided data included performance test curves, with input power, flow rate, and total dynamic head across a range of pump speeds from 600 RPM to 3,450 RPM. DOE compared the manufacturer-provided performance data to the DOE-estimated performance at the low-speed and high-speed load points and found less than a 5 percent difference between the input power reported by the manufacturers and the input power estimated by DOE calculations. DOE also compared WEF scores calculated based on the manufacturer-provided performance data to the WEF scores calculated based on DOE-estimated performance. For those six pumps, DOE also found less than a 5 percent difference between the WEF scores calculated based on manufacturer-provided test data and the WEF scores calculated based on DOE-estimated data. The small variation between the estimated input power and WEF and the actual input power and WEF provides DOE confidence in the methods used to estimate performance and the low-speed and high-speed load points.

5.3.2 Manufacturer Production Cost Dataset

DOE collected information about the MPC and the MSP of dedicated-purpose pool pumps and associated replacement motors across a range of pump capacities and pump varieties. DOE collected cost and price information from three main sources: manufacturer interviews, online retailer catalogs, and virtual teardowns. The data collection methods that DOE used for these three sources are described in the following sub-sections. DOE assembled this cost data into a unified manufacturer production cost dataset that describes the typical industry costs associated with manufacturing dedicated-purpose pool pumps. DOE aggregated data points from different sources to obfuscate any confidential data.

5.3.2.1 Manufacturer Interviews

DOE conducted confidential interviews with manufacturers of dedicated-purpose pool pumps. DOE guided these interviews using an interview protocol, which is included as appendix 12A of this TSD. DOE collected MPC and performance data from manufacturers for pumps and motors across a range of sizes and equipment classes. Data collected for individual DPPP models included the nominal horsepower and efficiency of the pump motor; the MPC of the motor and the finished pump; and the efficiency, flow rate, head, and input power of the pump at full load and at partial loads. During manufacturer interviews, DOE specifically inquired about potential changes in production costs associated with the different design options discussed in chapter 4 of this TSD.

5.3.2.2 Online Retailers

DOE collected retail price data for dedicated-purpose pool pumps and replacement motors sold by the online retailers Leslie's Swimming Pool Supplies,[8] INYO Pools,[9] and Pool Supply World.[10] These retail price data are publicly available on each retailer's website. DOE used this retail data to estimate MPCs for various pump models using several assumptions about supply chain markups. Chapter 6 of this TSD describes DOE's markups analysis and other assumptions regarding markups. DOE primarily used this analysis of retail price data to supplement and validate the data submitted by manufacturers.

5.3.2.3 Virtual Teardowns

One common method for determining the production cost of a piece of equipment is to disassemble the equipment piece-by-piece, compile a bill of materials, and estimate the material and labor costs associated with each producing and assembling each component. DOE refers to this practice as a physical teardown. A supplementary method, called a catalog teardown (or virtual teardown), uses manufacturer product literature and component data to estimate the costs of a product that was not physically torn down. DOE performed virtual teardown analyses to estimate the MPC of producing different varieties of DPPP equipment.

To conduct the virtual teardown analyses, DOE first selected a set of pool pump equipment that represents the pump varieties covered in the scope of this rule. (Section 5.4 of this chapter describes how DOE selected representative equipment for analysis.) Then, DOE collected component data from specification sheets and replacement parts catalogs and built a structured bill of materials for each representative pump unit. The bill of materials for each representative pump describes each component part of the pump; its weight, composition, and dimensions; its relationship to the other components; and the approximate order in which the components were assembled. These bills of materials describe each manufacturing operation in detail, including the type of equipment needed for fabrication or assembly (*e.g.*, injection molding machines, assembly stations, etc.), the process cycle times, and the labor inputs required. The result is a thorough and explicit model of the production process. The bill of materials estimates costs in four categories: (1) the materials costs of the raw materials used to fabricate parts and of the components that are purchased from suppliers; (2) the labor costs of fabrication, assembly, supervisory, and indirect labor; (3) the capital costs of equipment, tools, and buildings; and (4) the overhead costs arising from, for example, utilities, taxes, insurance, and maintenance. These cost categories are summed to provide an estimated MPC for each representative unit considered in the analysis.

5.4 REPRESENTATIVE EQUIPMENT FOR ANALYSIS

For the engineering analysis, DOE analyzed the MPC-efficiency relationships for the equipment classes specified in chapter 3 of this TSD. Generally, the manufacturing cost and the attainable efficiency of dedicated-purpose pool pumps vary as a function of pump capacity (*i.e.*, hydraulic horsepower). Because it is impractical to assess the MPC-efficiency relationship for all of the dedicated-purpose pool pump capacities available on the market, DOE selected a set of representative units to analyze. These representative units exemplify typical capacities in each equipment class and DOE used them to quantify the manufacturing costs and the energy savings potential for each equipment class. In general, to determine the representative capacities for each equipment class, DOE analyzed the distribution of available models and/or the shipments for each equipment class and discussed its findings with the DPPP Working Group. The following subsections discuss each equipment class in further detail.

5.4.1 Self-Priming Pool Filter Pumps

The scope of this direct final rule includes self-priming pool filter pumps with capacities less than 2.5 hhp at maximum speed on curve C. As described in chapter 3, the DPPP Working Group recommended that this range be subdivided into two equipment classes, with a breakpoint of 0.711 hhp. This breakpoint divides the range of self-priming pool filter pumps into a standard-size equipment class and a small-size equipment class. DOE used shipment distributions provided by manufacturers, distributions of models listed in the Pool Pump Performance Database, and feedback from the DPPP Working Group to select representative capacities for these equipment classes. DOE reviewed an initial selection of representative units with the DPPP Working Group. DOE revised the capacities of the representative units after the DPPP Working Group introduced a break point capacity to separate the small- and standard-size equipment classes.

For the small-size self-priming pool filter pump equipment class, DOE selected one representative unit with hydraulic horsepower of 0.44 hhp. For the standard-size self-priming pool filter pumps, DOE selected two representative units, at capacities of 0.95 hhp and 1.88 hhp. At the baseline efficiency level (discussed further in section 5.5), a 0.95-hhp pump requires shaft power of about 1.6 hp and is typically equipped with a motor rated between 1.7 and 2.2 thp. At the baseline efficiency level, a 1.88-hhp pump requires shaft power of about 3.0 hp and is typically equipped with a motor rated between 3.5 and 3.9 thp.

5.4.2 Non-Self-Priming Pool Filter Pumps

The scope of this direct final rule also includes non-self-priming pool filter pumps with capacities less than 2.5 hhp at maximum speed on curve C. However, the majority of non-self-priming pool filter pump models on the market deliver less than 1.0 hhp at maximum speed on curve C. Accordingly, the representative capacities DOE used to analyze the non-self-priming pool filter pump equipment class were different from the representative capacities used to analyze the self-priming pool filter pump equipment classes. Specifically, DOE selected two representative capacities for non-self-priming pool filter pumps, 0.09 hhp and 0.52 hhp at maximum speed on curve C. The smaller capacity (at 0.09 hhp) is representative of pumps that are typically sold with (or as replacements for) seasonal pools. These pumps are typically distributed in commerce on a skid with a sand filter, where the pump and the sand filter are connected with removable hoses. The larger capacity (at 0.52 hhp) represents pumps that are typically sold for applications where the pump is installed and operated below the waterline of the pool that it services, such as in aboveground pool applications. These pumps are typically distributed in commerce as standalone pumps.

5.4.3 Pressure Cleaner Booster Pumps

The pressure cleaner booster pumps available on the market are clustered in a small range of capacities. For this equipment class, DOE selected a capacity that is representative of the cluster of model capacities on the market. Specifically, DOE selected a representative capacity of 10 gpm of flow and 112 feet of head, which equates to 0.28 hhp. The flow rate of 10 gpm aligns with the testing load point specified for pressure cleaner booster pumps in the test procedure final rule. The DPPP Working Group recommended that pressure cleaner booster pumps be tested at the load point of 10 gpm and a head greater than 60 feet, to represent typical pressure cleaner booster pump operation.[g]

At 10 gpm, the pressure cleaner booster pump models from the three largest manufacturers (representing the majority of the pressure cleaner booster pump market) all achieve a similar head in a range from 100 feet to 127 feet of head. To represent the average performance of the pressure cleaner booster pump models available on the market, DOE selected a head value of 112 feet as the value that a representative unit would achieve at the test condition of 10 gpm.

5.4.4 Waterfall Pumps

The waterfall pumps on the market are clustered in a small range of capacities. The waterfall pumps from the three largest manufacturers (representing the majority of the pressure cleaner booster pump market) all provide flow rates between 23 gpm and 27 gpm at the test procedure load point of 17 feet of head. For this equipment class, DOE selected a capacity that is representative of the cluster of model capacities on the market. Specifically, DOE selected a representative capacity of 93 gpm of flow and 17 feet of head, which equates to 0.40 hhp. Seventeen feet of head aligns with the testing load point specified for waterfall pumps in the test procedure final rule. The DPPP Working Group recommended the testing load point of 17 feet of head (and flow corresponding to 17 feet of head on the pump curve) to represent the typical waterfall pump operation.

5.4.5 Integral Sand Filter and Integral Cartridge Filter Pool Pumps

In this direct final rule, DOE is establishing a prescriptive design standard, rather than a performance standard, for integral sand and cartridge filter pool pumps.[h] As such, in the test procedure final rule, DOE did not establish a test method for these equipment classes. However,

[g] The DPPP Working Group initially recommended that pressure cleaner booster pumps be tested at 90 feet of head and a volumetric flow rate that corresponds to 90 feet of head. However, the DPPP Working Group discussed that the minimum pressure requirement to drive a pressure cleaner is approximately 60 feet of head. Several group members expressed a desire that the test procedure allow better ratings for variable-speed pressure cleaner pumps that are able to reduce speed to avoid supplying (and wasting) excess pressure beyond what is required to drive the cleaner. The DPPP Working Group subsequently revised its recommendation to recommend that pressure cleaner booster pumps be tested at a flow rate of 10 gpm and the minimum head the pump can achieve that is greater than or equal to 60 feet. (Docket No. EERE-2015-BT-STD-0008, No. 82 Recommendation #8 at pp. 4)

[h] The DPPP Working Group considered two alternatives for this analysis: (1) a prescriptive standard that would require a timer for integrated cartridge and integrated sand filter pumps, and (2) a performance standard that would likely be achieved through the use of advanced motors. To help evaluate these alternatives, DOE developed cost-efficiency relationships for integrated cartridge and integrated sand filter pool pumps that describe (1) the use of a timer on all pumps, and (2) the use of advanced motors where possible. The DPPP Working Group reviewed these cost-efficiency relationships. DPPP Working Group members commented that a prescriptive standard requiring a timer may be economically justified, but that a performance standard with advanced motors would not be economically justified. (Docket No. EERE-2015-BT-STD-0008-0053, November 12 DPPP Working Group Meeting, at pp. 45-78

as a part of this direct final rule, DOE still evaluated the incremental MPC-efficiency relationship for the prescriptive standard. To do so, DOE established representative models based on performance characteristics of these pumps on system curve C.

DOE examined the models of integral sand and cartridge filter pool pumps available in the market and selected one representative equipment capacity (0.03 hhp at maximum speed on curve C) for integral sand filter pool pumps, and two representative equipment capacities (0.02 hhp and 0.18 hhp at maximum speed on curve C) for integral cartridge filter pool pumps. The DPPP Working Group reviewed the representative equipment capacities for integral sand filter and integral cartridge filter pumps and offered no objections.

5.4.6 Summary of Representative Units

Table 5.4.1 summarizes the representative capacities that DOE used to analyze dedicated-purpose pool pumps.

Table 5.4.1 Characteristics of Representative Units, by Equipment Class

DPPP Equipment Class	Test Point	Performance at Test Point at 100% Speed		
		Power hhp	Head feet	Flow gpm
Self-priming pool filter pump, standard-size	curve C	1.88	76.8	96.8
	curve C	0.95	48.7	77.1
Self-priming pool filter pump, small-size	curve C	0.44	29.2	59.7
Non-self-priming pool filter pump	curve C	0.52	32.6	63.1
	curve C	0.09	10.1	35.1
Pressure cleaner booster pump	10 gpm flow	0.28	112.0	10.0
Waterfall pump	17 ft. head	0.40	17.0	93.0
Integral sand filter pool pump	n/a*	0.03	4.9	24.4
Integral cartridge filter pool pump	n/a*	0.18	16.1	44.3
	n/a*	0.02	3.7	21.3

* DOE did not establish a test procedure for integral sand filter pool pumps or integral cartridge filter pool pumps, because these equipment classes are not subject to performance standards. The performance reported for integral pumps in this table is measured on curve C.

5.5 BASELINE CONFIGURATION AND PERFORMANCE

The baseline configuration defines the lowest efficiency equipment in each analyzed equipment class. The baseline configuration is a reference point used to determine the potential energy savings for all efficiency levels that are above the baseline. DOE established baseline configurations by reviewing the configurations and performance of pumps listed in the Pool Pump Performance Database. DOE determined that, for pool filter pumps (including all sub-varieties) and pressure cleaner booster pumps, the baseline configuration has the following characteristics:

- single-speed

- low-efficiency motor
- low hydraulic efficiency

To determine an appropriate level of performance for each representative pool filter pump unit at the baseline, DOE identified pool filter pumps in the Pool Pump Performance Database that have similar hydraulic capacity to the representative pool filter pump units, and that share the baseline equipment characteristics. DOE adopted the estimated WEF values of these identified pumps as the baseline performance level for each representative pool filter pump unit. Pressure cleaner booster pumps and waterfall pumps are not listed in the Pool Pump Performance Database. Manufacturers provided test data for several models of pressure cleaner booster pumps and waterfall pumps, and these test data enabled DOE to estimate the performance of representative units at the baseline.

The baseline configuration for integral filter pumps for which prescriptive standards were considered is characterized by median performance and lack of a timer mechanism. Table 5.5.1 summarizes the baseline configurations and performance levels for the representative units used in this analysis. These baseline configurations ultimately define the input power and the associated costs for the lowest efficiency equipment analyzed in each equipment class.

Table 5.5.1 Baseline Configurations and Performance for DPPP Representative Units

DPPP Representative Unit	Baseline Configuration	Baseline Performance WEF
Self-priming pool filter pump, 1.88 hhp	Single-speed, low efficiency motor, low hydraulic efficiency	1.74
Self-priming pool filter pump, 0.95 hhp		2.13
Self-priming pool filter pump, 0.44 hhp		2.69
Non-self-priming pool filter pump, 0.52 hhp		2.77
Non-self-priming pool filter pump, 0.09 hhp		3.93
Pressure cleaner booster pump		0.34
Waterfall pump		7.46
Integral sand filter pool pump	No timer	n/a
Integral cartridge filter pool pump, 0.18 hhp		n/a
Integral cartridge filter pool pump, 0.02 hhp		n/a

5.6 EFFICIENCY LEVELS

For each equipment class, DOE established and analyzed a set of efficiency levels above the baseline configuration to assess the relationship between MPC and DPPP efficiency. These efficiency levels are discrete tiers of energy efficiency that can be represented by pumps measured using the WEF test metric.

5.6.1 Design Option Applicability and Ordering

For the self-priming and non-self-priming pool filter pump varieties, DOE considered incremental improvements that could be applied to the baseline configuration; these improvements are related to three of the design options discussed in chapter 4: (1) improved motor efficiency, (2) ability to operate at reduced speeds, and (3) improved hydraulic design.

Specifically, for the “improved motor efficiency” design option, DOE considered three tiers of motor efficiency (low, medium, and high motor efficiency) for both single-speed and two-speed pump motors. The specific nameplate motor efficiency associated with these tiers varied by pump variety and capacity, and the numerical efficiency values that DOE associated with these tiers of motor efficiency are presented in Table 5.6.3. For the “ability to operate at reduced speeds” design option, DOE considered three motor speed configurations: single-speed, two-speed, and variable-speed. Finally, for the “improved hydraulic design” design option, DOE considered two hydraulic efficiencies (low and high hydraulic efficiency). The specific hydraulic efficiencies associated with these tiers varied by pump variety and capacity, and the numerical efficiency values that DOE associated with these tiers of hydraulic efficiency are presented in Table 5.6.4.

For pressure cleaner booster pumps, DOE evaluated the same design options as for pool filter pumps. However, DOE did not consider two-speed motors because pressure cleaner booster pumps only operate at one speed and cannot benefit from the ability to switch between two discrete speeds. Alternatively, DOE did consider variable-speed motors for pressure cleaner booster pumps, as the WEF metric accounts for energy savings available from reducing the pump speed to reach the minimum required pressure of 60 feet.

For waterfall pumps, DOE evaluated the same improved motor efficiency and improved hydraulic efficiency design options as for pool filter pumps, but did not evaluate the ability to operate at reduced speeds. This is because DOE determined that waterfall pumps only operate at one speed and therefore cannot benefit from the ability to switch speeds.

To order the design options for each equipment class, DOE considered all of the costs (both incremental MPCs and one-time product conversion costs) that manufacturers would incur with each design option. Based on data from manufacturer interviews and DPPP Working Group discussions, DOE concluded that a direct relationship exists between motor MPC and pump WEF score. DOE also concluded that there is a flat relationship between motor-related conversion costs and WEF score. Motors with higher efficiency or more speeds cost more than less efficient motors with fewer speeds (motor cost estimates are provided in Table 5.7.1), but manufacturers face similar conversion costs for all motor-related design options, regardless of whether they are substituting on the basis of motor efficiency or on the basis of motor speed configuration.

Alternatively, based on data from manufacturer interviews and DPPP Working Group discussions, DOE concluded that hydraulic redesign has a negligible effect on MPC, but results in significant conversion costs–much greater than those incurred for motor-related improvement. Complete discussions of incremental MPCs and conversion costs are found in section 5.7 and chapter 12 of this TSD, respectively.

Ultimately, DOE ordered its design options to first employ all motor-related design options, based on ascending MPC, followed by improved hydraulic design to reach the maximum technologically feasible efficiency level. The DPPP Working Group reviewed the ordering, offered no objections, and ultimately evaluated standards based on efficiency levels resulting from this ordering. Table 5.6.1 describes the design options applied to each equipment class at each efficiency level from the baseline up to the max tech level.

Table 5.6.1 Design Options by Efficiency Level for DPPP Varieties Subject to Performance Standards

<table>
<tr><th rowspan="3">Efficiency Level</th><th colspan="4">DPPP Variety</th></tr>
<tr><th colspan="2">Pool Filter Pumps</th><th rowspan="2">Waterfall Pump</th><th rowspan="2">Pressure Cleaner Booster Pump</th></tr>
<tr><th>Self-Priming</th><th>Non-Self-Priming*</th></tr>
<tr><td>0
(Baseline)</td><td colspan="2">1-speed motor,
Low-efficiency motor,
Low hydraulic efficiency</td><td>1-speed motor,
Low-efficiency motor,
Low hydraulic efficiency</td><td>1-speed motor,
Low-efficiency motor,
Low hydraulic efficiency</td></tr>
<tr><td>1</td><td colspan="2">1-speed motor,
Medium-efficiency motor,
Low hydraulic efficiency</td><td>1-speed motor,
Medium-efficiency motor,
Low hydraulic efficiency</td><td>1-speed motor,
Medium-efficiency motor,
Low hydraulic efficiency</td></tr>
<tr><td>2</td><td colspan="2">1-speed motor,
High-efficiency motor,
Low hydraulic efficiency</td><td>1-speed motor,
High-efficiency motor,
Low hydraulic efficiency</td><td>1-speed motor,
High-efficiency motor,
Low hydraulic efficiency</td></tr>
<tr><td>3</td><td colspan="2">2-speed motor,
Low-efficiency motor,
Low hydraulic efficiency</td><td>1-speed motor,
High-efficiency motor,
High hydraulic efficiency</td><td>Variable-speed motor,
Low hydraulic efficiency</td></tr>
<tr><td>4</td><td colspan="2">2-speed motor,
Medium-efficiency motor,
Low hydraulic efficiency</td><td></td><td>Variable-speed motor,
High hydraulic efficiency</td></tr>
<tr><td>5</td><td colspan="2">2-speed motor,
High-efficiency motor,
Low hydraulic efficiency</td><td></td><td></td></tr>
<tr><td>6</td><td colspan="2">Variable-speed motor,
Low hydraulic efficiency</td><td></td><td></td></tr>
<tr><td>7
(Max tech)</td><td colspan="2">Variable-speed motor,
High hydraulic efficiency</td><td></td><td></td></tr>
</table>

* As described in chapter 3 of this TSD, DOE did not consider efficiency levels above EL 2 for non-self-priming pool filter pumps that produce less than 49.4 gpm maximum flow on curve C.

DOE analyzed one design option for the integral cartridge filter pool pump and integral sand filter pool pump classes that are subject to prescriptive standards. Table 5.6.2 presents the two efficiency levels considered for those classes: the baseline (without a pool pump timer), and EL 1 (with a pool pump timer).

Table 5.6.2 Design Options by Efficiency Level for DPPP Varieties Subject to Prescriptive Standards

Efficiency Level	DPPP Variety	
	Integral Cartridge Filter Pumps	Integral Sand Filter Pumps
0 (Baseline)	Does not include pool pump timer	Does not include pool pump timer
1	Includes pool pump timer	Includes pool pump timer

5.6.2 Summary of Available Motor Efficiencies

For the improved motor efficiency design option, DOE selected a discrete motor efficiency (or efficiencies, for two-speed motors) for each representative unit at each efficiency level. Table 5.6.3 presents the motor efficiencies selected for each motor efficiency tier and motor configuration described in Table 5.6.1. DOE selected these motor efficiencies based on data listed in the Pool Pump Performance Database, publicly available catalog data, and motor data that manufacturers submitted to DOE. Motor components with the efficiencies listed in Table 5.6.3 are currently available on the market with frame sizes and capacities that are appropriate to drive the representative unit pumps. DOE presented its motor efficiency assumptions to the DPPP Working Group and subsequently refined them to incorporate feedback from the group.

Table 5.6.3 Motor Nameplate Efficiencies for Representative Units with Different Motor Configurations*

Motor Description	Motor Efficiencies (and Corresponding ELs) for Representative Units at High Speed Except as Noted						
	Self-Priming Pool Filter Pump			Non-Self-Priming Pool Filter Pump		Pressure Cleaner Booster Pump	Water-fall Pump
	0.44 hhp	0.95 hhp	1.88 hhp	0.09 hhp	0.52 hhp		
1-speed, low efficiency (Baseline)	55% (EL 0)	55% (EL 0)	75% (EL 0)	55% (EL 0)	55% (EL 0)	55% (EL 0)	65% (EL 0)
1-speed, mid efficiency	69% (EL 1)	69% (EL 1)	79% (EL 1)	69% (EL 1)	69% (EL 1)	67% (EL 1)	70% (EL 1)
1-speed, high efficiency	76% (EL 2)	77% (EL 2)	84% (EL 2)	72% (EL 2)	72% (EL 2)	72% (EL 2)	78% (EL 2-3)
2-speed, low	64% high,	64% high,	74% high,	n/a**	61% high,	n/a††	n/a††

efficiency	38% low (EL 3)	38% low (EL 3)	49% low (EL 3)		38% low (EL 3)		
2-speed, mid efficiency	70% high, 46% low (EL 4)	71% high, 46% low (EL 4)	76% high, 55% low (EL 4)	n/a**	68% high, 48% low (EL 4)	n/a††	n/a††
2-speed, high efficiency	73% high, 51% low (EL 5)	73% high, 51% low (EL 5)	83% high, 62% low (EL 5)	n/a**	72% high, 51% low (EL 5)	n/a††	n/a††
Variable-speed	81% (EL 6-7)	81% (EL 6-7)	82% (EL 6-7)	n/a†	81% (EL 6-7)	81% (EL 3-4)	n/a††

* The integral cartridge filter pool pump and integral sand filter pool pump equipment classes are not included in this table because DOE did not separately consider the motor costs for these equipment classes.
** As discussed in chapter 3 of this TSD, this analysis does not consider two-speed motor configurations for the extra-small non-self-priming pool filter pump representative unit. According to the test procedure final rule, this representative unit would always be subject to the single-speed test procedure because the half-speed flow rate for a 0.09-hhp pump would be 17.8 gpm, which is less than the test procedure minimum flow rate of 24.7 gpm.
† As discussed in chapter 3 of this TSD, this analysis does not consider variable-speed motor configurations for the extra-small non-self-priming pool filter pump representative unit.
†† Two-speed motors were not considered for waterfall pumps or pressure cleaner booster pumps, and variable-speed motors were not considered for waterfall pumps, because DOE assumes these pump varieties are always operated at a single speed.

5.6.3 Summary of Available Hydraulic Efficiencies

For the “improved hydraulic design” design option, DOE evaluated two discrete hydraulic efficiencies (“low” and “high”) for each representative unit. The low hydraulic efficiency represents the pump hydraulic efficiency of a baseline unit that has not been optimized. The high hydraulic efficiency represents the hydraulic efficiency of a pump that has been hydraulically redesigned to improve hydraulic efficiency, as described in the discussion of technology options in chapter 3 of this TSD.

For each equipment class, DOE assessed the potential energy efficiency improvements that could result from a hydraulic redesign. This assessment was informed by data listed in the Pool Pump Performance Database, performance and cost data submitted by manufacturers, confidential manufacturer interview responses, general industry research, and input gathered during the general pumps rulemaking. Chapter 3 of this TSD presents the ranges of hydraulic efficiency available in the market for different varieties and capacities of dedicated-purpose pool pumps. Table 5.6.4 presents the selected hydraulic efficiency values that DOE applied to each efficiency level described in Table 5.6.1.

Table 5.6.4 Hydraulic Efficiencies for Representative Units

Hydraulic Efficiency Description	Hydraulic Efficiencies and Corresponding ELs for Representative Units at Maximum Speed on Curve C						
	Self-Priming Pool Filter Pump			Non-Self-Priming Pool Filter Pump		Pressure Cleaner Booster Pump	Waterfall Pump
	0.44 hhp	0.95 hhp	1.88 hhp	0.09 hhp	0.52 hhp		
Low Hydraulic Efficiency (Applicable ELs)	45% (EL0-6)	59% (EL 0-6)	62% (EL 0-6)	23% (EL 0-2)	51% (EL 0-6)	24% (EL 0-3)	61% (EL 0-2)
High Hydraulic Efficiency (Applicable ELs)	49% (EL 7)	63% (EL 7)	72% (EL 7)	n/a*	67% (EL 7)	27% (EL 4)	67% (EL 3)

* DOE did not have sufficient data to evaluate a 0.09-hhp non-self-priming pool filter pump with high hydraulic efficiency.

5.6.4 Representative Unit Performance at Each Efficiency Level

In the previous sections of this chapter, DOE described efficiency levels and the available improvements in motor and hydraulic efficiency for different equipment classes. This section describes how DOE used that information to calculate the WEF value of each representative unit at each efficiency level.

The DPPP equipment classes within the scope of this direct final rule are varied in terms of the number of pump models that are offered on the market and in terms of the amount of data available for those models. Because of these variations, DOE calculated WEF values using slightly different methodologies for each equipment class. The following subsections describe the methodologies that DOE used for each equipment class.

Many of the calculations in this section depend on the relationship between the wire-to-water efficiency, the hydraulic efficiency, and the motor efficiency of a pump. This relationship was previously defined in Equation 5.13.

5.6.4.1 Self-Priming Pool Filter Pumps

This subsection describes how DOE used the baseline and incremental performance data presented in sections 5.5 through 5.6.3 to determine the WEF values for three representative self-priming pool filter pump units (with hydraulic power at 0.44 hhp, 0.95 hhp, and 1.88 hhp) from EL 1 through max tech.

Baseline through Efficiency Level 2. Efficiency levels one and two represent single-speed pumps. For EL 1 and EL 2, DOE held hydraulic efficiency constant at the baseline level and replaced the baseline maximum-speed motor efficiency with the EL 1 and EL 2 maximum-speed motor efficiencies (presented in Table 5.6.3). In doing so, DOE was able to calculate the wire-to-water efficiency, input power, and ultimately the WEF at maximum speed on curve C.

Efficiency Level 3 through Efficiency Level 5. Efficiency levels three through five represent two-speed pumps. The WEF score of a two-speed pump is calculated as a weighted average of the pump performance at two load points, the maximum speed on curve C and a low speed on curve C. For EL 3, EL 4, and EL 5, DOE determined maximum-speed pump performance on curve C using the same method as described above for EL 1 and EL 2. However, a dedicated-purpose pool pump operating at half-speed will exhibit lower hydraulic efficiency and lower motor efficiency compared to its full speed operation. To characterize the pump performance at half-speed, DOE referred to the Pool Pump Performance Database, which includes half-speed performance data for listings of two-speed self-priming pool filter pumps. For all three representative units, DOE identified pumps in the Pool Pump Performance Database that exemplify EL 3, with design characteristics of low motor efficiency, two-speed motor, and low hydraulic efficiency. DOE used the half-speed motor efficiency and input power reported in the database for these EL 3 units to estimate a representative baseline half-speed hydraulic efficiency. Then, DOE calculated the wire-to-water efficiency and the input power for EL 4 and EL 5 at half speed by holding the half-speed hydraulic efficiency constant at the level calculated for EL 3, and substituting the half-speed motor efficiencies assumed for EL 4 and EL 5 (presented in Table 5.6.3). DOE calculated the WEF scores for representative units at EL 4 and EL 5 using the flow and electrical input power at half speed and at maximum speed, as specified in the test procedure final rule and described in section 5.3.1.6.

Efficiency Levels 6 and 7. Efficiency levels six and seven represent variable-speed pumps. At EL 6, DOE assumed that the baseline motor would be replaced with the EL 6 motor presented in Table 5.6.3. Unlike for two-speed pumps, the high-speed load point for variable-speed pumps is at 80 percent of maximum flow rate on curve C, and the low-speed load point is at either 24.7 gpm flow or 31.1 gpm flow on curve C (depending on the pump capacity). Although the Pool Pump Performance Database contains performance data for many variable-speed pumps, pump data is not typically reported at these specific load points. Consequently, DOE utilized the variable-speed performance data available for other reported speeds to estimate performance for the representative units at these specific variable-speed load points.

Based on examination of speed-vs-efficiency curves for many variable-speed pumps and variable-speed motors, DOE concluded that a pool filter pump's wire-to-water efficiency at 80 percent of maximum flow rate (the high-speed load point) is approximately equal to the pump's wire-to-water efficiency at maximum speed. As such, DOE assumed that the hydraulic and motor efficiency of each variable-speed representative unit remains constant between 100 percent and 80 percent of maximum flow rate. See section 5.3.1.5 for a full discussion of pump efficiency curves.

However, examination of the same speed-vs-efficiency curves for pumps and motors indicated that that pump's wire-to-water efficiency will be lower at the low-speed test point, as hydraulic and motor efficiency tend to be significantly reduced at low speeds. To quantify the relationship between wire-to-water efficiency and speed reduction, DOE constructed a regression of the relative decrease in wire-to-water efficiency compared to the pump speed. This relationship allowed DOE to estimate wire-to-water efficiency, and thus input power, for each representative unit at the low-speed load point, based on each unit's wire-to-water efficiency at maximum speed on curve C. Section 5.3.1.5 presents the full details of this regression and describes how wire-to-water efficiency decreases with pump speed in DPPP applications. The DPPP Working Group reviewed this method of estimating low-speed performance and certain members expressed explicit agreement with the results of this low-speed estimation methodology. The remainder of the DPPP Working Group offered no objections, and ultimately evaluated standards based on this methodology.

At EL 6, DOE also estimated the hydraulic efficiency at the low-speed and high-speed load points using data from the Pool Pump Performance Database. To do this, DOE identified pumps in the Pool Pump Performance Database that exemplify EL 6 (those with a variable-speed motor and low hydraulic efficiency), and referenced the low-speed and high-speed motor efficiencies and input power values that DOE estimated for those units. Using Equation 5.5, DOE calculated the hydraulic output power at the low-speed and high-speed load points. Then, DOE used Equation 5.13 to calculate the hydraulic efficiency of the representative EL 6 pumps at the low-speed and high-speed load points.

Efficiency level seven represents a pump with the same motor as EL 6 combined with a wet end[i] that has improved hydraulic design relative to EL 6. DOE used Equation 5.13 to calculate the total pump efficiency and the input power for EL 7 at the low-speed and high-speed load points. DOE held the motor efficiencies constant at the EL 6 levels and substituted improved hydraulic efficiencies, up to the values specified in Table 5.6.4. Ultimately, DOE used the estimated low-speed and high-speed performance data to calculate WEF for representative units at EL 6 and EL 7, as specified in the test procedure final rule and described in section 5.3.1.6.

Table 5.6.5, Table 5.6.6, and Table 5.6.7 summarize the observations and calculations at the test procedure load points at each efficiency level for the self-priming pool filter pump representative units.

[i] DOE recognizes that industry uses the terms “wet end” and “bare pump” interchangeably. A bare pump is defined as “a pump excluding mechanical equipment, driver, and controls.” 10 CFR 431.462.

Table 5.6.5 Performance of Representative 0.44-hhp Self-Priming Pool Filter Pump, by Efficiency Level

EL	High-Speed Load Point					Low-Speed Load Point					WEF
	Motor Eff. (%)	WtW Eff. (%)	Flow (gpm)	Head (feet H_2O)	Input Power (W)	Motor Eff. (%)	WtW Eff. (%)	Flow (gpm)	Head (feet H_2O)	Input Power (W)	
EL 0	55	25	60	30	1,331	n/a	n/a	n/a	n/a	n/a	2.69
EL 1	69	31	60	30	1,061	n/a	n/a	n/a	n/a	n/a	3.37
EL 2	76	34	60	30	963	n/a	n/a	n/a	n/a	n/a	3.72
EL 3	64	29	60	30	1,143	38	14	30	7	288	4.68
EL 4	70	31	60	30	1,045	46	17	30	7	238	5.38
EL 5	73	33	60	30	1,002	51	19	30	7	215	5.77
EL 6	81	30	48	19	565	57	21	25	5	109	8.78
EL 7	81	40	48	19	424	57	29	25	5	82	11.71

Table 5.6.6 Performance of Representative 0.95-hhp Self-Priming Pool Filter Pump, by Efficiency Level

EL	High-Speed Load Point					Low-Speed Load Point					WEF
	Motor Eff. (%)	WtW Eff. (%)	Flow (gpm)	Head (feet H_2O)	Input Power (W)	Motor Eff. (%)	WtW Eff. (%)	Flow (gpm)	Head (feet H_2O)	Input Power (W)	
EL 0	55	33	77	49	2,172	n/a	n/a	n/a	n/a	n/a	2.13
EL 1	69	41	77	49	1,731	n/a	n/a	n/a	n/a	n/a	2.67
EL 2	77	46	77	49	1,551	n/a	n/a	n/a	n/a	n/a	2.98
EL 3	64	38	77	49	1,866	38	22	39	12	404	3.98
EL 4	71	42	77	49	1,682	46	27	39	12	334	4.60
EL 5	73	43	77	49	1,636	51	29	39	12	301	4.88
EL 6	81	39	62	32	940	57	27	31	8	170	6.89
EL 7	81	48	62	32	754	57	34	31	8	136	8.59

Table 5.6.7 Performance of Representative 1.88-hhp Self-Priming Pool Filter Pump, by Efficiency Level

EL	High-Speed Load Point					Low-Speed Load Point					WEF
	Motor Eff. (%)	WtW Eff. (%)	Flow (gpm)	Head (feet H_2O)	Input Power (W)	Motor Eff. (%)	WtW Eff. (%)	Flow (gpm)	Head (feet H_2O)	Input Power (W)	
EL 0	75	42	97	77	3,344	n/a	n/a	n/a	n/a	n/a	1.74
EL 1	79	49	97	77	2,860	n/a	n/a	n/a	n/a	n/a	2.03
EL 2	84	52	97	77	2,690	n/a	n/a	n/a	n/a	n/a	2.16
EL 3	74	46	97	77	3,053	49	35	48	19	501	3.45
EL 4	76	47	97	77	2,973	55	39	48	19	446	3.66
EL 5	83	57	97	77	2,461	62	41	48	19	428	4.18
EL 6	82	51	77	49	1,608	57	26	31	8	178	5.21
EL 7	82	59	77	49	1,203	57	35	31	8	133	6.97

5.6.4.2 Non-Self-Priming Pool Filter Pumps

This subsection describes how DOE used the baseline and incremental performance data presented in sections 5.5 through 5.6.3 to determine the WEF values for two representative non-self-priming pool filter pump units (with hydraulic power at 0.09 hhp and 0.52 hhp) from EL 1 through max tech. DOE analyzed the 0.09-hhp non-self-priming representative unit separately from the 0.52-hhp non-self-priming representative unit. [The DPPP Working Group ultimately determined that separate standard levels were not appropriate for standard-size non-self-priming and extra-small non-self-priming pool filter pumps (Docket No. EERE-2015-BT-STD-0008-0092, June 23 DPPP Working Group Meeting, pp. 277-280), and the two representative capacities are regulated together in one equipment class.]

DOE did not analyze any efficiency levels above EL 2 for the 0.09-hhp non-self-priming pool filter pump representative unit. As discussed in chapter 3 of this TSD, pool filter pumps that are below 49.4 gpm at maximum speed on curve C do not benefit from the design option described as the "ability to operate at reduced speeds." The representative unit characteristics in Table 5.4.1 show that the 0.09-hhp non-self-priming representative unit achieves a flow rate of 35.1 gpm at maximum speed on curve C. This flow rate is below the 49.4 gpm threshold, so DOE analyzed only single-speed efficiency levels (EL 0 through EL 2) for the 0.09-hhp non-self-priming pool filter pump.

Baseline through Efficiency Level 2. To calculate the WEF of non-self-priming pool filter pumps at EL 1 and EL 2 at maximum speed on curve C, DOE used the same methods as those described for self-priming pool filter pumps at EL 1 and EL 2. That is, DOE held hydraulic efficiency constant at the baseline level and replaced the baseline maximum-speed motor efficiency with the EL 1 and EL 2 maximum-speed motor efficiencies (presented in Table 5.6.3). In doing so, DOE was able to calculate the wire-to-water efficiency, input power, and ultimately the WEF at maximum speed on curve C.

Efficiency Level 3 through Efficiency Level 5. To calculate the WEF of 0.52-hhp non-self-priming pool filter pumps at ELs 3-5, DOE used the same methods as those described for self-priming pool filter pumps at ELs 3-5. For ELs 3-5, DOE determined maximum-speed pump performance on curve C using the same method as described above for EL 1 and EL 2. To characterize the pump performance at half-speed, DOE referred to the Pool Pump Performance Database, which includes half-speed performance data for listings of two-speed non-self-priming pool filter pumps. For both representative units, DOE identified pumps in the Pool Pump Performance Database that exemplify EL 3, with design characteristics of low motor efficiency, two-speed motor, and low hydraulic efficiency. DOE used the half-speed motor efficiency and input power reported in the database for these EL 3 units to estimate a representative baseline half-speed hydraulic efficiency. Then, DOE calculated the wire-to-water efficiency and the input power for EL 4 and EL 5 at half speed by holding the half-speed hydraulic efficiency constant at the level calculated for EL 3, and substituting the half-speed motor efficiencies assumed for EL 4 and EL 5 (presented in Table 5.6.3). DOE calculated the WEF scores for representative units at EL 4 and EL 5 using the flow and electrical input power at half speed and at maximum speed, as specified in the test procedure final rule and described in section 5.3.1.6.

Efficiency Levels 6 and 7. Efficiency levels 6 and 7 describe variable-speed pumps. Similar to previous ELs, DOE assumed that the baseline motor would be replaced with the EL 6 motor presented in Table 5.6.3. As described in the discussion of self-priming pool filter pumps, the high-speed test point for variable-speed pumps is at 80 percent of maximum flow rate on curve C, and the low-speed test point is at either 24.7 gpm flow or 31.1 gpm flow on curve C (depending on the pump capacity). However, the Pool Pump Performance Database does not contain performance data for any variable-speed non-self-priming pool filter pumps, and DOE is not aware of any non-self-priming pool filter pumps on the market that incorporate a variable-speed motor. To characterize EL 6 and EL 7, DOE estimated the performance of a hypothetical variable-speed non-self-priming pool filter pump. Based on examinations of power-flow curves for self-priming and non-self-priming pool filter pumps, DOE concluded that these two pump varieties experience similar degradation of motor and hydraulic efficiency as pump speed is reduced. DOE assumed that the wire-to-water efficiency of non-self-priming pumps at the high-speed load point is approximately the same as the wire-to-water efficiency at maximum speed. DOE estimated the performance of non-self-priming pumps at the high-speed load point using pump affinity laws. DOE estimated the wire-to-water efficiency of non-self-priming pumps at the low-speed load point by applying the same relationship of ERF and pump speed that was determined by regression of self-priming pool filter pump data. DOE applied the relationship specified in Equation 5.23 to the 0.52-hhp representative unit to estimate the pump's ERF and ultimately its wire-to-water efficiency at the low-speed load point.

For EL 7, DOE calculated the total efficiency and the input power at the low-speed load point by holding the low-speed and high-speed motor efficiencies constant at their EL 6 levels and substituting an improved hydraulic efficiency, up to the values specified in Table 5.6.4. Ultimately, DOE used the low-speed and high-speed performance data to calculate WEF for representative units at EL 6 and EL 7, as specified in the test procedure final rule and described in section 5.3.1.6.

Table 5.6.8 and Table 5.6.9 summarize the observations and calculations at the test procedure load points at each efficiency level for the non-self-priming pool filter pump representative units.

Table 5.6.8 Performance of Representative 0.09-hhp Non-Self-Priming Pool Filter Pump, by Efficiency Level

EL	High-Speed Load Point					Low-Speed Load Point					WEF
	Motor Eff. (%)	WtW Eff. (%)	Flow (gpm)	Head (feet H_2O)	Input Power (W)	Motor Eff. (%)	WtW Eff. (%)	Flow (gpm)	Head (feet H_2O)	Input Power (W)	
EL 0	55	13	35	10	537	n/a	n/a	n/a	n/a	n/a	3.93
EL 1	69	16	35	10	428	n/a	n/a	n/a	n/a	n/a	4.93
EL 2	72	16	35	10	410	n/a	n/a	n/a	n/a	n/a	5.14

Table 5.6.9 Performance of Representative 0.52-hhp Non-Self-Priming Pool Filter Pump, by Efficiency Level

EL	High-Speed Load Point					Low-Speed Load Point					WEF
	Motor Eff. (%)	WtW Eff. (%)	Flow (gpm)	Head (feet H_2O)	Input Power (W)	Motor Eff. (%)	WtW Eff. (%)	Flow (gpm)	Head (feet H_2O)	Input Power (W)	
EL 0	55	28	63	33	1,368	n/a	n/a	n/a	n/a	n/a	2.77
EL 1	69	36	63	33	1,091	n/a	n/a	n/a	n/a	n/a	3.47
EL 2	72	37	63	33	1,045	n/a	n/a	n/a	n/a	n/a	3.62
EL 3	61	31	63	33	1,234	38	16	32	8	306	4.62
EL 4	68	35	63	33	1,107	48	20	32	8	242	5.47
EL 5	72	37	63	33	1,045	51	21	32	8	228	5.80
EL 6	81	42	50	21	589	57	15	25	5	154	7.42
EL 7	81	54	50	21	366	57	24	25	5	96	11.96

5.6.4.3 Pressure Cleaner Booster Pumps

This subsection describes how DOE used the baseline and incremental performance data presented in sections 5.5 through 5.6.3 to determine the WEF value for one representative pressure cleaner booster pump (at 0.28 hhp at the load point of 10 gpm flow) from EL 1 through max tech. DOE is aware of fewer than 15 pressure cleaner booster pump models that are currently available on the market, and performance data for these pumps is not publicly available. Stakeholders submitted pump test data to DOE's contractor, and this data included motor efficiency and pump performance data for several different models of pressure cleaner booster pumps. These pump data enabled DOE to estimate pump performance at different load points and efficiency levels.

Baseline through Efficiency Level 2. To calculate the WEF of pressure cleaner booster pumps at EL 1 and EL 2 at the pressure cleaner booster pump load point of 10 gpm of flow, DOE used the same methods as those described for self-priming pool filter pumps at EL 1 and EL 2. That is, DOE held hydraulic efficiency constant at the baseline level and replaced the baseline maximum-speed motor efficiency with the EL 1 and EL 2 maximum-speed motor efficiencies (presented in Table 5.6.3). In doing so, DOE was able to calculate the wire-to-water efficiency, input power, and ultimately the WEF at the load point flow rate of 10 gpm.

Efficiency Level 3. Efficiency level three represents a variable-speed pump. As described in chapter 3 of this TSD, pressure cleaner booster pumps are tested at 100 percent speed or (for variable-speed pumps) at the lowest speed that can achieve 60 feet of head at the test procedure load point of 10 gpm.[j] DOE assumed that the representative unit's motor efficiency would improve from EL 2 to EL 3, as the shift from single-speed to variable-speed capability would likely be achieved by switching from induction motor technology to the more efficient ECM technology.[k] For EL 3, DOE held hydraulic efficiency constant and replaced the EL 2 motor efficiency with the EL 3 maximum speed motor efficiency (presented in Table 5.6.3). DOE used pump affinity laws[l] to calculate the electrical input power of the representative unit at 60 feet of head at 10 gpm flow.[m] In doing so, DOE was able to calculate the wire-to-water efficiency and ultimately WEF at the waterfall pump test point of 10 gpm flow.

Efficiency Level 4. Efficiency level four represents a variable-speed pressure cleaner booster pump with improved hydraulic design. DOE calculated the total efficiency and the input power for EL 4 by holding the motor efficiency constant at its EL 3 level and substituting an improved hydraulic efficiency at maximum speed on curve C, up to the value specified in Table 5.6.4.

Table 5.6.10 summarizes the observations and calculations at the test procedure load point at each efficiency level for the pressure cleaner booster pump representative unit.

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[j] The DPPP Working Group requested that DOE examine variable-speed pumps as a design option for pressure cleaner booster pumps. (Docket No. EERE-2015-BT-STD-0008-0095, March 22 DPPP Working Group Meeting, at pp. 197-203)

[k] As noted in chapter 3 of this TSD, ECMs are inherently more efficient than induction motors because their construction minimizes slip losses between the rotor and stator components.

[l] The pump affinity laws relevant to this calculation are stated in Eq. 1.10, Eq. 1.11, and Eq. 1.12.

[m] DOE calculated that, for the representative pressure cleaner booster pump, this operating point represents 73 percent of the pump's maximum speed. Based on examination of power-flow curves for many variable-speed self-priming pool filter pumps and variable-speed motor performance data, DOE concluded that this reduced-speed operation would incur negligible motor efficiency and hydraulic efficiency losses. Thus, DOE assumed that the representative pressure cleaner booster pump operating at 73 percent speed would exhibit the same motor efficiency and hydraulic efficiency as it would when operating at 100 percent speed.

Table 5.6.10 Performance of Representative 0.31-hhp Pressure Cleaner Booster Pump, by Efficiency Level

EL	High-Speed Load Point					WEF
	Motor Eff. (%)	WtW Eff. (%)	Flow (gpm)	Head (feet H_2O)	Input Power (W)	
EL 0	55	13	10	112	1,741	0.34
EL 1	67	16	10	112	1,429	0.42
EL 2	72	17	10	112	1,330	0.45
EL 3	81	20	10	112	1,182	0.51
EL 4	81	22	10	112	1,075	0.56

5.6.4.4 Waterfall Pumps

This subsection describes how DOE used the baseline and incremental performance data presented in sections 5.5 through 5.6.3 to determine the WEF value for one representative waterfall pump (at 0.40 hhp at the test point of 17 feet of head) from EL 1 through max tech. DOE is aware of fewer than 20 waterfall pump models that are currently available on the market, and performance data for these pumps is not publicly available. Stakeholders submitted pump test data to DOE, and this data included motor efficiency and pump performance data for several different models of waterfall pumps. These pump data enabled DOE to estimate pump performance at several efficiency levels.

Baseline through Efficiency Level 2. To calculate the WEF of waterfall pumps at EL 1 and EL 2 at the waterfall pump test point of 17 feet of head, DOE used the same methods as those described for self-priming pool filter pumps at EL 1 and EL 2. That is, DOE held hydraulic efficiency constant at the baseline level and replaced the baseline maximum-speed motor efficiency with the EL 1 and EL 2 maximum-speed motor efficiencies (presented in Table 5.6.3). In doing so, DOE was able to calculate the wire-to-water efficiency, input power, and ultimately the WEF at the test point pressure head of 17 feet of water.

Efficiency Level 3. Efficiency level three represents a single-speed pump with improved hydraulic design. DOE calculated the total efficiency and the input power for EL 3 by holding the motor efficiency constant at its EL 2 level and substituting an improved hydraulic efficiency at maximum speed on curve C, up to the values specified in Table 5.6.4.

Table 5.6.11 summarizes the observations and calculations at the test procedure load point at each efficiency level for the waterfall pump representative unit.

Table 5.6.11 Performance of Representative 0.40-hhp Waterfall Pump, by Efficiency Level

EL	High-Speed Load Point					WEF
	Motor Eff. (%)	WtW Eff. (%)	Flow (gpm)	Head (feet H_2O)	Input Power (W)	
EL 0	65	40	93	17	745	7.46
EL 1	70	43	93	17	698	7.95
EL 2	78	48	93	17	621	8.95
EL 3	78	53	93	17	564	9.85

5.6.4.5 Summary of Representative Unit Performance at Each Efficiency Level

Table 5.6.12 presents the performance in terms of WEF calculated for each of the representative units at each efficiency level.

Table 5.6.12 Performance of Representative Units at Each Efficiency Level

Efficiency Level	Representative Units						
	Self-Priming			Non-Self-Priming		Water-fall WEF	Pressure Cleaner WEF
	0.44 hhp WEF	0.95 hhp WEF	1.88 hhp WEF	0.09 hhp WEF	0.52 hhp WEF		
0 (Baseline)	2.69	2.13	1.74	3.93	2.77	7.46	0.34
1	3.37	2.67	2.03	4.93	3.47	7.95	0.42
2	3.72	2.98	2.16	5.14	3.62	8.95	0.45
3	4.68	3.98	3.45	n/a*	4.62	9.85	0.51
4	5.38	4.60	3.66	n/a*	5.47	n/a**	0.56
5	5.77	4.88	4.18	n/a*	5.80	n/a**	n/a**
6	8.78	6.89	5.21	n/a*	7.42	n/a**	n/a**
7 (Max Tech)	11.71	8.59	6.97	n/a*	11.96	n/a**	n/a**

* DOE evaluated 0.09-hhp non-self-priming pool pumps at single-speed efficiency levels only.
** The max tech efficiency level is EL 3 for waterfall pumps and EL 4 for pressure cleaner booster pumps.

5.6.5 Efficiency Level Structure for All Pump Capacities

The previous section summarizes the performance of the representative units at each efficiency level. However, the market for self-priming and non-self-priming pool filter pumps includes pumps at capacities other than these representative units. The self-priming and non-self-priming pool filter pump classes include pumps less than 2.5 hhp, and due to the properties of the WEF metric, the range of the maximum achievable WEF decreases as pump capacity increases. The attainable WEF score decreases as hydraulic power increases due to the relationship between the pump affinity laws and the WEF metric. The pump affinity laws (described in Equation 5.10, Equation 5.11, and Equation 5.12) state that when the flow rate of a pump increases, the pump hydraulic power increases at a rate cubically proportional to the flow rate increase. The WEF metric has flow rate in the numerator and input power (equivalent to hydraulic power divided by wire-to-water efficiency) in the denominator. All else being equal, as hydraulic power increases, the WEF efficiency metric must decrease. Typically, the achievable wire-to-water efficiency gets higher (more beneficial) as pump capacity increases. However, the cubic relationship between power and flow has a much larger impact on WEF than any increase in achievable wire-to-water efficiency. Figure 5.6.2 illustrates that for single-speed self-priming pool filter pumps in the Pool Pump Performance Database, the maximum achievable WEF score decreases as pump capacity increases.

To account for the relationship between WEF and capacity, DOE developed efficiency levels for self-priming and non-self-priming pool filter pump equipment classes using equations that specify WEF as a function of hydraulic power.

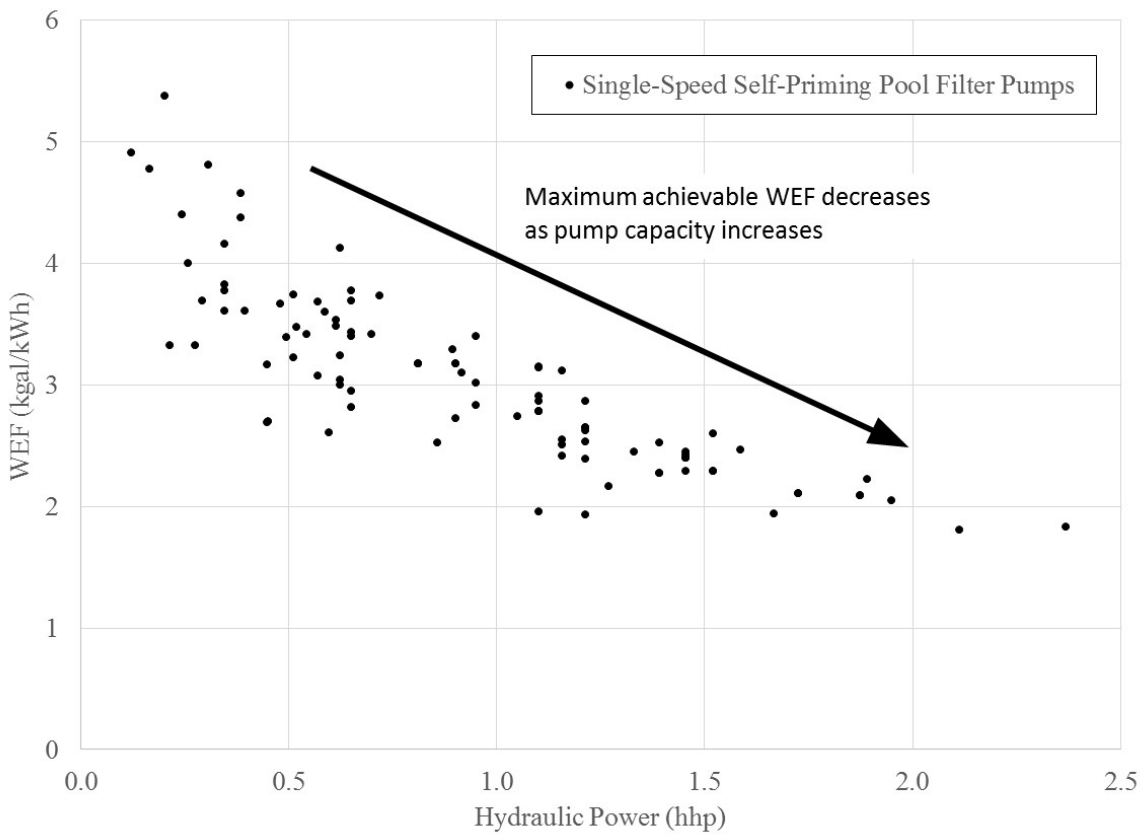

Figure 5.6.1 WEF Score Versus Pump Capacity for Single-Speed Self-Priming Pool Filter Pumps

For self-priming and non-self-priming pool filter pumps, DOE constructed mathematical functions that fit the performance of the representative units at each efficiency level. DOE observed that the natural logarithm function provides curves with the best fit (*i.e.*, the least error) when comparing the calculated curve values to the performance of representative units. DOE constructed scatterplots Figure 5.6.2 and Figure 5.6.3 to visualize the performance of the self-priming and non-self-priming pool filter pumps listed in the Pool Pump Performance Database, along with the representative unit performance at each efficiency level and the efficiency level curve equations.

DOE manually adjusted coefficients in the efficiency level curves to shape the curves to meet the needs of the DPPP Working Group. For instance, DOE adjusted the EL 6 curve for self-priming pool filter pumps so that all variable-speed self-priming pool filter pumps listed in the Pool Pump Performance Database would meet a standard set at EL 6. Ultimately, the DPPP Working Group evaluated the efficiency levels presented in this chapter as they negotiated energy conservation standard levels.

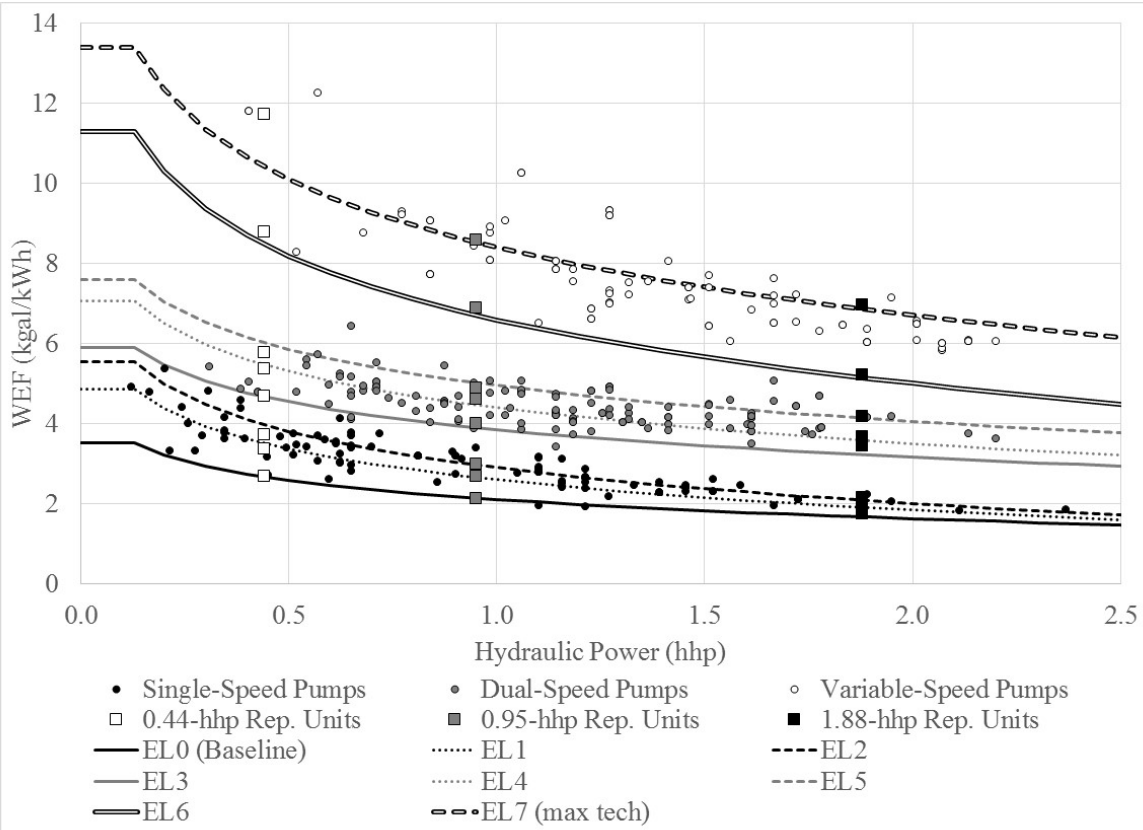

Figure 5.6.2 WEF versus Hydraulic Power for Self-Priming Pool Filter Pumps, Representative Units, and Efficiency Levels

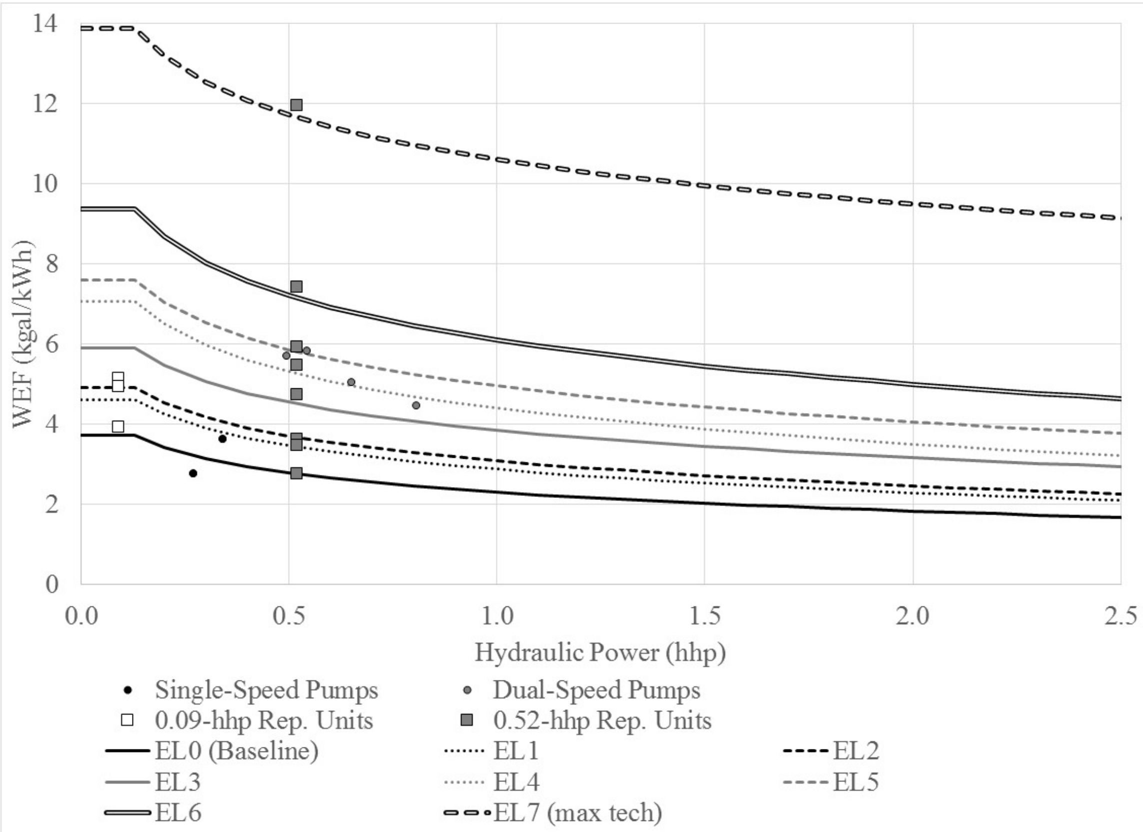

Figure 5.6.3 WEF versus Hydraulic Power for Non-Self-Priming Pool Filter Pumps, Representative Units, and Efficiency Levels

As evidenced in Figure 5.6.2 and Figure 5.6.3, the DPPP Working Group ultimately requested that each efficiency level curve become a flat line at 40 gpm (which is equivalent to 0.13 hhp on curve C) so that for each efficiency level curve, the WEF scores for all flow values below 40 gpm correspond to the WEF score for that efficiency level at 40 gpm. The DPPP Working Group made this request for both self-priming and non-self-priming pool filter pumps.

The pressure cleaner booster pumps on the market are clustered in a small range of capacities, with hydraulic power ranging from 0.26 hhp to 0.32 hhp at the test point of 10 gpm flow. Due to the limited range of available capacities, DOE did not use equations to describe the efficiency levels for pressure cleaner booster pumps. Instead, DOE selected fixed WEF values to represent the efficiency levels. The DPPP Working Group reviewed this method and recommended that DOE set a standard level for pressure cleaner booster pumps that is stated as a single value rather than as an equation.

For waterfall pumps, DOE performed the economic analyses on the waterfall pump representative units from baseline to max tech and presented the results to the DPPP Working Group. After reviewing the analyses, the DPPP Working Group determined that it was not economically justified to pursue standards for waterfall pumps. Consequently, DOE did not establish detailed potential standard levels for waterfall pumps beyond the aforementioned representative units.

Table 5.6.13 presents the equations used to calculate the WEF at each efficiency level as a function of hydraulic horsepower for self-priming and non-self-priming pool filter pumps. Table 5.6.14 presents the fixed WEF values at each efficiency level for pressure cleaner booster pumps.

Table 5.6.13 Efficiency Level WEF Equations for Self-Priming and Non-Self-Priming Pool Filter Pumps

Efficiency Level	**Equipment Class**			
	Self-Priming Pool Filter Pumps, Small and Standard Classes*		**Non-Self-Priming Pool Filter Pumps***	
	WEF**		**WEF****	
	⩽ 0.13 hhp	**> 0.13 hhp**	**⩽ 0.13 hhp**	**> 0.13 hhp**
0 (Baseline)	3.51	$-0.69 \times ln(\text{hhp}) + 2.10$	3.71	$-0.69 \times ln(\text{hhp}) + 2.30$
1	4.84	$-1.10 \times ln(\text{hhp}) + 2.60$	4.60	$-0.85 \times ln(\text{hhp}) + 2.87$
2	5.55	$-1.30 \times ln(\text{hhp}) + 2.90$	4.92	$-0.90 \times ln(\text{hhp}) + 3.08$
3	5.89	$-1.00 \times ln(\text{hhp}) + 3.85$	5.89	$-1.00 \times ln(\text{hhp}) + 3.85$
4	7.05	$-1.30 \times ln(\text{hhp}) + 4.40$	7.05	$-1.30 \times ln(\text{hhp}) + 4.40$
5	7.60	$-1.30 \times ln(\text{hhp}) + 4.95$	7.60	$-1.30 \times ln(\text{hhp}) + 4.95$
6	11.28	$-2.30 \times ln(\text{hhp}) + 6.59$	9.36	$-1.60 \times ln(\text{hhp}) + 6.10$
7 (Max Tech)	13.40	$-2.45 \times ln(\text{hhp}) + 8.40$	13.86	$-1.60 \times ln(\text{hhp}) + 10.60$

* As described in chapter 3 of this TSD, DOE did not consider efficiency levels above EL 2 for pool filter pumps that produce less than 49.4 gpm maximum flow on curve C.
** hhp represents the hydraulic power of the pump, measured at maximum speed on system curve C and reported in units of horsepower.

Table 5.6.14 Efficiency Level WEF Values for Pressure Cleaner Booster Pumps

Efficiency Level	**Equipment Class**
	Pressure Cleaner Booster Pumps, at 10 gpm flow
	WEF
0 (Baseline)	0.34
1	0.42
2	0.45
3	0.51
4	0.56

5.7 MANUFACTURER PRODUCTION COSTS

This section presents the MPCs for each equipment class at each efficiency level, and discusses the analytical methods used to develop these MPCs. Section 5.7.1 describes the principal drivers of manufacturing costs. Sections 5.7.2 and 5.7.3 focus on the motor costs and non-motor costs for pool filter pumps and pressure cleaner booster pumps. Section 5.7.4 focuses specifically on the costs of integral sand filter and integral cartridge filter pumps. Section 5.7.5 presents results in a series of cost-efficiency tables.

5.7.1 Principal Drivers of DPPP Manufacturing Costs

For most models of pool filter pumps and pressure cleaner booster pumps, the motor is the most expensive component of the pump. As discussed previously, for these equipment classes, all efficiency levels except max tech are defined by a motor substitution. In a motor substitution, the pump motor of a representative baseline (low efficiency, single-speed) unit is exchanged with a motor that will provide improved performance (*e.g.*, improved efficiency or ability to operate at reduced speed).

DOE researched the design and engineering constraints associated with motor substitution by examining manufacturer interview responses and holding discussions with the DPPP Working Group. DOE concluded that for the representative equipment capacities being considered, the wet end of the pump can be paired with a range of motors with various efficiencies and speed configurations without significant adaptations. In other words, a motor swap results in negligible incremental cost to the non-motor components of the dedicated-purpose pool pump. Thus, DOE concluded that the incremental MPC of the motor swap design options (improved motor efficiency and ability to operate at reduced speeds) may be considered equivalent to the incremental MPC of the motor component being swapped.

Consequently, for pool filter pumps and pressure cleaner booster pumps, DOE broke the equipment MPCs into two categories–motor costs and non-motor costs–and estimated the MPC of each separately. For integral cartridge and integral sand filter pool pumps, DOE did not break out the motor costs, because no motor design options were considered for these equipment classes.

5.7.2 Pool Filter Pump and Pressure Cleaner Booster Pump Motor Costs

DOE quantified motor MPCs at each efficiency level, for each representative unit. These MPCs represent the cost incurred by DPPP manufacturers to either purchase the motors from a supplier or assemble them in house. DOE estimated motor costs using two data sources: (1) estimates provided by manufacturers, and (2) publicly-available motor catalogs. The motor component costs presented in Table 5.7.1 represent aggregate cost estimates for the dedicated-purpose pool pump industry, and do not represent the costs incurred by any one pump manufacturer. The costs in Table 5.7.1 include all of the costs incurred to deliver finished motor components that are ready for assembly into a pump.[n] For variable-speed motors, the listed costs include the cost of controls (which include a variable-speed drive and a user interface), as variable-speed motors require this equipment to operate.

As discussed in chapter 3 of this TSD, variable-speed motors are not currently available in capacities smaller than 1.65 thp. The DPPP Working Group recommended that DOE consider

[n] For manufacturers that purchase third-party motors, these costs include shipping and delivery costs, as well as the overhead associated with ordering and inventory. For manufacturers that assemble motors in house, these costs include the components, labor, and depreciation associated with motor assembly.

only motors that that are currently available on the market. Specifically, the DPPP Working Group did not find it reasonable to assume that motor suppliers would develop smaller variable-speed motor that are not are already available on the market. Thus, DOE modeled a 1.65-thp variable-speed motor that would be the motor of choice for smaller representative units at efficiency levels that are defined by variable-speed motors. DOE determined that this motor size corresponds to the medium-sized representative unit for self-priming pool filter pumps since, on average, the variable-speed pool filter pumps rated at 1.65 thp in the Pool Pump Performance Database deliver about 0.95 hhp at maximum speed on curve C.

Table 5.7.1 MPC of DPPP Motor Components*

Motor Description	Representative Units by Hydraulic Horsepower, with Approximate Total Horsepower						
	Self-Priming Pool Filter Pump			Non-Self-Priming Pool Filter Pump		Pressure Cleaner Booster Pump	Waterfall Pump
	0.44 hhp (0.75 thp) $	0.95 hhp (1.65 thp) $	1.88 hhp (3.45 thp) $	0.09 hhp (0.22 thp) $	0.52 hhp (1.0 thp) $	0.31 hhp (1.25 thp) $	0.40 hhp (0.75 thp) $
1-speed low efficiency (Baseline)	55	66	142	24	46	53	58
1-speed, mid efficiency	68	85	177	30	50	63	69
1-speed, high efficiency	87	101	198	36	64	83	88
2-speed, low efficiency	90	102	226	n/a**	68	n/a††	n/a††
2-speed, mid efficiency	100	119	239	n/a**	82	n/a††	n/a††
2-speed, high efficiency	111	137	253	n/a**	96	n/a††	n/a††
Variable-speed	273	273	367	n/a†	273	273	n/a††

* The integral cartridge filter pool pump and integral sand filter pool pump equipment classes are not included in this table because DOE did not separately consider the motor costs for these equipment classes.
** As discussed in chapter 3 of this TSD, this analysis does not consider two-speed motor configurations for the 0.09-hhp non-self-priming pool filter pump representative unit. According to the test procedure final rule, this representative unit would always be subject to the single-speed test procedure because the half-speed flow rate for a 0.09-hhp pump would be 17.8 gpm, which is less than the test procedure minimum flow rate of 24.7 gpm.
† As discussed in chapter 3 of this TSD, this analysis does not consider variable-speed motor configurations for the 0.09-hhp non-self-priming pool filter pump representative unit.
†† Two-speed motors were not considered for waterfall pumps or pressure cleaner booster pumps, and variable-speed motors were not considered for waterfall pumps, because DOE assumes these pump varieties are always operated at a single-speed.

5.7.3 Pool Filter Pump and Pressure Cleaner Booster Pump Non-Motor Costs

The non-motor costs of manufacturing pool filter pumps and pressure cleaner booster pumps include the costs associated with manufacturing the wet end of the pump and the costs associated with assembling and packaging the pump. To determine the MPC of non-motor components, DOE developed a comprehensive spreadsheet model itemizing all parts and their associated costs. The spreadsheet model took inputs from virtual teardowns as well as data obtained through manufacturer interviews and independent research. For the virtual teardowns, DOE referenced catalogs of replacement pump parts and analyzed the materials and the manufacturing processes used to produce the various pump components. With this information, DOE calculated the amount a DPPP manufacturer would pay to produce each representative unit. The virtual teardown methodology is described in section 5.3.2.3.

Table 5.7.2 presents the non-motor MPCs associated with producing representative units in the pool filter pump and pressure cleaner booster pump equipment classes. DOE presented these costs to the DPPP Working Group and received no objections.

Table 5.7.2 Non-Motor MPC for Pool Filter Pump and Pressure Cleaner Booster Pump Classes*

	Representative Units						
	Self-Priming Pool Filter Pump			**Non-Self-Priming Pool Filter Pump**		**Pressure Cleaner Booster Pump**	**Water-fall Pump**
	0.44 hhp	**0.95 hhp**	**1.88 hhp**	**0.09 hhp**	**0.52 hhp**		
Non-Motor Costs	$47	$47	$50	$23	$24	$35	$42

*The integral cartridge filter pool pump and integral sand filter pool pump equipment classes are not included in this table because DOE did not separately consider the motor costs for these equipment classes.

DOE investigated the incremental MPC associated with manufacturing a pool filter pump with high hydraulic efficiency compared to a pool filter pump with low hydraulic efficiency. To do this, DOE identified several pairs of pool filter pumps wherein the two pumps in each pair have identical capacity and motor efficiency, but one pump has higher total efficiency than the other at maximum speed on curve C. DOE used a manufacturing cost model to individually model the MPCs of the higher-efficiency wet end and the lower-efficiency wet end. DOE determined that the MPC of producing a higher efficiency wet end is approximately equal to the MPC of producing a low efficiency wet end. Thus, DOE concluded that there is no incremental MPC associated with improving the hydraulic efficiency of a pool filter pump.[o] DOE presented this conclusion to the DPPP Working Group, which raised no objections.

5.7.4 Cost Analysis of Integral Filter Pool Pump Equipment Classes

DOE did not break out the motor component costs for integral filter pool pump equipment classes. DOE first estimated the MPC of the three representative units associated with these classes at the baseline efficiency level. DOE then estimated the incremental cost of the sole design option (pool pump timer) considered for these classes.

[o] DOE notes that manufacturers would still likely incur costs for component design, prototyping, tooling, and testing. These costs are not included in the per-unit MPC figures described in this section. Instead, these one-time conversion costs are discussed in the manufacturer impact analysis discussed in chapter 12 of the TSD.

5.7.4.1 Baseline MPCs of Integral Filter Pump Classes

DOE used several data sources to estimate the MPC of integral filter pumps at the baseline efficiency level:

- DOE received MPC estimates from manufacturers, including estimates of the MPC of integral filter pumps at the baseline level.
- DOE retrieved retail price data for integral filter pumps that are commercially available on the market. These retail prices represent the MPC of producing a unit plus the various markups and taxes that are applied along the distribution chain.[p] DOE aggregated retail price data for representative integral filter pump units and divided by a set of assumed markups to estimate the MPCs of representative units.
- DOE conducted a reverse-engineering teardown as a bottom-up approach to estimate the MPC of a representative unit. DOE purchased and disassembled an integral filter pump and created a manufacturing cost model to estimate the manufacturing costs associated with producing the pump at the same volumes as integral pump manufacturers.

DOE aggregated the cost data from these sources. Table 5.7.3 presents the estimated MPC for the three representative units of integral filter pool pumps.

Table 5.7.3 MPCs for Integral Filter Pump Equipment Classes

	Representative Equipment		
	Integral Sand Filter Pool Pump	**Integral Cartridge Filter Pool Pump**	
	0.03 hhp	**0.02 hhp**	**0.18 hhp**
Baseline MPC	$57	$17	$92

5.7.4.2 Incremental Cost of Pool Pump Timer Design Option

The only design option considered for the integral cartridge filter pool pump and integral sand filter pool pump equipment classes is the addition of a pool pump timer. The DPPP Working Group recommended a definition for pool pump timer. (Docket No. EERE-2015-BT-STD-0008, No. 82, Recommendation #4 at pp. 2) In agreement with this recommendation, the test procedure final rule defined a *pool pump timer* to mean a pool pump control that automatically turns off a dedicated-purpose pool pump after a run-time of no longer than 10 hours. The DPPP Working Group recommended that the prescriptive standard for including a timer with integral filter pumps should be fulfilled by a timer that is either integral to the pump or that is a separate component shipped with the pump. Based on manufacturer interviews, DOE concluded that the incremental cost of adding a pool pump timer would be approximately the same for all three representative units associated with the integral filter pump equipment classes.

DOE separately evaluated the costs of integrating a timer into an existing integral filter pump and the costs of including a timer with an existing pump. To estimate the cost of integrating a timer into an existing pump, DOE used MPC estimates provided by pump

[p] Markups are briefly discussed in section 1.9 of this notice and DOE's markup assumptions are presented in chapter 6 of the direct final rule TSD.

manufacturers. These data included manufacturer estimates of the incremental MPC of integrating a timer into existing integral pump products. To estimate the cost of including a timer with an existing pump, DOE conducted a retail price analysis of timers that are available off the shelf. DOE retrieved retail prices for off-the-shelf timers that would meet the criteria required for servicing an outdoor integral filter pump (*e.g.*, timer is waterproof, timer is electrically grounded, and is rated to an amperage greater than what the pump requires). DOE then discounted the retail price to estimate the price of timers purchased in bulk.

DOE aggregated the cost data from these sources, and DOE estimates that the industry average incremental cost of adding a pool pump timer to an integral filter pump is $6.67 per unit.

5.7.5 Cost-Efficiency Results

This subsection presents the cost-efficiency tables that result from the combination of motor and wet end costs at each efficiency level. Table 5.7.4 through Table 5.7.8 present results for each representative unit.

Table 5.7.4 MPCs for Self-Priming Pool Filter Pump Representative Units

Efficiency Level	Representative Unit Capacity on System Curve C		
	0.44 hhp	0.95 hhp	1.88 hhp
	MPC $	MPC $	MPC $
0 (Baseline)	102	113	192
1	115	132	227
2	134	148	248
3	137	149	276
4	147	166	290
5	158	184	303
6	320	320	417
7 (Max Tech)	320	320	417

Table 5.7.5 MPCs for Non-Self-Priming Pool Filter Pump Representative Units

Efficiency Level	Representative Unit Capacity on System Curve C	
	0.09 hhp	0.52 hhp
	MPC $	MPC $
0 (Baseline)	47	69
1	53	74
2	59	87
3	n/a*	91
4	n/a*	105
5	n/a*	119
6	n/a*	297
7 (Max Tech)	n/a*	297

* DOE did not analyze any efficiency levels above EL 2 for the 0.09-hhp non-self-priming pool filter pump representative unit, as discussed in chapter 3 of this TSD.

Table 5.7.6 MPCs for Pressure Cleaner Booster Pump Representative Units

Efficiency Level	Representative Unit Capacity 0.28 hhp at 10 gpm of flow MPC $
0 (Baseline)	88
1	99
2	118
3	308
4 (Max Tech)	308

Table 5.7.7 MPCs for Waterfall Pump Representative Units

Efficiency Level	Representative Unit Capacity 0.40 hhp at 17 feet of head MPC $
0 (Baseline)	100
1	110
2	130
3 (Max Tech)	130

Table 5.7.8 MPCs for Integral Filter Pump Representative Units

Efficiency Level	Representative Unit Capacity on System Curve C		
	Integral Sand Filter Pool Pump	Integral Cartridge Filter Pool Pump	
	0.03 hhp	0.02 hhp	0.18 hhp
	MPC $	MPC $	MPC $
0 (Baseline)	57	17	92
1 (With Timer)	64	23	99

5.8 OTHER ANALYTICAL OUTPUTS

The following subsections describe the additional analytical outputs that DOE generated in the engineering analysis.

5.8.1 MPC Cost Components

The manufacturer impact analysis (MIA) requires MPCs to be disaggregated into cost categories of material, labor, depreciation, and overhead costs. DOE estimated MPC breakdowns using the virtual teardown analysis and cost modeling described in section 5.3.2.3. DOE validated these MPC breakdowns during interviews with manufacturers. The MPC cost components are reported in the manufacturer impact analysis described in chapter 9 of this TSD.

5.8.2 Performance of Representative Units at Points Other than the Test Procedure Load Points

As discussed previously in section 5.3.1, the DOE test procedure specifies load points for the self-priming and non-self-priming pool filter pump, waterfall pump, and pressure cleaner booster pump equipment classes covered by this rule. For instance, the load points for self-priming and non-self-priming pool filter pumps are at specified pump speeds (and at specified flow rates, for variable-speed pumps) on system curve C, and the load point for pressure cleaner booster pumps is at 10 gpm of flow. In the field, the conditions in which these pumps operate will not exactly match the load points specified in the test procedure. For instance, some pool filter pumps may service pools with plumbing that approximates system curve A instead of system curve C, and some variable-speed pumps will be programmed to operate at speeds that are higher or lower than the test point speeds specified in the DOE test procedure. These variations in installation conditions are modeled in the energy use analysis, which is discussed in chapter 7 of this TSD. To facilitate the energy use analysis, DOE estimated the performance of the representative units across a variety of potential installation conditions. The following subsections present specific outputs of these estimations.

5.8.2.1 Performance at High-Speed and Low Speed on System Curves A and B

Section 5.6 describes how DOE estimated the performance of self-priming and non-self-priming representative units at the test procedure load points on system curve C. For self-priming and non-self-priming pool filter pumps, DOE also estimated the flow and EF of representative units operating on system curves A and B. DOE developed these estimates using the same methodology as described for the curve C. Specifically, for efficiency levels with single-speed motor configurations, DOE estimated the flow rate and EF on curves A and B at maximum speed, based on data reported in the Pool Pump Performance Database. For efficiency levels with two-speed motor configurations, DOE estimated flow and EF on curves A and B at maximum speed and at half speed, based on data reported for two-speed pumps in the Pool Pump Performance Database.

For efficiency levels with variable-speed motor configurations, DOE estimated flow and EF on curves A and B at 80 percent of maximum flow rate by assuming that wire-to-water efficiency remained constant between 100- and 80-percent speed and using pump affinity laws to estimate flow, head, and hydraulic horsepower performance. DOE estimated flow and EF on curves A and B at low-speed using regressions of ERF versus pump speed. These regressions were developed and applied using the method described in section 5.3.1.5.

Table 5.8.1 and Table 5.8.2 present the flow rate and EF on curves A, B, and C at the appropriate test procedure load points across all ELs for the different representative units. Table 5.8.1 presents self-priming pool filter pump data and Table 5.8.2 presents non-self-priming pool filter pump data.

Table 5.8.1 Self-Priming Pool Filter Pump Performance on Curves A, B, and C

Representative Unit Description	EL	Load Point	Curve A		Curve B		Curve C	
			Flow (gpm)	EF (Gal/Wh)	Flow (gpm)	EF (Gal/Wh)	Flow (gpm)	EF (Gal/Wh)
Self-priming pool filter pump, 0.44-hhp	EL 0	High	46	2.49	31	1.72	60	2.69
	EL 1	High	46	3.12	31	2.16	60	3.37
	EL 2	High	46	3.44	31	2.38	60	3.72
	EL 3	Low, High	26, 46	5.22, 2.90	17, 31	3.66, 2.00	30, 60	6.21, 3.13
	EL 4	Low, High	26, 46	6.32, 3.17	17, 31	4.43, 2.19	30, 60	7.52, 3.42
	EL 5	Low, High	26, 46	7.01, 3.30	17, 31	4.91, 2.28	30, 60	8.33, 3.57
	EL 6	Low, High	19, 37	10.3, 4.07	13, 25	6.47, 2.59	25, 48	13.6, 5.07
	EL 7	Low, High	19, 37	13.8, 5.43	13, 25	8.63, 3.45	25, 48	18.1, 6.76
Self-priming pool filter pump, 0.95-hhp	EL 0	High	63	1.72	39	1.20	77	2.13
	EL 1	High	63	2.16	39	1.51	77	2.67
	EL 2	High	63	2.41	39	1.68	77	2.98
	EL 3	Low, High	32, 63	4.85, 2.00	20, 39	3.55, 1.40	39, 77	5.72, 2.48
	EL 4	Low, High	32, 63	5.98, 2.22	20, 39	4.30, 1.55	39, 77	6.92, 2.75
	EL 5	Low, High	32, 63	6.51, 2.28	20, 39	4.76, 1.59	39, 77	7.68, 2.83
	EL 6	Low, High	25, 50	8.11, 3.10	16, 31	5.71, 2.13	31, 62	11.0, 3.94
	EL 7	Low, High	25, 50	10.1, 3.87	16, 31	7.12, 2.66	31, 62	13.7, 4.91
Self-priming pool filter pump, 1.88-hhp	EL 0	High	71	1.57	44	1.19	97	1.74
	EL 1	High	71	1.65	44	1.25	97	2.03
	EL 2	High	71	1.76	44	1.33	97	2.16
	EL 3	Low, High	36, 71	3.89, 1.55	21, 44	2.63, 1.17	48, 97	5.30, 1.90
	EL 4	Low, High	36, 71	4.68, 1.59	21, 44	3.12, 1.21	48, 97	6.51, 1.95
	EL 5	Low, High	36, 71	5.28, 1.95	21, 44	3.52, 1.38	48, 97	6.79, 2.36
	EL 6	Low, High	23, 57	8.69, 2.44	14, 34	5.85, 1.75	31, 77	10.5, 2.87
	EL 7	Low, High	23, 57	11.6, 3.27	14, 34	7.82, 2.33	31, 77	14.0, 3.84

Table 5.8.2 Non-Self-Priming Pool Filter Pump Performance on Curves A, B, and C

Representative Unit Description	EL	Load Point	Curve A		Curve B		Curve C	
			Flow (gpm)	EF (Gal/Wh)	Flow (gpm)	EF (Gal/Wh)	Flow (gpm)	EF (Gal/Wh)
Non-self-priming pool filter pump, 0.09-hhp	EL 0	High	33	3.37	23	2.39	35	3.93
	EL 1	High	33	4.23	23	3.00	35	4.93
	EL 2	High	33	4.41	23	3.13	35	5.14
Non-self-priming pool filter pump, 0.52-hhp	EL 0	High	50	2.38	31	1.77	63	2.77
	EL 1	High	50	2.99	31	2.22	63	3.47
	EL 2	High	50	3.12	31	2.32	63	3.62
	EL 3	Low, High	25, 50	5.00, 2.64	17, 31	3.51, 1.96	32, 63	6.18, 3.07
	EL 4	Low, High	25, 50	6.31, 2.95	17, 31	4.43, 2.19	32, 63	7.81, 3.42
	EL 5	Low, High	25, 50	6.70, 3.12	17, 31	4.71, 2.32	32, 63	8.30, 3.62
	EL 6	Low, High	19, 40	8.27, 4.43	12, 25	6.16, 3.29	25, 50	9.60, 5.14
	EL 7	Low, High	19, 40	13.3, 7.13	12, 25	9.92, 5.29	25, 50	15.5, 8.27

5.8.2.2 Performance of Variable-Speed Representative Units at Speeds near the Low-Speed Load Point on Curves A, B, and C

In the field, some variable-speed pumps will be programmed to operate at speeds that are higher or lower than the speed at the low-speed load point specified in the test procedure. To facilitate the modeling of various operation conditions, DOE developed equations to estimate EF as a function of flow for variable-speed representative units operating at reduced speeds near the low-speed test point. DOE developed these equations using the pump affinity laws and the regression of ERF versus pump speed described in section 5.3.1.5. Appendix 5A of this TSD details how these equations were developed.

The equations to estimate EF take the form shown in Equation 5.30, where the two equation constants, C_1 and C_2, determine the relationship between the flow rate and EF. DOE developed separate equation constants for each system curve (*i.e.*, A, B, and C), at each variable-speed efficiency level, for each representative pool filter pump unit. Table 5.8.3 presents the equation constants for the different representative units.

$$\mathrm{EF} = \frac{\mathrm{C}_1 \times \ln(Q) - C_2}{Q^2}$$

Equation 5.30

Where:

EF = energy factor, in gallons per watt-hour,
Q = flow rate, in gpm, and
C_1 and C_2 = equation constants.

Table 5.8.3 Equation Constants for Estimating Low-Speed Performance of Variable-Speed Self-Priming and Non-Self-Priming Pool Filter Pumps

Representative Unit Description*	EL	Curve A		Curve B		Curve C	
		C1	C2	C1	C2	C1	C2
Self-priming pool filter pump, 0.44-hhp	EL 6	3,279	4,313	995	999	5,974	10,963
	EL 7	3,883	6,282	1,162	1,510	7,918	14,423
Self-priming pool filter pump, 0.95-hhp	EL 6	4,304	7,016	1,243	1,535	7,766	16,188
	EL 7	5,189	10,028	1,418	2,169	9,603	19,956
Self-priming pool filter pump, 1.88-hhp	EL 6	4,512	7,889	1,279	1,733	8,762	20,288
	EL 7	5,603	11,497	1,512	2,496	11,713	27,005
Non-self-priming pool filter pump, 0.52-hhp	EL 6	4,614	6,450	1,385	1,392	8,364	15,757
	EL 7	5,965	10,119	1,783	2,317	10,834	20,337

* As discussed in chapter 3 of this TSD, this analysis does not consider variable-speed motor configurations for the 0.09-hhp non-self-priming pool filter pump representative unit.

5.8.2.3 Performance of Pressure Cleaner Booster Pump Representative Unit at Flow Rates near the Test Procedure Load Point

DOE developed equations to estimate the input power as a function of flow for the representative pressure cleaner booster pump unit operating near the test procedure load point of 10 gpm flow. DOE developed these equations by aggregating pump test data that manufacturers submitted to DOE and by applying the motor swapping methodology described in section 5.6.4.3. Table 5.8.4 presents the resulting equations, which estimate input power as a function of flow for the representative pressure cleaner booster pump at all efficiency levels.

Table 5.8.4 Performance Equations for the Representative Pressure Cleaner Booster Pump

Efficiency Level	Input Power, P_i, in Watts as a Function of Flow Rate, Q, in gpm
EL 0	$P_i = 27.3 \times Q + 1394.8$
EL 1	$P_i = 22.4 \times Q + 1145.0$
EL 2	$P_i = 20.8 \times Q + 1065.5$
EL 3	$P_i = 18.5 \times Q + 947.1$
EL 4	$P_i = 16.8 \times Q + 861.0$

5.8.2.4 Performance of Waterfall Pump Representative Unit at Flow Rates near the Test Procedure Load Point

DOE developed equations to estimate the input power as a function of flow for the representative waterfall pump unit operating near the test procedure load point of 17-feet of pressure head. DOE developed these equations by aggregating pump test data that manufacturers submitted to DOE and by applying the motor swapping methodology described in section 5.6.4.4. Table 5.8.5 presents the resulting equations, which estimate the input power as a function of flow for the representative waterfall pump at all efficiency levels.

Table 5.8.5 Performance Equations for the Representative Waterfall Pump

Efficiency Level	Input Power, P_i, in Watts as a Function of Flow Rate, Q, in gpm
EL 0	$P_i = 3.40 \times Q + 440$
EL 1	$P_i = 3.16 \times Q + 409$
EL 2	$P_i = 2.83 \times Q + 367$
EL 3	$P_i = 2.58 \times Q + 333$

5.9 MANUFACTURER SELLING PRICE

To account for manufacturers' non-production costs and profit margin, DOE applies a non-production cost multiplier (the manufacturer markup) to the MPC. The resulting MSP is the price at which the manufacturer distributes a unit into commerce.

DOE developed an average manufacturer markup by examining the annual Securities and Exchange Commission (SEC) 10-K reports filed by publicly traded manufacturers that are primarily engaged in pool pump manufacturing and whose combined product range includes pool pumps. DOE adjusted these estimates based on feedback received during confidential manufacturer interviews. DOE estimated a manufacturer markup of 1.46 for self-priming and waterfall pool pumps, 1.35 for non-self-priming and pressure cleaner booster pool pumps, and 1.27 for integral cartridge filter and integral sand filter pool pumps.

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APPENDIX 5A. VARIABLE-SPEED PUMP PERFORMANCE AT LOW SPEEDS

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APPENDIX 5A. VARIABLE-SPEED PUMP PERFORMANCE AT LOW SPEEDS

5A.1 INTRODUCTION

The engineering analysis in chapter 5 of this TSD defines the relationship between cost and efficiency for different varieties of dedicated-purpose pool pumps. In addition, the engineering analysis produced other analytical outputs that DOE uses in the downstream analyses, such as the energy use analysis discussed in chapter 7 of this TSD.

In the field, some variable-speed dedicated-purpose pool pumps are programmed to operate at speeds that are higher or lower than the speed needed to satisfy the low-speed load point specified in the test procedure. To facilitate modeling various operation conditions, DOE developed equations to estimate the energy factor (EF) as a function of flow (Q) for variable-speed representative units operating at speeds near the low-speed load point. This appendix describes how DOE derived these equations using the pump affinity laws and the regression of the efficiency reduction factor[1] (ERF).

5A.2 ESTIMATING VARIABLE-SPEED PUMP PERFORMANCE AT LOW SPEEDS

The pump affinity laws show that changes in pump rotational speed have a linear relationship to changes in flow rate; this is illustrated in Equation 5A.1. DOE arranged the pump affinity law to form Equation 5A.2, which expresses pump speed (*N*) in terms

[1] DOE defined the efficiency reduction factors as the relative decrease in wire-to-water efficiency as pump speed is reduced from 2,500 RPM to a lower speed. Chapter 5 of this TSD provides further details regarding the calculation of this term.

of the pump maximum speed (N_{max}), the flow rate at maximum speed (Q_{max}) and the flow rate (Q).

$$\frac{Q_1}{Q_2} = \frac{N_1}{N_2}$$

Equation 5A.1

Where:

N_1 and N_2 = pump rotational speed at two operating points,
Q_1 and Q_2 = flow rate at pump rotational speed one and two, and

$$N = \frac{Q \times N_{max}}{Q_{max}}$$

Equation 5A.2

Where:

N = pump rotational speed, in RPM,
N_{max} = the pump's maximum rotation speed, in RPM,
Q = flow rate, in gpm, and
Q_{max} = flow rate at the pump's maximum speed, in gpm.

Chapter 5 of this TSD describes how DOE developed a regression to estimate the wire-to-water efficiency of variable-speed pool filter pumps as a function of pump rotational speed. The result of this regression is an equation with regression constants (Equation 5A.3) that defines the ERF on curve C in terms of pump rotational speed.[2]

$$ERF_{curveC} = -0.513 \times \ ln(N) + 4.02$$

Equation 5A.3

DOE followed the same regression methodology to estimate the efficiency reduction factor for pumps operating on system curves A and B. Equation 5A.4 and Equation 5A.5 show the equations resulting from these regressions.

$$ERF_{curveA} = -0.538 \times \ ln(N) + 4.03$$

Equation 5A.4

$$ERF_{curveB} = -0.558 \ \times ln(N) + 4.19$$

Equation 5A.5

Where:

ERF = energy reduction factor at a speed less than 2,500 RPM on curve A, B, or C, as noted, unitless.

In Equation 5A.6, the ERF is applied to the wire-to-water efficiency at maximum speed ($\eta_{WtW.max}$) to estimate the wire-to-water efficiency at lower speeds (η_{WtW}).

[2] Equation 1C.3 shown here is identical to Equation 5.20 presented in chapter 5 of this TSD. The equation is repeated here to facilitate the description of the derivations presented in this appendix.

$$\eta_{WtW} = \eta_{\mathrm{WtW.max}} \times (1 - ERF)$$

Equation 5A.6

Where:

η_{WtW} = wire-to-water efficiency at reduced speed, in percent, and
$\eta_{WtW.max}$ = wire-to-water efficiency at maximum speed, in percent.

Equation 5A.7 through Equation 5A.9 illustrate how wire-to-water efficiency at low speeds may be estimated on curves A, B, and C as a function of flow and other known values by combining Equation 5A.2 and Equation 5A.6 with Equation 5A.3, Equation 5A.4, or Equation 5A.5. For the purposes of this analysis, these equations are valid only at speeds less than 2,500 RPM on curve A, B, or C.

$$\eta_{WtW,A} = \eta_{\mathrm{WtW.max,A}} \times \left(0.538 \times ln\left(\frac{Q \times N_{max,A}}{Q_{max,A}}\right) - 3.03\right)$$

Equation 5A.7

$$\eta_{WtW,B} = \eta_{\mathrm{WtW.max,B}} \times \left(0.558 \times ln\left(\frac{Q \times N_{max,B}}{Q_{max,B}}\right) - 3.19\right)$$

Equation 5A.8

$$\eta_{WtW,C} = \eta_{\mathrm{WtW.max,C}} \times \left(0.513 \times ln\left(\frac{Q \times N_{max,C}}{Q_{max,C}}\right) - 3.02\right)$$

Equation 5A.9

Where:

N_{max} = the pump's maximum rotation speed on curve A, B, or C, as noted, in RPM,
Q = flow rate, in gpm,
Q_{max} = flow rate at the pump's maximum speed on curve A, B, or C, as noted, in gpm.
η_{WtW} = wire-to-water efficiency on curve A, B, or C, as noted, in percent, and
$\eta_{WtW.max}$ = wire-to-water efficiency at maximum speed on curve A, B, or C, as noted, in percent.

Equation 5A.10 illustrates how pump hydraulic power, P_{hydro} is defined in terms of flow and head. The equations for system curves A, B, and C define the pump head in terms of flow, as shown in in Equation 5A.11 through Equation 5A.13.

$$P_{hydro} = \frac{Q \times H}{3956}$$

Equation 5A.10

Where:

P_{hydro} = hydraulic power in hp,
Q = flow rate in gpm, and
H = total dynamic head in feet of water.

$$H_{curveA} = 0.0167 \times (Q_{curveA})^2$$

Equation 5A.11

$$H_{curveB} = 0.050 \times (Q_{curveB})^2$$

Equation 5A.12

$$H_{curveC} = 0.0082 \times (Q_{curveC})^2$$

Equation 5A.13

Where:

H = total dynamic head on curve A, B, or C, as noted, in feet of water, and
Q = flow rate on curve A, B, or C, as noted, in gpm.

Hydraulic power on curves A, B, and C can be described in terms of flow by combining the hydraulic power definition (Equation 5A.10) with the system curve definitions (Equation 5A.11 through Equation 5A.13) and applying a conversion factor of 745.7 watts per horsepower. See Equation 5A.14 through Equation 5A.16.

$$P_{hydro,A} = 0.00315 \times (Q_{curveA})^3$$

Equation 5A.14

$$P_{hydro,B} = 0.00942 \times (Q_{curveB})^3$$

Equation 5A.15

$$P_{hydro,C} = 0.00155 \times (Q_{curveC})^3$$

Equation 5A.16

Where:
$P_{hydro,A}$ = pump hydraulic power on system curve A in watts,
$P_{hydro,B}$ = pump hydraulic power on system curve B in watts, and
$P_{hydro,C}$ = pump hydraulic power on system curve C in watts.

The input power, P_i, can be expressed in terms of the hydraulic power output and the wire-to-water efficiency, as in Equation 5A.17.

$$P_i = \frac{P_{hydro}}{\eta_{WtW}}$$

Equation 5A.17

Where:

P_i = input power, in watts.

The energy factor (EF) is defined in Equation 5A.18.

$$EF = \frac{Q \times 60}{P_i}$$

Equation 5A.18

Where:

EF = energy factor in gallons per watt-hour.

Equations for EF on curves A, B, and C are derived by combining the wire-to-water efficiency equations (Equation 5A.7 through Equation 5A.9) with the hydraulic power equations (Equation 5A.14 through Equation 5A.16) and the EF definition. See Equation 5A.19 through Equation 5A.21.

$$EF_A = \eta_{\mathrm{WtW.max,A}} \left(0.538 \times ln\left(\frac{Q_{curveA} \times N_{max,A}}{Q_{max,A}}\right) - 3.03\right)\left(\frac{Q_{curveA} \times 60}{0.00315 \times (Q_{curveA})^3}\right)$$

Equation 5A.19

$$EF_B = \eta_{\mathrm{WtW.max,B}} \left(0.558 \times ln\left(\frac{Q_{curveB} \times N_{max,B}}{Q_{max,B}}\right) - 3.19\right)\left(\frac{Q_{curveB} \times 60}{0.00942 \times (Q_{curveB})^3}\right)$$

Equation 5A.20

$$EF_C = \eta_{\mathrm{WtW.max,C}} \left(0.513 \times ln\left(\frac{Q_{curveC} \times N_{max,C}}{Q_{max,C}}\right) - 3.02\right)\left(\frac{Q_{curveC} \times 60}{0.00155 \times (Q_{curveC})^3}\right)$$

Equation 5A.21

Where:

EF = energy factor on curve A, B, or C, as noted, in gallons per watt-hour.

For simplicity, DOE reduced these equations to take the form shown in Equation 5A.22, where two equation constants, C_1 and C_2, define the relationship between the flow rate and EF. DOE developed separate equation constants for each system curve (*i.e.*, curves A, B, and C), at each variable-speed efficiency level, for each representative pool filter pump unit.

$$\mathrm{EF} = \frac{\mathrm{C}_1 \times \ln(Q) - C_2}{Q^2}$$

Equation 5A.22

Where:

C_1 and C_2 are equation constants.

The equation constants C_1 and C_2 depend upon the regression coefficients, the coefficients of the system curves (*i.e.*, curves A, B, and C), and the representative units' rotational speed, flow rate, and wire-to-water efficiency at maximum speed. For system curve A, constants C_1 and C_2 are calculated using Equation 5A.23 and Equation 5A.24:

$$\mathrm{C}_1 = 10254 \times \eta_{WtW.max}$$

Equation 5A.23

$$\mathrm{C}_2 = \eta_{WtW.max} \times \left[10254 \times \ln\left(\frac{N_{max}}{Q_{max}}\right) - 57752\right]$$

Equation 5A.24

For system curve B, constants C_1 and C_2 are calculated using Equation 5A.25 and Equation 5A.26:

$$\mathrm{C}_1 = 3552 \times \eta_{WtW.max}$$

Equation 5A.25

$$\mathrm{C}_2 = \eta_{WtW.max} \times \left[3552 \times \ln\left(\frac{N_{max}}{Q_{max}}\right) - 20308\right]$$

Equation 5A.26

For system curve C, constants C_1 and C_2 are calculated using Equation 5A.27 and Equation 5A.28:

$$\mathrm{C}_1 = 19913 \times \eta_{WtW.max}$$

Equation 5A.27

$$\mathrm{C}_2 = \eta_{WtW.max} \times \left[19913 \times \ln\left(\frac{N_{max}}{Q_{max}}\right) - 117229\right]$$

Equation 5A.28

DOE assumes a maximum speed, N_{max}, of 3,450 RPM for all pool filter pump representative units. The flow rate and the wire-to-water efficiency at maximum speed vary with the pump's efficiency level and capacity. Table 5A.1 reports these values as well as the equation constants C_1 and C_2 for the variable-speed representative units. These values for C_1 and C_2 are also reported in chapter 5 of this TSD.

Table 5A.1 Equation Constants for Estimating Low-Speed Performance of Variable-Speed Self-Priming and Non-Self-Priming Pool Filter Pumps*

EL	Curve A				Curve B				Curve C			
	Q_{max} gpm	$\eta_{WtW.max}$ %	C_1	C_2	Q_{max} gpm	$\eta_{WtW.max}$ %	C_1	C_2	Q_{max} gpm	$\eta_{WtW.max}$ %	C_1	C_2
Self-priming pool filter pump, 0.44-hhp												
6	46	32	3,279	4,313	31	28	995	999	60	30	5,974	10,963
7	46	39	3,883	6,282	31	33	1,162	1,510	60	40	7,918	14,423
Self-priming pool filter pump, 0.95-hhp												
6	63	42	4,304	7,016	39	35	1,243	1,535	77	39	7,766	16,188
7	63	52	5,189	10,028	39	41	1,418	2,169	77	48	9,603	19,956
Self-priming pool filter pump, 1.88-hhp												
6	71	44	4,512	7,889	44	36	1,279	1,733	97	44	8,762	20,288
7	71	56	5,603	11,497	44	43	1,512	2,496	97	59	11,713	27,005
Non-self-priming pool filter pump, 0.52-hhp												
6	50	45	4,614	6,450	31	39	1,385	1,392	63	42	8,364	15,757
7	50	59	5,965	10,119	31	51	1,783	2,317	63	54	10,834	20,337

* As discussed in chapter 3 of this TSD, this analysis does not consider variable-speed motor configurations for the 0.09-hhp non-self-priming pool filter pump representative unit.

CHAPTER 6. MARKUPS ANALYSIS

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CHAPTER 6. MARKUP ANALYSIS

6.1 INTRODUCTION

To carry out its analyses, the U.S. Department of Energy (DOE) determines the cost to the consumer of baseline products and the cost of more efficient units the consumer would purchase under new energy conservation standards. DOE calculates such costs based on engineering estimates of manufacturing costs plus appropriate markups for the various distribution channels for pool pumps.

DOE estimates a baseline markup and an incremental markup for each market participant besides manufacturers. DOE defines a baseline markup as a multiplier that converts the manufacturer selling price (MSP) of products with baseline efficiency to the consumer purchase price for the product at the same baseline efficiency level. An incremental markup is defined as the multiplier to convert the incremental increase in manufacturer selling price of higher efficiency products to the consumer purchase price for the same product. Because companies mark up the price at each point in the distribution channel, both baseline and incremental markups are dependent on the distribution channel, as described in section 6.2.

Generally, companies mark up the price of a product 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 takes account of the expenses of companies in the distribution channel, including overhead costs (sales, general, and administration); research and development (R&D) and interest expenses; depreciation; and taxes—and company profits. In order for sales of a product to contribute positively to company cash flow, the product's markup must be greater than the corporate gross margin. Products command lower or higher markups, depending on company expenses associated with the product and the degree of market competition.

6.2 DISTRIBUTION CHANNELS

The appropriate markups for determining consumer product prices depend on the type of distribution channels through which products move from manufacturers to consumers. The majority of pool pumps are purchased for residential use, but a small fraction of them are purchased to be installed in small to mid-size commercial buildings.[a] DOE estimated that 95 percent of pool pump shipments are for residential applications, and the rest go to commercial applications. According to manufacturer interviews, DOE assumes that pool pumps sold in residential and commercial application go through the same distribution channels.

DOE develops two primary markets describing the way most products pass from the manufacturer to the consumer. The first type of market applies to pool pump replacement with existing swimming pool, and the second type of market applies to new swimming pool

[a] Only the self-priming pool filter pumps with standard size 1.88 hhp, waterfall pumps and pressure cleaner booster pumps are considered in the commercial application.

construction. DOE estimates that 95 percent of total pool pump shipments are to pool pump replacement market and only five percent to new swimming pool construction market.

In the pool pump replacement market, the manufacturer generally sells the product to a wholesaler, who in turn sells it to either a pool service contractor or pool product retailer, who in turn sells it to the consumer. The pool pump wholesalers are the primary sales channel for pool pumps, with PoolCorp being the leading wholesale company in the market. Pool service contractors are responsible for installing and servicing pool pumps, and they generally purchase the products from pool pump wholesalers. In some cases, consumers purchase the pool pumps from a pool product retailer who often subcontract a pool service contractor or have a service branch with licensed pool service contractors to install the products for pool owners. The majority of pool product retailers are small and local, but there is one large national chain, Leslie’s Swimming Pool Supplies, making up a significant fraction of the pool product retail market. Based on the feedback received from manufacturer interviews, the pool service contractor channel and pool product retail channel make up to 79 percent and 21 percent of the pool pump replacement market, respectively. DOE welcomes information that could support improvement in characterizing the market structure of pool pumps.

In the new swimming pool construction market, DOE assumed that the entire pool pump shipment goes through a direct sale in which the manufacturer sells the product to the pool builder who then sells it to consumers. Figure 6.2.1 illustrates the three distribution channels for pool pumps.

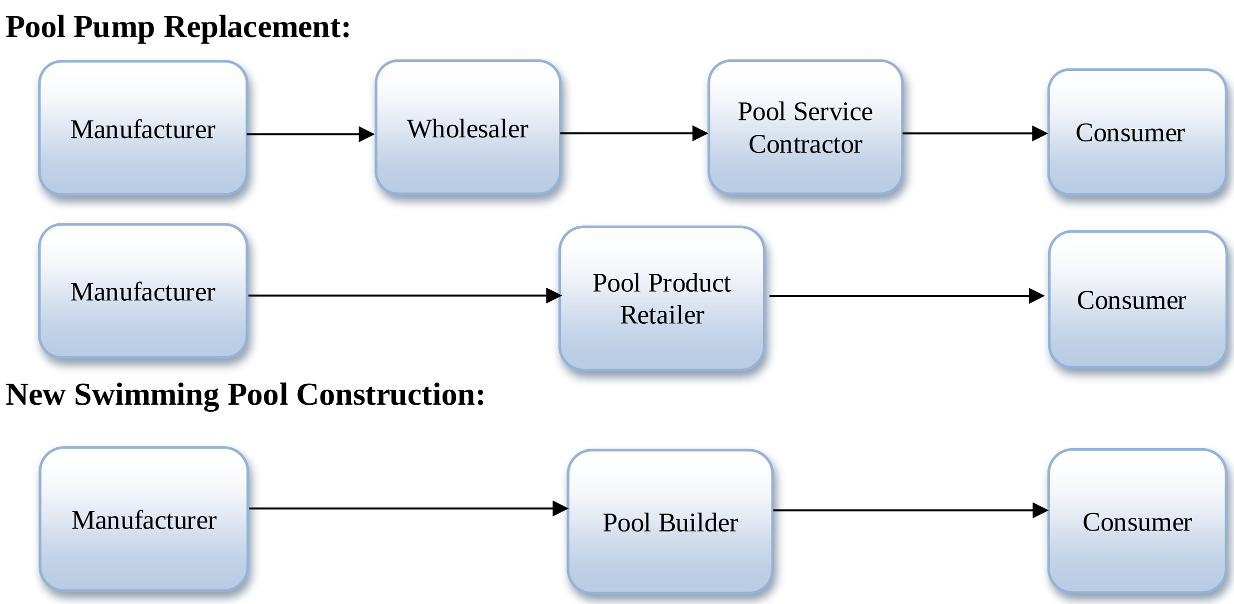

Figure 6.2.1 Distribution Channels for Pool Pumps

As discussed in the life-cycle cost analysis (see chapter 8), in some cases, only the motor component in the pool pump is replaced instead of the entire pool pump. DOE treated motor replacement as the repair of the pump. In this case, the replacement motor typically goes through different distribution channels than pool pumps. Based on motor manufacturers' and expert consultants' inputs, half of the motor replacement market is distributed via motor manufacturers, and the other half go through pool pump manufacturers. Within the motor manufacturer channel, DOE subdivided the shipment into two channels with equal fraction: (1) motor manufacturer sells the motor to wholesaler, who in turn sells it to contractor then to consumer, and (2) motor manufacturer sells the motor to wholesaler, who in turn sells it to retailer than to consumer via internet or direct sale at local store. Figure 6.2.2 illustrates the three distribution channels for motor replacement.

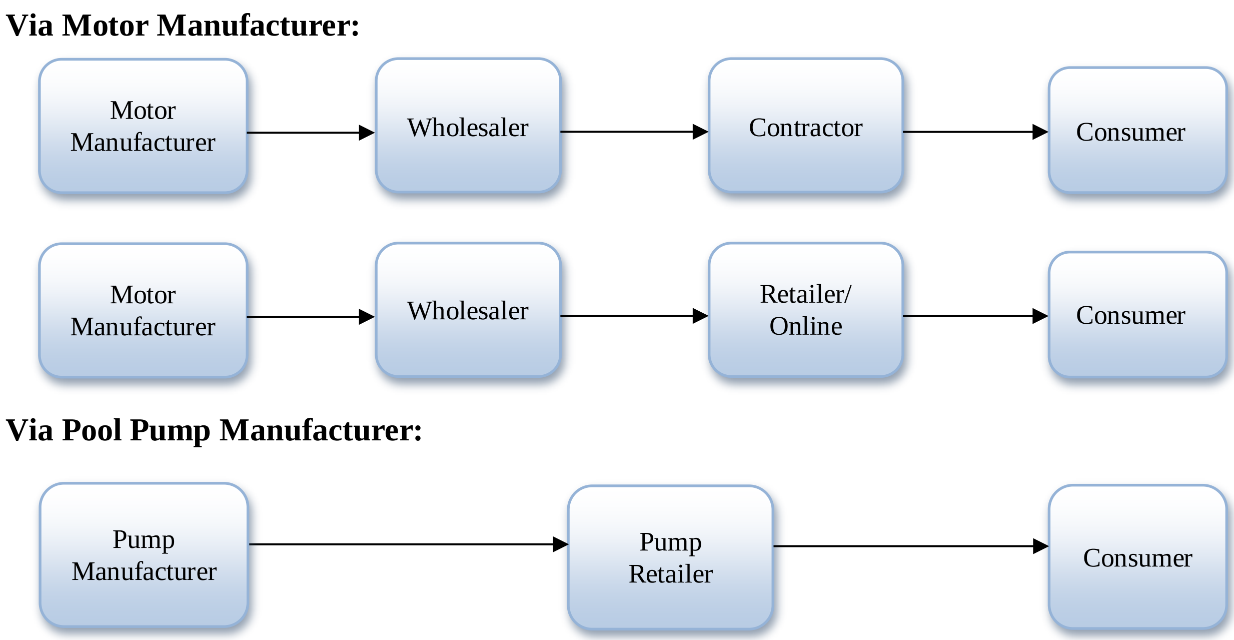

Figure 6.2.2 Distribution Channels for Motor Replacement

6.3 APPROACH FOR MANUFACTURER MARKUP

For pool pump sales, DOE uses manufacturer markups to transform a manufacturer's product cost into a manufacturer selling price for pool pumps. For motor replacement, DOE also uses manufacturer markups to transform a manufacturer's product cost into a manufacturer selling price for motors. The methodology to derive both types of manufacturer markups was described in the engineering analysis (chapter 5).

6.4 APPROACH FOR WHOLESALER, CONTRACTOR, RETAILER AND BUILDER MARKUPS

A change in energy efficiency standards usually increases the manufacturer selling price that wholesalers pay, and in turn the wholesale price that contractor, retailer or pool builder would pay. In the past, DOE used the same markups as for baseline products to estimate the product price of more efficient product. Applying a fixed markup on higher manufacturer selling price would imply an increase in the dollar margin earned by wholesalers and contractors, and an increase in per-unit profit.

Based on microeconomic theory, the degree to which firms can pass along a cost increase depends on the level of market competition, as well as the market structure on both supply and demand side (e.g., supply and demand elasticity). DOE examined industry data from IBISWorld and the results suggest that most of the industries relevant to heating equipment wholesalers and contractors are generally quite competitive (see appendix 6B).[1,2] Under relatively competitive markets, it may be tenable for pool pump wholesalers, contractors, retailer and builder to maintain a fixed markup for a short period of time after the input price increases, but the market competition should eventually force them to readjust their markups to reach a medium-term equilibrium of which per-unit profit is relatively unchanged before and after standards are implemented.

Thus, DOE concluded that applying fixed markups for both baseline products and higher-priced products meeting a standard is not viable in the medium to long term considering the competitive nature of the pool pump wholesale and contractor industry. DOE developed the incremental markup approach based on the widely accepted economic view that firms are not able to sustain a persistently higher dollar margin in a competitive market in the medium term. If the price of the product increases under standards, the only way to maintain the same dollar margin as before is for the markup (and percent gross margin) to decline.

To estimate the markup under standards, DOE derived an incremental markup that is applied to the incremental equipment costs of higher efficiency products. The overall markup on the products meeting standards is an average of the markup on the component of the cost that is equal to the baseline product and the markup on the incremental cost, weighted by the share of each in the total cost of the standards-compliant product.

DOE's incremental markup approach allows the part of the cost that is thought to be affected by the standard to scale with the change in manufacturer price. The income statements DOE used to develop wholesaler and contractor markups 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 pool pump wholesalers and contractors tend to handle multiple commodity lines, DOE contends that these aggregated data provide the most accurate indication of the expenses associated with pool pumps and the cost structure of distribution channel participants.

DOE uses these income statements to divide firm costs between those that are not likely to scale with the manufacturer price of equipment (labor and occupancy expenses, or "invariant" costs) and those that are (operating expenses and profit, or "variant" costs). For example, when the manufacturer selling price of equipment increases, only a fraction of a wholesaler's expenses increase (operating expenses and profit), while the remainder can be expected to stay relatively constant (labor and occupancy expenses). If the unit price of a pool pump increases by 20 percent under standards, it is unlikely that the cost of secretarial support in an administrative office or office rental expenses will increase proportionally.

See Appendix 6B for further evidence supporting the use of incremental markups in this analysis. The derivation of incremental markups for wholesalers, contractors, retailers and pool builders is described in the following sections.

6.4.1 Wholesaler Markups

6.4.1.1 Wholesaler Markups for Pool Pumps

According to the market assessment analysis and inputs from manufacturers, PoolCorp comprises around half of the pool wholesale market and has a modest degree of market power. Hence, DOE assumes that the markup used by PoolCorp is representative of the markup for pool wholesale industry. PoolCorp is a publicly owned company, so it is required by law to disclose financial information on a regular basis by the U.S. Securities and Exchange Commission (SEC)[3]. The annual 10-K report provides a comprehensive overview of the company's business and financial conditions. Relevant information required for calculating the markups includes the company's revenues and direct and indirect costs which are all available in the income statement section of the 10-K reports. Using the above assumptions, DOE applies the following two equations to calculate baseline and incremental markups with the financial data available from 10-K reports:

$$MU_{BASE} = \frac{Net\ Sales}{Cost\ of\ Sales}$$

Eq. 6.1

Incremental markups are coefficients that relate the change in the MSP of more energy-efficient models, or those products that meet the requirements of new energy conservation standards, to the change in the wholesaler sales price. DOE assumes that expenses like labor and occupancy costs remain fixed and need not be covered in the incremental markup. Profit and other operating costs were assumed to be variant and to scale with MSP. The SEC 10-K reports did not typically separate labor and occupancy costs from overall expenses, so DOE assumes that these fixed costs are encompassed by "selling, distribution and administrative expenses." DOE also assumes that "operating profit" (operating income) covers other operating costs and profit (*i.e.* variant cost). Each company's incremental markup was calculated as:

$$MU_{INCR} = 1 + \frac{Operating\ Profit}{Cost\ of\ Sales}$$

6.4.1.1 Wholesaler Markups for Motors

DOE based the wholesaler markups for replaced motors on financial data for "household appliances and electrical and electronic goods merchant wholesaler" sector from the 2012 U.S. Census *Annual Wholesale Trade Report* (AWTR)[4], which is the most recent survey that includes industry-wide detailed operating expenses for that economic sector. DOE organized the financial data into statements that break down cost components incurred by firms in the sector.

The baseline markup converts the manufacturer selling price of baseline products to the wholesaler sales price. DOE considers baseline models to be products sold under current market conditions (*i.e.*, without new energy conservation standards). DOE used the following equation to calculate an average baseline markup (MU_{BASE}) for retailers.

$$MU_{WHOLE\_BASE} = \frac{CGS_{WHOLE} + GM_{WHOLE}}{CGS_{WHOLE}}$$

Where:

MU_{WHOLE_BASE} = motor wholesaler's baseline markup,
CGS_{WHOLE} = motor wholesaler's CGS, and
GM_{WHOLE} = motor wholesaler's GM.

To estimate incremental retailer markups, as described previously, DOE divides wholesalers' operating expenses into two categories: (1) those that do not change when CGS increases because of amended efficiency standards ("invariant"), and (2) those that increase proportionately with CGS ("variant"). DOE defines invariant costs as including labor and occupancy expenses, because those costs likely will not increase as a result of a rise in CGS. All other expenses, as well as net profit, are assumed to vary in proportion to CGS. Although it is possible that some other expenses may not scale with CGS, DOE takes a conservative position that includes other expenses as variant costs. (Note: under DOE's approach, a high fixed cost component yields a low incremental markup.)

DOE used the following equation to calculate the incremental markup (MU_{INCR}) for wholesalers for motors.

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

Where:

MU_{WHOLE_INCR} = motor wholesaler's incremental markup,
CGS_{WHOLE} = motor wholesaler's cost of goods sold, and
VC_{WHOLE} = motor wholesaler's variant costs.

6.4.2 Contractor Markups

6.4.2.1 Pool Service Contractor Markup

DOE develops baseline and incremental markups for pool service contractor using the industry-level income statement for *Plumbing, Heating and Air-Conditioning Contractors* (NAICS 23822) sector from the 2012 U.S. Economic Census[5], which is the most disaggregated sector that includes pool contracting business. The baseline markups cover all of the pool contractor's costs (both *invariant costs* and *variant costs*). DOE calculates the baseline markup for pool service contractors using the following equation:

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

Eq. 6.2

Where:

MU_{CONT_BASE} = baseline pool service contractor markup,
CGS_{CONT} = pool service contractor's cost of goods sold,
GM_{CONT} = pool service contractor's gross margin,
IVC_{CONT} = pool service contractor's invariant costs, and
VC_{CONT} = pool service contractor's variant costs.

Analogously to wholesalers, DOE estimated the incremental pool service contractor markups by only marking up those costs that scale with a change in the MSP (variant costs, *VC*) for more energy-efficient products. As above, DOE assumed 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 Census data into each major cost category and estimated incremental markups using the following equation:

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

Eq. 6.3

Where:

MU_{CONT_INCR} = incremental pool service contractor markup,
CGS_{CONT} = pool service contractor's cost of goods sold, and
VC_{CONT} = pool service contractor's variant costs.

6.4.2.2 Motor Contractor Markup

DOE used information from RSMeans *Electrical Cost Data*[6] to estimate markups used by contractors in the installation of equipment with replacement motors. RSMeans *Electrical Cost*

Data estimates material expense markups for electrical contractors as 10 percent, leading to a markup factor of 1.10.

6.4.3 Retailer Markups

6.4.3.1 Pool Product Retailer Markup

According to the 2014 U.S. Residential Swimming Pool Market Report prepared by P.K. Data, Inc.[7], approximately 40 percent of the pool product retail market was dominated by four major home improvement centers, including Home Depot, Lowe's, Wal-Mart and Costco, and internet sales. Other smaller retailers comprise the rest of the of the pool product retail market.

Since those top four home improvement centers are publicly owned companies, they are required by law to disclose financial information on a regular basis by the U.S. Securities and Exchange Commission (SEC). Analogous to the methodology used in estimating the pool pump wholesaler markups, DOE estimated the baseline and incremental markups for each of the four home improvement centers mentioned above.

DOE estimated the retail markup through internet sales using the average markups of the four home improvement centers mentioned previously. In addition, DOE calculated the overall markups for aggregated pool product retail sector based on industry-level financial data for the *Miscellaneous Store Retailers* (NAICS 453) sector from the U.S. Census Bureau's 2012 Annual Retail Trade Survey (ARTS)[8], which is the most recent survey available with detailed operating expenses for this particular sector. DOE organizes the financial data into statements that break down cost components incurred by firms in this category. Although pool product retailers handle multiple commodity lines, the data provide the most accurate available indication of expenses for selling pool pumps.

The 2012 ARTS data contain total sales, gross margin and detailed operating expenses. DOE calculates the baseline markup (MU_{RET_BASE}) for pool retailers as an average markup using the following equation:

$$MU_{RET\_BASE} = \frac{CGS_{RET} + GM_{RET}}{CGS_{RET}}$$

Eq. 6.4

Where:

MU_{RET_BASE} = baseline pool product retailer markup,
CGS_{RET} = pool product retailer's cost of goods sold, and
GM_{RET} = pool product retailer's gross margin.

Incremental markups cover only those costs that scale with a change in CGS (variant costs, *VC*). DOE calculates the incremental markup (MU_{RET_INCR}) for pool retailers using the following equation:

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

Eq. 6.5

Where:

MU_{RET_INCR} = incremental pool product retailer markup,
CGS_{RET} = pool product retailer's cost of goods sold, and
VC_{RET} = pool product retailer's variant costs.

6.4.3.2 Motor Retailer Markup

As the majority of motor replacement for pool pumps is taken place in pool product retailers, DOE used the same methodology and Census data in estimating pool product retailer markups to estimate motor retailer markups.

6.4.4 Pool Builder Markup

The type of financial data used to estimate pool service contractor markups is also available for pool builders from the 2012 Economic Census. To estimate pool builder markups for pool pumps, DOE collects financial data from the *All Other Specialty Trade Contractors* (NAICS 23899)[10] sector from 2012 U.S. Economic Census, which is the most disaggregated series that includes outdoor swimming pool construction.

6.5 DERIVATION OF MARKUPS

6.5.1 Manufacturer Markup

DOE used U.S. Security and Exchange Commission (SEC) 10-K reports from publicly owned pool pump manufacturing companies to estimate manufacturer markups for pool pumps. Table 6.5.1 presents manufacturer markups for the product class considered in this direct final rule.

Table 6.5.1 Manufacturer Markups of Pool Pumps

Product Class	Markup
Self-Priming Pool Filter Pumps	1.46
Non-Self-Priming Pool Filter Pumps	1.35
Waterfall Pumps	1.46
Pressure Cleaner Booster Pumps	1.35
Integral Cartridge-Filter Pool Pumps	1.27
Integral Sand-Filter Pool Pumps	1.27

DOE also used U.S. Security and Exchange Commission (SEC) 10-K reports to estimate manufacturer markup for motors. The data result in a motor manufacturer markup of 1.48.

6.5.2 Wholesaler Markups

6.5.2.1 Wholesaler Markups for Pool Pumps

The annual SEC form 10-K report provides a comprehensive overview of the company's business and financial conditions. Relevant information required for calculating the markups includes the company's revenues and direct and indirect costs which are all available in the income statement section of the 10-K reports. The average baseline and incremental markups from 10-K report for PoolCorp in the past five years were summarized in Table 6.5.2. DOE assumes that the average markups for PoolCorp are representative of the wholesaler markups of pool pumps as PoolCorp accounts for a significant fraction of the wholesale market.

Table 6.5.2 Wholesaler Expenses and Markups

Company	Financial Figures $1,000	Year				
		2011	2012	2013	2014	2015
PoolCorp	Net Sales	1,793,318	1,953,974	2,079,700	2,246,562	2,363,139
	Cost of Sales	1,261,728	1,386,567	1,488,426	1,603,222	1,687,495
	Operating Profit	125,067	144,869	165,486	188,870	216,222
	Baseline MU	1.42	1.41	1.40	1.40	1.41
	Incremental MU	1.10	1.10	1.11	1.12	1.13
	Average (Baseline/Incremental)	**1.41/1.11**				

Source: U.S. Securities and Exchange Commission, 10-K reports 2011 to 2015, http://www.sec.gov/edgar/searchedgar/companysearch.html

6.5.2.2 Wholesaler Markups for Motors

The 2012 AWTR data for Household Appliances and Electrical and Electronic Goods Merchant Wholesalers provide total sales data and detailed operating expenses. To construct a complete data set for estimating markups, DOE needs to estimate CGS and GM. DOE took the percent GM value provided by U.S. Census 2012 Economic Census and combined with 2012 AWTR detail cost data to construct a complete income statement for motor wholesalers to estimate both baseline and incremental markups. Table 6.5.3 shows the calculation of the baseline retailer markup. (Appendix 6A contains the full set of data.)

Table 6.5.3 Markup Estimation for Motor Wholesalers

Descriptions	Per Dollar Sales Revenue *$*	Per Dollar Cost of Goods *$*
Direct Cost of Product Sales: Cost of goods sold	0.757	1.00
Labor and Occupancy Expenses	0.100	0.13
Other Operating Expenses: Depreciation, advertising, and insurance.	0.045	0.06
Operating Profit	0.098	0.13
Motor Wholesaler Baseline Markup (MU_{WHOLE_BASE})		1.32
Motor Wholesaler Incremental Markup (MU_{WHOLE_INCR})		1.19

Source: U.S. Census Bureau 2012 Annual Wholesale Trade Report (NAICS 4236 Household Appliance and Electrical and Electronic Goods Merchant Wholesalers) https://www.census.gov/wholesale/index.html

The first data column in Table 6.5.3 provides the cost of goods sold and a list of gross margin components as expenses per dollar of sales revenue. As shown in the table, the direct cost of sales represents about $0.76 per dollar sales revenue to the motor wholesaler, and the gross margin totals $0.24 per dollar sales revenue. DOE converts these expenses per dollar sales into revenue per dollar cost of goods sold by dividing each figure in the first data column by $0.76. For every $1.00 the motor wholesaler spends on product costs, the motor wholesaler earns $1.00 in sales revenue to cover the product cost and $0.32 to cover the other costs. This totals $1.32 in sales revenue earned for every $1.00 spent on product costs. This is equivalent to a baseline markup (MU_{WHOLE_BASE}) of 1.32 for pool contractors.

DOE is also able to use the data in column two in Table 6.5.3 to estimate the incremental markups, after classifying the costs as either invariant or variant. At one extreme, if all of the other costs scale with the product price (*i.e.*, all costs are variant), the increase in motor wholesaler price will be $1.32, implying that the incremental markup is 1.32 or the same as the baseline markup. At the other extreme, if none of the other costs are variant, then a $1.00 increase in the product price will lead to a $1.00 increase in the pool contractor price, for an incremental markup of 1.0. DOE believes the labor and occupancy costs are invariant and the other operating costs and profit scale with the product price (*i.e.*, are variant). In this case, for a $1.00 increase in the product price, the pool contractor price will increase by $1.19, giving a general contractor incremental markup (MU_{WHOLE_INCR}) of 1.19.

6.5.3 Contractor Markups

6.5.3.1 Pool Service Contractor Markups

The 2012 Economic Census provides Geographic Area Series for the *Plumbing, Heating and Air-Conditioning Contractors* (NAICS 23822) sector, which contains national average sales and cost data, including value of construction, cost of subcontract work, cost of materials, and payroll for construction workers. It also provides the cost breakdown of gross margin, including labor expenses, occupancy expenses, other operating expenses, and profit. The gross margin provided by the U.S. Census is disaggregated enough that DOE is able to determine the invariant (labor and occupancy expenses) and variant (other operating expenses and profits) costs for this particular sector. By using the equation mentioned in section 6.4.2.1, baseline and incremental markups were estimated. The markup results representing the plumbing, heating and air-conditioning contractor industry at the national aggregated level are presented in Table 6.5.4. (Appendix 6A contains the full set of data.)

Table 6.5.4 Pool Contractor Expenses and Markups Based on Census Bureau Data

Description	Pool Contractor Expenses or Revenue	
	Per Dollar Sales Revenue *$*	Per Dollar Cost of Goods *$*
Direct Cost of Product Sales: Cost of goods sold	0.66	1.00
Labor Expenses: Salaries (indirect) and benefits	0.18	0.26
Occupancy Expense: Rent, maintenance, and utilities	0.03	0.04
Other Operating Expenses: Depreciation, advertising, and insurance.	0.09	0.14
Net Profit Before Taxes	0.04	0.07
Pool Contractor Baseline Markup ($MU_{CONT\ BASE}$)		**1.51**
Pool Contractor Incremental Markup (MU_{CONT_INCR})		**1.20**

Source: U.S. Census Bureau. 2012. Plumbing, Heating, and Air-Conditioning Contractors. Sector 23: 238220. Construction: Industry Series: Preliminary Detailed Statistics for Establishments: 2012.

The first data column in Table 6.5.4 provides the cost of goods sold and a list of gross margin components as expenses per dollar of sales revenue. As shown in the table, the direct cost of sales represents about $0.66 per dollar sales revenue to the pool contractor, and the gross margin totals $0.34 per dollar sales revenue. DOE converts these expenses per dollar sales into revenue per dollar cost of goods sold by dividing each figure in the first data column by $0.66. For every $1.00 the pool contractor spends on product costs, the pool contractor earns $1.00 in sales revenue to cover the product cost and $0.51 to cover the other costs. This totals $1.51 in sales revenue earned for every $1.00 spent on product costs. This is equivalent to a baseline markup (MU_{CONT_BASE}) of 1.51 for pool contractors.

DOE is also able to use the data in column two in Table 6.5.4 to estimate the incremental markups, after classifying the costs as either invariant or variant. At one extreme, if all of the other costs scale with the product price (*i.e.*, all costs are variant), the increase in pool contractor price will be $1.51, implying that the incremental markup is 1.51 or the same as the baseline markup. At the other extreme, if none of the other costs are variant, then a $1.00 increase in the product price will lead to a $1.00 increase in the pool contractor price, for an incremental markup of 1.0. DOE believes the labor and occupancy costs are invariant and the other operating costs and profit scale with the product price (*i.e.*, are variant). In this case, for a $1.00 increase in the product price, the pool contractor price will increase by $1.20, giving a general contractor incremental markup (MU_{CONT_INCR}) of 1.20.

6.5.3.2 Motor Contractor Markup

As described in section 6.4.2.2, DOE estimated the motor contractor markup to be 1.10 based on information from RSMeans *Electrical Cost Data*.

6.5.4 Retailer Markups

6.5.4.1 Pool Product Retailer Markups

The annual SEC form 10-K report provides a comprehensive overview of the company's business and financial conditions. Relevant information required for calculating the markups includes the company's revenues and direct and indirect costs which are all available in the income statement section of the 10-K reports. The average baseline and incremental markups from 10-K report for the four major home improvement centers were summarized in Table 6.5.5.

Table 6.5.5 Markup Estimation for Four Home Improvement Centers

Company	Financial Figures $1,000	Year				
		2011	2012	2013	2014	2015
The Home Depot, Inc.	**Net Sales**	70,395,000	74,754,000	78,812,000	83,176,000	88,519,000
	Cost of Sales	46,133,000	48,912,000	51,422,000	54,222,000	58,254,000
	Operating Profit	6,661,000	7,766,000	9,166,000	10,469,000	11,774,000
	Baseline MU	1.53	1.53	1.53	1.53	1.53
	Incremental MU	1.14	1.16	1.18	1.19	1.20
	Average (Baseline/Incremental)	**1.53/1.18**				
Lowe's Companies, Inc.	**Net Sales**	50,208,000	50,521,000	53,417,000	56,223,000	59,074,000
	Cost of Sales	32,858,000	33,194,000	34,941,000	36,665,000	38,504,000
	Operating Profit	2,906,000	3,137,000	3,673,000	4,276,000	4,419,000
	Baseline MU	1.53	1.52	1.53	1.53	1.53
	Incremental MU	1.09	1.09	1.11	1.12	1.11
	Average (Baseline/Incremental)	**1.53/1.10**				
Wal-Mart Stores, Inc.	**Net Sales**	446,950,000	469,162,000	476,294,000	485,651,000	482,130,000
	Cost of Sales	335,127,000	352,488,000	358,069,000	365,086,000	363,526,020
	Operating Profit	26,558,000	27,801,000	26,872,000	27,147,000	24,105,000
	Baseline MU	1.33	1.33	1.33	1.33	1.33
	Incremental MU	1.08	1.08	1.08	1.07	1.07
	Average (Baseline/Incremental)	**1.33/1.07**				
Costco Wholesale Corp.	**Net Sales**	88,915,000	99,137,000	105,156,000	112,640,000	116,199,000
	Cost of Sales	77,739,000	86,823,000	91,948,000	98,458,000	101,105,000
	Operating Profit	2,439,000	2,759,000	3,053,000	3,220,000	3,624,000
	Baseline MU	1.14	1.14	1.14	1.14	1.15
	Incremental MU	1.03	1.03	1.03	1.03	1.04
	Average (Baseline/Incremental)	**1.14/1.03**				

Source: U.S. Securities and Exchange Commission, 10-K reports 2011 to 2015, http://www.sec.gov/edgar/searchedgar/companysearch.html

The 2012 ARTS data for Miscellaneous Store Retailers provide total sales data and detailed operating expenses. To construct a complete data set for estimating markups for rest of pool product retailers, DOE needs to estimate CGS and GM. The most recent 2013 ARTS publish a separate document containing historical sales and gross margin for miscellaneous store retailers. DOE took the GM value for 2012 and combined with 2012 ARTS detail cost data to construct a complete income statement for miscellaneous store retailers to estimate both baseline and incremental markups. Table 6.5.6 shows the calculation of the baseline retailer markup. (Appendix 6A contains the full set of data.)

Table 6.5.6 Markup Estimation for Miscellaneous Store Retailers

Descriptions	**Per Dollar Sales Revenue** ***$***	**Per Dollar Cost of Goods** ***$***
Direct Cost of Product Sales: Cost of goods sold	0.546	1.00
Labor Expenses: Salaries and benefits	0.166	0.30
Occupancy Expense: Rent, maintenance, and utilities	0.083	0.15
Other Operating Expenses: Depreciation, advertising, and insurance.	0.095	0.17
Operating Profit	0.110	0.20
Pool Retailer Baseline Markup (MU_{RET_BASE})		1.83
Pool Retailer Incremental Markup (MU_{RET_INCR})		1.38

Source: U.S. Census Bureau 2012 Annual Retail Trade Survey (NAICS 453 Miscellaneous Store Retailers) www.census.gov/retail/index.html#arts

In this case, direct product expenses (cost of goods sold) represent about $0.546 per dollar sales revenue, so for every $1 miscellaneous store retailers take in as sales revenue, $0.546 is used to pay the direct product prices. Labor expenses represent $0.166 per dollar sales revenue, occupancy expenses represent $0.083, other operating expenses represent $0.095, and profit accounts for $0.110 per dollar sales revenue.

DOE converts the expenses per dollar sales into expenses per dollar cost of goods sold, by dividing each figure in the first data column by $0.546 (*i.e.*, cost of goods sold per dollar of sales revenue). The data in column two show that, for every $1.00 the miscellaneous store retailer spends on product prices, miscellaneous store retailer allocates $0.30 to cover labor costs, $0.15 to cover occupancy expenses, $0.17 for other operating expenses, and $0.20 in profits. This totals to $1.83 in sales revenue earned for every $1.00 spent on product prices. Therefore, the miscellaneous store retailer baseline markup (MU_{RET_BASE}) is 1.83 ($1.83 ÷ $1 .00).

DOE also uses the data in column two to estimate the incremental markup. The incremental markup depends on which of the costs in Table 6.5.4 are variant and which are invariant with product prices. For example, for a $1.00 increase in the product prices, if all of the other costs scale with the product prices (*i.e.,* all costs are variant), the increase in retail price will be $1.83, implying that the incremental markup is 1.83, or the same as the baseline markup. At the other extreme, if none of the other costs are variant, then a $1.00 increase in the product prices will lead to a $1.00 increase in the retail price, for an incremental markup of 1.0. DOE believes that the labor and occupancy costs will be invariant and that the other operating costs and profit will scale with the product prices (*i.e.*, be variant). In this case, for a $1.00 increase in the product prices, the retail price will increase to match changes in "other" operating costs and operating profit of $0.205, which when divided by 54.6 cents in cost of goods sold yields an increase of $0.38, giving a miscellaneous store retailer incremental markup (MU_{RET_INCR}) of 1.38.

DOE then calculated the weighted average markups by combining these markups with their corresponding markup share, as shown in Table 6.5.7.

Table 6.5.7 Markup Summary for Pool Product Retailer

Retailer	Market Share	Baseline MU	Incremental MU
Home Depot		1.53	1.18
Lowe's	3%	1.53	1.10
Wal-Mart	15%	1.33	1.07
Costco	4%	1.14	1.03
Internet Sales	19%	1.41	1.10
Others	60%	1.83	1.38
Weighting Average Markups		1.64	1.26

6.5.4.2 Motor Retailer Markups

DOE assumed that most consumers would purchase replacement motor for pool pumps in pool product retailers; hence, DOE used the same markup values developed from the 2012 ARTS data for Miscellaneous Store Retailers for pool product retailers as a proxy for motor retailer markups. The baseline motor retailer markup is 1.83 and the incremental motor retailer markup is 1.38.

6.5.5 Pool Builder Markups

DOE derives the baseline and incremental markups for pool builders using the 2012 Economic Census industrial cost data for the *All Other Specialty Trade Contractors* (NAICS 23899) sector, which includes businesses associated with outdoor swimming pool construction. Even though this aggregated industrial series also consists of many other contracting businesses, this series is the most disaggregated sector that includes work related to building swimming pool. By using the equation mentioned above, baseline and incremental markups were estimated, the results are summarized in Table 6.5.8. (Appendix 6A contains the full set of data.)

Table 6.5.8 Pool Builder Expenses and Markups

Description	General Contractor Expenses or Revenue	
	Per Dollar Sales Revenue *$*	Per Dollar Cost of Goods *$*
Direct Cost of Product Sales: Cost of goods sold	0.66	1.00
Labor Expenses: Salaries (indirect) and benefits	0.13	0.20
Occupancy Expense: Rent, maintenance, and utilities	0.04	0.06
Other Operating Expenses: Depreciation, advertising, and insurance.	0.14	0.21
Net Profit Before Taxes	0.03	0.05
Pool Builder Baseline Markup		**1.53**
Pool Builder Incremental Markup		**1.26**

Source: U.S. Census Bureau. 2012. All Other Specialty Trade Contractors. Sector 23: 238990. Construction: Industry Series: Preliminary Detailed Statistics for Establishments: 2012

As shown in the first column, the direct cost of sales represents about $0.66 per dollar sales revenue to the pool builders. Labor expenses represent $0.13 per dollar sales revenue, occupancy expenses represent $0.04 per dollar sales revenue, other operating expenses represent $0.14, and profit makes up $0.03 per dollar sales revenue.

DOE converts these expenses per dollar sales into revenue per dollar cost of goods sold, by dividing each figure in the first data column by $0.66. The data in column two show that, for every $1.00 the pool builder spends on product costs, the pool builder earns $1.00 in sales revenue to cover the product cost, $0.20 to cover labor costs, $0.06 to cover occupancy expenses, $0.21 for other operating expenses, and $0.05 in profits. This totals to $1.53 in sales revenue earned for every $1.00 spent on product costs. Thus, the pool builder baseline markup is 1.53.

DOE is also able to use the data in column two in Table 6.5.5 to estimate the incremental markups, after classifying the costs as either invariant or variant. At one extreme, if all of the other costs scale with the product price (*i.e.*, all costs are variant), the increase in pool builder price will be $1.53, implying that the incremental markup is 1.53, or the same as the baseline markup. At the other extreme, if none of the other costs are variant, then a $1.00 increase in the product price will lead to a $1.00 increase in the pool builder price, for an incremental markup of 1.0. DOE believes the labor and occupancy costs are invariant and the other operating costs and profit scale with the product price (*i.e.*, are variant). In this case, for a $1.00 increase in the product price, the pool builder price will increase by $1.26, giving a pool builder incremental markup of 1.26.

6.6 DERIVATION OF CENSUS REGIONS MARKUPS

The ownership of pool pumps has very distinct regional pattern in which places with warmer climate have higher penetration rate, like Florida. To reflect this regional difference, regional markups were calculated for pool service contractors and pool builders because their markups are expected to be impacted the most depending where the owners reside. Pool service contractor and pool builder markups were divided into the 30 regions[b] provided by the latest 2009 Residential Energy Consumption Survey (RECS) [11] for residential applications and were divided into the nine regions provided by the latest 2012 Commercial Building Energy Consumption Survey (CBECS)[12] for commercial applications.

6.6.1 Estimation of Regional Pool Service Contractor Markups

The 2012 Economic Census provides Geographic Area Series for the *Plumbing, Heating and Air-Conditioning Contractors* (NAICS 23822) sector, which contains state-level sale and detailed cost data allowing DOE to estimate both baseline and incremental markups for pool service contractors. (Appendix 6A contains the full set of data.) DOE divides all states among the 30 RECS regions and then calculates average baseline and incremental markups in residential applications, as shown in Table 6.6.1.

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[b] RECS 2009 provides 27 regions (also called reportable domains). The 27th region includes Oregon, Washington, Alaska, and Hawaii. DOE subdivides Alaska and Hawaii into separate regions (28 and 29, respectively) based on cooling and heating degree days. In addition, West Virginia, which is in RECS 2009 region 14, was disaggregated into region 30 based on cooling and heating degree days.

Table 6.6.1 Regional Pool Service Contractor Markups in Residential Application

RECS Regions	State(s)	Baseline MU	Incremental MU
1	Connecticut, Maine, New Hampshire, Rhode Island, Vermont	1.506	1.222
2	Massachusetts	1.496	1.168
3	New York	1.577	1.268
4	New Jersey	1.586	1.260
5	Pennsylvania	1.490	1.169
6	Illinois	1.547	1.175
7	Indiana, Ohio	1.530	1.214
8	Michigan	1.598	1.262
9	Wisconsin	1.460	1.133
10	Iowa, Minnesota, North Dakota, South Dakota	1.417	1.149
11	Kansas, Nebraska	1.415	1.150
12	Missouri	1.421	1.129
13	Virginia	1.536	1.253
14	Delaware, District of Columbia, Maryland	1.482	1.140
15	Georgia	1.497	1.216
16	North Carolina, South Carolina	1.494	1.222
17	Florida	1.513	1.216
18	Alabama, Kentucky, Mississippi	1.423	1.164
19	Tennessee	1.464	1.181
20	Arkansas, Louisiana, Oklahoma	1.509	1.247
21	Texas	1.474	1.196
22	Colorado	1.489	1.212
23	Idaho, Montana, Utah, Wyoming	1.446	1.188
24	Arizona	1.440	1.142
25	Nevada, New Mexico	1.476	1.180
26	California	1.572	1.261
27	Oregon, Washington	1.468	1.137
28	Alaska	1.454	1.183
29	Hawaii	1.639	1.327
30	West Virginia	1.543	1.248

DOE also divides all states among the nine CBECS regions and then calculates average baseline and incremental markups in commercial applications, as shown in Table 6.6.2.

Table 6.6.2 Regional Pool Service Contractor Markups in Commercial Application

CBECS Regions	Census Divisions	Baseline MU	Incremental MU
1	New England	1.501	1.197
2	Middle Atlantic	1.552	1.236
3	East North Central	1.540	1.203
4	West North Central	1.418	1.144
5	South Atlantic	1.506	1.214
6	East South Central	1.438	1.170
7	West South Central	1.484	1.211
8	Mountain	1.461	1.179
9	Pacific	1.550	1.235

6.6.2 Estimation of Regional Pool Builder Markups

To derive regional pool builder markups for pool pumps in the new swimming pool construction market, DOE uses the Geographic Area Series for *All Other Specialty Trade Contractors* (NAICS 23899) from the 2012 Economic Census. This series consist of statewide sales and cost data required to calculate baseline markups for each state. However, a few cost categories were not disclosed for some states due to confidentiality agreement; therefore, the estimation of their incremental markups became unattainable. For states with insufficient cost data, DOE uses the average incremental markup of their neighboring states as the proxy. Lastly, DOE divides all states among the 30 RECS regions and then calculated average baseline and incremental markups for pool builders in residential application for each region. The final results are summarized in Table 6.6.3. To derive regional pool builder markups in commercial application, DOE also divides all states among the nine CBECS regions and then calculated average baseline and incremental markups, as shown in Table 6.6.4. (Appendix 6A contains the full set of data.)

Table 6.6.3 Regional Pool Builder Markups in Residential Application

RECS Regions	State(s)	Baseline MU	Incremental MU
1	Connecticut, Maine, New Hampshire, Rhode Island, Vermont	1.387	1.169
2	Massachusetts	1.493	1.179
3	New York	1.616	1.321
4	New Jersey	1.588	1.331
5	Pennsylvania	1.548	1.244
6	Illinois	1.651	1.326
7	Indiana, Ohio	1.481	1.198
8	Michigan	1.562	1.312
9	Wisconsin	1.502	1.252
10	Iowa, Minnesota, North Dakota, South Dakota	1.527	1.332
11	Kansas, Nebraska	1.519	1.265
12	Missouri	1.385	1.170
13	Virginia	1.423	1.175
14	Delaware, District of Columbia, Maryland	1.408	1.147
15	Georgia	1.392	1.197
16	North Carolina, South Carolina	1.445	1.196
17	Florida	1.501	1.254
18	Alabama, Kentucky, Mississippi	1.480	1.326
19	Tennessee	1.606	1.395
20	Arkansas, Louisiana, Oklahoma	1.707	1.386
21	Texas	1.483	1.246
22	Colorado	1.648	1.370
23	Idaho, Montana, Utah, Wyoming	1.585	1.337
24	Arizona	1.410	1.144
25	Nevada, New Mexico	1.453	1.167
26	California	1.546	1.275
27	Oregon, Washington	1.512	1.211
28	Alaska	1.840	1.488
29	Hawaii	1.583	1.156
30	West Virginia	1.772	1.206

Table 6.6.4 Regional Pool Builder Markups in Commercial Application

CBECS Regions	Census Divisions	Baseline MU	Incremental MU
1	New England	1.436	1.173
2	Middle Atlantic	1.589	1.300
3	East North Central	1.548	1.264
4	West North Central	1.485	1.270
5	South Atlantic	1.456	1.206
6	East South Central	1.524	1.350
7	West South Central	1.549	1.287
8	Mountain	1.522	1.253
9	Pacific	1.544	1.261

6.7 SALES TAX

The sales tax represents state and local sales taxes that are applied to the consumer price of the product. The sales tax is a multiplicative factor that increases the consumer product price. DOE only applies the sales tax to the consumer price of the product in the replacement market, not the new construction market. The common practice for selling larger residential appliances like pool pumps in the new swimming pool construction market is that pool builders would bear the added sales tax for the product, in addition to the cost of the product, and then mark up the entire cost in the final listing price to consumers. Therefore, no additional sales tax is added to the consumer product price for the new swimming pool construction market.

DOE derived state and local taxes from data provided by the Sales Tax Clearinghouse.[13] These data represent weighted averages that include county and city rates. DOE then derived average tax values for each 2009 RECS and 2012 CBECS region to match the regional markups used in both residential and commercial application, as shown in Table 6.7.1 and Table 6.7.2. Detailed sales tax data by each state can be found in appendix 6A.

Table 6.7.1 Average Sales Tax Rates by 2009 RECS Region

2009 RECS Regions	State(s)	Fraction of Population %	Tax Rate (2016) %
1	Connecticut, Maine, New Hampshire, Rhode Island, Vermont	2.5%	5.13%
2	Massachusetts	2.0%	6.25%
3	New York	5.8%	8.45%
4	New Jersey	2.8%	6.95%
5	Pennsylvania	3.8%	6.35%
6	Illinois	3.9%	8.45%
7	Indiana, Ohio	5.4%	7.10%
8	Michigan	3.2%	6.00%
9	Wisconsin	1.8%	5.40%
10	Iowa, Minnesota, North Dakota, South Dakota	3.1%	6.95%
11	Kansas, Nebraska	1.4%	7.44%
12	Missouri	1.8%	7.50%
13	Virginia	2.7%	4.00%
14	Delaware, District of Columbia, Maryland	2.4%	5.26%
15	Georgia	3.2%	7.05%
16	North Carolina, South Carolina	4.6%	6.99%
17	Florida	7.0%	6.65%
18	Alabama, Kentucky, Mississippi	3.6%	7.29%
19	Tennessee	2.0%	9.45%
20	Arkansas, Louisiana, Oklahoma	3.4%	9.17%
21	Texas	8.5%	7.95%
22	Colorado	1.6%	6.15%
23	Idaho, Montana, Utah, Wyoming	1.9%	5.33%
24	Arizona	2.5%	7.25%
25	Nevada, New Mexico	1.6%	7.57%
26	California	12.6%	8.45%
27	Oregon, Washington	3.5%	5.69%
28	Alaska	0.2%	1.30%
29	Hawaii	0.4%	4.35%
30	West Virginia	0.5%	6.20%
National Average			7.16%

Table 6.7.2 Average Sales Tax Rates by 2012 CBECS Region

CBECS 2012 Region	Census Divisions	Fraction of Population %	Tax Rate (2016) %
1	New England	4.6%	5.63%
2	Middle Atlantic	12.5%	7.47%
3	East North Central	14.4%	7.01%
4	West North Central	6.3%	7.22%
5	South Atlantic	20.4%	6.27%
6	East South Central	5.7%	8.06%
7	West South Central	12.0%	8.30%
8	Mountain	7.6%	6.62%
9	Pacific	16.7%	7.67%
National Average			7.16%

6.8 OVERALL MARKUPS

DOE uses the overall baseline markup to estimate the consumer product price of baseline models, given the manufacturer cost of the baseline models. As stated previously, DOE considers baseline models to be products sold under existing market conditions (*i.e.*, without new energy conservation standards). The following equation shows how DOE uses the overall baseline markup to determine the product price for baseline models.

$$CPP_{BASE} = COST_{MFG} \times (MU_{MFG} \times MU_{BASE} \times Tax_{SALES}) = COST_{MFG} \times MU_{OVERALL\_BASE}$$

Eq. 6.6

Where:

CPP_{BASE} = consumer product price for baseline models,
$COST_{MFG}$ = manufacturer cost for baseline models,
MU_{MFG} = manufacturer markup,
MU_{BASE} = baseline replacement or new pool channel markup,
Tax_{SALES} = sales tax (pool pump replacement applications only), and
$MU_{OVERALL\_BASE}$ = baseline overall markup.

Similarly, DOE uses 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 product 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 uses the overall incremental markup to determine the consumer product price for more energy-efficient models (*i.e.*, models meeting new energy conservation standards).

$$CPP_{STD} = COST_{MFG} \times MU_{OVERALL\_BASE} + \Delta COST_{MFG} \times (MU_{MFG} \times MU_{INCR} \times Tax_{SALES})$$
$$= CPP_{BASE} + \Delta COST_{MFG} \times MU_{OVERALL\_INCR}$$

Eq. 6.7

Where:

CPP_{STD} = consumer product price for models meeting new energy conservation standards,
CPP_{BASE} = consumer product price for baseline models,
$COST_{MFG}$ = manufacturer cost for baseline models,
$\Delta COST_{MFG}$ = change in manufacturer cost for more energy-efficient models,
MU_{MFG} = manufacturer markup,
MU_{INCR} = incremental replacement or new pool channel markup,
Tax_{SALES} = sales tax (pool pump replacement applications only),
$MU_{OVERALL\_BASE}$ = baseline overall markup (product of manufacturer markup, baseline replacement or new swimming pool construction channel markup, and sales tax), and
$MU_{OVERALL\_INCR}$ = incremental overall markup.

Table 6.8.1 and Table 6.8.2 summarize the national markups for each market participant under different distribution channels in pool pump sales and motor replacement, respectively.

Table 6.8.1 Summary of Overall Markups for Pool Pumps

	Replacement Market				**New Swimming Pool Construction**	
	Manufacturer →Wholesaler → Pool Contractor → Consumer		Manufacturer → Pool Retailer → Consumer		Manufacturer → Pool Builder → Consumer	
Market Share	75%		20%		5%	
	Baseline	Incremental	Baseline	Incremental	Baseline	Incremental
Manufacturer	1.27 to 1.46		1.27 to 1.46		1.27 to 1.46	
Wholesaler	1.41	1.10				
Pool Service Contractor	1.51	1.20				
Pool Product Retailer			1.64	1.26		
Pool Builder					1.53	1.26
Sales Tax					1.07	1.07

Table 6.8.2 Summary of Overall Markups for Motor Replacement

	Via Motor Manufacturer				**Via Pool Pump**	
	Motor Manufacturer → Wholesaler → Contractor → Consumer		Motor Manufacturer → Wholesaler → Retailer → Consumer		Pump Manufacturer → Pool Retailer → Consumer	
Market Share	25%		25%		50%	
	Baseline	Incremental	Baseline	Incremental	Baseline	Incremental
Manufacturer	1.48		1.48		1.27 to 1.46	
Wholesaler	1.32	1.19				
Contractor	1.10	1.10				
Retailer			1.83	1.38	1.64	1.26
Sales Tax	1.07	1.07	1.07	1.07	1.07	1.07

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APPENDIX 6A. DETAILED DATA FOR PRODUCT PRICE MARKUPS

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6A.1 DETAILED MOTOR WHOLESALER COST DATA

Chapter 6 provides revenues and costs in aggregated form by 'Cost of Goods Sold' and a list of cost categories under 'Gross Margin, for pool contractor in residential applications and mechanical contractor in commercial applications The tables are based on the 2012 Annual Wholesale Trade Report for "*Household Appliance and Electrical and Electronic Goods Merchant Wholesalers*" (NAICS 4236). The complete income statement for that sector is shown in Table 6A.1.1 by both dollar value and percentage terms.

Table 6A.1.1 Motor Wholesaler Expenses and Markups Used To Scale the Incremental Markups

Items	Amount ($1,000,000)	Percentage %	Scaling
Total Cost of Equipment Sales	**360,184**	**75.70**	
Gross Margin	**115,621**	**24.30**	
Labor & Occupancy Expenses	**47,437**	**9.97**	
Annual payroll	30,671	6.45	
Employer costs for fringe benefit	7,661	1.61	
Contract labor costs including temporary help	1,907	0.40	
Purchased utilities, total	602	0.13	
Purchased repairs and maintenance to buildings, structures, and offices	266	0.06	
Purchased communication services	911	0.19	
Purchased professional and technical services	2,243	0.47	
Lease and rental payments for buildings, structures, offices	2,487	0.52	
Taxes and license fees (mostly income taxes)	689	0.14	Baseline
Other Operating Expenses	**21,495**	**4.52**	
Expensed equipment (e.g. computer related supplies)	360	0.08	
Purchases of other materials, parts, and supplies (not for resale)	1,127	0.24	
Cost of purchased packaging and containers	410	0.09	
Cost of purchased transportation, shipping and warehousing services	3,160	0.66	
Cost of purchased advertising and promotional services	2,725	0.57	
Cost of purchased software	520	0.11	
Cost of data processing and other purchased computer services, except communications	413	0.09	
Lease and rental payments for machinery and equipment	286	0.06	
Purchased repairs and maintenance to machinery and equipment	467	0.10	
Depreciation and amortization charges	3,002	0.63	
Commissions paid	2,290	0.48	
Other Operating Expenses	6,735	1.42	Baseline & Incremental
Net Profit Before Income Taxes	**46,689**	**9.81**	Baseline & Incremental

Source: U.S. Census Bureau 2012 Annual Wholesale Trade Report (NAICS 4236 Household Appliance and Electrical and Electronic Goods Merchant Wholesalers) https://www.census.gov/wholesale/index.html

6A.2 DETAILED POOL CONTRACTOR DATA

Chapter 6 provides revenues and costs in aggregated form by ‘Cost of Goods Sold’ and a list of cost categories under ‘Gross Margin, for pool contractor in residential applications and mechanical contractor in commercial applications The tables are based on the 2012 Census of Business for “*Plumbing, Heating and Air-Conditioning Contractors*” (NAICS 238220). The complete income statement for that sector is shown in Table 6A.2.1 by both dollar value and percentage terms.

Table 6A.2.1 Pool Contractor Expenses and Markups Used To Scale the Incremental Markups

Item	**Dollar Value $1,000**	**Percentage %**	**Scaling**
Total Cost of Equipment Sales	**97,926,266**	**66.37**	
Total payroll, construction workers wages	28,352,603	19.22	
Cost of materials, components, and supplies	51,896,103	35.17	
Cost of construction work subcontracted out to others	14,726,652	9.98	
Total cost of selected power, fuels, and lubricants	2,950,908	2.00	
Gross Margin	**49,621,379**	**33.63**	
Payroll Expenses	**25,777,454**	**17.47**	Baseline
Total payroll, other employee wages	13,213,745	8.96	
Total fringe benefits	12,104,730	8.20	
Temporary staff and leased employee expenses	458,979	0.31	
Occupancy Expenses	**3,801,208**	**2.58**	Baseline
Rental costs of machinery and equipment	1,062,200	0.72	
Rental costs of buildings	1,545,872	1.05	
Communication services	664,786	0.45	
Cost of repair to machinery and equipment	528,350	0.36	
Other Operating Expenses	**13,644,716**	**9.25**	Baseline & Incremental
Purchased professional and technical services	903,002	0.61	
Data processing and other purchased computer services	139,701	0.09	
Expensed computer hardware and other equipment	221,937	0.15	
Expensed purchases of software	124,004	0.08	
Advertising and promotion services	977,065	0.66	
All other expenses	6,651,228	4.51	
Refuse removal (including hazardous waste) services	182,000	0.12	
Taxes and license fees	978,852	0.66	
Total depreciation ($1,000)	3,466,927	2.35	
Net Profit Before Income Taxes	**6,398,001**	**4.34**	Baseline & Incremental

Source: U.S. Census Bureau. 2012. Plumbing, Heating, and Air-Conditioning Contractors: 2012. Sector 23: 238220. Construction: Preliminary Detailed Statistics for Establishments: 2012.
Note: Pool contractor costs and expenses are first presented as *total dollar* values and then converted to *percentage* values.

6A.3 DETAILED POOL RETAILER COST DATA

Chapter 6 provides pool retailer revenue and costs based on data for miscellaneous store retailers from the 2012 U.S. Census Annual Retail Trade Survey (ARTS). Further disaggregated breakdowns of costs used to scale the incremental markup are shown in in Table 6A.3.1.

Table 6A.3.1 Pool Retailers Expenses and Markups

Item	Amount ($1,000,000)
Sales	$112,966
Cost of Goods Sold (CGS)	$61,696
Gross Margin (GM)	$51,270
Labor & Occupancy Expenses ("Invariant")	
Annual payroll	$15,491
employer costs for fringe benefit	$2,893
Contract labor costs including temporary help	$330
Purchased utilities, total	$1,243
Cost of purchased repair and maintenance services	$792
Cost of purchased professional and technical services	$789
Purchased communication services	$456
Lease and rental payments	$6,128
Subtotal:	$28,122
Other Operating Expenses & Profit ("Variant")	
Expensed equipment	$139
Cost of purchased packaging and containers	$245
Other materials and supplies not for resale	$803
Cost of purchased transportation, shipping and warehousing services	$592
Cost of purchased advertising and promotional services	$1,850
Cost of purchased software	$68
Cost of data processing and other purchased computer services, except communications + Commissions paid	$355
Depreciation and amortization charges	$1,415
Taxes and license fees	$653
Other operating expenses	$4,642
Gross profit before tax	$12,386
Subtotal:	$23,148
Baseline Markup = Sales/CGS	1.83
Incremental Markup = (CGS+Total Other Operating Expenses and Profit)/CGS	1.38

Source: U.S. Census Bureau 2012 Annual Retail Trade Survey (NAICS 453 Miscellaneous Store Retailers) http://www.census.gov/retail/index.html#arts

6A.4 DETAILED MOTOR RETAILERS COST DATA

Chapter 6 provides pool retailer revenue and costs based on data for Building Material and Garden Equipment and Supplies Dealers from the 2012 U.S. Census Annual Retail Trade Survey (ARTS). Further disaggregated breakdowns of costs used to scale the incremental markup are shown in in Table 6A.4.1.

Table 6A.4.1 Motor Retailers Expenses and Markups

Item	Amount ($1,000,000)
Sales	281,533
Cost of Goods Sold	186,375
Gross margin	95,158
Labor & Occupancy Expenses	**54,411**
Annual Payroll	35,414
Fringe benefits	7,625
Contract labor	474
Taxes and license fees	1,644
Lease and rental payments - building, structure, offices	4,342
Telephone and other communications	620
Purchased Utilities	2,295
Purchased repair and maintenance services - buildings, structure, offices	748
Purchased professional and technical services	810
Commissions paid	439
Other Operating Expenses & Profit	**19,850**
Expensed equipment	392
Expensed purchases of software	198
Depreciation and amortization	4,738
Purchases of other materials, parts, and supplies (not for resale)	1,480
Purchased packaging and other materials	150
Purchased transportation, shipping, and warehousing services	1,224
Advertising services	3,331
Purchased repair and maintenance services - machinery and equipment	1,102
Data processing and other computer services	162
Lease and rental payments - machinery, equipment	610
Other operating expenses	6,463
Net profit before taxes	20,897
Baseline Markup = Sales/CGS	1.51
Incremental Markup = (CGS+Total Other Operating Expenses and Profit)/CGS	1.22

Source: U.S. Census Bureau 2012 Annual Retail Trade Survey (NAICS 444 Building Material, Garden Equipment and Supplies Dealers) www.census.gov/retail/index.html#arts

6A.5 DETAILED POOL BUILDER COST DATA

Chapter 6 provides pool builder revenues and costs in aggregated form by 'Cost of Goods Sold' and a list of cost categories under 'Gross Margin.' The tables are based on the 2012 Census of Business for "*All Other Specialty Trade Contractors*" (NAICS 238990). The complete income statement for that sector is shown in Table 6A.3.1 by both dollar value and percentage terms.

Table 6A.5.1 Pool Builder Expenses and Markups Used To Scale the Incremental Markups

Item	Dollar Value $1,000	Percentage %	Scaling
Total Cost of Equipment Sales	**22,805,273**	**65.56**	
Total payroll, construction workers wages	6,030,240	17.34	
Cost of materials, components, and supplies	12,215,872	35.12	
Cost of construction work subcontracted out to others	3,365,770	9.68	
Total cost of selected power, fuels, and lubricants	1,193,391	3.43	
Gross Margin	**11,980,449**	**34.44**	
Payroll Expenses	**4,633,445**	**13.32**	Baseline
Total payroll, other employee wages	2,772,141	7.97	
Total fringe benefits	1,770,198	5.09	
Temporary staff and leased employee expenses	91,106	0.26	
Occupancy Expenses	**1,456,545**	**4.19**	Baseline
Rental costs of machinery and equipment	531,691	1.53	
Rental costs of buildings	433,525	1.25	
Communication services	142,393	0.41	
Cost of repair to machinery and equipment	348,936	1.00	
Other Operating Expenses	**4,720,325**	**13.57**	Baseline & Incremental
Purchased professional and technical services	229,916	0.66	
Data processing and other purchased computer services	28,343	0.08	
Expensed computer hardware and other equipment	57,654	0.17	
Expensed purchases of software	19,911	0.06	
Advertising and promotion services	194,849	0.56	
All other expenses	1,766,670	5.08	
Refuse removal (including hazardous waste) services	65,650	0.19	
Taxes and license fees	293,435	0.84	
Total depreciation ($1,000)	2,063,897	5.93	
Net Profit Before Income Taxes	**1,170,134**	**3.36**	Baseline & Incremental

Source: U.S. Census Bureau. 2012. All Other Specialty Trade Contractors: 2012. Sector 23: 238990. Construction: Preliminary Detailed Statistics for Establishments: 2012.

Note: Pool builder costs and expenses are first presented as *total dollar* values and then converted to *percentage* values.

6A.6 DETAILED WHOLESALER COST DATA

Chapter 6 shows motor wholesaler revenues and costs in aggregated form. Table 6A.4.1 in this appendix provides the complete breakdown of costs and expenses.

Table 6A.6.1 Disaggregated Costs and Expenses for Wholesalers

Item	Percent of Revenue %	Scaling
Cost of Goods Sold	**73.9**	
Gross Margin	**26.1**	
Payroll Expenses	**15.1**	Baseline
Executive Salaries & Bonuses	1.6	
Branch Manager Salaries and Commissions	1.3	
Sales Executive Salaries & Commissions	0.5	
Outside Sales Salaries & Commissions	2.3	
Inside/Counter Sales/Wages	2.6	
Purchasing Salaries/Wages	0.5	
Credit Salaries/Wages	0.2	
IT Salaries/Wages	0.2	
Warehouse Salaries/Wages	1.4	
Accounting	0.5	
Delivery Salaries/Wages	0.8	
All Other Salaries/Wages & Bonuses	0.8	
Payroll Taxes	1.0	
Group Insurance	1.0	
Benefit Plans	0.4	
Occupancy Expenses	**3.5**	Baseline
Utilities: Heat, Light, Power, Water	0.4	
Telephone	0.3	
Building Repairs & Maintenance	0.3	
Rent or Ownership in Real Estate	2.5	
Other Operating Expenses	**5.2**	Baseline & Incremental
Sales Expenses (incl. advertising & promotion)	0.9	
Insurance (business liability & casualty)	0.2	
Depreciation	0.4	
Vehicle Expenses	1.2	
Personal Property Taxes/Licenses	0.1	
Collection Expenses	0.3	
Bad Debt Losses	0.2	
Data Processing	0.3	
All Other Operating Expenses	1.6	
Total Operating Expenses	**23.8**	

Item	Percent of Revenue %	Scaling
Operating Profit	**2.3**	Baseline & Incremental
Other Income	0.4	
Interest Expense	0.4	
Other Non-operating Expenses	0.0	
Profit Before Taxes	**2.3**	

Source: Heating, Air-conditioning & Refrigeration Distributors International. 2013. 2013 Profit Report (2012 Data).

6A.7 DETAILED GENERAL CONTRACTOR COST DATA

Chapter 6 shows commercial building general contractor revenues and costs in aggregated form. Table 6A.5.1 shows the complete breakdown of costs and expenses of commercial building contractor provided by the U.S. Department of Census.

Table 6A.7.1 Commercial General Contractor Expenses and Markups

Item	Dollar Value *$1,000*	Percentage *%*	Scaling
Total Cost of Equipment Sales	**227,091,441**	**118.19**	
Total payroll, construction workers wages	13,739,662	7.15	
Cost of materials, components, and supplies	52,290,930	27.22	
Cost of construction work subcontracted out to others	159,555,486	83.04	
Total cost of selected power, fuels, and lubricants	1,505,363	0.78	
Gross Margin	**59,436,281**	**30.93**	
Payroll Expenses	**23,327,246**	**12.14**	
Total payroll, other employees' wages	15,668,244	8.15	
Total fringe benefits	6,992,590	3.64	
Temporary staff and leased employee expenses	666,412	0.35	Baseline
Occupancy Expenses	**3,556,983**	**1.85**	
Rental costs of machinery and equipment	1,157,567	0.60	
Rental costs of buildings	1,561,027	0.81	
Communication services	386,453	0.20	
Cost of repair to machinery and equipment	451,936	0.24	Baseline
Other Operating Expenses	**13,171,062**	**6.86**	
Purchased professional and technical services	1,369,654	0.71	
Data processing and other purchased computer services	211,790	0.11	
Expensed computer hardware and other equipment	314,009	0.16	
Expensed purchases of software	138,955	0.07	
Advertising and promotion services	387,863	0.20	
All other expenses	6,817,223	3.55	
Refuse removal (including hazardous waste) services	182,759	0.10	
Taxes and license fees	738,207	0.38	
Total depreciation ($1,000)	3,010,602	1.57	Baseline & Incremental
Net Profit Before Income Taxes	**19,380,990**	**10.09**	Baseline & Incremental

Source: U.S. Census Bureau. 2012. Residential Building Construction. Sector 23, EC0723I1: 236220 (Commercial Building Construction. Construction, Industry Series, Preliminary Detailed Statistics for Establishments: 2012.

6A.8 ESTIMATION OF REGIONAL MARKUP BY STATE

Table 6A.8.1 Pool Contractor Markup Estimation by State, 2012

State	Baseline MU	Incremental MU
Alabama	1.424	1.160
Alaska	1.454	1.183
Arizona	1.440	1.142
Arkansas	1.518	1.276
California	1.572	1.261
Colorado	1.489	1.212
Connecticut	1.469	1.173

State	Baseline MU	Incremental MU
Delaware	1.601	1.253
District of Columbia	1.480	1.197
Florida	1.513	1.216
Georgia	1.497	1.216
Hawaii	1.639	1.327
Idaho	1.496	1.202
Illinois	1.547	1.175
Indiana	1.523	1.225
Iowa	1.401	1.134
Kansas	1.402	1.129
Kentucky	1.445	1.170
Louisiana	1.532	1.271
Maine	1.484	1.225
Maryland	1.464	1.115
Massachusetts	1.496	1.168
Michigan	1.598	1.262
Minnesota	1.397	1.123
Mississippi	1.391	1.163
Missouri	1.421	1.129
Montana	1.551	1.183
Nebraska	1.435	1.182
Nevada	1.510	1.191
New Hampshire	1.502	1.196
New Jersey	1.586	1.260
New Mexico	1.430	1.166
New York	1.577	1.268
North Carolina	1.464	1.185
North Dakota	1.530	1.300
Ohio	1.534	1.207
Oklahoma	1.473	1.198
Oregon	1.468	1.138
Pennsylvania	1.490	1.169
Rhode Island	1.713	1.445
South Carolina	1.558	1.300
South Dakota	1.494	1.236
Tennessee	1.464	1.181
Texas	1.474	1.196
Utah	1.363	1.165
Vermont	1.431	1.184
Virginia	1.536	1.253
Washington	1.468	1.136
West Virginia	1.543	1.248
Wisconsin	1.460	1.133
Wyoming	1.551	1.275

Sources: U.S. Bureau of the Census. American Factfinder: 2012. Sector 23: Plumbing, Heating, and Air-Conditioning Contractors (NAICS 238220), Geographic Area Series: Detailed Statistics for Establishments: 2012
http://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml

Table 6A.8.2 Pool Builder Markup Estimation by State, 2012

State	Baseline Markup	Incremental Markup
Alabama	1.495	1.288
Alaska	1.840	1.488
Arizona	1.410	1.144
Arkansas	1.480	1.297
California	1.546	1.275
Colorado	1.648	1.370
Connecticut	1.386	1.134
Delaware	1.470	1.215
District of Columbia	1.400	1.138
Florida	1.501	1.254
Georgia	1.392	1.197
Hawaii	1.583	1.156
Idaho	1.526	1.317
Illinois	1.651	1.326
Indiana	1.629	1.283
Iowa	1.344	1.190
Kansas	1.448	1.225
Kentucky	1.535	1.323
Louisiana	1.944	1.492
Maine	1.360	1.211
Maryland	1.400	1.138
Massachusetts	1.493	1.179
Michigan	1.562	1.312
Minnesota	1.667	1.412
Mississippi	1.373	1.391
Missouri	1.385	1.170
Montana	1.590	1.338
Nebraska	1.628	1.326
Nevada	1.501	1.200
New Hampshire	1.340	1.211
New Jersey	1.588	1.331
New Mexico	1.389	1.122
New York	1.616	1.321
North Carolina	1.427	1.187
North Dakota	1.484	1.375
Ohio	1.396	1.149
Oklahoma	1.595	1.327
Oregon	1.445	1.184
Pennsylvania	1.548	1.244
Rhode Island	1.459	1.156
South Carolina	1.483	1.215
South Dakota	1.341	1.292
Tennessee	1.606	1.395
Texas	1.483	1.246
Utah	1.661	1.374
Vermont	1.426	1.211

State	Baseline Markup	Incremental Markup
Virginia	1.423	1.175
Washington	1.549	1.226
West Virginia	1.772	1.206
Wisconsin	1.502	1.252
Wyoming	1.352	1.195

Sources: U.S. Bureau of the Census, American Factfinder. 2012 Economic Census. Sector 23: All Other Specialty Trade Contractors (NAICS 238990), Geographic Area Series**:** Detailed Statistics for Establishments: 2012

Table 6A.8.3 Mechanical Contractor Markup Estimation by State, 2012

State	Replacement Baseline MU	Replacement Incremental MU	New Const. Baseline MU	New Const. Incremental MU
Alabama	1.476	1.202	1.393	1.134
Alaska	1.507	1.226	1.422	1.157
Arizona	1.492	1.183	1.408	1.116
Arkansas	1.574	1.322	1.485	1.248
California	1.629	1.307	1.538	1.234
Colorado	1.543	1.256	1.456	1.186
Connecticut	1.522	1.216	1.437	1.147
Delaware	1.659	1.299	1.566	1.226
District of Colum.	1.533	1.240	1.447	1.170
Florida	1.568	1.260	1.480	1.189
Georgia	1.552	1.260	1.464	1.189
Hawaii	1.698	1.376	1.603	1.298
Idaho	1.551	1.245	1.463	1.175
Illinois	1.603	1.217	1.513	1.149
Indiana	1.579	1.270	1.490	1.199
Iowa	1.452	1.176	1.370	1.109
Kansas	1.453	1.170	1.372	1.104
Kentucky	1.497	1.212	1.413	1.144
Louisiana	1.588	1.317	1.499	1.243
Maine	1.538	1.270	1.451	1.198
Maryland	1.517	1.156	1.432	1.091
Massachusetts	1.550	1.210	1.463	1.142
Michigan	1.656	1.308	1.563	1.235
Minnesota	1.448	1.164	1.367	1.098
Mississippi	1.441	1.205	1.360	1.137
Missouri	1.472	1.170	1.390	1.104
Montana	1.608	1.225	1.517	1.157
Nebraska	1.487	1.224	1.403	1.156
Nevada	1.565	1.234	1.477	1.165
New Hampshire	1.556	1.239	1.469	1.170
New Jersey	1.644	1.306	1.551	1.232
New Mexico	1.482	1.208	1.398	1.141
New York	1.635	1.314	1.543	1.240
North Carolina	1.517	1.228	1.431	1.159
North Dakota	1.586	1.347	1.496	1.272
Ohio	1.589	1.250	1.500	1.180
Oklahoma	1.526	1.242	1.441	1.172

State	Replacement Baseline MU	Replacement Incremental MU	New Const. Baseline MU	New Const. Incremental MU
Oregon	1.521	1.180	1.435	1.113
Pennsylvania	1.544	1.211	1.457	1.143
Rhode Island	1.775	1.497	1.675	1.413
South Carolina	1.615	1.347	1.524	1.271
South Dakota	1.548	1.281	1.461	1.208
Tennessee	1.517	1.223	1.432	1.155
Texas	1.528	1.239	1.442	1.169
Utah	1.412	1.207	1.333	1.139
Vermont	1.483	1.226	1.399	1.157
Virginia	1.592	1.299	1.502	1.226
Washington	1.522	1.177	1.436	1.111
West Virginia	1.599	1.293	1.509	1.220
Wisconsin	1.513	1.174	1.428	1.108
Wyoming	1.607	1.321	1.517	1.247

Sources: U.S. Bureau of the Census. American Factfinder: 2012. Sector 23: Plumbing, Heating, and Air-Conditioning Contractors (NAICS 238220), Geographic Area Series: Detailed Statistics for Establishments: 2012

Table 6A.8.4 Commercial Building General Contractor Baseline Markups by State

State	Baseline Markup	Incremental Markup
Alabama	1.321	1.212
Alaska	1.527	1.295
Arizona	1.214	1.096
Arkansas	1.289	1.205
California	1.317	1.183
Colorado	1.156	1.014
Connecticut	1.391	1.256
Delaware	1.212	1.091
District of Columbia	1.312	1.172
Florida	1.263	1.132
Georgia	1.146	1.052
Hawaii	1.510	1.344
Idaho	1.236	1.125
Illinois	1.186	1.089
Indiana	1.195	1.072
Iowa	1.224	1.115
Kansas	1.255	1.158
Kentucky	1.242	1.133
Louisiana	1.250	1.147
Maine	1.127	1.017
Maryland	1.291	1.182
Massachusetts	1.310	1.172
Michigan	1.192	1.099
Minnesota	1.244	1.129
Mississippi	1.323	1.200
Missouri	1.227	1.100
Montana	1.277	1.161
Nebraska	1.289	1.170
Nevada	1.594	1.470

State	Baseline Markup	Incremental Markup
New Hampshire	1.209	1.090
New Jersey	1.384	1.219
New Mexico	1.206	1.100
New York	1.304	1.169
North Carolina	1.206	1.090
North Dakota	1.263	1.173
Ohio	1.270	1.157
Oklahoma	1.194	1.110
Oregon	1.140	1.059
Pennsylvania	1.260	1.142
Rhode Island	1.535	1.423
South Carolina	1.297	1.176
South Dakota	1.214	1.134
Tennessee	1.234	1.142
Texas	1.206	1.103
Utah	1.253	1.169
Vermont	1.349	1.196
Virginia	1.346	1.234
Washington	1.246	1.123
West Virginia	1.278	1.145
Wisconsin	1.235	1.104
Wyoming	1.306	1.198

Sources: U.S. Bureau of the Census, American Factfinder. 2012 Economic Census. Sector 23: Subsectors 236220 (Commercial Building Construction). Sector 23: EC0723A1: Construction: Geographic Area Series: Detailed Statistics for Establishments: 2012.

6A.9 STATE SALES TAX RATES

Table 6A.9.1 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	8.65	Kentucky	6.00	North Dakota	6.15
Alaska	1.30	Louisiana	9.85	Ohio	7.15
Arizona	7.25	Maine	5.50	Oklahoma	8.45
Arkansas	9.00	Maryland	6.00	Oregon	--
California	8.45	Massachusetts	6.25	Pennsylvania	6.35
Colorado	6.15	Michigan	6.00	Rhode Island	7.00
Connecticut	6.35	Minnesota	7.30	South Carolina	7.20
Delaware	--	Mississippi	7.05	South Dakota	5.50
Dist. of Columbia	5.75	Missouri	7.45	Tennessee	9.45
Florida	6.65	Montana	--	Texas	7.95
Georgia	7.05	Nebraska	6.05	Utah	6.75
Hawaii	4.35	Nevada	8.00	Vermont	6.10
Idaho	6.00	New Hampshire	--	Virginia	5.60
Illinois	8.45	New Jersey	6.95	Washington	8.95
Indiana	7.00	New Mexico	6.85	West Virginia	6.10

Iowa	6.80	New York	8.45	Wisconsin	5.40
Kansas	8.30	North Carolina	6.90	Wyoming	5.40

Source: The Sales Tax Clearinghouse at https://thestc.com/STRates.stm (Accessed on April 18, 2016).

APPENDIX 6B. INCREMENTAL MARKUPS: THEORY AND EVIDENCE

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APPENDIX 6B. INCREMENTAL MARKUPS: THEORY AND EVIDENCE

6B.1 INTRODUCTION

Since 2004, the Department of Energy (DOE) has applied the incremental markup approach to estimate the increase in final product price of high-efficiency products as a function of the increase in manufacturing cost.[1] Under this approach, DOE applies a lower markup than the average markup to the incremental cost of higher-efficiency products, relative to the baseline product. The approach is described in detail in chapter 6.

DOE's incremental markup approach is based on the widely accepted economic view that prices closely reflect marginal costs in competitive markets and in those with some degree of concentration. Evaluating industry data in IBISWorld suggests that most of the industries relevant to HVAC wholesalers and contractors are considered to have low market concentration, high and increasing market competition and low to medium barriers to entry (see Table 6B.1.1).[2]

Table 6B.1.1 Competitive Environment of HVAC Sectors

Sector	Industry Concentration	Competition	Barriers to Entry
Home builders	Low	High and increasing	Low and steady
Commercial building construction	Low	High and steady	Medium and steady
Heating & air-conditioning contractors	Low	High and increasing	Medium and steady
Heating & air-conditioning wholesaling	Low	High and increasing	Medium and increasing

Examining gross margin and price data in HVAC wholesale industry over time, DOE finds that both gross margins and prices did not demonstrate any persistent trend; thus, this set of historical data has no bearing on firm markup behavior under product price increases, such as may occur as a result of standards.

To investigate markup behavior under product price increases, DOE evaluated time series gross margin data from three industries with rapidly changing input prices – the LCD television retail market, the U.S. oil and gasoline market, and the U.S. housing market. Additionally, DOE conducted an in-depth interview with an HVAC consultant who represents many individual contractors in the industry.

6B.2 MARGIN TRENDS UNDER PRICE VOLATILITY

Heating, Air-Conditioning and Refrigeration Distributors International (HARDI) published annual profit report with aggregated financial and operating data of its participating firms in HVAC wholesale industry. DOE evaluated the percent gross margins[a] and sales revenue per shipment received (as a proxy for average HVAC wholesale prices) reported from 1999 to 2012 for typical HARDI distributors.[b] As shown in Figure 6B.2.1, average HVAC wholesaler prices have experienced some fluctuations during this period of time, but the overall wholesale price trend is relatively stable, with a price increase of four percent from 1999 to 2012.

However, the existence of constant percent margin over time is not sufficient to identify an industry's markup practice without considering the underlying input price changes during the same period. If the prices have been relatively constant, the incremental markup approach will arrive at the same result as applying constant margin. In fact, the average HVAC wholesale prices have been relatively stable over time;[c] hence, the historically constant percent margins do not necessarily imply a constant percent margin in the future, especially in the case of increased input prices due to standards (Figure 6B.2.1).

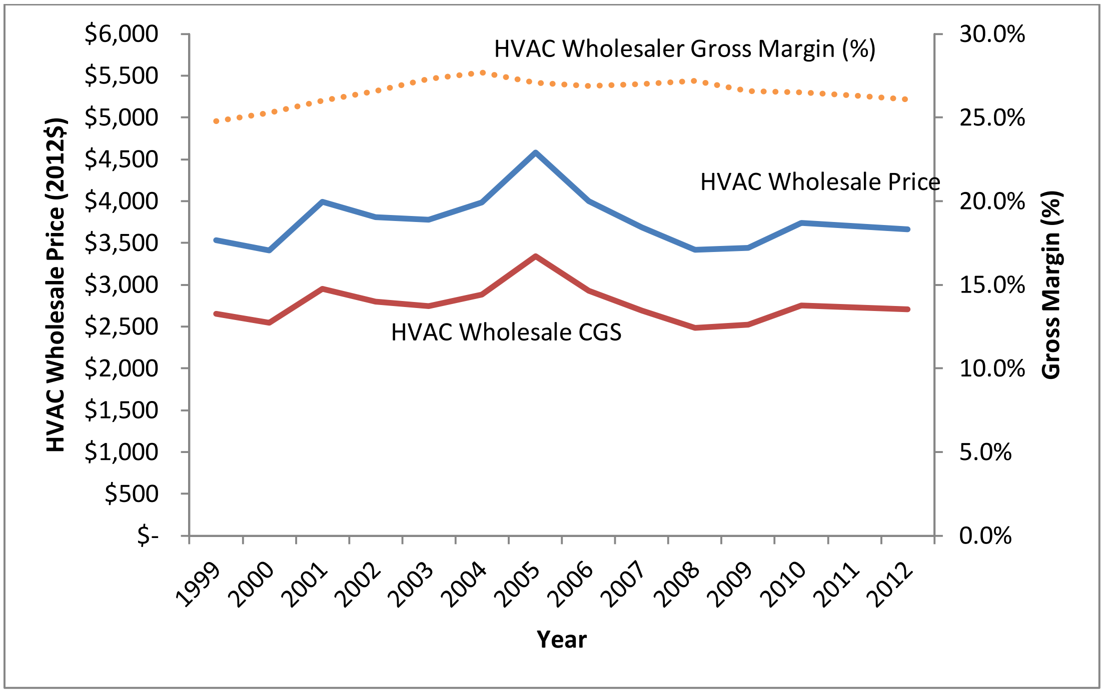

Figure 6B.2.1 HVAC Wholesale Prices, Cost of Goods Sold and Gross Margins

As historical data in HVAC wholesale markets cannot be used to address the question of margins under a price shock, DOE looked to other publicly available data for markets of a single

[a] Percent gross margin is defined as gross margin in percentage of sales revenue.
[b] The typical distributors are the firms with median financial results among all participating firms.
[c] In 2005 the HVAC market experienced a brief 15-percent price rise. The HVAC price increase may be attributed to the 2006 Central Air-Conditioner and Heat Pump Standard. Gross margins declined slightly at this time.

product that have experienced noticeable price changes, evaluating the prevalence of fixed percent gross margins.

To replicate the theorized conditions of efficiency standard implementation, DOE would ideally analyze a household durable that has experienced a consistent rise in price, such as may occur as a result of standards. The LCD television retail market, on the other hand, is a market with a consistently downward price trend since 2007. The material costs and retail prices of LCD televisions have both dropped substantially over this period. At the same time, average retailer gross margins have decreased from 25 percent in 2007 to only 6 percent in late 2014. Under the change in input price (*i.e.*, cost of goods sold (CGS)), retailers did not maintain constant percent gross margins (Figure 6B.2.2).[d]

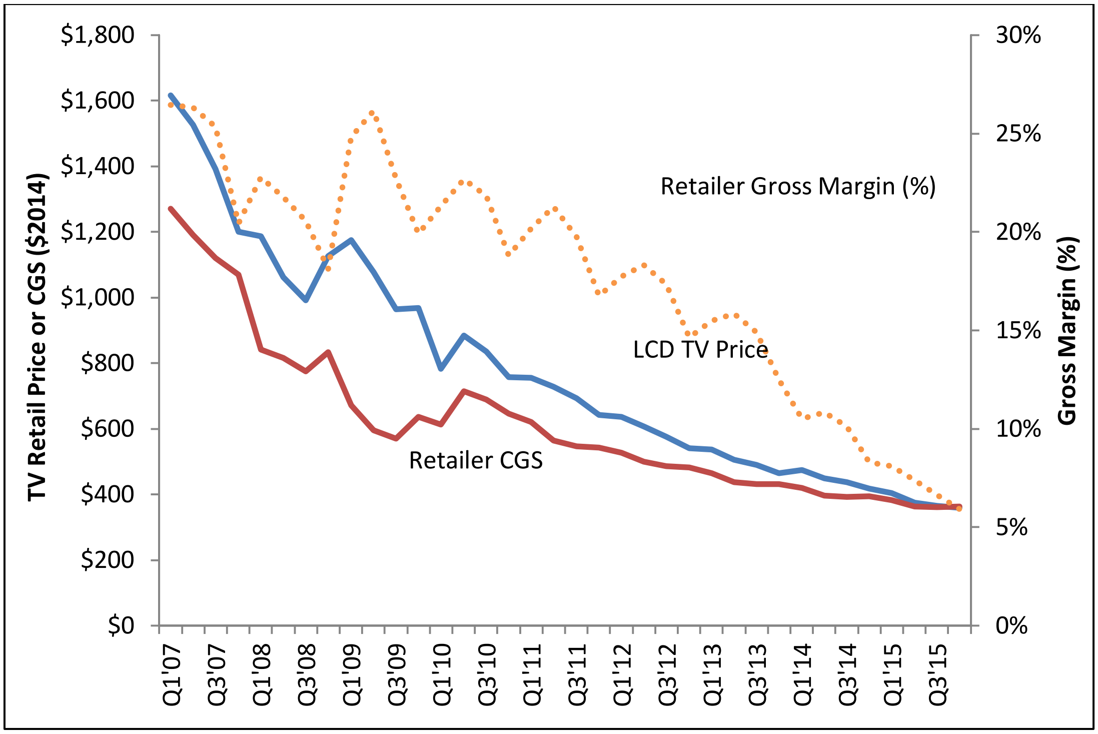

Figure 6B.2.2 LCD TV Prices, Cost of Goods Sold and Gross Margins

DOE also analyzed margin behavior in markets with upward price trends to test the prevalence of fixed percent gross margins. U.S. imported crude oil prices rose by $2.50 per gallon from 1995 to 2008, but the percent retail gross margins have decreased during the same period of time (Figure 6B.2.3).[3]

[d] LCD television data from DisplaySearch, a market research company affiliated with NPD Group.

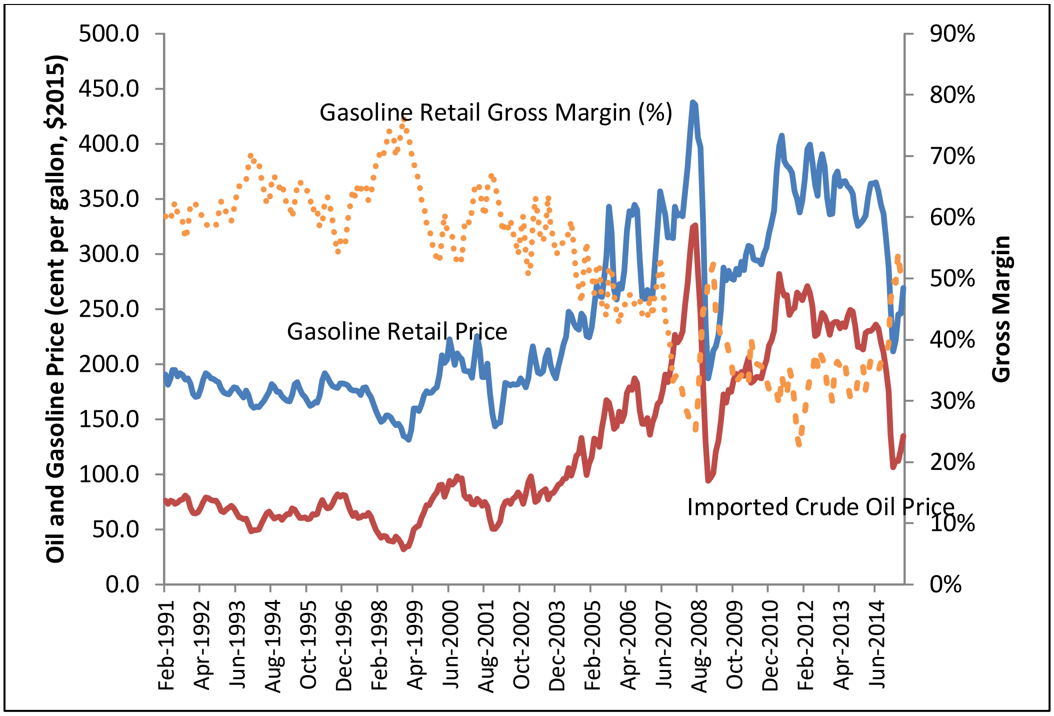

Figure 6B.2.3 Oil and Gasoline Price, Gross Margin

The U.S. inflation-adjusted median home sales prices and the costs of selling, measured by home sales price minus agent's commission fee, have increased substantially from 1991 to 2005. The percent gross margin in the housing market (*i.e.*, commission rate), however, has declined by 15 percent over this period (Figure 6B.2.4).[4–7,e] In short, fixed percent gross margins are not observed in this market with increasing costs.

[e] Federal Trade Commission and the U.S. Department of Justice published a report, titled "Competition in the Real Estate Brokerage Industry", which provides extensive literature review on the topic of housing prices and brokerage commission fee, and the empirical evidences are consistent with our findings. Access to the full report: https://www.ftc.gov/reports/competition-real-estate-brokerage-industry-report-federal-trade-commission-us-department

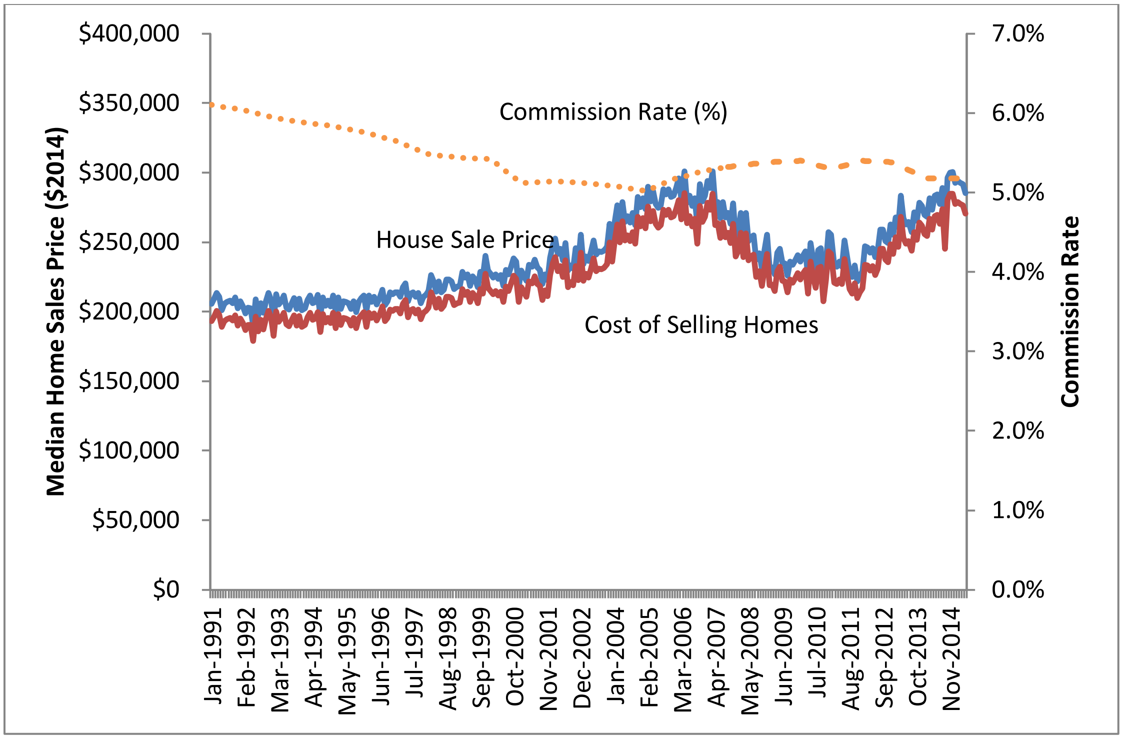

Figure 6B.2.4 House Sales Price, Costs of Selling Homes, and Realtor Commission (%)

After examining price and gross margin data in various markets, the results indicate that prices could go up or down in different circumstances, but in no case are percent gross margins observed to remain fixed over time. Hence, DOE does not expect that firms can sustain on applying constant markups on incremental costs of more efficient products after standards.

6B.3 SUMMARY OF CONSULTANT INTERVIEW

To gain insight into contractor markup determination, DOE interviewed an experienced consultant who specializes in the HVAC contracting field.[8] Because the incremental markup is applied in a very specific analytical situation where the input cost increases due to the standard while other costs remain the same, it was necessary to carefully craft the interview to accurately convey the concept. The list of key questions asked of the consultant includes the following points:

1. *Assuming the HVAC equipment price increases while the other costs remain constant (no change in labor, material, and operating costs), are contractors still able to keep the same markup over time as before?*
2. *Keeping a fixed markup when the equipment price goes up implies that the contractor's profitability would increase, assuming no other cost changes. Is this increase in profitability viable over time?*
3. *If contractors would have to adjust their markup in this situation due to competition, how long does it take for them to revisit their markup values and adjust the firm's profitability to a competitive level?*

The consultant responded as follows:

1. *Initially, contractors will attempt to use the same markup after the increase in input cost occurs, but, assuming there is no increase in other costs, "they'll eventually either have to lower their markup based on market pressures, or they'll choose to lower their markup when it's reviewed and recalculated."*
2. *Any increase in profit following an input cost increase is likely to be short-lived. "There are too many pressures on contractors to lower their prices for various reasons… We'll guess this isn't the first time over the past 40 years that equipment prices have increased because of regulatory changes rather than inflationary or commodity price increases. Construction today is not a more profitable industry than it was decades ago."*
3. *Contractor profit margins and markups are typically reevaluated every three to six months; this limits the timeframe in which higher-than-sustainable profits are likely to persist.*

The consultant's responses provide real-world evidence indicating that HVAC contractors aim to maintain fixed percent markups, but market pressures force them to reevaluate and adjust markups over time to stay competitive. This empirical phenomenon reinforces the underlying theory and assumptions inherent in the incremental markup approach used in DOE's post-standard price projections. While the consultant speaks specifically to the practices of HVAC contractors, his descriptions of firm response to cost increase over time in a competitive environment can be logically extended to wholesalers and retailers as well. DOE concludes that the combined evidence of changing percent gross margins across industries with cost changes and the support of the industry consultant justify the use of the incremental markup approach.

6B.4 CONSULTANT INTERVIEW REPORT

In this section, the original responses from consultant regarding markup practice in construction industry is presented as a supplementary material supporting the use of incremental markup when estimating the consumer product price of more efficient products.

To: Lawrence Berkeley National Laboratory
From: Michael Stone, Construction Programs & Results, Inc.
Date: January 26, 2015
Re: Supplementary questions on contractor markups

After a new energy efficiency standard is in place, the equipment prices generally go up as less efficient (cheaper) ones are eliminated on the market by new standard. The questions below are intended to help us understand the impact of increased equipment prices on contractors' markup practices and profitability. That is, how contractors react to this change in equipment price while the other costs remain constant.

(1) Assuming the equipment price increases while the other costs remain constant (no change in labor, material and operating costs), are contractors still able to keep the same markup over time as before?

Michael Stone (Michael): *Yes and no. The contractors will attempt to use the same markup over time, but, assuming no increase in other costs, they'll eventually either have to lower their markup based on market pressures, or they'll choose to lower their markup when it's reviewed and recalculated.*

Keep in mind the numbers and our answer assume a "pure" company; one that currently only installs the lower efficiency units and that in the future will only install the higher efficiency units. They don't perform any other service work or install any other equipment. Those companies don't exist in real life. So it's most likely that on individual sales, if under pressure, the contractor might choose to reduce their markup because they recognize the equipment price increase without other related cost increases. The markup change will happen when the company's finances are reviewed, and the equipment cost increase will be only one factor in the adjustment.

(2) Keeping a fixed markup when the equipment price goes up implies that the contractor's profitability would increase, assuming no other cost changes. Is this increase in profitability viable over time?

Michael: *Probably not. There are too many pressures on contractors to lower their prices for various reasons. Unless building owners suddenly have more money to spend and consider the work on their building valuable enough to pay what it's worth, profitability will stay the same.*

We'll guess this isn't the first time over the past 40 years that equipment prices have increased because of regulatory changes rather than inflationary or commodity price increases. Construction today is not a more profitable industry than it was decades ago.

(3) If contractors would have to adjust their markup in this situation due to competition, how long does it take for them to revisit their markup values and adjust the firm's profitability to a competitive level?

Michael: *Generally speaking, 3-6 months.*

(4) For commercial contractors, is the market as competitive as for residential contractors? Is there a significant difference in their ability to maintain a fixed markup between commercial and residential contractors? If so, please elaborate the differences.

Michael: *There are so many variations in how commercial contractors operate, and the market is considerably different than residential. But it is as competitive.*
Many of them get jobs because of their connections. They do a lot of marketing and schmoozing, promoting themselves to buyers. This enables them to get jobs easier. If they have long-time relationships with general contractors who are primarily concerned with getting a job well-built with few problems, they can have an easier time maintaining a fixed markup. If they have long-time relationships with general contractors who are more concerned about getting the job built at the lowest possible price, they might choose to cut their price to get jobs.
Others get jobs by competing to be the lowest price. If they have relationships and can influence the bid process, they might have a bid that's written with them in mind, making it easier for them to be low bid and still maintain a reasonable markup on the job. Other contractors just shoot to be the lowest bid and have a tough time being profitable (ie, no, they don't maintain a fixed markup).

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CHAPTER 7. ENERGY USE ANALYSIS

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CHAPTER 7. ENERGY USE ANALYSIS

7.1 INTRODUCTION

The purpose of the energy use analysis is to determine the annual energy consumption of pool pumps in use in the United States. In contrast to the U.S. Department of Energy (DOE) test procedure, which uses typical operating conditions in a laboratory setting, the energy use analysis seeks to estimate the range of energy consumption of the products in the field. DOE estimated the annual energy consumption of pool pumps at specified energy efficiency levels across a range of climate zones, building characteristics, and applications. The energy use analysis provides estimates of the distribution of annual energy consumption for pool pumps at the efficiency levels considered.

DOE estimates the energy consumption of pool pumps by developing samples primarily based on the Energy Information Administration's (EIA) 2009 Residential Energy Consumption Survey (RECS 2009) and EIA's 2012 Commercial Building Energy Consumption Survey (CBECS 2012). [1,2] These are the latest available surveys for residential households and commercial buildings.[a]

DOE estimated the pool pump energy consumption by using household characteristics and assumptions about the energy consumption. To complete the analysis, DOE calculated the energy consumption of alternative (more energy-efficient) products if they replaced the existing product in each housing unit or building.

7.2 POOL SAMPLES

DOE derived five separate samples for each pool pump market type as follows:

1) Residential single-family households with a swimming pool,
2) Community pools for single-family households,
3) Community pools for multi-family households,
4) Commercial indoor pools, and
5) Commercial outdoor pools.

For the first sample subset, which accounts for the vast majority of pool pumps, RECS 2009 records were used in the analysis if they met the following criterion:

- The household had a swimming pool.

For sample subset 4 (commercial indoor pools), CBECS 2012 records were used in the analysis if they met the following criterion:

[a] RECS 2009 includes energy-related data from 12,083 housing units that represent almost 113.6 million households. EIA is currently working on the 2015 version of RECS, which is not expected to be available until 2017.

- The building had an indoor swimming pool.

Neither RECS 2009 nor CBECS 2012 have sufficient information to distinguish other sample subsets (numbers 2, 3, and 5), as they do not include information about pools for common areas in multi-family residences and complexes. To determine the market share and sample for these sample subsets DOE used a combination of sources including RECS 2009, CBECS 2012, 2009 American Housing Survey,[3] and PK Data survey data.[4]

Dedicated-purpose pool pumps can be installed with either above-ground or in-ground swimming pools. Neither RECS 2009 nor CBECS 2012 indicate the pool type. DOE established separate sets of consumer samples for above-ground and in-ground pools by adjusting the original sample weights based on the number of installed in-ground and above-ground pools in 2014 per state provided by Association of Pool and Spa Professionals (APSP). (See Docket EERE-2015-BT-STD-0008-0010, No. 31 at pp. 14-15) The consumer samples for self-priming, waterfall and pressure cleaner booster pumps are drawn from the in-ground pool samples; the consumer samples for non-self-priming and integral pumps are obtained from the above-ground pool samples.

Appendix 7A presents the RECS 2009 and CBECS 2012 variables used in this analysis and their definitions, as well as further information about the derivation of the building sample. Table 7.2.1 shows the resulting sample weights for the five sample subsets and Table 7.2.2 shows the resulting sample weights by Census division for both above-ground and in-ground pools.

Table 7.2.1 Fraction of Dedicated-Purpose Pool Pumps by Sample Type

Type of Pool Pump	Description	Fraction of Pool Pumps %
1	Residential Single Family Swimming Pools	95.1
2	Community Pools (Single-Family)	0.8
3	Community Pools (Multi-Family)	0.4
4	Commercial Indoor Pools	0.3
5	Commercial Outdoor Swimming Pools	3.4

Table 7.2.2 Distribution of Pool Pumps by Census Division

Census Division	Original RECS 2009 Households with a Pool* %	Original CBECS 2012 Building Samples with a Pool** %	DOE Adjusted Fraction of Above-ground Pools %	DOE Adjusted Fraction of In-ground Pools %
New England	4.6	5.1	4.6	4.6
Middle Atlantic	17.4	13.9	11.0	8.8
East North Central	12.1	16.2	17.5	8.0
West North Central	3.9	7.1	7.7	2.2
South Atlantic	23.1	18.6	20.6	28.8
East South Central	6.1	6.0	6.4	2.5
West South Central	9.0	11.2	11.5	9.3
Mountain	7.5	6.8	7.3	9.4
Pacific	16.2	15.2	13.4	26.4

* Only includes subsample type 1 residential single family swimming pool.
** Only includes subsample type 4 commercial indoor pool.

7.3 CALCULATION OF ENERGY CONSUMPTION

DOE calculated the annual unit energy consumption (UEC) of pool pumps at the considered efficiency levels for each pool as follows:

$$UEC = UEC_{day} \times Annual\ days\ of\ operation$$

Where:
UEC_{day} = average unit energy consumption per day, kWh/day.

For single-speed pool pumps, the daily UEC is simply the pool pump power multiplied by the daily operating hours. For two-speed and variable-speed pool pumps, the daily UEC is the sum of low-speed mode and high-speed mode daily unit energy consumption:

$$\boldsymbol{UEC_{day}} = \sum_i (\boldsymbol{P_i} \times \boldsymbol{PPOH_i})$$

Where:
i = pool pump operating speed mode, low-speed mode or high-speed mode for two-speed and variable-speed pool pumps,
P_i = pool pump power consumption for mode i, watt, and
$PPOH_i$ = daily pool pump operating hours for mode i, hr.

7.3.1 Power Inputs

As explained in chapter 5, the pumping requirements of a pool can be expressed in terms of a system curve (A, B or C). [b] For each consumer in the sample of each equipment class, DOE specified the system curve used (A, B or C) by drawing from a probability distribution listed in Table 7.3.1, which was discussed and approved by the DPPP Working Group. (See Docket EERE-2015-BT-STD-0008-0094 pp. 144-147)

Table 7.3.1 Probability Distribution Used to Determine the System Curve (A, B or C) for Each Consumer Sample

System curve	Probability
A	35%
B	10%
C	55%

7.3.1.1 Self-Priming and Non-Self-Priming Pool Filter Pumps

For self-priming and non-self-priming pool pumps, DOE calculated the power inputs for operating speed mode i as:

$$P_i = \frac{Q_i * 60}{EF_i}$$

Where:
Q_i = pool pump flow rate for mode i, gallon / minute,
60 = number of minutes per hour, and
EF_i= pool pump energy factor for mode i, gallon / Wh.

[b] When a pump is teste on a system curve (such as curve C), any one of the measurements hydraulic power, P (hp), volumetric flow, Q (gpm) and total dynamic head, H (feet of water) can be used to calculate the other two measurements.

Table 7.3.2 Power Inputs for Self-Priming and Non-Self-Priming Pool Filter Pumps

	Single-speed	**Two-speed**		**Variable-speed**	
		Low-speed	High-speed	Low-speed	High-speed
Flow rate Q	Provided*	Provided*	Provided*	Specific to consumer	Provided*
Energy Factor	Provided*	Provided*	Provided*	Provided as a function of Q**	Provided*

* Values provided in the engineering analysis for each representative unit at each system curve (A, B or C).
** Function provided in the engineering analysis for each representative unit at each system curve (A, B or C).

As showed in Table 7.3.2, in the case of single-speed pumps, there is only one operating speed mode, of which Q and EF are provided in the engineering analysis for each representative unit at each system curve (A, B or C). In the case of two-speed pumps, Q and EF are provided for both low-speed and high-speed modes for each representative unit at each system curve. For variable-speed pumps, Q and EF are only provided for the high-speed mode, which, according to the DOE test procedure, corresponds to 80 percent of maximum speed. For the low-speed mode of variable-pumps, Q is specific to each consumer and EF can be calculated as it is provided in the engineering analysis as a function of Q. DOE defined the consumer-specific low-speed flow rate as:

$$Q^{i}_{low\ speed} = \frac{V_i}{Time\ per\ turn_i}$$

Where:
$Q^{i}_{low\ speed}$ = low-speed flow rate for consumer i,
V_i = pool volume for consumer i, and
$Time\ per\ turn_i$ = desired time per turnover for consumer i.

DOE developed a distribution for pool volume based on information given in several references.[5, 6, 7] The distribution was then adjusted and approved by the DPPP Working Group. (See Docket EERE-2015-BT-STD-0008-0094 pp. 163-171) Table 7.3.3 shows the resulting pool volume assumption made by DOE for all the equipment classes. Figure 7.3.1 and Figure 7.3.2 illustrate the log-normal pool size distribution for standard-size self-priming pool filter pumps (0.95 hhp) and the triangle pool size distribution for small-size self-priming pool filter pumps (0.44 hhp) respectively. Table 7.3.4 provides the assumptions that DOE made for the desired time per turnover for both residential and commercial applications. (See Docket EERE-2015-BT-STD-0008-0094 pp. 143-144) A minimum threshold of flow rate Q is considered according to the DOE test procedure.[c] The variable-speed EF can therefore be calculated, as it was provided in the engineering analysis as a function of Q for each representative unit on each system curve.

Table 7.3.3 Pool Volume Distribution (gallons)

Equipment Class	Log-Normal Distribution		
	Location	Mean	Standard Deviation
Standard-Size Self-Priming (0.95 hhp)	-15,000	20,000	5,000
Standard-Size Self-Priming (1.88 hhp)	0	22,000	5,000
Equipment Class	**Triangle Distribution**		
	Minimum	**Mode**	**Maximum**
Small-Size Self-Priming (0.44 hhp)	2,000	13,000	20,000
Extra-Small Non-Self-Priming	500	4,000	8,000
Standard-Size Non-Self-Priming	3,000	12,000	20,000
Integral Cartridge-Filter (0.02 hhp)	300	2,700	5,000
Integral Cartridge-Filter (0.18 hhp)	300	7,700	15,000
Integral Sand-Filter	300	2,200	4,000

[c] The threshold equals 24.7 gpm if pump hydraulic hp at max speed on curve C is ≤0.75, or equals 31.1 gpm if pump hydraulic hp at max speed on curve C is >0.75.

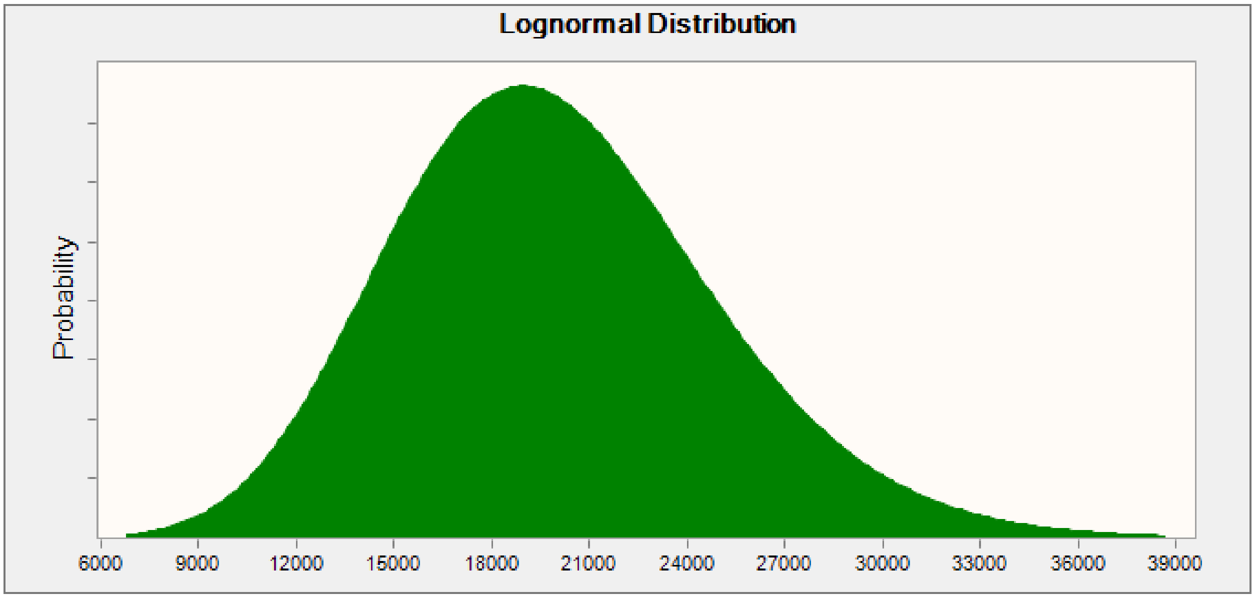

Figure 7.3.1 Log-Normal Pool Size Distribution for Standard-Size Self-Priming Pool Filter Pumps (0.95 hhp)

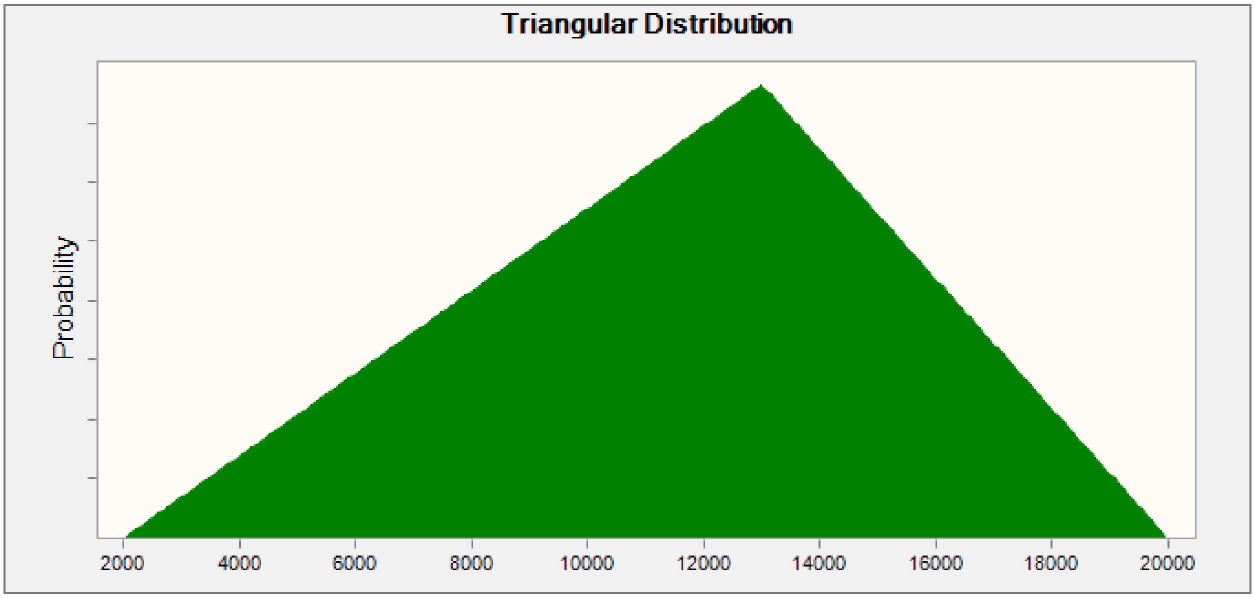

Figure 7.3.2 Triangular Pool Size Distribution for Small-Size Self-Priming Pool Filter Pumps (0.44 hhp)

Table 7.3.4 Assumption of Desired Time per Turnover for Residential and Commerical Samples

	Residential Samples	Commercial Samples	
Value	6 hours	6 hours	10 hours
Probability	100%	67%	33%

7.3.1.2 Pressure Cleaner Booster Pumps and Waterfall Pumps

The test procedure final rule established a test point at 10 gpm of flow rate for pressure cleaner booster pumps and a test point at 17 feet of head (H) for waterfall pumps. DOE developed a distribution for each of these equipment classes, in coordination with the DPPP Working Group, from which a flow rate or head value, respectively is drawn for each sampled consumer. (Pressure cleaner booster pumps: see Docket EERE-2015-BT-STD-0008-0092 pp. 310; waterfall pumps: see Docket EERE-2015-BT-STD-0008-0094 pp. 149-150) The head and flow rate distributions are provided in Table 7.3.5.

Table 7.3.5 Probability Distribution to Determine the Head Value for Waterfall Pumps and Flow Rate for Pressure Cleaner Booster Pumps for Their Consumer Samples

Equipment Class	Triangle Distribution for Head (feet)		
	Minimum	**Mode**	**Maximum**
Waterfall	12	17	22
	Discrete Distribution for Flow Rate (gpm)		
	Value (gpm)	**Probability**	
Pressure Cleaner Booster	8	5%	
	9	15%	
	10	28%	
	11	22%	
	12	15%	
	13	8%	
	14	4%	
	15	2%	

	16	1%

For waterfall pumps, DOE used the pump curve H = f(Q) provided in the engineering analysis for each representative unit to determine the flow rate Q associated with the selected head, from which the corresponding power can be calculated based on the power curve P = f(Q), also provided by the engineering analysis. For single-speed pressure cleaner booster pumps, DOE calculated the power directly from the power curve P = f(Q) from the engineering analysis. For variable-speed pressure cleaner booster pumps, DOE estimated power consumption at reduced speed (10 gpm) for consumers with sampled Q above 10 gpm by calculating the hydraulic power, estimating the wire-to-water efficiency from the full speed curve and recalculating the input power. See Table 7.3.6 and Table 7.3.7 for detailed calculation for the two efficiency levels of variable-speed pressure cleaner booster pumps.

Table 7.3.6 Power Consumption Calculation for Variable-Speed Pressure Cleaner Booster Pumps Efficiency Level 3

Flow (gpm)	Head (feet)	Power Out (watt)	Power In (watt)	Wire-to-Water Efficiency	Hypothetical Power Out (watt)	Hypothetical Power In (watt)	Percent of Power
8	115.3	174	1095	15.9%	174	1095	100.0%
9	113.8	193	1114	17.3%	193	1114	100.0%
10	112.3	212	1132	18.7%	212	1132	100.0%
11	110.7	229	1151	19.9%	209	1116	97.0%
12	109.0	246	1169	21.1%	205	1099	94.0%
13	107.2	263	1188	22.1%	202	1081	91.0%
14	105.3	278	1206	23.0%	198	1062	88.0%
15	103.4	292	1225	23.9%	195	1042	85.1%
16	101.3	305	1243	24.6%	191	1022	82.2%

Table 7.3.7 Power Consumption Calculation for Variable-Speed Pressure Cleaner Booster Pumps Efficiency Level 4

Flow (gpm)	Head (feet)	Power Out (watt)	Power In (watt)	Wire-to-Water Efficiency	Hypothetical Power Out (watt)	Hypothetical Power In (watt)	Percent of Power
8	115.3	174	995	17.5%	174	995	100.0%
9	113.8	193	1012	19.1%	193	1012	100.0%
10	112.3	212	1029	20.6%	212	1029	100.0%
11	110.7	229	1046	21.9%	209	1014	97.0%

12	109.0	246	1063	23.2%	205	999	94.0%
13	107.2	263	1079	24.3%	202	982	91.0%
14	105.3	278	1096	25.3%	198	965	88.0%
15	103.4	292	1113	26.2%	195	947	85.1%
16	101.3	305	1130	27.0%	191	929	82.2%

7.3.1.3 Integral Pumps

For integral pumps, the power value was provided for each representative unit. DOE did not apply a distribution to this value given that integral pumps are designed to be used for specific pools, and therefore the power is not expected to vary widely.

7.3.2 Operating Hours

7.3.2.1 Self-Priming and Non-Self-Priming Pool Filter Pumps

For self-priming and non-self-priming pool filter pumps in residential applications, DOE calculated the single-speed pump run time as:

$$PPOH_i = \frac{V_i \times N^i_{turns}}{Q_i}$$

Where:
$PPOH_i$ = daily pool pump operating hours for consumer i, hr,
V_i = pool volume for consumer i, gallon,
N^i_{turns} = number of turnovers per day for consumer i, and
Q_i = flow rate for consumer i, gpm, (based on the system curve drawn from the distribution listed in Table 7.3.1).

For two-speed and variable-speed pumps, DOE calculated run time at both high speed and low speed, as indicated in Table 7.3.6. For high speed, DOE assumed a maximum of 2 hours a day based on the ENERGY STAR calculator.[8] For low speed, DOE calculated the runtime in the same manner as for single-speed pumps and then subtracted two hours (for assumed high-speed operation). In the case that the high-speed operating hours are below two hours, the low-speed mode was considered not operating. In the two-speed analysis, DOE followed the recommendation of the DPPP Working Group (see Docket EERE-2015-BT-STD-0008-0079 pp. 199-203) and assumed that 5 percent of the consumers either would not purchase or would not correctly operate the timer control to switch from high-speed mode (the default mode) to low-speed mode. For these consumers, high-speed runtime was calculated in the same manner as for single-speed pumps, and low-speed runtime was assumed to be zero.

Table 7.3.8 Daily Operating Hour Calculation for Self-Priming and Non-Self-Priming Pool Filter Pumps

Pump Design	Low-Speed Operating Hours (hr)	High-Speed Operating Hours (hr)
Residential Application		
Single-Speed	$\frac{V_i \times N_{turns}^i}{Q_i}$	
Two-Speed w/ Timer Control Variable-Speed	$\begin{cases} If\ \frac{V_i \times N_{turns}^i}{Q_{high\ speed}^i} < 2, & 0 \\ else, & \frac{V_i \times N_{turns}^i}{Q_{low\ speed}^i} - 2 \end{cases}$	$max(\frac{V_i \times N_{turns}^i}{Q_{high\ speed}^i}, 2)$
Two-Speed w/o Timer Control	0	$\frac{V_i \times N_{turns}^i}{Q_{high\ speed}^i}$
Commercial Application		
Single-Speed	24	
Two-Speed Variable-Speed	22	2

For each equipment class, DOE developed distributions for the number of turnovers per day (i.e., the number of times a pool's contents can be filtered through its filtration equipment in a 24-hour period). Table 7.3.7 provides the probability distributions linked to the type of application and to the ambient condition of the sampled consumer (hot humid, warm or cold) from which the number of turnovers per day is drawn. This distribution was adjusted and approved by the Working Group. (See Docket EERE-2015-BT-STD-0008-0094 pp. 173-186) The assumption of ambient condition linked to the geographic location is shown in Table 7.3.9.

Table 7.3.9 Probability Distribution for Commercial and Residential Applications under Different Ambient Conditions

	Residential			Commercial
	Hot Humid	Warm	Cold	
Number of turnovers/day	**Probability Distribution**			
1	80%	60%	35%	5%
2	15%	35%	60%	5%
3	3%	3%	3%	10%
4	2%	2%	2%	80%

For commercial applications, as shown in Table 7.3.6, DOE assumed that single-speed pumps operate 24 hours a day. (EERE-2015-BT-STD-0008-0094 p. 151) For the two-speed and variable-speed pumps, based on the ENERGY STAR calculator, the high speed was assumed to operate 2 hours per day, while the low speed was assumed to operate the remaining 22 hours per day. (EERE-2015-BT-STD-0008-0094 pp. 172-185)

7.3.2.2 Pressure Cleaner Booster Pumps and Waterfall Pumps

For pressure cleaner booster pumps and waterfall pumps, DOE drew the operating hours from operating hours distributions suggested and approved by the DPPP Working Group (see Docket EERE-2015-BT-STD-0008-0094 pp. 159-162), as listed in Table 7.3.10.

Table 7.3.10 Operating Hour Distributions for Pressure Cleaner Booster Pumps and Waterfall Pumps

Equipment Class	Triangle Distribution (hr)		
	Minimum	**Mode**	**Maximum**
Pressure Cleaner Booster Pumps	2	2.5	3
	Log-Normal Distribution (hr)		
	Location	**Mean**	**Standard Deviation**

Waterfall Pumps (Residential)	0.5	2	2
Waterfall Pumps (Commercial)	2	12	2

7.3.2.3 Integral Pumps

For integral pumps, the DPPP Working Group suggested that 80 percent of the consumers use these pumps without a timer. (See Docket EERE-2015-BT-STD-0008-0094 p. 157) DOE assumed that integral pumps without a timer operate 12 hours per day, based on the recommendation of the DPPP Working Group (see Docket EERE-2015-BT-STD-0008-0094 pp. 155-157). For those that have a timer, DOE calculated the operating hours the same way as for residential single-speed self-priming pool filter pumps.

7.3.3 Annual Days of Operation

DOE calculated the annual unit energy consumption (UEC) by multiplying the daily operating hours by the annual days of operation, which depends on the number of months of pool operation. For each consumer sample, DOE assigned different annual days of operation depending on the region in which the dedicated-purpose pool pump is installed. Table 7.3.11 provides the assumptions of pool pump operating season based on geographic locations. This assignment was based on DOE's Energy Saver website assumptions[9] and PK Data that include average pool season length (i.e., operating months) by state, along with discussion of the geographic distribution of pool operating days by the DPPP Working Group. (See Docket EERE-2015-BT-STD-0008-0094 pp. 191-193)

Table 7.3.11 Ambient Condition and Pool Pump Operating Season Assumptions by Geographical Location

Location (States or Census Divisions)	Ambient Condition Assumption	Avg. Months of Pool Use	Pool Use Months
CT,ME,NH,RI,VT	Cold	4	5/1–8/31
MA	Cold	4	5/1–8/31
NY	Cold	4	5/1–8/31
NJ	Cold	4	5/1–8/31
PA	Cold	4	5/1–8/31
IL	Cold	4	5/1–8/31
IN,OH	Cold	4	5/1–8/31
MI	Cold	4	5/1–8/31
WI	Cold	4	6/1–9/30
IA,MN,ND,SD	Cold	4	6/1–9/30
KS,NE	Cold	4	6/1–9/30
MO	Cold	4	6/1–9/30
VA	Warm	7	4/1–10/31
DE,DC,MD	Warm	5	5/1–9/30
GA	Warm	7	4/1–10/31
NC,SC	Warm	7	4/1–10/31
FL	Hot Humid	12	1/1–12/31
AL,KY,MS	Hot Humid	12	1/1–12/31
TN	Hot Humid	12	1/1–12/31
AR,LA,OK	Warm	12	1/1–12/31
TX	Warm	12	1/1–12/31
CO	Cold	4	5/1–8/31
ID,MT,UT,WY	Cold	4	5/1–8/31
AZ	Warm	12	1/1–12/31
NV,NM	Warm	12	1/1–12/31
CA	Warm	12	1/1–12/31
OR,WA	Warm	3	6/1–8/31
AK	Warm	5	5/1–9/30
HI	Hot Humid	12	1/1–12/31
WV	Hot Humid	5	5/1–9/30
New England	Cold	4	5/1–8/31
Middle Atlantic	Cold	5	5/1–9/30
East North Central	Cold	5	5/1–9/30
West North Central	Cold	4	6/1–9/30
South Atlantic	Hot Humid	12	1/1–12/31
East South Central	Warm	12	1/1–12/31
West South Central	Warm	12	1/1–12/31
Mountain	Cold	4	5/1–8/31
Pacific	Warm	12	1/1–12/31

7.4 SUMMARY OF ENERGY USE RESULTS

This section presents the average annual energy use and the average energy savings for each considered energy efficiency level compared to the baseline energy efficiency for each pool pump equipment class. The LCC and PBP analysis uses the results calculated for each sampled pool. Note that standard-size self-priming pool filter pumps (1.88 hhp), waterfall pumps and pressure cleaner booster pumps have both residential and commercial applications. Therefore, the results listed below reflect the weighted annual energy uses that take into account the applications in both sectors for these equipment classes. The market share of residential and commercial applications (95% for residential and 5% for commercial and community applications) was obtained based on the APSP data[10], RECS 2009 and AHS 2009 data.

Table 7.4.1 through Table 7.4.10 present the average annual energy use and the average energy savings for each considered energy efficiency level compared to the baseline for all the equipment classes.

Table 7.4.1 Annual Energy Consumption for Standard-Size Self-Priming Pool Filter Pumps (0.95 hhp)

EL	Description	Annual Electricity Use	
		Total ***kWh/yr***	**Savings** ***kWh/yr***
0	Low efficiency single-speed motor Low hydro efficiency	4,495	–
1	Medium efficiency single-speed motor Low hydro efficiency	3,582	914
2	High efficiency single-speed motor Low hydro efficiency	3,211	1,284
3	Low efficiency two-speed motor Low hydro efficiency	2,443	2,062
4	Medium efficiency two-speed motor Low hydro efficiency	2,101	2,394
5	High efficiency two-speed motor Low hydro efficiency	1,971	2,524
6	Variable-speed motor Low hydro efficiency (High speed is 80% of max)	1,390	3,105
7	Variable-speed motor High hydro efficiency (High speed is 80% of max)	1,217	3,279

Table 7.4.2 Annual Energy Consumption for Standard-Size Self-Priming Pool Filter Pumps (1.88 hhp)

EL	Description	Annual Electricity Use	
		Total *kWh/yr*	**Savings** *kWh/yr*
0	Low efficiency single-speed motor Low hydro efficiency	6,328	–
1	Medium efficiency single-speed motor Low hydro efficiency	5,706	622
2	High efficiency single-speed motor Low hydro efficiency	5,358	970
3	Low efficiency two-speed motor Low hydro efficiency	3,524	2,803
4	Medium efficiency two-speed motor Low hydro efficiency	3,185	3,142
5	High efficiency two-speed motor Low hydro efficiency	2,761	3,567
6	Variable-speed motor Low hydro efficiency (High speed is 80% of max)	2,137	4,191
7	Variable-speed motor High hydro efficiency (High speed is 80% of max)	1,758	4,570

Table 7.4.3 Annual Energy Consumption for Small-Size Self-Priming Pool Filter Pumps (0.44 hhp)

EL	Description	Annual Electricity Use	
		Total *kWh/yr*	**Savings** *kWh/yr*
0	Low efficiency single-speed motor Low hydro efficiency	1,946	–
1	Medium efficiency single-speed motor Low hydro efficiency	1,553	393
2	High efficiency single-speed motor Low hydro efficiency	1,407	538
3	Low efficiency two-speed motor Low hydro efficiency	1,305	641
4	Medium efficiency two-speed motor Low hydro efficiency	1,136	810
5	High efficiency two-speed motor Low hydro efficiency	1,058	887
6	Variable-speed motor Low hydro efficiency (High speed is 80% of max)	714	1,232
7	Variable-speed motor High hydro efficiency (High speed is 80% of max)	597	1,349

Table 7.4.4 Annual Energy Consumption for Standard-Size Non-Self-Priming Pool Filter Pumps

EL	Description	Annual Electricity Use	
		Total *kWh/yr*	**Savings** *kWh/yr*
0	Low efficiency single-speed motor Low hydro efficiency	1,594	–
1	Medium efficiency single-speed motor Low hydro efficiency	1,271	323
2	High efficiency single-speed motor Low hydro efficiency	1,218	376
3	Low efficiency two-speed motor Low hydro efficiency	1,130	464
4	Medium efficiency two-speed motor Low hydro efficiency	955	639
5	High efficiency two-speed motor Low hydro efficiency	901	693
6	Variable-speed motor Low hydro efficiency (High speed is 80% of max)	501	1,093
7	Variable-speed motor High hydro efficiency (High speed is 80% of max)	369	1,225

Table 7.4.5 Annual Energy Consumption for Extra-Small Non-Self-Priming Pool Filter Pumps

EL	Description	Annual Electricity Use	
		Total *kWh/yr*	**Savings** *kWh/yr*
0	Low efficiency single-speed motor Low hydro efficiency	408	–
1	Medium efficiency single-speed motor Low hydro efficiency	325	83
2	High efficiency single-speed motor Low hydro efficiency	312	96

Table 7.4.6 Annual Energy Consumption for Waterfall Pumps

EL	Description	Annual Electricity Use	
		Total *kWh/yr*	**Savings** *kWh/yr*
0	Low efficiency single-speed motor Low hydro efficiency	539	–
1	Medium efficiency single-speed motor Low hydro efficiency	501	38
2	High efficiency single-speed motor Low hydro efficiency	450	90
3	High efficiency single-speed motor High hydro efficiency	409	131

Table 7.4.7 Annual Energy Consumption for Pressure Cleaner Booster Pumps

EL	Description	Annual Electricity Use	
		Total *kWh/yr*	**Savings** *kWh/yr*
0	Low efficiency single-speed motor Low hydro efficiency	1,218	–
1	Medium efficiency single-speed motor Low hydro efficiency	1,000	218
2	High efficiency single-speed motor Low hydro efficiency	930	288
3	Variable-speed motor Low hydro efficiency	799	418
4	Variable-speed motor High hydro efficiency	727	491

Table 7.4.8 Annual Energy Consumption for Integral Cartridge-Filter Pool Pumps (0.02 hhp)

EL	Description	Annual Electricity Use	
		Total *kWh/yr*	**Savings** *kWh/yr*
0	Without timer	306	–
1	With timer	118	188

Table 7.4.9 Annual Energy Consumption for Integral Cartridge-Filter Pool Pumps (0.18 hhp)

EL	Description	Annual Electricity Use	
		Total *kWh/yr*	**Savings** *kWh/yr*
0	Without timer	922	–
1	With timer	413	510

Table 7.4.10 Annual Energy Consumption for Integral Sand-Filter Pool Pumps

EL	Description	Annual Electricity Use	
		Total *kWh/yr*	**Savings** *kWh/yr*
0	Without timer	278	–
1	With timer	107	171

REFERENCES

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APPENDIX 7A. HOUSEHOLD VARIABLES

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APPENDIX 7A. HOUSEHOLD VARIABLES

7A.1 INTRODUCTION

DOE created a database containing a subset of the records and variables from DOE's Energy Information Administration (EIA)'s 2009 Residential Energy Consumption Survey (RECS 2009) and DOE's Energy Information Administration (EIA)'s 2012 Commercial Building Energy Consumption Survey (CBECS 2012) using Microsoft ACCESS.[1, 2] DOE used this RECS 2009 subset in the life-cycle cost (LCC) analysis of the dedicated-purpose pool pumps rulemaking. This appendix explains the variable name abbreviations and provides definitions of the variable values.

The RECS consists of three parts:

- Personal interviews with households for information about energy used, how it is used, energy-using appliances, structural features, energy efficiency measures, and demographic characteristics of the household.
- Telephone interviews with rental agents for households that have any of their energy use included in their rent. This information augments information collected from those households that may not be knowledgeable about the fuels used for space heating or water heating.
- Mail questionnaires sent to energy suppliers (after obtaining permission from households) to collect the actual billing data on energy consumption and expenditures.

For the entire RECS 2009 dataset, refer to www.eia.gov/consumption/residential/data/2009/index.cfm?view=microdata.

For the entire CBECS 2012 dataset, refer to http://www.eia.gov/consumption/commercial/data/2012/index.cfm?view=microdata.

7A.2 RESIDENTIAL SAMPLE DETERMINATION USING RECS DATA

The subset of RECS 2009 records used in the analysis met the following criterion:

- The household had a swimming pool or spa.

The RECS 2009 weighting indicates how commonly each household configuration occurs in the general population. There are 7.94 million households with a swimming pool according to the RECS 2009 (897 records). From this data, DOE created the subsamples for residential pool pumps consumers.

7A.3 COMMERCIAL SAMPLE DETERMINATION USING CBECS AND RECS DATA

The commercial building sample consists of four parts: 1) community pool in single family household communities; 2) community pool in multi-family household communities; 3) other commercial applications (indoor swimming pools); 4) other commercial applications (outdoor swimming pools).

There is limited data on the building sample associated with pool pumps in commercial applications with the exception of pool pumps in indoor swimming pools listed in CBECS 2012. The subset of CBECS 2012 records used in the analysis for indoor installation met the following criterion:

- The building had a swimming pool.

For the other three commercial subsamples DOE used the total CBECS and RECS weights of households and buildings by census division to estimate the weight of these subsamples by region as follows:

1. For community pool pumps in single-family and multi-family household communities: DOE assumed that there are on average about 250 housing units per shared community pool. DOE estimated that 44% of single family homes and 40% for multi-family homes live in communities with recreational facilities such as a swimming pool based on 2009 American Housing Survey. DOE assumed that half of these have a swimming pool (the weighting of which varies proportionally to the fraction of swimming pools in single family homes per census division, see Table 7A.3.1). In addition, DOE assumed that the fraction of single-family and multi-family community swimming pools with pool pumps is proportional to the fraction in single-family homes by census division (see Table 7A.3.1).
2. For other commercial application swimming pools: for indoor swimming pool samples, DOE only considered commercial buildings that are listed in CBECS 2012 with the primary activities as public assembly, education, and lodging that have a swimming pool. Based on PK Data on the total number of commercial pool pumps (309,000), DOE estimated the number of outdoor swimming pools by subtracting the number of indoor pools from CBECS 2012 samples. Similar to community pools, DOE assumed that the fraction of buildings with swimming pools is similar to that in single family homes by census division (see Table 7A.3.1).

Table 7A.3.1 Fraction of Single-Family Households with a Swimming Pool by Census Division (RECS 2009 Data)

Census Div.	Fraction of Swim Pools*
1	10.9%
2	14.9%
3	7.4%

4	5.0%
5	12.1%
6	8.9%
7	7.9%
8	20.7%
9	11.8%

* For community pools, DOE assumes that the fraction of communities with a recreational facility that has a swimming pool is 50 percent or 5 times more than the 10 percent fraction in single-family homes, so DOE multiplied these fractions by 5 to apply to the community pool weighting. For other commercial application (indoor pools), DOE assumed an 18 percent fraction for commercial properties with a pool, so it multiplied by 1.8.

Table 7A.3.2 summarizes the pool pump consumer subsamples and the estimated fraction of shipments by subsample type.

Table 7A.3.2 Fraction of Dedicated-Purpose Pool Pumps by Subsample Type

Type of Pool	Description	Fraction of Pool Pumps
1	Residential Single Family Swimming Pool	95.1%
2	Community Pools (Single-Family)	0.8%
3	Community Pools (Multi-Family)	0.4%
4	Commercial Indoor Swimming Pools	0.3%
5	Commercial Outdoor Swimming Pools	3.4%

7A.4 IN-GROUND AND ABOVE-GROUND SAMPLE DETERMINATION

Dedicated-purpose pool pumps can be installed with either above-ground or in-ground swimming pools. Although both RECS 2009 and CBECS 2012 weighting indicates how commonly each household configuration occurred in the general population in 2009 or 2012, respectively, there is no indication of the pool type. DOE established separate sets of consumer samples for above-ground and in-ground pools by adjusting the original sample weights based on the number of installed in-ground and above-ground pools in 2014 per state provided by APSP. EERE-2015-BT-STD-0008-0010, No. 31 at pp. 14-15)

The weight scale factor for pool samples for each reportable domain is calculated as follows:

$$Weight\ Scale\ Factor_i^{pool\ type,\ sector} = \frac{Desired\ Fraction_i}{Current\ Fraction_i^{data}}$$

Where
$pool\ type$ = in-ground pools or above-ground pools;
$sector$ = residential or commercial;

$Weight\ Scale\ Factor_i^{pool\ type}$ = weight scale factor for in-ground/above-ground pool samples for reportable domain i (or census division i respectively if for commercial sector);

$Desired\ Fraction_i$ = fraction of in-ground/above-ground pools in reportable domain i compared to national total number of in-ground/above-ground pools in 2014 based on the APSP data;

$data$ = residential sector data (from RECS 2009) or commercial sector data (from CBECS 2012, and RECS 2009 combined with AHS 2009);

$Current\ Fraction_i^{data}$ = fraction of in-ground/above-ground pools in reportable domain i (or census division respectively if for commercial sector) compared to national total number of in-ground/above-ground pools based on residential/commercial sector raw data.

The consumer samples for self-priming, waterfall and pressure cleaner booster pumps are drawn from the in-ground pool samples; the consumer samples for non-self-priming and integral pumps are obtained from the above-ground pool samples.

7A.5 RECS 2009 DATABASE VARIABLE RESPONSE CODES

Table 7A.4.1 lists the variables use in the analysis.

Table 7A.4.1 List of RECS 2009 Variables Used for Residential Pool Pumps

Variable	**Description**
Location Variables	
DIVISION	Census Division
REPORTABLE_DOMAIN	Reportable states and groups of states
HDD65	Heating degree days in 2009, base temperature 65F
Household Characteristics Variables	
NWEIGHT	Final sample weight
DOEID	Unique identifier for each respondent
TYPEHUQ	Type of housing unit
MONEYPY	2009 gross household income
NHSLDMEM	Number of household members
Seniors*	Number of household members age 65 or older
SWIMPOOL	Has a swimming pool
POOL	Has a heated swimming pool

* Not part of RECS 2009 variables.

Table 7A.4.2 provides the response codes for the RECS 2009 variables used in the electric pool pump sample.

Table 7A.4.2 Definitions of RECS 2009 Variables Used in Life-Cycle Cost Analysis

Variable	**Response Codes**	
DIVISION	1	New England Census Division (CT, MA, ME, NH, RI, VT)
	2	Middle Atlantic Census Division (NJ, NY, PA)
	3	East North Central Census Division (IL, IN, MI, OH, WI)
	4	West North Central Census Division (IA, KS, MN, MO, ND, NE, SD)
	5	South Atlantic Census Division (DC, DE, FL, GA, MD, NC, SC, VA, WV)
	6	East South Central Census Division (AL, KY, MS, TN)
	7	West South Central Census Division (AR, LA, OK, TX)
	8	Mountain North Sub-Division (CO, ID, MT, UT, WY)
	9	Mountain South Sub-Division (AZ, NM, NV)
	10	Pacific Census Division (AK, CA, HI, OR, WA)
DOEID	00001 - 12083	Unique identifier for each respondent
HDD65	Heating degree days in 2009, base temperature 65F	
MONEYPY	1	Less than $2,500
	2	$2,500 to $4,999
	3	$5,000 to $7,499
	4	$7,500 to $9,999
	5	$10,000 to $14,999
	6	$15,000 to $19,999
	7	$20,000 to $24,999
	8	$25,000 to $29,999
	9	$30,000 to $34,999
	10	$35,000 to $39,999
	11	$40,000 to $44,999
	12	$45,000 to $49,999
	13	$50,000 to $54,999
	14	$55,000 to $59,999
	15	$60,000 to $64,999
	16	$65,000 to $69,999
	17	$70,000 to $74,999
	18	$75,000 to $79,999
	19	$80,000 to $84,999
	20	$85,000 to $89,999
	21	$90,000 to $94,999
	22	$95,000 to $99,999
	23	$100,000 to $119,999
	24	$120,000 or More
NHSLDMEM	0 - 15	Number of household members
NWEIGHT	Final sample weight	

REPORTABLE_DOMAIN	1	Connecticut, Maine, New Hampshire, Rhode Island, Vermont
	2	Massachusetts
	3	New York
	4	New Jersey
	5	Pennsylvania
	6	Illinois
	7	Indiana, Ohio
	8	Michigan
	9	Wisconsin
	10	Iowa, Minnesota, North Dakota, South Dakota
	11	Kansas, Nebraska
	12	Missouri
	13	Virginia
	14	Delaware, District of Columbia, Maryland, West Virginia
	15	Georgia
	16	North Carolina, South Carolina
	17	Florida
	18	Alabama, Kentucky, Mississippi
	19	Tennessee
	20	Arkansas, Louisiana, Oklahoma
	21	Texas
	22	Colorado
	23	Idaho, Montana, Utah, Wyoming
	24	Arizona
	25	Nevada, New Mexico
	26	California
	27	Alaska, Hawaii, Oregon, Washington
Seniors*	0	No
	1	Yes
TYPEHUQ	1	Mobile Home
	2	Single-Family Detached
	3	Single-Family Attached
	4	Apartment in Building with 2 - 4 Units
	5	Apartment in Building with 5+ Units
SWIMPOOL	0	No
	1	Yes
	-2	Not Applicable
POOL	0	No
	1	Yes
	-2	Not Applicable

* Not part of RECS 2009 variables.

7A.6 CBECS 2012 DATABASE VARIABLE RESPONSE CODES

Table 7A.5.1 lists the variables use in the analysis.

Table 7A.5.1 CBECS 2012 Variables Used for Commercial Pool Pumps

Variable	**Description**
Location Variables	
CENDIV	Census division
HDD65	Heating degree days (base 65)
Household Characteristics Variables	
PUBID	Building identifier
ADJWT	Final full sample building weight
PBA	Principal building activity
OWNTYPE	Building owner
POOL	Indoor pool

Table 7A.5.2 provides the response codes for all CBECS 2012 variables used in the commercial pool pump sample.

Table 7A.5.2 CBECS 2012 Variable Response Codes

Variable	**Response Codes**
PUBID	Unique identifier for each respondent
ADJWT	Final sample weight
CENDIV	01 New England 02 Middle Atlantic 03 East North Central 04 West North Central 05 South Atlantic 06 East South Central 07 West South Central 08 Mountain 09 Pacific
HDD65	Heating degree days in 2003, base temperature 65F
PBA	01 Vacant 02 Office 04 Laboratory 05 Nonrefrigerated warehouse 06 Food sales 07 Public order and safety 08 Outpatient health care 11 Refrigerated warehouse 12 Religious worship 13 Public assembly 14 Education 15 Food service 16 Inpatient health care 17 Nursing 18 Lodging 23 Strip shopping mall

	24 Enclosed mall 25 Retail other than mall 26 Service 91 Other
OWNTYPE	01 Property management company 02 Other corporation/partnership/LLC 03 Religious organization 04 Other non-profit organization 05 Privately-owned school 06 Individual owner 07 Other nongovernment owner 08 Federal government 09 State government 10 Local government
POOL	0 = NO 1 = YES

REFERENCES

1 U.S. Department of Energy: Energy Information Administration, *Residential Energy Consumption Survey (RECS): 2009 RECS Survey Data*, 2009. (Last accessed January 7, 2015.) <www.eia.gov/consumption/residential/data/2009/>

2 U.S. Department of Energy: Energy Information Administration, *2012 Commercial Building Energy Consumption Survey*, *Consumption and Expenditures (CBECS)*, *Public Use Data*, 2015. <www.eia.gov/consumption/commercial/data/2012/index.cfm?view=microdata>

3 P.K. Data Inc., *Pool Pumps Market Data: Custom Compilation for Lawrence Berkeley National Laboratory*, 2015. Duluth, GA.

CHAPTER 8. LIFE-CYCLE COST AND PAYPACK PERIOD ANALYSIS

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CHAPTER 8. LIFE-CYCLE COST AND PAYPACK PERIOD ANALYSIS

8.1 INTRODUCTION

The effect of new or 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 consumers.

- LCC (life-cycle cost) is the total consumer cost of an appliance or product, generally over the life of the appliance or product. The LCC calculation includes total installed cost (product manufacturer selling price, distribution chain markups, sales tax, and installation costs), operating costs (energy, repair, and maintenance costs), product lifetime, and discount rate. Future operating costs are discounted to the time of purchase and summed over the lifetime of the appliance or product.
- PBP (payback period) measures the amount of time it takes consumers to recover the assumed higher purchase price of a more energy-efficient product through reduced operating costs. Inputs to the payback period calculation include the installed cost to the consumer and first-year operating costs.

Inputs to the LCC and PBP analysis of pool pumps 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 are performed with a series of Microsoft Excel spreadsheets that are accessible over the Internet (www1.eere.energy.gov/buildings/appliance_standards/).

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

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

Recognizing that several inputs to the determination of consumer LCC and PBP are either variable or uncertain, DOE conducted the LCC and PBP analysis by modeling both the uncertainty and variability of the inputs using Monte Carlo simulation and probability distributions. Appendix 8B provides a detailed explanation of Monte Carlo simulation and the use of probability distributions. DOE used Microsoft Excel spreadsheets combined with Crystal Ball (a commercially available add-in program) to develop LCC and PBP spreadsheet models that incorporate both Monte Carlo simulation and probability distributions.

In addition to using probability distributions to characterize several of the inputs to the analysis, DOE developed a sample of individual households, communities and buildings that have swimming pools. By developing these samples, DOE was able to calculate the LCC and PBP for each of them to account for the variability in energy consumption and/or energy price associated with a range of households, communities and buildings.

The LCC analysis uses the estimated energy use for each household, community and building as described in the energy use analysis in chapter 7. Energy use of pool pumps is sensitive to climate and therefore varies by location within the United States. Aside from energy use, other important factors influencing the LCC and PBP analysis include energy prices, installation costs, product distribution markups, and sales taxes.

DOE displays the LCC results as distributions of impacts compared to baseline conditions. The distribution of efficiencies without standards is developed for 2021 and reflects the expected distribution of efficiency levels by equipment class. Results, which are presented in section 8.4, are based on 10,000 samples per Monte Carlo simulation run. To illustrate the implications of the analysis, DOE generated a frequency chart that depicts the variation in LCC for each efficiency level being considered. The PBP results are displayed compared to the baseline efficiency level for each 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 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 product divided by the change in annual (first-year) operating cost of the equipment. It represents the number of years that it will take the consumer to recover the increased purchase cost through decreased operating costs. The PBP uses the same inputs as the LCC analysis, except the PBP does not require energy price trends or discount rates. Because the PBP is what is termed a simple payback, the required energy price is only for the year in which a new energy efficiency standard takes effect. The energy price DOE uses in the PBP calculation is the price projected for that year. Discount rates are also not required for calculating the simple PBP.

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, repair and maintenance 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 product meeting existing minimum efficiency (or baseline) standards. The MSP includes a markup that converts the cost of production (*i.e.*, the manufacturer cost) to a MSP.
- *Standard-level manufacturer selling price increase*: The standard-level MSP is the incremental change in MSP associated with producing product at each of the higher efficiency standard levels.
- *Markups and sales tax*: Markups and sales tax are the wholesaler and contractor markups 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 product. The installation cost represents all costs required to install the product but does not

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

The primary inputs for calculating the operating cost are:

- *Product energy consumption*: The equipment energy consumption is the site energy use associated with the use of the pool pump.
- *Energy prices*: Electricity prices are determined using average monthly energy prices.
- *Electricity price trends*: The Energy Information Administration's (EIA's) *Annual Energy Outlook 2016* (*AEO 2016*)[1] is used to forecast energy prices into the future.
- *Repair and maintenance costs*: The labor and material costs associated with repairing or replacing components that have failed. Maintenance costs are associated with maintaining the operation of the equipment.
- *Lifetime*: The age at which the pool pump is 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. In the figure, the grey boxes indicate inputs, the green boxes indicate intermediate outputs, and the yellow boxes indicate final outputs (the LCC and PBP). All of the inputs depicted in Figure 8.1.1 and summarized in Table 8.1.1 are discussed in section 8.2.

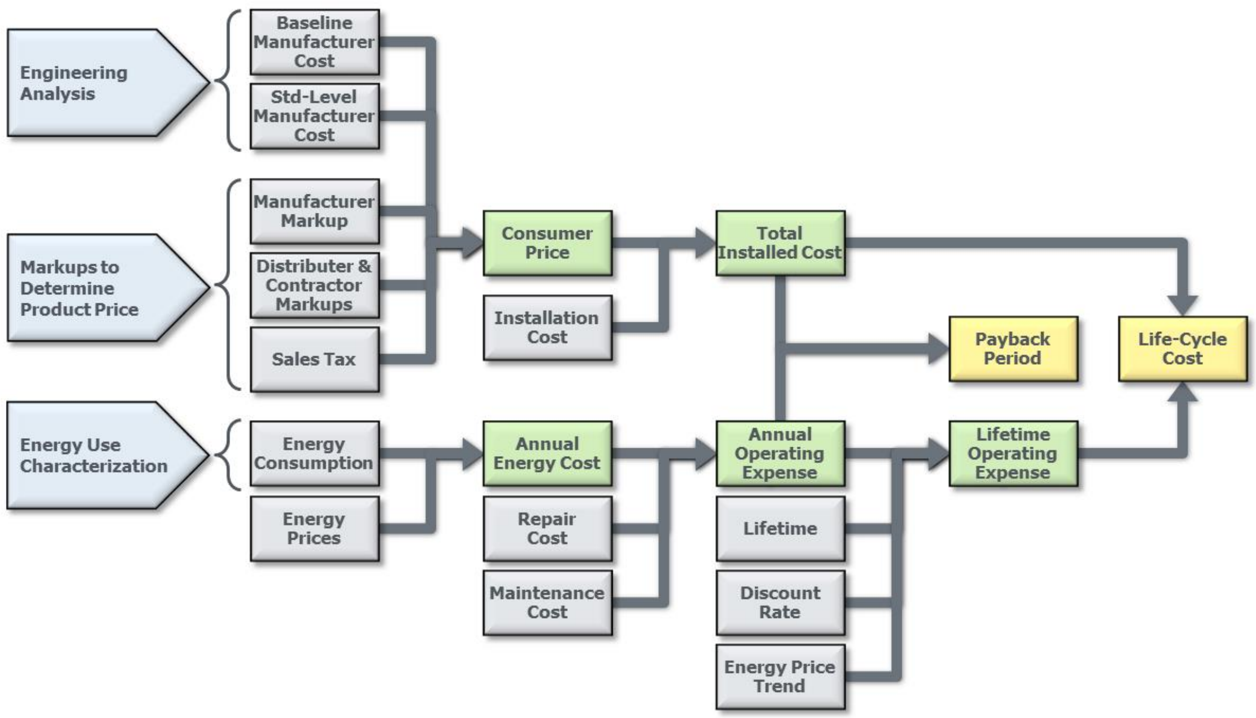

Figure 8.1.1 Flow Diagram of Inputs for the Determination of LCC and PBP

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

Inputs	**Description**
Affecting Installed Costs	
Equipment Cost	Derived from the manufacturer selling price (MSP) for each pool pump equipment class (from the engineering analysis) multiplied by pool wholesaler, pool contractor, pool retailer, and/or pool builder markups plus sales tax (from markups analysis). Used the probability distribution for the different markups to describe the variability.
Installation Cost	Includes incremental installation labor and material cost derived from manufacturer interviews. The total installed cost equals the consumer equipment price (manufacturer cost multiplied by the various markups plus sales tax) plus the incremental installation cost.
Affecting Operating Costs	
Annual Energy Use	See chapter 7.
Energy Prices	Calculated for RECS 2009 households and for CBECS 2012 buildings from monthly marginal average electricity in each of the 30 regions in RECS 2009 and in each of the 9 census divisions in CBECS 2012. Electricity prices were escalated by the *AEO 2016* no-CPP case forecasts to estimate future prices. Escalation was performed at the census division level and aggregated to the regions used in the study.
Repair and Maintenance Cost	Consider only motor replacement as repair cost, which includes labor cost from RS Means and motor cost provided with MPC. Assumed that repair costs would vary for higher efficiency levels.
Affecting Present Value of Annual Operating Cost Savings	
Product Lifetime	For residential applications, on average 7 years for self-priming and waterfall

	pumps, 5 years for non-self-priming and pressure cleaner booster pumps, and 4 years for integral pumps. For commercial applications, the residential equipment lifetime is adjusted according to the ratio of commercial to residential daily operating hours. Variability: Based on Weibull distribution.
Discount Rate	Mean real discount rates ranging from 2.46 percent to 5.88 percent for various classes of consumers based on Federal Reserve Board's *Survey of Consumer Finances*. Probability distributions are used for the discount rates.
Compliance Date	2021

8.1.3 Sample of Pool Pump Users

The LCC and PBP calculations detailed here are for a representative sample of individual pool pump users.

As explained in chapter 7, the Energy Information Administration (EIA)'s 2009 Residential Energy Consumption Survey (RECS 2009)[2] serves as the primary basis for determining the representative pool pump sample. RECS collects energy-related data for occupied primary housing units in the United States. RECS 2009 includes data from 12,083 housing units that represent almost 113.6 million households. In addition, DOE used data from EIA's 2012 Commercial Building Energy Consumption Survey (CBECS 2012) to derive the sample of pool pumps in commercial applications.[3]

Neither RECS nor CBECS provide data on community pools or outdoor swimming pools in commercial applications, so DOE created samples based on other available data. To develop samples for dedicated-purpose pool pumps in single or multi-family communities, DOE used a combination of RECS 2009, U.S. Census 2009 American Home Survey Data (2009 AHS),[4] and 2015 PK Data report.[5] To develop a sample for pool pumps in outdoor commercial swimming pools, DOE used a combination of CBECS 2012 and 2015 PK Data report.

8.2 LIFE-CYCLE COST ANALYSIS INPUTS

The life-cycle cost is the total consumer cost over the life of equipment, including purchase cost and operating costs (which are composed of energy costs, repair and maintenance costs). Future operating costs are discounted to the time of purchase and summed over the lifetime of the equipment. The 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 ($),
IC = total installed cost ($),

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

DOE expresses all costs in 2015$. 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 assumed to be 2021, the assumed effective date of energy conservation standards for pool pumps.

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:

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 product. As discussed in chapter 6, DOE defined three major distribution channels for pool pumps to describe how the equipment passes from the manufacturer to the consumer, which are shown in Table 8.2.1.

Table 8.2.1 Fraction of Dedicated-Purpose Pool Pump Distribution by Channel

Distribution Channel	Fraction of Dedicated-Purpose Pool Pumps %
Replacement for an Existing Pool	
Manufacturer → Wholesaler → Pool Service Contractor → Consumer	75
Manufacturer → Pool Product Retailer → Consumer	20
New Installation for a New Pool	
Manufacturer → Pool Builder → Consumer	5

The remainder of this section provides information about the variables DOE used to calculate the total installed cost for pool pump equipment.

8.2.1.1 Manufacturer Costs

DOE developed manufacturer production costs (MPC) for pool pumps as described in chapter 5, Engineering Analysis. The MPCs at each efficiency level for all the pool pump equipment classes are shown in the following tables. Chapter 5 contains additional details about DOE's cost assumptions and estimates.

Table 8.2.2 Manufacturer Production Cost for Standard-Size Self-Priming Pool Filter Pumps (0.95 hhp) by Efficiency Level

Efficiency Level	Manufacturer Production Cost 2015$	Incremental Cost 2015$
Baseline	$113.00	--
1	$132.00	$19.00
2	$148.00	$35.00
3	$149.00	$36.00
4	$166.00	$53.00
5	$184.00	$71.00
6	$320.23	$207.23
7	$320.23	$207.23

Table 8.2.3 Manufacturer Production Cost for Standard-Size Self-Priming Pool Filter Pumps (1.88 hhp) by Efficiency Level

Efficiency Level	Manufacturer Production Cost 2015$	Incremental Cost 2015$
Baseline	$191.77	--
1	$227.06	$35.29
2	$248.31	$56.54
3	$276.22	$84.45
4	$289.59	$97.82
5	$302.96	$111.19
6	$417.23	$225.46
7	$417.23	$225.46

Table 8.2.4 Manufacturer Production Cost for Small-Size Self-Priming Pool Filter Pumps (0.44 hhp) by Efficiency Level

Efficiency Level	Manufacturer Production Cost 2015$	Incremental Cost 2015$
Baseline	$102.03	--
1	$114.98	$12.95
2	$133.79	$31.76
3	$136.54	$34.51
4	$147.15	$45.12
5	$157.75	$55.72
6	$319.94	$217.91
7	$319.94	$217.91

Table 8.2.5 Manufacturer Production Cost for Standard-Size Non-Self-Priming Pool Filter Pumps by Efficiency Level

Efficiency Level	Manufacturer Production Cost 2015$	Incremental Cost 2015$
Baseline	$69.20	--
1	$73.93	$3.72
2	$87.42	$6.14
3	$91.44	$13.19
4	$105.30	$15.71
5	$119.16	$18.23
6	$296.50	$57.44
7	$296.50	$57.44

Table 8.2.6 Manufacturer Production Cost for Extra-Small Non-Self-Priming Pool Filter Pumps by Efficiency Level

Efficiency Level	Manufacturer Production Cost 2015$	Incremental Cost 2015$

Baseline	$46.88	--
1	$52.88	$6.00
2	$58.88	$12.00

Table 8.2.7 Manufacturer Production Cost for Waterfall Pumps by Efficiency Level

Efficiency Level	Manufacturer Production Cost 2015$	Incremental Cost 2015$
Baseline	$99.81	--
1	$110.47	$10.66
2	$129.62	$29.81
3	$129.62	$29.81

Table 8.2.8 Manufacturer Production Cost for Pressure Cleaner Booster Pumps by Efficiency Level

Efficiency Level	Manufacturer Production Cost 2015$	Incremental Cost 2015$
Baseline	$88.09	--
1	$98.75	$10.66
2	$117.90	$29.81
3	$308.39	$220.30
4	$308.39	$220.30

Table 8.2.9 Manufacturer Production Cost for Integral Cartridge Filter Pumps (0.02 hhp) by Efficiency Level

Efficiency Level	Manufacturer Production Cost 2015$	Incremental Cost 2015$
Baseline	$16.75	--
1	$23.42	$6.67

Table 8.2.10 Manufacturer Production Cost for Integral Cartridge Filter Pumps (0.18 hhp) by Efficiency Level

Efficiency Level	Manufacturer Production Cost 2015$	Incremental Cost 2015$
Baseline	$92.11	--
1	$98.78	$6.67

Table 8.2.11 Manufacturer Production Cost for Integral Sand Filter Pumps by Efficiency Level

Efficiency Level	Manufacturer Production Cost 2015$	Incremental Cost 2015$
Baseline	$56.95	--
1	$63.62	$6.67

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 various market participants, 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).

Based on the percentages of the market attributed to each distribution channel, Table 8.2.12 displays the weighted-average overall markups and their associated components for the baseline and incremental markups.

Table 8.2.12 Summary of Overall Markups for Pool Pumps

Equipment class	Baseline Markup	Incremental Markup
Self-Priming Pool Filter Pumps	3.12	2.03
Non-Self-Priming Pool Filer Pumps	2.88	1.88
Waterfall Pumps	3.12	2.03
Pressure Cleaner Booster Pumps	2.88	1.88
Integral Cartridge Filter Pumps	2.71	1.77
Integral Sand Filter Pumps	2.71	1.77

8.2.1.3 Future Product Prices

Examination of historical price data for certain appliances and equipment that have been subject to energy conservation standards indicates that the assumption of constant real prices and costs may, in many cases, overestimate long-term trends in appliance and equipment prices. Economic literature and historical data suggest that the real costs of these products may in fact trend downward over time according to “learning” or “experience” curves. Desroches et al. (2013) summarizes the data and literature currently available that is relevant to price projections for selected appliances and equipment.[6]

In light of these data and DOE's aim to improve the accuracy and robustness of its analyses, DOE decided to assess future costs by incorporating a price trend over time, consistent with the analysis in the available literature. DOE used this approach to project future prices of pool pumps at the considered efficiency levels.

To project an equipment price trend for pool pumps, DOE derived an inflation-adjusted index of the Producer Price Index (PPI) for pumps and pumping equipment over the period 1984-2015.[a] The PPI data reflect nominal prices, adjusted for product quality changes. The inflation-adjusted (deflated) price index for pumps and pumping equipment is calculated by dividing the PPI series by the Gross Domestic Product Chained Price Index (see Figure 8.2.1). These data show a general price index increase from 1987 through 2009. Since 2009, there has been no clear trend in the price index. Given the relatively slow global economic activity in 2009 through 2015, the extent to which the future trend can be predicted based on the last two decades is uncertain and the observed data do not provide a firm basis for projecting future cost trends for pump equipment. Therefore, for single-speed and two-speed pumps, DOE used a constant price assumption as the default trend to project future pool pump prices in 2021.

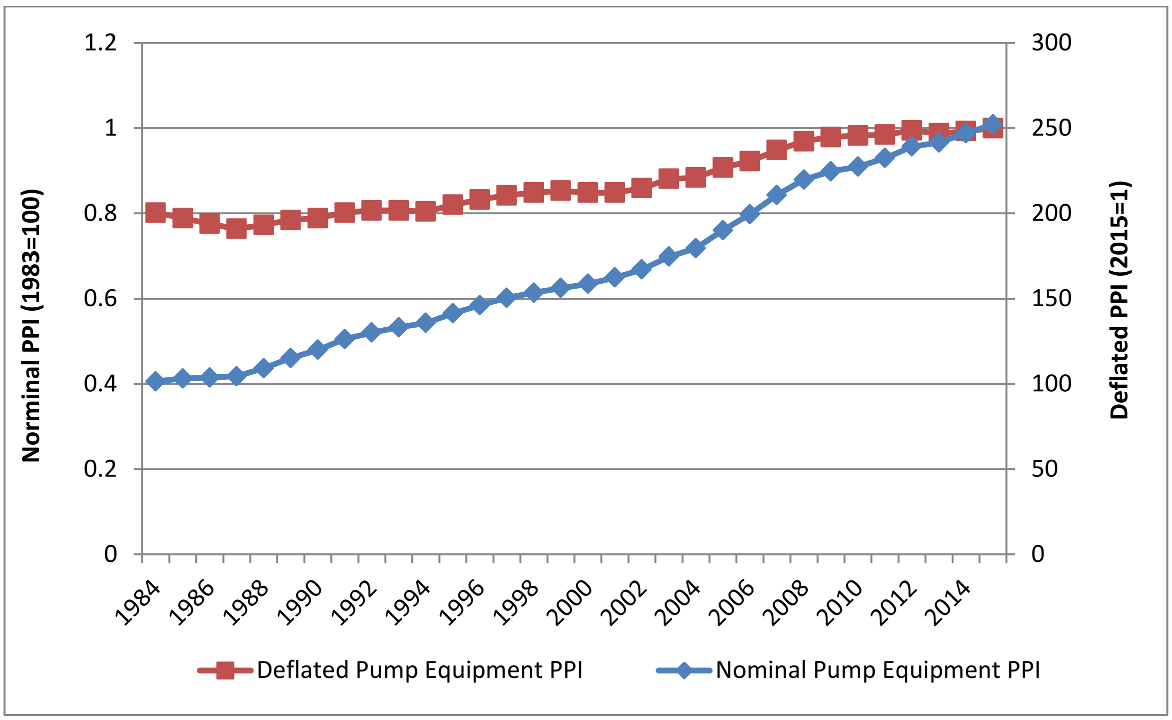

Figure 8.2.1 Historical Nominal and Deflated Producer Price Index for Pumps and Pumping Equipment from 1984 to 2015

For variable-speed pool pumps, however, DOE assumed that the controls portion of the electrically commutated motor would be affected by price learning. DOE used PPI data on

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[a] Series ID PCU333911333911; www.bls.gov/ppi/

“Semiconductors and related device manufacturing” between 1967 and 2015 (shown in Figure 8.2.2) to estimate the historic price trend of electronic components in the control.[b]

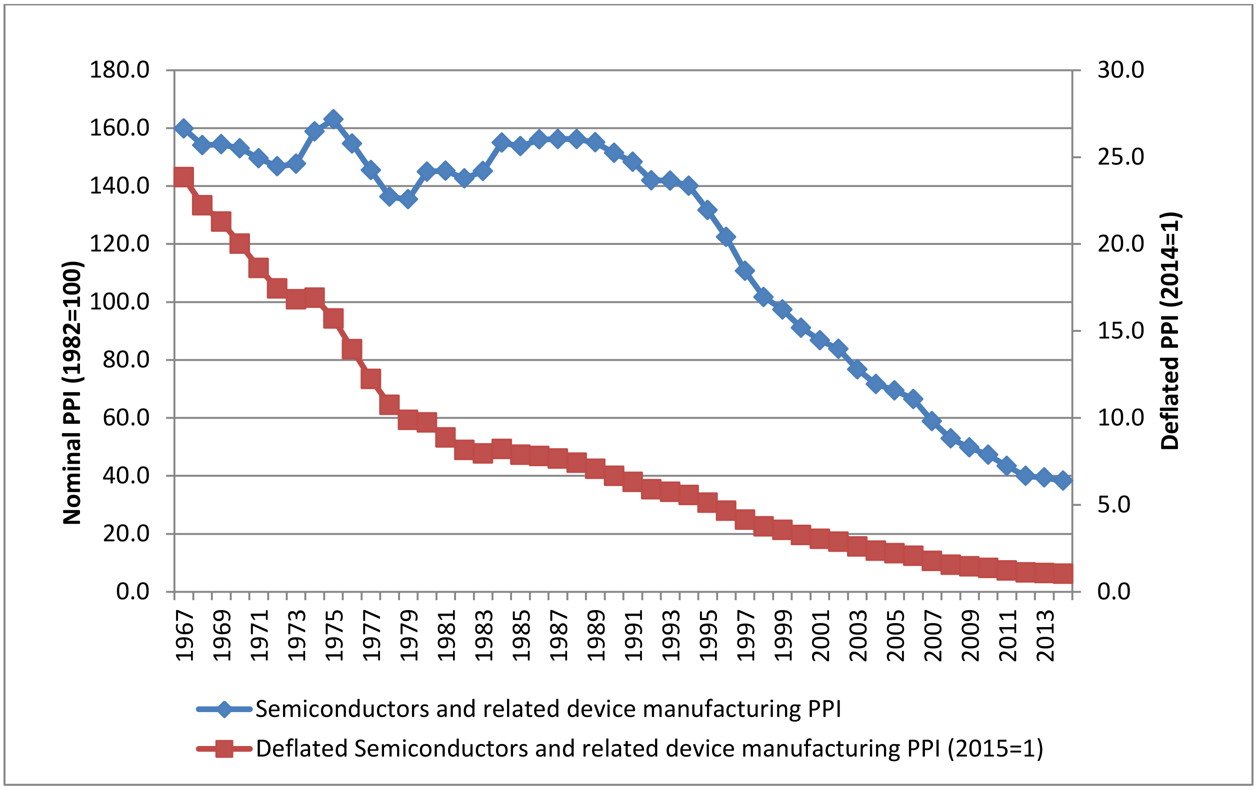

Figure 8.2.2 Historical Nominal and Deflated Producer Price Index for Semiconductors and Related Device Manufacturing from 1967 to 2015

Due to the limited historical shipment data for electronic components in the control, DOE used the aforementioned PPI series to fit to an exponential model having *year* as the explanatory variable. In this case, the exponential function takes the form of:

$$Y = a \cdot e^{bX}$$

where Y is the 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 semiconductor and related device manufacturing PPI versus *year* from 1967 to 2015. See Figure 8.2.3.

[b] Semiconductors and related device manufacturing PPI series ID: PCU334413334413; www.bls.gov/ppi/.

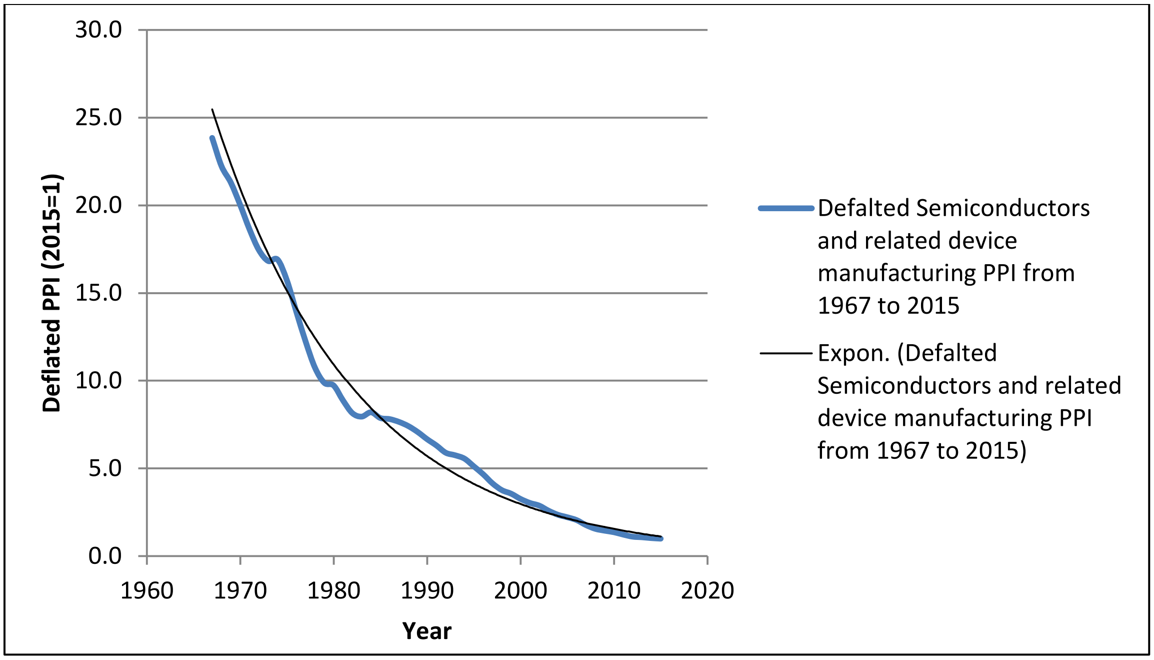

Figure 8.2.3 Relative Price of Semiconductors and Related Device Manufacturing from 1967 to 2015, with Exponential Fit

The regression performed as an exponential fit results in an R-square of 0.98 and a 6.3 percent annual rate of price decline. The final estimated exponential function for electronic components in the control of variable-speed pool pumps is:

$$Y = 8.86 \times 10^{56} \cdot e^{(-0.065)X}$$

For the LCC and PBP analysis, DOE renormalized the price factor index, setting 2015 equal to 1, to estimate the price of controls in variable-speed pool pumps in 2021, which is equal to 0.72. The estimated price forecast indices for both pool pumps and controls in variable-speed pool pumps are shown in Figure 8.2.4.

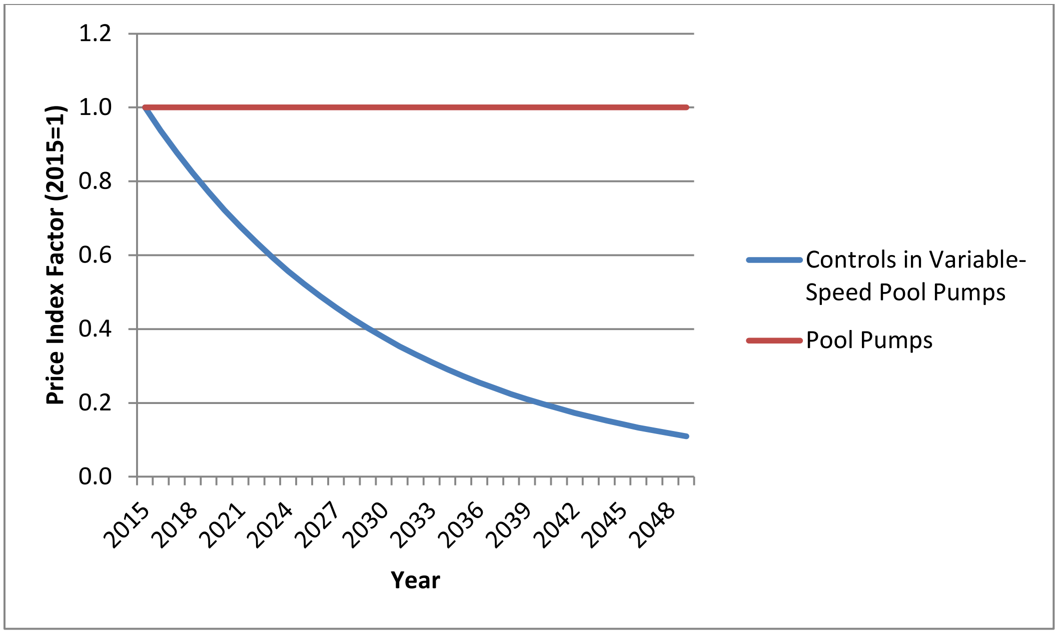

Figure 8.2.4 Price Forecast Indices for Pool Pumps and Controls in Variable-Speed Pool Pumps

8.2.1.4 Total Consumer Price

DOE derived the consumer product price for the baseline equipment by taking the product of the baseline manufacturer cost and the baseline overall markup (including the sales tax) as well as the learning rate in 2021 for the control part of variable-speed pumps. For each efficiency level above the baseline, DOE derived the consumer equipment price by taking the baseline equipment consumer price that account for the control part of variable-speed pumps and adding to it the product of the incremental manufacturer cost and the incremental overall markup (including the sales tax). Markups and sales tax can all 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 8.2.13 through Table 8.2.22 present the average consumer product price for each pool pump equipment class at each efficiency level examined in 2021.

Table 8.2.13 Average Consumer Price for Standard-Size Self-Priming Pool Filter Pumps (0.95 hhp) (2015$) in 2021

Efficiency Level	Average Consumer Price 2015$	Incremental Cost 2015$
Baseline	$354.40	--
1	$393.67	$39.26
2	$426.73	$72.32
3	$428.79	$74.39
4	$463.92	$109.52
5	$501.12	$146.71
6	$712.54	$358.13
7	$712.54	$358.13

Table 8.2.14 Average Consumer Price for Standard-Size Self-Priming Pool Filter Pumps (1.88 hhp) (2015$) in 2021

Efficiency Level	Average Consumer Price 2015$	Incremental Cost 2015$
Baseline	$601.31	--
1	$674.22	$72.91
2	$718.12	$116.81
3	$775.78	$174.47
4	$803.40	$202.09
5	$831.03	$229.71
6	$948.98	$347.67
7	$948.98	$347.67

Table 8.2.15 Average Consumer Price for Small-Size Self-Priming Pool Filter Pumps (0.44 hhp) (2015$) in 2021

Efficiency Level	Average Consumer Price 2015$	Incremental Cost 2015$
Baseline	$320.00	--
1	$346.76	$26.76
2	$385.63	$65.63
3	$391.31	$71.31
4	$413.23	$93.24
5	$435.14	$115.14
6	$700.20	$380.20
7	$700.20	$380.20

Table 8.2.16 Average Consumer Price for Standard-Size Non-Self-Priming Pool Filter Pumps (2015$) in 2021

Efficiency Level	Average Consumer Price 2015$	Incremental Cost 2015$
Baseline	$199.22	--
1	$208.19	$8.98
2	$233.80	$34.58
3	$241.43	$42.21
4	$267.73	$68.52
5	$294.04	$94.83
6	$566.26	$367.05
7	$566.26	$367.05

Table 8.2.17 Average Consumer Price for Extra-Small Non-Self-Priming Pool Filter Pumps (2015$) in 2021

Efficiency Level	Average Consumer Price 2015$	Incremental Cost 2015$
Baseline	$134.96	--
1	$146.35	$11.39
2	$157.74	$22.78

Table 8.2.18 Average Consumer Price for Waterfall Pumps (2015$) in 2021

Efficiency Level	Average Consumer Price 2015$	Incremental Cost 2015$
Baseline	$312.96	--
1	$334.99	$22.02
2	$374.55	$61.59
3	$374.55	$61.59

Table 8.2.19 Average Consumer Price for Pressure Cleaner Booster Pumps (2015$) in 2021

Efficiency Level	Average Consumer Price 2015$	Incremental Cost 2015$
Baseline	$255.40	--
1	$275.77	$20.36
2	$312.35	$56.95
3	$611.45	$356.05
4	$611.45	$356.05

Table 8.2.20 Average Consumer Price for Integral Cartridge Filter Pumps (0.02 hhp) (2015$) in 2021

Efficiency Level	Average Consumer Price 2015$	Incremental Cost 2015$
Baseline	$45.36	--
1	$57.27	$11.91

Table 8.2.21 Average Consumer Price for Integral Cartridge Filter Pumps (0.18 hhp) (2015$) in 2021

Efficiency Level	Average Consumer Price 2015$	Incremental Cost 2015$
Baseline	$249.46	--
1	$261.37	$11.91

Table 8.2.22 Average Consumer Price for Integral Sand Filter Pumps (2015$) in 2021

Efficiency Level	Average Consumer Price 2015$	Incremental Cost 2015$
Baseline	$154.23	--
1	$166.14	$11.91

8.2.1.5 Installation Cost

The installation cost is the cost to the consumer of installing a pool pump. The cost of installation covers all labor and material costs associated.

For two-speed pumps, DOE included the cost of a timer control and its installation where applicable. As recommended by the DPPP Working Group (see Docket EERE-2015-BT-STD-0008-0079 pp. 199-203), DOE assumed that 5 percent of the consumers would not purchase the timer control to switch from high-speed mode (the default mode) to low-speed mode. DOE used information obtained in the manufacturer interviews to calculate the supplemental installation labor costs for two-speed and variable-speed pumps.

Table 8.2.23 shows the incremental installation cost for each pool pump equipment class with different design options. To simplify the calculation, DOE only accounted for the difference in installation cost by efficiency levels. Those equipment classes that are not listed are considered to have the same installation cost for all the efficiency levels. For those efficiency levels that are not mentioned for the listing equipment classes, the installation costs are considered equal and not accounted in this analysis.

Table 8.2.23 Incremental Installation Cost for Dedicated-Purpose Pool Pumps

Equipment class	Efficiency Level	Design Option	Incremental Installation Cost 2015$
Self-Priming Pool Filter Pump	3,4,5	Two-speed w/ Timer	$160
		Two-speed wo/ Timer	$20
	6,7	Variable-speed	$20
Non-Self Priming Pool Filter Pump	3,4,5	Two-speed w/ Timer	$150
		Two-speed wo/ Timer	$10
	6,7	Variable-speed	$10
Pressure Cleaner Booster Pump	3,4	Variable-speed	$20

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 8.2.24 through Table 8.2.33 present the average total installed cost for each pool pump equipment class at each efficiency level examined.

Table 8.2.24 Average Total Installed Cost for Standard-Size Self-Priming Pool Filter Pumps (0.95 hhp) (2015$) in 2021

Efficiency Level	Average Total Installed Cost 2015$	Incremental Cost 2015$
Baseline	$354.40	--
1	$393.67	$39.26
2	$426.73	$72.32
3	$582.09	$227.68
4	$617.22	$262.81
5	$654.41	$300.01
6	$732.54	$378.13
7	$732.54	$378.13

Table 8.2.25 Average Total Installed Cost for Standard-Size Self-Priming Pool Filter Pumps (1.88 hhp) (2015$) in 2021

Efficiency Level	Average Total Installed Cost 2015$	Incremental Cost 2015$
Baseline	$601.31	--
1	$674.22	$72.91
2	$718.12	$116.81
3	$929.08	$327.76
4	$956.70	$355.38
5	$984.32	$383.01
6	$968.98	$367.67
7	$968.98	$367.67

Table 8.2.26 Average Total Installed Cost for Small-Size Self-Priming Pool Filter Pumps (0.44 hhp) (2015$) in 2021

Efficiency Level	Average Total Installed Cost 2015$	Incremental Cost 2015$
Baseline	$320.00	--
1	$346.76	$26.76
2	$385.63	$65.63
3	$544.60	$224.60
4	$566.53	$246.53
5	$588.43	$268.43
6	$720.20	$400.20
7	$720.20	$400.20

Table 8.2.27 Average Total Installed Cost for Standard-Size Non-Self-Priming Pool Filter Pumps (2015$) in 2021

Efficiency Level	Average Total Installed Cost 2015$	Incremental Cost 2015$
Baseline	$199.22	--
1	$208.19	$8.98
2	$233.80	$34.58
3	$384.72	$185.51
4	$411.03	$211.81
5	$437.34	$238.12
6	$576.26	$377.05
7	$576.26	$377.05

Table 8.2.28 Average Total Installed Cost for Extra-Small Non-Self-Priming Pool Filter Pumps (2015$) in 2021

Efficiency Level	Average Total Installed Cost 2015$	Incremental Cost 2015$
Baseline	$134.96	--
1	$146.35	$11.39
2	$157.74	$22.78

Table 8.2.29 Average Total Installed Cost for Waterfall Pumps (2015$) in 2021

Efficiency Level	Average Total Installed Cost 2015$	Incremental Cost 2015$
Baseline	$312.96	--
1	$334.99	$22.02
2	$374.55	$61.59
3	$374.55	$61.59

Table 8.2.30 Average Total Installed Cost for Pressure Cleaner Booster Pumps (2015$) in 2021

Efficiency Level	Average Total Installed Cost 2015$	Incremental Cost 2015$
Baseline	$255.40	--
1	$275.77	$20.36
2	$312.35	$56.95
3	$631.45	$376.05
4	$631.45	$376.05

Table 8.2.31 Average Total Installed Cost for Integral Cartridge Filter Pumps (0.02 hhp) (2015$) in 2021

Efficiency Level	Average Total Installed Cost 2015$	Incremental Cost 2015$
Baseline	$45.36	--
1	$57.27	$11.91

Table 8.2.32 Average Total Installed Cost for Integral Cartridge Filter Pumps (0.18 hhp) (2015$) in 2021

Efficiency Level	Average Total Installed Cost 2015$	Incremental Cost 2015$
Baseline	$249.46	--
1	$261.37	$11.91

Table 8.2.33 Average Total Installed Cost for Integral Sand Filter Pumps (2015$) in 2021

Efficiency Level	Average Total Installed Cost 2015$	Incremental Cost 2015$
Baseline	$154.23	--
1	$166.14	$11.91

8.2.2 Operating Cost Inputs

DOE defines the operating cost by the following equation:

$$OC = EC + RC + MC$$

Eq. 8.3

Where:

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

The remainder of this section provides information about the variables that DOE used to calculate the operating cost for pool pumps. The annual energy costs of the equipment are computed from energy consumption per unit for the baseline (efficiency level 0) and standard-compliant cases (efficiency level 1, 2, 3, and so on), 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 key equipment class, DOE calculated the annual energy use savings for each sample pool user at each efficiency level as described in chapter 7.

8.2.2.2 Energy Prices

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

<u>Derivation of Average and Marginal Monthly Prices</u>

EIA Data – Derivation of Average Annual Electricity Prices. DOE derived 2015 annual electricity prices from EIA Form 826 data.[7] The EIA Form 826 data include electricity prices by State. DOE calculated annual residential and commercial electricity prices for each RECS region or CBECS region by averaging monthly energy prices by State to get State electricity prices.

For areas with more than one State, DOE weighted each State's average energy price by its number of households in 2021. See appendix 8C for the calculated annual energy prices in 2015.

EIA Data – Derivation of Average Monthly Electricity Factors. To determine monthly prices for use in the analysis, DOE developed monthly electricity price factors based on long-term price data. See appendix 8C for a description of the method. DOE multiplied the average 2015 annual prices by the monthly price factors to derive electricity prices for each month.

EIA Data – Seasonal Electricity Marginal Price Factors. Monthly electricity prices were adjusted using seasonal marginal price factors to determine monthly marginal electricity prices. These marginal electricity prices are used to determine the cost to the consumer of the change in energy consumed. For a detailed discussion of the development of marginal energy price factors and for a comparison to other data and methods, see appendix 8C.

Table 8.2.34 presents the residential marginal monthly electricity prices derived for 2015 (in 2015$).

Table 8.2.34 Residential Marginal Monthly Electricity Prices for 2015 Using Marginal Price Factors (2015$/kWh)

Geographical Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Connecticut, Maine, New Hampshire, Rhode Island, Vermont	0.183	0.186	0.187	0.170	0.172	0.172	0.169	0.170	0.170	0.172	0.188	0.186
Massachusetts	0.210	0.213	0.213	0.169	0.170	0.173	0.167	0.170	0.172	0.169	0.211	0.218
New York	0.170	0.173	0.172	0.192	0.196	0.203	0.206	0.205	0.204	0.200	0.176	0.173
New Jersey	0.140	0.141	0.142	0.169	0.173	0.185	0.190	0.189	0.185	0.171	0.144	0.144
Pennsylvania	0.105	0.106	0.108	0.138	0.144	0.149	0.149	0.148	0.146	0.144	0.111	0.109
Illinois	0.075	0.079	0.081	0.112	0.116	0.115	0.115	0.113	0.114	0.114	0.082	0.076
Indiana, Ohio	0.079	0.081	0.084	0.123	0.127	0.128	0.126	0.126	0.126	0.126	0.088	0.083
Michigan	0.123	0.124	0.124	0.151	0.154	0.159	0.161	0.162	0.157	0.154	0.126	0.126
Wisconsin	0.115	0.117	0.118	0.138	0.140	0.142	0.139	0.139	0.141	0.140	0.121	0.118
Iowa, Minnesota, North Dakota, South Dakota	0.088	0.090	0.092	0.123	0.128	0.134	0.134	0.134	0.131	0.127	0.094	0.091
Kansas, Nebraska	0.073	0.076	0.078	0.126	0.130	0.139	0.141	0.142	0.140	0.129	0.081	0.076
Missouri	0.066	0.068	0.071	0.124	0.140	0.151	0.150	0.149	0.136	0.126	0.074	0.069
Virginia	0.082	0.084	0.086	0.116	0.121	0.123	0.124	0.124	0.122	0.119	0.088	0.084
Delaware, District of Columbia, Maryland	0.113	0.113	0.115	0.136	0.146	0.156	0.154	0.154	0.152	0.143	0.119	0.117
Georgia	0.087	0.089	0.092	0.125	0.130	0.139	0.141	0.142	0.136	0.128	0.091	0.087
North Carolina, South Carolina	0.089	0.091	0.093	0.110	0.110	0.108	0.110	0.111	0.112	0.114	0.096	0.092
Florida	0.104	0.105	0.106	0.117	0.116	0.115	0.116	0.117	0.117	0.117	0.108	0.106
Alabama, Kentucky, Mississippi	0.082	0.084	0.087	0.106	0.107	0.107	0.106	0.107	0.106	0.107	0.090	0.086
Tennessee	0.081	0.081	0.083	0.094	0.096	0.094	0.093	0.093	0.093	0.097	0.088	0.085
Arkansas, Louisiana, Oklahoma	0.063	0.065	0.068	0.092	0.094	0.096	0.096	0.097	0.098	0.097	0.069	0.065
Texas	0.094	0.095	0.098	0.110	0.112	0.116	0.116	0.116	0.115	0.114	0.100	0.098
Colorado	0.091	0.093	0.094	0.130	0.133	0.136	0.135	0.135	0.135	0.133	0.096	0.093
Idaho, Montana, Utah, Wyoming	0.091	0.092	0.092	0.109	0.113	0.116	0.118	0.117	0.115	0.114	0.095	0.094
Arizona	0.085	0.088	0.090	0.119	0.131	0.130	0.129	0.128	0.128	0.127	0.090	0.092
Nevada, New Mexico	0.102	0.105	0.106	0.127	0.126	0.124	0.124	0.124	0.125	0.128	0.109	0.106
California	0.180	0.176	0.174	0.185	0.198	0.203	0.208	0.208	0.201	0.187	0.181	0.183
Oregon, Washington	0.082	0.084	0.084	0.078	0.079	0.080	0.080	0.081	0.081	0.081	0.086	0.085
Alaska	0.167	0.168	0.173	0.165	0.171	0.171	0.174	0.172	0.169	0.170	0.177	0.174
Hawaii	0.265	0.265	0.265	0.333	0.338	0.342	0.344	0.347	0.345	0.349	0.279	0.278
West Virginia	0.078	0.079	0.081	0.093	0.095	0.093	0.092	0.093	0.094	0.096	0.084	0.080

Table 8.2.35 Commercial Marginal Monthly Electricity Prices for 2015 Using Marginal Price Factors (2015$/kWh)

Census Division	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
New England	0.169	0.173	0.170	0.153	0.152	0.159	0.160	0.159	0.160	0.155	0.166	0.171
Middle Atlantic	0.132	0.133	0.132	0.161	0.165	0.176	0.180	0.179	0.176	0.169	0.133	0.132
East North Central	0.066	0.069	0.069	0.103	0.104	0.105	0.105	0.106	0.104	0.105	0.069	0.068
West North Central	0.051	0.052	0.053	0.134	0.144	0.156	0.158	0.158	0.147	0.136	0.053	0.052
South Atlantic	0.071	0.073	0.073	0.094	0.094	0.094	0.095	0.096	0.095	0.095	0.073	0.072
East South Central	0.063	0.064	0.065	0.101	0.102	0.102	0.101	0.102	0.101	0.102	0.066	0.065
West South Central	0.050	0.051	0.051	0.080	0.081	0.082	0.082	0.082	0.081	0.081	0.050	0.050
Mountain	0.095	0.097	0.097	0.114	0.119	0.123	0.121	0.121	0.121	0.120	0.099	0.097
Pacific	0.110	0.113	0.112	0.236	0.249	0.277	0.292	0.289	0.283	0.272	0.119	0.113

Energy Price Trends by Census Division

To arrive at prices in future years, DOE multiplied the recent electricity prices by a projection of annual national-average residential electricity prices consistent with cases described on p. E-8 in *AEO 2016*.[c] DOE applies the projected energy price trends from 2015 to 2040 for each of the nine census divisions to each household in the sample based on the household's location. Figure 8.2.3 shows the national residential energy price factors. To estimate the trend after 2040, DOE used the average rate of change during 2030–2040. For more details, see appendix 8C.

c The standards finalized in this rulemaking will take effect a few years prior to the 2022 commencement of the Clean Power Plan compliance requirements. As DOE has not modeled the effect of CPP during the 30-year analysis period of this rulemaking, there is some uncertainty as to the magnitude and overall effect of the energy efficiency standards. These energy efficiency standards are expected to put downward pressure on energy prices relative to the projections in the AEO 2016 case that incorporates the CPP. Consequently, DOE used the electricity price projections found in the AEO 2016 No-CPP case as these electricity price projections are expected to be lower, yielding more conservative estimates for consumer savings due to the energy efficiency standards.

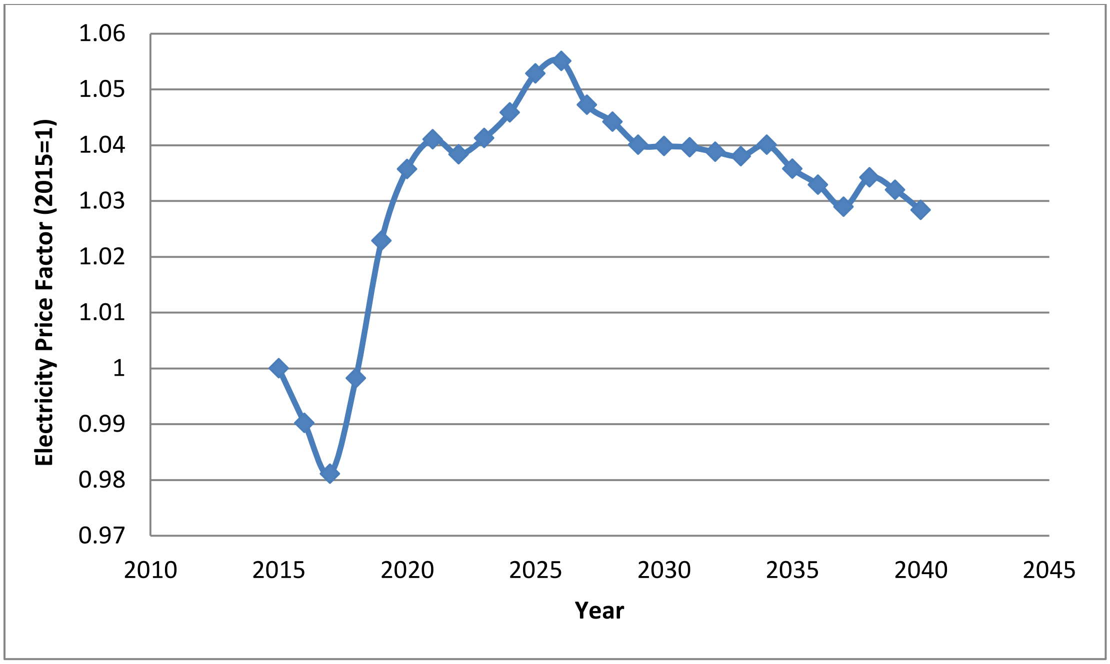

Figure 8.2.5 Projected National Residential Electricity Price Factors, 2015-2040

8.2.2.3 Maintenance and Repair Costs

The maintenance cost is the routine cost to the consumer of maintaining equipment operation. DOE assumed that for all the equipment classes of pool pumps, there is no change in maintenance with efficiency level, and therefore DOE did not include those costs in the model.

The repair cost is the cost to the consumer for replacing or repairing components in the pool pump that have failed (such as the heating element, controls, or condenser fan, or compressor). The primary repair cost for dedicated-purpose pool pumps is motor replacement, and cost of a motor does vary by efficiency level. DOE estimated that such replacement occurs at the halfway point in a pump's lifetime, but only for those dedicated-purpose pool pumps whose lifetime exceeds the average lifetime for the relevant equipment class. The cost of the motor was determined in the engineering analysis and the markups analysis. DOE used 2015 RS Means,[8] a well-known and respected construction cost estimation source, to estimate labor costs for pump motor replacement at each considered efficiency level.

RS Means 2015 Regional Labor Costs

DOE used regional material and labor costs to more accurately estimate repair costs by region. RS Means provides average national labor costs as shown in Table 8.2.36. Bare costs are given in RS Means, and overhead and profit (O&P) labor costs are the bare costs multiplied by the RS Means markups. DOE accounted for the difference in labor hours depending on the pool pump horsepower.

Table 8.2.36 RS Means 2015 Electrical Facilities Maintenance National Average Labor Cost

Motors and Generators	Crew	Labor Hours hr	Total Labor Cost (2015$)	
			Bare Costs 2015$	Incl. O & P 2015$
Replace part, up to ¼ HP	1 Electrician	1.333	73.00	109.00
Replace part, up to ¾ HP	1 Electrician	2	109.00	164.00

RS Means also provides material and labor cost factors for 295 cities and towns in the U.S. To derive average labor cost values by State, DOE weighted the material and labor cost factors by 2021 population projections. DOE used the material and labor cost factors for cost associated with electrician. Table 8.2.37 shows the final regional labor price factors used in the analysis by geographical area for residential pool pump motor replacement, and Table 8.2.38 shows the factors by Census division for pool pump motor replacement for community pools and commercial buildings.

Table 8.2.37 Labor Cost Price Factors by Geographical Area (for RECS 2009 Sample)

Geographical Area	Electrician
	Labor
Connecticut, Maine, New Hampshire, Rhode Island, Vermont	0.99
Massachusetts	1.16
New York	1.68
New Jersey	1.37
Pennsylvania	1.25
Illinois	1.27
Indiana, Ohio	0.89
Michigan	0.99
Wisconsin	0.95
Iowa, Minnesota, North Dakota, South Dakota	0.91
Kansas, Nebraska	0.77
Missouri	0.95
Virginia	0.71
Delaware, District of Columbia, Maryland	0.97
Georgia	0.69
North Carolina, South Carolina	0.48
Florida	0.68
Alabama, Kentucky, Mississippi	0.69
Tennessee	0.63
Arkansas, Louisiana, Oklahoma	0.62
Texas	0.61
Colorado	0.84
Idaho, Montana, Utah, Wyoming	0.70
Arizona	0.66
Nevada, New Mexico	0.93
California	1.21
Oregon, Washington	0.97
Alaska	1.17
Hawaii	1.27
West Virginia	0.90

Table 8.2.38 Labor Cost Price Factors by Census Division (for CBECS 2012 Sample)

Census Division	Electrician Labor
New England	1.07
Middle Atlantic	1.48
East North Central	1.02
West North Central	0.89
South Atlantic	0.68
East South Central	0.67
West South Central	0.62
Mountain	0.77
Pacific	1.16

Table 8.2.39 through Table 8.2.45 show the repair cost estimates for each pool pump equipment class and efficiency level except integral pumps. DOE assumed that for the three integral pump equipment classes, there is no change in repair cost with efficiency level, and therefore DOE did not include those costs in the model.

Table 8.2.39 Average Total Repair Cost for Standard-Size Self-Priming Pool Filter Pumps (0.95 hhp) (2015$) in 2021

Efficiency Level	Average Repair Cost 2015$	Incremental Cost 2015$
Baseline	$134.77	--
1	$151.05	$16.28
2	$164.76	$29.99
3	$165.62	$30.85
4	$180.19	$45.42
5	$195.61	$60.84
6	$299.33	$164.57
7	$299.33	$164.57

Table 8.2.40 Average Total Repair Cost for Standard-Size Self-Priming Pool Filter Pumps (1.88 hhp) (2015$) in 2021

Efficiency Level	Average Total Repair Cost 2015$	Incremental Cost 2015$
Baseline	$220.08	--
1	$250.40	$30.32
2	$268.66	$48.57
3	$292.44	$72.35
4	$303.91	$83.83
5	$315.39	$95.31
6	$395.47	$175.39
7	$395.47	$175.39

Table 8.2.41 Average Total Repair Cost for Small-Size Self-Priming Pool Filter Pumps (0.44 hhp) (2015$) in 2021

Efficiency Level	Average Total Repair Cost 2015$	Incremental Cost 2015$
Baseline	$102.23	--
1	$113.32	$11.10
2	$129.44	$27.22
3	$131.80	$29.57
4	$140.89	$38.67
5	$149.98	$47.75
6	$277.09	$174.86
7	$277.09	$174.86

Table 8.2.42 Average Total Repair Cost for Standard-Size Non-Self-Priming Pool Filter Pumps (2015$) in 2021

Efficiency Level	Average Total Repair Cost 2015$	Incremental Cost 2015$
Baseline	$103.06	--
1	$106.74	$3.68
2	$117.23	$14.17
3	$120.35	$17.29
4	$131.13	$28.07
5	$141.90	$38.85
6	$265.74	$162.69
7	$265.74	$162.69

Table 8.2.43 Average Total Repair Cost for Extra-Small Non-Self-Priming Pool Filter Pumps (2015$) in 2021

Efficiency Level	Average Total Repair Cost 2015$	Incremental Cost 2015$
Baseline	$62.12	--
1	$66.78	$4.67
2	$71.45	$9.33

Table 8.2.44 Average Total Repair Cost for Waterfall Pumps (2015$) in 2021

Efficiency Level	Average Total Repair Cost 2015$	Incremental Cost 2015$
Baseline	$126.21	--
1	$135.38	$9.18
2	$151.86	$25.66
3	$151.86	$25.66

Table 8.2.45 Average Total Repair Cost for Pressure Cleaner Booster Pumps (2015$) in 2021

Efficiency Level	Average Total Repair Cost 2015$	Incremental Cost 2015$
Baseline	$118.44	--
1	$126.58	$8.15
2	$142.88	$24.45
3	$287.33	$168.89
4	$287.33	$168.89

8.2.2.4 Lifetime

DOE defines lifetime as the age when a product is retired from service. DOE used lifetime estimates from manufacturer input and the DPPP Working Group’s discussion (see Docket EERE-2015-BT-STD-0008-0094 pp. 209-223) to calculate the distribution of pool pump lifetimes.

Table 8.2.46 shows the Weibull distribution parameters alpha, beta and the location for all the equipment classes and design options of pool pumps. More details can be found in appendix 8D.

Table 8.2.46 Lifetime Parameters for Dedicated-Purpose Pool Pumps

Equipment Class	Design Option	Weibull Parameters			Mean Lifetime (years)
		Alpha (scale)	Beta (shape)	Location (delay)	
Self-Priming Pool Filter Pump	Single Speed Two Speed	5.90	3.20	2.00	7.3
	Variable Speed	4.80	3.00	3.00	7.3
Non-Self Priming Pool Filter Pump	Single Speed Two Speed	3.65	2.90	2.00	5.3
	Variable Speed	2.55	2.99	3.00	5.3
Waterfall Pump	Single Speed	5.90	3.20	2.00	7.3
Pressure Cleaner Booster Pump	Single Speed	3.70	3.00	2.00	5.3
	Variable Speed	2.60	2.99	3.00	5.3
Integral Pump	Single Speed	2.50	3.00	2.00	4.2

8.2.2.5 Discount Rates

The discount rate is the rate at which future expenditures and savings are discounted to establish their present value. DOE estimates discount rates separately for residential and commercial end users. For residential end users, DOE calculates discount rates as the weighted average real interest rate across consumer debt and equity holdings. For commercial end users, DOE calculates commercial discount rates as the weighted average cost of capital (WACC), using the Capital Asset Pricing Model (CAPM).

Discount Rates for Residential Applications

The consumer discount rate is the rate at which future operating costs of residential products 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 in order to calculate the estimated net life-cycle cost of products of various efficiency levels and the life-cycle cost savings of higher-efficiency models as compared to the baseline for a representative sample of consumers.

DOE calculates the consumer discount rate using publicly available data (the Federal Reserve Board's *Survey of Consumer Finance*s (SCF)) to estimate a consumer's required rate of return or opportunity cost of funds related to appliances. In the economics literature, opportunity cost reflects potential foregone benefit resulting from choosing one option over another. Opportunity cost of capital refers to the rate of return that one could earn by investing in an alternate project with similar risk; similarly, opportunity cost may be defined as the cost associated with opportunities that are foregone when resources are not put to their highest-value use.

DOE's method views the purchase of a higher efficiency appliance as an investment that yields a stream of energy cost savings. The stream of savings is discounted at a rate reflecting (1) the rates of return associated with other investments available to the consumer, and (2) the observed costs of credit options available to the consumer to reflect the value of avoided debt. DOE notes that the LCC does not analyze the appliance purchase decision, so the implicit discount rate is not relevant in this model. The LCC estimates net present value over the lifetime of the product, so the appropriate discount rate will reflect the general opportunity cost of household funds, taking this time scale into account.

Given the long time horizon modeled in the LCC, the application of a marginal interest rate associated with an initial source of funds is inaccurate. Regardless of the method of purchase, consumers are expected to continue to rebalance their debt and asset holdings over the LCC analysis period, based on the restrictions consumers face in their debt payment requirements and the relative size of the interest rates available on debts and assets. DOE estimates the aggregate impact of this rebalancing using the historical distribution of debts and assets. The discount rate is the rate at which future savings and expenditures are discounted to establish their present value.

As shown in Table 8.2.47, DOE estimates separate discount rate distributions for six income groups, divided based on income percentile as reported in the SCF.[9] This disaggregation reflects the fact that low and high income consumers tend to have substantially different shares of debt and asset types, as well as facing different rates on debts and assets. Summaries of shares and rates presented in this chapter are averages across the entire population.

Table 8.2.47 Definitions of Income Groups

Income Group	Percentile of Income
1	1st to 20th
2	21st to 40th
3	41st to 60th
4	61st to 80th
5	81st to 90th
6	91th to 99th

Sources: Federal Reserve Board. *Survey of Consumer Finances (SCF)* for 1995, 1998, 2001, 2004, 2007, 2010, 2013.

Shares of Debt and Asset Classes

DOE's approach involved identifying all household debt or asset classes in order to approximate a consumer's opportunity cost of funds over the product's lifetime. This approach assumes that in the long term, consumers are likely to draw from or add to their collection of debt and asset holdings approximately in proportion to their current holdings when future expenditures are required or future savings accumulate. DOE now includes several previously excluded debt types (*i.e.*, vehicle and education loans, mortgages, all forms of home equity loan) in order to better account for all of the options available to consumers.

The average share of total debt plus equity and the associated rate of each asset and debt type are used to calculate a weighted average discount rate for each SCF household (Table

8.2.48). The household-level discount rates are then aggregated to form discount rate distributions for each of the six income groups.[d]

DOE estimated the average percentage shares of the various types of debt and equity using data from the SCF for 1995, 1998, 2001, 2004, 2007, 2010, and 2013.[e] DOE derived the household-weighted mean percentages of each source of financing throughout the 5 years surveyed. DOE posits that these long-term averages are most appropriate to use in its analysis.

Table 8.2.48 Types of Household Debt and Equity by Percentage Shares (%)

Type of Debt or Equity	**Income Group**					
	1	**2**	**3**	**4**	**5**	**6**
Debt:						
Mortgage	18.9%	24.1%	33.1%	38.1%	39.3%	25.0%
Home equity loan	3.1%	3.3%	2.6%	3.6%	4.5%	7.2%
Credit card	15.3%	13.0%	11.8%	8.7%	6.0%	2.7%
Other installment loan	25.1%	20.6%	17.3%	13.2%	9.6%	4.7%
Other residential loan	0.7%	0.6%	0.6%	0.7%	1.0%	1.2%
Other line of credit	1.6%	1.5%	1.3%	1.5%	2.1%	1.8%
Equity:						
Savings account	18.5%	16.0%	12.7%	10.6%	10.4%	7.9%
Money market account	3.6%	4.5%	4.0%	4.5%	5.0%	8.6%
Certificate of deposit	7.0%	7.8%	5.5%	5.0%	4.4%	4.2%
Savings bond	1.8%	1.7%	1.9%	2.2%	1.7%	1.1%
Bonds	0.2%	0.4%	0.5%	0.7%	0.8%	3.8%
Stocks	2.3%	3.1%	4.4%	5.7%	7.6%	15.8%
Mutual funds	2.1%	3.5%	4.3%	5.7%	7.6%	15.9%
Total	100.0	100.0	100.0	100.0	100.0	100.0

Sources: Federal Reserve Board. *Survey of Consumer Finances (SCF)* for 1995, 1998, 2001, 2004, 2007, 2010, 2013.

[d] Note that previously DOE performed aggregation of asset and debt types over households by summing the dollar value across all households and then calculating shares. Weighting by dollar value gave disproportionate influence to the asset and debt shares and rates of higher income consumers. DOE has shifted to a household-level weighting to more accurately reflect the average consumer in each income group.
[e] Note that two older versions of the SCF are also available (1989 and 1992); these surveys are not used in this analysis because they do not provide all of the necessary types of data (*e.g.*, credit card interest rates, etc). DOE contends that the 18-year span covered by the seven surveys included is sufficiently representative of recent debt and equity shares and interest rates.

Rates for Types of Debt

DOE estimated interest rates associated with each type of debt. The source for interest rates for mortgages, loans, credit cards, and lines of credit was the SCF for 1995, 1998, 2001, 2004, 2007, 2010, and 2013, which associates an interest rate with each type of debt for each household in the survey.

In calculating effective interest rates for home equity loans and mortgages, DOE accounted for the fact that interest on both such loans is tax deductible (Table 8.2.49). This rate corresponds to the interest rate after deduction of mortgage interest for income tax purposes and after adjusting for inflation (using the Fisher formula).[f] For example, a 6 percent nominal mortgage rate has an effective nominal rate of 5.5 percent for a household at the 25 percent marginal tax rate. When adjusted for an inflation rate of 2 percent, the effective real rate becomes 2.45 percent.

Table 8.2.49 Data Used to Calculate Real Effective Mortgage Rates (%)

Year	Average Nominal Interest Rate	Inflation Rate[10]	Applicable Marginal Tax Rate[11]	Average Real Effective Interest Rate
1995	8.2	2.83	24.2	3.3
1998	7.9	1.56	25.0	4.3
2001	7.6	2.85	24.2	2.8
2004	6.2	2.66	20.9	2.2
2007	6.3	2.85	20.6	2.1
2010	5.7	1.64	20.0	2.9
2013	5.7	1.64	20.0	2.9

Table 8.2.50 shows the household-weighted average effective real rates in each year and the mean rate across years. Because the interest rates for each type of household debt reflect economic conditions throughout numerous years and various phases of economic growth and recession, they are expected to be representative of rates in effect in 2021.

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

Table 8.2.50 Average Real Effective Interest Rates for Household Debt

Type of Debt	Income Group					
	1	**2**	**3**	**4**	**5**	**6**
Mortgage	6.6%	6.2%	6.1%	5.2%	5.0%	4.0%
Home equity loan	7.0%	6.9%	6.7%	5.9%	5.7%	4.3%
Credit card	15.2%	15.0%	14.5%	14.2%	14.0%	14.5%
Other installment loan	10.8%	10.3%	9.9%	9.4%	8.7%	8.6%
Other residential loan	9.8%	10.2%	8.9%	8.2%	7.7%	7.4%
Other line of credit	9.1%	10.9%	9.6%	8.8%	7.4%	6.1%

Sources: Federal Reserve Board. *Survey of Consumer Finances (SCF)* for 1995, 1998, 2001, 2004, 2007, 2010, and 2013.

Rates for Types of Assets

No similar rate data are available from the SCF for classes of assets, so DOE derived asset interest rates from various sources of national historical data (1983-2013). The interest rates associated with certificates of deposit,[12] savings bonds,[13] and bonds (AAA corporate bonds)[14] were collected from Federal Reserve Board time-series data. Rates on money market accounts came from Cost of Savings Index data.[15] Rates on savings accounts were estimated as one half of the rate for money market accounts, based on recent differentials between the return to each of these assets. The rates for stocks are the annual returns on the Standard and Poor's.[16] Rates for mutual funds are a weighted average of the stock rates (two-thirds weight) and the bond rates (one-third weight) in each year. DOE assumed rates on checking accounts to be zero.

DOE adjusted the nominal rates to real rates using the annual inflation rate for each year. Average nominal and real interest rates for the classes of household assets are listed in Table 8.2.51. Because the interest and return rates for each type of asset reflect economic conditions throughout numerous years, they are expected to be representative of rates that may be in effect in 2021. For each type, DOE developed a distribution of rates, as shown in appendix 8E.

Table 8.2.51 Average Nominal and Real Interest Rates for Household Equity

Type of Equity	Average Real Rate %
Savings accounts	1.0
Money market accounts	1.9
Certificates of deposit	1.9
Savings bonds	3.4
Bonds	4.2
Stocks	9.4
Mutual funds	7.4

Discount Rate Calculation and Summary

Using the asset and debt data discussed above, DOE calculated discount rate distributions for each income group as follows. First, DOE calculated the discount rate for each consumer in each of the six versions of the *SCF*, using the following formula:

$$DR_i = \sum_j Share_{i,j} \times Rate_{i,j}$$

Eq. 8.4

Where:

DR_i = discount rate for consumer i,
$Share_{i,j}$ = share of asset or debt type *j* for consumer i, and
$Rate_{i,j}$ = real interest rate or rate of return of asset or debt type *j* for consumer i.

The rate for each debt type is drawn from the SCF data for each household. The rate for each asset type is drawn from the distributions described above.

Once the real discount rate was estimated for each consumer, DOE compiled the distribution of discount rates in each survey by income group by calculating the proportion of consumers with discount rates in bins of 1 percent increments, ranging from 0-1 percent to greater than 30 percent. Giving equal weight to each survey, DOE compiled the six-survey distribution of discount rates.

Table 8.2.52 presents the average real effective discount rate for each of the six income groups. To account for variation among households, DOE sampled a rate for each RECS household from the distributions for the appropriate income group. (RECS provides household income data.) Appendix 8E presents the full probability distributions for each income group that DOE used in the LCC and PBP analysis.

Table 8.2.52 Average Real Effective Discount

Income Group	Discount Rate (%)
1	4.85
2	5.12
3	4.75
4	4.04
5	3.80
6	3.57
Overall Average	4.49

Discount Rates for Commercial Applications

DOE's method views the purchase of a higher efficiency appliance 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 a pool pump.[16] 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 a pool pump.[17]

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.[18] Detailed sectors included in the Damondaran Online database were assigned to the aggregate categories mapped to the following CBECS "Principal Building Activities" (PBAs): Office; Food Sales; Health Care; Warehouse; Public Assembly; Food Service; Lodging; Retail (Mall/Strip Mall); Retail (Other than Mall); Service (Table 8.2.52).

For the Education and Public Order & Safety sectors, DOE uses the real interest rates on 20-year state and local bonds, respectively.[19,20] State and local bond rates are also used for buildings identified as occupied by state or local government entities. Treasure bond rates are used for buildings identified as occupied by federal government entities.[16]

Though not included in CBECS, Damodaran Online data also includes manufacturing and similar industries that DOE groups in the Industrial sector. Based on CBECS PBA, sector discount rates are matched to the appropriate building sample records.

Table 8.2.53 Mapping of Sectors to CBECS Categories

Sector Name in Analysis	**CBECS PBA #**	**Applied to CBECS PBAs:**
Office	2	Office (2)
Food Sales	6	Food Sales (6)
Health Care	8	Outpatient health care (8); Inpatient health care (16); Nursing (17); Laboratory (4)
Warehouse	11	Nonrefrigerated warehouse (5); Refrigerated warehouse (11)
Public Assembly	13	Public Assembly (13); Religious worship (12)
Education	14	Education (14); Public order and safety (7)
Food Service	15	Food Service (15)
Lodging	18	Lodging (18)
Retail (Mall/Strip Mall)	24	Enclosed mall (24); Strip shopping mall (23)
Retail (Other than Mall)	25	Retail other than mall (25)
Service	26	Service (26)
Other[g]	91	Other (91)
Industrial*	N/A	N/A
State & Local	N/A	N/A
Federal	N/A	N/A

DOE estimated the cost of equity using the capital asset pricing model (CAPM).[21] CAPM assumes that the cost of equity (k_e) 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. In CAPM, 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 (R_f), 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, where the variables are defined as above:

$$k_{ei} = R_f + (\beta_i \times ERP)$$

Eq. 8.1

Where:

k_{ei} = cost of equity for firm *i*,
R_f = expected return on risk-free assets,
β_i = risk coefficient of firm *i*, 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

[g] Note that the discount rates for the “Other” sector are the weighted average of all companies in the data set.

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."[22]

By taking a forty-year geometric average of Federal Reserve data on annual nominal returns for 10-year Treasury bills, DOE estimated the following risk free rates for 2004 - 2013 (Table 8.2.54).[h19] DOE also estimated the ERP by calculating the difference between risk free rate and stock market return for the same time period, as estimated using Damodaran Online data on the historical return to stocks.[16]

Table 8.2.54 Risk free rate and equity risk premium, 2004 – 2013

Year	Risk free rate (%)	ERP (%)
2004	7.10%	3.25%
2005	7.11%	3.68%
2006	7.10%	3.49%
2007	7.08%	3.36%
2008	7.01%	2.40%
2009	6.88%	3.07%
2010	6.74%	3.23%
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 (R_a) 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:

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

Eq. 8.2

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*.

[h] Damodaran Online stopped providing detail financial data by company in 2014 (2013 data), limiting the time period available for DOE's analysis.

DOE estimates the weighted average cost of capital using the following equation:

$$WACC = k_{ei} \times w_{ei} + k_{di} \times w_{di}$$

Eq. 8.3

Where:

$WACC_i$ = weighted average cost of capital for firm *i*,
k_{ei} = cost of equity for firm *i*,
k_{di} = cost of debt financing for firm, *i*,
w_e = proportion of equity financing for firm *i*, and
w_d = proportion of debt financing for firm *i*.

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 sectors.

Table 8.2.55 shows the average WACC values for the major sectors. Tables providing full discount rate distributions by sector are included in appendix 8E. While WACC values for any sector may trend higher or lower over substantial periods of time, these values represent a cost of capital that is averaged over major business cycles.

Table 8.2.55 Weighted Average Cost of Capital for Sectors that Purchase Pool Pumps

Sector	Real Discount Rate (%)	Standard Deviation (%)
Public Assembly	6.31	1.13
Education	3.30	1.10
Lodging	6.99	1.85
State & Local Govt	3.30	1.10
Federal Govt	3.33	1.40

8.2.2.6 Compliance Date of Standard

The compliance date of any new energy efficiency standards for pool pumps is June 30, 2021. DOE calculated the LCC and PBP for all consumers as if they each would purchase a new pool pump in 2021.

8.2.2.7 Distribution of Efficiency Levels in the No-Standards Case

To estimate the share of consumers affected by a potential standard at a particular efficiency level, DOE considered the projected distribution (*i.e.*, market shares) of equipment efficiencies that consumers will purchase in the first compliance year, without amended energy conservation standards (no -standards case).

DOE estimated the market shares of the different efficiency levels for dedicated-purpose pool pumps in 2015 based on manufacturer interviews. To project efficiencies to the compliance year, 2021, DOE shifted 1 percent per year of the market share in the single-speed efficiency levels to the variable-speed efficiency levels. (See chapter 9 for more detail.) For the equipment classes that don't have variable-speed efficiency levels (i.e., waterfall pumps and integral pumps), efficiency was held constant at 2015 levels based on the Working Group discussion. (See Docket EERE-2015-BT-STD-0008-0078 pp. 138-141)

Table 8.2.57 through Table 8.2.59 show the estimated efficiency distributions for all the pool pump equipment classes in the no-standards case in 2021.

Table 8.2.56 No-Standards Case Market Share for Self-Priming and Non-Self-Priming Pool Filter Pumps by Efficiency Level in 2021

Efficiency Level	Self-Priming Pool Filter Pumps	Non-Self-Priming Pool Filter Pumps
0	39.0%	29.0%
1	15.0%	29.0%
2	10.0%	32.0%
3	2.0%	2.0%
4	2.0%	1.0%
5	2.0%	1.0%
6	11.0%	3.0%
7	19.0%	3.0%

Table 8.2.57 No-Standards Case Market Share for Waterfall Pumps and Pressure Cleaner Booster Pumps by Efficiency Level in 2021

Efficiency Level	Waterfall Pumps	Pressure Cleaner Booster Pumps
0	70.0%	13.5%
1	20.0%	70.5%
2	10.0%	10.0%
3	0.0%	3.0%
4	--	3.0%

Table 8.2.58 No-Standards Case Market Share for Integral Pumps by Efficiency Level in 2021

Efficiency Level	Integral Pumps
0	80.0%
1	20.0%

8.2.2.1 Distribution of Representative Units

DOE estimated the market shares of the different representative units for standard-size self-priming pool pumps and integral cartridge filter pool pumps in 2015 based on manufacturer interviews. To project market share to the compliance year, 2021, DOE used the market share calculated based on the projected shipments of each representative unit. DOE assumed that these representative units all had the same shipments growth rate, so the market share for representative units of standard-size self-priming pool pumps and of integral cartridge filter pool pumps remained the same in 2021 as in 2015. (See chapter 9 for more detail regarding the shipments projection.)

Table 8.2.59 Market Share for Representative Units of Standard-Size Self-Priming Pool Filter Pumps in 2021

Standard-Size Self-Priming Pool Filter Pump	Market Share
0.95 hhp	49%
1.88 hhp	51%

Table 8.2.60 Market Share for Representative Units of Integral Cartridge-Filter Pool Pumps in 2021

Integral Cartridge Filter Pool Pump	Market Share
0.02 hhp	74%
0.18 hhp	26%

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 product 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. 8.5

Where:

PBP = payback period in years,
Δ IC = difference in the total installed cost between the more efficient standard-level equipment (efficiency levels 1, 2, 3, etc.) and the baseline efficiency equipment (efficiency level 0), 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 product as a result of lower energy costs. Numerically, the rebuttable PBP is the ratio of the increase in purchase cost (*i.e.*, from a less efficient design to a more efficient design) to the decrease in annual energy expenditures; that is, the difference in first year annual energy cost as calculated from the DOE test procedure. The calculation excludes repair costs and maintenance costs.

The data inputs to PBP are the total installed cost of the equipment to the 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, the annual repair cost, and the annual maintenance cost (or, in the case of rebuttable PBP, only the annual energy cost). The PBP uses the same inputs as the LCC analysis, except that energy price trends are not required. Because the PBP is a "simple" payback, the required energy cost is only for the year in which a new standard is to take effect—in this case, 2021.

8.4 LIFE-CYCLE COST AND PAYBACK PERIOD RESULTS

DOE's approach for conducting the LCC and PBP analysis relies on developing samples of households and buildings that use the considered equipment. DOE also uses probability distributions to characterize the uncertainty in many of the inputs to the analysis. DOE uses a Monte Carlo simulation technique to perform the LCC and PBP calculations on the households and buildings in the sample. LCC and PBP calculations are performed 10,000 times on the sample of households or buildings established for each equipment class. Each LCC and PBP calculation is performed on a single household that is selected from the sample of the residential or commercial users. The selection of a household or a building is based on its sample weight (*i.e.*, how representative a particular household or building is of other households or buildings in the distribution—either regionally or nationally). Each LCC and PBP calculation also samples from the probability distributions that DOE develops to characterize many of the inputs to the analysis.

DOE calculated PBP relative to the baseline equipment in each equipment class. In contrast, DOE calculated LCC savings relative to the equipment it assigned to the households or buildings in the no-standards case. DOE assigned some households and buildings an equipment in the no-standards case that is more efficient than some of the standard levels. 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 equipment. The calculation of average LCC savings did not include households and buildings with zero LCC savings (no impact from a standard). DOE considered a household or a building to receive no impact at a given efficiency level if in the no-standards case DOE assigned it an equipment having an efficiency equal to or greater than the efficiency level in question.

The following sections present figures that illustrate the range of LCC and PBP effects among sample consumers.

Table 8.4.1 through Table 8.4.18 shows the LCC and PBP results by efficiency level for all the equipment classes of dedicated-purpose pool pumps. The efficiency levels correspond to those identified in the engineering analysis (chapter 5 of this Final Rule TSD). The simple payback is measured relative to the baseline equipment. The LCC savings are measured relative to the no-standards case efficiency distribution in the compliance year. No impacts occur when the no-standards case efficiency for a specific consumer equals or exceeds the efficiency at a given efficiency level; a standard would have no effect on the individual consumer because the equipment installed would already meet the standard.

For standard-size self-priming pool filter pumps (0.95 hhp), waterfall pumps and pressure cleaner booster pumps, the tables combine the results for residential and commercial users, which means that DOE had to assign an appropriate weight to the results for each type of user, assuming that 95 percent of shipments are to the residential sector and 5 percent are to the commercial sector.

Table 8.4.1 Average LCC and PBP Results by Efficiency Level for Standard-Size Self-Priming Pool Filter Pumps (0.95 hhp)

Efficiency Level	**Average Costs** *2015$*				**Simple Payback** *years*	**Average Lifetime** *years*
	Installed Cost	**First Year's Operating Cost**	**Lifetime Operating Cost**	**LCC**		
0	354	652	3,930	4,284		6.7
1	394	513	3,137	3,530	0.3	6.7
2	427	456	2,822	3,249	0.4	6.7
3	582	337	2,130	2,712	0.7	6.7
4	617	287	1,851	2,468	0.7	6.7
5	654	267	1,751	2,406	0.8	6.7
6	733	179	1,340	2,073	0.8	6.8
7	733	152	1,187	1,920	0.8	6.8

Note: The results for each EL are calculated assuming that all consumers use equipment with that efficiency level. The PBP is measured relative to the baseline equipment.

Table 8.4.2 Average LCC Savings Relative to the No-Standards Case Efficiency Distribution for Standard-Size Self-Priming Pool Filter Pumps (0.95 hhp)

Efficiency Level	Life-Cycle Cost Savings	
	% of Consumers that Experience Net Cost	Average Savings* *2015$*
1	0%	767
2	0%	836
3	9%	1,260
4	6%	1,469
5	6%	1,485
6	11%	1,782
7	9%	1,695

* The calculation does not include consumer with zero LCC savings (no impact).

Table 8.4.3 Average LCC and PBP Results by Efficiency Level for Standard-Size Self-Priming Pool Filter Pumps (1.88 hhp), All Sectors

Efficiency Level	Average Costs *2015$*				Simple Payback *years*	Average Lifetime *years*
	Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	601	891	5,172	5,774		6.7
1	674	799	4,692	5,367	0.9	6.7
2	718	746	4,422	5,140	0.9	6.7
3	929	475	3,035	3,964	0.9	6.7
4	957	424	2,754	3,711	0.9	6.7
5	985	360	2,399	3,383	0.8	6.7
6	969	265	1,934	2,903	0.6	6.8
7	969	208	1,606	2,575	0.6	6.8

Note: The results for each EL are calculated assuming that all consumers use equipment with that efficiency level. The PBP is measured relative to the baseline equipment.

Table 8.4.4 Average LCC Savings Relative to the No-Standards Case Efficiency Distribution for Standard-Size Self-Priming Pool Filter Pumps (1.88 hhp), All Sectors

Efficiency Level	Life-Cycle Cost Savings	
	% of Consumers that Experience Net Cost	Average Savings* *2015$*
1	2%	394
2	1%	509
3	11%	1,589
4	8%	1,790
5	3%	2,060
6	9%	2,481
7	7%	2,458

* The calculation does not include consumers with zero LCC savings (no impact).

Table 8.4.5 Average LCC and PBP Results by Efficiency Level for Standard-Size Self-Priming Pool Filter Pumps (Total), All Sectors

Efficiency Level	Average Costs *2015$*				Simple Payback *years*	Average Lifetime *years*
	Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	481	774	4,565	5,046		6.7
1	537	659	3,932	4,469	0.5	6.7
2	576	605	3,640	4,216	0.6	6.7
3	760	408	2,593	3,352	0.8	6.7
4	791	357	2,313	3,104	0.7	6.7
5	823	315	2,082	2,906	0.7	6.7
6	853	223	1,644	2,497	0.7	6.8
7	853	181	1,402	2,255	0.6	6.8

Note: The results for each EL are calculated assuming that all consumers use equipment with that efficiency level. The PBP is measured relative to the baseline equipment.

Table 8.4.6 Average LCC Savings Relative to the No-Standards Case Efficiency Distribution for Standard-Size Self-Priming Pool Filter Pumps (Total), All Sectors

Efficiency Level	Life-Cycle Cost Savings	
	% of Consumers that Experience Net Cost	Average Savings* *2015$*
1	1%	576
2	1%	669
3	10%	1,428
4	7%	1,633
5	5%	1,779
6	10%	2,140
7	8%	2,085

* The calculation does not include consumers with zero LCC savings (no impact).

Table 8.4.7 Average LCC and PBP Results by Efficiency Level for Small-Size Self-Priming Pool Filter Pumps

Efficiency Level	Average Costs *2015$*				Simple Payback *years*	Average Lifetime *years*
	Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	320	282	1,743	2,063		6.8
1	347	222	1,406	1,753	0.4	6.8
2	386	200	1,294	1,679	0.8	6.8
3	545	184	1,204	1,749	2.3	6.8
4	567	158	1,063	1,630	2.0	6.8
5	588	146	1,004	1,593	2.0	6.8
6	720	94	826	1,546	2.1	6.8
7	720	77	723	1,443	1.9	6.8

Note: The results for each EL are calculated assuming that all consumers use equipment with that efficiency level. The PBP is measured relative to the baseline equipment.

Table 8.4.8 Average LCC Savings Relative to the No-Standards Case Efficiency Distribution for Small-Size Self-Priming Pool Filter Pumps

Efficiency Level	Life-Cycle Cost Savings	
	% of Consumers that Experience Net Cost	Average Savings* *2015$*
1	0%	309
2	4%	295
3	33%	181
4	28%	293
5	27%	322
6	29%	360
7	26%	414

* The calculation does not include consumers with zero LCC savings (no impact).

Table 8.4.9 Average LCC and PBP Results by Efficiency Level for Standard-Size Non-Self-Priming Pool Filter Pumps

Efficiency Level	Average Costs *2015$*				Simple Payback *years*	Average Lifetime *years*
	Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	199	225	1,055	1,254		4.7
1	208	177	858	1,066	0.2	4.7
2	234	169	835	1,069	0.6	4.7
3	385	156	782	1,167	2.7	4.7
4	411	131	684	1,095	2.3	4.7
5	437	123	661	1,099	2.3	4.7
6	576	64	541	1,117	2.3	4.8
7	576	45	458	1,034	2.1	4.8

Note: The results for each EL are calculated assuming that all consumers use equipment with that efficiency level. The PBP is measured relative to the baseline equipment.

Table 8.4.10 Average LCC Savings Relative to the No-Standards Case Efficiency Distribution for Standard-Size Non-Self-Priming Pool Filter Pumps

Efficiency Level	Life-Cycle Cost Savings	
	% of Consumers that Experience Net Cost	Average Savings* *2015$*
1	0%	191
2	21%	92
3	67%	-37
4	58%	35
5	60%	31
6	51%	10
7	47%	93

* The calculation does not include consumers with zero LCC savings (no impact).

Table 8.4.11 Average LCC and PBP Results by Efficiency Level for Extra-Small Non-Self-Priming Pool Filter Pumps

Efficiency Level	Average Costs *2015$*				Simple Payback *years*	Average Lifetime *years*
	Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	135	57	305	440		
1	146	45	259	405	0.9	4.7
2	158	43	255	413	1.6	4.7

Note: The results for each EL are calculated assuming that all consumers use equipment with that efficiency level. The PBP is measured relative to the baseline equipment.

Table 8.4.12 Average LCC Savings Relative to the No-Standards Case Efficiency Distribution for Extra-Small Non-Self-Priming Pool Filter Pumps

Efficiency Level	Life-Cycle Cost Savings	
	% of Consumers that Experience Net Cost	Average Savings* *2015$*
1	4%	36
2	39%	10

* The calculation does not include consumers with zero LCC savings (no impact).

Table 8.4.13 Average LCC and PBP Results by Efficiency Level for Waterfall Pumps, All Sectors

Efficiency Level	Average Costs *2015$*				Simple Payback *years*	Average Lifetime *years*
	Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	313	73	500	813		6.6
1	335	67	481	816	4.5	6.6
2	375	60	459	834	5.4	6.6
3	375	54	429	803	3.7	6.6

Note: The results for each EL are calculated assuming that all consumers use equipment with that efficiency level. The PBP is measured relative to the baseline equipment.

Table 8.4.14 Average LCC Savings Relative to the No-Standards Case Efficiency Distribution for Waterfall Pumps, All Sectors

Efficiency Level	Life-Cycle Cost Savings	
	% of Consumers that Experience Net Cost	Average Savings* *2015$*
1	50%	-3
2	70%	-20
3	55%	13

* The calculation does not include consumers with zero LCC savings (no impact).

Table 8.4.15 Average LCC and PBP Results by Efficiency Level for Pressure Cleaner Booster Pumps, All Sectors

Efficiency Level	Average Costs *2015$*				Simple Payback *years*	Average Lifetime *years*
	Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	255	173	858	1,113		4.8
1	276	140	726	1,001	0.6	4.8
2	312	129	697	1,009	1.3	4.8
3	631	110	758	1,390	6.0	4.8
4	631	99	711	1,343	5.1	4.8

Note: The results for each EL are calculated assuming that all consumers use equipment with that efficiency level. The PBP is measured relative to the baseline equipment.

Table 8.4.16 Average LCC Savings Relative to the No-Standards Case Efficiency Distribution for Pressure Cleaner Booster Pumps, All Sectors

Efficiency Level	Life-Cycle Cost Savings	
	% of Consumers that Experience Net Cost	Average Savings* *2015$*
1	0%	111
2	47%	10
3	69%	-372
4	68%	-313

* The calculation does not include consumers with zero LCC savings (no impact).

Table 8.4.17 Average LCC and PBP Results by Efficiency Level for Integral Cartridge Filter Pump (0.02 hhp)

Efficiency Level	Average Costs *2015$*				Simple Payback *years*	Average Lifetime *years*
	Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	45	43	161	206		3.8
1	57	15	60	117	0.4	3.8

Note: The results for each EL are calculated assuming that all consumers use equipment with that efficiency level. The PBP is measured relative to the baseline equipment.

Table 8.4.18 Average LCC Savings Relative to the No-Standards Case Efficiency Distribution for Integral Cartridge Filter Pump (0.02 hhp)

Efficiency Level	Life-Cycle Cost Savings	
	% of Consumers that Experience Net Cost	Average Savings* *2015$*
1	3%	89

* The calculation does not include consumers with zero LCC savings (no impact).

Table 8.4.19 Average LCC and PBP Results by Efficiency Level for Integral Cartridge Filter Pump (0.18 hhp)

Efficiency Level	Average Costs *2015$*				Simple Payback *years*	Average Lifetime *years*
	Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	249	129	442	691		3.8
1	261	55	187	448	0.2	3.8

Note: The results for each EL are calculated assuming that all consumers use equipment with that efficiency level. The PBP is measured relative to the baseline equipment.

Table 8.4.20 Average LCC Savings Relative to the No-Standards Case Efficiency Distribution for Integral Cartridge Filter Pump (0.18 hhp)

Efficiency Level	Life-Cycle Cost Savings	
	% of Consumers that Experience Net Cost	Average Savings* *2015$*
1	4%	242

* The calculation does not include consumers with zero LCC savings (no impact).

Table 8.4.21 Average LCC and PBP Results by Efficiency Level for Integral Cartridge Filter Pump (Total)

Efficiency Level	Average Costs *2015$*				Simple Payback *years*	Average Lifetime *years*
	Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	98	65	234	332		3.8
1	110	26	93	203	0.4	3.8

Note: The results for each EL are calculated assuming that all consumers use equipment with that efficiency level. The PBP is measured relative to the baseline equipment.

Table 8.4.22 Average LCC Savings Relative to the No-Standards Case Efficiency Distribution for Integral Cartridge Filter Pump (Total)

Efficiency Level	Life-Cycle Cost Savings	
	% of Consumers that Experience Net Cost	Average Savings* *2015$*
1	3%	128

* The calculation does not include consumers with zero LCC savings (no impact).

Table 8.4.23 Average LCC and PBP Results by Efficiency Level for Integral Sand Filter Pump

Efficiency Level	Average Costs *2015$*				Simple Payback *years*	Average Lifetime *years*
	Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	154	39	133	287		3.83
1	166	14	48	214	0.5	3.83

Note: The results for each EL are calculated assuming that all consumers use equipment with that efficiency level. The PBP is measured relative to the baseline equipment.

Table 8.4.24 Average LCC Savings Relative to the No-Standards Case Efficiency Distribution for Integral Sand Filter Pump

Efficiency Level	Life-Cycle Cost Savings	
	% of Consumers that Experience Net Cost	Average Savings* *2015$*
1	3%	73

* The calculation does not include consumers with zero LCC savings (no impact).

8.4.1.1 Distribution of Impacts

The figures in this section show the distribution of LCCs in the no-standards case for each equipment class. The figures are presented as frequency charts that show the distribution of LCCs, and LCC impacts with their corresponding probability of occurrence. DOE generated the figures for the distributions from a Monte Carlo simulation run based on 10,000 samples.

No-Standards Case LCC Distributions

DOE can generate a frequency chart like the one shown in Figure 8.4.1 for each efficiency level and equipment class to show the no-standards case LCC distributions.

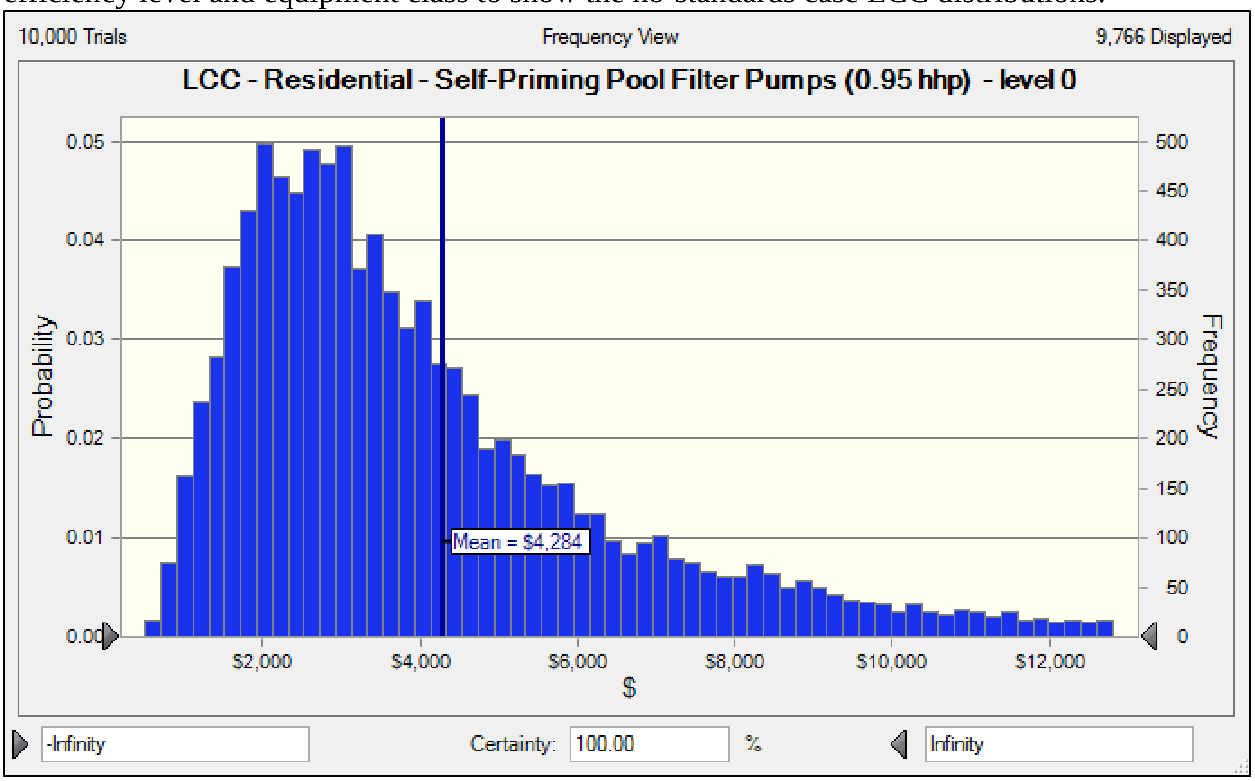

Figure 8.4.1 Standard-Size Self-Priming Pool Filter Pumps (0.95 hhp): No-Standards Case LCC Distribution

Standard-Level Distributions of LCC Impacts

Figure 8.4.2 is an example of a frequency chart that shows the distribution of LCC differences for the case of Efficiency Level 6 for standard-size self-priming pool filter pumps (0.95 hhp). In the figure, a text box next to a vertical line at a given value on the x-axis shows the mean change in LCC (a savings of $1,782 in the example here). The note, “Certainty is 100.00% from $0 to +Infinity,” means that 100 percent of owners of efficiency level 6 standard-size self-priming pool filter pumps (0.95 hhp) will have LCC savings or not be affected by the efficiency level compared to the no-standards case. Refer to section 8.2.2.7 on the distribution of efficiency levels under the no-standards case. DOE can generate a frequency chart like the one shown in Figure 8.4.2 for each efficiency level and equipment class.

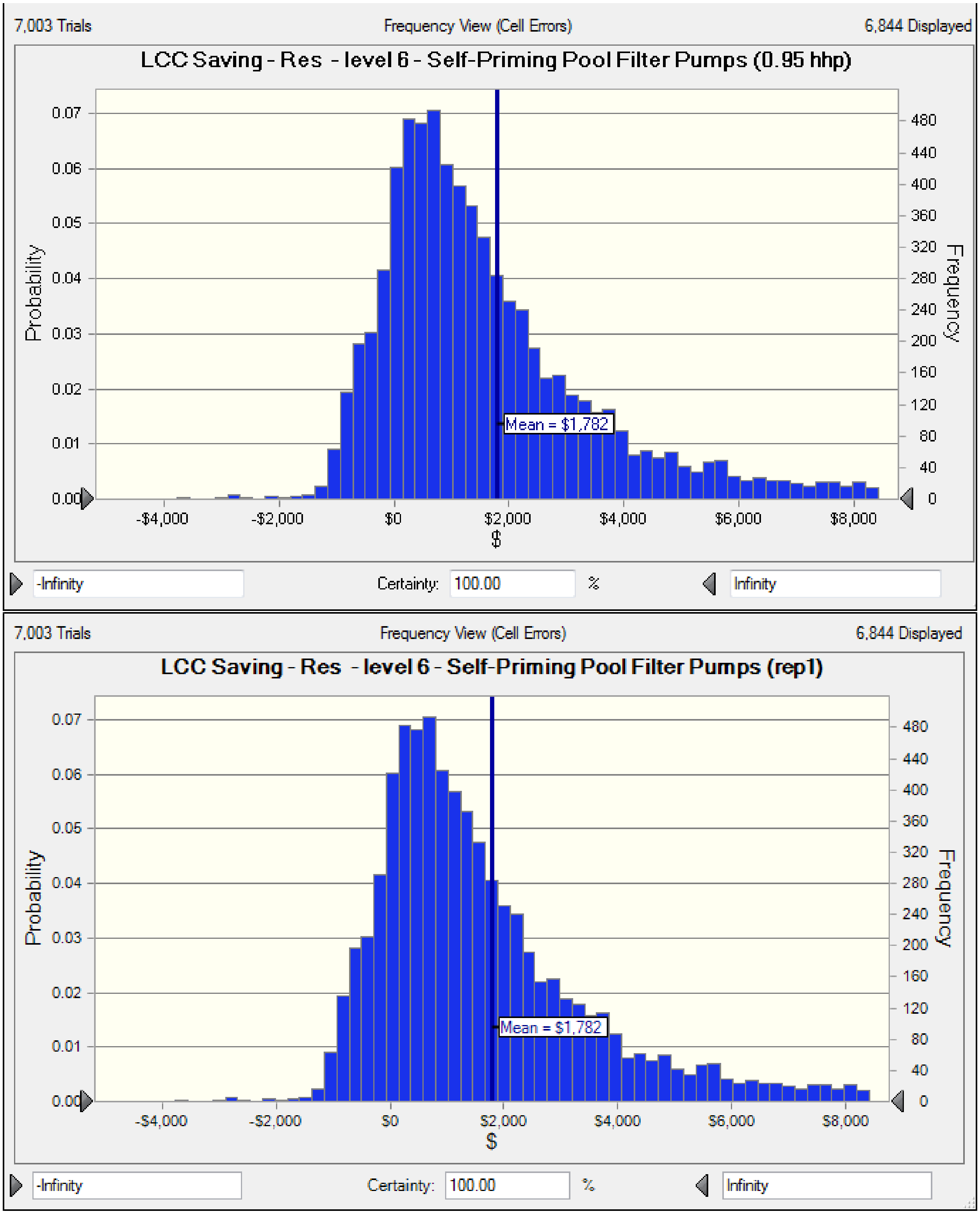

Figure 8.4.2 Standard-Size Self-Priming Pool Filter Pumps (0.95 hhp): Distribution of LCC Impacts at Efficiency Level 6

8.4.1.1 Range of LCC Savings

Figure 8.4.3 through Figure 8.4.10 show the range of LCC savings for all efficiency levels considered for each pool pump equipment. For each efficiency 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 households have LCC savings in excess of that value. The "whiskers" at the bottom and the top of the box indicate the 5th and 95th percentiles. The small box shows the average LCC savings for each standard level.

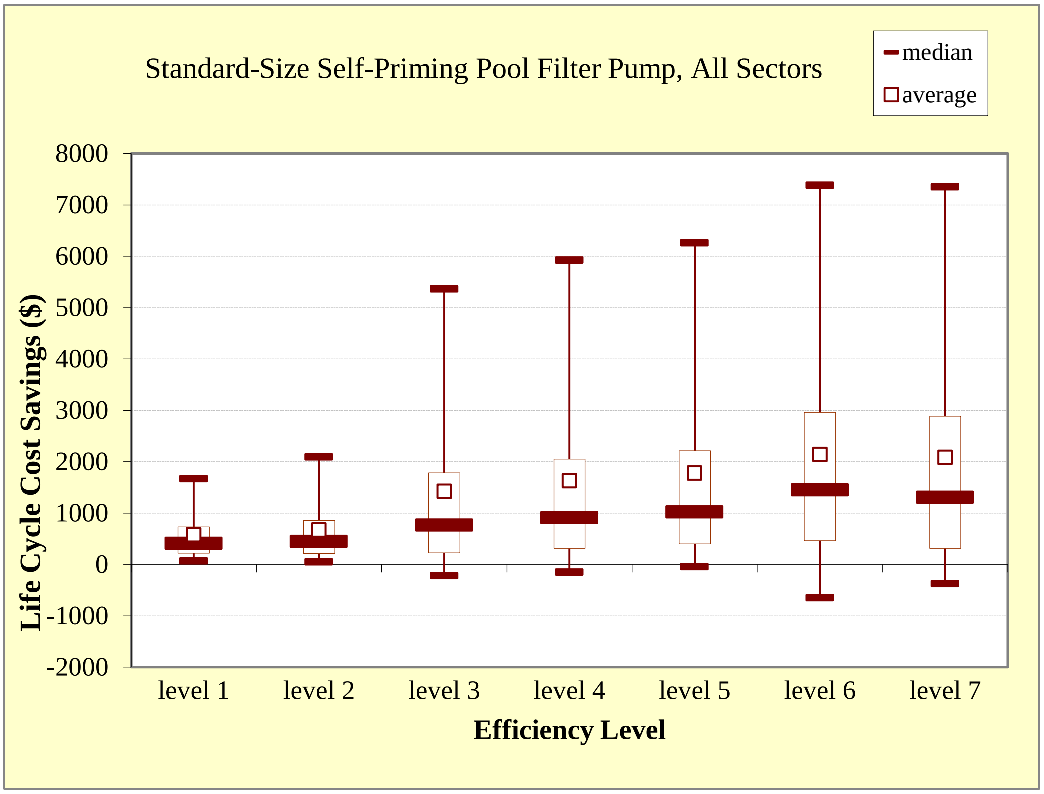

Figure 8.4.3 Distribution of LCC Savings for Standard-Size Self-Priming Pool Filter Pumps

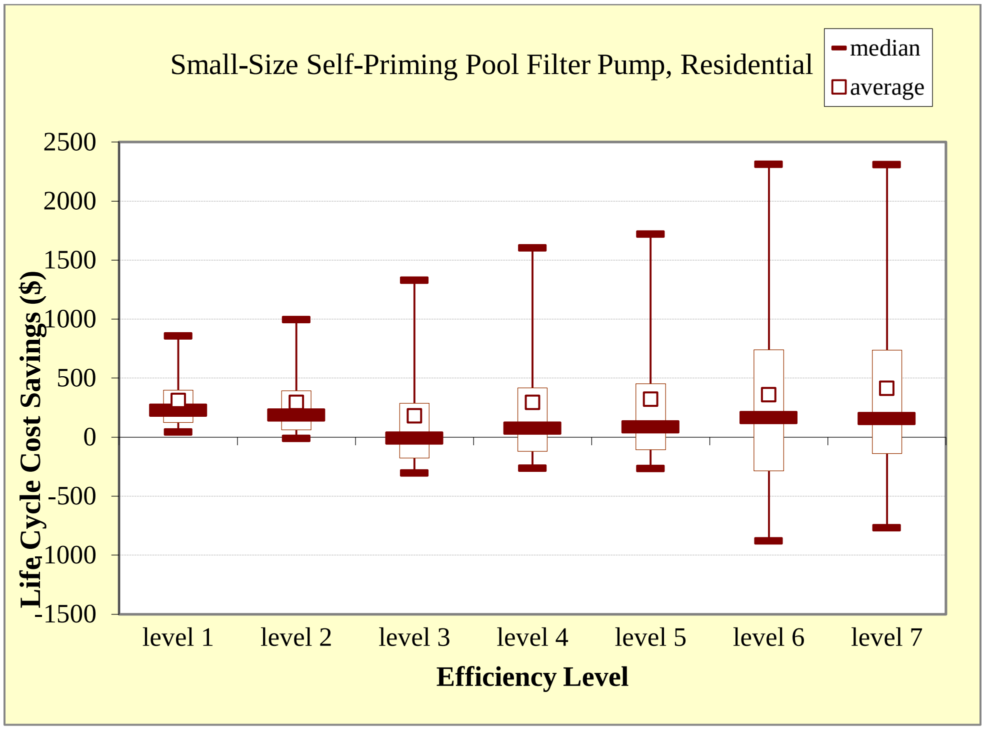

Figure 8.4.4 Distribution of LCC Savings for Small-Size Self-Priming Pool Filter Pumps

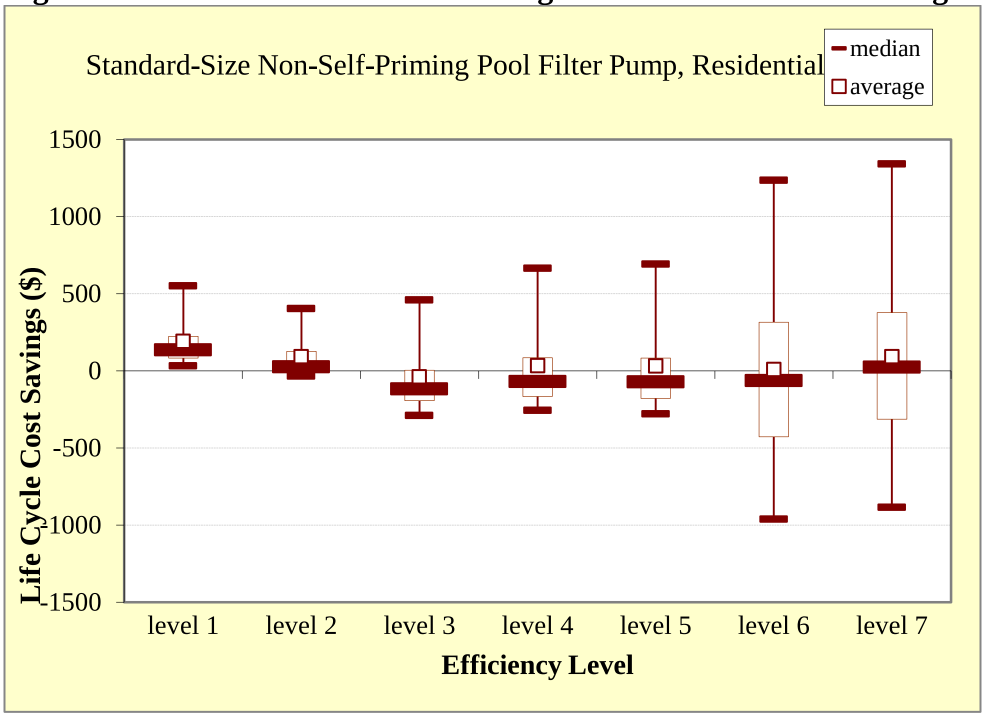

Figure 8.4.5 Distribution of LCC Savings for Standard-Size Non-Self-Priming Pool Filter Pumps

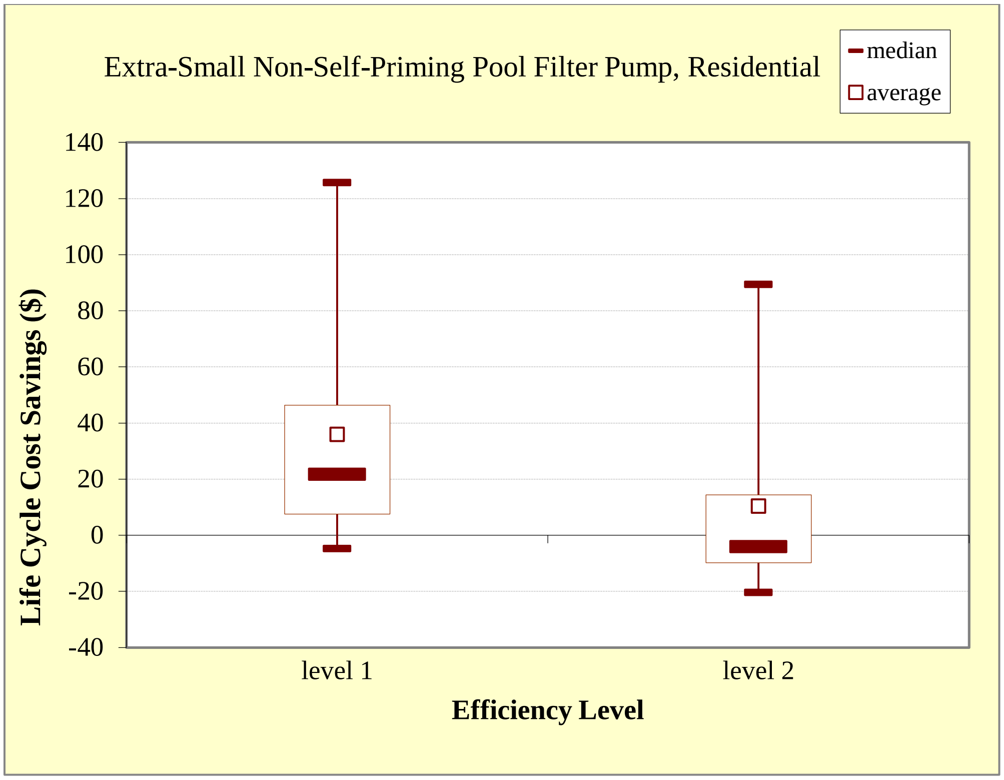

Figure 8.4.6 Distribution of LCC Savings for Extra-Small Non-Self-Priming Pool Filter Pumps

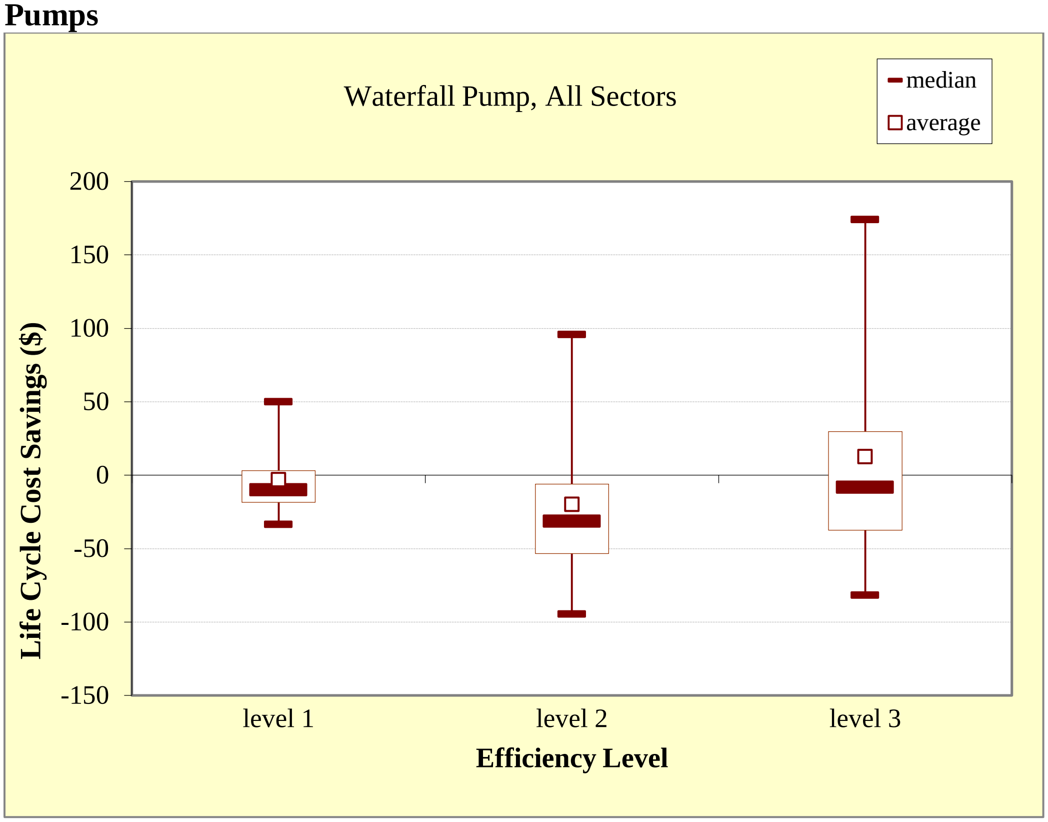

Figure 8.4.7 Distribution of LCC Savings for Waterfall Pumps

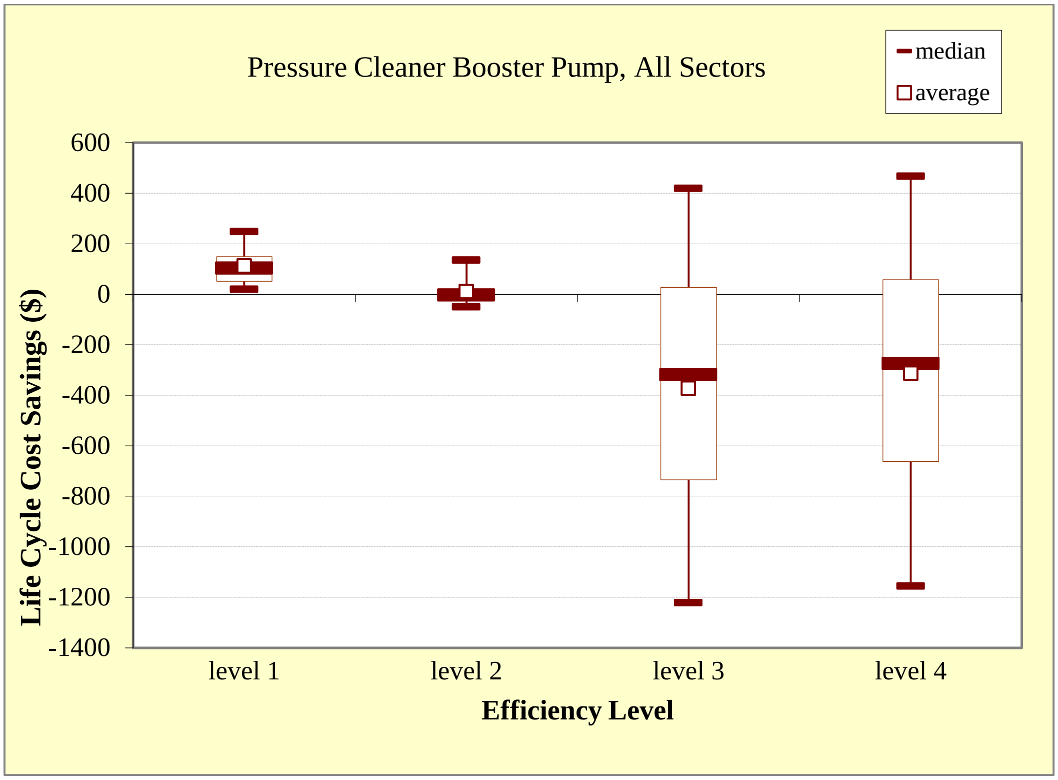

Figure 8.4.8 Distribution of LCC Savings for Pressure Cleaner Booster Pumps

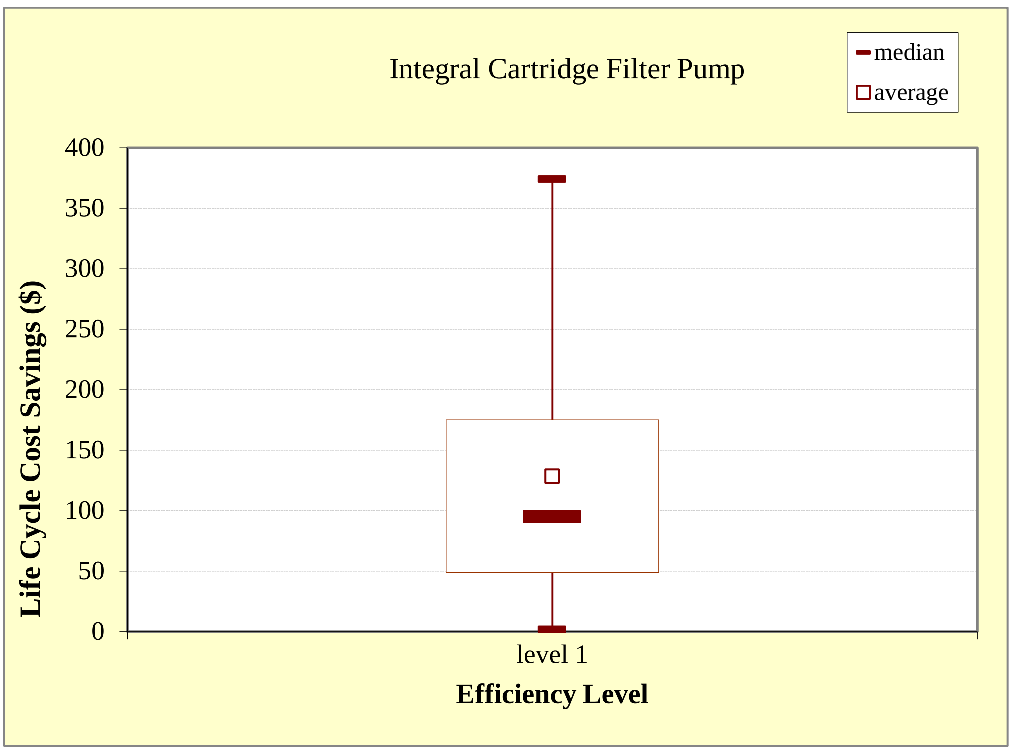

Figure 8.4.9 Distribution of LCC Savings for Integral Cartridge Filter Pumps

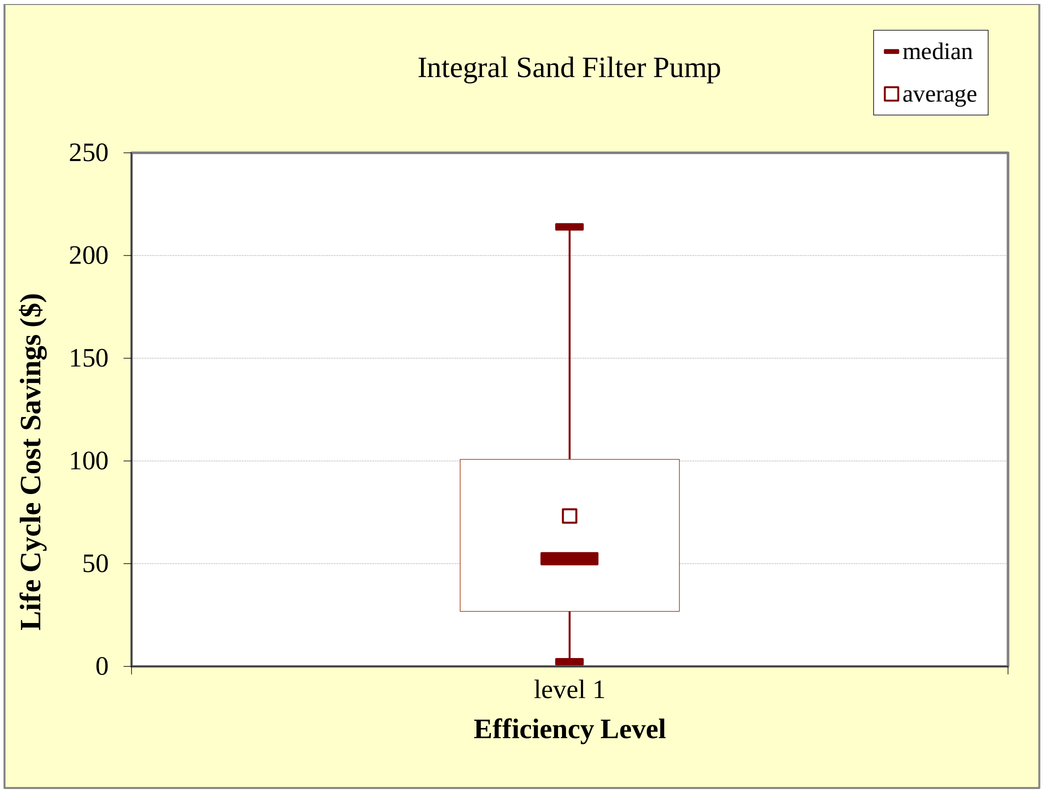

Figure 8.4.10 Distribution of LCC Savings for Integral Sand Filter Pumps

8.5 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 product 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 analysis described in section 8.3, however, the rebuttable PBP is not based on the use of household samples and 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.

Other than the use of single-point values, the most notable difference between the distribution PBP and the rebuttable PBP is the latter's reliance on the DOE test procedure to determine a product's annual energy consumption.

8.5.1 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 are all based on the single-point values used in the distributional LCC and PBP analysis.
- Energy prices are 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 effective date of the standard is assumed to be 2021.

8.5.2 Results

DOE calculates rebuttable PBPs for each standard level relative to the distribution of equipment energy efficiencies estimated for the baseline. In other words, DOE did not determine the rebuttable PBP relative to the no-standards case energy efficiency, but relative to the distribution of equipment energy efficiencies for the baseline (*i.e.*, the case without new energy conservation standards). Table 8.5.1 through Table 8.5.4 present the rebuttable PBPs for each equipment class of dedicated-purpose pool pumps.

Table 8.5.1 Rebuttable Payback Period (years) for Self-Priming Pool Filter Pumps

EL	Self-Priming, Standard Size (0.95 hhp)	Self-Priming, Standard Size (1.88 hhp)	Self-Priming, Standard Size (Total)	Self-Priming, Small Size (0.44 hhp)
1	0.3	0.6	0.5	0.5
2	0.4	0.7	0.5	0.9
3	1.0	0.8	0.9	2.4
4	0.9	0.8	0.8	2.1
5	1.0	0.8	0.8	2.1
6	1.0	0.7	0.8	2.4
7	0.9	0.7	0.8	2.1

Table 8.5.2 Rebuttable Payback Period (years) for Non-Self-Priming Pool Filter Pumps

EL	Non-Self-Priming, Standard Size	Non-Self-Priming, Extra Small
1	0.2	1.0
2	0.7	1.8
3	2.8	--
4	2.4	--
5	2.5	--
6	2.8	--
7	2.5	--

Table 8.5.3 Rebuttable Payback Period (years) for Waterfall Pumps and Pressure Cleaner Booster Pumps

EL	Waterfall Pumps	Pressure Cleaner Booster Pumps
1	3.9	0.6
2	4.7	1.4
3	3.2	7.8
4	--	6.5

Table 8.5.4 Rebuttable Payback Period (years) for Integral Pumps

EL	Integral Cartridge Filter (0.02 hhp)	Integral Cartridge Filter (0.18 hhp)	Integral Cartridge Filter (Total)	Integral Sand Filter
1	0.5	0.2	0.3	0.5

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APPENDIX 8A. USER INSTRUCTIONS FOR LIFE-CYCLE COST AND PAYBACK PERIOD SPREADSHEET

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APPENDIX 8A. USER INSTRUCTIONS FOR LIFE-CYCLE COST AND PAYBACK PERIOD SPREADSHEET

8A.1 DEFINITIONS

The interested reader can examine and reproduce detailed results of the U.S. Department of Energy's (DOE's) life-cycle cost (LCC) and payback period (PBP) analysis for dedicated-purpose pool pumps by using Microsoft Excel spreadsheets available on DOE's website at https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=67. To fully execute the spreadsheets requires both Microsoft Excel and Crystal Ball software. Both applications are commercially available. Crystal Ball is available at www.decisioneering.com.

The latest version of the workbook, which is posted on the DOE website, was tested using Microsoft Excel 2010. The LCC and PBP workbook for pool pump equipment comprises the following worksheets.

Summary	Presents the results of an analysis in terms of average LCC, LCC savings, and simple PBP for dedicated-purpose pool pumps. A table includes, for each efficiency level considered, installed price; lifetime operating cost; LCC average savings; and the percentage of customers that would incur a net cost from each standard level. The user can stipulate three parameters for a simulation run: whether the AEO energy price trend reflects an economic case that is reference, low-growth, or high-growth (reference is default); the number of simulation runs to be performed within a range of 1000–10,000 (10,000 is default); and analysis group, i.e., national or senior only.
Overall Summary	Presents the results of combined and weighted LCC results by equipment class.
LCC & Payback	The *LCC&Payback* worksheet shows LCC and PBP calculation results for different efficiency levels for a single Residential Energy Consumption Survey (RECS) 2009 household. During a Crystal Ball simulation, the spreadsheet records the LCC and PBP values for every sampled household.
Rebuttable Payback	The *Rebuttable Payback* worksheet contains the installation costs, equipment efficiencies, energy use calculations, and the simple PBP calculations for each efficiency level.
RECS Households	The *RECS Households* worksheet contains the RECS 2009 household data for each equipment type. During a Crystal Ball

	simulation, DOE uses these household characteristics to determine the analysis parameters.
CBECS Samples	The *CBECS Sample* worksheet contains the CBECS 2012 building data, and community pool sample data developed based on RECS 2009 and AHS 2009 some of the equipment classes. During a Crystal Ball simulation, DOE uses these sample characteristics to determine the analysis parameters.
Energy Use	Provides energy use components for all equipment classes at every efficiency level.
Base Case Efficiency Distribution	Gives the market shares for efficiency levels in the no-standards case, projected for 2021.
Equipment & Installation Cost	Develops total installed cost for pool pumps in 2015$. This sheet provides baseline and incremental manufacturer costs, retail price, sales tax, and installation cost for all product classes and each efficiency level. Includes the assumptions used about markups and sales tax.
Energy Prices	Contains the regional prices for electricity used in the LCC and PBP analysis.
Energy Price Trends	Contains the electricity and natural gas price trends for the reference, high, and low economic growth scenarios based on AEO 2016.
Discount Rate	Contains data from which an average discount rate and a distribution of discount rates are determined.
Lifetime	Presents the average lifetime, in years, for all equipment classes, the Weibull parameters used for the survival function, and a graph of the Weibull retirement function for dedicated-purpose pool pumps.
Forecast Cells	Gives details regarding base-case efficiency distributions for all pool pumps. Median, minimum, maximum, and average values are given, along with 5^{th}, 25^{th}, 50^{th}, 75^{th}, and 95^{th} percentile values. Included are product prices and details of the LCC and PBP (LCC savings in terms of money, energy, and the percentages of customers that would experience a net cost, no impact, or net savings from each efficiency level).

8A.2 BASIC INSTRUCTIONS

Basic instructions for operating the LCC spreadsheet are provided below.

1. After downloading the LCC file from DOE’s website, use Microsoft Excel to open it. At the bottom of the workbook, click on the tab for the sheet labeled *Summary*.

2. Use Excel’s “View/Zoom” command in the top menu bar to change the size of the display so that it fits your monitor.

3. Use the graphical interface in the spreadsheet to choose parameters or enter data. You can change the default choices for the three inputs listed under “User Input” (energy price trend, start year, and number of simulation runs). To change a default input, select the desired value from the drop-down choices by the input box.

4. After selecting the desired parameters, click the “Run” button. The spreadsheet will minimize until the simulation is complete, and will then re-open with the updated results.

APPENDIX 8B. UNCERTAINTY AND VARIABILITY IN LCC ANALYSIS FOR DEDICATED-PURPOSE POOL PUMPS

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APPENDIX 8B. UNCERTAINTY AND VARIABILITY IN LCC ANALYSIS FOR DEDICATED-PURPOSE POOL PUMPS

8B.1 INTRODUCTION

Analysis of energy conservation standards involves calculations of impacts, for example, the impact of a standard on consumer life-cycle cost (LCC). In order to perform the calculation, the analyst must first: 1) specify the equation or model that will be used; 2) define the quantities in the equation; and 3) provide numerical values for each quantity. In the simplest case, the equation is unambiguous (contains all relevant quantities and no others), each quantity has a single numerical value, and the calculation results in a single value. However, unambiguity and precision are rarely the case. In almost all cases, the model and/or the numerical values for each quantity in the model are not completely known (i.e., there is uncertainty) or the model and/or the numerical values for each quantity in the model depend upon other conditions (i.e., there is variability).

Thorough analysis involves accounting for uncertainty and variability. While the simplest analysis involves a single numerical value for each quantity in a calculation, arguments can arise about what the appropriate value is for each quantity. Explicit analysis of uncertainty and variability is intended to provide more complete information to the decision-making process.

8B.2 UNCERTAINTY

When making observations of past events or speculating about the future, imperfect knowledge is the rule rather than the exception. For example, the energy actually consumed by a particular appliance type (such as the average U.S. water heater, direct heating equipment, or pool heater) is not directly recorded, but rather estimated based upon available information. Even direct laboratory measurements have some margin of error. When estimating numerical values expected for quantities at some future date, the exact outcome is rarely known in advance.

8B.3 VARIABILITY

Variability means that different applications or situations produce different numerical values when calculating a quantity. Specifying an exact value for a quantity may be difficult because the value depends on something else. For example, water heater energy consumption depends upon the specific circumstances and behaviors of the occupants (e.g., number of persons, length and temperature of showers, etc.). Variability makes specifying an appropriate population value more difficult in as much as any one value may not be representative of the entire population. Surveys can be helpful here, and analysis of surveys can relate the variable of interest (e.g., hours of use) to other variables that are better known or easier to forecast (e.g., persons per household).

8B.4 APPROACHES TO UNCERTAINTY AND VARIABILITY

This section describes two approaches to uncertainty and variability:

- scenario analysis, and
- probability analysis.

Scenario analysis uses a single numerical value for each quantity in a calculation, then changes one (or more) of the numerical values and repeats the calculation. A number of calculations are done, which provide some indication of the extent to which the result depends upon the assumptions. For example, the life-cycle cost of an appliance could be calculated for energy rates of 2, 8, and 14¢ per kWh.

The advantages of scenario analysis are that each calculation is simple; a range of estimates is used and crossover points can be identified. (An example of a crossover point is the energy rate above which the life-cycle cost is reduced, holding all other inputs constant. That is, the crossover point is the energy rate at which the consumer achieves savings in operating expense that more than compensate for the increased purchase expense.) The disadvantage of scenario analysis is that there is no information about the likelihood of each scenario.

Probability analysis considers the probabilities within a range of values. For quantities with variability (e.g., electricity rates in different households), surveys can be used to generate a frequency distribution of numerical values (e.g., the number of households with electricity rates at particular levels) to estimate the probability of each value. For quantities with uncertainty, statistical or subjective measures can be used to provide probabilities (e.g., manufacturing cost to improve energy efficiency to some level may be estimated to be $10 ± $3).

The major disadvantage of the probability approach is that it requires more information, namely information about the shapes and magnitudes of the variability and uncertainty of each quantity. The advantage of the probability approach is that it provides greater information about the outcome of the calculations, that is, it provides the probability that the outcome will be in a particular range.

Scenario and probability analysis provide some indication of the robustness of the policy given the uncertainties and variability. A policy is robust when the impacts are acceptable over a wide range of possible conditions.

8B.5 PROBABILITY ANALYSIS AND THE USE OF CRYSTAL BALL

To quantify the uncertainty and variability that exist in inputs to the engineering, LCC, and payback period (PBP) analyses, DOE used Microsoft Excel spreadsheets combined with Crystal Ball, a commercially available add-in, to conduct probability analyses. The probability analyses used Monte Carlo simulation and probability distributions.

Simulation refers to any analytical method meant to imitate a real-life system, especially when other analyses are too mathematically complex or too difficult to reproduce. Without the aid of simulation, a spreadsheet model will only reveal a single outcome, generally the most likely or average scenario. Spreadsheet risk analysis uses both a spreadsheet model and simulation to automatically analyze the effect of varying inputs on outputs of the modeled system. One type of spreadsheet simulation is Monte Carlo simulation, which randomly generates values for uncertain variables again and again to simulate a model. Monte Carlo simulation was named for Monte Carlo, Monaco, where the primary attractions are casinos containing games of chance. Games of chance such as roulette wheels, dice, and slot machines, exhibit random behavior. The random behavior in games of chance is similar to how Monte Carlo simulation selects variable values at random to simulate a model. When you roll a die, you know that either a 1, 2, 3, 4, 5, or 6 will come up, but you do not know which for any particular roll. It's the same with the variables that have a known range of values but an uncertain value for any particular time or event (e.g., equipment lifetime, discount rate, and installation cost).

For each uncertain variable (one that has a range of possible values), possible values are defined with a probability distribution. The type of distribution selected is based on the conditions surrounding that variable. Types of probability distributions include those in Figure 8B.5.1.

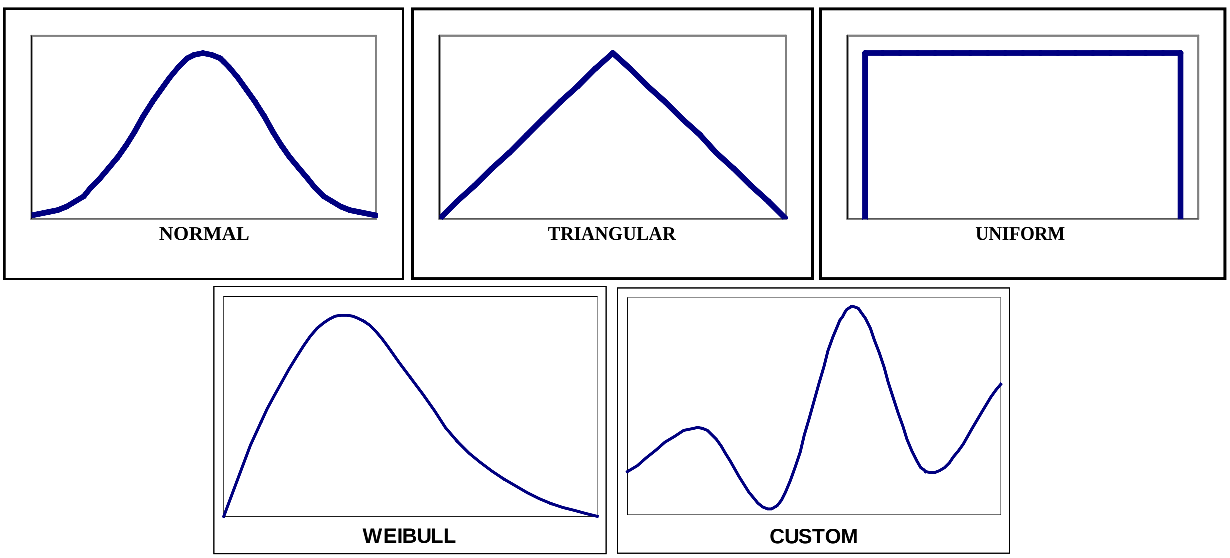

Figure 8B.5.1 Normal, Triangular, Uniform, Weibull, and Custom Probability Distributions

During a simulation, multiple scenarios of a model are calculated by repeatedly sampling values from the probability distributions for the uncertain variables and using those values for the cell. Crystal Ball simulations can consist of as many trials (or scenarios) as desired—hundreds or even thousands. During a single trial, Crystal Ball randomly selects a value from the defined possibilities (the range and shape of the probability distribution) for each uncertain variable and then recalculates the spreadsheet.

APPENDIX 8C. ENERGY PRICE CALCULATIONS FOR DEDICATED-PURPOSE POOL PUMPS

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APPENDIX 8C. ENERGY PRICE CALCULATIONS FOR DEDICATED-PURPOSE POOL PUMPS

8C.1 INTRODUCTION

Figure 8C.1.1 depicts the energy price calculation process, which also encompasses average energy price, seasonal marginal price factor, and monthly price factor calculations.

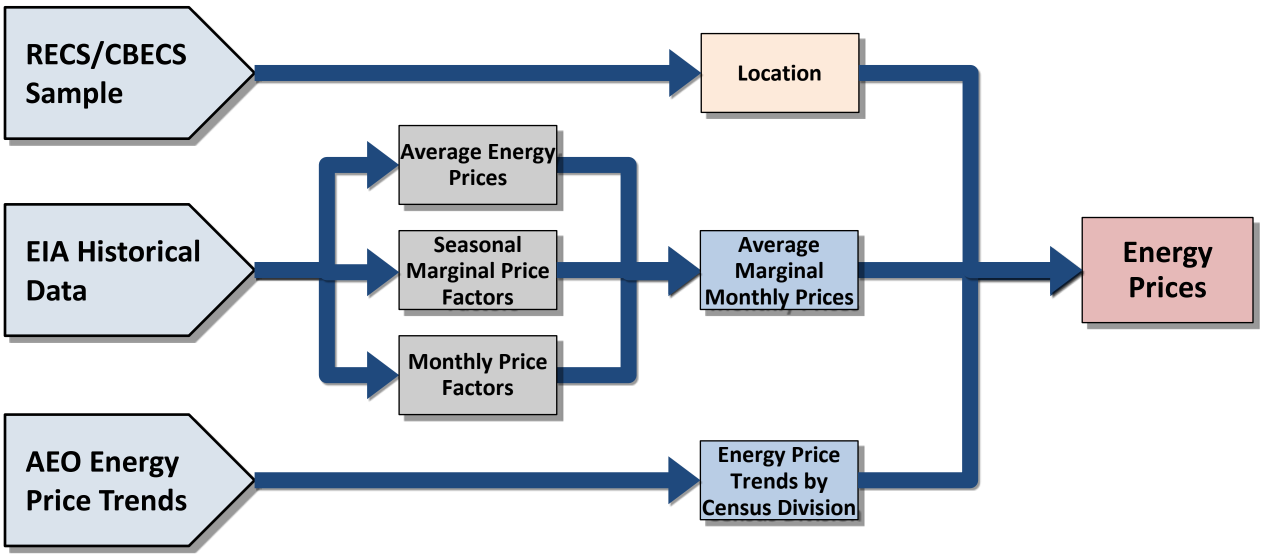

Figure 8C.1.1 Energy Price Calculation Process

8C.2 RECS/CBECS SAMPLE MAPPING PROCESS

To match the state data from the Energy Information Administration (EIA) to the Residential Energy Consumption Survey (RECS) 2009[1] household and Commercial Building Energy Consumption Survey (CBECS) 2012[2] building samples, DOE used the 2014 U.S. installed pool bases by state provided by APSP. RECS 2009 utilizes 27 regions (also called reportable domains) and CBECS 2012 provides 9 census divisions. The 27th RECS region includes Oregon, Washington, Alaska, and Hawaii. DOE subdivided Alaska and Hawaii into separate regions (28 and 29, respectively), based on cooling and heating degree days. In addition, West Virginia, which is in RECS region 14, was disaggregated into region 30 based on cooling and heating degree days.

8C.3 AVERAGE MARGINAL MONTHLY PRICES

8C.3.1 Average Annual Prices Determination

8C.3.1.1 Annual Electrical Prices

DOE derived 2015 annual electricity prices from EIA Form 826 data.[3] The EIA Form

826 data include residential and commercial energy prices by state. Table 8C.3.1 shows the monthly residential electricity prices for each state reported in the EIA Form 826. Table 8E.3.2 shows the monthly commercial electricity prices for each state reported in the EIA Form 826.

Table 8C.3.1 2015 Monthly Residential Electricity Prices by State from EIA (2015¢/kWh)

Geographical Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg. 2015
United States	12.10	12.29	12.34	12.64	12.95	12.93	12.99	12.93	13.06	12.73	12.73	12.36	12.67
Alabama	10.99	11.23	11.78	12.30	12.19	12.01	11.90	12.05	12.31	12.00	11.46	11.23	11.79
Alaska	19.36	19.31	19.64	19.62	20.26	21.07	21.27	21.01	20.61	20.61	20.28	19.60	20.22
Arizona	11.05	11.58	11.51	12.26	12.69	12.74	12.83	12.64	12.74	12.22	11.29	10.75	12.03
Arkansas	8.73	9.09	9.02	10.10	10.27	10.36	10.38	10.39	10.52	10.00	10.15	9.51	9.88
California	17.42	17.15	17.04	12.48	17.35	17.21	18.01	18.24	18.38	14.98	17.36	17.30	16.91
Colorado	11.40	11.70	11.73	12.00	12.00	12.46	12.60	12.47	12.43	11.74	11.58	11.44	11.96
Connecticut	21.06	21.88	22.02	22.30	23.08	22.58	20.44	19.23	19.25	20.08	20.01	19.43	20.95
Delaware	12.07	13.50	12.72	13.74	14.44	14.02	13.24	13.55	13.66	14.40	14.51	13.45	13.61
District of Columbia	12.00	13.14	12.36	13.20	13.22	12.78	13.64	13.03	12.73	13.90	13.71	13.34	13.09
Florida	11.93	12.09	11.63	11.70	11.59	11.71	11.94	11.77	11.81	11.61	11.69	11.49	11.75
Georgia	10.43	10.74	10.58	11.25	11.68	12.28	13.28	12.20	12.10	11.09	10.44	10.22	11.36
Hawaii	33.08	30.62	30.87	30.45	30.11	30.39	30.05	29.87	28.52	28.22	27.16	26.86	29.68
Idaho	9.66	9.41	9.59	9.79	11.58	10.04	10.67	10.29	10.08	10.31	9.39	9.64	10.04
Illinois	11.51	11.90	11.96	13.40	13.39	12.59	12.58	12.42	12.69	13.47	13.19	11.81	12.58
Indiana	10.64	10.63	10.76	11.88	11.57	11.43	11.14	11.16	11.38	11.75	11.64	11.11	11.26
Iowa	10.22	10.69	10.87	11.93	12.32	13.46	13.57	13.92	12.26	11.68	11.42	10.61	11.91
Kansas	11.34	11.72	12.05	13.04	12.95	12.72	12.33	12.44	12.26	12.34	12.79	12.29	12.36
Kentucky	9.50	9.57	9.70	10.54	10.24	10.05	9.95	10.27	10.34	10.72	10.67	10.34	10.16
Louisiana	8.80	8.81	8.81	9.22	9.68	9.27	9.24	9.60	9.61	9.55	9.05	8.70	9.20
Maine	15.62	16.66	15.50	15.52	15.66	15.73	15.42	15.49	15.60	15.60	15.55	15.52	15.66
Maryland	13.07	13.14	13.16	13.76	13.65	14.68	13.95	13.95	14.12	15.34	14.98	14.67	14.04
Massachusetts	20.78	21.70	22.10	21.67	20.70	19.52	18.04	17.99	18.84	18.39	18.32	19.60	19.80
Michigan	13.59	13.77	13.81	14.06	14.23	14.70	15.30	15.43	14.56	14.59	14.68	14.58	14.44
Minnesota	11.51	11.58	11.53	12.22	12.66	13.08	13.07	12.97	12.87	12.74	12.05	11.77	12.34
Mississippi	11.06	11.06	11.11	12.12	12.20	11.78	11.16	10.96	11.07	11.16	11.55	11.16	11.37
Missouri	9.23	9.37	9.46	10.76	11.84	12.68	12.58	12.37	11.45	11.05	11.03	10.39	11.02
Montana	10.74	10.33	10.63	10.92	11.25	11.58	11.42	11.31	11.44	11.27	10.85	10.42	11.01
Nebraska	9.18	9.69	9.76	10.63	10.98	12.06	12.20	12.19	12.29	10.72	10.53	9.68	10.83
Nevada	12.70	13.47	13.62	13.49	13.53	13.13	12.01	12.36	12.39	12.99	12.71	12.41	12.90
New Hampshire	19.15	19.49	19.55	19.70	19.49	18.70	17.74	17.13	17.23	17.73	18.14	18.00	18.50
New Jersey	15.49	15.49	15.57	15.88	15.65	16.44	16.76	16.66	16.00	15.55	15.66	15.54	15.89
New Mexico	12.19	12.53	12.11	12.38	12.41	13.13	13.32	13.35	12.78	12.71	11.83	11.36	12.51
New York	19.31	19.78	19.02	17.75	18.09	18.79	18.74	18.41	18.41	18.33	18.26	17.53	18.54
North Carolina	10.54	10.68	11.24	12.11	11.42	11.11	11.47	11.63	11.91	12.11	11.41	10.96	11.38
North Dakota	8.34	8.70	8.78	10.14	10.48	11.62	11.16	11.16	11.21	10.59	9.31	8.84	10.03
Ohio	12.07	12.04	12.16	12.60	12.95	13.05	13.29	13.09	12.56	12.88	13.00	12.61	12.69
Oklahoma	8.56	9.46	9.51	11.17	11.03	10.29	9.98	10.27	10.57	11.12	10.26	9.00	10.10
Oregon	10.30	10.43	10.49	10.64	10.81	10.95	11.06	10.68	10.88	10.92	10.68	10.39	10.69
Pennsylvania	12.96	13.04	13.16	13.57	14.07	14.42	14.22	14.24	14.33	14.49	14.40	14.12	13.92
Rhode Island	17.73	20.16	20.00	21.06	18.64	18.31	17.59	18.86	21.60	19.68	18.63	19.88	19.35

Geographical Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg. 2015
South Carolina	11.77	12.03	12.22	13.10	12.69	12.52	12.49	12.59	12.76	12.65	12.65	12.05	12.46
South Dakota	10.02	10.24	10.17	10.92	11.28	11.63	11.76	11.72	11.82	11.68	10.97	10.27	11.04
Tennessee	9.96	9.85	9.79	10.60	10.58	10.43	10.31	10.28	10.31	10.61	10.77	10.40	10.32
Texas	11.55	11.70	11.63	12.17	12.11	11.85	11.58	11.51	11.58	11.41	11.48	11.33	11.66
Utah	10.33	10.47	10.49	10.58	11.09	11.34	11.94	11.45	11.42	10.58	10.71	10.56	10.91
Vermont	16.48	16.54	16.66	17.24	17.49	17.38	17.06	17.11	17.26	17.43	17.65	17.17	17.12
Virginia	10.80	11.01	10.94	11.41	11.63	11.81	11.66	11.69	11.85	11.52	11.48	10.98	11.40
Washington	8.13	8.65	8.67	8.82	8.89	9.39	9.34	9.36	9.37	9.40	9.37	9.19	9.05
West Virginia	9.06	9.15	9.62	10.13	10.05	10.47	10.71	10.63	10.79	10.98	10.73	10.43	10.23
Wisconsin	13.74	13.85	13.96	14.50	14.82	15.22	14.62	14.64	14.82	14.86	14.19	13.83	14.42
Wyoming	10.28	10.43	10.61	10.88	11.25	11.40	11.62	11.50	11.49	11.55	10.99	10.57	11.05

Table 8C.3.2 2015 Monthly Commercial Electricity Prices by State from EIA (2015¢/kWh)

Geographical Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg. 2015
United States	10.26	10.60	10.52	10.32	10.44	10.81	11.02	10.90	10.94	10.69	10.27	10.11	10.57
Alabama	10.63	11.15	10.92	10.94	11.15	11.15	10.98	11.02	11.01	10.80	10.63	10.54	10.91
Alaska	17.24	17.33	17.56	17.44	18.21	18.01	18.66	18.26	18.24	17.97	17.72	17.23	17.82
Arizona	9.53	9.66	9.68	10.08	10.78	11.38	11.48	11.17	11.05	10.56	9.54	9.56	10.37
Arkansas	7.62	7.91	7.84	8.11	8.39	8.59	8.60	8.58	8.61	8.27	8.20	8.17	8.24
California	13.85	13.98	13.91	13.88	14.87	16.91	18.39	18.14	18.22	17.12	14.81	13.77	15.65
Colorado	9.18	9.68	9.73	9.92	9.95	9.67	10.26	10.18	10.16	9.83	9.78	9.35	9.81
Connecticut	16.71	17.41	17.32	16.39	16.51	15.88	14.95	15.10	15.15	15.80	15.24	15.19	15.97
Delaware	9.13	11.00	11.63	9.22	11.02	10.47	10.09	10.00	10.18	10.10	10.71	10.68	10.35
District of Columbia	12.20	11.61	12.60	12.43	11.61	12.37	11.85	11.49	12.18	11.73	12.03	12.41	12.04
Florida	9.91	10.24	9.81	9.67	9.55	9.57	9.56	9.54	9.59	9.58	9.57	9.42	9.67
Georgia	9.78	10.21	9.25	9.40	9.86	9.54	11.31	9.78	9.63	9.62	9.05	9.11	9.71
Hawaii	30.92	27.69	27.97	26.81	26.48	27.02	27.30	27.28	26.68	25.92	24.64	24.96	26.97
Idaho	7.59	7.81	7.77	7.89	7.96	8.21	8.08	8.13	7.67	7.71	7.59	7.40	7.82
Illinois	8.62	8.73	9.19	8.90	8.92	8.85	9.01	9.05	9.13	9.02	8.84	8.46	8.89
Indiana	9.63	9.63	9.66	9.78	9.60	9.63	9.50	9.44	9.42	9.48	9.62	9.37	9.56
Iowa	8.14	8.31	8.45	8.62	8.84	10.22	10.61	10.92	9.33	8.74	8.21	7.97	9.03
Kansas	9.53	9.67	10.04	10.18	10.14	10.32	10.22	10.11	9.94	9.88	9.85	9.90	9.98
Kentucky	8.90	9.24	9.36	9.60	9.37	9.12	9.15	9.45	9.42	9.40	9.47	9.31	9.32
Louisiana	8.84	8.75	8.74	8.61	8.81	8.33	8.34	8.64	8.64	8.66	8.44	8.38	8.60
Maine	14.74	15.59	13.32	12.72	12.78	12.38	12.39	12.65	12.57	13.05	13.19	12.54	13.16
Maryland	11.10	11.59	11.67	11.29	10.86	10.98	10.92	11.07	10.81	10.88	10.63	10.86	11.06
Massachusetts	16.53	17.77	17.29	15.52	14.86	15.07	15.28	15.39	15.63	15.24	14.53	15.18	15.69
Michigan	10.05	10.43	10.35	10.39	10.89	10.88	11.22	10.94	10.42	10.49	10.55	10.38	10.58
Minnesota	9.07	8.97	8.89	9.34	9.63	10.40	10.16	10.05	9.86	9.55	9.14	8.94	9.50
Mississippi	10.97	11.06	10.96	10.94	10.96	10.86	10.37	10.21	10.27	10.25	10.29	10.41	10.63
Missouri	7.80	7.96	7.86	8.20	9.35	10.42	10.43	10.46	9.20	8.65	8.57	8.49	8.95
Montana	10.83	10.06	10.30	10.22	10.27	10.41	10.16	9.98	10.14	10.13	10.10	9.73	10.19
Nebraska	8.37	8.47	8.60	8.66	8.86	9.49	9.66	9.48	9.39	8.63	8.44	8.48	8.88

Geographical Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg. 2015
Nevada	9.42	9.76	9.73	9.44	9.47	9.36	8.78	9.12	9.25	9.13	8.98	8.71	9.26
New Hampshire	15.75	16.47	16.42	15.50	15.11	14.62	14.26	14.04	14.19	14.43	14.41	14.66	14.99
New Jersey	11.98	12.85	13.15	12.90	12.74	13.86	13.89	13.75	13.34	12.52	12.45	11.92	12.95
New Mexico	10.24	10.39	10.11	10.09	10.16	11.02	11.30	11.13	10.73	10.29	9.88	9.59	10.41
New York	14.62	15.96	15.07	14.46	14.48	15.79	16.19	15.95	16.12	15.34	14.04	13.88	15.16
North Carolina	8.44	8.59	8.86	8.50	8.55	8.69	8.95	8.90	8.95	8.86	8.37	8.71	8.70
North Dakota	8.11	8.30	8.17	9.15	8.76	9.52	9.27	9.46	9.23	9.00	8.42	8.47	8.82
Ohio	9.63	9.87	9.76	10.00	9.83	10.12	10.14	10.05	9.95	10.10	10.20	9.89	9.96
Oklahoma	7.03	7.17	7.35	7.06	7.22	8.02	8.14	8.22	7.93	7.72	7.09	6.85	7.48
Oregon	8.72	8.87	8.86	8.89	8.89	8.81	8.91	8.58	8.81	8.95	8.84	8.65	8.82
Pennsylvania	9.54	9.96	10.01	9.53	9.60	9.68	9.41	9.42	9.51	9.60	9.53	9.53	9.61
Rhode Island	18.00	20.36	18.77	17.05	14.53	14.10	14.08	14.47	14.80	14.57	14.54	15.26	15.88
South Carolina	9.92	10.34	10.12	9.77	9.98	10.41	10.18	10.32	10.38	9.84	10.05	9.96	10.11
South Dakota	8.80	8.80	8.58	8.79	8.64	8.99	9.30	9.31	9.12	8.99	8.81	8.59	8.89
Tennessee	10.10	10.08	10.03	10.21	10.15	10.36	10.27	10.27	10.31	10.22	10.26	10.21	10.21
Texas	8.06	8.10	8.02	7.63	7.86	7.89	7.73	7.76	7.78	7.59	7.65	7.59	7.81
Utah	7.97	8.31	8.28	8.46	9.22	9.49	9.11	9.12	9.42	8.90	8.20	7.80	8.69
Vermont	14.06	14.35	14.29	14.62	14.86	14.75	14.42	14.40	14.48	14.82	14.60	14.53	14.52
Virginia	8.48	8.53	8.48	8.22	8.17	8.24	8.19	8.13	8.13	8.06	8.16	8.08	8.24
Washington	7.66	8.19	8.23	8.02	7.98	8.11	8.16	8.06	8.18	8.35	8.47	8.51	8.16
West Virginia	7.81	8.06	8.71	8.79	8.49	8.60	8.67	8.70	8.81	9.01	9.12	8.77	8.63
Wisconsin	10.60	10.78	10.85	10.90	11.05	11.58	11.29	11.39	11.43	11.09	10.60	10.63	11.02
Wyoming	8.74	8.70	9.16	9.26	9.28	9.36	9.25	9.12	9.29	9.47	9.22	8.62	9.12

DOE calculated both residential and commercial annual electricity prices for each RECS 2009 or CBECS 2012 geographical area by averaging monthly electricity prices by State to get State electricity prices in 2015. For areas with more than one State, DOE weighted each state's average price by its number of shipments. Table 8C.3.3 shows the 2014 number of pool bases -weighted average residential electricity prices in 2015 for each adjusted RECS 2009 geographic area. Table 8C.3.4 shows the shipment-weighted average commercial electricity prices for each CBECS 2012 geographic area.

Table 8C.3.3 DOE Average Residential Electricity Prices by Region in 2015

	Geographic Area	2015$/kWh
1	Connecticut, Maine, New Hampshire, Rhode Island, Vermont	$0.196
2	Massachusetts	$0.198
3	New York	$0.185
4	New Jersey	$0.159
5	Pennsylvania	$0.139
6	Illinois	$0.126
7	Indiana, Ohio	$0.123
8	Michigan	$0.144
9	Wisconsin	$0.144
10	Iowa, Minnesota, North Dakota, South Dakota	$0.120
11	Kansas, Nebraska	$0.118
12	Missouri	$0.110
13	Virginia	$0.114
14	Delaware, District of Columbia, Maryland	$0.140
15	Georgia	$0.114
16	North Carolina, South Carolina	$0.117
17	Florida	$0.117
18	Alabama, Kentucky, Mississippi	$0.111
19	Tennessee	$0.103
20	Arkansas, Louisiana, Oklahoma	$0.097
21	Texas	$0.117
22	Colorado	$0.120
23	Idaho, Montana, Utah, Wyoming	$0.107
24	Arizona	$0.120
25	Nevada, New Mexico	$0.128
26	California	$0.169
27	Oregon, Washington	$0.096
28	Alaska	$0.202
29	Hawaii	$0.297
30	West Virginia	$0.102
31	U.S. Average	$0.127

Table 8C.3.4 DOE Average Commercial Electricity Prices by Region in 2015

	Geographic Area	2015$/kWh
1	New England	$0.155
2	Middle Atlantic	$0.129
3	East North Central	$0.099
4	West North Central	$0.092
5	South Atlantic	$0.096
6	East South Central	$0.102
7	West South Central	$0.079
8	Mountain	$0.099
9	Pacific	$0.147
10	U.S. Average	$0.106

8C.3.2 Monthly Energy Price Factors Determination

For pool pumps, the Department of Energy (DOE) developed monthly energy price factors and used monthly energy consumption data for the life-cycle cost and payback period calculation. DOE developed monthly energy price factors to capture robust seasonal trends in monthly energy prices. To convert available annual energy prices into monthly energy prices, DOE determined monthly energy price factors.

8C.3.2.1 Monthly Residential Electricity Price Factor Calculations

DOE collected historical electricity prices from 1996 to 2015 from EIA's Form 826. These data are published annually and include monthly electricity sales, revenues from electricity sales, and average price for the residential, commercial, industrial, and transportation sectors by year and by state. DOE aggregated the data into 30 geographical areas as described in section 8E.2.

For each geographic region, DOE determined average electricity prices from 1996 to 2015 by weighting the average residential electricity prices for each state by the number of pool bases in 2014 in each state.

As an example, to illustrate the methodology for producing monthly price factors, the following tables and charts show the calculation of monthly average electricity price factors, based on New York historic electricity price data. Table 8C.3.5 shows the average residential electricity prices for New York.

Table 8C.3.5 1996-2015 Average Residential Electricity Prices for New York from EIA (nominal cents/kWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
1996	13.39	13.46	13.71	13.80	14.00	14.54	14.67	14.78	14.59	13.97	13.83	13.75	14.04
1997	13.75	13.67	13.83	13.69	13.84	14.70	14.80	14.68	14.56	14.01	13.93	13.84	14.11
1998	13.87	13.73	13.77	13.84	14.05	13.78	13.78	13.65	13.66	13.29	13.04	12.92	13.62
1999	12.85	12.75	12.95	13.34	12.85	13.44	13.44	13.54	13.74	13.64	13.44	13.24	13.27
2000	12.90	13.18	13.33	13.52	13.54	14.22	15.40	14.77	14.52	14.12	13.94	13.98	13.95
2001	13.89	13.93	13.58	13.44	14.01	14.41	14.99	14.61	14.23	14.22	13.53	13.25	14.01
2002	12.95	13.00	12.81	12.69	13.30	14.01	14.19	14.16	14.42	13.87	13.37	13.19	13.50
2003	12.77	13.30	13.91	14.55	14.77	14.98	15.14	14.94	14.92	14.75	14.23	13.63	14.32
2004	13.32	14.02	13.98	14.03	14.20	14.99	15.36	15.32	15.10	14.93	14.88	14.29	14.53
2005	14.05	14.53	14.40	14.64	15.36	15.58	15.63	16.16	16.69	17.36	17.57	16.53	15.71
2006	16.61	16.66	15.89	16.36	16.56	17.33	17.56	17.74	17.92	17.22	16.33	15.88	16.84
2007	16.09	15.89	16.83	17.14	17.50	18.17	17.27	17.96	17.15	17.48	16.94	16.66	17.09
2008	16.86	17.31	16.92	18.08	18.79	19.42	19.66	20.93	19.49	17.57	16.95	16.61	18.22
2009	16.83	16.72	16.40	16.57	16.86	18.22	18.79	18.21	18.75	18.12	16.72	17.47	17.47
2010	17.30	18.05	17.55	18.92	19.21	19.41	20.11	19.35	20.09	18.36	18.25	17.72	18.69
2011	17.25	17.45	17.58	17.63	18.30	19.07	19.22	19.25	18.84	18.78	17.93	17.26	18.21
2012	16.79	16.51	16.64	16.70	17.33	18.31	18.38	18.12	18.52	18.44	17.44	17.47	17.55
2013	17.93	19.10	18.16	17.67	18.35	19.32	20.03	19.14	19.56	18.88	18.49	18.18	18.73
2014	19.57	21.69	20.90	19.54	20.59	20.88	20.48	19.51	19.41	19.43	19.45	19.26	20.06
2015	19.31	19.78	19.02	17.75	18.09	18.79	18.74	18.41	18.41	18.33	18.26	17.53	18.54

DOE then calculated monthly energy price factors by dividing the monthly prices by the annual average for each year. Table 8C.3.6 and Figure 8C.3.1 show the calculated results for New York.

Table 8C.3.6 Monthly Resiential Electricity Price Factors for 1996-2015 for New York

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996	0.95	0.96	0.98	0.98	1.00	1.04	1.04	1.05	1.04	0.99	0.98	0.98
1997	0.97	0.97	0.98	0.97	0.98	1.04	1.05	1.04	1.03	0.99	0.99	0.98
1998	1.02	1.01	1.01	1.02	1.03	1.01	1.01	1.00	1.00	0.98	0.96	0.95
1999	0.97	0.96	0.98	1.01	0.97	1.01	1.01	1.02	1.04	1.03	1.01	1.00
2000	0.92	0.94	0.96	0.97	0.97	1.02	1.10	1.06	1.04	1.01	1.00	1.00
2001	0.99	0.99	0.97	0.96	1.00	1.03	1.07	1.04	1.02	1.02	0.97	0.95
2002	0.96	0.96	0.95	0.94	0.99	1.04	1.05	1.05	1.07	1.03	0.99	0.98
2003	0.89	0.93	0.97	1.02	1.03	1.05	1.06	1.04	1.04	1.03	0.99	0.95
2004	0.92	0.96	0.96	0.97	0.98	1.03	1.06	1.05	1.04	1.03	1.02	0.98
2005	0.89	0.93	0.92	0.93	0.98	0.99	0.99	1.03	1.06	1.11	1.12	1.05
2006	0.99	0.99	0.94	0.97	0.98	1.03	1.04	1.05	1.06	1.02	0.97	0.94
2007	0.94	0.93	0.98	1.00	1.02	1.06	1.01	1.05	1.00	1.02	0.99	0.97
2008	0.93	0.95	0.93	0.99	1.03	1.07	1.08	1.15	1.07	0.96	0.93	0.91
2009	0.96	0.96	0.94	0.95	0.97	1.04	1.08	1.04	1.07	1.04	0.96	1.00
2010	0.93	0.97	0.94	1.01	1.03	1.04	1.08	1.04	1.07	0.98	0.98	0.95
2011	0.95	0.96	0.97	0.97	1.00	1.05	1.06	1.06	1.03	1.03	0.98	0.95
2012	0.96	0.94	0.95	0.95	0.99	1.04	1.05	1.03	1.06	1.05	0.99	1.00
2013	0.96	1.02	0.97	0.94	0.98	1.03	1.07	1.02	1.04	1.01	0.99	0.97
2014	0.98	1.08	1.04	0.97	1.03	1.04	1.02	0.97	0.97	0.97	0.97	0.96
2015	1.04	1.07	1.03	0.96	0.98	1.01	1.01	0.99	0.99	0.99	0.99	0.95

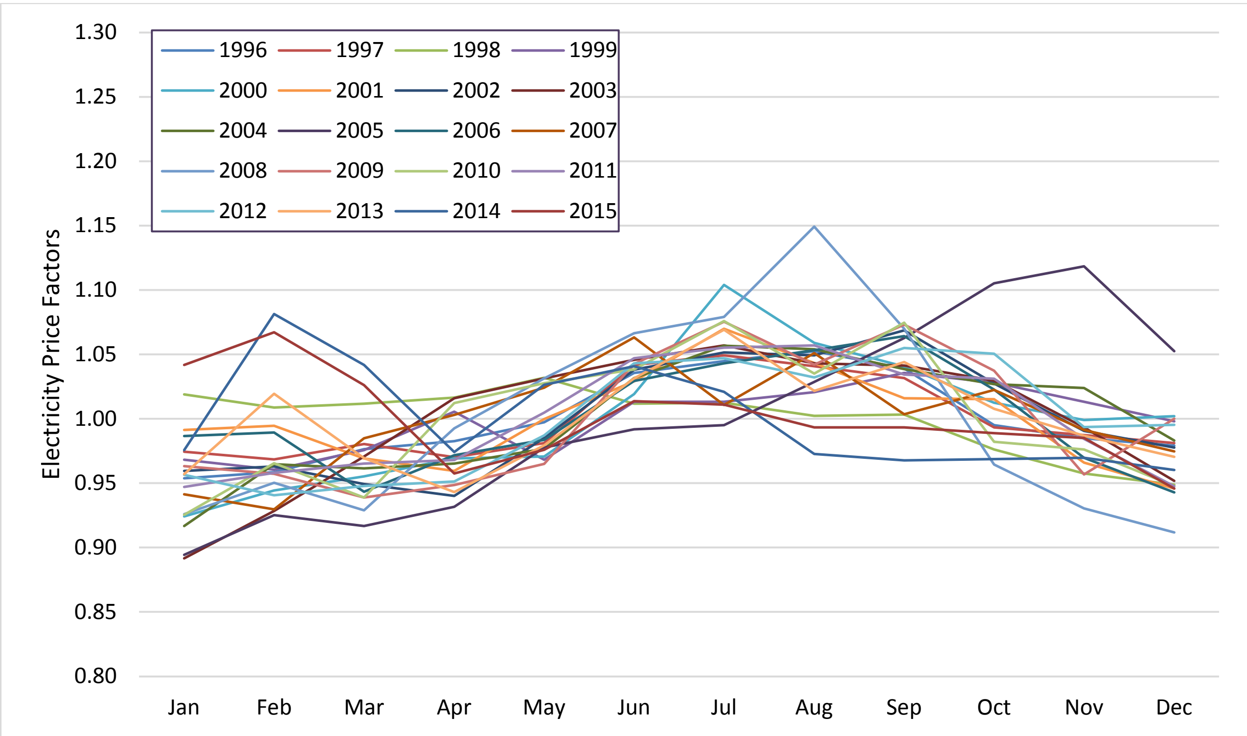

Figure 8C.3.1 Monthly Electricity Price Factors for 1996-2015 for New York

DOE then averaged the monthly energy price factors for 1996 to 2015 to develop an average energy price factor for each month. DOE performed the same calculations for each geographic region to develop the shipment-weighted average monthly energy price factors shown in Table 8C.3.7, which includes the results for New York.

Table 8C.3.7 Monthly Residential Electricity Price Factors

Geographical Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Connecticut, Maine, New Hampshire, Rhode Island, Vermont	0.93	0.94	0.95	0.96	0.97	0.97	0.95	0.96	0.96	0.97	0.95	0.94
Massachusetts	0.94	0.95	0.95	0.95	0.95	0.97	0.94	0.95	0.96	0.95	0.94	0.97
New York	0.91	0.93	0.92	0.93	0.95	0.98	1.00	0.99	0.99	0.97	0.94	0.92
New Jersey	0.91	0.91	0.92	0.92	0.94	1.00	1.03	1.03	1.00	0.93	0.93	0.93
Pennsylvania	0.89	0.90	0.91	0.94	0.97	1.01	1.01	1.00	0.99	0.97	0.94	0.92
Illinois	0.86	0.90	0.92	0.97	1.01	1.00	1.00	0.98	0.99	0.99	0.93	0.87
Indiana, Ohio	0.86	0.88	0.91	0.96	1.00	1.01	0.99	0.99	0.99	0.99	0.96	0.90
Michigan	0.92	0.92	0.92	0.94	0.95	0.98	0.99	1.00	0.97	0.95	0.94	0.94
Wisconsin	0.91	0.92	0.93	0.95	0.97	0.98	0.96	0.96	0.97	0.97	0.95	0.93
Iowa, Minnesota, North Dakota, South Dakota	0.87	0.89	0.90	0.94	0.98	1.02	1.02	1.02	0.99	0.97	0.93	0.90
Kansas, Nebraska	0.83	0.87	0.89	0.94	0.97	1.03	1.05	1.06	1.04	0.96	0.92	0.87
Missouri	0.80	0.82	0.86	0.91	1.04	1.12	1.11	1.10	1.00	0.93	0.90	0.84
Virginia	0.87	0.89	0.91	0.95	0.99	1.00	1.01	1.01	0.99	0.97	0.94	0.90
Delaware, District of Columbia, Maryland	0.87	0.87	0.89	0.91	0.98	1.05	1.04	1.04	1.02	0.96	0.92	0.90
Georgia	0.86	0.89	0.92	0.93	0.97	1.03	1.05	1.05	1.01	0.95	0.91	0.86
North Carolina, South Carolina	0.89	0.92	0.93	0.97	0.97	0.95	0.97	0.97	0.98	1.00	0.96	0.92
Florida	0.93	0.95	0.95	0.96	0.95	0.94	0.95	0.96	0.96	0.96	0.97	0.95
Alabama, Kentucky, Mississippi	0.88	0.90	0.93	0.97	0.98	0.98	0.97	0.98	0.98	0.98	0.96	0.92
Tennessee	0.91	0.91	0.93	0.96	0.98	0.96	0.95	0.95	0.95	0.99	0.98	0.96
Arkansas, Louisiana, Oklahoma	0.85	0.89	0.92	0.96	0.98	1.00	1.00	1.00	1.02	1.00	0.94	0.88
Texas	0.89	0.90	0.93	0.95	0.96	0.99	0.99	0.99	0.98	0.98	0.94	0.92
Colorado	0.90	0.92	0.92	0.95	0.97	0.99	0.98	0.98	0.98	0.97	0.95	0.92
Idaho, Montana, Utah, Wyoming	0.90	0.91	0.91	0.93	0.96	0.99	1.00	1.00	0.98	0.97	0.94	0.93
Arizona	0.84	0.87	0.89	0.94	1.04	1.03	1.02	1.01	1.01	1.00	0.89	0.91
Nevada, New Mexico	0.92	0.94	0.95	0.97	0.96	0.95	0.95	0.95	0.95	0.98	0.97	0.95
California	0.95	0.93	0.92	0.89	0.96	0.98	1.00	1.00	0.97	0.90	0.96	0.97
Oregon, Washington	0.92	0.94	0.94	0.94	0.94	0.96	0.96	0.97	0.97	0.97	0.97	0.96
Alaska	0.90	0.91	0.93	0.94	0.97	0.97	0.99	0.98	0.96	0.97	0.96	0.94
Hawaii	0.93	0.93	0.93	0.93	0.94	0.96	0.96	0.97	0.97	0.98	0.97	0.97
West Virginia	0.90	0.91	0.93	0.96	0.99	0.97	0.96	0.96	0.97	1.00	0.97	0.93
United States	0.89	0.90	0.92	0.95	0.97	0.99	0.99	0.99	0.99	0.97	0.95	0.92

8C.3.2.2 Monthly Commercial Electricity Price Factor Calculations

DOE collected historical electricity prices from 1996 to 2015 from EIA's Form 826. These data are published annually and include annual electricity sales, revenues from electricity sales, and average price for the residential, commercial, industrial, and transportation sectors by State. DOE aggregated the data into the nine Census divisions as described in section 8E.2.

The 2014 number of pool bases-weighted average monthly commercial electricity price factors are shown in Table 8C.3.8.

Table 8C.3.8 Monthly Commercial Electricity Price Factors

Geographical Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
New England	0.94	0.96	0.94	0.94	0.93	0.98	0.98	0.97	0.98	0.95	0.92	0.95
Middle Atlantic	0.91	0.92	0.92	0.91	0.94	1.00	1.02	1.01	1.00	0.96	0.92	0.92
East North Central	0.91	0.93	0.94	0.95	0.96	0.98	0.98	0.98	0.96	0.97	0.95	0.93
West North Central	0.86	0.89	0.90	0.91	0.97	1.06	1.07	1.07	0.99	0.92	0.90	0.89
South Atlantic	0.93	0.96	0.95	0.95	0.95	0.95	0.96	0.96	0.96	0.96	0.96	0.95
East South Central	0.93	0.94	0.95	0.95	0.96	0.96	0.95	0.96	0.95	0.96	0.96	0.96
West South Central	0.93	0.95	0.96	0.94	0.95	0.97	0.97	0.97	0.96	0.96	0.94	0.94
Mountain	0.89	0.91	0.91	0.93	0.97	1.01	0.99	0.99	0.99	0.99	0.94	0.91
Pacific	0.85	0.87	0.87	0.88	0.92	1.03	1.08	1.07	1.05	1.01	0.93	0.88
United States	0.91	0.93	0.93	0.93	0.94	0.99	1.00	1.00	0.99	0.97	0.94	0.92

8C.3.3 Seasonal Marginal Price Factors Determination

Marginal energy prices are the prices consumers pay for the last unit of energy used. DOE used the marginal energy prices for each building to determine the cost of saved energy associated with the use of higher-efficiency equipments. Because marginal prices reflect a change in a consumer's bill associated with a change in energy consumed, such prices are appropriate for determining energy cost savings associated with possible changes to efficiency standards.

EIA provides historical monthly electricity consumption and expenditures by state. This data was used to determine 10-year average marginal prices for the RECS 2009 geographical areas, which are then used to convert average monthly energy prices into marginal monthly energy prices. Because a pool pump operates during specific seasons, DOE determined summer and winter marginal price factors.

EIA also provides RECS 2009 billing data that was gathered from a subset of RECS housing records. For each household with billing data, the following are provided for each billing cycle: the start and end date, the electricity consumption in kWh, and the electricity cost in dollars. This data was used to validate marginal electricity price factors by RECS 2009 geographical area.

8C.3.3.1 Marginal Price Factor Calculation for Electricity

Table 8C.3.9 and Table 8C.3.10 show the resulting electricity marginal price factors for both residential and commercial sectors.

Table 8C.3.9 Residential Marginal Electricity Price Factors using EIA 2006-2015 Data

Geographical Area	Summer	Winter
Connecticut, Maine, New Hampshire, Rhode Island, Vermont	0.91	1.01
Massachusetts	0.90	1.13
New York	1.12	1.01
New Jersey	1.16	0.98
Pennsylvania	1.06	0.85
Illinois	0.91	0.70
Indiana, Ohio	1.04	0.75
Michigan	1.12	0.93
Wisconsin	1.00	0.88
Iowa, Minnesota, North Dakota, South Dakota	1.09	0.85
Kansas, Nebraska	1.14	0.75
Missouri	1.23	0.75
Virginia	1.08	0.83
Delaware, District of Columbia, Maryland	1.07	0.93
Georgia	1.18	0.88
North Carolina, South Carolina	0.97	0.85
Florida	1.04	0.95
Alabama, Kentucky, Mississippi	0.98	0.85
Tennessee	0.95	0.86
Arkansas, Louisiana, Oklahoma	0.99	0.76
Texas	1.00	0.91
Colorado	1.15	0.85
Idaho, Montana, Utah, Wyoming	1.09	0.94
Arizona	1.05	0.84
Nevada, New Mexico	1.03	0.87
California	1.23	1.12
Oregon, Washington	0.87	0.93
Alaska	0.87	0.92
Hawaii	1.21	0.96
West Virginia	0.94	0.85
United States	1.07	0.85

Table 8C.3.10 Commercial Marginal Electricity Price Factors using EIA 2006-2015 Data

Geographical Area	Summer	Winter
New England	1.05	1.16
Middle Atlantic	1.37	1.12
East North Central	1.09	0.74
West North Central	1.60	0.64
South Atlantic	1.04	0.80
East South Central	1.04	0.67
West South Central	1.08	0.68

Mountain	1.23	1.07
Pacific	1.84	0.88
United States	1.32	0.75

8C.3.4 Results

DOE applied the regional monthly energy price factors to develop residential and commercial average monthly energy prices for 2015 for electricity (Table 8C.3.11 and Table 8C.3.12). Each geographical area was matched with the appropriate Census Region.

Table 8C.3.11 Residential Average Monthly Electricity Prices for 2015 Using Monthly Price Factors (2015$/kWh)

Geographical Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Connecticut, Maine, New Hampshire, Rhode Island, Vermont	$0.18	$0.18	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.18
Massachusetts	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19
New York	$0.17	$0.17	$0.17	$0.17	$0.18	$0.18	$0.18	$0.18	$0.18	$0.18	$0.17	$0.17
New Jersey	$0.14	$0.14	$0.15	$0.15	$0.15	$0.16	$0.16	$0.16	$0.16	$0.15	$0.15	$0.15
Pennsylvania	$0.12	$0.12	$0.13	$0.13	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14	$0.13	$0.13
Illinois	$0.11	$0.11	$0.12	$0.12	$0.13	$0.13	$0.13	$0.12	$0.12	$0.12	$0.12	$0.11
Indiana, Ohio	$0.11	$0.11	$0.11	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.11
Michigan	$0.13	$0.13	$0.13	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14
Wisconsin	$0.13	$0.13	$0.13	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14	$0.13
Iowa, Minnesota, North Dakota, South Dakota	$0.10	$0.11	$0.11	$0.11	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.11	$0.11
Kansas, Nebraska	$0.10	$0.10	$0.11	$0.11	$0.11	$0.12	$0.12	$0.12	$0.12	$0.11	$0.11	$0.10
Missouri	$0.09	$0.09	$0.09	$0.10	$0.11	$0.12	$0.12	$0.12	$0.11	$0.10	$0.10	$0.09
Virginia	$0.10	$0.10	$0.10	$0.11	$0.11	$0.11	$0.12	$0.12	$0.11	$0.11	$0.11	$0.10
Delaware, District of Columbia, Maryland	$0.12	$0.12	$0.12	$0.13	$0.14	$0.15	$0.14	$0.14	$0.14	$0.13	$0.13	$0.13
Georgia	$0.10	$0.10	$0.10	$0.11	$0.11	$0.12	$0.12	$0.12	$0.11	$0.11	$0.10	$0.10
North Carolina, South Carolina	$0.10	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11	$0.12	$0.12	$0.11	$0.11
Florida	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11
Alabama, Kentucky, Mississippi	$0.10	$0.10	$0.10	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11	$0.10
Tennessee	$0.09	$0.09	$0.10	$0.10	$0.10	$0.10	$0.10	$0.10	$0.10	$0.10	$0.10	$0.10
Arkansas, Louisiana, Oklahoma	$0.08	$0.09	$0.09	$0.09	$0.09	$0.10	$0.10	$0.10	$0.10	$0.10	$0.09	$0.09
Texas	$0.10	$0.10	$0.11	$0.11	$0.11	$0.12	$0.12	$0.12	$0.11	$0.11	$0.11	$0.11
Colorado	$0.11	$0.11	$0.11	$0.11	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.11	$0.11
Idaho, Montana, Utah, Wyoming	$0.10	$0.10	$0.10	$0.10	$0.10	$0.11	$0.11	$0.11	$0.11	$0.10	$0.10	$0.10
Arizona	$0.10	$0.10	$0.11	$0.11	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.11	$0.11
Nevada, New Mexico	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12
California	$0.16	$0.16	$0.16	$0.15	$0.16	$0.17	$0.17	$0.17	$0.16	$0.15	$0.16	$0.16
Oregon, Washington	$0.09	$0.09	$0.09	$0.09	$0.09	$0.09	$0.09	$0.09	$0.09	$0.09	$0.09	$0.09
Alaska	$0.18	$0.18	$0.19	$0.19	$0.20	$0.20	$0.20	$0.20	$0.19	$0.20	$0.19	$0.19
Hawaii	$0.27	$0.27	$0.28	$0.28	$0.28	$0.28	$0.29	$0.29	$0.29	$0.29	$0.29	$0.29
West Virginia	$0.09	$0.09	$0.10	$0.10	$0.10	$0.10	$0.10	$0.10	$0.10	$0.10	$0.10	$0.09
United States	$0.11	$0.11	$0.12	$0.12	$0.12	$0.13	$0.13	$0.13	$0.13	$0.12	$0.12	$0.12

Table 8C.3.12 Commercial Average Monthly Electricity Prices for 2015 Using Monthly Price Factors (2015$/kWh)

Geographical Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
New England	$0.15	$0.15	$0.15	$0.15	$0.14	$0.15	$0.15	$0.15	$0.15	$0.15	$0.14	$0.15
Middle Atlantic	$0.12	$0.12	$0.12	$0.12	$0.12	$0.13	$0.13	$0.13	$0.13	$0.12	$0.12	$0.12
East North Central	$0.09	$0.09	$0.09	$0.09	$0.10	$0.10	$0.10	$0.10	$0.10	$0.10	$0.09	$0.09
West North Central	$0.08	$0.08	$0.08	$0.08	$0.09	$0.10	$0.10	$0.10	$0.09	$0.08	$0.08	$0.08
South Atlantic	$0.09	$0.09	$0.09	$0.09	$0.09	$0.09	$0.09	$0.09	$0.09	$0.09	$0.09	$0.09
East South Central	$0.09	$0.10	$0.10	$0.10	$0.10	$0.10	$0.10	$0.10	$0.10	$0.10	$0.10	$0.10
West South Central	$0.07	$0.07	$0.08	$0.07	$0.07	$0.08	$0.08	$0.08	$0.08	$0.08	$0.07	$0.07
Mountain	$0.09	$0.09	$0.09	$0.09	$0.10	$0.10	$0.10	$0.10	$0.10	$0.10	$0.09	$0.09
Pacific	$0.13	$0.13	$0.13	$0.13	$0.14	$0.15	$0.16	$0.16	$0.15	$0.15	$0.14	$0.13
United States	$0.10	$0.10	$0.10	$0.10	$0.10	$0.10	$0.11	$0.11	$0.10	$0.10	$0.10	$0.10

DOE applied the marginal price factors to the monthly electricity prices to develop marginal residential and commercial monthly electricity prices for 2015 (Table 8C.3.13 and Table 8C.3.14).

Table 8C.3.13 Residential Marginal Monthly Electricity Prices for 2015 Using Marginal Price Factors (2015$/kWh)

Geographical Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Connecticut, Maine, New Hampshire, Rhode Island, Vermont	$0.18	$0.19	$0.19	$0.17	$0.17	$0.17	$0.17	$0.17	$0.17	$0.17	$0.19	$0.19
Massachusetts	$0.21	$0.21	$0.21	$0.17	$0.17	$0.17	$0.17	$0.17	$0.17	$0.17	$0.21	$0.22
New York	$0.17	$0.17	$0.17	$0.19	$0.20	$0.20	$0.21	$0.20	$0.20	$0.20	$0.18	$0.17
New Jersey	$0.14	$0.14	$0.14	$0.17	$0.17	$0.19	$0.19	$0.19	$0.18	$0.17	$0.14	$0.14
Pennsylvania	$0.11	$0.11	$0.11	$0.14	$0.14	$0.15	$0.15	$0.15	$0.15	$0.14	$0.11	$0.11
Illinois	$0.07	$0.08	$0.08	$0.11	$0.12	$0.12	$0.11	$0.11	$0.11	$0.11	$0.08	$0.08
Indiana, Ohio	$0.08	$0.08	$0.08	$0.12	$0.13	$0.13	$0.13	$0.13	$0.13	$0.13	$0.09	$0.08
Michigan	$0.12	$0.12	$0.12	$0.15	$0.15	$0.16	$0.16	$0.16	$0.16	$0.15	$0.13	$0.13
Wisconsin	$0.12	$0.12	$0.12	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14	$0.12	$0.12
Iowa, Minnesota, North Dakota, South Dakota	$0.09	$0.09	$0.09	$0.12	$0.13	$0.13	$0.13	$0.13	$0.13	$0.13	$0.09	$0.09
Kansas, Nebraska	$0.07	$0.08	$0.08	$0.13	$0.13	$0.14	$0.14	$0.14	$0.14	$0.13	$0.08	$0.08
Missouri	$0.07	$0.07	$0.07	$0.12	$0.14	$0.15	$0.15	$0.15	$0.14	$0.13	$0.07	$0.07
Virginia	$0.08	$0.08	$0.09	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.09	$0.08
Delaware, District of Columbia, Maryland	$0.11	$0.11	$0.12	$0.14	$0.15	$0.16	$0.15	$0.15	$0.15	$0.14	$0.12	$0.12
Georgia	$0.09	$0.09	$0.09	$0.13	$0.13	$0.14	$0.14	$0.14	$0.14	$0.13	$0.09	$0.09
North Carolina, South Carolina	$0.09	$0.09	$0.09	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11	$0.10	$0.09
Florida	$0.10	$0.11	$0.11	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.11	$0.11
Alabama, Kentucky, Mississippi	$0.08	$0.08	$0.09	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11	$0.09	$0.09
Tennessee	$0.08	$0.08	$0.08	$0.09	$0.10	$0.09	$0.09	$0.09	$0.09	$0.10	$0.09	$0.09
Arkansas, Louisiana, Oklahoma	$0.06	$0.07	$0.07	$0.09	$0.09	$0.10	$0.10	$0.10	$0.10	$0.10	$0.07	$0.06
Texas	$0.09	$0.10	$0.10	$0.11	$0.11	$0.12	$0.12	$0.12	$0.11	$0.11	$0.10	$0.10
Colorado	$0.09	$0.09	$0.09	$0.13	$0.13	$0.14	$0.13	$0.14	$0.14	$0.13	$0.10	$0.09
Idaho, Montana, Utah, Wyoming	$0.09	$0.09	$0.09	$0.11	$0.11	$0.12	$0.12	$0.12	$0.12	$0.11	$0.09	$0.09
Arizona	$0.09	$0.09	$0.09	$0.12	$0.13	$0.13	$0.13	$0.13	$0.13	$0.13	$0.09	$0.09
Nevada, New Mexico	$0.10	$0.11	$0.11	$0.13	$0.13	$0.12	$0.12	$0.12	$0.12	$0.13	$0.11	$0.11
California	$0.18	$0.18	$0.17	$0.18	$0.20	$0.20	$0.21	$0.21	$0.20	$0.19	$0.18	$0.18
Oregon, Washington	$0.08	$0.08	$0.08	$0.08	$0.08	$0.08	$0.08	$0.08	$0.08	$0.08	$0.09	$0.09
Alaska	$0.17	$0.17	$0.17	$0.17	$0.17	$0.17	$0.17	$0.17	$0.17	$0.17	$0.18	$0.17
Hawaii	$0.27	$0.27	$0.27	$0.33	$0.34	$0.34	$0.34	$0.35	$0.35	$0.35	$0.28	$0.28
West Virginia	$0.08	$0.08	$0.08	$0.09	$0.10	$0.09	$0.09	$0.09	$0.09	$0.10	$0.08	$0.08
United States	$0.10	$0.10	$0.10	$0.13	$0.13	$0.13	$0.13	$0.13	$0.13	$0.13	$0.10	$0.10

Table 8C.3.14 Commercial Marginal Monthly Electricity Prices for 2015 Using Marginal Price Factors (2015$/kWh)

Geographical Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
New England	$0.17	$0.17	$0.17	$0.15	$0.15	$0.16	$0.16	$0.16	$0.16	$0.15	$0.17	$0.17
Middle Atlantic	$0.13	$0.13	$0.13	$0.16	$0.16	$0.18	$0.18	$0.18	$0.18	$0.17	$0.13	$0.13
East North Central	$0.07	$0.07	$0.07	$0.10	$0.10	$0.11	$0.11	$0.11	$0.10	$0.10	$0.07	$0.07
West North Central	$0.05	$0.05	$0.05	$0.13	$0.14	$0.16	$0.16	$0.16	$0.15	$0.14	$0.05	$0.05
South Atlantic	$0.07	$0.07	$0.07	$0.09	$0.09	$0.09	$0.09	$0.10	$0.10	$0.09	$0.07	$0.07
East South Central	$0.06	$0.06	$0.06	$0.10	$0.10	$0.10	$0.10	$0.10	$0.10	$0.10	$0.07	$0.07
West South Central	$0.05	$0.05	$0.05	$0.08	$0.08	$0.08	$0.08	$0.08	$0.08	$0.08	$0.05	$0.05
Mountain	$0.10	$0.10	$0.10	$0.11	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.10	$0.10
Pacific	$0.11	$0.11	$0.11	$0.24	$0.25	$0.28	$0.29	$0.29	$0.28	$0.27	$0.12	$0.11
United States	$0.07	$0.07	$0.07	$0.13	$0.13	$0.14	$0.14	$0.14	$0.14	$0.14	$0.07	$0.07

8C.4 ENERGY PRICE TRENDS

8C.4.1 Residential Energy Price Trends

DOE used *Annual Energy Outlook 2016* (*AEO 2016*)[4] for the nine census divisions. DOE applied the projected energy price for each of the nine census divisions to each household in the sample based on the household's location.

To arrive at prices in future years, DOE multiplied the recent electricity prices by a projection of annual national-average residential electricity prices consistent with cases described on p. E-8 in AEO 2016.[a] DOE converted the forecasted energy prices into energy price factors, with 2015 as the base year. Figure 8C.4.1 shows the national residential electricity price factor trend. To estimate the trend after 2040, DOE followed past guidelines provided to the Federal Energy Management Program (FEMP) by EIA and used the average rate of change during 2030–2040 for electricity.

[a] The standards finalized in this rulemaking will take effect a few years prior to the 2022 commencement of the Clean Power Plan compliance requirements. As DOE has not modeled the effect of CPP during the 30-year analysis period of this rulemaking, there is some uncertainty as to the magnitude and overall effect of the energy efficiency standards. These energy efficiency standards are expected to put downward pressure on energy prices relative to the projections in the AEO 2016 case that incorporates the CPP. Consequently, DOE used the electricity price projections found in the AEO 2016 No-CPP case as these electricity price projections are expected to be lower, yielding more conservative estimates for consumer savings due to the energy efficiency standards.

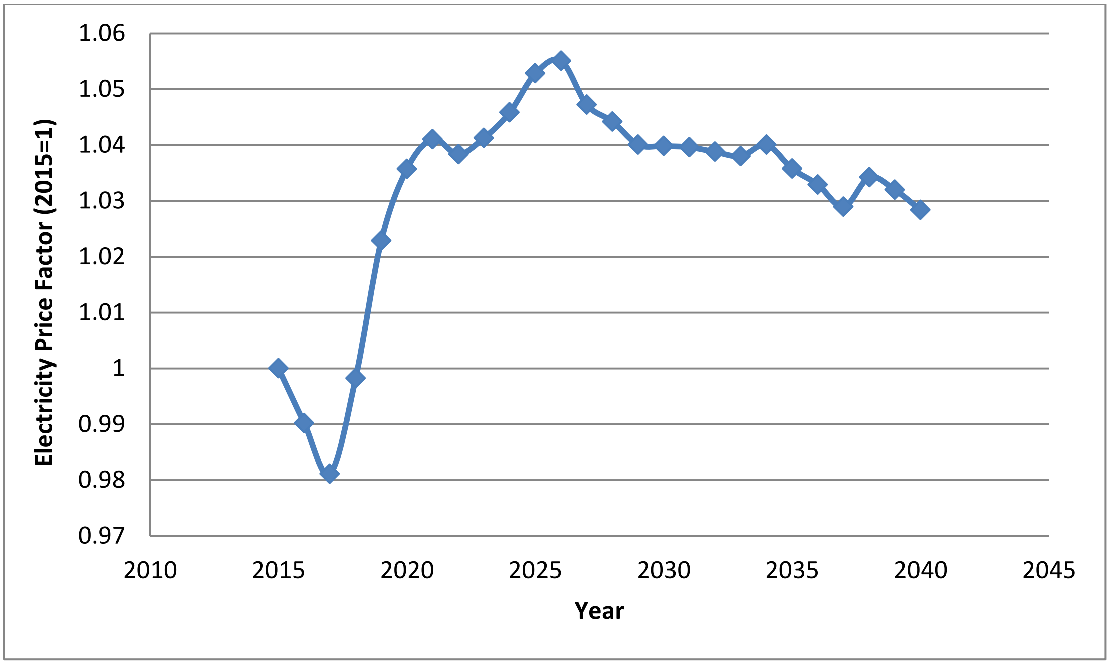

Figure 8C.4.1 Projected Residential National Electricity Price Factors

Figure 8C.4.2 shows the residential regional electricity price factor trends, disaggregated by the nine census divisions.

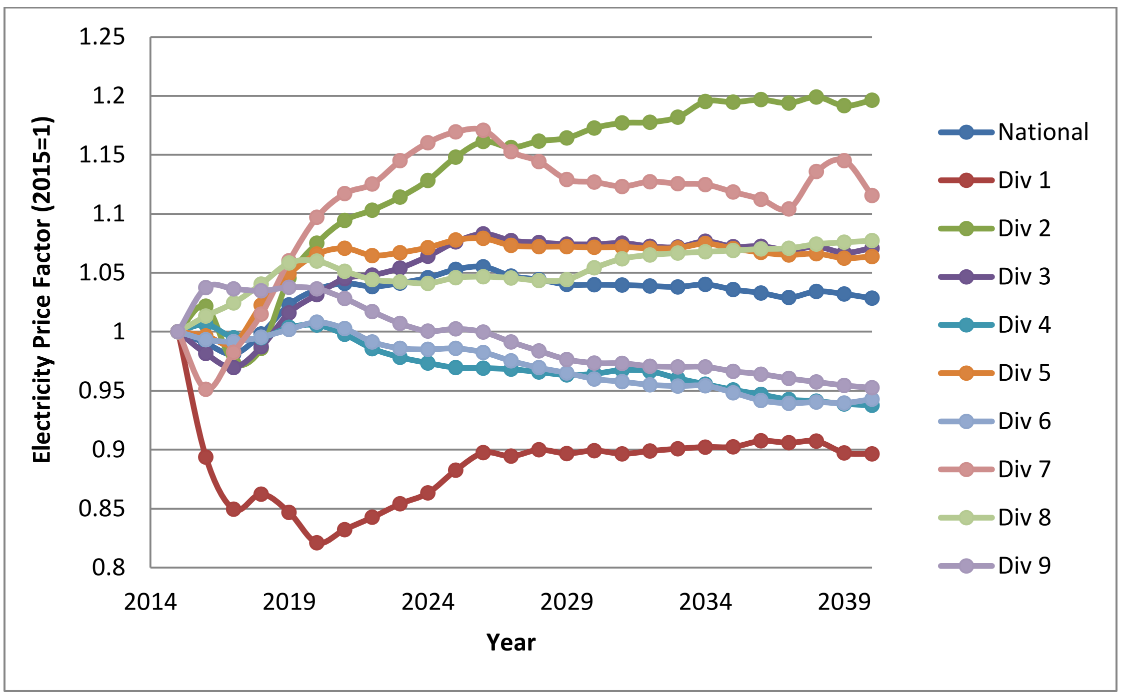

Figure 8C.4.2 Projected Residential Division Electricity Price Factors

8C.4.2 Commercial Energy Price Trends

DOE applied the same methodology to the projected energy price for each of the nine census divisions to each building in the commercial sample, based on the building's location.

To arrive at prices in future years, DOE multiplied the recent electricity prices by a projection of annual national-average residential electricity prices consistent with cases described on p. E-8 in AEO 2016.[b] DOE converted the forecasted energy prices into energy price factors, with 2015 as the base year. Figure 8C.4.3shows the national commercial electricity price factor trend. To estimate the trend after 2040, DOE followed past guidelines provided to the Federal Energy Management Program (FEMP) by EIA and used the average rate of change during 2030–2040 for electricity.

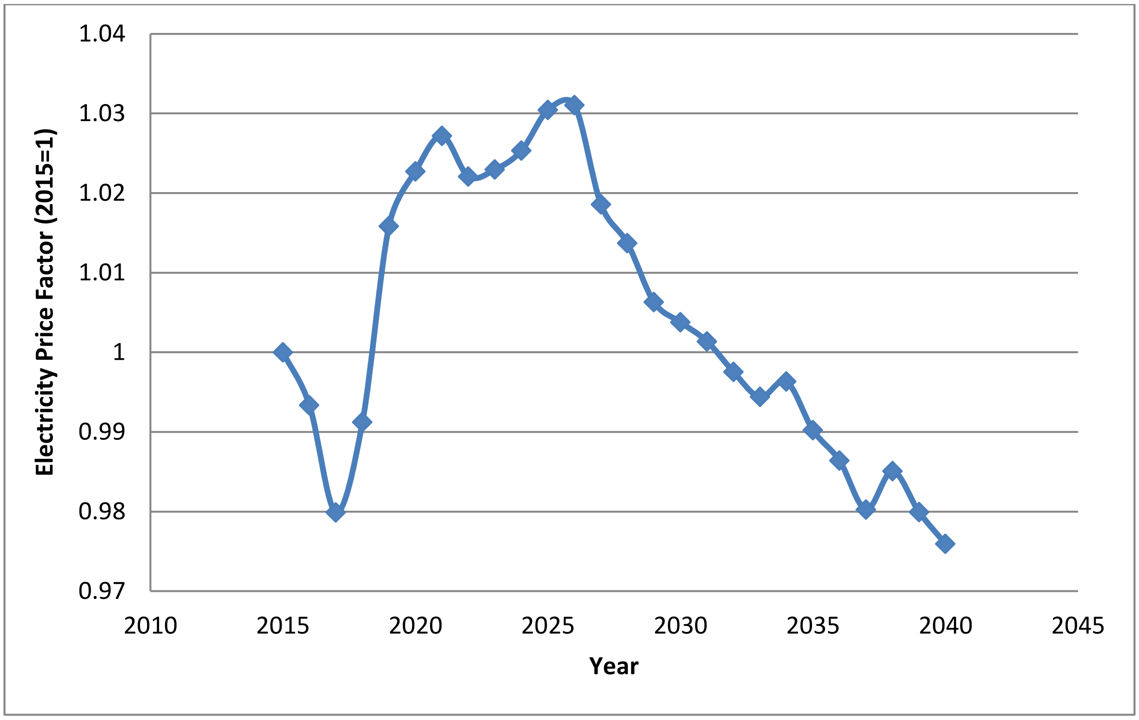

Figure 8C.4.3 Projected Commercial National Electricity Price Factors

Figure 8C.4.4 shows the commercial regional electricity price factor trends, disaggregated by the nine census divisions.

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[b] The standards finalized in this rulemaking will take effect a few years prior to the 2022 commencement of the Clean Power Plan compliance requirements. As DOE has not modeled the effect of CPP during the 30-year analysis period of this rulemaking, there is some uncertainty as to the magnitude and overall effect of the energy efficiency standards. These energy efficiency standards are expected to put downward pressure on energy prices relative to the projections in the AEO 2016 case that incorporates the CPP. Consequently, DOE used the electricity price projections found in the AEO 2016 No-CPP case as these electricity price projections are expected to be lower, yielding more conservative estimates for consumer savings due to the energy efficiency standards.

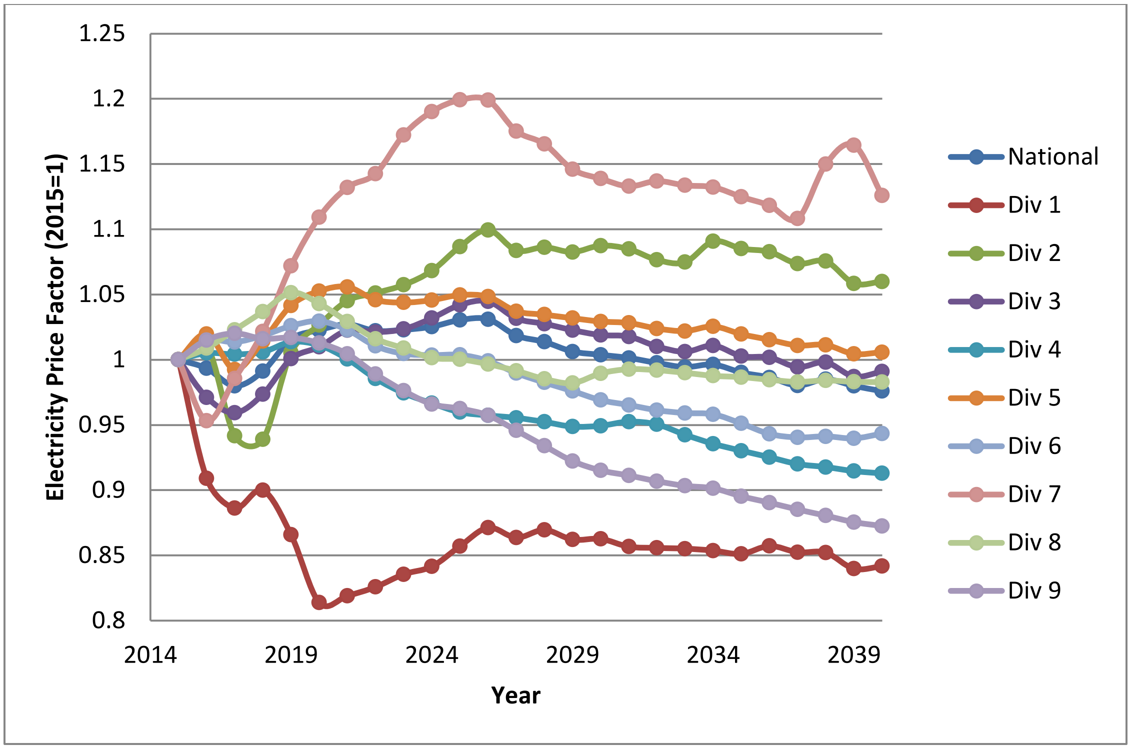

Figure 8C.4.4 Projected Commercial Division Electricity Price Factors

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3 U.S. Department of Energy: Energy Information Administration, *Form EIA-826 Database Monthly Electric Utility Sales and Revenue Data*, 2015.<www.eia.gov/electricity/data/eia826/>

4 U.S. Department of Energy: Energy Information Administration, *Annual Energy Outlook 2016 with Projections to 2040*, 2016. Washington, DC. <www.eia.gov/forecasts/aeo/>

APPENDIX 8D. DEDICATED-PURPOSE POOL PUMP LIFETIME DETERMINATION

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APPENDIX 8D. DEDICATED-PURPOSE POOL PUMP LIFETIME DETERMINATION

8D.1 INTRODUCTION

The U.S. Department of Energy (DOE) characterized the lifetime of six types of dedicated-purpose pool pumps being considered for energy efficiency standards (self-priming pool filter pumps, non-self-priming pool filter pumps, waterfall pumps, pressure cleaner booster pumps, integral cartridge filter pool pumps and integral sand filter pool pumps). DOE characterized pool pumps equipment lifetimes using a Weibull probability distribution that ranged from the minimum to maximum lifetime estimates, as described in chapter 8, section 8.2.2. The Weibull distribution is recommended for evaluating lifetime data, because it can be shaped to match low, most likely (or average), and high values. The probability of exceeding the high value is contained in the long tail of the Weibull distribution.[1]

8D.2 DERIVATION OF WEIBULL DISTRIBUTION PARAMETERS

Weibull distributions utilize available data to assign low, average, and high values to a random variable that has unknown distribution parameters. DOE applied Weibull distributions to product lifetime data to derive low, average, and high lifetime values, along with a percentile containing a high value. A similar approach is described in a technical note to the software Crystal Ball, which uses a most likely value in place of an average value.[2] The Weibull distribution can be defined as:

$$f(x) = \frac{\beta}{\alpha}\left(\frac{x-L}{\alpha}\right)^{\beta-1} exp^{-\left(\frac{x-L}{\alpha}\right)^{\beta}}$$

Where:

L = location,
α = scale, and
β= shape.

The cumulative distribution therefore is:

$$F(x) = 1 - exp^{-\left(\frac{x-L}{\alpha}\right)^{\beta}}$$

Based on available data, Weibull distribution parameters are specified as follows.

1. The output deviates must be greater than the expert opinion of low value.
2. The average, x_{avg}, must be equal to the average value from the available data.
3. The high value, xb, must correspond to some particular percentile point (*e.g.*, 95 percent or 90 percent).

The values for the parameters in the equations were determined using the approach outlined in Crystal Ball's technical note.[2]

Crystal Ball can be used to check a solution by specifying a Weibull distribution that has the calculated parameters (location, scale, and shape) in an assumption cell, then generating a forecast that equals that assumption. The forecast histogram and statistics will confirm whether the Weibull distribution matches the desired shape.

This solution can be checked using Crystal Ball by specifying a Weibull distribution with the calculated parameters (location, scale, and shape) in an assumption cell and generate a forecast that equals the assumption. Forecast histogram and statistics verify that the Weibull distribution matches the desired shape.

Table 8D.2.1 shows the average values used to determine the Weibull distribution parameters alpha and beta. The location parameter was obtained based on the warranty period provided by the manufacturers. For self-priming, non-self-priming and pressure cleaner booster pumps, DOE developed two lifetime estimates based on design option—one for single-speed and two-speed, and another for variable-speed. DOE estimated that the maximum lifetime percentile for both fuel types was 99 percent.

Table 8D.2.1 Distribution Parameters for Pool Pumps

Equipment Class	Design Option	Weibull Parameters			Maximum Percentile %	Mean Lifetime *years*
		Alpha (scale)	**Beta (shape)**	**Location (delay)**		
Self-Priming Pool Filter Pump	Single-Speed Two-Speed	5.90	3.20	2.00	99	7.3
	Variable - Speed	4.80	3.00	3.00	99	7.3
Non-Self-Priming Pool Filter Pump	Single-Speed Two-Speed	3.65	2.90	2.00	99	5.3
	Variable - Speed	2.55	2.99	3.00	99	5.3
Waterfall Pump	Single-Speed	5.90	3.20	2.00	99	7.3
Pressure Cleaner Booster Pump	Single-Speed	3.70	3.00	2.00	99	5.3
	Variable - Speed	2.60	2.99	3.00	99	5.3
Integral Pump	Single-Speed	2.50	3.00	2.00	99	4.2

Figure 8D.2.1 through Figure 8C.2.4 show the Weibull distribution as well as the cumulative Weibull distribution for each fuel type of conventional cooking products.

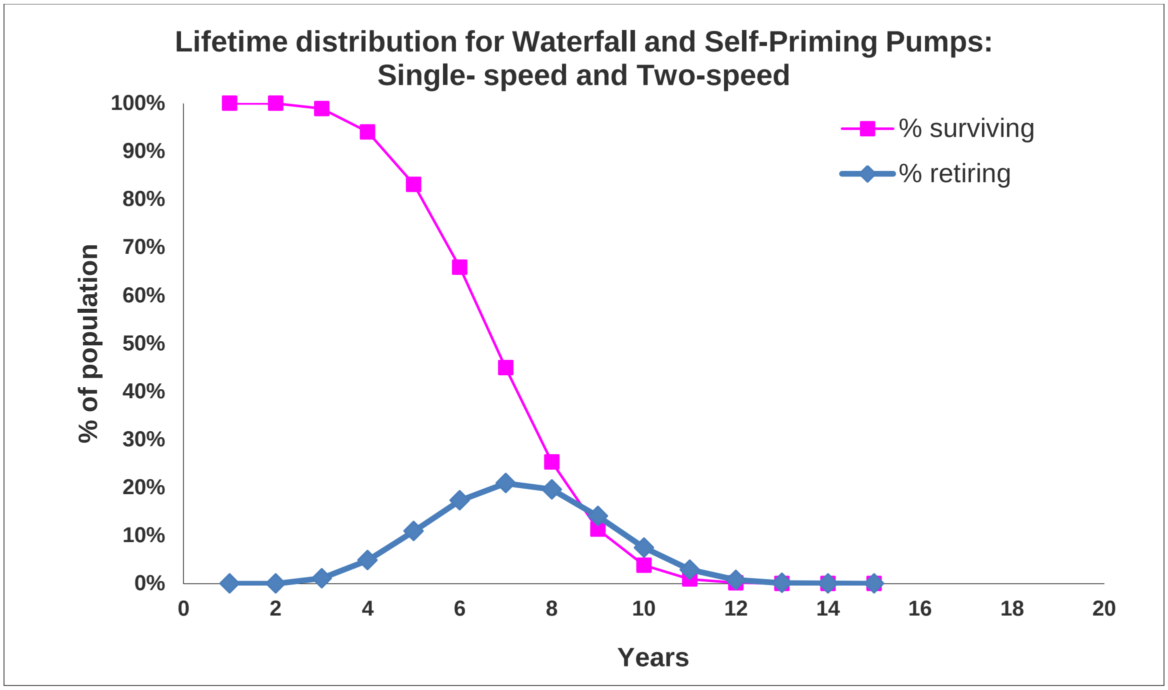

Figure 8D.2.1 Retiring and Surviving Probability for Waterfall Pumps and Self-Priming Pool Filter Pumps (Single-speed and Two-speed)

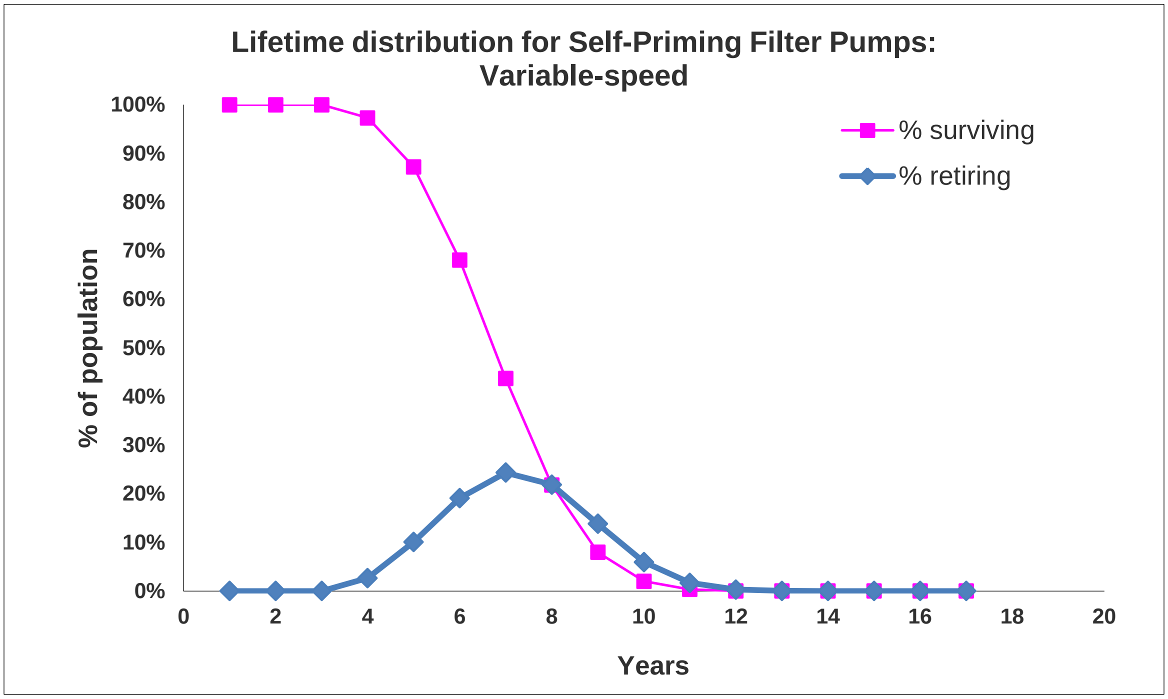

Figure 8D.2.2 Retiring and Surviving Probability for Self-Priming Pool Filter Pumps (Variable-speed)

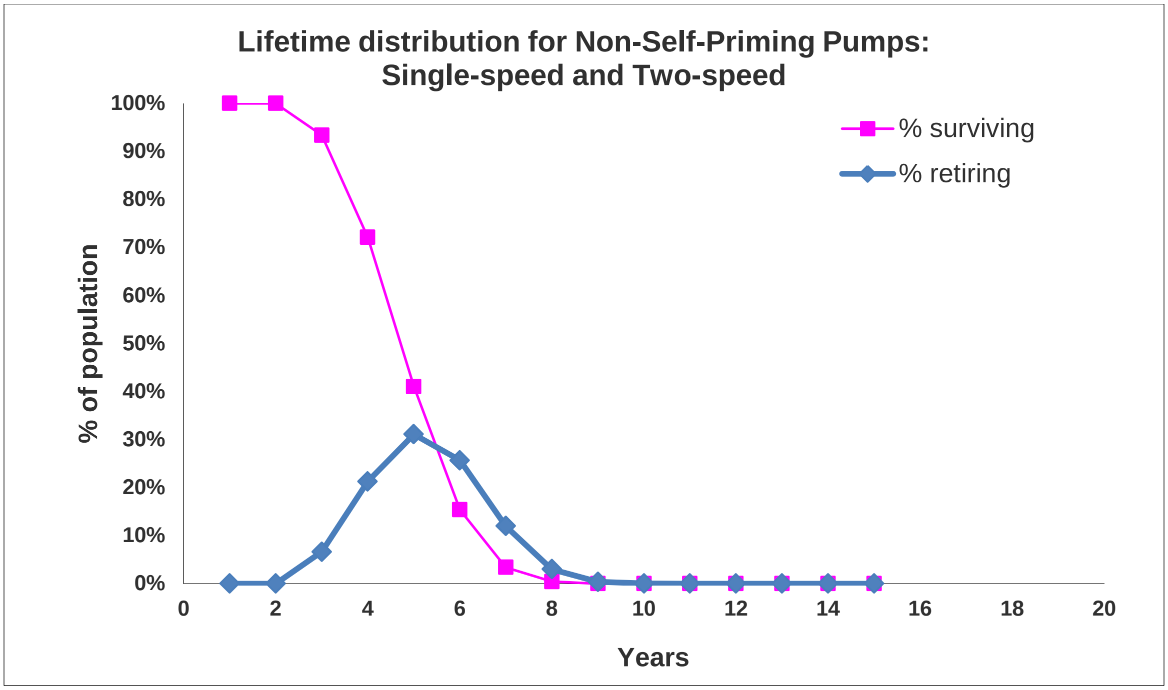

Figure 8D.2.3 Retiring and Surviving Probability for Non-Self-Priming Pool Filter Pumps (Single-speed and Two-speed)

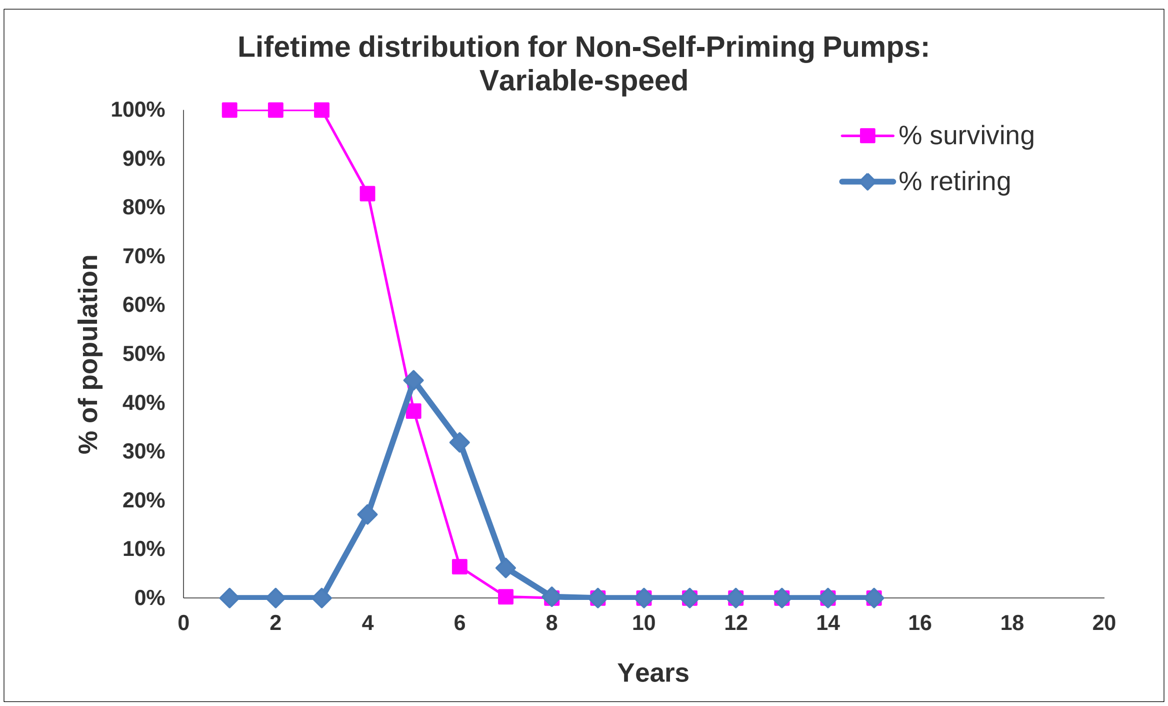

Figure 8D.2.4 Retiring and Surviving Probability for Non-Self-Priming Pool Filter Pumps (Variable-speed)

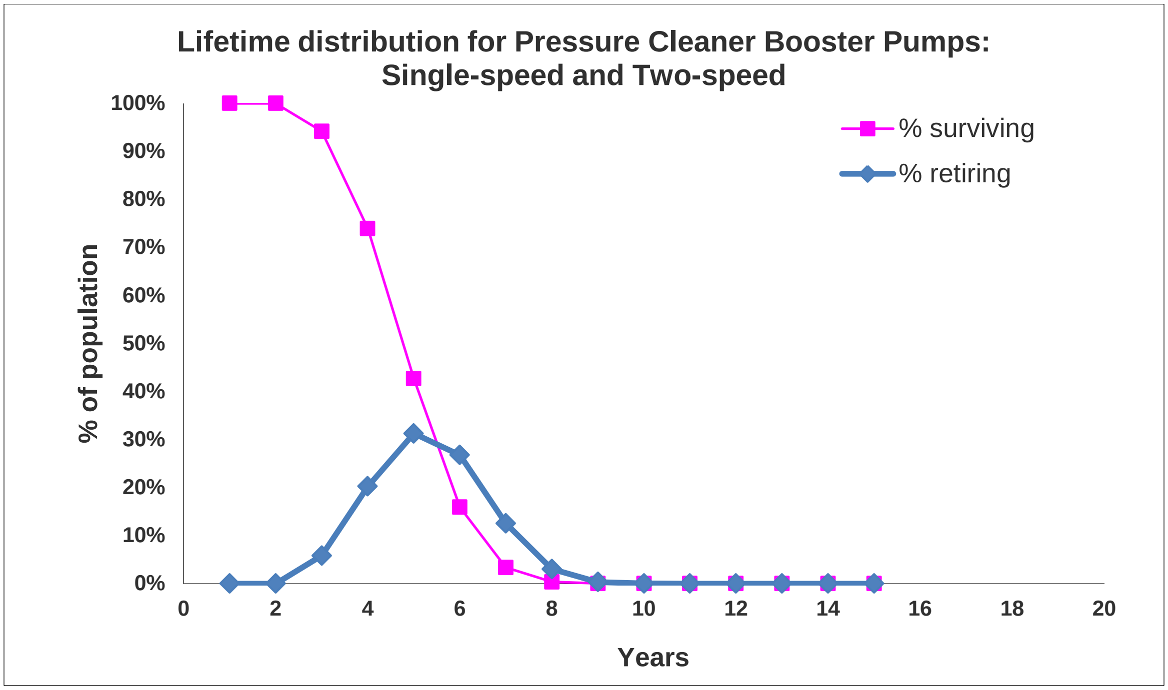

Figure 8D.2.5 Retiring and Surviving Probability for Pressure Cleaner Booster Pumps (Single-speed and Two-speed)

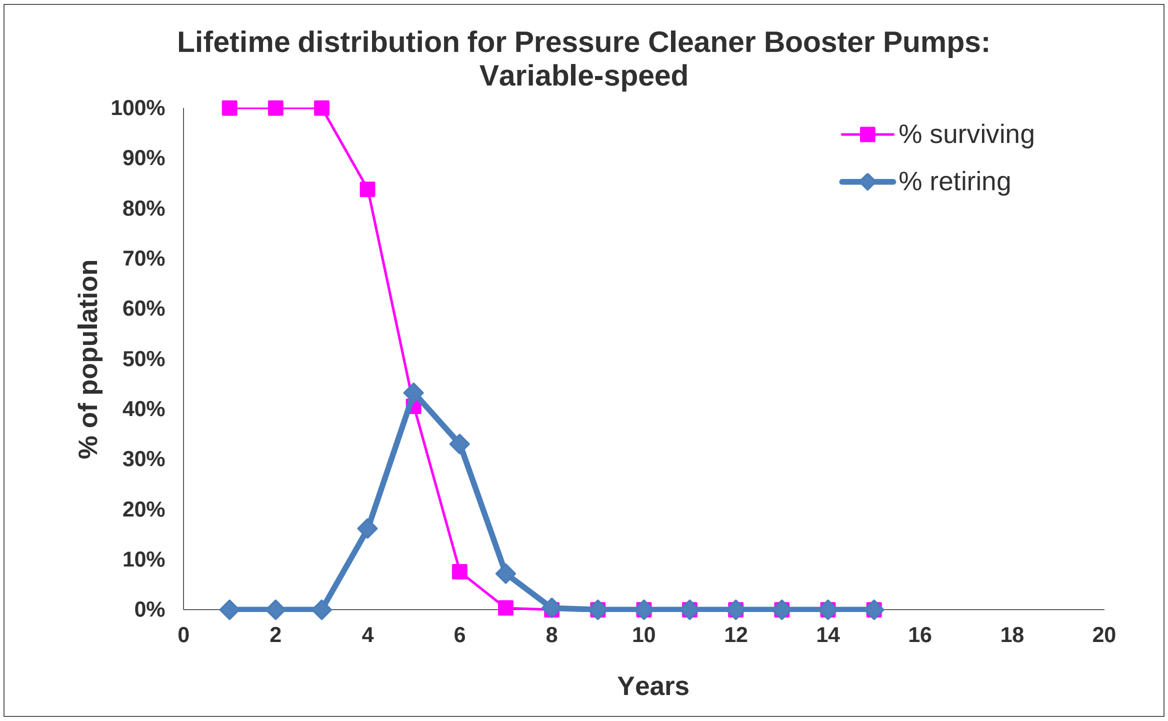

Figure 8D.2.6 Retiring and Surviving Probability for Pressure Cleaner Booster Pumps (Variable-speed)

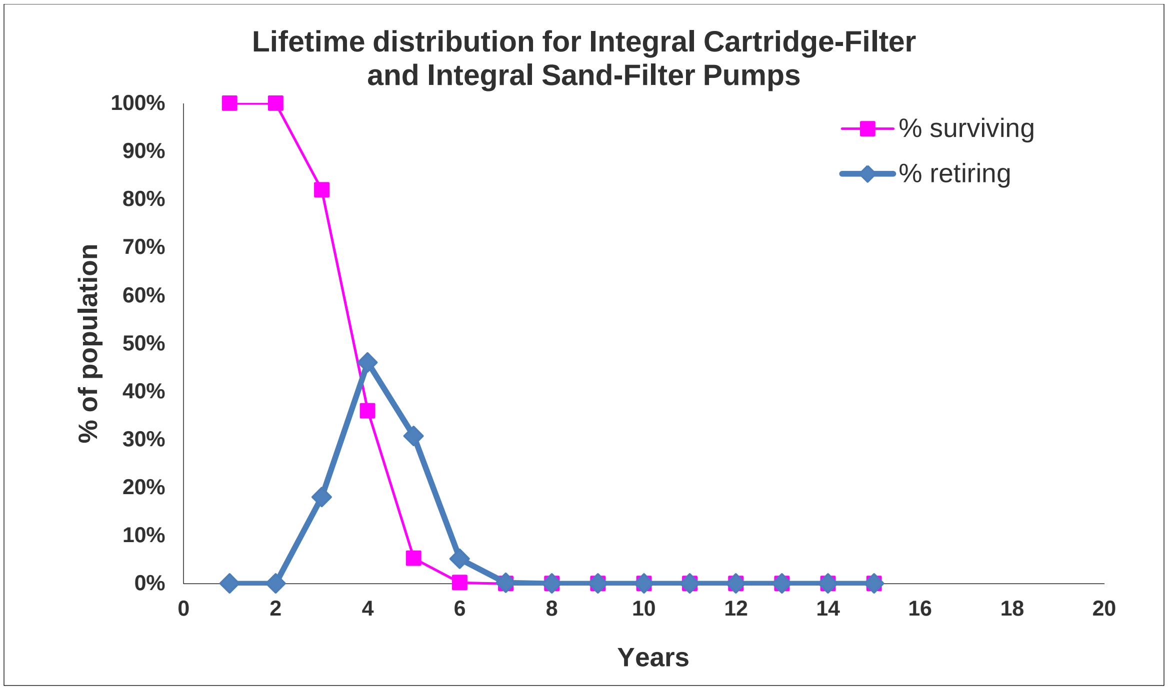

Figure 8D.2.7 Retiring and Surviving Probability for Integral Cartridge-Filter Pumps and Integral Sand-Filter Pumps

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APPENDIX 8E. DISTRIBUTIONS USED FOR DISCOUNT RATES

8E.1 INTRODUCTION

The Department of Energy (DOE) estimated discount rate distributions by consumer type: residential and commercial consumers. This appendix describes the distributions used.

8E.2 DISTRIBUTIONS USED FOR RESIDENTIAL CONSUMER DISCOUNT RATES

The Department of Energy (DOE) derived consumer discount rates for the life-cycle cost (LCC) analysis using data on interest or return rates for various types of debt and equity to calculate a real effective discount rate for each household in the Federal Reserve Board's *Survey of Consumer Finances* (*SCF*) in 1995, 1998, 2001, 2004, 2007, 2010and 2013.[1] To account for variation among households in rates for each of the types, DOE sampled a rate for each household in its building sample from a distribution of discount rates for each of six income groups. This appendix describes the distributions used.

8E.2.1 Distribution of Rates for Debt Classes

Figure 8E.2.1 through Figure 8E.2.6 show the distribution of real interest rates for different types of household debt. The data source for the interest rates for mortgages, home equity loans, credit cards, installment loans, other residence loans, and other lines of credit is the Federal Reserve Board's *SCF* in 1995, 1998, 2001, 2004, 2007, 2010, and 2013. DOE adjusted the nominal rates to real rates using the annual inflation rate in each year.

Using the appropriate *SCF* data for each year, DOE adjusted the nominal mortgage interest rate and the nominal home equity loan interest rate for each relevant household in the *SCF* for mortgage tax deduction and inflation. In cases where the effective interest rate is equal to or below the inflation rate (resulting in a negative real interest rate), DOE set the real effective interest rate to zero.

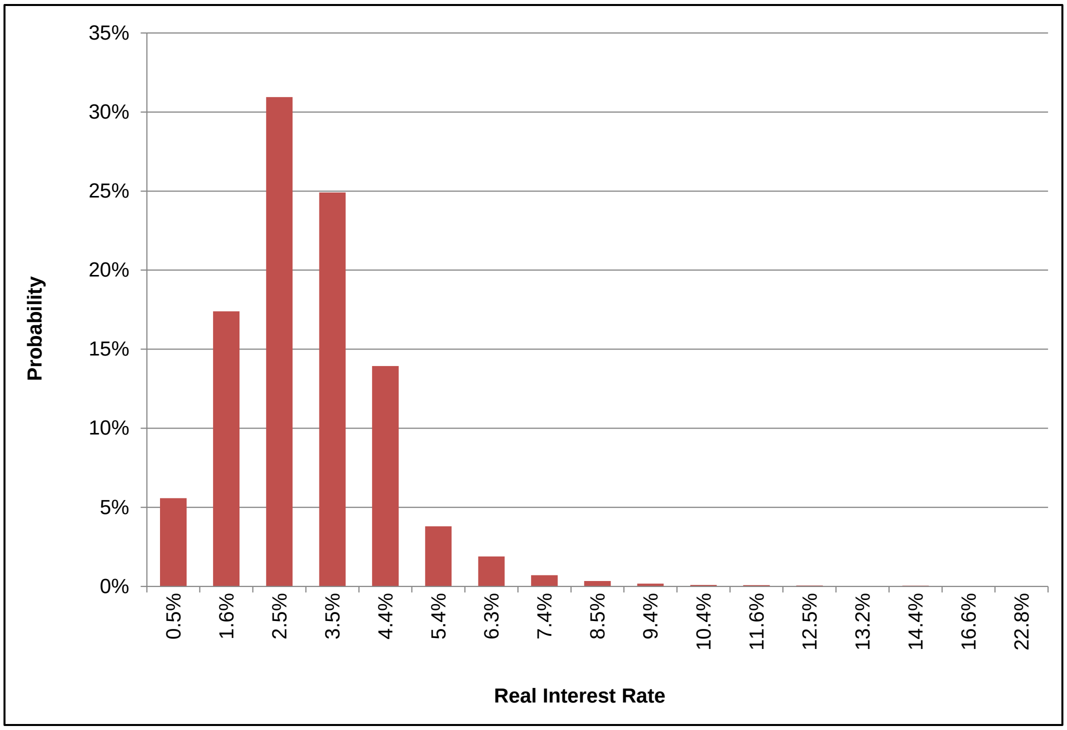

Figure 8E.2.1 Distribution of Mortgage Interest Rates

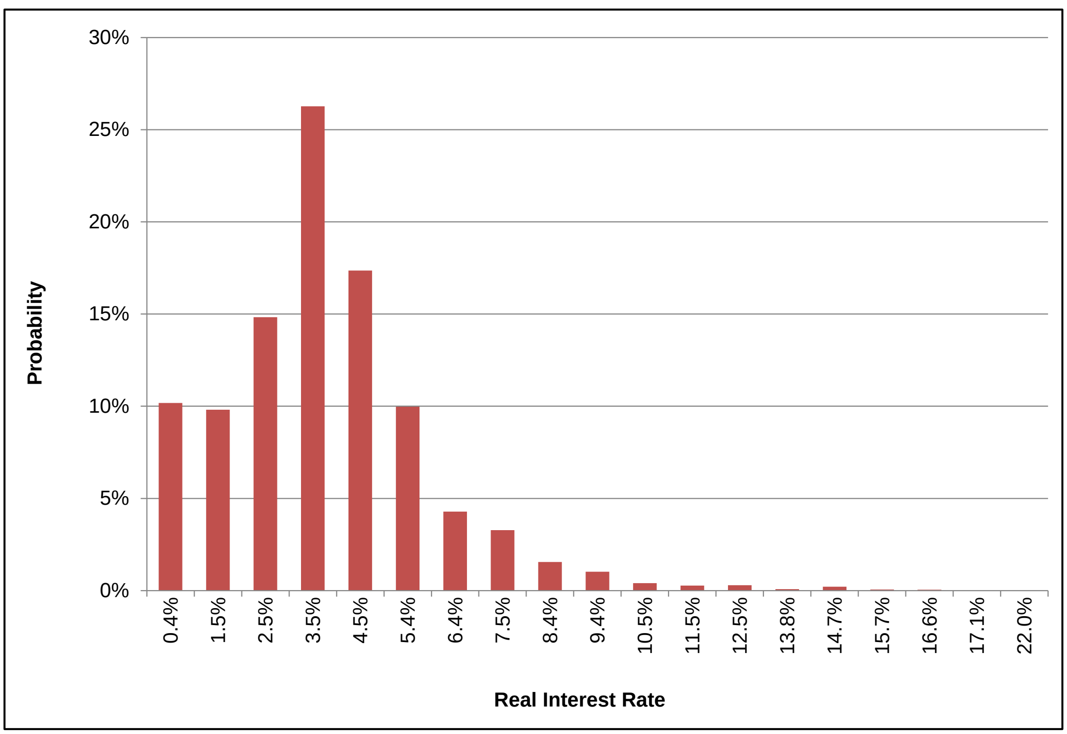

Figure 8E.2.2 Distribution of Home Equity Loan Interest Rates

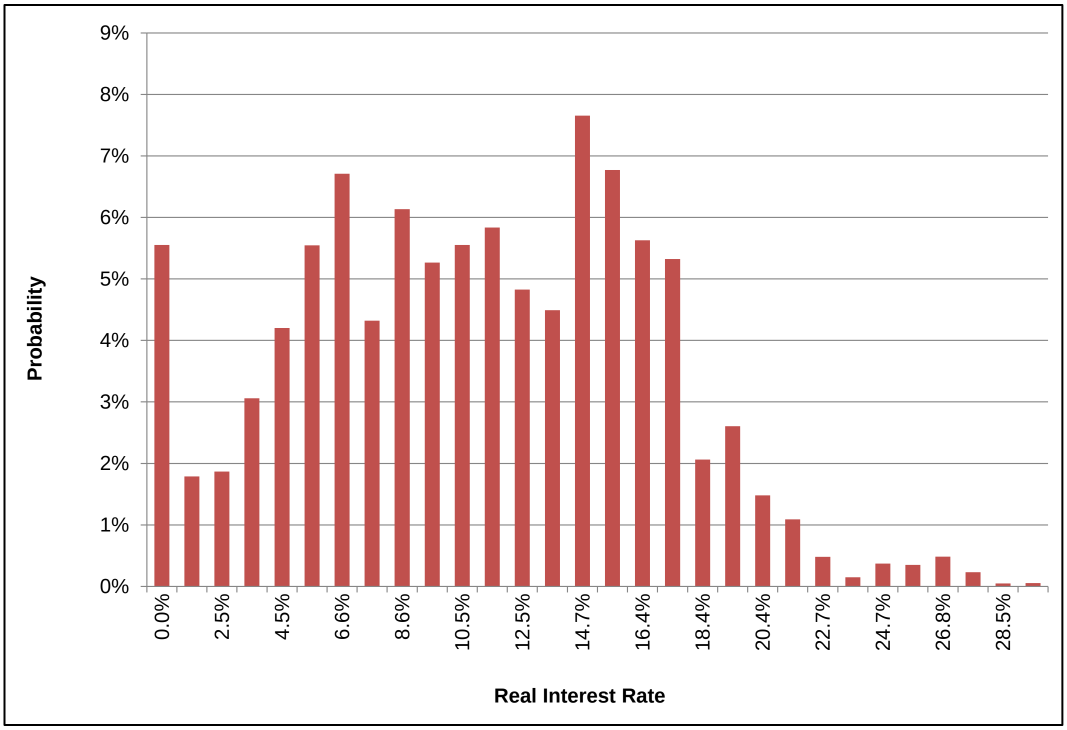

Figure 8E.2.3 Distribution of Credit Card Interest Rates

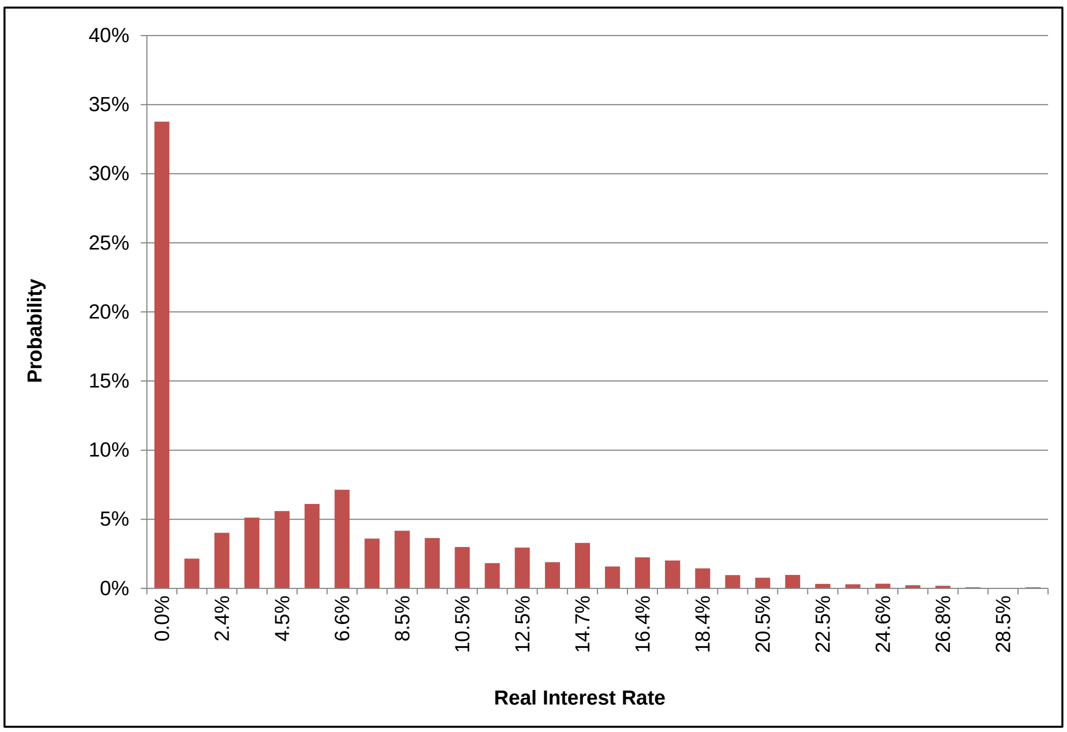

Figure 8E.2.4 Distribution of Installment Loan Interest Rates

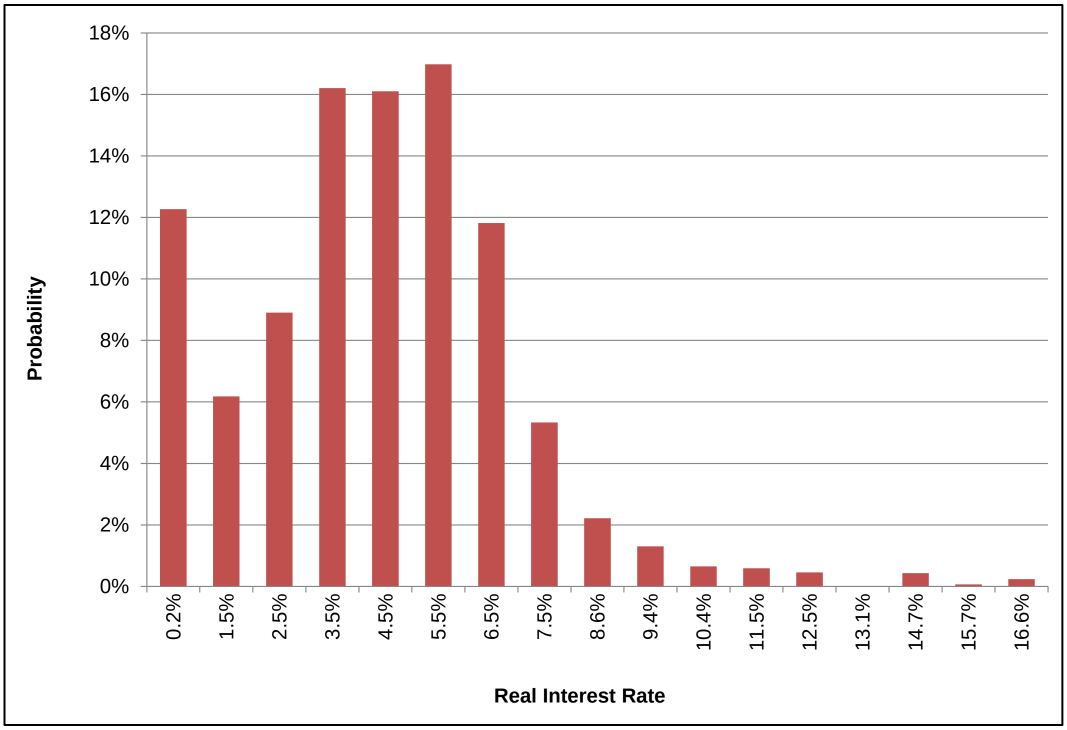

Figure 8E.2.5 Distribution of Other Residence Loan Interest Rates

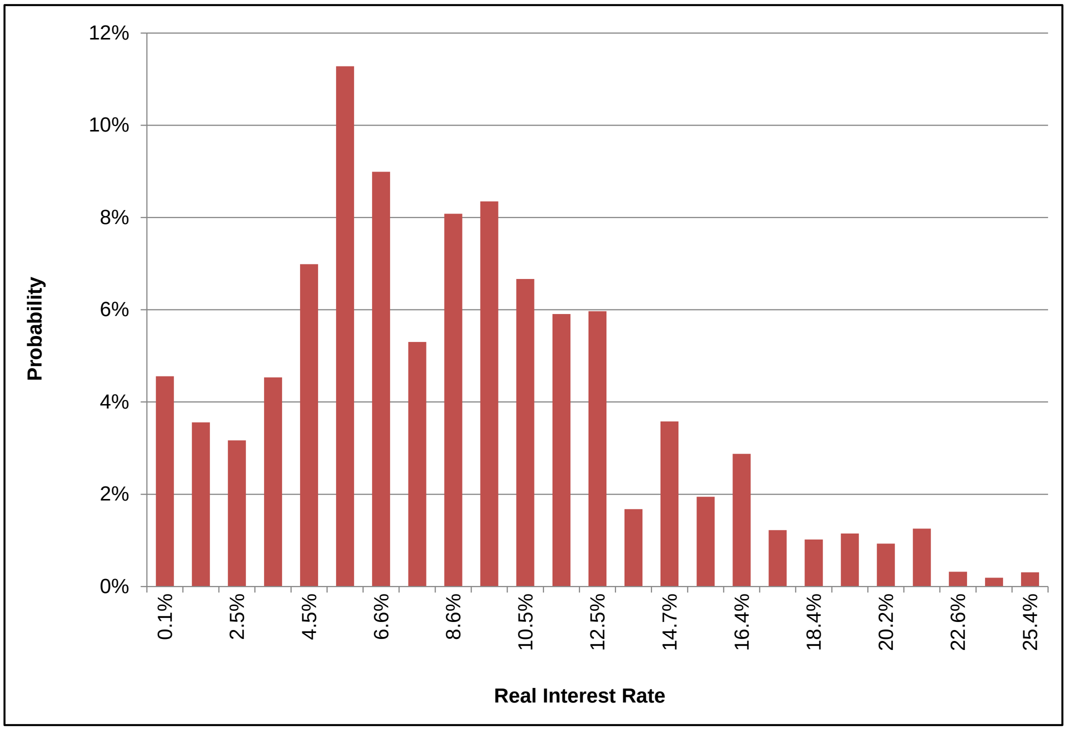

Figure 8E.2.6 Distribution of Other Lines of Credit Loan Interest Rates

8E.2.2 Distribution of Rates for Equity Classes

Figure 8E.2.7 through Figure 8E.2.13 show the distribution of real interest rates for different types of equity. Data for equity classes are not available from the Federal Reserve Board's *SCF*, so DOE derived data for these classes from national-level historical data (1984-2015). The interest rates associated with certificates of deposit (CDs),[2] savings bonds,[3] and AAA corporate bonds[4] are from Federal Reserve Board time-series data. DOE assumed rates on checking accounts to be zero. Rates on savings and money market accounts are from Cost of Savings Index data.[5] The rates for stocks are the annual returns on the Standard and Poor's (S&P) 500.[6] The mutual fund rates are a weighted average of the stock rates (two-thirds weight) and the bond rates (one-third weight) in each year. DOE adjusted the nominal rates to real rates using the annual inflation rate in each year.

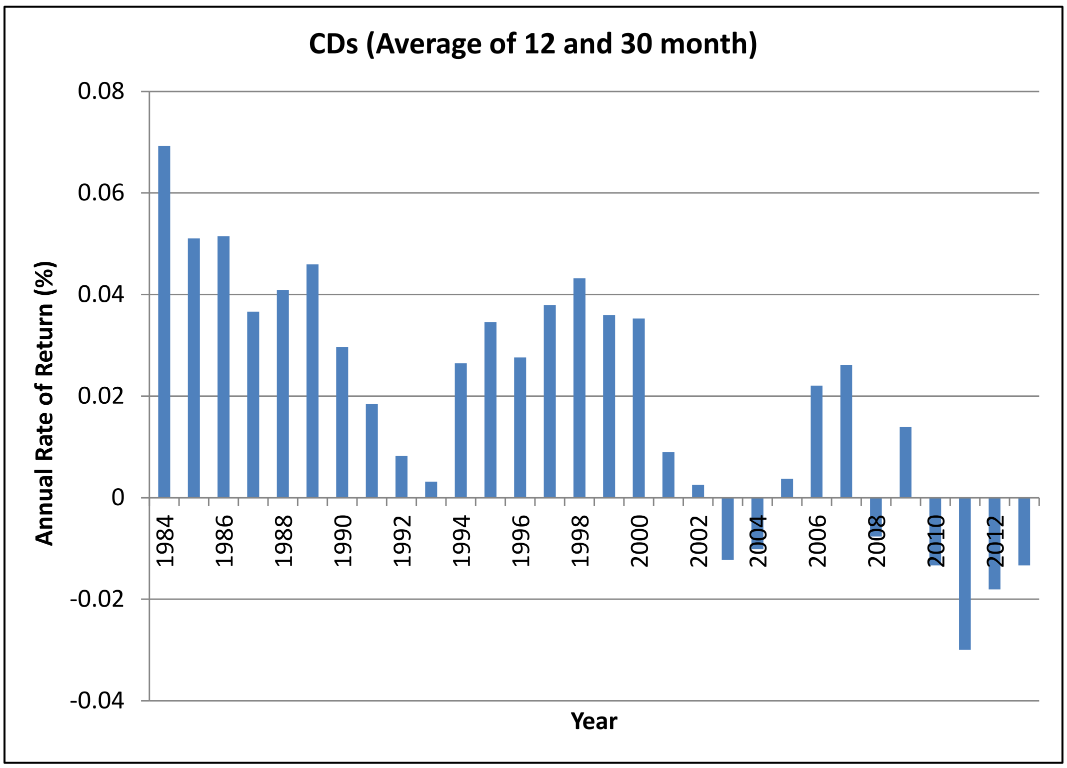

Figure 8E.2.7 Distribution of Annual Rate of Return on CDs

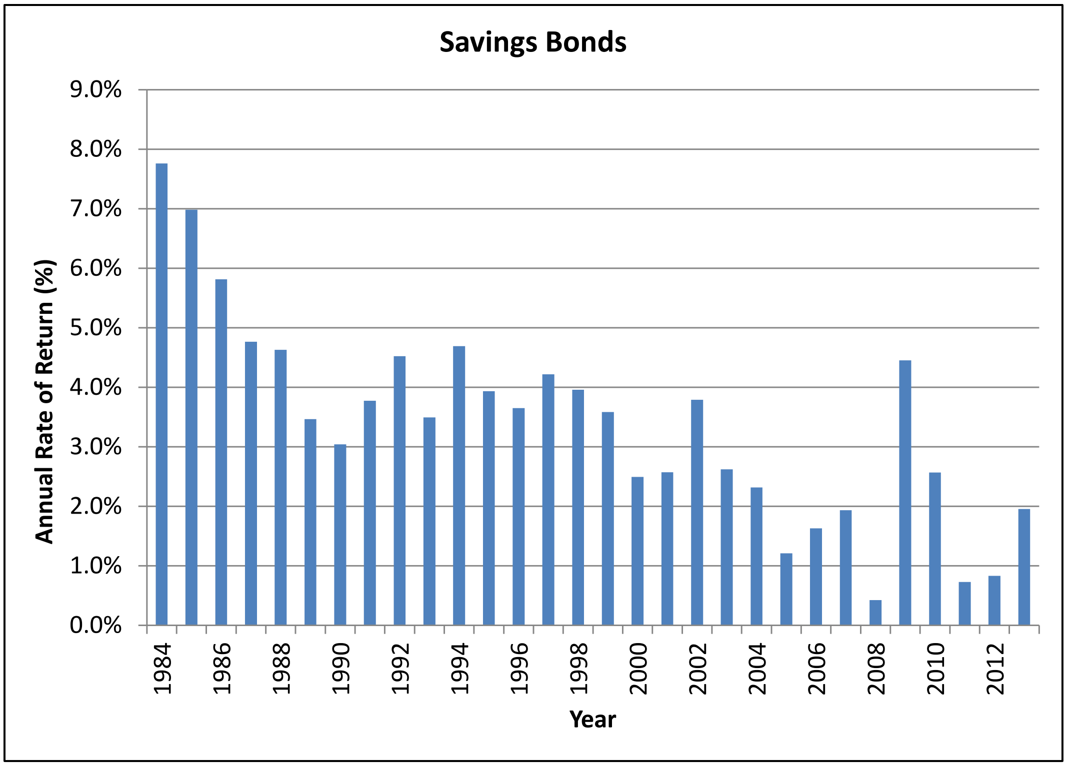

Figure 8E.2.8 Distribution of Annual Rate of Return on Savings Bonds

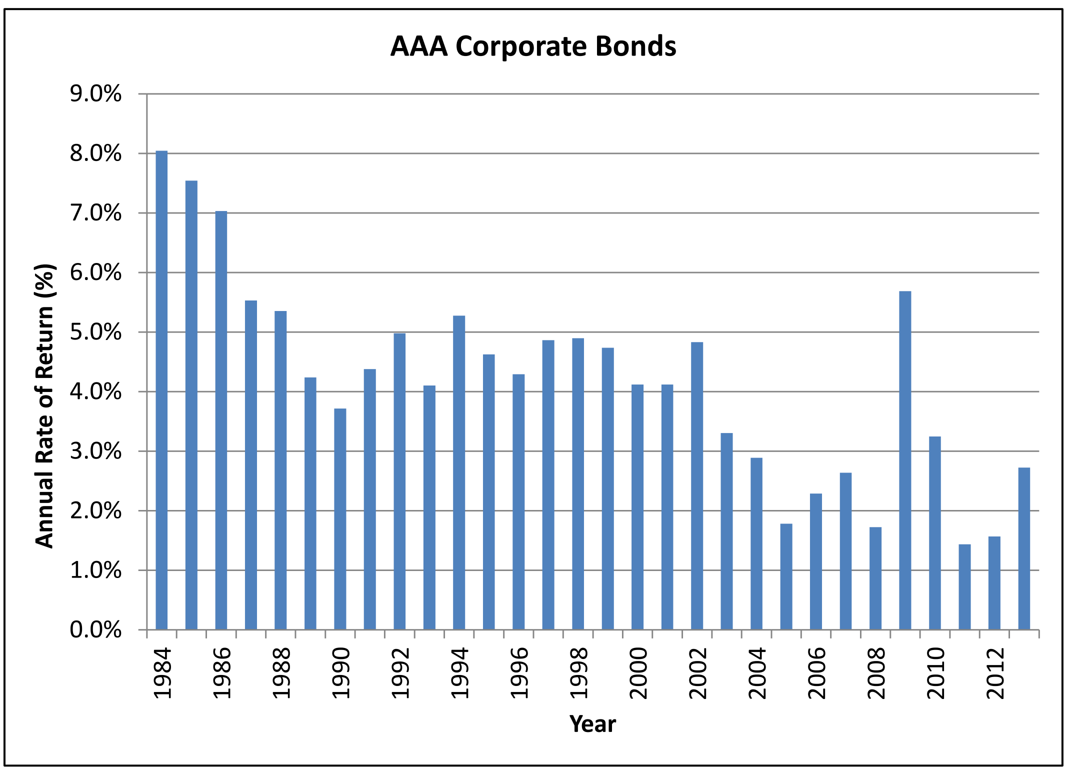

Figure 8E.2.9 Distribution of Annual Rate of Return on Corporate AAA Bonds

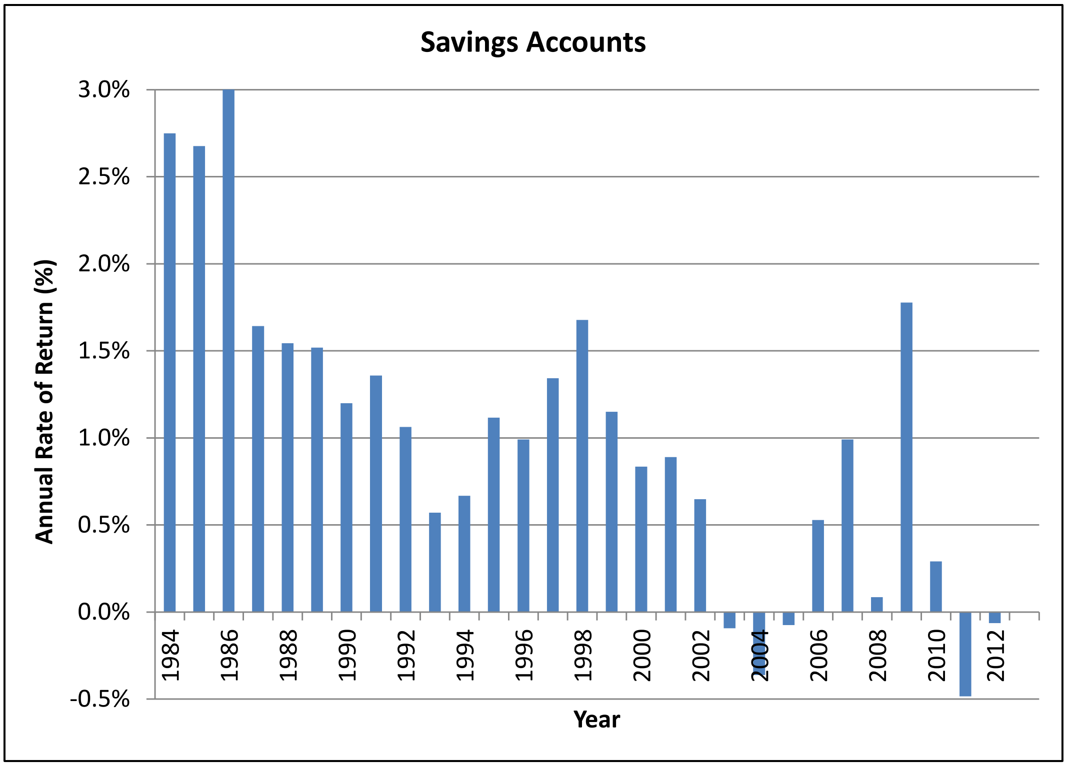

Figure 8E.2.10 Distribution of Annual Rate of Savings Accounts

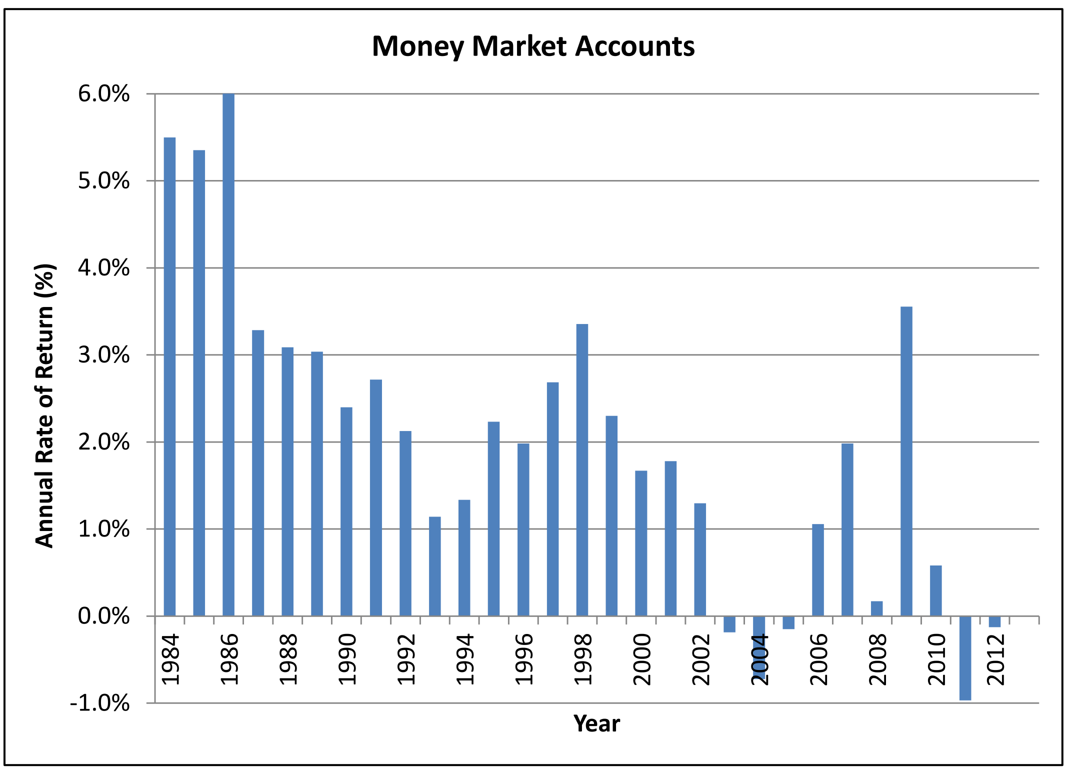

Figure 8E.2.11 Distribution of Annual Rate of Money Market Accounts

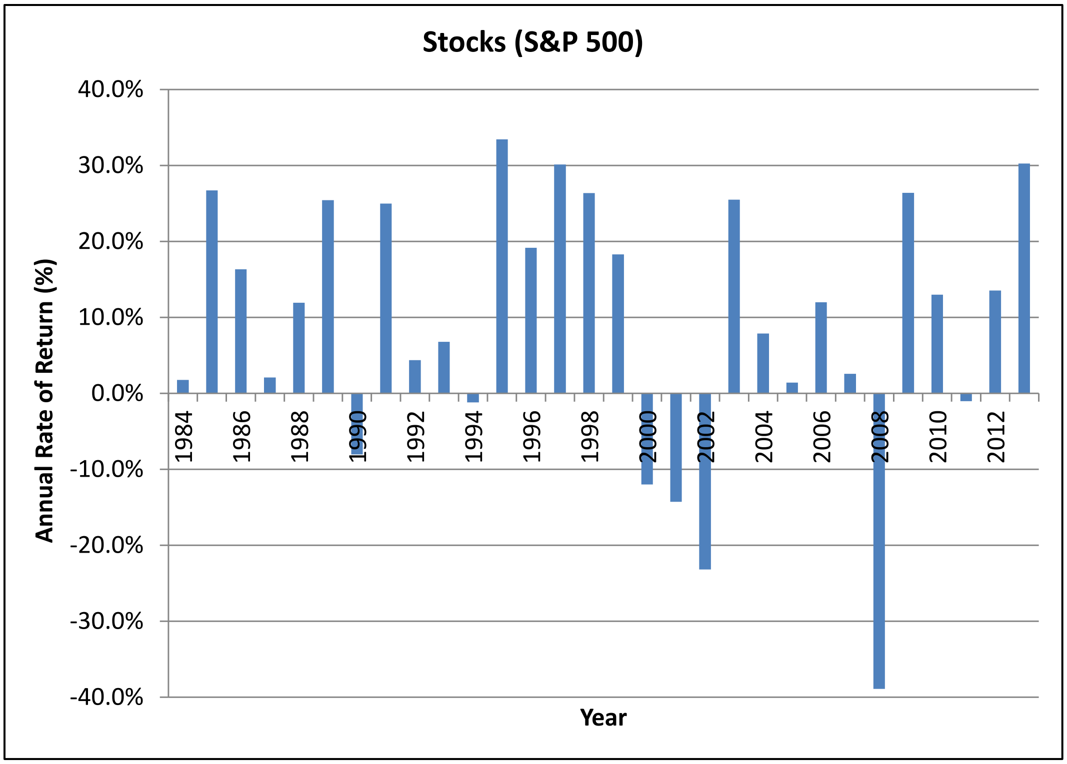

Figure 8E.2.12 Distribution of Annual Rate of Return on S&P 500

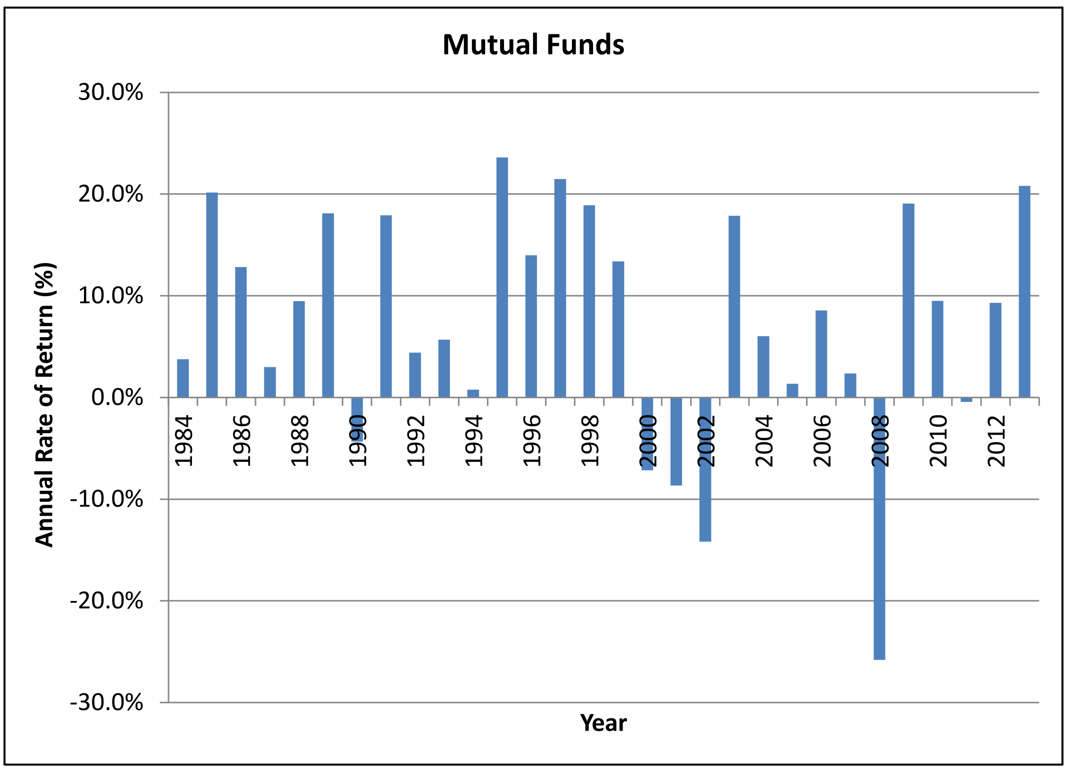

Figure 8E.2.13 Distribution of Annual Rate of Return on Mutual Funds

8E.3 DISTRIBUTION OF REAL EFFECTIVE DISCOUNT RATES BY INCOME GROUP

Figure 8E.3.1 and Table 8E.3.1 present the distributions of real discount rates for each income group.

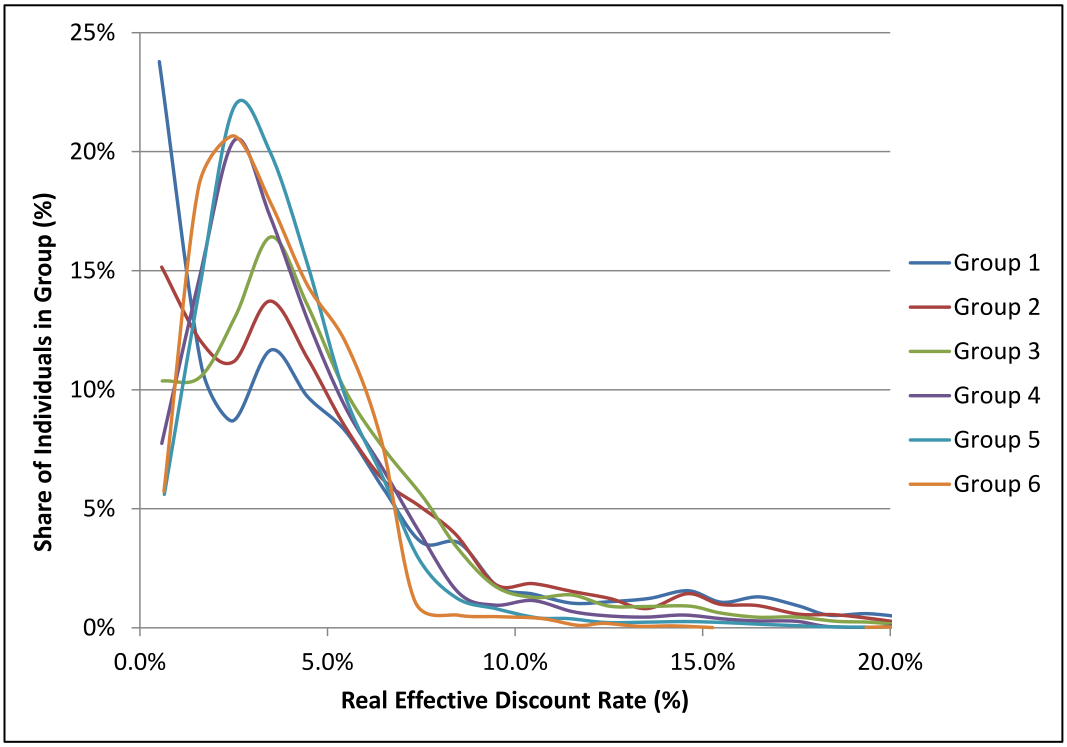

Figure 8E.3.1 Distribution of Real Discount Rates by Income Group

Table 8E.3.1 Distribution of Real Discount Rates by Income Group

DR Bin	Income Group 1 (1-20 percentile)		Income Group 2 (21-40 percentile)		Income Group 3 (41-60 percentile)		Income Group 4 (61-80 percentile)		Income Group 5 (81-90 percentile)		Income Group 6 (90-99 percentile)	
	Rate	Weight	Rate	Weight	Rate	Weight	Rate	Weight	Rate	Weight	Rate	Weight
0-1	0.5%	0.238	0.6%	0.152	0.6%	0.104	0.6%	0.077	0.6%	0.056	0.6%	0.057
1-2	1.6%	0.110	1.6%	0.120	1.6%	0.105	1.6%	0.146	1.6%	0.142	1.6%	0.185
2-3	2.5%	0.087	2.5%	0.112	2.6%	0.131	2.5%	0.205	2.5%	0.219	2.5%	0.207
3-4	3.5%	0.117	3.5%	0.137	3.5%	0.164	3.5%	0.173	3.5%	0.200	3.5%	0.178
4-5	4.5%	0.097	4.5%	0.113	4.5%	0.136	4.5%	0.129	4.5%	0.153	4.5%	0.144
5-6	5.5%	0.083	5.5%	0.084	5.5%	0.100	5.5%	0.093	5.5%	0.098	5.5%	0.120
6-7	6.5%	0.058	6.5%	0.062	6.5%	0.075	6.5%	0.067	6.5%	0.063	6.4%	0.079
7-8	7.5%	0.036	7.5%	0.051	7.6%	0.054	7.4%	0.041	7.4%	0.029	7.3%	0.011
8-9	8.5%	0.036	8.4%	0.039	8.4%	0.034	8.5%	0.015	8.4%	0.012	8.5%	0.005
9-10	9.5%	0.017	9.5%	0.018	9.5%	0.017	9.5%	0.010	9.5%	0.008	9.6%	0.005
10-11	10.5%	0.014	10.5%	0.019	10.5%	0.013	10.5%	0.011	10.6%	0.004	10.7%	0.004
11-12	11.5%	0.010	11.5%	0.015	11.5%	0.014	11.5%	0.007	11.4%	0.004	11.7%	0.001
12-13	12.5%	0.011	12.5%	0.012	12.5%	0.009	12.4%	0.005	12.4%	0.002	12.4%	0.002
13-14	13.6%	0.012	13.5%	0.008	13.5%	0.009	13.5%	0.004	13.5%	0.002	13.3%	0.001
14-15	14.6%	0.016	14.6%	0.014	14.6%	0.009	14.5%	0.005	14.6%	0.003	14.2%	0.001
15-16	15.5%	0.011	15.5%	0.010	15.5%	0.006	15.6%	0.004	15.6%	0.002	15.3%	0.000
16-17	16.5%	0.013	16.5%	0.009	16.5%	0.004	16.5%	0.003	16.5%	0.001	0.0%	0.000
17-18	17.5%	0.009	17.6%	0.006	17.5%	0.005	17.5%	0.003	17.6%	0.001	17.7%	0.001
18-19	18.4%	0.005	18.5%	0.005	18.6%	0.003	18.4%	0.001	18.2%	0.000	0.0%	0.000
19-20	19.4%	0.006	19.4%	0.004	19.4%	0.002	19.7%	0.000	19.7%	0.000	19.4%	0.000
20-21	20.6%	0.004	20.4%	0.002	20.5%	0.001	20.3%	0.001	20.5%	0.000	20.3%	0.000
21-22	21.4%	0.003	21.4%	0.002	21.4%	0.001	21.5%	0.001	0.0%	0.000	21.4%	0.000
22-23	22.5%	0.002	22.4%	0.001	22.6%	0.001	22.9%	0.000	22.8%	0.000	22.3%	0.000
23-24	23.6%	0.001	23.4%	0.001	23.6%	0.001	0.0%	0.000	0.0%	0.000	24.0%	0.000
24-25	24.6%	0.001	24.5%	0.000	24.6%	0.000	24.1%	0.000	24.3%	0.000	0.0%	0.000
25-26	25.4%	0.001	25.4%	0.001	25.5%	0.000	0.0%	0.000	0.0%	0.000	0.0%	0.000
26-27	26.5%	0.001	26.5%	0.000	26.4%	0.000	0.0%	0.000	0.0%	0.000	0.0%	0.000
27-28	27.8%	0.000	27.6%	0.000	27.8%	0.000	0.0%	0.000	0.0%	0.000	0.0%	0.000
28-29	28.2%	0.000	0.0%	0.000	0.0%	0.000	0.0%	0.000	0.0%	0.000	0.0%	0.000
29-23	29.9%	0.000	29.3%	0.000	0.0%	0.000	0.0%	0.000	0.0%	0.000	0.0%	0.000
>30	59.1%	0.001	142.7%	0.002	0.0%	0.000	53.3%	0.000	0.0%	0.000	0.0%	0.000

8E.4 COMMERCIAL DISCOUNT RATE DISTRIBUTIONS BY SECTOR

DOE derived commercial discount rates (*i.e.*, weighted average cost of capital) for the life-cycle cost (LCC) analysis using the capital asset pricing model and firm-level data provided by Damodaran Online.[7] State and local government discount rates were estimated using the rate of return on 20-year municipal bonds, as provided by the Federal Reserve Board. Separate distributions were constructed for each major industry. Table 8E.4.1 through Table 8E.4.3 show the probability distributions of commercial discount rates by industry.

Table 8E.4.1 Public Assembly (13) Discount Rate Distribution

Bin	Bin Range	Rates	Distribution (Company Count)	Distribution (Firm Value)	Company Count (#)	Firm Value ($ million)
1	<0%					
2	0-1%					
3	1-2%					
4	2-3%	2.9%	0.1%	0.0%	1	1,627
5	3-4%	3.5%	0.8%	0.4%	11	33,322
6	4-5%	4.8%	19.0%	10.9%	248	949,484
7	5-6%	5.6%	40.2%	33.2%	524	2,904,006
8	6-7%	6.4%	26.3%	35.0%	343	3,060,165
9	7-8%	7.5%	8.2%	9.8%	107	861,404
10	8-9%	8.4%	3.4%	8.9%	44	779,801
11	9-10%	9.2%	1.2%	1.1%	16	97,422
12	10-11%	10.2%	0.7%	0.2%	9	14,142
13	11-12%	11.5%	0.1%	0.5%	1	40,882
14	12-13%	12.5%	0.1%	0.1%	1	4,783
15	13-14%					
	Wtd Avg		**5.99%**	**6.31%**		

Table 8E.4.2 Education (14) and State & Local Government Discount Rate Distribution

Bin	Bin Range	Rates	Distribution (Year Count)	Year Count (#)
1	<0%			
2	0-1%			
3	1-2%	1.5%	12.9%	4
4	2-3%	2.8%	25.8%	8
5	3-4%	3.5%	45.2%	14
6	4-5%	4.1%	6.5%	2
7	5-6%	5.1%	6.5%	2
8	6-7%	6.3%	3.2%	1
9	7-8%			
10	8-9%			
11	9-10%			
12	10-11%			
13	11-12%			
14	12-13%			
15	13-14%			
	Wtd Avg		**3.30%**	

Table 8E.4.3 Lodging (18) Discount Rate Distribution

Bin	Bin Range	Rates	Distribution (Company Count)	Distribution (Firm Value)	Company Count (#)	Firm Value ($ million)
1	<0%					
2	0-1%					
3	1-2%					
4	2-3%					
5	3-4%	3.8%	0.9%	0.0%	4	412
6	4-5%	4.8%	17.1%	12.3%	75	207,046
7	5-6%	5.7%	35.5%	24.2%	156	408,986
8	6-7%	6.5%	30.1%	29.1%	132	491,011
9	7-8%	7.5%	8.4%	10.5%	37	177,713
10	8-9%	8.5%	4.6%	9.2%	20	155,529
11	9-10%	9.3%	1.6%	4.9%	7	82,374
12	10-11%	10.8%	1.4%	5.4%	6	91,959
13	11-12%	11.9%	0.5%	4.3%	2	73,322
14	12-13%					
15	13-14%					
	Wtd Avg		**6.21%**	**6.99%**		

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CHAPTER 9. SHIPMENTS ANALYSIS

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CHAPTER 9. SHIPMENTS ANALYSIS

9.1 INTRODUCTION

This chapter describes the data and methods that DOE used to generate shipment projections for each of the equipment classes being considered in this analysis of standards for pool pumps. DOE uses projections of annual product shipments to calculate the national impacts of potential new energy conservation standards on energy use, NPV, and future manufacturer cash flows. Accordingly, outputs from the shipments analysis are inputs to the Life-cycle Cost Analysis (Chapter 8), National Impact Analysis (Chapter 10), and Manufacturer Impact Analysis (Chapter 12).

The calculations for shipment projections were implemented as part of the National Impact Analysis (NIA). DOE performs the NIA calculations discussed here using a Microsoft Excel® spreadsheet developed for this rulemaking. Stakeholders are invited to download and examine the spreadsheet, which is available at: www.regulations.gov; docket number: EERE-2015-BT-STD-0008.

Section 9.2 describes how pool pump shipments in the base year were formulated. Section 9.3 presents the methodology for developing a shipments projection in the absence of new standards. Section 9.4 covers the projection of shipments by efficiency, which determines a distribution of shipments of pool pumps by efficiency level (EL) and hence the percentage of shipments affected by a standard at a given level. Section 9.5 discusses the potential impacts of standards on the shipments projection. The outputs from the shipments analysis are shown in Section 9.6.

9.2 BASE YEAR SHIPMENTS FORMULATION

The base year used for pool pumps shipments was 2015. Due to a lack of historical shipments data, DOE primarily gathered its base year shipments data from manufacturer interviews and Working Group input. Table 9.6.1 shows the base year shipments for each equipment class, as well as shipments at the start and end of the analysis period.

9.3 SHIPMENT PROJECTIONS IN THE NO-STANDARDS CASE

Shipments were projected from the base year of 2015 throughout the end of the analysis period (2050) using annual growth rates obtained from Working Group recommendations.[1] The growth rate for each equipment class can be seen in Table 9.3.1.

Table 9.3.1 Pool Pump Annual Shipments Growth Rates

Equipment Class	Growth Rate
Standard-Size Self-Priming Pool Filter Pump	3.1%
Small-Size Self-Priming Pool Filter Pump	3.1%
Standard-Size Non-Self-Priming Pool Filter Pump	3.1%
Extra-Small Non-Self-Priming Pool filter Pump	3.1%
Waterfall Pump	3.1%
Pressure Cleaner Booster Pump	1.4%
Integral Cartridge Filter Pool Pump	2.0%
Integral Sand Filter Pool Pump	2.0%

Shipments for the base year (2015), the start of the compliance period (2021), and the end of the compliance period (2050) are presented in Table 9.6.1. Figure 9.3.1 presents the no-standards case pool pump shipment projections obtained using these growth rates.

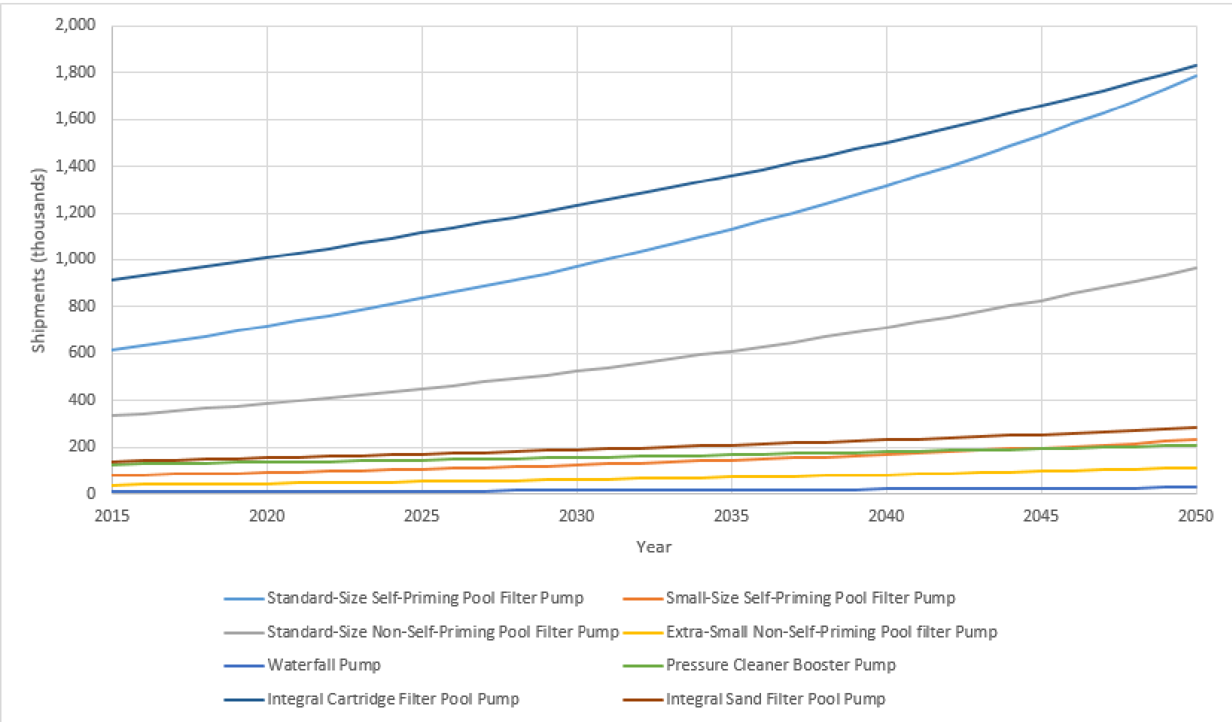

Figure 9.3.1 Pool Pumps Shipment Projections, No-Standards Case

9.4 EFFICIENCY DISTRIBUTION PROJECTION

To evaluate the potential impacts of an energy conservation standard for pool pumps set at a particular EL, DOE developed a no-standards-case efficiency projection, which represents DOE's estimate of the future state of the market with respect to efficiency if energy conservation standards for the equipment classes covered under this rulemaking are not adopted. The impact of a standard is then the relative improvement in efficiency compared to this projection. DOE's starting point in developing no-standards-case efficiency distributions was determining base year efficiency distributions (2015), or the current market share of products at each proposed EL. DOE estimated the market shares of the different efficiency levels for pool pumps in 2015 based on manufacturer interviews.

In order to project the trend in efficiency for pool pumps over the entire shipments analysis period, DOE used an annual one percent market share shift from single-speed efficiency levels to variable-speed efficiency levels, as agreed upon by the Working Group.[2] This shift was used in all equipment classes that have at least one variable-speed efficiency level available, including Standard-Size Self-Priming Pool Filter Pumps, Small-Size Self-Priming Pool Filter Pumps, Standard-Size Non-Self-Priming Pool Filter Pumps, and Pressure Cleaner Booster Pumps. The efficiency distributions of the remaining equipment classes (Extra-Small Non-Self-Priming Pool filter Pumps, Waterfall Pumps, Integral Cartridge Filter Pool Pumps, and Integral Sand Filter Pool Pumps) were held constant at 2015 levels. Table 9.6.3 presents these trends in the no-standards case for the years 2015 to 2050.

9.5 EFFECT OF STANDARDS ON POOL PUMP SHIPMENTS

9.5.1 Efficiency of Pool Pumps

In addition to quantifying the projected impact of standards on total shipments, DOE also considers the change in the mix of product efficiencies due to standards. DOE assumed that manufacturers will respond to standards by improving those products that do not meet the standards to the standard level, but no higher, while the products that were already as or more efficient than the standard remain unaffected. This is referred to as a "roll-up" response to standards.

The mechanics of the roll-up response are detailed in Table 9.5.1. The "No-Standards Case" gives the efficiency distribution with no standard. In the "Standard Set at EL 1" scenario, all the shipments from EL 0 are rolled up to EL 1, the level of the standard. The same methodology is applied to the other standards cases.

Table 9.5.1 Roll-Up Market Response for a Hypothetical Pool Pump Equipment Class

Case	Percent of Market at Each Efficiency Level				
	EL 0	**EL 1**	**EL 2**	**EL 3**	**EL 4**
No-Standards Case	25	50	25	0	0
Standard Set at EL 1	0	75	25	0	0
Standard Set at EL 2	0	0	100	0	0
Standard Set at EL 3	0	0	0	100	0
Standard Set at EL 4	0	0	0	0	100

9.5.2 Price Elasticity of Demand for Pool Pumps

Projected shipments in the standards case typically deviate from the no-standards case. The magnitude of the difference between the standards case and no-standards case shipments projections depends on the calculated purchase price increase and the operating cost savings from the standard. Standards case projections typically show elasticity of demand, usually manifested as a decrease in shipments relative to the no-standards case as increases in product prices resulting from standards may depress shipment volumes.

To DOE's knowledge, price elasticity estimates are not readily available in existing literature for pool pumps. Therefore, elasticities were estimated from Working Group recommendations and data obtained from manufacturer interviews.

In the new construction segment, DOE implemented a relative price elasticity, which is the percentage drop in shipments divided by the percentage increase in pool pump price (including the total installed cost of the pool itself) due to standards. However, DOE determined that where the cost of the pool far exceeds the incremental cost of a more-efficient pump (i.e., inground pool installations or, where timers are considered, larger inflatable/rigid steel-framed installations), shipments would not be affected by an increase in purchase price of the pool pump. Therefore, a relative price elasticity was only applied to Standard-Size Non-Self-Priming Pool Filter Pumps, as well as smaller Integral Cartridge Filter Pool Pumps and Integral Sand Filter Pool Pumps. Table 9.5.2 shows the elasticity of each equipment class that DOE implemented.[3] Elasticity of -0.2 was only applied to approximately 40% of the Integral Cartridge Filter Pool Pump and Integral Sand Filter Pool Pump shipments, thus yielding an effective elasticity of -0.08 for these two categories rather than -0.2. The 40% value represents the smallest and least expensive segment of this market, where an increase in pump price due to standards is significant relevant to the pool price.

Table 9.5.2 Elasticity for Pool Pumps

Equipment Class	Elasticity
Standard-Size Self-Priming Pool Filter Pump	0
Small-Size Self-Priming Pool Filter Pump	0
Standard-Size Non-Self-Priming Pool Filter Pump	-0.2
Extra-Small Non-Self-Priming Pool filter Pump	0
Waterfall Pump	0
Pressure Cleaner Booster Pump	0
Integral Cartridge Filter Pool Pump	-0.08
Integral Sand Filter Pool Pump	-0.08

9.5.3 Repair-Replace Model for Pool Pumps

For the replacement segment of the market, DOE implemented a repair-replace model in which, based on input from motor manufacturers, under dual speed or variable speed standards cases, 60 percent of the time the pump is repaired (i.e., motor replacement), and in the remaining 40 percent of the time the pump is replaced by a new pump and motor.[4] Comparatively, in the no-standards case, the reverse is true. In this case, the pump is repaired approximately 40 percent of the time, and a new pump and motor purchased 60 percent of the time to replace a failed pump. This repair-replace decision, in turn, causes more pumps to be repaired in the standards case than in the no-standards case, thus delaying standards case shipments to future years.

In the no-standards case, the 40 percent of pumps that are repaired are included in the standard lifetime distribution, as discussed in Chapter 8 of this TSD. As a result, in the relevant standards cases, the shipments model only accounts for the repair-replace decision at the end of life. As some pumps were already repaired during their initial lifetime, fewer than 60 percent of pumps must be repaired at end-of-life in order to achieve 60 percent repairs overall. Therefore, DOE assumed that in the relevant standards cases, 44 percent of pumps would be repaired at end-of-life.[a] DOE notes that this calculation does not take into account the iterative nature of lifetime, but was determined to be adequate for this implementation, as it has a minor impact on the overall results.

The pumps repaired at end-of-life are drawn only from efficiency levels below the efficiency level selected for each TSL. Pumps in the no-standards case at or above the efficiency level selected for each TSL do not receive life-extending repairs, as anyone purchasing such a pump has already been faced with the higher purchase price of a dual speed or variable speed pump. After the stock has turned over once (meaning there are no more pre-standards pumps left in the stock), there are no more life-extending repairs.

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[a] Starting with 100 pumps, 40 are repaired during the first lifetime. At the end-of-life for all those 100 pumps, 44 are repaired and 56 are replaced. This results in a total of 84 repairs and 56 replacements, or a 60:40 split.

Pumps that are repaired at end-of-life receive life extensions equal to the lifetime of a replacement pump.

9.6 RESULTS

In DOE's projection, pool pump shipments grow from 2.3 million units in 2015 to 5.4 million units in 2050. Table 9.6.1 shows DOE's shipments projection in the no-standards case for each of the pool pump equipment classes.

Table 9.6.1 Pool Pump Shipments by Equipment Class and Sector in the No-standards Case

Equipment Class	2015	2021	2050
Standard-Size Self-Priming Pool Filter Pump	616,320	739,368	1,782,202
Small-Size Self-Priming Pool Filter Pump	80,000	95,972	231,335
Standard-Size Non-Self-Priming Pool Filter Pump	333,333	399,883	963,894
Extra-Small Non-Self-Priming Pool filter Pump	39,524	47,415	114,290
Waterfall Pump	10,000	11,996	28,917
Pressure Cleaner Booster Pump	128,571	139,643	208,164
Integral Cartridge Filter Pool Pump	914,205	1,029,543	1,828,309
Integral Sand Filter Pool Pump	141,270	159,093	282,524
Total	2,263,224	2,622,913	5,439,635

Table 9.6.2 displays DOE's assumptions about the efficiency of pool pumps in 2021 in the no-standards case. The percentages show, for each equipment class, what fraction of new products sold each year are at each efficiency level (EL). For Standard-Size Self-Priming Pool Filter Pumps, Small-Size Self-Priming Pool Filter Pumps, Standard-Size Non-Self-Priming Pool Filter Pumps, and Pressure Cleaner Booster Pumps, these market shares are assumed to change throughout the analysis period as described in section 9.4 and Table 9.6.3.

Table 9.6.2 No-standards Case Pool Pump Efficiency in 2021

Equipment Class	Percent of Market at each Efficiency Level							
	EL 0	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6	EL 7
Standard-Size Self-Priming Pool Filter Pump	39.0%	15.0%	10.0%	2.0%	2.0%	2.0%	11.0%	19.0%
Small-Size Self-Priming Pool Filter Pump	39.0%	15.0%	10.0%	2.0%	2.0%	2.0%	11.0%	19.0%
Standard-Size Non-Self-Priming Pool Filter Pump	29.0%	29.0%	32.0%	2.0%	1.0%	1.0%	3.0%	3.0%
Extra-Small Non-Self-Priming Pool filter Pump	33.3%	33.3%	33.3%	n/a	n/a	n/a	n/a	n/a
Waterfall Pump	70.0%	20.0%	10.0%	0.0%	n/a	n/a	n/a	n/a
Pressure Cleaner Booster Pump	13.5%	70.5%	10.0%	3.0%	3.0%	n/a	n/a	n/a
Integral Cartridge Filter Pool Pump	80.0%	20.0%	n/a	n/a	n/a	n/a	n/a	n/a
Integral Sand Filter Pool Pump	80.0%	20.0%	n/a	n/a	n/a	n/a	n/a	n/a

Table 9.6.3 shows DOE's assumptions about the efficiency of pool pumps in the no-standards case, in 2015 (the base year), 2021 (start of compliance period), 2030, 2040, and 2050 (end of compliance period). The percentages show, for each equipment class, what fraction of new products sold each year are at each efficiency level (EL).

Table 9.6.3 Projected Market Shares of Pool Pumps by Efficiency Level in the No-standards Case, 2015-2050

Equipment Class	EL	2015	2021	2030	2040	2050
Standard-Size Self-Priming Pool Filter Pump, & Small-Size Self-Priming Pool Filter Pump	EL 0	45.0%	39.0%	30.0%	20.0%	10.0%
	EL 1	15.0%	15.0%	15.0%	15.0%	15.0%
	EL 2	10.0%	10.0%	10.0%	10.0%	10.0%
	EL 3	2.0%	2.0%	2.0%	2.0%	2.0%
	EL 4	2.0%	2.0%	2.0%	2.0%	2.0%
	EL 5	2.0%	2.0%	2.0%	2.0%	2.0%
	EL 6	8.0%	11.0%	15.5%	20.5%	25.5%
	EL 7	16.0%	19.0%	23.5%	28.5%	33.5%
Standard-Size Non-Self-Priming Pool Filter Pump	EL 0	32.0%	29.0%	24.5%	19.5%	14.5%
	EL 1	32.0%	29.0%	24.5%	19.5%	14.5%
	EL 2	32.0%	32.0%	32.0%	32.0%	32.0%
	EL 3	2.0%	2.0%	2.0%	2.0%	2.0%
	EL 4	1.0%	1.0%	1.0%	1.0%	1.0%
	EL 5	1.0%	1.0%	1.0%	1.0%	1.0%
	EL 6	0.0%	3.0%	7.5%	12.5%	17.5%
	EL 7	0.0%	3.0%	7.5%	12.5%	17.5%
Extra-Small Non-Self-Priming Pool Filter Pump	EL 0	33.3%	33.3%	33.3%	33.3%	33.3%
	EL 1	33.3%	33.3%	33.3%	33.3%	33.3%
	EL 2	33.3%	33.3%	33.3%	33.3%	33.3%
Waterfall Pump	EL 0	70.0%	70.0%	70.0%	70.0%	70.0%
	EL 1	20.0%	20.0%	20.0%	20.0%	20.0%
	EL 2	10.0%	10.0%	10.0%	10.0%	10.0%
	EL 3	0.0%	0.0%	0.0%	0.0%	0.0%
Pressure Cleaner Booster Pump	EL 0	16.5%	13.5%	9.0%	4.0%	0.0%
	EL 1	73.5%	70.5%	66.0%	61.0%	55.0%
	EL 2	10.0%	10.0%	10.0%	10.0%	10.0%
	EL 3	0.0%	3.0%	7.5%	12.5%	17.5%
	EL 4	0.0%	3.0%	7.5%	12.5%	17.5%
Integral Cartridge Filter Pool Pump, & Integral Sand Filter Pool Pump	EL 0	80.0%	80.0%	80.0%	80.0%	80.0%
	EL 1	20.0%	20.0%	20.0%	20.0%	20.0%

REFERENCES

1 US Department of Energy Dedicated Purpose Pool Pumps Working Group Meeting. 04-18-2016. EERE-2015-BT-STD-0008-0078, pp. 106-120. https://www.regulations.gov/document?D=EERE-2015-BT-STD-0008-0078

2 US Department of Energy Dedicated Purpose Pool Pumps Working Group Meeting. 04-18-2016. EERE-2015-BT-STD-0008-0078, pp. 138-141. https://www.regulations.gov/document?D=EERE-2015-BT-STD-0008-0078

3 US Department of Energy Dedicated Purpose Pool Pumps Working Group Meeting. 04-19-2016. EERE-2015-BT-STD-0008-0079, pp. 67-72, 138-139. https://www.regulations.gov/document?D=EERE-2015-BT-STD-0008-0079

4 US Department of Energy Dedicated Purpose Pool Pumps Working Group Meeting. 05-18-2016. EERE-2015-BT-STD-0008-0100 pp. 173-175. https://www.regulations.gov/document?D=EERE-2015-BT-STD-0008-0100

CHAPTER 10. NATIONAL IMPACT ANALYSES

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CHAPTER 10. NATIONAL IMPACT ANALYSES

10.1 INTRODUCTION

This chapter describes the method the U.S. Department of Energy (DOE) used to estimate the national impacts of each trial standard level (TSL) considered for pool pumps and presents the results of its calculations. For each TSL, DOE evaluated the following impacts: (1) national energy savings (NES) attributable to each potential standard level; (2) monetary value of the lifetime energy savings to consumers of pool pumps; (3) increased total installed costs; and (4) the net present value (NPV) of the difference between the value of the operating cost savings and the increased total installed costs.

The calculations were performed using a Microsoft Excel spreadsheet model, which is accessible on the Internet (https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=67). The spreadsheet model, termed the national impact analysis (NIA) model, calculates energy savings and NPV for the nation. Details and instructions for using the NIA model are provided in appendix 10A. Figure 10.1.1 presents a graphical flow diagram of the NIA spreadsheet model.

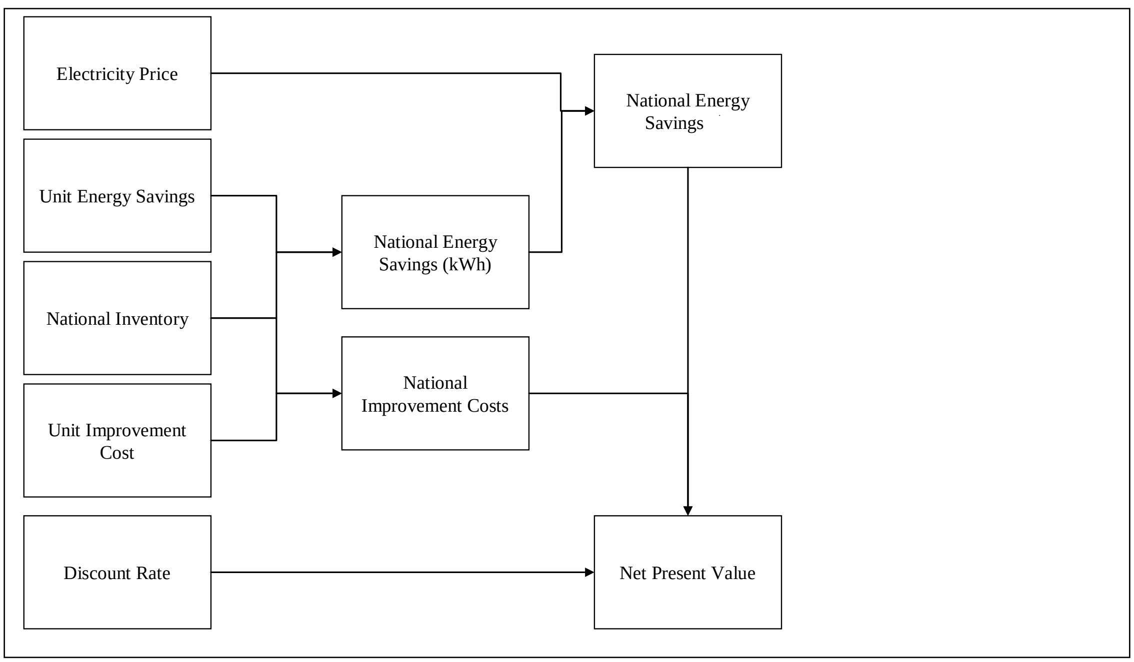

Figure 10.1.1 Flow Chart Showing Calculation of National Energy Savings and Net Present Value

The NIA calculation started with the shipments model, described in chapter 9, which DOE used to project future purchases of pool pumps. Chapter 9 includes an analysis of consumers' sensitivities to total installed cost, operating expense, and income (otherwise known as elasticities) and describes how DOE captured those elasticities within the NIA model. DOE used the annual shipments projection to produce an accounting of annual NES, annual national energy cost savings, and annual national incremental non-energy costs resulting from purchasing, installing and operating the units projected to be shipped in each year of the analysis period during their estimated lifetime.

To calculate the annual NES, DOE first estimated the lifetime primary and fuel-fuel-cycle[a] (FFC) energy consumption at the unit level and for each year in the analysis period. The unit's lifetime primary and FFC energy consumption were then scaled up to the national level based on the annual shipments projection and according to two scenarios: (a) the *no-standards case*, with no energy efficiency standards; and (b) the *standards case* scenario, where energy efficiency standards are set at the energy efficiency level corresponding to each of the TSLs.

DOE followed a similar procedure to calculate the annual national energy cost savings and the annual national incremental installed or non-energy costs. DOE first estimated the lifetime energy cost and the lifetime non-energy costs at the unit level and for each year in the analysis period. The unit lifetime energy and non-energy costs, estimated for units shipped in each year in the analysis period, were then scaled up to the national level based on the annual shipments projection and for the same—*no-standards case* and *standards case*—scenarios described previously. DOE then calculated the difference between the aggregated national energy cost savings and national incremental non-energy costs to obtain the NPV of each TSL and summed these values across the TSLs to produce the total NPV.

The two models used in the NIA—the NES model and the NPV model—are described more fully in subsequent sections. The descriptions include overviews of how DOE performed each model's calculations and summaries of the major inputs. After the technical model descriptions, this chapter presents the results of the NIA calculations.

10.2 TRIAL STANDARD LEVELS

DOE analyzed the benefits and burdens of five trial standard levels (TSLs) for pool pumps (Table 10.2.1).

[a] The full-fuel-cycle energy consumption adds to the primary energy consumption the energy consumed by the energy supply chain upstream to power plants.

Table 10.2.1 Trial Standard Levels for Pool Pumps

Equipment Class	Trial Standard Level				
	1	2	3	4	5
	Efficiency Level				
Standard-Size Self-Priming Pool Filter Pump	2	5	6	6	7
Small-Size Self-Priming Pool Filter Pump	2	5	2	6	7
Standard-Size Non-Self-Priming Pool Filter Pump	1	4	1	6	7
Extra-Small Non-Self-Priming Pool filter Pump	1	1	1	2	2
Waterfall Pump	1	1	0	2	3
Pressure Cleaner Booster Pump	1	1	1	3	4
Integral Cartridge Filter Pool Pump	0	0	1	0	0
Integral Sand Filter Pool Pump	0	0	1	0	0

10.3 PROJECTED EFFICIENCY TRENDS

A key component of the NIA is the energy efficiency projected over time for the no-standards case and for each of the standards cases (with potential new standards).

10.3.1 Compliance Year

For each equipment class, DOE developed a distribution of efficiencies in the no-standards case for 2021 (the assumed compliance date for new standards), as described in chapter 8. In each standards case, DOE assumed a "roll-up" scenario to establish the efficiency distribution for 2021. Product efficiencies in the no-standards case that did not meet the standard under consideration would "roll up" to meet the new standard level. All efficiency shares in the no-standards case that were above the standard under consideration would not be affected. Table 10.3.1 and Table 10.3.2 present the efficiency distributions for the no-standards case and standards cases for pool pumps.

Table 10.3.1 No-Standards Case Pool Pump Efficiency in 2021

	EL 0	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6	EL 7
Standard-Size Self-Priming Pool Filter Pump	39.0%	15.0%	10.0%	2.0%	2.0%	2.0%	11.0%	19.0%
Small-Size Self-Priming Pool Filter Pump	39.0%	15.0%	10.0%	2.0%	2.0%	2.0%	11.0%	19.0%
Standard-Size Non-Self-Priming Pool Filter Pump	29.0%	29.0%	32.0%	2.0%	1.0%	1.0%	3.0%	3.0%
Extra-Small Non-Self-Priming Pool	33.3%	33.3%	33.3%	n/a	n/a	n/a	n/a	n/a

filter Pump								
Waterfall Pump	70.0%	20.0%	10.0%	0.0%	n/a	n/a	n/a	n/a
Pressure Cleaner Booster Pump	13.5%	70.5%	10.0%	3.0%	3.0%	n/a	n/a	n/a
Integral Cartridge Filter Pool Pump	80.0%	20.0%	n/a	n/a	n/a	n/a	n/a	n/a
Integral Sand Filter Pool Pump	80.0%	20.0%	n/a	n/a	n/a	n/a	n/a	n/a

Table 10.3.2 Standards Case Pool Pumps Effiency in 2021

	EL 0	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6	EL 7
Standard-Size Self-Priming Pool Filter Pump	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	81.0%	19.0%
Small-Size Self-Priming Pool Filter Pump	0.0%	0.0%	64.0%	2.0%	2.0%	2.0%	11.0%	19.0%
Standard-Size Non-Self-Priming Pool Filter Pump	0.0%	58.0%	32.0%	2.0%	1.0%	1.0%	3.0%	3.0%
Extra-Small Non-Self-Priming Pool filter Pump	0.0%	66.7%	33.3%	n/a	n/a	n/a	n/a	n/a
Waterfall Pump	70.0%	20.0%	10.0%	0.0%	n/a	n/a	n/a	n/a
Pressure Cleaner Booster Pump	0.0%	84.0%	10.0%	3.0%	3.0%	n/a	n/a	n/a
Integral Cartridge Filter Pool Pump	0.0%	100.0%	n/a	n/a	n/a	n/a	n/a	n/a
Integral Sand Filter Pool Pump	0.0%	100.0%	n/a	n/a	n/a	n/a	n/a	n/a

10.3.2 Projected Efficiency Trends After 2021

Table 10.3.3 shows DOE's efficiency trend for pool pumps in the no-standards case, from year 2021 to 2050. The percentages show, for each equipment class, what fraction of new products sold each year are at each efficiency level (EL). For Standard-Size Self-Priming Pool Filter Pumps, Small-Size Self-Priming Pool Filter Pumps, Standard-Size Non-Self-Priming Pool Filter Pumps, and Pressure Cleaner Booster Pumps, the single-speed efficiency level market shares are assumed to shift to variable-speed levels by 1% per year throughout the analysis period, as agreed upon by the Working Group.[1] The market shares of other equipment classes remained fixed. This is described further in section 9.4.

Table 10.3.3 Projected Efficiency Distributions of Pool Pumps in the No-Standards Case, 2021-2050

		2021	2030	2040	2050
Standard-Size Self-Priming Pool Filter Pump, & Small-Size Self-Priming Pool Filter Pump	EL 0	39.0%	30.0%	20.0%	10.0%
	EL 1	15.0%	15.0%	15.0%	15.0%
	EL 2	10.0%	10.0%	10.0%	10.0%
	EL 3	2.0%	2.0%	2.0%	2.0%

	EL 4	2.0%	2.0%	2.0%	2.0%
	EL 5	2.0%	2.0%	2.0%	2.0%
	EL 6	11.0%	15.5%	20.5%	25.5%
	EL 7	19.0%	23.5%	28.5%	33.5%
Standard-Size Non-Self-Priming Pool Filter Pump	EL 0	29.0%	24.5%	19.5%	14.5%
	EL 1	29.0%	24.5%	19.5%	14.5%
	EL 2	32.0%	32.0%	32.0%	32.0%
	EL 3	2.0%	2.0%	2.0%	2.0%
	EL 4	1.0%	1.0%	1.0%	1.0%
	EL 5	1.0%	1.0%	1.0%	1.0%
	EL 6	3.0%	7.5%	12.5%	17.5%
	EL 7	3.0%	7.5%	12.5%	17.5%
Extra-Small Non-Self-Priming Pool Filter Pump	EL 0	33.3%	33.3%	33.3%	33.3%
	EL 1	33.3%	33.3%	33.3%	33.3%
	EL 2	33.3%	33.3%	33.3%	33.3%
Waterfall Pump	EL 0	70.0%	70.0%	70.0%	70.0%
	EL 1	20.0%	20.0%	20.0%	20.0%
	EL 2	10.0%	10.0%	10.0%	10.0%
	EL 3	0.0%	0.0%	0.0%	0.0%
Pressure Cleaner Booster Pump	EL 0	13.5%	9.0%	4.0%	0.0%
	EL 1	70.5%	66.0%	61.0%	55.0%
	EL 2	10.0%	10.0%	10.0%	10.0%
	EL 3	3.0%	7.5%	12.5%	17.5%
	EL 4	3.0%	7.5%	12.5%	17.5%
Integral Cartridge Filter Pool Pump, & Integral Sand Filter Pool Pump	EL 0	80.0%	80.0%	80.0%	80.0%
	EL 1	20.0%	20.0%	20.0%	20.0%

10.4 NATIONAL ENERGY SAVINGS

DOE calculates annual national energy savings (NES) and cumulative NES throughout the analysis period, which extends over the lifetime of pool pumps shipped from 2021 to 2050. Positive values of NES represent energy savings, meaning national energy consumption under the proposed standards is lower than in the no-standards case.

10.4.1 Definition

DOE calculates annual NES (NES_y) as the difference between two annual energy consumption (*AEC*) projections: a no-standards case and a standards case (with new standards).

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

Cumulative energy savings are the sum of each annual *NES* throughout the analysis period, which extends over the lifetime of pool pumps shipped from 2021 to 2050. This calculation is represented by the following equation.

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

DOE calculated *AEC* by multiplying the number or stock of a given product (by vintage) by its unit energy consumption (also by vintage). The calculation of the national *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 product stock, $STOCK_V$;
NES_y =	national annual energy savings (quads);
NES_{cum} =	national cumulative energy savings (quads);
$STOCK_V$ =	stock of product (millions of units) of vintage *V* that survive in the year for which DOE calculated annual energy consumption;
UEC_V =	annual energy consumption per product 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 no-standards case;
std =	designates the quantity corresponding to the standards case;
y =	year in the forecast; and
cum =	cumulative over the forecast period; and
V =	year in which the product was purchased as a new unit.

The stock of equipment depends on annual shipments and the lifetime of the given product. As described in chapter 9, DOE projected shipments for the no-standards case and each standards case.

10.4.2 Inputs to Calculation

The inputs for calculating NES are:

- shipments;
- product stock (*$STOCK_V$*);
- annual energy consumption per unit (*UE*C);
- national annual energy consumption (*AEC*); and
- a power plant primary energy use factor (*src_conv*).

10.1.4.1 Shipments and Product Stock

DOE projected shipments of each equipment class under the no-standards case and each standards case. Several factors affect projected shipments, including purchase cost, operating cost, and household income. As noted previously, the increased cost of more-efficient products causes some consumers to forego buying the products. Consequently, shipments projected under the standards cases are lower than under the no-standards case. The method DOE used to calculate and generate the shipments projections for each considered equipment class is described in detail in chapter 9, Shipments Analysis.

The product stock in a given year is the number of products shipped from earlier years that survive in that year. The NIA shipments model tracks the number of units shipped each year. DOE assumes that products have an increasing probability of retiring as they age. The probability of survival as a function of years since purchase is the survival function. Chapter 9 provides additional details on the survival function that DOE used.

10.4.2.2 Annual Energy Consumption per Unit

DOE developed annual per-unit energy consumption as a function of product energy efficiency for each equipment class (see chapter 7, Energy Use Analysis, and chapter 8, Life-Cycle Cost and Payback Period Analysis). Because annual per-unit energy consumption depends directly on energy efficiency, DOE used the shipments-weighted energy efficiencies for the no-standards and standards cases, along with the annual energy use data presented in chapter 8, to estimate the shipments-weighted average annual per-unit energy consumption under the no-standards case and standards cases.

As noted previously, DOE assumed that efficiency distributions change over the analysis period for Standard-Size Self-Priming Pool Filter Pumps, Small-Size Self-Priming Pool Filter Pumps, Standard-Size Non-Self-Priming Pool Filter Pumps, and Pressure Cleaner Booster Pumps. EL definitions remain constant at 2016 levels however. Because annual per-unit energy consumption is a function of energy efficiency, DOE held the values shown in Table 10.4.1 constant throughout the projection period.

Table 10.4.1 Annual Energy Consumption per Unit (kWh/yr)

Equipment Class	EL 0	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6	EL 7
Standard-Size Self-Priming Pool Filter Pump (1 hp rep size)	4495	3582	3211	2433	2101	1971	1390	1217
Standard-Size Self-Priming Pool Filter Pump (3 hp rep size)	6328	5706	5358	3524	3185	2761	2137	1758
Small-Size Self-Priming Pool Filter Pump	1946	1553	1407	1305	1136	1058	714	597
Standard-Size Non-Self-Priming Pool Filter Pump	1594	1271	1218	1130	955	901	501	369
Extra-Small Non-Self-Priming Pool filter Pump	408	325	312	n/a	n/a	n/a	n/a	n/a
Waterfall Pump	539	501	450	409	n/a	n/a	n/a	n/a
Pressure Cleaner Booster Pump	1218	1000	930	799	727	n/a	n/a	n/a
Integral Cartridge Filter Pool Pump (1/15 hp rep size)	306	118	n/a	n/a	n/a	n/a	n/a	n/a
Integral Cartridge Filter Pool Pump (1/2 hp rep size)	922	413	n/a	n/a	n/a	n/a	n/a	n/a
Integral Sand Filter Pool Pump	278	107	n/a	n/a	n/a	n/a	n/a	n/a

10.1.4.3 National Annual Energy Consumption

National annual energy consumption is the product of the annual energy consumption per unit and the number of units of each vintage. This calculation accounts for differences in unit energy consumption from year to year. The equation for determining annual energy consumption, shown in section 10.3, is repeated here.

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

In determining national annual energy consumption, DOE initially calculates annual energy consumption at the site and then applies a conversion factor to calculate primary energy consumption.

10.1.4.4 Primary Energy Factors

For electricity use, the conversion from site kWh to power plant primary energy uses a marginal heat rate factor that accounts for losses associated with the generation, transmission, and distribution of electricity. DOE derived these marginal factors using data published with the Energy Information Administration (EIA's) *Annual Energy Outlook 2016* (*AEO2016*),[2] following the methodology outlined in appendix 15A. The factors depend on the sector and end-use, and also vary with time due to changes in the mix of fuels used for electric power generation. Figure 10.4.1 shows the site-to-primary factors from 2021 to the end of the AEO analysis period (2040). For years after 2040, DOE held the factors constant and equal to their 2040 values.

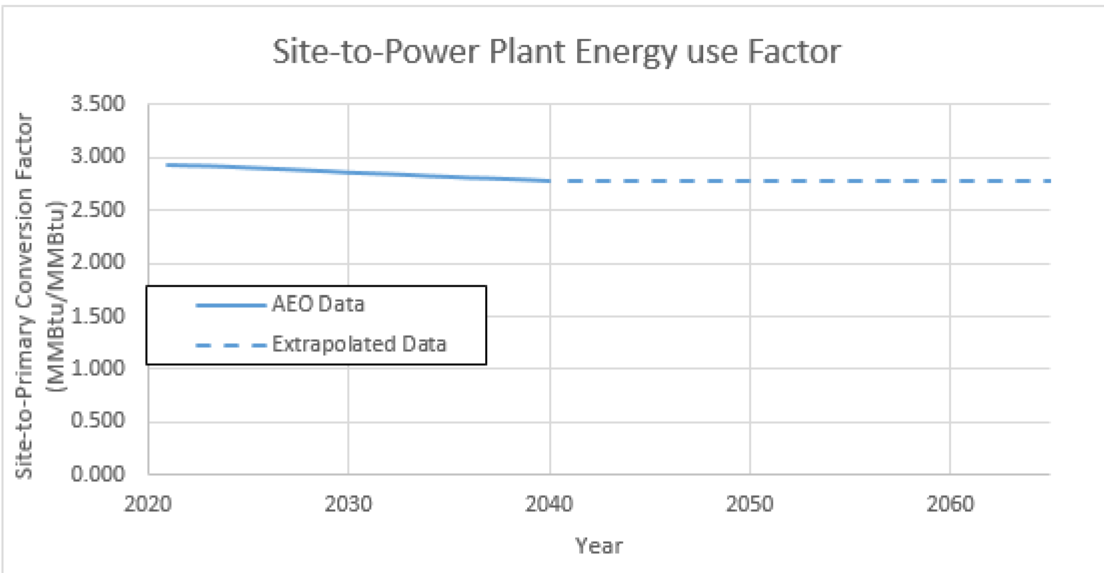

Figure 10.4.1 Site-to-Power Plant Energy Use Factor

10.1.4.5 Full-Fuel-Cycle Energy Factors

The full-fuel-cycle energy use is equal to the primary energy use plus the energy consumed "upstream" of power plants in the extraction, processing and distribution of fuels. The FFC energy use was calculated by applying a fuel-specific FFC energy multiplier to the primary energy use. DOE developed FFC multipliers using the data and projections generated by the National Energy Modeling System (NEMS) used for *AEO2016*. 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. The multplier for electricity represents the energy needed to produce and deliver the fuels that are consumed in electricity generation. The multipliers are dimensionless numbers that express the upstream energy use as a percentage of the primary energy use.

Because the FFC energy multipliers depend on the fuel type, the FFC energy is calculated starting with the annual site energy consumption, *ASEC*. The equation is:

$$FFC(L,y) = \sum_F ASEC(L,F,y) * h(F,y) * \mu(F,y).$$

Where:

ASEC = annual site energy consumption
L = trial standard level
F = fuel type
y = analysis year
h = energy unit conversion factor
μ = full fuel cycle multiplier
FFC = annual full fuel cycle energy consumption

If a product uses only one fuel, then the FFC energy is equal to the primary energy *APEC* multiplied by the FFC multipler μ.

As with the NES, DOE calculated cumulative, national level energy savings in the full-fuel-cycle metric by calculating the difference relative to the no-standards case and summing over the analysis period:

$$NES\text{-}FFC(L,y) = FFC(L{=}0,y) - FFC(L,y),$$

$$NES\text{-}FFC_{cum}(L) = \sum_y NES\text{-}FFC(L,y)$$

The method used to calculate FFC energy multipliers and the derived values are described in appendix 10B.

10.5 NET PRESENT VALUE

DOE calculated the net present value (NPV) of the increased product cost and reduced operating cost associated with the difference between the no-standards case and each potential standards case for pool pumps.

10.5.1 Definition

The NPV is the value in the present of a time-series of costs and savings. The NPV is described by the following 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 product 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 product (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 product (by vintage) by its per-unit total installed cost increase (also by vintage). Total annual savings in operating cost and increases in installed 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 product stock, $STOCK_V$;
TIC = total annual increase in installed cost each year summed over vintages of the product stock, $STOCK_V$;
DF = discount factor in each year;
$STOCK_V$ = stock of product (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;
V = year in which the product was purchased as a new unit; and
y = year in the forecast.

DOE determined the PVC for each year from the compliance date of the standard until 2050. DOE determined the PVS for each year from the compliance date of the standard until the year when units purchased in 2050 retire. DOE calculated costs and savings as the difference between each standards case and the no-standards case.

DOE calculated a discount factor from the discount rate and the number of years between the "present" (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.

10.5.2 Inputs to Calculation

The inputs to calculation of the net present value (NPV) are:

- total installed cost per unit,
- annual per-unit savings in operating cost,
- shipments,
- equipment stock ($STOCK_V$),
- total annual increases in installed cost (*TIC*),
- total annual operating cost (*OCS*),
- discount factor (*DF*),
- present value of costs (*PVC*), and
- 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 no-standards 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, repair, and maintenance costs. The *total annual savings in operating cost* are equal to the change in the annual operating costs (difference between no-standards 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.

10.1.6.1 Total Installed Cost per Unit

DOE described the total per-unit installed cost for each equipment class as a function of product efficiency in chapter 8. Because the total per-unit annual installed cost depends directly on efficiency, DOE used the shipments-weighted efficiencies for the base and standards cases, combined with the total installed cost presented in chapter 8, to estimate the shipments-weighted total per-unit average annual installed cost under the base and standards cases. Table 10.5.1 shows the average installed cost of pool pumps in 2021 for the base and standards cases for the equipment classes with the largest market shares.

Table 10.5.1 Average Installed Cost per Unit in 2021

Equipment Class	No-Standards Case	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
Standard-Size Self-Priming Pool Filter Pump (1 hp rep size)	$386.77	$451.43	$671.23	$726.95	$726.95	$726.95
Standard-Size Self-Priming Pool Filter Pump (3 hp rep size)	$588.85	$689.65	$940.37	$908.87	$908.87	$908.87
Small-Size Self-Priming Pool Filter Pump	$389.93	$455.56	$658.36	$455.56	$790.13	$790.13
Standard-Size Non-Self-Priming Pool Filter Pump	$249.18	$258.15	$460.98	$258.15	$626.22	$626.22
Extra-Small Non-Self-Priming Pool filter Pump	$184.92	$196.31	$196.31	$196.31	$207.70	$207.70
Waterfall Pump	$392.81	$414.84	$414.84	$392.81	$454.40	$454.40
Pressure Cleaner Booster Pump	$335.43	$355.80	$355.80	$355.80	$711.48	$711.48
Integral Cartridge Filter Pool Pump (1/15 hp rep size)	$45.36	$45.36	$45.36	$57.27	$45.36	$45.36
Integral Cartridge Filter Pool Pump (1/2 hp rep size)	$249.46	$249.46	$249.46	$261.37	$249.46	$249.46
Integral Sand Filter Pool Pump	$154.23	$154.23	$154.23	$166.14	$154.23	$154.23

10.1.6.2 Annual Operating Cost per Unit

The per-unit annual operating cost includes costs for energy, repair, and maintenance. DOE determined the per-unit annual savings in energy costs by multiplying the per-unit annual savings in energy consumption developed for each equipment class by the appropriate energy price.

Estimates of the per-unit annual energy consumption for the no-standards case and each standards case were presented in section 10.3.2.1. DOE projected the per-unit annual energy consumption for the no-standards case for all equipment classes by applying a growth trend in efficiency.

Energy prices and trends in energy prices are described in chapter 8. DOE projected energy prices based on the cases described on p. E-8 of *AEO2016*[2].[b]

DOE described the total per-unit repair and maintenance costs for each equipment class as a function of product efficiency in chapter 8. Because the per-unit repair and maintenance costs depend directly on efficiency, DOE used the efficiencies for the no-standards and standards cases presented in section 10.2, combined with the repair and maintenance costs presented in chapter 8, to estimate the per-unit average repair and maintenance costs under the no-standards and standards cases.

Table 10.5.2 shows the average operating cost of pool pumps in 2021 for the no-standards and standards cases for the equipment classes with the largest market shares. The operating costs change over time, depending on changes in annual energy use and energy prices.

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[b] The standards finalized in this rulemaking will take effect a few years prior to the 2022 commencement of the Clean Power Plan compliance requirements. As DOE has not modeled the effect of CPP during the 30-year analysis period of this rulemaking, there is some uncertainty as to the magnitude and overall effect of the energy efficiency standards. These energy efficiency standards are expected to put downward pressure on energy prices relative to the projections in the AEO 2016 case that incorporates the CPP. Consequently, DOE used the electricity price projections found in the AEO 2016 No-CPP case as these electricity price projections are expected to be lower, yielding more conservative estimates for consumer savings due to the energy efficiency standards.

Table 10.5.2 Annual Average Operating Cost per Unit in 2021

Equipment Class	No-Standards Case	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
Standard-Size Self-Priming Pool Filter Pump (1 hp rep size)	$615.30	$439.51	$269.80	$190.30	$190.30	$166.56
Standard-Size Self-Priming Pool Filter Pump (3 hp rep size)	$857.53	$726.09	$374.17	$289.55	$289.55	$238.24
Small-Size Self-Priming Pool Filter Pump	$266.33	$192.64	$144.87	$192.64	$97.68	$81.75
Standard-Size Non-Self-Priming Pool Filter Pump	$214.43	$170.97	$128.48	$170.97	$67.41	$49.62
Extra-Small Non-Self-Priming Pool filter Pump	$54.90	$43.75	$43.75	$43.75	$41.96	$41.96
Waterfall Pump	$73.11	$67.96	$67.96	$73.11	$60.93	$55.39
Pressure Cleaner Booster Pump	$165.04	$135.47	$135.47	$135.47	$108.33	$98.47
Integral Cartridge Filter Pool Pump (1/15 hp rep size)	$41.09	$41.09	$41.09	$15.86	$41.09	$41.09
Integral Cartridge Filter Pool Pump (1/2 hp rep size)	$124.03	$124.03	$124.03	$55.48	$124.03	$124.03
Integral Sand Filter Pool Pump	$37.35	$37.35	$37.35	$14.33	$37.35	$37.35

10.1.6.3 Equipment Stock

The stock of equipment in any given year depends on annual shipments and the lifetime of a given equipment class. The NIA model keeps track of the number of units shipped each year. The lifetime of a unit determines how many units shipped in previous years survive in the given year. DOE assumes that products have an increasing probability of retiring as they age. The probability of survival as a function of years since purchase is termed the survival function. Refer to the specific section for each equipment class in chapter 9 for further details on the survival functions that DOE used in its analysis.

10.1.6.4 Increases in Total Annual Installed Cost

The increase in total annual installed cost for a product under any given standards case is the product of the increase in total installed cost per unit attributable to the standard and the number of units of each vintage. This method accounts for differences in total installed cost from year to year. The equation for determining the total annual installed cost increase for a given candidate standards level is:

$$TIC = \sum STOCK_V \times UTIC_V$$

10.1.6.5 Savings in Total Annual Operating Cost

The savings in total annual operating cost for any given candidate standards level is the product of the annual per-unit savings in operating cost attributable to the standard and the number of units of each vintage. This method accounts for the year-to-year differences in annual operating cost savings. The equation for determining the total annual savings in operating cost for a given candidate standard level, which was presented in section 10.4.1, is repeated here.

$$OCS = \sum STOCK_V \times UOCS_V$$

10.1.6.6 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:

$$\boldsymbol{DF} = \frac{1}{(1+\boldsymbol{r})^{(y-yp)}}$$

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 pool pumps (chapter 8), it used national discount rates to calculate national NPV. DOE estimated NPV using both a 3-percent and a 7-percent 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.[3] DOE defined the present year as 2016.

10.1.6.7 Present Value of Increased Installed Cost

The present value of increased installed cost is the difference between installation cost in each standards case and the no-standards case discounted to the present and summed throughout the period over which DOE is considering the installation of units (from the compliance date of standards, 2021, through 2050). DOE calculated annual increases in installed cost as the difference in total installed cost for new equipment purchased each year, multiplied by the shipments in the standards case.

10.1.6.8 Present Value of Savings

The present value of annual savings in operating cost is the difference between the no-standards case and each standards case discounted to the present and summed throughout the period from the compliance date, 2021, to the time when the last unit installed in 2050 is retired from service.

Savings represent decreases in operating cost (including electricity, repair, and maintenance) associated with the more energy efficient equipment purchased in each standards case compared to the no-standards case. 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.

10.6 RESULTS

10.6.1 National Energy Savings

This section provides the national energy savings that DOE calculated for each of the TSLs analyzed for pool pumps. DOE based the inputs to the NIA model on weighted-average values, producing results that are discrete point values, rather than a distribution of values such as is generated by the life-cycle cost and payback period analysis.

Table 10.6.1 National Energy Savings (Primary) from Pool Pump Standards, by TSL (Quadrillion Btu)

Equipment Class	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
Standard-Size Self-Priming Pool Filter Pump (1 hp rep size)	0.36	0.95	1.3	1.3	1.4
Standard-Size Self-Priming Pool Filter Pump (3 hp rep size)	0.30	1.6	2.0	2.0	2.3
Small-Size Self-Priming Pool Filter Pump	0.04	0.08	0.04	0.13	0.16
Standard-Size Non-Self-Priming Pool Filter Pump	0.05	0.21	0.05	0.47	0.56
Extra-Small Non-Self-Priming Pool filter Pump	0.00	0.00	0.00	0.00	0.00
Waterfall Pump	0.00	0.00	0.00	0.00	0.00
Pressure Cleaner Booster Pump	0.00	0.00	0.00	0.03	0.05
Integral Cartridge Filter Pool Pump (1/15 hp rep size)	0.00	0.00	0.15	0.00	0.00
Integral Cartridge Filter Pool Pump (1/2 hp rep size)	0.00	0.00	0.12	0.00	0.00
Integral Sand Filter Pool Pump	0.00	0.00	0.03	0.00	0.00
Total	0.75	2.9	3.6	3.9	4.4

Table 10.6.2 National Energy Savings (Full-Fuel Cycle) from Pool Pump Standards, by TSL (Quadrillion Btu)

Equipment Class	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
Standard-Size Self-Priming Pool Filter Pump (1 hp rep size)	0.38	1.0	1.3	1.3	1.5
Standard-Size Self-Priming Pool Filter Pump (3 hp rep size)	0.31	1.7	2.1	2.1	2.4
Small-Size Self-Priming Pool Filter Pump	0.04	0.09	0.04	0.14	0.16
Standard-Size Non-Self-Priming Pool Filter Pump	0.06	0.22	0.06	0.49	0.59
Extra-Small Non-Self-Priming Pool filter Pump	0.00	0.00	0.00	0.00	0.00
Waterfall Pump	0.00	0.00	0.00	0.00	0.00
Pressure Cleaner Booster Pump	0.00	0.00	0.00	0.04	0.05
Integral Cartridge Filter Pool Pump (1/15 hp rep size)	0.00	0.00	0.16	0.00	0.00
Integral Cartridge Filter Pool Pump (1/2 hp rep size)	0.00	0.00	0.13	0.00	0.00
Integral Sand Filter Pool Pump	0.00	0.00	0.03	0.00	0.00
Total	0.79	3.0	3.8	4.1	4.6

10.6.2 Net Present Value of Consumer Benefit

This section provides results of calculating the NPV for each standard level considered for pool pumps. Results were calculated for the nation as a whole. Results, which are cumulative, are shown as the discounted dollar value of the net savings. 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 such as produced by the life-cycle cost and payback period analyses.
A negative NPV indicates that the costs of a standard at a given efficiency level exceed the savings.

Table 10.6.3 Net Present Value from Pool Pump Standards at a 3 Percent Discount Rate, by TSL (2015$ billion)

Equipment Class	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
Standard-Size Self-Priming Pool Filter Pump (1 hp rep size)	2.6	6.0	7.9	7.9	8.8
Standard-Size Self-Priming Pool Filter Pump (3 hp rep size)	1.8	10	13	13	15
Small-Size Self-Priming Pool Filter Pump	0.24	0.33	0.24	0.49	0.66
Standard-Size Non-Self-Priming Pool Filter Pump	0.39	0.06	0.39	0.54	1.2
Extra-Small Non-Self-Priming Pool filter Pump	0.01	0.01	0.01	0.01	0.01
Waterfall Pump	0.00	0.00	0.00	0.00	0.01
Pressure Cleaner Booster Pump	0.02	0.02	0.02	-0.65	-0.54
Integral Cartridge Filter Pool Pump (1/15 hp rep size)	0.00	0.00	0.99	0.00	0.00
Integral Cartridge Filter Pool Pump (1/2 hp rep size)	0.00	0.00	0.90	0.00	0.00
Integral Sand Filter Pool Pump	0.00	0.00	0.18	0.00	0.00
Total	5.1	17	24	21	25

Table 10.6.4 Net Present Value from Pool Pump Standards at a 7 Percent Discount Rate, by TSL (2015$ billion)

Equipment Class	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
Standard-Size Self-Priming Pool Filter Pump (1 hp rep size)	1.3	2.9	3.8	3.8	4.2
Standard-Size Self-Priming Pool Filter Pump (3 hp rep size)	0.90	5.0	6.3	6.3	7.2
Small-Size Self-Priming Pool Filter Pump	0.12	0.16	0.12	0.23	0.31
Standard-Size Non-Self-Priming Pool Filter Pump	0.19	0.01	0.19	0.20	0.50
Extra-Small Non-Self-Priming Pool filter Pump	0.01	0.01	0.01	0.00	0.00
Waterfall Pump	0.00	0.00	0.00	0.00	0.00
Pressure Cleaner Booster Pump	0.01	0.01	0.01	-0.34	-0.29
Integral Cartridge Filter Pool Pump (1/15 hp rep size)	0.00	0.00	0.49	0.00	0.00
Integral Cartridge Filter Pool Pump (1/2 hp rep size)	0.00	0.00	0.45	0.00	0.00
Integral Sand Filter Pool Pump	0.00	0.00	0.09	0.00	0.00
Total	2.5	8.1	11	10	12

REFERENCES

1 US Department of Energy Dedicated Purpose Pool Pumps Working Group Meeting. 04-18-2016. EERE-2015-BT-STD-0008-0078, pp. 138-141. https://www.regulations.gov/document?D=EERE-2015-BT-STD-0008-0078

2 Energy Information Administration, *Annual Energy Outlook 2016 with Projections to 2040*. Washington, DC. http://www.eia.gov/forecasts/aeo/pdf/0383(2016).pdf

3 U.S. Office of Management and Budget (OMB), Circular A-4: Regulatory Analysis, 2003. (Posted September 17, 2003) (Last accessed August, 2016.) http://www.whitehouse.gov/sites/default/files/omb/assets/regulatory_matters_pdf/a-4.pdf

APPENDIX 10A. USER INSTRUCTIONS FOR SHIPMENTS AND NIA SPREADSHEET

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APPENDIX 10A. USER INSTRUCTIONS FOR SHIPMENTS AND NIA SPREADSHEET

10A.1 INTRODUCTION

The results obtained for the shipments analysis and the national impact analysis (NIA) can be examined and reproduced using the Microsoft Excel spreadsheet available on the U.S. Department of Energy Building Technologies website at: http://www.eere.energy.gov/buildings/appliance_standards/.

The spreadsheets are posted on the DOE website[a] and represent the latest version that has been tested with Microsoft Excel 2013.

To execute the spreadsheet requires Microsoft Excel 2003 or a later version. The NIA spreadsheet performs calculations to project the change in national energy use and net present value (NPV) due to an energy conservation standard. The energy use and associated costs for a given standard are determined first by calculating the shipments and then calculating the energy use and costs for all equipment shipped under that standard. The differences between the standards and no standards case can then be compared and the overall energy savings and present values determined.

The NIA spreadsheet or workbook consists of the following worksheets:

Summary	Contains user input selections in column D (economic growth rate, discount rate, analysis period, energy savings scenario, price trend, price elasticity, and TSL), as well as a results table displaying Cumulative Full-fuel cycle (FFC) Energy Savings, Operating Cost Savings, Incremental Equipment Costs, and NPV for the user selected input values.
Self-Priming 1HP	Contains yearly equipment costs, operating costs, energy consumption, and efficiency distributions for no-standards and standards cases for the Standard-Size Self-Priming Pool Filter Pump (1 hp rep size) product class throughout the analysis period.
Self-Priming 3HP	Similar to Self-Priming 1HP worksheet.
Self-Priming XS	Similar to Self-Priming 1HP worksheet.
Non-Self-Priming	Similar to Self-Priming 1HP worksheet.
Non-Self-Priming XS	Similar to Self-Priming 1HP worksheet.

[a] https://www.regulations.gov/docket?D=EERE-2015-BT-STD-0008. (Last accessed August 31, 2016.) This material is available in Docket #EERE-2015-BT-STD-0008 at regulations.gov.

Waterfall	Similar to Self-Priming 1HP worksheet.
Pres Cleaner Booster	Similar to Self-Priming 1HP worksheet.
Int Cart-Filter 0.067HP	Similar to Self-Priming 1HP worksheet.
Int Cart-Filter 0.5HP	Similar to Self-Priming 1HP worksheet.
Int Sand-Filter	Similar to Self-Priming 1HP worksheet.
PC Inputs	Contains equipment costs and energy consumption for each product class and efficiency level, as well as repair costs for each product class, and finally, total installed costs for relevant product classes.
Shipments	Contains projected shipments (new installations and replacements) for each product class in the no standards case and standards case throughout the analysis period for the selected Economic Growth scenario. Elasticity for each product class is also shown.
Hist Shipments	Contains historical shipments and efficiency distributions for each product class, as well the number of repaired units and their energy consumption.
Price Indices	Contains the price indices by product class under reference, low price, and high price scenarios.
Lifetime	Contains the probability of survival at a given age for both new pumps and replacements.
Energy Factors	Contains the annual site-to-primary and FFC conversion factors.
Energy Price	Contains projected average energy prices for the three electricity price scenarios.

10A.2 BASIC INSTRUCTIONS

Basic instructions for operating the NIA spreadsheets are as follows:

1. Once the NIA spreadsheets have been downloaded from the World Wide Web, open the file using Excel. At the bottom, click on the tab for the worksheet 'Summary'.

2. Use Excel's View/Zoom commands at the top menu bar to change the size of the display to make it fit your monitor.

3. The user can change the model parameters listed in the grey box in column D. The parameters are:
    a. Economic Growth: To change the value, use the drop-down arrow and select the desired scenario (Reference, Low, or High).
    b. Discount Rate: To change the value, use the drop-down arrow and select the desired scenario (3%, or 7%).
    c. Analysis Period: To change the value, use the drop-down arrow and select the desired scenario (Full – 30 years; or Short – 9 years).
    d. Energy Savings: To change the value, use the drop-down arrow and select the desired scenario (Site, Primary, or FFC).
    e. Price Trend: To change the value, use the drop-down arrow and select the desired scenario (Reference, Low price, or High price).
    f. Price Elasticity: To change the value, use the drop-down arrow and select the desired scenario (Yes, or No).
    g. TSL: To change TSL being analyzed, use the drop-down arrow and select the desired TSL.

4. The results are automatically updated and are reported in the summary tables to the right of the model parameters. Results are shown for the selected inputs.

APPENDIX 10B. FULL-FUEL-CYCLE ANALYSIS

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APPENDIX 10B. FULL-FUEL-CYCLE ANALYSIS

10B.1 INTRODUCTION

This appendix summarizes the methods the U.S. Department of Energy (DOE) used to calculate the estimated full-fuel-cycle (FFC) energy savings from potential energy conservation 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. DOE's method of analysis previously encompassed only site energy and the energy lost through generation, transmission, and distribution of electricity. In 2011 DOE announced its intention, based on recommendations from the National Academy of Sciences, to use FFC measures of energy use and emissions when analyzing proposed energy conservation standards.[1] This appendix summarizes the methods DOE used to incorporate impacts of the full fuel cycle into the analysis.

In the national energy savings calculation, DOE estimates the site, primary and full-fuel-cycle (FFC) energy consumption for each standard level, for each year in the analysis period. DOE defines these quantities as follows:

- Site energy consumption is the physical quantity of fossil fuels or electricity consumed at the site where the end-use service is provided.[a] The site energy consumption is used to calculate the energy cost input to the NPV calculation.
- Primary energy consumption is defined by converting the site fuel use from physical units, for example cubic feet for natural gas, or kWh for electricity, to common energy units (million Btu or mmBtu). For electricity the conversion factor is a marginal heat rate that incorporates losses in generation, transmission and distribution, and depends on the sector, end use and year.
- The full-fuel-cycle (FFC) energy use is equal to the primary energy use plus the energy consumed "upstream" of the site in the extraction, processing and distribution of fuels. The FFC energy use was calculated by applying a fuel-specific FFC energy multiplier to the primary energy use.

For electricity from the grid, site energy is measured in terawatt-hours (TWh). The primary energy of a unit of grid electricity is equal to the heat content of the fuels used to generate that electricity, including transmission and distribution losses.[b] DOE typically measures the primary energy associated with the power sector in quads (quadrillion Btu). Both primary fuels and electricity are used in upstream activities. The treatment of electricity in full-fuel-cycle analysis must distinguish between electricity generated by fossil fuels and electricity generated from renewable sources (wind, solar, and hydro). For the former, the upstream fuel cycle relates

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[a] For fossil fuels, this is the site of combustion of the fuel.
[b] For electricity sources like nuclear energy and renewable energy, the primary energy is calculated using the convention described below.

to the fuel consumed at the power plant. There is no upstream component for the latter, because no fuel *per se* is used.

10B.2 MARGINAL HEAT RATES

DOE uses heat rates to convert site electricity savings in TWh to primary energy savings in quads. The heat rates are developed as a function of the sector, end-use and year of the analysis period. For this analysis DOE uses output of the DOE/Energy Information Administration (EIA)'s National Energy Modeling System (NEMS).[2] EIA uses the NEMS model to produce the *Annual Energy Outlook* (*AEO*). DOE's approach uses the most recently available edition, in this case *AEO2016*.[3] The *AEO* publication includes a reference case and a series of side cases incorporating different economic and policy scenarios. DOE's heat rate calculation methods depend on the scenarios available with the current AEO publication. When the data allow it, DOE calculates marginal heat rates as the ratio of the change in fuel consumption to the change in generation for each fossil fuel type, where the change is defined as the difference between the reference case and the side case. The marginal approach relies on the availability of side cases where the primary difference from the reference case is a reduction in demand for electricity, with relatively little change in the fuel mix and the economic and demographic drivers of electricity use. This approach was used with the *AEO2014* and *AEO2015*, and is documented in the appendices to rules published in that time frame. The marginal methodology, and the conditions under which it applies, are also discussed in Coughlin (2014).[4]

AEO2016 includes several side cases with identical assumptions about economic and demographic growth, technology development *etc*. that differ only in the way the Clean Power Plan (CPP) is implemented. These include the Reference case, which assumes a cap on the total mass of CO_2 emissions, the *CPP Rate* case, which assumes that states implement a cap on the CO_2 emissions intensity of the electricity sector, and the *No CPP* case in which the CPP is not adopted. DOE used the *AEO2016* No CPP case as its reference projection for the energy sector.

The side cases published with *AEO2016* do not allow for calculation of marginal heat rates, so DOE based its calculation of heat rates on grid-average data. Using data for the No CPP case, DOE calculated heat rates in four steps:

1. DOE defined fuel-specific grid-average heat rates, as the ratio of primary energy consumed per unit of electricity generated for coal, natural gas and petroleum-based fuels. For renewable and nuclear generation, DOE adopted the EIA convention of assigning a constant heat rate of 10.5 Btu/Wh to nuclear power and 9.5 Btu/Wh to electricity from renewable sources. DOE calculated these heat rates for each of five geographic regions. The five regions consist of aggregations of the NERC reliability regions, which also map to aggregations of the NEMS Electricity Market Module regions as follows: region 1 consists of NERC regions NPCC and RFC, region 2 contains the SERC and FRCC regions, region 3 is MRO, region 4 ERCOT plus SPP, and region 5 is WECC. The fuel specific heat rates by region are shown in Figure 10B.2.1.

2. For each sector and end-use, DOE calculated regional weights based on the fraction of electricity consumption for that end-use in each of the five regions. DOE based this calculation on the AEO projection of end-use electricity consumption by census division,

and a table matrix provided with the NEMS code that breaks down sectoral electricity use by both EMM region and census division. This calculation provides regional weights that vary by sector, end-use and year.

3. Within each region, DOE calculated the fraction of generation allocated to each fuel type based on AEO projections of generation by EMM region, for the major fuel types: coal, natural gas, nuclear, oil, and renewables. This grid-average calculation shows that approximately 15-20% of generation is allocated to nuclear. The grid-average calculation is being used as an approximation to the marginal calculation, and all DOE's previous marginal calculations have shown that within NEMS nuclear power is never on the margin (*i.e.* total nuclear power generation is constant across all scenarios). To be consistent with previous marginal analyses, DOE zeroed out the nuclear portion of the generation fraction and redistributed the nuclear share proportionally across the other fuel types. The result is a set of factors defining the fraction of generation by fuel type for marginal reductions in demand that vary by region and year.

4. DOE multiplied the regional end-use weights by the product of the fraction of generation by fuel type and the fuel specific heat rates in each region, and summed over all regions and fuel types, to define a heat rate for each sector/end-use. This calculation also includes the transmission and distribution losses. In equation form:

$$h(u,y) = (1 + TDLoss)*\sum_{r,f} w(u,r)\ G(r,f,y)\ H(r,f,y)$$

Where:

$TDLoss$ = the fraction of total generation that is lost in transmission and distribution, equal to 0.07037
u = an index representing the sector/end-use (e.g. commercial cooling)
r = the region
y = the analysis year
f = the fuel type
$w(u,r)$ = the regional weight
$H(r,f,y)$ = the fuel-specific heat rate plotted in Figure 10B.2.1
$G(r,f,y)$ = the fraction of generation provided by fuel type f in region r and year y
$h(u,y)$ = the end-use specific marginal heat rate

The sector/end-use specific marginal heat rates are shown in Table 10B.2.1. These marginal heat rates convert site electricity to primary energy in quads; i.e., the units used in the table are quads per TWh.

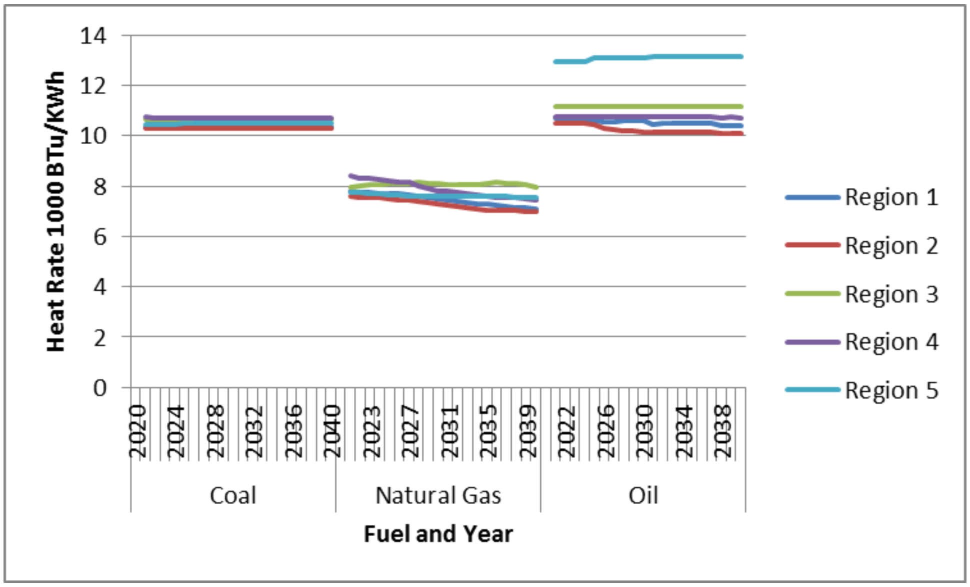

Figure 10B.2.1 Fuel Specific Heat Rates by Region

Table 10B.2.1 Electric Power Heat Rates (quads/TWh) by Sector and End-Use

	2021	2025	2030	2035	2040
Commercial Sector					
cooking	9.995E-03	9.908E-03	9.744E-03	9.599E-03	9.453E-03
lighting	1.002E-02	9.930E-03	9.775E-03	9.644E-03	9.503E-03
office equipment (non-pc)	1.003E-02	9.938E-03	9.792E-03	9.678E-03	9.543E-03
office equipment (pc)	1.001E-02	9.924E-03	9.772E-03	9.643E-03	9.500E-03
other uses	1.003E-02	9.939E-03	9.784E-03	9.655E-03	9.513E-03
refrigeration	1.002E-02	9.936E-03	9.778E-03	9.641E-03	9.495E-03
space cooling	1.001E-02	9.919E-03	9.750E-03	9.607E-03	9.468E-03
space heating	1.005E-02	9.972E-03	9.825E-03	9.701E-03	9.559E-03
ventilation	1.002E-02	9.933E-03	9.775E-03	9.640E-03	9.494E-03
water heating	1.000E-02	9.916E-03	9.757E-03	9.620E-03	9.480E-03
Industrial Sector					
all uses	1.006E-02	9.977E-03	9.826E-03	9.699E-03	9.560E-03
Residential Sector					
ceiling fans	1.003E-02	9.947E-03	9.789E-03	9.652E-03	9.501E-03
clothes dryers	1.000E-02	9.916E-03	9.759E-03	9.622E-03	9.487E-03
cooking	1.001E-02	9.919E-03	9.765E-03	9.633E-03	9.498E-03
electronics	1.002E-02	9.928E-03	9.778E-03	9.654E-03	9.516E-03
freezers	1.003E-02	9.949E-03	9.797E-03	9.667E-03	9.530E-03
furnace fans	1.006E-02	9.979E-03	9.834E-03	9.714E-03	9.560E-03
lighting	1.002E-02	9.931E-03	9.781E-03	9.659E-03	9.525E-03
other uses	1.001E-02	9.924E-03	9.764E-03	9.623E-03	9.486E-03
refrigeration	1.002E-02	9.936E-03	9.788E-03	9.668E-03	9.533E-03
space cooling	9.996E-03	9.907E-03	9.741E-03	9.597E-03	9.465E-03
space heating	9.996E-03	9.912E-03	9.756E-03	9.615E-03	9.478E-03
water heating	9.979E-03	9.895E-03	9.734E-03	9.589E-03	9.451E-03

10B.3 FFC METHODOLOGY

The methods used to calculate FFC energy use are summarized here. The mathematical approach to determining FCC is discussed in Coughlin (2012).[5] Details related to the modeling of the fuel production chain are presented in Coughlin (2013).[6]

When all energy quantities are normalized to the same units, FFC energy use can be represented as the product of the primary energy use and an FFC multiplier. Mathematically the FFC multiplier is a function of a set of parameters that represent the energy intensity and material losses at each stage of energy production. Those parameters depend only on physical data, so the calculations require no assumptions about prices or other economic factors. Although the parameter values may differ by geographic region, this analysis utilizes national averages.

The fuel cycle parameters are defined as follows.

- a_x is the quantity of fuel *x* burned per unit of electricity produced for grid electricity. The calculation of a_x includes a factor to account for losses incurred through the transmission and distribution systems.

- b_y is the amount of grid electricity used in producing 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).

All the parameters are calculated as functions of an annual time step; hence, when evaluating the effects of potential new standards, a time series of annual values is used to estimate the FFC energy and emissions savings in each year of the analysis period and cumulatively.

The FFC multiplier is denoted µ (mu). A separate multiplier is calculated for each fuel used on site. Also calculated is a multiplier for electricity that reflects the fuel mix used in its generation. The multipliers are dimensionless numbers 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.

The method for performing the full-fuel-cycle analysis utilizes data and projections published in the *AEO 2016*.[3] Table 10B.3.1 summarizes the data used as inputs to the calculation of various parameters. The column titled "AEO Table" gives the name of the table that provided the reference data.

Table 10B.3.1 Dependence of FFC Parameters on *AEO* Inputs

Parameter(s)	Fuel(s)	*AEO* Table	Variables
q_x	All	Conversion factors	MMBtu per physical unit
a_x	All	Electricity supply, disposition, prices, and emissions Energy consumption by sector and source	Generation by fuel type Electric energy consumption by the power sector
b_c, c_{nc}, c_{pc}	Coal	Coal production by region and type	Coal production by type and sulfur content
b_p, c_{np}, c_{pp}	Petroleum	Refining industry energy consumption Liquid fuels supply and disposition International liquids supply and disposition Oil and gas supply	Refining-only energy use Crude supply by source Crude oil imports Domestic crude oil production
c_{nn}	Natural gas	Oil and gas supply Natural gas supply, disposition, and prices	U.S. dry gas production Pipeline, lease, and plant fuel
z_x	All	Electricity supply, disposition, prices, and emissions	Power sector emissions

The *AEO 2016* does not provide all the information needed to estimate total energy use in the fuel production chain. Coughlin (2013) describes the additional data sources needed to complete the analysis. The time dependence in the FFC multipliers, however, arises exclusively from variables taken from the *AEO*.

10B.4 ENERGY MULTIPLIERS FOR THE FULL FUEL CYCLE

FFC energy multipliers for selected years are presented in Table 10B.4.1. The 2040 value was held constant for the analysis period beyond 2040, which is the last year in the *AEO 2016* projection. The multiplier for electricity reflects the shares of various primary fuels in total electricity generation throughout the forecast period.

Table 10B.4.1 Energy Multipliers for the Full Fuel Cycle (Based on *AEO 2016*)

	2021	2025	2030	2035	2040
Electricity	1.041	1.043	1.045	1.044	1.045
Natural gas	1.108	1.106	1.104	1.105	1.106
Petroleum fuels	1.171	1.171	1.172	1.173	1.174

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APPENDIX 10C. NET PRESENT VALUE UNDER ALTERNATIVE SCENARIOS

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APPENDIX 10C. NET PRESENT VALUE UNDER ALTERNATIVE SCENARIOS

10C.1 INTRODUCTION

This appendix presents net present value (NPV) results using inputs from alternative scenarios. The tables in section 10C.2 show how the cumulative net present value of consumer benefits from standards varies with energy prices. DOE examined three scenarios, which are based on the energy price forecasts in the High Economic Growth, Low Economic Growth, and Reference No-CPP cases in EIA's *Annual Energy Outlook 2016*.

10C.2 NIA RESULTS BY ECONOMIC GROWTH SCENARIO

Table 10C.2.1 and Table 10C.2.2 contain NPV results for pool pumps at 3 percent and 7 percent discount rates, respectively. In each table cell, results are displayed in the following format:

"Reference Benefits Result" ["Low Benefits Result" to "High Benefits Result"]

The "Reference Benefits Result" consists of the reference case shipments scenario, the reference growth energy prices scenario, and the reference price index scenario. The reference price index scenario consists of a constant price assumption for single-speed and two-speed pumps, and a six percent annual price decline rate to represent price learning for the controls portion of ECM motors in variable-speed pumps.

The "Low Benefits Result" consists of the low economic growth shipments scenario, the low growth energy prices scenario, and the high price index scenario. The high price index scenario, like the reference price index scenario, is composed of a constant price assumption for single-speed and two-speed pumps. However, the price learning applied to variable-speed pumps is based on an exponential fit to the integral horsepower motors and generators PPI from 1969 to 2015 for the equipment classes with integral sized motors, and an exponential fit to the fractional horsepower motors PPI from 2001 to 2015 for the equipment classes with fractional sized motors.

The "High Benefits Result" consists of the high economic growth shipments scenario, the high growth energy prices scenario, and the low price index scenario. The low price index scenario is also composed of a constant price assumption for single-speed and two-speed pumps. However, the price learning applied to variable-speed pumps is based on an exponential fit to the integral horsepower motors and generators PPI from 1991 to 2000 for equipment classes with integral sized motors (self-priming 1 hp and self-priming 3 hp), and an exponential fit to fractional horsepower motors PPI from 1967 to 2015 for equipment classes with fractional sized motors (small-size self-priming pool filter pumps, standard-size non-self-priming pool filter pumps, extra-small non-self-priming pool filter pumps, waterfall pumps, pressure cleaner booster pumps, integral sand filter pool pumps, and integral cartridge filter pool pumps)

Table 10C.2.1 NPV Results by Economic Growth Scenario, 3 Percent Discount Rate (2015$ billions)

Product Class	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
Standard-Size Self-Priming Pool Filter Pump (1 hp rep size)	2.6 [2.3 to 2.8]	6.0 [5.4 to 6.6]	7.9 [7.1 to 8.7]	7.9 [7.1 to 8.7]	8.8 [8.0 to 9.7]
Standard-Size Self-Priming Pool Filter Pump (3 hp rep size)	1.8 [1.7 to 2.0]	10 [9.4 to 12]	13 [12 to 15]	13 [12 to 15]	15 [14 to 17]
Small-Size Self-Priming Pool Filter Pump	0.24 [0.22 to 0.26]	0.33 [0.31 to 0.36]	0.24 [0.22 to 0.26]	0.49 [0.45 to 0.54]	0.66 [0.60 to 0.73]
Standard-Size Non-Self-Priming Pool Filter Pump	0.39 [0.35 to 0.43]	0.06 [0.09 to 0.05]	0.39 [0.35 to 0.43]	0.54 [0.52 to 0.59]	1.2 [1.1 to 1.3]
Extra-Small Non-Self-Priming Pool filter Pump	0.01 [0.01 to 0.01]	0.01 [0.01 to 0.01]	0.01 [0.01 to 0.01]	0.01 [0.01 to 0.01]	0.01 [0.01 to 0.01]
Waterfall Pump	0 [0 to 0]	0 [0 to 0]	0 [0 to 0]	0 [0 to 0]	0.01 [0.01 to 0.01]
Pressure Cleaner Booster Pump	0.02 [0.02 to 0.02]	0.02 [0.02 to 0.02]	0.02 [0.02 to 0.02]	-0.65 [-0.57 to -0.72]	-0.54 [-0.48 to -0.60]
Integral Cartridge Filter Pool Pump (1/15 hp rep size)	0 [0 to 0]	0 [0 to 0]	0.99 [0.89 to 1.1]	0 [0 to 0]	0 [0 to 0]
Integral Cartridge Filter Pool Pump (1/2 hp rep size)	0 [0 to 0]	0 [0 to 0]	0.90 [0.81 to 1.0]	0 [0 to 0]	0 [0 to 0]
Integral Sand Filter Pool Pump	0 [0 to 0]	0 [0 to 0]	0.18 [0.16 to 0.20]	0 [0 to 0]	0 [0 to 0]
Total	5.1 [4.6 to 5.6]	17 [15 to 19]	24 [21 to 26]	21 [19 to 24]	25 [23 to 28]

Table 10C.2.2 NPV Results by Economic Growth Scenario, 7 Percent Discount Rate (2015$ billions)

Product Class	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
Standard-Size Self-Priming Pool Filter Pump (1 hp rep size)	1.3 [1.2 to 1.4]	2.9 [2.7 to 3.2]	3.8 [3.4 to 4.1]	3.8 [3.4 to 4.1]	4.2 [3.8 to 4.6]
Standard-Size Self-Priming Pool Filter Pump (3 hp rep size)	0.90 [0.83 to 0.98]	5.0 [4.6 to 5.4]	6.3 [5.7 to 6.9]	6.3 [5.7 to 6.9]	7.2 [6.6 to 7.9]
Small-Size Self-Priming Pool Filter Pump	0.12 [0.11 to 0.13]	0.16 [0.15 to 0.18]	0.12 [0.11 to 0.13]	0.23 [0.21 to 0.25]	0.31 [0.28 to 0.33]
Standard-Size Non-Self-Priming Pool Filter Pump	0.19 [0.18 to 0.21]	0.01 [0.03 to 0.00]	0.19 [0.18 to 0.21]	0.20 [0.2 to 0.21]	0.50 [0.47 to 0.54]
Extra-Small Non-Self-Priming Pool filter Pump	0.01 [0.01 to 0.01]	0.01 [0.01 to 0.01]	0.01 [0.01 to 0.01]	0 [0 to 0]	0 [0 to 0]
Waterfall Pump	0 [0 to 0]	0 [0 to 0]	0 [0 to 0]	0 [0 to 0]	0 [0 to 0]
Pressure Cleaner Booster Pump	0.01 [0.01 to 0.01]	0.01 [0.01 to 0.01]	0.01 [0.01 to 0.01]	-0.34 [-0.30 to -0.37]	-0.29 [-0.26 to -0.32]
Integral Cartridge Filter Pool Pump (1/15 hp rep size)	0 [0 to 0]	0 [0 to 0]	0.49 [0.44 to 0.53]	0 [0 to 0]	0 [0 to 0]
Integral Cartridge Filter Pool Pump (1/2 hp rep size)	0 [0 to 0]	0 [0 to 0]	0.45 [0.41 to 0.49]	0 [0 to 0]	0 [0 to 0]
Integral Sand Filter Pool Pump	0 [0 to 0]	0 [0 to 0]	0.09 [0.08 to 0.10]	0 [0 to 0]	0 [0 to 0]
Total	2.5 [2.3 to 2.7]	8.1 [7.4 to 8.8]	11 [10 to 12]	10 [9.3 to 11]	12 [11 to 13]

CHAPTER 11. CONSUMER SUBGROUP ANALYSIS

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CHAPTER 11. CONSUMER SUBGROUP ANALYSIS

11.1 INTRODUCTION

The consumer subgroup analysis evaluates impacts on groups or customers who may be disproportionately affected by any national energy conservation standard. The U.S. Department of Energy (DOE) evaluates impacts on particular subgroups of consumers by analyzing the life-cycle cost (LCC) impacts and payback period (PBP) for those consumers from the considered energy efficiency levels. DOE determined the impact on consumer subgroups using the LCC spreadsheet models for dedicated-purpose pool pumps. Chapter 8 explains in detail the inputs to the models used in determining LCC impacts and PBPs.

DOE evaluated the impacts of the considered energy efficiency levels for pool pumps on households occupied solely by senior citizens (*i.e.*, senior-only households).

This chapter describes the subgroup identification in further detail and gives the results of the LCC and PBP analyses for the considered subgroup.

11.2 SUBGROUPS DEFINITION

11.2.1 Senior-Only Households

Senior-only households have occupants who are all at least 65 years of age. Based on the Energy Information Administration's 2009 Residential Energy Consumption Survey (RECS 2009),[1] senior-only households comprise 17 percent of the country's households.

11.2.2 Distribution of Subgroup Households with Pool Pumps

Of the 12,083 households (representing 113.6 million households nationwide) in the 2009 RECS database, 897 (representing 7.9 million households nationwide) have a swimming pool. With the weight adjustment factor developed based on the 2014 number of in-ground and above-ground pool bases (See Chapter 7 for details), Table 11.2.1 shows the household sample sizes for in-ground and above-ground pools.

Table 11.2.1 Household Population Data for Dedicated-Purpose Pool Pumps

Equipment Class	General Population		Senior-Only Households	
	No. of Records	Number of Houses (million)	No. of Records	Number of Houses (million)
Swimming Pool	897	7.94	82	0.74
In-ground Pool	897	7.93 (Adjusted)	82	0.87 (Adjusted)
Above-ground Pool	897	7.90 (Adjusted)	82	0.66 (Adjusted)

11.2.3 Estimation of Impacts

To calculate the subgroup results, DOE extracted the results of senior-only households from the national LCC results. Then DOE calculated the LCC and PBP statistics for the subgroup from the individual households.

11.3 RESULTS

Table 11.3.1 through Table 11.3.24 summarize the LCC and PBP results for all the equipment classes for senior-only households.

Table 11.3.1 Average LCC and PBP Results by Efficiency Level for Standard-Size Self-Priming Pool Filter Pumps (0.95 hhp) for Senior-Only Households

Efficiency Level	Average Costs *2015$*				Simple Payback *years*	Average Lifetime *years*
	Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	356	724	4,322	4,678		6.7
1	395	567	3,435	3,830	0.3	6.7
2	428	504	3,082	3,511	0.3	6.7
3	584	372	2,321	2,905	0.6	6.7
4	619	316	2,007	2,625	0.6	6.7
5	656	293	1,893	2,550	0.7	6.7
6	735	195	1,431	2,166	0.7	6.8
7	735	166	1,260	1,995	0.7	6.8

Note: The results for each EL are calculated assuming that all consumers use equipment with that efficiency level. The PBP is measured relative to the baseline equipment.

Table 11.3.2 Average LCC Savings Relative to the No-Standards Case Efficiency Distribution for Standard-Size Self-Priming Pool Filter Pumps (0.95 hhp) for Senior-Only Households

Efficiency Level	Life-Cycle Cost Savings	
	% of Consumers that Experience Net Cost	Average Savings* *2015$*
1	0%	850
2	0%	932
3	9%	1,400
4	6%	1,638
5	6%	1,663
6	10%	2,009
7	8%	1,910

* The calculation does not include consumer with zero LCC savings (no impact).

Table 11.3.3 Average LCC and PBP Results by Efficiency Level for Standard-Size Self-Priming Pool Filter Pumps (1.88 hhp) for Senior-Only Households

Efficiency Level	Average Costs *2015$*				Simple Payback *years*	Average Lifetime *years*
	Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	604	904	5,445	6,048		6.7
1	677	811	4,942	5,619	0.8	6.7
2	721	758	4,653	5,373	0.8	6.7
3	932	527	3,341	4,273	0.9	6.7
4	960	472	3,032	3,992	0.8	6.7
5	987	400	2,630	3,617	0.8	6.7
6	972	285	2,047	3,019	0.6	6.8
7	972	224	1,695	2,668	0.5	6.8

Note: The results for each EL are calculated assuming that all consumers use equipment with that efficiency level. The PBP is measured relative to the baseline equipment.

Table 11.3.4 Average LCC Savings Relative to the No-Standards Case Efficiency Distribution for Standard-Size Self-Priming Pool Filter Pumps (1.88 hhp) for Senior-Only Households

Efficiency Level	Life-Cycle Cost Savings	
	% of Consumers that Experience Net Cost	Average Savings* *2015$*
1	2%	433
2	1%	559
3	11%	1,580
4	8%	1,813
5	3%	2,131

6	9%	2,664
7	6%	2,639

* The calculation does not include consumers with zero LCC savings (no impact).

Table 11.3.5 Average LCC and PBP Results by Efficiency Level for Standard-Size Self-Priming Pool Filter Pumps (Total) for Senior-Only Households

Efficiency Level	Average Costs *2015$*				Simple Payback *years*	Average Lifetime *years*
	Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	483	816	4,896	5,379		6.7
1	539	692	4,206	4,745	0.5	6.7
2	578	634	3,885	4,463	0.6	6.7
3	762	452	2,843	3,605	0.8	6.7
4	793	395	2,531	3,324	0.7	6.7
5	826	348	2,270	3,096	0.7	6.7
6	856	241	1,746	2,602	0.7	6.8
7	856	196	1,482	2,339	0.6	6.8

Note: The results for each EL are calculated assuming that all consumers use equipment with that efficiency level. The PBP is measured relative to the baseline equipment.

Table 11.3.6 Average LCC Savings Relative to the No-Standards Case Efficiency Distribution for Standard-Size Self-Priming Pool Filter Pumps (Total) for Senior-Only Households

Efficiency Level	Life-Cycle Cost Savings	
	% of Consumers that Experience Net Cost	Average Savings* *2015$*
1	1%	637
2	1%	741
3	10%	1,492
4	7%	1,727
5	4%	1,902
6	9%	2,344
7	7%	2,282

* The calculation does not include consumers with zero LCC savings (no impact).

Table 11.3.7 Average LCC and PBP Results by Efficiency Level for Small-Size Self-Priming Pool Filter Pumps for Senior-Only Households

Efficiency Level	Average Costs *2015$*				Simple Payback *years*	Average Lifetime *years*
	Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	321	312	1,908	2,229		6.8
1	348	245	1,531	1,879	0.4	6.8
2	387	220	1,404	1,791	0.7	6.8
3	546	204	1,311	1,857	2.1	6.8
4	568	175	1,153	1,721	1.8	6.8
5	590	162	1,086	1,676	1.8	6.8
6	723	103	876	1,599	1.9	6.8
7	723	84	761	1,483	1.8	6.8

Note: The results for each EL are calculated assuming that all consumers use equipment with that efficiency level. The PBP is measured relative to the baseline equipment.

Table 11.3.8 Average LCC Savings Relative to the No-Standards Case Efficiency Distribution for Small-Size Self-Priming Pool Filter Pumps for Senior-Only Households

Efficiency Level	Life-Cycle Cost Savings	
	% of Consumers that Experience Net Cost	Average Savings* *2015$*
1	0%	348
2	4%	336
3	33%	213
4	27%	342

5	25%	377
6	27%	446
7	24%	501

* The calculation does not include consumers with zero LCC savings (no impact).

Table 11.3.9 Average LCC and PBP Results by Efficiency Level for Standard-Size Non-Self-Priming Pool Filter Pumps for Senior-Only Households

Efficiency Level	Average Costs *2015$*				Simple Payback *years*	Average Lifetime *years*
	Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	200	260	1,189	1,389		4.7
1	209	204	960	1,168	0.2	4.7
2	234	195	932	1,166	0.5	4.7
3	385	181	879	1,264	2.4	4.7
4	411	151	763	1,174	1.9	4.7
5	438	142	734	1,172	2.0	4.7
6	577	72	570	1,147	2.0	4.8
7	577	49	472	1,048	1.8	4.8

Note: The results for each EL are calculated assuming that all consumers use equipment with that efficiency level. The PBP is measured relative to the baseline equipment.

Table 11.3.10 Average LCC Savings Relative to the No-Standards Case Efficiency Distribution for Standard-Size Non-Self-Priming Pool Filter Pumps for Senior-Only Households

Efficiency Level	Life-Cycle Cost Savings	
	% of Consumers that Experience Net Cost	Average Savings* *2015$*
1	0%	217
2	19%	109
3	66%	-28
4	56%	62
5	57%	64
6	49%	86
7	43%	182

* The calculation does not include consumers with zero LCC savings (no impact).

Table 11.3.11 Average LCC and PBP Results by Efficiency Level for Extra-Small Non-Self-Priming Pool Filter Pumps for Senior-Only Households

Efficiency Level	Average Costs *2015$*				Simple Payback *years*	Average Lifetime *years*
	Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	135	66	339	475		
1	147	52	284	431	0.8	4.7
2	158	50	279	437	1.4	4.7

Note: The results for each EL are calculated assuming that all consumers use equipment with that efficiency level. The PBP is measured relative to the baseline equipment.

Table 11.3.12 Average LCC Savings Relative to the No-Standards Case Efficiency Distribution for Extra-Small Non-Self-Priming Pool Filter Pumps for Senior-Only Households

Efficiency Level	Life-Cycle Cost Savings	
	% of Consumers that Experience Net Cost	Average Savings* *2015$*
1	4%	42
2	37%	15

* The calculation does not include consumers with zero LCC savings (no impact).

Table 11.3.13 Average LCC and PBP Results by Efficiency Level for Waterfall Pumps for Senior-Only Households

Efficiency Level	Average Costs *2015$*				Simple Payback *years*	Average Lifetime *years*
	Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	314	70	533	847		6.6
1	336	65	511	847	4.1	6.6
2	376	57	485	861	4.9	6.6
3	376	52	451	827	3.4	6.6

Note: The results for each EL are calculated assuming that all consumers use equipment with that efficiency level. The PBP is measured relative to the baseline equipment.

Table 11.3.14 Average LCC Savings Relative to the No-Standards Case Efficiency Distribution for Waterfall Pumps for Senior-Only Households

Efficiency Level	Life-Cycle Cost Savings	
	% of Consumers that Experience Net Cost	Average Savings* *2015$*
1	47%	0
2	67%	-14
3	52%	21

* The calculation does not include consumers with zero LCC savings (no impact).

Table 11.3.15 Average LCC and PBP Results by Efficiency Level for Pressure Cleaner Booster Pumps for Senior-Only Households

Efficiency Level	Average Costs *2015$*				Simple Payback *years*	Average Lifetime *years*
	Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	256	197	954	1,211		4.8
1	277	159	802	1,079	0.5	4.8
2	314	147	767	1,080	1.1	4.8
3	634	124	818	1,451	5.2	4.8
4	634	112	764	1,397	4.4	4.8

Note: The results for each EL are calculated assuming that all consumers use equipment with that efficiency level. The PBP is measured relative to the baseline equipment.

Table 11.3.16 Average LCC Savings Relative to the No-Standards Case Efficiency Distribution for Pressure Cleaner Booster Pumps for Senior-Only Households

Efficiency Level	Life-Cycle Cost Savings	
	% of Consumers that Experience Net Cost	Average Savings* *2015$*
1	0%	134
2	38%	20
3	69%	-353
4	68%	-287

* The calculation does not include consumers with zero LCC savings (no impact).

Table 11.3.17 Average LCC and PBP Results by Efficiency Level for Integral Cartridge Filter Pump (0.02 hhp) for Senior-Only Households

Efficiency Level	Average Costs *2015$*				Simple Payback *years*	Average Lifetime *years*
	Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	45	51	189	235		3.8
1	57	17	66	123	0.4	3.8

Note: The results for each EL are calculated assuming that all consumers use equipment with that efficiency level. The PBP is measured relative to the baseline equipment.

Table 11.3.18 Average LCC Savings Relative to the No-Standards Case Efficiency Distribution for Integral Cartridge Filter Pump (0.02 hhp), for Senior-Only Households

Efficiency Level	Life-Cycle Cost Savings	
	% of Consumers that Experience Net Cost	Average Savings* *2015$*
1	3%	111

* The calculation does not include consumers with zero LCC savings (no impact).

Table 11.3.19 Average LCC and PBP Results by Efficiency Level for Integral Cartridge Filter Pump (0.18 hhp)

Efficiency Level	Average Costs *2015$*				Simple Payback *years*	Average Lifetime *years*
	Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	250	154	519	769		3.8
1	262	61	206	468	0.1	3.8

Note: The results for each EL are calculated assuming that all consumers use equipment with that efficiency level. The PBP is measured relative to the baseline equipment.

Table 11.3.20 Average LCC Savings Relative to the No-Standards Case Efficiency Distribution for Integral Cartridge Filter Pump (0.18 hhp), for Senior-Only Households

Efficiency Level	Life-Cycle Cost Savings	
	% of Consumers that Experience Net Cost	Average Savings* *2015$*
1	4%	302

* The calculation does not include consumers with zero LCC savings (no impact).

Table 11.3.21 Average LCC and PBP Results by Efficiency Level for Integral Cartridge Filter Pump (Total), for Senior-Only Households

Efficiency Level	Average Costs *2015$*				Simple Payback *years*	Average Lifetime *years*
	Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	99	78	275	374		3.8
1	111	29	102	213	0.3	3.8

Note: The results for each EL are calculated assuming that all consumers use equipment with that efficiency level. The PBP is measured relative to the baseline equipment.

Table 11.3.22 Average LCC Savings Relative to the No-Standards Case Efficiency Distribution for Integral Cartridge Filter Pump (Total), for Senior-Only Households

Efficiency Level	Life-Cycle Cost Savings	
	% of Consumers that Experience Net Cost	Average Savings* *2015$*
1	3%	161

* The calculation does not include consumers with zero LCC savings (no impact).

Table 11.3.23 Average LCC and PBP Results by Efficiency Level for Integral Sand Filter Pumps, for Senior-Only Households

Efficiency Level	Average Costs *2015$*				Simple Payback *years*	Average Lifetime *years*
	Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	155	46	157	311		3.8
1	166	16	52	219	0.4	3.8

Note: The results for each EL are calculated assuming that all consumers use equipment with that efficiency level. The PBP is measured relative to the baseline equipment.

Table 11.3.24 Average LCC Savings Relative to the No-Standards Case Efficiency Distribution for Integral Sand Filter Pumps for Senior-Only Households

Efficiency Level	Life-Cycle Cost Savings	
	% of Consumers that Experience Net Cost	Average Savings* *2015$*
1	3%	92

* The calculation does not include consumers with zero LCC savings (no impact).

11.3.1 Comparison of Senior-Only to the General Population

Table 11.3.25 through Table 11.3.32 compare the LCC savings and simple payback period for the senior only subgroup with those for all households with each equipment class of pool pumps. Overall, the senior-only households show slightly higher LCC savings and shorter PBPs from purchasing more-efficient pool pumps.

Table 11.3.25 Comparison of LCC Savings and PBP for Consumer Subgroup and All Households for Standard-Size Self-Priming Pool Filter Pump

EL	Average Life-Cycle Cost Savings 2015$		Simple Payback Period years	
	Senior-Only Households	All Households	Senior-Only Households	All Households
1	637	561	0.5	0.6
2	741	651	0.6	0.6
3	1,492	1,308	0.8	0.8
4	1,727	1,514	0.7	0.8
5	1,902	1,664	0.7	0.8
6	2,344	2,054	0.7	0.7
7	2,282	2,004	0.6	0.7

Table 11.3.26 Comparison of LCC Savings and PBP for Consumer Subgroup and All Households for Small-Size Self-Priming Pool Filter Pump

EL	Average Life-Cycle Cost Savings 2015$		Simple Payback Period years	
	Senior-Only Households	All Households	Senior-Only Households	All Households
1	348	309	0.4	0.4
2	336	295	0.7	0.8
3	213	181	2.1	2.3
4	342	293	1.8	2.0
5	377	322	1.8	2.0
6	446	360	1.9	2.1
7	501	414	1.8	1.9

Table 11.3.27 Comparison of LCC Savings and PBP for Consumer Subgroup and All Households for Standard-Size Non-Self-Priming Pool Filter Pump

EL	Average Life-Cycle Cost Savings 2015$		Simple Payback Period years	
	Senior-Only Households	All Households	Senior-Only Households	All Households
1	217	191	0.2	0.2
2	109	92	0.5	0.6
3	-28	-37	2.4	2.7
4	62	35	1.9	2.3
5	64	31	2.0	2.3
6	86	10	2.0	2.3
7	182	93	1.8	2.1

Table 11.3.28 Comparison of LCC Savings and PBP for Consumer Subgroup and All Households for Extra-Small Non-Self-Priming Pool Filter Pump

EL	Average Life-Cycle Cost Savings 2015$		Simple Payback Period Years	
	Senior-Only Households	All Households	Senior-Only Households	All Households
1	42	36	0.8	0.9
2	15	10	1.4	1.6

Table 11.3.29 Comparison of LCC Savings and PBP for Consumer Subgroup and All Households for Waterfall Pump

EL	Average Life-Cycle Cost Savings 2015$		Simple Payback Period Years	
	Senior-Only Households	All Households	Senior-Only Households	All Households
1	0	-4	4.1	4.7
2	-14	-22	4.9	5.6
3	21	9	3.4	3.8

Table 11.3.30 Comparison of LCC Savings and PBP for Consumer Subgroup and All Households for Pressure Cleaner Booster Pump

EL	Average Life-Cycle Cost Savings 2015$		Simple Payback Period Years	
	Senior-Only Households	All Households	Senior-Only Households	All Households
1	134	112	0.5	0.6
2	20	10	1.1	1.3
3	-353	-372	5.2	6.0
4	-287	-312	4.4	5.1

Table 11.3.31 Comparison of LCC Savings and PBP for Consumer Subgroup and All Households for Integral Cartridge Filter Pool Pump

EL	Average Life-Cycle Cost Savings 2015$		Simple Payback Period years	
	Senior-Only Households	All Households	Senior-Only Households	All Households
1	161	128	0.3	0.4

Table 11.3.32 Comparison of LCC Savings and PBP for Consumer Subgroup and All Households for Integral Sand Filter Pool Pump

EL	Average Life-Cycle Cost Savings 2015$		Simple Payback Period Years	
	Senior-Only Households	All Households	Senior-Only Households	All Households
1	92	73	0.4	0.5

REFERENCES

1. U.S. Department of Energy–Energy Information Administration. *2009 RECS Survey Data*. (Last accessed December 15, 2015.) http://www.eia.gov/consumption/residential/data/2009/.

CHAPTER 12. MANUFACTURER IMPACT ANALYSIS

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CHAPTER 12. MANUFACTURER IMPACT ANALYSIS

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 consumers of the products subject to such a standard." (42 U.S.C. 6312(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 new energy conservation standards on manufacturers of dedicated-purpose pool pumps 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 the products 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 new energy conservation standards by comparing changes in INPV between the no-standards case and the various trial standard levels (TSLs) in the standards cases. The qualitative part of the MIA addresses product characteristics, manufacturer characteristics, market and product trends, as well as the impact of standards on subgroups of manufacturers, including small manufacturers.

12.2 METHODOLOGY

DOE conducted the MIA in three phases. Phase I, "Industry Profile," consisted of preparing an industry characterization for the dedicated-purpose pool pump (DPPP) industry, including data on market share, sales volumes and trends, pricing, employment, and financial structure. In Phase II, "Industry Cash Flow," DOE used a GRIM to assess the impacts of new energy conservation standards on dedicated-purpose pool pumps.

In Phase II, DOE created a GRIM for dedicated-purpose pool pumps, as well as an interview guide for dedicated-purpose pool pumps to gather information on the potential impacts of new energy conservation standards could have on DPPP manufacturers. DOE presented the MIA results for dedicated-purpose pool pumps based on a set of considered TSLs. These TSLs are described in section 12.3.4.

In Phase III, "Subgroup Impact Analysis," DOE interviewed manufacturers that account for the large majority of pool pump sales. Interviewees included large and small manufacturers with various market shares and market focuses, providing a representative cross-section of the industry. During interviews, DOE discussed financial topics specific to each manufacturer and obtained each manufacturer's view of the DPPP industry. The interviews provided DOE with valuable information for evaluating the impacts of new energy conservation standards on manufacturer cash flows, investment requirements, and employment.

12.2.1 Phase I: Industry Profile

In Phase I of the MIA, DOE prepared a profile of the DPPP industry that built upon the market and technology assessment prepared for this rulemaking (see chapter 3 of this direct final rule technical support document (TSD)). Before initiating the detailed impact study, DOE collected information on the past and present structure and market characteristics of the industry. This information included market share data, unit shipments, manufacturer markups, and cost structures for various manufacturers. The industry profile includes: (1) detail on the overall market and product characteristics; (2) estimated manufacturer market shares; (3) financial parameters such as net property, plant, and equipment (PPE); selling, general and administrative (SG&A) expenses; cost of goods sold.; and (4) trends in the number of firms, specific DPPP markets, and general product characteristics. The industry profile included a cost analysis of DPPP manufacturers that DOE used to derive preliminary financial inputs for the GRIM (*e.g.*, revenues, depreciation, SG&A, and research and development (R&D) expenses).

DOE also used public information to further calibrate its initial characterization of the DPPP industry, including Securities and Exchange Commission (SEC) 10–K reports,[1] and corporate annual reports. DOE supplemented this public information with data released by privately held companies.

12.2.2 Phase II: Industry Cash-Flow Analysis

Phase II focused on the potential financial impacts of new energy conservation standards on manufacturers of dedicated-purpose pool pumps. New energy conservation standards can affect manufacturer cash flows 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 dedicated-purpose pool pumps.

The GRIM uses several factors to determine a series of annual cash flows from the announcement year of new energy conservation standards until several years after the standards' compliance date. These factors include annual expected revenues, costs of sales, SG&A, R&D, taxes, and capital expenditures related to the new standards. Inputs for the GRIM include manufacturer production costs (MPCs), developed in the engineering analysis, and shipments forecasts, developed in the shipments analysis. DOE developed three markup scenarios for the GRIM based on discussions with manufacturers. The financial parameters were developed using publicly available manufacturer data and were revised with information submitted confidentially during manufacturer interviews.

The GRIM results compare the no-standards case to the standard case projections for the industry. The financial impact of new energy conservation standards is the difference between the discounted annual cash flows in the no-standards case and the standards case at each TSL.

12.2.3 Phase III: Subgroup Analysis

In Phase III DOE assesses potential differential impacts on a subgroup of manufacturers, where average cost and financial assumptions to develop an industry cash-flow model are not adequate. During interviews, DOE identified one manufacturer subgroup, small manufacturers, that could be disproportionately impacted by new energy conservation standards. Additionally, DOE analyzes impacts on manufacturing capacity, direct employment, and cumulative regulatory burden in Phase III.

12.2.3.1 Small Manufacturer Subgroup

As part of Phase III, DOE investigated the small manufacturer subgroup. DOE used the Small Business Administration (SBA) size standards 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 this rulemaking.[1] For the dedicated-purpose pool pumps under review, the SBA bases its small manufacturer 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 manufacturer.

Table 12.2.1 SBA and NAICS Classifications of Small Manufacturers Potentially Affected by This Rulemaking

Industry Description	Revenue Limit	Employee Limit	NAICS
Pump and pumping equipment manufacturing	N/A	750	333911

DOE used publicly available information, such as databases from the California Energy Commission (CEC), The Association of Pool & Spa Professionals (APSP), and ENERY STAR; individual company websites; and market research tools (*e.g.*, Hoover's reports) to create a list of companies that manufacture dedicated-purpose pool pumps covered by this direct final rule. Additionally, DOE asked interested parties and industry representatives if they were aware of other small manufacturers in the industry. DOE screened out companies that do not produce the covered equipment, do not meet the SBA's definition of a "small business", are foreign owned and operated, or do not manufacture dedicated-purpose pool pumps in the United States.

During its research, DOE identified five companies that manufacture dedicated-purpose pool pumps covered by this rulemaking in the United States and qualify as small manufacturers. During interviews, DOE solicited data from manufacturers on differential impacts that these small manufacturers might experience from new energy conservation standards. DOE was not able to certify that this rulemaking for dedicated-purpose pool pumps would not have a significant economic impact on a substantial number of small entities. The results of this subgroup analysis on small manufacturers are presented in section 12.5.

12.2.3.2 Manufacturer Interviews

The interview process provides an opportunity for interested parties to express their views on important issues privately, allowing confidential or sensitive information to be considered in the rulemaking process. Before the interviews, DOE distributed an interview guide

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[1] The size standards are available on the SBA's website at www.sba.gov/sites/default/files/files/Size_Standards_Table.pdf

that provided a starting point to identify relevant issues and help identify the impacts of new energy conservation standards on individual manufacturers or subgroups of manufacturers in the DPPP industry. The MIA interview topics included (1) key issues, (2) company overview, organizational characteristics, and revenues, (3) markups and profitability, (4) financial parameters, (5) conversion costs, (6) industry structure and competition, (7) direct employment impact assessment, (8) cumulative regulatory burden, and (9) impacts on small businesses. The interview guides are presented in appendix 12A.

DOE used these interviews to tailor the GRIM to reflect unique financial characteristics of DPPP manufacturers. DOE contacted companies from its database of manufacturers and interviewed small and large companies to provide an accurate representation of the industry. Interviews were scheduled in advance to provide opportunity for key individuals to be available for comment. Although a written response to the questionnaire was acceptable, DOE sought interactive interviews, which helped clarify responses and helped identify additional issues. The resulting information provides valuable inputs to the GRIM developed for the DPPP industry and is protected by non-disclosure agreements and resides with DOE's contractors

12.2.3.3 Manufacturing Capacity Impact

One significant outcome of new energy conservation standards could be the obsolescence of existing manufacturing assets, including tooling and investment. The manufacturer interview guide has a series of questions to help identify impacts of new standards on manufacturing capacity. These include questions regarding capacity utilization and plant location decisions in the United States (with and without new standards); the ability of manufacturers to upgrade or remodel existing facilities to accommodate the new requirements; the nature and value of any potential stranded assets; and estimates for any one-time changes to existing PPE. DOE estimates how one-time capital investments affect the cash-flow estimates in the DPPP GRIM. These estimates can be found in section 12.3.7; DOE's discussion of the capacity impacts can be found in section 12.6.1.

12.2.3.4 Direct Employment Impact

The impact of new energy conservation standards on direct 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 DPPP industry. The interviews also solicited manufacturer views on changes in direct employment patterns that may result from new standards. The direct employment impacts section of the interview guide focused on current direct employment levels associated with manufacturers at each production facility, expected future employment levels with and without new energy conservation standards, and differences in workforce skills and issues related to retraining employees. The direct employment impacts are reported in section 12.6.2.

12.2.3.5 Cumulative Regulatory Burden

One aspect of assessing manufacturer burden involves considering the cumulative impact of multiple DOE standards and the product-specific regulatory actions of other Federal agencies that affect the manufacturers of a covered product or equipment. While any one regulation may not impose a significant burden on manufacturers, the combined effects of several existing or 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. In addition to energy conservation standards, other regulations can significantly affect manufacturers' financial operations. Multiple regulations affecting the same manufacturer can strain profits and lead companies to abandon product lines or markets with lower expected future returns than competing equipment. For these reasons, DOE conducts an analysis of cumulative regulatory burden as part of its rulemakings pertaining to appliance efficiency. Discussion of the cumulative regulatory burden can be found in section 12.6.3.

12.3 GRIM INPUTS AND ASSUMPTIONS

The GRIM serves as the main tool for assessing the impacts on industry due to new 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 new energy conservation standards.

12.3.1 Overview of the GRIM

The basic structure of the GRIM, illustrated in Figure 12.3.1, is an annual cash-flow analysis that uses MPCs, manufacturer selling prices (MSPs), shipments, and industry financial parameters as inputs, and accepts a set of regulatory conditions such as changes in costs, investments, and associated margins. The GRIM uses a number of inputs to arrive at a series of annual cash flows, beginning with the reference year of the analysis, 2016, and continuing to the terminal year of the analysis, 2050. The model calculates the INPV by summing the stream of annual discounted cash flows during this period and adding a discounted terminal value.[2]

The GRIM projects cash flows using standard accounting principles and compares changes in INPV between the no-standards case and the standards cases induced by new energy conservation standards. The difference in INPV between the no-standards case and the standards case at each TSL represents the estimated financial impact of the new energy conservation standards on manufacturers. Appendix 12B provides more technical details and user information for the GRIM.

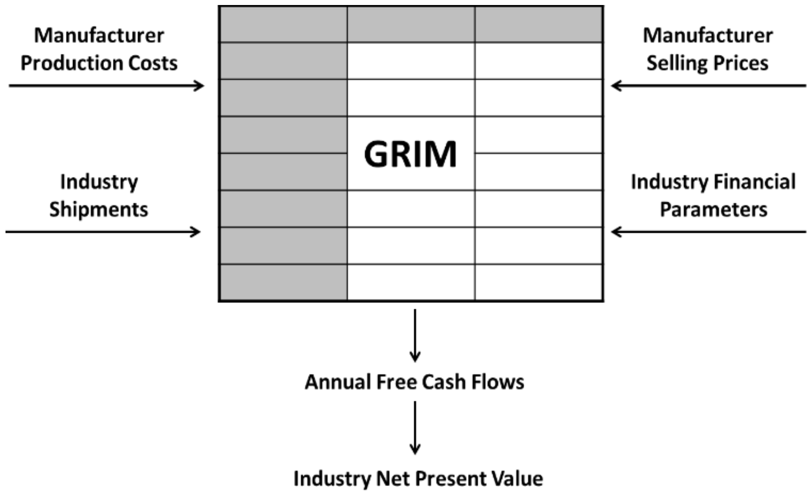

Figure 12.3.1 GRIM Inputs to Calculate Cash Flow

12.3.2 Financial Parameters

DOE used SEC-10K reports and the financial parameters used in the commercial and industrial pump rulemaking to estimate financial parameters for the DPPP industry. During interviews, DPPP manufacturers were asked to provide their own figures for the parameters. Where applicable, DOE adjusted the parameters in the GRIM using this manufacturer specific feedback.

Manufacturers of integral-cartridge filter pool pumps, integral-sand filter pool pumps and extra small non-self-priming pool filter pumps typically manufacture their dedicated purpose in China and they have a different financial structure than manufacturers of the other equipment classes. Therefore DOE used a different set of financial parameters for these equipment classes compared to all self-priming pool filter pumps, standard-size non-self-priming pool filter pumps, waterfall pumps, and pressure cleaner booster pumps. Table 12.3.1 presents the financial parameters for both groups of dedicated-purpose pool pumps used in the GRIM.

Table 12.3.1 GRIM Revised Dedicated-Purpose Pool Pump Industry Financial Parameters

Parameter	Self-Priming, Non-Self-Priming, Waterfall and Pressure Cleaner Booster Pumps	Integral-Cartridge, Integral-Sand and Extra-Small Non-Self-Priming Pool Pumps
Tax Rate ***% of taxable income***	32.0%	28.8%
Working Capital ***% of revenues***	18.6%	7.5%
SG&A ***% of revenues***	21.6%	4.4%
R&D ***% of revenues***	1.6%	1.5%
Depreciation ***% of revenues***	1.9%	1.0%
Capital Expenditures ***% of revenues***	2.5%	1.1%
Net PPE ***% of revenues***	15.0%	5.4%

12.3.3 Corporate Discount Rate

DOE used the weighted average cost of capital (WACC) as the discount rate to calculate the INPV. A company's assets are financed by a combination of debt and equity. The WACC is the total cost of debt and equity weighted by their respective proportions in the capital structure of the industry. The WACC can be calculated using the following formula:

$$WACC = After\ tax\ Cost\ of\ Debt\ x\ Debt\ Ratio + Cost\ of\ Equity\ x\ Equity\ Ratio$$

Eq. 12.1

The cost of equity is the rate of return that equity investors (including, potentially, the company) expect to earn on a company's stock. These expectations are reflected in the market price of the company's stock. Bond ratings are a tool to measure default risk and arrive at a cost of debt. Each bond rating is associated with a particular spread. One way of estimating a company's cost of debt is to treat it as a spread (usually expressed in basis points) over the risk-free rate.

DOE estimated the WACC at 11.8 percent based on value used in the commercial and industrial pumps rulemaking. DOE presented this number during confidential manufacturer interviews and during the working group meetings. In general manufacturers agreed to use a discount rate of 11.8 percent.

12.3.4 Trial Standard Levels

DOE developed TSLs for dedicated-purposed pool pumps consistent with the engineering analysis. Table 12.3.2 presents the efficiency levels at each TSL for the dedicated-purposed pool pumps analyzed by DOE. For more information regarding the development of TSLs for dedicated-purposed pool pumps see chapter 5 of this direct final rule TSD.

Table 12.3.2 Trial Standard Levels for Dedicated-Purposed Pool Pumps

Dedicated-Purposed Pool Pump Equipment Class Description	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
Self-priming (small-size) Pool Filter Pump	EL 2	EL 5	EL 2	EL 6	EL 7
Self-priming (standard-size) Pool Filter Pump	EL 2	EL 5	EL 6	EL 6	EL 7
Non-self-priming (extra-small-size) Pool Filter Pump	EL 1	EL 1	EL 1	EL 2	EL 2
Non-self-priming (standard-size) Pool Filter Pump	EL 2	EL 4	EL 1	EL 6	EL 7
Waterfall Pump	EL 1	EL 1	Baseline	EL 2	EL 3
Pressure cleaner booster Pump	EL 1	EL 1	EL 1	EL 3	EL 4
Integral cartridge-filter Pool Pump	Baseline	Baseline	EL 1	Baseline	Baseline
Integral sand-filter Pool Pump	Baseline	Baseline	EL 1	Baseline	Baseline

- TSL 1 represents the efficiency levels with the highest NPV based on single-speed technology and no hydraulic improvements.
- TSL 2 represents the efficiency levels with the highest NPV based on dual speed for relevant equipment classes, and in other classes the same efficiency level as in TSL 1.
- TSL 3 represents the standard levels recommended by the DPPP Working Group.
- TSL 4 represents the combination of highest efficiency levels without hydraulic improvements (variable speed for relevant equipment classes).
- TSL 5 represents the maximum technologically feasible energy efficiency for all equipment classes.

12.3.5 Shipment Analysis Forecast

INPV, which is the key GRIM output, depends on industry revenue, which depends on the quantity and prices of dedicated-purpose pool pumps shipped in each year of the analysis period. Industry revenue calculations require forecasts of: (1) total annual shipment volume of dedicated-purpose pool pumps; (2) the distribution of shipments across the equipment class (because prices vary by equipment class); and, (3) the distribution of shipments across ELs (because prices vary with efficiency).

DOE estimated shipments in 2015 using data collected from manufacturer interviews. Shipments were projected from 2015 throughout the end of the analysis period (2050) using growth rates obtained from manufacturer interviews, the Veris Consulting report, several macroeconomic indicators, and data and comments received during the DPPP working Group meetings. More information about the shipments analysis can be found in chapter 9.

12.3.6 Production Costs

Manufacturing a higher-efficiency product is typically more expensive than manufacturing a baseline product due to the use of more complex components, which are typically more costly than baseline components. The increases in the MPCs of the analyzed products can affect the revenues, gross margins, and cash flow of the industry, making these equipment costs key inputs for the GRIM and the MIA.

In the MIA, DOE used the MPCs calculated in the engineering analysis, as described in chapter 5. The engineering analysis also estimated the incremental material, labor, depreciation, and overhead costs for equipment at each efficiency level within an equipment class.

To calculate the MSP, DOE applied a manufacturer markup to the DPPP manufacturer production costs. In the standards cases, manufacturer markups vary depending on the markup scenario. DOE used manufacturer interviews, and publicly available financial information for manufacturers to estimate the preservation of gross margin markup for each equipment class. DOE estimated a manufacturer markup of 1.46 for all self-priming and waterfall pumps, 1.35 for all non-self-priming and pressure cleaner booster pumps, and 1.27 for integral cartridge-filter and integral sand-filter pool pumps. Table 12.3.3 through Table 12.3.12 show the MPCs, manufacturer markups and MSPs for each representative size.

Table 12.3.3 Manufacturer Production Cost Breakdown (2015$) for 0.44hhp Small-Size Self-Priming Dedicated-Purposed Pool Pumps

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	83.82	6.11	2.83	9.27	102.03	1.46	148.96
EL 1	96.29	6.11	3.19	9.39	114.98	1.46	167.87
EL 2	114.40	6.11	3.71	9.57	133.79	1.46	195.33
EL 3	117.05	6.11	3.79	9.59	136.54	1.46	199.35
EL 4	127.27	6.11	4.08	9.69	147.15	1.46	214.84
EL 5	137.48	6.11	4.38	9.79	157.75	1.46	230.32
EL 6	293.67	6.11	8.88	11.29	319.94	1.46	467.11
EL 7	293.67	6.11	8.88	11.29	319.94	1.46	467.11

Table 12.3.4 Manufacturer Production Cost Breakdown (2015$) for 0.95hhp Standard-Size Self-Priming Pool Filter Pumps

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	94.38	6.11	3.13	9.37	113.00	1.46	164.98
EL 1	112.68	6.11	3.66	9.55	132.00	1.46	192.72
EL 2	128.09	6.11	4.11	9.70	148.00	1.46	216.08
EL 3	129.05	6.11	4.13	9.71	149.00	1.46	217.54
EL 4	145.42	6.11	4.60	9.86	166.00	1.46	242.36
EL 5	162.76	6.11	5.10	10.03	184.00	1.46	268.64
EL 6	293.94	6.11	8.88	11.30	320.23	1.46	467.54
EL 7	293.94	6.11	8.88	11.30	320.23	1.46	467.54

Table 12.3.5 Manufacturer Production Cost Breakdown (2015$) for 1.88hhp Standard-Size Self-Priming Pool Filter Pumps

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	170.04	6.27	5.32	10.13	191.77	1.46	279.98
EL 1	204.04	6.27	6.30	10.46	227.06	1.46	331.51
EL 2	224.51	6.27	6.89	10.65	248.31	1.46	362.53
EL 3	251.39	6.26	7.66	10.91	276.22	1.46	403.28
EL 4	264.26	6.26	8.03	11.03	289.59	1.46	422.80
EL 5	277.14	6.26	8.40	11.15	302.96	1.46	442.32
EL 6	387.19	6.26	11.57	12.21	417.23	1.46	609.16
EL 7	387.19	6.26	11.57	12.21	417.23	1.46	609.16

Table 12.3.6 Manufacturer Production Cost Breakdown (2015$) for 0.09hhp Extra-Small-Size Non-Self-Priming Pool Filter Pumps

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	36.36	4.73	1.20	4.58	46.88	1.35	63.29
EL 1	42.16	4.73	1.36	4.64	52.88	1.35	71.39
EL 2	47.95	4.72	1.51	4.70	58.88	1.35	79.49

Table 12.3.7 Manufacturer Production Cost Breakdown (2015$) for 0.52hhp Standard-Size Non-Self-Priming Pool Filter Pumps

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	58.06	4.19	1.77	5.18	69.20	1.35	93.42
EL 1	62.61	4.19	1.90	5.23	73.93	1.35	99.81
EL 2	75.60	4.19	2.24	5.39	87.42	1.35	118.02
EL 3	79.47	4.19	2.35	5.43	91.44	1.35	123.44
EL 4	92.81	4.19	2.70	5.59	105.30	1.35	142.16
EL 5	106.16	4.19	3.06	5.75	119.16	1.35	160.87
EL 6	276.93	4.20	7.61	7.77	296.50	1.35	400.28
EL 7	276.93	4.20	7.61	7.77	296.50	1.35	400.28

Table 12.3.8 Manufacturer Production Cost Breakdown (2015$) for 0.40hhp at 17ft of Head Waterfall Pumps

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	84.43	5.91	2.77	6.70	99.81	1.46	145.72
EL 1	94.69	5.91	3.06	6.81	110.47	1.46	161.29
EL 2	113.12	5.92	3.60	6.99	129.62	1.46	189.25
EL 3	113.12	5.92	3.60	6.99	129.62	1.46	189.25

Table 12.3.9 Manufacturer Production Cost Breakdown (2015$) for 0.28hhp at 10gpm of Flow Pressure Cleaner Booster Pumps

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	75.75	5.52	2.26	4.56	88.09	1.35	118.92
EL 1	86.02	5.51	2.53	4.68	98.75	1.35	133.31
EL 2	104.47	5.51	3.02	4.90	117.90	1.35	159.17
EL 3	287.92	5.50	7.91	7.06	308.39	1.35	416.33
EL 4	287.92	5.50	7.91	7.06	308.39	1.35	416.33

Table 12.3.10 Manufacturer Production Cost Breakdown (2015$) for 0.02hhp Integral Cartridge-filter Pool Pumps

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	11.69	2.87	0.20	1.99	16.75	1.27	21.27
EL 1	16.34	4.01	0.28	2.78	23.42	1.27	29.74

Table 12.3.11 Manufacturer Production Cost Breakdown (2015$) for 0.18hhp Integral Cartridge-filter Pool Pumps

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	60.83	13.56	1.11	16.61	92.11	1.27	116.98
EL 1	65.24	14.54	1.19	17.81	98.78	1.27	125.45

Table 12.3.12 Manufacturer Production Cost Breakdown (2015$) for 0.03hhp Integral Sand-filter Pool Pumps

EL	Materials	Labor	Depreciation	Overhead	MPC	Markup	MSP
Baseline	44.39	5.84	0.69	6.04	56.95	1.27	72.33
EL 1	49.58	6.53	0.77	6.74	63.62	1.27	80.80

12.3.7 Capital and Product Conversion Costs

Energy conservation standards could cause manufacturers to incur conversion costs to bring their production facilities and equipment designs into compliance. DOE evaluated the level of conversion-related expenditures that would be needed to comply with each considered efficiency level in each equipment class. For the MIA, DOE classified these conversion costs into two major groups: (1) product conversion costs; and (2) capital conversion costs. Product conversion costs are investments in research and development, testing, marketing, and other non-capitalized costs necessary to make product designs to comply with new energy conservation standards. Capital conversion costs are investments in property, plant, and equipment necessary to adapt or change existing production facilities such that new compliant product designs can be fabricated and assembled.

In general, DOE assumes all conversion-related investments occur between the year of publication of the direct final rule and the year by which manufacturers must comply with the new standards. DOE used inputs from manufacturer interviews and feedback from the working group meetings to evaluate the level of conversion costs manufacturers would likely incur to comply with new energy conservation standards. The majority of design options analyzed represent the implementation of more efficient motors, either single-speed, two-speed, or variable-speed. For standard-size self-priming, small-size self-priming, standard-size non-self-priming, waterfall, and pressure cleaner booster pumps, the max-tech efficiency level represents a hydraulic wet-end redesign. For extra-small non-self-priming pool pumps max-tech represents the implementation of a more efficient single-speed motor, and for integral cartridge filter pool pumps and integral sand filter pool pumps DOE analyzed the incorporation of a timer as a design option.

DOE estimated that the implementation of a two-speed motor requires additional testing burden for the validation and qualification of the motor compared to a single-speed motor replacement. DOE estimated that the implementation of a variable-speed motor has additional controls on the interface that need to be tested and qualified, which requires the expertise of electrical engineers and additional safety testing and certifications.

In addition to motor redesign costs and testing and certification costs, DOE estimated the per-model cost for new tooling and machinery that would be needed as a result of new standards. DOE approximated capital conversion costs of $100,000 per wet-end when incorporating single-speed, two-speed, or variable-speed motors in dedicated-purpose pool pumps. These estimates are based on comments from manufacturers made during working group meetings that a motor change could alter the dimensions of a dedicated-purpose pool pump and require investments in packaging machines and other equipment.

Max-tech represents a hydraulic wet-end redesign for all equipment classes except for extra-small non-self-priming pool filter pumps, integral cartridge filter pumps, and integral sand filter pumps. DOE estimated product conversion costs for a hydraulic redesign at $500,000 per wet-end, in addition to the previously discussed $500,000 per model to incorporate a variable-speed motor. The hydraulic redesign costs represent research and development costs associated with optimizing the impeller and the volute for efficiency. For capital conversion costs, at max-tech, DOE estimated $1.5 million per wet-end for self-priming and waterfall pool pumps,

$750,000 per wet-end for non-self-priming pool pumps, and $375,000 per wet-end for pressure cleaner booster pumps. These estimates vary based on the type of tooling and machinery that is used to manufacture pumps in different equipment classes.

Max-tech for extra-small non-self-priming pool filter pumps represents the incorporation of a more efficient single-speed motor. DOE used the conversion cost estimates previously described to implement a single-speed motor.

After gathering per-model and per-wet-end conversion cost estimates, DOE analyzed self-priming pool pump equipment offerings to estimate the number of dedicated-purpose pool pumps that would be redesigned at each efficiency level. DOE used catalogs from the three largest dedicated-purpose pool pump manufacturers that have approximately 75 percent of all self-priming pool pump models in the market based on DOE's product database. DOE first listed all self-priming pool pumps of the three manufacturers and estimated their efficiency based on descriptions found in catalogs. All analyzed manufacturer catalogs list the number of speeds (*i.e.*, single-speed, two-speed, multi-speed, or variable-speed) and the catalogs provided an estimate of their efficiency (*i.e.*, single-speed standard efficiency compared to single-speed energy efficient). Table 12.3.13 summarizes how DOE mapped catalog data to self-priming pool filter pump efficiency levels. DOE conservatively assumed that no dedicated-purpose pool pumps are currently at EL 7 (*i.e.*, max-tech).

Table 12.3.13 Catalog Efficiency Descriptors Mapped against Analyzed Self-Priming Pool Filter Pump Efficiency Levels

Motor Type	Catalog Description	Assumed Efficiency Level
Single-Speed	Standard Efficiency	Baseline
Single-Speed	Energy Efficient	EL 2
Two-Speed	Standard Efficiency	EL 3
Two-Speed	Energy Efficient	EL 5
Variable-Speed / Multi-Speed	Not Listed	EL 6

After DOE estimated the efficiency of each dedicated-purpose pool pump, DOE grouped dedicated-purpose pool pumps together for each manufacturer based on their performance characteristics, including: the pump wet-ends, port size, voltage, total horsepower, and pump performance curve (*i.e.*, head vs. flow curve). This allowed DOE to make a mapping with DPPP characteristics on one axis and pump efficiency level on the other axis. DOE used this mapping to estimate the number of dedicated-purpose pool pumps that would be redesigned if a standard were set at each efficiency level. DOE assumed that:

- Pumps with the same performance characteristics, but a different efficiency can replace each other.
- There can be no gaps in equipment offerings. At least one pump has to meet the efficiency at each performance characteristic.
- A redesigned single or two-speed pump can only replace one other pump. A variable speed pump can replace multiple single and two-speed pumps with the same wet-end, port size, voltage, and similar total horsepower.

These assumptions allowed DOE to estimate the number of self-priming pool filter pumps needed to be redesigned at each efficiency level for each manufacturer. To estimate the total number of industry redesigns DOE divided the number of redesigns per efficiency level by the percent of models that belongs to the three largest manufacturers.

DOE did not have reliable performance data for non-self-priming, waterfall, and pressure cleaner booster pool pumps. Therefore, DOE used the shipments distribution to estimate the number of dedicated-purpose pool pumps that do not meet each efficiency level. In the absence of data, DOE assumed manufacturers would redesign 25 percent of non-compliant non-self-priming pool filter pump models. Further, DOE assumed that all non-compliant pressure cleaner booster and waterfall models would be redesigned due to the limited number of models in the market.

The design option analyzed for integral-cartridge filter and integral sand-filter pool pumps represents the incorporation of a timer. Based on confidential interviews with manufacturers that represent the majority of the market, DOE estimates that the R&D required to design a dedicated-purpose pool pump with a timer requires a full month of work for three engineers, and involves testing and certification costs. DOE estimated that the per model product conversion costs associated with adding a timer are $50,000 for integral-cartridge filter pool pumps and $60,000 for integral-sand filter pumps. DOE used specification sheets to determine the number of integral-cartridge filter pumps and integral-sand filter pumps that do not have a timer and multiplied this by the per model product conversion cost to calculate industry product conversion costs.

In addition, manufacturers that own tooling and machinery may incur capital conversion costs to replace molding machines and tooling. DOE estimated that the capital conversion costs associated with these activities would be $220,000 per manufacturer. DOE multiplied this by the number of manufacturers that own tooling and machinery, to calculate industry capital conversion costs.

12.3.7.1 Testing and Certification Costs

DOE also estimated the magnitude of the aggregate industry compliance testing costs needed to conform to new energy conservation standards. Although compliance testing costs are a subset of product conversion costs, DOE estimated these costs separately. DOE pursued this approach because no energy conservation standards currently exist for dedicated-purpose pool pumps; as such, all basic models will be required to be tested and certified to comply with new energy conservation standards regardless of the level of such a standard. As a result, the industry-wide magnitude of these compliance testing costs will be constant, regardless of the selected standard level.

DOE notes that new energy conservation standards will require every model offered for sale to be tested according to the sampling plan proposed in the test procedure final rule. This sampling plan specifies that a minimum of two units must be tested to certify a basic model as compliant. DOE estimated the industry-wide magnitude of compliance testing by multiplying the estimated number of models currently in each equipment class by the cost to test each model. DOE used product specification sheets and information from manufacturer interviews to estimate the total number of pool pump models in each equipment class. DOE estimated testing and certification costs based on input from third-party test labs and manufacturers to be $11,000 per model, which applies to all self-priming, all non-self-priming, pressure cleaner booster and waterfall pumps.

12.3.8 Manufacturer Markup Scenarios

DOE modeled three standards case markup scenarios for dedicated-purpose pool pumps to represent the uncertainty regarding the potential impacts on prices and profitability for DPPP manufacturers following the implementation of new energy conservation standards. The three markup scenarios are: (1) a preservation of gross margin markup scenario; (2) a preservation of operating profit markup scenario; and (3) a two-tiered markup scenario. Each scenario leads to different manufacturer markup values, which, result in varying revenue and cash-flow impacts on DPPP manufacturers when applied to the inputted MPCs.

12.3.8.1 Preservation of Gross Margin Markup Scenario

Under the preservation of gross margin markup scenario DOE applied a single uniform markup across all efficiency levels for all dedicated-purpose pool pumps. As production costs increase with efficiency, this scenario implies that the absolute dollar markup will increase as well. DOE used manufacturer interviews, and publicly available financial information for manufacturers to estimate the preservation of gross margin markup for each equipment class. DOE estimated a manufacturer markup of 1.46 for all self-priming and waterfall pumps, 1.35 for all non-self-priming and pressure cleaner booster pumps, and 1.27 for integral cartridge-filter and integral sand-filter pool pumps. These manufacturer markups cover SG&A expenses, R&D expenses, interest, and profit. Because this markup scenario assumes that manufacturers would be able to maintain their gross margin percentage as production costs increase in response to new standards, it represents the upper bound to industry profitability under new standards.

12.3.8.2 Preservation of Operating Profit Markup Scenario

The preservation of operating profit markup scenario assumes that manufacturers are able to maintain only the no-standards case total operating profit in absolute dollars in the standards cases, despite higher equipment costs and investment. The no-standards case total operating profit is derived from marking up the cost of goods sold for each equipment by the preservation of gross margin markup. In the standards cases for the preservation of operating profit markup scenario, DOE adjusted the DPPP manufacturer markups in the GRIM at each TSL to yield approximately the same earnings before interest and taxes in the standards cases in the year after the compliance date of the new DPPP standards as in the no-standards case. Under this scenario manufacturers are able to maintain the same operating profit in absolute dollars in the standards cases that was earned in the no-new standards case, meaning that manufacturers are not able to yield additional operating profit from higher production costs and the investments that are required to comply with new DPPP energy conservation standards.

Table 12.3.14 through Table 12.3.23 present the preservation of operating profit markups for dedicated-purpose pool pumps.

Table 12.3.14 Preservation of Operating Profit Markups for 0.44hhp Small-Size Self-Priming Pool Filter Pumps

EL	Baseline	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6	EL 7
Baseline	1.460							
EL 1	1.460	1.460						
EL 2	1.460	1.460	1.432					
EL 3	1.460	1.460	1.460	1.460				
EL 4	1.460	1.460	1.460	1.460	1.460			
EL 5	1.460	1.460	1.460	1.460	1.460	1.415		
EL 6	1.460	1.460	1.460	1.460	1.460	1.460	1.372	
EL 7	1.460	1.460	1.460	1.460	1.460	1.460	1.460	1.389

Table 12.3.15 Preservation of Operating Profit Markups for 0.95hhp Standard-Size Self-Priming Pool Filter Pumps

EL	Baseline	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6	EL 7
Baseline	1.460							
EL 1	1.460	1.460						
EL 2	1.460	1.460	1.433					
EL 3	1.460	1.460	1.460	1.460				
EL 4	1.460	1.460	1.460	1.460	1.460			
EL 5	1.460	1.460	1.460	1.460	1.460	1.410		
EL 6	1.460	1.460	1.460	1.460	1.460	1.460	1.377	
EL 7	1.460	1.460	1.460	1.460	1.460	1.460	1.460	1.393

Table 12.3.16 Preservation of Operating Profit Markups for 1.88hhp Standard-Size Self-Priming Pool Filter Pumps

EL	Baseline	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6	EL 7
Baseline	1.460							
EL 1	1.460	1.460						
EL 2	1.460	1.460	1.435					
EL 3	1.460	1.460	1.460	1.460				
EL 4	1.460	1.460	1.460	1.460	1.460			
EL 5	1.460	1.460	1.460	1.460	1.460	1.414		
EL 6	1.460	1.460	1.460	1.460	1.460	1.460	1.394	
EL 7	1.460	1.460	1.460	1.460	1.460	1.460	1.460	1.407

Table 12.3.17 Preservation of Operating Profit Markups for 0.09hhp Extra-Small-Size Non-Self-Priming Pool Filter Pumps

EL	Baseline	EL 1	EL 2
Baseline	1.350		
EL 1	1.350	1.334	
EL 2	1.350	1.350	1.321

Table 12.3.18 Preservation of Operating Profit Markups for 0.52hhp Standard-Size Non-Self-Priming Pool Filter Pumps

EL	Baseline	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6	EL 7
Baseline	1.350							
EL 1	1.350	1.348						
EL 2	1.350	1.350	1.350					
EL 3	1.350	1.350	1.350	1.350				
EL 4	1.350	1.350	1.350	1.350	1.333			
EL 5	1.350	1.350	1.350	1.350	1.350	1.350		
EL 6	1.350	1.350	1.350	1.350	1.350	1.350	1.314	
EL 7	1.350	1.350	1.350	1.350	1.350	1.350	1.350	1.316

Table 12.3.19 Preservation of Operating Profit Markups for 0.40hhp at 17ft of Head Waterfall Pumps

EL	Baseline	EL 1	EL 2	EL 3
Baseline	1.460			
EL 1	1.460	1.448		
EL 2	1.460	1.460	1.430	
EL 3	1.460	1.460	1.460	1.430

Table 12.3.20 Preservation of Operating Profit Markups for 0.28hhp at 10gpm of Flow Pressure Cleaner Booster Pumps

EL	Baseline	EL 1	EL 2	EL 3	EL 4
Baseline	1.350				
EL 1	1.350	1.349			
EL 2	1.350	1.350	1.350		
EL 3	1.350	1.350	1.350	1.318	
EL 4	1.350	1.350	1.350	1.350	1.319

Table 12.3.21 Preservation of Operating Profit Markups for 0.02hhp Integral Cartridge-filter Pool Pumps

EL	Baseline	EL 1
Baseline	1.270	
EL 1	1.270	1.223

Table 12.3.22 Preservation of Operating Profit Markups for 0.18hhp Integral Cartridge-filter Pool Pumps

EL	Baseline	EL 1
Baseline	1.270	
EL 1	1.270	1.259

Table 12.3.23 Preservation of Operating Profit Markups for 0.03hhp Integral Sand-filter Pool Pumps

EL	Baseline	EL 1
Baseline	1.270	
EL 1	1.270	1.253

12.3.8.3 Two-Tiered Markup Scenario

DOE implemented the two-tiered markup scenario because multiple manufacturers stated in interviews that they offer tiers of equipment lines that are differentiated, in part, by efficiency level. Specifically, manufacturers stated that they earn lower markups on self-priming pool filter pumps that have variable-speed functionality, compared to self-priming pool filter pumps with single or two-speed functionality. As higher standards push more consumers to purchase variable-speed motors, manufacturers lose sales of higher margin single- and two-speed motor dedicated-purpose pool pumps. Therefore, average manufacturer markups decrease.

Table 12.3.24 through Table 12.3.26 present the two-tiered markups for all self-priming pool filter pumps. DOE used the preservation of operating profit manufacturer markups for all non-self-priming, waterfall, pressure cleaner booster, integral cartridge-filter, and integral sand-filter pool pumps presented earlier in Table 12.3.17 through Table 12.3.23 to reflect the lower bound of manufacturer profitability for these equipment classes.

Table 12.3.24 Two-Tier Markups for 0.44hhp Small-Size Self-Priming Pool Filter Pumps

EL	Baseline	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6	EL 7
Baseline	1.513							
EL 1	1.513	1.513						
EL 2	1.513	1.513	1.513					
EL 3	1.513	1.513	1.513	1.513				
EL 4	1.513	1.513	1.513	1.513	1.513			
EL 5	1.513	1.513	1.513	1.513	1.513	1.513		
EL 6	1.425	1.425	1.425	1.425	1.425	1.425	1.425	
EL 7	1.425	1.425	1.425	1.425	1.425	1.425	1.425	1.425

Table 12.3.25 Two-Tier Markups for 0.95hhp Standard-Size Self-Priming Pool Filter Pumps

EL	Baseline	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6	EL 7
Baseline	1.511							
EL 1	1.511	1.511						
EL 2	1.511	1.511	1.511					
EL 3	1.511	1.511	1.511	1.511				
EL 4	1.511	1.511	1.511	1.511	1.511			
EL 5	1.511	1.511	1.511	1.511	1.511	1.511		
EL 6	1.423	1.423	1.423	1.423	1.423	1.423	1.423	
EL 7	1.423	1.423	1.423	1.423	1.423	1.423	1.423	1.423

Table 12.3.26 Two-Tier Markups for 1.88hhp Standard-Size Self-Priming Pool Filter Pumps

EL	Baseline	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6	EL 7
Baseline	1.505							
EL 1	1.505	1.505						
EL 2	1.505	1.505	1.505					
EL 3	1.505	1.505	1.505	1.505				
EL 4	1.505	1.505	1.505	1.505	1.505			
EL 5	1.505	1.505	1.505	1.505	1.505	1.505		
EL 6	1.417	1.417	1.417	1.417	1.417	1.417	1.417	
EL 7	1.417	1.417	1.417	1.417	1.417	1.417	1.417	1.417

12.4 INDUSTRY FINANCIAL IMPACTS

Using the inputs and scenarios described in the previous sections, the GRIM estimated indicators of financial impacts on the DPPP industry. The following sections detail additional inputs and assumptions for dedicated-purpose pool pumps. The main results of the MIA are also reported in this section. The MIA consists of two key financial metrics: INPV and annual cash flows.

12.4.1 Impacts on Industry Net Present Value

The INPV measures the industry value and is used in the MIA to compare the economic impacts of different TSLs in the standards cases. The INPV is different from DOE’s net present value (NPV), which is applied to consumers of the U.S. economy. The INPV is the sum of all net cash flows discounted at the industry’s cost of capital, or discount rate. The DPPP GRIM estimates cash flows from 2016 to 2050. This timeframe models both the short-term impacts on the industry from the announcement of the standards until the compliance date (2016 until the compliance year of 2021) and a long-term assessment over the 30-year analysis period used in the shipment analysis (2021 – 2050).

In the MIA, DOE compares the INPV of the no-standards case to that of each TSL in the standards cases. The difference between the no-standards case INPV and the standards case INPV at each TSL is an estimate of the economic impacts that implementing a particular TSL would have on the DPPP industry. For the DPPP industry, DOE examined the three manufacturer markup scenarios described in section 12.3.8; the preservation of gross margin markup scenario, preservation of operating profit markup scenario, and the two-tiered markup scenario.

Table 12.4.1 through Table 12.4.3 present the INPV estimates for the three markup scenarios analyzed for the DPPP industry.

Table 12.4.1 Manufacturer Impact Analysis for Dedicated-Purpose Pool Pumps under the Preservation of Gross Margin Markup Scenario

	Units	No-Standards Case	Trial Standard Level				
			1	2	3	4	5
INPV	2015$ MM	212.8	209.0	197.8	219.8	195.9	110.5
Change in INPV	2015$ MM	-	(3.7)	(15.0)	7.0	(16.9)	(102.3)
Change in INPV	%	-	(1.8)	(7.1)	3.3	(7.9)	(48.1)
Product Conversion Costs	2015$ MM	-	11.7	29.8	30.8	61.7	116.3
Capital Conversion Costs	2015$ MM	-	3.5	6.0	4.8	6.7	83.3
Total Investment Required	2015$ MM	-	15.2	35.8	35.6	68.4	199.5

Table 12.4.2 Manufacturer Impact Analysis for Dedicated-Purpose Pool Pumps under the Preservation of Operating Profit Markup Scenario

	Units	No-Standards Case	Trial Standard Level				
			1	2	3	4	5
INPV	2015$ MM	212.8	201.0	178.8	166.5	126.2	36.8
Change in INPV	2015$ MM	-	(11.7)	(34.0)	(46.3)	(86.6)	(176.0)
Change in INPV	%	-	(5.5)	(16.0)	(21.8)	(40.7)	(82.7)
Product Conversion Costs	2015$ MM	-	11.7	29.8	30.8	61.7	116.3
Capital Conversion Costs	2015$ MM	-	3.5	6.0	4.8	6.7	83.3
Total Investment Required	2015$ MM	-	15.2	35.8	35.6	68.4	199.5

Table 12.4.3 Manufacturer Impact Analysis for Dedicated-Purpose Pool Pumps under the Two-Tiered Markup Scenario

	Units	No-Standards Case	Trial Standard Level				
			1	2	3	4	5
INPV	2015$ MM	212.8	210.9	200.2	182.6	144.9	59.3
Change in INPV	2015$ MM	-	(1.9)	(12.6)	(30.2)	(67.8)	(153.5)
Change in INPV	%	-	(0.9)	(5.9)	(14.2)	(31.9)	(72.1)
Product Conversion Costs	2015$ MM	-	11.7	29.8	30.8	61.7	116.3
Capital Conversion Costs	2015$ MM	-	3.5	6.0	4.8	6.7	83.3
Total Investment Required	2015$ MM	-	15.2	35.8	35.6	68.4	199.5

12.4.2 Impacts on Annual Cash Flow

While INPV is useful for evaluating the long-term effects of new energy conservation standards, short-term changes on 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 might 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 free cash flows, Figure 12.4.1 through Figure 12.4.3 present the annual free cash flows from 2016 through 2028 for the no-standards case and each TSL in the standards cases.

Annual cash flows are discounted to the reference year, 2016. Between 2016 and the 2021 compliance year of the new energy conservation standards, cash flows are driven by the level of conversion costs and the proportion of these investments spent every year. After the announcement date (*i.e.*, the publication date of the direct final rule), industry cash flows begin to decline as companies use their financial resources to prepare for the new energy conservation standards. The more stringent the new energy conservation standards, 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 new energy conservation standards take effect is driven by two competing factors. In addition to capital and product conversion costs, new energy conservation standards could create stranded assets (*i.e.*, tooling and equipment that would have enjoyed longer use if the energy conservation standards 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 new energy conservation standards. 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 inventories of more expensive equipment, and higher accounts receivable for more expensive equipment. Depending on these two competing factors, cash flow can either be positively or negatively affected in the year the standards takes effect.

In the years following the compliance date of the new standards, the impact on cash flow depends on the operating revenue. In the preservation of gross margin markup scenario, the manufacturer markup is held constant to yield the same gross margin percentage in the standards case at each TSL as in the no-standards case in the year after the standards take effect. The implicit assumption is that manufacturers can freely pass on conversion costs and mark up higher cost units. The result under this scenario is that operating cash flow increases (in absolute terms) as revenue increases. At TSLs where production costs increase substantially, this scenario drives large increases in operating cash flow relative to the no-standards case. The larger the production cost increase, the more likely it is that the increase in operating cash flow after the standards take effect will outweigh the initial conversion costs.

Under the preservation of operating profit scenario, cash flow decreases at each TSL in the standards case compared to the no-standards case because the absolute dollar amount of the gross margin does not change despite an increase in sales and cost of goods sold. Therefore, the gross margin percentage is reduced.

Under the two-tiered markup scenario, cash flow decreases at each TSL in the standards case compared to the no-standards case because manufacturers reduce profit margins on variable-speed self-priming pool filter pumps as these products become the baseline, higher volume product.

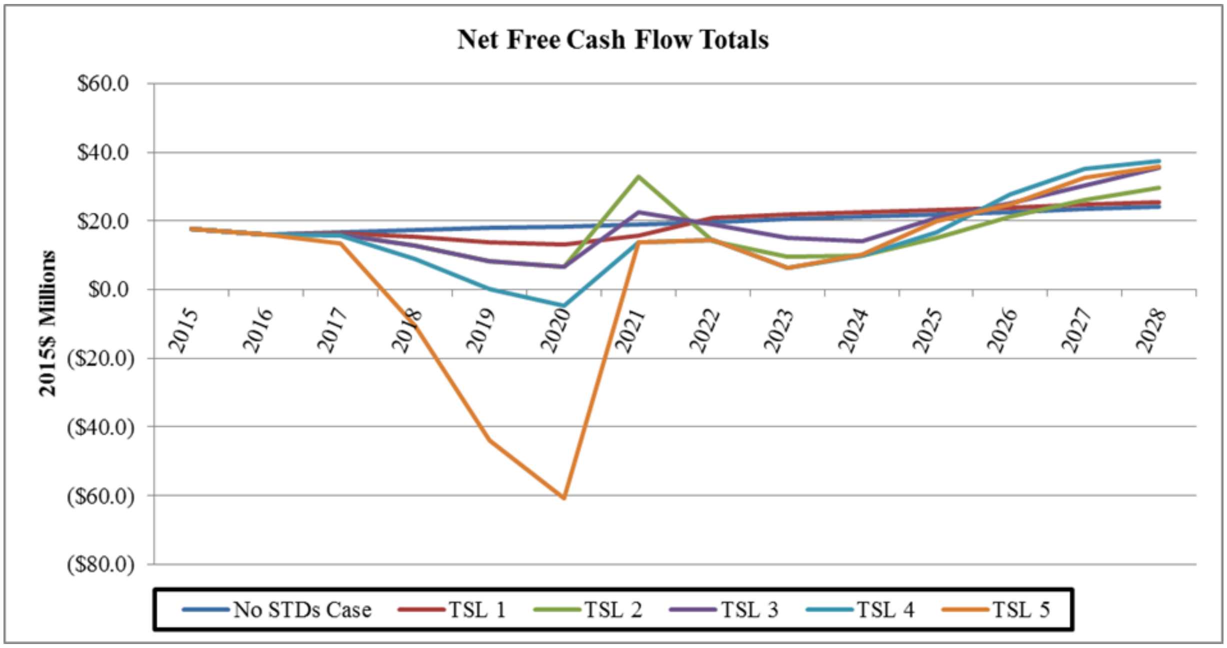

Figure 12.4.1 Annual Industry Free Cash Flows for Dedicated-Purpose Pool Pumps – Preservation of Gross Margin Markup Scenario

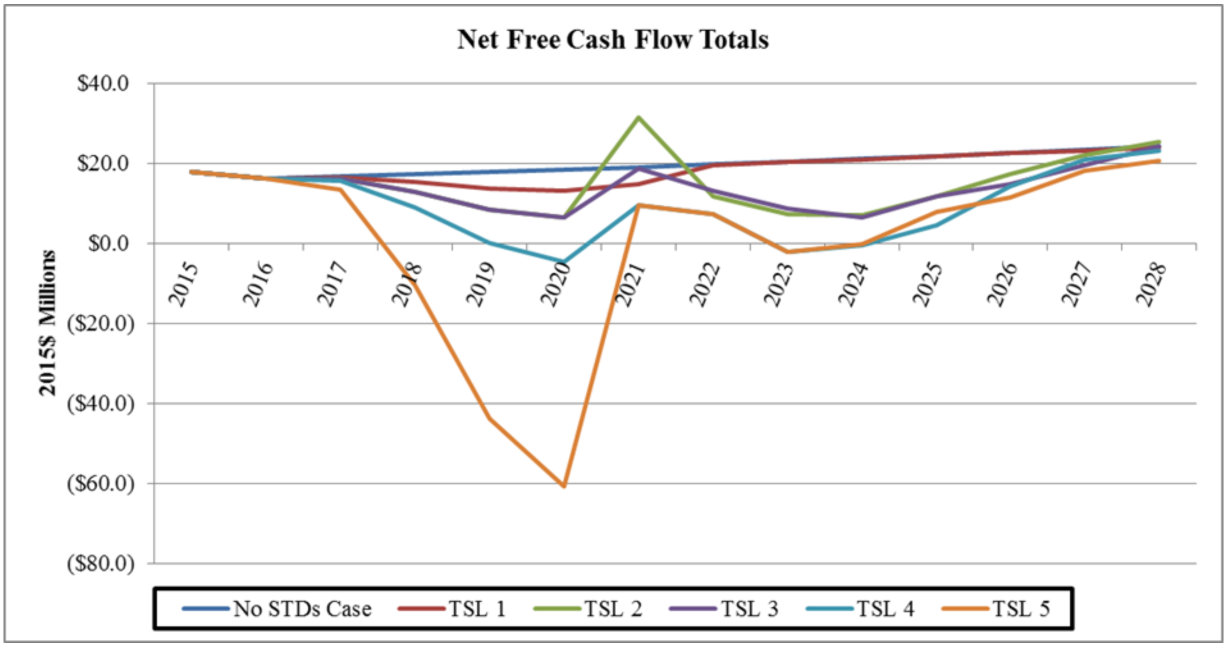

Figure 12.4.2 Annual Industry Free Cash Flows for Dedicated-Purpose Pool Pumps – Preservation of Operating Profit Markup Scenario

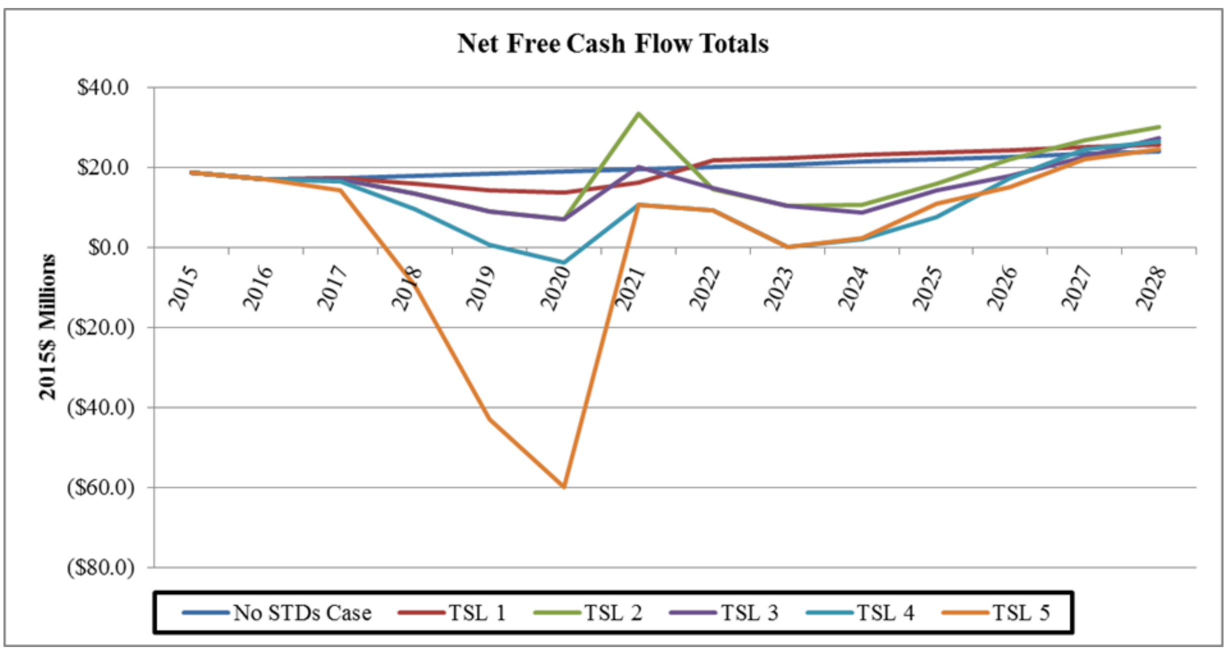

Figure 12.4.3 Annual Industry Free Cash Flows for Dedicated-Purpose Pool Pumps – Two-Tiered Markup Scenario

12.5 IMPACTS ON MANUFACTURER SUBGROUPS

As described in Section 12.2.3, DOE identified one subgroup of DPPP manufacturers; small manufacturers. The results of this subgroup analysis are described in the following section.

12.5.1 Impacts on Small Manufacturers

12.5.1.1 Description and Estimated Number of Small Entities Regulated

For manufacturers of dedicated purpose pool pumps, the SBA has set a size threshold, which defines those entities classified as "small businesses" for the purposes of the statute. DOE used the SBA's small business size standards to determine whether any small entities would be subject to the requirements of the rule. See 13 CFR part 121. The size standards are listed by North American Industry Classification System (NAICS) code and industry description available at: www.sba.gov/sites/default/files/files/Size_Standards_Table.pdf. The size standards are codified at 13 CFR part 121. To be categorized as a small business under NAICS code 333911, "Pump and Pumping Equipment Manufacturing," a DPPP manufacturer and its affiliates may employ a maximum of 750 employees. The 750-employee threshold includes all employees in a business' parent company and any other subsidiaries.

To estimate the number of companies that manufacture dedicated-purpose pool pumps covered by this rulemaking, DOE conducted a market survey using publicly available information. During its market survey, DOE used publicly available information, such as databases from the CEC, APSP, and ENERY STAR; individual company websites; and market research tools (*e.g.*, Hoover's reports) to create a list of companies that manufacture dedicated-purpose pool pumps covered by this direct final rule. During manufacturer interviews, DOE also asked stakeholders and industry representatives if they were aware of any additional small manufacturers. DOE then reviewed the list of companies manufacturing equipment covered by this direct final rule, used publicly available data sources (*e.g.*, Hoovers, Cortera, and LinkedIn), and direct contact with various companies to determine if they met the SBA's definition of a small business manufacturer. DOE screened out companies that do not offer equipment affected by this direct final rule, do not meet the definition of a "small business," are foreign owned and operated, or do not manufacture dedicated-purpose pool pumps in the United States.

For dedicated purpose pool pumps, DOE identified 21 companies that sell dedicated-purpose pool pumps covered by this rulemaking. Of these, DOE identified five as domestic small businesses.

12.5.1.2 Description and Estimate of Compliance Requirements

DOE identified five small DPPP manufacturers. The small manufacturers make small-size self-priming pool filter pumps, standard-size self-priming pool filter pumps, standard-size non-self-priming pool filter pumps, and pressure cleaner booster pumps. Accordingly, this analysis of small business impacts focuses exclusively on these equipment classes.

To evaluate impacts facing manufacturers of dedicated-purpose pool pumps, DOE estimated both the capital conversion costs (*i.e.*, investments in property, plant, and equipment) and product conversion costs (*i.e.*, expenditures on R&D, testing, marketing, and other non-depreciable expense) manufacturers would incur to bring their manufacturing facilities and equipment designs into compliance with adopted standards. As outlined in chapter 5, the design options analyzed to comply with the adopted energy conservation standards include changing the motor to either variable-speed for standard-size self-priming pool filter pumps, or a more efficient single-speed motor for small-size self-priming, non-self-priming, and pressure cleaner booster pumps. DOE estimated per-model and per-wet-end redesign costs to determine product and capital conversion costs.

DOE used manufacturer specification sheets and product catalogs to estimate the number of models that each small business needs to redesign to comply with the adopted standards. DOE then multiplied this number by the per model redesign costs. This methodology is outlined in more detail in section 12.3.7.

The largest burden small businesses face is to bring standard-size self-priming pool filter pumps into compliance with the adopted standard. All five small businesses manufacture standard-size self-priming pool filter pumps and all of them make at least one compliant variable-speed pool filter pump. These small manufacturers could decide to ramp up the production of their already-compliant models and discontinue their non-compliant equipment. However, this could cause gaps in equipment offerings for manufacturers. Therefore, it is likely that manufacturers will redesign some non-compliant pool filter pumps to fill potential gaps in their equipment offerings. As described in section 12.3.7, DOE assumed that one variable-speed pool filter pump can replace multiple single- and two-speed pool filter pumps. Using this assumption DOE estimated that small businesses will incur $5.3 million in conversion costs to bring non-compliant standard-size self-priming pool filter pumps into compliance.

Four small businesses make small-size self-priming pool filter pumps. The adopted efficiency level for this equipment class analyzes the incorporation of a more efficient single-speed motor. All four manufacturers make multiple single-speed models and some might need to be redesigned to maintain a complete equipment offering. DOE expected that two small businesses will not incur any conversion costs, and the other two small businesses will incur a combined total of $0.6 million in conversion costs to bring non-compliant small-size self-priming pool filter pumps into compliance.

DOE identified four small businesses that make standard-size non-self-priming pool filter pumps. The adopted efficiency level for this equipment class can be achieved through the incorporation of a more efficient single-speed motor. Two manufacturers offer all non-self-priming pool filter pumps in both single- and two-speed configurations. DOE estimated that these manufacturers will not incur any conversion costs, because they could discontinue non-compliant single-speed pool pumps and still continue to have the same product offering with their two-speed pool pumps. The two other manufacturers have a greater number of single-speed than two-speed non-self-priming pool filter pumps and DOE expected these manufacturers will redesign some dedicated-purpose pool pumps to maintain a complete product offering. In total, small manufacturers of non-self-priming pool filter pumps are estimated to redesign two standard-size non-self-priming pool pumps and incur $0.7 million in conversion costs to bring non-compliant equipment into compliance.

Only one pressure cleaner booster pool pump model is offered in the market by small businesses. DOE did not have performance data for this pump; however, based on the no-standards case shipments distribution, 87 percent of pressure cleaner booster shipments already meet or exceed the adopted standard. Therefore, DOE expected that this model does not have to be redesigned under the adopted standard.

DOE estimated that the five small business will incur a total of $6.6 million in conversion costs to bring non-complaint standard-size self-priming, small-size self-priming, standard-size non-self-priming, and pressure cleaner booster pumps into compliance. Using publicly available data, DOE estimated the average annual revenue of the five small manufacturers to be $53.6 million.[2] DOE expected small manufacturers will be able to spread their conversion costs over the four-and-a-half year compliance period between the expected publication of a final rule (2016) and the expected compliance year (2021). Given these assumptions, DOE estimated that conversion costs are 0.55 percent of total small business four-and-a-half year revenue. While the standards creates additional business risk for these small businesses, DOE's calculations show that the conversion costs associated with this increase in efficiency are moderate.

12.6 Other Impacts

12.6.1 Impacts on Manufacturing Capacity

DOE did not identify any significant capacity constraints for the design options being evaluated for this rulemaking. 46 percent of small-size self-priming, 30 percent of standard-size self-priming, 67 percent of extra-small non-self-priming, 71 percent of standard-size non-self-priming, 86 percent of pressure cleaner booster, 100 percent of waterfall, 20 percent of integral cartridge-filter, and 20 percent of integral sand-filter pool pump shipments already meet or exceed the adopted standard levels. In addition, the design options being evaluated are widely available as products that are on the market today.

DOE believes there is a sufficient supply of variable-speed motors to be used in all standard-size self-priming pool filter pumps in 2021. Variable speed motors are used a wide variety of equipment, and dedicated-purpose pool pumps only represent a small fraction all the equipment that use variable speed motors. As such existing production lines can cope with the change in equipment offerings, and DOE does not expect the industry to experience capacity constraints due to the increase in demand of variable speed motors or for any other reason directly resulting from new energy conservation standards.

12.6.2 Direct Employment

To quantitatively assess the impacts of new energy conservation standards on employment, DOE used the GRIM to estimate the domestic labor expenditures and number of employees in the no-standards case and at each TSL from 2016 through 2050. DOE used statistical data from the U.S. Census Bureau's 2014 Annual Survey of Manufacturers (ASM) and the results of the engineering analysis to calculate industry-wide labor expenditures and domestic employment levels. Labor expenditures related to equipment manufacturing depend on the labor intensity of the equipment, 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.

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[2] This estimate is based on estimates from Hoovers (www.hoovers.com), Last accessed September 6, 2016.

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 multiplied by the labor rate found in the ASM). The estimates of production workers in this section cover workers, including line supervisors, 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 production worker estimates only account for workers who manufacture the specific equipment covered by this rulemaking.

DOE calculated the total direct employment associated with the covered equipment by multiplying the number of production workers by the ratio of "number of employees" to "production workers average per year" calculated using the employment data in the 2014 ASM. Using the GRIM, DOE estimates there would be 101 domestic production workers for original equipment manufacturers in 2021 in the absence of new energy conservation standards. Using ASM data, DOE estimated 175 full-time employees work directly on the covered equipment. Table 12.6.1 shows the range of the impacts of energy conservation standards on U.S. production on dedicated-purpose pool pumps.

Table 12.6.1 Total Number of Domestic Dedicated-Purpose Pool Pump Workers in 2021

	No-Standards Case	Trial Standard Level				
		1	2	3	4	5
Domestic Production Workers in 2021 (without changes in production locations)	101	101	80	94	78	78
Total Number of Domestic Employees in 2021	175	175	139	163	135	135
Potential Changes in Domestic Production Workers in 2021	-	(10) - 0	(25) – (21)	(51) – (7)	(51) – (23)	(51) – (23)

The employment impacts shown in Table 12.6.1 represent the potential employment changes that could result following the compliance date for dedicated-purpose pool pumps. The upper end of the results in the table (less severe) estimates the decline in employment due to the decrease in the number of DPPPs sold in 2021, as more customers repair their dedicated-purpose pool pumps instead of replacing them as they would in the no-standards case. This case assumes that manufacturers would continue to produce the same scope of covered equipment within the United States. The lower end of the range (more severe) represents the maximum potential decrease to employment due to production moving to lower labor-cost countries, in addition to the decrease in the number of DPPPs sold in 2021.

DOE estimated the lower end of the range based on manufacturer interviews. Manufacturers could move production abroad depending on the requirements of a standard for self-priming pool filter pumps. Based on the complexity of the motor technology used in dedicated-purpose pool pumps, either single-speed, two-speed, or variable-speed, DOE estimated that the number of domestic production workers could be reduced by 10 percent if standards were set at TSL 1 (represented by a single-speed motor for self-priming pool filter pumps), 25 percent if standards were set at TSL 2 (represented by a two-speed motor for self-priming pool filter pumps), and 50 percent if standards were set at TSL 3, TSL 4, or TSL 5 (represented by a variable-speed motor for self-priming pool filter pumps).

The direct employment impacts shown are independent of the employment impacts from the broader U.S. economy, which are documented in the employment impact analysis found in chapter 16 of the direct final rule TSD.

12.6.3 Cumulative Regulatory Burden

One aspect of assessing manufacturer burden involves considering the cumulative impact of multiple DOE standards and the product-specific regulatory actions of other Federal agencies that affect the manufacturers of a covered product or equipment. While any one regulation may not impose a significant burden on manufacturers, the combined effects of several existing or 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. In addition to energy conservation standards, other regulations can significantly affect manufacturers' financial operations. Multiple regulations affecting the same manufacturer can strain profits and lead companies to abandon product lines or markets with lower expected future returns than competing equipment. For these reasons, DOE conducts an analysis of cumulative regulatory burden as part of its rulemakings pertaining to appliance efficiency.

Some DPPP manufacturers also make other products or equipment that could be subject to energy conservation standards set by DOE. DOE looks at these regulations that could affect DPPP manufacturers that will take effect approximately 3 years before or after the estimated 2021 compliance date or during the compliance period of the new energy conservation standards for dedicated-purpose pool pumps.

The compliance dates and expected industry conversion costs of relevant energy conservation standards are indicated in Table 12.6.2. Also, included in the table are Federal regulations that have compliance dates beyond the three years before or after the DPPP compliance date.

Table 12.6.2 Compliance Dates and Expected Conversion Expenses of Federal Energy Conservation Standards Affecting Dedicated-Purpose Pool Pump Manufacturers

Federal Energy Conservation Standard	Number of Manufacturers*	Number of Manufacturers from Today's Rule**	Approx. Standards Year	Industry Conversion Costs Millions $	Industry Conversion Costs / Revenue***
Small, Large, and Very Large Commercial Package Air Conditioning and Heating Equipment 81 FR 2420 (January 15, 2016)	13	1	2018	520.8 (2014$)	4.9%
Commercial Packaged Boilers 81 FR 15836	45	1	2019	27.5 (2014$)	2.3%

(March 24, 2016)†					
Commercial Water Heaters 81 FR 34440 (May 31, 2016)†	25	1	2019	29.8 (2014$)	3.0%
Commercial Warm Air Furnaces 81 FR 2420 (January 15, 2016)	13	1	2019	7.5 to 22.2 (2014$)	1.7% to 5.2%
Furnace Fans 79 FR 3813 (July 3, 2014)	38	1	2019	40.6 (2013$)	1.6%
Commercial Compressors 81 FR 40197 (June 21, 2016)†	40	1	2019	99.0 to 125.1 (2014$)	3.1% to 3.9%
Commercial and Industrial Pumps 80 FR 17826 (January 26, 2016)	86	5	2020	81.2 (2014$)	5.6%
Residential Boilers 81 FR 2320 (January 15, 2016)	36	2	2021	2.5 (2014$)	<1%
Residential Furnace 80 FR 13120 (March 12, 2015)†	14	1	2021	55.0 (2013$)	<1%
Direct Heating Equipment and Residential Water Heaters 75 FR 20112 (April 16, 2010)††	39	1	2015	17.5 (2009$)	4.9%
Residential Central Air Conditioners and Heat Pumps 76 FR 37408 (June 27, 2011)††	39	4	2015	44.0 (2009$)	0.1%
External Power Supplies 79 FR 7846 (February 10, 2014)††	243	1	2016	43.4 (2012$)	2.3%
Walk-in Cooler and Walk-in Freezer Components 79 FR 32049 (June 3, 2014)††	63	1	2017	33.6 (2012$)	2.7%

* This column presents the total number of manufacturers identified in the energy conservation standard rule contributing to cumulative regulatory burden.
** This column presents the number of manufacturers producing dedicated-purpose pool pumps that are also listed as manufacturers in the energy conservation standard contributing to cumulative regulatory burden.
*** This column presents conversion costs as a percentage of cumulative revenue for the industry during the conversion period. The conversion period is the timeframe over which manufacturers must make conversion cost investments and lasts from the announcement year of the final rule to the standards year of the final rule. This period typically ranges from 3 to 5 years, depending on the energy conservation standard.
† 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 or SNOPR.
†† DOE has assessed whether this rule will have significant impacts on manufacturers that are also subject to significant impacts from other EPCA rules with compliance dates within three years of this rule's compliance date. However, DOE recognizes that a manufacturer incurs costs during some period before a compliance date as it prepares to comply, such as by revising product designs and manufacturing processes, testing products, and preparing certifications. As such, to

illustrate a broader set of rules that may also create additional burden on manufacturers, DOE has included another rule with compliance dates that fall within six years of the compliance date of this rule by expanding the timeframe of potential cumulative regulatory burden. Note that the inclusion of any given rule in this Table does not indicate that DOE considers the rule to contribute significantly to cumulative impact. DOE has chosen to broaden its list of rules in order to provide additional information about its rulemaking activities. DOE will continue to evaluate its approach to assessing cumulative regulatory burden for use in future rulemakings to ensure that it is effectively capturing the overlapping impacts of its regulations. DOE plans to seek public comment on the approaches it has used here (i.e., both the 3 and 6 year timeframes from the compliance date) in order to better understand at what point in the compliance cycle manufacturers most experience the effects of cumulative and overlapping burden from the regulation of multiple products.

In addition to the Federal energy conservation standards listed in Table 12.6.2, there are appliance standards in progress that do not yet have a proposed rule or final rule. The compliance date, manufacturer lists, and analysis of conversion costs are not available at this time. These appliance standards include pool heaters 80 FR 15922 (March 17, 2015), circulator pumps 80 FR 51483, (August 25, 2015), central air conditioners, and commercial and industrial fans and blowers.

12.6.3.1 State Regulations

DOE identified state regulations that can impose burdens to manufacturers. Five states, including Arizona, Connecticut, Florida, New York, and Washington, have adopted swimming pool pump standards based on the standards that were implemented in California in 2006. These six states: (1) prohibit the use of capacitor start induction run motors in residential pool filter pumps with some exceptions; (2) require that motors with a total horsepower of one or greater to have the capability of operate at two or more speeds; and (3) have certain requirements for pool pump controls.[3]

12.7 CONCLUSION

The following section summarizes the impacts of the scenarios DOE believes are most likely to capture the range of impacts on DPPP manufacturers as a result of new energy conservation standards.

At TSL 1, DOE estimates impacts on INPV range from -$11.7 million to -$1.9 million, or a change in INPV of -5.5 percent to -0.9 percent. At TSL 1, industry free cash-flow is expected to decrease by $5.3 million to $13.2 million, compared to the no-standards case value of $18.5 million in 2020, the year leading up to the standards.

DOE estimates that 46 percent of all self-priming shipments, 67 percent of extra-small non-self-priming shipments, 71 percent of standard-size non-self-priming shipments, 87 percent of pressure cleaner booster shipments, 30 percent of waterfall shipments, 100 percent of integral cartridge filter shipments, and 100 percent of integral sand filter DPPP shipments would already meet or exceed the efficiency levels required at TSL 1 in the standards year. To bring non-

[3] www.appliance-standards.org/product/pool-pumps

compliant equipment into compliance, DOE expects DPPP manufacturers to incur $11.7 million in product conversion costs for redesign and testing. In addition, DOE estimates manufacturers will incur $3.5 million in capital conversion costs at TSL 1.

At TSL 1, the shipment-weighted average MPC for all dedicated-purpose pool pumps increases by 6.1 percent relative to the no-standards case shipment-weighted average MPC for all dedicated-purpose pool pumps in 2021, the year of compliance for new DPPP energy conservation standards. In the preservation of gross margin markup scenario, manufacturers are able to fully pass on this cost increase to consumers. The increase in shipment-weighted average MPC for all dedicated-purpose pool pumps is outweighed by the $15.2 million in conversion costs, causing a slightly negative change in INPV at TSL 1 under the preservation of gross margin markup scenario.

Under the preservation of operating profit markup scenario, manufacturers earn the same operating profit as would be earned in the no-standards case, but manufacturers do not earn additional profit from their investments. The average manufacturer markup for both the preservation of operating profit and two-tiered markup scenarios is calculated by averaging the DPPP industry manufacturer markup, for all DPPP equipment classes in aggregate, from the year of compliance (2021) until the terminal year (2050). In this preservation of operating profit markup scenario, the 6.1 percent increase in the shipment-weighted average MPC for all dedicated-purpose pool pumps results in a slight reduction in average manufacturer markup, from 1.413 in the no-standards case to 1.409 at TSL 1. The slight reduction in average manufacturer markup and $15.2 million in conversion costs causes a negative change in INPV at TSL 1 under the preservation of operating profit markup scenario.

Under the two-tiered markup scenario, where manufacturers earn lower markups for more efficient products, the average manufacturer markup increases from 1.409 in the no-standards case to 1.412 at TSL 1. The increase in the average manufacturer markup and the increase in the shipment-weighted average MPC for all dedicated-purpose pool pumps are outweighed by the $15.2 million in conversion costs, causing a slightly negative change in INPV at TSL 1 under the two-tiered markup scenario

At TSL 2, DOE estimates impacts on INPV range from -$34.0 million to -$12.6 million, or a change in INPV of -16.0 percent to -5.9 percent. At TSL 2, industry free cash-flow is expected to decrease by $11.9 million to $6.6 million, compared to the no-standards case value of $18.5 million in 2020, the year leading up to the standards.

DOE estimates that 32 percent of all self-priming shipments, 67 percent of extra-small non-self-priming shipments, 7 percent of standard-size non-self-priming shipments, 87 percent of pressure cleaner booster shipments, 30 percent of waterfall shipments, 100 percent of integral cartridge filter shipments, and 100 percent of integral sand filter pool pump shipments would already meet or exceed the efficiency levels required at TSL 2 in the standards year. To bring non-compliant equipment into compliance, DOE expects dedicated-purpose pool pump manufacturers to incur $29.8 million in product conversion costs for redesign and testing. In addition, DOE estimates manufacturers will incur $6.0 million in capital conversion costs associated with TSL 2, to make investments in tooling and machinery required to incorporate the design options analyzed at TSL 2.

At TSL 2, the shipment-weighted average MPC for all dedicated-purpose pool pumps decreases by 3.4 percent relative to the no-standards case shipment-weighted average MPC for all dedicated-purpose pool pumps in 2021. At TSL 2, consumers will repair existing self-priming and non-self-priming pool pumps instead of replacing the entire pump, which reduces shipments in the standards year by 0.5 million compared to the no-standards case shipments. In the preservation of gross margin markup scenario, the decrease in the shipment-weighted average MPC for all dedicated-purpose pool pumps, the reduction in shipments, and the $35.8 million in conversion costs, causes a negative change in INPV at TSL 2 under the preservation of gross margin markup scenario.

Under the preservation of operating profit markup scenario, the 3.4 percent decrease in the shipment-weighted average MPC for all dedicated-purpose pool pumps results in a reduction in average manufacturer markup, from 1.413 in the no-standards case to 1.399 at TSL 2. The reduction in average manufacturer markup, the reduction in shipments, and the $35.8 million in conversion costs causes a negative change in INPV at TSL 2 under the preservation of operating profit markup scenario.

Under the two-tiered markup scenario, where manufacturers earn lower markups for more efficient products, the average manufacturer markup slightly increases from 1.409 in the no-standards case to 1.412 at TSL 2. The increase in the average manufacturer markup is outweighed by the reduction in shipments, and the $35.8 million in conversion costs, causing a negative change in INPV at TSL 2 under the two-tiered markup scenario.

At TSL 3, DOE estimates impacts on INPV range from -$46.3 million to $7.0 million, or a change in INPV of -21.8 percent to 3.3 percent. At TSL 3, industry free cash flow is expected to decrease by $11.9 million to $6.6 million, compared to the no-standards case value of $18.5 million in 2020, the year leading up to the standards.

DOE estimates that 46 percent of small-size self-priming shipments, 30 percent of standard-size self-priming shipments, 67 percent of extra-small non-self-priming shipments, 71 percent of standard-size non-self-priming shipments, 87 percent of pressure cleaner booster shipments, 100 percent of waterfall shipments, 20 percent of integral cartridge filter shipments, and 20 percent of integral sand filter pool pump shipments would already meet or exceed the efficiency levels required at TSL 3 in the standards year. To bring non-compliant equipment into compliance, DOE expects DPPP manufacturers to incur $30.8 million in product conversion costs for redesign and testing. In addition, DOE estimates manufacturers will incur $4.8 million in capital conversion costs to make changes to machinery and tooling.

At TSL 3, the shipment-weighted average MPC for all dedicated-purpose pool pumps increases by 10.5 percent relative to the no-standards case shipment-weighted average MPC for all dedicated-purpose pool pumps in 2021. At TSL 3 consumers repair existing self-priming pool filter pumps instead of replacing the entire pump, which reduces shipments in the standards year by 0.3 million compared to the no-standards case shipments. In the preservation of gross margin markup scenario, the increase in the shipment-weighted average MPC for all dedicated-purpose pool pumps outweighs the reduction in shipments in the standards year, and the $35.6 million in conversion costs, which causes a slightly positive change in INPV at TSL 3 under the preservation of gross margin markup scenario.

Under the preservation of operating profit markup scenario, the 10.5 percent increase in the shipment-weighted average MPC for all dedicated-purpose pool pumps results in a reduction in average manufacturer markup, from 1.413 in the no-standards case to 1.380 at TSL 3. The reduction in average manufacturer markup, the reduction in shipments, and $35.6 million in conversion costs causes a negative change in INPV at TSL 3 under the preservation of operating profit markup scenario.

Under the two-tiered markup scenario, where manufacturers earn lower markups for more efficient products, the average manufacturer markup decreases from 1.409 in the no-standards case to 1.389 at TSL 3. The decrease in the average manufacturer markup, the reduction in shipments, and the $35.6 million in conversion costs cause a negative change in INPV at TSL 3 under the two-tiered markup scenario.

At TSL 4, DOE estimates impacts on INPV range from -$86.6 million to -$16.9 million, or a change in INPV of -40.7 percent to -7.9 percent. At TSL 4, industry free cash-flow is expected to decrease by $23.1 million to -$4.6 million, compared to the no-standards case value of $18.5 million in 2020, the year leading up to the standards.

DOE estimates that 30 percent of all self-priming shipments, 33 percent of extra-small non-self-priming shipments, 6 percent of standard-size non-self-priming shipments, 6 percent of pressure cleaner booster shipments, 10 percent of waterfall shipments, 100 percent of integral cartridge filter shipments and 100 percent of integral sand filter pool pump shipments would already meet or exceed the efficiency levels required at TSL 4 in the standards year. To bring non-compliant equipment into compliance, DOE expects DPPP manufacturers to incur $61.7 million in product conversion costs for redesign and testing. In addition, DOE estimates manufacturers will incur $6.7 million in capital conversion costs associated with TSL 4 to make changes to machinery and tooling.

At TSL 4, the shipment-weighted average MPC for all dedicated-purpose pool pumps increases by 39.4 percent relative to the no-standards case shipment-weighted average MPC for all dedicated-purpose pool pumps in 2021. At TSL 4, consumers repair existing self-priming, non-self-priming, and pressure cleaner booster pumps instead of replacing the entire pump, which reduces total shipments in the standards year by 0.6 million units compared to the no-standards case shipments. In the preservation of gross margin markup scenario, the increase in the shipment-weighted average MPC for all dedicated-purpose pool pumps is outweighed by the reduction in shipments and the $68.4 million in conversion costs, which causes a negative change in INPV at TSL 4 under the preservation of gross margin markup scenario.

Under the preservation of operating profit markup scenario, the 39.4 percent increase in the shipment-weighted average MPC for all dedicated-purpose pool pumps results in a reduction in average manufacturer markup, from 1.413 in the no-standards case to 1.367 at TSL 4. The reduction in average manufacturer markup, the reduction in shipments, and $68.4 million in conversion costs causes a significantly negative change in INPV at TSL 4 under the preservation of operating profit markup scenario.

Under the two-tiered markup scenario, where manufacturers earn lower markups for more efficient products, the average manufacturer markup decreases from 1.409 in the no-standards case to 1.376 at TSL 4. The decrease in the average manufacturer markup, the reduction in shipments, and the $68.4 million in conversion costs cause a significantly negative change in INPV at TSL 4 under the two-tiered markup scenario.

At TSL 5, DOE estimates impacts on INPV range from -$176.0 million to -$102.3 million, or a change in INPV of -82.7 percent to -48.1 percent. At TSL 5, industry free cash flow is expected to decrease by $79.3 million to -$60.9 million, compared to the no-standards case value of $18.5 million in 2020, the year leading up to the standards.

DOE estimates that 19 percent of all self-priming shipments, 33 percent of extra-small non-self-priming shipments, 3 percent of standard-size non-self-priming shipments, 3 percent of pressure cleaner booster shipments, 0 percent of waterfall shipments, 100 percent of integral cartridge filter shipments and 100 percent of integral sand filter pool pump shipments would already meet the efficiency levels required at TSL 5 in the standards year. To bring non-compliant equipment into compliance, DOE expects dedicated-purpose pool pump manufacturers to incur $116.3 million in product conversion costs for redesign and testing. In addition, DOE estimates manufacturers will incur $83.3 million in capital conversion costs associated with TSL 5 to make changes to machinery and tooling.

At TSL 5, the shipment-weighted average MPC for all dedicated-purpose pool pumps increases by 39.4 percent relative to the no-standards case shipment-weighted average MPC for all dedicated-purpose pool pumps in 2021. At TSL 5, consumers repair existing self-priming, non-self-priming, and pressure cleaner booster pumps instead of replacing the entire pump, which reduces total shipments in the standards year by 0.6 million units compared to the no-standards case shipments. In the preservation of gross margin markup scenario, the increase in the shipment-weighted average MPC for all dedicated-purpose pool pumps is outweighed by the reduction in shipments and the $199.5 million in conversion costs, which causes a significantly negative change in INPV at TSL 5 under the preservation of gross margin markup scenario.

Under the preservation of operating profit markup scenario, the 39.4 percent increase in the shipment-weighted average MPC for all dedicated-purpose pool pumps results in a reduction in average manufacturer markup, from 1.413 in the no-standards case to 1.363 at TSL 5. The reduction in average manufacturer markup, the reduction in shipments, and $199.5 million in conversion costs causes a significantly negative change in INPV at TSL 5 under the preservation of operating profit markup scenario.

Under the two-tiered markup scenario, where manufacturers earn lower markups for more efficient products, the average manufacturer markup decreases from 1.409 in the no-standards case to 1.375 at TSL 5. The decrease in the average manufacturer markup, the reduction in shipments, and the $199.5 million in conversion costs cause a negative change in INPV at TSL 5 under the two-tiered markup scenario.

REFERENCES

1 Securities and Exchange Commission, Annual 10-K Reports, Various Years, Washington DC. <www.sec.gov>

2 McKinsey & Company, Inc. Valuation: Measuring and Managing the Value of Companies, 3rd Edition, Copeland, Koller, Murrin. New York: John Wiley & Sons, 2000.

APPENDIX 12A. MANUFACTURER IMPACT ANALYSIS INTERVIEW GUIDE

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APPENDIX 12A. MANUFACTURER IMPACT ANALYSIS INTERVIEW GUIDE

Purpose

As part of the rulemaking process for developing a test procedure and an energy conservation standard for dedicated purpose pool pumps (DPPPs), the U.S. Department of Energy (DOE) is conducting manufacturer interviews. The interview process is intended to gather data and information to: (1) inform DOE's test procedure development and technical and economic analyses, and (2) inform DOE's understanding of how a test procedure and an energy conservation standard will affect companies that manufacture equipment covered by the standard.

Method

Navigant Consulting, Inc. (Navigant) and Lawrence Berkeley National Laboratory (LBNL) are circulating this guide to manufacturers that have invited Navigant and LBNL for interviews. Navigant and LBNL have entered into mutual non-disclosure agreements (NDAs) with each participating manufacturer receiving this interview guide, and all information exchanged during interviews and provided in response to this questionnaire will be treated as confidential. In their analyses, Navigant and LBNL will aggregate responses from individual manufacturers in order to provide aggregated values to DOE. This aggregation is intended to protect the proprietary information of individual manufacturers.

Topics Covered

The questions that follow range from technical engineering questions, to requests about specific financial figures for use in industry modeling, to general questions intended to solicit qualitative comments.

12A.1 INTRODUCTION TO EQUIPMENT VARIETIES AND TEST PROCEDURES

1.1 Definitions

When DOE considers standards for equipment, it seeks to provide a clear and unambiguous definition of the equipment, so that it is obvious which equipment is subject to standards and which equipment is not.

As agreed to by the DPPP ASRAC Working Group, DOE plans to analyze energy conservation standards for pool filter pumps, waterfall pumps, and pressure cleaner booster pumps. DOE is considering the definitions listed below, as established by the DPPP Working Group. Questions in this interview guide will refer to these pump varieties.

- **Pool Filter Pump** means an end suction pump that either (1) includes an integrated basket strainer, or (2) does not include an integrated basket strainer, but requires a basket strainer for operation, as stated in manufacturer literature provided with the pump; and may be distributed in commerce connected to, or packaged with, a sand filter, removable cartridge filter, or other filtration accessory, so long as the bare pump and filtration accessory are connected with consumer-removable connections that allow the pump to be plumbed to bypass the filtration accessory for testing.

  There are two subsets of pool filter pumps:
  - Self-priming pool filter pump means a pool filter pump that is a self-priming pump.
  - Non-self-priming pool filter pump means a pool filter pump that is not a self-priming pump.
- **Waterfall Pump** means a pool filter pump with maximum head less than or equal to 30 feet, and a maximum nominal speed less than or equal to 1800 rpm.
- **Pressure Cleaner Booster Pump** is not yet formally defined. DOE will propose a formal definition in the Notice of Proposed Rulemaking for the DPPP test procedure, or the DPPP ASRAC Working Group may discuss formal definitions when it reconvenes in 2016. The definition will capture pool pumps used specifically in pressure-side cleaner applications.
- **Integral Cartridge-Filter Pool Pump** means a pump that requires a removable cartridge filter, installed on the suction side of the pump, for operation; and the pump cannot be plumbed to bypass the cartridge filter for testing.
- **Integral Sand-Filter Pool Pump** means a pump distributed in commerce with a sand filter that cannot be bypassed for testing.

1.2 Test Procedure

To provide consistent rating and testing methodologies, DOE also develops a standardized test procedure and metric to describe the energy performance of a DPPP. As agreed to by the DPPP Working Group, the energy performance of dedicated-purpose pool pumps is described in terms of the Weighted Energy Factor (WEF), which is determined based on a ratio of the flow provided by the pump over the input power to the pump at one or more load points, as shown in the following equation:

$$WEF = \frac{\sum_{i=1}^{n}\left(w_i \times \frac{Q_i}{1000} \times 60\right)}{\sum_{i=1}^{n}\left(w_i \times \frac{P_i}{1000}\right)}$$

Where:

- *WEF* = Weighted Energy Factor in kgal/kWh;
- w_i = weighting factor at each load point i;
- Q_i = flow at each load point i in gal/min;
- P_i = input power to the motor (or controls, if present) at each load point i in Watts;
- i = load point(s), defined uniquely for each pool pump variety; and
- n = number of load point(s), defined uniquely for each pool pump variety.

The load points (i) and weights (w_i) used in determining WEF for each pump variety are:

Pool Pump Varieties	**Speed Type**	**Test Points**				**Weight (w_i)**
		# of Points (n)	**Load Point (i)**	**Flow Rate (Q)**	**Head (H)**	
Self-Priming Pool Filter Pumps And **Non-Self-Priming Pool Filter Pumps**	Single	1	High	$Q_{high}(gpm) = Q_{max\_speed@C} =$ Flow at max speed on Curve C	H = 0.0082 × $Q_{high}{}^2$	1.0
	Two-Speed	2	Low	$Q_{low}(gpm) = 0.5 \times Q_{max\_speed@C}$ $= 39.21\ x\ P_{hydro,max@C}(HP)^{1/3}$ (at half max speed)	H = 0.0082 × $Q_{low}{}^2$	0.8
			High	$Q_{high}(gpm) = Q_{max\_speed@C} =$ Flow at max speed on Curve C	H = 0.0082 × $Q_{high}{}^2$	0.2
	Variable and Multi-Speed	2	Low	$Q_{low}(gpm)$ • If pump hydraulic HP at max speed on Curve C is >0.75, then Q_{low} = 31.1 gpm • If pump hydraulic HP at max speed on Curve C is ≤ 0.75, then Q_{low} = 24.7 gpm (a pump may vary speed to achieve this load point)	H ≥ 0.0082 × $Q_{low}{}^2$	0.8
			High	$Q_{high}(gpm) = 0.8 \times Q_{max\_speed@C}$ (at 80% max speed) (a pump may vary speed to achieve this load point)	H = 0.0082 × $Q_{high}{}^2$	0.2
Waterfall Pumps	Single	1	High	Flow corresponding to specified head (on max speed pump curve)	17 ft	1.0
Pressure Cleaner Booster Pumps	All	1	High	Flow corresponding to specified head (on max speed pump curve)	90 ft	1.0

The DPPP Working Group also recommended that the test procedure be based on wire-to-water testing in accordance with HI 40.6-2014 (with potential minor modifications in order to ensure test repeatability). To inform further development and specification of the test procedure for dedicated-purpose pool pumps, the questions in section 19 of this guide will ask about existing test facilities, instrumentation, testing capability, and test protocols with respect to the requirements in HI 40.6-2014 and the recommendations of the DPPP Working Group discussed above.

Engineering Analysis

The goal of the engineering analysis is to quantify the relationship between improvements in equipment efficiency and incremental manufacturer production costs. In other words, our goal is to understand how the design of different pumps would change if efficiency improvements were required to meet mandatory energy conservation standards, and to understand how those changes would affect your manufacturing costs. To accomplish this, DOE first seeks to understand how manufacturers would approach the task of improving equipment efficiency. Once the efficiency improvement approach is understood, DOE seeks to understand the impacts on production costs. DOE often conducts the cost side of this analysis by combining two approaches: (1) a top-down approach, where DOE solicits manufacturer input regarding total manufacturing costs of specific units, and (2) a bottom-up approach, where DOE estimates manufacturing costs based on the cost of materials and value-adding processes. To inform this analysis, the following sections will ask about the designs and costs of different pump varieties.

12A.2 BASELINE DESIGN AND DESIGN OPTIONS

When DOE considers energy conservation standards for equipment, it first defines "baseline" models that represent the lowest efficiency (WEF) observed in the market for different equipment varieties. In this case, DOE will look at different pool pump varieties and sizes (based on horsepower). The baseline level is the reference to which the impacts and costs of different efficiency improvements are compared.

After establishing the baseline, DOE researches and evaluates all "design options" that can be used to improve the efficiency (in this case, WEF) above the "baseline" model. DOE then combines the most cost-effective design options to establish what are known as "efficiency levels." DOE performs economic analyses for each efficiency level and compares these results to the baseline, to evaluate the economic feasibility of each level. Ultimately, DOE (or in this case, the ASRAC working group) may select certain efficiency levels to serve as energy conservation standards for certain equipment varieties.

At this time, DOE has not yet established formal design options or efficiency levels. However, DOE's research indicates that the following preliminary design options may be used by manufacturers to improve the WEF of a baseline model. These design options will be discussed, in-detail, throughout this interview guide.

- Adding reduced motor-speed capability; e.g., switching to a dual-, multi-, or variable-speed motor
- Improvements in motor efficiency
- Improvements in hydraulic (pump) efficiency, including:
    - Improvements to hydraulic design
    - Reductions in parasitic losses (i.e., bearings, seals, etc.)

2.1 The consultant team's research suggests the following characteristics for baseline (lowest efficiency) self-priming and non-self-priming pool filter pumps, waterfall pumps, and pressure cleaner booster pumps. Please indicate whether you think these are accurate characteristics of baseline models, and if there are any other efficiency-related characteristics that we should consider.

Table 2-1 Characteristics of Baseline Model Pool Pumps

Characteristics of Baseline Model		Manufacturer Comments
Motor Speed	Single-Speed • Capacitor-Start Capacitor-Run(CSCR), or • Permanent Split Capacitor (PSC)	
Motor Efficiency	Lowest available	
Hydraulic Efficiency	• Less efficient hydraulic design • Less efficient bearings and seals	
(other – please specify)		

2.2 As previously discussed, DOE has identified three possible routes to improve WEF. These design options, along with illustrative examples, are presented in Table 2-2. Please comment on these design options. Are these options effective ways to improve energy efficiency, given the current market of available products? What are the limitations of using these options? Which design options do you use in your product lines? Are there any additional design options that you use to increase wire-to-water efficiency?

Table 2-2 Design Options for All Pool Pump Varieties

Design Option	Example	Manufacturer Comments
Increase number of motor speeds	This could involve switching to a two-speed, multi-speed, or variable-speed motor.	
Improve the motor efficiency	This could involve selecting a higher efficiency motor.	
Improve the pump hydraulic efficiency	Improve the hydraulic design • This could involve a hydraulic redesign and optimization of the volute and impeller flow paths. Reduce parasitic losses • This could involve the use of low-friction bearings and seals, or other improvements to internal components.	
(other – please specify)		

2.3 What are your primary constraints when designing more efficient equipment (e.g. safety issues, cost, or durability)?

2.4 Is the pool pump market moving towards a particular size (horsepower) or motor configuration?

2.5 Several questions specific to two-speed and multi-speed pool filter pumps are below:

(A) It appears that many previously-listed two-speed pool filter pumps have been taken off the market in the past 5-10 years. Are two-speed pool filter pumps being retired more quickly than other varieties? If so, why?

(B) What portion of the two-speed pool filter pumps on the market now are shipped with any kind of controls, such as an internal SPDT switch, an external toggle switch, or an integrated timer? (We estimate that 50% of two-speed pump models on the market are sold with some kind of controls. Is that accurate?)

(C) Considering the two-speed pool filter pumps sold with controls, what controls are used and in what proportions? Please provide feedback in Table 2-3.

Table 2-3 Controls Shipped with two-speed Pumps

Type of controls	**Estimated proportion of pumps sold with controls**	**Manufacturer Feedback**
SPDT switch inside pump	10%	
Toggle switch attached to pump	30%	
Timer integrated in pump	60%	
Other (please describe)		

(D) What is the incremental cost to pump manufacturers of purchasing a two-speed motor with an integrated timer compared to a two-speed motor with no controls? (This is a timer that switches between low speed and high speed at an interval that is programmed by the installer. We estimate the cost to manufacturers is $15.)

12A.3 COST VS. EFFICIENCY RELATIONSHIP

After defining the baseline configuration and available design options, DOE quantifies the costs and benefits of improving the equipment efficiencies above this baseline. For Dedicated Purpose Pool Pumps, the working group has recommended the use of WEF as the formal efficiency metric. However, within this interview guide the consultant team will typically ask for efficiency improvement in terms of more basic parameters, such as hydraulic (pump) efficiency, motor efficiency, and wire-to-water (total) efficiency. Ultimately, the consultant team can use these basic efficiency parameters to investigate impacts on WEF.

3.1 We would like to understand the specific cost and efficiency impacts of different motor sizes and types that are typically used in DPPPs. Table 3-1 lists the different motor types and sizes that we have observed in DPPP models on the market. Please complete Table 3-1 by providing the typical purchase costs and efficiencies of the different motors, and by providing the model number(s) of the motor(s) you purchase with these characteristics. For purchase costs, we are asking for the delivered price at the shipping dock of your facility, inclusive of all processing and shipping costs. If you purchase several motor models within one category, please provide a weighted average of the price and efficiency, with weights based on the volumes at which you purchase each model.

If you have a motor price list available, please attach a copy of it to this interview guide.

Table 3-1 Baseline and Increment Cost and Efficiency of Motors

		Purchase Costs ($) [Consultant Estimates are in Brackets – Please Enter Your Data Below the Estimates]				**Typical Motor Efficiency [Consultant Estimates are in Brackets – Please Enter Your Data Below the Estimates]**				**Associated Motor Model Number**			
	Total HP	**1-hp**	**2-hp**	**3½-4-hp**	**5-hp**	**1-hp**	**2-hp**	**3½-4-hp**	**5-hp**	**1-hp**	**2-hp**	**3½-4-hp**	**5-hp**
Single Speed PSC	Lowest Efficiency (Baseline Config.)	[REDACTED]				[51%]	[67%]	[74%]					
	Medium Efficiency												
	Highest Efficiency												
Single Speed CSCR	Lowest Efficiency	[REDACTED]				[63%]	[69%]	[75%]					
	Medium Efficiency												
	Highest Efficiency												
Two-Speed PSC (without controller or timer)	Lowest Efficiency	[REDACTED]				[61%]	[73%]	[75%]					
	Medium Efficiency												
	Highest Efficiency												
Variable Speed ECM/ PMM	Lowest Efficiency	[REDACTED]				[80%]	[80%]	[80%]					
	Medium Efficiency												
	Highest Efficiency												
3-Phase Induction, without VFD	Lowest Efficiency			[REDACTED]				[85%]	[86%]				
	Medium Efficiency												
	Highest Efficiency												

3.2 Are there any changes in assembly or packaging costs (labor and/or materials) that might result when using two-speed or variable speed motors, as compared to single speed motors?

3.3 Preliminary research indicates that most plastic pump parts (including volutes, impellers, casing, pipe adapters, etc.) are typically made in-house in a variety of injection-molding machines. Please indicate what parts you typically make in-house versus those that are made by outside vendors.

Parts Fabricated In-House:	Parts Sourced from Outside Vendors:

3.4 We would like to understand the cost and efficiencies of the different bare pumps that are typically used in DPPPs. This will help us to determine the potential efficiency improvements that can be achieved, independent of the motor type. Table 3-2 lists the types of pumps that we have observed in DPPP models on the market. Please complete Table 3-2 by providing the typical manufacturing costs and hydraulic efficiencies of the different bare pumps, and by providing the model number(s) or SKU(s) associated with each category of equipment you produce. For manufacturing costs, please include direct labor, direct materials, and overhead (which includes depreciation costs). If you produce several bare pumps in the same category on the table, please provide a weighted average of the price and efficiency, with weights based on the volumes at which you produce each model.

Table 3-2 Baseline and Increment Cost and Efficiency for Bare Pumps

	Total HP	**1-hp**	**2-hp**	**3½ - 4-hp**	**1-hp**	**2-hp**	**3½ - 4-hp**	**1-hp**	**2-hp**	**3½ - 4-hp**
		Total Bare Pump Manufacturing Cost ($) [Consultant Estimates are in Brackets – Please Enter Your Data Below the Estimates]			**Typical Hydraulic Efficiency on Curve-C at Max Speed [Consultant Estimates are in Brackets – Please Enter Your Data Below the Estimates]**			**Associated Model Name, Model Number, or SKU**		
Self-Priming Pool Filter Pump	Lowest Efficiency	[REDACTED]			[39%]	[52%]	[60%]			
	Medium Efficiency									
	Highest Efficiency									
Non-Self - Priming Pool Filter Pump	Lowest Efficiency									
	Medium Efficiency									
	Highest Efficiency									
Waterfall Pumps	Lowest Efficiency									
	Medium Efficiency									
	Highest Efficiency									
Pressure Cleaner Booster Pump										

3.5 We would like to understand the manufacturer production costs and wire-to-water efficiencies of your completed pump equipment. DOE defines manufacturer production cost (MPC) as all direct costs associated with manufacturing a product. It includes direct labor, direct materials, and overhead (which includes depreciation costs). The per unit production costs are necessary for DOE to estimate labor expenditures and other cash flow calculations. Please complete Table 3-3 through Table 3-6 below by providing the typical MPCs and wire-to-water efficiencies of your different pump products, and by providing the model name(s) or SKUs of the products you make in each category. If you produce several models within one category, please provide a weighted average of the MPC and efficiency, with weights based on the volumes at which you produce each model.

Table 3-3 Baseline and Incremental Cost and Efficiency for Complete Pumps– Self Priming Pool Filter Pumps

		Total MPC ($)				Wire-to-Water Efficiency on Curve-C at Max Speed[1] (%)				Associated Model Name, Model Number, or SKU			
Motor Type and Pump Performance		**1-hp[2]**	**2-hp**	**3½-4-hp**	**5-hp**	**1-hp**	**2-hp**	**3½-4-hp**	**5-hp**	**1-hp**	**2-hp**	**3½-4-hp**	**5-hp**
Single Speed PSC or CSCR	Lowest Efficiency (Baseline)												
	Highest Efficiency												
Two-Speed PSC (without controller or timer)	Lowest Efficiency												
	Highest Efficiency												
Variable Speed ECM/PMM	Lowest Efficiency												
	Highest Efficiency												
3-Phase Induction, no Variable Freq. Drive	Lowest Efficiency												
	Highest Efficiency												

[1] If wire-to-water efficiency data on Curve C is not available, please provide wire-to-water efficiency data on Curve A and note that you provided Curve A data.

[2] All horsepower ("hp") listed on this table refer to Total Horsepower.

Table 3-4 Baseline and Incremental Cost and Efficiency for Complete Pumps– Non-Self-Priming Pool Filter Pumps

		Total MPC ($)				**Wire-to-Water Efficiency on Curve-C at Max Speed[3] (%)**				**Associated Model Name, Model Number, or SKU**			
Motor Type and Pump Performance		**1-hp[4]**	**2-hp**	**3½-4-hp**	**5-hp**	**1-hp**	**2-hp**	**3½-4-hp**	**5-hp**	**1-hp**	**2-hp**	**3½-4-hp**	**5-hp**
Single Speed PSC or CSCR	Lowest Efficiency (Baseline)												
	Highest Efficiency												
Two-Speed PSC (without controller or timer)	Lowest Efficiency												
	Highest Efficiency												
Variable Speed ECM/PMM	Lowest Efficiency												
	Highest Efficiency												
3-Phase Induction, no Variable Freq. Drive	Lowest Efficiency												
	Highest Efficiency												

[3] If wire-to-water efficiency data on Curve C is not available, please provide wire-to-water efficiency data on Curve A and note that you provided Curve A data.
[4] All horsepower ("hp") listed on this table refer to Total Horsepower.

Table 3-5 Baseline and Incremental Cost and Efficiency for Complete Pumps– Waterfall Pumps

		1 Total Horsepower Waterfall Pump		
Motor Type and Pump Performance		**Total MPC ($)**	**Wire-to-Water Efficiency on Curve-C[5] at Max Speed**	**Associated Model Name, Number, or SKU**
Single Speed PSC or CSCR	Lowest Efficiency (Baseline)			
	Highest Efficiency			
Two-Speed PSC (without controller or timer)	Lowest Efficiency			
	Highest Efficiency			
Variable Speed ECM/PMM	Lowest Efficiency			
	Highest Efficiency			

Table 3-6 Baseline Cost and Efficiency for Complete Pumps– Pressure Cleaner Booster Pumps

	1 Total Horsepower PCBP		
Motor Type and Pump Performance	**Total MPC ($)**	**Wire-to-Water Efficiency on Curve-C[5] at Max Speed**	**Associated Model Name, Number, or SKU**
Single Speed PSC or CSCR			

[5] If wire-to-water efficiency data on Curve C is not available, please provide wire-to-water efficiency data on Curve A and note that you provided Curve A data.

3.6 For their economics analyses, DOE requires MPC to be broken out into Materials, Labor, Overhead, and Depreciation. Having an accurate estimate of the production costs for the industry allows DOE to better examine impacts to profitability and employment due that might occur due to potential energy conservation standards. Please provide your manufacturer production cost percentages[6] for baseline pump models (i.e., single speed, low efficiency) in Table 3-7 below.

Table 3-7 Breakdown of Manufacturer Production Costs for Baseline Pumps, Percent of Total COGS

Components of Manufacturer Production Costs	Baseline Self-Priming Pool Filter Pumps	Baseline Non-Self-Priming Pool Filter Pumps	Baseline Waterfall Pumps	Baseline Pressure Cleaner Booster Pumps
Materials				
Labor				
Overhead				
Depreciation				

[6] The manufacturer production cost percentages shown in Table 3-7 are the values that make up COGS. These are percentages of total COGS.

12A.4 INTEGRAL CARTRIDGE PUMPS AND INTEGRAL SAND FILTER PUMPS

4.1 The ASRAC working group has recommended analysis of a prescriptive design-based standard for **integral cartridge filter pumps** and **integral sand filter pumps**. The design-based standard could require manufacturers to ship a programmable timer with these pump varieties or to integrate a programmable timer into these pump varieties. If your company manufactures either of these pump varieties, please comment in Table 4-1 and Table 4-2 on the characteristics of a baseline model and the costs of adding or integrating a timer into the baseline model.

Table 4-1 Baseline Cost and Integrated Timer Cost for Integrated Sand Filter Pumps

Pump Characteristics and Costs	**Nameplate Motor Horsepower**	
	1/10-hp	**1/4-hp**
Total wire-to-water efficiency of a baseline model		
Manufacturing Production Cost (MPC) per unit of a baseline integrated sand filter pump without a timer ($)		
Proportion of your shipments of integrated sand filter pumps that already include a programmable timer (%)		
Incremental manufacturing cost per Unit (Additional $) for a …		
Programmable timer shipped with (but not integrated into) the pump		
Programmable timer integrated into the pump		

Table 4-2 Baseline Cost and Integrated Timer Cost for Integrated Cartridge Filter Pumps

Pump Characteristics and Costs	**Nameplate Motor Horsepower**	
	1/15-hp	**1/2-hp**
Total wire-to-water efficiency of a baseline model		
Manufacturing Production Cost (MPC) per unit of a baseline integrated cartridge filter pump without a timer ($)		
Proportion of your shipments of integrated cartridge filter pumps that already include a programmable timer (%)		
Incremental manufacturing cost per Unit (Additional $) for a …		
Programmable timer shipped with (but not integrated into) the pump		
Programmable timer integrated into the pump		

12A.5 PUMP PERFORMANCE DATA REQUEST

Currently, the consultant team has very little performance data for Non-Self-Priming Pool Filter Pumps, Waterfall Pumps, and Pressure Cleaner Booster Pumps. Such data is essential, if the team is to establish efficiency levels and properly conduct the rulemaking analyses.

5.1 Please attach any available performance data for Non-Self-Priming Pool Filter Pumps, Waterfall Pumps, and Pressure Cleaner Booster Pumps that you manufacture.

12A.6 NON-SELF-PRIMING POOL FILTER PUMPS

The consultant team understands that self-priming pumps are typically less efficient (hydraulically) than their non-self-priming analogue. The team is interested in quantifying this difference in efficiency.

6.1 Please attach any available literature or test data relevant to the differences in hydraulic efficiency between self-priming and non-self-priming pool filter pumps.

12A.7 PART LOAD / REDUCED SPEED HYDRAULIC (PUMP) AND MOTOR EFFICIENCY

The consultant team is interested in better understanding the following relationships for pool filter pumps equipped with a variable speed ECM:

(a) Hydraulic efficiency vs. rotational speed
(b) Motor efficiency vs. rotational speed

7.1 To help the consultant team better understand these relationships, we request any readily available test data pertaining to these relationships. Specifically, we are interested in data structured in a format similar to the sample table supplied below. However, all forms of data are appreciated.

Pump Model Number:		XYZ		
Motor Model Number		ABC		
Motor Nameplate Efficiency		90%		
Speed (RPM)	Flow (GPM)	Head (Feet)	Hydraulic Efficiency (%)	Motor Efficiency
3500				
3000				
2500				
2000				
1500				
1000				

7.2 We are also interested in any standalone ECM torque-speed-efficiency curves that you may have available.

Market, Shipments, and Economics

DOE conducts energy use and economic analyses to determine whether potential efficiency levels would save energy and be economically justified. In order to conduct these analyses, DOE requires market information related to shipments, distribution channels, lifetime, and additional economic parameters.

12A.8 SHIPMENTS AND DISTRIBUTION

8.1 Please provide information on your company's shipments (# of units shipped) over the last five years as well as what percentage of the total market for each equipment variety your company's shipments represent. Please use the columns on the right to indicate the percent of equipment that is purchased complete from other manufacturers for resale under your own brand name, as well as the percent of all shipments that are manufactured in the United States.

Table 8-1 Shipment Information (total units shipped)

Equipment Variety	2010	2011	2012	2013	2014	Estimated US Market Share (% of U.S. Market)	% Private Label*	% Manufactured in U.S.**
Self-Priming Pool Filter Pump								
Non-Self-Priming Pool Filter Pump								
Waterfall Pump								
Pressure Cleaner Booster Pump								
Integral Sand-Filter Pool Pump								
Integral Cartridge-Filter Pool Pump								

* Please provide the percentage of your shipments (by units sold), that are purchased complete from other manufacturers for resale under your own brand name. Please use the percentage from the most recent year's data.
** Please provide the percentage of your shipments (by units sold), that are manufactured in a factory residing in the United States. Please use the percentage from the most recent year's data.

8.2 Please provide, for an average year, the breakdown of shipments by total HP, in the table below, where total HP = nameplate HP * service factor.
If this information is not available, does the breakdown of model availability by HP (as indicated by publically available databases) serve as a reasonable proxy for the breakdown of shipments? If not, how might it differ?

Table 8-2 Shipment Breakdown by HP (%)

Equipment Variety	0.5	0.75	1	1.5	2	3	>3	TOTAL
Self-Priming Pool Filter Pump								100%
Non-Self-Priming Pool Filter Pump								100%
Waterfall Pump								100%
Pressure Cleaner Booster Pump								100%

8.3 Are shipments by HP related to sector? In other words, are pumps >3 HP (or any other size) more likely to be shipped to commercial than residential customers?

8.4 Are shipments by horsepower related to pool volume? I.e., are larger horsepower models typically installed in pools of greater volume? Are smaller horsepower models typically installed in pools of smaller volume? If no, please elaborate?

8.5 Do you have any information on:

(A) The distribution of shipments by market (new construction versus replacement)?

(B) The distribution of shipments by region? [Here we are particularly interested in whether certain pump varieties are more typically sold in certain areas of the country than others.]

(C) The relationship, if any, of pressure cleaner booster pump shipments to filter pump shipments?

(D) The relationship, if any, of waterfall pump shipments to filter pump shipments?

8.6 What percentage of shipments in each equipment variety have the following characteristics:

Table 8-3 Shipment Breakdown by Motor and Efficiency Characteristics

Equipment Variety	Single-Speed, Low-Efficiency (Baseline)	Single-Speed, High Efficiency	Dual/Multi-Speed Low-Efficiency	Dual/Multi-Speed High-Efficiency	Variable-Speed Low Efficiency	Variable-Speed High Efficiency	TOTAL
Self-Priming Pool Filter Pump							100%
Non-Self-Priming Pool Filter Pump							100%
Waterfall Pump							100%
Pressure Cleaner Booster Pump							100%

If this information is not available, does the breakdown (distribution) of available models serve as a reasonable proxy for the breakdown (distribution) of shipments? If not, how might it differ?

8.7 How much change in shipments do you expect for each equipment variety during the next 5, 10, and 30 year periods?

Table 8-4 Expected Change in Shipments

Equipment Variety	**Expected Percent Change**		
	5 years	**10 years**	**30 years**
Self-Priming Pool Filter Pump			
Non-Self-Priming Pool Filter Pump			
Waterfall Pump			
Pressure Cleaner Booster Pump			
Integral Sand-Filter Pool Pump			
Integral Cartridge-Filter Pool Pump			

8.8 What are the primary drivers for expected changes in sales? Are these changes related to the new construction market or other economic indicators?

8.9 In the absence of federal standards on pool pumps, how would you expect efficiency to change over the next 5, 10, and 30 years compared to the breakdown in Table 8-3?

Table 8-5 Expected Change in Shipments

Equipment Variety	Expected Change in Efficiency		
	5 years	**10 years**	**30 years**
Example	*VSD/ECM sales increase by 5%; efficiency increases in single-speed pumps*	*Multi-speed pumps mostly out of market*	*X% of sales are with VSD/ECM*
Self-Priming Pool Filter Pump			
Non-Self-Priming Pool Filter Pump			
Waterfall Pump			
Pressure Cleaner Booster Pump			
Integral Sand-Filter Pool Pump			
Integral Cartridge-Filter Pool Pump			

8.10 If your company's manufacturer selling price increased by a given percent, what percentage change in sales (if any) would you expect to see for each equipment variety?

Table 8-6 Expected Change in Sales Based on Change in MSP

Equipment Variety	Change in Manufacturer Selling Price		
	10%	**25%**	**50%**
Self-Priming Pool Filter Pump			
Non-Self-Priming Pool Filter Pump			
Waterfall Pump			
Pressure Cleaner Booster Pump			

8.11 Alternatively, how would you expect your organization's total shipments to change given the energy conservation standard scenarios listed below:

Table 8-7 Expected Change in Sales for Difference Energy Conservation Standard Scenarios

Equipment Variety	Energy Conservation Standard Scenario:		
	Half of the single-speed pumps (the worst performing) are removed from the market.	All single-speed pumps are removed from the market	All single-and dual/multi- speed pumps are removed from the market
	Requires improved hydraulic efficiency, improved motor efficiency, or swap to dual- or variable-speed motor	*Requires swap to dual- or variable-speed motor*	*Requires swap variable-speed motor*
Self-Priming Pool Filter Pump			
Non-Self-Priming Pool Filter Pump			
Waterfall Pump			
Pressure Cleaner Booster Pump			

8.12 DOE understands there are two typical market channels: 1) the distributor model, and 2) the retail model. Please provide % of sales through each channel, or otherwise describe more appropriate channels with % of sales.

Table 8-8 Shipments by Distribution Channel

Distribution Channel	**% of Sales**
1) Distributor Model (Manufacturer → Distributor → Pool Service Contractor → Customer)	
2) Retail Model (Manufacturer → Retail Store → Customer)	
3) Other:	
4) Other:	
TOTAL	100%

12A.9 LIFETIME, INSTALLATION, MAINTENANCE, AND REPAIR

9.1 What are the minimum, maximum, and average lifetimes for the different varieties of DPPPs? What is the typical failure mode of each kind of pump?

Table 9-1 Lifetime and Failure Modes for DPPPs

Equipment Variety	**Min Lifetime (years)**	**Mean Lifetime (years)**	**Max Lifetime (years)**	**How many times will the motor typically be replaced over the lifetime of the pump?**
Self-Priming Pool Pump				
Non-Self-Priming Pool Pump				
Waterfall Pump				
Pressure Cleaner Booster Pump				
Integral Sand-Filter Pool Pump				

Integral Cartridge-Filter Pool Pump				

9.2 What is the primary cause of variation in lifetime? For example: climate, hours of operation, etc.?

9.3 What is the typical failure mode of a dedicated-purpose pool pump?

9.4 In what circumstances or failure modes are pumps typically repaired rather than replaced?

9.5 Does the lifetime, failure mode, or repair versus replacement practice vary by Total HP?

9.6 Does the lifetime, failure mode, or repair versus replacement practice vary by efficiency? For example, do variable speed pumps last longer or shorter than single-speed pumps? Do dual/multi-speed or variable speed motors fail more frequently than single-speed motors?

9.7 What is the approximate installation cost, yearly maintenance, and one-time repair costs for each equipment variety by motor type?

Table 9-2 Installation Costs

Equipment Variety	Pump with Single-Speed PSC or CSCR Motor	Pump with Two-Speed PSC Motor	Pump with a Variable-Speed Motor
Self-Priming Pool Filter Pump			
Non-Self-Priming Pool Filter Pump			
Waterfall Pump			
Pressure Cleaner Booster Pump			

(A) If the installation costs are different for different motor types, please explain why:

Table 9-3 Yearly Maintenance Costs

Equipment Variety	Pump with Single-Speed PSC or CSCR Motor	Pump with Two-Speed PSC Motor	Pump with a Variable-Speed Motor
Self-Priming Pool Filter Pump			
Non-Self-Priming Pool Filter Pump			
Waterfall Pump			
Pressure Cleaner Booster Pump			

(B) If the maintenance costs are different for different motor types, please explain why:

Table 9-4 One-Time Repair Costs

Equipment Variety	Pump with Single-Speed PSC or CSCR Motor	Pump with Two-Speed PSC Motor	Pump with a Variable-Speed Motor
Self-Priming Pool Filter Pump			
Non-Self-Priming Pool Filter Pump			
Waterfall Pump			
Pressure Cleaner Booster Pump			

(C) Please describe the type of repair represented by these costs:

(D) If the repair costs are different for different motor types, please explain why.

Manufacturer Impact Analysis

12A.10 KEY ISSUES

DOE is interested in understanding the impact of 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 (MIA).

10.1 In general, what are the key concerns for your company regarding this rulemaking for dedicated purpose pool pumps?

10.2 For the issues identified in 10.1, how do the issues apply to different pump varieties?

10.3 Please discuss the severity of the issues identified in 10.1, with respect to the follow three scenarios:

Scenario 1: A standard level that removes approximately half of the worst performing single-speed pool filter pumps from the market.

Scenario 2: A standard level that removes all single-speed pool filter pumps from the market.

Scenario 3: A standard level that removes all single- and two-speed pool filter pumps from the market.

12A.11 COMPANY OVERVIEW, ORGANIZATIONAL CHARACTERISTICS, AND REVENUES

DOE is interested in understanding manufacturer impacts at the plant or profit center level directly pertinent to DPPP production. However, the context surrounding plant operation and details of plant production and costs are not always readily available from public sources. DOE assesses the probable future of DPPP manufacturing activity with and without energy conservation standards.

11.1 Do you have a parent company and/or subsidiary? If so, please provide their name(s).

11.2 What percentage of your overall company revenue comes from pool pumps covered by this rulemaking?

11.3 Please provide information on your company's annual revenues, by pump variety, over the last five years.

Table 11-1 Pool Pumps – Annual Revenues by Equipment Variety ($)

Equipment Variety	2010	2011	2012	2013	2014
Self-Priming Pool Filter Pump					
Non-Self-Priming Pool Filter Pump					
Waterfall Pump					
Pressure Cleaner Booster Pump					
Integral Sand-Filter Pool Pump					
Integral Cartridge-Filter Pool Pump					

12A.12 MARKUPS AND PROFITABILITY

One of the primary objectives of the Manufacturer Impact Analysis is to assess the impact of energy conservation standards on industry profitability. In this section, DOE would like to understand the current markup structure of the industry and how setting energy conservation standards would impact your company's markup structure and profitability.

Manufacturer production costs include the direct materials, direct labor, production specific overhead, and depreciation of production related assets required to produce a given product. The manufacturer markup is a multiplier applied to manufacturer production costs to cover non-production costs, such as SG&A and R&D, as well as profit. *It does not reflect a profit margin.*

The manufacturer production cost times the manufacturer markup equals the manufacturer selling price. Manufacturer selling price is the price manufacturers charge their first customers, but *does not* include additional costs along the distribution channels.

Based on the Commercial and Industrial Pumps Rulemaking, DOE estimated a manufacturer markup of 1.35 to 1.46 for all DPPPs; this corresponds to a gross margin of 26% to 32% respectively.

12.1 Please estimate the <u>average industry markup</u> for pool pump equipment. In addition, please estimate the average markup within your organization. Provide your answers in the table below. If the industry markup differs from your organizations, please elaborate.

Table 12-1 Organization and Industry Markups

	Consultant Team Estimate	Estimate of Average Markup for the <u>Entire Industry</u>	Estimate of Average Markup for <u>Your Organization</u>
Average Markup For Pool Pump Equipment	1.35 – 1.46		

12.2 How are markups determined in this industry? How are markups determined within your organization?

12.3 Within your organization, do markups vary between pump varieties? If so, please provide an average markup for each pool pump variety.

Table 12-2 Markups by Pump Variety

	Self-Priming Pool Filter Pump	Non-Self-Priming Pool Filter Pump	Waterfall Pump	Pressure Booster Cleaner Pump	Integral Cartridge Filter Pump	Integral Sand Filter Pump
Average Markup						

12.4 Within each pump variety, does the manufacturer markup vary with efficiency? For instance, do you see higher or lower markups on more efficient models?

12.5 Would you expect new energy conservation standards to affect your markup structure? For instance, would you decrease your markups to keep prices down? Conversely, would you increase your markups to recover redesign costs and capital expenditures? If so, please explain why.

Please consider the following scenarios:

Scenario 1: A standard level that removes approximately half of the worst performing single-speed pool filter pumps from the market.

Scenario 2: A standard level that removes all single-speed pool filter pumps from the market.

Scenario 3: A standard level that removes all single- and two-speed pool filter pumps from the market.

12A.13 FINANCIAL PARAMETERS

Navigant Consulting, Inc. (NCI) is developing 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.

13.1 Please compare your company's financial parameters for pool pumps to the parameters estimated below.

Table 13-1 Financial Parameters for Pool Pump Equipment Manufacturers

GRIM Input	Definition	DOE Estimated Value	Your Actual
Income Tax Rate	Corporate effective income tax paid (percentage of earnings before taxes, EBT)	32.0%	
Discount Rate	Weighted average cost of capital (average of corporate cost of debt and return on equity plus inflation)	11.8%	
Working Capital	Current assets less current liabilities (percentage of revenues)	18.6%	
Net Property, Plant & Equipment	Fixed assets, or long-lived assets, including building, machinery, and equipment less accumulated depreciation (percentage of revenues)	15.0%	
SG&A	Selling, general, and administrative expenses (percentage of revenues)	21.6%	
R&D	Research and development expenses (percentage of revenues)	1.6%	
Depreciation	Amortization of fixed assets (percentage of revenues)	2.6%	
Capital Expenditures	Outlay of cash to acquire or improve capital assets (percentage of revenues, not including acquisition or sale of business units)	2.4%	

13.2 Are the figures in Table 13-1 representative of the industry as a whole? If not, why?

12A.14 CONVERSION COSTS

Energy conservation standards may cause the industry to incur capital and product conversion costs. With a detailed understanding of the conversion costs necessitated by different potential standard levels, DOE can better model the impact of energy conservation standards on the industry. The MIA considers three types of conversion expenditures:

- **Capital conversion costs**: One-time investments in plant, property, and equipment (PPE) necessitated by energy conservation standards. These may be incremental changes to existing PPE or the replacement of existing PPE. These include expenditures on buildings, equipment, and tooling.
- **Product conversion costs**: One-time investments in research, development, testing, marketing and other costs for redesigning equipment necessitated by energy conservation standards.
- **Stranded assets**: Assets replaced before the end of their useful lives as a direct result of the adoption of energy conservation standards.

14.1 How many unique models of pool pumps covered by this rulemaking do you offer? For the purposes of this question, a unique model is defined as a unique bare pump (wet end) and motor combination. Please specify model count by pump variety, below.

Table 14-1 Model Count by Pump Variety

	Self-Priming Pool Filter Pump	Non-Self-Priming Pool Filter Pump	Waterfall Pump	Pressure Booster Cleaner Pump	Integral Cartridge-Filter Pool Pump	Integral Sand-Filter Pool Pump
Model Count						

14.2 Are there any models or varieties of pool pump equipment that you expect will soon be phased out of production (in the absence of energy conservation standards)?

14.3 How do you plan to address low efficiency pool filter pump models (self-priming and non-self-priming) that do not meet a potential energy conservation standard? Please consider the following scenarios:

Scenario 1: A standard level that removes approximately half of the worst performing single-speed pool filter pumps from the market. For a failing model, would you:
(a) improve the hydraulically efficiency of the bare pump,
(b) improve the efficiency of the motor (but still use single speed),
(c) a combination of (a) and (b),
(d) switch to a two-speed motor,
(e) switch to a variable-speed motor, or
(f) drop the pump from production and replace it with an existing model?

Scenario 2: A standard level that removes all single-speed pool filter pumps from the market. For a failing model, would you:
(a) switch to a two-speed motor,
(b) switch to a variable-speed motor, or
(c) drop the pump from production and replace it with an existing model?

Scenario 3: A standard level that removes all single- and two-speed pool filter pumps from the market. For a failing model, would you:
(a) switch to a variable-speed motor, or
(b) drop the pump from production and replace it with an existing model?

14.4 Please discuss any new machinery, tooling, or production equipment that would be required for a pool pump that undergoes a redesign to improve hydraulic efficiency. Additionally, please discuss any existing machinery, tooling, or production equipment that may be rendered obsolete as a result of a hydraulic redesign.

14.5 Please discuss any new machinery, tooling, or production equipment that would be required for a pool pump that undergoes a motor redesign or swap. Additionally, please discuss any existing machinery, tooling, or production equipment that may be rendered obsolete as a result of a motor redesign or swap.

14.6 For each energy conservation and redesign scenario listed in Table 14-2, please provide estimates of the total capital and product conversion costs, as well as labor hours and descriptions of staff needed to complete the redesign. If for any scenario you expect to drop certain pump types from production, rather than invest in improving those models, please indicate as such – your costs for those pumps will be zero.

Table 14-2 Estimated Conversion Costs and Descriptions for Self-Priming Pool Filter Pumps

Energy Conservation Standard Scenario Description		Description of Redesign Choices (from question 14.3)	Total Capital Conversion Costs	Total Product Conversion Costs	Total Labor Hours (Engineering, Test, Marketing, etc)	Headcount and description of staff involved
1	A standard level that removes approximately half of the worst performing single-speed pool filter pumps from the market					
2	A standard level that removes all single-speed pool filter pumps from the market.					
3	A standard level that removes all single- and two-speed pool filter pumps from the market.					
4	A standard level that removes all single- and two-speed pool filter pumps from the market, and removes half of all variable speed pumps from the market.					

Table 14-3 Estimated Conversion Costs and Descriptions for Non-Self-Priming Pool Filter Pumps

Energy Conservation Standard Scenario Description		Description of Redesign Choices (from question 14.3)	Total Capital Conversion Costs	Total Product Conversion Costs	Total Labor Hours (Engineering, Test, Marketing, etc.)	Headcount and description of staff involved
1	A standard level that removes approximately half of the worst performing single-speed pool filter pumps from the market					
2	A standard level that removes all single-speed pool filter pumps from the market.					
3	A standard level that removes all single- and two-speed pool filter pumps from the market.					
4	A standard level that removes all single- and two-speed pool filter pumps from the market, and removes half of all variable speed pumps from the market.					

Table 14-4 Estimated Conversion Costs and Descriptions for Waterfall Pumps

Energy Conservation Standard Scenario Description		Description of Redesign Choices	Total Capital Conversion Costs	Total Product Conversion Costs	Total Labor Hours (Engineering, Test, Marketing, etc.)	Headcount and description and of staff involved
1	A standard level that removes approximately half of the worst performing single-speed (PSC or CSCR) waterfall pumps from the market					
2	A standard level that removes approximately all of the single-speed (PSC or CSCR) waterfall pumps from the market (and requires ECM levels of motor efficiency for compliance)					

Table 14-5 Estimated Conversion Costs and Descriptions for Pressure Booster Cleaner Pumps

Energy Conservation Standard Scenario Description		Description of Redesign Choices	Total Capital Conversion Costs	Total Product Conversion Costs	Total Labor Hours (Engineering, Test, Marketing, etc.)	Headcount and description and of staff involved
1	A standard level that removes approximately half of the worst performing single-speed (PSC or CSCR) PBCP pumps from the market					
2	A standard level that removes approximately all of the single-speed (PSC or CSCR) PCBP pumps from the market (and requires ECM levels of motor efficiency for compliance)					

14.7 Regarding the improvements to hydraulic efficiency—do the number of employees and the amount of time (and ultimately cost) vary by target hydraulic efficiency? I.e., does it take more hours and manpower to redesign to high efficiency, than it does to redesign to medium efficiency? If so, please elaborate.

14.8 What labeling is currently provided on the pool pump nameplate and how much does it cost to provide this information? How much would it cost to add additional fields/information to the pool pump nameplate? Please consider both recurring costs (which impact MPC), as well as any upfront investment or conversion costs.

14.9 A new energy conservation standard may require covered equipment to update all marketing and literature to display the "official" DOE energy conservation standard metric (in this case WEF). Please estimate the average cost to revise marketing and literature material for a single pump model or family. In addition, please estimate the total cost to your organization to revise all marketing materials to display the WEF metric.

12A.15 INDUSTRY STRUCTURE AND COMPETITION

15.1 How would you expect industry competition to change under the following energy conservation standard scenarios? Do you expect accelerated industry consolidation? Please describe your expectations.

Scenario 1: A standard level that removes approximately half of the worst performing single-speed pool filter pumps from the market.

Scenario 2: A standard level that removes all single-speed pool filter pumps from the market.

Scenario 3: A standard level that removes all single- and two-speed pool filter pumps from the market.

15.2 Would a new energy conservation standard affect your ability to compete? Would you expect your market share to change due to standards? Please consider this question with respect to the scenarios discussed in the previous question.

Scenario 1:

Scenario 2:

Scenario 3:

15.3 To your knowledge, are there any niche manufacturers for which the adoption of energy conservation standards would have a particularly severe impact? Please consider this question with respect to the scenarios discussed in the previous questions.

Scenario 1:

Scenario 2:

Scenario 3:

15.4 If energy conservation standards were adopted, would you anticipate any component or tooling constraints? (For instance, if many manufacturers are purchasing components or retooling at the same time as one another)? Please consider this question with respect to the scenarios discussed in the previous questions.

Scenario 1:

Scenario 2:

Scenario 3:

15.5 For any design changes that would require new production equipment, please describe how much downtime would be required. What impact would downtime have on your business? Are there any design changes that could not be implemented before the compliance date of the final rule for certain pump varieties?

15.6 What percentage of your DPPPs sold within the United States are manufactured domestically?

12A.16 DIRECT EMPLOYMENT IMPACT ASSESSMENT

The impact of 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 DPPP employment and solicit manufacturer views on how domestic employment patterns might be affected by energy conservation standards.

16.1 Where are your DPPP manufacturing facilities that produce products for the United States located? What varieties of pumps are manufactured at each location? Please provide annual shipment figures for your company's DPPP manufacturing at each location by product class. Please also provide employment levels at each of these facilities.

Table 16-1: Pool Pump Manufacturing Facilities

Location	Equipment	Employees (Production)	Employees (Non-production)	Units/Year Produced
Ex: Memphis, TN	*Self-Priming Pool Pump*	*75*	*25*	*10,000*

16.2 Would your domestic employment levels be expected to change significantly if energy conservation standards are required? If so, please explain how and why they would change if a more stringent standard were adopted for pool pumps. Please consider the following scenarios:

Scenario 1: A standard level that removes approximately half of the worst performing single-speed pool filter pumps from the market.

Scenario 2: A standard level that removes all single-speed pool filter pumps from the market.

Scenario 3: A standard level that removes all single- and two-speed pool filter pumps from the market.

16.3 Would the workforce skills necessary under new energy conservation standards require extensive retraining or replacement of employees at your manufacturing facilities? Please consider this question with respect to the scenarios discussed in the previous question.

Scenario 1:

Scenario 2:

Scenario 3:

16.4 Would energy conservation standards impact your domestic vs. foreign manufacturing or sourcing decisions for pool pumps? Are there design options that would cause you to move existing domestic production facilities outside the U.S. for pool pumps? Please consider this question with respect to the scenarios discussed in the previous questions.

Scenario 1:

Scenario 2:

Scenario 3:

16.5 Would pool pump energy conservation standards require extensive retraining of your service/field technicians? If so, could you expand on how your service infrastructure would be impacted in general as a result of energy conservation standards for pool pumps? Please consider this question with respect to the scenarios discussed in the previous questions.

Scenario 1:

Scenario 2:

Scenario 3:

12A.17 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 equipment or industry.

17.1 Below is a list of regulations that could affect manufacturers of pool pumps. Please provide any comments on the listed regulations and provide an estimate for your expected compliance cost. Are there other recent or impending standards that manufacturers of pool pump equipment face from DOE or other U.S. federal agencies?

Table 17-1: Other Regulations Identified

Regulation	Approx. Compliance Date	Expected Expenses / Comments
Commercial and Industrial Pumps	2020	
Pool Heaters	2019*	
State Regulations (AZ, CT, FL, NY, WA)		
Others		
Others		

*Estimated compliance date

17.2 Under what circumstances would you be able to coordinate expenditures related to these other regulations with these energy conservation standards, thereby lessening the cumulative burden?

12A.18 IMPACTS ON SMALL BUSINESSES

18.1 The Small Business Association (SBA) denotes a small business in the pool pump manufacturing industry as having no more than 500 employees (NAICS category 333911: "Pump and Pumping Equipment Manufacturing."[7] By this definition, is your company considered a small business?

18.2 Below is a list of small business manufacturers of pool pumps 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 energy conservation standards than others?

- AquaPro Systems
- Asia Connection LLC
- Fluidra USA, LLC
- SNTech, Inc.
- Speck Pumps
- SpectraLight Technologies
- United Aqua Group / AQUATECH CORPORATION

[7] DOE uses the SBA small business size standards effective July 14, 2014, to determine whether a company is a small business. To be categorized as a small business, a manufacturer of pool pumps may employ a maximum of 500 employees. The 500-employee threshold includes all employees in a business's parent company and any other subsidiaries. Pool pump manufacturing activity falls in the North American Industry Classification System (NAICS) category 333911: Pump and Pumping Equipment Manufacturing.

18.3 Are there any reasons that a small business might be at a disadvantage relative to a larger business under energy conservation standards? If so, would small business manufacturers face different incremental impacts from energy conservation standards than the rest of the industry? Please consider such factors as technical expertise, access to capital, bulk purchasing power for materials/components, engineering resources, and any other relevant issues.

Please consider this question with respect to the following scenarios:

Scenario 1: A standard level that removes approximately half of the worst performing single-speed pool filter pumps from the market.

Scenario 2: A standard level that removes all single-speed pool filter pumps from the market.

Scenario 3: A standard level that removes all single- and two-speed pool filter pumps from the market.

18.4 To your knowledge, are there any small business manufacturers for which the adoption of energy conservation standards would have a particularly severe impact? Please consider this question with respect to the scenarios discussed in the previous question.

Scenario 1:

Scenario 2:

Scenario 3:

Test Procedures

The DOE test procedure for dedicated-purpose pool pumps must be repeatable and seek to minimize test variability, while not being unduly burdensome to conduct. Therefore, to inform further development and specification of the test procedure for dedicated-purpose pool pumps, the questions in this section will ask about existing test facilities, instrumentation, testing capability, and test protocols with respect to the requirements in HI 40.6-2014 and the recommendations of the DPPP Working Group discussed above. This helps DOE ascertain the source of variability in existing testing programs conducted by manufacturers and assess the burden associated with improving the test procedure to reduce uncertainty and increase precision.

12A.19 TEST PROCEDURES AND TEST EQUIPMENT

Test Protocol

19.1 When testing pool pumps, do you currently test to a particular test protocol (e.g. HI 1.6, HI 14.6, APSP 15, CA Title 20, ENERGY STAR, etc.)? If you do not reference an existing industry test protocol, please briefly describe any testing done on pool pumps to generate ratings.

19.2 Are there any additional instructions or modifications to your selected testing protocol that your testing personnel reference in order to conduct the test properly? If so, please provide them.

19.3 How long does it take to complete testing on a single pump unit, including setting up the pump in the 1. test stand, 2. stabilization, 3. conducting the test (recording data), and 4. disassembly? How much time is allocated to each of the previous four testing activities? Please provide your response in the table below.

Table 19-1 Breakdown of Time Required to Test One Pump

	1. Setup	2. Stabilization	3. Conducting the Test	4. Disassembly	Other (Please Specify)	Total
Time Required Per-Pump						

19.4 How much time is required to analyze the test data to produce ratings of EF, efficiency, or other metrics for each pump? Please indicate if the estimate is for each pump model, each pump unit, each pump model line (model family), or for all products.

19.5 In general, how much testing is performed to produce ratings provided in manufacturer literature? (i.e., is testing typically performed on each pump model? How many units of each model? How many different sizes of each model?)

19.6 Does your general test program vary based on pool pump variety? If so, please indicate in the table below.

Table 19-2 Variation in Testing by Equipment Variety

Equipment Variety	**Normal Test Program (More, same, or less than your answers to 19.1 – 19.5)**	**Difference, if any (*any additional tests or eliminated tests)***
Self-Priming Pool Filter Pump		
Non-Self-Priming Pool Filter Pump		
Waterfall Pump		
Pressure Cleaner Booster Pump		

19.7 Does your general test program vary based on efficiency or size of each pool pump model? If so, please describe how the testing of such pool pumps varies from the test program characterized in your responses to questions 19.1 and 19.2. If your test programs vary by efficiency or pool pump model size, please characterize these variations, as compared to your answer in question 19.3.

Testing Costs

19.8 Based on the test program described in your answers to questions 19.1 – 19.3, please describe the current cost of testing per unit. Please also specify the number of tests completed to yield reliable data. Similar to question 19.6, do these costs vary with pool pump variety? If so, please provide the cost per unit and number of tests to yield reliable results for the different pool pump varieties.

19.9 Do you expect the cost of pump testing to change as a result of mandatory test procedures and standards for dedicated-purpose pool pumps? If so, how?

19.10 How much does it currently cost to certify equipment with CA Title 20 and/or ENERGY STAR? Please specify if the value provided is per unit, per model, per model family, or for all products. Do you expect this value to change as a result of any potential energy conservation standards and, if so, how much?

19.11 Are there any other testing and certification costs not discussed above of which DOE should be aware? If so, please describe them.

Test Facility

19.12 Please describe the general equipment necessary to test pool pumps, including the size and cost of each item in the table below. If not available, please describe the total cost of a test facility capable of testing pool pumps in accordance with your responses to questions 19.1, 19.2, and 19.6.

Table 19-3 Test Equipment

Equipment	Type	Size/Range	Approx. Cost	Notes
Water Reservoir				
Water Conditioning Equipment (if necessary)				
Power Conditioning Equipment (if necessary)				
Piping and Associated Valves				
Pressure Measurement Equipment	Manometer			
	Bourdon tube			
	Digital indicator			
	Transducer			
Flow Measurement Equipment	Weighing or volumetric tank			
	Venturi meter			
	Nozzle			
	Orifice plate			
	Weir			
	Turbine			
	Magnetic flow			
	Rotometer			
	Propeller			
	Ultrasonic			
	Other:			

Table 19-3 Test Equipment (Continued)

Equipment	Type	Size/Range	Approx. Cost	Notes
Electrical Measurement Equipment	Dynomometer			
	Torque bar			
	Calibrated motor			
	Integrating watt-hour meter			
	Watt-amp-volt meter (portable)			
	Watt-amp-volt meter (permanent)			
	Other:			
Speed Measurement Equipment	Tachometer			
	Eddy current drag			
	Electronic			
	Frequency responsive device (e.g. vibrating reed, photocell, stroboscope)			
	Torque meter (speed)			
	Other			
Temperature Measurement Equipment				
Data Acquisition System				
Other:				
Other:				
Total				

19.13 Please indicate the recording frequency for each measurement and if the data is recorded manually or digitally.

Table 19-4 Data Recording Frequency

Equipment	Type	Manual or Digital Reading	If Digital		
			Sampling Interval	Recording Interval	Integrated or Instantaneous
Pressure Measurement Equipment	Manometer				
	Bourdon tube				
	Digital indicator				
	Transducer				
Flow Measurement Equipment	Weighing or volumetric tank				
	Venturi meter				
	Nozzle				
	Orifice plate				
	Weir				
	Turbine				
	Magnetic flow				
	Rotometer				
	Propeller				
	Ultrasonic				
	Other:				
Electrical Measurement Equipment	Dynomometer				
	Torque bar				
	Calibrated motor				
	Integrating watt-hour meter				
	Watt-amp-volt meter (portable)				
	Watt-amp-volt meter (permanent)				
	Other:				

Table 19-4 Data Recording Frequency (Continued)

Equipment	Type	Manual or Digital Reading	If Digital		
			Sampling Interval	Recording Interval	Integrated or Instantaneous
Speed Measurement Equipment	Tachometer				
	Eddy current drag				
	Electronic				
	Frequency responsive device (e.g. vibrating reed, photocell, stroboscope)				
	Torque meter (speed)				
	Other				
Temperature Measurement Equipment					
Data Acquisition System					
Other:					
Other:					

19.14 Please describe the accuracy of current testing equipment and calibration interval. Please specify if values are with respect to the measured value or full scale of the measuring equipment.

Table 19-5 Instrument Accuracy

Equipment	**Type**	**Instrument Accuracy** *(Please indicate if specified w.r.t. measured value or full-scale)*	**Calibration Interval**
Pressure Measurement Equipment	Manometer		
	Bourdon tube		
	Digital indicator		
	Transducer		
Flow Measurement Equipment	Weighing or volumetric tank		
	Venturi meter		
	Nozzle		
	Orifice plate		
	Weir		
	Turbine		
	Magnetic flow		
	Rotometer		
	Propeller		
	Ultrasonic		
	Other:		
Electrical Measurement Equipment	Dynomometer		
	Torque bar		
	Calibrated motor		
	Integrating watt-hour meter		
	Watt-amp-volt meter (portable)		
	Watt-amp-volt meter (permanent)		
	Other:		

Table 19-5 Instrument Accuracy (Continued)

Equipment	Type	Instrument Accuracy *(Please indicate if specified w.r.t. measured value or full-scale)*	Calibration Interval
Speed Measurement Equipment	Tachometer		
	Eddy current drag		
	Electronic		
	Frequency responsive device (e.g. vibrating reed, photocell, stroboscope)		
	Torque meter (speed)		
	Other		
Temperature Measurement Equipment			
Data Acquisition System			
Other:			
Other:			

If not available, please describe currently test equipment accuracy with respect to the instrument accuracy requirements specified in applicable industry test procedures, as listed in the following Table.

Table 19-6 Variation in Testing By Equipment Variety

Measured quantity	**HI 1.6 – 2000/APSP 15/CA Title 20**	**ENERGY STAR**	**Mfgr Equipment Accuracy**
Rate of flow	±1.5%	± 1.5%	
Differential head	±1.0%	± 1.0%	
Discharge head	±0.5%	± 1.0%	
Suction head	±0.5%	± 1.0%	
Driver power input	±1.5%	± 2.0% (for ≥0.5W) OR ± 0.01W (for < 0.5W)	
Speed of rotation	±0.3%	N.S.	
Torque	N.S.	N.S.	
Temperature	N.S.	N.S.	
Notes:	Table 1.6.5.4.2	Section 4.2	

APPENDIX 12B. GOVERNMENT REGULATORY IMPACT MODEL OVERVIEW

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APPENDIX 12B.GOVERNMENT REGULATORY IMPACT MODEL OVERVIEW

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 products with regulations taking effect over a period of time, and of multiple regulations on the same products.

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 no-standards case) and under different trial standard levels (TSLs) (*i.e.*, the standards cases).

Output from the model consists of summary financial metrics, graphs of major variables, and, when appropriate, access to the complete cash flow calculation.

12B.2 DEDICATED-PURPOSE POOL PUMP DESCRIPTION

DOE analyzed the impacts of standards on dedicated-purpose pool pumps. 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. The line items below are definitions of listed items on the printout of the output sheet (see section 12B.3).

1) ***Revenues:*** Annual revenues - computed by multiplying equipment's unit prices at each efficiency level by the appropriate manufacturer markup;

2) ***Total Shipments:*** The total covered units shipped;

3) ***Materials:*** 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 COGS that includes an allowance for the total amount of fixed assets used to produce that one unit;

6) ***Overhead:*** The portion of COGS that includes indirect labor, indirect material, energy use, maintenance, property taxes, and insurance related to assets;

7) ***Standard SG&A:*** Selling, general, and administrative costs are computed as a percentage of ***Revenues (1)***;

8) ***R&D:*** the GRIM separately accounts for ordinary research and development (R&D) as a percentage of ***Revenues (1)***;

9) ***Product Conversion Costs:*** Product conversion costs are investments in research, development, testing, marketing, and other costs focused on making product designs comply with new energy conservation standards. The GRIM allocates these costs over the period between the standards' 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) ***Per Unit EBIT:*** The average amount of ***EBIT (11)*** per covered unit shipped;

13) ***EBIT/Revenues: EBIT (11)*** as a percentage of sales to compare with the industry's average reported in financial statements;

14) ***Taxes:*** Taxes on ***EBIT (11)*** are calculated by multiplying the tax rate contained in the Financial Parameters tab by ***EBIT (11)***;

15) ***Net Operating Profits after Taxes (NOPAT):*** Computed by subtracting ***Taxes (14)*** from ***EBIT (11)***;

16) ***NOPAT repeated: NOPAT (15)*** is repeated in the Statement of Cash Flows;

17) ***Depreciation repeated: Depreciation (5)*** is added back in the Statement of Cash Flows because it is a non-cash expense;

18) ***Stranded Assets repeated: Stranded Assets (10)*** is added back in the Statement of Cash Flows because it is a non-cash expense;

19) ***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;

20) ***Cash Flow from Operations:*** Calculated by taking ***NOPAT (16)***, adding back non-cash items such as ***Depreciation (17)*** and ***Stranded Assets (18)***, and subtracting the ***Change in Working Capital (19)***;

21) ***Ordinary Capital Expenditures:*** Ordinary investments in property, plant, and equipment to maintain and replace existing production assets, computed as a percentage of ***Revenues (1)***;

22) ***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 amended

regulations; the GRIM allocates these costs over the period between the standards' announcement and compliance dates;

23) ***Free Cash Flow:*** Calculated by taking annual ***Cash Flow from Operations (20)*** and subtracting ***Ordinary Capital Expenditures (21)*** and ***Capital Conversion Costs (22)***;

24) Free Cash Flow repeated: Free Cash Flow (23) is repeated in the Discounted Cash Flow section;

25) ***Terminal Value:*** Estimate of the continuing value of the industry after the analysis period. Computed by growing the ***Free Cash Flow (24)*** at the beginning of 2050 at a constant rate in perpetuity;

26) ***Present Value Factor:*** Factor used to calculate an estimate of the present value of an amount to be received in the future;

27) ***Discounted Cash Flow: Free Cash Flow (23)*** multiplied by the ***Present Value Factor (26)***. For the end of 2050, the discounted cash flow includes the discounted ***Terminal Value (25)***; and

28) ***Industry Value through the end of 2050***: The sum of ***Discounted Cash Flows (27)***.

12B.3 DEDICATED-PURPOSE POOL PUMP DETAILED CASH FLOW EXAMPLE

		Ancmt Yr					Std Yr		
ndustry Income Statement (in 2015$ millions)	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Revenues	$ 325.6	$ 338.3	$ 351.5	$ 365.2	$ 379.4	$ 394.10	$ 409.4	$ 425.2	$ 441.6
Total Shipments *(million units)*	2.3	2.3	2.4	2.4	2.5	$ 2.6	$ 2.6	2.7	2.8
- Materials	$ 196.2	$ 204.3	$ 212.7	$ 221.3	$ 230.4	$ 239.72	$ 249.4	$ 259.5	$ 270.0
- Labor	$ 12.6	$ 12.9	$ 13.2	$ 13.6	$ 13.9	$ 14.24	$ 14.6	$ 15.0	$ 15.3
- Depreciation	$ 5.7	$ 5.9	$ 6.1	$ 6.4	$ 6.7	$ 6.92	$ 7.2	$ 7.5	$ 7.8
- Overhead	$ 15.7	$ 16.2	$ 16.6	$ 17.1	$ 17.6	$ 18.06	$ 18.6	$ 19.1	$ 19.6
- Standard SG&A	$ 60.8	$ 63.4	$ 66.0	$ 68.8	$ 71.6	$ 74.58	$ 77.7	$ 80.8	$ 84.2
- R&D	$ 5.0	$ 5.2	$ 5.4	$ 5.6	$ 5.9	$ 6.08	$ 6.3	$ 6.6	$ 6.8
- Product Conversion Costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
- Stranded Assets	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Earnings Before Interest and Taxes (EBIT)	$ 29.5	$ 30.5	$ 31.4	$ 32.4	$ 33.4	$ 34.49	$ 35.6	$ 36.7	$ 37.9
Per Unit EBIT *($/unit)*	$ 13.1	$ 13.1	$ 13.2	$ 13.3	$ 13.4	$ 13.48	$ 13.6	$ 13.7	$ 13.7
EBIT/Revenues (%)	*9.1%*	*9.0%*	*8.9%*	*8.9%*	*8.8%*	$ *0.09*	*8.7%*	*8.6%*	*8.6%*
- Taxes	$ 9.2	$ 9.5	$ 9.8	$ 10.1	$ 10.4	$ 10.72	$ 11.1	$ 11.4	$ 11.8
Net Operating Profit after Taxes (NOPAT)	**$ 20.4**	**$ 21.0**	**$ 21.7**	**$ 22.3**	**$ 23.0**	**$ 23.77**	**$ 24.5**	**$ 25.3**	**$ 26.1**
	1.408								

Cash Flow Statement									
NOPAT	$ 20.4	$ 21.0	$ 21.7	$ 22.3	$ 23.0	$ 23.77	$ 24.5	$ 25.3	$ 26.1
+ Depreciation	$ 5.7	$ 5.9	$ 6.1	$ 6.4	$ 6.7	$ 6.92	$ 7.2	$ 7.5	$ 7.8
+ Loss on Disposal of Stranded Assets	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
- Change in Working Capital	$ -	$ 2.2	$ 2.3	$ 2.41	$ 2.51	$ 2.60	$ 2.7	$ 2.8	$ 2.9
Cash Flows from Operations	$ 26.0	$ 24.7	$ 25.5	$ 26.32	$ 27.2	$ 28.09	$ 29.0	$ 30.0	$ 31.0
- Ordinary Capital Expenditures	$ 7.4	$ 7.7	$ 8.0	$ 8.3	$ 8.7	$ 9.02	$ 9.4	$ 9.8	$ 10.2
- Capital Conversion Costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Free Cash Flow	**$ 18.6**	**$ 17.0**	**$ 17.5**	**$ 18.0**	**$ 18.5**	**$ 19.08**	**$ 19.6**	**$ 20.2**	**$ 20.8**

Discounted Cash Flow									
Free Cash Flow	$ 18.6	$ 17.0	$ 17.5	$ 18.0	$ 18.5	$ 19.1	$ 19.6	$ 20.2	$ 20.8
Terminal Value	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Present Value Factor	*0.000*	*1.000*	*0.894*	*0.800*	*0.716*	*0.640*	*0.573*	*0.512*	*0.458*
Discounted Cash Flow	**$ -**	**$ 17.0**	**$ 15.6**	**$ 14.4**	**$ 13.3**	**$ 12.2**	**$ 11.2**	**$ 10.4**	**$ 9.5**

INPV at Baseline	**$ 212.8**

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 emissions and, if present, 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 potential standards on emissions of two additional greenhouse gases, methane (CH_4) and nitrous oxide (N_2O), as well as the impacts 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. The methodology is based on results published for the *Annual Energy Outlook 2016 (AEO 2016),* including a set of side cases that implement a variety of efficiency-related policies.[1] The methodology is described in appendix 13A to this TSD, and in the report "Utility Sector Impacts of Reduced Electricity Demand" (Coughlin, 2014).[4]

The emissions intensity factors are expressed in terms of physical units per MWh or MMBtu of site energy savings. Total emissions reductions are estimated by multiplying the emissions intensity factor by the energy savings calculated in the national impact analysis (chapter 10). The emissions factors used in the calculations are provided in appendix 13A. For power sector emissions, the factors depend on the sector and end use. The results presented here use factors from the power plant types that supply electricity for homes and commercial buildings.

13.2 AIR QUALITY REGULATIONS AND EMISSIONS IMPACTS

Each annual version of the Annual Energy Outlook (AEO) incorporates the projected impacts of existing air quality regulations on emissions. *AEO 2016* generally represents current Federal and State legislation and final implementation regulations in place as of the end of February 2016. DOE's estimation of impacts accounts for the presence of the emissions control programs discussed in the following paragraphs.

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 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.[a] 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.[d] *AEO2016* assumes implementation of CSAPR.

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 2016* 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 be far below the cap established by CSAPR, 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.

CSAPR established a cap on NO_x emissions in 28 eastern States and the District of Columbia.[e] Energy conservation standards are expected to have little effect on NO_x emissions in

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[a] See *EME Homer City Generation, LP v. EPA*, 696 F.3d 7, 38 (D.C. Cir. 2012).

[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).

[d] On July 28, 2015, the D.C. Circuit issued its opinion regarding CSAPR on remand from the Supreme Court. The court largely upheld CSAPR, but remanded to EPA without vacatur certain States' emission budgets for reconsideration. *EME Homer City Generation, LP v. EPA*, 795 F.3d 118 (D.C. Cir. 2015).

[e] CSAPR also applies to NO_X and it supersedes the regulation of NO_X under CAIR.

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 CSAPR, 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 marginal mercury emissions reductions using the reference and side cases published with *AEO 2016*, which incorporate the MATS.

DOE used the *AEO2016* No Clean Power Plan (CPP) case as a basis for developing emissions factors for the electric power sector.

13.3 EMISSIONS IMPACT RESULTS

Table 13.3.1 presents the estimated cumulative emissions reductions for the lifetime of products sold in 2021-2050 for each TSL. Negative values indicate that emissions increase.

Table 13.3.1 Cumulative Emissions Reduction for Potential Standards for Pool Pumps

	TSL				
	1	**2**	**TSL Rec**	**4**	**5**
Power Sector Emissions					
CO_2 (million metric tons)	40	152	192	205	233
SO_2 (thousand tons)	30	115	145	155	176
NO_X (thousand tons)	22	82	103	110	125
Hg (tons)	0.10	0.39	0.50	0.53	0.60
CH_4 (thousand tons)	4.2	16	20	22	25
N_2O (thousand tons)	0.61	2.3	2.9	3.1	3.5
Upstream Emissions					
CO_2 (million metric tons)	2.2	8.3	11	11	13
SO_2 (thousand tons)	0.26	0.99	1.2	1.3	1.5
NO_X (thousand tons)	32	122	154	165	188
Hg (tons)	0.00	0.00	0.00	0.00	0.00
CH_4 (thousand tons)	196	749	948	1,013	1,155
N_2O (thousand tons)	0.01	0.06	0.07	0.07	0.08
Total Emissions					
CO_2 (million metric tons)	42	160	202	216	246
SO_2 (thousand tons)	31	116	147	156	178
NO_X (thousand tons)	53	203	257	275	313
Hg (tons)	0.10	0.39	0.50	0.53	0.60
CH_4 (thousand tons)	200	765	968	1,035	1,179
N_2O (thousand tons)	0.62	2.3	3.0	3.2	3.6

Figure 13.3.1 through Figure 13.3.6 show the annual reductions for total emissions for each type of emission from each TSL. The reductions reflect the lifetime impacts of products sold in 2021-2050.

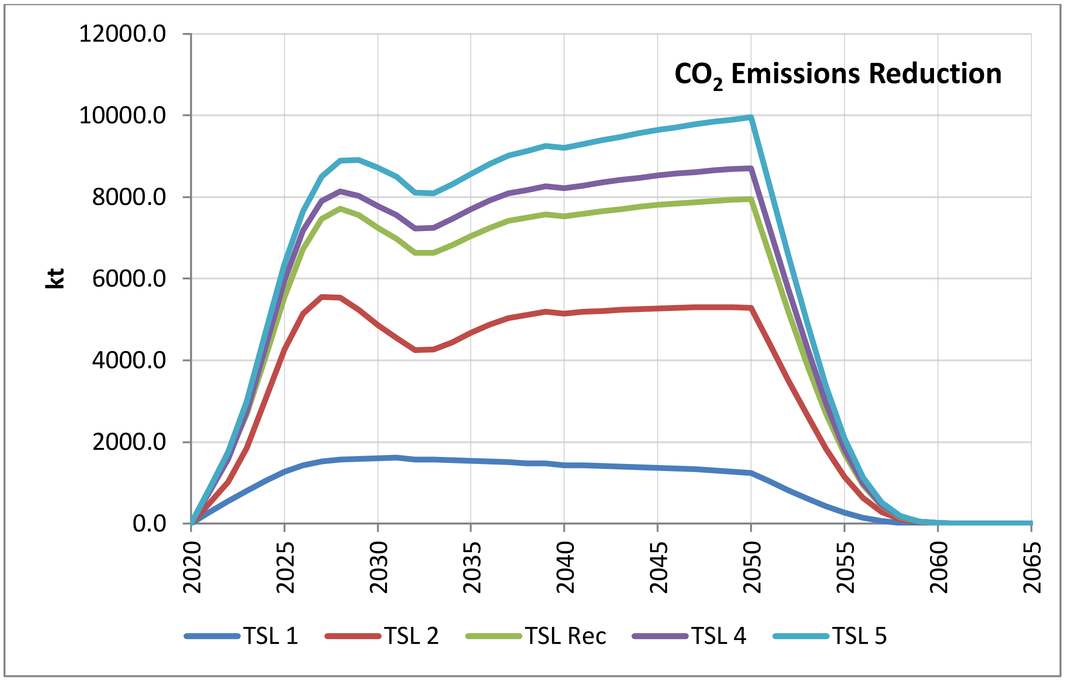

Figure 13.3.1 Pool Pumps: CO_2 Total Emissions Reduction

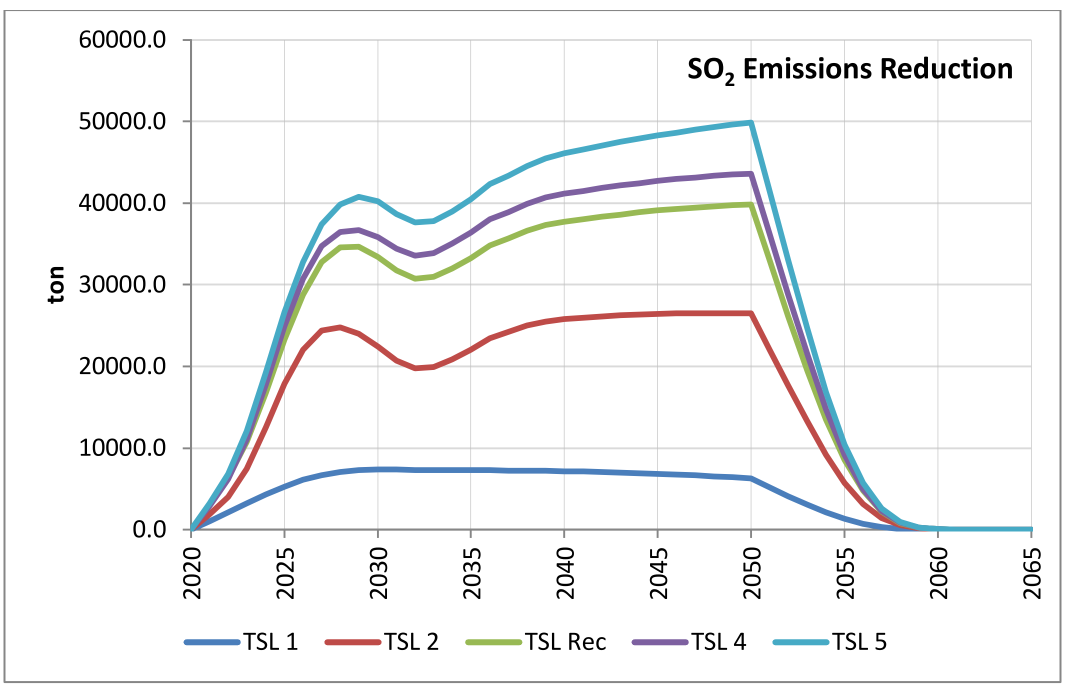

Figure 13.3.2 Pool Pumps: SO_2 Total Emissions Reduction

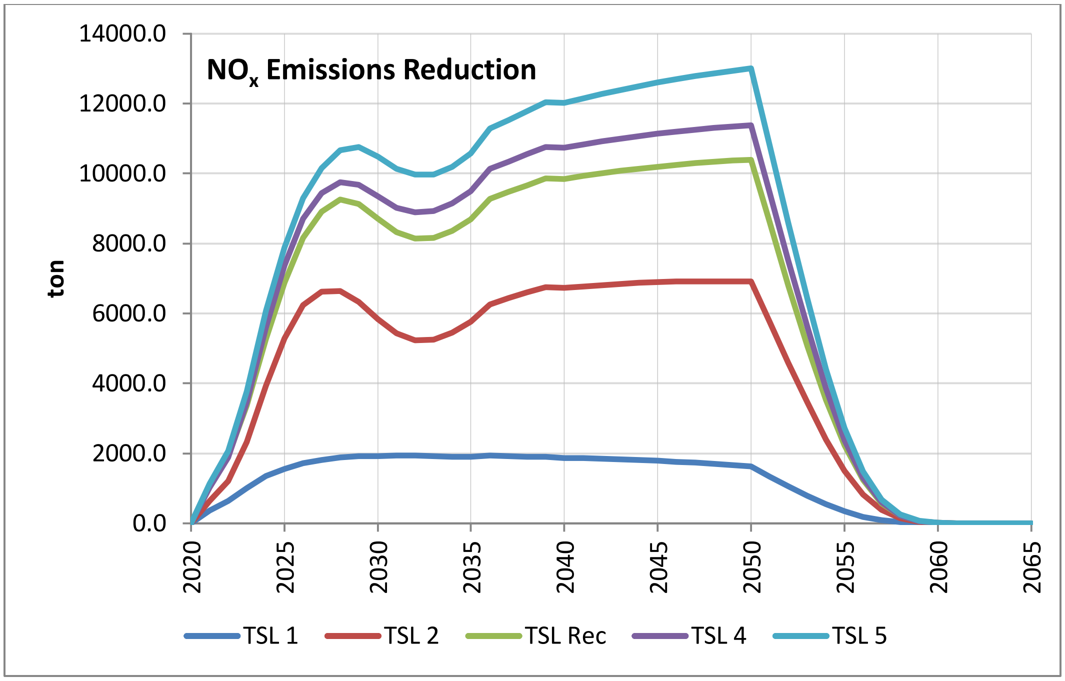

Figure 13.3.3 Pool Pumps: NO_x Total Emissions Reduction

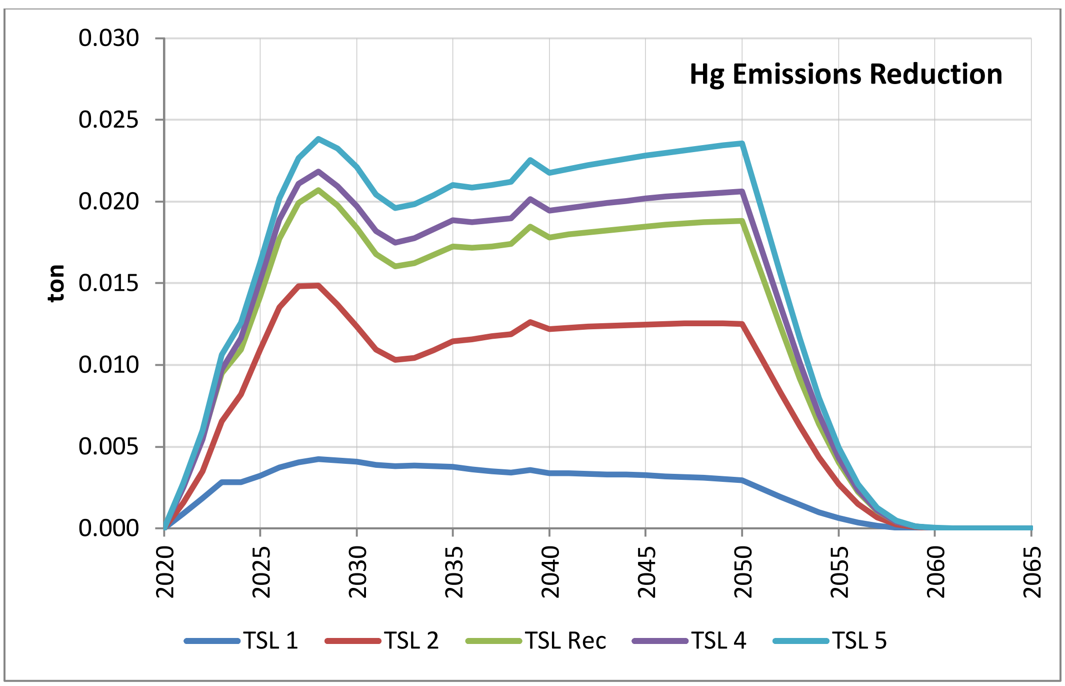

Figure 13.3.4 Pool Pumps: Hg Total Emissions Reduction

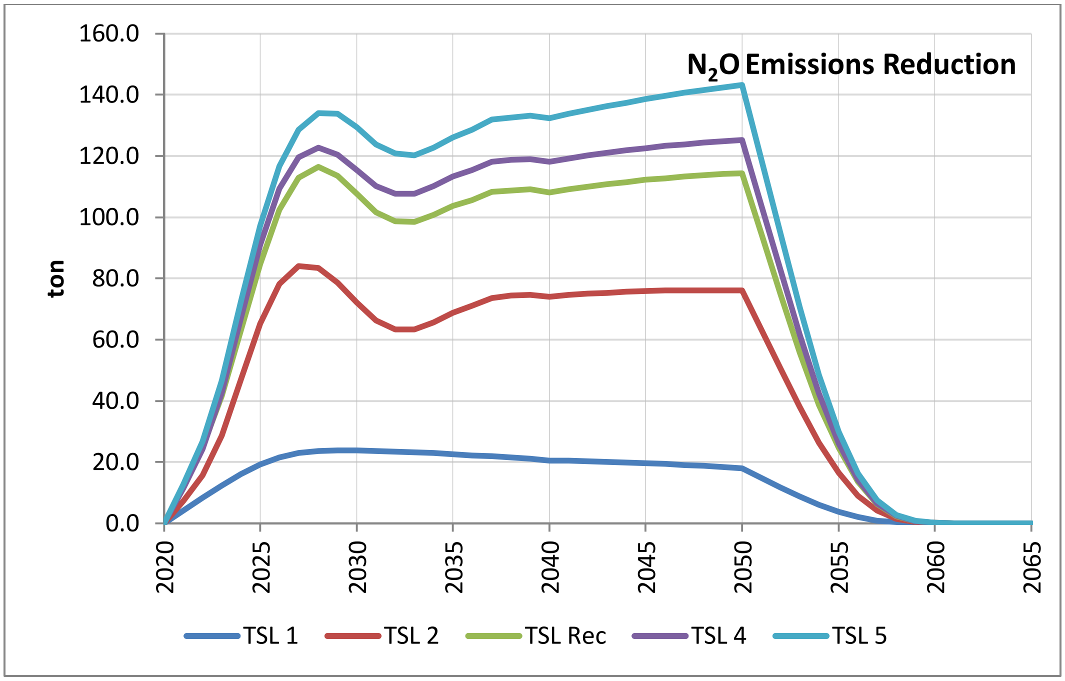

Figure 13.3.5 Pool Pumps: N_2O Total Emissions Reduction

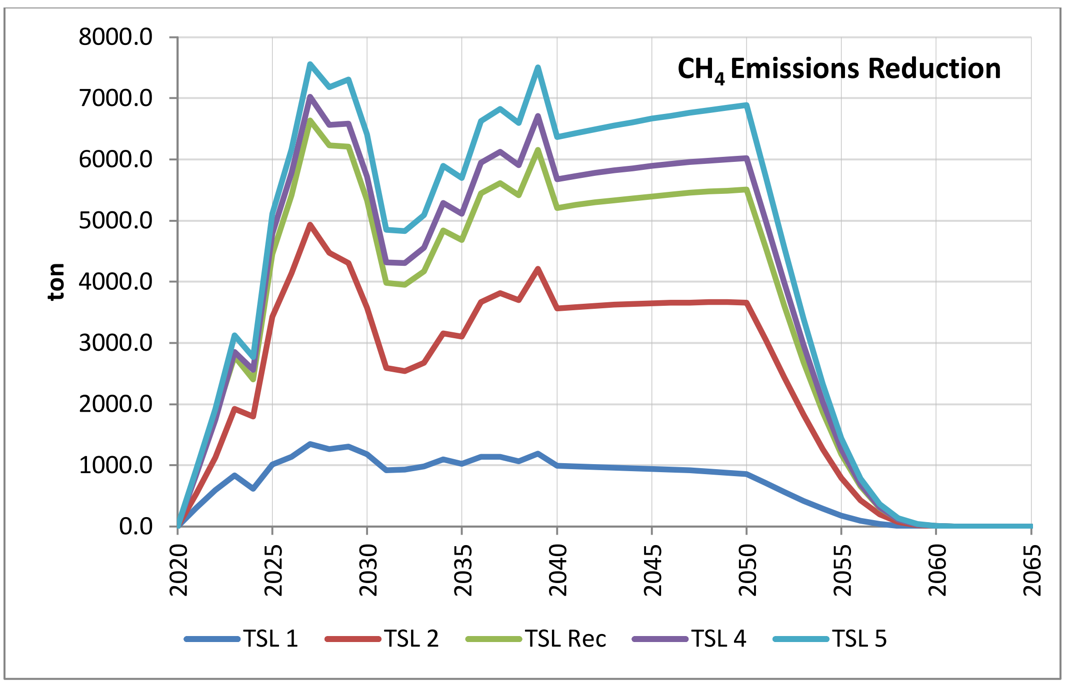

Figure 13.3.6 Pool Pumps: CH_4 Total Emissions Reduction

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APPENDIX 13A. EMISSIONS ANALYSIS METHODOLOGY

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APPENDIX 13A. EMISSIONS ANALYSIS METHODOLOGY

13A.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. DOE's methodology is based on results published with the most recent edition of the *Annual Energy Outlook (AEO)* which is published by the Energy Information Agency (EIA). For this analysis DOE used *AEO2016*.[1] DOE used the *AEO2016* No Clean Power Plan (CPP) case as its reference projection to be consistent with the NIA.

DOE developed end-use specific emissions intensity coefficients, in units of mass of pollutant per kWh of site electricity, for each pollutant. The methodology is based on the more general approach used for all the utility sector impacts calculations, which is described in appendix 15A of this TSD and in the report "Utility Sector Impacts of Reduced Electricity Demand" (Coughlin, 2014).[2] This appendix describes the methodology used to estimate the upstream emissions factors, and presents the values used for all emissions factors.

13A.2 POWER SECTOR AND SITE EMISSIONS FACTORS

Power sector marginal emissions factors are calculated by looking at the difference, over the full analysis period, between the AEO reference case and selected policy side cases. For *AEO2016*, DOE used the difference between the Reference case (with CPP included) and the No CPP case to estimate the marginal emissions intensity of affected fossil generation. The analysis produces a set of emissions intensity factors that quantify the reduction in emissions of a given pollutant per unit reduction of fuel used in electricity generation for each of the primary fossil fuel types (coal, natural gas and oil). These factors are combined with estimates of the fraction of generation allocated to each fuel type, also calculated from *AEO2016* data, for each sector and end-use. The result is a set of end-use specific marginal emissions intensity factors, summarized in the tables below. Total emissions reductions are estimated by multiplying the intensity factors times the energy savings calculated in the national impact analysis (chapter 10). Power sector emissions factors are presented in Table 13A.4.2 through Table 13A.4.7.

Site combustion of fossil fuels in buildings (for example in water-heating, space-heating or cooking applications) also produces emissions of CO_2 and other pollutants. To quantify the reduction in these emissions from a considered standard level, DOE used emissions intensity factors from Environmental Protection Agency (EPA) publications.[3] These factors, presented in

Table 13A.4.1, are constant in time. The EPA defines SO_2 emissions in terms of a formula that depends on the sulfur content of the fuel. The typical use of petroleum-based fuels in buildings if for heating, and a typical sulfur content for heating oils is a few hundred parts-per-million (ppm). The value provided in Table 13A.4.1 corresponds to a sulfur content of approximately 100 ppm.

13A.3 UPSTREAM FACTORS

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 FFC accounting approach is described briefly in appendix 10B and in Coughlin (2013).[4] When demand for a particular fuel is reduced, there is a corresponding reduction in the upstream activities associated with production of that fuel (mining, refining etc.) These upstream activities also consume energy and therefore produce combustion emissions. The FFC accounting estimates the total consumption of electricity, natural gas and petroleum-based fuels in these upstream activities. The relevant combustion emissions factors are then applied to this fuel use to determine the total upstream emissions intensities from combustion, per unit of fuel delivered to the consumer.

In addition to combustion emissions, extraction and processing of fossil fuels also produces fugitive emissions of CO_2 and CH_4. Fugitive emissions of CO_2 are small relative to combustion emissions, comprising about 2-3 percent of total CO_2 emissions for natural gas and 1-2 percent for petroleum fuels. In contrast, the fugitive emissions of methane from fossil fuel production are relatively large compared to combustion emissions of CH_4. 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.

Fugitive emissions factors for CO_2 and methane from coal mining and natural gas production were estimated based on a review of recent studies compiled by Burnham (2011).[5] 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.[6,7] The value for methane, if it were translated to a leakage rate, would be equivalent to 1.3%. Actual leakage rates of methane at various stages of the production process are highly variable and the subject of ongoing research. In a comprehensive review of the literature, Brandt et al. (2014)[8] find that, while regional studies with very high emissions rates may not be representative of typical natural gas systems, it is also true that official inventories have most likely underestimated methane emissions. As more data are made available, DOE will continue to update these estimated emissions factors.

Upstream emissions factors account for both fugitive emissions and combustion emissions in extraction, processing, and transport of primary fuels. 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 13A.4.1 presents the electricity upstream emissions factors for selected years. The caps that apply to power sector NO_X emissions do not apply to upstream combustion sources, so some components of the upstream fuel cycle (particularly off-road mobile engines) can contribute significantly to the upstream NO_x emissions factors.

13A.4 DATA TABLES

Summary tables of all the emissions factor data used by DOE for rules using *AEO 2016* are presented in the tables below. Table 13A.4.1 provides combustion emissions factors for fuels commonly used in buildings. Table 13A.4.2 to Table 13A.4.7 present the marginal power sector emissions factors as a function of sector and end use for a selected set of years. Table 13A.4.8 to Table 13A.4.10 provide the upstream emissions factors for all pollutants, for site electricity, natural gas and petroleum fuels. In all cases, the emissions factors are defined relative to site use of the fuel.

Table 13A.4.1 Site Combustion Emissions Factors

Species	Natural Gas lb/mmcf	Distillate Oil lb/1000 gal
CO_2	1.2E+05	2.3E+04
SO_2	6.0E-01	1.2E+01
NOx	9.6E+01	1.9E+01
N_2O	2.3E-01	4.5E-01
CH_4	2.3E+00	7.0E-01

Table 13A.4.2 Power Sector Emissions Factors for CO_2 (Tons of CO_2 per MWh of Site Electricity Use)

	2020	2025	2030	2035	2040
Commercial Sector					
cooking	7.048E-01	6.382E-01	6.106E-01	5.773E-01	5.429E-01
lighting	6.907E-01	6.090E-01	5.808E-01	5.508E-01	5.189E-01
office equipment (non-pc)	6.534E-01	5.653E-01	5.387E-01	5.121E-01	4.828E-01
office equipment (pc)	6.917E-01	6.045E-01	5.771E-01	5.481E-01	5.165E-01
other uses	6.885E-01	6.075E-01	5.801E-01	5.510E-01	5.199E-01
refrigeration	7.103E-01	6.329E-01	6.057E-01	5.752E-01	5.428E-01
space cooling	6.737E-01	6.232E-01	5.953E-01	5.607E-01	5.264E-01
space heating	7.127E-01	6.199E-01	5.947E-01	5.696E-01	5.418E-01
ventilation	7.064E-01	6.220E-01	5.942E-01	5.647E-01	5.328E-01
water heating	6.857E-01	6.216E-01	5.945E-01	5.621E-01	5.289E-01
Industrial Sector					
all uses	6.792E-01	6.120E-01	5.865E-01	5.556E-01	5.244E-01
Residential Sector					
ceiling fans	7.440E-01	6.485E-01	6.180E-01	5.872E-01	5.536E-01
clothes dryers	6.728E-01	6.138E-01	5.869E-01	5.536E-01	5.198E-01
cooking	6.683E-01	6.050E-01	5.786E-01	5.467E-01	5.137E-01
electronics	6.656E-01	5.856E-01	5.605E-01	5.333E-01	5.034E-01
freezers	6.858E-01	6.139E-01	5.874E-01	5.570E-01	5.253E-01
furnace fans	7.656E-01	6.313E-01	5.998E-01	5.758E-01	5.480E-01
lighting	6.574E-01	5.817E-01	5.553E-01	5.261E-01	4.953E-01
other uses	6.701E-01	6.230E-01	5.995E-01	5.677E-01	5.343E-01
refrigeration	6.611E-01	5.818E-01	5.562E-01	5.287E-01	4.989E-01
space cooling	6.771E-01	6.332E-01	6.029E-01	5.634E-01	5.250E-01
space heating	6.708E-01	6.239E-01	6.011E-01	5.703E-01	5.395E-01
water heating	6.862E-01	6.344E-01	6.072E-01	5.715E-01	5.360E-01

Table 13A.4.3 Power Sector Emissions Factors for Hg (tons/TWh of Site Electricity Use)

	2020	2025	2030	2035	2040
Commercial Sector					
cooking	2.043E-03	1.573E-03	1.496E-03	1.366E-03	1.259E-03
lighting	1.985E-03	1.558E-03	1.477E-03	1.356E-03	1.254E-03
office equipment (non-pc)	1.827E-03	1.486E-03	1.410E-03	1.301E-03	1.210E-03
office equipment (pc)	1.903E-03	1.562E-03	1.484E-03	1.366E-03	1.275E-03
other uses	2.003E-03	1.564E-03	1.487E-03	1.371E-03	1.267E-03
refrigeration	2.043E-03	1.610E-03	1.537E-03	1.415E-03	1.310E-03
space cooling	2.220E-03	1.514E-03	1.430E-03	1.298E-03	1.151E-03
space heating	1.983E-03	1.637E-03	1.572E-03	1.467E-03	1.379E-03
ventilation	2.039E-03	1.600E-03	1.519E-03	1.399E-03	1.293E-03
water heating	2.031E-03	1.537E-03	1.462E-03	1.336E-03	1.224E-03
Industrial Sector					
all uses	2.030E-03	1.569E-03	1.506E-03	1.386E-03	1.274E-03
Residential Sector					
ceiling fans	2.097E-03	1.692E-03	1.610E-03	1.489E-03	1.380E-03
clothes dryers	1.944E-03	1.497E-03	1.425E-03	1.297E-03	1.189E-03
cooking	1.902E-03	1.494E-03	1.425E-03	1.301E-03	1.197E-03
electronics	1.861E-03	1.502E-03	1.430E-03	1.318E-03	1.223E-03
freezers	1.960E-03	1.556E-03	1.488E-03	1.369E-03	1.266E-03
furnace fans	1.997E-03	1.771E-03	1.681E-03	1.578E-03	1.506E-03
lighting	1.871E-03	1.480E-03	1.404E-03	1.285E-03	1.182E-03
other uses	2.013E-03	1.502E-03	1.442E-03	1.320E-03	1.203E-03
refrigeration	1.857E-03	1.500E-03	1.429E-03	1.318E-03	1.223E-03
space cooling	2.142E-03	1.497E-03	1.414E-03	1.271E-03	1.123E-03
space heating	1.947E-03	1.495E-03	1.440E-03	1.319E-03	1.213E-03
water heating	1.941E-03	1.513E-03	1.445E-03	1.311E-03	1.203E-03

Table 13A.4.4 Power Sector Emissions Factors for NO_x (tons/MWh of Site Electricity Use)

	2020	2025	2030	2035	2040
Commercial Sector					
cooking	4.193E-04	3.306E-04	2.646E-04	2.546E-04	2.557E-04
lighting	3.937E-04	3.203E-04	2.612E-04	2.517E-04	2.522E-04
office equipment (non-pc)	3.547E-04	2.983E-04	2.458E-04	2.371E-04	2.372E-04
office equipment (pc)	3.785E-04	3.156E-04	2.582E-04	2.494E-04	2.496E-04
other uses	3.963E-04	3.220E-04	2.643E-04	2.545E-04	2.553E-04
refrigeration	4.171E-04	3.359E-04	2.770E-04	2.676E-04	2.684E-04
space cooling	4.303E-04	3.246E-04	2.538E-04	2.410E-04	2.434E-04
space heating	4.110E-04	3.408E-04	2.946E-04	2.879E-04	2.896E-04
ventilation	4.000E-04	3.272E-04	2.670E-04	2.574E-04	2.583E-04
water heating	4.133E-04	3.244E-04	2.611E-04	2.515E-04	2.533E-04
Industrial Sector					
all uses	4.350E-04	3.407E-04	2.910E-04	2.796E-04	2.780E-04
Residential Sector					
ceiling fans	4.198E-04	3.458E-04	2.866E-04	2.760E-04	2.756E-04
clothes dryers	4.172E-04	3.228E-04	2.615E-04	2.513E-04	2.515E-04
cooking	4.052E-04	3.184E-04	2.593E-04	2.495E-04	2.497E-04
electronics	3.749E-04	3.079E-04	2.529E-04	2.445E-04	2.453E-04
freezers	4.191E-04	3.322E-04	2.787E-04	2.689E-04	2.688E-04
furnace fans	3.792E-04	3.429E-04	2.965E-04	2.893E-04	2.894E-04
lighting	3.806E-04	3.075E-04	2.522E-04	2.428E-04	2.430E-04
other uses	4.358E-04	3.310E-04	2.709E-04	2.617E-04	2.626E-04
refrigeration	3.757E-04	3.086E-04	2.553E-04	2.466E-04	2.472E-04
space cooling	4.452E-04	3.298E-04	2.582E-04	2.447E-04	2.453E-04
space heating	4.300E-04	3.286E-04	2.689E-04	2.611E-04	2.643E-04
water heating	4.273E-04	3.280E-04	2.623E-04	2.524E-04	2.530E-04

Table 13A.4.5 Power Sector Emissions Factors for SO_2 (tons/MWh of Site Electricity Use)

	2020	2025	2030	2035	2040
Commercial Sector					
cooking	6.250E-04	4.593E-04	4.376E-04	3.810E-04	3.808E-04
lighting	5.429E-04	4.367E-04	4.482E-04	3.956E-04	3.878E-04
office equipment (non-pc)	4.420E-04	3.974E-04	4.390E-04	3.944E-04	3.839E-04
office equipment (pc)	4.736E-04	4.205E-04	4.536E-04	4.088E-04	4.076E-04
other uses	5.504E-04	4.408E-04	4.556E-04	4.023E-04	3.891E-04
refrigeration	5.753E-04	4.604E-04	4.656E-04	4.116E-04	4.044E-04
space cooling	7.916E-04	4.793E-04	4.170E-04	3.360E-04	3.004E-04
space heating	4.781E-04	4.549E-04	4.935E-04	4.493E-04	4.449E-04
ventilation	5.528E-04	4.461E-04	4.640E-04	4.097E-04	3.971E-04
water heating	6.331E-04	4.549E-04	4.306E-04	3.711E-04	3.620E-04
Industrial Sector					
all uses	5.998E-04	4.742E-04	4.634E-04	4.044E-04	3.903E-04
Residential Sector					
ceiling fans	5.329E-04	4.652E-04	5.001E-04	4.480E-04	4.322E-04
clothes dryers	6.128E-04	4.517E-04	4.128E-04	3.558E-04	3.552E-04
cooking	5.723E-04	4.409E-04	4.183E-04	3.648E-04	3.625E-04
electronics	4.869E-04	4.153E-04	4.348E-04	3.876E-04	3.816E-04
freezers	5.589E-04	4.565E-04	4.499E-04	3.971E-04	3.911E-04
furnace fans	3.203E-04	4.306E-04	5.526E-04	5.197E-04	5.145E-04
lighting	5.144E-04	4.200E-04	4.238E-04	3.708E-04	3.606E-04
other uses	6.820E-04	4.729E-04	4.153E-04	3.549E-04	3.492E-04
refrigeration	4.845E-04	4.169E-04	4.376E-04	3.901E-04	3.816E-04
space cooling	7.839E-04	4.852E-04	3.995E-04	3.202E-04	2.954E-04
space heating	6.499E-04	4.648E-04	4.113E-04	3.542E-04	3.544E-04
water heating	6.347E-04	4.591E-04	4.084E-04	3.528E-04	3.595E-04

Table 13A.4.6 Power Sector Emissions Factors for CH_4 (tons/MWh of Site Electricity Use)

	2020	2025	2030	2035	2040
Commercial Sector					
cooking	6.421E-05	6.242E-05	5.866E-05	5.520E-05	5.095E-05
lighting	6.338E-05	6.141E-05	5.776E-05	5.451E-05	5.042E-05
office equipment (non-pc)	6.170E-05	5.960E-05	5.615E-05	5.310E-05	4.917E-05
office equipment (pc)	6.337E-05	6.143E-05	5.785E-05	5.466E-05	5.056E-05
other uses	6.329E-05	6.136E-05	5.779E-05	5.460E-05	5.055E-05
refrigeration	6.439E-05	6.261E-05	5.900E-05	5.573E-05	5.159E-05
space cooling	6.272E-05	6.080E-05	5.700E-05	5.344E-05	4.923E-05
space heating	6.456E-05	6.277E-05	5.942E-05	5.649E-05	5.264E-05
ventilation	6.393E-05	6.202E-05	5.839E-05	5.516E-05	5.103E-05
water heating	6.342E-05	6.157E-05	5.787E-05	5.447E-05	5.033E-05
Industrial Sector					
all uses	6.361E-05	6.195E-05	5.850E-05	5.523E-05	5.121E-05
Residential Sector					
ceiling fans	6.555E-05	6.367E-05	5.994E-05	5.668E-05	5.242E-05
clothes dryers	6.327E-05	6.137E-05	5.762E-05	5.413E-05	4.995E-05
cooking	6.299E-05	6.109E-05	5.741E-05	5.401E-05	4.987E-05
electronics	6.244E-05	6.044E-05	5.694E-05	5.380E-05	4.980E-05
freezers	6.375E-05	6.192E-05	5.835E-05	5.507E-05	5.101E-05
furnace fans	6.591E-05	6.394E-05	6.045E-05	5.767E-05	5.374E-05
lighting	6.221E-05	6.015E-05	5.657E-05	5.330E-05	4.927E-05
other uses	6.331E-05	6.162E-05	5.804E-05	5.465E-05	5.049E-05
refrigeration	6.230E-05	6.032E-05	5.684E-05	5.371E-05	4.975E-05
space cooling	6.336E-05	6.141E-05	5.737E-05	5.353E-05	4.915E-05
space heating	6.342E-05	6.174E-05	5.814E-05	5.476E-05	5.071E-05
water heating	6.397E-05	6.220E-05	5.834E-05	5.471E-05	5.041E-05

Table 13A.4.7 Power Sector Emissions Factors for N_2O (tons/MWh of Site Electricity Use)

	2020	2025	2030	2035	2040
Commercial Sector					
cooking	9.200E-06	8.932E-06	8.379E-06	7.874E-06	7.250E-06
lighting	9.083E-06	8.789E-06	8.254E-06	7.780E-06	7.178E-06
office equipment (non-pc)	8.845E-06	8.530E-06	8.023E-06	7.579E-06	7.002E-06
office equipment (pc)	9.083E-06	8.793E-06	8.267E-06	7.802E-06	7.199E-06
other uses	9.071E-06	8.783E-06	8.258E-06	7.793E-06	7.198E-06
refrigeration	9.229E-06	8.964E-06	8.433E-06	7.957E-06	7.348E-06
space cooling	8.980E-06	8.694E-06	8.136E-06	7.618E-06	7.000E-06
space heating	9.260E-06	8.994E-06	8.500E-06	8.074E-06	7.507E-06
ventilation	9.162E-06	8.877E-06	8.344E-06	7.873E-06	7.265E-06
water heating	9.085E-06	8.809E-06	8.267E-06	7.770E-06	7.162E-06
Industrial Sector					
all uses	9.123E-06	8.874E-06	8.366E-06	7.890E-06	7.299E-06
Residential Sector					
ceiling fans	9.400E-06	9.118E-06	8.570E-06	8.094E-06	7.468E-06
clothes dryers	9.065E-06	8.782E-06	8.231E-06	7.722E-06	7.109E-06
cooking	9.027E-06	8.742E-06	8.203E-06	7.706E-06	7.099E-06
electronics	8.949E-06	8.650E-06	8.136E-06	7.679E-06	7.090E-06
freezers	9.140E-06	8.866E-06	8.341E-06	7.864E-06	7.267E-06
furnace fans	9.459E-06	9.165E-06	8.651E-06	8.246E-06	7.668E-06
lighting	8.916E-06	8.609E-06	8.082E-06	7.607E-06	7.014E-06
other uses	9.071E-06	8.818E-06	8.293E-06	7.798E-06	7.186E-06
refrigeration	8.930E-06	8.634E-06	8.122E-06	7.667E-06	7.085E-06
space cooling	9.072E-06	8.782E-06	8.191E-06	7.631E-06	6.988E-06
space heating	9.087E-06	8.835E-06	8.306E-06	7.812E-06	7.218E-06
water heating	9.163E-06	8.899E-06	8.334E-06	7.803E-06	7.171E-06

Table 13A.4.8 Electricity Upstream Emissions Factors

Species	Unit	2021	2025	2030	2035	2040
CH_4	g/MWh	2.13E+03	2.22E+03	2.29E+03	2.29E+03	2.32E+03
CO_2	kg/MWh	2.83E+01	2.89E+01	2.92E+01	2.89E+01	2.89E+01
Hg	g/MWh	1.15E-05	1.10E-05	1.02E-05	9.44E-06	8.50E-06
N_2O	g/MWh	2.40E-01	2.36E-01	2.29E-01	2.17E-01	2.03E-01
NO_x	g/MWh	3.59E+02	3.67E+02	3.72E+02	3.72E+02	3.75E+02
SO_2	g/MWh	4.92E+00	4.90E+00	4.65E+00	4.37E+00	4.06E+00

Table 13A.4.9 Natural Gas Upstream Emissions Factors

Species	Unit	2021	2025	2030	2035	2040
CH_4	g/ mcf	6.76E+02	6.76E+02	6.74E+02	6.77E+02	6.78E+02
CO_2	kg/ mcf	7.13E+00	7.02E+00	6.91E+00	6.99E+00	7.02E+00
N_2O	g/ mcf	1.11E-02	1.09E-02	1.07E-02	1.09E-02	1.09E-02
NO_x	g/ mcf	1.01E+02	9.91E+01	9.73E+01	9.87E+01	9.93E+01
SO_2	g/ mcf	3.03E-02	2.97E-02	2.92E-02	2.96E-02	2.98E-02

Table 13A.4.10 Fuel Oil Upstream Emissions Factors

	Unit	2021	2025	2030	2035	2040
CH_4	g/bbl	9.14E+02	9.22E+02	9.37E+02	9.47E+02	9.54E+02
CO_2	kg/bbl	7.01E+01	6.99E+01	7.01E+01	7.04E+01	7.07E+01
Hg	g/bbl	7.23E-06	6.81E-06	6.31E-06	6.12E-06	5.88E-06
N_2O	g/bbl	6.09E-01	6.01E-01	5.92E-01	5.85E-01	5.82E-01
NO_x	g/bbl	7.78E+02	7.69E+02	7.59E+02	7.53E+02	7.51E+02
SO_2	g/bbl	1.49E+01	1.48E+01	1.44E+01	1.42E+01	1.42E+01

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CHAPTER 14. MONETIZATION OF EMISSIONS REDUCTION BENEFITS

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14.1 INTRODUCTION

As part of its assessment of energy conservation standards for pool pumps, the U.S. Department of Energy (DOE) estimated the monetary benefits likely to result from the reduced emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and nitrogen oxides (NO_X) that are expected to result from each trial standard level (TSL) considered for this rulemaking. This chapter summarizes the basis for the monetary values used for each of these emissions and presents the estimated benefits.

14.2 MONETIZING CARBON DIOXIDE EMISSIONS

14.2.1 Social Cost of Carbon

The social cost of carbon (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. Estimates of the SCC are provided in dollars per metric ton of carbon dioxide. 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.

Under section 1(b) of Executive Order 12866, 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 presented here is to allow agencies to incorporate the monetized social benefits of reducing 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.

As part of the interagency process that developed these SCC estimates, technical experts from numerous agencies met on a regular basis to explore the technical literature in relevant fields, discuss key model inputs and assumptions, and consider public comments. 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.

14.2.2 Monetizing Carbon Dioxide Emissions

When attempting to assess the incremental economic impacts of carbon dioxide emissions, the analyst faces a number of serious challenges. A report from the National Research

Council[1] 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 limits of both quantification and monetization, SCC estimates can be useful in estimating the social benefits of reducing carbon dioxide emissions. Most Federal regulatory actions can be expected to have marginal impacts on global emissions. For such policies, the 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 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.

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. These 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 this preliminary effort were presented in several proposed and final rules.

14.2.3 Current Approach and Key Assumptions

After the release of the interim values, the interagency group reconvened on a regular basis to generate improved 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 (IAMs) commonly used to estimate the SCC: the FUND, DICE, and PAGE models. These models are frequently cited in the peer-reviewed literature and were used in the last assessment of the Intergovernmental Panel on Climate Change. Each model was given equal weight in the SCC values that were developed.

Each model takes a slightly different approach to model how changes in emissions result in changes in economic damages. 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: (1) climate sensitivity; (2) socio-economic and emissions trajectories; and (3) 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 socio-economic 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 2010 the interagency group selected four SCC values for use in regulatory analyses.[2] 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. The values grow 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,[a] although preference is given to consideration of the global benefits of reducing CO_2 emissions.

In 2013 the interagency working group issued revised SCC values that were generated using the most recent versions of the three integrated assessment models that have been published in the peer-reviewed literature. These values, which were slightly revised in July 2015, were used in the current analysis.[3] Table 14.2.1 shows the updated sets of SCC estimates in five year increments from 2010 to 2050. Appendix 14A provides the full set of SCC estimates. The central value that emerges is the average SCC across models at the 3 percent discount rate. However, for purposes of capturing the uncertainties involved in regulatory impact analysis, the interagency group emphasizes the importance of including all four sets of SCC values.

[a] It is recognized that this calculation for domestic values is 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.

Table 14.2.1 Annual SCC Values from 2013 Interagency Update (Revised July 2015), 2010–2050 (in 2007 dollars per metric ton CO_2)

Year	Discount Rate %			
	5	**3**	**2.5**	**3**
	Average	**Average**	**Average**	**95th Percentile**
2010	10	31	50	86
2015	11	36	56	105
2020	12	42	62	123
2025	14	46	68	138
2030	16	50	73	152
2035	18	55	78	168
2040	21	60	84	183
2045	23	64	89	197
2050	26	69	95	212

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 Research Council report mentioned above 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. There are 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 interagency group intends to 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.

DOE converted the values from the 2013 interagency report (revised July 2015) to 2015$ using the implicit price deflator for gross domestic product (GDP) from the Bureau of Economic Analysis. For example, for each of the four cases specified, the values used for emissions in 2020 are $13.5, $47.4, $69.9, and $139 per metric ton avoided. DOE derived values after 2050 based on the trend in 2010-2050 in each of the four cases.

DOE multiplied the CO_2 emissions reduction estimated for each year by the SCC value for that year in each of the four cases. To calculate a present value of the stream of monetary values, DOE discounted the values in each of the four cases using the specific discount rate that had been used to obtain the SCC values in each case.

14.3 MONETIZING METHANE AND NITROUS OXIDE EMISSIONS

While carbon dioxide is the most prevalent greenhouse gas emitted into the atmosphere, other GHGs are also important contributors. These include methane and nitrous oxide. Global warming potentials (GWPs) are often used to convert emissions of non-CO_2 GHGs to CO_2-equivalents to facilitate comparison of policies and inventories involving different GHGs. While GWPs allow for some useful comparisons across gases on a physical basis, using the social cost of carbon to value the damages associated with changes in CO_2-equivalent emissions is not optimal. This is because non-CO_2 GHGs differ not just in their potential to absorb infrared radiation over a given time frame, but also in the temporal pathway of their impact on radiative forcing, which is relevant for estimating their social cost but not reflected in the GWP. Physical impacts other than temperature change also vary across gases in ways that are not captured by GWP.

In light of these limitations and the paucity of peer-reviewed estimates of the social cost of non-CO_2 gases in the literature, the 2010 SCC Technical Support Document did not include an estimate of the social cost of non-CO_2 GHGs and did not endorse the use of GWP to approximate the value of non-CO_2 emission changes in regulatory analysis. Instead, the Interagency Working Group (IWG) noted that more work was needed to link non-CO_2 GHG emission changes to economic impacts.

Since that time, new estimates of the social cost of non-CO_2 GHG emissions have been developed in the scientific literature, and a recent study by Marten *et al*. (2015) provided the first set of published estimates for the social cost of CH_4 and N_2O emissions that are consistent with the methodology and modeling assumptions underlying the IWG SC-CO_2 estimates.[b] Specifically, Marten *et al.* used the same set of three integrated assessment models, five socioeconomic and emissions scenarios, equilibrium climate sensitivity distribution, three constant discount rates, and the aggregation approach used by the IWG to develop the SC-CO2 estimates. An addendum to the IWG's Technical Support Document on Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866 summarizes the Marten *et al.* methodology and presents the social cost of methane (SC-CH_4) and social cost of nitrous oxide (SC-N_2O) estimates from that study as a way for agencies to incorporate the social benefits of reducing CH_4 and N_2O emissions into benefit-cost analyses of regulatory actions that have small, or "marginal," impacts on cumulative global emissions.[c]

[b] Marten, A.L., Kopits, E.A., Griffiths, C.W., Newbold, S.C., and A. Wolverton. 2015. Incremental CH_4 and N_2O Mitigation Benefits Consistent with the U.S. Government's SC-CO2 Estimates. Climate Policy. 15(2): 272-298 (published online, 2014).

[c] United States Government–Interagency Working Group on Social Cost of Greenhouse Gases. Addendum to Technical Support Document on Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866: Application of the Methodology to Estimate the Social Cost of Methane and the Social Cost of Nitrous Oxide. August 2016. https://www.whitehouse.gov/sites/default/files/omb/inforeg/august_2016_sc_ch4_sc_n2o_addendum_final_8_26_16.pdf.

The methodology and estimates described in the addendum have undergone multiple stages of peer review and their use in regulatory analysis has been subject to public comment. The estimates are presented with an acknowledgement of the limitations and 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, just as the IWG has committed to do for the SC-CO_2. The OMB has determined that the use of the Marten *et al.* estimates in regulatory analysis is consistent with the requirements of OMB's Information Quality Guidelines Bulletin for Peer Review and OMB Circular A-4.

The SC-CH_4 and SC-N_2O estimates are presented in Table 14.3.1. Following the same approach as with the SC-CO_2 values for 2010, 2020, 2030, 2040, and 2050 are calculated by combining all outputs from all scenarios and models for a given discount rate. Values for the years in between are calculated using linear interpolation. The full set of annual SC-CH_4 and SC-N_2O estimates between 2010 and 2050 is reported in appendix 14A of the final rule TSD. DOE derived values after 2050 based on the trend in 2010–2050 in each of the four cases in the IWG addendum.

Table 14.3.1 Annual SC-CH_4 and SC-N_2O Estimates from 2016 IWG Addendum (2007$ per Metric Ton CO_2)

	SC-CH_4				SC-N_2O			
	Discount Rate and Statistic				Discount Rate and Statistic			
	5%	3%	2.5%	3%	5%	3%	2.5 %	3%
Year	Average	Average	Average	95th percentile	Average	Average	Average	95th percentile
2010	370	870	1,200	2,400	3,400	12,000	18,000	31,000
2015	450	1,000	1,400	2,800	4,000	13,000	20,000	35,000
2020	540	1,200	1,600	3,200	4,700	15,000	22,000	39,000
2025	650	1,400	1,800	3,700	5,500	17,000	24,000	44,000
2030	760	1,600	2,000	4,200	6,300	19,000	27,000	49,000
2035	900	1,800	2,300	4,900	7,400	21,000	29,000	55,000
2040	1,000	2,000	2,600	5,500	8,400	23,000	32,000	60,000
2045	1,200	2,300	2,800	6,100	9,500	25,000	34,000	66,000
2050	1,300	2,500	3,100	6,700	11,000	27,000	37,000	72,000

DOE multiplied the CH_4 and N_2O emissions reduction estimated for each year by the SC-CH_4 and SC-N_2O estimates for that year in each of the four cases. To calculate a present value of the stream of monetary values, DOE discounted the values in each of the four cases using the specific discount rate that had been used to obtain the SC-CH_4 and SC-N_2O estimates in each case.

14.4 VALUATION OF OTHER EMISSIONS

As noted in chapter 13, new or amended energy conservation standards would reduce NO_X emissions from electricity generation in those 22 States that are not affected by caps. For each of the considered TSLs, DOE estimated monetized values of NO_X emissions reductions from electricity generation using benefit-per-ton estimates for NO_X associated with $PM_{2.5}$ from the *Regulatory Impact Analysis for the Clean Power Plan Final Rule,* published in October 2015 by EPA's Office of Air Quality Planning and Standards.[d] The report includes low and high values for 2020, 2025, and 2030 that use discount rates of 3 percent and 7 percent (see Tables 4A-3, 4A-4, and 4A-5 in the report). The results reported in this chapter use the low benefit per ton estimates to be conservative.[e]

DOE refined the data provided by EPA to estimate monetized values of NO_X emissions reduction by sector. For this analysis DOE used linear interpolation to define values for the years between 2020 and 2025 and between 2025 and 2030; for years beyond 2030 the value is held constant. Appendix 14B provides methodological details and NOx values from the approach DOE developed. The results presented here use NOx monetized values for the residential sector. DOE multiplied the emissions reduction (in tons) in each year by the associated $/ton values, and then discounted each series using discount rates of 3 percent and 7 percent as appropriate.

DOE is evaluating appropriate values to use to monetize avoided SO_2 and Hg emissions. DOE did not monetize these emissions for the current analysis.

14.5 RESULTS

Table 14.5.1 Global Present Value of CO_2 Emissions Reduction for Potential Standards for Pool Pumps

TSL	SCC Case			
	5% discount rate, average	3% discount rate, average	2.5% discount rate, average	3% discount rate, 95th percentile
	billion 2015$			
1	327	1,442	2,269	4,388
2	1,207	5,385	8,496	16,402
TSL Rec	1,524	6,804	10,734	20,724
4	1,624	7,256	11,450	22,104
5	1,841	8,242	13,011	25,113

[d] Available at http://www.epa.gov/sites/production/files/2015-08/documents/cpp-final-rule-ria.pdf.
[e] For the monetized NO_X benefits associated with PM2.5, the reported benefits are based on an estimate of premature mortality derived from the ACS study (Krewski et al. 2009), which is the lower of the two EPA central tendencies. Using the lower value is more conservative when making the policy decision concerning whether a particular standard level is economically justified. If the benefit-per-ton estimates were based on the Six Cities study (Lepuele et al. 2012), the values would be nearly two-and-a-half times larger.

Table 14.5.2 Domestic Present Value of CO_2 Emissions Reduction for Potential Standards for Pool Pumps

TSL	SCC Case			
	5% discount rate, average	3% discount rate, average	2.5% discount rate, average	3% discount rate, 95th percentile
	billion 2015$			
1	23 to 75	101 to 332	159 to 522	307 to 1,009
2	85 to 278	377 to 1,239	595 to 1,954	1,148 to 3,772
TSL Rec	107 to 351	476 to 1,565	751 to 2,469	1,451 to 4,767
4	114 to 374	508 to 1,669	802 to 2,634	1,547 to 5,084
5	129 to 424	577 to 1,896	911 to 2,993	1,758 to 5,776

Table 14.5.3 Present Value of Methane Emissions Reduction for Potential Standards for Pool Pumps

TSL	SC-CH_4 Case			
	5% Discount Rate, Average	3% Discount Rate, Average	2.5% Discount Rate, Average	3% Discount Rate, 95th Percentile
	billion 2015$			
1	69	206	289	549
2	256	782	1,100	2,082
TSL Rec	324	989	1,392	2,632
4	346	1,057	1,487	2,812
5	393	1,203	1,694	3,202

Table 14.5.4 Present Value of Nitrous Oxide Emissions Reduction for Potential Standards for Pool Pumps

TSL	SC-N_2O Case			
	5% Discount Rate, Average	3% Discount Rate, Average	2.5% Discount Rate, Average	3% Discount Rate, 95th Percentile
	billion 2015$			
1	1.8	7.2	11	19
2	6.5	27	42	72
TSL Rec	8.3	34	54	91
4	8.8	36	57	97
5	10	41	65	110

Table 14.5.5 Present Value of NO_X Emissions Reduction for Potential Standards for Pool Pumps

TSL	3% discount rate	7% discount rate
	billion 2015$	
1	103	47
2	378	167
TSL Rec	477	210
4	508	222
5	575	250

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APPENDIX 14A. SOCIAL COST OF GREENHOUSE GASES

14A.1 SOCIAL COST OF CARBON ESTIMATES FROM 2013 INTERAGENCY UPDATE (REVISED 2015)[a]

Table 14A.1.1 Annual SCC Values from 2013 Interagency Update (Revised July 2015), 2010–2050 (in 2007 dollars per metric ton CO_2)

	Discount Rate			
Year	5.0% Average	3.0% Average	2.5% Average	3.0% 95th percentile
2010	10	31	50	86
2011	11	32	51	90
2012	11	33	53	93
2013	11	34	54	97
2014	11	35	55	101
2015	11	36	56	105
2016	11	38	57	108
2017	11	39	59	112
2018	12	40	60	116
2019	12	41	61	120
2020	12	42	62	123
2021	12	42	63	126
2022	13	43	64	129
2023	13	44	65	132
2024	13	45	66	135
2025	14	46	68	138
2026	14	47	69	141
2027	15	48	70	149
2028	15	49	71	146
2029	15	49	72	149
2030	16	50	73	152
2031	16	51	74	155
2032	17	52	75	158
2033	17	53	76	161
2034	18	54	77	164
2035	18	55	78	168
2036	19	56	79	171

[a] Interagency Working Group on Social Cost of Carbon. *Technical Support Document: -Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis -Under Executive Order 12866*. 2015. United States Government. (Last accessed October 23, 2015.) https://www.whitehouse.gov/sites/default/files/omb/inforeg/scc-tsd-final-july-2015.pdf.

2037	19	57	81	174
2038	20	58	82	177
2039	20	59	83	180
2040	21	60	84	183
2041	21	61	85	186
2042	22	61	86	189
2043	22	62	87	192
2044	23	63	88	194
2045	23	64	89	197
2046	24	65	90	200
2047	24	66	92	203
2048	25	67	93	206
2049	25	68	94	209
2050	26	69	95	212

14A.2 SOCIAL COST OF METHANE AND SOCIAL COST OF NITROUS OXIDE ESTIMATES FROM 2016 INTERAGENCY REPORT[b]

Table 14A.2.1 Annual SCC Values from 2013 Interagency Update (Revised July 2015), 2010–2050 (in 2007 dollars per metric ton CO_2)

	SC-CH4				SC-N2O			
Year	**5% Average**	**3% Average**	**2.5% Average**	**High Impact (3% 95th)**	**5% Averag**	**3% Average**	**2.5% Average**	**High Impact (3% 95th)**
2010	370	870	1,200	2,400	3,400	12,000	18,000	31,000
2011	380	910	1,200	2,500	3,500	12,000	18,000	32,000
2012	400	940	1,300	2,600	3,700	12,000	19,000	33,000
2013	420	970	1,300	2,700	3,800	13,000	19,000	34,000
2014	440	1,000	1,300	2,700	3,900	13,000	20,000	34,000
2015	450	1,000	1,400	2,800	4,000	13,000	20,000	35,000
2016	470	1,100	1,400	2,900	4,200	14,000	20,000	36,000

[b] United States Government–Interagency Working Group on Social Cost of Greenhouse Gases. Addendum to Technical Support Document on Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866: Application of the Methodology to Estimate the Social Cost of Methane and the Social Cost of Nitrous Oxide. August 2016. https://www.whitehouse.gov/sites/default/files/omb/inforeg/august_2016_sc_ch4_sc_n2o_addendum_final_8_26_16.pdf.

2017	490	1,100	1,500	3,000	4,300	14,000	21,000	37,000
2018	510	1,100	1,500	3,000	4,400	14,000	21,000	38,000
2019	520	1,200	1,500	3,100	4,600	15,000	22,000	38,000
2020	540	1,200	1,600	3,200	4,700	15,000	22,000	39,000
2021	560	1,200	1,600	3,300	4,900	15,000	23,000	40,000
2022	590	1,300	1,700	3,400	5,000	16,000	23,000	41,000
2023	610	1,300	1,700	3,500	5,200	16,000	23,000	42,000
2024	630	1,400	1,800	3,600	5,400	16,000	24,000	43,000
2025	650	1,400	1,800	3,700	5,500	17,000	24,000	44,000
2026	670	1,400	1,900	3,800	5,700	17,000	25,000	45,000
2027	700	1,500	1,900	3,900	5,900	17,000	25,000	46,000
2028	720	1,500	2,000	4,000	6,000	18,000	26,000	47,000
2029	740	1,600	2,000	4,100	6,200	18,000	26,000	48,000
2030	760	1,600	2,000	4,200	6,300	19,000	27,000	49,000
2031	790	1,600	2,100	4,300	6,500	19,000	27,000	50,000
2032	820	1,700	2,100	4,500	6,800	19,000	28,000	51,000
2033	850	1,700	2,200	4,600	7,000	20,000	28,000	52,000
2034	880	1,800	2,200	4,700	7,200	20,000	29,000	54,000
2035	900	1,800	2,300	4,900	7,400	21,000	29,000	55,000
2036	930	1,900	2,400	5,000	7,600	21,000	30,000	56,000
2037	960	1,900	2,400	5,100	7,800	21,000	30,000	57,000
2038	990	2,000	2,500	5,200	8,000	22,000	31,000	58,000
2039	1,000	2,000	2,500	5,400	8,200	22,000	31,000	59,000
2040	1,000	2,000	2,600	5,500	8,400	23,000	32,000	60,000
2041	1,100	2,100	2,600	5,600	8,600	23,000	32,000	61,000
2042	1,100	2,100	2,700	5,700	8,800	23,000	33,000	62,000
2043	1,100	2,200	2,700	5,800	9,100	24,000	33,000	64,000
2044	1,200	2,200	2,800	5,900	9,300	24,000	34,000	65,000
2045	1,200	2,300	2,800	6,100	9,500	25,000	34,000	66,000
2046	1,200	2,300	2,900	6,200	9,800	25,000	35,000	67,000
2047	1,300	2,400	2,900	6,300	10,000	26,000	35,000	68,000
2048	1,300	2,400	3,000	6,400	10,000	26,000	36,000	69,000
2049	1,300	2,500	3,000	6,500	10,000	26,000	36,000	71,000
2050	1,300	2,500	3,100	6,700	11,000	27,000	37,000	72,000

APPENDIX 14B. BENEFIT-PER-TON VALUES FOR NO_X EMISSIONS FROM ELECTRICITY GENERATION

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APPENDIX 14B. BENEFIT-PER-TON VALUES FOR NO_X EMISSIONS FROM ELECTRICITY GENERATION

14B.1 INTRODUCTION

This appendix describes the analytical methodology DOE uses to incorporate regional variability in NO_X valuations into the emissions monetization. The regional values assigned to NO_X emissions are taken from the EPA Clean Power Plan Final Rule,[1] and summarized in Table 14B.2.1. EPA provides a range of estimates of the present value of NO_X emissions reductions in three regions (East, West, and California) and three years (2020, 2025, and 2030). These data are combined with regional information on electricity consumption and NO_X emissions to define a weighted-average national value for NO_X as a function of end-use.

DOE's methodology is based on results published with the most recent edition of the *Annual Energy Outlook (AEO)* which is published by the Energy Information Agency (EIA). For this analysis DOE used *AEO2016*.[2] In *AEO2016* EIA incorporated the EPA Clean Power Plan (CPP) into the Reference case. The CPP plan period is 2020-2030, over which time states must achieve a mandated a limit on CO_2 emissions from electricity generation. EIA also published a side case (No CPP) using the same assumptions as the Reference case but without implementation of the CPP. On February 9, 2016 the US Supreme Court granted a stay halting implementation of the CPP. Because the fate of the CPP is uncertain, DOE used the *AEO2016* No CPP case as its reference projection for the energy sector.

The AEO2016 data are used to define two sets of factors that enter into the calculation: the distribution of end-use electricity consumption by region, and the relative NO_X emissions intensity (in units of tons per MWh of electricity sales) in each region.

The rest of this appendix provides a more detailed description of the methodology and results.

14B.2 METHODOLOGY

14B.2.1 EPA Data

The EPA Clean Power Plan Final Rule includes estimates of the present value of the benefits of NO_X (as PM2.5) emissions reductions (*benefit-per-ton* estimates) in a given year, for three years (2020, 2025 and 2030). Because NO_X, and other pollutants whose production is enhanced by the presence of NO_X, persist in the atmosphere over a period of years, reductions in any given year will have benefits in subsequent years. These future benefits are discounted and summed to provide a single value for the reduction of one ton of emissions in the EPA model year. EPA publishes a range of values, defined by high and low, and using discount rates of 3% and 7% as mandated by OMB. These values are presented in Table 14B.2.1.

The regions used by EPA are East, West and California (CPP final rule, page 4A-7). The east region includes census divisions 1 through 7 (New England, Mid-Atlantic, East North Central, West North Central, East South Central, West South Central), South Atlantic). The West includes the Mountain and Pacific contiguous census divisions, minus California.

For this analysis DOE used linear interpolation to define values for the years between 2020 and 2025 and between 2025 and 2030; for years beyond 2030 the value is held constant.

Table 14B.2.1 EPA Benefit-per-Ton Estimates for NOx (as $PM_{2.5}$) for the Electricity Generating Utility Sector (2011$/short ton)

Range	Discount Rate	Year	US-average	East	West	California
Low	7%	2020	2,700	2,800	610	19,000
		2025	2,900	3,000	670	22,000
		2030	3,100	3,200	740	24,000
Low	3%	2020	3,000	3,100	670	22,000
		2025	3,200	3,300	750	24,000
		2030	3,400	3,500	820	26,000
High	7%	2020	5,600	6,300	1,400	44,000
		2025	6,000	6,800	1,500	49,000
		2030	6,400	7,200	1,700	54,000
High	3%	2020	6,800	7,000	1,500	49,000
		2025	7,300	7,500	1,700	54,000
		2030	7,800	8,000	1,900	60,000

* From Table 4A-3 through Table 4A-5 in the Regulatory Impact Analysis for the Clean Power Plan Final Rule.

14B.2.2 AEO Data

DOE used two data sets from the *AEO2016* reference case for this analysis. The first is the annual end-use energy consumption by sector (residential, commercial, industrial) for each of AEO's Electricity Market Module (EMM) regions.[4] The regions can be mapped in a straightforward way to the East, West and California regions defined by EPA: EMM regions 1 through 18 are assigned to the East, regions 19, 21 and 22 to the West, and 20 to California.

These data are used to define a set of factors W(r, y) where

- r is an index defining the region (East, West, California),
- y is the year (2019 to 2040),
- W_u(r, y) is the fraction of energy consumption for end-use u that occurs in region r in year y.

With these definitions, Σ_r W(r, y) = 1 in each year.

The second data set is total NO_X emissions (tons) and total retail electricity sales for each of the EMM regions.[4] These data are used to estimate a NO_X emissions intensity coefficient *Z(r,y)*, that represents the total emissions of NO_X in that region per unit of electricity sold to final consumers. The NO_X emissions are scaled to electricity sold, not electricity generated, in region *r*. This ensures that the coefficient correctly measures the local NO_X response to a local reduction in electricity use. The emissions intensities *Z(r,y)* are time-dependent, as shown in Figure 14B.2.1. The figure shows that emissions intensities within California are lower than in the rest of the country; also that there is a relatively steep decline in the California emissions intensity around 2025.

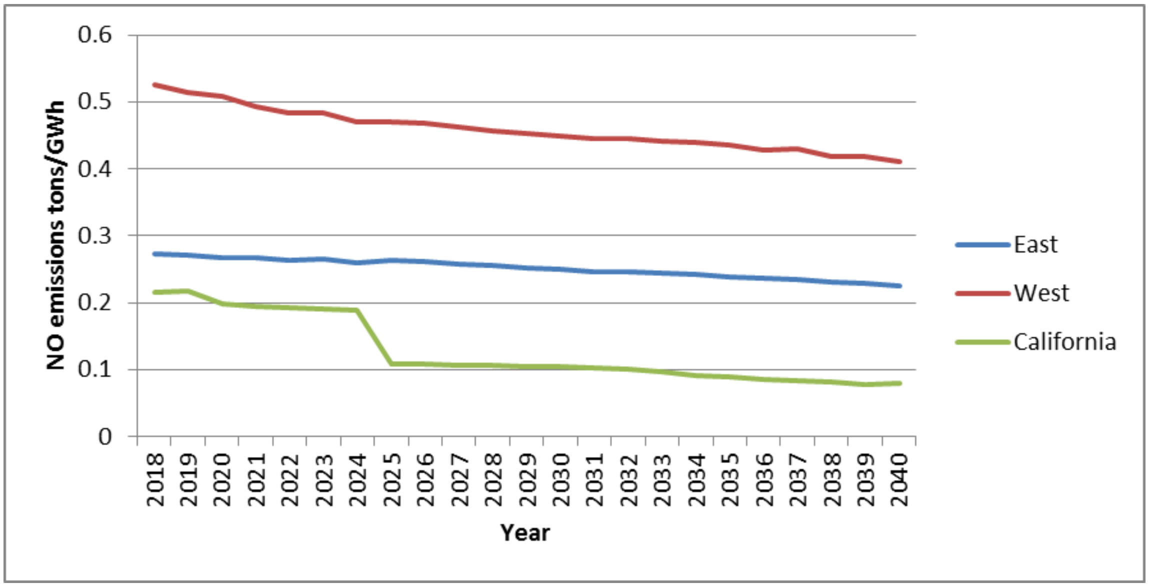

Figure 14B.2.1 Time series of the ratio of NO_X tons/GWh of electricity sold by region

14B.2.3 Equations

Consistent with its treatment of other utility and environmental impacts, DOE defines a times series of national average NO_X valuations for each sector. Previous analyses included variation in NOx prices by end-use as well as sector, but given the large uncertainty in these numbers, DOE has determined that this additional detail is not quantitatively meaningful. These national values incorporate the regional EPA prices defined in Table 14B.2.1.

The notation is:

- m is a label for the EPA scenario (low-7%, low-3%, etc.),
- $P_m(r,y)$ is the EPA NO_X price for scenario m, year y and region r,

- Z(r,y) is equal to total NO_X emissions per GWh of electricity sold in region r and year y.

The product *W(r, y) * Z(r,y)* is equal to the quantity of NO_X emitted in region *r* due to electricity consumption of one GWh. These regional NO_X emissions are used to weight the regional NO_X prices to arrive at a single value for that end use:

$$V_m(y) = [\ \Sigma_r\ W(\ r,\ y)\ {*}Z(r,y)\ {*}P_m(r,y)\ ]\ /[\ \Sigma_r\ W(\ r,\ y)\ {*}Z(r,y)\ ].$$

The results of this calculation are shown in the section below. DOE's prices are not significantly different than the EPA estimate of the US average. Although the EPA prices are held constant after 2030, the DOE prices show a slight decrease in the period 2030-2040 due to the trends in NO_X intensity shown in Figure 14B.2.1.

14B.3 RESULTS

Table 14B.3.1 NOX values based on the EPA price for low range, 7% discount rate (2011$/short ton)

	2020	2025	2030	2035	2040
Commercial Sector	3,219	3,139	3,390	3,340	3,306
Industrial Sector	2,800	2,839	3,053	3,019	2,998
Residential Sector	2,938	2,936	3,148	3,103	3,071

Table 14B.3.2 NO_X values based on the EPA price for low range, 3% discount rate (2011$/short ton)

	2020	2025	2030	2035	2040
Commercial Sector	3,670	3,449	3,701	3,648	3,611
Industrial Sector	3,181	3,122	3,337	3,300	3,277
Residential Sector	3,336	3,228	3,440	3,391	3,356

Table 14B.3.3 NO_X values based on the EPA price for high range, 7% discount rate (2011$/short ton)

	2020	2025	2030	2035	2040
Commercial Sector	7,450	7,083	7,635	7,523	7,446
Industrial Sector	6,469	6,415	6,877	6,801	6,753
Residential Sector	6,780	6,632	7,091	6,990	6,916

Table 14B.3.4 NO_X values based on the EPA price for high range, 3% discount rate (2011$/short ton)

	2020	2025	2030	2035	2040
Commercial Sector	8,262	7,820	8,485	8,362	8,276
Industrial Sector	7,171	7,084	7,644	7,559	7,505
Residential Sector	7,517	7,323	7,881	7,768	7,687

REFERENCES

1 U.S. Environmental Protection Agency. Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units; Final Rule. *Federal Register*. October 23, 2015. vol. 80, no. 205: pp. 64662–64964. (Last accessed January 21, 2016.) https://www.gpo.gov/fdsys/pkg/FR-2015-10-23/pdf/2015-22842.pdf

2 U.S. Energy Information Administration. *Annual Energy Outlook 2015 with Projections to 2040*. 2015. Washington, D.C. Report No. DOE/EIA-0383(2015). (Last accessed December 15, 2015.) http://www.eia.gov/forecasts/aeo/pdf/0383(2015).pdf

3 U.S. Department of Energy–Energy Information Administration. *Form EIA-861 Annual Electric Power Industry Report Database.* (Last accessed December 15, 2015.) http://www.eia.gov/electricity/data/eia861/index.html

4 U.S. Energy Information Administration. *Assumptions to the Annual Energy Outlook 2015: Electricity Market Module*. 2015. Washington, D.C. (Last accessed January 21, 2016.) https://www.eia.gov/forecasts/aeo/assumptions/pdf/electricity.pdf

CHAPTER 15. UTILITY IMPACT ANALYSIS

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CHAPTER 15. UTILITY IMPACT ANALYSIS

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. DOE's methodology is based on results published for the *Annual Energy Outlook 2016 (AEO 2016),* including a set of the side cases that implement a variety of efficiency-related policies.[2]

DOE used the No Clean Power Plan (CPP) side case published with *AEO2016* as the basis for developing factors for emissions from the electric power sector and other utility impacts.

DOE's *AEO*-based methodology has a number of advantages:

- 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 reference and side cases to estimate the utility impacts enhances the transparency of DOE's analysis.

The details of the methodology vary based on the number and type of side cases published with each edition of the *AEO*. The approach adopted for *AEO2016* is described in appendix 15A. A more detailed discussion of the general approach is presented in K. Coughlin, "Utility Sector Impacts of Reduced Electricity Demand."[3]

This chapter presents the results for pool 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 2016*. 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. Changes in generation by fuel type lead in turn to changes in total power sector emissions of SO_2, NO_x, Hg, and CO_2.

DOE defined impact factors describing the change in emissions, 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 site energy savings calculated in the NIA (chapter 10) to produce estimates of the utility impacts. The utility impact factors are presented in appendix 15A. For pool pumps DOE used the impact factors for homes and commercial buildings.

15.3 UTILITY IMPACT RESULTS

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. The changes have been calculated based on the impact factors for capacity presented in appendix 15A. 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.

[b] These units are identical to GW/TWh.

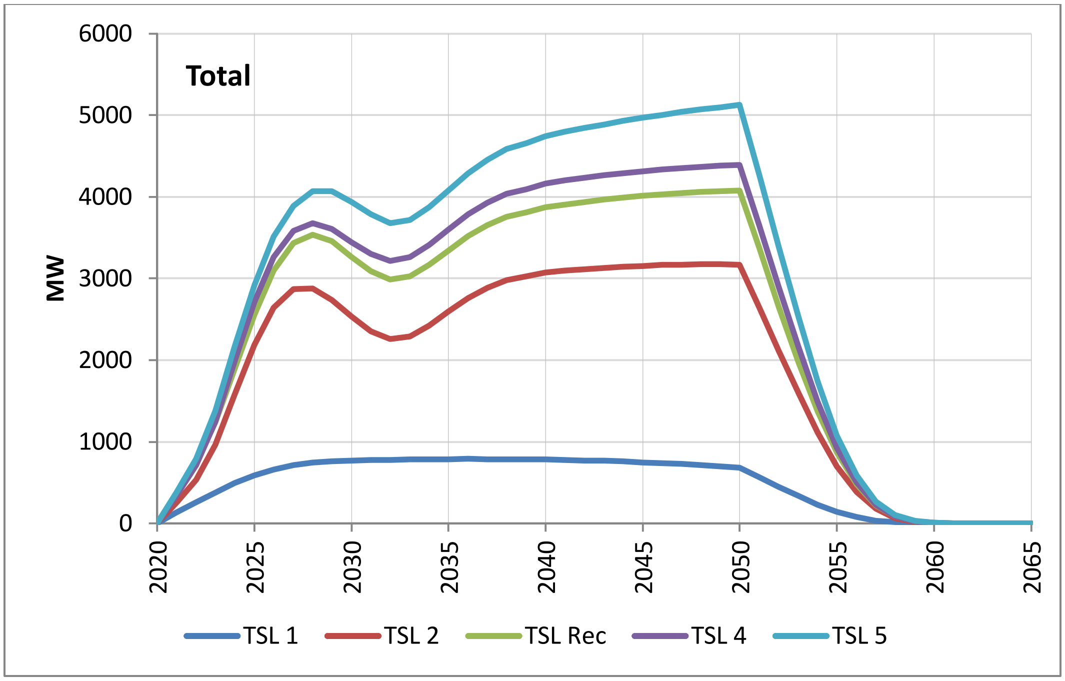

Figure 15.3.1 Pool Pumps: Total Electric Capacity Reduction

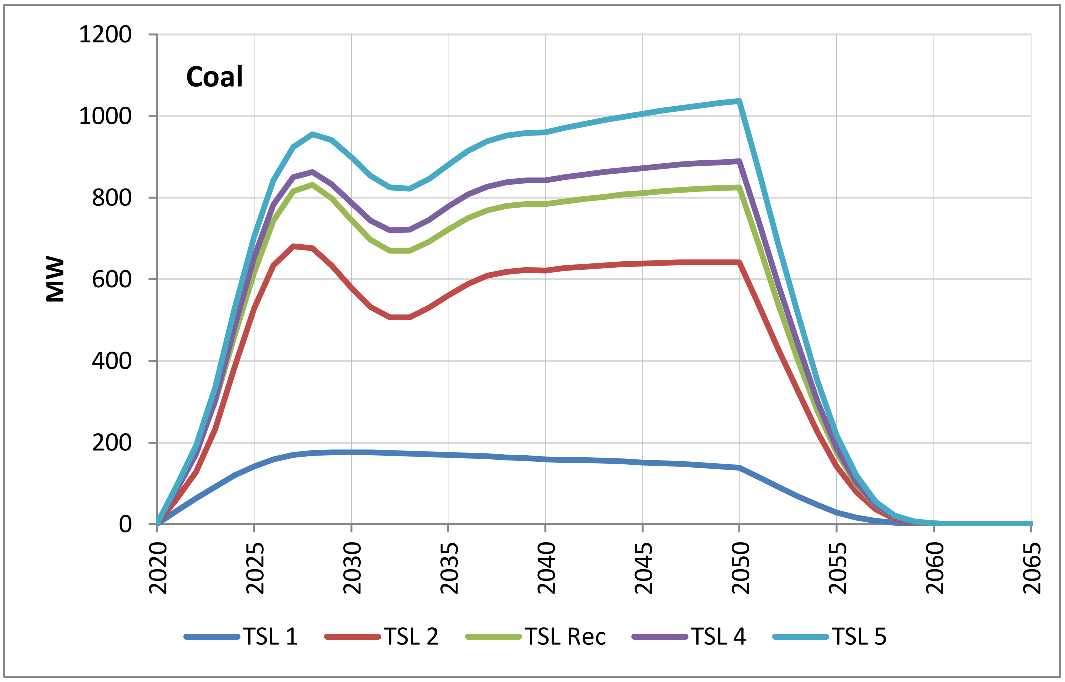

Figure 15.3.2 Pool Pumps: Coal Capacity Reduction

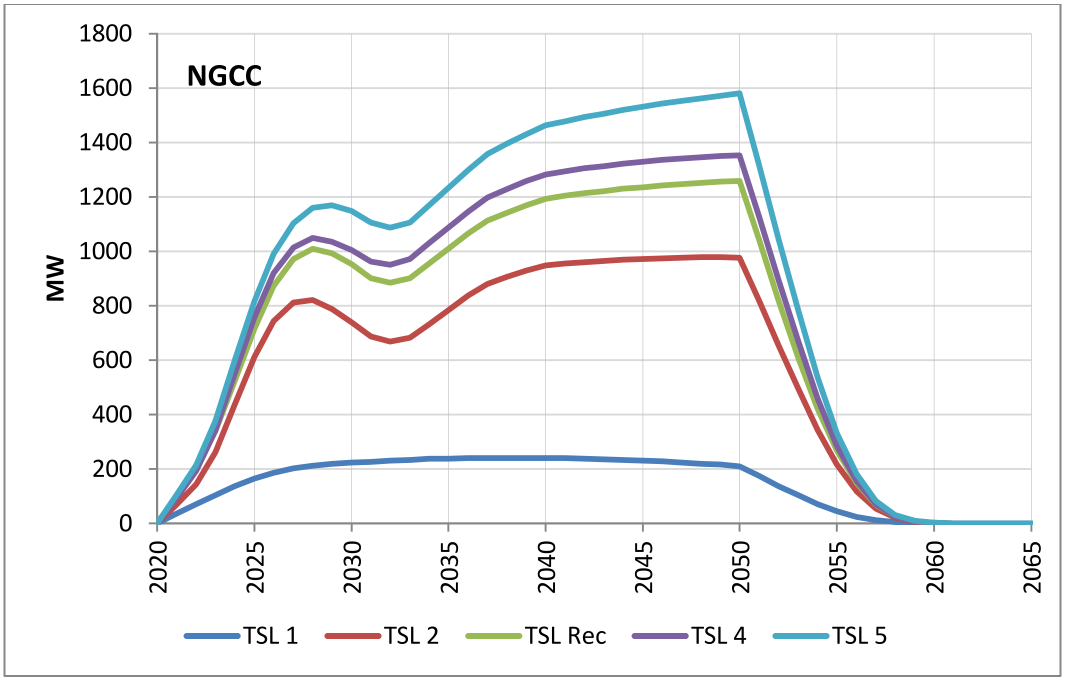

Figure 15.3.3 Pool Pumps: Gas Combined Cycle Capacity Reduction

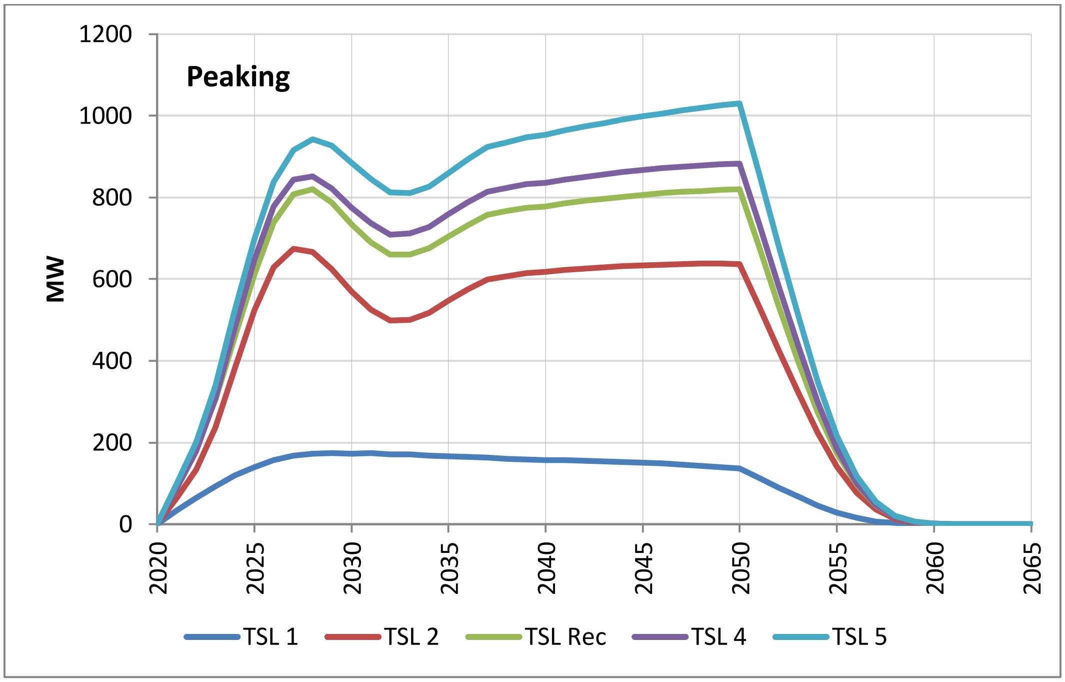

Figure 15.3.4 Pool Pumps: Peaking Capacity Reduction

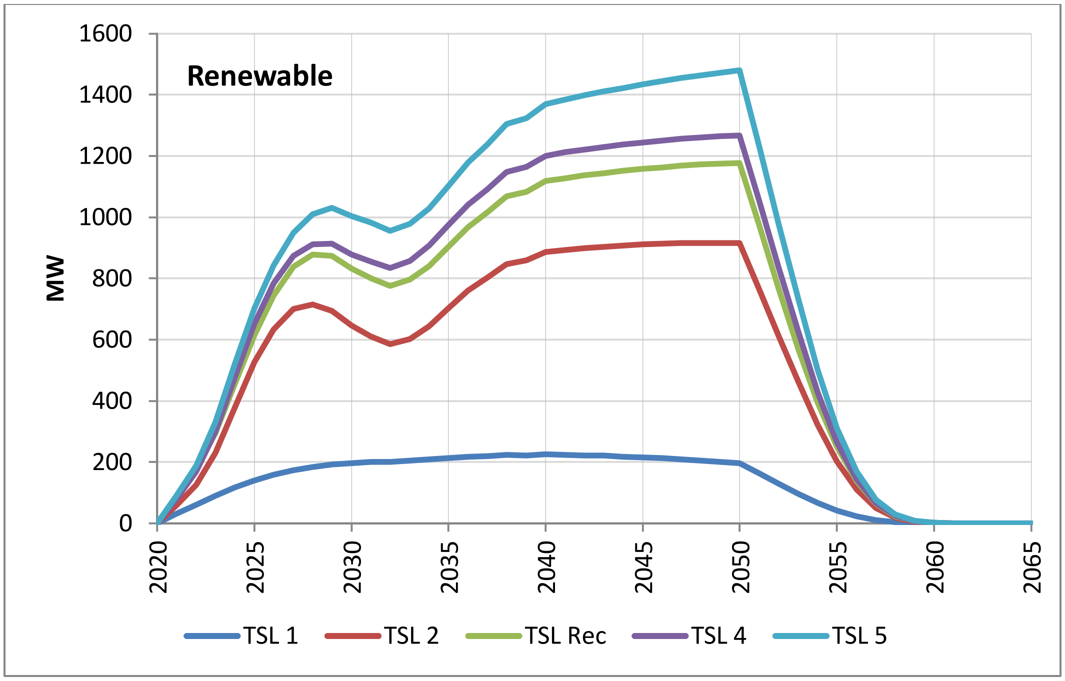

Figure 15.3.5 Pool Pumps: Renewables Capacity Reduction

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. The change by fuel type has been calculated based on factors calculated as described in appendix 15A.

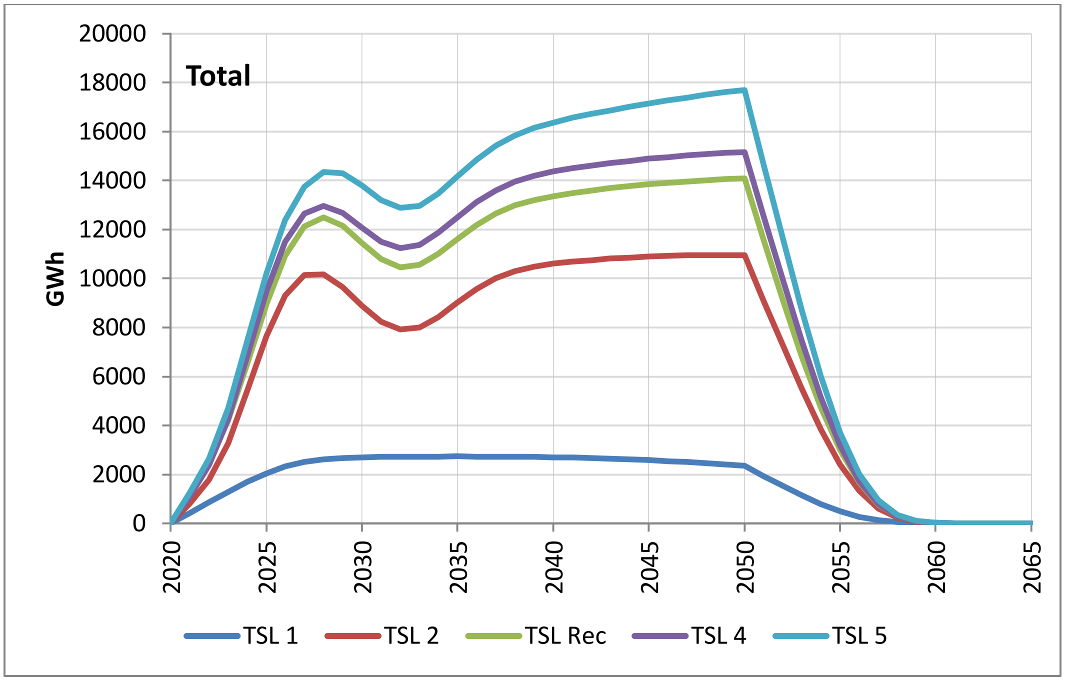

Figure 15.3.6 Pool Pumps: Total Generation Reduction

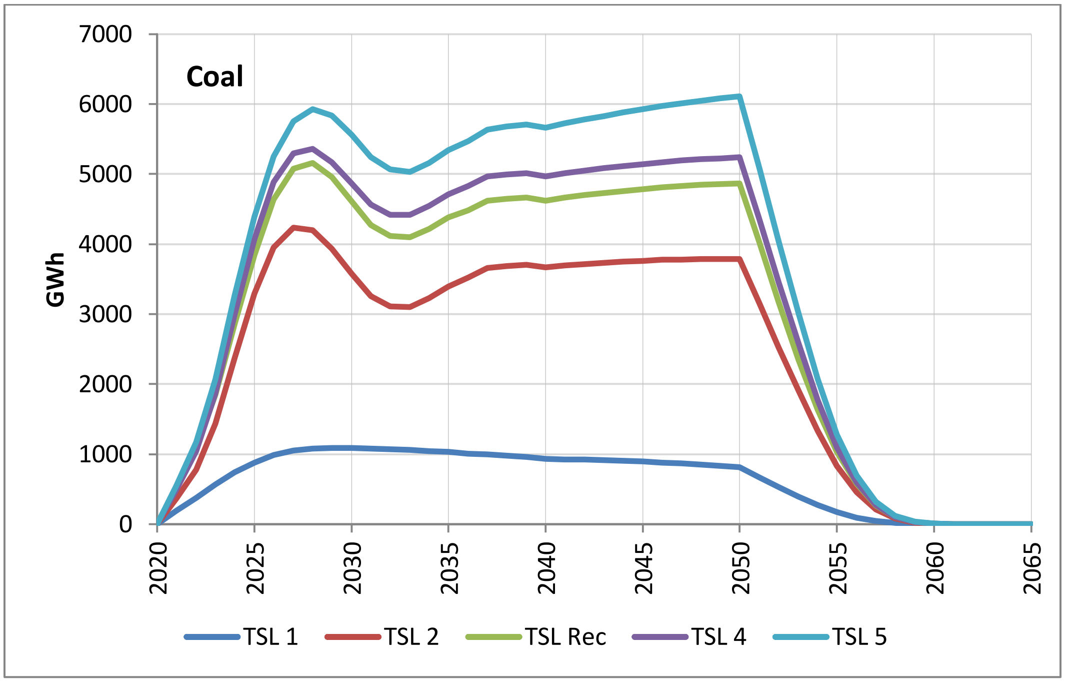

Figure 15.3.7 Pool Pumps: Coal Generation Reduction

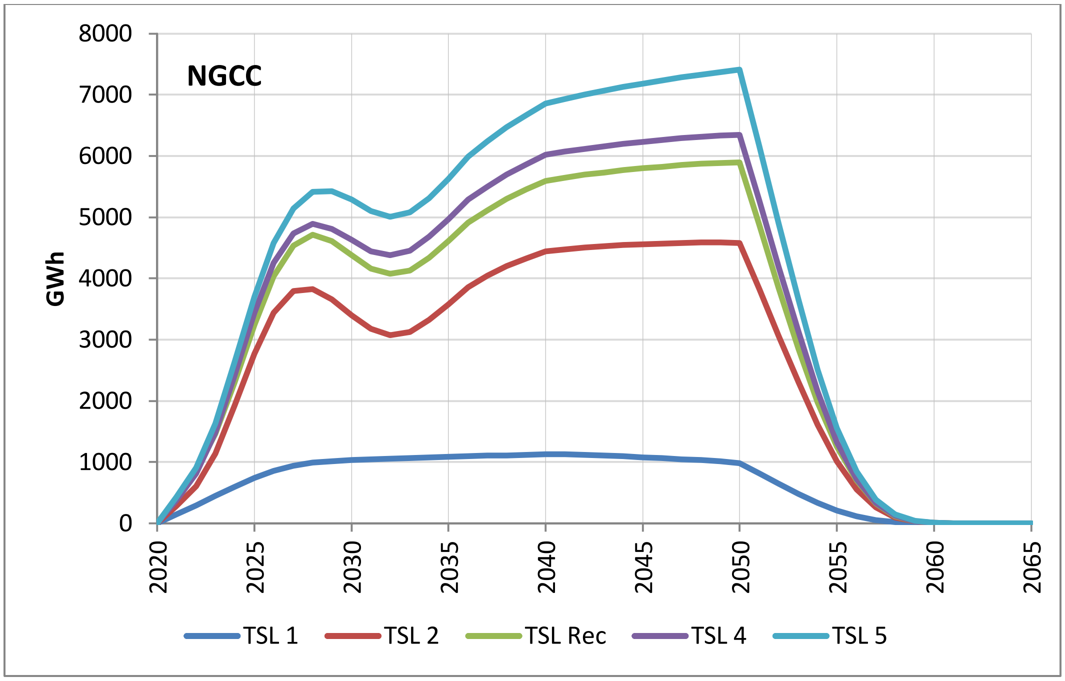

Figure 15.3.8 Pool Pumps: Gas Combined Cycle Generation Reduction

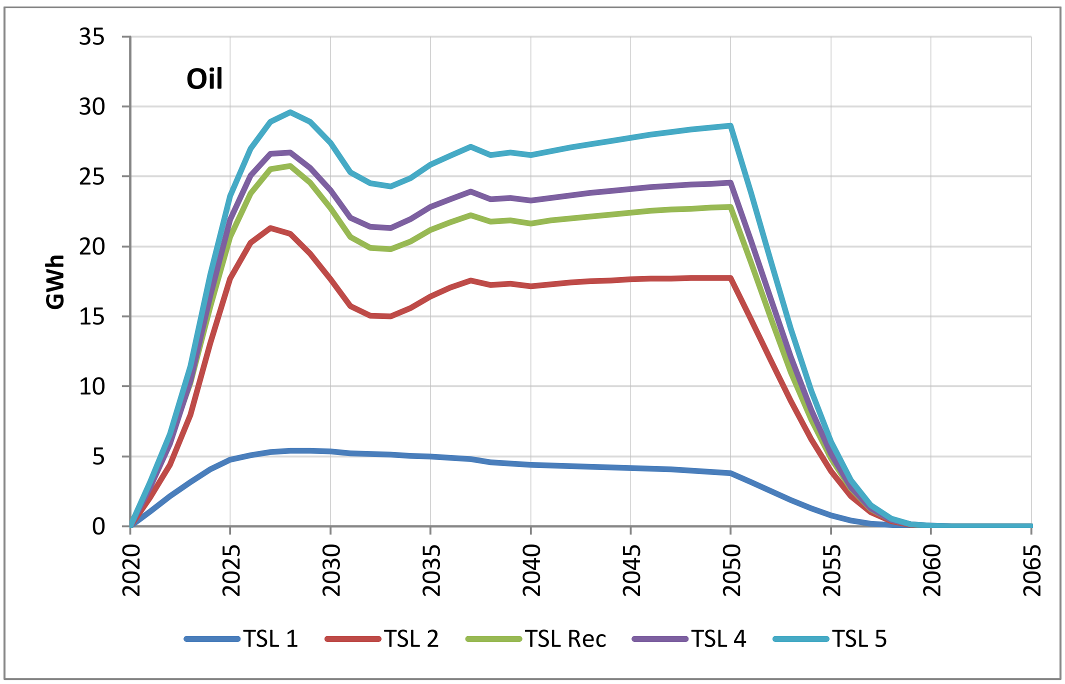

Figure 15.3.9 Pool Pumps: Oil Generation Reduction

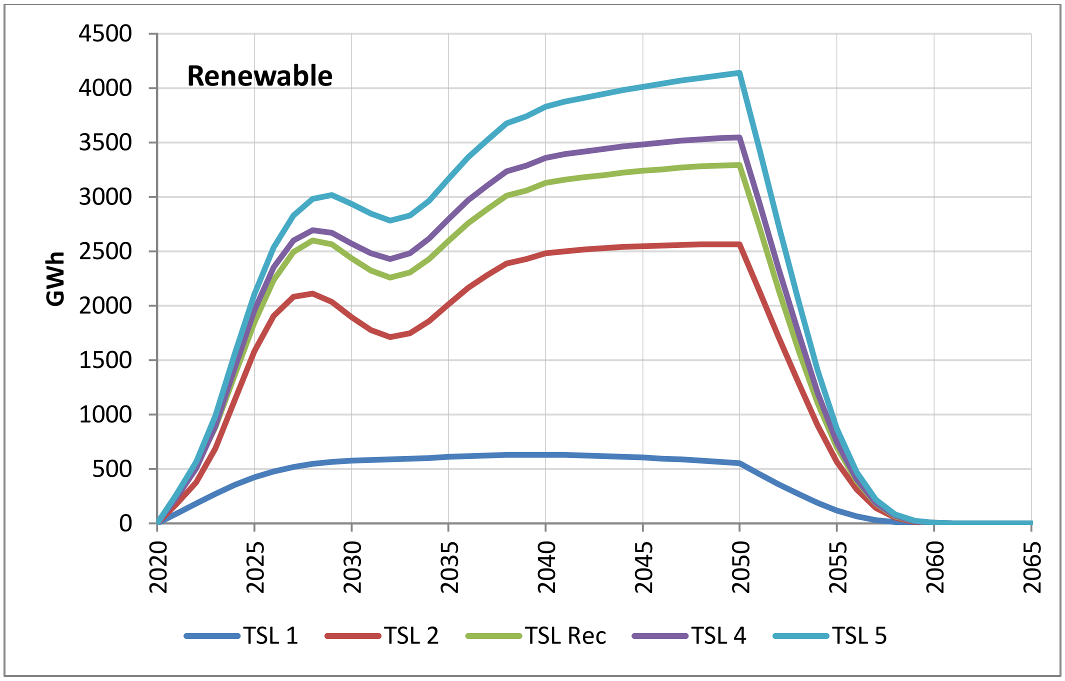

Figure 15.3.10 Pool Pumps: Renewables Generation Reduction

15.3.3 Results Summary

Table 15.3.1 presents a summary of the utility impact results for pool pumps.

Table 15.3.1 Pool Pumps: Summary of Utility Impact Results

	TSL				
	1	2	TSL Rec	4	5
Installed Capacity Reduction (MW)					
2025	587	2,191	2,559	2,712	2,920
2030	770	2,534	3,264	3,445	3,937
2035	787	2,594	3,341	3,597	4,075
2040	783	3,073	3,873	4,162	4,744
Electricity Generation Reduction (GWh)					
2025	2,054	7,666	8,956	9,489	10,218
2030	2,703	8,891	11,451	12,085	13,811
2035	2,735	9,010	11,605	12,495	14,154
2040	2,701	10,607	13,368	14,366	16,374

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3 Coughlin, K. *Utility Sector Impacts of Reduced Electricity Demand*, 2014. Lawrence Berkeley National Laboratory. Report No. LBNL-6864E. http://www.osti.gov/scitech/biblio/1165372/

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15A.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). These changes are estimated by multiplying the site savings of electricity by a set of *impact factors* which measure the corresponding change in generation by fuel type, installed capacity, and power sector emissions. This Appendix describes the methods that DOE used to calculate these impact factors. The methodology is more fully described in Coughlin (2014).[1]

DOE's analysis uses output of the DOE/Energy Information Administration (EIA)'s *Annual Energy Outlook* (*AEO*). The *AEO* includes a reference case and a set of side cases that implement a variety of economic and policy scenarios. In 2015 EIA announced the adoption of a two-year release cycle for the *AEO*, alternating between a full set of scenarios and a shorter edition containing only five scenarios.[2] DOE adapts its calculation methodology according to the number and type of scenarios available with each *AEO* publication, as described below.

DOE used the *AEO2016* No Clean Power Plan (CPP) case as a basis for developing its utility and emissions impacts analyses.

15A.2 METHODOLOGY

Marginal reductions in electricity demand lead to marginal reductions in power sector generation, emissions, and installed capacity. Generally, DOE quantifies these reductions using marginal impact factors, which are time series defining the change in some power sector quantity that results from a unit change in site electricity demand. Because load shapes affect the mix of generation types on the margin, these impact factors depend on end-use and sector.

DOE's approach examines a series of *AEO* side cases related to efficiency policy to estimate the relationship between marginal demand reductions and power sector variables. In *AEO2016* all side cases except the No-CPP case include the CPP. Consequently DOE has adapted it's methodology to use grid-average, rather than marginal, data for the utility impacts estimation. DOE continues to use marginal emissions intensity factors for the emissions analysis, as described in appendix 13A.

The purpose of the utility impacts analysis is to relate changes in electricity demand to the corresponding changes in three quantities: power sector generation (TWh) by fuel type, power sector fuel consumption (quads) by fuel type, and power sector installed capacity (GW) by fuel and technology type.

For this analysis, DOE used the AEO projections of generation, fuel consumption and installed capacity by Electricity Market Module (EMM) region. DOE aggregated the data for the 22 EMM regions into 5 regions which are also aggregations of the NERC reliability regions:

region 1 consists of NERC regions NPCC and RFC, region 2 contains the SERC and FRCC regions, region 3 is MRO, region 4 ERCOT plus SPP, and region 5 is WECC.

The relationship between fuel consumption and generation is defined by the heat rate (quads/TWh). DOE's approach to calculating heat rates is described in appendix 10B of this TSD. DOE defined a heat rate $H(f,r,y)$ for each fuel type f, region r and year y. The fuel types are coal, natural gas, nuclear, oil and renewables. DOE's uses the EIA convention assigning a heat rate of 10.5 Btu/Wh to nuclear power and 9.5 Btu/Wh to electricity from renewable sources. The heat rates include the transmission and distribution loss factor.

The relationship between installed capacity and generation is defined by a capacity factor (GW/TWh). For each of the five aggregated EMM regions, and each year, DOE used the ratio of total installed capacity by technology type to total annual generation by fuel type to define capacity factors. The technology types are coal, natural gas combined-cycle (NGCC), oil and gas steam (OGS), combustion turbine-diesel (CTD), nuclear and renewable sources. For NGCC the capacity factor is defined as the ration of NGCC capacity to natural gas generation. For both CTD and OGS DOE defined a *peak* capacity type, with capacity factor equal to the ratio of the sum of CTD plus OGS capacity to oil-fired generation. The AEO projections of nuclear generation and installed capacity are nearly the same for all scenarios, which implies that the installed capacity for nuclear is not affected by small changes in demand; hence DOE assumed a capacity factor of zero for nuclear power in its utility impacts estimates. The result is a set of capacity factors $C(p,r,y)$ for each power plant technology type p, region r and year y.

Within each region, DOE calculated the fraction of generation allocated to each fuel type based on AEO projections of generation by EMM region, for the major fuel types: coal, natural gas, nuclear, oil, and renewables. This grid-average calculation shows that approximately 15-20% of generation is allocated to nuclear. As the grid-average calculation is an approximation to the marginal calculation, and all DOE's previous marginal calculations have shown that within NEMS nuclear power is never on the margin, DOE zeroed out the nuclear portion of the generation fraction and redistributed the nuclear share proportionally across the other fuel types. The result is a set of factors $G(r,f,y)$ defining the fraction of generation by fuel type for marginal reductions in demand that vary by region and year.

To relate the regional supply-side data to demand-side electricity use by sector and end-use DOE calculated regional weighting factors. These weights define the distribution of electricity consumption for sector/end-use u over the five regions r. This calculation uses the AEO projection of end-use electricity consumption by census division, and a matrix provided with the NEMS code that cross-tabulates sectoral electricity use by both EMM region and census division. This calculation provides regional weights $w(u,r,y)$.

The regional weights are combined with the supply side generation fuel shares and capacity factors to define impact factors as a function of sector/end-use and year. In equation form,

$$G'(u, f, y) = \sum_r w(u, r, y)\, G(r, f, y),$$

$$C'(u, p, y) = \sum_r w(u, r, y)\, C(r, p, y).$$

Eq. 15A.1

Where:

u = an index representing the sector/end-use (e.g. commercial cooling)
r = the region
y = the analysis year
f = the fuel type
p = the power plant technology type
$w(u,r,y)$ = the regional weight
$G(r,f,y)$ = the fraction of generation provided by fuel type f in region r and year y
$G'(u,f,y)$ = the fraction of generation provided by fuel type f for end-use u in year y
$C(r,f,y)$ = the capacity factor for plant type p in region r and year y
$C'(u,f,y)$ = the capacity factor for plant type p for end-use u in year

15A.3 MODEL RESULTS

Representative values of the impact factors for fuel share by fuel type, and capacity by technology type are provided in the tables below. The tables show the factors for two years, 2025 and 2040. The marginal heat rates are presented in appendix 10B and emissions factors are presented in in appendix 13A.

15A.3.1 Electricity Generation

Table 15A.3.1 and Table 15A.3.2 show the distribution across fuel types of a unit reduction in electricity demand by sector and end-use, referred to above as fuel-share weights. The fuel types are coal, natural gas, petroleum, renewables and nuclear. The values for cooling are representative of peaking loads, while the values for refrigeration are representative of flat loads. The data are shown for 2025 and 2040.

Table 15A.3.1. Fuel-Share Weights by Sector and End-Use (Values for 2025)

	Coal	Natural Gas	Nuclear	Oil	Renewables
Commercial Sector					
cooking	43.5%	36.9%	0.0%	0.2%	19.3%
lighting	42.8%	35.7%	0.0%	0.2%	21.2%
office equipment (non-pc)	41.6%	34.7%	0.0%	0.2%	23.5%
office equipment (pc)	42.9%	35.6%	0.0%	0.2%	21.2%
other uses	42.8%	35.5%	0.0%	0.2%	21.5%
refrigeration	43.7%	35.9%	0.0%	0.2%	20.2%
space cooling	42.2%	37.1%	0.0%	0.2%	20.4%
space heating	43.9%	34.3%	0.0%	0.2%	21.6%
ventilation	43.3%	35.9%	0.0%	0.2%	20.6%
water heating	42.9%	36.5%	0.0%	0.2%	20.4%
Industrial Sector					
all uses	43.3%	34.3%	0.0%	0.2%	22.2%
Residential Sector					
ceiling fans	44.5%	35.7%	0.0%	0.2%	19.5%
clothes dryers	42.8%	36.2%	0.0%	0.2%	20.8%
cooking	42.6%	35.9%	0.0%	0.2%	21.3%
electronics	42.2%	35.3%	0.0%	0.2%	22.3%
freezers	43.2%	35.1%	0.0%	0.2%	21.5%
furnace fans	44.8%	34.0%	0.0%	0.2%	20.9%
lighting	41.9%	35.2%	0.0%	0.2%	22.6%
other uses	42.9%	36.2%	0.0%	0.2%	20.6%
refrigeration	42.1%	35.0%	0.0%	0.2%	22.7%
space cooling	42.7%	37.3%	0.0%	0.2%	19.7%
space heating	43.1%	36.4%	0.0%	0.2%	20.3%
water heating	43.4%	37.1%	0.0%	0.2%	19.3%

Table 15A.3.2 Fuel-Share Weights by Sector and End-Use (Values for 2040)

	Coal	Natural Gas	Nuclear	Oil	Renewables
Commercial Sector					
cooking	34.9%	42.9%	0.0%	0.2%	22.1%
lighting	34.6%	41.2%	0.0%	0.2%	24.0%
office equipment (non-pc)	33.8%	39.6%	0.0%	0.2%	26.5%
office equipment (pc)	34.7%	41.1%	0.0%	0.2%	24.0%
other uses	34.7%	41.0%	0.0%	0.2%	24.2%
refrigeration	35.4%	41.7%	0.0%	0.2%	22.7%
space cooling	33.6%	42.8%	0.0%	0.2%	23.5%
space heating	36.3%	39.8%	0.0%	0.2%	23.7%
ventilation	35.0%	41.7%	0.0%	0.2%	23.2%
water heating	34.5%	42.0%	0.0%	0.2%	23.3%
Industrial Sector					
all uses	35.2%	39.7%	0.0%	0.2%	24.9%
Residential Sector					
ceiling fans	36.0%	41.7%	0.0%	0.2%	22.1%
clothes dryers	34.2%	41.7%	0.0%	0.2%	24.0%
cooking	34.2%	41.3%	0.0%	0.2%	24.4%
electronics	34.2%	40.6%	0.0%	0.2%	25.1%
freezers	35.0%	40.5%	0.0%	0.2%	24.3%
furnace fans	37.2%	39.7%	0.0%	0.2%	22.9%
lighting	33.8%	40.3%	0.0%	0.2%	25.7%
other uses	34.6%	41.9%	0.0%	0.2%	23.3%
refrigeration	34.1%	40.1%	0.0%	0.2%	25.6%
space cooling	33.5%	42.7%	0.0%	0.2%	23.6%
space heating	34.7%	42.2%	0.0%	0.2%	22.9%
water heating	34.5%	42.8%	0.0%	0.2%	22.5%

15A.3.2 Installed Capacity

Table 15A.3.3 and Table 15A.3.4 show the total change in installed capacity (GW) per unit of site electricity demand reduction for the five principal capacity types: coal, natural gas, peaking, renewables, and nuclear. The peaking category is the sum of the two NEMS categories oil and gas steam and combustion turbine/diesel. Data are shown for 2025 and 2040.

Table 15A.3.3. Capacity Impact Factors in GW per TWh Reduced Site Electricity Demand (Values for 2025)

	Coal	Natural Gas	Nuclear	Peaking	Renewables
Commercial Sector					
cooking	6.99E-02	8.06E-02	0.00E+00	6.95E-02	6.42E-02
lighting	6.88E-02	7.90E-02	0.00E+00	6.83E-02	6.96E-02
office equipment (non-pc)	6.67E-02	7.79E-02	0.00E+00	6.66E-02	7.64E-02
office equipment (pc)	6.88E-02	7.87E-02	0.00E+00	6.82E-02	6.94E-02
other uses	6.87E-02	7.87E-02	0.00E+00	6.82E-02	7.04E-02
refrigeration	7.02E-02	7.89E-02	0.00E+00	6.91E-02	6.63E-02
space cooling	6.78E-02	8.20E-02	0.00E+00	6.92E-02	6.86E-02
space heating	7.05E-02	7.62E-02	0.00E+00	6.82E-02	7.00E-02
ventilation	6.95E-02	7.91E-02	0.00E+00	6.90E-02	6.76E-02
water heating	6.89E-02	8.03E-02	0.00E+00	6.88E-02	6.76E-02
Industrial Sector					
all uses	6.94E-02	7.68E-02	0.00E+00	6.76E-02	7.28E-02
Residential Sector					
ceiling fans	7.15E-02	7.83E-02	0.00E+00	6.99E-02	6.39E-02
clothes dryers	6.86E-02	7.98E-02	0.00E+00	6.81E-02	6.90E-02
cooking	6.83E-02	7.93E-02	0.00E+00	6.78E-02	7.03E-02
electronics	6.77E-02	7.85E-02	0.00E+00	6.73E-02	7.30E-02
freezers	6.94E-02	7.78E-02	0.00E+00	6.79E-02	7.04E-02
furnace fans	7.20E-02	7.52E-02	0.00E+00	6.93E-02	6.66E-02
lighting	6.73E-02	7.85E-02	0.00E+00	6.70E-02	7.42E-02
other uses	6.89E-02	8.00E-02	0.00E+00	6.83E-02	6.86E-02
refrigeration	6.75E-02	7.81E-02	0.00E+00	6.70E-02	7.42E-02
space cooling	6.85E-02	8.20E-02	0.00E+00	6.92E-02	6.65E-02
space heating	6.90E-02	8.01E-02	0.00E+00	6.84E-02	6.76E-02
water heating	6.96E-02	8.08E-02	0.00E+00	6.90E-02	6.45E-02

Table 15A.3.4 Capacity Impact Factors in GW per TWh Reduced Site Electricity Demand (Values for 2040)

	Coal	Natural Gas	Nuclear	Peaking	Renewables
Commercial Sector					
cooking	5.92E-02	9.06E-02	0.00E+00	5.88E-02	7.89E-02
lighting	5.84E-02	8.82E-02	0.00E+00	5.84E-02	8.41E-02
office equipment (non-pc)	5.67E-02	8.59E-02	0.00E+00	5.74E-02	9.09E-02
office equipment (pc)	5.85E-02	8.79E-02	0.00E+00	5.84E-02	8.34E-02
other uses	5.84E-02	8.79E-02	0.00E+00	5.86E-02	8.42E-02
refrigeration	5.98E-02	8.87E-02	0.00E+00	5.92E-02	7.98E-02
space cooling	5.71E-02	9.16E-02	0.00E+00	5.83E-02	8.46E-02
space heating	6.08E-02	8.55E-02	0.00E+00	5.96E-02	8.16E-02
ventilation	5.91E-02	8.89E-02	0.00E+00	5.90E-02	8.11E-02
water heating	5.84E-02	8.96E-02	0.00E+00	5.84E-02	8.29E-02
Industrial Sector					
all uses	5.92E-02	8.58E-02	0.00E+00	5.86E-02	8.65E-02
Residential Sector					
ceiling fans	6.07E-02	8.87E-02	0.00E+00	6.01E-02	7.69E-02
clothes dryers	5.80E-02	8.89E-02	0.00E+00	5.77E-02	8.52E-02
cooking	5.78E-02	8.83E-02	0.00E+00	5.77E-02	8.61E-02
electronics	5.76E-02	8.73E-02	0.00E+00	5.78E-02	8.71E-02
freezers	5.90E-02	8.69E-02	0.00E+00	5.85E-02	8.49E-02
furnace fans	6.19E-02	8.50E-02	0.00E+00	6.07E-02	7.68E-02
lighting	5.69E-02	8.70E-02	0.00E+00	5.74E-02	8.97E-02
other uses	5.86E-02	8.94E-02	0.00E+00	5.82E-02	8.36E-02
refrigeration	5.75E-02	8.66E-02	0.00E+00	5.77E-02	8.85E-02
space cooling	5.71E-02	9.13E-02	0.00E+00	5.78E-02	8.55E-02
space heating	5.89E-02	8.97E-02	0.00E+00	5.83E-02	8.23E-02
water heating	5.87E-02	9.05E-02	0.00E+00	5.81E-02	8.13E-02

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CHAPTER 16. EMPLOYMENT IMPACT ANALYSIS

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16.1 INTRODUCTION

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 pool pumps. Job increases or decreases reported in this chapter are separate from the direct pool heater production sector employment impacts reported in the manufacturer impact analysis (chapter 12), and reflect the net employment impact of efficiency standards on all 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 products, 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 for 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. Because input/output models do not allow prices to bring markets into equilibrium, they are best used for short-run analysis. DOE therefore include 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[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 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 so 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 affects the overall level of employment.

ImSET uses a 187-sector model of the national economy to predict the economic effects of residential and commercial buildings 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 products. The increased cost of products leads to higher employment in the product manufacturing sectors and lower employment in other economic sectors. Second, commercial firm and residential spending are redirected from utilities and energy producers toward firms that supply production inputs for energy-efficient products. Third, investment funds from utilities and energy producers are released for use in other sectors of the economy. When consumers use less energy, 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 pool heater 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 pool heater 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 a standard in its first year on three aggregate sectors, the pool heater production sector, the energy generation sector, and the general consumer goods sector (as mentioned above ImSET's calculations are made at a much more disaggregate level). By raising energy efficiency, the standard generally increases the purchase price of pool pumps; 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 energy. The reduction in energy demand causes a reduction in employment in that sector. Finally, based on the net impact of increased expenditures on pool pumps and reduced expenditures on energy, 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, which generates more employment, the converse is true for workers laid off).

Table 16.4.1 presents the modeled net employment impact from the standards in 2021, rounded to the nearest hundred jobs. For context, the U.S. labor force had approximately 157 million people in December 2015.[a] Approximately 80% of self-priming pool pumps and 15% of all other types of pool pumps are domestically produced, with the remainder imported. The net employment impact estimate is sensitive to assumptions regarding the return to the U.S. economy of money spent on imported pool pumps. The two scenarios bounding the ranges presented in Table 16.4.1 represent situations in which none of the money spent on imported pool pumps returns to the U.S. economy and all of the money spent on imported pool pumps 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 pool pumps is likely to return, with employment impacts falling within the ranges presented below.

Table 16.4.1 Net National Short-term Change in Employment (1000 Jobs)

Trial Standard Level	2021	2026
TSL 1	0.5 to 0.6	3.5
TSL 2	1.3 to 1.4	11.0 to 12.3
TSL 3	1.9 to 2.0	16.2 to 16.6
TSL 4	1.5 to 1.8	15.4 to 17.3
TSL 5	1.7 to 2.0	16.7 to 18.5

For context, the Office of Management of Budget currently assumes that the unemployment rate may decline to 5.4 percent by 2017.[5] The unemployment rate in 2021 is projected to remain 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 RESULTS

Over the long term DOE expects the energy savings to consumers to increasingly dominate the increase in product costs, resulting in increased aggregate savings to consumers. As a result, DOE expects demand for energy to decline over time and demand for other goods to

[a] Bureau of Labor Statistics: Labor Force Statistics (Available at http://www.bls.gov/data/#employment).

increase. Because the utility and energy production sectors are 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 utilities and energy producers towards consumer goods. Note that in 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 in general 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 2026, are included in the second column of Table 16.4.1.

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17.1 INTRODUCTION

The Administrator of the Office of Information and Regulatory Affairs (OIRA) in the OMB has determined that the regulatory action described in the Federal Register notice associated with this TSD is a significant regulatory action under section (3)(f) of 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, the Department of Energy (DOE) used an integrated National Impact Analysis (NIA)-RIA model built on a modified[a] version of the NIA model discussed in chapter 10. DOE identified four non-regulatory policy alternatives that possibly could provide incentives for the same energy efficiency levels as the ones in the recommended trial standard level (TSL) for the pool pumps that 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.[b] 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 recommended standards for the five equipment classes of pool pumps covered by this RIA.[c]

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

Sections 17.2 and 17.3 discuss the analysis of four selected policies listed in Table 17.1.1 (excluding the alternative of "No New Regulatory Action"). Section 17.4 presents the results of the policy alternatives.

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[a] For this RIA, DOE developed an alternative NIA model where shipments in the policy case do not account for price-elasticity of demand or any repair-replace decision making. DOE believes that the national benefits from standards calculated this way are more comparable to the benefits from the alternative policies.

[b] In other RIAs DOE has evaluated the benefits from government bulk purchases. However, according to the 2009 Residential Energy Consumption Survey (http://www.eia.gov/consumption/residential/data/2009/), no housing units in public housing authority use pool pumps. Therefore, DOE assumed that there is no market for this alternative policy and, consequently, did not include it in this analysis.

[c] This RIA covers the following five equipment classes of pool pumps as they make up 90% of cumulative shipments: Self-Priming, Non-Self-Priming, Integral Cartridge-Filter 1/15 HP, Integral Cartridge-Filter 1/2 HP, Integral Sand-Filter. In chapter 10, results for Integral Cartridge-Filter 1/15 HP and Integral Cartridge-Filter 1/2 HP are combined.

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 pool pumps. 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 this technical support document (TSD) describes the NIA spreadsheet model. Appendix 17A discusses the NIA-RIA integrated model approach.

DOE quantified the effect of each alternative on the purchase of equipment that meets the efficiency levels corresponding to 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 products that did not meet the TSL target levels in the no-standards case, 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 pool pumps attributable to each policy alternative.

Increasing the efficiency of a product 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 recommended 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.

- National Energy Savings (NES), given in quadrillion Btus (quads), describes the cumulative national energy saved over the lifetime of equipment purchased during the 30-year analysis period starting in the effective date of the policy (2021-2050).
- Net Present Value (NPV), represents the value of net monetary savings in 2016, expressed in 2015$, from equipment purchased during the 30-year analysis period starting in the effective date of the policy (2021-2050). DOE calculated the NPV as the difference between the present values of installed equipment cost and operating expenditures in the no-standards case and the present values of those costs in each policy

case. DOE calculated operating expenses (including energy costs) for the life of the product.

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' response 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 pool pumps relative to their no-standards case efficiency scenario (which involves no new regulatory action). The analysis considered that each alternative policy would induce consumers to purchase units having the same technology as required by standards (the target level), according to the minimum energy efficiency 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 energy efficiencies from the technologies stipulated for pool pumps for each TSL.

Table 17.2.1 Energy Efficiency by TSL (WEF)

	TSL 1	TSL 2	**TSL Rec***	TSL 4	TSL5
Self-Priming	5.55	7.60	**11.28**	11.28	13.40
Non-Self-Priming	4.60	7.05	**4.60**	9.36	13.86
Integral Cart-Filter 1/15 HP	-	-	**(timer)****	-	-
Integral Cart-Filter 1/2 HP	-	-	**(timer)****	-	-
Integral Sand-Filter	-	-	**(timer)****	-	-

* Recommended TSL

** The pump must be distributed in commerce with a pool pump timer that is either integral to the pump or a separate component that is shipped with the pump.

DOE assumed that the effects of non-regulatory policies would last from the effective date of standards—2021—through the end of the analysis period, which is 2050.

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 assumptions to avoid double-counting policy impacts. The resulting policy impacts are therefore not additive, and 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 pool pumps.

17.3 NON-REGULATORY POLICY ASSUMPTIONS

The following subsections describe DOE's analysis of the impacts of the five non-regulatory policy alternatives to the standards recommended for pool pumps. (Because the alternative of "No New Regulatory Action" has no energy or economic impacts, essentially representing the NIA no-standards case, DOE did not perform any additional analysis for that alternative.) DOE developed estimates of the market penetration of more efficient products 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 pool pumps constitutes the no-standards case, as described in chapter 10, National Impact Analysis. The no-standards 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 equipment. This policy provides a consumer rebate for purchasing pool pumps that operate at the same efficiency levels as stipulated in each TSL.

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.,[d] 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, 8] used different approaches: other economic parameters (e.g., payback

[d] XENERGY is now owned by KEMA, Inc. (www.kema.com)

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, 6] DOE decided that the most appropriate available method for this RIA 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 17A 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 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, 6, 9]

DOE modeled the effects of a consumer rebate policy for pool pumps by determining, for each TSL, the increase in market penetration of equipment meeting the target level relative to their market penetration in the no-standards case. It used the interpolation method presented in Blum et al (2011)[10] to create customized penetration curves based on relationships between actual no-standards 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 pool pumps. 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 covered by this RIA so they can best reflect the market barrier levels that consumer rebates for pool pumps would face. Section 17.3.2.2 shows the resulting interpolated curves used in the analysis.

17.3.2.2 Analysis

DOE estimated the effect of increasing the B/C ratio of pool pumps via a rebate that would pay all of the increased installed cost of units that meet the target efficiency levels compared to units meeting the baseline efficiency level.[e] To inform its estimate of an appropriate

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[e] The baseline technology is defined in the engineering analysis, chapter 5, as the technology that represents the basic characteristics of pool pumps. A baseline unit typically is one that just meets current Federal energy conservation standards and provides basic consumer utility.

rebate amount, DOE performed a thorough nationwide search for existing rebate programs for pool pumps in July, 2016. It gathered data from a sample of utility and agency rebate programs that includes 45 rebates for pool pumps initiated by 38 utilities or agencies in various States. DOE then estimated a market representative rebate value for each equipment class covered by this RIA which it applied in the calculation of the B/C ratio of pool pumps under the effect of consumer rebates. (Appendix 17A, identifies the rebate programs and details the methodology DOE used to estimate a market representative rebate amount.) DOE assumed that rebates would remain in effect at the same level throughout the forecast period (2021-2050).

DOE first calculated the B/C ratio of a pool pumps without a rebate using the difference in total installed costs (C) and lifetime operating cost savings[f] (B) between a unit meeting the target level and a 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 for each TSL on the B/C ratio of pool pumps shipped in the first year of the analysis period.

Table 17.3.1 Benefit/Cost Ratios Without and With Rebates

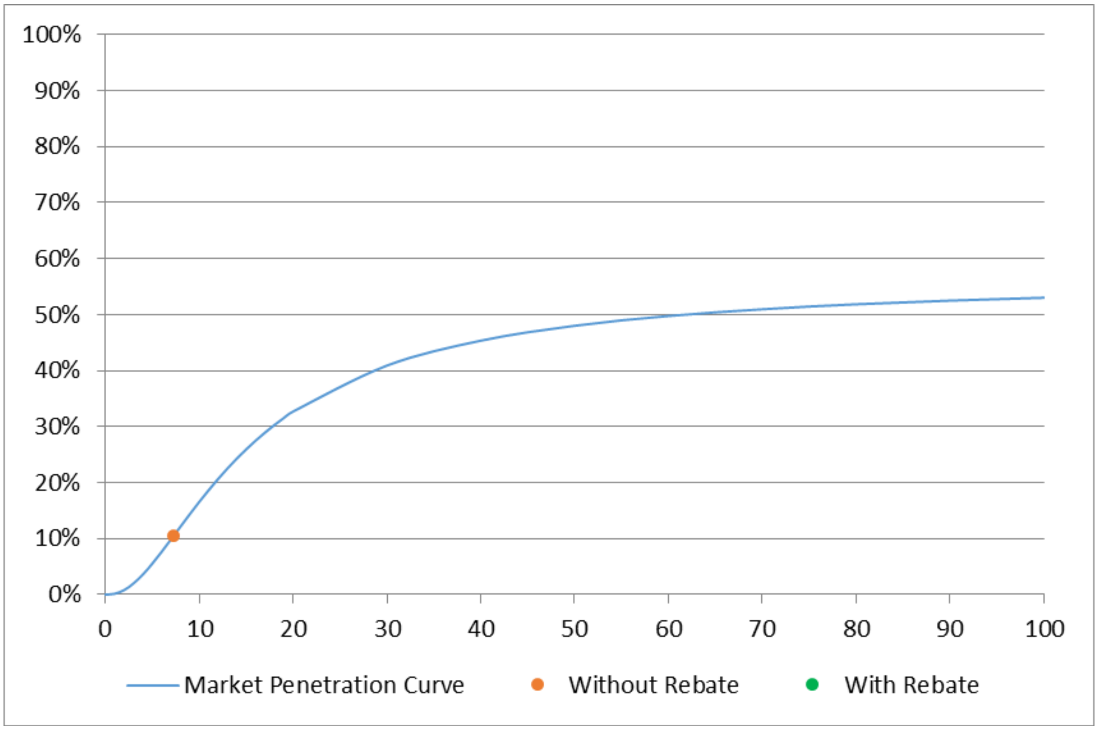
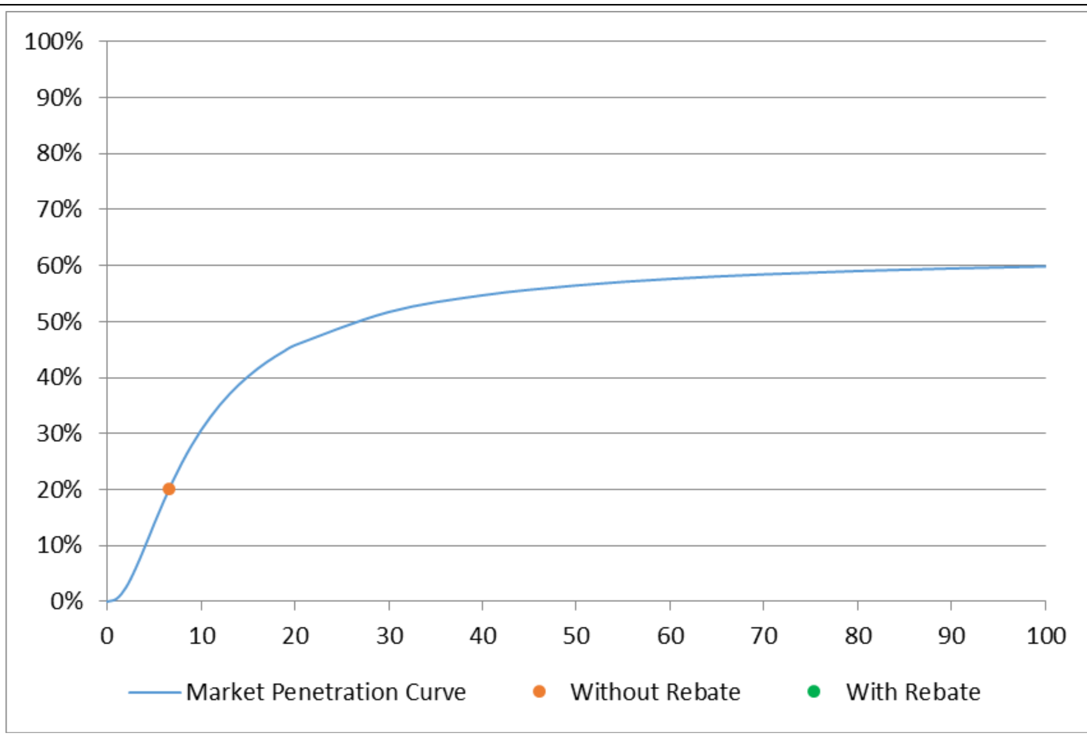
	TSL 1	TSL 2	**TSL Rec***	TSL 4	TSL 5
Self-Priming					
B/C Ratio Without Rebate	-	6.4	**7.3**	7.3	7.8
Rebate Amount	-	367.19	**367.19**	367.19	367.19
B/C Ratio With Rebate	-	infinite	**infinite**	infinite	infinite
Estimated Market Barriers	-	High	**Mod-High**	Mod-High	Mod-High
Non-Self-Priming					
B/C Ratio Without Rebate	-	1.5	-	1.3	1.5
Rebate Amount	-	367.19	-	367.19	367.19
B/C Ratio With Rebate	-	infinite	-	infinite	infinite
Estimated Market Barriers	-	Mod-High	-	Mod	Mod
Integral Cart-Filter 1/15 HP					
B/C Ratio Without Rebate	-	-	**6.6**	-	-
Rebate Amount	-	-	**185.00**	-	-
B/C Ratio With Rebate	-	-	**infinite**	-	-
Estimated Market Barriers	-	-	**Mod-High**	-	-
Integral Cart-Filter 1/2 HP					
B/C Ratio Without Rebate	-	-	**17.9**	-	-
Rebate Amount	-	-	**185.00**	-	-
B/C Ratio With Rebate	-	-	**infinite**	-	-
Estimated Market Barriers	-	-	**High**	-	-
Integral Sand-Filter					
B/C Ratio Without Rebate	-	-	**6.0**	-	-
Rebate Amount	-	-	**185.00**	-	-
B/C Ratio With Rebate	-	-	**infinite**	-	-
Estimated Market Barriers	-	-	**Mod**	-	-

*Recommended TSL

[f] The cash flow of the operating cost savings is discounted to the purchase year using a 7 percent discount rate.

** Mod: Moderate market barriers; Mod-High: Moderate-to-High market barriers.

DOE used the B/C ratio along with the customized penetration curves shown in Figure 17.3.1 to estimate the percentage of consumers who would purchase pool pumps that meet the target levels both with and without a rebate incentive. The estimated levels of market barriers corresponding to the penetration curves DOE calculated to represent the market behavior for pool pumps at the recommended TSL are indicated (highlighted) in Table 17.3.1.

<table>
<tr><th colspan="2">Recommended TSL</th></tr>
<tr><td>Self-Priming</td><td>
</td></tr>
<tr><td>Integral Cart-Filter 1/15 HP</td><td>
</td></tr>
</table>

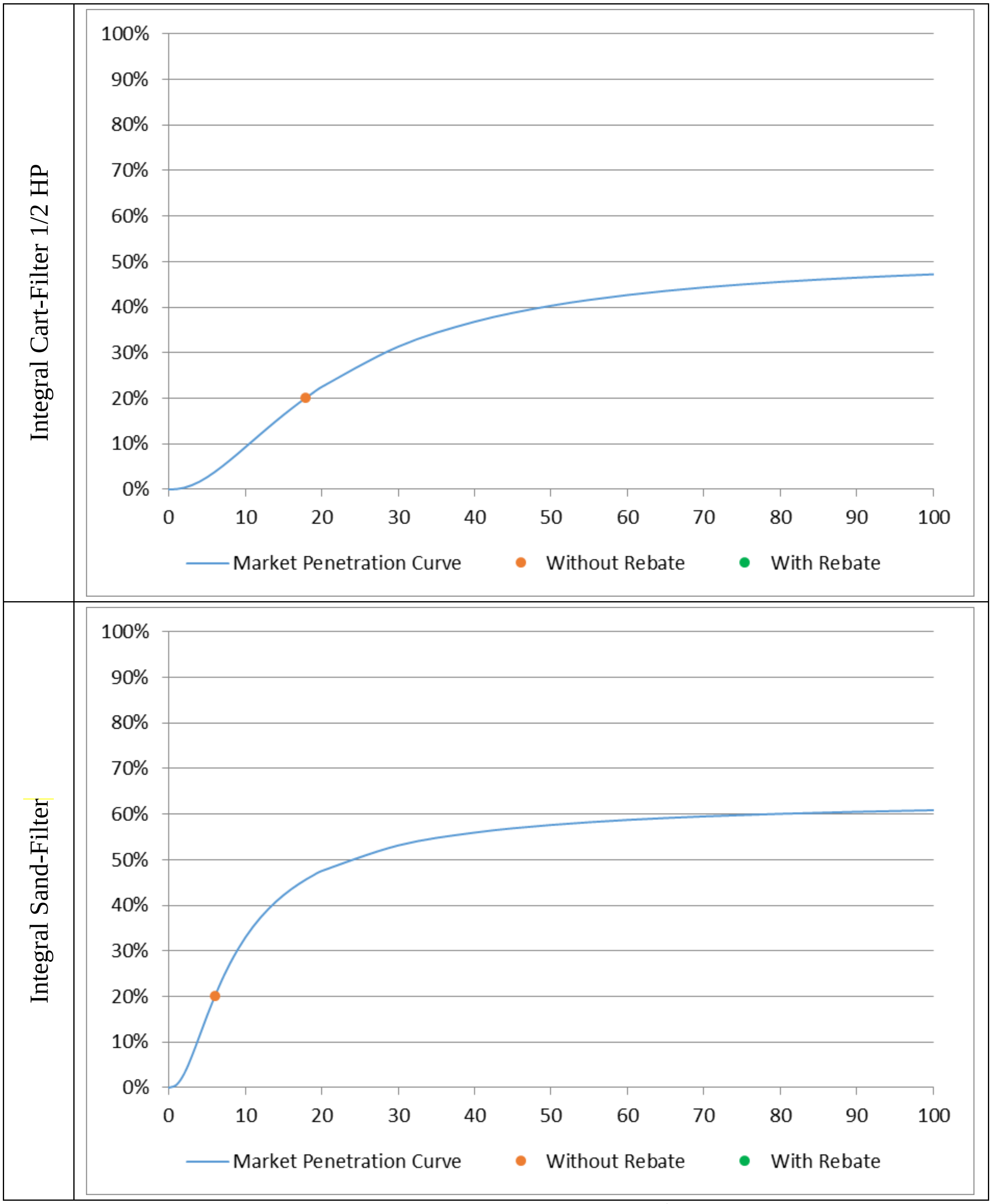


Figure 17.3.1 Market Penetration Curves for Pool Pumps[g]

[g] Because the B/C ratio with rebates is infinite for all equipment classes (see Table 17.3.1), the data points that refer to the market penetration with rebates are not shown in the charts.

DOE next estimated the percent increase represented by the change in penetration rate shown on the corresponding penetration curve. It then added this percent increase to the market share of units that meet the target level in the no-standards case to obtain the market share of units that meet the target level in the rebate policy case.

Table 17.3.2 summarizes DOE's assumptions for pool pumps regarding the market penetration of products in 2021 that meet the target levels at each TSL given a consumer rebate.

Table 17.3.2 Market Penetrations in 2021 Attributable to Consumer Rebates

	TSL 1	TSL 2	**TSL Rec***	TSL 4	TSL 5
Self-Priming					
Base-Case Market Share	-	2.0%	**10.5%**	10.5%	18.5%
Policy Case Market Share	-	50.0%	**56.7%**	56.7%	60.8%
Increased Market Share	-	48.0%	**46.2%**	46.2%	42.3%
Non-Self-Priming					
Base-Case Market Share	-	1.0%	-	2.5%	2.5%
Policy Case Market Share	-	61.7%	-	68.4%	66.1%
Increased Market Share	-	60.7%	-	65.9%	63.6%
Integral Cart-Filter 1/15 HP					
Base-Case Market Share	-	-	**20.0%**	-	-
Policy Case Market Share	-	-	**62.8%**	-	-
Increased Market Share	-	-	**42.8%**	-	-
Integral Cart-Filter 1/2 HP					
Base-Case Market Share	-	-	**20.0%**	-	-
Policy Case Market Share	-	-	**52.1%**	-	-
Increased Market Share	-	-	**32.1%**	-	-
Integral Sand-Filter					
Base-Case Market Share	-	-	**20.0%**	-	-
Policy Case Market Share	-	-	**63.8%**	-	-
Increased Market Share	-	-	**43.8%**	-	-

*Recommended TSL

DOE used the resulting annual increases in market shares as inputs to represent the rebate policy case scenario in its NIA-RIA model. Appendix 17A shows the annual market share increases due to this policy for the whole forecast period. Section 17.4 presents the resulting market penetration trends for the policy case of consumer rebates for pool pumps.

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.[11, 12] 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.[13]

In preparing its assumptions to estimate the effects of tax credits on consumer purchases of pool pumps, 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.[14] 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.[15, 16] 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.[17] 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 pool pumps to warrant adjusting its analysis method for the Consumer Tax Credits policy case. Appendix 17A 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.[18] 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 17A.

DOE applied the assumed 60 percent participation described above to the increase in 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 customized penetration curves it developed for pool pumps (See Figure 17.3.1).

Table 17.3.3 summarizes DOE's assumptions for pool pumps regarding the market penetration of products in 2021 that meet the target levels at each TSL given a consumer tax credit.

Table 17.3.3 Market Penetrations in 2021 Attributable to Consumer Tax Credits

	TSL 1	TSL 2	**TSL Rec***	TSL 4	TSL 5
Self-Priming					
Base-Case Market Share	-	2.0%	**10.5%**	10.5%	18.5%
Policy Case Market Share	-	30.8%	**38.2%**	38.2%	43.9%
Increased Market Share	-	28.8%	**27.7%**	27.7%	25.4%
Non-Self-Priming					
Base-Case Market Share	-	1.0%	-	2.5%	2.5%
Policy Case Market Share	-	37.4%	-	42.1%	40.7%
Increased Market Share	-	36.4%	-	39.6%	38.2%
Integral Cart-Filter 1/15 HP					
Base-Case Market Share	-	-	**20.0%**	-	-
Policy Case Market Share	-	-	**45.7%**	-	-
Increased Market Share	-	-	**25.7%**	-	-
Integral Cart-Filter 1/2 HP					
Base-Case Market Share	-	-	**20.0%**	-	-
Policy Case Market Share	-	-	**39.2%**	-	-
Increased Market Share	-	-	**19.2%**	-	-
Integral Sand-Filter					
Base-Case Market Share	-	-	**20.0%**	-	-
Policy Case Market Share	-	-	**46.3%**	-	-
Increased Market Share	-	-	**26.3%**	-	-

*Recommended TSL

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 17A shows the annual market share increases due to this policy for the whole forecast period. Section 17.4 presents the resulting market penetration trends for the policy case of consumer tax credits for pool pumps that meet the efficiency level for the recommended TSL.

17.3.4 Manufacturer Tax Credits

To analyze the potential effects of a policy that offers tax credits to manufacturers that produce pool pumps that meet the target efficiency levels 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.[h] Because the direct price effect is approximately equivalent to the announcement effect,[11] 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 products. 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.[19] 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 17A presents details on Federal manufacturer tax credits.

DOE applied the assumption of 30 percent participation to the increase in penetration rates predicted for the rebate policy to estimate the effects of a manufacturer tax credit policy. In doing so, DOE incorporated the assumptions for consumer response to financial incentives from the customized penetration curves it developed for pool pumps. (See Figure 17.3.1).

Table 17.3.4 summarizes DOE's assumptions for pool pumps regarding the market penetration of products in 2021 that meet the target levels at each TSL given a manufacturer tax credit.

Table 17.3.4 Market Penetrations in 2021 Attributable to Manufacturer Tax Credits

	TSL 1	TSL 2	**TSL Rec***	TSL 4	TSL 5
Self-Priming					
Base-Case Market Share	-	2.0%	**10.5%**	10.5%	18.5%
Policy Case Market Share	-	16.4%	**24.4%**	24.4%	31.2%
Increased Market Share	-	14.4%	**13.9%**	13.9%	12.7%
Non-Self-Priming					
Base-Case Market Share	-	1.0%	-	2.5%	2.5%
Policy Case Market Share	-	19.2%	-	22.3%	21.6%
Increased Market Share	-	18.2%	-	19.8%	19.1%
Integral Cart-Filter 1/15 HP					
Base-Case Market Share	-	-	**20.0%**	-	-
Policy Case Market Share	-	-	**32.9%**	-	-
Increased Market Share	-	-	**12.9%**	-	-
Integral Cart-Filter 1/2 HP					

[h] 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.

Base-Case Market Share	-	-	**20.0%**	-	-
Policy Case Market Share	-	-	**29.6%**	-	-
Increased Market Share	-	-	**9.6%**	-	-
Integral Sand-Filter					
Base-Case Market Share	-	-	**20.0%**	-	-
Policy Case Market Share	-	-	**33.1%**	-	-
Increased Market Share	-	-	**13.1%**	-	-

*Recommended TSL

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 17A shows the annual market share increases due to this policy for the whole forecast period. Section 17.4 presents the resulting market penetration trends for the policy case of manufacturer tax credits for pool pumps.

17.3.5 Voluntary Energy Efficiency Targets

DOE assumed that voluntary energy efficiency targets would lead manufacturers of pool pumps to gradually stop producing units that operate below the efficiency levels 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.[20, 21, 22]

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 products over time. During the rebate analysis, when assessing the B/C ratio and market penetration in the no-standards case for pool pumps, DOE observed that the level of market barriers for more efficient pool pumps are in the range of moderate barriers to a high level of market barriers. DOE estimates that voluntary energy efficiency targets could reduce these barriers to lower levels over 10 years. Table 17.3.5 presents the levels of market barriers DOE estimated for pool pumps in the no-standards case and in the policy case of voluntary energy efficiency targets. DOE followed the methodology presented by Blum et al

(2011)[10] to evaluate the effects that such a reduction in market barriers would have on the market penetration of efficient pool pumps.[i] 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 Market Barriers Changes Attributable to Voluntary Energy Efficiency Targets (Recommended TSL)

	No-standards case	**Voluntary Energy Efficiency Targets**
Self-Priming	Moderate-High	Moderate
Non-Self-Priming	Moderate-High	Moderate
Integral Cart-Filter 1/15 HP	Moderate-High	Moderate
Integral Cart-Filter 1/2 HP	High	Moderate-High
Integral Sand-Filter	Moderate	Moderate

Table 17.3.6 summarizes DOE's assumptions for pool pumps regarding the market penetration of products in 2021that meet the target levels at each TSL given voluntary energy efficiency targets. Table 17.3.7 expands on Table 17.3.6 to include, for the recommended TSL, DOE's assumptions regarding the market penetration of units in selected years.

Table 17.3.6 Market Penetrations in 2021 Attributable to Voluntary Energy Efficiency Targets

	TSL 1	TSL 2	**TSL Rec***	TSL 4	TSL 5
Self-Priming					
Base-Case Market Share	10.0%	2.0%	**10.5%**	10.5%	18.5%
Policy Case Market Share	11.0%	3.4%	**12.6%**	12.6%	21.3%
Increased Market Share	1.0%	1.4%	**2.1%**	2.1%	2.8%
Non-Self-Priming					
Base-Case Market Share	29.5%	1.0%	**29.5%**	2.5%	2.5%
Policy Case Market Share	33.1%	1.2%	**33.1%**	2.9%	2.7%
Increased Market Share	3.6%	0.2%	**3.6%**	0.4%	0.2%
Integral Cart-Filter 1/15 HP					
Base-Case Market Share	-	-	**20.0%**	-	-
Policy Case Market Share	-	-	**21.7%**	-	-
Increased Market Share	-	-	**1.7%**	-	-
Integral Cart-Filter 1/2 HP					
Base-Case Market Share	-	-	**20.0%**	-	-
Policy Case Market Share	-	-	**21.9%**	-	-
Increased Market Share	-	-	**1.9%**	-	-
Integral Sand-Filter					

[i] For the calculation of B/C ratios DOE discounted the cash flow of the operating cost savings to the purchase year using a 7 percent discount rate.

Base-Case Market Share	-	-	**20.0%**	-	-
Policy Case Market Share	-	-	**21.3%**	-	-
Increased Market Share	-	-	**1.3%**	-	-

*Recommended TSL

Table 17.3.7 Market Penetrations in Selected Years Attributable to Voluntary Energy Efficiency Targets for the Recommended TSL

	2021	2030	2050
Self-Priming			
Base-Case Market Share	10.5%	15.0%	25.0%
Policy Case Market Share	12.6%	38.8%	41.4%
Increased Market Share	2.1%	23.8%	16.4%
Non-Self-Priming			
Base-Case Market Share	29.5%	25.0%	15.0%
Policy Case Market Share	33.1%	50.0%	30.0%
Increased Market Share	3.6%	25.0%	15.0%
Integral Cart-Filter 1/15 HP			
Base-Case Market Share	20.0%	20.0%	20.0%
Policy Case Market Share	21.7%	33.1%	32.5%
Increased Market Share	1.7%	13.1%	12.5%
Integral Cart-Filter 1/2 HP			
Base-Case Market Share	20.0%	20.0%	20.0%
Policy Case Market Share	21.9%	35.7%	35.2%
Increased Market Share	1.9%	15.7%	15.2%
Integral Sand-Filter			
Base-Case Market Share	20.0%	20.0%	20.0%
Policy Case Market Share	21.3%	30.7%	30.1%
Increased Market Share	1.3%	10.7%	10.1%

The increased market shares attributable to voluntary energy efficiency targets shown in Table 17.3.6 were used as inputs in the NIA-RIA model. Appendix 17A shows the annual market share increases due to this policy for the whole forecast period. Section 17.4 presents the resulting market penetration trends for the policy case of voluntary energy efficiency targets for pool pumps that meet the efficiency level for the recommended TSL.

17.4 IMPACTS OF NON-REGULATORY ALTERNATIVES

Figure 17.4.1 through Figure 17.4.5 show the effects of each non-regulatory policy alternative on the market penetration of more efficient pool pumps. Relative to the no-standards case, the alternative policy cases increase the market shares that meet the target level. Recall the recommended standards (not shown in the figures) would result in a 100-percent market penetration of products that meet the more efficient technology.

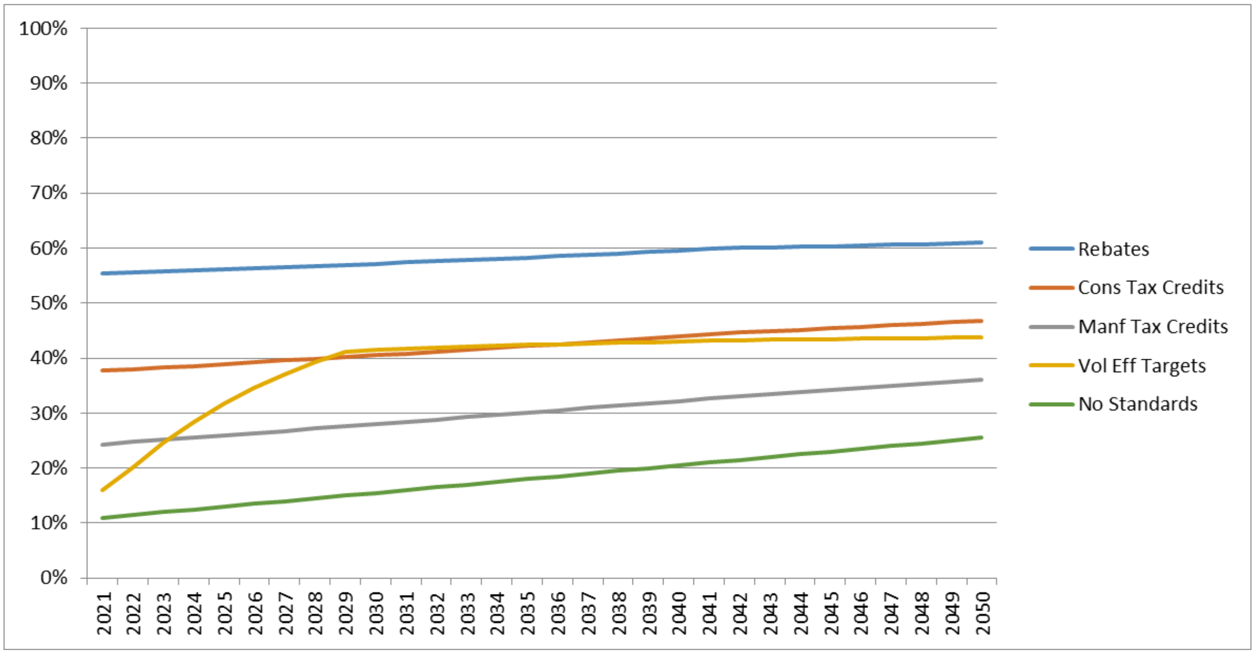


Figure 17.4.1 Market Penetration of Efficient Self-Priming (Recommended TSL)

Figure 17.4.2 Market Penetration of Efficient Non-Self-Priming (Recommended TSL)

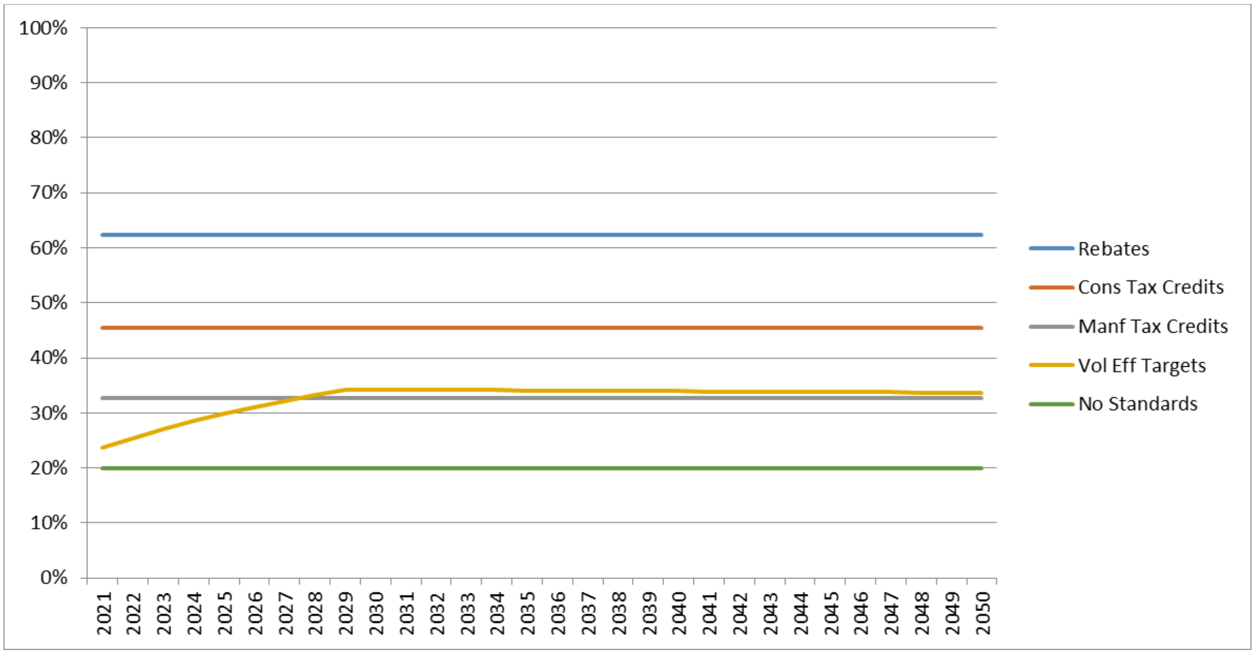


Figure 17.4.3 Market Penetration of Efficient Integral Cart-Filter 1/15 HP (Recommended TSL)

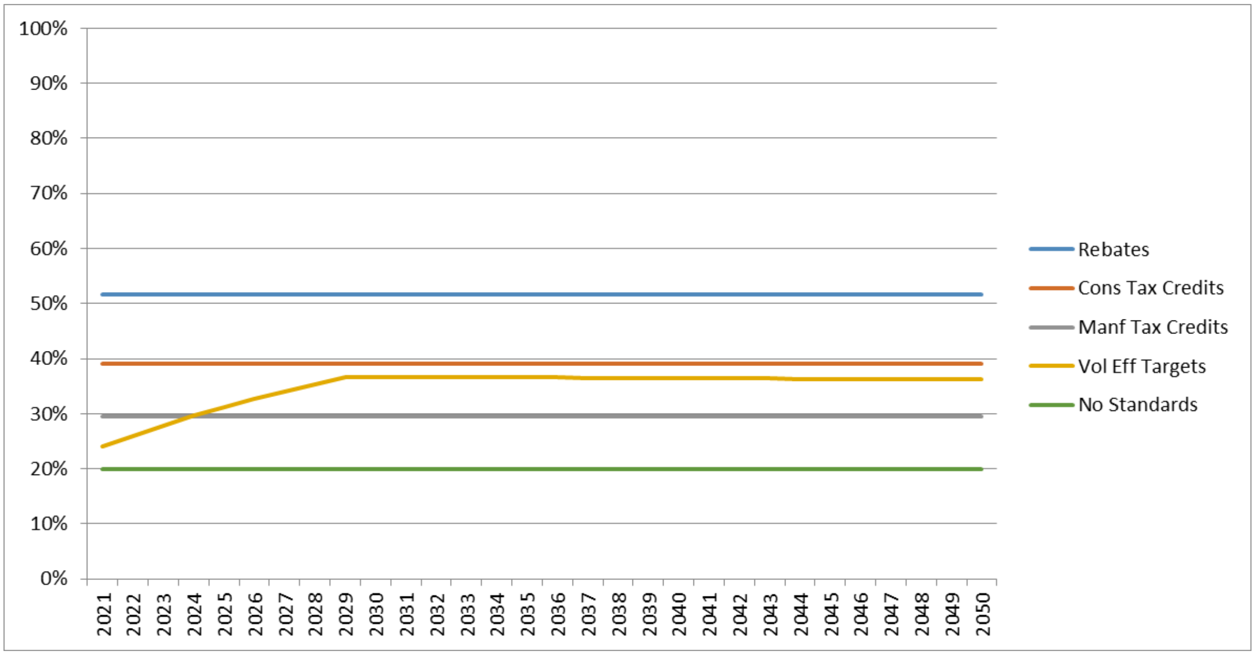


Figure 17.4.4 Market Penetration of Efficient Integral Cart-Filter 1/2 HP (Recommended TSL)

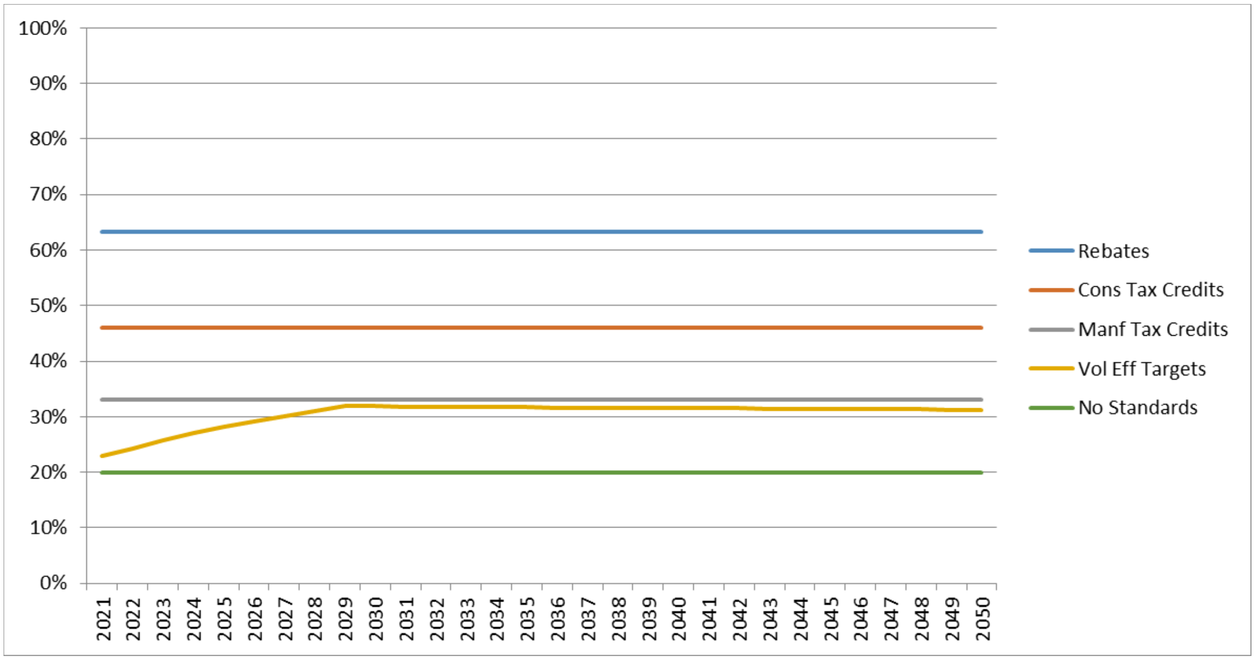


Figure 17.4.5 Market Penetration of Efficient Integral Sand-Filter (Recommended TSL)

Table 17.4.1 shows the national energy savings and net present value for the five non-regulatory policy alternatives analyzed in detail for pool pumps. The target level for each policy corresponds to the same efficient technology recommended for standards in the recommended TSL. The case in which no regulatory action is taken with regard to pool pumps constitutes the no-standards case (or "No New Regulatory Action" scenario), in which NES and NPV are zero by definition. For comparison, the tables include the impacts of the recommended standards calculated as described in footnote ‘a’. Energy savings are given in quadrillion British thermal units (quads) of primary energy savings.[j] The NPVs shown in Table 17.4.1 are based on two discount rates, 7 percent and 3 percent.

The policy with the highest projected cumulative energy savings is consumer rebates. Savings from tax credits range from 18.3 percent to 36.7 percent. Voluntary energy efficiency targets have the lowest cumulative energy savings. Overall, the energy saving benefits from the alternative policies, range from 6.3 percent to 61.2 percent of the benefits from the recommended standards calculated as described in footnote ‘a’.

[j] For the alternative policies whose market penetration depends on B/C ratio, the energy savings in 0 correspond to the case where the cash flow of the operating cost savings was discounted to the purchase year using a 7 percent discount rate.

Table 17.4.1 Impacts of Non-Regulatory Policy Alternatives (Recommended TSL)

Policy Alternative	Energy Savings* *quads*		Net Present Value* *million 2015$*	
			7% Disc Rate	3% Disc Rate
Consumer Rebates	2.147	(61.2%)***	6,829	13,919
Consumer Tax Credits	1.288	(36.7%)	4,097	8,352
Manufacturer Tax Credits	0.644	(18.3%)	2,049	4,176
Voluntary Energy Efficiency Targets	0.222	(6.3%)	585	1,403
Recommended Standards**	3.511	(100.0%)	10,908	22,850

* For products shipped 2021-2050.
**Calculated as described in footnote ‘a’.
***The percentages show how the energy savings from each policy alternative compare to the primary energy savings from the recommended standards (represented in the table as 100%), when the latter are calculated as described in footnote ‘a’.

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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;
- Market penetration curves used to analyze consumer rebates and voluntary energy efficiency targets, including:
    - Background material on XENERGY's approach,
    - DOE's adjustment of these curves for this analysis, and
    - The method DOE used to derive interpolated, customized curves;
- Detailed table of rebates offered for the considered product, as well as DOE's approach to estimate a market representative rebate value for this RIA; and
- Background material on Federal and State tax credits for appliances.

17A.2 MARKET SHARE ANNUAL INCREASES BY POLICY

Table 17A.2.1 through Table 17A.2.5 shows the annual increases in market shares of pool pumps meeting the target efficiency levels for the recommended TSL. DOE used these market share increases as inputs to the NIA-RIA spreadsheet model.

Table 17A.2.1 Annual Increases in Market Shares Attributable to Alternative Policy Measures for Self-Priming (Recommended TSL)

Year	Consumer Rebates	Consumer Tax Credits	Manufacturer Tax Credits	Vol Energy Eff Targets
2021	44.5%	26.7%	13.3%	4.9%
2022	44.2%	26.5%	13.2%	8.6%
2023	43.8%	26.3%	13.1%	12.6%
2024	43.5%	26.1%	13.0%	15.9%
2025	43.2%	25.9%	12.9%	18.7%
2026	42.8%	25.7%	12.9%	21.0%
2027	42.6%	25.6%	12.8%	23.0%
2028	42.3%	25.4%	12.7%	24.7%
2029	42.0%	25.2%	12.6%	26.2%
2030	41.7%	25.0%	12.5%	26.0%
2031	41.4%	24.9%	12.4%	25.7%
2032	41.1%	24.7%	12.3%	25.4%
2033	40.9%	24.5%	12.3%	25.1%
2034	40.6%	24.3%	12.2%	24.7%
2035	40.3%	24.2%	12.1%	24.4%
2036	40.0%	24.0%	12.0%	24.0%
2037	39.8%	23.9%	11.9%	23.7%
2038	39.5%	23.7%	11.9%	23.3%
2039	39.3%	23.6%	11.8%	22.9%
2040	39.1%	23.4%	11.7%	22.5%
2041	38.9%	23.3%	11.7%	22.1%
2042	38.5%	23.1%	11.6%	21.7%
2043	38.2%	22.9%	11.4%	21.3%
2044	37.8%	22.7%	11.3%	20.9%
2045	37.4%	22.4%	11.2%	20.5%
2046	37.0%	22.2%	11.1%	20.0%
2047	36.6%	22.0%	11.0%	19.6%
2048	36.2%	21.7%	10.9%	19.2%
2049	35.8%	21.5%	10.8%	18.7%
2050	35.5%	21.3%	10.6%	18.3%

Table 17A.2.2 Annual Increases in Market Shares Attributable to Alternative Policy Measures for Non-Self-Priming (Recommended TSL)

Year	Consumer Rebates	Consumer Tax Credits	Manufacturer Tax Credits	Vol Energy Eff Targets
2021	0.5%	0.3%	0.2%	7.8%
2022	1.0%	0.6%	0.3%	12.2%
2023	1.5%	0.9%	0.5%	16.3%
2024	2.0%	1.2%	0.6%	19.5%
2025	2.5%	1.5%	0.8%	22.2%
2026	3.0%	1.8%	0.9%	24.5%
2027	3.5%	2.1%	1.1%	26.0%
2028	4.0%	2.4%	1.2%	25.5%
2029	4.5%	2.7%	1.4%	25.0%
2030	5.0%	3.0%	1.5%	24.5%
2031	5.5%	3.3%	1.7%	24.0%
2032	6.0%	3.6%	1.8%	23.5%
2033	6.5%	3.9%	2.0%	23.0%
2034	7.0%	4.2%	2.1%	22.5%
2035	7.5%	4.5%	2.3%	22.0%
2036	8.0%	4.8%	2.4%	21.5%
2037	8.5%	5.1%	2.6%	21.0%
2038	9.0%	5.4%	2.7%	20.5%
2039	9.5%	5.7%	2.9%	20.0%
2040	10.0%	6.0%	3.0%	19.5%
2041	10.5%	6.3%	3.2%	19.0%
2042	11.0%	6.6%	3.3%	18.5%
2043	11.5%	6.9%	3.5%	18.0%
2044	12.0%	7.2%	3.6%	17.5%
2045	12.5%	7.5%	3.8%	17.0%
2046	13.0%	7.8%	3.9%	16.5%
2047	13.5%	8.1%	4.1%	16.0%
2048	14.0%	8.4%	4.2%	15.5%
2049	14.5%	8.7%	4.4%	15.0%
2050	14.5%	8.7%	4.4%	14.5%

Table 17A.2.3 Annual Increases in Market Shares Attributable to Alternative Policy Measures for Integral Cart-Filter 1/15 HP (Recommended TSL)

Year	Consumer Rebates	Consumer Tax Credits	Manufacturer Tax Credits	Vol Energy Eff Targets
2021	42.4%	25.4%	12.7%	3.7%
2022	42.4%	25.4%	12.7%	5.4%
2023	42.4%	25.4%	12.7%	7.0%

2024	42.4%	25.4%	12.7%	8.5%
2025	42.4%	25.4%	12.7%	9.9%
2026	42.4%	25.4%	12.7%	11.1%
2027	42.4%	25.4%	12.7%	12.2%
2028	42.4%	25.4%	12.7%	13.2%
2029	42.4%	25.4%	12.7%	14.3%
2030	42.4%	25.4%	12.7%	14.2%
2031	42.4%	25.4%	12.7%	14.2%
2032	42.4%	25.4%	12.7%	14.2%
2033	42.4%	25.4%	12.7%	14.2%
2034	42.4%	25.4%	12.7%	14.2%
2035	42.4%	25.4%	12.7%	14.1%
2036	42.4%	25.4%	12.7%	14.1%
2037	42.4%	25.4%	12.7%	14.0%
2038	42.4%	25.4%	12.7%	14.0%
2039	42.4%	25.4%	12.7%	14.0%
2040	42.4%	25.4%	12.7%	13.9%
2041	42.4%	25.4%	12.7%	13.9%
2042	42.4%	25.4%	12.7%	13.9%
2043	42.4%	25.4%	12.7%	13.9%
2044	42.4%	25.4%	12.7%	13.8%
2045	42.4%	25.4%	12.7%	13.8%
2046	42.4%	25.4%	12.7%	13.8%
2047	42.4%	25.4%	12.7%	13.7%
2048	42.4%	25.4%	12.7%	13.7%
2049	42.4%	25.4%	12.7%	13.7%
2050	42.4%	25.4%	12.7%	13.6%

Table 17A.2.4 Annual Increases in Market Shares Attributable to Alternative Policy Measures for Integral Cart-Filter 1/2 HP (Recommended TSL)

Year	Consumer Rebates	Consumer Tax Credits	Manufacturer Tax Credits	Vol Energy Eff Targets
2021	31.7%	19.0%	9.5%	4.1%
2022	31.7%	19.0%	9.5%	6.0%
2023	31.7%	19.0%	9.5%	7.9%
2024	31.7%	19.0%	9.5%	9.6%
2025	31.7%	19.0%	9.5%	11.3%
2026	31.7%	19.0%	9.5%	12.7%
2027	31.7%	19.0%	9.5%	14.1%
2028	31.7%	19.0%	9.5%	15.4%
2029	31.7%	19.0%	9.5%	16.7%
2030	31.7%	19.0%	9.5%	16.7%
2031	31.7%	19.0%	9.5%	16.7%

2032	31.7%	19.0%	9.5%	16.7%
2033	31.7%	19.0%	9.5%	16.7%
2034	31.7%	19.0%	9.5%	16.6%
2035	31.7%	19.0%	9.5%	16.6%
2036	31.7%	19.0%	9.5%	16.6%
2037	31.7%	19.0%	9.5%	16.5%
2038	31.7%	19.0%	9.5%	16.5%
2039	31.7%	19.0%	9.5%	16.5%
2040	31.7%	19.0%	9.5%	16.4%
2041	31.7%	19.0%	9.5%	16.4%
2042	31.7%	19.0%	9.5%	16.4%
2043	31.7%	19.0%	9.5%	16.4%
2044	31.7%	19.0%	9.5%	16.3%
2045	31.7%	19.0%	9.5%	16.3%
2046	31.7%	19.0%	9.5%	16.3%
2047	31.7%	19.0%	9.5%	16.3%
2048	31.7%	19.0%	9.5%	16.2%
2049	31.7%	19.0%	9.5%	16.2%
2050	31.7%	19.0%	9.5%	16.2%

Table 17A.2.5 Annual Increases in Market Shares Attributable to Alternative Policy Measures for Integral Sand-Filter (Recommended TSL)

Year	Consumer Rebates	Consumer Tax Credits	Manufacturer Tax Credits	Vol Energy Eff Targets
2021	43.3%	26.0%	13.0%	3.0%
2022	43.3%	26.0%	13.0%	4.3%
2023	43.3%	26.0%	13.0%	5.7%
2024	43.3%	26.0%	13.0%	7.0%
2025	43.3%	26.0%	13.0%	8.1%
2026	43.3%	26.0%	13.0%	9.1%
2027	43.3%	26.0%	13.0%	10.0%
2028	43.3%	26.0%	13.0%	11.0%
2029	43.3%	26.0%	13.0%	11.9%
2030	43.3%	26.0%	13.0%	11.9%
2031	43.3%	26.0%	13.0%	11.8%
2032	43.3%	26.0%	13.0%	11.8%
2033	43.3%	26.0%	13.0%	11.8%
2034	43.3%	26.0%	13.0%	11.8%
2035	43.3%	26.0%	13.0%	11.7%
2036	43.3%	26.0%	13.0%	11.7%
2037	43.3%	26.0%	13.0%	11.6%
2038	43.3%	26.0%	13.0%	11.6%
2039	43.3%	26.0%	13.0%	11.6%
2040	43.3%	26.0%	13.0%	11.5%

2041	43.3%	26.0%	13.0%	11.5%
2042	43.3%	26.0%	13.0%	11.5%
2043	43.3%	26.0%	13.0%	11.5%
2044	43.3%	26.0%	13.0%	11.4%
2045	43.3%	26.0%	13.0%	11.4%
2046	43.3%	26.0%	13.0%	11.4%
2047	43.3%	26.0%	13.0%	11.3%
2048	43.3%	26.0%	13.0%	11.3%
2049	43.3%	26.0%	13.0%	11.3%
2050	43.3%	26.0%	13.0%	11.3%

17A.3 NIA-RIA INTEGRATED MODEL

For this analysis, DOE used its integrated NIA-RIA[a] model approach that the Department built on the NIA model discussed in chapter 10 and documented in appendix 10-A.The resulting integrated NIA-RIA model features both the NIA and RIA inputs, analyses and results. It has the capability to generate results, by equipment class and TSL, for the mandatory standards and each of the RIA policies. Separate modules estimate increases in market penetration of more efficient equipment for consumer rebates, voluntary energy efficiency targets and bulk government purchases.[b] The consumer rebates module calculates benefit-cost (B/C) ratios and market barriers, and generates customized market penetration curves for each equipment class; the voluntary energy efficiency targets module relies on the market barriers calculated in the consumer rebates module to project a reduction in those barriers over the first ten years of the forecast period and estimate the market effects of such a reduction. A separate module summarizes the market impacts from mandatory standards and all policy alternatives, and an additional module produces all tables and figures presented in chapter 17 as well as the tables of market share increases for each policy reported in Section 17A.2 of this appendix.

17A.4 MARKET PENETRATION CURVES

This section first discusses the theoretical basis for the market penetration curves that DOE used to analyze the Consumer Rebates and Voluntary Energy Efficiency Targets policies. 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 pool pumps that meet the target efficiency levels at each TSL. The resulting curves are presented in chapter 17.

17A.4.1 Introduction

XENERGY, Inc.[c], 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.

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[a] NIA = National Impact Analysis; RIA = Regulatory Impact Analysis

[b] As mentioned in chapter 17, the increase in market penetrations for consumer tax credits and manufacturer tax credits are estimated as a fraction of the increase in market penetration of consumer rebates.

[c] XENERGY is now owned by KEMA, Inc. (www.kema.com)

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 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).

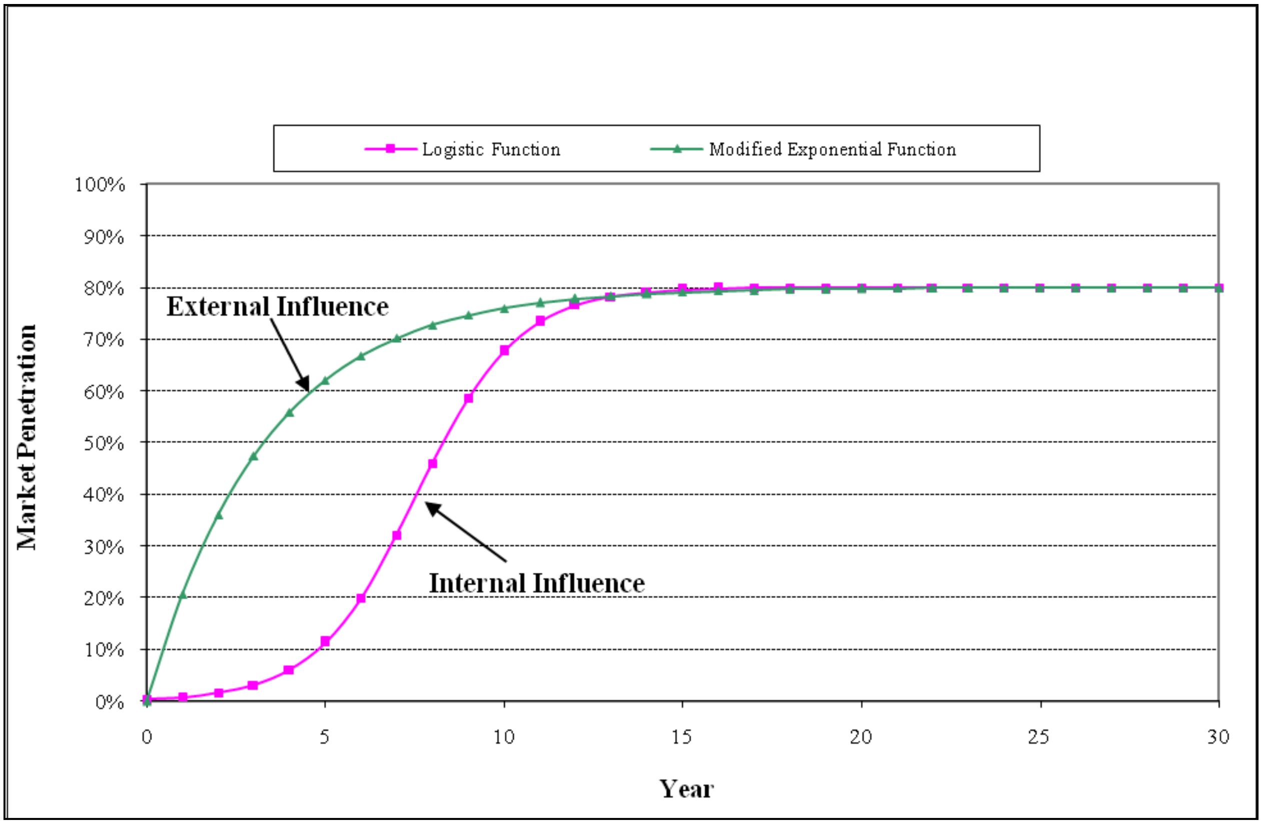

Figure 17A.4.1 S-Curves Showing Effects of External and Internal Sources on Adoption of New Technologies

17A.4.2 Adjustment of XENERGY 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, 7] 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 great than 100 percent, as might occur for products with high no-standards 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.[d] 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.[e] 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)[8] 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.

DOE used the above referred method to interpolate market implementation curves, to generate customized curves that were used to estimate the effects of consumer rebates and voluntary energy efficiency targets for each equipment class covered by this RIA. For consumer rebates, DOE derived such curves based on an algorithm that finds the market implementation curve that best fits, for the first year of the analysis period, the B/C ratio of the target efficiency level and the market penetration of equipment with that level of energy efficiency in the no-standards case. For the analysis of voluntary energy efficiency targets, DOE departs from the market barriers level corresponding to the market implementation curve it derived for consumer rebates, to linearly decrease it over the ten initial years of the analysis period. For each year, as market barriers decline, the corresponding market implementation curve leads – for the same B/C ratio – to higher market penetrations.

[d] The RIA chapter refers to these curves as *penetration curves*. This section, in references to the original source, uses the term *implementation curve*.

[e] 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 are considered in this RIA proportional to the impacts from rebates.

17A.5 CONSUMER REBATE PROGRAMS

DOE performed an internet search for rebate programs that offered incentives for pool pumps in July, 2016. Some organizations nationwide, comprising electric utilities and regional agencies, offer rebate programs for this equipment. Table 17A.5.2 provides the organizations' names, states, rebate amounts, and program websites (as they were available in July, 2016). If there is more than one entry for an organization, it offers different rebates in different states. When an organization offers rebates through several utilities, it is represented only once in that table.

DOE relied on the data it gathered from the 45 rebate programs offered by the 38 organizations listed in Table 17A.5.2 to calculate two market representative rebate amounts for pool pumps: one that applies to units meeting Energy Star requirements, and one for units with more than one speed. DOE calculated both market representative rebate amounts as the simple averages of the rebate values offered by the programs listed in Table 17A.5.2 towards units the corresponding criteria. The representative rebates are respectively $185.00 and $367.19. Table 17A.5.1 presents the rebate amounts DOE calculated for equipment class at each TSL.

Table 17A.5.1 Rebates Amounts for Pool Pumps*

	TSL 1	TSL 2	TSL Rec	TSL 4	TSL5
Self-Priming	-	367.19	367.19	367.19	367.19
Non-Self-Priming	-	367.19	-	367.19	367.19
Integrated Cart-Filter 1/15 HP	-	-	185.00	-	-
Integrated Cart-Filter 1/2 HP	-	-	185.00	-	-
Integrated Sand-Filter	-	-	185.00	-	-

* For some TSLs, the target efficiency level of some equipment classes does not meet the requirements – Energy Star or more than one speed – to receive a rebate.

Table 17A.5.2 Rebates Programs for Pool Pumps[f]

Organization	State	Rebate	Website
Salt River Project	AZ	$100	http://www.savewithsrp.com/rd/poolpump.aspx
Tucson Electric Power	AZ	$200	https://www.tep.com/efficiency/home/poolpumps/
UniSource Energy Services	AZ	$200	https://www.uesaz.com/efficiency/home/electric/poolpumps/
Anaheim Public Utilities	CA	$100	http://www.anaheim.net/1467/Home-Incentives-Program-Rebates
City of Palo Alto	CA	$200	http://www.cityofpaloalto.org/gov/depts/utl/residents/resrebate/smartenergy/pool_pumps.asp
City of Roseville	CA	$200	http://www.roseville.ca.us/electric/home/rebates/poolpumps.asp
Glendale Water and Power	CA	$100	http://www.glendaleca.gov/smart-home-rebate-program
Glendale Water and Power	CA	$125	http://www.glendaleca.gov/smart-home-rebate-program
Imperial Irrigation District	CA	$200	http://www.iid.com/energy/save-energy-and-money/your-home/residential-rebates
LA Depart of Water & Power	CA	$500	https://www.ladwp.com/ladwp/faces/ladwp/residential/r-savemoney/r-sm-rebatesandprograms?_adf.ctrl-state=dv1balp3w_30&_afrLoop=33545754421964
LA Depart of Water & Power	CA	$1,000	https://www.ladwp.com/ladwp/faces/ladwp/residential/r-savemoney/r-sm-rebatesandprograms?_adf.ctrl-state=dv1balp3w_30&_afrLoop=33545754421964
Modesto Irrigation Distric	CA	$200	http://www.mid.org/rebates/home/
PG&E	CA	$100	https://www.pge.com/en_US/residential/save-energy-money/savings-solutions-and-rebates/rebates-by-product/pool-pumps-and-motors/pool-pumps-and-

[f] This table is based on rebate programs DOE found to be available through an extensive internet search during July, 2016. Some of the programs referenced—and consequently their websites—may no longer be available by the time this document is published. To view the webpages hyperlinked in this table, copy the website address into a web browser's address window (rather than simply clicking on the hyperlinked text).

Organization	State	Rebate	Website
			motors.page?WT.mc_id=Vanity_pools
Redding Electric Utility	CA	$400	http://www.cityofredding.org/Home/ShowDocument?id=9049
Riverside Public Utilities	CA	$200	http://www.greenriverside.com/pool-spa-pump&zone=residential
San Diego Gas & Electric	CA	$200	http://www.sdge.com/buyers-guide-item/3883/variable-speed-pool-pumps
Silicon Valley Power	CA	$100	http://www.siliconvalleypower.com/for-residents/rebates
SMUD	CA	$150	https://www.smud.org/en/residential/save-energy/rebates-incentives-financing/pool-and-spa.htm
Southern California Edison	CA	$200	https://www.sce.com/wps/portal/home/residential/rebates-savings/rebates/!ut/p/b0/04_Sj9CPykssy0xPLMnMz0vMAfGjzOINLdwdPTyDDTzdXU0dDTydDCxDTH3MjEPNzfSDU_P0C7IdFQEl6A0N/
Southern California Edison	CA	$1000	https://www.sce.com/wps/portal/home/residential/rebates-savings/multifamily-rebate-program/!ut/p/b1/rVPBctowEP2WHDhqtJJsWRxN4xoZJwzBtMEXjxA2VYuNg9VMk6-vaD3TASaUdKqDRiu9fbPv7Qrn-BHnjXo2G2XNrlHbQ5zzgog4HMs5SDFhHsiRF2XTDzSepOAASweAN1YIx_nxQ0BBJp-idDoiFATFn3G
The City of Pasadena	CA	$900	http://www.cityofpasadena.net/waterandpower/HomeEnergyRebates/
The City of Pasadena	CA	$950	http://www.cityofpasadena.net/waterandpower/HomeEnergyRebates/
Turlock Irrigation District	CA	$200	http://www.tid.org/node/51
Hawaii Energy	HI	$225	https://hawaiienergy.com/for-businesses/incentives/pumps-motors
Indiana Michigan Power	IN	$50	http://www.electricideas.com/home/home-energy-products-program/
Duke Energy	KY	$300	http://www.duke-energy.com/kentucky/savings/smart-saver.asp#C0R4
CLECO	LA	$250	https://www.cleco.com/-/cleco-energy-efficiency-programs-for-your-

Organization	State	Rebate	Website
			home?redirect=https%3A%2F%2Fwww.cleco.com%2Fenergy-efficiency-programs%3Fp_p_id%3D101_INSTANCE_29MkSPk1STVh%26p_p_lifecycle%3D0%26p_p_state%3Dnormal%26p_p_mode%3Dview%26p_p_col_id%3Dcolumn-
Energy Smart NOLA	LA	$250	https://www.energysmartnola.info/sites/default/files/ENO_PoolPump_Rebate_Form_121015.pdf
Efficiency United	MI	200	http://efficiencyunited.com/residential/we-energies/home-performance
Lansing Board of Water & Light	MI	$250	http://www.lbwl.com/energysavers/
Dakota Electric	MN	$200	https://www.dakotaelectric.com/residential/programs/rebates/misc-rebates
Duke Energy	NC	$300	http://www.duke-energy.com/north-carolina/savings/pool-pump.asp
South River EMC	NC	$100	http://www.sremc.com/node/149
PNM	NM	$300	https://www.pnm.com/poolpump
PSEG Long Island	NY	$450	https://www.psegliny.com/files.cfm/poolpump-overview.pdf
American Municipal Power - Efficiency Smart Residential Program	OH	$112.5	http://www.efficiencysmart.org/for-your-home/efficient-product-rebates
Duke Energy	OH	$300	http://www.duke-energy.com/ohio/savings/smart-saver.asp#C0R3
Energy Trust of Oregon	OR	$200	http://energytrust.org/residential/incentives/water-heating/pool-pump
PECO	PA	$200	https://www.peco.com/WaystoSave/ForYourHome/Pages/SmartHomeRebates.aspx
PPL Electric Utilities	PA	$350	https://pplelectricsavings.com/HomeEquipment/Products
Duke Energy	SC	$300	http://www.duke-energy.com/south-carolina/savings/smart-saver.asp#C0R4
Austin Energy	TX	$300	http://powersaver.austinenergy.com/wps/portal/psp/residential/offerings/appliances-and-equipment/pool-pumps/!ut/p/a1/jZFNU4MwEIZ_Sw8cabbgB-

Organization	State	Rebate	Website
			ONQcaiVMROK3JxYhsgM5CsSaCjv96gpzpl7F4yu3nefTcbUpKClIIOvKaGS0HbMS-v3sALvGUEXpLF2S0k22wbZg8RQO5b4PUIyJ4uIbl-9tJ87S-CzeJM_USE8J_-_gwDT62iVU1KpKZxuagkKShiy6nYMe1SsXfZR8-xY8KQAqVsXew71KM0FO9-YKWKVUwxNe-V3UljDN444ADKA1OaDvaC9tpwwQRT9ed8JzsHDqhHQhna2lOjA4ppvrcmfKzIynbkoj5p00j9M8pke_JCyuOXB2HsQfIIsZ_GOdxdwF_gxNf8AtO7x25TfKXLdkirdVLPZt-CNGzF/dl5/d5/L2dBISEvZ0FBIS9nQSEh/
Co Serv	TX	$100	http://www.coserv.com/Together-We-Save/Residential-Rebates/Pool-Pump-Rebate
CPS Energy	TX	$200	https://www.cpsenergy.com/en/my-home/ways-to-save/rebates-rebate/pool-pump-rebate.html
Efficiency Vermont	VT	$600	https://www.efficiencyvermont.com/rebates/list/pool-pumps

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.[9, 10] 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).[11] 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.[9, 12]
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 distributors 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.[13, 14]

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.*[15] 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 <u>any</u> 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.[16], [17], [18] 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 of pool pumps covered by this RIA. 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.[19] The Emergency Economic Stabilization Act of 2008[20] 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.[12] 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.[21]

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.[22, 23] 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).[22, 24]

Montana has had an Energy Conservation Tax Credit for residential measures since 1998.[25] 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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