FINAL RULE TECHNICAL SUPPORT DOCUMENT ENERGY CONSERVATION PROGRAM FOR CONSUMER PRODUCTS AND CERTAIN COMMERCIAL AND INDUSTRIAL EQUIPMENT:

FLUORESCENT LAMP BALLASTS

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CHAPTER 1. INTRODUCTION

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CHAPTER 1. INTRODUCTION

1.1 PURPOSE OF THE DOCUMENT

This technical support document (TSD) is a stand-alone report that provides the technical analyses supporting the information in the final rule for fluorescent lamp ballasts.

1.2 OVERVIEW OF THE APPLIANCES AND COMMERCIAL EQUIPMENT STANDARDS PROGRAM

Part B of Title III of the Energy Policy and Conservation Act (EPCA) of 1975 (42 U.S.C. 6291–6309) established the energy conservation program for consumer products other than automobiles, covering major household appliances. Additional amendments to EPCA have given the U.S. Department of Energy (DOE) the authority to regulate the energy efficiency of several products, including certain fluorescent lamp ballasts, the products that are the focus of this document.

DOE designs any new or amended standard to achieve the maximum improvement in energy efficiency that is technologically feasible and economically justified. (42 U.S.C. 6295(o)(2)(A)) To determine whether economic justification exists, DOE must review comments on the proposal and determine that the benefits of the proposed standard exceed its burdens to the greatest extent practicable, weighing the following seven factors:

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

(2) the savings in operating costs throughout the estimated average life of the products compared to any increases in the price, initial charges, or maintenance expenses 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 imposition of the standard;

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

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

(6) the need for national energy conservation; and

(7) other factors the Secretary considers relevant.

(42 U.S.C. 6295(o)(2)(B)(i))

1.3 OVERVIEW OF FLUORESCENT LAMP BALLAST STANDARDS

Amendments to EPCA in the National Appliance Energy Conservation Amendments of 1988 (NAECA 1988), Pub. L.100-357, established energy conservation standards for fluorescent lamp ballasts.[a] (42 U.S.C. 6295(g)(5)) These same amendments also required that DOE: (1) conduct two rulemaking cycles to determine whether these standards should be amended; and (2) for each rulemaking cycle, determine whether the standards in effect for fluorescent lamp ballasts should be amended so that they would be applicable to additional fluorescent lamp ballasts. (42 U.S.C. 6295(g)(7)(A)-(B))

On September 19, 2000, DOE published a final rule in the *Federal Register* which completed the first of the two rulemaking cycles to evaluate and amend the energy conservation standards for fluorescent lamp ballasts (hereafter "the 2000 Ballast Rule"). 65 FR 56740. This rulemaking established a consensus standard, representing an agreement between the fluorescent lamp ballast industry and energy-efficiency advocacy organizations. The standard levels adopted replaced the ballast efficacy factors that were promulgated in NAECA 1988 for certain fluorescent lamp ballasts. A table of the standards codified by DOE can be found in Appendix 3A under title 10 of the Code of Federal Regulations (CFR) part 430.32(m)(3).

Congress promulgated new energy conservation standards for certain fluorescent lamp ballasts under the Energy Policy Act of 2005 (EPACT 2005), Pub. L. 109-58. (EPACT section 135(c)(2); codified at 42 U.S.C. 6295(g)(8)(A)) On October 18, 2005, DOE published a final rule in the *Federal Register* codifying those new fluorescent lamp ballast standards at 10 CFR 430.32(m). 70 FR 60407. These standards established minimum ballast efficacy requirements for "energy saver" versions of full-wattage ballasts, such as the F34T12 ballast. A table of the standards promulgated by EPACT 2005 can be found in Appendix 3A under 10 CFR 430.32(m)(5).

In summary, fluorescent lamp ballasts that are currently regulated under EPCA, as amended, include fluorescent lamp ballasts that are designed to operate one and two nominally 40 watt (W) and 34W 4-foot T12 medium bipin lamps (F40T12 and F34T12), two nominally 75W and 60W 8-foot T12 single pin slimline lamps (F96T12 and F96T12/ES), and two nominally 110W and 95W 8-foot T12 high output (HO) lamps (F96T12 and F96T12/ES) at nominal input voltages of 120 or 277 volts with an input current frequency of 60 hertz. 10 CFR 430.32(m). Ballasts that were excluded from regulation in the 2000 Ballast Rule include: (1)

[a] Although fluorescent lamp ballasts are typically understood to be a product used in the commercial and industrial sectors, it is the "consumer products" section of the statute which grants authority to DOE to cover and regulate this product. In the United States Code, Title 42 "The Public Health and Welfare," Chapter 77 "Energy Conservation," Subchapter III "Improving Energy Efficiency," there are two parts which cluster together the group of products which DOE regulates. First, there is "Part A – Energy Conservation Program for Consumer Products Other than Automobiles" which includes a range of consumer products, some which may be classified as being used primarily in the residential sector, such as refrigerators, dishwashers and clothes washers. However, Part A also includes consumer products that might also be used primarily in the commercial sector, such as fluorescent lamps, fluorescent lamp ballasts, and urinals. Second, Subchapter III has "Part A-1 – Certain Industrial Equipment," which includes products that are primarily used in the commercial and industrial sectors, such as electric motors and pumps, and packaged terminal air conditioners and heat pumps.

ballasts designed for dimming to 50 percent or less of its maximum output; (2) ballasts designed for use with two F96T12HO lamps at ambient temperatures of -20 degrees Fahrenheit (F) or less and for use in an outdoor sign; (3) ballasts with a power factor of less than 0.90 and designed and labeled for use only in residential building applications; and (4) replacement ballasts as defined in paragraph (m)(4)(ii).[b] 10 CFR 430.32(m)(2), (m)(4).

The standards promulgated by EPACT 2005 included similar exemptions, but these exemptions expired for ballasts manufactured after July 1, 2010 and sold by the manufacturer on or after October 1, 2010. 10 CFR 430.32(m)(6) and (m)(7). Thus, the following ballasts that operate certain "energy saver" lamps are currently subject to standards: (1) ballasts designed for dimming to 50 percent or less of its maximum output; (2) ballasts designed for use with two F96T12HO lamps at ambient temperatures of 20 degrees F or less and for use in an outdoor sign;[c] (3) ballasts with a power factor of less than 0.90 and designed and labeled for use only in residential building applications; and (4) replacement ballasts. 10 CFR 430.32(m)(7).

On December 19, 2007, the President signed the Energy Independence and Security Act of 2007 (EISA 2007) (Pub. L. 110-140) which makes numerous amendments to EPCA and directs DOE to undertake several new rulemakings for appliance energy efficiency standards. EISA 2007 did not amend standards for fluorescent lamp ballasts, but instead directed DOE to consider standby mode and off mode energy use for these ballasts. More specifically, EISA 2007 directed DOE to amend its test procedure for fluorescent lamp ballasts to incorporate a measure of standby mode and off mode energy consumption. (42 U.S.C. 6295(gg)(2)(B)(ii)) DOE published a final rule for the standby and off mode test procedure on October 22, 2009. 74 FR 54445. In addition, pursuant to 42 U.S.C. 6295(o), DOE is directed to incorporate standby mode and off mode energy use in any amended (or new) standard adopted after July 1, 2010. Because this energy conservation standards rulemaking for fluorescent lamp ballasts will be completed in 2011, the requirement to incorporate standby mode energy use into the energy conservation standards analysis is applicable.

This rulemaking encompasses DOE's second cycle of review to determine whether the standards in effect for fluorescent lamp ballasts should be amended and whether standards should be made applicable to additional fluorescent lamp ballasts as stated under section 325(g)(7)(B) of EPCA. This rulemaking also addresses 42 U.S.C. 6295(o) in which DOE is directed to incorporate standby mode and off mode energy use in any amended (or new) standard adopted after July 1, 2010.

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[b] The exclusion provided for replacement ballasts requires that they meet certain criteria in order to be considered a replacement ballast, such as being designed to replace an existing ballast in a previously installed luminaire and being marked "FOR REPLACEMENT USE ONLY." This exclusion only applies to replacement ballasts manufactured on or before June 30, 2010. After that date, replacement ballasts will no longer be excluded. (10 CFR 430.32(m)(4)(ii)(A)) See Appendix A for the exact language of the exclusion for replacement ballasts.

[c] Note that in 10 CFR 430.32(m)(7), the temperature exemption granted under EPACT 2005 is slightly different than that contained in sections (m)(2) and (m)(4). In subsection (m)(7), ballasts designed for use with two F96T12HO/ES lamps at ambient temperatures "of 20 degrees F or less" and designated for use in an outdoor sign are exempt from the standards in paragraph (m)(5). The other sections require the ballast to be for ambient temperatures of *negative* 20 degrees F or less.

1.4 PROCESS FOR SETTING ENERGY CONSERVATION STANDARDS

DOE considers the participation of interested parties to be a very important part of the standards-setting process. DOE encourages the participation of all interested parties during the comment period of each rulemaking stage. Beginning with the rulemaking framework document for fluorescent lamp ballasts (the framework document) and during subsequent comment periods, interactions among interested parties provide a balanced discussion of the information that is required for the standards rulemaking.

In conducting the active mode test procedure and the energy conservation standard rulemakings, DOE involves interested parties through formal public notifications (*i.e.*, *Federal Register* notices). For this fluorescent lamp ballast energy conservation standards rulemaking, DOE will employ the procedures set forth in DOE's Process Rule (Procedures for Consideration of New or Revised Energy Conservation Standards for Consumer Products, 61 FR 36974, July 15, 1996, 10 CFR Part 430, Subpart C, Appendix A) to the extent they are appropriate for developing energy conservation standards for the ballasts covered under this rulemaking.

Before DOE determines whether to establish or amend energy conservation standards for fluorescent lamp ballasts, it must first solicit comments on a proposed standard. (42 U.S.C. 6295(o)(2)(B)(i)). DOE must design each new or amended standard for these products to achieve the maximum improvement in energy efficiency that is technologically feasible and economically justified, and would result in significant energy savings. (42 U.S.C. 6295(o)(2)(A) and (3)) To determine whether a proposed standard complies with these requirements, DOE must, after receiving comments on the proposed standard, determine whether the benefits of the standard exceed its burdens to the greatest extent practicable, weighing the seven factors described above.

Subsequent to the publication of the framework document, the standards rulemaking process involves preliminary analyses followed by two additional formal, major public notices, which are published in the *Federal Register*. The preliminary analyses are designed to publicly vet the models and tools used in the rulemaking and to facilitate public participation before the proposed rule stage. After the preliminary analyses are vetted, DOE issues the first major notice, the notice of proposed rulemaking (NOPR), which presents a discussion of comments received in response to the preliminary analyses of the impacts of standards on consumers, manufacturers, and the nation; DOE's weighing of the impacts; and the proposed standards. The second notice is the final rule, which presents a discussion of comments received in response to the NOPR; the revised analysis of the impacts of standards; DOE's weighing of the impacts; the standards adopted by DOE; and the compliance dates of the standards.

Table 1.4.1 Analyses Under the Process Rule

Preliminary Analysis	NOPR	Final Rule*
Market and technology assessment	Revised ANOPR analyses	Revised analyses
Screening analysis	Life-cycle cost sub-group analysis	
Engineering analysis	Manufacturer impact analysis	
Energy use characterization	Utility impact analysis	
Product price determination	Employment impact analysis	
Life-cycle cost and payback period analyses	Environmental assessment	
Shipments analysis	Regulatory impact analysis	
National impact analysis		
Preliminary manufacturer impact analysis		
* During the final rule phase, DOE considers the comments submitted by the U.S. Department of Justice concerning the impact of any lessening of competition that is likely to result from the imposition of the standard. (42 U.S.C. 6295(o)(2)(B)(v))		

In January 2008, DOE published a rulemaking framework document for fluorescent lamp ballasts, which describes the procedural and analytical approaches DOE anticipated using to evaluate the establishment of energy conservation standards for fluorescent lamp ballasts.[d]

DOE held a public meeting on February 6, 2008 (hereafter "framework public meeting"), to discuss procedural and analytical approaches to the rulemaking, and to inform and facilitate the involvement of interested parties in the rulemaking process. The analytical framework presented at the framework public meeting described rulemaking analyses, such as the engineering analysis and the life-cycle cost (LCC) and payback period (PBP) analyses, the methods proposed for conducting them, and the relationships among the various analyses. See Table 1.4.1 for all the analyses discussed at the framework public meeting to be undertaken in each of the formal public rulemaking documents.[e]

During the framework public meeting and the framework document comment period, interested parties, including manufacturers, trade associations, and environmental advocates submitted several comments about the fluorescent lamp ballast rulemaking. The major issues discussed were: (1) the rulemaking's scope of coverage; (2) the development of product classes; (3) the possible use of a of a new energy efficiency metric for ballasts; (4) the updating of the active mode test procedure and developing a standby mode and off mode test procedure; (5) the methodology for the engineering analyses; (6) the lifetime of a ballast and lamp; (7) the methodology for developing shipment estimates; and (8) the use of marginal versus average electricity rates. Written comments submitted during the framework document comment period

[d] A PDF copy of the framework document is available at www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/ballast_framework_011408.pdf.
[e] PDF copies of the slides and other material associated with the framework public meeting are available at www1.eere.energy.gov/buildings/appliance_standards/residential/ballast_framework_mtg.html.

elaborated upon the issues raised at the public meeting. A detailed discussion of comments from interested parties is available in chapter 2 of the preliminary TSD.[f]

As part of the information gathering and sharing process, DOE organized and held preliminary interviews with fluorescent lamp ballast manufacturers and fixture manufacturers who operate in the U.S. ballast market. DOE had five objectives for these interviews: (1) solicit feedback on the scope of coverage for the rulemaking; (2) solicit feedback on the engineering analysis (including methodology, prices, and ballast technologies); (3) solicit feedback on topics related to the preliminary manufacturer impact analysis; (4) provide an opportunity early in the rulemaking process to express specific concerns to DOE; and (5) foster cooperation between manufacturers and DOE. During the manufacturer interviews, DOE discussed these and other issues regarding market data, distribution channels, anticipated consumer responses to standards, production and product mix, conversion costs, and cumulative regulatory burden.

DOE published a notice announcing the availability of the preliminary analysis in March 2010 and held a public meeting on April 26, 2010.[g] At this meeting, DOE presented the methodologies and results of the analyses set forth in the preliminary TSD. Interested parties discussed the following major issues at the public meeting: the pros and cons of various efficiency metrics; how test procedure variation might affect efficiency measurements; special requirements for environments sensitive to electromagnetic interference (EMI); product class divisions; manufacturer selling prices and overall pricing methodology; markups; the maximum technologically feasible ballast efficiency; regulatory burden; and shipments. Written comments received since publication of the March 2010 notice, including those received at the April 2010 public meeting, have contributed to DOE's proposed resolution of the issues in this rulemaking. A detailed discussion of comments from interested parties is available in the NOPR *Federal Register* notice for this rulemaking.[h]

Following the publication of the preliminary analysis and the preliminary analysis public meeting, DOE held additional meetings with manufacturers as part of the consultative process for the manufacturer impact analysis conducted during the NOPR phase. The interviews covered several key issues, including: (1) test procedure follow-up; (2) preliminary TSD follow-up; (3) key issues for this rulemaking; (4) company overview and organizational characteristics; (5) manufacturer markups and profitability; (6) shipment projections; (7) financial parameters; (8) conversion costs; (9) cumulative regulatory burden; (10) direct employment impact assessment; (11) manufacturing capacity and non-US sales; (12) impact on competition; and (13) impacts on small businesses.

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[f] A PDF copy of the complete preliminary TSD is available at www1.eere.energy.gov/buildings/appliance_standards/residential/fluorescent_lamp_ballasts_ecs_prelim_tsd.html.

[g] PDF copies of the preliminary analysis notice and the slides and other material associated with the preliminary analysis public meeting are available at www1.eere.energy.gov/buildings/appliance_standards/residential/fluorescent_lamp_ballasts_ecs_prelim_pub_mtg.html.

[h] A PDF copy of the NOPR is available at www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/flballasts_nopr_fr_notice.pdf.

For the LCC, PBP and national impact analyses (NIA), DOE developed spreadsheets using Microsoft Excel®. The LCC and PBP spreadsheets calculate the economic impacts of replacing products with standard-compliant ones. The NIA spreadsheets calculate the national energy savings (NES) and national net present values (NPVs) at various energy efficiency levels and include a model that forecasts the impacts of energy conservation standards at various levels on product shipments.[i]

On April 11, 2011, DOE published the NOPR in the *Federal Register*. DOE sought comment in particular on the following issues: (1) the exemption for T8 magnetic ballasts in EMI-sensitive environments; (2) the appropriateness of establishing efficiency standards using an equation dependent on lamp-arc power; (3) the inclusion of several different ballast types in the same product class; (4) the methodology used to calculate manufacturer selling prices; (5) the efficiency levels considered; (6) the maximum technologically feasible level; (7) markups; (8) the inclusion T12 ballasts in the baseline analysis for life cycle costs; (9) the magnitude and timing of forecasted shipments; (10) the methodology and inputs DOE used for the manufacturer impact analysis—specifically, DOE's assumptions regarding markups, capital costs, and conversion costs; (12) the potential impacts of amended standards on small fluorescent lamp ballast manufacturers; (13) the trial standard levels (TSLs) considered; (14) the proposed standard level; and (15) potential approaches to maximize energy savings while mitigating impacts to certain fluorescent ballast consumer subgroups.

On May 10, 2011, DOE held a public meeting to hear oral comments on and solicit information relevant to the proposed rule.[j] At this meeting, the National Electrical Manufacturers Association (NEMA) presented test data that they found inconsistent with the data collected by DOE and that could affect the standards established in the final rule. In general, NEMA's ballast luminous efficiency values appeared to be lower than those obtained by DOE. NEMA and other stakeholders agreed that there were discrepancies between the two data sets and emphasized the importance of identifying the source of the differences. In addition, DOE received comments on the methodology used to account for compliance certification requirements, design variation, and lab-to-lab variation and on the appropriate shape of DOE's proposed efficiency level curves. Subsequent to the public meeting, the consent decree was amended so that DOE could review the test results provided by NEMA and seek comment on this data.[k]

Therefore, DOE published a notice of data availability (NODA) on August 24, 2011 to: (1) announce the availability of additional test data collected by DOE and the data submitted by

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[i] These spreadsheets are available at www1.eere.energy.gov/buildings/appliance_standards/residential/fluorescent_lamp_ballasts.html.
[j] PDF copies of the slides and other material associated with the NOPR public meeting are available at www1.eere.energy.gov/buildings/appliance_standards/residential/fluorescent_ballasts_nopr_public_meeting.html.
[k] The consolidated Consent Decree in New York v. Bodman, No. 05 Civ. 7807 (S.D.N.Y. filed Sept. 7, 2005) and Natural Resources Defense Council v. Bodman, No. 05 Civ. 7808 (S.D.N.Y. filed Sept. 7, 2005), as amended, now requires the U.S. Department of Energy to publish, as that term is defined in the consent decree, a final rule amending energy conservation standards for fluorescent lamp ballasts no later than October 28, 2011.

NEMA; (2) address the differences between test data obtained by DOE and test data submitted by NEMA; (3) describe the methodological changes DOE was considering for the final rule based on the additional data; (4) present efficiency levels developed using the revised methodology and all available test data; and (5) request public comment on these analyses.

DOE received comments on both the NOPR and NODA from organizations including manufacturers, trade associations, energy conservation advocates, and electric utilities. A detailed discussion of stakeholder comments and DOE's revised analysis is available in the final rule *Federal Register* notice for this rulemaking.

1.5 STRUCTURE OF THE DOCUMENT

This final rule TSD outlines the analytical approaches used in this rulemaking. The TSD consists of 18 chapters and 14 appendices.

Chapter 1	Introduction: provides an overview of the appliance standards program and how it applies to the rulemaking for fluorescent lamp ballasts; and outlines the structure of the document
Chapter 2	Analytical Framework: describes the rulemaking process and provides an overview of each analysis
Chapter 3	Market and Technology Assessment: characterizes the fluorescent lamp ballast market and the technologies available for increasing ballast luminous efficiency and outlines product classes
Chapter 4	Screening Analysis: determines which technology options are viable for consideration in the engineering analysis
Chapter 5	Engineering Analysis: describes DOE's approach to the engineering analysis and discusses how manufacturer costs and selling prices relate to ballast luminous efficiency
Chapter 6	Energy Use Characterization: discusses the sources and methods for developing energy use estimates for fluorescent lamp ballasts
Chapter 7	Markups Analysis: discusses the methods DOE used for establishing markups to get from manufacturer selling price to installed customer prices
Chapter 8	LCC and PBP Analyses: discusses the economic effects of standards and compares the LCC and PBP of fluorescent lamp ballasts with and without higher energy conservation standards

Chapter 9	Trial Standard Levels: discusses the efficiency levels for each analyzed product class as they pertain to the trial standard levels chosen for fluorescent lamp ballasts
Chapter 10	Shipments Analysis: discusses the methods used for forecasting shipments with and without energy conservation standards
Chapter 11	National Impact Analysis: describes the national forecast of energy consumption, efficiency of new ballasts, and annual fluorescent lamp ballast sales in the absence or presence of new standards
Chapter 12	Life-Cycle Cost Sub-Group Analysis: discusses the effects of standards on a subgroup of fluorescent lamp ballast consumers and compares the LCC and PBP of products with and without efficiency standards for these consumers
Chapter 13	Manufacturer Impact Analysis: discusses the effects of standards on the finances and profitability of fluorescent lamp ballast manufacturers
Chapter 14	Utility Impact Analysis: discusses the effects of standards on electric utilities
Chapter 15	Employment Impact Analysis: discusses the effects of standards on national employment
Chapter 16	Environmental Assessment: discusses the effects of standards on pollutants such as sulfur dioxide and nitrogen oxides, as well as carbon emissions
Chapter 17	Monetization of Emissions: quantifies the impacts of reduced emissions as a result of standards
Chapter 18	Regulatory Impact Analysis: discusses the impact of non-regulatory alternatives to energy conservation standards
Appendix AA	Acronyms and Abbreviations: provides a set of acronyms and abbreviations used throughout the TSD.
Appendix 3A	Fluorescent Lamp Ballasts in the United States Code and Code of Federal Regulations: provides a set of existing statutory and regulatory definitions and requirements for fluorescent lamp ballasts
Appendix 5A	Material Prices: analyzes how commodity price changes affect the manufacturer selling price of ballasts

Appendix 5B	T5 Miniature Bipin Baseline Ballasts: describes the methodology behind developing low efficiency T5 baseline ballasts
Appendix 5C	Test Data: lists the test data used for the fluorescent lamp ballast engineering analysis
Appendix 5D	Analysis of Potential Efficiency Improvements: presents details of an analysis of efficiency improvements for commercially available ballasts
Appendix 5E	Electromagnetic Interference: presents research regarding EMI generated by electronic ballasts
Appendix 8A	User Instructions for Life-Cycle Cost and Payback Period Spreadsheet
Appendix 8B	Manufacturer Price Projections
Appendix 11A	User Instructions for Shipments and NIA Spreadsheet
Appendix 11B	Annualized Results
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CHAPTER 2. ANALYTICAL FRAMEWORK

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CHAPTER 2. ANALYTICAL FRAMEWORK

2.1 INTRODUCTION

Sections 6295(o)(2)(A) and (3) of Title 42 United States Code (42 U.S.C. 6295(o)(2)(A) and (3)) require that energy conservation standards set by the U.S. Department of Energy (DOE) be technologically feasible and economically justified, and achieve the maximum improvement in energy efficiency. This chapter provides a description of the general analytical framework that DOE uses in developing such standards, and in particular, standards for fluorescent lamp ballasts. The analytical framework is a description of the methodology, the analytical tools, and relationships among the various analyses that are part of this rulemaking. For example, the methodology that addresses the statutory requirement for economic justification includes analyses of life-cycle cost (LCC); economic impact on manufacturers and users; national benefits; impacts, if any, on utility companies; and impacts, if any, from lessening competition among manufacturers. DOE also solicits the views of the Department of Justice (DOJ) on any lessening of competition that is likely to result from the imposition of a proposed standard.

Figure 2.1.1 summarizes the analytical components of the standards-setting process. The central parts of this figure are the analyses contained in the boxes. The key inputs to the left and key outputs to the right 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. Dotted lines connecting analyses show types of information that feed from one analysis to another. While Figure 2.1.1 summarizes the inputs, outputs, and analyses of a typical standards rulemaking, individual inputs and outputs may vary by rulemaking. For example, as discussed in chapters 5, 6, and 7, this rulemaking combines the results of the engineering analysis, energy use characterization, and the markups analysis to derive typical inputs for the LCC and national impact analysis (NIA).

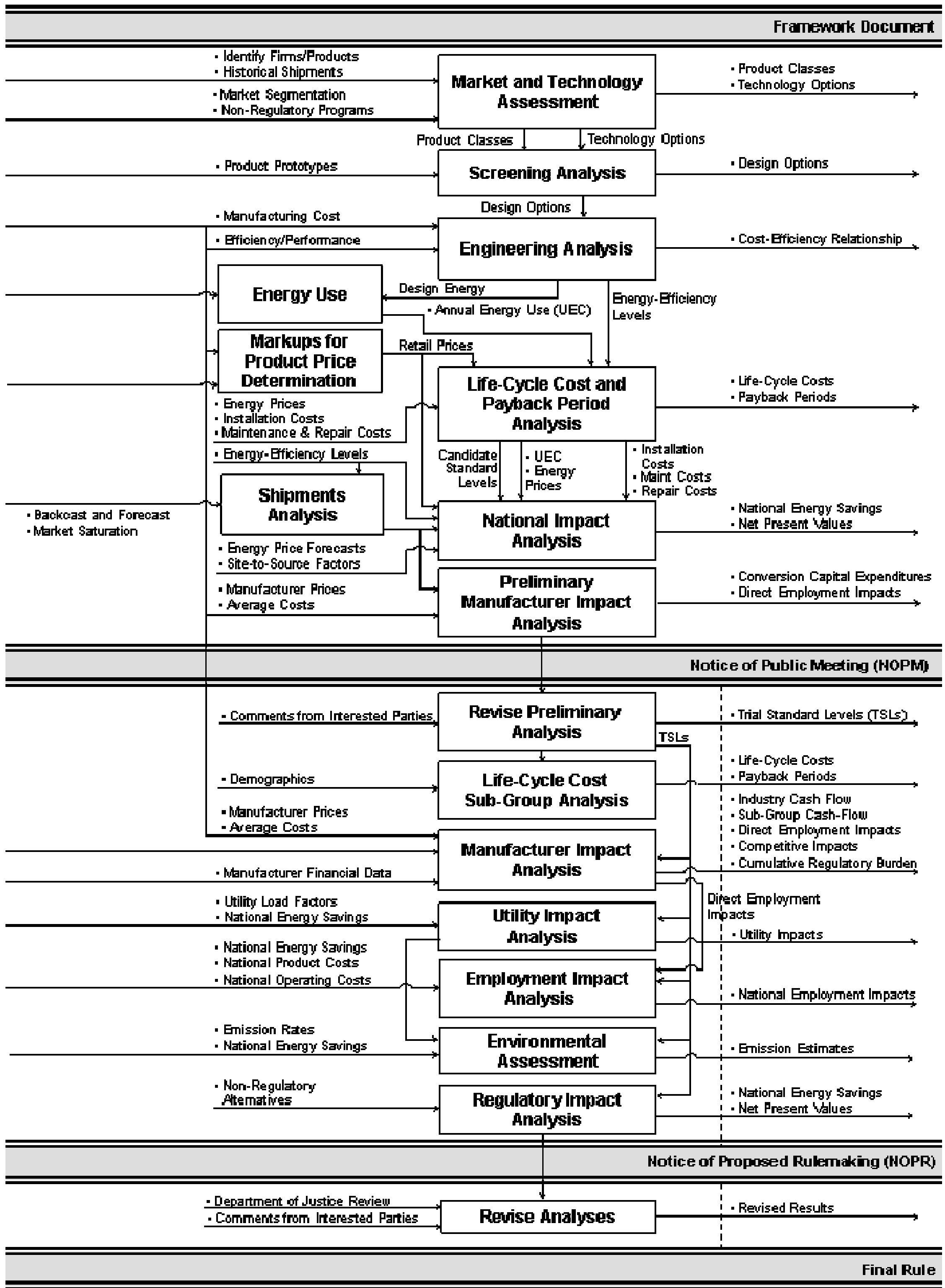

Figure 2.1.1 Flow Diagram of Analyses for the Ballast Rulemaking Process

The analyses performed in the final rule stage and reported in this technical support document (TSD) include:

A market and technology assessment to characterize the fluorescent ballast market; to identify technology options that improve efficiency; and to develop product classes.

A screening analysis to review each technology option and determine if it is technologically feasible; practical to manufacture, install, and service; would adversely affect lamp utility or lamp availability; or would have adverse impacts on health and safety.

An engineering analysis to determine manufacturer selling prices (MSPs) associated with more efficient fluorescent lamp ballasts;

An energy use analysis to determine the annual energy consumption of fluorescent lamp ballasts.

A markup analysis that converts average MSPs to consumer installed prices.

A life-cycle cost analysis that calculates, at the consumer level, the discounted savings in operating costs throughout the estimated average life of the ballast, compared to any increase in the installed costs likely to result directly from imposition of the standard.

A payback period (PBP) analysis to estimate the amount of time it takes consumers to recover the higher purchase expense of more energy efficient ballasts through lower operating costs.

A shipments analysis to estimate yearly shipments of covered fluorescent lamp ballasts over the analysis period.

An NIA that assesses the aggregate impacts at the national level of potential energy conservation standards as measured by the net present value (NPV) of total consumer economic impacts and national energy savings (NES).

An LCC subgroup analysis that evaluates the economic impacts on identifiable groups of customers of fluorescent lamp ballasts, including various categories of ballast purchasers or owners who may experience disproportionate impacts from a national energy conservation standard.

A manufacturer impact analysis (MIA) to calculate the financial impacts of energy conservation standards on ballast manufacturers and to identify impacts on competition, employment at manufacturing plants, and manufacturing capacity.

A utility impact analysis that estimates the effects of adopted standards on the installed capacity and the generating base of electric utilities.

An employment impact analysis that estimates the impacts of standards on net jobs eliminated or created in the general economy as a consequence of increased spending on the installed price of ballasts and reduced customer spending on energy

An environmental assessment to provide estimates of the effects of amended energy conservation standards on emissions of carbon (CO_2), sulfur dioxide (SO_2), nitrogen oxides (NO_X), and mercury (Hg).

A regulatory impact analysis (RIA) that discusses the impacts of non-regulatory alternatives to energy conservation standards.

2.2 BACKGROUND

As described in chapter 1 of the TSD, in September 1995, the Department announced a formal effort to consider further improvements to the process used to develop appliance efficiency standards. The Department called on energy-efficiency groups, manufacturers, trade associations, state agencies, utilities, and other interested parties to provide input to this effort. As a result of this combined effort, the Department published *Procedures, Interpretations and Policies for Consideration of New or Revised Energy Conservation Standards for Consumer Products* (the "Process Rule"), 10 CFR 430, Subpart C, Appendix A. The Process Rule outlined the procedural improvements identified by the interested parties, and included a review of the: 1) economic models, 2) analytic tools, 3) methodologies, 4) non-regulatory approaches, and 5) prioritization of future rules. The Process Rule recommended that the Department take into account uncertainty and variability by carrying out scenario or probability analysis.

DOE developed the analytical framework for the fluorescent lamp ballast rulemaking under the Process Rule. DOE documented this analytical framework in the *Energy Conservation Standards Rulemaking Framework for Fluorescent Lamp Ballasts* (hereafter, "framework document"), and presented the analytical approach to stakeholders during a public meeting held on February 6, 2008 (hereafter "framework public meeting"). This document is available at www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/ballast_framework_011408.pdf. The following sections provide a general description of the different analytical components of the rulemaking framework.

2.3 MARKET AND TECHNOLOGY ASSESSMENT

The market and technology assessment characterizes the relevant product markets and existing technology options, including prototype designs, and outlines product classes.

2.3.1 Market Assessment

When initiating a standards rulemaking, DOE develops information on the industry structure and market characteristics of the product(s) concerned. This activity consists of both quantitative and qualitative efforts to assess the industry based on publicly available information. As such, DOE addresses: (1) industry structure and manufacturer market shares, (2) existing regulatory and non-regulatory efficiency improvement initiatives, and (3) trends in product characteristics and retail markets. This information serves as resource material throughout the rulemaking.

DOE has used and will use the most reliable and accurate data available at the time of each analysis in this rulemaking. DOE welcomes and will consider any submissions of additional data.

2.3.2 Technology Assessment

DOE typically uses information relating to existing technology options to develop more efficient fluorescent lamp ballast designs. DOE prepared a list of technologies for consideration which could improve the efficiency of these products. To develop this list, DOE reviewed manufacturer catalogs, recent trade publications and technical journals, and consulted with technical experts.

2.3.3 Product Classes

DOE divides covered products into classes by: (a) the type of energy used; and (b) capacity of the product or any other performance-related feature that justifies different standard levels, such as features affecting consumer utility. (42 U.S.C. 6295(q)) In general, DOE defined product classes using information obtained from manufacturers, trade associations, and other interested parties.

2.4 SCREENING ANALYSIS

The screening analysis examines the technology options from the technology assessment as to whether they: (1) are technologically feasible; (2) are practical to manufacture, install, and service; (3) do not have an adverse impact on product utility or availability; and (4) do not have adverse impacts on health and safety. As described above, DOE develops an initial list of technology options from the technologies identified in the technology assessment. Then, in consultation with interested parties, DOE reviews the list to determine if these technologies meet the screening criteria. In the engineering analysis, DOE only considers design options that meet all four of the screening criteria.

2.5 ENGINEERING ANALYSIS

DOE performed an engineering analysis to establish the relationship between the manufacturer selling price and the energy efficiency of ballasts. The relationship between the MSP and energy efficiency serves as the basis of the cost-benefit calculations for individual consumers, manufacturers, and the Nation.

In the engineering analysis, DOE selects representative product classes to analyze. It then selects representative ballast types within those representative product classes, and develops ballast designs that represent more efficient versions of the baseline ballasts. DOE then uses these ballast designs to develop efficiency levels (ELs) and calculates price for each of these levels. The primary output of the engineering analysis is a set of cost-efficiency curves. In a subsequent life-cycle cost analysis (chapter 8 of the TSD), DOE used the cost-efficiency curves to determine customer prices for each product by applying the appropriate distribution channel markups. The engineering analysis also develops system power ratings in which DOE uses to develop energy consumption in chapter 6 of the TSD.

2.5.1 Representative Product Classes

DOE reviewed covered ballasts and the associated product classes. DOE identified and selected certain product classes as "representative" product classes and concentrated its analytical effort on these classes. DOE chose these representative product classes primarily because of their high market volumes.

2.5.2 Baseline Ballasts

DOE selected representative ballast types within each representative product class. For each representative ballast type, DOE selected a baseline model as a reference point against which to measure changes resulting from energy conservation standards. Typically, a baseline ballast is a unit that just meets current Federal energy conservation standards and provides basic consumer utility. To determine energy savings and changes in price, DOE compared each higher energy efficiency level with the baseline unit. DOE considered the ballast's characteristics in choosing the most appropriate baseline ballast for each ballast type. These characteristics include the ballast's starting method (*e.g.*, rapid start (RS), instant start (IS), or programmed start (PS)), input voltage (277 volts (V) vs. 120V), type (electronic vs. magnetic), power factor (PF), total harmonic distortion, ballast factor (BF), input power, ballast efficiency, and whether the ballast can operate at multiple voltages[a] (universal voltage) or only one (dedicated voltage). For some of the representative ballast types, DOE selected multiple baseline ballasts, to ensure consideration of different high-volume ballasts and their associated consumer economics.

2.5.3 More Efficient Ballast Designs

DOE selected more-efficient ballasts for each of the baseline models considered for each representative ballast type. DOE only considered technologies that met all four criteria in the screening analysis. DOE considered these technologies either explicitly as design options or implicitly as design options incorporated into commercially available ballasts at the efficiency levels evaluated. These selections were made such that potential substitutions maintained light output within 10 percent of the baseline lamp's light output when possible. In identifying the more-efficient substitutes, DOE surveyed and tested many of the manufacturers' product offerings for ballast efficiency to identify the efficiency levels corresponding to the highest number of models.

2.5.4 Efficiency Levels

Having identified the more-efficient substitutes for each of the baseline ballasts, DOE developed efficiency levels based on the consideration of several factors including: (1) the design options associated with the specific ballasts being studied; (2) the ability of ballasts across

[a] Universal voltage ballasts can operate at 120V or 277V.

wattages to comply with the standard level of a given product class;[b] and (3) the maximum technologically feasible level.

2.6 ENERGY USE CHARACTERIZATION

The energy use characterization provides estimates of annual energy use for representative lamp-and-ballast systems that DOE evaluates in the LCC and PBP analyses and the NIA. To develop annual energy use estimates, DOE multiplied annual usage (in hours per year) by the system input power (in watts). To derive annual energy usage, DOE used data published in the U.S. Lighting Market Characterization: Volume I (LMC), the Residential Energy Consumption Survey (RECS), the Commercial Building Energy Survey (CBECS) and the Manufacturer Energy Consumption Survey (MECS).

2.7 MARKUPS ANALYSIS

In this rulemaking, DOE developed ballast manufacturer selling prices using three main inputs: (1) teardown data; (2) manufacturer price lists (blue books); and (3) confidential manufacturer-supplied MSPs and incremental MPC values (chapter 5 of the TSD). DOE then applied distribution channel markups and sales tax to derive end-user prices (chapter 7 of the TSD). By combining the engineering analysis results and the distribution channel markups analysis, DOE derived typical inputs for use in the LCC analysis and the NIA.

2.8 LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

Energy conservation standards on equipment usually reduce operating expenses and increase end-user prices. DOE analyzed the net effect of amended standards on end-users by evaluating the net LCC using the cost-efficiency relationship derived in the engineering analysis, as well as the energy usage and costs derived from the energy use characterization. Inputs to the LCC calculation include the installed cost to the end-user (purchase price plus installation cost), disposal costs (ballast and lamp recycling), operating expenses (energy expenses and maintenance costs), the lifetime of the ballast, and a discount rate. Chapter 8 of the TSD describes these inputs.

DOE estimated electricity prices for commercial, industrial, and residential consumers by using Energy Information Administration (EIA) data. EIA's *Annual Energy Outlook 2010* (*AEO2010*) was the default source of projections for future electricity prices.

DOE developed discount rates by estimating the cost of capital to end users that purchase the ballasts covered under this rulemaking. For commercial and industrial end users, DOE used the cost of capital to estimate the present value of cash flows to be derived from a typical

[b] Efficacy levels span multiple ballasts of different wattages. In selecting ELs, DOE considered whether these multiple ballasts can meet the efficiency levels.

company project or investment. Most companies use both debt and equity capital to fund investments, so the cost of capital is the weighted-average cost to the firm of equity and debt financing. This corporate finance approach is referred to as the weighted-average cost of capital. DOE used currently available economic data in developing discount rates.

For residential end users, DOE derived the discount rates from estimates of the interest or "finance cost" to purchase residential products. The finance cost of raising funds to purchase residential products can be interpreted as (1) the financial cost of any debt incurred to purchase residential products, principally interest charges on debt; or (2) the opportunity cost of any equity used to purchase residential products, principally interest earnings on household equity. Household equity is represented by holdings in assets such as stocks and bonds, as well as the return on homeowner equity. DOE obtained data required to determine the cost of debt and equity from the Federal Reserve Board's triennial *Survey of Consumer Finances*.

For more detail on the LCC see chapter 8 of the TSD. Chapter 8 also describes the PBP analysis, which calculates the amount of time needed to recover the additional cost that consumers pay for increased efficiency. Numerically, the simple payback period is the ratio of the increase in purchase price to the decrease in annual energy costs.

2.9 SHIPMENTS ANALYSIS

Shipments of ballasts are key inputs to the national energy savings and net present value calculations in the NIA model. Shipments are also a necessary input to the MIA. DOE followed a three-step process to forecast ballast shipments. First, DOE used historical shipment data from the U.S. Census Bureau to estimate the total historical shipments of each ballast type analyzed. Second, DOE calculated an installed stock for each ballast type based on the average service lifetime of each ballast type. Third, by modeling ballast purchasing events, such as replacement and new construction, and applying growth rate, replacement rate, and emerging technologies penetration rate assumptions, DOE developed annual shipment projections.

2.9.1 Shipment Scenarios

To calculate shipments, DOE created base-case and standards-case shipment scenarios. As rapidly emerging new lighting technologies (such as light-emitting diodes) could penetrate the fluorescent lamp ballast market and significantly affect shipment forecasts, DOE created two base-case shipment scenarios: existing technologies and emerging technologies. The existing technologies scenario, considering only technologies that have already achieved technological and market maturation, assumes more limited penetration of other higher efficiency products than the emerging technologies scenario.

To characterize consumer behavior in the standards case, DOE develops two shipment scenarios, "roll-up" and "shift." The roll-up scenario represents a standards case in which all products in the base case that do not meet the standard would roll up to meet the new standard level. Consumers who in the base case purchase ballasts above the standard level are not affected as they are assumed to continue to purchase the same base case ballast in the roll-up scenario. The roll-up scenario characterizes consumers primarily driven by the first-cost of the ballast. In contrast, the shift scenario models a standards case in which *all* base case consumer purchases are affected by the standard (whether or not their base case efficiency is below the standard).

2.10 NATIONAL IMPACT ANALYSIS

The national impact analysis assesses the net present value of total end-user LCC and national energy savings. DOE determined both the NPV and NES for the performance levels considered for the ballast product classes analyzed. To make the analysis more transparent to all interested parties, DOE prepared an NES spreadsheet model to forecast energy savings and the national economic costs and savings resulting from amended standards. The NES model does not use probability distributions for inputs or outputs. To assess the impact of input uncertainty on the NES and NPV results, DOE can conduct sensitivity analyses by running scenarios on input variables relevant to interested parties. Chapter 11 of the TSD describes DOE's assessment of the aggregate economic impacts at the national level.

2.10.1 National Energy Savings Analysis

The inputs for determining NES are (1) annual energy consumption per unit; (2) shipments; (3) stock; (4) national energy consumption (calculated from consumption per unit and equipment stock); (5) site-to-source conversion factors; (6) a heating, ventilation, air conditioning (HVAC) factor; and (7) rebound rates. DOE calculated the national energy consumption by multiplying the number of units, or stock, of lamp-and-ballast systems (by vintage, which represents the age of the ballasts) by the unit energy consumption (also by vintage). Then, DOE calculated national annual energy savings from the difference between national energy consumption in the base case (without amended efficiency standards) and in each higher-efficiency standards case. DOE estimated energy consumption and savings based on site energy, and converted the electricity consumption and savings to source energy. DOE also examined potential energy savings due to HVAC interactions, as well as rebound effects (an energy savings "take-back") based on consumer usage patterns. Cumulative energy savings are the sum of the annual NES, which DOE determined over the analysis period.

2.10.2 Net Present Value Analysis

The inputs DOE used to determine the NPV were (1) total annual installed cost, (2) total annual operating cost savings, (3) discount factor, (4) present value of costs, and (5) present value of savings. DOE calculates net savings each year as the difference between total operating cost savings and increases in total installed costs (including price and installation cost). DOE calculates savings over the life of the equipment, accounting for differences in yearly energy rates. DOE calculates NPV as the difference between the present value of operating cost savings and the present value of increased total installed costs. DOE discounts future costs and savings to the present with a discount factor.

DOE calculated increases in total installed costs as the product of the difference in the total installed cost between the base case and standards case and the annual shipments in the standards case. Because purchase costs of the higher-efficiency products in the standards case are generally greater than the purchase costs of products in the base case, price increases appear as negative values in the NPV. DOE expressed operating cost savings as decreases in operating costs associated with the lower energy consumption of equipment in the standards case compared to the base efficiency case. Total operating cost savings are the product of savings per unit and the number of units of each vintage surviving in a particular year.

2.11 LIFE-CYCLE COST SUB-GROUP ANALYSIS

A consumer subgroup comprises a subset of the population that is likely, for one reason or another, to be impacted disproportionately by new or revised energy conservation standards. For this rulemaking, DOE identified low-income consumers, houses of worship, historical facilities, and institutions that serve low-income populations as consumers that would be disproportionately impacted by the proposed standards. The LCC sub-group analysis evaluates impacts on these consumer sub-groups by accounting for variations in key inputs to the LCC analysis.

2.12 MANUFACTURER IMPACT ANALYSIS

DOE performed a MIA to estimate the financial impact of higher energy conservation standards on fluorescent lamp ballast manufacturers, and to calculate the impact of such standards on domestic manufacturing employment and capacity. The MIA has both quantitative and qualitative aspects. The quantitative part of the MIA primarily relies on two separate Government Regulatory Impact Models (GRIMs)—industry-cash-flow models customized for this rulemaking. The GRIM inputs are data characterizing the industry cost structure, shipments, and revenues. The key output is the industry net present value. Different sets of assumptions (scenarios) produce different results. The qualitative part of the MIA addresses factors such as product characteristics, characteristics of particular firms, and market and product trends, and includes an assessment of the impacts of standards on subgroups of manufacturers. The complete MIA is outlined in chapter 13 of the TSD.

DOE conducted the MIA in three phases. Phase 1, "Industry Profile," consisted of the preparation of an industry characterization. Phase 2, "Industry Cash Flow," focused on the industry as a whole. DOE used publicly available information developed in Phase 1 to adapt the GRIM structure to facilitate the analysis of amended ballast standards. In Phase 3, "Subgroup Impact Analysis," DOE conducted interviews with manufacturers representing the majority of domestic ballast sales. During these interviews, DOE discussed engineering, manufacturing, procurement, and financial topics specific to each company, and also obtained each manufacturer's view of the industry as a whole. The interviews provided valuable information DOE used to evaluate the impacts of an amended energy conservation standard on manufacturer cash flows, manufacturing capacities, and employment levels.

2.13 UTILITY IMPACT ANALYSIS

The utility impact analysis includes an analysis of the impact of higher energy conservation standards on the electric utility industries. DOE adapted the National Energy Modeling System (NEMS) produced by the EIA for this analysis. EIA's NEMS is a large multi-sector general-equilibrium model of the U.S. energy sector that has been developed over the past decade by the EIA, primarily for the purpose of preparing DOE's *AEO*. In prior rulemakings, a variant of NEMS (currently termed NEMS-BT, BT referring to the DOE's Building Technologies Program) was developed to better address the specific impacts of an equipment efficiency standard.

The NEMS produces a widely recognized baseline energy forecast for the United States through the year 2030, and is available in the public domain. The typical NEMS outputs include forecasts of electricity sales, price, and avoided electric generating capacity. DOE conducted the utility impact analysis as a scenario departing from the latest *AEO* reference case. In other words, the energy savings impacts from amended energy conservation standards were modeled using NEMS-BT to generate forecasts that deviate from the *AEO* reference case.

2.14 EMPLOYMENT IMPACT ANALYSIS

The imposition of standards can impact employment both directly and indirectly. Direct employment impacts are changes in the number of employees at the factories that produce the covered ballast types, along with the affiliated distribution and service companies, resulting from the imposition of new standards. 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 the imposition of standards. 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. The ImSET model was developed for DOE's Office of Planning, Budget, and Analysis, and estimates the employment and income effects of energy-saving technologies in buildings, industry, and transportation. In comparison with simple economic multiplier approaches, ImSET allows for more complete and automated analysis of the economic impacts of energy conservation investments.

2.15 ENVIRONMENTAL ASSESSMENT

The intent of the environmental assessment is to quantify and consider the environmental effects of amended energy conservation standards for fluorescent lamp ballasts. The primary environmental effects of these standards would be reduced power plant emissions resulting from reduced consumption of electricity. DOE assesses these environmental effects by using NEMS-BT to provide key inputs to its analysis. The portion of the environmental assessment that is produced by NEMS-BT considers CO_2, NO_X, and Hg. The environmental assessment also considers impacts on SO_2 emissions.

Pursuant to the National Environmental Policy Act of 1969 (NEPA) and the requirements of DOE Order 451.1B: NEPA Compliance Program, DOE has prepared an environmental assessment of the impacts of the new and amended standards for the final rule (final rule TSD chapter 16). DOE found that the environmental effects associated with the standards for ballasts were not significant. Therefore, DOE issued a Finding of No Significant Impact (FONSI), pursuant to NEPA, the regulations of the Council on Environmental Quality (40 CFR parts 1500–1508), and DOE's regulations for compliance with NEPA (10 CFR part 1021). The FONSI is available in the docket for this rulemaking.

2.15.1 Carbon Dioxide

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

2.15.2 Sulfur Dioxide

DOE has preliminarily determined that SO_2 emissions from affected Electric Generating Units (EGUs) are subject to nationwide and regional emissions cap and trading programs that are likely to eliminate the standards' impact on SO_2 emissions. The costs of meeting such emission cap requirements are reflected in the electricity prices and forecasts used in DOE's analysis of the standards. Title IV of the Clean Air Act sets an annual emissions cap on SO_2 for all affected EGUs. SO_2 emissions from 28 eastern states and the District of Columbia (DC) are also limited under the Clean Air Interstate Rule (CAIR, published in the Federal Register on May 12, 2005. 70 FR 25162 (May 12, 2005)), which created an allowance-based trading program. Although CAIR was remanded to the Environmental Protection Agency (EPA) by the U.S. Court of Appeals for the District of Columbia Circuit (DC Circuit) (see *North Carolina v. EPA*, 550 F.3d 1176 (DC Cir. 2008)), it remained in effect temporarily, consistent with the DC Circuit's earlier opinion in *North Carolina v. EPA*, 531 F.3d 896 (DC Cir. 2008). On July 6, 2010, EPA issued the Transport Rule proposal, a replacement for CAIR (75 FR 45210 (Aug. 2, 2010)), and on July 6, 2011, EPA issued the final Transport Rule, entitled the Cross-State Air Pollution Rule (www.epa.gov/crossstaterule/). 76 FR 48208 (August 8, 2011). Because the NEMS used for the final rule assumes the implementation of CAIR, DOE has not been able to take into account the effects of the Cross-State Air Pollution Rule for this rulemaking.[c]

The attainment of the emissions caps is flexible among EGUs and is enforced through the use of emissions allowances and tradable permits. Under existing Environmental Protection Agency (EPA) regulations, any excess SO_2 emission allowances resulting from the lower

[c] DOE notes that future iterations of the NEMS-BT model will incorporate any changes necessitated by issuance of the Cross-State Air Pollution Rule.

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. However, if the standard resulted in a permanent increase in the quantity of unused emission allowances, there would be an overall reduction in SO_2 emissions from the standards. While there remains some uncertainty about the ultimate effects of efficiency standards on SO_2 emissions covered by the existing cap and trade system, the NEMS-BT modeling system that DOE used to forecast emissions reductions currently indicates that no physical reductions in power sector emissions would occur for SO_2.

Even if there is no significant reduction in the overall emissions of SO_2 that results from the standard, there may still be some economic benefit from reduced demand for SO_2 emission allowances that is not fully reflected in the cost savings experienced by individual consumers. Electricity savings that decrease the overall demand for SO_2 emissions allowances could lower allowance prices and thereby result in some economic benefits for all electricity consumers, not just those that reduced their electricity use as a result of an efficiency standard. DOE did not to monetize this particular benefit because the effect on the SO_2 allowance price from any single energy conservation standard is likely to be small and highly uncertain.

2.15.3 Nitrogen Oxides

As discussed in the previous section, the NEMS used for the final rule assumes the implementation of CAIR, which established a cap on NO_X emissions in 28 eastern states and DC. With CAIR in effect, the energy conservation standards for fluorescent lamp ballasts are expected to have little or no physical effect on NO_X emission in those states covered by CAIR, for the same reasons that they may have little effect on SO_2 emissions. However, the standards established in this final rule would be expected to reduce NO_X emissions in the 22 states not affected by CAIR. For these 22 states, DOE uses the NEMS-BT to estimate NO_X emissions reductions from the standards adopted in this final rule.

Standards may produce an environmental-related economic benefit in the form of lower prices for emissions allowance credits. As with SO_2 allowance prices, DOE did not to monetize this particular benefit because the effect on the NO_X allowance price from any single energy conservation standard is likely small and highly uncertain.

2.15.4 Mercury

Similar to emissions of SO_2 and NO_X, future emissions of Hg would have been subject to emissions caps. In May 2005, EPA issued the Clean Air Mercury Rule (CAMR). 70 FR 28606 (May 18, 2005). CAMR would have permanently capped emissions of mercury for new and existing coal-fired power plants in all states by 2010. However, on February 8, 2008, the DC Circuit issued its decision in New Jersey v. Environmental Protection Agency, in which the DC Circuit, among other actions, vacated the CAMR. 517 F.3d 574 (DC Cir. 2008). EPA has decided to develop emissions standards for power plants under the Clean Air Act (Section 112), consistent with the DC Circuit's opinion on the CAMR. See www.epa.gov/air/mercuryrule/pdfs/certpetition_withdrawal.pdf. Pending EPA's forthcoming revisions to the rule, DOE is excluding the CAMR from its Environmental Analysis. In the absence of CAMR, a DOE standard would likely reduce Hg emissions and DOE used NEMS-BT to estimate these emission reductions.

2.15.5 Particulate Matter

DOE acknowledges that particulate matter (PM) impacts are of concern due to human exposures that can impact health. But impacts of PM emissions reduction are much more difficult to estimate than other emissions reductions due to the complex interactions between PM, other power plant emissions, meteorology, and atmospheric chemistry that impact human exposure to particulates. Human exposure to PM usually occurs at a significant distance from the power plants that are emitting particulates and particulate precursors. When power plant emissions travel this distance, they undergo highly complex atmospheric chemical reactions. Although the EPA does keep inventories of direct PM emissions of power plants, in its source attribution reviews, the EPA does not separate direct PM emissions from power plants from the sulfate particulates indirectly produced through complex atmospheric chemical reactions. The great majority of PM emissions from power plants are of these secondary particles (secondary sulfates). Thus, it is not useful to examine how the amended standard impacts direct PM emissions independent of indirect PM production and atmospheric dynamics. Therefore, DOE did not assess the impact of these standards on particulate emissions. Further, even the cumulative impact of PM emissions from power plants and indirect emissions of pollutants from other sources is unlikely to be significant.

2.16 MONETIZATION OF EMISSIONS REDUCTION BENEFITS

For those emissions for which real national emission reductions are anticipated (CO_2, Hg, and NO_X for 22 states), only ranges of estimated economic values based on environmental damage studies of varying quality and applicability are available. Therefore, DOE reported estimates of monetary benefits derived using these values and considered these benefits in weighing the costs and benefits of each of the standard levels considered.

In order to estimate the monetary value of benefits resulting from reduced CO_2 emissions, DOE used in its analysis the most current Social Cost of Carbon (SCC) values developed and/or agreed to by interagency reviews. 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 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.

At the time of this notice, the most recent interagency estimates of the potential global benefits resulting from reduced CO_2 emissions in 2010$ were $4.9, $22.1, $36.3, and $67.1 per metric ton avoided. For emission 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 preference will be given to consideration of the global benefits of reducing CO_2

emissions. See appendix 17A for the full range of annual SCC estimates from 2010 to 2050. To calculate a present value of the stream of monetary values, DOE discounted 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 GHG 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 the potential monetary benefit of reduced NO_X, and Hg emissions resulting from the standard levels it considers. For NO_X emissions, available estimates suggest a very wide range of monetary values for NO_X emissions, ranging from \$370 per ton to \$3,800 per ton of NO_X from stationary sources, measured in 2001\$ (equivalent to a range of \$450 to \$4,623 per ton in 2010\$). Refer to the U.S. Office of Management and Budget (OMB), Office of Information and Regulatory Affairs, "2006 Report to Congress on the Costs and Benefits of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities," for additional information.

In accordance with OMB guidance, DOE conducted two calculations of the monetary benefits derived using each of the economic values used for NO_X, one using a real discount rate of 3 percent and another using a real discount rate of 7 percent.[d]

DOE is aware of multiple agency efforts to determine the appropriate range of values used in evaluating the potential economic benefits of reduced Hg emissions. DOE has decided to await further guidance regarding consistent valuation and reporting of Hg emissions before it once again monetizes Hg emissions in its rulemakings.

2.17 REGULATORY IMPACT ANALYSIS

DOE prepared an RIA pursuant to Executive Order 12866, "Regulatory Planning and Review," 58 FR 51735, October 4, 1993, which is subject to review under the Executive Order by the Office of Information and Regulatory Affairs at the Office of Management and Budget. The RIA addressed the potential for non-regulatory approaches to supplant or augment energy conservation standards to improve the energy efficiency of fluorescent lamp ballasts on the market.

2.18 DEPARTMENT OF JUSTICE REVIEW

Section 325(o)(2)(B)(i)(V) of the Energy Policy and Conservation Act states that, before the Secretary of Energy may prescribe a new or amended energy conservation standard, the Secretary shall ask the U.S. Attorney General to make a determination of "the impact of any lessening of competition…that is likely to result from the imposition of the standard." (42 U.S.C. 6295) Pursuant to this requirement, DOE solicited the views of DOJ on any lessening of

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[d] OMB, Circular A-4: Regulatory Analysis (Sept. 17, 2003).

competition that is likely to result from the imposition of a proposed standard and gave the views provided full consideration when assessing economic justification of new and amended standards.

CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

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CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

3.1 INTRODUCTION

This chapter consists of three sections: the market assessment, the technology assessment, and a discussion of product classes. The market assessment provides an overall picture of the market for the products concerned, including the nature of the products, industry structure, and manufacturer market shares; regulatory and non-regulatory efficiency improvement programs; and market trends and quantities of products sold. The technology assessment identifies a list of technologies to consider in the screening analysis. The product classes section discusses the product classes the U.S. Department of Energy (DOE) considered using for this rulemaking and how they were developed.

The information DOE gathers from the market and technology assessment serves as resource material for use throughout the rulemaking. DOE considers both quantitative and qualitative information from publicly available sources and interested parties.

3.1.1 Definitions

Section 321 of the Energy Policy and Conservation Act (EPCA) contains definitions for fluorescent lamp ballast and associated terms. DOE codified in the Code of Federal Regulations (CFR) the statutory definitions and definitions of supplementary terms for fluorescent lamp ballasts in 10 CFR 430.2. Appendix 3A lists these terms and their definitions.

As part of this energy conservation standards rulemaking, DOE is extending coverage to additional fluorescent lamp ballasts. (42 U.S.C. 6295(g)(7)(B)) The following sections describe in more detail the definitions in EPCA for fluorescent lamp ballasts and note DOE's interpretation of the definitions. Please see the final rule *Federal Register* notice for this rulemaking for more discussion on DOE's consideration of additional fluorescent lamp ballasts and its interpretation of EPCA's definitions.

3.1.1.1 Ballast Efficacy Factor

Section 321(30)(A) of EPCA (42 U.S.C. 6291(30)(A)) defines ballast efficacy factor (BEF) as:

> *Ballast efficacy factor* means the relative light output divided by the power input of a fluorescent lamp ballast, as measured under test conditions specified in American National Standards Institute (ANSI) Standard C82.2–1984.

3.1.1.2 Ballast Luminous Efficiency

The fluorescent lamp ballast active mode test procedure adopted a new metric for describing the performance of a fluorescent lamp ballast called ballast luminous efficiency (BLE). As of the compliance date of any standards promulgated by this fluorescent lamp ballast standards rulemaking, ballasts would be tested using the new BLE procedure, not the current procedure which measures ballast efficacy factor (BEF). Information on the active mode test procedure can be found on DOE's website.[a]

Ballast luminous efficiency means the total lamp arc power divided by the ballast input power multiplied by the appropriate frequency adjustment factor. BLE describes the percentage of ballast input power that is used in the lamp column to produce light. Power delivered to the lamp cathodes (filaments) is not included in the output measurement and is considered a ballast loss. BLE is then multiplied by a frequency adjustment factor depending on the frequency at which a ballast operates a lamp. Low-frequency operation of a lamp produces fewer lumens per lamp arc watt than high-frequency operation, therefore DOE uses an adjustment factor to account for the decrease in system efficacy. In general, the BLE metric results in reduced measurement variation, reduced testing burden, and a more straightforward efficiency metric than the current BEF metric and test procedure.

3.1.1.3 Fluorescent Lamp

10 CFR 430.2 defines a fluorescent lamp as:

Fluorescent lamp means a low pressure mercury electric-discharge source in which a fluorescing coating transforms some of the ultraviolet energy generated by the mercury discharge into light, including only the following:

(1) any straight-shaped lamp (commonly referred to as 4-foot medium bipin lamps) with medium bipin bases of nominal overall length of 48 inches and rated wattage of 25 or more;
(2) any U-shaped lamp (commonly referred to as 2-foot U-shaped lamps) with medium bipin bases of nominal overall length between 22 and 25 inches and rated wattage of 25 or more;
(3) any rapid start lamp (commonly referred to as 8-foot high output lamps) with recessed double contact (RDC) bases of nominal overall length of 96 inches;
(4) any instant start lamp (commonly referred to as 8-foot slimline lamps) with single pin bases of nominal overall length of 96 inches and rated wattage of 52 or more;
(5) any straight-shaped lamp (commonly referred to as 4-foot miniature bipin standard output lamps) with miniature bipin bases of nominal overall length between 45 and 48 inches and rated wattage of 26 or more; and
(6) any straight-shaped lamp (commonly referred to 4-foot miniature bipin high output lamps) with miniature bipin bases of nominal overall length between 45 and 48 inches and rated wattage of 49 or more.

This definition reflects the version adopted in the final rule for general service fluorescent lamps (the 2009 Lamps Rule).[b] 74 FR 34080, 34176-77 (July 14, 2009).

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[a] DOE's website for fluorescent lamp ballasts can be found at http://www1.eere.energy.gov/buildings/appliance_standards/residential/fluorescent_lamp_ballasts.html.

3.1.1.4 Fluorescent Lamp Ballast

Fluorescent lamp ballast means a device that is used to start and operate fluorescent lamps by providing a starting voltage and current and limiting the current during normal operation.

As part of this rulemaking, under the authority of 42 U.S.C. 6295(i)(5), DOE is including the following list of fluorescent lamp ballasts in the scope of coverage:

(1) ballasts that operate 4-foot medium bipin lamps with a rated wattage[c] of 25 watts (W) or more and an input voltage at or between 120 volts (V) and 277V;
(2) ballasts that operate 2-foot medium bipin U-shaped lamps with a rated wattage of 25W or more and an input voltage at or between 120V and 277V;
(3) ballasts that operate 8-foot high output lamps with an input voltage at or between 120V and 277V;
(4) ballasts that operate 8-foot slimline lamps with a rated wattage of 52W or more and an input voltage at or between 120V and 277V;
(5) ballasts that operate 4-foot miniature bipin standard output lamps with a rated wattage of 26W or more and an input voltage at or between 120V and 277V;
(6) ballasts that operate 4-foot miniature bipin high output lamps with a rated wattage of 49W or more and an input voltage at or between 120V and 277V;
(7) ballasts that operate 4-foot medium bipin lamps with a rated wattage of 25W or more, an input voltage at or between 120V and 277V, a minimum power factor (PF) of 0.50, and that are designed and labeled for use in residential applications; and
(8) ballasts that operate 8-foot high output lamps with an input voltage at or between 120V and 277V, that are designed, labeled, and marketed for use in outdoor signs.

DOE is not expanding the scope of coverage to: (1) dimming ballasts beyond those which are already covered; (2) low frequency T8 ballasts that are designed, labeled, and marketed for use in EMI-sensitive environments and sold in packages of 10 or fewer; and (3) PS ballasts that operate 4-foot MBP T8 lamps and deliver on average less than 140mA to each lamp.[d]

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[b] The 2009 Lamps Rule was published in the Federal Register on July 14, 2009 and is available at http://www1.eere.energy.gov/buildings/appliance_standards/residential/incandescent_lamps.html
[c] The 2009 Lamps Rule adopted a new definition for rated wattage that can be found in 10 CFR 430.2.
[d] The standards promulgated by EPACT 2005 contained exemptions for ballasts designed for dimming to 50 percent or less of its maximum output. However, these exemptions expired for ballasts manufactured after July 1, 2010 and sold by the manufacturer on or after October 1, 2010 that operate certain energy saver lamps (one or two F34T12, two F96T12/ES, or two F96T12HO/ES). 10 CFR 430.32(m)(6) and (m)(7).

3.2 MARKET ASSESSMENT

The following market assessment identifies the manufacturer trade association and domestic manufacturers of fluorescent lamp ballasts; discusses manufacturer market share, regulatory programs, and non-regulatory initiatives; defines product classes; provides historical shipment data, shipment projections, and equipment lifetime estimates; and summarizes market performance data.

3.2.1 Trade Associations

The National Electrical Manufacturers Association (NEMA) is the trade association for fluorescent lamp ballasts. NEMA's Lighting Systems Division is one of eight product divisions. The division's 47 member companies comprise 85-95 percent of the U.S. commercial and industrial market, as well as large portions of the institutional and educational markets.[1] In addition to ballasts, NEMA's Lighting Systems Division also oversees products such as fluorescent lamps, emergency lighting, lighting controls, luminaires, solid state lighting, and other emerging lighting technologies. NEMA provides an organization through which manufacturers of lighting equipment can work together on projects that affect their industry and business. NEMA's activities relating to energy efficiency include:[2]

- "[a]dvising the DOE and executive agencies on lighting research and market transformation needs;
- engaging in legislative work on energy and lighting issues;
- monitoring energy-efficiency rulemakings and standards affecting lighting products by federal and state agencies;
- promoting the national voluntary luminaire rating and information program under the National Lighting Collaborative;
- supporting adoption of 1999 ASHRAE/IESNA 90.1 lighting provisions;
- working with market transformation and environmental groups to advance market use of energy-efficient lighting technologies;
- advising DOE and the U.S. Environmental Protection Agency (EPA) on ENERGY STAR Buildings and ENERGY STAR voluntary product labeling programs; and
- advocating market-based approaches to enhance the use and penetration of energy-efficient technologies."

3.2.2 Manufacturers and Market Share

The following list contains the names of manufacturers that produce fluorescent lamp ballasts:

- Acuity Brands Lighting
- Advance Transformer
- American Ballast
- Antron Compact Electronics
- Axis Technologies
- Ballast Wise
- Bodine
- CEW
- Cooper Lighting
- EBW Electronics
- Espen Technology, Inc.
- Etlin-Daniels
- Fulham
- France
- General Electric Consumer & Industrial
- Hatch Transformer

- Holophane
- Howard Industries
- Iota Engineering
- Keystone Technologies
- Lamar Lighting
- SOLA Ballasts
- Lighting Components
- Lightolier
- Lutron Electronics Company, Inc.
- MaxLite
- OSRAM Sylvania
- Pacific Lighting and Electric
- PQL
- Radionic
- Robertson Worldwide
- Sage Lighting Ltd.
- SLI Lighting
- Sunpark Electronics Corp.
- Superior Lamps, Inc.
- TCP
- Ultrasave Lighting Ltd.
- Universal Lighting Technologies
- Ventex
- Venture Lighting International
- Wide-Lite

Four manufacturers hold the majority of the domestic market share of fluorescent lamp ballasts:

- GE Consumer and Industrial of General Electric, Inc. (hereafter, "GE"),
- OSRAM Sylvania of Siemens AG (hereafter "Osram Sylvania"),
- Advance Transformer of Philips Lighting (hereafter "Philips"), and
- Universal Lighting Technologies (hereafter "Universal").

The lighting divisions of some of these companies also manufacture other products, such as fluorescent lamps, high intensity discharge lamps, light emitting diodes, and compact fluorescent lamps.

3.2.2.1 Small Businesses

Small businesses may be particularly affected by the promulgation of minimum energy conservation standards for fluorescent lamp ballasts. The Small Business Administration lists small business size standards that are matched to industries as they are described in the North American Industry Classification System (NAICS). A size standard is the largest that a for-profit concern can be and still qualify as a small business for Federal Government programs. These size standards are generally the average annual receipts or the average employment of a firm. For fluorescent lamp ballasts, the size standard is matched to NAICS code 335311, *Power, Distribution, & Specialty Transformer Manufacturing*, which has a size standard of 750 employees or fewer.[3]

DOE studies the potential impacts on these small businesses in detail as part of the manufacturer impact analysis.

3.2.3 Regulatory Programs

Several Federal and international regulatory programs affect the markets for fluorescent lamp ballasts. The following section summarizes U.S., Canadian, and European regulatory initiatives relevant to the ballasts covered by this rulemaking. While the following discussion is not exhaustive in describing all regulatory action related to fluorescent lamp ballasts, it provides detail on some notable initiatives that characterize recent developments in the lighting market.

3.2.3.1 Federal Energy Conservation Standards

EPCA (42 U.S.C. 6291–6309) established an energy conservation program for major household appliances. Additional amendments to EPCA gave DOE the authority to regulate the energy efficiency of several products, including certain fluorescent lamp ballasts. Amendments to EPCA in the National Appliance Energy Conservation Amendments of 1988 (NAECA 1988), Pub. L.100357, established energy conservation standards for fluorescent lamp ballasts.[e] (42 U.S.C. 6295(g)(5)) The standards promulgated by NAECA 1988 can be found in Table 3.2.1. These amendments also required that DOE (1) conduct two rulemaking cycles to determine whether these standards should be amended; and (2) for each rulemaking cycle, determine whether the standards in effect for fluorescent lamp ballasts should be amended so that they would be applicable to additional fluorescent lamp ballasts. (42 U.S.C. 6295(g)(7)(A)(B))

Table 3.2.1 EPCA Standards for Fluorescent Lamp Ballasts

Application for Operation of	Ballast Input Voltage *V*	Total Nominal Lamp Watts *W*	Ballast Efficacy Factor
One F40T12 Lamp	120	40	1.805
	277	40	1.805
Two F40T12 Lamps	120	80	1.060
	277	80	1.050
Two F96T12 Lamps	120	150	0.570
	277	150	0.570
Two F96 T12 High Output (HO) Lamps	120	220	0.390
	277	220	0.390

On September 19, 2000, DOE published a final rule in the *Federal Register* that completed the first of the two rulemaking cycles to evaluate and amend the energy conservation standards for fluorescent lamp ballasts (hereafter "the 2000 Ballast Rule"). 65 FR 56740. This rulemaking established a consensus standard, representing an agreement between the fluorescent lamp ballast industry and energy-efficiency advocacy organizations. The standard levels DOE adopted replaced the ballast efficacy factors promulgated in NAECA 1988 for certain fluorescent lamp ballasts. Table 3.2.2 shows the standards codified by DOE. 10 CFR 430.32(m)(3)

[e] Ballasts are used primarily in the commercial and industrial sectors. While Part B includes a range of consumer products that are used primarily in the residential sector, such as refrigerators, dishwashers, and clothes washers, Part B also includes several products used primarily in the commercial sector, including fluorescent lamp ballasts. (Part C of Title III – Certain Industrial Equipment, codified in the U.S. Code as Part A-1, concerns products used primarily in the commercial and industrial sectors, such as electric motors and pumps, commercial refrigeration equipment, and packaged terminal air conditioners and heat pumps.)

Table 3.2.2 2000 Ballast Rule Standards for Fluorescent Lamp Ballasts

Application for Operation of	Ballast Input Voltage *V*	Total Nominal Lamp Watts *W*	Ballast Efficacy Factor
One F40T12 Lamp	120	40	2.29
	277	40	2.29
Two F40T12 Lamps	120	80	1.17
	277	80	1.17
Two F96T12 Lamps	120	150	0.63
	277	150	0.63
Two F96 T12 HO Lamps	120	220	0.39
	277	220	0.39

Several years later Congress promulgated new energy conservation standards for certain fluorescent lamp ballasts under the EPACT 2005, Pub. L. 10958. (EPACT section 135(c)(2); codified at 42 U.S.C. 6295(g)(8)(A)). On October 18, 2005, DOE published a final rule in the *Federal Register* codifying those new fluorescent lamp ballast standards into the Code of Federal Regulations at 10 CFR 430.32(m). 70 FR 60407. These standards established minimum ballast efficacy requirements for "energy saver" versions of full-wattage ballasts, such as the F34T12 ballast. Table 3.2.3 shows the standards prescribed by EPACT 2005. 10 CFR 430.32(m)(5)

Table 3.2.3 EPACT 2005 Standards for Fluorescent Lamp Ballasts

Application for Operation of	Ballast Input Voltage *V*	Total Nominal Lamp Watts *W*	Ballast Efficacy Factor
One F34T12 Lamp	120	34	2.61
	277	34	2.61
Two F34T12 Lamps	120	68	1.35
	277	68	1.35
Two F96T12/ES Lamps	120	120	0.77
	277	120	0.77
Two F96 T12 HO/ES Lamps	120	190	0.42
	277	190	0.42

In summary, fluorescent lamp ballasts that are currently regulated under EPCA, as amended, include ballasts that are designed to operate one and two nominally 40W and 34W 4-foot T12 medium bipin lamps (F40T12 and F34T12), two nominally 75W and 60W 8-foot T12 single pin slimline lamps (F96T12 and F96T12/ES), and two nominally 110W and 95W 8-foot T12 RDC high output lamps (F96T12 and F96T12/ES) at nominal input voltages of 120 or 277 volts with an input current frequency of 60 Hz and a power factor of 0.90 or greater. 10 CFR 430.32(m). Ballasts that were excluded from regulation include (1) ballasts designed for dimming to 50 percent or less of its maximum output, (2) ballasts designed for use with two F96T12 high output (HO) lamps at ambient temperatures of 20 degrees F or less and for use in an outdoor sign[f] (3) ballasts with a power factor of less than 0.90 that are designed and labeled

[f] In 10 CFR 430.32(m)(7), the temperature exemption granted under EPACT 2005 is slightly different than that contained in sections (m)(2) and (m)(4). In subsection (m)(7), ballasts designed for use with two F96T12HO/ES lamps at ambient temperatures "of 20degrees F or less" and designated for use in an outdoor sign are exempt from

for use only in residential building applications, and (4) replacement ballasts as defined in paragraph (m)(4)(ii).[g] These exemptions expired for ballasts designed to operate one or two F34T12, two F96T12/ES, or two F96T12HO/ES lamps that are manufactured after July 1, 2010 and sold by the manufacturer on or after October 1, 2010. 10 CFR 430.32(m)(2), (m)(4), and (m)(7).

On December 19, 2007, the President signed the Energy Independence and Security Act of 2007 (EISA 2007) (Pub. L. 110140), which makes numerous amendments to EPCA and directs DOE to undertake several new rulemakings for appliance energy efficiency standards. EISA 2007 did not amend standards for fluorescent lamp ballasts, but instead directed DOE to amend its test procedure for fluorescent lamp ballasts to incorporate a measure of standby mode and off mode energy consumption by March 31, 2009. (42 U.S.C. 6295(gg)(2)(B)(ii)) In addition, pursuant to 42 U.S.C. 6295(o), DOE is directed to incorporate standby mode and off mode energy use in any amended or new standard adopted after July 1, 2010. Because this energy conservation standards rulemaking for fluorescent lamp ballasts will be completed in 2011, the requirement to incorporate standby mode energy use into the energy conservation standards analysis is applicable.

DOE published a final rule test procedure to comply with the standby mode and off mode energy use provisions from EISA 2007 that apply to fluorescent lamp ballasts that are (or could be) covered by this rulemaking. DOE stated in that final rule that standby mode energy use, as defined in EISA 2007,[h] is nonexistent for typical ballasts that operate on a switch or a motion sensor. DOE also stated that standby mode energy use is only applicable to ballasts with a lighting control system. One example of these new ballast designs is a DALI[i]-enabled ballast. DALI-enabled ballasts exhibit standby power, as they have internal circuitry that is integral to the design of the ballast that remains on and active, even when the ballast is not driving any lamps. DOE noted that fluorescent lamp ballasts never meet the definition of "off mode."

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the standards in paragraph (m)(5). The other sections require the ballast to be for ambient temperatures of *negative* 20 degrees F or less.

[g] The exclusion provided for replacement ballasts requires that they meet certain criteria to be considered a replacement ballast, such as being designed to replace an existing ballast in a previously installed luminaire and being marked "FOR REPLACEMENT USE ONLY." This exclusion only applies to replacement ballasts manufactured on or before June 30, 2010. After that date, replacement ballasts will no longer be excluded. (10 CFR 430.32(m)(4)(ii)(A)) See appendix A of this TSD for the exact language of the exclusion for replacement ballasts.

[h] In amending 42 U.S.C. 6295(gg)(1)(a)(i), (ii), and (iii), section 310 of EISA 2007 defines "active mode," "off mode," and "standby mode" as follows: "The term 'active mode' means the condition in which an energy-using product—(I) is connected to a main power source; (II) has been activated; and (III) provides 1 or more main functions." "The term 'off mode' means the condition in which an energy-using product— (I) is connected to a main power source; and (II) is not providing any standby or active mode function." "The term 'standby mode' means the condition in which an energy-using product (I) is connected to a main power source; and (II) offers 1 or more of the following user-oriented or protective functions: (aa) To facilitate the activation or deactivation of other functions (including active mode) by remote switch (including remote control), internal sensor, or timer. (bb) Continuous functions including information or status displays (including clocks) or sensor-based functions."

[i] DALI stands for Digital Addressable Lighting Interface, which is a system that enables communication between a central lighting controls system and the individual components, including the ballasts.

Pursuant to EPCA section 325(gg)(2)(A), 42 U.S.C. 6295(gg)(2)(A), DOE has considered whether to incorporate standby mode into a single amended or new metric. DOE has not adopted standards for standby mode energy use in this rulemaking. For more information, see the final rule *Federal Register* notice.

3.2.3.2 California Energy Commission

The California Energy Commission (CEC) specifies appliance standards that are "applicable as state law to the sale and offering for sale of appliances in California."[4] The current standards took effect on August 9, 2009. The new regulations updated standards to match the current federal energy conservation standards with one exception. The CEC regulations maintain the exemption for ballasts designed to operate one or two F34T12, two F96T12/ES, or two F96T12HO/ES lamps that: (1) are designed for dimming to 50 percent or less of its maximum output, (2) are designed for use with two F96T12 HO lamps at ambient temperatures of 20 degrees F or less and for use in an outdoor sign, and (3) have a power factor of less than 0.90 and are designed and labeled for use only in residential building applications.

3.2.3.3 Canadian Energy Efficiency Standards

The Natural Resources Canada (NRCan) Office of Energy Efficiency regulates the energy efficiency of fluorescent lamp ballasts in Canada. In 1992, Parliament passed the Energy Efficiency Act (S.C. 1992, c. 36), which concerns minimum performance levels for energy-using products, effective in February 1995. Fluorescent lamp ballasts were included in the first set of energy efficiency regulations, published in November 1994.[5] An amendment published in April 2003 updated Canada's regulations to the minimum levels put forth in the 2000 Ballast Rule. It also proposed two effective dates: April 1, 2005 for new installations and April 1, 2010 for existing installations (replacement ballasts).[6] Amendment 9, published in the *Canadian Gazette* Part II on November 15, 2006, introduced standards for ballasts that operate energy-saving lamps and F32T8 lamps, modified the criteria for exempted ballasts, and repealed the effective date for fluorescent lamp ballasts.[7] Table 3.2.4[8] shows the current Canadian standards for fluorescent lamp ballasts.

Table 3.2.4 Canadian Standards for Fluorescent Lamp Ballasts

Application for Operation of	Ballast Input Voltage *V*	Total Nominal Lamp Wattage | *W*	Minimum Ballast Efficacy Factor
One F40T12 Lamp*	120	40	2.29
	277	40	2.29
	347	40	2.22
One F34T12 Lamp	120	34	2.61
	277	34	2.61
	347	34	2.53
Two F40T12 Lamps	120	80	1.17
	277	80	1.17
	347	80	1.12
Two F34T12 Lamps	120	68	1.35
	277	68	1.35
	347	68	1.29
Two F96T12(IS) Lamps**	120	150	0.63

Application for Operation of	Ballast Input Voltage *V*	Total Nominal Lamp Wattage | *W*	Minimum Ballast Efficacy Factor
	277	150	0.63
	347	150	0.62
Two F96T12(ES) Lamps	120	120	0.77
	277	120	0.77
	347	120	0.76
Two 110W F96T12 HO Lamps	120	220	0.390
	277	220	0.390
	347	220	0.380
Two F96T12 HO(ES) Lamps	120	190	0.42
	277	190	0.42
	347	190	0.41
Two F32T8 Lamps	120	64	1.250
	277	64	1.230
	347	64	1.200
*Also for use on 40W/48T10/RS lamps **Also for use on 60W/96T12/IS lamps			

The Canadian standards listed above apply to residential as well as commercial ballasts. Canadian standards consider an input voltage of 347V in addition to 120V and 277V, which is consistent with the Canadian electrical distribution network. Canadian standards also require a minimum power factor of 0.9 (consistent with U.S. standards) for all ballasts except residential ballasts.

3.2.3.4 European Energy Efficiency Standards

Directive 2005/32/EC of the European Parliament and the Council of the European Union amended Council Directive 92/42/EEC and Directives 96/57/EC and 2000/55/EC to establish a framework for setting energy efficiency requirements for energy-using products. Energy efficiency standards for fluorescent lamp ballasts have yet to be published.

3.2.4 Non-Regulatory Initiatives

DOE reviewed several national, regional, and local voluntary programs that promote the use of energy efficient lighting in the United States. These include the Federal Energy Management Program's (FEMP's) program for energy efficient lighting, the Consortium for Energy Efficiency's (CEE's) High Performance Commercial Lighting Initiative, the ENERGY STAR Program, and the Northeast Energy Efficiency Partnership (NEEP). The following section summarizes some of these programs for the ballasts covered by this rulemaking. While it is not an exhaustive list, the discussion provides detail on some notable initiatives that characterize recent developments in the lighting market.

3.2.4.1 Federal Energy Management Program

FEMP helps Federal buyers identify and purchase energy efficient products including certain fluorescent ballasts. Section 161 of EPACT 1992 encourages energy efficient Federal procurement. Section 104 of EPACT 2005 requires that each agency incorporate energy efficiency criteria consistent with ENERGY STAR and FEMP-designated products for "...all procurements involving energy consuming products and systems, including guides specifications, project specifications, and construction, renovation, and service contracts that include provision of energy consuming products and systems, and into the factors for the evaluation of offers received for the procurement." Executive Order 13123 and Federal Acquisition Regulation (FAR) section 23.704 direct agencies to purchase products in the upper 25 percent of energy efficiency, including all models that qualify for the ENERGY STAR product labeling program. 64 FR 30851, 30854 (June 8, 1999). FEMP provides recommendations for how to buy energy efficient fluorescent ballasts, including the products shown in Table 3.2.5.[9] FEMP offers buyers support tools such as efficiency guidelines, cost-effectiveness examples, and a cost calculator. FEMP also offers training, on-site audits, demonstrations, and design assistance.

Table 3.2.5 Federal Energy Management Program Efficiency Recommendation

Lamp Type	Number of Lamps	Recommended BEF	Best Available BEF
Four-Foot and U-Tube Lamps			
T8, 32 Watts	1	2.54 or higher	3.00
	2	1.44 or higher	1.54
	3	0.93 or higher	1.06
	4	0.73 or higher	0.79
T12, 34 Watts	1	2.64 or higher	3.05
	2	1.41 or higher	1.53
	3	0.93 or higher	0.95
Eight-Foot Lamps			
T8, 59 Watts	2	0.80 or higher	0.81
T12, 60 Watts	2	0.80 or higher	0.80

3.2.4.2 Consortium for Energy Efficiency

CEE has both a Residential Lighting Initiative and a High-Performance Commercial Lighting Initiative. CEE launched its commercial lighting initiative in November 2004 to help identify and select energy efficient commercial lighting products and practices. Initial efforts focused on designating high-performance T8 lighting products. In January 2007, the initiative was expanded to include reduced-wattage T8 products. Table 3.2.6 and Table 3.2.7 summarize CEE's specifications for high-performance and reduced-wattage T8 ballasts.

Table 3.2.6 CEE High-Performance T8 Ballast Specifications[10]

Instant Start Ballast			
Lamps	**Low BF** *$BF \leq 0.85$*	**Normal BF** *$0.85 < BF < 1.0$*	**High BF** *$BF \geq 1.01$*
1	≥ 3.08	≥ 3.11	≥ 3.03
2	≥ 1.60	≥ 1.58	≥ 1.55
3	≥ 1.04	≥ 1.05	≥ 1.04
4	≥ 0.79	≥ 0.80	≥ 0.77
6	N/A	N/A	≥ 0.52

Programmed Rapid Start Ballast			
1	≥ 2.84	≥ 2.84	≥ 2.95
2	≥ 1.48	≥ 1.47	≥ 1.51
3	≥ 0.97	≥ 1.00	≥ 1.00
4	≥ 0.76	≥ 0.75	≥ 0.75
6	N/A	N/A	≥ 0.50
Ballast Frequency 20 to 33 kHz or ≥ 40 kHz, Power Factor ≥ 0.90, Total Harmonic Distortion ≤ 20%			

Table 3.2.7 CEE Reduced Wattage T8 Ballast Specifications[11]

Instant Start Ballast, 28W Systems	
Lamps	**All BF Ranges**
1	≥ 3.52
2	≥ 1.76
3	≥ 1.16
4	≥ 0.88
Instant Start Ballast, 25W Systems	
1	≥ 3.95
2	≥ 1.98
3	≥ 1.32
4	≥ 0.99
Ballast Frequency 20 to 33 kHz or ≥ 40 kHz, Power Factor ≥ 0.90, Total Harmonic Distortion ≤ 20%	

CEE created separate standards for normal wattage T8 ballasts based on ballast factor, which compares the ratio of light output of lamps operated by a specific ballast to the light output of the same lamps operated by a standard reference ballast. However, CEE chose not to create standards by ballast factor for reduced-wattage ballasts. Additionally, CEE did not specify performance based on input voltage. CEE's specifications state that multi-voltage ballasts must meet or exceed the listed BEF when operating on at least one of the intended operating voltages.

3.2.4.3 NEMA Premium

NEMA maintains a labeling program for "NEMA Premium" ballasts based on CEE's specifications for high-efficiency 4-foot T8 ballasts. The program is intended to promote energy efficiency and assist end-users in identifying the most efficient ballasts on the market.[12] As of July 2010, NEMA's website indicates that fluorescent lamp ballasts manufactured by Acuity Brands Lighting, Cooper Lighting,, Espen Technologies, GE, Hatch Transformers Inc., Holophane an Acuity Brands Company, Keystone Technologies, Philips Lighting Electronics North America, Osram Sylvania, Robertson Worldwide, Sunpark Electronics Corp., and Universal Lighting Technologies all qualify for the NEMA Premium label.

The NEMA Premium label for fluorescent lamp ballasts is similar to NEMA's existing program for motors. In November 2004, NEMA released state-level shipment data that showed an increase in NEMA Premium motor shipments of 30 percent between 2001 and 2002 and 14 percent between 2002 and 2003.[13]

3.2.4.4 ENERGY STAR

ENERGY STAR is a joint program of DOE and EPA designed to protect the environment by promoting energy efficient products and practices.[14] ENERGY STAR specifies criteria for residential lighting fixtures, which contain three parts: a lamp, a ballast, and the fixture that holds the lamp and ballast. Products that qualify for the ENERGY STAR label may not use magnetic ballasts in indoor fixtures. The ENERGY STAR specifications also define criteria for lamp start time, power factor, lamp current crest factor, ballast operating temperature, electromagnetic interference, frequency, transient protection, end of life protection, dimming, and safety.[15]

3.2.4.5 Energy Efficient Commercial Building Deduction

EPACT 2005 created the Energy Efficient Commercial Buildings Deduction (26 U.S.C 179D), which established a tax deduction for building owners who incur expenses for energy efficiency upgrades. Effective for property in service from January 1, 2006 through December 31, 2008, the deduction allows partial deductions for improvements in interior lighting. Though the statute does not specify required lamp types or efficacies, it does call for an overall reduction in lighting power density (to qualify the lighting power density must be below the minimum required by the ASHRAE/IES 90.1), and specifically, encourages the use of higher-performance and reduced-wattage fluorescent lamps. The Emergency Economic Stabilization Act of 2008 (HR-1424), approved and signed on October 3, 2008, extends the benefits of EPACT 2005 through December 31, 2013.

3.2.4.6 Northeast Energy Efficiency Partnerships

NEEP is a regional nonprofit organization that promotes energy efficiency in the Northeast. NEEP runs a High Efficiency Commercial Lighting Initiative to "achieve cost-effective energy and demand by overcoming market barriers to the availability and widespread market adoption of advanced T8 fluorescent lighting systems."[16] NEEP coordinates with multiple local and state governments, utilities, and other initiatives, such as Efficiency Vermont[j] and the Long Island Power Authority, to promote efficient lighting products.[17, 18]

3.2.5 Historical Shipments

Awareness of annual product shipment trends is an important aspect of the market assessment and the development of the standards rulemaking. For this rulemaking, DOE used publicly available ballast shipments from the U.S. Census from 1990 to 2005.[19] DOE used this data for three main purposes. First, the shipment data and market trend information contributed to the shipments analysis and base-case forecast for ballasts (chapter 10 of the TSD). By using historical shipment data and expert opinion on market trends and calibrating forecast assumptions with recent data, DOE believes it has based the shipments model and base-case forecasts on a sound dataset. Second, DOE used the data to select the representative product

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[j] Efficiency Vermont offers technical assistance and financial incentives to encourage energy efficiency in Vermont. This organization offers rebates of $10 for the upgrade to or installation of High Performance T8 systems.

classes and representative units for analysis. Generally, DOE selected product classes and units to reflect the highest volume, most common ballast types used in the United States today (chapter 5 of the TSD). Third, DOE used the data to develop the installed stock of ballasts for the national impact analysis (chapter 11 of the TSD). Based on its understanding of trends in the market, DOE estimated how the market would respond to various efficiency levels.

The historical shipment data for ballasts is broken down into many subcategories beginning with magnetic versus electronic type ballasts. Under each technology type, the shipments are categorized by a variety of characteristics. Commercial and residential ballasts are delineated by corrected versus uncorrected power factor (section 3.3.3.5). Ballasts are also defined by starting method (section 3.3.3.1), maximum number of lamps driven (one, two, three, or four), lamp wattage, lamp diameter, and a few additional specific characteristics. Based on interviews with ballast manufacturers, DOE learned that the U.S. Census data represents about 90 percent of T8 and T5 shipments and about 70 percent of T12 electronic shipments. DOE also learned that the U.S. Census does not include shipment data for major residential ballasts or dimming ballasts. The Census data also does not provide shipments for every permutation of ballast performance characteristics, but does provide data for establishing trends for the major categories. Ballasts that operate T8 lamps comprised the majority of shipments in 2005. These are followed (in order of 2005 unit sales) by T12 ballasts, compact fluorescent lamp ballasts, T5 ballasts, and other small subsets.

Figure 3.2.1 depicts the ballast market based on shipments reported to the U.S. Census in 2005.

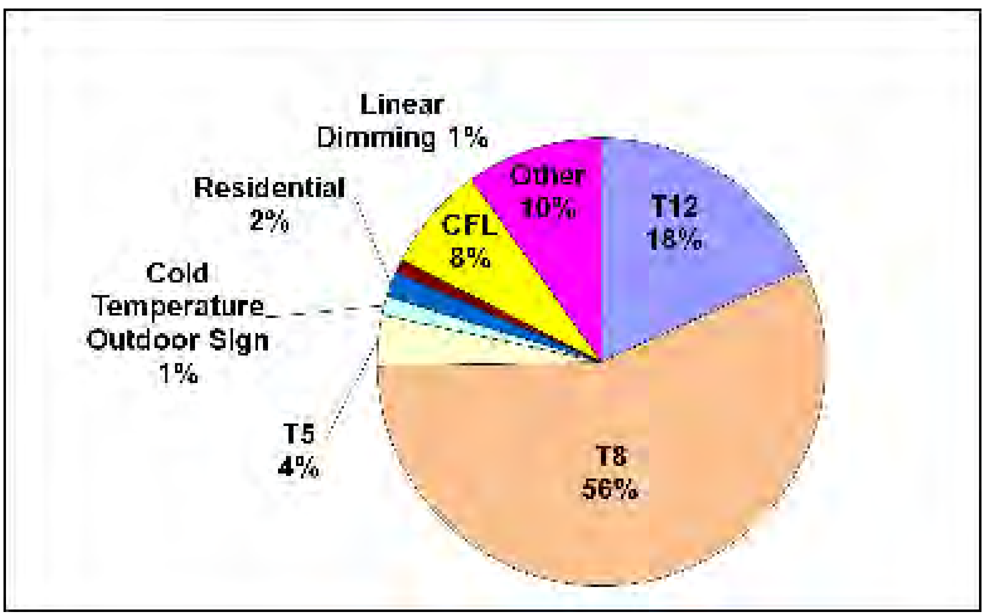


Figure 3.2.1 2005 Ballast Market Share

In 2005, corrected power-factor (commercial) magnetic ballasts were not broken out into smaller categories for shipments reporting. DOE used subcategory unit shipment proportions from the 2000 corrected power-factor magnetic ballast category to extrapolate the disaggregation of shipments for 2005. This estimation provided data points for 4- and 8-foot magnetic T12 ballasts as well as 8-foot HO magnetic T12 ballasts. The 2005 U.S. Census Data also did not report magnetic residential and linear dimming ballast shipments. To estimate magnetic residential ballast shipments, DOE extended the linear decline in magnetic residential ballasts from 2002-2004 to extrapolate a value for 2005. DOE used a similar approach to estimate linear dimming ballast shipments.

Electronic ballasts have slowly replaced magnetic ballasts, as seen in Figure 3.2.2. In 1990, magnetic ballasts represented about 96 percent of shipments, while the 2005 magnetic ballast market share dropped to 27 percent. This trend was in part due to energy conservation standards for T12 ballasts. The most recent energy conservation standards for fluorescent lamp ballasts effectively eliminated the sale of 4-foot T12 medium bipin (MBP), 2-foot T12 U-shaped, and 8-foot T12 slimline magnetic ballasts. The standard began to go into effect for certain 4-foot T12 MBP, 8-foot T12 slimline ballasts, and 8-foot HO ballasts in 2005. The final phase of the standard became effective in 2010, when replacement 4-foot T12 MBP, 8-foot T12 single pin (SP) slimline, and 8-foot HO magnetic ballasts are no longer be sold. (10 CFR 430.32(m)(4)(ii) and 430.32(m)(5)-(6))

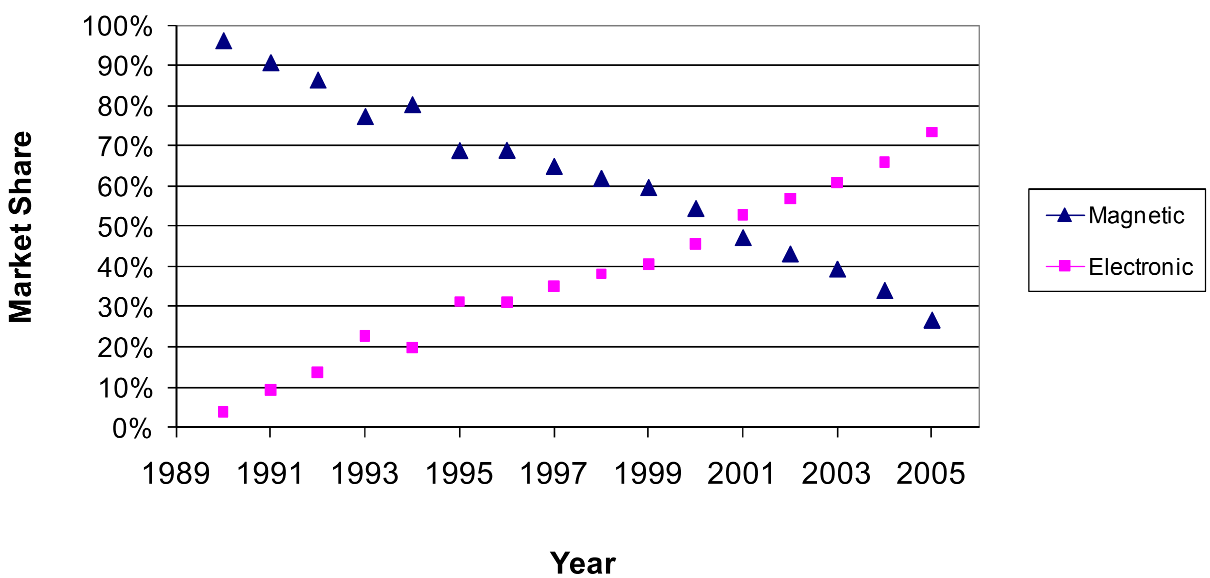


Figure 3.2.2 Magnetic and Electronic Ballast Market Share

The vast majority of 4-foot T12 MBP and 2-foot T12 U-shaped ballasts are magnetic (about 77 percent of the T12 market in 2005), and the vast majority of 4-foot T8 MBP and 2-foot T8 U-shaped ballasts are electronic (about 97 percent of T8 ballast shipments in 2005). Therefore, the decline in magnetic ballasts mirrors a decline in T12 ballast shipments. Similarly, the increase in electronic ballasts mirrors an increase in 4-foot T8 MBP and 2-foot T8 U-shaped ballast shipments. Figure 3.2.3 and Table 3.2.8 show these shipment trends. The trend in ballast shipments is followed by similar trends in 4-foot T8 MBP and 2-foot T8 U-shaped lamp shipments and 4-foot T12 MBP and 2-foot T12 U-shaped lamp shipments. DOE received general service fluorescent lamp historical shipments from NEMA from 2001 to 2005.[20] Based on conversations with manufacturers, DOE believes these trends continue beyond 2005.

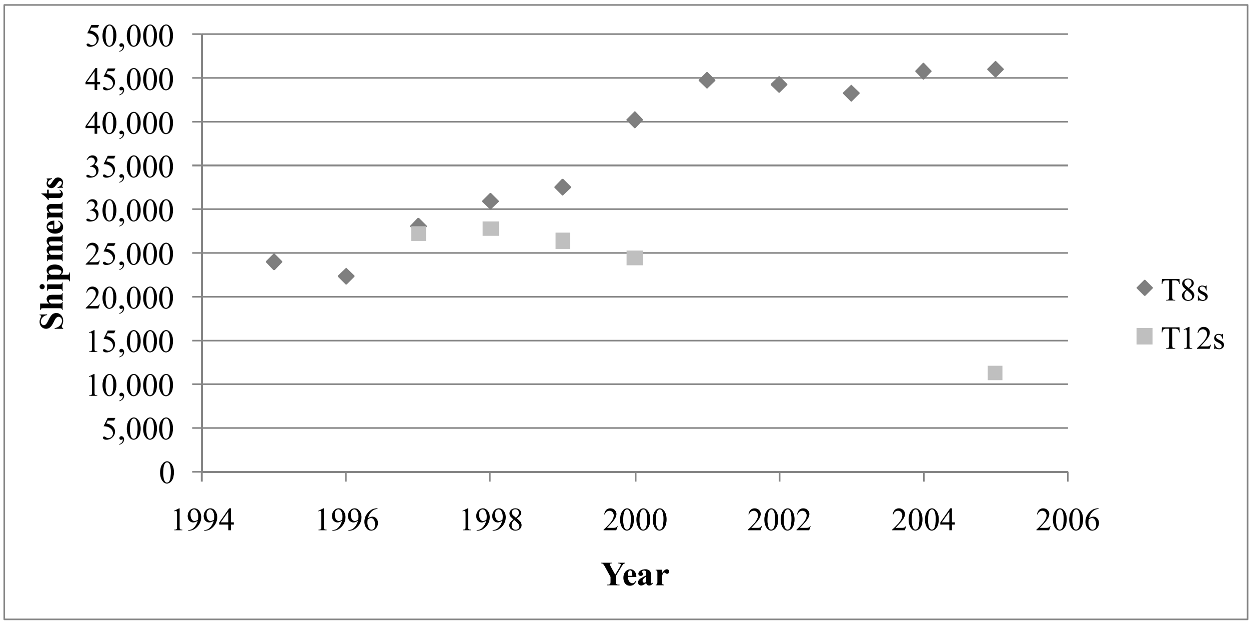


Figure 3.2.3 Shipments of Ballasts that Operate Four-Foot MBP Lamps

Table 3.2.8 Shipments of Four-Foot T8 MBP and Two-Foot T8 U-Shaped Ballasts and Lamps and Four-Foot T12 MBP and Two-Foot U-Shaped Ballasts and Lamps

	Unit Sales by Year										
	1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Four-Foot T12 Ballast	(D)	(D)	27,227	27,704	26,395	24,463	(D)	(D)	(D)	(D)	11,218
Four-Foot T8 Ballast	23,965	22,317	28,032	30,883	32,488	40,179	44,700	44,215	43,219	45,727	45,951
Four-Foot T8 Lamp	(D)	(D)	(D)	(D)	(D)	(D)	172,143	170,416	179,312	204,922	224,189
Four-Foot T12 Lamp	(D)	(D)	(D)	(D)	(D)	(D)	222,236	215,312	191,391	182,864	171,503
	(D) indicates data not made public.										

Table 3.2.9 shows similar trends for 8-foot T12 and T8 SP slimline ballasts and lamps. In general, 8-foot SP slimline T12 ballasts and lamps are experiencing a decrease in shipments, whereas 8-foot SP slimline T8 ballasts and lamps are experiencing an increase in shipments. The increase in shipments for 8-foot SP slimline T8 lamps is smaller than for 4-foot T8 shipments. According to manufacturers and lighting experts, this is because a portion of the 8-foot T12 SP slimline ballast market is being transferred to the 4-foot T8 ballast market.

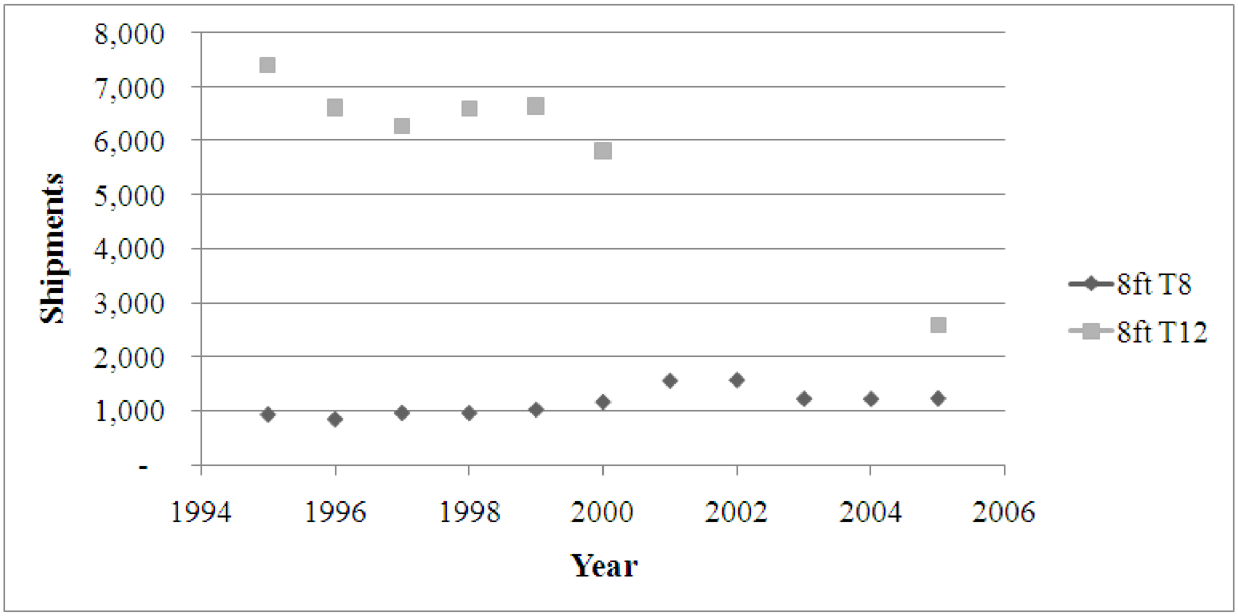


Figure 3.2.4 Shipments of Eight-Foot Slimline T8 and Eight-Foot SP Slimline T12 Ballasts

Table 3.2.9 Shipments of Eight-Foot Slimline T8 and Eight-Foot SP Slimline T12 Ballasts and Lamps

	Unit Sales by Year										
	1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Eight-Foot Slimline T12 Ballast	7,394	6,612	6,268	6,601	6,638	5,813	(D)	(D)	(D)	(D)	2,599
Eight -Foot Slimline T8 Ballast	932	847	961	959	1,020	1,160	1,547	1,560	1,218	1,214	1,224
Eight -Foot Slimline T12 Lamp	(D)	(D)	(D)	(D)	(D)	(D)	43,265	41,443	37,170	36,263	33,636
Eight -Foot Slimline T8 Lamp	(D)	(D)	(D)	(D)	(D)	(D)	4,405	5,300	5,183	5,727	5,176
	(D) indicates data not made public.										

Table 3.2.10 shows that T12 high-output ballast shipments decreased from 1995 to 2005. Data for high output ballasts were not reported in 1997 or from 2001 to 2005. DOE estimated the 2005 market share using the method described earlier. A portion of the ballasts listed in Table 3.2.10 are rated for cold-temperature outdoor signage applications, which were excluded from previous energy conservation standards. The Census data for high output ballasts are not exclusive to ballasts that operate 8-foot RDC HO lamps, but information from manufacturers indicates these ballasts represent most of the high output market. Discussions with lighting experts and lamp manufacturers indicate that they expect any migration of the 8-foot RDC HO market to go toward T5 HO fluorescent systems and metal halide systems. High output ballast shipments likely follow a similar trend to the 8-foot HO lamp shipments. Both ballast and lamp

shipments show the high output market share is much smaller than for 8-foot slimline T8 and T12 ballasts and lamps.

Table 3.2.10 T12 High-Output Ballast Market Share

	Unit Sales by Year*										
	1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Eight-Foot T12 RDC HO Ballast	3,538	3,322	(D)	2,305	3,089	2,682	(D)	(D)	(D)	(D)	1,199
Eight-Foot T12 RDC HO Lamp	N/A	N/A	N/A	N/A	N/A	N/A	23,887	24,398	24,206	24,591	25,442
Eight-Foot T8 RDC HO Lamp	N/A	N/A	N/A	N/A	N/A	N/A	691	647	467	674	420
	(D) indicates data not made public.										

*Data from 1995 and 1996 include electronic and magnetic ballast shipments. Data from 1997-2005 include only magnetic shipments. Lamps shipments are available for 2001-2005 only.

Based on public data, Figure 3.2.5 shows magnetic residential ballast shipments have decreased from 1995 to 2004.[k] Shipments data for this category were unavailable for 2005. Because the major manufacturers in the residential sector are not members of NEMA, shipments in the residential sector are likely larger than those reported in the U.S. Census data. Residential ballasts have been excluded from energy conservation standards until the expiration of the exemption imposed by EPACT 2005.

[k] U.S. Census data does not report shipments of electronic residential (low-power-factor) ballasts.

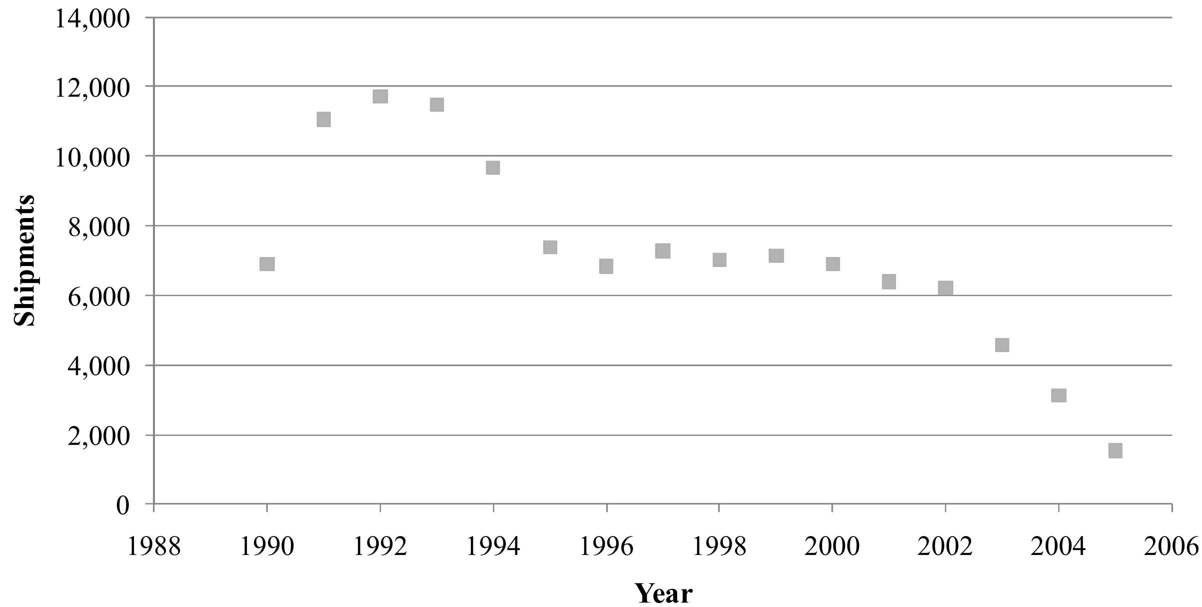


Figure 3.2.5 Shipments of Residential Ballasts

T5 ballasts have been growing steadily since reported shipments began in 2002 (Figure 3.2.6). T5 normal output ballast shipments were not reported in the U.S. Census data. Conversations with ballast manufacturers indicated some growth in normal output T5 ballasts due to replacements of 4-foot electronic T8 ballasts. In addition, manufacturers indicated that significant growth in T5 ballast shipments has been driven by 4-lamp T5 high output ballast systems replacing high-bay metal halide systems in the industrial sector. Based on information from ballast manufacturers, DOE believes these trends continued beyond 2005.

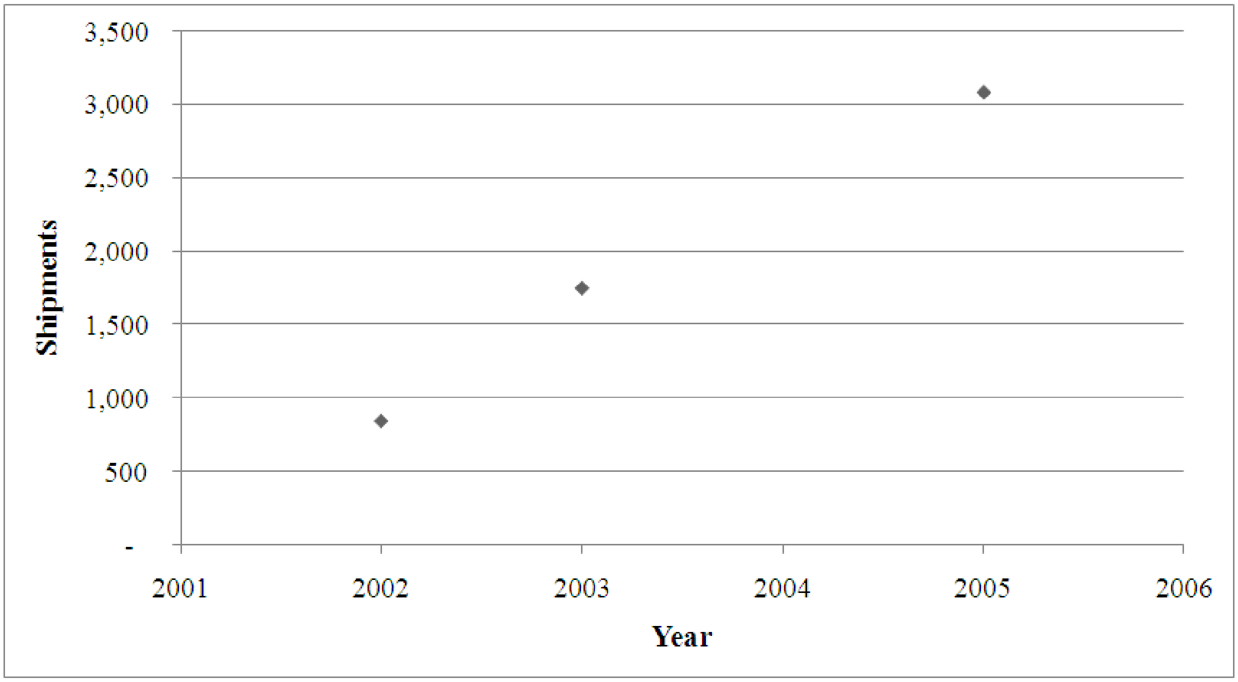


Figure 3.2.6 Shipments of T5 High-Output Ballasts

3.3 TECHNOLOGY ASSESSMENT

The purpose of the technology assessment is to develop a list of technologies that can be used to improve the efficiency of fluorescent lamp ballasts. The following assessment provides a description of the basic construction and operation of the fluorescent lamp and fluorescent lamp ballast, followed by technology options to improve efficiency.

3.3.1 Basic Structure of Fluorescent Lamps

The fluorescent lamp is a low-pressure gas discharge source. The lamps are tubular in shape and available in a variety of lengths, diameters, and wattages.

Lamp types are designated by a series of letters and numbers. The letter "F" is used to designate a fluorescent lamp. It is followed by a two-digit number that identifies either the nominal lamp wattage for nominally 4-foot lamps or the lamp length in inches for 8-foot lamps. These digits are followed by the letter "T," for tubular, which is followed by the lamp diameter in eighths of an inch. Additional designations are sometimes used: for example, "HO" if the lamp is high output or "/ES" if the lamp is an energy saver or reduced-wattage lamp. Table 3.3.1 shows the nomenclature that defines the diameter, lamp length, and lamp wattage for some common fluorescent lamps.

Table 3.3.1 Common Linear Fluorescent Lamp Nomenclature

Lamp Nomenclature	Nominal Lamp Length *feet*	Nominal Lamp Wattage *W*	Lamp Diameter *inches*
F32T8	4	32	1
F40T12	4	40	1 ½
F54T5 HO	4	54	5/8
F96T12	8	75	1 ½
F96T12 HO	8	110	1 ½
F96T12 HO/ES	8	95	1 ½

The fluorescent lamp consists of a glass bulb or tube, filled with low pressure mercury vapor and inert gas, with electrodes sealed onto both ends of the tube. The fluorescent lamp has five major components: bulb, electrodes, base, gas fill, and phosphors. Two electrodes are hermetically sealed to both ends of the bulb. The electrodes are usually constructed from coiled tungsten wires coated with a mixture of alkaline oxides. A base provides an electrical connection to these electrodes and also supports the lamp. Depending on the start method and operational properties of the lamp (*e.g.*, dimming, wattage, etc.), lamp designs may use different bases such as single pin, medium bipin, and recessed double contact. Once voltage is applied to the electrodes, the tungsten coil and coatings emit large quantities of electrons when the coating is at the proper temperature (1,000–1,300 degrees Kelvin). These electrons then collide with gaseous mercury atoms, exciting electrons within those atoms. As the electrons decay to their stable or ground state, they emit ultraviolet (UV) radiation primarily at 254 nanometers. In addition to the mercury vapor, an inert gas or a combination of gases is added to the lamp primarily to moderate the collisions of mercury ions and minimize evaporation of the electrode coating. The UV radiation is then absorbed by the phosphors and reemitted as light.

3.3.2 Electrical Characteristics of a Fluorescent Discharge Lamp

Regardless of shape, size, or type, all fluorescent lamps require a ballast to initiate and maintain the arc discharge.

To achieve arc formation, the gas plasma has to be excited, ionized, and broken down (to become a virtual negative resistance, almost a short circuit). This requires an initial high cathode emission and a high electric field (*i.e.*, voltage). Once the arc is achieved, current limiting has to be involved to prevent run-away and almost immediate lamp burnout. These two phenomena (*i.e.*, ignition and current limiting/control) are required in all fluorescent lamps, regardless of shape, size, or type. Both functions constitute the major function of a ballast. Figure 3.3.1 shows a graphical representation of this relationship from ignition (Townsend, glow, and abnormal glow) through arc discharge.

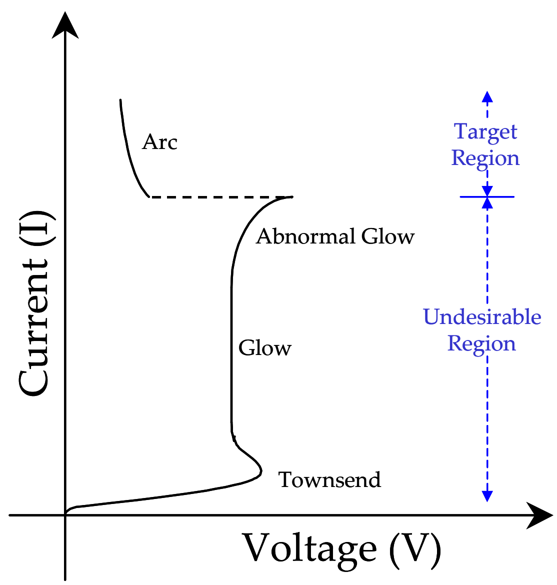


Figure 3.3.1 Electrical Characteristic of a Gas Discharge Lamp
Source: Adapted from Murdoch, *Illuminating Engineering: From Edison's Lamp to the LED*, 2nd Edition, 2003.

A voltage pulse several times that of the lamp operating voltage may be required to initiate the arc discharge. During this process, the lamp's operating point must pass through the Townsend, glow, and abnormal-glow as quickly as possible. Rapid start (RS) and programmed start (PS) systems use tertiary cathode heating to catalyze this process, while instant start (IS) operation simply uses a higher starting voltage.

In general, tertiary cathode heating is believed to have a positive impact on lamp life. The reduction in filament heating caused by instant start operation increases the rate of loss of the low–work function coating due to reduced ion bombardment at the cathode (also known as sputtering). This causes the tungsten wire coating to deteriorate more rapidly over time, which contributes to higher failure rates. Therefore, lamps that operate on RS or PS ballasts can have longer lifetimes than lamps that operate on IS ballasts. Lamp life not only depends on the starting method of the ballast, but can also depend on the lamp current crest factor. For more information on starting method and lamp current crest factor, see section 3.3.3.

3.3.3 Fluorescent Lamp Ballast Overview

Fluorescent lamp ballasts are devices that by means of resistance, inductance, capacitance, or electronic elements, singly or in combination, control the current, voltage, and waveform to properly start and safely operate fluorescent lamps (ANSI C82.13-2002). The following sections discuss basic ballast operation and the two main ballast technologies: magnetic and electronic.

A ballast has four critical functions:

1. provide controlled cathode heating to aid in starting and maintaining the arc discharge,
2. deliver high voltage to start and ignite the lamp,

3. regulate (limit) electric current flowing through the lamp after ignition to avoid current run-away and self-destruction, and
4. regulate (compensate) for variations in line voltage. Good regulation ensures that small variations in line voltage result in even smaller variations in lamp lumen output.

Ballast types can be subdivided into two main groups: magnetic (low frequency) and electronic (high frequency). Magnetic ballasts were the first technology used to operate ballasts. Electronic ballasts were developed later in the 1980s because of their high efficiency. Section 3.3.4 provides additional discussion on these and other technology options that can be used to increase the efficiency of fluorescent lamp ballasts.

There are many performance parameters used to describe the operation of a fluorescent lamp ballast. These include starting method, ballast factor, ballast efficacy factor, ballast luminous efficiency, power factor, total harmonic distortion (THD), electromagnetic interference (EMI), and fluorescent system safety requirements. These performance parameters are briefly discussed below.

3.3.3.1 Starting Method

Fluorescent ballasts can be categorized by the manner in which they operate the lamp, or more specifically, how the lamp is started. The most common ballasts use three different methods to start a fluorescent lamp: rapid start, programmed start, and instant start. These methods are all defined in ANSI C82.11-2002. The starting method primarily affects the ballast's switching cycle capability (*i.e.*, the number of times one can switch the lamp on and off before it expires) and the power consumption of the ballast.

Rapid start ballasts heat the electrodes for a set amount of time before lamp ignition. The coil heating reduces the open circuit voltage required to start the lamp, but coil heat remains constant after starting and consumes additional power.[21] The major benefit of this starting technique is that it leads to a longer lamp life than the starting technique of an IS ballast. For example, if the lamp is switched on and off every 3 hours, the fluorescent lamp life would be approximately 25 percent lower for an IS ballast than for a RS ballast. However, when the lamp is frequently switched on and off (*e.g.*, every 15 or 30 minutes), the lamp life on instant start and rapid start ballasts can be similar.[23] In general, RS ballasts provide between 15,000 and 17,000 switching cycles.[22, 23]

A more recent and advanced version of the RS ballast is the PS ballast. Like the RS ballast, the PS ballast heats the lamp filaments to a certain temperature for a prescribed amount of time before applying a high-voltage pulse to ignite the lamp. Some programmed start ballasts remove all power to the electrodes after ignition (also known as cathode cut-out), resulting in some energy savings over other PS systems. However, due to added internal circuitry, PS ballasts cannot be as efficient as IS ballasts. PS ballasts can provide between 50,000 to 100,000 switching cycles depending on ballast design.[22, 24] A lamp operating on a PS ballast can last more than three times longer than it would on a RS or IS ballast.[22]

Instant start ballasts rely on higher voltage to initiate the discharge rather than applying a steady filament voltage. These ballasts apply a very high voltage pulse to the lamp to rapidly ionize the gas in the lamp and initiate the arc instantly, without the need for heating the electrodes. Because IS electronic ballasts do not provide lamp electrode heating, these ballasts are inherently more efficient, saving approximately 2 W of energy per lamp compared to RS ballasts. However, due to the high applied voltage necessary to start the lamp, the electrodes of a lamp operated by an IS ballast deteriorate more quickly than the heated electrodes of a lamp operated by a RS or PS ballast, resulting in decreased lamp life. IS ballasts can provide between 10,000 and 15,000 switching cycles depending on the ballast design.[22, 23]

3.3.3.2 Ballast Factor

The ballast factor is defined as the output of a ballast delivered to a reference lamp in terms of power or light divided by the output of the relevant reference ballast delivered to the same lamp (ANSI C82.13-2002). To calculate the light output of a lamp-and-ballast system, one would multiply the light output of the lamp by both the number of lamps operated by the ballast and its ballast factor. Because ballast factor affects the light output of the system, manufacturers design ballasts with a range of ballast factors to allow consumers to vary the light output (and thus power consumed) of a fluorescent system. In general, ballasts that operate 4-foot MBP lamps and designed with a ballast factor of around 0.88 are deemed normal ballast factor. Low ballast factor ballasts have a ballast factor of 0.78 or less; high ballast factor ballasts typically have a ballast factor of 1.10 or higher.

3.3.3.3 Ballast Efficacy Factor

Ballast efficacy factor (BEF) is a measure of ballast system performance or efficacy. According to Appendix Q to Subpart B of Part 430 in the CFR, this factor is defined as:

$$\mathrm{BEF} = \frac{\textit{Relative Light Output}}{\textit{Input Power}}$$ **Equation 3.1**

Where:

BEF = ballast efficacy factor;
$\textit{Relative Light Output}$ = the light output delivered through the use of a ballast divided by the light output delivered through the use of a reference ballast, expressed as a percent; and
$\textit{InputPower}$ = the power consumption in watts of a ballast and fluorescent lamp or lamps.

3.3.3.4 Ballast Luminous Efficiency

Ballast luminous efficiency means the total lamp arc power divided by the ballast input power multiplied by the appropriate frequency adjustment factor. BLE describes the percentage of ballast input power that is used in the lamp column to produce light. Power delivered to the lamp cathodes (filaments) is not included in the output measurement and is considered a ballast loss. BLE is then multiplied by an adjustment factor depending on the frequency at which a ballast operates a lamp. Low-frequency operation of a lamp produces fewer lumens per lamp arc watt than high-frequency operation, therefore DOE uses a frequency adjustment factor to account for the decrease in system efficacy. In general, the BLE metric results in reduced measurement variation, reduced testing burden, and a more straightforward efficiency metric than the existing BEF metric and test procedure. In this final rule, DOE evaluated ballast performance in terms of the ballast luminous efficiency metric.

3.3.3.5 Power Factor

The power factor is calculated by determining the ratio of the active power to the apparent power. PF depends on the current's wave shape as well as the phase relationship between the current and the voltage. The power input is measured with a wattmeter capable of indicating the average power in watts. The ballast input voltage multiplied by the ballast input current is the ballast's apparent power (ANSI C82.13-2002).

$$Power\ Factor = \frac{Power\ Input}{Ballast\ Input\ Voltage * Ballast\ Input\ Current}$$ **Equation 3.2**

Where:
$PowerFactor$ = power factor,
$PowerInput$ = input power in watts to ballast,
$BallastInputVoltage$ = input voltage in volts to ballast, and
$BallastInputCurrent$ = input current in amps to ballast.

Power factors range between 0 and 1. A power factor of 1 indicates that the voltage and current wave forms are in phase and not distorted. Fluorescent ballasts can be characterized by two classes of power factor: high power factor (HPF) of 0.9 or greater, and normal power factor (NPF) of 0.6 or greater. HPF ballasts use about one-half the current of NPF ballasts. The primary cause of low power factor in magnetic ballasts is the inductance of the ballast transformers. It can be corrected with the addition of the proper capacitor. In electronic ballasts, the primary cause of low power factor is due to total harmonic distortion (defined below) caused by a non-linear load. According to ANSI C82.77-2002, commercial ballasts must have a HPF while residential fluorescent ballasts (with an input power below 120W) must have a power factor of 0.5 or greater.

3.3.3.6 Total Harmonic Distortion

Another important performance parameter is harmonic distortion. Line current harmonics are the components of the line current that oscillate at integer multiples of the fundamental frequency of the power supply (*e.g.*, 60 Hz, 120 Hz, 180 Hz, etc). Harmonics of a fundamental frequency are an undesirable byproduct of any non-linear system operation, generating noise and wasted power. Total harmonic distortion refers to the ratio of the root mean square (rms) values of the harmonic content to that of the fundamental current, expressed as a percentage. It may also be called harmonic factor:

$$THD(fund) = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + \ldots}}{\sqrt{I_1^2}}$$ **Equation 3.3**

Where:

THD = total harmonic distortion; and
I_n = the rms current of harmonic *n*, where n=1 is the fundamental harmonic.

High THD figures are not acceptable and are detrimental to many kinds of electronic devices connected to the power line. They are also considered a "pollutant" to the environment because of radio frequency noise. Therefore, ANSI C82.11-2002 requires that the THD of electronic ballasts not exceed 32 percent. Electronic ballasts today are typically rated at less than 20 percent THD. Magnetic ballasts are typically rated in the 20 to 28 percent range.

3.3.3.7 Electromagnetic Interference

Many devices found in office environments, such as computers, photocopiers, facsimile machines, and fluorescent lighting systems, can generate electromagnetic waves. The effects of these waves vary based on their strength and the susceptibility of nearby equipment. Alternating current in electronic devices produces a magnetic field, which in turn induces an AC voltage in a nearby electronic device. Electromagnetic interference takes two forms: conducted or radiated. Conducted EMI occurs when electronic devices induce currents in the local power network that in turn negatively affect other devices on that network. Radiated EMI is associated with the electric and magnetic field inherent in electronic devices. EMI can be minimized with proper grounding and wiring techniques.[25] EMI limits for both consumer and non-consumer lighting products sold in the United States are listed in 47 CFR 18 subpart C. These regulations require that consumer/residential (Class B) ballasts have lower maximum conducted EMI requirements than non-consumer (Class A) products. The International Committee on Radio Interference has more stringent regulations concerning EMI. However, fluorescent lamp ballasts sold in the United States currently do not have to meet these regulations. More detail on electromagnetic interference can be found in appendix 5E.

3.3.3.8 Safety

A ballast will continue to drive or reignite a lamp when the lamp reaches the end of its life. Usually, the failure of the lamp will have no adverse consequences. Occasionally, the ballast will continue to try to drive a failed lamp repeatedly until the temperature in the region of the electrode increases rapidly and causes overheating of the lamp electrodes. This can be avoided through additional circuitry that provides end-of-life (EOL) protection. Some ballasts in the United States are required to have EOL protection (*e.g.*, ballasts that operate T5 lamps). However, the most popular T8 ballasts are not. International standards (IEC 600797-1 Ed. 4) require all fluorescent lamp ballasts regardless of lamp diameter to have EOL protection.

Another safety issue arises when a lamp is not inserted properly into the lamp holder, which can cause arcing. This problem can either be addressed through better design of the lamp holders, or by adding circuitry to the ballast that detects arcing and reduces the output voltage so that the arc cannot be sustained.

3.3.4 Fluorescent Lamp Ballast Technology Options

The following section discusses the two major technologies used in fluorescent lamp ballast design—magnetic ballasts and electronic ballasts—and additional technology options (improved components and improved circuit design) that can incrementally improve the efficiencies of a magnetic or electronic ballast.

3.3.4.1 Magnetic Ballasts

The main components of a magnetic ballast are a magnetic choke to limit the current, a step-up transformer to obtain a high starting voltage, and a capacitor that corrects for the ballast's low power factor. Multi-lamp magnetic ballasts also have one or more additional capacitors to sequence the starting of the lamps. Magnetic ballasts operate at an input frequency of 60 Hz and operate the lamp(s) at the same frequency.

The main core-and-coil assembly consists of a capacitor and laminated transformer steel wound with copper or aluminum magnet wire. The assembly is infused with a potting material (*e.g.*, hot asphalt) containing fiber such as silica and housed in a steel case. Figure 3.3.2 presents a labeled graphic of the interior of a standard magnetic ballast.

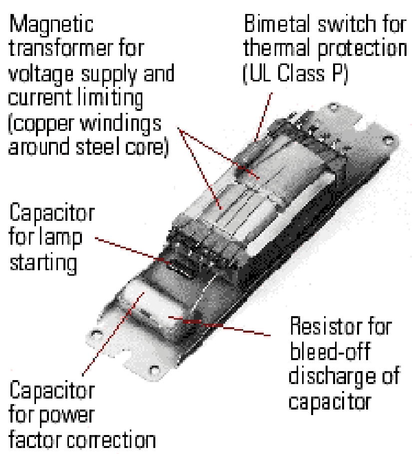


Figure 3.3.2 Cutaway View of a Typical Magnetic Fluorescent Ballast

The core and coil assembly functions as a voltage transformer and a current limiter (choke). A capacitor enables the ballast to use energy from the alternating current power line more efficiently, which is then referred to as a HPF or PF corrected ballast. The purpose of the insulating material is to conduct heat away from the transformer coils and ensure tightness of transformer coils to eliminate vibrational noise.

Because of their low frequency operation, magnetic ballasts are less energy efficient than electronic ballasts (Figure 3.3.3). Magnetic ballasts fail to optimize lumen output for a given wattage. These ballasts also release the energy not used to operate the lamp as heat in the transformer windings. This heat is dissipated to the environment by the ballast potting material and its metal or plastic enclosures.

3.3.4.2 Electronic Ballasts

For equivalent light output, electronic ballasts consume about 10 percent less energy than magnetic ballasts. An electronic ballast starts and operates fluorescent lamps at frequencies typically greater than 20 kHz using electronic components rather than the traditional core and coil assembly. The electronic ballast takes the input 60 Hz power, rectifies it, and converts it into a high frequency using an oscillator circuit.

Higher operating frequency generates greater lumen output. Figure 3.3.3 shows the increase in lumen output relative to 60 Hz operation as a function of frequency. The gain in light output by increasing operating frequency begins to plateau around 20 kHz. Therefore, electronic ballasts typically operate at frequencies above 20 kHz.

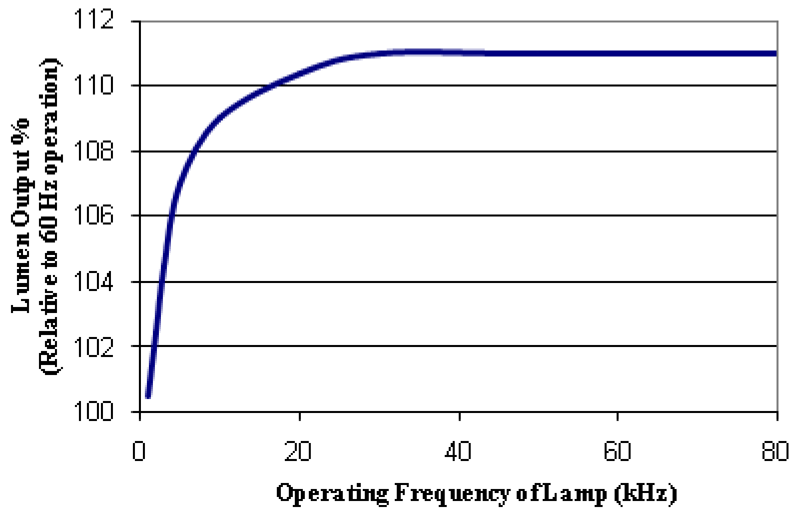


Figure 3.3.3 Fluorescent Lamp Efficacy vs. Operating Frequency of Lamp
Source: Adapted from IESNA, 2002.

Not only is the lamp more efficient at higher frequencies, but the ballasting action (current-limiting) at high frequency requires smaller components. This reduces ballast losses and makes the ballast more efficient. In addition, the ballast noise becomes inaudible at higher frequencies and there is no 60-cycle flicker like that associated with fluorescent lamps that operate with magnetic ballasts.

Whereas typical magnetic ballasts generally have three components (*i.e.*, core, coil, and capacitor), electronic ballasts have additional blocks of electronic components. Figure 3.3.4 shows the interior of an electronic ballast.

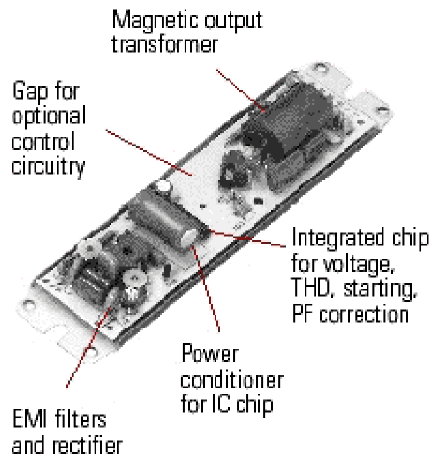


Figure 3.3.4 Cutaway View of an Electronic Fluorescent Ballast

Figure 3.3.5 presents an example of a functional block diagram of a fixed-light output electronic ballast. Auxiliary functions performed by a typical electronic ballast include electromagnetic interference filtering to block ballast-generated noise, input rectification, PF correction for sinusoidal input current, a direct-current (DC) filter, a direct-current to alternating-current (DC-AC) inverter, a feedback/controller for high-frequency operation, and a final output stage to power the lamp.

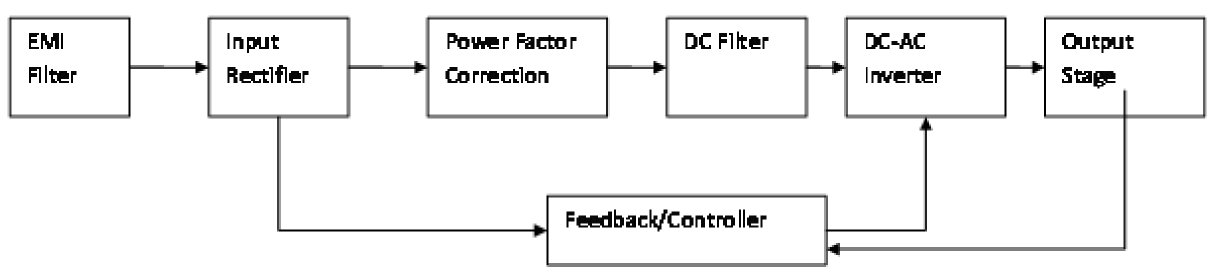
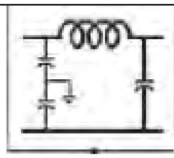
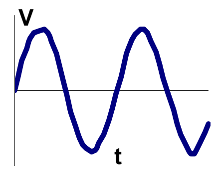
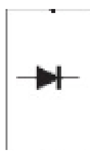
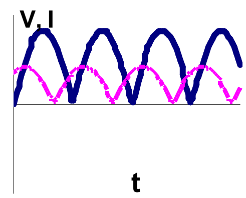
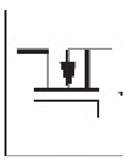
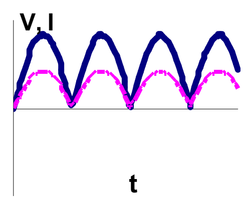
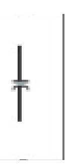
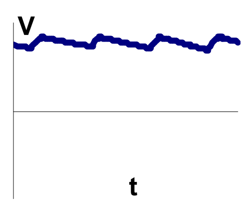
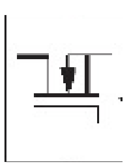
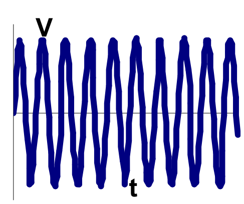
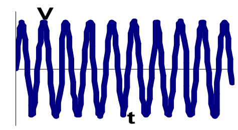
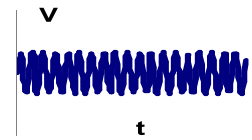


Figure 3.3.5 Fixed-Light Output Electronic Fluorescent Ballast Block Diagram
Source: T. Ribarich, *A Systems Approach to Ballast IC Design,* El Segundo, CA, 1999, and Philips Semiconductor, *Power Semiconductor Applications*, 1994.

Table 3.3.2 provides a description of each component in a typical electronic ballast, the efficiency impact of these components, and the waveform at each stage of the fluorescent lamp ballast circuit.

Table 3.3.2 Basic Building Blocks of a Fixed-Light Output Fluorescent Lamp Ballast and Associated Characteristics

Circuit Stage	Function	Efficiency Impact	Waveform (not to scale)
 EMI Filter	Impedes EMI by providing a high impedance path to EMI and a low impedance path to the desired input. The circuit also protects against high voltage pikes.	Very Low	
 Input Rectifier	Begins to convert incoming AC to DC using diodes. A full-bridge rectifier, one type of input rectifier, is composed of four diodes, which “rectify” the full AC waveform as shown in the waveform on the right. The current is not in phase with the voltage.	Low	
 Power Factor Correction	Corrects the current so it is in phase with the voltage. Power factor correction can be achieved through a buck or boost-converter circuit topology.	Low-Medium	
 DC Filter	Reduces “ripple” of the DC current waveform using capacitors. The most common type of capacitor used is the electrolytic capacitor.	Low	
 DC-AC Inverter	Converts incoming DC to high-frequency AC. The resonant half-bridge self-oscillating circuit is one type of circuit topology that can be used to accomplish this task.	Medium-High	

 Output Stage	When the lamp is not started, the circuit operates in resonance to increase output voltage to start the lamp. Once the lamp is started, the circuit operates at a frequency off of resonance to continue operating the lamp. A resonant filter topology is one type of circuit topology used in the output stage.	High	Starting:  Operation: 
Feedback/Controller	An integrated circuit (IC) that controls the frequency output of the DC-AC inverter. It can also protect against under voltage lockout and lamp faults.	Low	N/A

3.3.4.3 Improved Components

A common way to increase the efficiency of both magnetic and electronic ballasts is to improve the quality of their components. Magnetics (transformers and inductors), diodes, capacitors, and transistors are the main components that affect efficiency.

Magnetics (transformers and inductors): In high frequency ballasts, magnetics influence the efficiency of the EMI, power factor correction (PFC), and output stage of the ballast. In low frequency ballasts, magnetics influence the efficiency of the output stage and current-limiting portion of the ballast.

There are two loss mechanisms associated with magnetics: core losses and winding losses. Core losses involve the magnetic properties of the core material, which exhibits power losses in the form of hysteresis and eddy currents within the core itself. Winding losses come from the resistance in the winding, typically copper. There are several technology options that can improve the efficiency of a magnetic component's core losses. These include improved silicon steel, amorphous steel, or increased amounts of amorphous steel. Litz wire can be used as a technology option to improve a magnetic component's winding losses.

One way to reduce magnetic component power loss at light loads is to select magnetics with higher quality core materials. There are two types of core materials that ballasts can use: silicon steel (thinly laminated steel alloyed with silicon) and amorphous steel. Core performance of silicon steel can be enhanced by magnetically orienting the grain structure in the metal. Even larger gains in efficiency can be achieved using amorphous materials. To further increase the efficiency of the ballast using amorphous materials, one can create the core of the inductor from laminated sheets of amorphous steel, insulated from each other. However, this method can increase the size and weight of the ballast.

Another way to reduce the magnetic component's power loss is to select materials with lower winding losses. High-frequency operation (typical of electronic ballasts) can increase winding losses as two additional loss mechanisms, skin effect and proximity effect, become more prominent. One way to reduce both the skin effect and proximity effect is to use litz wire, which consists of a number of individually insulated magnet wires twisted or braided into a uniform pattern. Skin effect refers to the tendency of AC current to flow through a conductor's surface or "skin" rather than a conductor's core. Because litz wire increases the amount of surface area current can flow through, overall winding losses can be reduced as the effective wire resistance is decreased. When conductors are close together, the magnetic field of one conductor will reduce the area that the current flows through in another conductor, increasing its winding losses. This effect, called the proximity effect, can be also be improved by using litz wire.

Diodes: In electronic ballasts, the input rectifier inverts the negative half of the AC sine wave and makes it positive. Several technology options can be used to improve the efficiency of this portion of the circuit. The power consumed by a diode is the product of the current flowing through the diode multiplied by the voltage drop across it. Conventional diodes have a voltage drop of about 0.6 V. Use of a Schottky diode[1] would reduce the voltage drop across the diodes by about 0.3 V to 0.4 V. However, as discussed in Appendix 5D, DOE was unable to identify a Schottky diode that could be used as a direct replacement for the conventional diodes typically used in ballasts.

Capacitors: In both magnetic and electronic ballasts, capacitors are used in the PFC and output stage of the circuit design. In electronic ballasts, capacitors are also used in the DC Filter stage of the electronic circuit. One way to improve the efficiency of each portion of the circuit is to use capacitors with low effective series resistance (ESR). Capacitors with a low ESR are also more reliable because they are cooler than capacitors with a higher ESR.

Transistors: In electronic ballasts, transistors are used in both the power factor correction and the DC-AC inverter portion of the circuit. The transistor dissipates energy due to its drain-to-source resistance (R_{DS_ON}) when the current flows through the transistor to the transformer. Using transistors with low R_{DS_ON} can reduce this loss. For example, the efficiency of electronic ballast's bipolar transistors can be improved by using metal-oxide-semiconductor field-effect transistors (MOSFETs), which are transistors with a lower drain-to-source resistance.

3.3.4.4 Improved Circuit Design

Another method of increasing the efficiency of both magnetic and electronic ballasts is to improve the ballast's circuit design. Examples of improved circuit design include cathode cut-out technology, integrated circuits, improved starting method, and synchronous rectification.

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[1] A Schottky diode is a metal semiconductor diode with a smaller voltage drop than a conventional diode. Schottky diodes therefore consume less power.

Cathode Cut-out: Both rapid start and programmed start ballasts provide heat to the filament while starting a lamp. As discussed in section 3.3.3.1, providing filament power while starting the lamp can increase its lifetime. Removing the power provided to the filament after the lamp has been started using an electronic circuit will increase the efficiency of both programmed start and rapid start ballasts. Removing this power can reduce the power the ballast consumes by as much as 2 watts per lamp.

Integrated Circuits: In certain cases, a ballast's efficiency can be improved by substituting integrated circuits for discrete components. For example, some ballasts use bipolar transistors in a resonant half-bridge self-oscillating circuit to convert incoming DC to AC. The efficiency of this circuit can be improved by substituting the components in that circuit with an integrated circuit.[26]

Starting Method: RS and PS ballasts are inherently less efficient than IS ballasts, which use extra power to provide filament power to the ballast to increase its lifetime. Although these ballasts can cut out the filament power during lamp operation (using the cathode cut-out technology option discussed above), the extra circuit required to remove this power contributes to the overall losses.

DOE only considered starting method as a technology option in case of the migration from RS to IS ballasts. DOE's research indicates that IS ballasts are common replacements for RS ballasts, and though the lamp lifetime is sometimes lower in IS ballasts than RS ballasts, it does not seem to be significant enough to affect consumer utility. As discussed in section 3.3.3.1, lamp lifetime in IS ballasts is approximately 25 percent less compared to RS ballasts when operated on a 3-hour start. However, lamps operated on RS ballasts have the same lifetime as lamps operated on IS ballasts when operated on short start cycles. This is typical when ballasts are used with occupancy sensors to save energy. Conversely, the lifetime of a lamp that operates on a PS ballast with occupancy sensors can be as much as three times longer than the lifetime of a lamp that operates on an IS or RS ballasts. Because IS ballasts have more limited utility as replacements for PS ballasts, IS ballasts are not considered a technology option for improving the efficiency of PS ballasts.

3.4 PRODUCT CLASSES

When evaluating and establishing energy conservation standards, DOE divides covered products into classes by the type of energy used, capacity, or other performance-related features that affect efficiency, and factors such as the utility of the product to users. (See 42 U.S.C. 6295(q)) DOE then conducts its analysis and considers establishing or amending standards to provide separate standard levels for each product class. DOE applied the criteria of 42 U.S.C. 6295(q) to fluorescent lamp ballasts to develop product classes for this final rule TSD. This section describes the product classes DOE considers for this rulemaking.

In amending EPCA, NAECA 1988 established eight product classes for fluorescent lamp ballasts (Table 3.4.1).

Table 3.4.1 EPCA Product Classes Established by NAECA 1988 for Fluorescent Lamp Ballasts

Application for Operation of	Ballast Input Voltage	Total Nominal Lamp Watts
One F40T12 Lamp	120	40
	277	40
Two F40T12 Lamps	120	80
	277	80
Two F96T12 Lamps	120	150
	277	150
Two F96T12 HO Lamps	120	220
	277	220

In further amendments to EPCA, EPACT 2005 established an additional eight product classes for fluorescent lamp ballasts (Table 3.4.2).

Table 3.4.2 EPCA Product Classes Established by EPACT 2005 for Fluorescent Lamp Ballasts

Application for Operation of	Ballast Input Voltage	Total Nominal Lamp Watts
One F34T12 Lamp	120	34
	277	34
Two F34T12 Lamps	120	68
	277	68
Two F96T12/ES Lamps	120	120
	277	120
Two F96T12 HO/ES Lamps	120	190
	277	190

In addition to the lamps and lamp ballasts identified in Table 3.4.1 and Table 3.4.2, the fluorescent lamp ballast market today includes ballasts that operate smaller diameter lamps such as T8 and T5 lamps (section 3.3.1). These fluorescent lamp-and-ballast systems are gaining in market share, whereas T12 systems are becoming less popular and losing market share. This market shift accelerated in 2010, when the exclusion from the standard levels established by the 2000 Ballast Rule and EPACT 2005 for replacement ballasts expired. The standard levels established by the 2000 Ballast Rule and EPACT 2005 for fluorescent lamp ballasts are difficult to meet using magnetic ballast technology. Because magnetic ballasts comprise the large majority of T12 ballast sales, DOE believes that since the standards took effect, there has been an increase in shipments of electronic ballasts that operate T8 and T5 lamps.

Because of these market changes and because DOE is expanding its scope of covered product for fluorescent lamp ballasts, DOE is amending the product classes for these ballasts. The following sections summarize all of the factors that DOE considered as determinants of product class. In general, when considering the characteristics below, DOE considered three main factors as affecting consumer utility: (1) the lumen package of the lamp-and-ballast system; (2) the physical constraints of the lamp-and-ballast system; and (3) the use of the ballast in an application for which other ballasts are not suitable. When referring to efficiency, DOE is referring to BLE.

3.4.1 Power versus Efficiency Relationship

DOE believes that there are both fixed and variable losses in any fluorescent ballast. Fixed losses consist of switching losses, due to components such as transistors, and fixed voltage drops across certain components, such as diodes. These components are necessary for proper ballast operation but will always contribute some amount to overall ballast losses. In ballasts that operate low powers, fixed losses comprise a significant amount of the power lost. Variable losses consist primarily of resistive losses (also referred to as I^2R losses) which increase as current increases. Ballasts that operate higher powers also operate at a higher current and therefore have greater resistive losses. At a certain power level, resistive losses will be greater than fixed losses, as these losses continue to increase as power increases.

Using test data, DOE empirically found a power-law equation best modeled the relationship between the BLE metric and total lamp arc power. In general, as lamp arc power increases, BLE increases as well. DOE believes this is because the fixed losses of a ballast become proportionally less significant at higher lamp arc powers. Because this power-efficiency relationship exists, DOE is able to set efficiency levels as a function of lamp arc power. Thus, several factors that affect the total lamp arc power operated by a ballast (such as lamp length, ballast factor, and number of lamps operated) do not necessarily require separate product classes.

3.4.2 Starting Method

DOE found RS and PS ballasts to be inherently less efficient than IS ballasts because RS and PS ballasts provide filament power to the lamp. Although some PS ballasts cut out the filament power during normal operation (using the cathode cut-out technology option discussed above), the extra circuitry to remove this power still consumes some amount of power. In the BLE metric, cathode heating is counted as a loss because it does not directly contribute to the creation of light. Therefore, RS and PS ballasts will have lower BLEs than comparable IS ballasts.

DOE confirmed that RS and IS ballasts were commonly used as substitutes for each other, indicating consumers find no added benefit or utility associated with RS relative to IS. Both RS and PS ballasts use cathode heating; however, only PS ballasts limit the voltage across the lamp tube to prevent glow discharge during the initial cathode heating. This prevention of glow discharge also increases lamp lifetime in frequent on/off cycling applications. DOE found PS ballasts were commonly used in conjunction with occupancy sensors (a frequent on/off cycling application). DOE determined that because of their ability to limit voltage, PS ballasts offer the user a distinct utility. As a result of this unique utility and the difference in efficiency associated with these ballasts, DOE decided to establish separate product classes for programmed start ballasts.

3.4.3 Lumen Package

Lumen package refers to the quantity of light that a lamp-and-ballast system provides to a consumer. To obtain a high lumen package, certain lamps are designed to operate with ballasts that run the lamps at high currents. For example, 8-foot HO lamps and 4-foot MiniBP HO lamps tend to operate at higher currents than 8-foot slimline lamps and 4-foot MiniBP standard output

(SO) lamps, respectively. This difference in operating design increases the quantity of light per unit of lamp length. Consumers tend to use systems with different lumen packages for different applications. For example, high-lumen-output systems may be installed in certain high-ceiling or outdoor applications where large quantities of light are needed. Alternatively, standard-lumen-output systems might be installed in lower-ceiling applications such as offices or hospitals, where the distance between the light source and the illuminated surface is not as large. Notable differences in the application of ballasts designed to operate SO lamps versus HO lamps indicate a difference in utility.

However, BLE is not dependent on system light output, but rather on the total power operated by the ballast. As HO lamps have higher rated powers than comparable (same length, diameter) SO lamps, DOE believed ballasts that operate HO lamps would be more efficient than comparable ballasts that operate SO lamps. An analysis of test data generally confirmed this prediction. Therefore, because the power-efficiency equation accounts for HO versus SO lamp operation, DOE is not establishing separate product classes for ballasts that operate HO lamps, with one exception as explained in the following paragraph.

DOE found that ballasts that operate 8-foot HO lamps did not follow the expected relationship. Compared to 8-foot slimline ballasts, DOE found that 8-foot HO ballasts exhibited lower BLEs although they operated higher lamp powers. This may be because this ballast type has a different topology, or circuit design, than other ballast types (*e.g.*, 4-foot MBP and 8-foot slimline ballasts). Because DOE has established that lumen package offers a unique utility, and in this case a change in lumen package is accompanied by a change in BLE from what the efficiency equation would predict, DOE established a separate product class for ballasts that operate 8-foot HO lamps.

3.4.4 Sign Ballasts

Ballasts that are designed for use in outdoor signs have slightly different characteristics than those ballasts that operate in the commercial sector. First, sign ballasts are designed to operate in cold temperature environments – as low as negative 20 degrees Second, sign ballasts are classified by the total length (in feet) of lamps they can operate as well as the total number of lamps. Third, sign ballasts have an Underwriters Laboratories (UL) Type 2 rating for the enclosure whereas regular 8-foot HO ballasts are rated for UL Type 1. Type 2 enclosures are moisture resistant and have special coating to resist rust so it can used in plastic sign applications without a separate metal enclosure. To operate in outdoor environments and to be able to handle numerous lamp combinations, sign ballasts contain more robust components compared to regular 8-foot HO ballasts in the commercial sector. Thus, sign ballasts are inherently less efficient. For this reason, sign ballasts did not achieve the expected BLE predicted by the power-efficiency relationship.

Although regular 8-foot HO ballasts are also rated for operation in cold temperature environments, they cannot always serve as substitutes for sign ballasts due to their lack of moisture seals and more limited load specifications. For these reasons, and the associated differences in BLE compared to ballasts of similar lamp arc power, DOE established a separate product class for sign ballasts.

3.4.5 Residential Ballasts

Separate minimum power factor and electromagnetic interference requirements exist for residential and commercial ballasts. Residential ballasts have more stringent (or lower maximum allowable) conducted EMI requirements than commercial ballasts; they also have less stringent (or lower minimum allowable) power factor requirements. Based on these differing requirements, DOE concluded that residential ballasts offer a unique utility in that they serve distinct market sectors and applications. DOE examined test data and found that residential ballasts are unable to achieve similar maximum efficiencies as commercial ballasts. Specifically, 4-lamp residential ballasts could not meet the same efficiency levels as their commercial counterparts. Therefore, because residential ballasts offer a unique utility in serving distinct market sectors and applications, and may not be able to meet commercial efficiency levels, DOE established separate product classes for: (1) IS/RS ballasts that operate 4-foot MBP and 8-foot slimline lamps in the residential sector and (2) PS ballasts that operate 4-foot MBP lamps in the residential sector.

3.4.6 Product Classes

For all the reasons discussed above, DOE established the ballast product classes listed in Table 3.4.3.

Table 3.4.3 Product Classes for Fluorescent Lamp Ballasts

Description	Product Class Number
IS and RS ballasts (not classified as residential) that operate 4-foot MBP lamps 2-foot U-shaped lamps 8-foot slimline lamps	1
PS ballasts (not classified as residential) that operate 4-foot MBP lamps 2-foot U-shaped lamps 4-foot MiniBP SO lamps 4-foot MiniBP HO lamps	2
IS and RS ballasts (not classified as sign ballasts) that operate 8-foot HO lamps	3
PS ballasts (not classified as sign ballasts) that operate 8-foot HO lamps	4
Sign ballasts that operate 8-foot HO lamps	5
IS and RS residential ballasts that operate 4-foot MBP lamps 2-foot U-shaped lamps 8-foot slimline lamps	6
PS residential ballasts that operate 4-foot MBP lamps 2-foot U-shaped lamps	7

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CHAPTER 4. SCREENING ANALYSIS

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CHAPTER 4. SCREENING ANALYSIS

4.1 INTRODUCTION

This chapter discusses the U.S. Department of Energy's (DOE's) screening analysis of the technology options identified for fluorescent lamp ballasts. As discussed in chapter 3 of the technical support document (TSD), DOE consults with industry, technical experts, and other interested parties to develop a list of technology options for consideration. The purpose of the screening analysis is to determine which options to consider further and which to screen out.

Section 325(o)(2) of the Energy Policy and Conservation Act (EPCA) provides that any new or revised standard must be designed to achieve the maximum improvement in energy efficiency that is determined to be technologically feasible and economically justified. (42 U.S.C. 6295(o)(2)) In view of the EPCA requirements appendix A to subpart C of title 10, Code of Federal Regulations (CFR), 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 efficiency 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 provide guidance to DOE for determining which design options are unsuitable for further consideration:

1. **Technological feasibility.** DOE will consider technologies incorporated in commercial products or in working prototypes to be technologically feasible.

2. **Practicability to manufacture, install, and service.** If mass production and reliable installation and servicing of a technology in commercial products could be achieved on the scale necessary to serve the relevant market at the time the standard comes into effect, then DOE will consider that technology practicable to manufacture, install, and service.

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

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

Section 4.2 discusses the technology options DOE screened out from further consideration. Section 4.3 lists the remaining design options DOE considered in its analyses.

4.2 SCREENED-OUT TECHNOLOGIES

This section addresses the technologies that DOE screened out, having considered the following four factors: (1) technological feasibility; (2) practicability to manufacture, install, and service; (3) adverse impacts on product utility to consumers; and (4) adverse impacts on health or safety.

DOE examined all of the technology options presented in the technology assessment. Of those options, DOE screened out one: laminated sheets of amorphous steel. The following discussion details DOE's consideration of this option in the context of the four screening criteria.

The transformer affects the efficiency of magnetic and electronic ballasts. For electronic ballasts, transformers influence the efficiency of the electromagnetic interference, power factor correction, and output stage of the ballast. For magnetic ballasts, the transformer influences the efficiency of the output stage and current-limiting portion of the ballast. Ballast efficiency can be improved by using higher-quality inductors. One method of decreasing transformer losses is to create the core of the inductor from laminated sheets of amorphous steel, insulated from each other.

DOE screened out this technology because this method increases the size and weight of the ballast. DOE has learned that the overall market trend is to create increasingly smaller ballast sizes for use in smaller and more highly optimized fixtures. As the trend toward smaller fixtures has existed for a number of years, new building designs are already incorporating smaller plenum spaces. Thus, an increase in the size of a ballast could affect its ability to be used in certain existing buildings or in new construction. Accordingly, DOE considers any increase in the existing footprint of a ballast to have adverse impacts on product utility and product availability. Additionally, larger inductors may cause problems installing and servicing ballasts because the existing fixture may not be able to accommodate the heavier weight. Therefore, DOE screened out laminated sheets of amorphous steel as a design option because it fails to meet the screening criteria of practicality to manufacture, install, and service, and has adverse impacts on product utility.

4.3 REMAINING TECHNOLOGIES

After screening out laminated sheets of amorphous steel in accordance with the policies set forth in 10 CFR Part 430, Subpart C, Appendix A, (4)(a)(4) and 5(b), DOE considered the design options in the following table as viable means for improving ballast efficiency. Chapter 3 provides a detailed description of these design options, which DOE considered in the engineering analysis (chapter 5).

Table 4.3.1 Fluorescent Lamp Ballast Design Options

Technology Option		Description
Electronic Ballast		Use an electronic ballast design.
Improved Components	Transformers	Use grain-oriented silicon steel or amorphous steel to reduce core losses.
		Use litz wire to reduce winding losses.
	Diodes	Use diodes with lower losses.
	Capacitors	Use capacitors with a lower effective series resistance.
	Transistors	Use transistors with low drain-to-source resistance.
Improved Circuit Design	Cathode Cutout	Remove filament heating after lamp has started.
	Integrated Circuits	Substitute discrete components with an integrated circuit.
	Starting Method	Use instant start instead of rapid start as a starting method for lamp operation.

CHAPTER 5 ENGINEERING ANALYSIS

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CHAPTER 5 ENGINEERING ANALYSIS

5.1 INTRODUCTION

The U.S. Department of Energy (DOE) performed an engineering analysis to establish the relationship between the manufacturer production cost (MPC) and the energy efficiency of fluorescent lamp ballasts (hereafter "ballasts"). The relationship between the MPC and energy efficiency, or the cost-efficiency relationship, serves as the basis for cost-benefit calculations for individual customers, manufacturers, and the Nation. This section provides an overview of the engineering analysis, discusses the representative product classes, establishes baseline unit specifications for those product classes, discusses incremental efficiency levels (ELs), discusses the analysis and results for the representative product classes, and establishes a scaling methodology to those product classes not analyzed.

The primary inputs of the engineering analysis are the design options from the screening analysis (final rule technical support document (TSD) chapter 4). Additional inputs include cost and efficiency data derived from teardown analysis and test data. The primary output of the engineering analysis is a set of cost-efficiency curves. In a subsequent life-cycle cost (LCC) analysis (final rule TSD chapter 8), DOE used the industry cost-efficiency curves to determine customer prices for each product analyzed in the engineering analysis by applying the appropriate distribution channel markups.

5.2 METRIC

In the fluorescent lamp ballast active mode test procedure final rule, DOE adopted a new metric for describing the performance of a fluorescent lamp ballast called ballast luminous efficiency (BLE). After the compliance date of any standards promulgated by this fluorescent lamp ballast standards rulemaking, ballasts would be tested using the new BLE procedure, not the current BEF procedure. Information on the active mode test procedure can be found on DOE's website.[a]

Ballast luminous efficiency means the total fluorescent lamp arc power divided by the fluorescent lamp ballast input power multiplied by the appropriate frequency adjustment factor. BLE describes the percentage of ballast input power that is used in the lamp column to produce light.[b] This percentage is then multiplied by a frequency adjustment factor depending on the frequency at which the ballast operates a lamp. Low-frequency operation of a lamp produces fewer lumens per lamp arc watt than high-frequency operation, so DOE uses an adjustment factor to account for the decrease in system efficacy. In general, the BLE metric results in reduced measurement variation, reduced testing burden, and a more straightforward efficiency metric than the existing BEF metric and test procedure.

[a] DOE's website for fluorescent lamp ballasts can be found at http://www1.eere.energy.gov/buildings/appliance_standards/residential/fluorescent_lamp_ballasts.html.

[b] Power delivered to the lamp cathodes (filaments) is not included in the output measurement and is considered a loss.

5.3 METHODOLOGY OVERVIEW

DOE typically structures its engineering analysis around one of three methodologies: (1) the design option approach, which calculates the incremental cost of adding specific design options to the baseline model; (2) the efficiency level approach, which calculates the relative costs of achieving increases in energy efficiency levels, without regard to the particular design options used to achieve such increases; and/or (3) the reverse engineering, cost assessment approach, which involves a "bottom-up" manufacturing cost assessment based on a detailed bill of materials (BOM) derived from teardowns of products being analyzed. Deciding which methodology to use for the engineering analysis depends on the product, the technologies under study, and any historical data DOE can draw upon. To establish the industry cost-efficiency curves for ballasts, DOE used both the efficiency level approach to identify incremental improvements in efficiency for each product and the cost assessment approach to develop a cost for each efficiency level.

DOE generally follows five steps in the engineering analysis:

Determine Representative Product Classes: DOE first reviews covered ballasts and the associated product classes. When multiple product classes exist, DOE selects certain classes as "representative" and concentrates its analytical effort on these. DOE selects representative product classes primarily because of their high market volumes. For those product classes it does not analyze, DOE extrapolates the efficiency levels from representative product classes to other product classes.

Select Baseline Ballasts: Within the representative product classes, DOE analyzes representative ballast types. For each representative ballast type, DOE establishes baseline ballasts. Generally, a baseline ballast is a commercially available ballast that just meets existing Federal energy conservation standards and provides basic consumer utility. The baseline serves as a reference point for each representative ballast type, against which DOE measures changes from potential amended energy conservation standards. To determine energy savings and changes in price, DOE compares each higher energy-efficiency level with the baseline unit.

If no standard exists for that specific ballast, the baseline ballast represents the typical ballast sold within a representative ballast type with the lowest ballast luminous efficiency. To determine the BLE, DOE tests a range of ballasts from multiple manufacturers. Appendix 5C presents these test results. DOE selects specific characteristics such as starting method, ballast factor (BF), and input voltage to characterize the most common ballast. DOE also selects multiple baseline ballasts for some representative ballast types to ensure consideration of different consumer economics.

Select More Efficient Lamp-and-Ballast Designs: DOE selects commercially available ballasts with higher BLEs as replacements for each baseline ballast in the representative ballast types by considering the design options identified in the technology assessment and screening analysis (final rule TSD chapter 4). DOE can identify many of the distinguishing design options associated with each ballast. However, at some levels, these design options cannot be identified by the product number or catalog description, and therefore are assumed to be used in the ballast to achieve a higher BLE. In identifying more efficient substitutes, DOE uses a database of commercially available ballasts. DOE then tests these ballasts to establish their appropriate BLE. Appendix 5C presents these test results. All BLE values were calculated according to the method adopted by the active mode test procedure.

Because fluorescent lamp ballasts are designed to operate fluorescent lamps, DOE considers properties of the entire lamp and ballast system in the engineering analysis. Though ballasts are capable of operating several different lamp wattages, DOE chooses the most common fluorescent lamp used with each ballast for analysis. DOE develops the engineering analysis based on two substitution cases. In the first case, the consumer is not allowed to change the spacing of the fixture and therefore replaces one baseline ballast with a more efficient ballast. In this case, light output is maintained to within 10 percent of the baseline system lumen output.[c] In the second case, the consumer is allowed to change the spacing of the fixture. Therefore, the consumer either purchases more or fewer ballasts to maintain light output and DOE normalizes the light output relative to the baseline ballast.

Determine Efficiency Levels. DOE develops ELs based on three factors: (1) the design options associated with the specific ballasts studied; (2) the ability of ballasts operating lamps across different lamp wattages to comply with the EL of a given product class; and (3) the maximum technologically feasible efficiency level. Therefore, DOE's efficiency levels are based upon test data collected from products currently on the market. As discussed in section 5.4, DOE developed efficiency levels using an equation that relates the total lamp arc power operated by a ballast to ballast luminous efficiency.

Conduct Price Analysis. DOE generates a bill of materials by disassembling multiple manufacturers' ballasts that span a range of efficiency levels for each of the representative ballast types. The BOMs describe the product in detail, including all manufacturing steps required to make and/or assemble each part. DOE then develops a cost model that converts the BOMs and efficiency levels into MPCs. By applying derived manufacturer markups to the MPCs, DOE calculates the manufacturer selling prices (MSPs)[d] and constructs industry cost-efficiency curves.

DOE was not able to generate a BOM for all ballasts in this engineering analysis. In these cases, DOE evaluated blue book and retail prices for those ballasts and estimated an MSP for each one. For fluorescent lamps, DOE referenced the retail price for those lamps in the rulemaking for general service fluorescent and incandescent reflector lamps (hereafter "the 2009 Lamps Rule").[e]

The sections that follow discuss how DOE applies this methodology to each product class to create the engineering analysis and the methodology DOE used to develop ballast prices.

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[c] In some instances (*e.g.*, when switching from T12 to T8 ballasts), light output slightly exceeds these limits. These instances are discussed in more depth in the appropriate sections below.
[d] The MSP is the price at which the manufacturer can recover all production and non-production costs and earn a profit. Non-production costs include selling, general, and administration (SG&A) costs, the cost of research and development, and interest.
[e] The final rule for general service fluorescent and incandescent reflector lamps was published in the *Federal Register* on July 14, 2009. It is available at http://edocket.access.gpo.gov/2009/pdf/E9-15710.pdf.

5.4 EFFICIENCY LEVELS

5.4.1 General Methodology

DOE tested many different types of ballasts from various manufacturers, including extensive testing of the representative ballast types. DOE tested a minimum of four samples for over 90 percent of tested ballast models. DOE was unable to test a minimum of four samples for some models because they had been discontinued or were unavailable for purchase. After compiling the test data, DOE plotted BLE versus total lamp arc power for both standard and high efficiency products from multiple manufacturers. DOE observed distinct groupings when comparing a dedicated manufacturer's high and standard efficiency products.

Based on an application of several equation forms of efficiency levels, DOE concluded that a power law equation best modeled the observed trend between total lamp arc power and BLE. A power law equation takes the form:

$$BLE = \frac{A}{1 + B * power^{-C}}$$

Where:

power = total lamp arc power.

Eq. 5.1

DOE fit power law regressions to the NEMA supplied test data to calculate the exponent "C." For the instant start and rapid start (IS/RS) ballasts, DOE found the exponent "C" to be 0.25. The exponent 0.25 is also a quantity used in relating power to relative losses (analog of efficiency) for distribution transformers, and fluorescent lamp ballasts similarly employ transformers and inductors. The programmed start (PS) NEMA data suggested a different exponent for ballasts that use the PS starting method. DOE believes that this alternate shape is attributable to the PS ballasts' higher fixed losses due to internal control circuitry and heating of lamp electrodes (cathode heating). As these losses are a larger proportion of total losses at lower powers, the PS product classes have a steeper slope across the range of wattages. Using NEMA's data for PS ballasts, DOE found the exponent "C" to be 0.37.

Next, with the exponents set for the two starting method categories, DOE fit the power law equation to the reported value data (calculated in accordance with 10 CFR 429.26) by adjusting the coefficient "B" to delineate among criteria such as different product lines, ballasts that operate different lamp types, and other clusters in efficiency data. Then, to develop efficiency levels, DOE applied a lab-to-lab adjustment factor of 0.7 percent (derived from all available test data) to these curve-fits.

5.4.2 Conversion of Existing BEF Standards to BLE

When selecting a baseline unit for a representative ballast type with an existing energy conservation standard, DOE uses the ballast with a measured BLE that just meets the existing standard. Because DOE sets standards using the BLE metric, DOE converted the existing BEF standards to BLE so that it could compare the measured BLE values to the standard.

First, DOE determined that the existing BEF standard corresponded to two BLE values: one for low-frequency ballasts and a second for high-frequency ballasts. For low-frequency ballasts, DOE multiplied BEF by the number of lamps assigned to the standard, by the low-frequency reference lamp arc power included in the fluorescent lamp ballast test procedure (76 FR 25211, (May 4, 2011); hereafter "May 2011 test procedure"), the adjustment factor, and then divided by 100 as shown in the following equation:

$$BLE = \frac{Number\ of\ Lamps * Reference\ Lamp\ Arc\ Power * Adjustment\ Factor}{100}$$

Eq. 5.2

Inclusion of the adjustment factor in the correlation is necessary because the BLE metric is equal to lamp arc power divided by ballast input power and multiplied by the appropriate adjustment factor for each ballast type. The results of this conversion are listed in Table 5.1. The conversion provides a good estimate of the corresponding BLE standard for the existing BEF standards. However, depending on testing variation, a ballast's BF, and other electrical characteristics, measured BLE values could be slightly different than predicted by the conversion equation.

Table 5.1 Existing BEF Standards Converted to BLE

Application for operation of	BEF Standard	Equivalent BLE	
		Low Freq	High Freq
One F40T12 lamp	2.29	0.831	0.832
Two F40T12 lamps	1.17	0.849	0.850
Two F96T12 lamps	0.63	0.888	0.897
Two F96T12/HO lamps	0.39	0.777	0.780
One F34T12 lamp	2.61	0.777	0.778
Two F34T12 lamps	1.35	0.804	0.805
Two F96T12/ES lamps	0.77	0.876	0.884
Two F96T12/HO/ES lamps	0.42	0.711	0.713

5.4.3 Maximum Technologically Feasible Efficiency Levels

The most stringent EL in each product class represents the maximum technologically feasible level of efficiency identified by DOE. All max-tech ELs were developed based on commercially available ballasts that DOE purchased and tested. DOE developed the equations to just allow the most efficient tested units that are technologically feasible for a sufficient diversity of products (spanning several ballast factors, number of lamps per ballast, and types of lamps operated) within each product class.

5.5 MEASUREMENT VARIATION AND COMPLIANCE REQUIREMENTS

As stated in 10 CFR 429.26, manufacturers are required to test a minimum of four fluorescent lamp ballasts and report the lower of either the mean efficiency of the samples or the output of a compliance certification equation based on the lower 99 percent confidence limit of the sample. The lower 99 percent confidence limit equation requires a calculation of the standard deviation of the sample set to account for measurement variation. Because over 90 percent of ballast models tested by DOE include samples obtained during two different years, the standard deviation for these models also incorporates design variation that is present in the sample set.

In order to be consistent with compliance certification requirements, DOE tested a minimum of four samples of each ballast model, with the exception of models that have been discontinued or were unavailable for purchase. To account for certification requirements, DOE calculated a new data set which represents the reported value for all ballast models. DOE used these reported values to develop the efficiency levels described in section 5.4.

In addition to compliance requirements, DOE also believes it is important to account for lab-to-lab variation. Using model-specific test data supplied by several manufacturers (representative of three different manufacturer labs) and DOE's BLE data (representative of the two labs used by DOE), DOE determined that on average, the BLE test data from DOE's primary lab was 0.7 percent more efficient than the average test lab. DOE attributes this offset to systematic lab-to-lab variation and therefore reduced the efficiency levels by 0.7 percent so that they are representative of ballasts tested at the average test lab.

5.6 PRICING ANALYSIS OVERVIEW

DOE developed prices using three main inputs. The first input was teardown data. DOE compared teardown-sourced MSPs from the same manufacturer to establish incremental costs between ELs for a representative ballast type. The second input was blue book prices from manufacturer price lists. DOE estimated MSPs from these blue book prices by using manufacturer-specific ratios between blue book prices and teardown- or aggregated manufacturer-sourced MSPs. The third input was confidential manufacturer-supplied MSPs and incremental MPC values. DOE aggregated these inputs to establish MSPs for ELs of representative ballast types for which all data were available. In addition, DOE used ratios of online supplier retail prices to scale to certain ELs where both teardown and blue book prices were unavailable. In general, DOE used a combination of the teardown- and blue book-sourced prices throughout the analysis and used the aggregated manufacturer supplied MSPs for normalization and comparison purposes.

5.6.1 Teardown-Sourced MSPs

Developing the teardown-sourced MSPs for different fluorescent lamp ballasts involved two main inputs: a teardown analysis to develop the MPC and a markup analysis to arrive at the MSP. Figure 5.1 shows the general breakdown of costs and profit associated with manufacturing and selling a product. The full cost of production is broken down into two main costs: the full production cost or manufacturer production cost, and the non-production cost. The non-production cost plus profits is equal to the manufacturer markup. DOE totaled the cost of materials, labor, and direct overhead used to manufacture a product in order to calculate the MPC.[f] Section 5.6.1.1 describes how DOE arrived at the MPC. Section 5.6.1.2 describes how DOE established a markup that estimates non-production costs and profit.

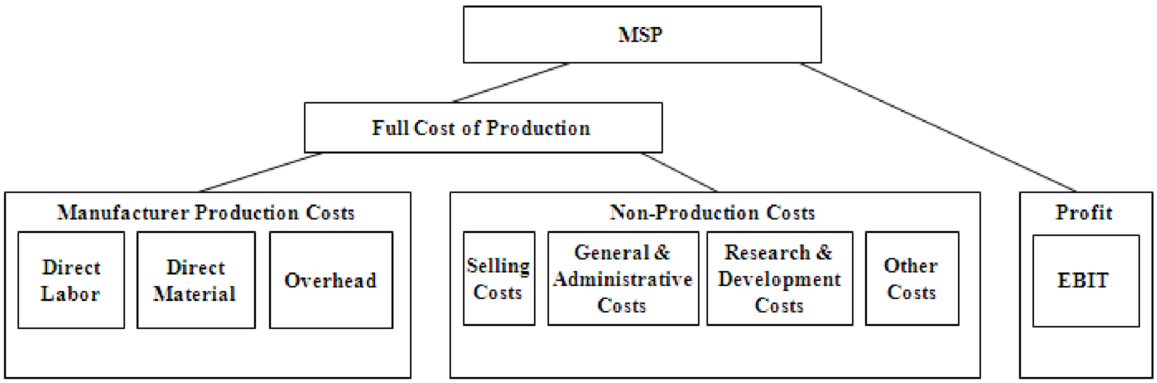

Figure 5.1 Manufacturer Selling Price

5.6.1.1 Manufacturer Production Costs

The MPC is composed of direct labor, direct material, and overhead costs. DOE conducted a teardown analysis to in which it created a bill of materials included in the ballast and an estimate of the direct labor required to assemble and test the finished product. The following paragraphs describe the inputs to the direct labor and materials costs and DOE's method of estimating overhead.

Direct material costs represent the direct purchase price of components (resistors, connecting wires, etc.) identified in the teardown bill of materials. DOE conducted customized teardown analyses for select commercially available fluorescent lamp ballasts. DOE also conducted a teardown analysis on some ballasts removed from a manufacturing facility before adding potting, a type of black pitch. For these ballasts, DOE needed to estimate the cost of potting material to calculate the full material and labor costs. Based on information provided by members of the potting industry, DOE estimated the material and labor costs for potting to be about 60 cents for the standard ballast enclosure, which is 1 x 1.5 x 8 inches. Therefore, DOE added 60 cents to the teardown estimates for "pre-potting" ballasts to estimate the full material and labor costs.

Due to recent economic trends in the commodities market, the estimated MPCs could exhibit significant variation depending on the timeframe for component materials price quotes. The teardown estimates reflect component pricing for January 2009. DOE investigated how January 2009 estimates would change if a 5-year average of materials prices was used instead of a January 2009 spot price. As described in appendix 5A, DOE found the price variation to be insignificant and did not incorporate these material price changes into its analysis.

[f] When viewed from the company-wide perspective, the sum of all material, labor, and overhead costs equals the company's sales cost, also referred to as the cost of goods sold (COGS).

The direct labor costs include fabrication and assembly labor. The teardown results also included estimates for direct labor costs associated with the assembly of the product. Separate labor rates were used for components that required manual (hand) insertion versus those that were automated. Based on conversations with manufacturers, DOE assumed the ballasts were manufactured in Mexico and China and applied the corresponding labor rates.

The teardown results did not include overhead estimates. Overhead includes indirect material and labor costs, maintenance, depreciation, taxes, and insurance related to assets. DOE used financial data to estimate the overhead cost by calculating it as a percentage of the MPC.

DOE estimated the depreciation cost from a representative electronics fabrication company's U.S. Securities and Exchange Commission (SEC) 10-k, finding it to be about 2.6 percent of the cost of goods sold or the MPC. To determine the material and labor percentage, DOE marked down aggregated confidential MSPs to an MPC using the manufacturer markup (5.6.1.2). Then, DOE computed the ratio of aggregated teardown-sourced material and labor costs to the manufacturer markdown sourced MPC. DOE found the material and labor costs to be about 93.8 percent of the MPC. DOE then subtracted the materials and labor and depreciation percentages from 100 percent to back out the remainder of overhead as a percentage of MPC. Overhead was estimated to be 3.6 percent of the MPC, which is reasonable as electronics manufacturing generally has low overhead costs. DOE found overhead and depreciation to be about 6.2 percent of the MPC or 6.6 percent of the material and labor costs. The 6.6 percent factor was then used to mark up the material and labor costs contained in the teardown results to the full production cost or MPC.

Selection of Units

DOE carefully selected units for the teardown analysis to create useful data to estimate manufacturer production costs. DOE mapped out a matrix of product specifications and then compared ballasts that differ by only one attribute. Ballasts are described by a long list of specifications, so DOE concentrated on the specifications it expected to have the greatest effect on efficiency. This list included high versus regular advertised efficiency, maximum number of lamps driven, starting method, and universal versus dedicated input voltage. In addition to strategically selecting ballast specification characteristics, DOE also selected common ballast models from major manufacturers. This choice helped DOE capture the most accurate incremental price difference by tearing down high volume, mainstream products.

Unfortunately, DOE was only able to select unpotted ballasts for the teardown analysis. Some ballast manufacturers add potting to the ballast enclosure to improve durability. The potting reduces vibration damage and acts as a heat sink for the circuit board. Because the sticky potting inhibits visual observation of the components, DOE was unable to reverse engineer many ballasts through a teardown analysis. As a result, DOE only conducted teardowns for unpotted ballasts and ballasts removed from a manufacturing facility before the potting procedure. Section 5.6 discusses how DOE estimated prices for those ballasts it could not or chose not to tear down.

DOE selected thirteen fluorescent lamp ballasts to tear down for the engineering analysis. Table 5.2 lists the ballast types submitted for teardowns.

Table 5.2 Ballast Types for Teardowns

Ballast	Starting Method	For Operation of	Input Voltage	Regular vs. High Efficiency
1	PS	2 F32T8	Universal	HE
2	PS	2 F32T8	Dedicated	REG
3 and 4	IS	2 F32T8	Universal	HE
5	IS	2 F32T8	Universal	REG
6	IS	2 F32T8	Dedicated	REG
7	IS	4 F32T8	Dedicated	REG
8	IS	4 F32T8	Universal	REG
9	IS	4 F32T8	Universal	HE
10 and 11	IS	2 F59T8	Universal	HE
12	IS	2 F59T8	Dedicated	REG
13	IS	2 F59T8	Universal	REG

5.6.1.2 Manufacturer Markup

More efficient products typically have higher manufacturing costs than baseline products. To meet new or amended energy conservation standards, manufacturers often must introduce design changes to their existing products or discontinue less efficient products, resulting in standards-compliant products that have higher MPCs than baseline products. Depending on the competitive environment for these particular products, some or all of the increased production costs can be "passed through" from manufacturers to customers in the form of higher purchase prices. As production costs increase, manufacturers also typically incur additional overhead at the factory and corporate levels. The MSP must cover both of these additional contributions to overhead if a company is to maintain its current level of profitability.

As discussed previously, overhead costs within the DOE model are a function of investments, material costs, labor costs, or total costs, depending on the overhead category. Together, materials, labor, and factory overhead comprise the manufacturer production cost. DOE applies another multiplier to the manufacturer production cost to account for corporate non-production costs and profit. This latter multiplier, the manufacturer markup, is the focus of this section.

The manufacturer markup is an integral part of the overall markup from production costs to installation costs. However, the manufacturer markup is different than the other markups in the distribution chain (which includes wholesalers, distributors, retailers, contractors, etc.) that convert MSP to customer price. The customer prices and installation costs are key inputs to the LCC analysis, payback period (PBP) analysis, and national impact analysis (NIA). Through the use of the manufacturer and distribution chain markups and installation costs, DOE can calculate the first costs that customers would face under the various efficiency levels. DOE evaluates the tradeoff between the increase in first cost and the resulting energy cost savings at each efficiency level in the LCC and PBP analyses (chapter 8) and NIA analysis (chapter 10). In this section, DOE presents its methodology for converting the MPCs to manufacturer selling prices using the manufacturer markup.

DOE calculated the MSP for fluorescent lamp ballasts by multiplying the MPC by the calculated manufacturer markup. In general, the manufacturer markup should ensure that the

MSP of the product is high enough to recover the full cost of the product (*i.e.*, full production and non-production costs), and yield a satisfactory profit.

Publicly owned companies are required by law to disclose financial information on a regular basis by filing different forms with the U.S. Securities and Exchange Commission. The SEC form 10-K, filed by companies on an annual basis, provides a comprehensive overview of the company's business and financial conditions. Relevant information in the 10-K reports includes the company's revenues and direct and indirect costs. For the manufacturer markup, DOE used 10-K reports from publicly owned ballast manufacturing companies. The financial figures necessary for calculating the manufacturer markup are net sales, costs of sales, and gross profit. The income statement section of the 10-K reports often reports these figures.

DOE calculated the manufacturer markup by using financial figures from manufacturers' SEC 10-K reports, such as the net sales (revenues) and cost of sales to calculate gross profit and gross profit margins. DOE used averages of the financial figures spanning 2002 to 2008 to calculate the markup. DOE used the following equations to calculate the gross profit and gross profit margins:

$$Gross\ Profit\ (\$) = Net\ Sales - Cost\ of\ Sales$$

Eq. 5.3

$$Gross\ Profit\ Margin\ (\%) = \frac{Gross\ Profit}{Net\ Sales}$$

Eq. 5.4

Table 5.3 contains the calculated gross profit margins for four sample manufacturers.

Table 5.3 Gross Profit Margin for Four Fluorescent Lamp Ballast Manufacturers*

Parameter	Industry-Weighted Average	Manufacturer			
		A	B	C	D
Net Sales Million $	66,614	90,705	46,952	38,118	63,862
Cost of Sales Million $	44,203	58,350	29,567	27,562	44,804
Gross Profit Million $	22,411	32,355	17,385	10,556	19,057
Gross Profit Margin %	**33.6**	**35.7**	**37.0**	**27.7**	**29.8**
* Data taken from 2002, 2003, 2004, 2005, 2006, 2007, and 2008 SEC 10-K reports.					

To calculate the time-average gross profit margin for each firm, DOE first summed the gross profit for all the years and then divided the result by the sum of the net sales for those years. Each manufacturer's markup was calculated as:

$$Manufacturer\ Markup = \frac{1}{1 - Gross\ Profit\ Margin} = \frac{Net\ Sales}{Cost\ of\ Sales}$$

Eq. 5.5

Table 5.4 shows the manufacturer markups using this method.

Table 5.4 Calculated Manufacturer Markups for Fluorescent Lamp Ballasts

Manufacturer	Manufacturer Markup
Manufacturer A	1.55
Manufacturer B	1.59
Manufacturer C	1.38
Manufacturer D	1.43
Average	**1.50**

DOE calculated the average manufacturer markup to be 1.50 based on the estimated market share of each manufacturer. In other words, fluorescent lamp ballast manufacturers, on average, sell their products to the next party in the distribution channel at 50 percent above the manufacturing production cost.

Although publicly owned companies file SEC 10-K reports, the financial information summarized is not always exclusive to the fluorescent lamp ballast portion of their business. It can include financial information from other product sectors, whose margins could be quite different from those of the fluorescent lamp ballast industry. Therefore, during interviews, DOE asked manufacturers to provide both the manufacturer markup and the manufacturer selling price of fluorescent lamp ballasts sold through two main distribution chains: from the manufacturer to an original equipment manufacturer (OEM), and from the manufacturer to a distributor.

DOE supplemented the information provided in Table 5.4 with information from manufacturer interviews. During interviews, manufacturers generally indicated that the average markups for fluorescent lamp ballasts were lower than the markup for the parent company. After considering these two additional sources of information, DOE determined that a manufacturer markup of approximately 1.40 on an aggregate basis for the fluorescent lamp ballast industry was appropriate.

DOE used these multipliers in the engineering analysis to determine the teardown-sourced MSPs for each representative ballast type. DOE used a constant markup to reflect the MSPs of the baseline products as well as more efficient products. DOE took this approach because amended standards may make high-efficiency products, which currently are considered premium products, the baseline and commodity products in the future.

DOE noticed that teardowns of ballasts from different manufacturers sometimes resulted in different MSPs, although they had approximately the same measured BLE. DOE believed this could potentially be due to differences in the brand of component used in the ballasts or design preferences particular to different manufacturers. As a result, DOE normalized the teardown-sourced MSPs so that the incremental difference between ELs would be less impacted by differences in component prices from one manufacturer to another. Using this technique, DOE assigned teardown-sourced MSPs to efficiency levels at which a ballast was torn down.

5.6.2 Blue Book-Sourced MSPs

For the blue book-sourced MSPs, DOE developed manufacturer-specific discount ratios between blue book prices and either teardown-sourced MSPs or aggregated manufacturer-supplied MSPs. If teardown-sourced MSPs were available, DOE used these values to create discount ratios; otherwise DOE selected an aggregated manufacturer-supplied MSP. When a blue book value was not available from any manufacturer for a particular EL, DOE used a retail price scaling technique. DOE scaled the blue book-sourced price of an adjacent efficiency level using a ratio of retail prices (from a single online supplier) between ballasts in the adjacent EL and the EL without a blue book-sourced price. For example, if a blue book value was not available for EL2, a ratio of retail prices between EL2 and EL3 could be used to scale the blue book-sourced MSP from EL3 to EL2.

5.6.3 Manufacturer-Sourced MSPs

DOE received confidential MSPs and incremental price and cost data from manufacturers. To develop the confidential manufacturer-supplied MSPs, DOE aggregated the prices so that confidential information was not revealed. If an MSP was not available from multiple manufacturers, DOE did not report the value or use it for normalization purposes. For representative ballast types with prices normalized to a teardown value, DOE normalized the manufacturer-supplied MSPs to the teardown MSP.

5.6.4 Final MSP

To calculate the final MSP for each EL in each product class, DOE applied the following methodology. For ELs with teardown-sourced MSPs, DOE averaged the teardown-sourced MSP with the blue book-sourced MSP to assign the final MSP value. For ELs without a teardown-sourced MSP, DOE used the blue book MSP directly as the final MSP.

As mentioned in sections 5.6.2 and 5.6.3, DOE selected certain teardown MSPs or manufacturer supplied MSPs for normalization. DOE generally normalized to the primary baseline (baseline with the most shipments) or the least stringent EL with either a teardown- or manufacturer-sourced MSP. For example, DOE normalized to the F32T8 baseline/EL1 for the 2-lamp 4-foot MBP IS and RS representative ballast type (using a teardown-sourced MSP) because this baseline represents the majority of shipments prior to the imposition of standards. Table 5.83 indicates the EL used for normalization for each representative ballast type.

5.7 REPRESENTATIVE PRODUCT CLASSES

As discussed in the market and technology assessment (final rule TSD chapter 3), DOE is revising the existing product classes defined by the Energy Policy and Conservation Act (EPCA). DOE decided to analyze five of the seven product classes as representative. The representative product classes represent the most commonly sold ballasts and the majority of the ballast shipment volume.

Although DOE did not analyze the product classes for PS ballasts that operate 8-foot high output lamps and PS residential ballasts that operate 4-foot MBP lamps as representative, DOE established standards based on representative product classes directly analyzed. Section 5.19

provides more information on extending standards to the product classes DOE did not directly analyze.

Table 5.5 **Fluorescent Lamp Ballast Product Classes**

Description	Product Class Number
IS and RS ballasts (not classified as residential) that operate: 4-foot MBP lamps 2-foot U-shaped lamps 8-foot slimline lamps	1
PS ballasts (not classified as residential) that operate: 4-foot MBP lamps 2-foot U-shaped lamps 4-foot MiniBP SO lamps 4-foot MiniBP HO lamps	2
IS and RS ballasts (not classified as sign ballasts) that operate: 8-foot HO lamps	3
PS ballasts (not classified as sign ballasts) that operate: 8-foot HO lamps	4
Sign ballasts that operate: 8-foot HO lamps	5
IS and RS residential ballasts that operate: 4-foot MBP lamps 2-foot U-shaped lamps 8-foot slimline lamps	6
PS residential ballasts that operate: 4-foot MBP lamps 2-foot U-shaped lamps	7

5.8 REPRESENTATIVE BALLAST TYPES

DOE chose to analyze at least one representative ballast type for each lamp type. Analyzing multiple ballast types allows for a more accurate assessment of the impacts of standards as each ballast type consumes a different amount of energy and has a different MPC.

The IS/RS product class includes ballasts that operate 4-foot MBP and 2-foot U-shaped lamps and 8-foot slimline lamps. For the ballasts that operate 4-foot MBP and 2-foot U-shaped lamps, DOE chose to analyze multiple representative ballast types. U.S. Census data indicate that approximately 50 percent of ballasts that operate F32T8 lamps (the most common 4-foot MBP lamp) are one and two-lamp ballasts while the remaining 50 percent are three- and four-lamp ballasts.[1] Based on its discussions with manufacturers and industry experts, DOE estimates that approximately 40 percent of ballasts that operate F32T8 lamps are two-lamp ballasts, 30 percent are four-lamp ballasts, 20 percent are three-lamp ballasts, and the remaining 10 percent are one-lamp ballasts. U.S. Census data also indicates that the vast majority of ballasts that operate 4-foot MBP T12 lamps are two-lamp ballasts. Therefore, DOE chose to concentrate on analyzing four-lamp and two-lamp ballasts that operate 4-foot MBP lamps as representative ballast types. DOE limited its representative ballast types to only include those ballasts that exhibit a normal ballast factor (BF), as this BF is the most common.[g] Finally, DOE estimates that the majority of ballast that operate 8-foot slimline lamps are two-lamp ballasts. Therefore, DOE analyzes 2-lamp 8-foot slimline lamps as a representative ballast type.

The PS product class includes ballasts that operate 4-foot MBP and 2-foot U-shaped lamps, 4-foot T5 miniature bipin (MiniBP) standard-output (SO) lamps, and 4-foot T5 miniature bipin (MiniBP) high-output (HO) lamps. DOE estimates the majority of ballasts that operate 4-foot T5 miniature bipin standard-output lamps operate two lamps. Therefore, DOE analyzed the two-lamp variant as the representative ballast type for ballasts that operate T5 SO lamps. DOE also decided to study two-lamp ballasts that operate 4-foot T5 MiniBP HO lamps as a representative ballast type. Based on discussions with manufacturers and industry experts, DOE estimates that approximately 60 percent of ballasts that operate 4-foot T5 MiniBP HO lamps are two-lamp ballasts, 30 percent are three-lamp ballasts, and the remainder are one-lamp or four-lamp ballasts. Although IS and RS ballasts are the most common ballasts that operate 4-foot MBP lamps, PS ballasts are growing in market share. DOE found that similar to IS and RS ballasts, PS ballasts that operate 4-foot MBP lamps are commonly two- and four-lamp ballasts. Therefore, DOE analyzed two-lamp and four-lamp PS ballasts that operate 4-foot MBP lamps as representative ballast types.

For the sign ballast product class, DOE chose to analyze four-lamp sign ballasts as a representative ballast type because industry experts report these are the most common sign ballasts.

For the 8-foot HO IS and RS product class, DOE chose to study only the IS and RS ballasts that operate two 8-foot HO lamps as representative ballast type as the two lamp variety is the most common type.

For the IS/ RS residential ballasts product class, DOE chose to analyze IS and RS ballasts that operate two 4-foot MBP lamps as the representative ballast type. Residential ballasts are a significant portion of the 4-foot MBP ballast market and the 2-lamp IS and RS variety is the most common.

Sections 5.9 through 5.18 describe how the EL equations delineate the representative ballast types. In these sections, DOE presents representative ballasts at each EL for each representative ballast type. When discussing these representative units, DOE presents the tested BLE of the unit. Because DOE is setting efficiency levels in terms of an equation that relates lamp arc power to BLE, the particular efficiency value a ballast is subject to is specific to the lamp arc power provided by the ballast. The representative units present a “representative”

[g] DOE defines low ballast factor as being less than or equal to 0.78, normal ballast factor as being greater than 0.78 but less than 1.10, and high ballast factor as being greater than or equal to 1.10.

efficiency level that just meets the EL requirements based on the representative unit's total lamp arc power.

5.9 INSTANT AND RAPID START BALLASTS THAT OPERATE TWO FOUR-FOOT MBP AND TWO-FOOT U-SHAPED LAMPS IN THE COMMERCIAL SECTOR

The IS and RS product class includes three representative ballast types, including IS and RS ballasts that operate two 4-foot MBP and 2-foot U-shaped lamps in the commercial sector. DOE presents its analysis of this ballast type in the following sections.

5.9.1 Baseline Models

DOE selected baseline models as reference points for each representative ballast type, against which DOE measured changes resulting from potential amended energy conservation standards. As discussed in section 5.3, a baseline ballast just meets current Federal energy conservation standards and provides basic consumer utility. To determine energy savings and changes in price, DOE compared each higher energy efficiency level with the baseline unit.

DOE chose to analyze two baseline ballasts for the two-lamp 4-foot and 2-foot U-shaped MBP IS and RS normal BF representative ballast type (hereafter referred to as the 2-lamp MBP IS and RS representative ballast type). Census data indicate that 2001 shipments of 4-foot and 2-foot U-shaped MBP T12 ballasts represented 14 percent of all 4-foot and 2-foot U-shaped MBP ballast shipments, while 4-foot and 2-foot U-shaped MBP T8 ballasts represented 86 percent of all 4-foot and 2-foot U-shaped MBP ballast shipments.[h] Therefore, DOE analyzed both T12 and T8 ballasts as a baseline ballast. Because the 2009 Lamps Rule eliminated all currently commercially available T12 lamps by 2012, DOE created an F34T12 lamp that complied with the 2009 Lamps Rule to pair with T12 ballasts (see Table 5.7). DOE chose to analyze only those T12 ballasts that operate F34T12 lamps because only the most efficient T12 lamps will be available when this ballast rulemaking takes effect. For the T8 baseline, DOE chose to analyze only those ballasts that operate the F32T8 lamp because it is the most common 4-foot MBP T8 lamp.

DOE considered the ballast's characteristics in choosing the most appropriate F32T8 and F34T12 ballasts for the 2-lamp MBP IS and RS representative ballast type. These characteristics included the ballast's starting method (*e.g.*, RS, or IS), input voltage (277 volts (V) vs. 120V), power factor (PF), total harmonic distortion (THD), ballast factor, input power, BLE, and type (electronic vs. magnetic), and whether the ballast can operate at multiple voltages[i] (universal voltage) or only one (dedicated voltage). Finally, DOE considered whether the ballast just meets existing Federal minimum energy conservation standards. In considering each of these characteristics, DOE chose a baseline ballast that exhibits the characteristics of the least efficient and most common ballast.

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[h] More recent census data for ballasts are available. However, shipments of T12 ballasts have not been publicly released for all product classes after 2001. DOE used 2001 Census data for all analysis in this chapter.
[i] Universal voltage ballasts can operate at 120V or 277V.

The Federal minimum energy conservation standard for ballasts that operate two F34T12 lamps became effective for ballasts manufactured on or after July 1, 2009. (10 CFR Part 430.32 (m)(5)). This energy conservation standard effectively allowed only electronic F34T12 ballasts. Therefore, DOE chose an electronic ballast as the F34T12 baseline ballast. To determine the BLE of the baseline ballast, DOE tested multiple ballasts operating a reference F34T12 lamp. The BLE, BF, and input power of the most common T12 ballast that just meets the minimum energy conservation standard of 80.5 percent (BEF of 1.35[j]) is shown in Table 5.6 below. The majority of F34T12 electronic ballasts in product catalogs are RS, dedicated voltage, have a high PF (~0.98) and a THD <20 percent. The ballast that just meets the energy conservation standard also exhibits these characteristics. DOE also chose a ballast that has an input voltage of 277V because the majority of ballasts operate in commercial buildings at 277V.

Currently there is no federal minimum energy conservation standard for ballasts that operate F32T8 lamps. Therefore, in choosing the baseline ballast for this lamp type, DOE chose the most common, least efficient ballast on the market. DOE tested a range of F32T8 ballasts from multiple ballast manufacturers and found that the least efficient but most common ballast exhibited the characteristics shown in Table 5.6 below. The vast majority of T8 ballasts are IS, electronic, and have a high PF (>0.97). Furthermore, the least efficient T8 ballasts are dedicated voltage and have a THD <20 percent. Finally, like the F34T12 baseline ballast, DOE chose a ballast that has an input voltage of 277V as the majority of ballasts operate in commercial buildings at 277V.

Table 5.6 Baseline Ballasts for the 2-lamp MBP IS and RS Representative Ballast Type

For operation of	Starting Method, Input Voltage, Ballast Type, PF, THD	BF	Input Power *W*	BLE (%)	Federal Energy Conservation Standard
2, F34T12 lamps	RS, 277V, Electronic, Dedicated Voltage >0.98 PF, <20% THD	0.80	60.7	78.3%	80.5%
2, F32T8 lamps	IS, 277V, Electronic, Dedicated Voltage, >0.98 PF, <20% THD	0.90	57.1	86.0%	N/A

DOE paired both commercial and industrial 4-foot and 2-foot U-shaped MBP ballasts with an appropriate F34T12 and a reduced wattage F32T8 lamp, which was designed to reflect the distribution of energy-saving lamps on the market. The 2009 Lamps Rule adopted a standard that eliminated T12 lamps that are currently commercially available. However, the 2009 Lamps Rule did not prohibit manufacturers from developing a more efficient T12 lamp that can meet the standard by the time the rulemaking takes effect in 2012. Because the ballast rulemaking takes effect in 2014, the efficacy of T12 lamps can potentially be improved by the use of rare earth phosphor to a point at which it complies with the 2009 Lamps Rule. Therefore, DOE paired T12 ballasts with a T12 lamp it invented that just meets the energy conservation standard adopted by the 2009 Lamps Rule. The characteristics of the T12 and T8 lamps paired with 4-foot MBP ballasts in this rulemaking are listed in the table below.

[j] The conversions of BEF to BLE are presented in section 5.4

In order to account for the increased use of energy-saving lamps, DOE incorporated the distribution of full- and reduced-wattage lamps on the market. In the 2009 Lamps rule, DOE estimated the distribution of lamps by wattage that would be compliant with the 2012 energy conservation standards. DOE used these distributions to develop weighted-average lamp wattages (*e.g.*, a rated wattage of 30.8 W for 4-foot MBP T8 lamps) to pair with both T8 and T5 ballasts. In addition, DOE also updated the ballast luminous efficiency, system input power, system lumen output, lamp lifetime, and lamp price to reflect the distribution of lamp wattages.

Table 5.7 Lamps for Use with F32T8 and F34T12 Ballasts

Lamp Type	CCT	Rated Efficacy*	Initial Light Output	Mean Light Output	Life	CRI
	K	*lm/W*	*lm*	*lm*	*hr*	
F34T12	4,100	92.9	3,160	2,997	24,000	N/A
F32T8	4,100	92.9	2,860	2,712	24,091	85

* Rated efficacy is based on the rated wattage of the F34T12 lamp, which is 34W, and the weighted-average lamp wattage of 4-ft T8 MBP lamps for the F32T8 lamp, which is 30.77W.

These combinations of lamps and ballasts represent the most common configurations for these ballasts in existing and new installations. Together, these lamp and ballast combinations create a system lumen package of approximately 4,779 mean lumens (and 5,040 initial lumens) for the baseline F34T12 ballast and approximately 4,847 mean lumens (and 5,111 initial lumens) for the baseline F32T8 ballast.

5.9.2 Efficiency Levels

For the 2-lamp MBP IS and RS representative ballast type, DOE conducted a survey of the fluorescent lamp ballast market to determine what types of products are available to consumers. As discussed in section 5.4, for each representative ballast type, DOE tested many of the manufacturers' product offerings for BLE to develop efficiency level equations. After establishing these efficiency level equations, DOE selected representative units for each EL. Because the baseline ballasts have different BLE values and represent various design options, for some representative ballast types, ELs affect only one of the two baseline ballasts. For example, EL1 may require a more efficient T12 ballast than the baseline T12 ballast, but not require a ballast more efficient than the T8 baseline. However, the full range of ELs ultimately specifies requirements that are above the BLE values of all the baseline ballasts sold, and therefore affect all baseline ballasts. Finally, DOE determined the maximum improvement in BLE that is technologically feasible ("max-tech") for fluorescent lamp ballasts, as required by section 325(o) of EPCA. (42 U.S.C. 6295(o)). To determine this level, DOE conducted a survey of the fluorescent lamp ballast market and the research fields that support the market. DOE believes that within a given product class, no working prototypes exist that have a distinguishably higher BLE than currently available ballasts. However, DOE is exploring a level above that which is commercially available in appendix 5F of this final rule TSD (hereafter referred to as the advanced technology scenario).

The following section identifies the steps and technologies associated with each EL DOE considered for the 2-lamp MBP IS and RS representative ballast type. As discussed in the screening analysis (final rule TSD chapter 4), DOE used design options that achieve a higher BLE than the baseline ballast. Because the baseline ballast is an electronic ballast, improvements required the use of the following design options: improved components and improved circuit design.

EL1. This level affects the F34T12 baseline ballast but not the F32T8 baseline ballast. It is met by the least efficient F32T8 baseline ballast. No T12 ballasts meet this level. In addition, ballasts must use improved circuit designs (a starting method that is IS rather than RS).

EL2. This level affects both the baseline ballasts. No T12 ballast that is commercially available can meet this level. Ballasts at this level use better components and more efficient circuit designs than those ballasts that just meet EL1.

EL3. This level again affects both the baseline ballasts and represents the maximum technologically feasible level. This level represents a modest improvement in efficiency over EL2. Ballasts at this level use slightly better components and circuit designs than those ballasts that just meet EL2.

Table 5.8 Summary of ELs for Two-Lamp MBP IS and RS Ballasts

Efficiency Level	BLE Requirement With Variation Reduction
EL1	0.993/(1+0.46*total lamp arc power^-0.25)
EL2	0.993/(1+0.31*total lamp arc power^-0.25)
EL3	0.993/(1+0.27*total lamp arc power^-0.25)

Figure 5.2 illustrates the three ELs on a plot of the reported values of 2-lamp MBP IS and RS ballasts. A circle indicates a representative unit selected by DOE. Diamonds indicate other 2-lamp MBP IS and RS ballasts tested by DOE.

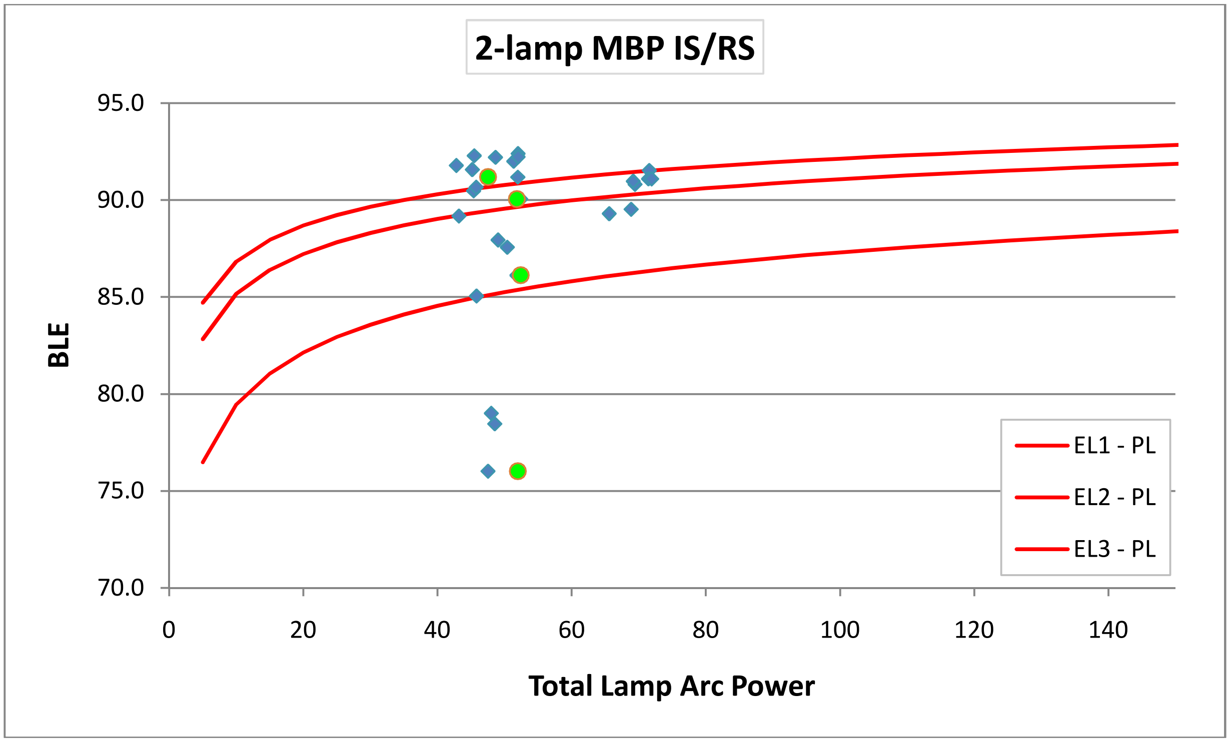


Figure 5.2 Efficiency Levels for the 2-lamp MBP IS and RS Representative Ballast Type

Table 5.9 provides detailed information on the 2-lamp MBP IS and RS ballast designs used in the engineering analysis and subsequent analyses. In general, for the 2-lamp MBP IS and RS representative ballast type, ballasts at higher efficiencies can operate at multiple voltages, have a lower THD, and similar BF and PF as the baseline ballast designs.

Table 5.9 Two-Lamp 4-Foot MBP Commercial Ballasts in the IS and RS Representative Ballast Type

Efficiency Level	For Operation Of	Ballast Type	Starting Method	Input Voltage	Universal or Dedicated Voltage	Power Factor	THD (%)	Ballast Factor	Input Power (W)	Lamp Arc Power (W)	BLE (%)
Baseline	2 F34T12 Lamps	Electronic	RS	277	Universal	0.99	<10%	0.80	60.7	47.5	78.3
Baseline /EL1	2 F32T8 Lamps	Electronic	IS	277	Dedicated	0.98	<20%	0.90	57.1	49.1	86.0
EL2	2 F32T8 Lamps	Electronic	IS	277	Universal	0.98	<10%	0.90	55.1	49.6	90.1
EL3	2 F32T8 Lamps	Electronic	IS	277	Universal	0.98	<9%	0.90	54.0	49.2	91.1

5.9.3 Lamp and Ballast Prices

DOE analyzed each EL for the 2-lamp MBP IS and RS representative ballast type to develop appropriate MSPs. For the F34T12 baseline ballast, DOE based the price on blue book-sourced MSPs described in section 5.6.2 and for the F32T8 ballasts (EL1 though EL3), DOE generated an MSP from an average of teardown- and blue book-sourced MSPs. As shown in Table 5.10, DOE found the MSP for the F34T12 ballast was higher than the baseline F32T8 ballast. The F34T12 electronic ballast is sold at lower volumes than the electronic F32T8 ballasts. DOE attributes the smaller shipments volume to its high cost relative to its efficiency. Otherwise, MSP increases with increased efficiency.

Table 5.10 Summary of the Manufacturing Selling Prices for the 2-Lamp MBP IS and RS Commercial Representative Ballast Type

Efficiency Level	Lamp Type	Starting Method	MSP (2009$)
Baseline	F34T12	RS	$8.41
Baseline/EL1	F32T8	IS	$6.94
EL2	F32T8	IS	$8.85
EL3	F32T8	IS	$9.27

The following table depicts the appropriate lamp prices for the baseline lamps as used in the 2009 Lamps Rule. Although DOE calculated the performance characteristics of a T12 lamp such that it would comply with the standard adopted by the 2009 Lamps Rule, DOE assumed that the price of this T12 lamp would be the same as the representative T12 lamp that met trial standard level (TSL) 3 in the 2009 Lamps Rule. DOE believes that both TSL3 in the 2009 Lamps Rule and the market situation in 2014 are instances in which a very efficient T12 lamp competes directly with cheaper T8 lamps. Therefore, DOE believes that price competition will prevent manufacturers from raising the price of T12 lamps any higher than the price at which the most efficient T12 lamps are currently sold.

Table 5.11 Retail Prices for Four-Foot Medium Bipin Fluorescent Lamps

Lamp Type	Retail Price (2007$)
F34T12	$5.83
F32T8	$3.19

5.9.4 Results

As discussed above, DOE evaluated multiple baseline ballasts for the relevant representative ballast types to provide a comprehensive understanding of the consumer economics. DOE based its engineering analysis on two substitution cases. In the first case, the consumer is not allowed to change the spacing of the fixtures and therefore replaces one baseline ballast with a more efficient ballast. In this case, light output is maintained to within 8 to 15 percent of the baseline system lumen output dependent on comparison to a F32T8 or F34T12 baseline. Percentage change in mean lumen output is shown in Table 5.12 and Table 5.13. In the second case, the consumer is allowed to change the spacing of the fixture. To show how energy savings would change due to this change in fixture spacing, DOE shows the normalized system input power. The following formula is used to normalize the system input power of the standards-case system to the mean lumen output of the baseline system:

$$Normalized\ InputPower_{S\tan dardsCase} = \frac{MLO_{Baseline}}{MLO_{S\tan dardsCase}} * InputPower_{S\tan dardsCase}$$

Where:

$NormalizedInputPower_{S\tan dardsCase}$ = Input power of the standards-case system that matches the light output of the baseline system

$MLO_{Baseline}$ = Mean lumen output of the baseline system

$MLO_{S\tan dardsCasee}$ = Mean lumen output of the standards-case system

$InputPower_{S\tan dardsCasee}$ = Input power of the standards-case system

Eq. 5.6

Table 5.12 and Table 5.13 also present the retail price of the replacement lamps (e.g., if it is a 2-lamp system the retail price is the price of two lamps). Table 5.12 presents the engineering characteristics of the ballast replacement options for the baseline F32T8 system in the 2-lamp MBP IS and RS representative ballast type. If a direct substitution is made, mean lumen output does not change by more than one percent relative to the mean lumen output of the baseline system.

Table 5.12 Two-lamp MBP IS and RS Representative Ballast Type with F32T8 Baseline

Efficiency Level	For Operation Of	Ballast Type	Starting Method	Input Voltage	Universal or Dedicated Voltage	Ballast Factor	Input Power (W)	Lamp Arc Power (W)	BLE (%)	System Initial Light Output (lm)	System Mean Light Output (lm)	Percentage Change Mean Lumen Output (%)	Ballast Manufacturer Selling Price (2009$)	Lamp Retail Price (2007$)	Normalized Input Power (W)
Baseline /EL1	2 F32T8 Lamps	Electronic	IS	277	Dedicated	0.90	57.1	49.1	86.0	5111	4847	0%	$6.94	$6.38	56.3
EL2	2 F32T8 Lamps	Electronic	IS	277	Universal	0.90	55.1	49.6	90.1	5170	4902	1%	$8.85	$6.38	53.7
EL3	2 F32T8 Lamps	Electronic	IS	277	Universal	0.90	54.0	49.2	91.1	5124	4859	0%	$9.27	$6.38	53.1

Table 5.13 presents the engineering characteristics of the ballast replacement options for the baseline F34T12 system in the 2-lamp MBP IS and RS representative ballast type. If a direct substitution is made, mean lumen output does not change by more than three percent relative to the mean lumen output of the baseline system. The representative F34T12 baseline ballast has a relatively low BF of 0.80. Typical F32T8 replacements have a higher ballast factor which results in increased total lumen output.

Table 5.13 Two-lamp MBP IS and RS Representative Ballast Type with F34T12 Baseline

Efficiency Level	For Operation Of	Ballast Type	Starting Method	Input Voltage	Universal or Dedicated Voltage	Ballast Factor	Input Power (W)	Lamp Arc Power (W)	BLE (%)	System Initial Light Output (lm)	System Mean Light Output (lm)	Percentage Change Mean Lumen Output (%)	Ballast Manufacturer Selling Price (2009$)	Lamp Retail Price (2007$)	Normalized Input Power (W)
Baseline	2 F34T12 Lamps	Electronic	RS	277	Universal	0.80	61.1	47.5	77.8	5040	4779	0%	$8.41	$11.65	60.7
EL1	2 F32T8 Lamps	Electronic	IS	277	Dedicated	0.90	57.1	49.1	86.0	5111	4847	1%	$6.94	$6.38	56.3
EL2	2 F32T8 Lamps	Electronic	IS	277	Universal	0.90	55.1	49.6	90.1	5170	4902	3%	$8.85	$6.38	53.7
EL3	2 F32T8 Lamps	Electronic	IS	277	Universal	0.90	54.0	49.2	91.1	5124	4859	2%	$9.27	$6.38	53.1

5.10 INSTANT AND RAPID START BALLASTS THAT OPERATE FOUR FOUR-FOOT MBP AND TWO-FOOT U-SHAPED LAMPS IN THE COMMERCIAL SECTOR

The IS and RS product class includes three representative ballast types, including IS and RS ballasts that operate four 4-foot MBP and 2-foot U-shaped lamps in the commercial sector. DOE presents its analysis of this ballast type in the following sections.

5.10.1 Baseline Models

Although census data indicates that both T12 and T8 ballasts that operate 4-foot and 2-foot U-shaped MBP lamps exist in the market, DOE research found that only T8 ballasts operate four lamps. Therefore, DOE analyzed only a T8 ballast as a baseline ballast for the 4-lamp 4-foot and 2-foot U-shaped MBP IS and RS normal BF representative ballast type (hereafter referred to as the 4-lamp MBP IS and RS representative ballast type). Furthermore, DOE chose to analyze only those ballasts that operate the F32T8 lamp because this lamp is the most common 4-foot MBP T8 lamp.

In choosing the most appropriate F32T8 ballast for this representative ballast type, DOE considered the ballast's characteristics. Because there is no Federal energy conservation standard, DOE chose a baseline ballast that exhibits the characteristics of the least efficient and most common ballast.

DOE tested a range of F32T8 ballasts from multiple ballast manufacturers and found that the least efficient but most common ballast exhibited the characteristics shown in Table 5.14 below. The vast majority of T8 ballasts are IS, electronic, have a high PF (>0.98), and have a THD <10 percent. Finally, DOE chose a ballast that has an input voltage of 277V as the majority of ballasts operate in commercial buildings at 277V.

Table 5.14 Baseline Ballast for the 4-lamp MBP IS and RS Representative Ballast Type

For Operation of	Starting Method, Input Voltage, Ballast Type, PF, THD	BF	Input Power *W*	BLE (%)	Federal Energy Conservation Standard
4, F32T8 Lamps	IS, 277V, Electronic, Universal Voltage, >0.99 PF, <10% THD	0.89	106.2	92.0%	N/A

As discussed above, DOE paired both commercial and industrial 4-foot MBP and 2-foot U-shaped ballasts with an appropriate reduced wattage F32T8 lamp, which was designed to reflect the distribution of energy-saving lamps on the market. The characteristics of these lamps are listed in the table below.

Table 5.15 Lamp for Use with F32T8 Ballasts

Lamp Type	CCT	Rated Efficacy*	Initial Light Output	Mean Light Output	Life	CRI
	K	*lm/W*	*lm*	*lm*	*hr*	
F32T8	4,100	92.9	2,860	2,712	24,091	85
* Rated efficacy is based on the weighted-average lamp wattage of 4-ft T8 MBP lamps which is 30.77W.						

This combination of lamp and ballast represents the most common configuration for these ballasts in existing and new installations. Together, this lamp and ballast combination creates a system lumen package of approximately 9,644 mean lumens (and 10,170 initial lumens) for the baseline F32T8 IS ballast.

5.10.2 Efficiency Levels

The following discussion identifies the steps and technologies associated with each EL DOE considered for the 4-lamp MBP IS and RS representative ballast type. As discussed in the screening analysis (final rule TSD chapter 4), DOE used design options that achieve a higher BLE than the baseline ballast. Because the baseline ballast is an electronic T8 ballast, improvements required the use of the following design options: improved components and improved circuit design. For the 4-lamp MBP IS and RS representative ballast type, DOE identified three ELs. EL3 represents the maximum technologically feasible level.

Baseline/EL2. Though ballasts in other representative ballast types in the IS and RS product class were identified at EL1 or below, the least efficient 4-lamp MBP IS and RS ballasts tested just met EL2.

EL3. This level requires the use of improved components and represents the maximum technologically feasible level.

Table 5.16 Summary of ELs for Four-lamp MBP IS and RS Ballasts

Efficiency Level	BLE Requirement With Variation Reduction
EL1	0.993/(1+0.46*total lamp arc power^-0.25)
EL2	0.993/(1+0.31*total lamp arc power^-0.25)
EL3	0.993/(1+0.27*total lamp arc power^-0.25)

Figure 5.3 illustrates the three ELs on a plot of 4-lamp MBP IS and RS ballasts. A star indicates a representative unit tested by DOE. Diamonds indicate other 4-lamp MBP IS and RS ballasts tested by DOE.

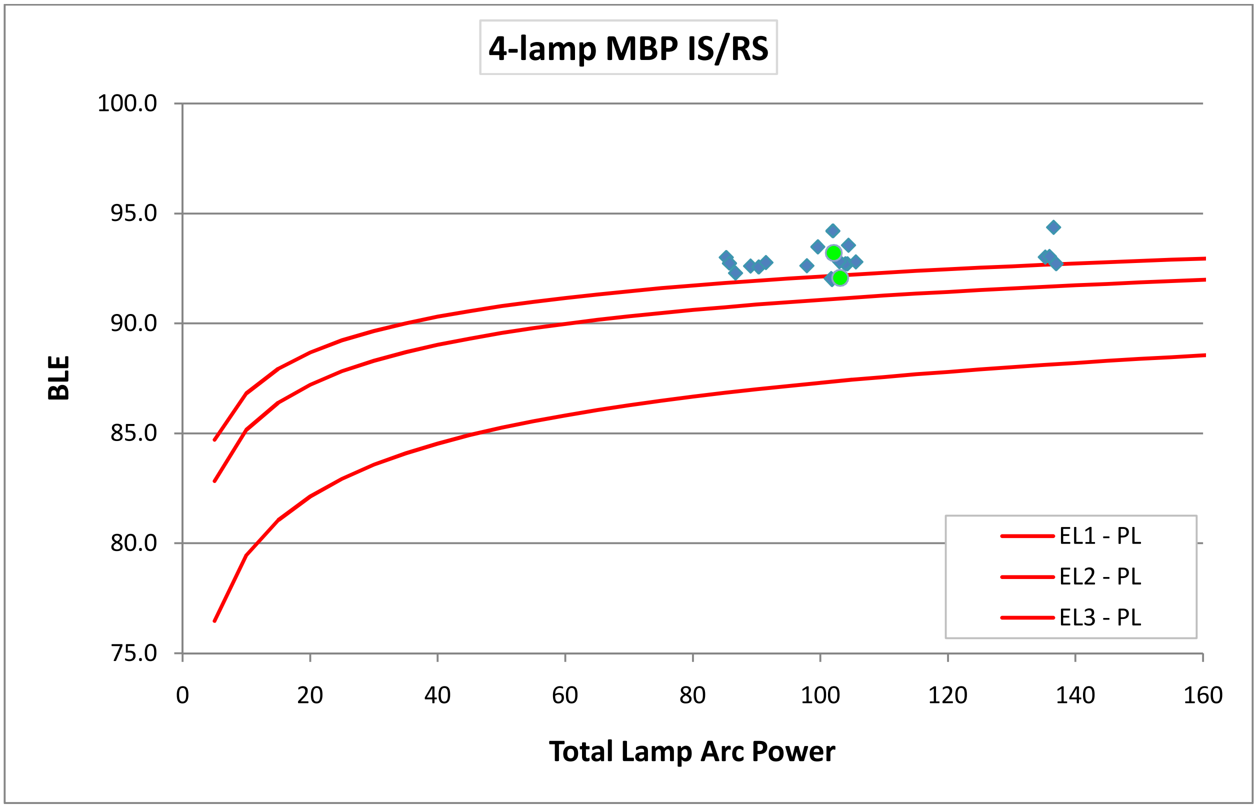


Figure 5.3 Efficiency Levels for the 4-lamp MBP IS and RS Representative Ballast Type

Table 5.17 provides detailed information on the 4-foot MBP ballast designs used in the engineering analysis and subsequent analyses. In general, for the 4-lamp MBP IS and RS representative ballast type, ballasts at higher efficiencies can operate at multiple voltages and have a similar BF and PF as the baseline ballast designs.

Table 5.17 Ballast Designs for the 4-lamp MBP IS and RS Representative Ballast Type

Efficiency Level	For Operation Of	Ballast Type	Starting Method	Input Voltage	Universal or Dedicated Voltage	Power Factor	THD (%)	Ballast Factor	Input Power	Lamp Arc Power	BLE (%)
Baseline /EL2	4 F32T8 Lamps	Electronic	IS	277	Universal	0.99	<10	0.89	106.2	97.6	92.0
EL3	4 F32T8 Lamps	Electronic	IS	277	Universal	0.98	<10	0.88	103.5	96.6	93.3

5.10.3 Lamp and Ballast Prices

DOE analyzed each EL for the 4-lamp MBP IS and RS representative ballast type to develop appropriate MSPs. The baseline/EL2 and EL3 MSPs were calculated using the average of the teardown- and blue book-sourced MSPs. DOE found that the MSP increased with increased efficiency for this representative ballast type as depicted in Table 5.18.

Table 5.18 Summary of the Manufacturing Selling Price for the 4-lamp MBP IS and RS Representative Ballast Type

Efficiency Level	Lamp Type	Starting Method	MSP (2009$)
Baseline/EL2	F32T8	IS	$9.79
EL3	F32T8	IS	$11.63

The following table depicts the appropriate lamp prices for the baseline lamps as used in the 2009 Lamps Rule (see section 5.9.3).

Table 5.19 Retail Prices for Four-Foot Medium Bipin Fluorescent Lamps

Lamp Type	Retail Price (2007$)
F32T8	$3.19

5.10.4 Results

Table 5.20 presents the engineering characteristics of the ballast replacement option for the baseline F32T8 system in the 4-lamp MBP IS and RS representative ballast type. Because the BF of EL3 is slightly lower than the baseline system, the normalized input power is higher than the measured input power. If a direct substitution is made, mean lumen output does not change by more than one percent relative to the mean lumen output of the baseline system.

Table 5.20 Four-Lamp MBP IS and RS Representative Ballast Type with F32T8 Baseline

Efficiency Level	For Operation Of	Ballast Type	Starting Method	Input Voltage	Universal or Dedicated Voltage	Ballast Factor	Input Power (W)	Lamp Arc Power (W)	BLE (%)	System Initial Light Output (lm)	System Mean Light Output (lm)	Percentage Change Mean Lumen Output (%)	Ballast Manufacturer Selling Price (2009$)	Lamp Retail Price (2007$)	Normalized Input Power (W)
Baseline/EL2	4 F32T8 Lamps	Electronic	IS	277	Universal	0.89	106.2	97.6	92.0	10,170	9.644	0%	$9.79	$12.76	106.2
EL3	4 F32T8 Lamps	Electronic	IS	277	Universal	0.88	103.5	96.6	93.3	10,068	9.547	-1%	$11.63	$12.76	104.6

5.11 INSTANT AND RAPID START BALLASTS THAT OPERATE TWO EIGHT-FOOT SP SLIMLINE LAMPS

The IS and RS product class includes three representative ballast types, including IS and RS ballasts that operate two 8-foot SP slimline lamps. DOE presents its analysis of this ballast type in the following sections.

5.11.1 Baseline Models

For the 2-lamp 8-foot SP slimline normal BF representative ballast type; hereafter referred to as the 8-foot SP slimline representative ballast type), DOE chose to analyze two baseline ballasts. Census data indicates that 2001 shipments of 8-foot SP slimline T12 ballasts represented approximately 50 percent of all shipments while 8-foot SP slimline T8 ballasts represented the remaining approximately 50 percent.[11] Therefore, DOE analyzed both a T12 and T8 ballast as baseline ballasts. Because the 2009 Lamps Rule eliminated all currently commercially available T12 lamps by 2012, DOE created an F96T12/ES lamp that complied with the 2009 Lamps Rule to pair with T12 ballasts (see section 5.9.1). Because only the most efficient T12 lamps will be available when this ballast rulemaking takes effect, DOE chose to analyze only those T12 ballasts that operate F96T12/ES lamps for this rulemaking. For the T8 baseline, DOE chose to analyze only those ballasts that operate the F96T8 lamp because this lamp is the most common 8-foot SP slimline T8 lamp.

The Federal minimum energy conservation standards for ballasts that operate two F96T12/ES lamps became effective for ballasts manufactured on or after July 1, 2009. (10 CFR Part 430.32 (m)(5)). This energy conservation standard effectively allowed only electronic F96T12/ES ballasts. Therefore, DOE chose an electronic ballast as the F96T12/ES baseline ballast. To determine the BLE of the baseline ballast, DOE tested multiple ballasts operating a reference F96T12/ES lamp. The BLE, BF, and input power of the most common F96T12/ES ballast that just meets the minimum energy conservation standard of 88.4 percent (BEF of 0.77) is shown in Table 5.21 below. All T12 electronic ballasts in product catalogs are IS, dedicated voltage, and have a high PF. The ballast that just meets the energy conservation standard also exhibits these characteristics. DOE also chose a ballast that has an input voltage of 277V because the majority of ballasts operate in commercial buildings at 277V. There are multiple THD values for electronic F96T12/ES. These range from <20 percent to <14 percent and <10 percent. DOE chose a ballast with a THD of <20 percent because it represented the least efficient T12 ballast.

Currently there is no federal minimum energy conservation standard for ballasts that operate F96T8 lamps. Therefore, in choosing the baseline ballast for this lamp type, DOE chose the most common, least efficient ballast on the market. DOE tested a range of F96T8 ballasts from multiple ballast manufacturers and found that the least efficient but most common ballast exhibited the characteristics shown in the table below. The vast majority of F96T8 ballasts are IS, electronic, and have a high PF (>0.98). Furthermore, the majority of the least efficient T8 ballasts are universal voltage and have a THD <10 percent. Finally, like the F96T12/ES baseline

[11] More recent census data for ballasts is available. However, shipments of T12 ballasts have not been publicly released after 2001. T12 ballast shipments also include data for the 6-foot SP slimline ballast which DOE estimates is negligible when compared to the 8-foot shipments.

ballast, DOE chose a ballast that has an input voltage of 277V as the majority of ballasts operate in commercial buildings at 277V.

Table 5.21 Baseline Ballasts for the Eight-Foot SP Slimline Representative Ballast Type

For Operation of	Starting Method, Input Voltage, Ballast Type, PF, THD	BF	Input Power (W)	BLE (%)	Federal Energy Conservation Standard
2, F96T12/ES Lamps	IS, 277V, Electronic, Dedicated Voltage, >0.98, PF, <20% THD	0.88	113.5	88.9	88.4
2, F96T8 Lamps	IS, 277V, Electronic, Universal Voltage, >0.98 PF, <10% THD	0.88	107.8	91.6%	N/A

As discussed above, DOE paired 8-foot SP slimline ballasts with an appropriate F96T12/ES or reduced wattage F96T8 lamp, which was designed to reflect the distribution of energy-saving lamps on the market. The characteristics of these lamps are listed in the table below.

Table 5.22 Lamps for Use with F96T8 and F96T12/ES Ballasts

Lamp Type	CCT	Rated Efficacy*	Initial Light Output	Mean Light Output	Life	CRI
	K	*lm/W*	*lm*	*lm*	*hr*	
F96T12/ES	4,100	99.6	6,025	5,604	15,000	N/A
F96T8	4,100	99.6	5,909	5,497	16,667	82
* Rated efficacy is based on the rated wattage of the F96T12/ES lamp, which is 60.5W and the weighted-average lamp wattage of T8 8-foot SP slimline lamps for the F96T8 lamp, which is 59.34W.						

This combination of lamp and ballast represents the most common configuration for these ballasts in existing and new installations. Together, this lamp-and-ballast combination creates a system lumen package of approximately 9,855 mean lumens (and 10,593 initial lumens) for the baseline F96T12/ES ballast, approximately 9,641 mean lumens (and 10,364 initial lumens) for the baseline F96T8 IS ballast.

5.11.2 Efficiency Levels

The following discussion identifies the steps and technologies associated with each EL DOE considered for the 8-foot SP slimline representative ballast type. As discussed in the screening analysis (final rule TSD chapter 4), DOE used design options that achieve a higher BLE than the baseline ballast. Because the baseline ballasts are electronic ballasts, improvements required the use of the following design options: improved components and improved circuit design. For the 8-foot SP slimline representative ballast type, DOE identified three ELs. EL3 represents the maximum technologically feasible level.

Baseline/EL1. EL1 for the IS and RS representative product class does not affect the 8-foot SP slimline representative ballast type. The baseline T12 ballast just meets EL1.

Baseline/EL2. This level affects the baseline T12 ballast but not the baseline T8 ballast. The least efficient T8 ballast just meets this level. Ballasts at this level use better components and more efficient circuit designs than those ballasts that just meet EL1.

EL3. This level affects both the baseline T12 and T8 ballast. No T12 ballasts meet this level. T8 ballasts at this level use slightly better components and circuit designs than those ballasts that just meet EL2. EL3 also represents the maximum technologically feasible level.

Table 5.23 Summary of ELs for Eight-foot SP Slimline Ballasts

Efficiency Level	BLE Requirement With Variation Reduction
EL1	0.993/(1+0.46*total lamp arc power^-0.25)
EL2	0.993/(1+0.31*total lamp arc power^-0.25)
EL3	0.993/(1+0.27*total lamp arc power^-0.25)

Figure 5.4 illustrates the three ELs on a plot of 8-foot SP Slimline ballasts. A circle indicates a representative unit tested by DOE. Diamonds indicate other 8-foot SP Slimline ballasts tested by DOE.

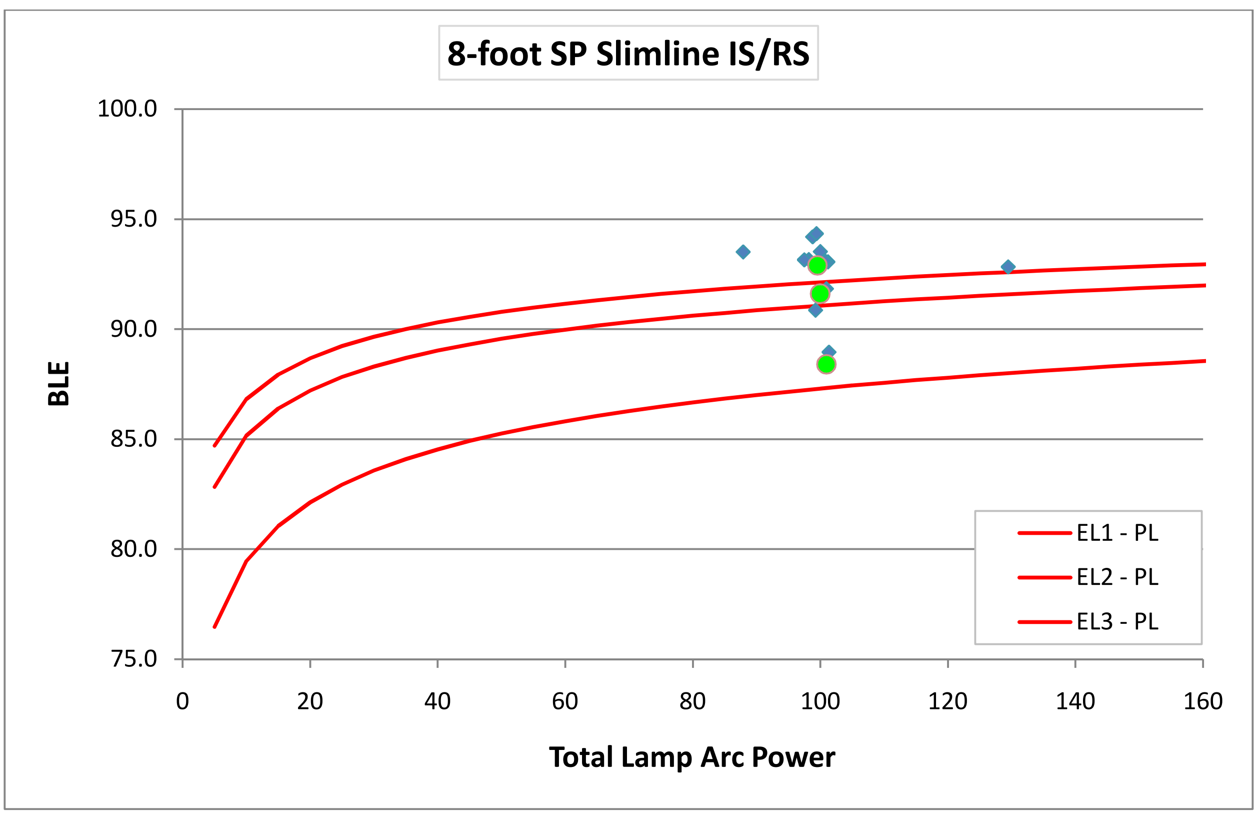


Figure 5.4 Efficiency Levels for the Eight-Foot SP Slimline Representative Ballast Type

Table 5.24 provides detailed information on the 8-foot SP slimline ballast designs used in the engineering analysis and subsequent analyses. For the F96T8 and F96T12/ES ballasts, the ballast characteristics remain the same as the baseline system.

Table 5.24 Ballast Designs for the Eight-Foot SP Slimline Representative Ballast Type

Efficiency Level	For Operation Of	Ballast Type	Starting Method	Input Voltage	Universal or Dedicated Voltage	Power Factor	THD (%)	Ballast Factor	Input Power (W)	Lamp Arc Power (W)	BLE (%)
Baseline /EL1	2 F96T12ES Lamps	Electronic	IS	277	Dedicated	0.98	<20	0.88	113.5	100.9	88.9
Baseline /EL2	2 F96T8 Lamps	Electronic	IS	277	Universal	0.98	<10	0.88	107.8	98.7	91.6
EL3	2 F96T8 Lamps	Electronic	IS	277	Dedicated	0.98	<10	0.87	105.8	98.3	92.9

5.11.3 Lamp and Ballast Prices

DOE analyzed each EL for the 8-foot SP slimline representative ballast type to develop appropriate MSPs. DOE based the EL3 MSP on an average of teardown- and blue book-sourced MSPs, while the EL1 and EL2 MSPs were based on only blue book-sourced MSPs. DOE found that the MSP increased with increased efficiency for all ELs.

Table 5.25 Manufacturing Selling Prices for the Eight-Foot SP Slimline Representative Ballast Type

Efficiency Level	Lamp Type	MSP (2009$)
Baseline/EL1	F96T12/ES	$8.84
Baseline/EL2	F96T8	$10.05
EL3	F96T8	$10.29

The following table depicts the appropriate lamp prices for the baseline lamps as used in the 2009 Lamps Rule (see section 5.9.3).

Table 5.26 Retail Prices for Eight-Foot SP Slimline Fluorescent Lamps

Lamp Type	Retail Price (2007$)
F96T12/ES	$7.00
F96T8	$6.07

5.11.4 Results

Table 5.27 presents the engineering characteristics of the ballast replacement options for the baseline F96T12/ES system in the 8-foot SP slimline representative ballast type. Because the

BF of the standards-case systems are slightly less than the baseline system, the normalized input power is higher than the measured input power. If a direct substitution is made, mean lumen output does not change by more than three percent relative to the mean lumen output of the baseline system.

Table 5.27 Eight-Foot SP Slimline Representative Ballast Type with F96T12/ES Baseline

Efficiency Level	For Operation Of	Ballast Type	Starting Method	Input Voltage	Universal or Dedicated Voltage	Ballast Factor	Input Power (W)	Lamp Arc Power (W)	BLE (%)	System Initial Light Output (lm)	System Mean Light Output (lm)	Percentage Change Mean Lumen Output (%)	Ballast Manufacturer Selling Price (2009$)	Lamp Retail Price (2007$)	Normalized Input Power (W)
Baseline /EL1	2 F96T12ES Lamps	Electronic	IS	277	Dedicated	0.88	113.5	100.9	88.9	10,593	9,855	0%	$8.84	$14.00	113.5
Baseline /EL2	2 F96T8 Lamps	Electronic	IS	277	Universal	0.88	107.8	98.7	91.6	10,364	9,641	-2%	$10.05	$12.14	110.2
EL3	2 F96T8 Lamps	Electronic	IS	277	Dedicated	0.87	105.8	98.3	92.9	10,318	9,599	-3%	$10.29	$12.14	108.6

Table 5.28 presents the engineering characteristics of the ballast replacement options for the baseline F96T8 system in the 8-foot SP slimline representative ballast type. Because the BF of the standards-case systems are slightly less than the baseline system, the normalized input power is closer to the measured input power. If a direct substitution is made, mean lumen output does not change by more than 0.4 percent (rounded in Table 5.28 to zero percent) relative to the mean lumen output of the baseline system.

Table 5.28 Eight-Foot SP Slimline Representative Ballast Type with F96T8 Baseline

Efficiency Level	For Operation Of	Ballast Type	Starting Method	Input Voltage	Universal or Dedicated Voltage	Ballast Factor	Input Power (W)	Lamp Arc Power (W)	BLE (%)	System Initial Light Output (lm)	System Mean Light Output (lm)	Percentage Change Mean Lumen Output (%)	Ballast Manufacturer Selling Price (2009$)	Lamp Retail Price (2007$)	Normalized Input Power (W)
Baseline /EL2	2 F96T8 Lamps	Electronic	IS	277	Universal	0.88	107.8	98.7	91.6	10,364	9,641	0%	$10.05	$12.14	110.2
EL3	2 F96T8 Lamps	Electronic	IS	277	Dedicated	0.87	105.8	98.3	92.9	10,318	9,599	0%	$10.29	$12.14	108.6

5.12 INSTANT START AND RAPID START RESIDENTIAL BALLASTS THAT OPERATE TWO FOUR-FOOT MBP AND TWO-FOOT U-SHAPED LAMPS

The IS and RS residential product class includes one representative ballast type: ballasts that operate two 4-foot MBP and 2-foot U-shaped lamps in the residential sector. DOE presents its analysis of this ballast type in the following sections.

5.12.1 Baseline Models

For the residential 2-lamp 4-foot MBP and 2-foot U-shaped IS and RS representative ballast type (hereafter referred to as the residential representative ballast type), DOE chose to analyze two baseline ballasts. Census data indicates that the market share of low power factor magnetic ballasts was about 7 percent during the years from 1995 to 2002, and then decreased to about 1.5 percent in 2005.[12] However, DOE believes that the Census data does not accurately reflect the residential ballast market. First, electronic ballasts are a common option for residential fluorescent lighting fixtures, but they are not reported in the Census data. Second, many residential ballasts are manufactured overseas by foreign companies which do not share shipment data with the U.S. Census. Through manufacturer interviews, DOE learned that both T12 and T8 ballasts are popular in the residential market. Therefore, DOE analyzed both a T12 and T8 ballast as a baseline ballast. Because the 2009 Lamps Rule will eliminate all currently commercially available T12 lamps by 2012, DOE created an F34T12 lamp that complied with the 2009 Lamps Rule to pair with T12 ballasts (see section 5.9.1). Because only the most efficient T12 lamps will be available when this ballast rulemaking takes effect, DOE chose to analyze only those T12 ballasts that operate F34T12 lamps for this rulemaking. For the T8 baseline, DOE paired its T8 baseline ballast with an F32T8 lamp because DOE believed it was the most common wattage lamp at that diameter.

The Federal minimum energy conservation standard for ballasts that operate two F34T12 lamps is effective for residential ballasts manufactured on or after July 1, 2010. (10 CFR Part 430.32 (m)(5)). This energy conservation standard effectively allowed only electronic F34T12 ballasts. Therefore, DOE chose an electronic ballast as the T12 residential baseline ballast. To determine the BLE of the baseline ballast, DOE tested multiple ballasts operating a reference F34T12 lamp. The BLE, BF, and input power of the most common T12 ballast that just meets the minimum energy conservation standard of 80.5 percent (BEF of 1.35) is shown in Table 5.29 below. DOE research discovered that most ballasts sold in the residential market are sold as part of a fixture. Therefore, DOE researched the most common fixtures sold in the residential market. DOE then obtained the fixtures, removed the ballast, and tested the ballast to determine the least efficient and most common option. Other residential ballasts were procured independent of a fixture. The majority of ballasts in the residential market operate two lamps, have an input voltage of 120V, have a low power factor ($0.5<PF<0.9$), and are sold in striplights (also known as shoplights). The baseline T12 ballast exhibits these characteristics. The BLE, BF, and input power of the T12 and T8 baseline ballasts are shown in Table 5.29.

[12] Low power factor ballasts are ballasts with a power factor less than 0.9 and are typically used in residential applications.

For the T8 baseline, DOE also chose the most common, least efficient ballast on the market. DOE tested a range of F32T8 ballasts from multiple ballast manufacturers and in multiple fixtures. DOE found that the least efficient but most common ballast exhibited the characteristics shown in the table below. The majority of F32T8 ballasts in the residential sector operate two lamps, are electronic, are IS, and operate at a dedicated voltage of 120V. The characteristics of the T8 baseline ballast are summarized in Table 5.29.

Table 5.29 Baseline Ballasts for the Residential Representative Ballast Type

For Operation of	Starting Method, Input Voltage, Ballast Type, PF	BF	Input Power (W)	BLE (%)	Federal Energy Conservation Standard
2, F34T12 Lamps	RS, 120V, Electronic, Dedicated Voltage, >0.50 PF	0.82	62.6	77.7	80.5%
2, F32T8 Lamps	IS, 120V, Electronic, Dedicated Voltage, >0.50 PF	0.81	50.9	87.2%	N/A

As discussed above, DOE paired both commercial and industrial 4-foot and 2-foot U-shaped MBP ballasts with an appropriate F34T12 and a reduced wattage F32T8 lamp, which was designed to reflect the distribution of energy-saving lamps on the market. The characteristics of these lamps are listed in the table below.

Table 5.30 Lamps for Use with F32T8 and F34T12 Ballasts

Lamp Type	CCT	Rated Efficacy*	Initial Light Output	Mean Light Output	Life	CRI
	K	*lm/W*	*lm*	*lm*	*hr*	
F34T12	4,100	92.9	3,160	2,997	24,000	N/A
F32T8	4,100	92.9	2,860	2,712	24,091	85
* Rated efficacy is based on the rated wattage of the F34T12 lamp, which is 34W and the weighted-average lamp wattage of 4-ft T8 MBP lamps for the F32T8 lamp, which is 30.77W						

This combination of lamp and ballast represents the most common configuration for these ballasts in existing and new installations. Together, these lamp-and-ballast combinations create a system lumen package of approximately 4,889 mean lumens (and 5,155 initial lumens) for the baseline F34T12 ballast, and approximately 4,384 mean lumens (and 4,623 initial lumens) for the baseline F32T8 ballast.

5.12.2 Efficiency Levels

The following discussion identifies the steps and technologies associated with each EL DOE considered for the residential representative ballast type. As discussed in the screening analysis (final rule TSD chapter 4), DOE used design options that achieve a higher BLE than the baseline ballast. Because the baseline ballasts are electronic ballasts, improvements required the use of the improved components and improved circuit design. For the residential representative ballast type, DOE identified three ELs. EL2 represents the maximum technologically feasible level.

EL1. This level affects the F34T12 baseline ballast but not the F32T8 baseline ballast. No T12 ballasts meet this level. In addition, ballasts must use improved circuit designs (a starting method that is IS rather than RS).

EL.2 This level again affects both baseline ballasts and represents the maximum technologically feasible level. This level represents a modest improvement in efficiency over EL1. Ballasts at this level use slightly better components and circuit designs than those ballasts that just meet EL1.

Table 5.31 Summary of ELs for Residential Ballasts

Efficiency Level	BLE Requirement With Variation Reduction
EL1	0.993/(1+0.41*total lamp arc power^-0.25)
EL2	0.993/(1+0.29*total lamp arc power^-0.25)

Figure 5.5 illustrates the three ELs on a plot of residential ballasts. A circle indicates a representative unit tested by DOE. Diamonds indicate other residential ballasts tested by DOE.

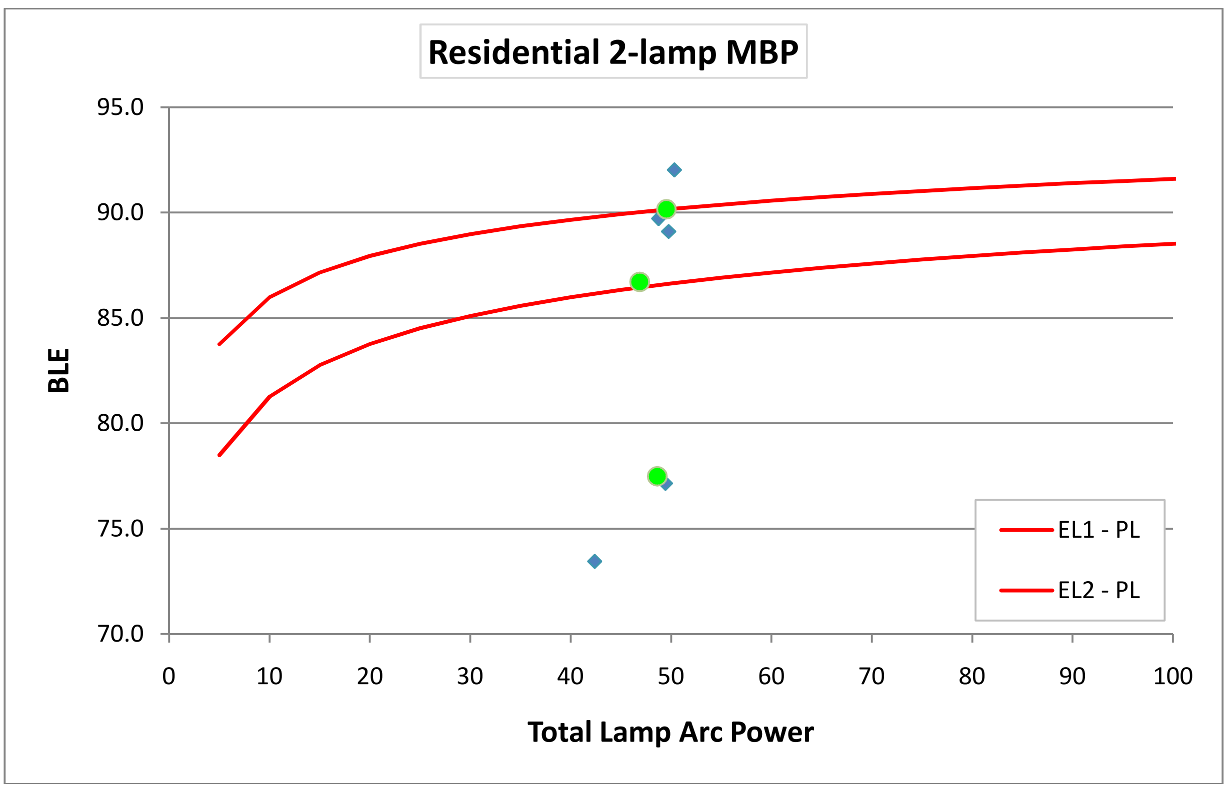


Figure 5.5 Efficiency Levels for the Residential Representative Ballast Type

Table 5.32 provides detailed information on the 4-foot MBP ballast designs used in the engineering analysis and subsequent analyses.

Table 5.32 Ballast Designs for the Residential Representative Ballast Type

Efficiency Level	For Operation Of	Ballast Type	Starting Method	Input Voltage	Universal or Dedicated Voltage	Power Factor	THD (%)	Ballast Factor	Input Power (W)	Lamp Arc Power (W)	BLE (%)
Baseline	2 F34T12 Lamps	Electronic	RS	120	Dedicated	-	<20	0.82	62.6	48.6	77.7
Baseline /EL1	2 F32T8 Lamps	Electronic	IS	120	Dedicated	-	-	0.81	50.9	44.7	87.2
EL2	2 F32T8 Lamps	Electronic	IS	120	Dedicated	>0.5	<120	0.85	52.1	46.6	90.0

5.12.3 Lamp and Ballast Prices

DOE analyzed each EL for the residential representative ballast type to develop appropriate MSPs. For the baseline and EL1, DOE used blue book-sourced MSPs. For EL2, DOE used a manufacturer-sourced MSP. DOE found the MSP for the F34T12 ballast was higher than the baseline/EL1 F32T8 ballast. The F34T12 electronic ballast is sold at lower volumes than electronic F32T8 ballasts. DOE attributes the smaller shipments volume to its high cost relative to its efficiency. Table 5.33 lists the MSPs for the residential representative ballast type.

Table 5.33 Manufacturing Selling Prices for the Residential Representative Ballast Type

Efficiency Level	Lamp Type	MSP (2009$)
Baseline	F34T12	$4.68
Baseline/EL1	F32T8	$3.77
EL2	F32T8	$4.62

The following table depicts the appropriate lamp prices for the baseline lamps as used in the 2009 Lamps Rule.

Table 5.34 Retail Prices for Four-Foot MBP Fluorescent Lamps

Lamp Type	Retail Price (2007$)
F34T12	$5.83
F32T8	$3.19

5.12.4 Results

Table 5.35 presents the engineering characteristics of the ballast replacement options for the baseline F34T12 system in the residential representative ballast type. If a direct substitution is made, mean lumen output can increase by as much as ten percent over the mean lumen output of the baseline system because of the difference in ballast factor. For the residential sector, DOE believes that consumers are more likely to purchase replacement fixtures rather than direct ballast replacements.

Table 5.35 Residential Representative Ballast Type with F34T12 Baseline

Efficiency Level	For Operation Of	Ballast Type	Starting Method	Input Voltage	Universal or Dedicated Voltage	Ballast Factor	Input Power (W)	Lamp Arc Power (W)	BLE (%)	System Initial Light Output (lm)	System Mean Light Output (lm)	Percentage Change Mean Lumen Output (%)	Ballast Manufacturer Selling Price (2009$)	Lamp Retail Price (2007$)	Normalized Input Power (W)
Baseline	2 F34T12 Lamps	Electronic	IS	120	Dedicated	0.82	62.6	48.6	77.7	5,155	4,889	0%	$4.68	$11.65	62.6
Baseline/EL1	2 F32T8 Lamps	Electronic	IS	120	Dedicated	0.81	50.9	44.7	87.2	4,623	4,384	-10%	$3.77	$6.38	56.8
EL2	2 F32T8 Lamps	Electronic	IS	120	Dedicated	0.85	52.1	46.6	90.0	4,886	4,633	-5%	$4.62	$6.38	55.0

Table 5.36 presents the engineering characteristics of the ballast replacement options for the baseline F32T8 system in the residential representative ballast type If a direct substitution is made, mean lumen output does not change by more than five percent relative to the mean lumen output of the baseline system.

Table 5.36 Residential Representative Ballast Type with F32T8 Baseline

Efficiency Level	For Operation Of	Ballast Type	Starting Method	Input Voltage	Universal or Dedicated Voltage	Ballast Factor	Input Power (W)	Lamp Arc Power (W)	BLE (%)	System Initial Light Output (lm)	System Mean Light Output (lm)	Percentage Change Mean Lumen Output (%)	Ballast Manufacturer Selling Price (2009$)	Lamp Retail Price (2007$)	Normalized Input Power (W)
Baseline/ EL1	2 F32T8 Lamps	Electronic	IS	120	Dedicated	0.81	50.9	44.7	87.2	4,623	4,384	0%	$3.77	$6.38	56.8
EL2	2 F32T8 Lamps	Electronic	IS	120	Dedicated	0.85	52.1	46.6	80.0	4,886	4,633	5%	$4.62	$6.38	55.0

5.13 PROGRAMMED START BALLASTS THAT OPERATE TWO FOUR-FOOT MBP AND TWO-FOOT U-SHAPED LAMPS

The PS product class includes four representative ballast types, including PS ballasts that operate two 4-foot MBP and 2-foot U-shaped lamps. DOE presents its analysis of this ballast type in the following sections.

5.13.1 Baseline Models

For the 2-lamp 4-foot MBP and 2-foot U-shaped PS normal BF representative ballast type (hereafter the 2-lamp MBP PS representative ballast type), DOE found that only F32T8 ballasts operate in this representative ballast type. DOE tested a range of F32T8 PS ballasts from multiple ballast manufacturers and found that the least efficient of these ballasts exhibited the characteristics shown in Table 5.37 below. This ballast, like the majority of PS ballasts on the market, is electronic, has a high PF (~0.98), has a low THD (<10 percent), and is universal voltage.

Table 5.37 Baseline Units for the 2-lamp MBP PS Representative Ballast Type

For operation of	Starting Method, Input Voltage, Ballast Type, PF, THD	BF	Input Power	BLE (%)	Federal Energy Conservation Standards (BEF)
2, F32T8 lamps	PS, 277V, Electronic, >0.98, <10% THD, Universal Voltage	0.91	60.0	83.2%	N/A

As discussed above, DOE paired 4-foot MBP ballasts with an appropriate reduced wattage F32T8 lamp, which was designed to reflect the distribution of energy-saving lamps on the market. The characteristics of these lamps are listed in the table below.

Table 5.38 Lamps for Use with F32T8 Ballasts

Lamp Type	CCT	Rated Efficacy*	Initial Light Output	Mean Light Output	Life	CRI
	K	*lm/W*	*lm*	*lm*	*hr*	
F32T8	4,100	92.9	2,860	2,712	24,091	85
* Rated efficacy is based on the weighted-average lamp wattage of 4-ft T8 MBP lamps which is 30.77W.						

This combination of lamp and ballast represents the most common configuration for these ballasts in existing and new installations. Together, these lamp-and-ballast combinations create a system lumen package of approximately 4,929 mean lumens (and 5,198 initial lumens) for the baseline F32T8 ballast.

5.13.2 Efficiency Levels

The following discussion identifies the steps and technologies associated with each EL DOE considered for the 2-lamp MBP PS representative ballast type. As discussed in the screening analysis (final rule TSD chapter 4), DOE considered design options that achieve a higher BLE than the baseline ballast. Because the baseline ballast is a T8 electronic ballast, improvements required the use of the following design options: improved components and improved circuit design. For the 2-lamp MBP PS ballasts, DOE identified three ELs. EL3 represents the maximum technologically feasible level.

EL1. DOE did not identify 2-lamp 4-foot MBP PS ballasts at EL1, though other ballasts in the PS product class did fall in EL1.

EL2. EL2 requires the use of improved circuit designs for the 2-lamp MBP PS ballast. Specifically, ballasts at this level use some reduction of cathode heating of the filament after the lamp starts.

EL3. EL3 represents the maximum technologically feasible EL. Ballasts at this level will use slightly better components and circuit designs than those ballasts that just meet EL2.

Table 5.39 Summary of ELs for Two-Lamp MBP PS Ballasts

Efficiency Level	BLE Requirement With Variation Reduction
EL1	0.993/(1+0.60*total lamp arc power^-0.37)
EL2	0.993/(1+0.55*total lamp arc power^-0.37)
EL3	0.993/(1+0.51*total lamp arc power^-0.37)

Figure 5.6 illustrates the three ELs on a plot of 2-lamp MBP PS ballasts. A circle indicates a representative unit tested by DOE. Diamonds indicate other 2-lamp MBP PS ballasts tested by DOE.

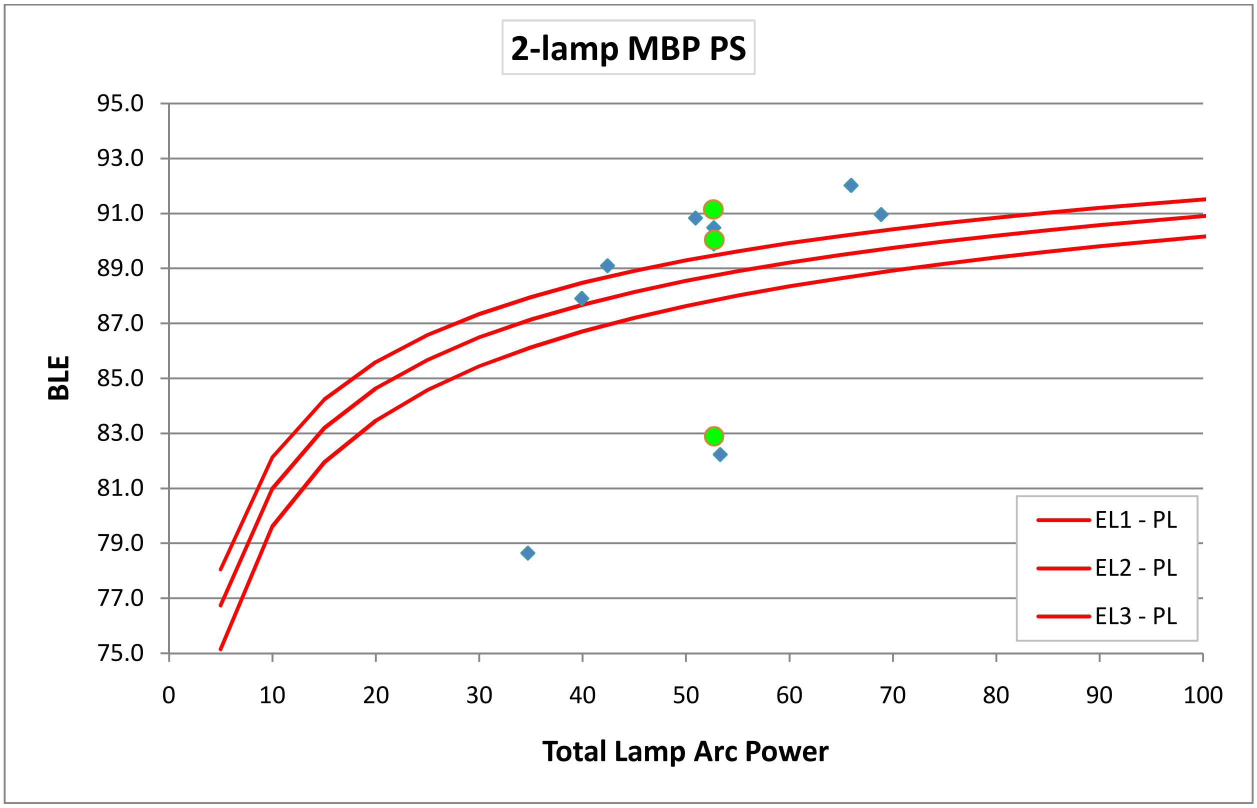


Figure 5.6 Efficiency Levels for the 2-lamp MBP PS Representative Ballast Type

Table 5.40 provides detailed information on the 2-foot MBP PS ballast designs used in the engineering analysis and subsequent analyses.

Table 5.40 Ballast Designs for the 2-lamp MBP PS Representative Ballast Type

Efficiency Level	For Operation Of	Ballast Type	Starting Method	Input Voltage	Universal or Dedicated Voltage	Power Factor	THD (%)	Ballast Factor	Input Power (W)	Lamp Arc Power (W)	BLE (%)
Baseline	2 F32T8 Lamps	Electronic	PS	277	Universal	0.98	<10%	0.91	60.0	49.9	83.2
EL1	2 F32T8 Lamps	-	-	-	-	-	-	-	-		-
EL2	2 F32T8 Lamps	Electronic	PS	277	Universal	0.98	<10%	0.91	55.6	49.9	89.9
EL3	2 F32T8 Lamps	Electronic	PS	277	Universal	0.98	<10%	0.91	54.7	49.8	91.0

5.13.3 Lamp and Ballast Prices

DOE analyzed each EL for the 2-lamp MBP PS representative ballast type to develop appropriate MSPs. DOE based the baseline and EL3 MSPs on an average of teardown- and blue book-sourced MSPs. For EL2, the MSP was based on blue-book sourced MSPs. DOE found that the MSP increased with increased efficiency for this representative ballast type as depicted in Table 5.41.

Table 5.41 Summary of the Manufacturing Selling Prices for the 2-lamp MBP PS Representative Ballast Type

Efficiency Level	Lamp Type	Starting Method	MSP (2009$)
Baseline	F32T8	PS	$8.39
EL2	F32T8	PS	$9.28
EL3	F32T8	PS	$9.59

The following table depicts the appropriate lamp prices for the baseline lamps as used in the 2009 Lamps Rule (see section 5.9.3).

Table 5.42 Retail Prices for Four-Foot Medium Bipin Fluorescent Lamps

Lamp Type	Retail Price (2007$)
F32T8	$3.19

5.13.4 Results

Table 5.43 presents the engineering characteristics of the ballast replacement options for the baseline F32T8 system in the 2-lamp MBP PS representative ballast type. If a direct substitution is made, mean lumen output does not change by more than 0.1 percent (rounded to zero percent in Table 5.43) relative to the mean lumen output of the baseline system.

Table 5.43 Two-lamp MBP PS Representative Ballast Type

Efficiency Level	For Operation Of	Ballast Type	Starting Method	Input Voltage	Universal or Dedicated Voltage	Ballast Factor	Input Power (W)	Lamp Arc Power (W)	BLE (%)	System Initial Light Output (lm)	System Mean Light Output (lm)	Percentage Change Mean Lumen Output (%)	Ballast Manufacturer Selling Price (2009$)	Lamp Retail Price (2007$)	Normalized Input Power (W)
Baseline	2 F32T8 Lamps	Electronic	PS	277	Universal	0.91	60.0	49.9	83.2	5,198	4,929	0%	$8.39	$6.38	60.0
EL1	2 F32T8 Lamps	Electronic	PS	277	-	-	-		-	-	-	-	-	-	-
EL2	2 F32T8 Lamps	Electronic	PS	277	Universal	0.91	55.6	49.9	89.9	5,200	4,931	0%	$9.28	$6.38	55.5
EL3	2 F32T8 Lamps	Electronic	PS	277	Universal	0.91	54.7	49.8	91.0	5,191	4,922	0%	$9.59	$6.38	54.8

5.14 PROGRAMMED START BALLASTS THAT OPERATE FOUR FOUR-FOOT MBP AND FOUR TWO-FOOT U-SHAPED LAMPS

The PS product class includes four representative ballast types, including PS ballasts that operate four 4-foot MBP and 2-foot U-shaped lamps. DOE presents its analysis of this ballast type in the following sections.

5.14.1 Baseline Models

For the 4-lamp 4-foot MBP and 2-foot U-shaped PS normal BF representative ballast type (hereafter referred to as the 4-lamp MBP PS representative ballast type), DOE also found that F32T8 lamps are the only MBP lamps operated. Currently there is no federal minimum energy conservation standard for ballasts that operate F32T8 lamps. Therefore, in choosing the baseline ballast for this representative ballast type, DOE chose the most common, least efficient ballast on the market. DOE tested a range of F32T8 PS ballasts from multiple ballast manufacturers and found that the least efficient of these ballasts exhibited the characteristics shown in Table 5.44. This ballast, like the majority of PS ballasts on the market, is electronic, has a high PF (~0.98) and has a low THD (<10 percent).

Table 5.44 Baseline Ballasts for the 4-lamp MBP PS Representative Ballast Type

For Operation of	Starting Method, Input Voltage, Ballast Type, PF, THD	BF	Input Power *W*	BLE (%)	Federal Energy Conservation Standard
4, F32T8 Lamps	PS, 277V, Electronic, Dedicated Voltage, 0.98 PF, <10% THD	0.84	111.6	81.9	N/A

As discussed above, DOE paired 4-foot MBP ballasts with an appropriate reduced wattage F32T8 lamp, which was designed to reflect the distribution of energy-saving lamps on the market. The characteristics of these lamps are listed in the table below.

Table 5.45 Lamps for Use with F32T8 Ballasts

Lamp Type	CCT	Rated Efficacy*	Initial Light Output	Mean Light Output	Life	CRI
	K	*lm/W*	*lm*	*lm*	*hr*	
F32T8	4,100	92.9	2,712	2,860	24,091	85
* Rated efficacy is based on the weighted-average lamp wattage of 4-ft T8 MBP lamps which is 30.77W.						

This combination of lamp and ballast represents the most common configuration for these ballasts in existing and new installations. Together, these lamp-and-ballast combinations create a system lumen package of approximately 9,025 mean lumens (and 9,517 initial lumens) for the baseline F32T8 ballast.

5.14.2 Efficiency Levels

The following discussion identifies the steps and technologies associated with each EL DOE considered for the 4-lamp MBP PS representative ballast type. As discussed in the screening analysis (final rule TSD chapter 4), DOE considered design options that achieve a higher BLE than the baseline ballast. Because the baseline ballast is a T8 electronic ballast, improvements required the use of the following design options: improved components and improved circuit design. For PS ballasts, DOE identified three ELs. EL3 represents the maximum technologically feasible level.

EL1. This level requires the use of improved circuit designs for the 4-lamp MBP PS ballast. Specifically, ballasts at this level use a reduced level of cathode heating of the filament after the lamp starts.

EL2. DOE did not identify 4-lamp MBP PS ballasts at EL2, though other ballasts in the PS product class did fall in EL2.

EL3. This level represents the maximum technologically feasible level and an improvement in efficiency over EL1. Ballasts that just meet EL3 may use slightly higher levels of cathode cutback after the lamp starts as well as improved components.

Table 5.46 Summary of ELs for Four-lamp MBP PS Ballasts

Efficiency Level	BLE Requirement With Variation Reduction
EL1	0.993/(1+0.60*total lamp arc power^-0.37)
EL2	0.993/(1+0.55*total lamp arc power^-0.37)
EL3	0.993/(1+0.51*total lamp arc power^-0.37)

Figure 5.7 illustrates three ELs on a plot of 4-lamp MBP PS ballasts. A circle indicates a representative unit tested by DOE. Diamonds indicate other 4-lamp MBP PS ballasts tested by DOE.

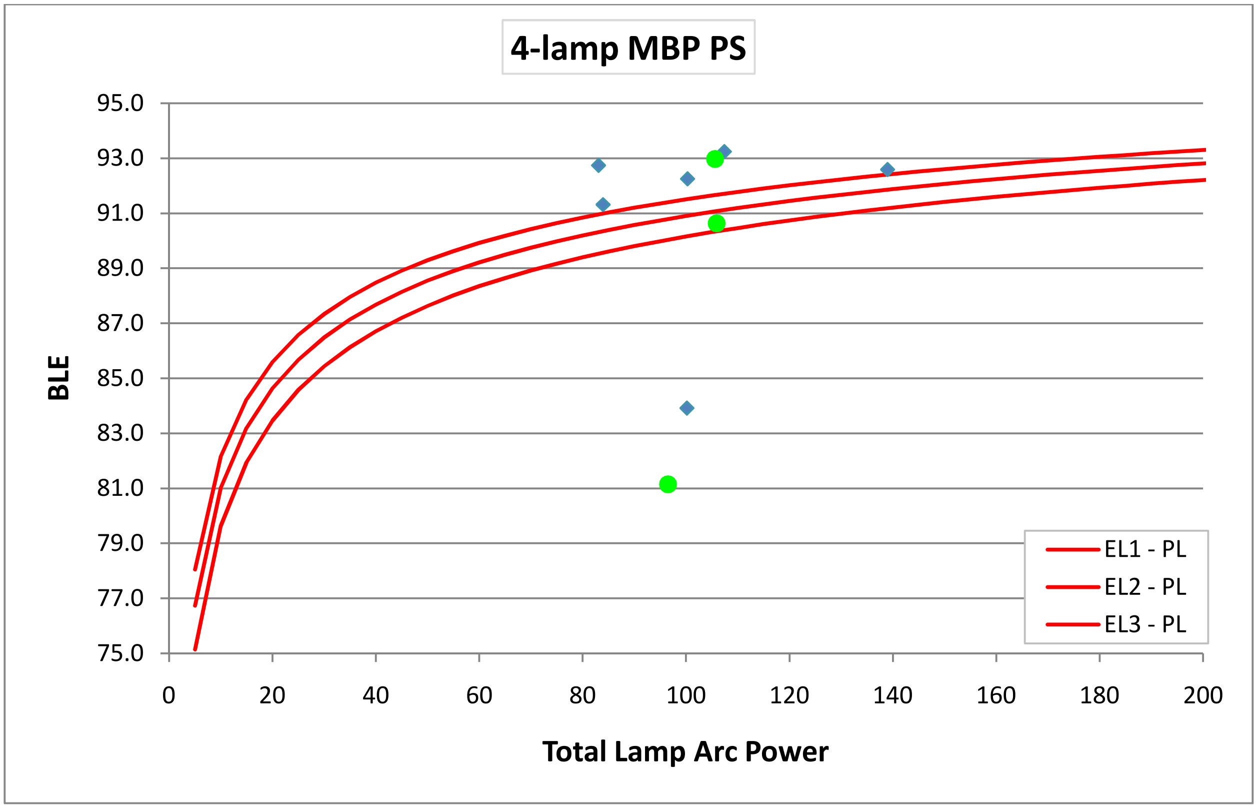


Figure 5.7 Efficiency Levels for the 4-lamp MBP PS Representative Ballast Type

Table 5.47 provides detailed information on the 4-lamp MBP PS ballast designs used in the engineering analysis and subsequent analyses.

Table 5.47 Ballast Designs for the 4-lamp MBP PS Representative Ballast Type

Efficiency Level	For Operation Of	Ballast Type	Starting Method	Input Voltage	Universal or Dedicated Voltage	Power Factor	THD (%)	Ballast Factor	Input Power (W)	Lamp Arc Power (W)	BLE (%)
Baseline	4 F32T8 Lamps	Electronic	PS	277	Universal	0.98	<10	0.83	111.6	92.0	81.9
EL1	4 F32T8 Lamps	Electronic	PS	277	Universal	0.98	<10	0.91	110.8	100.3	90.5
EL2	4 F32T8 Lamps	-	-	-	-	-	-	-	-	-	-
EL3	4 F32T8 Lamps	Electronic	PS	277	Universal	0.97	<10	0.91	107.7	100.0	92.8

5.14.3 Lamp and Ballast Prices

DOE analyzed each EL for the 4-lamp MBP PS representative ballast type to develop appropriate MSPs. The baseline, EL1, and EL3 MSPs were based on blue book-sourced MSPs.

DOE found that the MSP increased with increased efficiency for this representative ballast type as depicted in Table 5.48.

Table 5.48 Summary of the Manufacturing Selling Price for the 4-lamp MBP PS Representative Ballast Type

Efficiency Level	Lamp Type	Starting Method	MSP (2009$)
Baseline	F32T8	PS	$9.05
EL1	F32T8	PS	$11.84
EL3	F32T8	PS	$13.33

The following table depicts the appropriate lamp prices for the baseline lamps as used in the 2009 Lamps Rule (see section 5.9.3).

Table 5.49 Retail Prices for Four-Foot Medium Bipin Fluorescent Lamps

Lamp Type	Retail Price (2007$)
F32T8	$3.19

5.14.4 Results

presents the engineering characteristics of the ballast replacement option for the baseline F32T8 system in the PS representative ballast type. Because the BF of the standards-case systems at EL1 and EL3 is higher than the baseline system, the normalized input power is lower than the measured input power. If a direct substitution is made, mean lumen output does not change by more than ten percent relative to the mean lumen output of the baseline system.

Table 5.50 Four-Lamp MBP PS Representative Ballast Type with F32T8 Baseline

Efficiency Level	For Operation Of	Ballast Type	Starting Method	Input Voltage	Universal or Dedicated Voltage	Ballast Factor	Input Power (W)	Lamp Arc Power (W)	BLE (%)	System Initial Light Output (lm)	System Mean Light Output (lm)	Percentage Change Mean Lumen Output (%)	Ballast Manufacturer Selling Price (2009$)	Lamp Retail Price (2007$)	Normalized Input Power (W)
Baseline	4 F32T8 Lamps	Electronic	PS	277	Universal	0.83	111.6	92.0	81.9	9,517	9,025	0%	$9.05	$12.76	111.6
EL1	4 F32T8 Lamps	Electronic	PS	277	Universal	0.91	110.8	100.3	90.5	10,444	9,904	10%	$11.84	$12.76	101.0
EL2	4 F32T8 Lamps	Electronic	PS	277	-	-	-		-	-	-	-	-	-	-
EL3	4 F32T8 Lamps	Electronic	PS	277	Universal	0.91	107.7	100.0	92.8	10,416	9,877	9%	$13.33	$12.76	98.4

5.15 PROGRAMMED START BALLASTS THAT OPERATE TWO FOUR-FOOT MINIBP T5 SO LAMPS

The PS product class includes four representative ballast types, including ballasts that operate two 4-foot Mini-BP T5 SO lamps. DOE presents its analysis of this ballast type in the following sections.

5.15.1 Baseline Models

For the 2-lamp 4-foot MiniBP T5 SO normal BF representative ballast type (hereafter referred to as the 4-foot T5 SO representative ballast type), DOE chose to analyze one baseline ballast. DOE believes that F28T5 lamps encompass the vast majority of 4-foot T5 SO lamp sales.[13] Therefore, DOE has chosen to only analyze the F28T5 baseline ballast.

Currently there is no federal minimum energy conservation standard for ballasts that operate F28T5 lamps. In addition, only relatively efficient electronic 4-foot T5 SO ballasts are sold on the U.S. market. DOE recognizes, however, that electronic 4-foot T5 SO ballasts similar to the baseline levels of the 4-foot MBP T8 PS representative ballast type may be introduced to the U.S. market and purchased widely by consumers if a standard for 4-foot T5 SO ballasts is not established. Because these inefficient 4-foot T5 SO ballasts do not exist currently, DOE developed a baseline inefficient 4-foot T5 SO ballast by determining the difference in BLE between baseline and EL2 2-lamp MBP PS ballasts. More information on how DOE developed this baseline model is outlined in appendix 5B. The baseline 4-foot T5 SO ballast has the characteristics shown in the table below. Although this ballast is not commercially available today, it represents the lowest efficiency ballast that may be commercially available when standards take effect.

Table 5.51 Baseline Ballast for Four-Foot T5 MiniBP SO Representative Ballast Type

For Operation of	BF	Ballast Type	Input Power (W)	BLE (%)	Federal Energy Conservation Standard
F28T5	1.01	Electronic	67.6	82.3%	N/A

As discussed above, DOE paired the 2-lamp 4-foot SO ballast with an appropriate reduced wattage F28T5 lamp, which was designed to reflect the distribution of energy-saving lamps on the market. The characteristics of this lamp are listed in the table below.

[13] Currently only one manufacturer sells a 4-foot MiniBP T5 lamp that is not a F28T5. This lamp is a reduced wattage (F26T5).

Table 5.52 Lamps for Use with F28T5 Ballasts

Lamp Type	CCT	Rated Efficacy*	Initial Light Output	Mean Light Output	Life	CRI
	K	*lm/W*	*lm*	*lm*	*hr*	
F28T5	4,100	106.1	2,928	2,705	20,570	85
* Rated efficacy is based on the weighted-average lamp wattage of F28T5 lamps, which is 27.59W.						

This combination of lamp and ballast represents the most common configuration for these ballasts in existing and new installations. Together, this lamp-and-ballast combination creates a system lumen package of approximately 5,453 mean lumens (and 5,903 initial lumens).

5.15.2 Efficiency Levels

The following discussion identifies the steps and technologies associated with each EL DOE considered for the 4-foot T5 SO representative ballast type. As discussed in the screening analysis (final rule TSD chapter 4), DOE used design options that achieve a higher BLE than the baseline ballast. Because the baseline ballast is an inefficient ballast, improvements required the use of the following design options: improved components and improved circuit design. For the 4-foot T5 SO representative ballast type, DOE identified three ELs. The highest EL represents the maximum technologically feasible level.

EL1. This level represents an improvement over the baseline T5 efficiency. This level is characterized by the least efficient electronic ballasts that are commercially available today.

EL2. Ballasts at this level use slightly better components and circuit designs than those ballasts that meet EL1.

EL3. This level represents an improvement in efficiency over EL2. EL3 is just met by the most efficient T5 ballast tested and represents the max-tech EL. Ballasts at this level use slightly better components and circuit designs than those ballasts that meet EL2.

Table 5.53 Summary of ELs for 4-foot T5 SO Ballasts

Efficiency Level	BLE Requirement With Variation Reduction
EL1	0.993/(1+0.60*total lamp arc power^-0.37)
EL2	0.993/(1+0.55*total lamp arc power^-0.37)
EL3	0.993/(1+0.51*total lamp arc power^-0.37)

Figure 5.8 illustrates the three ELs on a plot of 4-foot T5 SO ballasts. A circle indicates a representative unit tested by DOE. Diamonds indicate other 4-foot T5 SO ballasts tested by DOE.

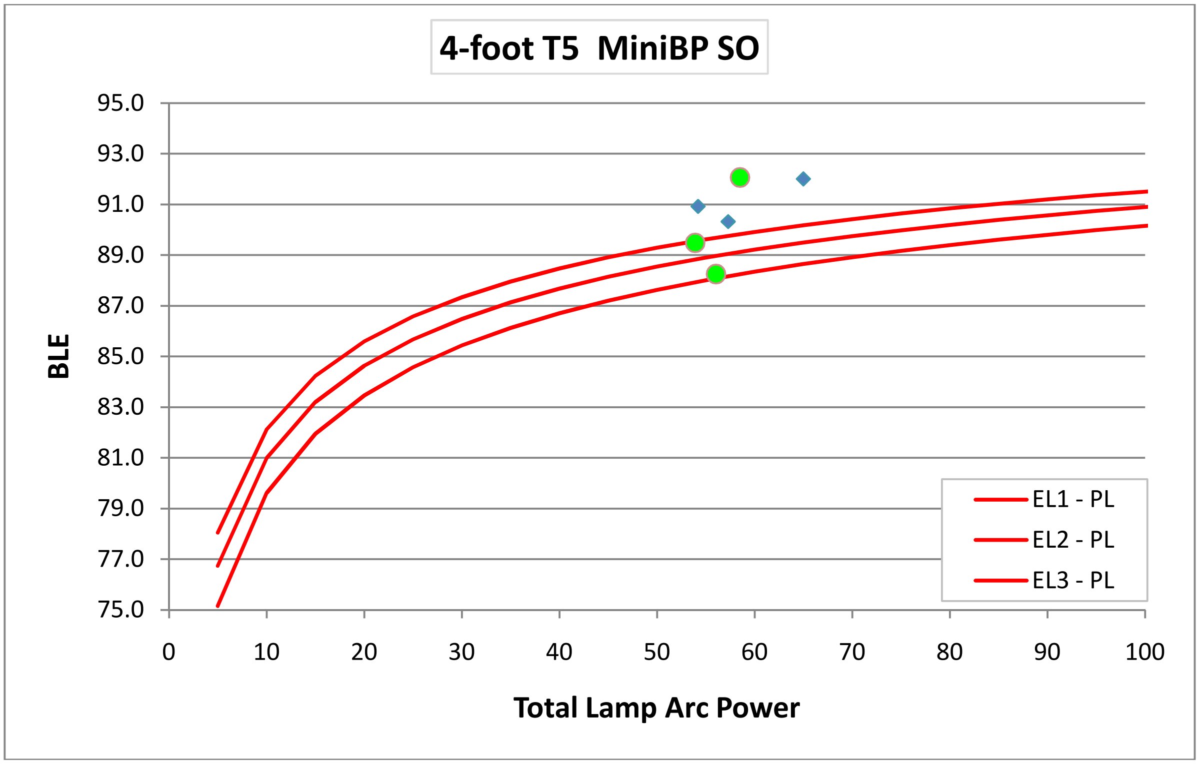


Figure 5.8 Efficiency Levels for the Four-Foot T5 MiniBP SO Representative Ballast Type

Table 5.54 provides detailed information on the 4-foot MiniBP SO ballast designs used in the engineering analysis and subsequent analyses. For the F28T5 ballasts, the ballast characteristics either improve or remain the same as the baseline system.

Table 5.54 Ballast Designs for the Four-Foot T5 MiniBP SO Representative Ballast Type

Efficiency Level	For Operation Of	Ballast Type	Starting Method	Input Voltage	Universal or Dedicated Voltage	Power Factor	THD (%)	Ballast Factor	Input Power (W)	Lamp Arc Power (W)	BLE (%)
Baseline	2 F28T5 Lamps	Electronic	PS	277	Universal	0.99	<10	1.01	67.6	55.6	82.3
EL1	2 F28T5 Lamps	Electronic	PS	277	Universal	0.99	<10	1.01	62.7	55.6	88.7
EL2	2 F28T5 Lamps	Electronic	PS	277	Universal	0.98	<10	0.97	59.7	53.5	89.6
EL3	2 F28T5 Lamps	Electronic	PS	277	Universal	0.98	<10	1.05	63.1	58.1	92.0

5.15.3 Lamp and Ballast Prices

DOE analyzed each EL for the 4-foot T5 SO representative ballast type to develop appropriate MSPs. The EL1, EL2, and EL3 MSPs were estimated using the blue book-sourced MSPs as described in section 5.6.2. To determine a price for the baseline T5 ballast, DOE assumed that the ratio of the baseline 2-lamp, 4-foot T8 MBP PS ballast to the EL2 price for the same ballast type would be the same as the ratio of the baseline to EL1 for 4-foot T5 SO ballasts – a ballast type that operates a similar wattage. DOE found that the MSP increased with increased efficiency as depicted in the table below.

Table 5.55 Manufacturing Selling Prices for the Four-Foot T5 MiniBP SO Representative Ballast Type

Efficiency Level	Lamp Type	MSP (2009$)
Baseline	F28T5	$10.78
EL1	F28T5	$10.85
EL2	F28T5	$11.92
EL3	F28T5	$15.36

The following table depicts the appropriate lamp prices for the baseline lamps as used in the 2009 Lamps Rule.

Table 5.56 Retail Prices for Four-Foot MiniBP SO Fluorescent Lamps

Lamp Type	Retail Price (2007$)
F28T5	$3.49

5.15.4 Results

Table 5.57 presents the engineering characteristics of the ballast replacement options for the baseline F28T5 system for the 4-foot T5 SO representative ballast type. Because the BF of the standards-case system at EL2 is slightly lower than the baseline system, the normalized input power is slightly higher than the measured input power. The opposite is true at EL3. If a direct substitution is made, mean lumen output does not change by more than four percent relative to the mean lumen output of the baseline system.

Table 5.57 Four-Foot T5 MiniBP SO Representative Ballast Type with F28T5 Baseline

Efficiency Level	For Operation Of	Ballast Type	Starting Method	Input Voltage	Universal or Dedicated Voltage	Ballast Factor	Input Power (W)	Lamp Arc Power (W)	BLE (%)	System Initial Light Output (lm)	System Mean Light Output (lm)	Percentage Change Mean Lumen Output (%)	Ballast Manufacturer Selling Price (2009$)	Lamp Retail Price (2007$)	Normalized Input Power (W)
Baseline	2 F28T5 Lamps	Electronic	PS	277	Universal	1.01	67.6	55.6	82.3	5,903	5,453	0%	$10.78	$6.98	67.6
EL1	2 F28T5 Lamps	Electronic	PS	277	Universal	1.01	62.7	55.6	88.7	5,903	5,453	0%	$10.85	$6.98	62.7
EL2	2 F28T5 Lamps	Electronic	PS	277	Universal	0.97	59.7	53.5	89.6	5,678	5,246	-4%	$11.92	$6.98	62.1
EL3	2 F28T5 Lamps	Electronic	PS	277	Universal	1.05	63.1	58.1	92.0	6,161	5,692	4%	$15.36	$6.98	60.4

5.16 PROGRAMMED START BALLASTS THAT OPERATE TWO FOUR-FOOT MINIBP T5 HO LAMPS

The PS product class includes four representative ballast types, including ballasts that operate two 4-foot MiniBP T5 HO lamps. DOE presents its analysis of this ballast type in the following sections.

5.16.1 Baseline Models

For the 2-lamp 4-foot MiniBP T5 HO normal BF representative ballast type (hereafter referred to as the 4-foot T5 HO representative ballast type), DOE chose to analyze one baseline ballast. DOE believes that F54T5HO lamps encompass the vast majority of 4-foot T5 HO lamps sales.[14] Therefore, DOE has chosen to only analyze the F54T5HO baseline ballast.

Currently there is no federal minimum energy conservation standard for ballasts that operate F54T5HO lamps. In addition, only relatively efficient 4-foot T5 HO electronic ballasts are sold on the U.S. market. Like the 4-foot T5 SO representative ballast type, DOE recognizes that inefficient 4-foot T5 HO ballasts may be introduced to the U.S. market and purchased widely by consumers if a standard for 4-foot T5 HO ballasts is not established. Because inefficient 4-foot T5 HO ballasts do not exist currently, DOE developed a baseline model 4-foot T5 HO ballast by determining the difference in BLE between baseline and EL2 2-lamp MBP PS ballasts. More information on how DOE developed this baseline model is outlined in appendix 5B and section 5.15.1. The baseline 4-foot T5 HO ballast has the characteristics shown in the table below. Although this ballast is not commercially available today, it is the lowest efficiency ballast that may be commercially available when standards take effect.

Table 5.58 Baseline Ballast for the Four-Foot T5 MiniBP HO Representative Ballast Type

For Operation of	BF	Ballast Type	Input Power (W)	BLE (%)	Federal Energy Conservation Standard
F54T5HO	0.95	Electronic	123.5	82.1%	N/A

As discussed above, DOE paired the 2-lamp 4-foot T5 HO ballast with an appropriate reduced wattage F54T5HO lamp, which was designed to reflect the distribution of energy-saving lamps on the market. The characteristics of this lamp are listed in the table below.

[14] Currently only two manufacturers sell a 4-foot MiniBP T5 HO lamp that is not a F54T5HO. One manufacturer sells a reduced wattage (F51T5HO). Another manufacturer sells a F49T5HO.

Table 5.59 Lamps for Use with F54T5HO Ballasts

Lamp Type	CCT	Rated Efficacy*	Initial Light Output	Mean Light Output	Life	CRI
	K	*lm/W*	*lm*	*lm*	*hr*	
F54T5HO	4,100	93.8	5,000	4,600	20,000	85
* Rated efficacy is based on the weighted-average lamp wattage of F28T5HO lamps, which 53.28W.						

This combination of lamp and ballast represents the most common configuration for these ballasts in existing and new installations. Together, this lamp-and-ballast combination creates a system lumen package of approximately 8,755 mean lumens (and 9,516 initial lumens).

5.16.2 Efficiency Levels

The following discussion identifies the steps and technologies associated with each EL DOE considered for the 4-foot T5 HO representative ballast type. As discussed in the screening analysis (final rule TSD chapter 4), DOE used design options that achieve a higher BLE than the baseline ballast. Because the baseline ballast is an inefficient electronic ballast, improvements required the use of the following design options: improved components and improved circuit design. The highest EL represents the maximum technologically feasible level.

EL1. This level represents an improvement over the baseline T5 efficiency. This level is characterized by the least efficient electronic ballasts on the market today.

EL2. Ballasts at this level use slightly better components and circuit designs than those ballasts that meet EL1.

EL3. EL3 represents the maximum technologically feasible level. Ballasts at this level use slightly better components and circuit designs than those ballasts that meet EL2.

Table 5.60 Summary of ELs for Four-foot T5 HO Ballasts

Efficiency Level	BLE Requirement With Variation Reduction
EL1	0.993/(1+0.60*total lamp arc power^-0.37)
EL2	0.993/(1+0.55*total lamp arc power^-0.37)
EL3	0.993/(1+0.51*total lamp arc power^-0.37)

Figure 5.9 illustrates the three ELs on a plot of 4-foot T5 HO ballasts. A circle indicates a representative unit tested by DOE. Diamonds indicate other 4-foot T5 HO ballasts tested by DOE.

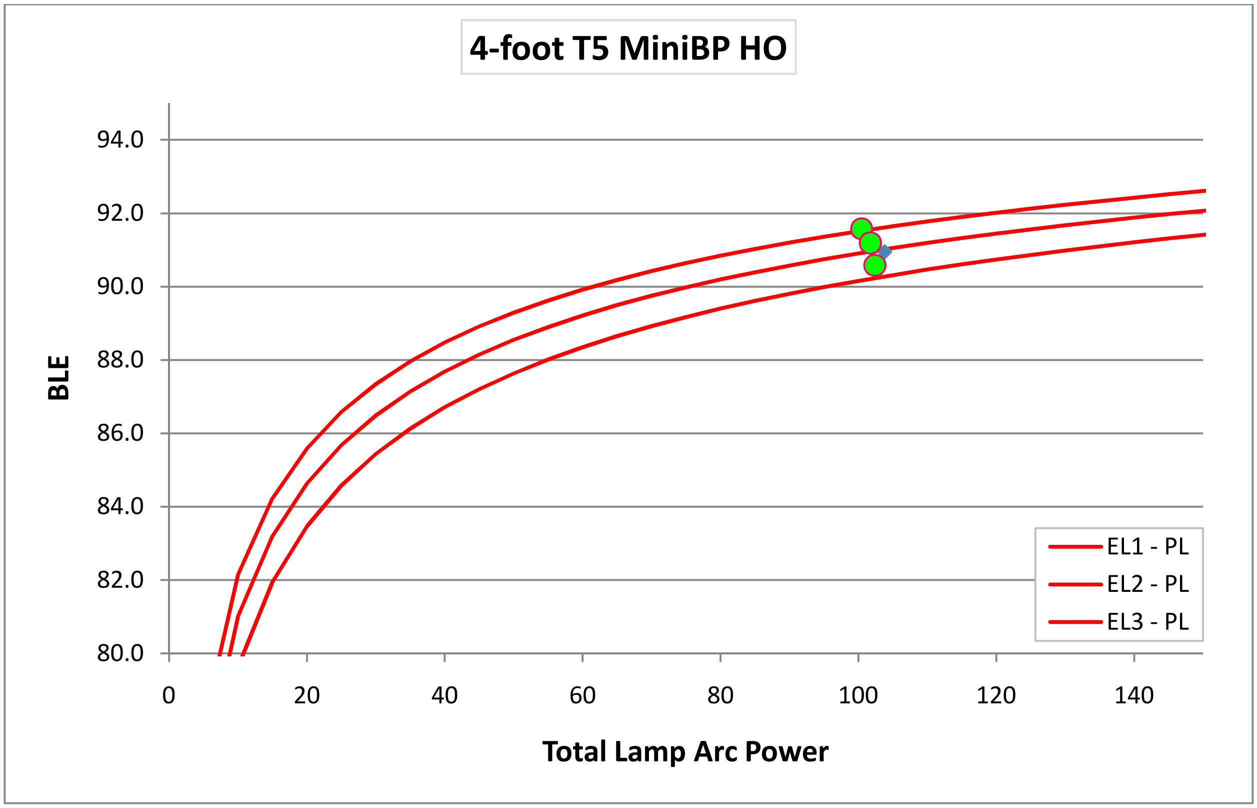


Figure 5.9 Efficiency Levels for the Four-Foot T5 MiniBP HO Representative Ballast Type

Table 5.61 provides detailed information on the 4-foot T5 HO ballast designs used in the engineering analysis and subsequent analyses. For the F54T5HO ballasts, the ballast characteristics either improve or remain the same as the magnetic baseline system.

Table 5.61 Ballast Designs for the Four-Foot T5 MiniBP HO Representative Ballast Type

Efficiency Level	For Operation Of	Ballast Type	Starting Method	Input Voltage	Universal or Dedicated Voltage	Power Factor	THD (%)	Ballast Factor	Input Power (W)	Lamp Arc Power (W)	BLE (%)
Baseline	2 F54T5HO Lamps	Electronic	PS	277	Universal	0.98	<10	0.95	123.5	101.4	82.1
EL1	2 F54T5HO Lamps	Electronic	PS	277	Universal	0.98	<10	0.95	112.0	101.4	90.6
EL2	2 F54T5HO Lamps	Electronic	PS	277	Universal	0.98	<8	0.93	108.7	100.7	91.5
EL3	2 F54T5HO Lamps	Electronic	PS	277	Universal	0.98	<10	0.95	109.1	100.8	92.3

5.16.3 Lamp and Ballast Prices

DOE analyzed each EL for the 4-foot T5 HO representative ballast type to develop appropriate MSPs. The EL1, EL2, and EL3 MSPs were estimated using the blue book-sourced MSPs as described in section 5.6.2. DOE used the same technique described for establishing the baseline T5 SO ballast MSP to establish an MSP for the baseline T5 HO baseline. DOE assumed that the ratio of the baseline 4-lamp 4-foot T8 MBP PS ballast to the 4-lamp 4-foot T8 PS EL3 ballast would be the same as the ratio between the baseline/EL2 to EL1 4-foot T5 HO ballasts. DOE found that the MSP increased with increased efficiency as depicted in the table below.

Table 5.62 Manufacturing Selling Prices for the Four-Foot T5 MiniBP HO Representative Ballast Type

Efficiency Level	Lamp Type	MSP (2009$)
Baseline	F54T5HO	$9.61
EL1	F54T5HO	$12.58
EL2	F54T5HO	$14.70
EL3	F54T5HO	$16.76

The following table depicts the appropriate lamp prices for the baseline lamps as used in the 2009 Lamps Rule.

Table 5.63 Retail Prices for Four-Foot MiniBP HO Fluorescent Lamps

Lamp Type	Retail Price (2007$)
F54T5HO	$4.66

5.16.4 Results

Table 5.64 presents the engineering characteristics of the ballast replacement options for the baseline F54T5HO system in the 4-foot T5 HO representative ballast type. Because the BF of the standards-case system is slightly lower than the baseline system at EL2 and EL3, the normalized input power is slightly higher than the measured input power. If a direct substitution is made, mean lumen output does not change by more than two percent relative to the mean lumen output of the baseline system.

Table 5.64 Four-Foot T5 MiniBP HO Representative Ballast Type with F54T5HO Baseline

Efficiency Level	For Operation Of	Ballast Type	Starting Method	Input Voltage	Universal or Dedicated Voltage	Ballast Factor	Input Power (W)	Lamp Arc Power (W)	BLE (%)	System Initial Light Output (lm)	System Mean Light Output (lm)	Percentage Change Mean Lumen Output (%)	Ballast Manufacturer Selling Price (2009$)	Lamp Retail Price (2007$)	Normalized Input Power (W)
Baseline	2 F54T5HO Lamps	Electronic	PS	277	Universal	0.95	123.5	101.4	82.1	9,516	8,755	0%	$9.61	$9.32	123.5
EL1	2 F54T5HO Lamps	Electronic	PS	277	Universal	0.95	112.0	101.4	90.6	9,516	8,755	0%	$12.58	$9.32	112.0
EL2	2 F54T5HO Lamps	Electronic	PS	277	Universal	0.94	108.7	100.7	91.5	9,337	8,590	-2%	$14.70	$9.32	110.8
EL3	2 F54T5HO Lamps	Electronic	PS	277	Universal	0.95	109.1	100.8	92.3	9,456	8,700	-1%	$16.76	$9.32	109.8

5.17 BALLASTS THAT OPERATE TWO EIGHT-FOOT RDC HO LAMPS

5.17.1 Baseline Models

For the 2-lamp 8-foot RDC HO IS and RS representative ballast type (hereafter referred to as the 8-foot HO representative ballast type), DOE chose to analyze two baseline ballasts. DOE found the market share of 8-foot HO (T8 and T12) standard application ballasts (excluding cold temperature sign ballasts) to be about 0.5 percent. DOE believes most of the 8-foot HO ballasts currently shipped are T12. However, the 2009 Lamps Rule will reduce the number of T12 HO lamps and increase the number of T8 HO lamps shipped by promulgating more stringent lamp standards. Therefore, DOE analyzed both T12 and T8 ballasts as baseline ballasts. Because the 2009 Lamps Rule eliminated all currently commercially available T12 lamps by 2012, DOE created an F96T12HO/ES lamp that complied with the 2009 Lamps Rule to pair with T12 ballasts (see section 5.9.1). Because only the most efficient T12 lamps will be available when this ballast rulemaking takes effect, DOE chose to analyze only those T12 ballasts that operate F96T12HO/ES lamps for this rulemaking. For the T8 baseline, DOE chose to analyze only those ballasts that operate the F96T8HO lamp because this lamp is the most common 8-foot HO T8 lamp.

The Federal minimum energy conservation standards for ballasts that operate two F96T12HO/ES lamps became effective for ballasts manufactured on or after July 1, 2009. (10 CFR Part 430.32 (m)(5)). This energy conservation standard did not eliminate magnetic ballasts from the market. Therefore, DOE chose a magnetic ballast as the F96T12HO/ES baseline ballast. To determine the BLE of the baseline ballast, DOE tested multiple ballasts operating a reference F96T12HO/ES lamp. The BLE, BF, and input power of the most common T12 ballast that just meets the minimum energy conservation standard of 68.0 percent (BEF of 0.42) is shown in Table 5.65 below. All T12 magnetic ballasts in product catalogs are RS, dedicated voltage, and have a high PF (>0.90). The ballast that just meets the energy conservation standard also exhibits these characteristics. DOE also chose a ballast that has an input voltage of 277V because the majority of ballasts operate in commercial buildings at 277V. THD values range from <25 percent to <18 percent. DOE chose a ballast with a THD of <18 percent because it represented the least efficient T12 ballast.

Currently there is no federal minimum energy conservation standard for ballasts that operate F96T8HO lamps. Therefore, in choosing the baseline ballast for this lamp type, DOE chose the most common, least efficient ballast on the market. DOE tested a range of F96T8HO ballasts from multiple ballast manufacturers and found that the least efficient but most common ballast exhibited the characteristics shown in the table below. The vast majority of F96T8HO ballasts are electronic and have a high PF (>0.95). Furthermore, the majority of the least efficient T8 ballasts have a THD <20 percent. Finally, like the F96T12HO/ES baseline ballast, DOE chose a ballast that has an input voltage of 277V as the majority of ballasts operate in commercial buildings at 277V.

Table 5.65 Baseline Ballasts for the Eight-Foot RDC HO Representative Ballast Type

For Operation of	Starting Method, Input Voltage, Ballast Type, PF, THD	BF	Input Power (W)	BLE (%)	Federal Energy Conservation Standard
2, F96T12HO/ES Lamps	RS, 277V, Magnetic, Dedicated Voltage, ≥0.90, PF, <18% THD	0.89	235.2	68.0%	68.0%
2, F96T8HO Lamps	RS, 277V, Electronic, Dedicated Voltage, >0.98 PF, <20% THD	0.78	177.0	79.8%	N/A

DOE paired 8-foot HO ballasts with an appropriate F96T12HO/ES or F96T8HO lamp. DOE chose 8-foot HO lamps that just meet the ECS issued in the 2009 Lamps Rule which requires compliance in 2012 as these will be the most common lamps available after the ballast rule takes effect. The characteristics of these lamps are listed in the table below.

Table 5.66 Lamps for Use with F96T8HO and F96T12HO/ES Ballasts

Lamp Type	CCT	Rated Efficacy*	Initial Light Output	Mean Light Output	Life	CRI
	K	*lm/W*	*lm*	*lm*	*hr*	
F96T12HO/ES	4,100	91.9	8,910	8,019	12,000	N/A
F96T8HO	4,100	91.9	7,900	7,100	24,000	78
* Rated efficacy is based on the rated wattage of the lamps, which for the F96T12HO/ES lamp is 97W and for the F96T8HO lamp is 86W. F96T12HO/ES lamps are rated with a low-frequency reference ballast. F96T8HO lamps are rated with a high-frequency reference ballast.						

This combination of lamp and ballast represents the most common configuration for these ballasts in existing and new installations. Together, this lamp-and-ballast combination creates a system lumen package of approximately 13,915 mean lumens (and 15,461 initial lumens) for the baseline F96T12HO/ES ballast, approximately 11,133 mean lumens (and 12,387 initial lumens) for the baseline F96T8HO ballast.

5.17.2 Efficiency Levels

The following discussion identifies the steps and technologies associated with each EL DOE considered for the 8-foot RDC HO representative ballast type. As discussed in the screening analysis (final rule TSD chapter 4), DOE used design options that achieved a higher BLE than the baseline ballast. Because the baseline ballast is a magnetic ballast, improvements required the use of the following design options: electronic ballasts, improved components, and improved circuit design. For the 8-foot RDC HO representative ballast type, DOE identified three ELs. EL3 represents the maximum technologically feasible level.

EL1. This level only affects the T12 baseline and represents a modest improvement over the baseline T12 efficiency. Ballasts at this level are electronic instead of magnetic. Both T12 and T8 ballasts can meet this level.

EL2. Again, this level affects only the T12 baseline. No T12 ballasts meet this level. The least efficient T8 ballasts just meet this level.

EL3. This level affects both the T8 and T12 baseline. EL3 is met by the most efficient T8 ballast tested and represents the max-tech EL. These T8 ballasts use slightly better components and circuit designs than EL2.

Table 5.67 Summary of ELs for Eight-foot RDC HO Ballasts

Efficiency Level	BLE Requirement With Variation Reduction
EL1	0.993/(1+1.01*total lamp arc power^-0.25)
EL2	0.993/(1+0.38*total lamp arc power^-0.25)
EL3	0.993/(1+0.28*total lamp arc power^-0.25)

Figure 5.10 illustrates the three ELs on a plot of 8-foot HO (IS and RS) ballasts. A circle indicates a representative unit tested by DOE. Diamonds indicate other 8-foot RDC HO ballasts tested by DOE.

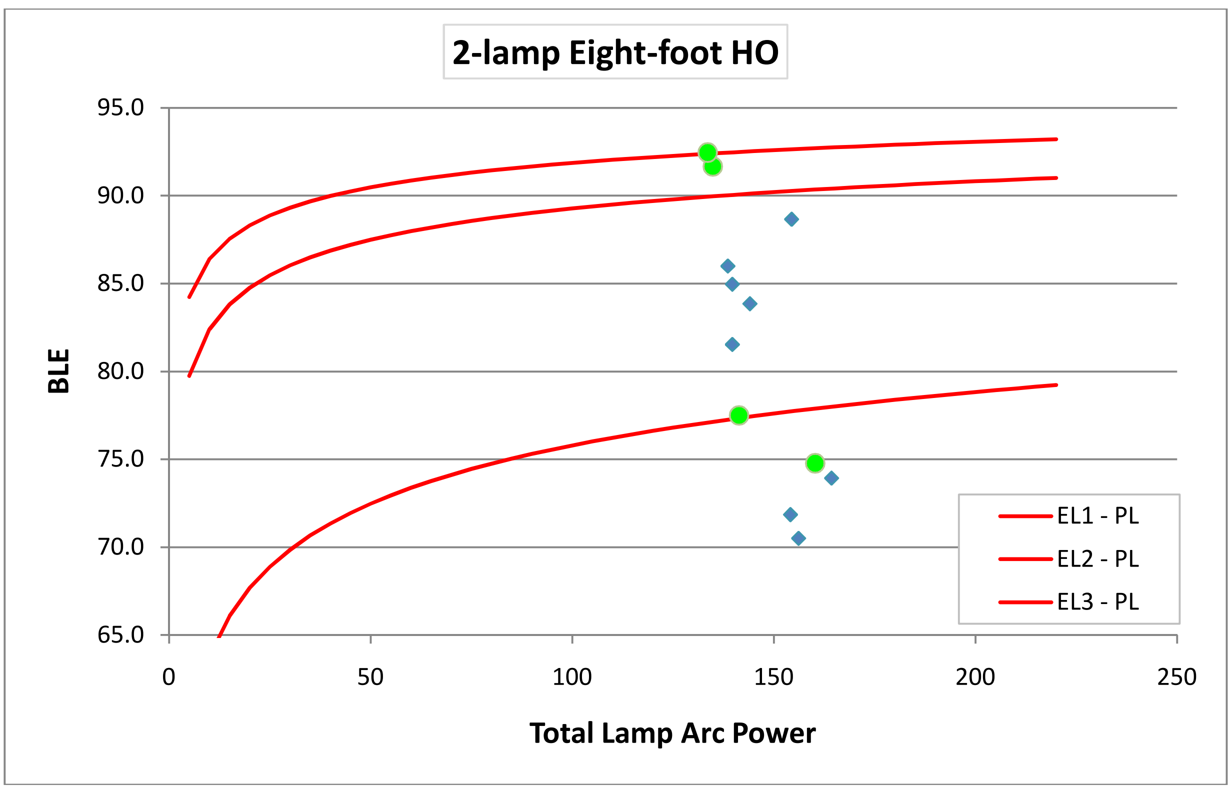


Figure 5.10 Efficiency Levels for the Eight-Foot RDC HO Representative Ballast Type

Table 5.68 provides detailed information on the 8-foot HO ballast designs used in the engineering analysis and subsequent analyses. For the more efficient F96T12HO/ES and F96T8HO ballasts, the ballast factor is lower than that of the baseline ballast.

Table 5.68 Ballast Designs for the Eight-Foot RDC HO Representative Ballast Type

Efficiency Level	For Operation Of	Ballast Type	Starting Method	Input Voltage	Universal or Dedicated Voltage	Power Factor	THD (%)	Ballast Factor	Input Power (W)	Lamp Arc Power (W)	BLE (%)
Baseline	2 F96T12HO/ES Lamps	Magnetic	RS	277	Dedicated	<0.9	<10	0.87	198.8	156.2	73.9
EL1	2 F96T12HO/ES Lamps	Electronic	RS	277	Dedicated	0.98	<20	0.83	176.0	141.4	80.4
Baseline /EL2	2 F96T8HO Lamps	Electronic	IS	277	Dedicated	0.95	<20	0.78	147.1	134.8	91.7
EL3	2 F96T8HO Lamps	Electronic	IS	277	Universal	0.97	<14	0.78	144.5	133.6	92.5

5.17.3 Lamp and Ballast Prices

DOE analyzed each EL for the 8-foot HO representative ballast type to develop appropriate MSPs. The baseline, EL1, baseline/EL2 and EL3 were each estimated using blue book-sourced MSPs as described in section 5.6.2.

Table 5.69 Manufacturing Selling Prices for the Eight-Foot RDC HO Representative Ballast Type

Efficiency Level	Lamp Type	MSP (2009$)
Baseline	F96T12HO/ES	$13.25
EL1	F96T12HO/ES	$9.55
Baseline/EL2	F96T8HO	$8.15
EL3	F96T8HO	$11.05

The following table depicts the appropriate lamp prices for the baseline lamps as used in the 2009 Lamps Rule (see section 5.9.3).

Table 5.70 Retail Prices for Eight-Foot RDC HO Fluorescent Lamps

Lamp Type	Retail Price (2007$)
F96T12HO/ES	$12.35
F96T8HO	$6.57

5.17.4 Results

Table 5.71 presents the engineering characteristics of the ballast replacement options for the baseline F96T12HO/ES system in the 8-foot HO representative ballast type. Because the BF of the standards-case system decreases at higher ELs, the normalized input power is higher than the measured input power. If a direct substitution is made, mean lumen output decreases relative to the baseline system.

DOE found that the baseline/EL2 ballast has higher normalized input power than the EL1 ballast, even though the EL2/baseline ballast is more efficient than the EL1 ballast. The reason for this result is that the F96T12HO/ES lamp is more efficacious than the F96T8HO lamp. DOE selected lamps that just meet the 2009 Lamps Rule standards to pair with its representative ballasts. Though both the F96T12HO/ES lamp and F96T8HO lamp are required to meet the same lumens per watt energy conservation standard, the F96T12HO/ES lamp is tested with a low-frequency ballast while the F96T8HO lamp is tested with a high-frequency ballast. As a result, the 8-foot HO lamp efficacy standard is less stringent for the F96T8HO lamp because it receives an efficacy boost due to high-frequency operation. This difference in lamp efficacy outweighs the increase in ballast efficiency at baseline/EL2, but not at EL3.

Table 5.71 Eight-Foot RDC HO Representative Ballast Type with F96T12HO/ES Baseline

Efficiency Level	For Operation Of	Ballast Type	Starting Method	Input Voltage	Universal or Dedicated Voltage	Ballast Factor	Input Power (W)	Lamp Arc Power (W)	BLE (%)	System Initial Light Output (lm)	System Mean Light Output (lm)	Percentage Change Mean Lumen Output (%)	Ballast Manufacturer Selling Price (2009$)	Lamp Retail Price (2007$)	Normalized Input Power (W)
Baseline	2 F96T12HO/ES Lamps	Magnetic	RS	277	Dedicated	0.87	198.8	156.2	73.9	15,461	13,915	0%	$13.25	$24.70	198.8
EL1	2 F96T12HO/ES Lamps	Electronic	RS	277	Dedicated	0.83	176.0	141.4	80.4	14,838	13,354	-4%	$9.55	$24.70	183.4
Baseline /EL2	2 F96T8HO Lamps	Electronic	IS	277	Dedicated	0.78	147.1	134.8	91.7	12,387	11,133	-20%	$8.15	$13.13	183.9
EL3	2 F96T8HO Lamps	Electronic	IS	277	Universal	0.78	144.5	133.6	92.5	12,273	11,030	-21%	$11.05	$13.13	182.3

Table 5.72 presents the engineering characteristics of the ballast replacement options for the baseline F96T8HO system for the 8-foot RDC HO representative ballast type. Because the BF of the standards-case system is lower than the baseline system, the normalized input power is higher than the measured input power. If a direct substitution is made, mean lumen output decreases relative to the baseline system.

Table 5.72 Eight-Foot RDC HO Representative Ballast Type with F96T8HO Baseline

Efficiency Level	For Operation Of	Ballast Type	Starting Method	Input Voltage	Universal or Dedicated Voltage	Ballast Factor	Input Power (W)	Lamp Arc Power (W)	BLE (%)	System Initial Light Output (lm)	System Mean Light Output (lm)	Percentage Change Mean Lumen Output (%)	Ballast Manufacturer Selling Price (2009$)	Lamp Retail Price (2007$)	Normalized Input Power (W)
Baseline/ EL2	2 F96T8HO Lamps	Electronic	IS	277	Dedicated	0.78	147.1	134.8	91.7	12,387	11,133	0%	$8.15	$13.13	183.9
EL3	2 F96T8HO Lamps	Electronic	IS	277	Universal	0.78	144.5	133.6	92.5	12,273	11,030	-1%	$11.05	$13.13	182.3

5.18 SIGN BALLASTS THAT OPERATE FOUR EIGHT-FOOT HO LAMPS

5.18.1 Baseline Models

For sign ballasts that operate four 8-foot HO lamps (hereafter referred to as the sign ballast representative ballast type), DOE chose to analyze one baseline ballast. DOE evaluated the outdoor sign ballast market and found the market share to be relatively small – about 1 percent in 2005. However, despite their small market share, high output ballasts designed outdoor signage have large potential energy savings per ballast. Moving from a magnetic to an electronic sign ballast can reduce energy consumption by as much as 25 to 35 percent. DOE research indicated that ballasts that operate in outdoor signs or in other cold temperature applications are designed for use with T12 lamps. Therefore, DOE chose a T12 ballast as a baseline for this representative ballast type. DOE paired the ballast with an F96T12HO lamp that represented the most common outdoor sign lamp available in the market today.

Current standards cover ballasts that operate two F96T12HO/ES lamps designed to operate at ambient temperatures of −20 °F or less and designed for use in an outdoor sign expired for ballasts manufactured after July 1, 2010. (10 CFR 430.32(m)) However, DOE determined that four-lamp, full-wattage F96T12HO lamp and ballast systems were the most common. Therefore, in choosing the baseline ballast for this market sector, DOE tested several sign ballasts that operate F96T12HO lamps and chose the most common and least efficient ballast on the market as listed in Table 5.73. The vast majority of sign ballasts are magnetic, RS, and operate at a low BF. Furthermore, the majority of the least efficient sign ballasts are dedicated voltage and operate four 8-foot HO lamps. Finally, DOE chose a ballast that has an input voltage of 120V as the majority of ballasts operate in outdoor signs at 120V. The BEF, BF, and input power of this ballast are shown in Table 5.73.

Table 5.73 Baseline Ballasts for the Sign Ballast Representative Ballast Type

For Operation of	Starting Method, Input Voltage, Ballast Type	BF	Input Power (W)	BLE (%)	Federal Minimum Energy Conservation Standard
4, F96T12HO Lamps	RS, 120V, Magnetic, Dedicated Voltage	0.73	390.3	74.6%	N/A

DOE paired 8-foot HO ballasts with an appropriate F96T12HO lamp. Because lamps used in outdoor sign applications were not covered by the 2009 Lamps Rule, DOE chose a 8-foot HO lamp that represents the most common lamp available in the market today. The characteristics of this lamp are listed in the table below.

Table 5.74 Lamps for Use with F96T12HO Sign Ballasts

Lamp Type	CCT	Rated Efficacy*	Initial Light Output	Mean Light Output	Life	CRI
	K	*lm/W*	*lm*	*lm*	*hr*	
F96T12HO	4200	63.3	8,600	6,966	12,000	60

This combination of lamp and ballast represents the most common configuration for these ballasts in existing and new installations. Together, this lamp-and-ballast combination creates a system lumen package of approximately 20,350 mean lumens (and 25,124 initial lumens) for the baseline F96T12HO ballast.

5.18.2 Efficiency Levels

The following discussion identifies the steps and technologies associated with each EL DOE considered for the sign ballast representative ballast type. As discussed in the screening analysis (final rule TSD chapter 4), DOE used design options that achieve a higher BLE than the baseline ballast. Because the baseline ballast is a magnetic ballast, improvements required the use of an electronic ballast. For the sign ballast representative ballast type, DOE identified one EL. EL1 represents the maximum technologically feasible level.

EL1. This level represents an improvement in efficiency over the baseline ballast. Ballasts at this level are electronic rather than the magnetic ballasts that meet the baseline level.

Table 5.75 Summary of ELs for Sign Ballasts

Efficiency Level	BLE Requirement With Variation Reduction
EL1	0.993/(1+0.47*total lamp arc power^-0.25)

Figure 5.11 illustrates the one EL on a plot of sign ballasts. A circle indicates a representative unit tested by DOE. Diamonds indicate other sign ballasts tested by DOE.

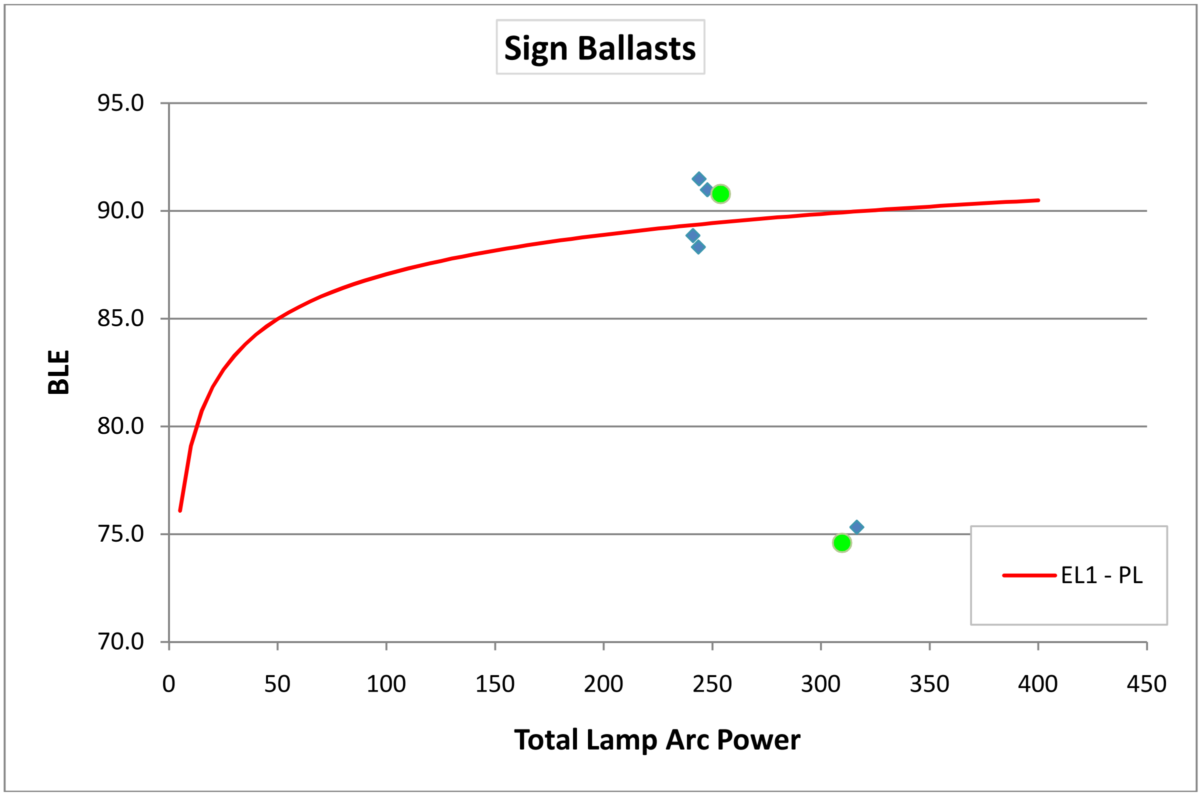


Figure 5.11 Efficiency Levels for the Sign Ballast Representative Ballast Type

Table 5.76 provides detailed information on the 8-foot HO ballast designs used in the engineering analysis and subsequent analyses.

Table 5.76 Ballast Designs for the Sign Ballast Representative Ballast Type

Efficiency Level	For Operation Of	Ballast Type	Starting Method	Input Voltage	Universal or Dedicated Voltage	Power Factor	THD (%)	Ballast Factor	Input Power (W)	Lamp Arc Power (W)	BLE (%)
Baseline	2 F96T12HO Lamps	Magnetic	RS	120	Dedicated	-	-	0.73	390.3	309.7	74.6
EL1	2 F96T12HO Lamps	Electronic	IS	120	Universal	-	-	0.63	279.6	253.8	90.8

5.18.3 Lamp and Ballast Prices

DOE analyzed each EL for the sign ballast representative ballast type to develop appropriate MSPs. In general, DOE developed ratios between online ballast suppliers and teardown-sourced MSPs. Using these supplier-specific ratios, DOE scaled online sign ballast prices to the MSP. As depicted in the table below, DOE found the EL1 MSP to be less than the baseline. Manufacturers indicated the magnetic ballast (baseline) would be sold at a higher price than the more efficient electronic ballast (EL1) due to higher prices of raw material.

Table 5.77 Manufacturing Selling Prices for the Sign Ballast Representative Ballast Type

Efficiency Level	Lamp Type	MSP (2009$)
Baseline	F96T12HO	$40.23
EL1	F96T12HO	$35.58

Because DOE did not analyze 8-foot HO cold temperature fluorescent lamps in the 2009 Lamps Rule, DOE developed the price for that lamp using the same methodology employed in the 2009 Lamps Rule. The resultant price is shown in the table below.

Table 5.78 Retail Prices for Eight-Foot HO Cold Temperature Fluorescent Lamps

Lamp Type	Retail Price (2007$)
F96T12HO	$4.84

5.18.4 Results

Table 5.79 presents the engineering characteristics of the ballast replacement options for the baseline F96T12HO system in the sign ballast representative ballast type. Because the BF of the standards-case system is lower than the baseline system, the normalized input power is higher than the measured input power. If a direct substitution is made, mean lumen output would decrease by no more than thirteen percent because of the lower ballast factor.

Table 5.79 Sign Ballast Representative Ballast Type with F96T12HO Baseline

Efficiency Level	For Operation Of	Ballast Type	Starting Method	Input Voltage	Universal or Dedicated Voltage	Ballast Factor	Input Power (W)	Lamp Arc Power (W)	BLE (%)	System Initial Light Output (lm)	System Mean Light Output (lm)	Percentage Change Mean Lumen Output (%)	Ballast Manufacturer Selling Price (2009$)	Lamp Retail Price (2007$)	Normalized Input Power (W)
Baseline	4 F96T12HO Lamps	Magnetic	RS	120	Dedicated	0.73	390.3	309.7	74.6	25,124	20,350	0%	$40.23	$19.34	390.3
EL1	4 F96T12HO Lamps	Electronic	IS	120	Universal	0.63	279.6	253.8	90.8	21,810	17,666	-13%	$35.58	$19.34	322.1

5.19 SCALING TO PRODUCT CLASSES NOT ANALYZED

DOE identified and selected certain product classes as "representative" product classes on which to concentrate its analytical effort. DOE chose these representative product classes primarily due to their high market volumes. Variables such as number of lamps and ballast factor are accounted for in the EL equation due to the change in lamp arc power. DOE did not analyze 8-foot HO PS ballasts or 4-foot MBP PS residential ballasts directly. Thus, it was necessary to develop a scaling relationship for these product classes. To do so, DOE compared 4-foot MBP IS/RS ballasts to their PS counterparts. DOE found the average reduction in BLE to be 2 percent.

Because DOE established different curve shapes for IS/RS versus PS product classes, DOE input the arc power of the representative unit at each EL into the IS/RS efficiency level equation to calculate the minimum required BLE. DOE then fit an efficiency level with a PS exponent (the exponent "C" is 0.37 for PS ballasts) such that it passed through the minimum required BLE by adjusting the coefficient "B". Then, DOE applied the 2 percent reduction factor to the overall equation to account for the expected difference in efficiency between IS and PS ballasts. Because multiple representative ballast types existed in the same product class, DOE sought to match the stringency of the PS curve to the IS curve at the highest arc power within that product class.

Table 5.80 Summary of ELs for the 8-foot HO PS Product Class

Efficiency Level	BLE Requirement With Variation Reduction
EL1	0.973/(1+1.86*total lamp arc power^-0.37)
EL2	0.973/(1+0.70*total lamp arc power^-0.37)
EL3	0.973/(1+0.52*total lamp arc power^-0.37)

Table 5.81 Summary of ELs for the Residential 4-foot MBP PS Product Class

Efficiency Level	BLE Requirement With Variation Reduction
EL1	0.973/(1+0.71*total lamp arc power^-0.37)
EL2	0.973/(1+0.50*total lamp arc power^-0.37)

5.20 EFFICIENCY LEVEL SUMMARY

Table 5.82 lists the EL equations developed by DOE

Table 5.82 Efficiency Level Equations

BLE = A/(1+B*total lamp arc power^-C) where A, B, and C are as follows:

Representative Product Class	Efficiency Level	A	B	C
IS and RS ballasts (not classified as residential) that operate: 4-foot MBP lamps 2-foot U-shaped lamps 8-foot slimline lamps	EL 1	0.993	0.46	0.25
	EL 2		0.31	
	EL 3		0.27	
PS ballasts (not classified as residential) that operate: 4-foot MBP lamps 2-foot U-shaped lamps 4-foot MiniBP SO lamps 4-foot MiniBP HO lamps	EL 1	0.993	0.60	0.37
	EL 2		0.55	
	EL 3		0.51	
IS and RS ballasts (not classified as sign ballasts) that operate: 8-foot HO lamps	EL 1	0.993	1.01	0.25
	EL 2		0.38	
	EL 3		0.28	
PS ballasts (not classified as sign ballasts) that operate: 8-foot HO lamps	EL 1	0.973	1.86	0.37
	EL 2		0.70	
	EL 3		0.52	
Sign ballasts that operate: 8-foot HO lamps	EL 1	0.993	0.47	0.25
IS and RS residential ballasts that operate: 4-foot MBP lamps 2-foot U-shaped lamps 8-foot slimline lamps	EL 1	0.993	0.41	0.25
	EL 2		0.29	
PS residential ballast that operate: 4-foot MBP lamps	EL 1	0.973	0.71	0.37

2-foot U-shaped lamps	EL 2		0.50	

The following figures depict the EL equations for each representative product class on a plot of the ballasts tested in that representative product class.

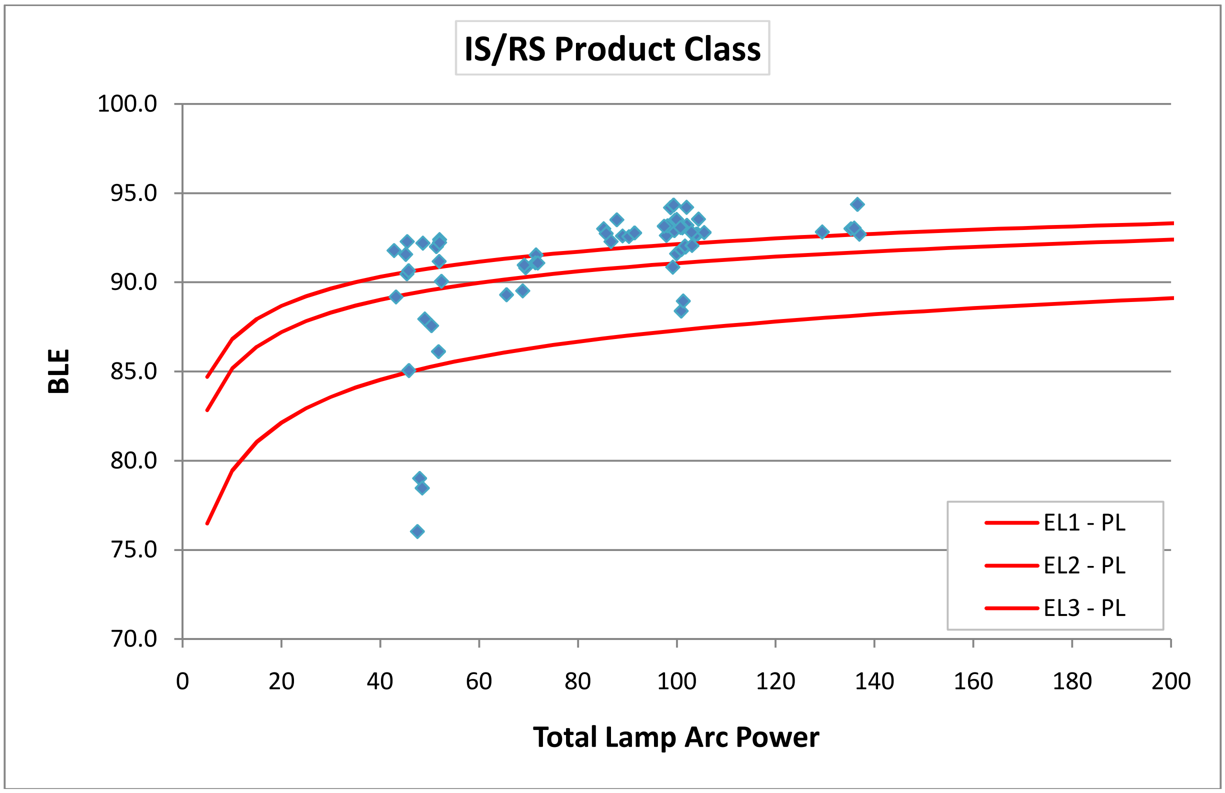


Figure 5.12 IS and RS Product Class

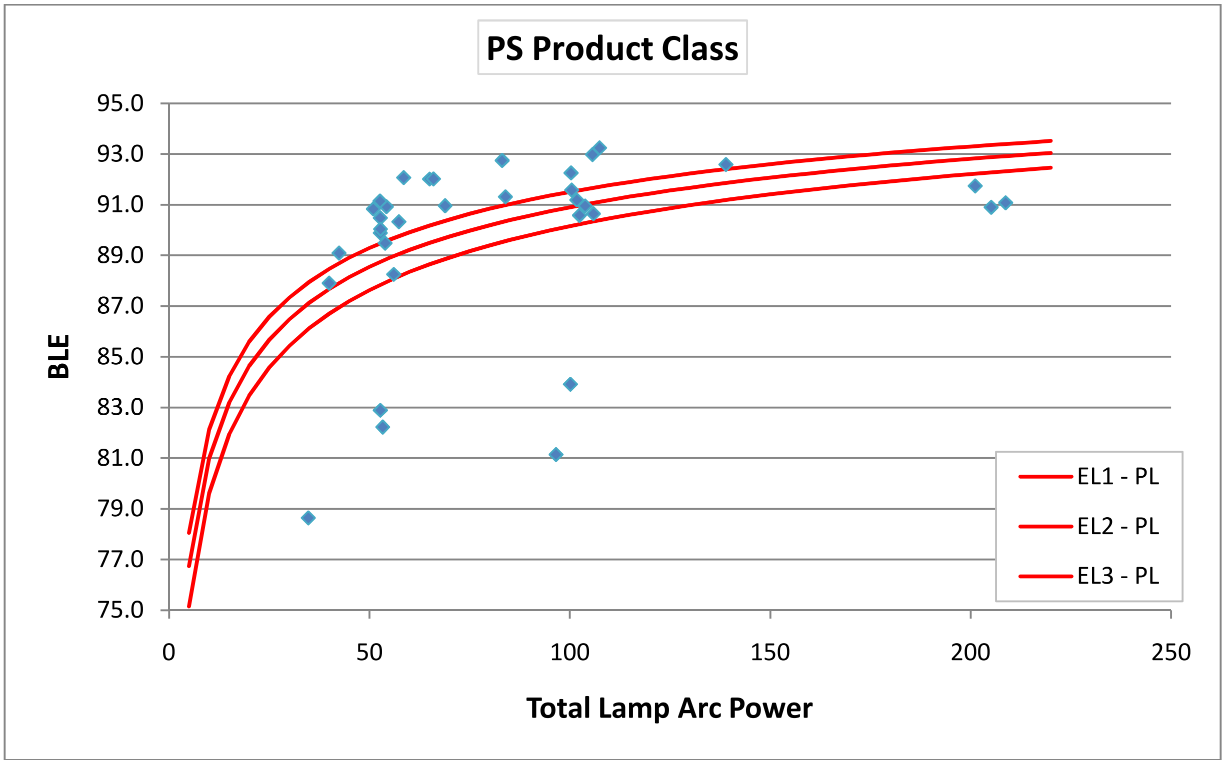


Figure 5.13 PS Product Class

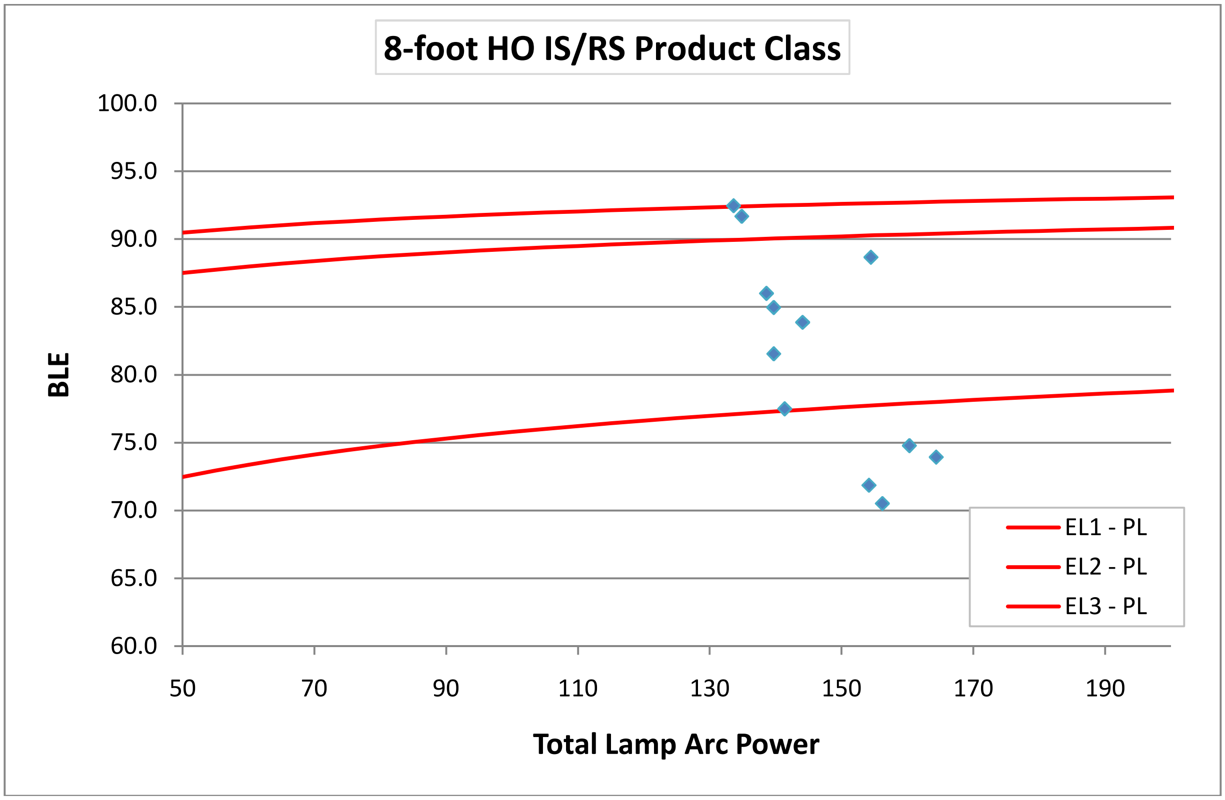


Figure 5.14 Eight-foot HO Product Class

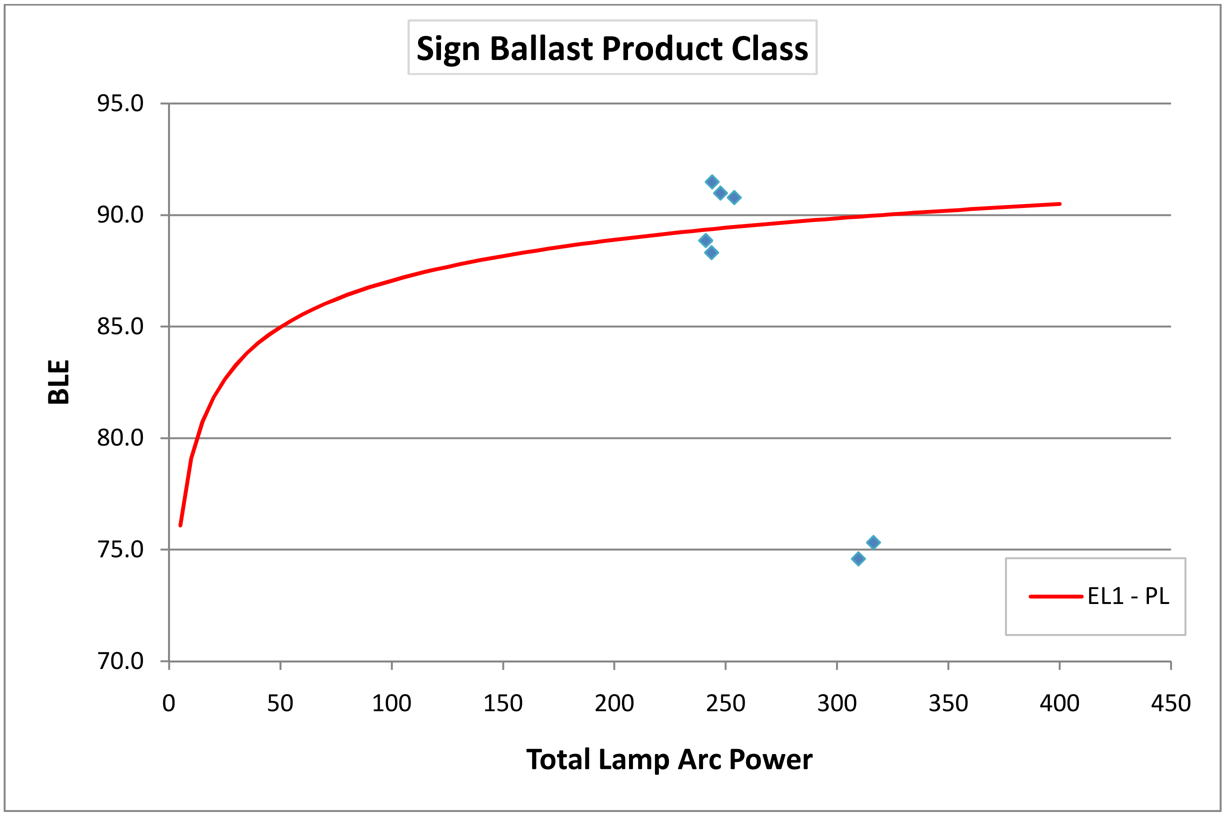


Figure 5.15 Sign Ballast Product Class

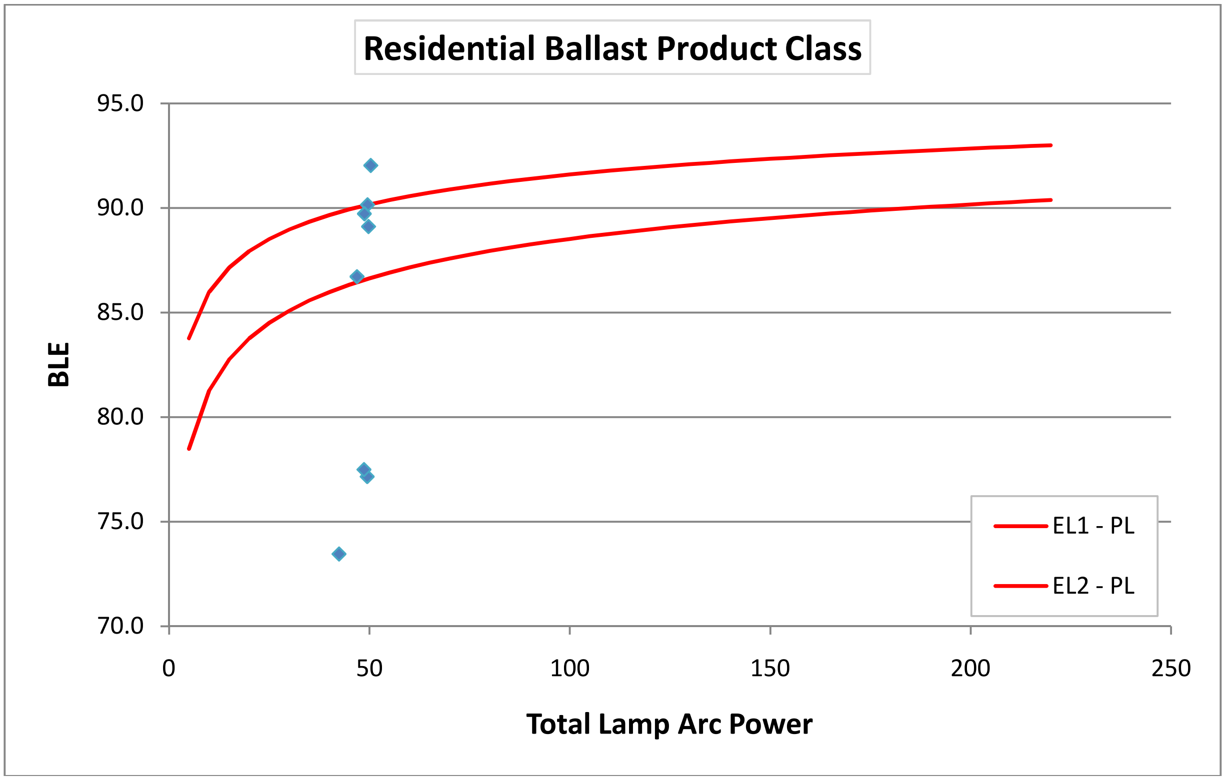


Figure 5.16 Residential Ballast Product Class

5.21 MSP COMPARISON

As described in section 5.6, DOE developed MSP using three main inputs. These inputs included physical teardown analysis, blue book manufacturer price lists, and confidential manufacturer supplied data. Table 5.83 lists the prices based on each information source for each representative ballast type. DOE also presents plots for the three representative ballast types with the most complete data in Figure 5.17, Figure 5.18, and Figure 5.19. All manufacturer supplied MSP data included in these figures are aggregations of multiple data points.

As described in section 5.6, DOE used an average of blue book- and teardown-based MSPs when developing the final MSP to be assigned to an EL. Manufacturer MSPs were used for normalization and verification purposes. DOE chose to use the blue book and teardown data because this data was available in the public domain allowing for verification by DOE and interested parties. Manufacturer data is less verifiable by interested parties, so DOE decided not to use it as the primary data source for developing MSP data. Furthermore, manufacturer data was not available for all ELs in all representative ballast types.

Table 5.83 Summary of MSP Data

		Final (2009$)	Blue Book (2009$)	Teardown (2009$)	Manufacturer (2009$)
Two-Lamp MBP IS and RS	Baseline	8.41	8.41		11.89
	Baseline/EL 1*	6.94	6.94	6.94	6.94
	EL 2	8.85	8.36	9.34	7.45

	EL 3	9.27	8.51	10.04	9.06
Four-Lamp MBP IS and RS	Baseline/EL 2*	9.79	9.79	9.79	9.79
	EL 3	11.63	12.18	11.09	12.47
Eight-foot SP Slimline	Baseline/EL 1	8.84	8.84		12.75
	Baseline/EL 2	10.05	10.05		8.75
	EL 3*	10.29	10.29	10.29	10.29
Two-Lamp MBP IS and RS Residential	Baseline	4.68	4.68		
	Baseline/EL 1	3.77	3.77		
	EL 2				
	EL 3*	4.62	4.62		4.62
Two-Lamp MBP PS	Baseline*	8.39	8.39	8.39	8.39
	EL 1				
	EL 2	9.28	10.38		
	EL 3	9.59	9.61	9.58	13.64
Four-Lamp MBP PS	Baseline	9.05	9.05		
	EL 1*	11.84	11.84		11.84
	EL 2				
	EL 3	13.33	13.33		
Two Lamp T5 MiniBP SO	Baseline	10.78	9.63		
	EL 1*	10.85	10.85		
	EL 2	11.92	11.92		11.92
	EL 3	15.36	15.36		
Two Lamp T5 MiniBP HO	Baseline	9.61	9.61		
	EL 1*	12.58	12.58		12.58
	EL 2	14.70	14.70		
	EL 3	16.76	16.76		12.08
Eight-foot RDC HO IS and RS	Baseline*	13.25	13.25		13.25
	EL 1	9.55	9.55		17.54
	Baseline/EL 2	8.15	8.15		
	EL 3	11.05	11.05		
Sign Ballasts	Baseline	40.23	40.23		
	EL 1	35.58	35.58		
* MSPs were normalized to the EL marked with an asterisk.					

Figure 5.17 Two-Lamp MBP IS and RS Representative Ballast Type MSP Data

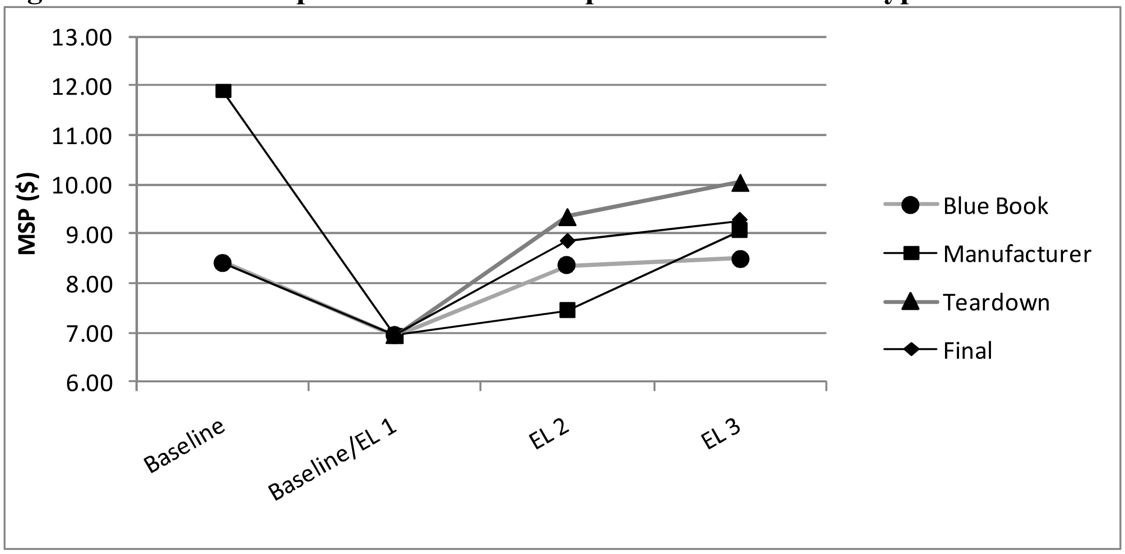


Figure 5.18 Two-Lamp MBP PS Representative Ballast Type MSP Data

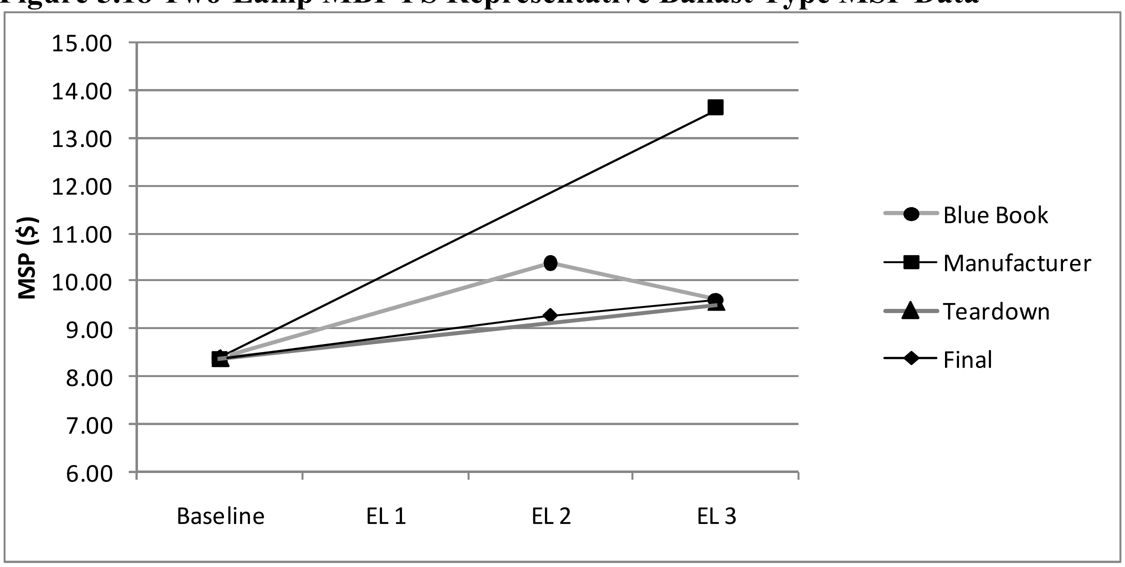
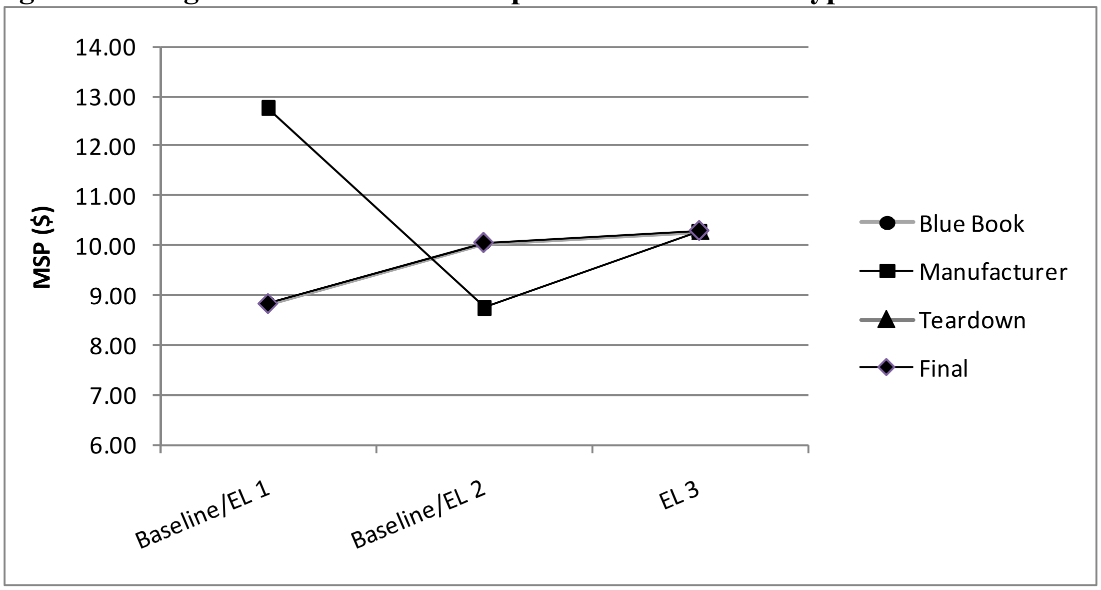


Figure 5.19 Eight-Foot SP Slimline Representative Ballast Type MSP Data



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CHAPTER 6. ENERGY USE CHARACTERIZATION

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CHAPTER 6. ENERGY USE CHARACTERIZATION

6.1 INTRODUCTION

This chapter presents the methodology the U.S. Department of Energy (DOE) followed to estimate the annual energy use of the fluorescent lamp-and-ballast system designs DOE considered in its analyses for this final rule. Because fluorescent lamp ballasts are designed to operate fluorescent lamps, DOE chose the most common fluorescent lamp used with each ballast to develop representative lamp-and-ballast systems. Fluorescent lamps will not be regulated under the adopted ballast rulemaking; however, the energy use analysis considered the input power of the entire lamp-and-ballast system. The results of this analysis, which represent typical energy use in the field, were critical inputs to the life-cycle cost (LCC) and payback period (PBP) analyses (final rule technical support document [TSD] chapter 8) and the national impact analysis (NIA; final rule TSD chapter 11). DOE required information on annual energy use to determine the potential energy and operating cost savings to consumers from the use of more efficient products.

DOE determined the annual energy use of the lamp-and-ballast systems using information on their rated input power (*i.e.*, the rate of energy they use) and the way consumers use them (*i.e.*, operating hours per year). The engineering analysis (final rule TSD chapter 5) discusses the power ratings of lamp-and-ballast systems. The following sections discuss the inputs and calculations DOE used to develop annual operating hours and annual energy use for the products considered in this analysis.

6.2 LAMP AND BALLAST SYSTEM OPERATING HOURS

To characterize the country's average use of lamp-and-ballast systems for a typical year, DOE developed annual operating hours by sector. For the LCC, DOE accounted for variability in operating hours by developing a distribution of operating hours for the LCC spreadsheet. This distribution captured variation across nine census divisions (New England, Middle Atlantic, East North Central, West North Central, South Atlantic, East South Central, West South Central, Mountain, and Pacific) and large states (California, Florida, New York, and Texas), building types, and lamp-and-ballast systems for three sectors (residential, commercial, and industrial).

DOE's analysis relied on a combination of data from the U.S. Lighting Market Characterization (LMC) Volume 1[1] and data from the Energy Information Administration's (EIA's) 2003 Commercial Building Energy Consumption Survey (CBECS),[2] 2005 Residential Energy Consumption Survey (RECS),[3] and 2006 Manufacturer Energy Consumption Survey (MECS).[4] RECS was updated in 2009, but these updates did not address lighting usage; therefore, DOE used RECS 2005 data for this final rule. The EIA studies provide information on the distribution of U.S. buildings by building type and census division. The LMC, which is based on thousands of building audits and surveys, provides national-level data on annual operating hours by building type and lamp type for all sectors. For the commercial and industrial sectors, these operating hours are divided by application (assembly, athletic, bathroom, boarding, class, dining, display, exit, exterior-architectural, exterior-parking, exit-sign, exterior, food preparation, hall, healthcare, office, ship/rec, shop, storage, task, unknown, and utility). For the residential sector, these operating hours are divided by room type (bathroom, bedroom, closet, dining room, family room, garage, hall, kitchen, living room, office, outdoor, utility room, and other).

DOE associated LMC operating hour data by building type with EIA data by building type and census division to derive annual operating hours by census division and large states. This allowed DOE to correlate the electricity price distribution (final rule TSD chapter 8) and sales tax distribution (final rule TSD chapter 7) with the operating hour distribution by census division and large states in the LCC spreadsheet. The following paragraphs describe data sources DOE used to develop annual operating hours by sector.

For the residential sector, DOE used RECS building data and LMC residential sector operating hour data to develop a distribution of annual operating hours for fluorescent lamp-and-ballast systems. The 2005 RECS data indicates the probability that a certain building type resides within a census division. The LMC indicates the occurrence of certain room types within a given building type and the operating hour characteristics in these rooms. DOE used aggregated data from the LMC to associate average annual operating hours per building type. DOE chose to aggregate operating hour data to the building rather than at the room level because DOE believes it more closely represents the impact on an individual consumer. However, DOE used operating hour data at the room level to generate uncertainty results for the final rule analyses.

DOE used a similar approach to develop a distribution of annual operating hours in the commercial sector. However, instead of room type, DOE aggregated LMC annual operating hour data by application to develop average annual operating hours by building type. The 2003 CBECS data indicates the probability that a certain building type exists within in a certain census division. Once the LCC model selects a building, DOE associates the aggregated LMC annual operating hour average with the building type selected. Like the residential sector, DOE chose to aggregate LMC operating hour data to the building level for the commercial and industrial sectors because it more closely represents the impact on consumers.

To develop a distribution of annual operating hours in the industrial sector, DOE used an approach consistent with that used for the commercial sector. The 2006 MECS data indicates the probability that a certain building type exists. DOE aggregated LMC annual operating hour data by industrial application to develop average annual operating hours by building type. Once the model selected a building, DOE associated the aggregated LMC operating hour average with the building type selected. Table 6.2.1 summarizes the weighted average annual operating hours per sector.

Table 6.2.1 Average Annual Lamp-and-Ballast System Operating Hours by Sector

Sector	**Average Annual Operating Hours** *hr/yr*
Residential	789
Commercial	3,886
Industrial	4,747

In the case of programmed-start (PS) ballasts operating two-lamp and four-lamp 4-foot medium bipin (MBP) F32T8 lamps, DOE assumed that these lamp-and-ballast systems are operated on occupancy sensors in the commercial sector. Occupancy sensors detect the presence or absence of people within their coverage area and turn lights on and off accordingly, thereby reducing operating time and energy use. DOE examined a range of estimates for energy savings from occupancy sensors compiled in E Source[5] and other sources[6] and, based on these estimates, assumed energy savings of 30 percent for operating lamp-and-ballast systems on occupancy sensors in the commercial sector. To account for these energy savings, DOE reduced average operating hours for affected lamp-and-ballast systems by 30 percent. **Error! Reference source not found.** presents the adjusted average annual operating hours for PS lamp-and-ballast systems operating on occupancy sensors in the commercial sector.

Table 6.2.2 Two- and Four-Lamp 4-Foot MBP PS Product Classes (F32T8 Baseline) – Adjusted Average Annual Operating Hours for Commercial Sector

Sector	**Average Annual Operating Hours** *hr/yr*
Commercial	2,721

6.3 RESULTS OF THE ENERGY USE CHARACTERIZATION

This section presents the annual energy use estimates for fluorescent lamp-and-ballast system designs. DOE calculated the annual energy use using annual operating hours and input power rating estimates. DOE used the annual energy use results in the LCC and PBP analyses and the NIA to calculate the operating cost of systems and estimate the potential energy savings of considered efficiency levels.

Using annual operating hours and system rated input power ratings, DOE calculated the annual energy use of the entire lamp-and-ballast system. The engineering analysis (final rule TSD chapter 5) references both measured system input power and normalized system input power, with the latter used to normalize input power between baseline and standards-case systems to maintain the same approximate light output.

Table 6.3.1 details (1) the measured and normalized input power ratings for all the lamp-and-ballast systems DOE assessed in the LCC and PBP analysis for each product class; and (2) average annual energy use per lamp-and-ballast system based on measured and normalized input power, using the U.S. weighted average of annual operating hours in each sector (see Table 6.2.1 and Table 6.2.2).

Table 6.3.1 Input Power Ratings and Average Annual Energy Use for Ballasts

Product Class and Ballast Type	Efficiency Level	Input Power *W*		Annual Energy Use *kWh*	
		Measured	**Normalized**	**Measured**	**Normalized**
IS and RS ballasts that operate:					
Two 4-foot MBP lamps (commercial)	Baseline (T12)	60.7	60.7	236.0	236.0
	Baseline (T8)/1	57.1	56.3	221.9	218.8
	2	55.1	53.7	214.1	208.7
	3	54.0	53.1	209.8	206.4
Four 4-foot MBP lamps	Baseline/2	106.2	106.2	412.6	412.6
	3	103.5	104.6	402.4	406.5
Two 8-foot slimline lamps	Baseline (T12)/1	113.5	113.5	441.1	441.1
	Baseline (T8)/2	107.8	110.2	418.9	428.2
	3	105.8	108.6	411.2	422.2
PS ballasts that operate:					
Two 4-foot MBP lamps	Baseline	60.0	60.0	163.1	163.1
	2	55.6	55.5	151.1	151.1
	3	54.7	54.8	148.9	149.1
Four 4-foot MBP lamps	Baseline	111.6	111.6	303.5	303.5
	1	110.8	101.0	301.5	274.8
	3	107.7	98.4	293.0	267.7
Two 4-foot MiniBP SO lamps	Baseline	67.6	67.6	262.8	262.8
	1	62.7	62.7	243.7	243.7
	2	59.7	62.1	232.0	241.2
	3	63.1	60.4	245.1	234.8
Two 4-foot MiniBP HO lamps	Baseline	123.5	123.5	586.4	586.4
	1	112.0	112.0	531.6	531.6
	2	108.7	110.8	515.9	525.8
	3	109.1	109.8	518.0	521.3
Ballasts that operate:					
Two 8-foot HO lamps	Baseline (T12)	198.8	198.8	943.7	943.7
	1	176.0	183.4	835.4	870.5
	Baseline (T8)/2	147.1	183.9	698.3	872.8
	3	144.5	182.3	686.0	865.4
Sign ballasts that operate:					
Four 8-foot HO lamps	Baseline	390.3	390.3	1516.8	1,516.8
	1	279.6	322.1	1086.6	1,251.7
IS and RS ballasts that operate:					
Two 4-foot MBP lamps (residential)	Baseline (T12)	62.6	62.6	49.4	49.4
	Baseline (T8)/1	50.9	56.8	40.2	44.8
	2	52.1	55.0	41.1	43.4

IS = instant start
RS = rapid start
PS = programmed start
MBP = medium bipin
MiniBP = miniature bipin
SO = standard output
HO = high output

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CHAPTER 7. MARKUPS ANALYSIS

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CHAPTER 7. MARKUPS ANALYSIS

7.1 INTRODUCTION

This chapter describes the methodology the U.S. Department of Energy (DOE) followed in developing end-user prices and sales tax in its analyses for the fluorescent lamp ballasts final rule. In this rulemaking, DOE performed teardown analyses and a manufacturer markup analysis to develop manufacturer selling prices (MSPs) for representative ballast designs (final rule technical support document [TSD] chapter 5). DOE then applied distribution channel markups and sales tax to derive end-user prices. By combining the engineering analysis results and the distribution channel markups analysis, DOE derived typical inputs for use in the life-cycle cost (LCC) analysis and the national impact analysis (NIA). In particular, DOE developed end-user prices for ballast designs associated with evaluated efficiency levels.

The end-user product price depends on how the end user purchases the product. For commercial and industrial ballast designs, two types of distribution channels describe how most ballasts pass from the manufacturer to the end user. The first distribution channel applies to ballasts installed in fixtures. In this distribution channel, the manufacturer sells the ballast to an original equipment manufacturer (OEM)—in this case, the fixture manufacturer—who in turn sells it to an electrical wholesaler (*i.e.*, distributor), who sells it to a contractor, who passes it on to the end user. The second distribution channel applies to ballasts not installed in fixtures (*e.g.*, replacement ballasts). In this distribution channel, the manufacturer sells the ballast to an electrical wholesaler, who sells it to a contractor, who passes it on to the end user. Figure 7.1.1 illustrates the two main distribution channels for commercial and industrial ballasts. For residential ballast designs, DOE assumed that the manufacturer sells the ballast to an OEM who in turn sells it in a fixture to a home improvement retailer, where it is purchased by the end user.

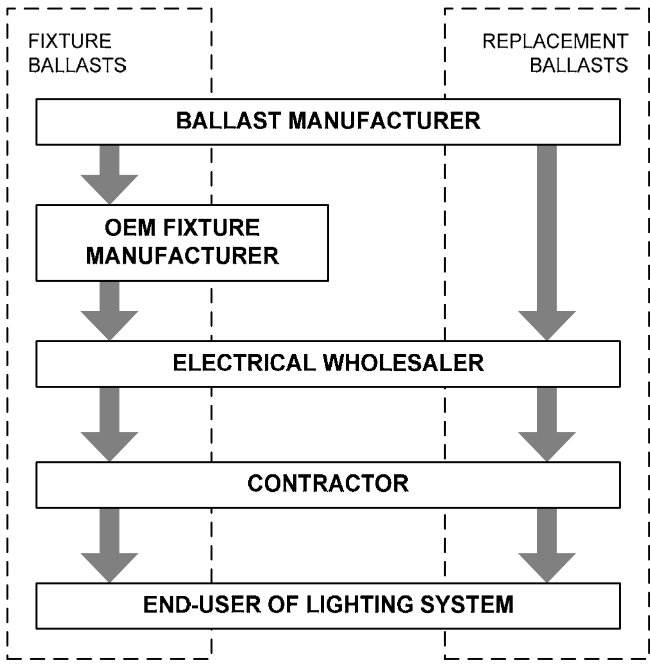

Figure 7.1.1 Distribution Channels for Commercial and Industrial Ballasts

For commercial and industrial ballast designs, DOE assumed ballasts in fixtures represent 63 percent of the market and replacement ballasts represent 37 percent. These percentages are from the Fluorescent Ballasts Energy Conservation Standards Final Rule published on September 19, 2000 (hereafter "the 2000 Ballast Rule"). 65 FR 56740. DOE could not obtain retailer sales data detailing the breakdown between residential fixture ballasts and replacement ballasts, and therefore assumed that ballasts in fixtures represented 100 percent of the residential market.

To meet new or amended energy conservation standards, manufacturers often introduce design changes to their product lines that result in increased production costs and MSPs. DOE assumed that some or all of the increased production costs can be passed through the distribution channels and eventually to end users in the form of higher sales prices.

At each point in the distribution channel, companies apply "markup" to the MSP to cover their business costs and profit margin. DOE models this markup as a multiplier. In financial statements, gross profit is the difference between the company revenue and the company cost of sales. It includes all corporate overhead costs (sales, general, and administration), materials and labor costs, research and development and interest expenses, depreciation and taxes, and profits. For sales of a product to contribute positively to company cash flow, the product's markup must be greater than the sum of cost of sales and business costs for that product. DOE calculated the end-user sales price by multiplying the MSP by the various markups and applying sales tax.

The end-user prices and installation costs are key inputs to the LCC analysis, payback period (PBP) analysis, and the NIA. Using the distribution channel markups and installation costs, DOE calculated the initial costs that consumers would face under the various efficiency levels evaluated. DOE evaluated the tradeoff between the increase in first cost and the resulting energy cost savings at each efficiency level in the LCC and PBP analyses (final rule TSD chapter 8) and NIA analysis (final rule TSD chapter 11).

The following equation describes how DOE determined the product prices for commercial and industrial ballast designs installed in fixtures:

$$P_{END} = (P_{MFR} \times MU_{OEM} \times MU_{WHOLE} \times MU_{CONT} \times MU_{TAX}) \qquad \textbf{Eq. 7.1}$$

Where:

P_{END} = product price to the end user ($),
P_{MFR} = MSP of baseline or standard-level product ($),
MU_{OEM} = OEM markup,
MU_{WHOLE} = wholesaler markup,
MU_{CONT} = contractor markup, and
MU_{TAX} = sales tax markup.

For replacement ballasts, the equation is the same as above except that the OEM markup (MU_{OEM}) is omitted. For residential ballast designs, DOE substituted a home improvement retailer markup ($MU_{RETAILER}$) for the wholesaler markup, and eliminated the contractor markup (to reflect the end user's direct purchase).

For each party involved in the distribution of the product, the markups presented above are further differentiated between a "baseline markup" and an "incremental markup," as described below. A third type of markup, the "overall markup," describes the product of all the markups within a distribution channel.

7.1.1 Baseline Markups

Baseline markups are defined as coefficients that relate the manufacturer price of baseline ballast designs to the OEM, wholesaler, or contractor baseline sales price, as shown in the following equations:

$$P_{OEM\_BASE} = (P_{MFR\_BASE} \times MU_{OEM\_BASE}) \qquad \textbf{Eq. 7.2}$$

$$P_{WHOLE\_BASE} = (P_{OEM\_BASE} \times MU_{WHOLE\_BASE}) \qquad \textbf{Eq. 7.3}$$

$$P_{CONT\_BASE} = (P_{WHOLE\_BASE} \times MU_{CONT\_BASE}) \qquad \textbf{Eq. 7.4}$$

$$P_{END\_BASE} = (P_{CONT\_BASE} \times MU_{TAX}) \qquad \textbf{Eq. 7.5}$$

Where:

P_{OEM_BASE} = OEM selling price of baseline product ($),
P_{MFR_BASE} = MSP of baseline product ($),
MU_{OEM_BASE} = OEM markup for baseline product,

P_{WHOLE_BASE} =	wholesaler selling price of baseline product ($),
MU_{WHOLE_BASE} =	wholesaler markup for baseline product,
P_{CONT_BASE} =	contractor selling price of baseline product ($),
MU_{CONT_BASE} =	contractor markup for baseline product,
P_{END_BASE} =	end-user purchase price for baseline product ($), and
MU_{TAX} =	sales tax markup.

For residential fixture ballast designs, the equations are same as above except that the wholesaler is replaced with a home improvement retailer and the retailer baseline selling price is determined by applying the retailer baseline markup to the MSP for the OEM fixture. Because the contractor is omitted, the end-user baseline price is determined by applying sales tax to the retailer baseline selling price:

$$P_{RETAILER\_BASE} = (P_{OEM\_BASE} \times MU_{RETAILER\_BASE}) \qquad \textbf{Eq. 7.6}$$

$$P_{END\_BASE} = (P_{RETAILER\_BASE} \times MU_{TAX}) \qquad \textbf{Eq. 7.7}$$

For replacement ballasts (commercial and industrial only), the equations are the same as above except that the OEM ($P_{OEM\_BASE} = (P_{MFR\_BASE} \times MU_{OEM\_BASE})$) is omitted and the wholesaler baseline selling price is determined by applying the wholesaler baseline markup to the MSP for baseline products:

$$P_{WHOLE\_BASE} = (P_{MFR\_BASE} \times MU_{WHOLE\_BASE}) \qquad \textbf{Eq. 7.8}$$

7.1.2 Incremental Markups

Incremental markups are defined as coefficients that relate changes in the manufacturer price of higher efficiency product to change the OEM, wholesale, or contractor sales price, as shown in the following equations:

$$P_{OEM\_INCR} = (P_{MFR\_INCR} \times MU_{OEM\_INCR}) \qquad \textbf{Eq. 7.9}$$

$$P_{WHOLE\_INCR} = (P_{OEM\_INCR} \times MU_{WHOLE\_INCR}) \qquad \textbf{Eq. 7.10}$$

$$P_{CONT\_INCR} = (P_{WHOLE\_INCR} \times MU_{CONT\_INCR}) \qquad \textbf{Eq. 7.11}$$

$$P_{END\_INCR} = (P_{WHOLE\_INCR} \times MU_{TAX}) \qquad \textbf{Eq. 7.12}$$

Where:

P_{OEM_INCR} =	incremental OEM price for product with increased efficiency ($),
P_{MFR_INCR} =	incremental manufacturer price for product with increased efficiency ($),
MU_{OEM_INCR} =	incremental OEM markup for product with increased efficiency,
P_{WHOLE_INCR} =	incremental wholesaler price for product with increased efficiency ($),
MU_{WHOLE_INCR} =	incremental wholesaler markup for product with increased efficiency,

$P_{CONT\_INCR} =$ incremental contractor price for product with increased efficiency ($),
$MU_{CONT\_INCR} =$ incremental contractor markup for product with increased efficiency,
$P_{END\_INCR} =$ incremental end-user price for baseline product ($), and
$MU_{TAX} =$ sales tax markup.

For residential fixture ballast designs, the equations are same as above except that the wholesaler is replaced with a home improvement retailer and the incremental retailer selling price is determined by applying the retailer incremental markup to the incremental MSP for the OEM fixture. Because the contractor is omitted, the end-user baseline price is determined by applying sales tax to the incremental retailer selling price:

$$P_{RETAILER\_INCR} = (P_{OEM\_INCR} \times MU_{RETAILER\_INCR}) \qquad \textbf{Eq. 7.13}$$

$$P_{END\_INCR} = (P_{RETAILER\_INCR} \times MU_{TAX}) \qquad \textbf{Eq. 7.14}$$

For replacement ballasts, the equations are the same as above except that incremental OEM ($P_{OEM\_INCR} = (P_{MFR\_INCR} \times MU_{OEM\_INCR})$) is omitted and the incremental wholesaler price is determined by applying the incremental wholesaler markup to the incremental manufacturer price for product with increased efficiency:

$$P_{WHOLE\_INCR} = (P_{MFR\_INCR} \times MU_{WHOLE\_INCR}) \qquad \textbf{Eq. 7.15}$$

7.1.3 Overall Markups

Overall markups, including both overall baseline and overall incremental markups, relate the manufacturer price to the final consumer price (P_{END}) as indicated by the following equation:

$$P_{END} = (P_{END\_BASE} + P_{END\_INCR}) \qquad \textbf{Eq. 7.16}$$

7.2 ESTIMATION OF ORIGINAL EQUIPMENT MANUFACTURER, WHOLESALER, RETAILER, CONTRACTOR, AND SALES TAX MARKUPS

7.2.1 Financial Information Sources

Publicly owned companies are required by law to disclose financial information on a regular basis by filing different forms with the U.S. Securities and Exchange Commission (SEC). Filed annually, the SEC form 10-K provides a comprehensive overview of the company's business and financial conditions. Relevant information in the 10-K reports includes the company's revenues and direct and indirect costs. To generate markups for this rulemaking, DOE used 10-K reports from publicly owned lighting fixture manufacturers, electrical wholesalers, and home improvement retailers.

Because SEC financial data represents overall company conditions and is not product-specific, DOE investigated how markups derived from 10-K reports compared to actual product markups. With assistance from the National Electrical Manufacturers Association (NEMA), DOE attempted to contact several representative fixture OEMs regarding markups for fixture ballasts, but did not receive feedback in time for publication of the April 2011 Notice of Proposed Rulemaking (NOPR). 76 FR 20090 (April 11, 2011). DOE coordinated with the National Association of Electrical Distributors (NAED) in contacting two representative electrical wholesalers, who confirmed that DOE's calculated markups were consistent with their actual ballast markups.[1,2] To validate its retail markups for residential ballasts, DOE contacted The Home Depot and Lowe's,[3,4] but both organizations declined to comment, citing competition concerns. Based on this research and absent other data sources, DOE used SEC form 10-K data in developing markups for the NOPR.

The financial figures necessary for calculating the company markup are net sales, costs of sales, and gross profit. The income statement section of the 10-K reports often lists these figures. For the April 2011 NOPR, DOE used averages of the financial figures spanning 2005 to 2009 to calculate the markups. In response to the April 2011 NOPR, DOE received no adverse comments regarding its calculated markups. Given this and NAED's express confirmation of DOE's wholesaler markups, DOE retained its NOPR markups for the final rule. A review of 2010 financial figures showed only minor differences compared to 2009, which DOE determined would have an insignificant effect the 5-year averages used in calculating markups.

DOE used the following equations to calculate the gross profit and gross profit margins:

$$\text{Gross Profit (\$)} = \text{Net Sales} - \text{Cost of Sales} \qquad \textbf{Eq. 7.17}$$

$$\text{Gross Profit Margin} = \frac{\text{Gross Profit}}{\text{Net Sales}} \qquad \textbf{Eq. 7.18}$$

To calculate the time-average gross profit margin for each company, DOE first summed the gross profit for all the years and then divided the result by the sum of the net sales for the same years. DOE then used the gross profit margins to calculate baseline markups on existing product (*i.e.*, prior to efficiency changes resulting from enactment of adopted efficiency standards). Each company's baseline markup was calculated as:

$$\text{Baseline Markup} = \frac{1}{(1 - \text{Gross Profit Margin})} = \frac{\text{Net Sales}}{\text{Cost of Sales}} \qquad \textbf{Eq. 7.19}$$

Table 7.2.1, Table 7.2.2, and Table 7.2.3 contain the calculated gross profit margins for a sample of fixture OEMs, electrical wholesalers, and home improvement retailers, respectively.

Table 7.2.1 Gross Profit Margins for Fixture OEMs*

Company	Financial Figure $	Year 2009	2008	2007	2006	2005
A	Net Sales	1,657,404	2,026,644	1,964,781	1,841,039	2,172,854
	Cost of Sales	1,022,308	1,210,849	1,220,466	1,188,202	1,324,311
	Gross Profit	635,096	815,795	744,315	652,837	848,543
	Gross Profit Margin (%)	38.3	40.3	37.9	35.5	39.1
	Average Gross Profit Margin: 38.2%					
B	Net Sales	5,069,600	6,521,300	5,903,100	5,184,600	4,730,400
	Cost of Sales	3,483,800	4,396,700	3,970,000	3,521,500	3,243,800
	Gross Profit	1,585,800	2,124,600	1,933,100	1,663,100	1,486,600
	Gross Profit Margin (%)	31.3	32.6	32.7	32.1	31.4
	Average Gross Profit Margin: 32.0%					
C	Net Sales	2,355,600	2,704,400	2,533,900	2,414,300	2,104,900
	Cost of Sales	1,629,700	1,901,000	1,798,100	1,757,500	1,509,900
	Gross Profit	725,900	803,400	735,800	656,800	595,000
	Gross Profit Margin (%)	30.8	29.7	29.0	27.2	28.3
	Average Gross Profit Margin: 29.0%					

* Unless noted, all numbers are in thousands of dollars. This table includes 2005, 2006, 2007, 2008, and 2009 SEC 10-K reports.

Table 7.2.2 Gross Profit Margins for Electrical Wholesalers*

Company	Financial Figure $	Year 2009	2008	2007	2006	2005
A	Net Sales	4,377,882	5,400,154	5,258,301	5,009,143	4,288,043
	Cost of Sales	3,522,932	4,354,935	4,225,983	4,047,692	3,477,009
	Gross Profit	854,950	1,045,219	1,032,318	961,451	811,034
	Gross Profit Margin (%)	19.5	19.4	19.6	19.2	18.9
	Average Gross Profit Margin: 19.3%					
B	Net Sales	4,263,954	6,110,840	6,003,452	5,320,603	4,421,103
	Cost of Sales	3,724,061	4,904,164	4,781,336	4,234,079	3,580,398
	Gross Profit	539,893	1,206,676	1,222,116	1,086,524	840,705
	Gross Profit Margin (%)	12.7	19.7	20.4	20.4	19.0
	Average Gross Profit Margin: 18.4%					

* Unless noted, all numbers are in thousands of dollars. This table includes 2005, 2006, 2007, 2008, and 2009 SEC 10-K reports.

Table 7.2.3 Gross Profit Margins for Home Improvement Retailers*

Company	Financial Figure $	Year				
		2009	2008	2007	2006	2005
A	Net Sales	71,288,000	77,349,000	79,022,000	77,019,000	73,094,000
	Cost of Sales	47,298,000	51,352,000	52,476,000	51,081,000	48,664,000
	Gross Profit	23,990,000	25,997,000	26,546,000	25,938,000	24,430,000
	Gross Profit Margin (%)	33.7	33.6	33.6	33.7	33.4
	Average Gross Profit Margin: 33.6%					
B	Net Sales	48,230,000	48,283,000	46,927,000	43,243,000	36,464,000
	Cost of Sales	31,729,000	31,556,000	30,729,000	28,453,000	24,224,000
	Gross Profit	16,501,000	16,727,000	16,198,000	14,790,000	12,240,000
	Gross Profit Margin (%)	34.2	34.6	34.5	34.2	33.6
	Average Gross Profit Margin: 34.2%					

* Unless noted, all numbers are in thousands of dollars. This table includes 2005, 2006, 2007, 2008, and 2009 SEC 10-K reports.

The baseline markup covers non-production costs and profit. Table 7.2.4, Table 7.2.5, and Table 7.2.6 show the baseline markups using this method for OEMs, electrical wholesalers, and home improvement retailers, respectively.

Table 7.2.4 Calculated OEM Baseline Markups for Fluorescent Lamp Ballasts

Company	Baseline Markup
OEM – A	1.62
OEM – B	1.47
OEM – C	1.41
Average	1.50

Table 7.2.5 Calculated Electrical Wholesaler Baseline Markups for Fluorescent Lamp Ballasts

Company	Baseline Markup
Wholesaler A	1.24
Wholesaler B	1.23
Average	1.23

Table 7.2.6 Calculated Home Improvement Retailer Baseline Markups for Fluorescent Lamp Ballasts

Company	Baseline Markup
Wholesaler A	1.51
Wholesaler B	1.52
Average	1.51

The incremental markup applied to higher-efficiency products is lower than the baseline markup because DOE assumes that expenses like labor and occupancy costs remain fixed and need not be recovered in the markup. Profits and other operating costs are assumed to be variable and to scale with the MSP.

The surveyed SEC 10-K reports did not typically separate labor and occupancy costs from overall expenses, so DOE assumed that these fixed costs are encompassed by “Selling, Distribution, and Administrative Expenses” (the most common terminology observed in the surveyed reports). DOE assumed that “Operating Profit” (operating income) covers other operating costs and profit (*i.e.*, variable costs). Each company's incremental markup was calculated as:

$$\text{Incremental Markup} = 1 + \left(\frac{\text{Operating Profit}}{\text{Cost of Sales}}\right) \qquad \textbf{Eq. 7.20}$$

Table 7.2.7, Table 7.2.8, and Table 7.2.9 contain the calculated incremental markups for the sampled fixture OEMs, electrical wholesalers, and home improvement retailers, respectively.

Table 7.2.7 Calculated OEM Incremental Markups for Fluorescent Lamp Ballasts*

Company	Financial Figure $	Year				
		2009	2008	2007	2006	2005
A	Cost of Sales	1,022,308	1,210,849	1,220,466	1,188,202	1,324,311
	Operating Profit	153,753	261,060	222,423	152,119	106,745
	Calculated Incremental Markup	1.15	1.22	1.18	1.13	1.08
	Average Incremental Markup: 1.15					
B	Cost of Sales	3,483,800	4,396,700	3,970,000	3,521,500	3,243,800
	Operating Profit	544,100	877,600	844,100	694,100	559,800
	Calculated Incremental Markup	1.16	1.20	1.21	1.20	1.17
	Average Incremental Markup: 1.19					
C	Cost of Sales	1,629,700	1,901,000	1,798,100	1,757,500	1,509,900
	Operating Profit	294,700	346,000	299,400	233,900	226,800
	Calculated Incremental Markup	1.18	1.18	1.17	1.13	1.15
	Average Incremental Markup: 1.16					
ALL	Average Incremental Markup (All OEMs): 1.17					

* Except for calculated incremental markup, all numbers are in thousands of dollars. This table includes 2005, 2006, 2007, 2008, and 2009 SEC 10-K reports.

Table 7.2.8 Calculated Electrical Wholesaler Incremental Markups for Fluorescent Lamp Ballasts*

Company	Financial Figure $	Year				
		2009	2008	2007	2006	2005
A	Cost of Sales	3,522,932	4,354,935	4,225,983	4,047,692	3,477,009
	Operating Profit	72,498	151,863	161,787	122,022	64,789
	Calculated Incremental Markup	1.02	1.03	1.04	1.03	1.02
	Average Incremental Markup: 1.03					
B	Cost of Sales	3,724,061	4,904,164	4,781,336	4,234,079	3,580,398
	Operating Profit	179,952	345,667	394,224	364,983	209,286
	Calculated Incremental Markup	1.05	1.07	1.08	1.09	1.06
	Average Incremental Markup: 1.07					
ALL	Average Incremental Markup (All Wholesalers): 1.05					

* Except for calculated incremental markup, all numbers are in thousands of dollars. This table includes 2005, 2006, 2007, 2008, and 2009 SEC 10-K reports.

Table 7.2.9 Calculated Home Improvement Retailer Incremental Markups for Fluorescent Lamp Ballasts*

Company	Financial Figure $	Year				
		2009	2008	2007	2006	2005
A	Cost of Sales	47,298,000	51,352,000	52,476,000	51,081,000	48,664,000
	Operating Profit	4,359,000	7,242,000	8,866,000	9,047,000	7,926,000
	Calculated Incremental Markup	1.09	1.14	1.17	1.18	1.16
	Average Incremental Markup: 1.15					
B	Cost of Sales	31,729,000	31,556,000	30,729,000	28,453,000	24,224,000
	Operating Profit	3,506,000	4,511,000	4,998,000	4,496,000	3,520,000
	Calculated Incremental Markup	1.11	1.14	1.16	1.16	1.15
	Average Incremental Markup: 1.14					
ALL	Average Incremental Markup (All Wholesalers): 1.15					

* Except for calculated incremental markup, all numbers are in thousands of dollars. This table includes 2005, 2006, 2007, 2008, and 2009 SEC 10-K reports.

7.2.2 Weighted Markups

For commercial and industrial ballast designs, DOE adjusted the calculated average baseline and incremental markups to reflect estimated proportions of ballasts sold through the OEM and wholesaler distribution channels. DOE used information from the 2000 Ballast Rule, which estimates that ballasts sold to OEM fixture manufacturers represent 63 percent of the market while ballasts sold to electrical wholesalers represent 37 percent of the market. DOE then multiplied by a contractor markup of 1.13 (obtained from the 2000 Ballast Rule) to the resulting weighted average baseline and incremental markups to develop total weighted markups. For residential ballast designs, DOE could not obtain retailer sales data detailing the breakdown between residential fixture ballasts and replacement ballasts, and therefore assumed that ballasts in fixtures represented 100 percent of the residential market.The weighted total baseline and incremental markups are provided in Table 7.2.10.

Table 7.2.10 Weighted Total Baseline and Incremental Markups for Fluorescent Lamp Ballasts

Ballast Design	Weighted Total Markups	
	Baseline	Incremental
Commercial/Industrial	1.83	1.30
Residential	2.27	1.34

7.2.3 Sales Tax

The sales tax represents state and local sales taxes applied to end-user cost and is a multiplicative factor that increases the end-user cost. DOE obtained information on state and local sales tax from the Sales Tax Clearinghouse (Table 7.2.11).[5] These data represent weighted averages that include county and city rates. DOE then calculated population-weighted average tax values for each census division and four large states. These values allowed DOE to correlate the sales tax distribution with the electricity price distribution (final rule TSD chapter 8) and the operating hour distribution (final rule TSD chapter 6) that DOE uses in the LCC spreadsheet. DOE also calculated a national population-weighted average sales tax for use as a single-value input to the LCC, should users want single-average results. DOE also used this result in the NIA, where DOE did not use a distribution of inputs.[6]

Table 7.2.11 State and Local 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	7.30	Kentucky	6.00	North Dakota	5.80
Alaska	1.40	Louisiana	8.75	Ohio	6.80
Arizona	8.15	Maine	5.00	Oklahoma	8.20
Arkansas	8.25	Maryland	6.00	Oregon	0.00
California	9.20	Massachusetts	6.25	Pennsylvania	6.40
Colorado	6.40	Michigan	6.00	Rhode Island	7.00
Connecticut	6.00	Minnesota	7.20	South Carolina	7.15
Delaware	0.00	Mississippi	7.00	South Dakota	5.50
D.C.	6.65	Missouri	7.25	Tennessee	9.40
Florida	6.65	Montana	0.00	Texas	8.05
Georgia	6.95	Nebraska	6.00	Utah	6.70
Hawaii	4.35	Nevada	7.85	Vermont	6.05
Idaho	6.05	New Hampshire	0.00	Virginia	5.00
Illinois	8.20	New Jersey	6.95	Washington	8.80
Indiana	7.00	New Mexico	6.55	West Virginia	6.00
Iowa	6.85	New York	8.45	Wisconsin	5.45
Kansas	8.05	North Carolina	7.85	Wyoming	5.35

Table 7.2.12 shows the distribution of sales tax rates that DOE developed for the LCC and PBP analyses. The distribution ranges from a minimum of 5.23 percent in the Pacific census division to a maximum of 9.20 percent in California with a weighted average value of 7.25 percent nationwide.

Table 7.2.12 Regional Average Tax Rates

Region or Large State	Weighted Sales Tax %
New England	5.55
Mid Atlantic	6.62
East North Central	6.88
West North Central	7.06
South Atlantic	6.47
East South Central	7.67
West South Central	8.44
Mountain	6.82
Pacific	5.23
New York	8.45
California	9.20
Texas	8.05
Florida	6.65
U.S. Average	**7.25**

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CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSES

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CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSES

8.1 INTRODUCTION

This chapter describes the analysis the U.S. Department of Energy (DOE) conducted to evaluate the economic impacts on individual consumers of adopted amended energy conservation standards for fluorescent lamp ballasts (hereafter “ballasts”). Because ballasts are designed to operate fluorescent lamps, DOE chose the most common fluorescent lamp used with each ballast to develop representative lamp-and-ballast systems. Fluorescent lamps will not be regulated under the adopted amended energy conservation standards for ballasts; however, the characteristics of complete lamp-and-ballast systems (*e.g.*, energy consumption, installed cost, etc.) must be considered for estimating economic impacts of analyzed ballast designs.

New and amended standards usually decrease operating costs and increase purchase costs for consumers. This chapter describes the three metrics used in this analysis to determine the impact of standards on individual consumers:

- **Life-cycle cost** (LCC) is the total (discounted) consumer cost over the analysis period including purchase price, operating costs (including energy expenditures), and installation costs.

- **Payback period** (PBP) is the number of years it takes a customer to recover the generally higher purchase price of a more energy efficient product through the operating cost savings of using the more energy efficient product. The PBP is calculated as the change in first cost divided by the change in operating costs in the first year.

- **Rebuttable payback period** is a special case in which the PBP is calculated based on laboratory conditions, specifically DOE test procedure inputs. DOE calculated the aforementioned LCC and PBP using a range of inputs, which are designed to reflect actual conditions.

Sections 8.2 and 8.3 discuss inputs to the LCC and PBP, respectively. Section 8.4 discusses the different purchasing events DOE analyzed, which affect consumer economics. Section 8.5 presents the results for the LCC and PBP calculations. Key variables and calculations are presented for each metric. DOE performed the calculations discussed here using a series of Microsoft Excel spreadsheets developed for this rulemaking. Stakeholders are invited to download and examine the spreadsheets available at www1.eere.energy.gov/buildings/appliance_standards/residential/fluorescent_lamp_ballasts.html. Appendix 8A presents details and instructions for using the spreadsheets.

8.1.1 General Approach for LCC and PBP Analyses

Recognizing that several inputs to the LCC and PBP analysis are either variable or uncertain, DOE incorporated Monte Carlo simulation and probability distributions into its LCC and PBP model in this final rule. DOE incorporated both Monte Carlo simulation and probability distributions by using Microsoft Excel spreadsheets combined with Crystal Ball, a commercially available add-in program.

The relationship between increasing selling price and increasing energy efficiency is the predominant influence on the LCC and PBP results. However, other factors related to the characteristics of the consumer using the products also affect the results. Based on the geographic region, sector, and application in which a consumer uses the ballasts, factors such as energy prices, sales tax, and energy usage can vary. DOE accounted for this variability by using the Monte Carlo simulation and separate sensitivity runs.

For the LCC and PBP analyses, DOE considered variability in the discount rate. DOE also modeled variability in operating hours by sector, ballast type, and building applications. By developing samples by building type, DOE could account for the variability in operating hours, electricity price, and sales tax among a variety of buildings. DOE used the Energy Information Administration's (EIA's) 2005 Residential Energy Consumption Survey (RECS),[1] 2003 Commercial Buildings Energy Consumption Survey (CBECS),[2] and 2006 Manufacturing Energy Consumption Survey (MECS)[3] to develop samples by building type, as well as U.S. Lighting Market Characterization: Volume I (LMC)[4] to develop the operating hour characteristics by application in those buildings. The LCC and PBP spreadsheets present the results of the analysis as average values, relative to the baseline conditions.

In the standards case for the LCC and PBP analyses, DOE assumed that consumers will achieve energy savings by choosing a ballast that meets or exceeds the standard and generally keeps system light output within 10 percent of the output of the baseline system. While consumers would have other choices in addition to those presented in the LCC, DOE considered only energy-saving ballast designs in the LCC.

DOE considered various scenarios that would prompt consumers to buy a ballast in the base versus standards cases. Specifically, the "event" that prompts the purchase of a new ballast (either a ballast failure or new construction/renovation) is assumed to influence the cost-effectiveness of the consumer purchase decision. For example, DOE assumed that a consumer would replace a failed ballast with an identical ballast in the base case, or a new standards-compliant lamp-and-ballast system with comparable light output in the standards case. Section 8.4 discusses the ballast purchasing events in more detail. The LCC and PBP spreadsheet reports results per purchasing event.

DOE conducted the LCC and PBP analyses on the baseline ballasts from the representative product classes identified in the ballast market and technology assessment (final rule technical support document (TSD) chapter 3). The following list shows the representative product classes that DOE evaluated in this analysis.

- Product Class 1: Instant-start (IS) and rapid-start (RS) ballasts that operate:
    - two 4-foot medium bipin (MBP) lamps (commercial sector)
    - four 4-foot medium bipin lamps
    - two 8-foot slimline lamps
- Product Class 2: Programmed-start (PS) ballasts that operate:
    - two 4-foot MBP lamps
    - four 4-foot MBP lamps

    - two 4-foot miniature bipin (MiniBP) standard output (SO) lamps
    - two 4-foot MiniBP high output (HO) lamps
- Product Class 3: Ballasts that operate two 8-foot HO lamps
- Product Class 5: Sign ballasts that operate four 8-foot HO lamps
- Product Class 6: Instant-start (IS) and rapid-start (RS) ballasts that operate:
    - two 4-foot medium bipin lamps (residential sector)

For the LCC and PBP analyses in this rulemaking, DOE used a time period corresponding with the service life of the baseline ballast, assumed as 49,054 hours (commercial and industrial sectors) and 11,835 hours (residential sector).

8.1.2 Overview of LCC and PBP Inputs

As mentioned previously, the LCC represents the total consumer expense over the lifetime of each ballast. Expenses include purchase expenses, operating costs (including energy expenditures), and installation costs. DOE discounted future operating costs to the time of purchase and summed them over the analysis period. The PBP represents the number of years it takes customers to recover the purchase price of more energy efficient equipment through lower operating costs. The PBP was calculated as the change in first cost divided by the change in operating costs in the first year.

DOE categorized inputs to the LCC and PBP analysis as follows: (1) inputs for establishing the purchase expense, otherwise known as the total installed cost; and (2) inputs for calculating the expenses incurred during operation of the lamp-and-ballast system, otherwise known as the operating cost.

The primary inputs for establishing the LCC and PBP are:

- End-User Product Price: The end-user product prices represent the consumer price before tax and installation.

- Sales Tax: DOE then applied sales tax to convert the end-user product price to a final product price including sales tax. Chapter 7 of the final rule TSD describes the sales tax markup in detail.

- Installation Cost: This input represents the cost to the commercial or industrial customers of installing the lamp-and-ballast systems. The installation cost represents all costs required to install the system but does not include the end-user product price. The installation cost includes labor and overhead. Thus, the total installed cost equals the end-user product price, including sales tax plus the installation cost.

- Disposal Costs: After a ballast or fluorescent lamp reaches its end of life, some consumers pay to recycle those items. The disposal costs represent the cost of recycling a ballast or fluorescent lamp and are only applicable to those consumers in the commercial and industrial sectors.

The primary inputs for calculating the operating cost include the following:

- Annual Operating Hours: The annual operating hours are the hours that a lamp-and-ballast system is estimated to be in use during 1 year. The energy use analysis (final rule TSD chapter 6) details how DOE determined the system operating hours as a function of end-user sector, end-user application, and building type.

- Power Rating: The power consumption is the site-energy usage rate associated with operating the lamp-and-ballast system. The energy use analysis (final rule TSD chapter 6) details how DOE determined the power ratings for the lamp-and-ballast systems considered in the analyses.

- Electricity Prices: DOE used the average price per kilowatt-hour (*i.e.*, $/kWh) paid by customers. DOE determines electricity prices using national average residential, commercial, and industrial electricity prices for the sample calculation. For the Monte Carlo distribution, DOE used average residential, commercial, and industrial values for 13 regions and large States. DOE developed all electricity price inputs using 2010 EIA data.

- Electricity Price Trends: DOE used the EIA's Annual Energy Outlook 2010 (*AEO2010*) to forecast electricity prices.[5] For the results presented in this chapter, DOE used the October *AEO2010* reference case.

- Lifetime: Lifetime is the total hours in operation after which the consumer retires the ballast from service.

- Discount Rate: The discount rate is the rate at which DOE discounted future expenditures to establish their present value.

- Analysis Period: Analysis period is the time span over which DOE calculated the LCC for each ballast.

Figure 8.1.1 depicts the relationships between the installed cost and operating cost inputs for the calculation of the LCC and PBP. In this figure, the rectangular boxes indicate the inputs, the parallelograms indicate intermediate calculated values, and the diamond boxes indicate the analysis outputs (the LCC and PBP).

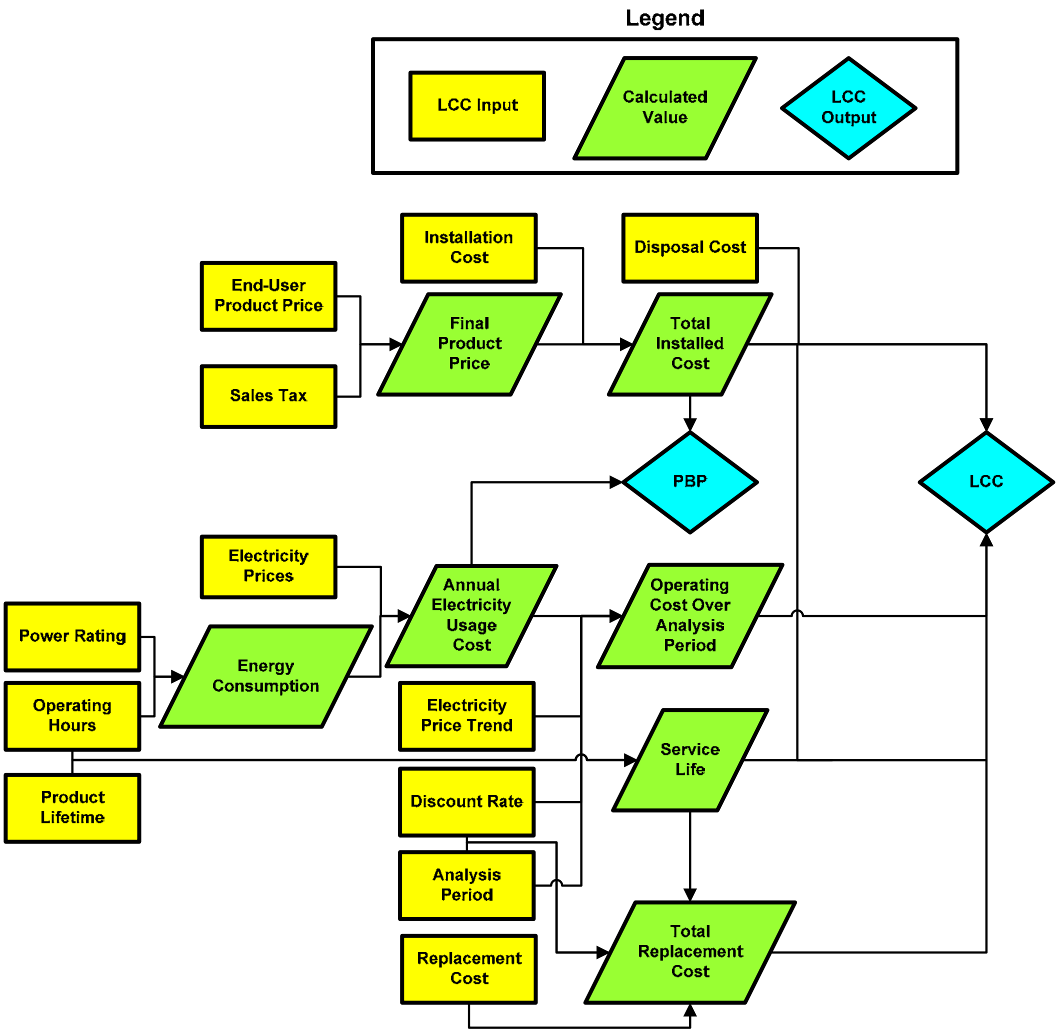

Figure 8.1.1 Flow Diagram of Inputs for the Determination of LCC and PBP

Table 8.1.1 summarizes the input values that DOE used to calculate the LCC and PBP for ballasts. Each row summarizes the total installed, operating, and replacement cost inputs, discount rate, electricity price trend, and ballast lifetime. DOE characterized all of the total cost inputs with single-point values, but characterized several of the operating cost inputs with probability distributions that capture the input's uncertainty and/or variability in the Monte Carlo analysis. Table 8.1.1 also lists the final rule TSD chapter that details the inputs.

Table 8.1.1 Summary of Inputs for the Life-Cycle Cost and Payback Period Analyses

Factor	Weighted-Average Value	Final Rule TSD Reference Section
Total Installed Cost Primary Inputs		
End-User Product Price	Varies with lamp-and-ballast system	Chapters 5, 7, Appendix 8B
Sales Tax	Varies by census region	Chapter 7
Installation Cost	Varies by equipment installed and sector	Chapter 8
Operating Cost Primary Inputs		
Annual Operating Hours	Vary by lamp-and-ballast system type, sector, and building type	Chapter 6
Power Rating	Varies with lamp-and-ballast type	Chapter 6
Electricity Prices	Vary by sector and census region	Chapter 8
Electricity Price Trends	Vary with price forecast scenario	Chapter 8
Discount Rate	Varies with sector	Chapter 8
Analysis Period	Varies with sector	Chapter 8
Replacement Cost Primary Inputs		
Total Installed Cost	Varies with lamp-and-ballast system, census region, equipment installed and sector	Chapters 7, 8
Ballast Lifetime	Varies with lamp-and-ballast system	Chapters 5, 8
Disposal Cost	Varies by lamp-and ballast system type and sector	Chapter 8
Discount Rate	Varies with sector	Chapter 8
Analysis Period	Varies with sector	Chapter 8

Sections 8.2 and 8.3 discuss the inputs depicted in this table of installed costs and operating costs.

8.2 LIFE-CYCLE COST INPUTS

8.2.1 Definition

LCC is the total customer cost over the life of a product, including total installed costs, operating costs, replacement costs, and residual value. Future operating costs and replacement costs are discounted to the analysis start year (2014) and summed over the analysis period. The LCC is defined by the following equation:

$$LCC = IC + \sum_{t=1}^{N}\left(\frac{OC_t + RC_t}{(1+r)^t} + \frac{DC_t}{(1+r)^t}\right) \qquad \textbf{Eq. 8.1}$$

Where:

LCC = life-cycle cost ($),
IC = total installed cost ($),
N = ballast lifetime,
$\sum$ = sum over the ballast lifetime, from year 1 to year *N*,
OC = operating cost ($),
RC = lamp replacement cost ($),
r = discount rate,

t =	year for which operating cost, replacement cost, or disposal cost is determined, and
DC =	disposal cost of the ballast or lamp.

DOE expressed all the costs in its LCC and PBP analyses in 2010$.

8.2.2 Total Installed Cost Inputs

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

$$IC = FPP + INST \qquad \textbf{Eq. 8.2}$$

Where:

FPP =	final product price (*i.e.*, customer price for the product only, including sales tax; $), and
$INST$ =	installation cost or the customer price to install products (*i.e.*, the cost for labor and materials; $).

In the markups analysis (final rule TSD chapter 7), DOE developed end-user product prices and sales taxes to derive final product prices. DOE then applied installation costs where necessary to derive the total installed costs for use in the LCC. The inputs to determine total installed costs are:

- end-user product price ($)
- sales tax ($), and
- installation cost ($).

The end-user product price represents the average purchase price a consumer pays before sales tax for lamp-and-ballast designs. The sales tax represents State and local sales taxes applied to the end-user product price. It is a multiplicative factor that increases the end-user product price. The installation cost represents all costs required to install the lamp-and-ballast system but does not include the final product price. The installation cost includes labor and overhead. Thus, the total installed cost equals the final product price plus the installation cost. DOE calculated the total installed cost for the ballasts analyzed based on the following equation:

$$\begin{aligned} IC &= FPP + INST \\ &= PRICE \times MU_{TAX} + INST \end{aligned} \qquad \textbf{Eq. 8.3}$$

Where:

IC =	total installed cost,
FPP =	final product price,
$INST$ =	installation cost,
$PRICE$ =	end-user product price, and
MU_{TAX} =	sales tax mark up.

On February 22, 2011, DOE published a notice of data availability (NODA, 76 FR at 9696) stating that DOE may consider improving regulatory analysis by addressing product and equipment price trends. DOE notes that learning curve analysis characterizes the reduction in production cost mainly associated with labor-based performance improvement and higher investment in new capital equipment at the microeconomic level. Experience curve analysis tends to focus more on entire industries and aggregates over various casual factors at the macroeconomic level: "Experience curve" and "progress function" typically represent generalizations of the learning concept to encompass behavior of all inputs to production and cost (i.e., labor, capital, and materials)." The economic literature often uses these two terms interchangeably. The term "learning" is used here to broadly cover these general macroeconomic concepts.

Consistent with the February 2011 NODA, DOE examined historical producer price indices (PPI) for fluorescent lamp ballasts and found both positive and negative real price trends depending on the specific time period examined. Therefore, in the absence of a definitive trend, DOE assumed in its price forecasts for the notice of proposed rulemaking (NOPR) that the real prices of fluorescent ballasts are constant in time and that fluorescent ballast prices will trend the same way as prices in the economy as a whole. DOE is aware that there have been significant changes in both the regulatory environment and mix of fluorescent ballast and control technologies that create analytical challenges for estimating longer term product price trends from the product-specific PPI data. DOE performed price trend sensitivity calculations to examine the dependence of the analysis results on different analytical assumptions.

DOE received no comments on the April 2011 NOPR regarding its ballast price trend basis. For this final rule, DOE also considered adjusting ballast prices using forecasted price indices (called deflators) used by EIA to develop the *AEO*. When adjusted for inflation, the deflator-based price indices decline from 100 in 2010 to approximately 54 in 2043. The effect is diminished significantly when discounting is taken into account. Deflator-based net present value (NPV) results from the national impacts analysis (NIA) were approximately 9 percent higher than NPV values based on constant real prices for ballasts. Given this minor difference in estimated NPV, and that DOE did not receive negative comments on its constant real price basis in the NOPR, DOE retained its constant real price approach for this final rule. A more detailed discussion of price trend modeling and calculations is provided in appendix 8B of the final rule TSD.

Chapter 7 of the final rule TSD provides detail on the end-user product price and sales tax. Discussion about installation costs follows.

8.2.2.1 Installation Costs

On September 19, 2000, DOE issued a final rule establishing energy conservation standards for ballasts (hereafter "the 2000 Ballast Rule"). 65 FR at 56740; 10 CFR 430.23(m)(4). To account for relamping that occurs during the analysis period, DOE used estimates of the prevalence of group versus spot relamping from the 2000 Ballast Rule. DOE then weighed the spot and group relamping times by the amount of spot versus group relamping to derive weighted averaged relamping times. According to the 2000 Ballast Rule, group relamping occurs, on average, 25 percent of the time for 4-foot MBP systems, 37 percent for 8-foot slimline systems, and 31 percent for 8-foot recessed double contact (RDC) HO systems.[6] DOE used these percentages to calculate an average time to change fluorescent lamps in conjunction with ballast purchase events. The 2000 Ballast Rule did not address relamping for signs; consequently, DOE assumed that labor times and costs are the same as for standard 8-foot RDC HO systems.

Table 8.2.1 lists average labor times to install a fluorescent lamp and ballast. For new construction and renovation purchase events, DOE added 2.5 minutes to the labor times in the table to account for the installation of a luminaire disconnect. This is because the 2005 National Electric Code requires a means for disconnecting luminaires before they are serviced for lamp or ballast replacements.[7]

Table 8.2.1 Labor Times for Fluorescent Lamp-and-Ballast Systems (Commercial and Industrial)[*]

Lamp-and-Ballast System Type	Time *minutes*			
	Relamp			Install Lamps and Ballasts[**]
	Spot	Group	Average	
Two-Lamp 4-Foot MBP and 2-Foot U-Shaped	27.0	14.0	23.8	30.0
Four-Lamp 4-Foot MBP and 2-Foot U-Shaped	28.0	15.0	24.8	40.0
Two-Lamp 8-Foot Slimline	20.5	10.5	16.8	55.0
Two-Lamp 8-Foot RDC HO	26.5	13.5	22.5	60.0
Two-Lamp 4-Foot MiniBP	27.0	14.0	23.8	30.0
Four-Lamp 8-Foot RDC HO (Sign Ballasts)	26.5	13.5	22.5	60.0

[*] Labor times are obtained from the 2000 Ballast Rule.
[**] For new construction and renovation ballast purchase events, labor times are increased by 2.5 minutes to allow for the installation of a luminaire disconnect.

For lamp-and-ballast system installations, DOE derived labor rates for electricians and helpers from *RS Means*.[8] Labor rates are the sum of the wage rate, employer-paid fringe benefits (*i.e.*, vacation pay, employer-paid health, and welfare costs), and any appropriate training and industry advancement funds costs. According to *RS Means*, an electrician's average hourly rate with overhead and profit is typically $70.04 (in 2010$), and a helper's average hourly rate is $45.44 (in 2010$). DOE assumed that 50 percent of the electrician labor rate plus 50 percent of the helper labor rate (for a total of $57.74) make up the lamp-and-ballast system installation labor rate.

For lamp replacements in the commercial sector, DOE assumed that the task is performed by a general maintenance worker. DOE obtained the labor rate of $16.61 (adjusted to 2010$ from $15.01 in 2005) from the U.S. Bureau of Labor Statistics for a General Maintenance Worker.[9] Using these labor rates and the labor times listed in Table 8.2.1, DOE derived the average cost to install a lamp and the average cost to install a lamp and ballast, as shown in Table 8.2.2.

Table 8.2.2 Relamping and Lamp-and-Ballast Labor Costs for Fluorescent Lamp-and-Ballast Systems (Commercial and Industrial)*

Lamp-and-Ballast System Type	Labor Cost *2010$*	
	Relamping	Lamp-and-Ballast Installation
Two-Lamp 4-Foot MBP and 2-Foot U-Shaped	6.58	28.87
Four-Lamp 4-Foot MBP and 2-Foot U-Shaped	6.85	38.49
Two-Lamp 8-Foot Slimline	4.65	52.93
Two-Lamp 8-Foot RDC HO	6.22	57.74
Two-Lamp 4-Foot MiniBP	6.58	28.87
Four-Lamp 8-Foot RDC HO (Sign Ballasts)	6.22	57.74

* For new construction and renovation ballast purchase events, labor times are increased by 2.5 minutes to allow for the installation of a luminaire disconnect.

8.2.3 Operating Cost Inputs

The operating cost represents the costs incurred in the operation of the lamp-and-ballast system. The inputs for operating costs are:

- annual operating hours,
- power rating (W),
- electricity prices ($/kWh),
- electricity price trends,
- discount rate (%), and
- analysis period (yr).

The analysis period, discount rate, and effective date of the amended standard are required for determining the operating cost and for establishing the operating cost present value. The electricity consumption for the baseline and other efficiency levels (ELs) examined enable comparison of standards' operating costs.

The annual operating hours are the estimated hours that a lamp-and-ballast system is in use during 1 year. Power rating refers to the rate of site energy usage associated with operating the lamp-and-ballast system. DOE used both the annual operating hours and power rating to calculate the total annual energy consumption. Electricity prices used in the analysis were the price per kilowatt-hour in cents or dollars (*e.g.*, $/kWh) paid by each customer for electricity. DOE used electricity price trends to forecast electricity prices for future year analysis. These trends with the electricity price and annual energy consumption were used to calculate the energy cost in each year. DOE defined energy cost by the following equation:

$$\begin{aligned} OC &= E_{cons} \times EP \times EPT \\ &= (PWR \times OH) \times EP \times EPT \end{aligned} \qquad \textbf{Eq. 8.4}$$

Where:

OC = operating costs,
E_{cons} = annual energy consumed,
EP = electricity price,
EPT = electricity price trend factor relative to 2009,
PWR = power rating (rate of energy use, measured in watts), and
OH = annual operating hours.

The remainder of this section provides information about each of the above input variables that DOE used to calculate the operating costs.

8.2.3.1 Operating Hours

The energy use analysis (final rule TSD chapter 6) details how DOE determined the annual energy consumption for baseline and standard-compliant products. An important input to determining the energy consumption was the total hours per year that the product is in operation. DOE also used the operating hours to calculate the ballast service life, which was ultimately used in calculating the total replacement cost.

As described in chapter 6 of the final rule TSD, DOE established operating hour distributions for fluorescent lamp-and-ballast systems. In conjunction with data from LMC, DOE used data from EIA's CBECS 2003, RECS 2005,[a] and the MECS 2006. These three EIA studies provide information on the distribution of buildings within the United States by building type and census division. DOE associated the LMC's operating hour data by building type with the EIA's data by building type and census division to derive operating hours by census division and large States. This allowed DOE to correlate its electricity price distribution and sales tax distribution (final rule TSD chapter 7) with its operating hour distribution by census division and large State in the LCC spreadsheet. Table 8.2.3 presents the mean operating hours for lamp-and-ballast systems for each sector.

Table 8.2.3 Average Operating Hours by Sector

Sector	Average Annual Operating *hr/yr*
Residential	789
Commercial	3,886
Industrial	4,747

In this rulemaking, DOE evaluated two- and four-lamp PS ballasts operating 4-foot MBP lamps in the commercial sector, and assumed these lamp-and-ballast systems are operated on occupancy sensors. Occupancy sensors detect the presence or absence of people within their coverage area and turn lights on and off accordingly, thereby reducing operating time and energy consumption. Based on a range of estimated energy savings from occupancy sensors compiled by E Source and others,[10, 11] DOE assumed energy savings of 30 percent for operating lamp-and-ballast systems on occupancy sensors in the commercial sector. To account for these energy savings, DOE reduced average operating hours for affected lamp-and-ballast systems by 30

[a] RECS was updated in 2009, but these updates did not address lighting usage; therefore, DOE used RECS 2005 data for this final rule.

percent. Table 8.2.4 presents the adjusted mean operating hours for lamp-and-ballast systems operating on occupancy sensors in the commercial sector.

Table 8.2.4 Average Operating Hours for Two- and Four-Lamp PS Ballasts Operating 4-Foot MBP Lamps in the Commercial Sector

Sector	**Lamp-and Ballast System Type**	**Annual Operation** ***hr/yr***
Commercial	Two- and Four-Lamp PS Ballast Operating 4-Foot T8 MBP Lamps	2,720

8.2.3.2 Power Rating

As described in the energy use and end load characterization (final rule TSD chapter 6), DOE used the power rating (in watts) with the annual operating hours (in hours) to calculate the annual energy usage (in kilowatt-hours) of the lamp-and-ballast designs DOE considered.

8.2.3.3 Electricity Prices

DOE estimated electricity prices for residential, commercial, and industrial consumers in each of the 13 regions and large States by using EIA Form 826 data. Table 8.2.5 lists the 13 geographic regions.

Table 8.2.5 Electricity Prices by Census Division, 2010

Census Division	**Electricity Prices** ***2010$/kWh***		
	Residential	**Commercial**	**Industrial**
New England	0.164	0.149	0.129
Middle Atlantic	0.143	0.117	0.092
East North Central	0.115	0.094	0.066
West North Central	0.097	0.079	0.058
South Atlantic	0.109	0.090	0.068
East South Central	0.096	0.094	0.061
West South Central	0.089	0.078	0.055
Mountain	0.105	0.088	0.063
Pacific	0.108	0.097	0.069
New York State	0.186	0.160	0.097
California	0.152	0.140	0.109
Texas	0.116	0.092	0.063
Florida	0.115	0.098	0.089
U.S. Weighted Average	0.123	0.105	0.078

* DOE uses average retail electricity prices for each of the sectors, across all months in 2010.

DOE used EIA form 826, Sales and Revenue Spreadsheets, to generate average retail electricity prices for each sector. The spreadsheet contains average electricity prices for each State, by year, by sector. In the LCC and subsequent analyses, DOE used 2010 electricity prices from the form 826 worksheet, current as of May 2011.

8.2.3.4 Electricity Price Trend

The electricity price trend projects the future cost of electricity to 2035. DOE calculated the LCC and PBP using three separate projections from *AEO2010*: reference case, low economic growth, and high economic growth.[5] These three cases reflect the uncertainty of economic growth in the forecast period. The high and low growth cases show the projected effects of alternative growth assumptions on energy markets. DOE normalized these three *AEO2010* scenarios to the 2010 electricity price, and then used that electricity price factor to scale the 2010 electricity prices. Figure 8.2.1 through Figure 8.2.3 show the residential, commercial, and industrial electricity price trends, respectively, based on the three *AEO2010* projections. DOE calculated average growth rates from the preceding 10 years to predict electricity price trends from 2036–2044. The LCC results presented in this chapter are based on the *AEO2010* reference case.[b]

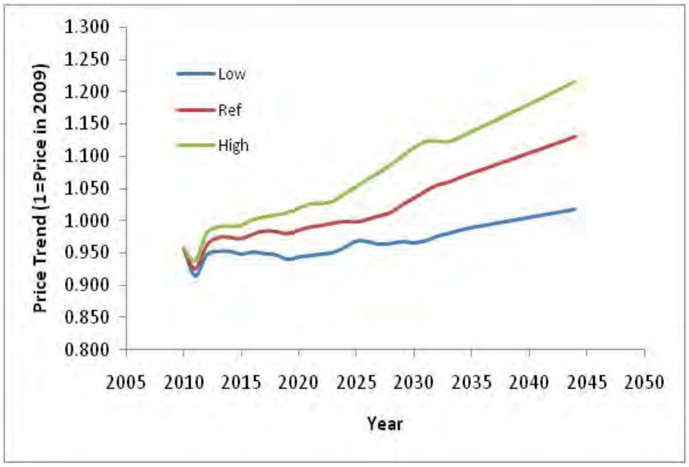

Figure 8.2.1 Residential Sector Electricity Price Trend

[b] DOE used *AEO2010* in both its NOPR and its final rule analyses. DOE published a NODA on August 24, 2011 to address ballast test data and engineering analysis issues, and seek public comment (see www1.eere.energy.gov/buildings/appliance_standards/residential/notice_of_data_availability.html). The comment period on the NODA closed on September 14, 2011, and DOE was required by consent decree to publish the final amended standards for fluorescent lamp ballasts by October 28, 2011. (*State of New York, et al. v. Bodman et al.*, 05 Civ. 7807 (LAP) and *Natural Resources Defense Council, et al. v. Bodman, et al.*, 05 Civ. 7808 (LAP) (Nov. 3, 2006), as amended on June 20, 2011.) The additional time required for DOE to consider the comments and information submitted by interested parties did not allow sufficient time for DOE to update the final rule analyses using *AEO2011*. DOE has determined, however, that the *AEO2011* 30-year annual growth rates for energy consumption (electric power) and electricity generating capacity are almost identical to those in *AEO2010*. The forecasted near-term electricity prices in *AEO2010* are slightly higher than in *AEO2011*, and would produce slightly shorter payback periods. However, these payback periods and other LCC and NIA results are not expected to vary significantly using *AEO2010* and *AEO2011*.

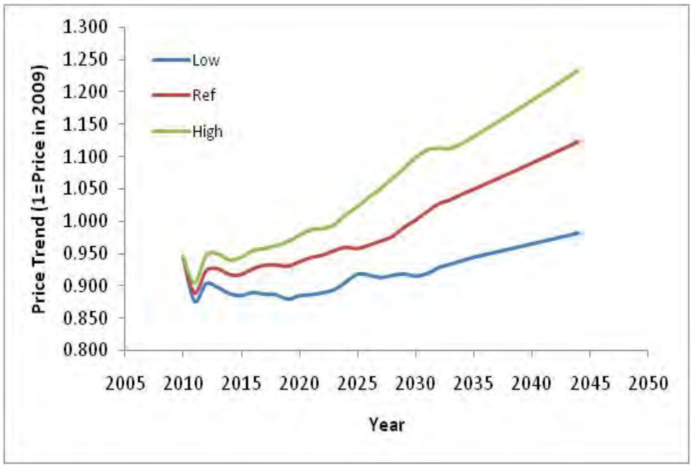

Figure 8.2.2 Commercial Sector Electricity Price Trend

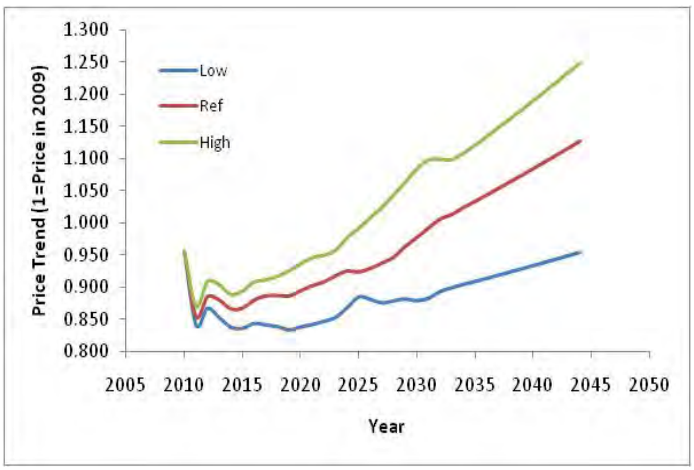

Figure 8.2.3 Industrial Sector Electricity Price Trend

In the LCC spreadsheet, these electricity price trends are used to project electricity prices into the future, which are then multiplied by the annual energy usage. The resulting operating costs are presented in both the LCC spreadsheets and the LCC results tables in this chapter.

8.2.4 Lifetime

DOE defined lifetime as the age in hours in operation when a ballast or lamp is retired from service. For ballasts in the commercial and industrial sectors, DOE used the average ballast lifetime used in the 2000 Ballast Rule (49,054 hr). Combining DOE's estimate of 49,054 hours and the average operating hours for fluorescent lamps in the commercial and industrial sectors (Table 8.2.3) yielded average ballast lifetimes of 12.6 years and 10.3 years, respectively. The commercial sector lifetime is consistent with a study on the "measure life" of ballasts (*i.e.*, the true service life of a ballast in the field), which found that the average ballast lifetime after a retrofit in the commercial sector is 13 years, and the average ballast lifetime after new construction is 15 years.[12] Manufacturer interviews indicated that ballasts in the industrial sector are typically operated in higher temperature environments and are commonly replaced on an approximate 10-year renovation cycle, which corroborates the shorter estimated lifetime. DOE found in a separate measure life report that the average fixture and ballast in the residential sector lasts for 15 years.[13] Therefore, DOE established 15 years as the average ballast lifetime in the residential sector. Assuming the average annual operating lifetime of a fluorescent lamp in the residential sector of 789 hours as discussed in section 8.2.3.1, the ballast lifetime is therefore 11,835 hours in the residential sector.

As with the calculation of relamping costs, DOE averaged the group versus spot relamping impact on lamp lifetime by their frequency of occurrence. DOE assumed that 4-foot MBP lamps and 4-foot MiniBP lamps subject to group relamping practices operate for 75 percent of their rated lives. DOE obtained this estimate from the 2000 Ballast Rule. Additionally, 8-foot slimline and RDC HO lamps subject to group relamping practices were assumed to operate for 63 and 69 percent of their rated lives, respectively. DOE then applied these life impact factors to the rated lifetimes from the manufacturing literature for the lamps in the lamp-and-ballast systems it was analyzing. For 4-foot MBP lamps and 4-foot MiniBP lamps, the average lifetime DOE used in the analysis is 94 percent of the rated lifetime. For 8-foot slimline lamps, the average lifetime was 91 percent of the rated lifetime. For 8-foot RDC HO lamps, the average lifetime was 92 percent of the rated lifetime.

As discussed in the technology assessment (final rule TSD chapter 3), ballast technology options (*e.g.*, starting method) often affect the lifetime of the lamp. For this reason, the baseline and standard level designs for the LCC and PBP analyses have a range of lamp lifetimes.

8.2.5 Replacement Cost

As stated previously, the lifetime is the age (total hours in operation) at which a ballast or lamp is retired from service. The lifetime paired with the operating hours yields the service life of the ballast or lamp in years. Because lamp lifetimes are typically shorter than ballast lifetimes, DOE addressed lamp replacements within the analysis period for the lamp-and-ballast system designs considered. Replacement costs included the labor and materials costs associated with replacing a lamp at the end of its lifetime. By using the service life and replacement cost, DOE calculated the total replacement cost each year. All costs are in 2010$.

Each year in which a lamp reaches the end of its life, a new lamp is purchased and installed at the beginning of that year, and the first cost and installation cost are discounted back to the base year of the analysis period. During years in which replacement is necessary, DOE based the replacement costs on the total installed cost inputs, as seen in the following equation:

$$\begin{aligned} RC &= FPP_L + INST_L \\ &= PRICE_L \times MU_{TAX} + INST_L \end{aligned} \qquad \textbf{Eq. 8.5}$$

Where:

RC =	replacement cost, expressed in dollars,
FPP_L =	final product price (price for the product only) expressed in dollars,
$INST_L$ =	installation cost,
$PRICE_L$ =	end-user product price expressed in dollars, and
MU_{TAX} =	sales tax.

For the years when no replacement is necessary, the replacement costs were set to zero. The replacement costs only included the end-user product price of the lamp and the installation cost of the lamp, rather than prices or costs associated with the entire lamp-and-ballast system. For the LCC and PBP analyses, the analysis period corresponded with the ballast lifetime; for this reason, ballast replacement were not considered and only lamp price and labor costs were included in the calculation of total installed costs.

8.2.6 Disposal Cost

When a ballast or fluorescent lamp fails, some consumers choose to recycle these system components. The cost of recycling the ballast or lamp is its disposal cost. DOE performed research on recycling costs for ballasts and fluorescent lamps and found that, on average, disposing of a ballast costs about $3.50 and disposing of lamps costs about 10 cents per linear foot.[14] Ballast recycling rate data were not available, so DOE conservatively assumed 5 percent of ballasts used in the commercial and industrial sectors are recycled, and assumed no ballasts are recycled in the residential sector. A report released by the Association of Lighting and Mercury Recyclers in 2004 noted that, nationwide, approximately 30 percent of lamps used by businesses and 2 percent of lamps in the residential sector are recycled.[15] Thus, DOE applied a cost of 10 cents per linear foot in the commercial and industrial sectors every time a lamp was replaced during the LCC analysis period. DOE was unable to obtain reliable ballast recycling rate data, but projected that the likely higher ballast recycling costs would largely discourage voluntary ballast recycling by commercial and industrial consumers. DOE therefore did not include ballast recycling costs in the LCC analysis. Given the low (2 percent) estimated lamp recycling rate in the residential sector, DOE assumed that residential consumers would be even less likely to voluntarily incur the higher recycling costs for ballasts. Therefore, DOE excluded the recycling or disposal costs for lamps or ballasts from the LCC analysis for residential ballast designs.

8.2.7 Analysis Period

The analysis period is the time span over which the LCC is calculated. DOE based the analysis period on the baseline ballast life in a certain sector divided by the annual operating hours of that ballast. If the user chooses to run the LCC using weighted average values (*i.e.*, in "sample calculation" mode), then the analysis period is based on the baseline ballast life divided by the average annual operating hours for that ballast in a chosen sector. For example, the baseline ballast life for commercial and industrial sectors is 49,054 hours. If the user chooses to analyze this ballast in the commercial sector, then the analysis period is the ballast lifetime of 49,054 hours divided by the average annual operating hours of this product in the commercial sector, 3,886 hours per year, or 12.6 years. If the user chooses to run the LCC using the Monte Carlo simulation (*i.e.*, in "Crystal Ball mode"), the analysis period is based on the baseline ballast life divided by Crystal Ball's chosen annual operating hours. For example, the user may choose to evaluate a product in the commercial sector using Crystal Ball. If Crystal Ball selects a building used for religious worship, the analysis period for the ballast for that selection will be based on a ballast lifetime of 49,054 hours divided by the annual operating hours in a building used for religious worship, 2,238 hours per year (22 years).

8.2.8 Discount Rate

The discount rate is the rate at which DOE discounted future expenditures to establish their present values. DOE derived the discount rates for this rulemaking separately for residential, commercial, and industrial consumers. For residential consumers, DOE estimated the discount rate by looking across all possible debt or asset classes that might be used to purchase ballasts. For the commercial and industrial consumers, DOE estimated the cost of capital for commercial and industrial companies by examining both debt and equity capital, and developed an appropriately weighted average of the cost to the company of equity and debt financing.

8.2.8.1 Residential Discount Rate

DOE's approach involved identifying all possible debt or asset classes that might be used to purchase replacement equipment, including household assets that might be affected indirectly (*e.g.*, household assets sold to pay off a loan or credit card debt that might have been used to finance the actual equipment purchase). DOE did not include debt from primary mortgages and equity of assets considered non-liquid (such as retirement accounts), since these would likely not be used to finance lighting equipment purchases. DOE estimated the average shares of the various debt and equity classes in the average U.S. household equity and debt portfolios using the Federal Reserve's *Survey of Consumer Finances* (*SCF*) data for 1989, 1992, 1995, 1998, 2001, and 2004.[16] Table 8.2.6 shows the average shares of each considered class. DOE used the mean share of each class across the 6 survey years (15 years) as the basis for estimating household financing of lighting equipment.

Table 8.2.6 Average Shares of Household Debt and Equity Types

Type	SCF						
	1989	1992	1995	1998	2001	2004	Mean %
Home Equity Loans	4.3	4.5	2.7	2.8	2.8	4.4	3.6
Credit Cards	1.6	2.1	2.6	2.2	1.7	2.0	2.0
Other Installment Loans	2.8	1.7	1.4	1.7	1.1	1.3	1.7
Other Residential Loans	4.4	6.9	5.2	4.3	3.1	5.8	4.9
Other Line of Credit	1.1	0.6	0.4	0.2	0.3	0.5	0.5
Checking Accounts	5.8	4.7	4.9	3.9	3.6	4.2	4.5
Savings and Money Market	19.2	18.8	14.0	12.8	14.2	15.1	15.7
Certificate of Deposit (CD)	14.5	11.7	9.4	7.0	5.4	5.9	9.0
Savings Bond	2.2	1.7	2.2	1.1	1.2	0.9	1.5
Bonds	13.8	12.3	10.5	7.0	7.9	8.4	10.0
Stocks	22.4	24.0	25.9	36.9	37.5	28.0	29.1
Mutual Funds	8.0	11.1	20.9	20.1	21.3	23.4	17.5
Total*	100.1	100.1	100.1	100.0	100.1	99.9	100.0

* Total may not equal 100 percent due to rounding.

DOE estimated interest or return rates associated with each type of equity and debt. The data source for the interest rates for loans, credit cards, and lines of credit was the Federal Reserve Board's *SCF* in 1989, 1992, 1995, 1998, 2001, and 2004. The top half of Table 8.2.7 shows the average nominal interest rates in each year and the inflation rates used to calculate real rates. For home equity loans, DOE calculated effective interest rates in a similar manner as for mortgage rates, since interest on such loans is tax deductible. The bottom half of the table shows the average effective real interest rates in each year and the mean rate across all the years. Since the interest rates for each debt carried by households in these years were established over 15 years, DOE believes they are representative of rates that may be in effect in 2014.

Table 8.2.7 Average Nominal and Real Interest Rates for Household Debt Classes

Type	**SCF**						
	1989	**1992**	**1995**	**1998**	**2001**	**2004**	**Mean %**
Nominal Interest Rates (%)							
Home Equity Loans	11.5	9.6	9.6	9.8	8.7	5.7	9.2
Credit Cards*	--	--	14.2	14.5	14.2	11.7	13.6
Other Installment Loans	9.0	7.8	9.3	7.8	8.7	7.4	8.3
Other Residential Loans	8.8	7.6	7.7	7.7	7.5	6.0	7.5
Other Line of Credit	14.8	12.7	12.4	11.9	14.7	8.8	12.5
Inflation Rate	4.82	3.01	2.83	1.56	2.85	2.66	--
Real Interest Rates (%)							
Home Equity Loans	3.8	4.3	4.4	5.8	3.8	1.9	4.0
Credit Cards*	--	--	11.0	12.7	11.1	9.1	11.0
Other Installment Loans	4.9	5.8	7.0	6.6	6.1	5.4	6.0
Other Residential Loans	4.0	4.7	4.8	6.0	4.6	3.3	4.6
Other Line of Credit	9.6	9.4	9.3	10.2	7.3	6.0	8.7

* No interest rate data available for credit cards in 1989 or 1992.

To account for variation among new households, DOE sampled a rate for each household from a distribution of rates for each of the above debt classes. DOE developed a probability distribution of interest rates for each debt class based on the *SCF* data.

Similar rate data were not available from the *SCF* for the asset classes, so DOE derived data for these classes from national historical data. The interest rates associated with CDs,[17] savings bonds,[18] and bonds (AAA corporate bonds) [19] were from Federal Reserve Board time-series data 1977–2005. DOE assumed rates on checking accounts to be zero. Rates on savings and money market accounts were from Cost of Savings Index data covering 1984–2005.[20] The rates for stocks were the annual returns on the Standard and Poor's (S&P) 500 1977–2005.[21] The mutual fund rates were a weighted average of the stock rates (two-thirds weight) and the bond rates (one-third weight) in each year from 1977 to 2005. DOE adjusted the nominal rates to real rates using the annual inflation rate in each year. Average nominal and real interest rates for the classes of assets are shown in Table 8.2.8. Since the interest and return rates for each asset type cover a range of time, DOE believed they are representative of rates that may be in effect in 2014.

Table 8.2.8 Average Nominal and Real Interest Rates for Household Equity Types

Type	Average Rate %	
	Nominal	Real
Checking Accounts	--	0.0
Savings and Money Market	5.5	2.3
CDs	6.9	2.4
Savings Bonds	8.0	3.5
Bonds	8.8	4.2
Stocks	13.3	8.8
Mutual Funds	11.6	7.0

To account for variation among new households, DOE sampled a rate for each household from a distribution of rates for each of the above asset types. DOE developed a normal probability distribution of interest rates for each asset type by using the mean value and standard deviation from the distribution.

Table 8.2.9 summarizes the mean real effective rates of each type of equity or debt. DOE determined the average share of each debt and asset using SCF data for 1989, 1992, 1995, 1998, 2001, and 2004. Each year of SCF data provides the debt and asset shares for U.S. households. DOE averaged the debt and asset shares over the 6 years of survey data to arrive at the shares shown below. The average rate across all types of household debt and equity, weighted by the shares of each class, was 5.6 percent.

Table 8.2.9 Shares and Interest or Return Rates Used for Household Debt and Equity Types

Type	Average Share of Household Debt Plus Equity %*	Mean Effective Real Rate %**
Home Equity Loans	3.6	4.0
Credit Cards	2.0	11.0
Other Installment Loans	1.7	6.0
Other Residential Loans	4.9	4.6
Other Line of Credit	0.5	8.7
Checking Accounts	4.5	0.0
Savings and Money Market Accounts	15.7	2.3
CDs	9.0	2.4
Savings Bonds	1.5	3.5
Bonds	10.0	4.2
Stocks	29.1	8.8
Mutual Funds	17.5	7.0
Total/Weighted-Average Discount Rate	100.0	5.6

* Not including primary mortgage or retirement accounts.
** Adjusted for inflation and, for home equity loans, loan interest tax deduction.

8.2.8.2 Commercial Discount Rate

Most companies use both debt and equity capital to fund investments; for most companies, therefore, the cost of capital is the weighted average of the cost to the firm of equity and debt financing.[22]

DOE estimated the cost of equity financing using the Capital Asset Pricing Model (CAPM). Among the most widely used models to estimate the cost of equity financing, the CAPM assumes that the cost of equity is proportional to the amount of systematic risk associated with a firm. For example, the cost of equity financing tends to be high when a firm faces a large degree of systematic risk, and the cost tends to be low when the firm faces a small degree of systematic risk.

The degree of systematic risk facing a firm and the subsequent cost of equity financing are determined by several variables, including the risk coefficient of a firm (beta, β), the expected return on risk-free assets (R_f), and the additional return expected on assets facing average market risk (known as the equity risk premium, or ERP). The beta indicates the degree of risk associated with a given firm, relative to the level of risk (or price variability) in the overall stock market. Betas usually vary between 0.5 and 2.0. A firm with a beta of 0.5 faces half the risk of other stocks in the market; a firm with a beta of 2.0 faces twice the overall stock market risk.

Following this approach, the cost of equity financing for a particular company is by the equation:

$$k_e = R_f + (\beta \times ERP) \qquad \textbf{Eq. 8.6}$$

Where:

k_e =	the cost of equity for a company, expressed in dollars,
R_f =	the expected return of the risk free asset, expressed in dollars,
B =	the risk coefficient, and
ERP =	the expected equity risk premium, expressed in dollars.

The cost of debt financing (k_d) is the yield or interest rate paid on money borrowed by a company (raised, for example, by selling bonds). As defined here, the cost of debt includes compensation for default risk and excludes deductions for taxes.

DOE estimated the cost of debt for companies by adding a risk adjustment factor to the current yield on long-term corporate bonds (the risk-free rate). This procedure was used to estimate current and future company costs to obtain debt financing. The adjustment factor is based on indicators of company risk, such as credit rating or variability of stock returns.

The discount rate of companies is the weighted average cost of debt and equity financing, less expected inflation. DOE estimated the discount rate using the equation:

$$k = k_e \times w_e + k_d \times w_d \qquad \textbf{Eq. 8.7}$$

Where:

k =	the (nominal) cost of capital,
k_e and k_d =	the expected rates of return on equity and debt, respectively, and
w_e and w_d =	the proportion of equity and debt financing, respectively.

The real discount rate deducts expected inflation from the nominal rate.

The expected return on risk-free assets, or the risk-free rate, is defined by the current yield on long-term (20-year) government bonds, as suggested by Ibbotson's Associates[23] and Damodaran.[24] The ERP represents the difference between the expected (average) stock market return and the risk-free rate. As Table 8.2.10 shows, DOE uses an ERP estimate of 3.07 percent, which it took from the Damodaran Online site (a private website associated with New York University's Stern School of Business, which aggregates information on corporate finance, investment, and valuation).[25]

Table 8.2.10 Variables Used to Estimate Company Discount Rates

Variable	Symbol	Average Value %	Source
Risk-Free Asset Return	R_f	6.9	Damodaran Online
Equity Risk Premium	*ERP*	3.07	Damodaran Online
Expected Inflation	*R*	1.9	U.S. Bureau of Economic Analysis
Cost of Debt (After Tax)	k_d	6.8	Damodaran Online
Debt Financing Share	w_d	31.6	Damodaran Online
Systematic Firm Risk	*B*	0.95	Damodaran Online

DOE calculated an expected inflation of 1.9 percent from the average of five quarters' change in gross domestic product prices.[26] DOE obtained the cost of debt, debt financing share, and systematic firm risk from the Damodaran Online website. Table 8.2.10 shows average values across all private companies. However, the cost of debt, percentage of debt financing, and systematic firm risk vary by sector.

In the commercial building sector, ballasts are purchased and owned by commercial building property owners, commercial companies, industrial companies, and the government. DOE used a sample of 4,207 companies drawn from these owner categories to represent ballast purchasers. It took the sample from the list of companies included in the Value Line investment survey[27] and listed on the Damodaran Online website. DOE obtained the cost of debt, the firm beta, the percentage of debt and equity financing, the risk-free return, and the equity risk premium from Damodaran Online.

DOE estimated the cost of debt financing for these companies from the long-term government bond rate and the standard deviation of the stock price. For government-office-type owners, the discount rate represents an average of the Federal rate and the State and local bond rate. DOE drew the Federal rate directly from the U.S. Office of Management and Budget discount rate for investments in government building energy efficiency.[28] DOE estimated the State and local discount rate from the interest rate on State and local bonds between 1977 and 2001.[29] DOE used this information to estimate the weighted-average cost of capital for the sample of companies included in the commercial and industrial company database.

The cost of capital may be viewed as the discount rate that should be used to reduce the future value of typical company project cash flows. It is a nominal discount rate, since anticipated future inflation is included in both stock and bond expected returns. Deducting expected inflation from the cost of capital provides estimates of the real discount rate by ownership category (Table 8.2.11). The mean real discount rate for these companies varied between 2.3 percent (government offices) and 8.3 percent (commercial companies).

Table 8.2.11 Real Discount Rates by Ballast Ownership Category

Ownership Category	Mean Real Discount Rate %	Standard Deviation %	Number of Observations
Industrial Companies	7.2	1.1	1,925
Commercial Companies	6.9	1.2	2,146

DOE's approach for estimating the cost of capital provided a measure of the discount rate spread as well as the average discount rate. DOE inferred the discount rate spread by ownership category from the standard deviation, which ranged between 1.1 percent and 1.2 percent (Table 8.2.11). DOE defined Industrial and Commercial companies as companies with Standard Industrial Classification codes 2,000–3,999 and 5,000+, respectively. Table 8.2.12 shows the average discount rate by sector.

Table 8.2.12 Average Discount Rate by Sector

Sector	Discount Rate %
Industrial	7.2
Commercial	6.9
Residential	5.6

8.2.9 Effective Date of Standard

The compliance date is when a covered product is required to meet a new or amended standard. The Energy Policy and Conservation Act (EPCA) requires that any new or amended standards established in this rule apply to products manufactured after a date that is 5 years after (i) the effective date of the previous amendment; or (ii) if the previous final rule did not amend the standards, the earliest date by which a previous amendment could have been effective; except that in no case may any amended standard apply to products manufactured within 3 years after publication of the final rule establishing such amended standard. (42 U.S.C. 6295(g)(7)(C)) DOE is required by a 2006 consent decree, as amended, to publish any amended standards for ballasts by October 28, 2011.[c] In accordance with 42 U.S.C. 6295(g)(7)(C), the compliance date is 3 years after the publication of any final new and amended standards. DOE calculated the LCC for all end users as if each one would purchase a new ballast in the year compliance with the standard is required.

Table 8.2.13 presents the anticipated effective dates of standards for representative ballast designs addressed in the LCC and PBP analyses. The new standards will also affect additional ballast designs not directly addressed in the LCC and PBP analyses (*e.g.*, one- and three-lamp versions of ballasts operating 4-foot MBP lamps).

[c] *State of New York, et al. v. Bodman et al.*, 05 Civ. 7807 (LAP) and *Natural Resources Defense Council, et al. v. Bodman, et al.*, 05 Civ. 7808 (LAP) (Nov. 3, 2006), as amended on June 20, 2011.

Table 8.2.13 Effective Dates of Standards for Ballast Designs Addressed in Life-Cycle Cost and Payback Period Analyses*

Ballast Design	Existing Standard	Effective Date of Existing Standard		Effective Date of Amended Standard
Two-Lamp F34T12 Two-Lamp F96T12/ES Two-Lamp F96T12HO/ES	42 U.S.C. 6295(g)(8)	Manufactured for Luminaires	July 1, 2009	July 1, 2014
		Sold to Luminaire Manufacturer	October 1, 2009	October 1, 2014
		Incorporated into Luminaires	July 1, 2010	July 1, 2015
		Manufactured as Replacement	July 1, 2010	July 1, 2015
		Sold as Replacement	October 1, 2010	October 1, 2015
Commercial and Industrial Two-Lamp F32T8 Four-Lamp F32T8 Two-Lamp F96T8 Two-Lamp F96T8HO Two-Lamp F28T5 Two-Lamp F54T5HO	N/A	N/A		October 2014
Residential, Low-PF Two-Lamp F34T12 Two-Lamp F32T8	N/A**	N/A		October 2014

* The new standards also affect additional ballast designs not directly addressed in the LCC and PBP analyses (*e.g.*, one- and three-lamp versions of ballasts operating 4-foot MBP lamps), with an effective date of October 2014.
** Residential ballasts were not regulated under the 2000 Ballast Rule.

DOE calculated the LCCs for all consumers as if each would purchase a new product in the year the amended standard takes effect. However, DOE based the cost of the equipment on the most recent available data; all dollar values are expressed in 2010$.

8.3 PAYBACK PERIOD INPUTS

8.3.1 Definition

The PBP is the amount of time it takes the consumer to recover the assumed higher purchase cost of a 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 annual operating expenditures. This type of calculation is known as a “simple” PBP, because is does not take into account changes in operating cost over time or the time value of money. That is, the calculation is done at an effective discount rate of 0 percent.

The equation for PBP is:

$$PBP = \frac{\Delta IC}{\Delta OC} \qquad \textbf{Eq. 8.8}$$

Where:

PBP = payback period (years),

ΔIC = difference in the total installed cost between the more efficacious standard level; equipment (efficacy levels 1, 2, etc.) and baseline (efficacy level 0) equipment, and

ΔOC = difference in annual operating costs.

PBPs are expressed in years. PBPs greater than the life of the product mean that the increased total installed cost of the more efficacious product is not recovered in reduced operating costs over the lifetime of that product. Negative PBP values indicate standards that reduce both operating costs and installed costs. Entries of "N/A" indicate standard levels that do not reduce operating costs; ballasts of this type prevent the consumer from ever recovering the increased purchase cost.

8.3.2 Rebuttable Presumption Payback Period

Section 325(o)(2)(B)(iii) of the EPCA establishes a rebuttable presumption that an amended standard for ballasts is economically justified if the Secretary of Energy finds that the additional cost to the consumer of purchasing a product complying with an energy conservation standard level will be less than three times the value of the energy savings during the first year that the consumer will receive as a result of the standard, as calculated under the applicable test procedure. (42 U.S.C. 6295(o)(2)(B)(iii)) This rebuttable presumption test is an alternative path to establishing economic justification compared to consideration of the seven factors set forth in 42 U.S.C. 6295(o)(2)(B)(i)(I)–(VII).

The applicable ballast test procedure measures input power for the lamp-and-ballast system rather than measuring energy consumption (*i.e.*, measured over a duration or operating time period). Therefore, to calculate energy savings for the rebuttable presumption payback period, one would need to multiply the input power rating of the lamp-and-ballast system by the usage profile (*i.e.*, hours of operation) of that system. For the engineering analysis, DOE measured the input power of ballasts operating actual lamps, essentially duplicating real-world operating conditions for these lamp-and-ballast systems. Energy savings calculations in the LCC and PBP analyses use both the real-world system power ratings as well as the applicable usage profiles. Because DOE calculated PBPs in a methodology consistent with the rebuttable presumption test in the LCC and PBP analyses, DOE did not perform a stand-alone rebuttable presumption analysis, as it is already embodied in the LCC and PBP analyses. Because calculations of energy savings in the LCC are based under real-world conditions, DOE also relied on standard PBPs for this rulemaking.

8.3.3 Inputs

The data inputs to PBP were the total installed cost of the product to the consumer for each EL and the annual (first year) operating costs for each EL. The inputs to the total installed cost were the final product price and the installation cost. The inputs to the operating costs were the lamp-and-ballast system input power rating, annual operating hours, and electricity cost. The PBP used the same inputs as the LCC calculation described in section 8.2, except that electricity price trends were not required. Since the PBP is a "simple" (undiscounted) PBP, the required electricity cost was only for the year in which an amended energy conservation standard is to take effect (*e.g.*, 2014). The electricity price DOE used in the PBP calculation for electricity cost was the price projected for 2014, expressed in 2010$. DOE did not use discount rates in the PBP calculation.

8.4 BALLAST PURCHASING EVENTS

DOE designed the LCC and PBP analyses for this rulemaking around scenarios where consumers need to purchase a ballast; DOE refers to these collectively as "ballast purchasing events." Each of these events may present the consumer with a different set of ballast or lamp-and-ballast designs and therefore a different set of LCC savings for a certain EL. For ballasts, DOE identified two possible scenarios under which consumers would purchase a ballast and potentially be affected by an amended energy conservation standard. These scenarios were: (1) ballast failure; and (2) new construction/renovation. The two ballast purchasing events are described in more detail below. In addition to these descriptions, Table 8.4.1 and Table 8.4.2 summarize the ballast purchasing events considered in this analysis.

- Ballast failure: This is a scenario in which the installed ballast has failed. DOE recognizes that energy conservation standards set by the 2000 Ballast Rule and the Energy Policy Act of 2005 (EPAct 2005), Pub. L. 109-58, were effective in 2010 and may affect the types of systems available to the consumer to purchase. These standards essentially banned the sale of most magnetic 4-foot MBP and 8-foot slimline ballasts. The 2000 Ballast Rule, however, allows the continued sale of magnetic cold temperature ballasts, which operate a large portion of the installed base of T12 RDC HO lamps. Magnetic ballasts will also continue to be sold for the residential sector. Therefore, in the baseline, most users who had a magnetic or electronic T12 ballast would be expected to replace it with an electronic T12 ballast and corresponding standards-compliant lamp (if available), but failed HO ballasts as well as residential ballasts and fixtures are expected to be replaced with magnetic ballasts or fixtures containing magnetic ballasts. Users who had a T8 ballast fail would be expected to replace it with a T8 ballast and corresponding standards-compliant lamp. However, in the standards case, end-users would generally select a standards-compliant lamp-ballast combination such that the system light output never drops below 10 percent of the baseline system.
- New construction and renovation: This ballast purchasing event encompasses all the new fixture installations where the lighting design will be completely new or can be completely changed. In response to this event, the spatial layout of fixtures in the building space is not constrained to any previous configuration. Because new fixtures can be installed, consumers could install a lamp-and-ballast system that would not maintain the light output of the baseline system. For instance, if the lamp and ballast light output of the standards case system is lower than the base case system, consumers can increase the number of standards case lamp-and-ballast systems installed in the building by a certain percentage to maintain the light output of base case lamp-and-ballast systems. Table 8.4.1, Table 8.4.2, and Table 8.4.3 outline the events and actions taken by consumers in response to those events both in the base case and in the standards case.

Table 8.4.1 Framework of Event-Type Scenarios for Ballasts Operating 4-Foot and 8-Foot T12 Lamps (including MBP, Slimline, and RDC HO)

Event	Base Case Action	Standards Case Action
Type 1. Ballast Failure	Installs a T12 ballast and lamps in the existing fixture. HO ballasts are magnetic, while other ballasts are electronic.	Installs a new T12 or T8 ballast and lamps, where the system light output generally never drops below 90 percent of the baseline system.
Type 2. New Construction and Renovation	Installs a new T12 system.	Installs a new T12 or T8 system, where the system light output never drops below 90 percent of the baseline system. Light output can be maintained through spacing.

Table 8.4.2 Framework of Event-Type Scenarios for Ballasts Operating 4-Foot and 8-Foot T8 Lamps (including MBP, Slimline, and RDC HO)

Event	Base Case Action	Standards Case Action
Type 1. Ballast Failure	Installs a T8 electronic ballast and lamps in the existing fixture.	Installs new T8 ballast and lamps, where the system light output generally never drops below 90 percent of the baseline system.
Type 2. New Construction and Renovation	Installs a new T8 system.	Installs a new T8 system, where the system light output never drops below 90 percent of the baseline system. Light output can be maintained through spacing.

Table 8.4.3 Framework of Event-Type Scenarios for Ballasts Operating 4-Foot T5 MiniBP Lamps

Event	Base Case Action	Standards Case Action
Type 1. Ballast Failure/Replacement	Installs a T5 electronic ballast and lamps in the existing fixture.	Installs new T5 ballast and lamps, where the system light output never drops below 90 percent of the baseline system.
Type 2. New Construction and Renovation	Installs a new T5 system.	Installs a new T5 system, where the system light output never drops below 90 percent of the baseline system. Light output can be maintained through spacing.

8.5 LIFE-CYCLE COST AND PAYBACK PERIOD RESULTS

This section presents LCC results for each lamp-and-ballast design DOE considered. This section uses the terms "positive LCC savings" and "negative LCC savings." When an amended standard results in "positive LCC savings," the LCC of the standards-compliant system is less than the LCC of the baseline system and the consumer benefits. A consumer is adversely affected when an amended standard results in "negative LCC savings" (*i.e.*, when the LCC of the standards-compliant system is higher than the LCC of the baseline system).

As stated earlier, DOE conducted a series of LCC calculations for each baseline lamp-and-ballast system. Key inputs consisted of using historical electricity prices from electricity price projections from the *AEO2010* reference case, and an analysis period corresponding to the lifetime and operating hours of each ballast, to a maximum of 30 years. In all cases, DOE considered only designs that save energy and maintain light output above a maximum 10 percent decrease from the baseline lamp or system whenever possible.

All replacement options were designed around two possible ballast purchasing events where consumers be affected by an amended energy conservation standard. These events are ballast failure/replacement, and new construction/renovation. The LCC spreadsheet calculates the LCC impacts for each of these scenarios separately.

Table 8.5.1 through Table 8.5.14 present the results, by product class, for each of the representative ballast designs by ballast purchasing event, for each trial standard level (TSL). Each table includes the average total LCC and the average LCC savings, as well as the fraction of product consumers for which the LCC will either decrease (net benefit), or increase (net cost) relative to the base-case forecast. The last outputs in the tables are the median PBPs for the consumer that is purchasing a design compliant with the TSL.

In general, the results show higher installed prices and lower operating costs at higher ELs. However, this is not always the case. For example, ballasts operating 4-foot MBP T8 lamps in the residential sector (Table 8.5.4) have higher operating costs at the higher EL than at the baseline efficiency. This is from the higher input power for the evaluated EL, which would result in increased energy use and costs despite its more efficient design.

Table 8.5.1 Product Class 1 - IS and RS Ballasts That Operate Two 4-Foot MBP Lamps (Commercial, T12 Baseline): LCC and PBP Results

Trial Standard Level	**Efficiency Level**	**Life-Cycle Cost** ***2010$***			**Life-Cycle Cost Savings**			**Median Payback Period*** ***years***
		Installed Cost	**Discounted Operating Cost**	**LCC**	**Average Savings** ***2010$***	**Percent of Consumers that Experience**		
						Net Cost	**Net Benefit**	
Event I: Replacement								
	Baseline	64	247	311	--	--	--	--
1	1	57	225	282	29	0	100	-3.35
2	2	59	218	277	34	0	100	-1.66
3A, 3B	3	60	214	274	37	0	100	-1.30
Event II: New Construction / Renovation								
	Baseline	67	247	314	--	--	--	--
1	1	59	222	281	32	0	100	-2.97
2	2	62	213	275	39	0	100	-1.43
3A, 3B	3	62	211	273	40	0	100	-1.19

* Negative PBP values indicate standards that reduce operating costs and installed costs.

Table 8.5.2 Product Class 1 - IS and RS Ballasts That Operate Two 4-Foot MBP Lamps (Commercial, T8 Baseline): LCC and PBP Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2010$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2010$*	Percent of Consumers that Experience		
						Net Cost	Net Benefit	
Event I: Replacement								
1	Baseline / 1	56	225	281	--	--	--	--
2	2	59	218	277	5	0	100	3.62
3A, 3B	3	59	214	273	8	0	100	2.86
Event II: New Construction / Renovation								
1	Baseline / 1	58	225	283	--	--	--	--
2	2	61	216	277	7	0	100	2.76
3A, 3B	3	62	214	275	8	0	100	2.74

Table 8.5.3 Product Class 1 - IS and RS Ballasts That Operate Four 4-Foot MBP Lamps: LCC and PBP Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2010$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2010$*	Percent of Consumers that Experience		
						Net Cost	Net Benefit	
Event I: Replacement								
1, 2	Baseline / 2	78	412	490	--	--	--	--
3A, 3B	3	81	403	484	7	0	100	2.65
Event II: New Construction / Renovation								
1, 2	Baseline / 2	81	412	493	--	--	--	--
3A, 3B	3	83	406	490	3	0	100	4.43

Table 8.5.4 Product Class 1 - IS and RS Ballasts That Operate Two 8-Foot Slimline Lamps (T12 Baseline): LCC and PBP Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2010$*			Life-Cycle Cost Savings			Median Payback Period* *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2010$*	Percent of Consumers that Experience		
						Net Cost	Net Benefit	
Event I: Replacement								
1	Baseline / 1	90	457	547	--	--	--	--
2	2	90	432	521	26	0	100	-0.12
3A, 3B	3	90	425	514	33	0	100	0.01
Event II: New Construction / Renovation								
1	Baseline / 1	92	457	549	--	--	--	--
2	2	92	440	532	17	0	100	-0.17
3A, 3B	3	92	435	527	22	0	100	0.01

* Negative PBP values indicate standards that reduce operating costs and installed costs.

Table 8.5.5 Product Class 1 - IS and RS Ballasts That Operate Two 8-Foot Slimline Lamps (T8 Baseline): LCC and PBP Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2010$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2010$*	Percent of Consumers that Experience		
						Net Cost	Net Benefit	
Event I: Replacement								
1, 2	Baseline /2	90	432	522	--	--	--	--
3A, 3B	3	91	425	515	7	0	100	0.46
Event II: New Construction / Renovation								
1, 2	Baseline /2	93	432	524	--	--	--	--
3A, 3B	3	93	426	519	5	0	100	0.61

Table 8.5.6 Product Class 2 - PS Ballasts That Operate Two 4-Foot MBP Lamps: LCC and PBP Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2010$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2010$*	Percent of Consumers that Experience		
						Net Cost	Net Benefit	
Event I: Replacement								
	Baseline	59	205	263	--	--	--	--
1, 2	2	60	191	251	12	0	100	1.09
3A, 3B	3	60	188	249	15	0	100	1.25
Event II: New Construction / Renovation								
	Baseline	61	205	266	--	--	--	--
1, 2	2	62	191	253	13	0	100	1.09
3A, 3B	3	63	189	252	14	0	100	1.26

Table 8.5.7 Product Class 2 - PS Ballasts That Operate Four 4-Foot MBP Lamps: LCC and PBP Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2010$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2010$*	Percent of Consumers that Experience		
						Net Cost	Net Benefit	
Event I: Replacement								
	Baseline	77	375	452	--	--	--	--
1	1	81	373	454	-2	100	0	20.52
2, 3A, 3B	3	83	363	446	6	1	99	6.00
Event II: New Construction / Renovation								
	Baseline	79	375	454	--	--	--	--
1	1	83	342	425	29	0	100	1.43
2, 3A, 3B	3	85	334	419	35	0	100	1.76

Table 8.5.8 Product Class 2 - PS Ballasts That Operate Two 4-Foot MiniBP SO Lamps: LCC and PBP Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2010$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2010$*	Percent of Consumers that Experience		
						Net Cost	Net Benefit	
Event I: Replacement								
	Baseline	64	268	332	--	--	--	--
1	1	64	251	315	18	0	100	0.05
2	2	66	240	306	27	0	100	0.55
3A, 3B	3	70	252	322	10	0	100	3.82
Event II: New Construction / Renovation								
	Baseline	66	268	335	--	--	--	--
1	1	67	251	317	18	0	100	0.05
2	2	68	248	316	18	0	100	0.78
3A, 3B	3	73	242	315	19	0	100	2.41

Table 8.5.9 Product Class 2 - PS Ballasts That Operate Two 4-Foot MiniBP HO Lamps: LCC and PBP Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2010$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2010$*	Percent of Consumers that Experience		
						Net Cost	Net Benefit	
Event I: Replacement								
	Baseline	64	357	421	--	--	--	--
1	1	68	326	395	26	0	100	1.05
2	2	71	318	389	32	0	100	1.40
3A, 3B	3	74	319	393	28	0	100	2.03
Event II: New Construction / Renovation								
	Baseline	67	357	423	--	--	--	--
1	1	71	326	397	26	0	100	1.05
2	2	74	323	397	26	0	100	1.63
3A, 3B	3	77	321	397	26	0	100	2.13

Table 8.5.10 Product Class 3 - IS and RS Ballasts That Operate Two 8-Foot HO Lamps (T12 Baseline): LCC and PBP Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2010$*			Life-Cycle Cost Savings			Median Payback Period* *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2010$*	Percent of Consumers that Experience		
						Net Cost	Net Benefit	
Event I: Replacement								
	Baseline	116	631	747	--	--	--	--
1	1	111	571	682	65	0	100	-0.66
2, 3A	2	97	420	517	230	0	100	-0.69
3B	3	101	413	514	233	0	100	-0.53
Event II: New Construction / Renovation								
	Baseline	119	631	750	--	--	--	--
1	1	114	590	704	46	0	100	-0.98
2, 3A	2	99	517	616	134	0	100	-1.26
3B	3	103	513	616	134	0	100	-0.97

* Negative PBP values indicate standards that reduce operating costs and installed costs.

Table 8.5.11 Product Class 3 - IS and RS Ballasts That Operate Two 8-Foot HO Lamps (T8 Baseline): LCC and PBP Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2010$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2010$*	Percent of Consumers that Experience		
						Net Cost	Net Benefit	
Event I: Replacement								
1, 2, 3A	Baseline / 2	94	420	514	--	--	--	--
3B	3	98	413	511	3	3	97	4.57
Event II: New Construction / Renovation								
1, 2, 3A	Baseline / 2	96	420	517	--	--	--	--
3B	3	100	417	517	-1	84	16	9.50

Table 8.5.12 Product Class 5 - Sign Ballasts That Operate Four 8-Foot HO Lamps: LCC and PBP Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2010$*			Life-Cycle Cost Savings			Median Payback Period* *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2010$*	Percent of Consumers that Experience		
						Net Cost	Net Benefit	
Event I: Replacement								
	Baseline	164	1,483	1,646	--	--	--	--
1, 2, 3A, 3B	1	157	1,086	1,244	403	0	100	-0.16
Event II: New Construction / Renovation								
	Baseline	166	1,483	1,649	--	--	--	--
1, 2, 3A, 3B	1	160	1,239	1,398	251	0	100	-0.26

* Negative PBP values indicate standards that reduce operating costs and installed costs.

Table 8.5.13 Product Class 6 - IS and RS Ballasts That Operate Two 4-Foot MBP Lamps (Residential, T12 Baseline): LCC and PBP Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2010$*			Life-Cycle Cost Savings			Median Payback Period* *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2010$*	Percent of Consumers that Experience		
						Net Cost	Net Benefit	
Event I: Replacement								
	Baseline	53	71	124	--	--	--	--
1, 2, 3A	1	46	56	102	21	0	100	-5.46
3B	2	47	58	105	19	0	100	-4.92
Event II: New Construction / Renovation								
	Baseline	55	71	126	--	--	--	--
1, 2, 3A	1	48	63	111	15	0	100	-9.45
3B	2	49	61	110	16	0	100	-6.35

* Negative PBP values indicate standards that reduce operating costs and installed costs.

Table 8.5.14 Product Class 6 - IS and RS Ballasts That Operate Two 4-Foot MBP Lamps (Residential, T8 Baseline): LCC and PBP Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2010$*			Life-Cycle Cost Savings			Median Payback Period* *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2010$*	Percent of Consumers that Experience		
						Net Cost	Net Benefit	
Event I: Replacement								
1, 2, 3A	Baseline / 1	45	56	101	--	--	--	--
3B	2	46	58	104	-2	100	0	N/A
Event II: New Construction / Renovation								
1, 2, 3A	Baseline / 1	47	56	104	--	--	--	--
3B	2	49	55	103	1	27	73	8.18

* Entries of "N/A" indicate standard levels that do not reduce operating costs.

Table 8.5.15 shows the rebuttable presumption payback periods that are less than 3 years. Negative PBP values indicate standards that reduce operating costs and installed costs.

Table 8.5.15 Ballast Efficiency Levels with Rebuttable Payback Period Less Than 3 Years

Product Class	Efficiency Level	Mean Payback Period* *years* Event I: Replacement	Mean Payback Period* *years* Event II: New Construction / Renovation
IS and RS ballasts that operate:			
Two 4-foot MBP lamps (commercial, T12 baseline)	1	-3.19	-2.82
	2	-1.57	-1.34
	3	-1.22	-1.11
Two 4-foot MBP lamps (commercial, T8 baseline)	2		2.55
	3	2.64	2.53
Four 4-foot MBP lamps	3	2.46	
Two 8-foot slimline lamps (T12 baseline)	2	-0.11	-0.16
	3	0.01	0.01
Two 8-foot slimline lamps (T8 baseline)	3	0.43	0.56
PS ballasts that operate:			
Two 4-foot MBP lamps	1, 2	1.01	1.01
	3	1.15	1.17
Four 4-foot MBP lamps	1		1.32
	3		1.63
Two 4-foot MiniBP SO lamps	1	0.05	0.05
	2	0.50	0.72
	3		2.23
Two 4-foot MiniBP HO lamps	1	1.07	1.07
	2	1.42	1.66
	3	2.06	2.17
IS and RS ballasts that operate:			
Two 8-foot HO lamps (T12 baseline)	1	-0.67	-1.00
	2	-0.72	-1.32
	3	-0.55	-1.01
Sign Ballasts that operate:			
Four 8-foot HO lamps in outdoor signs	1, 2, 3	-0.15	-0.24
IS and RS ballasts that operate:			
Two 4-foot MBP lamps (residential, T12 baseline)	1	-5.14	-8.98
	2	-4.63	-6.01

* Negative PBP values indicate standards that reduce operating costs and installed costs.

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CHAPTER 9. TRIAL STANDARD LEVELS

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CHAPTER 9. TRIAL STANDARD LEVELS

9.1 INTRODUCTION

The U.S. Department of Energy (DOE) generated national energy savings (NES) and net present value (NPV) results based on trial standard levels (TSLs). The TSLs designate an efficiency level (EL) for each product class. ELs are developed for each product class in the engineering analysis. In this chapter, DOE is only presenting the TSLs of the product classes that DOE analyzed directly (the "representative product classes").

9.2 REPRESENTATIVE PRODUCT CLASSES

In chapter 3 of the technical support document (TSD), DOE identifies five product classes for fluorescent lamp ballasts. Rather than analyze all product classes, DOE selected certain product classes as "representative" to analyze in further detail. Representative product classes include: (1) instant start (IS) and rapid start (RS) ballasts that operate 4-foot medium bipin (MBP) and 8-foot slimline lamps; (2) programmed start (PS) ballasts that operate 4-foot MBP, 4-foot T5 miniature bipin (MiniBP) standard output (SO), and 4-foot T5 MiniBP high output (HO) lamps; (3) IS and RS ballasts that operate 8-foot HO lamps; (4) sign ballasts; and (5) IS and RS residential ballasts. Details on how these product classes were selected can be found in chapter 5 of the TSD. Table 9.1 shows all of the product classes and designates those which were considered to be representative.

Table 9.1 Fluorescent Lamp Ballast Product Classes

Description	Product Class Number
IS and RS ballasts (not classified as residential) that operate: 4-foot MBP lamps 2-foot U-shaped lamps 8-foot slimline lamps	1 (representative)
PS ballasts (not classified as residential) that operate: 4-foot MBP lamps 2-foot U-shaped lamps 4-foot MiniBP SO lamps 4-foot MiniBP HO lamps	2 (representative)
IS and RS ballasts (other than sign ballasts) that operate: 8-foot HO lamps	3 (representative)
PS ballasts (other than sign ballasts) that operate: 8-foot HO lamps	4
Sign ballasts that operate: 8-foot HO lamps	5 (representative)
IS and RS residential ballasts that operate: 4-foot MBP lamps 8-foot slimline lamps	6 (representative)
PS residential ballasts that operate: 4-foot MBP lamps	7

9.3 TRIAL STANDARD LEVELS

DOE analyzed the benefits and burdens of a number of TSLs for the ballasts that are the subject of today's final rule. Table 9.2 presents the TSLs and the corresponding product class ELs. See the engineering analysis in chapter 5 of the TSD for a more detailed discussion of the ELs.

Table 9.2 Trial Standard Levels

Description	TSL1	TSL2	TSL3A	TSL3B
IS and RS ballasts (not classified as residential) that operate: 4-foot MBP lamps 2-foot U-shaped lamps 8-foot slimline lamps	EL1	EL2	EL3	EL3
PS ballasts (not classified as residential) that operate: 4-foot MBP lamps 2-foot U-shaped lamps 4-foot MiniBP SO lamps 4-foot MiniBP HO lamps	EL1	EL2	EL3	EL3
IS and RS ballasts (other than sign ballasts) that operate: 8-foot HO lamps	EL1	EL2	EL2	EL3
PS ballasts (other than sign ballasts) that operate: 8-foot HO lamps	EL1	EL2	EL2	EL3
Sign ballasts that operate: 8-foot HO lamps	EL1	EL1	EL1	EL1
IS and RS residential ballasts that operate: 4-foot MBP lamps 8-foot slimline lamps	EL1	EL1	EL1	EL2
PS residential ballasts that operate: 4-foot MBP lamps	EL1	EL1	EL1	EL2

TSL 1, which would set energy conservation standards at EL1 for all product classes, would eliminate the majority of currently available 4-foot MBP T12 RS (commercial and residential), low-efficiency 4-foot MBP T8 PS, magnetic 8-foot HO, and magnetic sign ballasts. Based on these impacts, TSL 1 would likely cause a migration from 4-foot MBP T12 RS ballasts (both commercial and residential) to 4-foot MBP T8 IS ballasts. TSL 1 also prevents inefficient T5 standard output and high output ballasts from becoming prevalent in future years. DOE would not anticipate any impact of TSL 1 on consumers of 8-foot slimline ballasts.

TSL 2 would establish energy conservation standards at EL2 for the IS/RS, PS, and 8-foot HO IS/RS product classes. This level would likely eliminate low efficiency two-lamp 4-foot MBP T8 IS commercial ballasts and the least efficient T12 8-foot slimline ballasts, causing a migration toward high efficiency two lamp 4-foot MBP T8 IS ballasts and 8-foot T8 slimline ballasts. DOE does not anticipate any impact of TSL 2 on four-lamp 4-foot MBP T8 IS ballast consumers. For PS ballasts, high-efficiency 4-foot MBP T8 ballasts and high-efficiency T5 standard output and high output ballasts are required at TSL 2. For the 8-foot HO IS/RS product class, this level would likely result in the elimination of the majority of current T12 electronic ballasts, but can be met with T8 electronic ballasts. As with TSL 1, TSL 2 would continue to use EL1 for the residential IS/RS product class, eliminating currently available 4-foot MBP T12 RS ballasts, but allowing higher efficiency T8 residential ballasts. In addition, the sign ballast efficiency level remains unchanged from TSL1.

TSL 3A would establish energy conservation standards at the maximum technologically feasible level for all product classes except for residential and 8-foot HO IS/RS product classes. As with TSL 2, the 8-foot HO IS/RS product class at TSL 3A results in the elimination of current T12 electronic ballasts, but can be met with T8 electronic ballasts. Consistent with TSLs 1 and 2, TSL 3A also requires EL1 for the residential IS/RS product class. This TSL represents the most stringent efficiency requirements where a positive LCC savings for each representative product class is maintained.

TSL 3B represents the maximum technologically feasible level for all product classes. This level would establish energy conservation standards at EL1 for sign ballasts, EL2 for residential IS/RS product classes, and EL3 for the commercial IS/RS and PS, and 8-foot HO IS/RS product classes. TSL 3B represents the highest EL analyzed in all representative product classes and is the max tech TSL. Ballasts that meet TSL 3B represent the most efficient models tested by DOE in their respective representative product classes.

CHAPTER 10. SHIPMENTS ANALYSIS

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CHAPTER 10. SHIPMENTS ANALYSIS

10.1 INTRODUCTION

Shipments of fluorescent lamp ballasts (FLB or ballasts) are key inputs to the national energy savings (NES) and net present value (NPV) calculations. Shipments are also a necessary input to the manufacturer impact analysis, which the U.S. Department of Energy (DOE) conducts in developing its final rules. This chapter describes DOE's methodology for projecting annual shipments and presents initial inputs and results for ballasts.

In the shipments analysis, DOE developed a base-case shipment forecast for each ballast type to depict what would happen to energy use and consumer costs for the purchase and operation of lamp-and-ballast systems in the absence of amended Federal energy conservation standards. In determining the base case, DOE considered historical shipments, emerging technologies, the mix of efficiencies sold in the absence of amended standards, and how that mix might change over time. To evaluate the impacts of standards on ballasts, DOE then compared the base-case projection with forecasts of what could happen if DOE promulgates amended standards (the standards case). DOE considered multiple shipments scenarios to characterize both the base- and standards-case shipments. As an input to determine the cumulative NES and NPV of standards, DOE compared forecasted shipments of a base to a standards case over the national impact analysis (NIA) analysis period, 2014–2043.

The shipments model and the national impacts model are integrated into a single Microsoft Excel spreadsheet accessible at www1.eere.energy.gov/buildings/appliance_standards/residential/fluorescent_lamp_ballasts.html. Appendix 10A discusses how to access the spreadsheet and provides basic instructions for its use. This final rule technical support document (TSD) chapter explains the shipments models. Section 10.2 presents the shipments model methodology for ballasts; section 10.3 describes the data inputs, historical shipments, base-case scenarios, and shipments forecasts; section 10.4 discusses the impacts of new and amended standards on the mix of ballast designs; and section 10.5 presents the shipments results for the different trial standard levels (TSLs).

10.2 SHIPMENTS MODEL METHODOLOGY

In general, DOE followed a three-step process to forecast ballast shipments. First, DOE used 1990 to 2005 historical shipment data from U.S. Census Bureau to estimate historical shipments of each ballast type analyzed. Second, DOE calculated an installed stock for each ballast type in 2005 based on the lifetime distribution of each ballast type. Third, by modeling ballast purchasing events, such as replacement for failed ballasts and new construction, and applying growth rate, replacement rate, substitution among and within product classes and emerging technologies penetration rate assumptions, DOE developed annual shipment projections for the analysis period.

10.2.1 Analyzed Product Classes, Market Sectors, and Market Segments

DOE forecasted annual shipments for the ballast and market sectors presented in Table 10.2.1. The shipments model analyzed all ballast types at TSLs that assign efficiency levels for each product class.

Table 10.2.1 Product Classes and Market Sectors Analyzed in the Shipments Analysis

Description	Product Class Number
IS and RS ballasts that operate Non-residential 4-foot MBP lamps 8-foot slimline lamps	1
PS ballasts that operate Non-residential 4-foot MBP lamps 4-foot MiniBP SO lamps 4-foot MiniBP HO lamps	2
IS and RS ballasts that operate 8-foot RDC HO lamps	3
Sign ballasts that operate 8-foot RDC HO lamps	5
IS and RS residential ballasts that operate 4-foot MBP lamps	6

HO = high output, IS = instant start, MBP = medium bipin, MiniBP= miniature bipin, PS = programmed start, RDC = recessed double contact, RS = rapid start, SO = standard output

In its shipments model, DOE considered specific market segments ("ballast purchase events") to develop estimates of annual shipments. These two market segments correspond to the ballast purchase events that DOE used in the life-cycle cost (LCC) and payback period (PBP) analyses (final rule TSD chapter 8). These included ballast failure (Event I) and new construction/renovation (Event II). For each market segment, DOE made certain assumptions about how consumers are likely to purchase new ballasts or lamp-and-ballast systems. DOE used these purchasing assumptions to develop the ballast shipment forecasts.

10.2.1.1 Ballast Failure

For those consumer purchases triggered by a ballast failure, DOE assumed that the consumer will purchase a ballast identical to the one that has retired, if it is available. If, in the standards case, the base-case ballast design is not standards-compliant (and therefore unavailable as a replacement option), then DOE assumed consumers will purchase a new, standards-compliant lamp-and-ballast system from the same product class such that the system light output, if possible, never drops below 10 percent of the baseline system. In some instances this means a single ballast is replaced with two ballasts (*e.g.*, replacing one two-lamp, 8-foot slimline lamp-and-ballast system with two two-lamp, 4-foot MBP lamp-and-ballast systems). Table 10.2.2 presents a full listing of the modeled lamp-and-ballast system replacement trends.

Table 10.2.2 Modeled Fluorescent Lamp-and-Ballast Replacement Trends

Retired Lamp-and-Ballast System	Replacement Lamp-and-Ballast System
4-foot T12 electronic MBP (commercial sector)	87.5% 4-foot T8 MBP
	12.5% 4-foot T5 MiniBP SO
4-foot T8 MBP (commercial sector)	87.5% replace in kind
	12.5% 4-foot T5 MiniBP SO
4-foot T12 electronic MBP (residential sector)	20% replace in kind
	80 % 4-foot T8 MBP
4-foot T8 MBP (residential sector)	replace in kind
8-foot T12 slimline	10% 8-foot T8 slimline
	10% replace in kind
	80% two 4-foot T8 MBPs
8-foot T8 slimline	replace in kind
4-foot T5 MiniBP SO	replace in kind
4-foot T5 MiniBP HO	replace in kind
8-foot T12 RDC HO	5% replace in kind
	90% two 4-foot T5 MiniBP HO systems
	5% 8-foot T8 RDC HO
8-foot T8 RDC HO	90% two 4-foot T5 MiniBP HO systems
	10% replace in kind
8-foot T12 magnetic RDC HO in signs	replace in kind

DOE established the timing of ballast replacements in response to ballast failure by tracking ballast shipments and then predicting when these ballasts are expected to retire based on their lifetime distribution. DOE recognized that ballast lifetimes vary, and modeled ballasts lifetimes with Weibull distributions with maximum lifetimes as follows:

- Commercial sector – 20 years
- Industrial sector – 15 years
- Residential sector – 30 years

Average lifetimes were adjusted to match average service life in final rule TSD chapter 8.

10.2.1.2 New Construction/Renovation

For consumer purchases triggered by new construction and renovation, DOE began by assuming that consumers may purchase new lamp-and-ballast systems to service their particular lumen demand from within their current product class. DOE therefore produced initial shipment estimates due to new construction and renovation by deriving growth rates for each product class. The growth rates are based on the Energy Information Administration's (EIA's) *Annual Energy Outlook 2010* (*AEO2010*),[1] which estimates annual commercial floor space and residential building growth. Because the *AEO* does not provide industrial floor space forecasts, DOE used commercial floor space growth values to establish a growth rate for the industrial sector. DOE assumed that the intensity of ballasts per unit of floor space remains constant (*i.e.,* sector growth rates are assumed to be the only source of overall growth in the ballasts market). For renovation/retrofit, DOE assumed that each year 1 percent of ballasts in residential sector (3 percent of ballasts in commercial and industrial sectors) that do not fail (and are not replaced due to failure) are retrofitted.

However, for several product classes DOE research indicated that the ballasts market is moving in a particular direction. In such instances, DOE adjusted its forecasted growth rates for particular ballast types accordingly. In almost all cases DOE's approach was to make these adjustments by substituting growth in one product class for another, without adjusting the overall number of forecasted shipments. The only exception is that wherever ballasts operating 4-foot lamps replace ballasts operating 8-foot lamps, DOE assumed this occurs at a 2:1 ratio. In determining what shipment trends to assume for this rulemaking, DOE referenced its previous analysis of fluorescent lamp-and-ballast shipments, performed as part of its proposed rulemaking for general service fluorescent lamp and incandescent reflector lamps rulemaking (74 FR 34080 (July 14, 2009)); hereafter "the 2009 Lamps Rule").

For the commercial sector, historical lamps shipment data and manufacturer interviews indicated significant growth for only 4-foot T8 MBP and 4-foot T5 MiniBP SO systems; consequently, DOE modeled all purchases due to new construction in the commercial sector as being one of these two lamp-and-ballast systems. DOE modeled commercial sector 4-foot T5 MiniBP SO and HO shipment growth based on a migration from other product classes. DOE's research indicated that shipment growth of 4-foot T5 MiniBP SO ballasts is primarily driven by a migration from the 4-foot MBP market. As this migration requires the purchase of a new fixture, to establish 4-foot MiniBP T5 SO shipments, DOE allotted a portion of what would otherwise be the 4-foot MBP fixture new construction/renovation market to 4-foot T5 MiniBP systems. In the 2009 Lamps Rule, DOE first calculated the size of this potential market for new 4-foot T5 MiniBP SO systems in each year. DOE then determined the portion of this market that would be serviced by 4-foot T5 MiniBP SO systems by calculating the share that resulted in T5 shipments consistent with 2006 and 2007 data. For the ballasts shipments model, DOE held the resulting percentage—approximately 12.5 percent of the new construction/renovation market—constant throughout the analysis period. For 8-foot T12 sign ballasts, DOE assumed that the new construction market would be split evenly between electronic and magnetic ballasts—50 percent each, even in the absence of new and amended standards. This recognized that electronic ballasts provide significant energy savings and would be an attractive replacement for some users.

In the industrial sector, confidential historical shipments showed a declining number of 8-foot RDC HO lamps. Therefore, DOE assumed all system purchases due to new construction in the industrial sector are 4-foot T5 MiniBP HO systems (another rapidly growing market). In the 2009 Lamps Rule, DOE developed 4-foot T5 MiniBP HO ballast shipments by modeling a migration from two different lighting markets. Similar to 8-foot RDC HO systems, marketing literature indicates a large portion of 4-foot MiniBP T5 HO systems serve high-bay applications due to their highly concentrated light output. Historical shipment data for 8-foot RDC HO lamps showed substantial declines in 2006 and 2007, indicating T5 HO systems may be rapidly displacing 8-foot RDC HO systems. In addition, DOE's research indicated that a significant portion of 4-foot T5 MiniBP HO growth can be attributed to their penetration into the high intensity discharge (HID) lamp high- and low-bay markets. Therefore, to calculate the growth in 4-foot MiniBP T5 HO ballast shipments, DOE assumed that these systems were penetrating both the 8-foot RDC HO and HID markets. Similar to its analysis for T5 SO systems, DOE established that the new construction/renovation market segment represents the available market for 4-foot MiniBP T5 HO systems. DOE obtained HID shipment data from the HID lamps rulemaking determination (75 FR 37975 (July 1, 2010)), from which DOE calculated the total lumens servicing low-bay and high-bay applications. Consistent with historical 4-foot T5

MiniBP HO and 8-foot RDC HO shipments, DOE assumed 4-foot T5 MiniBP HO systems fully penetrate the 8-foot RDC HO new construction/renovation market segment as well as the HID new construction/renovation market segment. These same assumptions were applied in this final rule.

For the residential sector, manufacturer interviews indicated that the majority of new residential 4-foot MBP fixtures use T8 MBP systems. Consequently, DOE modeled only 4-foot T8 MBP lamp-and-ballast systems for new construction in the residential sector.

10.3 BASE-CASE INPUTS AND FORECASTS

This section describes the two base-case scenarios DOE employed in its analysis and the base-case input market-share apportioning for ballasts and presents the base-case forecasts for each ballast type along with historical ballast shipments data.

10.3.1 Base-Case Scenarios Analyzed

DOE recognizes that rapidly emerging new lighting technologies could penetrate the fluorescent lighting market and significantly affect ballast shipment forecasts. These technologies, such as solid-state lighting (SSL), which encompasses light-emitting diodes (LEDs), already are or eventually could be significantly more efficacious and longer lasting than the sources they replace. For this final rule, DOE also considered the penetration of dimming ballasts (*e.g.*, as used in daylight harvesting systems), which would affect shipments of the fixed-output ballasts considered in this rulemaking.

If emerging technologies achieve their potential, they may significantly affect the benefit calculations from efficiency standards. However, to calculate NES and NPV change due to emerging technologies, DOE would need to accurately forecast the anticipated price and performance points of each emerging technology, a difficult and highly speculative task. Because of this high degree of uncertainty, DOE considered two base-case scenarios for ballasts: existing technologies and emerging technologies. DOE believes evaluating two base-case scenarios will more completely and transparently characterize the uncertainty in estimating emerging technologies' market penetration and the consequent impact on NPV and NES. Incorporating emerging technologies in the base case does not affect the relative benefits of each TSL and prevents uncertain projections of market share, price, or performance from obscuring the benefits derived from more efficient ballast designs alone.

The assumptions and methodology that drive these scenarios and the details specific to each are described in sections 10.3.2 and 10.3.3, respectively. In general, DOE calculated the market penetration of analyzed emerging technologies annually for 2006–2043, assessing each sector separately. DOE then decreased the analyzed market size in each year in each sector by the amount that corresponded to the highest level of market penetration achieved by the technologies.

For its base-case analysis, DOE estimated the market penetration of SSL systems and dimming ballasts into the projected installed stock. In general, the existing technologies scenario considers only the market penetration of technologies that have reached maturation in terms of price and efficiency. For the final rule, DOE added penetration by dimming fluorescent lamp ballasts to it emerging technologies scenario. Although dimming ballasts are an existing technology, DOE considered them an "emerging application" for fluorescent lighting applications and included dimming ballasts with SSL products in its emerging technologies shipments scenario. Because SSL penetration has increased since the inception of this rulemaking, DOE increased its estimated penetration rate earlier in the shipments analysis period. DOE also increased the maximum penetration of 40.6 percent (for SSL in the April 2011 NOPR) to a maximum penetration of 75 percent (for SSL and dimming ballasts combined). This increased penetration resulted in decreased shipments for affected ballast types for the lower boundary, base case shipments scenario.

Consistent with the 2009 Lamps Rule and its current research, DOE assumed no SSL penetration for residential linear fluorescent applications. DOE stated in the April 2011 NOPR that residential energy codes will drive the market toward higher efficacy lighting systems, but that the related market growth will be greater for compact fluorescent lamp (CFL)-based fixtures than for 4-foot MBP fluorescent systems. As discussed in DOE's SSL Multi Year Program Plan (updated May 2011), the vast majority of residential sockets are dedicated to incandescent lamps, for which screw-base compact fluorescent and SSL lamps are direct replacements.[a] DOE's review of available residential fixture surveys confirms that linear fluorescent fixtures are typically relegated to utility room, laundry, and some kitchen applications. A comparison of recent California residential lighting data for 2005 and 2009 shows no significantly increased installation of linear fluorescent systems, and DOE believes that residential consumers will continue to opt for lower-first-cost fluorescent systems rather than installing more expensive SSL replacements for linear fluorescent lamps and fixtures. DOE received no adverse comments to the April 2011 NOPR for not including SSL penetration in its residential ballast shipments. Given the limited residential applications for linear fluorescent systems, DOE retained this approach for this final rule.

DOE generally followed a five-step process for each scenario to estimate the market penetration of the analyzed emerging technologies and account for their impact on NES and NPV. First, DOE developed price, performance, and efficiency forecasts for each of the analyzed emerging technologies. Second, using those estimates, DOE calculated the PBP of each technology in the relevant sector using the difference between its purchase price, annual electricity cost, and annual replacement cost relative to the fluorescent lamp-and-ballast system it replaces. Specifically, DOE used the following formula to calculate simple PBP:

$$\text{Simple Payback} = \frac{-\Delta\text{Purchase Price (\$/klm)}}{\Delta\text{Annual Electricity Cost (\$/klm/yr)} + \Delta\text{Annual Replacement Cost (\$/klm/yr)}}$$

Where:

Δ =the difference between the two technology options compared,
Purchase Price = includes the lamp price and fixture price,

[a] U.S. Department of Energy – Office of Energy Efficiency and Renewable Energy. Solid-State Lighting Research and Development: Multi Year Program Plan. March 2011 (Updated May 2011). Washington, D.C. Available at http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/ssl_mypp2011_web.pdf.

Annual Electricity Cost = a function of the mean annual operating hours and efficiency for each technology option, the electricity price, and the lumen demand, and
Annual Replacement Cost = a function of the mean ballast life, annual operating hours, ballast price, and labor charge.

Third, DOE used the relationship between PBP and market penetration to predict the market penetration of each technology in the relevant sector annually for 2006–2043. DOE assumed this relationship is valid for other emerging lighting technologies (*i.e.*, given a PBP duration, a technology will achieve a certain market penetration; the shorter the PBP, the greater the expected market penetration). DOE used a 5-year average of the market penetrations predicted by the relationship as its final market penetration. The 5-year average represents the time DOE assumed it takes products with lower PBPs to penetrate the market.

Fourth, when necessary, DOE applied a scaling factor to the predicted market penetration to account for observed market trends. Fifth, the projected installed stock of covered products in each year affected by emerging technologies also exhibits decline, similar to shipments. Thus, emerging technologies have the effect of lowering the energy savings of a potential new standard. For those covered ballasts remaining, the cost effectiveness of LCC savings (and thus the relative cost effectiveness of each TSL) is not impacted.

10.3.2 Historical Shipments

DOE used U.S. Census Bureau Current Industrial Reports (CIRs) for ballasts to estimate historical shipments for affected ballast designs.[2, 3] The census data contain National Electrical Manufacturers Association (NEMA) shipments for individual ballast designs (*e.g.*, two-lamp F96T8) as well as aggregated shipments for multiple designs to keep manufacturer information confidential. For some ballast designs, all shipments are withheld in the CIR to prevent disclosing data for individual companies.

DOE estimated historical ballast shipments for 1990–2005 (CIRs for ballasts were discontinued in 2006). For those reporting years for which specific shipments data were not available, DOE extrapolated historical shipments based on trends within the available data, and/or market trends identified in ballast manufacturer interviews, the 2009 Lamps Rule, and the fluorescent lamp ballasts energy conservation standards final rule published on September 19, 2000 (hereafter “the 2000 Ballast Rule”). 65 FR 56740; 10 CFR 430.23(m)(4). Where shipments data were aggregated and not available for specific ballast designs, DOE estimated historical shipments based on apportionment estimates and market trends identified in ballast manufacturer interviews, the 2009 Lamps Rule, and the 2000 Ballast Rule. To validate these estimation methods, DOE requested historical ballast and residential fixture shipments from NEMA, but was unable to obtain this data.

Recognizing that shipment estimates based on CIR data reflect only the shipments of NEMA members, DOE increased these estimates to account for the volume of ballasts that non-NEMA companies import or manufacture. Based on ballast manufacturer interviews and conservative estimates, NEMA shipments were assumed to account for 50–90 percent of total ballast shipments, depending on the ballast design. Table 10.3.1 presents estimated NEMA and non-NEMA shipment percentages for ballast designs considered in this rulemaking. Table 10.3.2 provides historical fluorescent lamp ballast shipments estimates for the entire U.S. market.

Table 10.3.1 Estimated NEMA and Non-NEMA Shipment Percentages for Fluorescent Lamp Ballasts

Year	4-Foot T8 MBP	4-Foot T12 MBP	8-Foot T8 Slimline	8-Foot T12 Slimline	8-Foot T8 RDC HO	8-Foot T12 RDC HO	4-Foot T5 MiniBP SO	4-Foot T5 MiniBP HO	4-Foot T8 & T12 MBP (residential)
NEMA	90	70	90	70	90	60	90	90	50
Non-NEMA	10	30	10	30	10	40	10	10	50
Total	100	100	100	100	100	100	100	100	100

Table 10.3.2 Total Historical Fluorescent Lamp Ballast Shipments (Millions)

Year	4-Foot T8 MBP	4-Foot T12 MBP	8-Foot T8 Slimline	8-Foot T12 Slimline	8-Foot T8 RDC HO	8-Foot T12 RDC HO	4-Foot T5 MiniBP SO	4-Foot T5 MiniBP HO	Total
1990	11.3	7.6	0.1	1.0	0.1	3.1	0.0	0.0	23.2
1991	24.6	8.7	0.2	1.0	0.1	3.1	0.0	0.0	37.8
1992	36.3	9.3	0.4	1.0	0.1	3.5	0.0	0.0	50.5
1993	58.4	9.3	0.7	0.9	0.1	3.6	0.0	0.0	73.0
1994	51.9	7.9	0.6	0.9	0.1	3.7	0.0	0.0	65.0
1995	70.5	6.7	1.0	0.9	0.1	3.8	0.0	0.0	83.1
1996	67.2	6.1	0.9	0.9	0.1	3.5	0.0	0.0	78.7
1997	79.3	6.3	1.1	0.7	0.1	3.2	0.0	0.0	90.7
1998	85.8	6.1	1.1	0.7	0.1	2.8	0.0	0.0	96.4
1999	88.6	6.1	1.1	0.6	0.1	3.7	0.0	0.0	100.2
2000	99.8	5.8	1.3	0.6	0.1	3.2	0.0	0.0	110.9
2001	116.1	5.4	1.7	0.6	0.1	3.1	0.0	0.0	127.1
2002	118.8	5.2	1.7	0.6	0.1	3.2	0.9	0.9	131.5
2003	116.4	3.9	1.4	0.5	0.1	3.2	1.9	1.9	129.3
2004	118.6	2.7	1.3	0.5	0.1	3.2	3.2	3.2	133.0
2005	114.4	1.3	1.4	0.5	0.1	3.3	3.4	3.4	127.8

10.3.3 Calculation of Installed Stock

Based on historical ballast shipments estimated from U.S. Census Bureau CIR data and assumed lifetime distributions, DOE calculated the 2006 ballast stock. For a mature market, DOE estimated the installed stock at the beginning of an analysis period by summing the historical shipments for the years that correspond to the service lifetime of each ballast type for every sector.

In the future years, installed stock was calculated by subtracting from the previous year's stock the number of ballasts that were estimated to fail and the number of ballasts that were estimated to be retrofitted, and adding current year's shipments. Current year's shipments were composed of ballasts that were purchased to replace failed ballasts and ballasts retired due to retrofitting ballasts as well as ballasts shipped to new construction. These new shipments were adjusted by substitution factors, described in Table 10.2.2 and section 10.2.1.2.

10.3.4 Base-Case Market-Share Apportionment

As discussed in the engineering analysis (final rule TSD chapter 5) and the LCC and PBP analyses (final rule TSD chapter 8), consumers have a variety of choices in replacement ballasts and lamp-and-ballast systems. When choosing lighting systems, consumers often make their choices considering attributes such as lifetime, efficiency, price, lumen output, rated wattage, and total system power. DOE captured these considerations by designing product classes that account for these consumer preferences. As discussed earlier, the shipments for ballasts depend on such input assumptions as ballast lifetime and system lumen output. In addition, other ballast or lamp-and-ballast system properties such as price and energy consumption were key inputs to the NES and NPV calculations. Therefore, within each product class, DOE believed it was necessary to directly account for the mix of technologies that consumers select in the base case and standards case. To account for the range of possible consumer choices, DOE developed technology market-share apportionments. These market-share apportionments were used to estimate historical shipments and installed stock for each ballast design in the base case.

DOE was not able to obtain detailed historical ballast shipment data from NEMA to develop percentage market shares for the analyzed ballast designs. For the preliminary TSD and April 2011 notice of proposed rulemaking (NOPR), DOE was able to develop a general assumed market-share apportionment based on manufacturer interview findings regarding shipments of 4-foot T8 MBP electronic ballasts. Interviewed manufacturers provided estimated percentages of standard-efficiency and high-efficiency T8 ballasts sold through original equipment manufacturer fixture and electrical wholesaler distribution channels, from which DOE developed weighted apportionments for the two efficiency levels. Specifically, DOE assumed that 69 percent of shipped 4-foot T8 MBP electronic ballasts are standard-efficiency designs and 31 percent are high-efficiency designs.

In response to the April 2011 NOPR, ballast manufacturers commented that at least 80 percent of NEMA manufacturers' current ballast shipments are classified as "NEMA Premium" (*i.e.*, high efficiency). DOE reviewed the occurrence of NEMA Premium products in its tested ballasts (including baseline products) and adjusted the market share apportionments of higher efficiency level ballasts in the commercial 4-foot MBP IS and RS, and PS product classes. Given the occurrence of NEMA premium products in the representative baseline ballast designs, DOE could not verify the commenters' estimated 80 percent market share for higher efficiency designs. However, based on its review, DOE assigned a 64 percent market share to the higher efficiency level designs and a 36 percent market share to baseline ballast designs in the IS and RS, and PS product classes. For each product class in the base case, DOE divided the high-efficiency apportionment among the higher efficiency level (EL) designs.

10.3.5 Base-Case Forecast Results

Figure 10.3.1 and Figure 10.3.2, respectively, present the base-case ballast shipment forecasts for the existing technologies case and emerging technologies case from 2014–2043, modeled from the 2006 installed stock (based on 1990–2005 historical shipments) and growth rates, substitution rates, and retrofit rates. For categories of ballasts that are expected to experience penetration of emerging technologies (for instance, two-lamp 4-foot MBP), base-case scenarios would differ, while for the rest the series are the same.

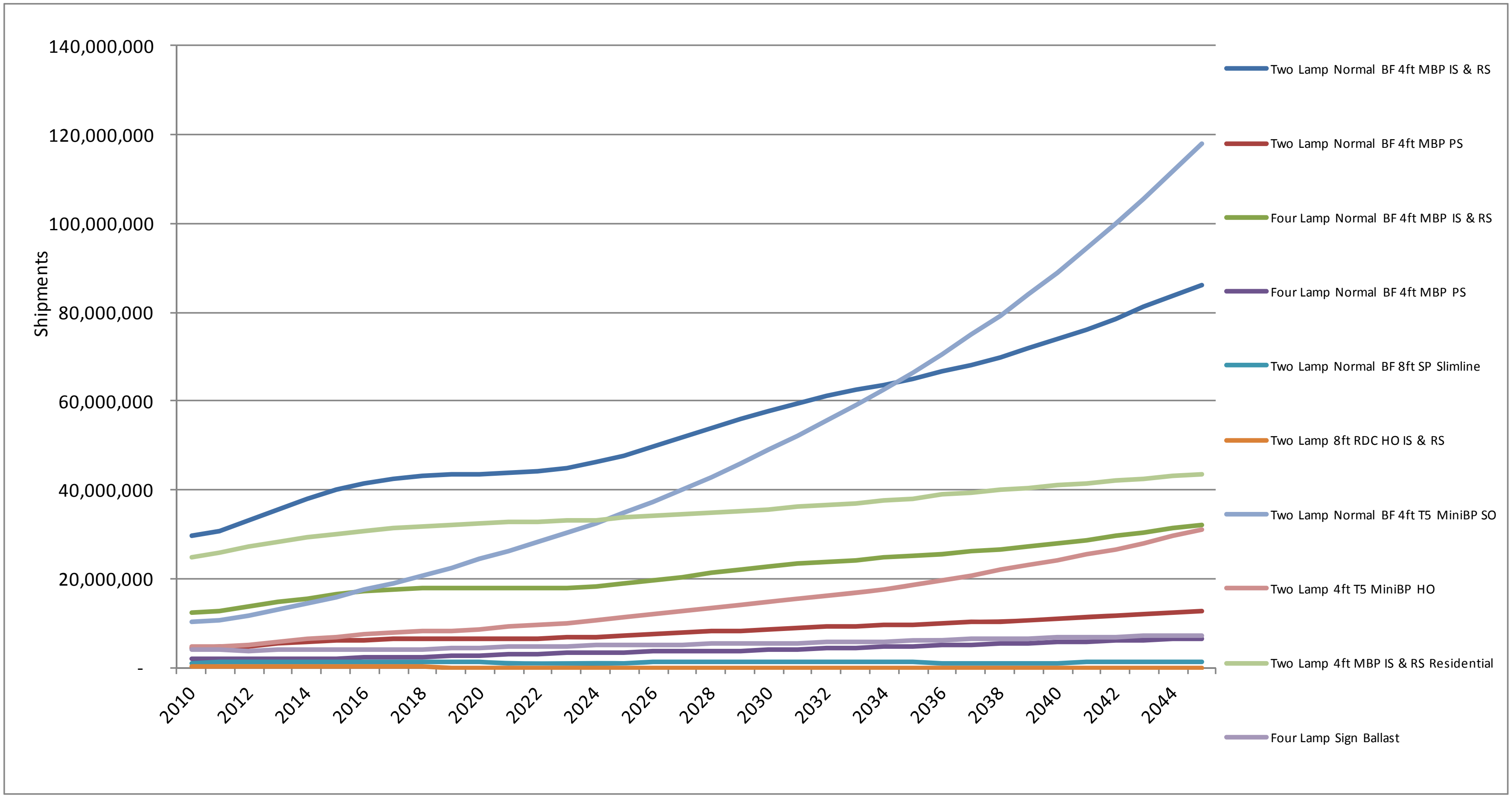

Figure 10.3.1 Base-Case Forecasted Ballast Shipments (Existing Technologies Scenarios)

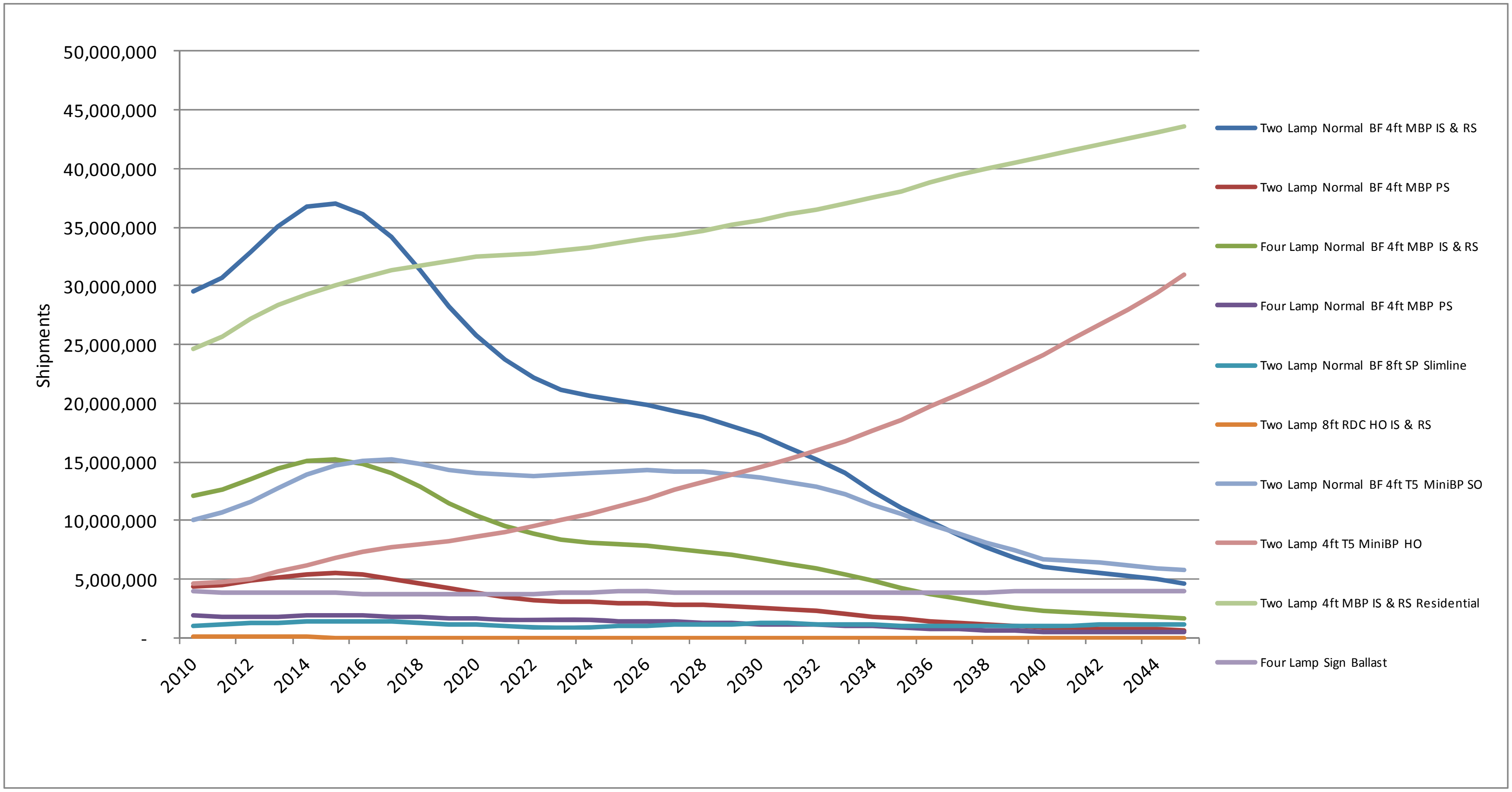

Figure 10.3.2 Base-Case Forecasted Ballast Shipments (Emerging Technologies Scenarios)

10.3.6 Base-Case Forecast by Market Segment

Figure 10.3.3 through Figure 10.3.6 present the base-case ballast shipments forecast by market segment (*i.e.*, ballast failure/replacement, or new construction/renovation) for representative product classes. For three of the product classes, shipments of replacements dominate shipments related to new construction/renovation over the analysis period. Note that 8-foot slimline ballasts are only shipped for replacement. They are substituted in the new construction by T5 ballast systems. The figures below are for the existing technologies scenario.

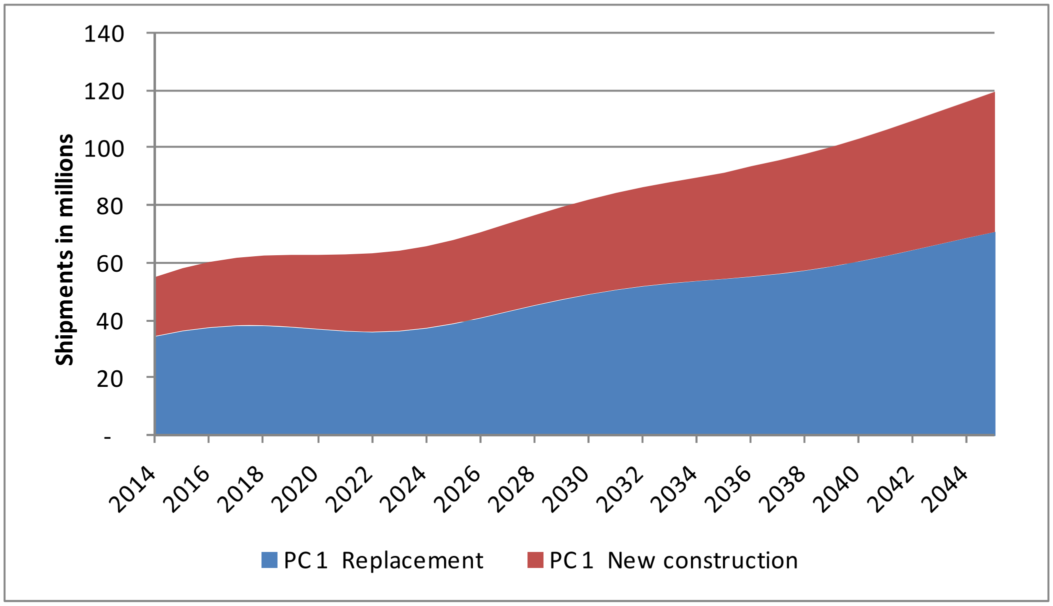

Figure 10.3.3 Product Class 1—IS and RS Ballasts That Operate Non-residential 4-Foot MBP and 8-Foot Slimline Lamps: Ballast Shipments Forecast by Market Segment (Existing Technologies Scenario)

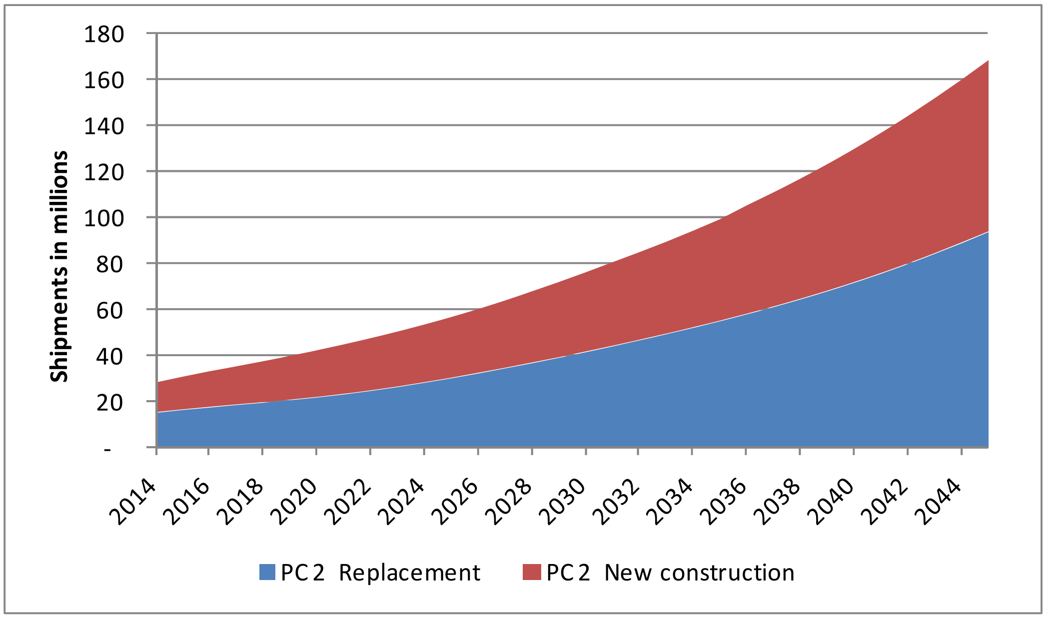

Figure 10.3.4 Product Class 2—PS Ballasts That Operate 4-Foot MBP, MiniBP SO, and MiniBP HO Lamps: Ballast Shipments Forecast by Market Segment (Existing Technologies Scenario)

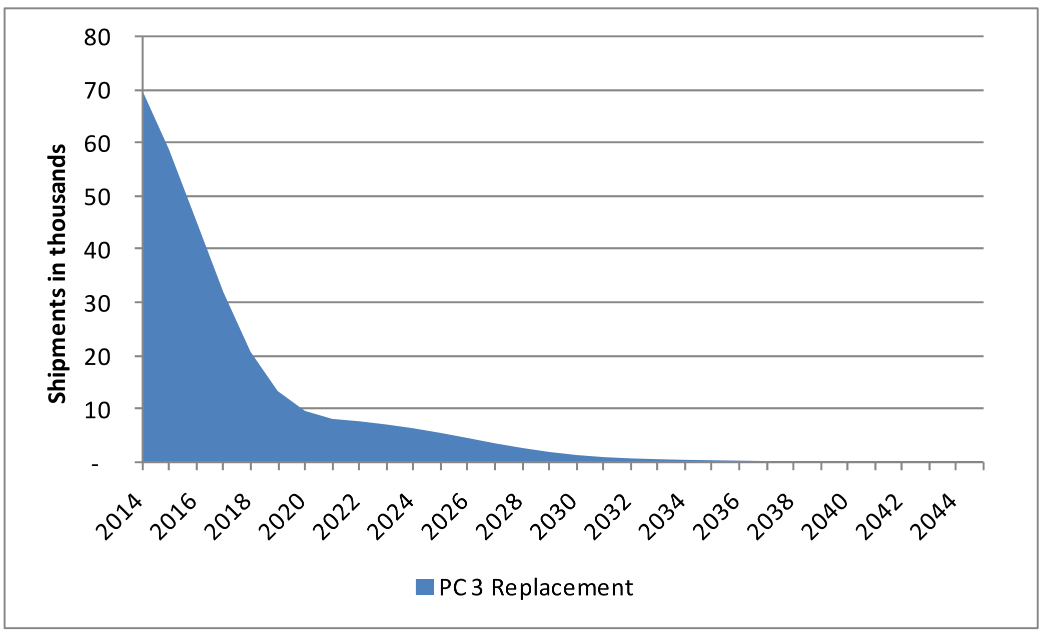

Figure 10.3.5 Product Class 3—Ballasts That Operate 8-Foot RDC HO Lamps: Ballast Shipments Forecast by Market Segment (Existing Technologies Scenario)

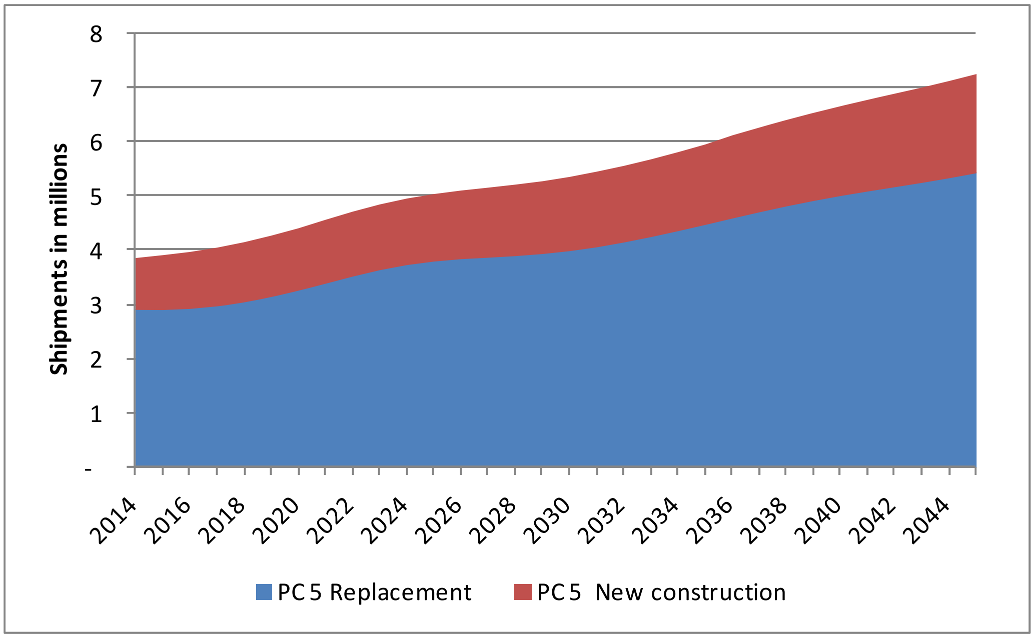

Figure 10.3.6 Product Class 5—Sign Ballasts That Operate 8-Foot RDC HO Lamps: Ballast Shipments Forecast by Market Segment (Existing Technologies Scenario)

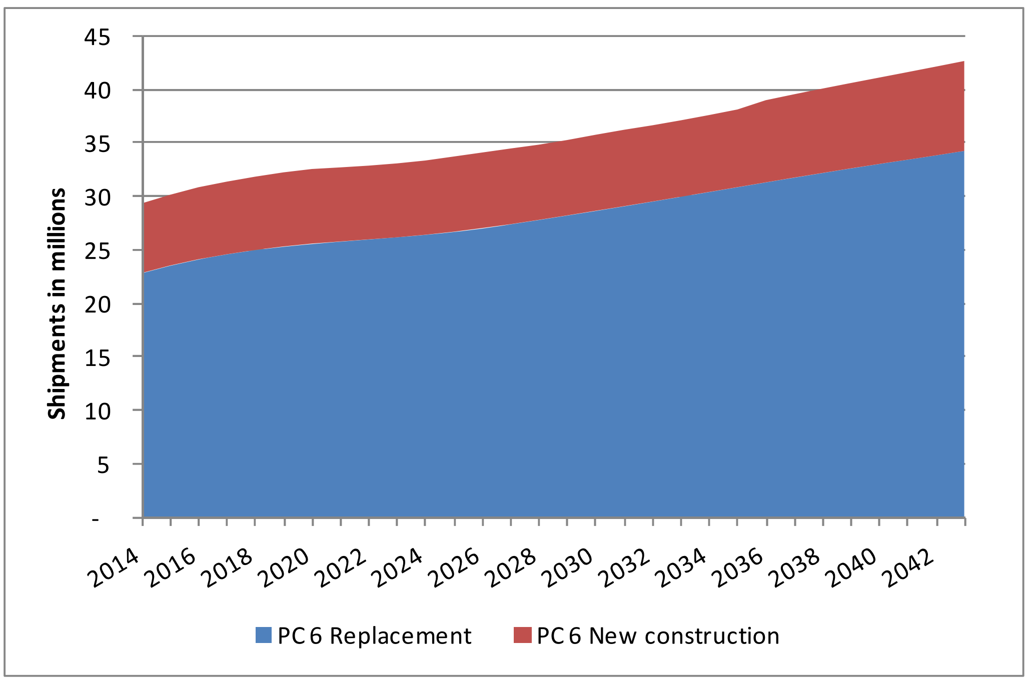

Figure 10.3.7 Product Class 6—IS and RS Residential Ballasts That Operate 4-Foot MBP Lamps: Ballast Shipments Forecast by Market Segment (Existing Technologies Scenario)

10.4 STANDARDS-CASE INPUTS

To characterize consumer behavior in the standards case, DOE considered many characteristics that consumers take into account when purchasing their lamp-and-ballast systems.

Specifically, DOE regarded system price, system energy consumption, and system lumen output as three key drivers of consumer purchases.

DOE developed two sets of two shipments scenarios to characterize consumers that may weigh these factors differently. To evaluate a standards case, DOE modeled a standards-case scenario and compared it to the base case.

The first set of standards-case scenarios for ballasts included the roll-up and shift scenarios. The ***roll-up*** scenario represented a standards case in which all product efficiencies in the base case that do not meet the standard would roll up to meet the new standard level. Consumers who purchase ballasts above the standard level in the base case are not affected as they were assumed to continue to purchase the same base-case ballast or lamp-and-ballast system in the roll-up scenario. The roll-up scenario characterizes consumers primarily driven by the first cost of the analyzed equipment. In a roll-up scenario, DOE assumed consumers will buy the first standard-compliant lamp-and-ballast system available. In contrast, in a ***shift*** scenario, DOE assumed consumers seek to shift to an efficiency level that keeps their purchase the same number of efficiency levels above the baseline as in the base case. The shift scenario modeled a standards case in which all base-case consumer purchases are affected by the standard. In this scenario, any consumer may purchase a more efficient ballast. As the standard level increases, market share incrementally accumulates at the highest EL because it represents "max tech" (*i.e.*, moving beyond it is impossible given available technology options). The shift scenario characterizes consumers primarily concerned with system energy consumption, and reflects an upper bound scenario.

In this rulemaking, DOE modeled shift scenario with a modification. It assumed that all the ballasts that are below the EL established by the standard would roll up to the level required by the standard, and only the consumers of the ELs above the established standard would shift to a higher efficiency level than required. This adjustment would allow ballast shipments to be divided more realistically among ELs, when more than one EL is available on the market. Energy savings will be lower compared to "pure" shift scenario, but they represent a re-attainable boundary.

In either the roll-up or shift scenario, consumers will attempt to buy a ballast from the same product class as their previously demanded system, except where additional replacement trends are modeled (as given in Table 10.2.2). The structure of these product classes is such that at each EL level lumen output is within 10 percent of the baseline system's lumen output.

Each of these pairs of scenarios (roll-up and shift) occurs in combination with the existing and emerging technologies scenarios from the base case, for a total of four standards-case scenarios.

Many tables for the shipments analysis, NIA (final rule TSD chapter 11), and some other downstream analyses present only two of the four possible shipments scenarios: existing technology, shift and emerging technology, roll-up. These scenarios are presented because they produce the upper and lower bound scenarios for the energy impacts of this rulemaking, respectively.

10.5 RESULTS

The following sections show the shipments forecasts for the various efficiency levels over time and by shipments scenario. DOE's forecasts of the resultant stock forecasts for the various efficiency levels over time and by scenario are presented in final rule TSD chapter 11.

Figure 10.5.1 through Figure 10.5.10 present the shipments forecasts for the base case and standards cases for ballasts in the existing technologies, shift scenario. As noted, this reflects the upper-bound scenario for energy use. For the standards case, shipments are shown at what they are modeled as in the TSL 3A scenario.

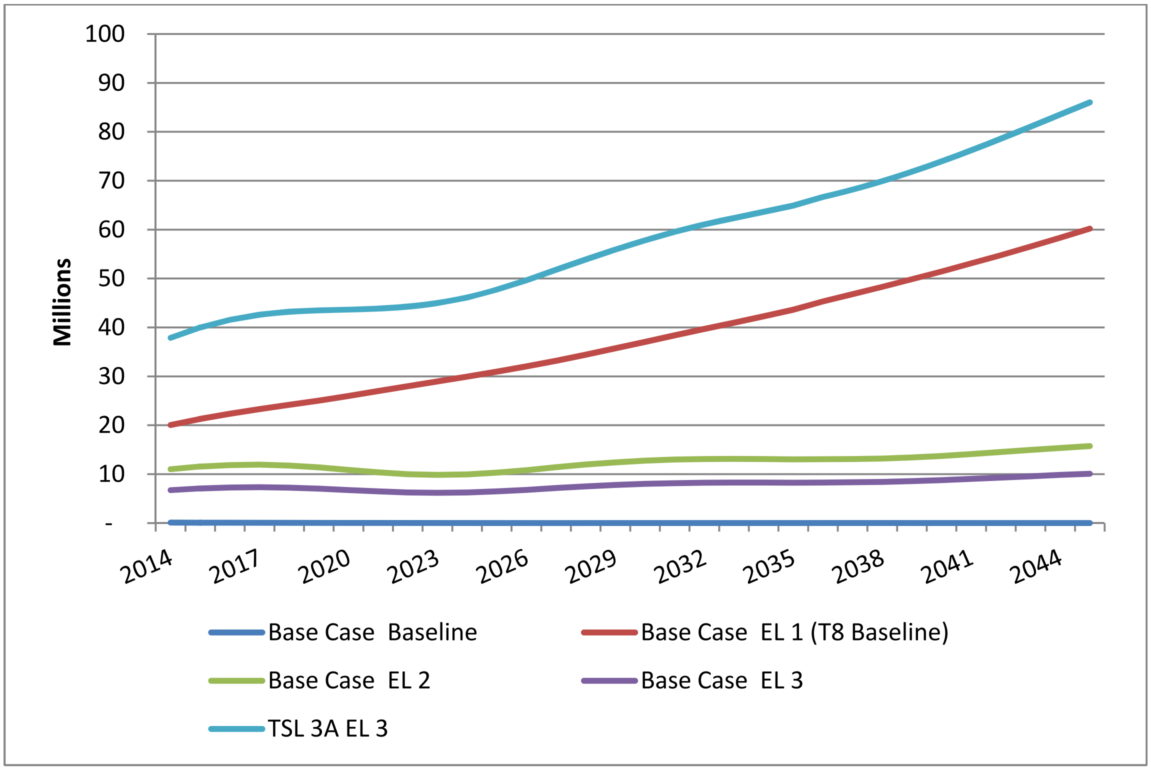

Figure 10.5.1 Product Class 1—IS and RS Ballasts That Operate Two Non-residential 4-Foot MBP Lamps: Base-Case and Standards-Case Ballast Shipments Forecasts (Existing Technologies, Shift Scenario)

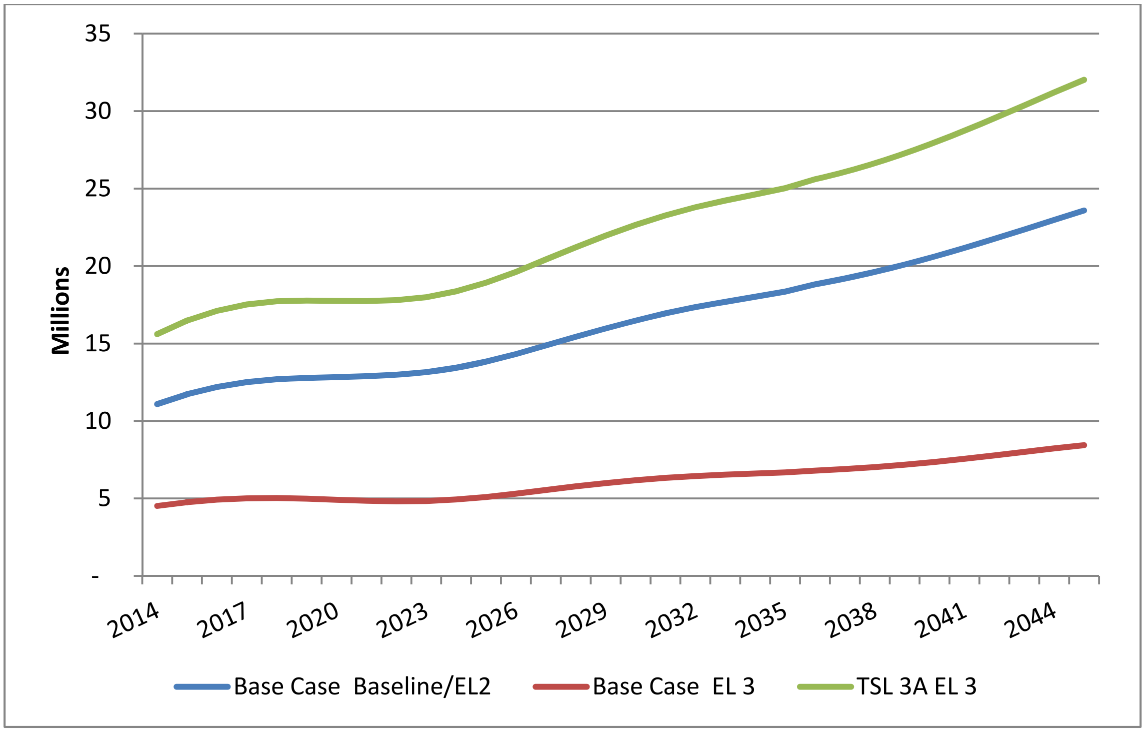

Figure 10.5.2 Product Class 1—IS and RS Ballasts That Operate Four Non-residential 4-Foot MBP Lamps: Base-Case and Standards-Case Ballast Shipments Forecasts (Existing Technologies, Shift Scenario)

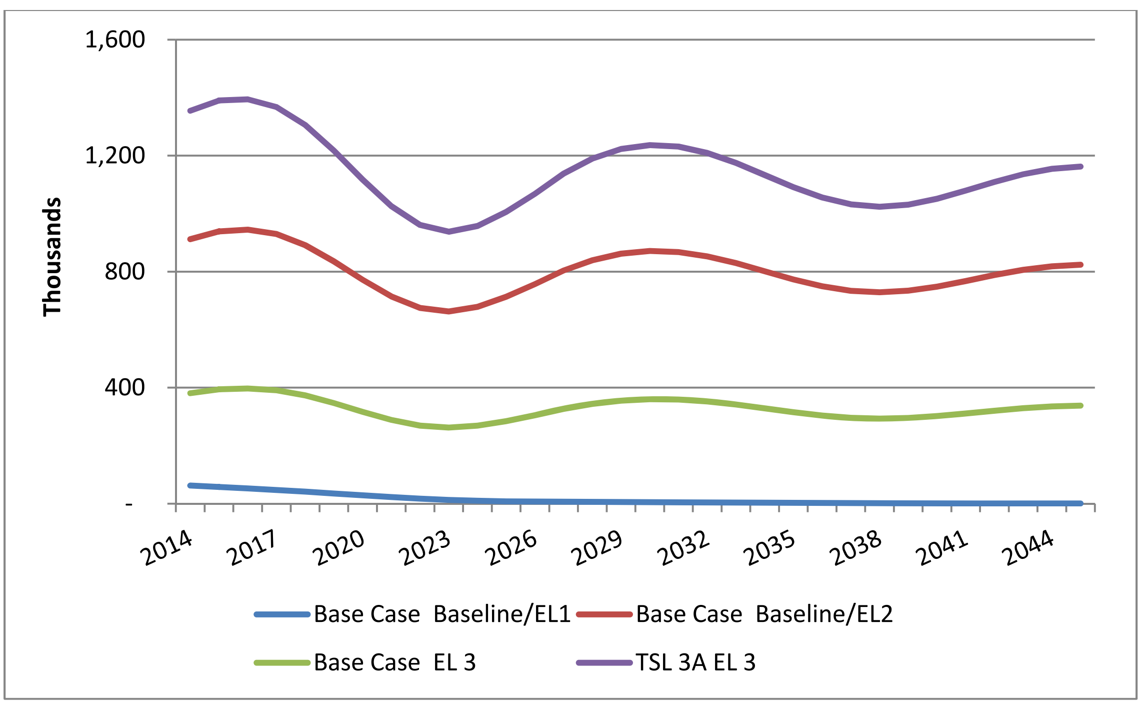

Figure 10.5.3 Product Class 1—IS and RS Ballasts That Operate Two 8-Foot Slimline Lamps: Base-Case and Standards-Case Ballast Shipments Forecasts (Existing Technologies, Shift Scenario)

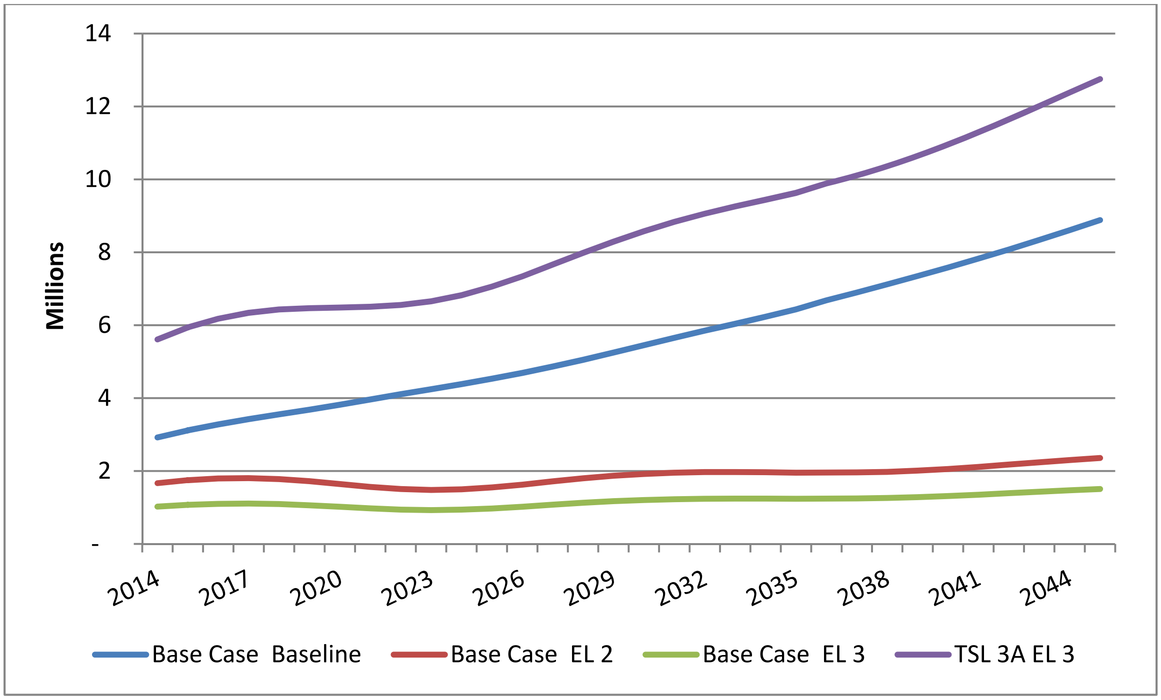

Figure 10.5.4 Product Class 2—PS Ballasts That Operate Two 4-Foot MBP Lamps: Base-Case and Standards-Case Ballast Shipments Forecasts (Existing Technologies, Shift Scenario)

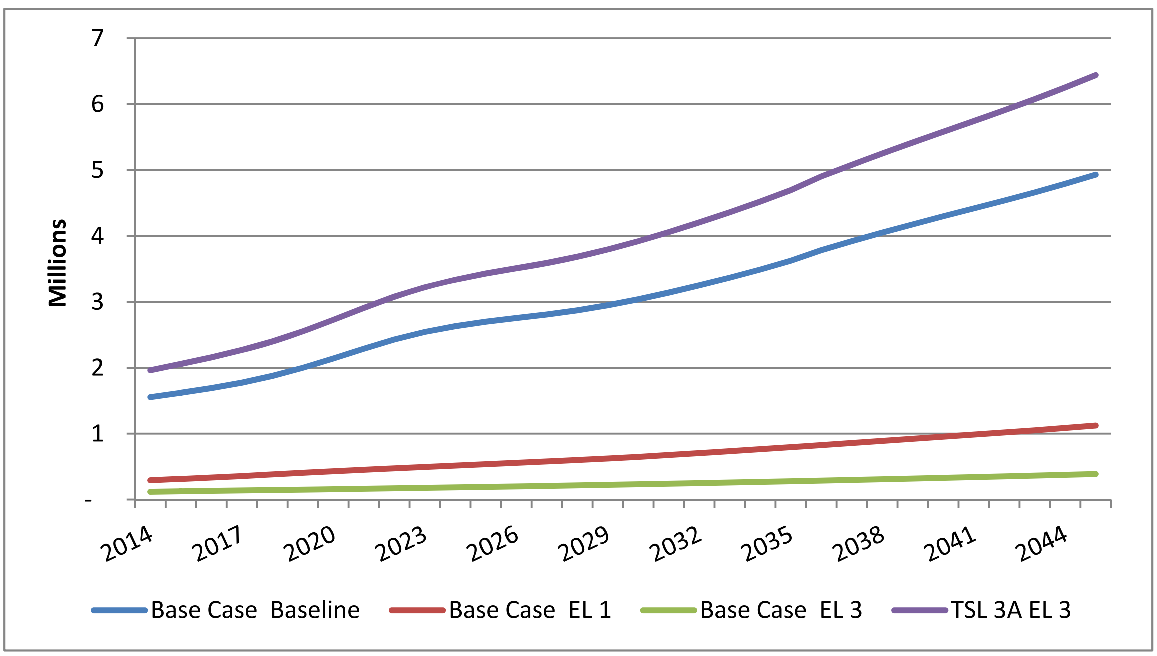

Figure 10.5.5 Product Class 2—PS Ballasts That Operate Four 4-Foot MBP Lamps: Base-Case and Standards-Case Ballast Shipments Forecasts (Existing Technologies, Shift Scenario)

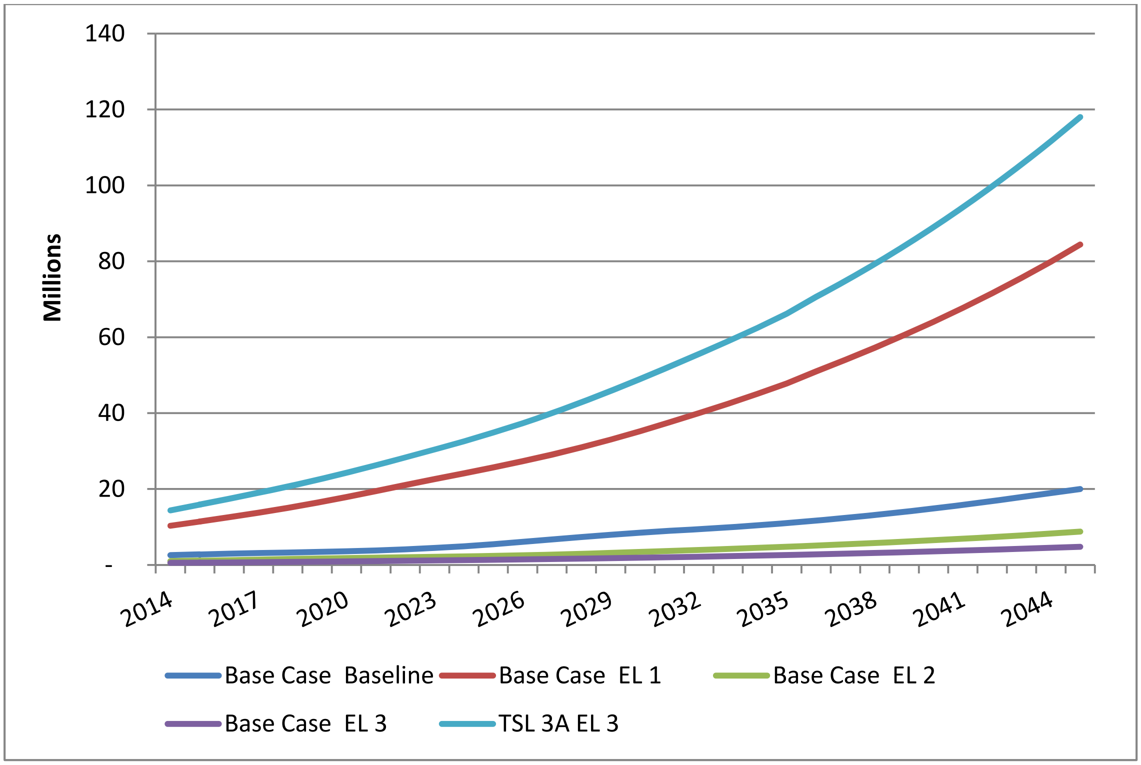

Figure 10.5.6 Product Class 2—PS Ballasts That Operate Two 4-Foot MiniBP SO Lamps: Base-Case and Standards-Case Ballast Shipments Forecasts (Existing Technologies, Shift Scenario)

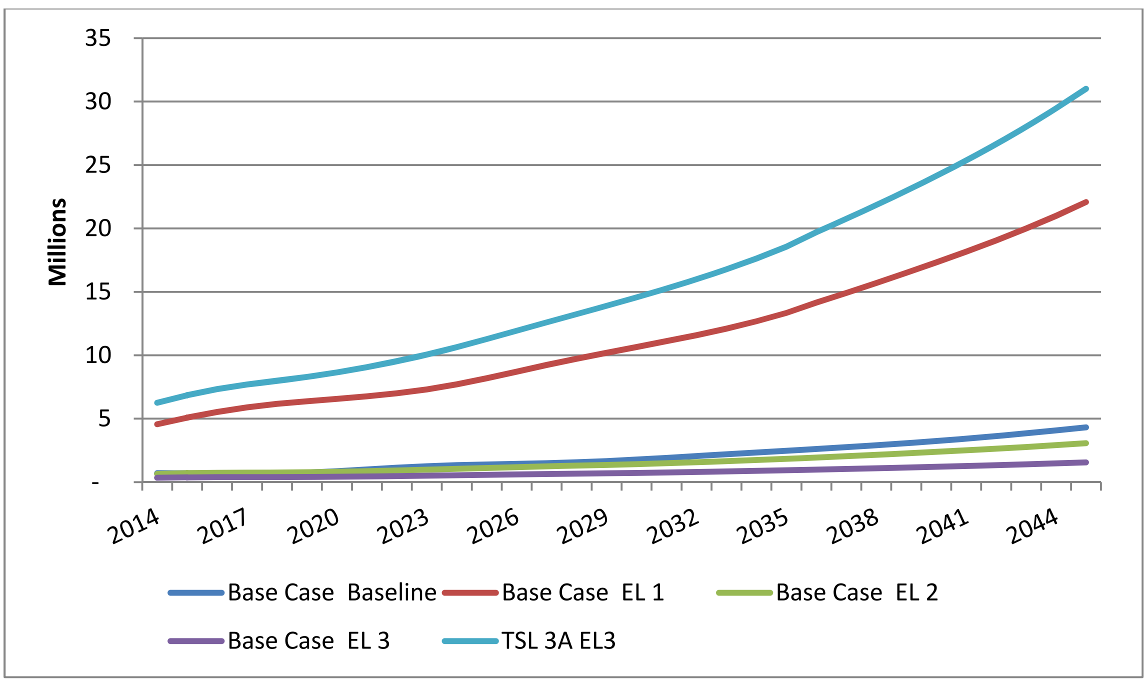

Figure 10.5.7 Product Class 2—PS Ballasts That Operate Two 4-Foot MiniBP HO Lamps: Base-Case and Standards-Case Ballast Shipments Forecasts (Existing Technologies, Shift Scenario)

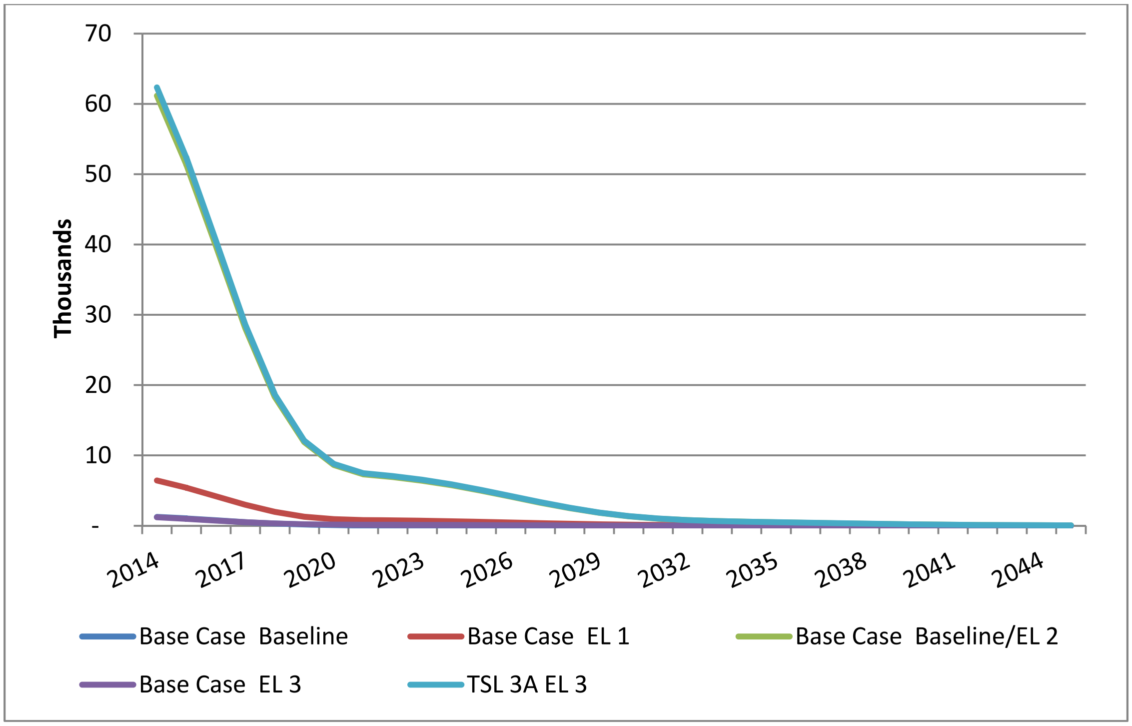

Figure 10.5.8 Product Class 3—Ballasts That Operate Two 8-Foot RDC HO Lamps: Base-Case and Standards-Case Ballast Shipments Forecasts (Existing Technologies, Shift Scenario)

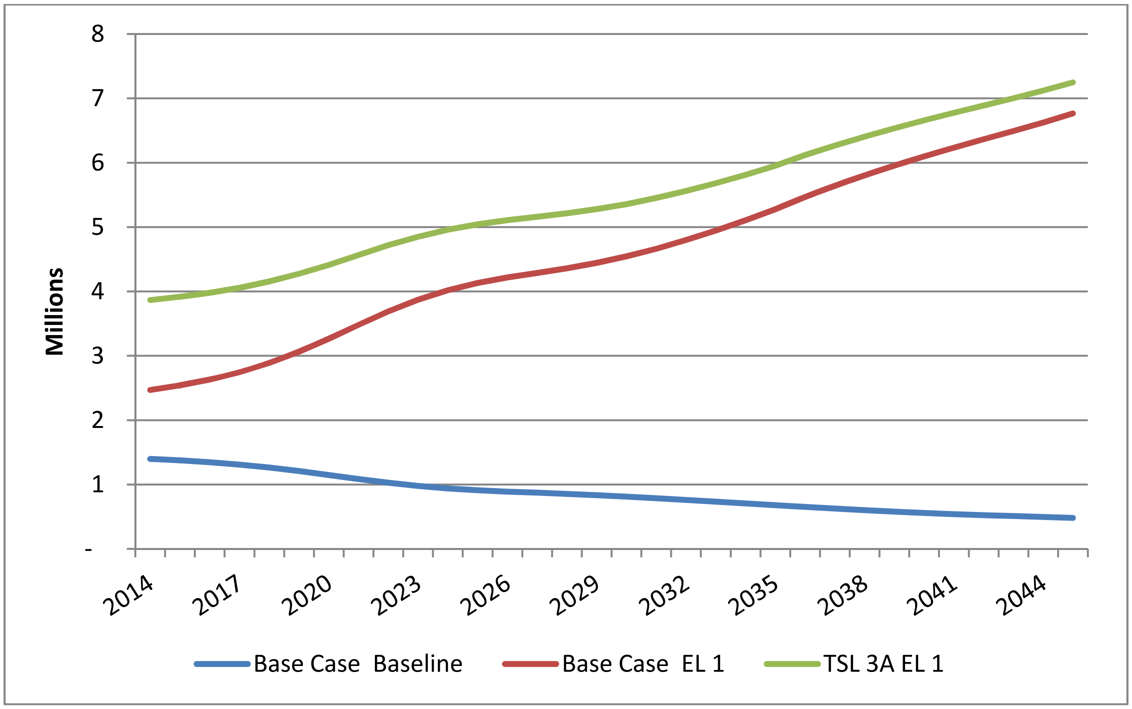

Figure 10.5.9 Product Class 5—Sign Ballasts That Operate Four 8-Foot RDC HO Lamps in Outdoor Signs: Base-Case and Standards-Case Ballast Shipments Forecasts (Existing Technologies, Shift Scenario)

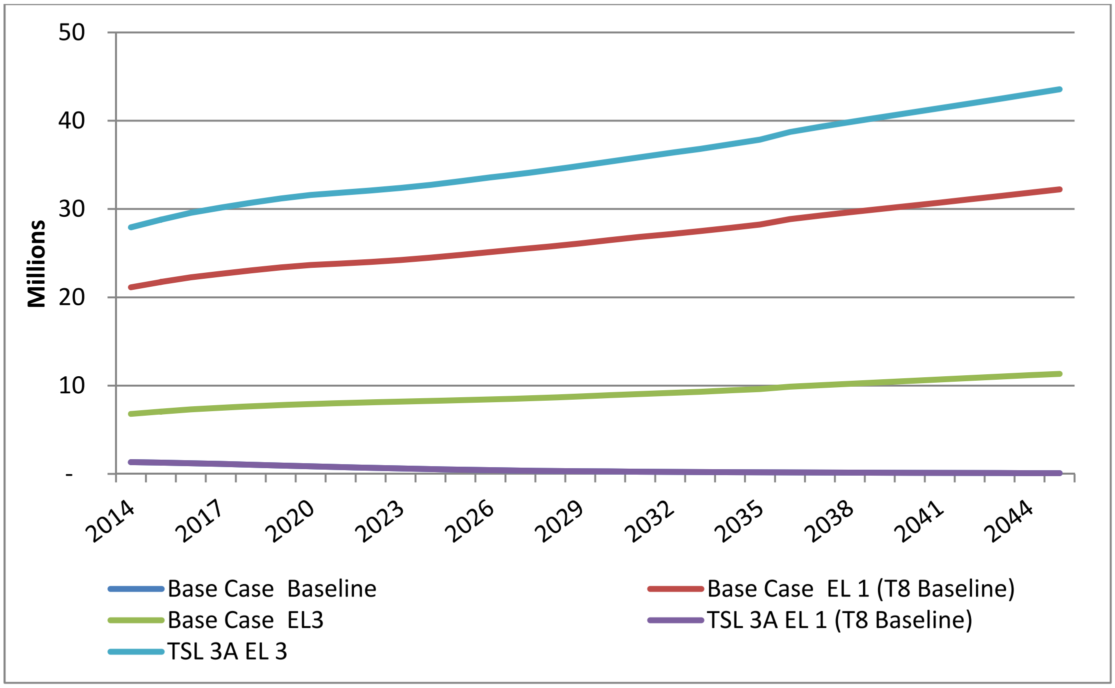

Figure 10.5.10 Product Class 6—IS and RS Residential Ballasts That Operate Two 4-Foot MBP Lamps: Base-Case and Standards-Case Ballast Shipments Forecasts (Existing Technologies, Shift Scenario)

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2. U.S. Census Bureau. *Current Industrial Reports, Fluorescent Lamp Ballasts: 2005*. July 2006. Washington, D.C. <http://www.census.gov/industry/1/mq335c055.pdf>.

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CHAPTER 11. NATIONAL IMPACTS ANALYSIS

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CHAPTER 11. NATIONAL IMPACTS ANALYSIS

11.1 INTRODUCTION

This chapter of the final rule technical support document (TSD) describes the method for estimating the national impacts of trial standard levels (TSLs) for analyzed fluorescent lamp ballasts (hereafter "ballasts"). Because ballasts are designed to operate fluorescent lamps, the U.S. Department of Energy (DOE) chose the most common fluorescent lamp used with each ballast to develop representative lamp-and-ballast systems. Fluorescent lamps will not be regulated under the new and amended energy conservation standards for ballasts; however, the characteristics of complete lamp-and-ballast systems (*e.g.*, energy consumption, installed cost) must be considered for estimating the national impacts of ballast TSLs.

In the national impact analysis (NIA), DOE assessed the cumulative national energy savings (NES) and the cumulative national economic impacts of TSLs. DOE measured energy savings as the cumulative quadrillion British thermal units (quads) of energy a TSL is expected to save the nation. DOE measured economic impacts as the net present value (NPV) in dollars of total customer costs and savings expected to result from a TSL. The analysis period over which DOE calculated the NPV and NES is from 2014 to 2043.

DOE determined both the NPV and NES for each TSL and each representative product class it selected in the engineering analysis (final rule TSD chapter 5). In this rulemaking, DOE considered up to four TSLs for each of the representative ballast product classes.

DOE performed all NIA calculations using a Microsoft Excel spreadsheet, available at www.eere.energy.gov/buildings/appliance_standards/residential/fluorescent_lamp_ballasts.html. Appendix 11A provides instructions for using the spreadsheet.

The following sections describe in detail the methodology and inputs for the NIA. Several NIA inputs, including per-unit costs, per-unit energy consumption, and national shipments, are discussed in other analyses. In describing the inputs to the NIA, this chapter references those analyses and presents new information on installed stock. Section 11.2 discusses DOE's ballast shipment forecasts by TSL, the installed stock of ballasts, and the mix of efficiencies of that stock. Section 11.3 discusses DOE's calculation of national energy consumption in the base and standards cases, and the resulting difference in NES between these cases. Section 11.4 discusses the NPV calculation. Section 11.5 presents the NES and NPV results by representative product class.

11.2 BASE-CASE AND STANDARDS-CASE FORECASTED EFFICIENCY DISTRIBUTIONS, BALLAST STOCKS, AND AVERAGE EFFICIENCY

The characteristics of DOE's shipment forecasts (such as equipment costs and operating costs) and projected ballast stocks (such as average efficiency and energy consumption) are key aspects of DOE's NES and NPV estimates. This section describes these key characteristics of stock and shipments as they relate to the NES and NPV.

The projected distribution of ballast efficiencies shipped and ballast efficiencies in stock are key factors in determining the NPV. Two inputs to the NPV are the per-unit total installed cost and per-unit annual operating cost. The per-unit total installed cost often varies with the efficiency of ballasts shipped. Therefore, when higher efficiency ballasts are shipped, higher installed costs are often incurred. The final rule TSD chapter 8 describes how per-unit total installed costs vary as a function of efficiency for each lamp ballast.

Per-unit annual energy consumption (AEC) is a key input to the NPV (as an input to the per-unit operating cost) and NES. The per-unit AEC is a function of lamp-and-ballast system characteristics in the installed stock. The total installed stock of lamp-and-ballast systems is used to determine total AEC, a key input into the NES and NPV calculations.

Also important to determining NES and NPV is the average efficiency of the lamp ballast stock. The engineering analysis (final rule TSD chapter 5) discusses the relationship between lamp-and-ballast system design, system input power, and ballast efficiency. The energy use characterization (final rule TSD chapter 6) describes how the per-unit energy consumption varies as a function of system input power and market sector application for each lamp-and-ballast system design.

Sections 11.3.3 and 11.4.2 discuss inputs to calculation of the NES and NPV in further detail.

11.2.1 Installed Ballast Stock

The installed ballast stock in a given year is the total number of ballasts shipped that year and in prior years that are still operating. The NES model tracks the ballasts shipped each year, and ballasts are retired when they reach the end of their lifetime. From this information and the shipments forecasts presented in chapter 10, DOE established the installed ballast stock profile for all analyzed ballast product classes. Figure 11.2.1 through Figure 11.2.10 show these ballast stocks in the base case for the existing technologies, shift scenario. At TSL 3B, the roll-up and shift scenarios are the same: both scenarios assume that the entire market moves to TSL 3B, or the highest efficiency level available for product classes that do not have an available TSL 3B efficiency level option.

For most types of ballasts, installed stock increases over time, particularly in the existing technologies scenario. However, some ballast types experience a decline in stocks over the analysis period due to growing substitution for other ballast types, as shown in chapter 10.

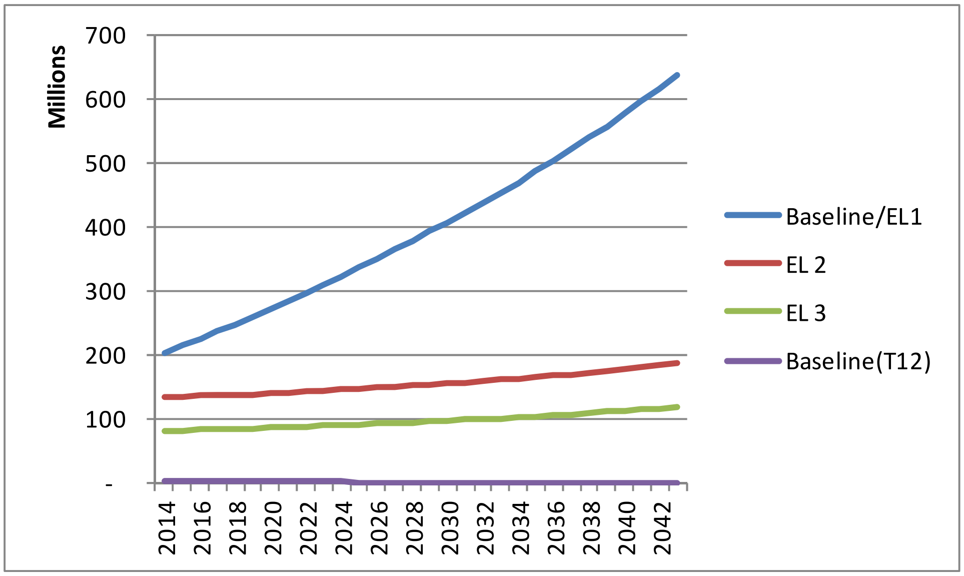

Figure 11.2.1 Product Class 1 – Instant-Start (IS) and Rapid-Start (RS) Ballasts That Operate Two Non-residential 4-Foot Medium Bipin (MBP) Lamps: Installed Ballast Stock (Base Case Existing Technologies)

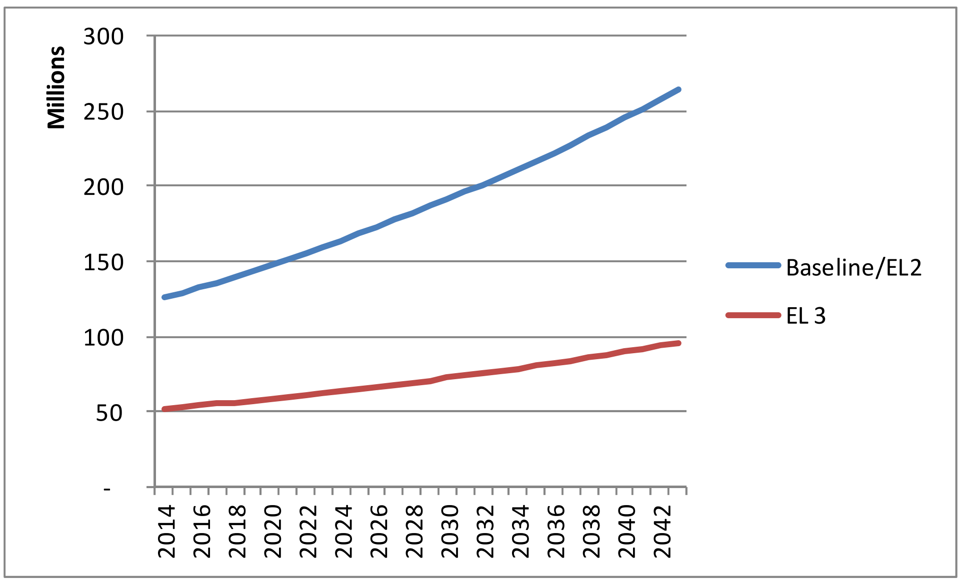

Figure 11.2.2 Product Class 1 – IS and RS Ballasts That Operate Four Non-residential 4-Foot MBP Lamps: Installed Ballast Stock (Base Case Existing Technologies)

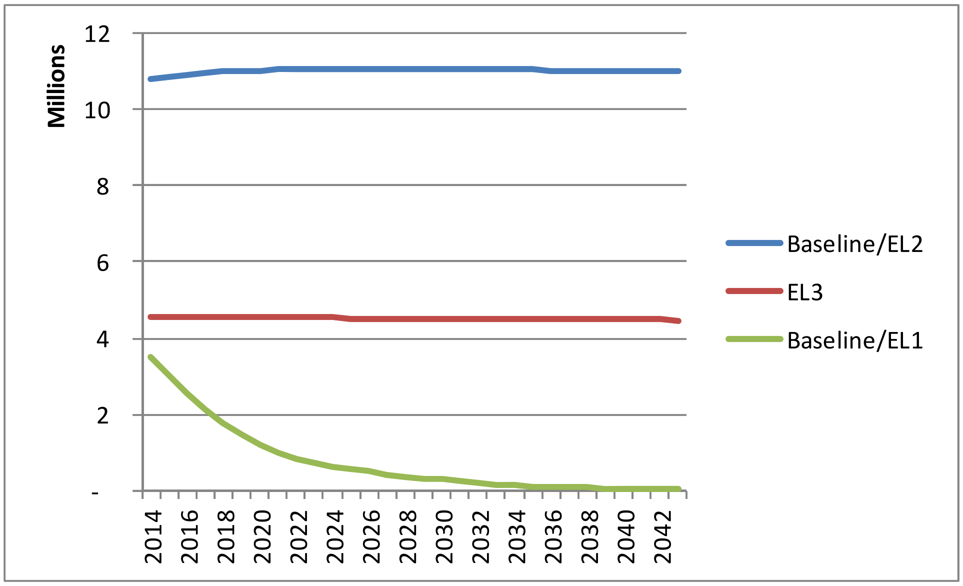

Figure 11.2.3 Product Class 1 – IS and RS Ballasts That Operate Two 8-Foot Slimline Lamps: Installed Ballast Stock (Base Case Existing Technologies)

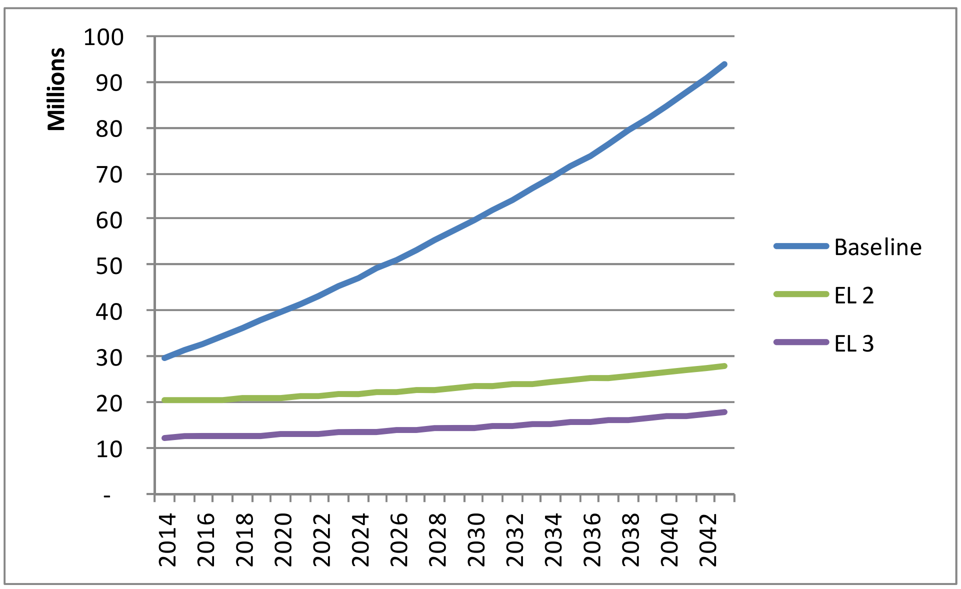

Figure 11.2.4 Product Class 2 – Programmed-Start (PS) Ballasts That Operate Two 4-Foot MBP Lamps: Installed Ballast Stock (Base Case Existing Technologies)

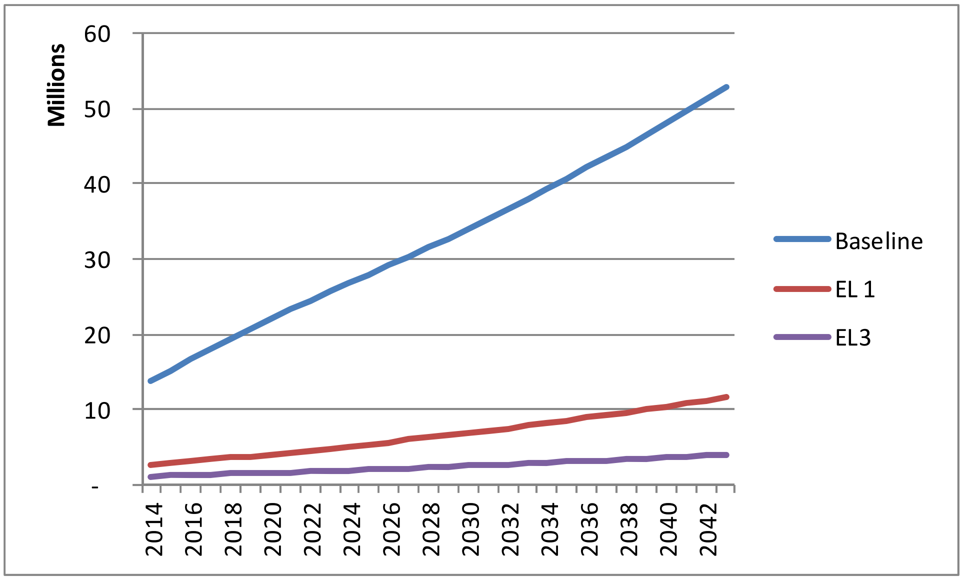

Figure 11.2.5 Product Class 2 – PS Ballasts That Operate Four 4-Foot MBP Lamps: Installed Ballast Stock (Base Case Existing Technologies)

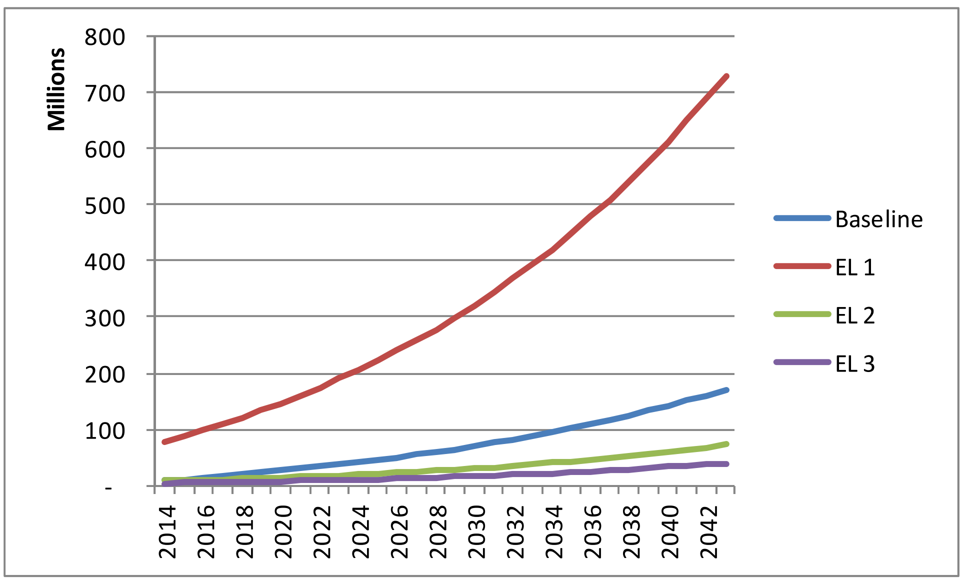

Figure 11.2.6 Product Class 2 – PS Ballasts That Operate Two 4-Foot Miniature Bipin (MiniBP) Standard Output (SO) Lamps: Installed Ballast Stock (Base Case Existing Technologies)

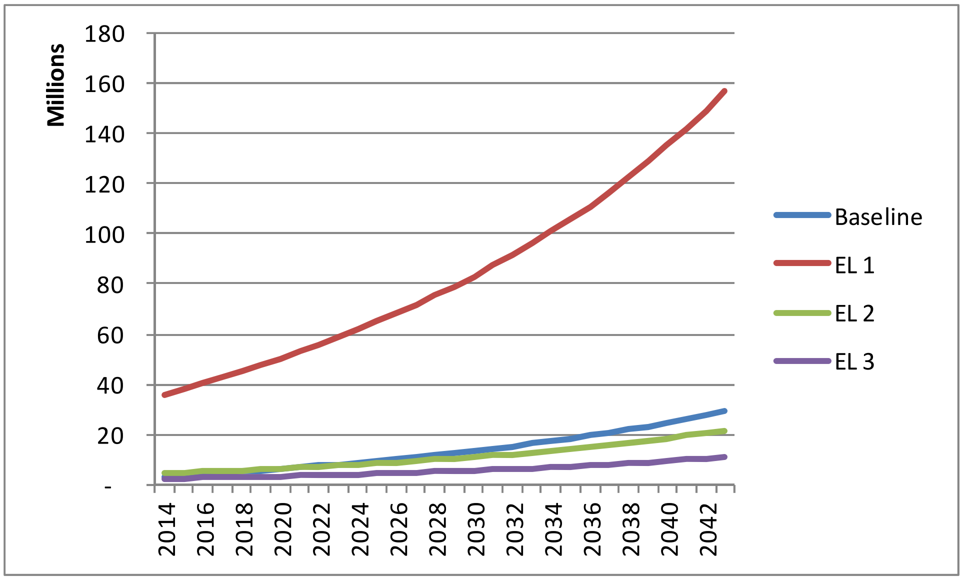

Figure 11.2.7 Product Class 2 – PS Ballasts That Operate Two 4-Foot MiniBP High Output (HO) Lamps: Installed Ballast Stock (Base Case Existing Technologies)

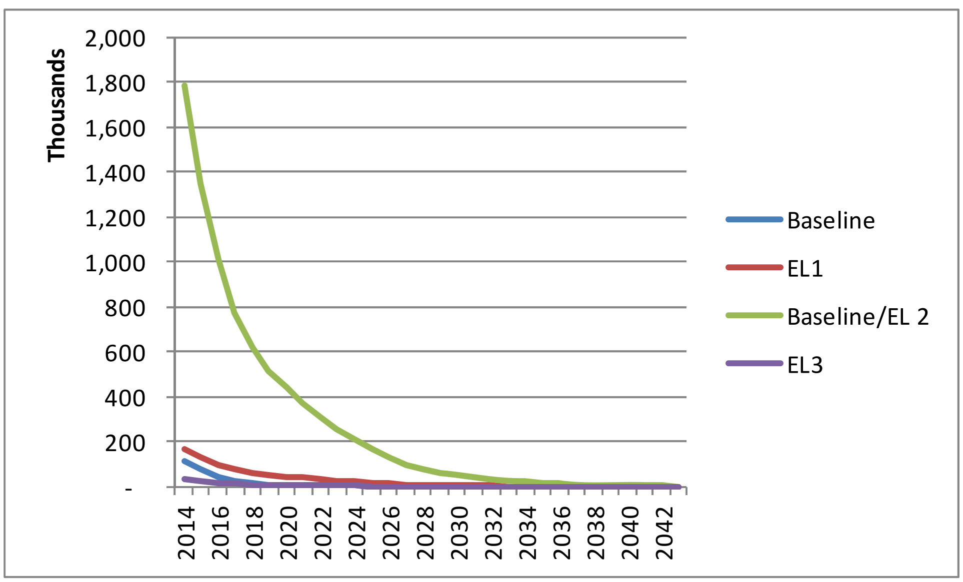

Figure 11.2.8 Product Class 3 – IS and RS Ballasts That Operate Two 8-Foot HO Lamps: Installed Ballast Stock (Base Case Existing Technologies)

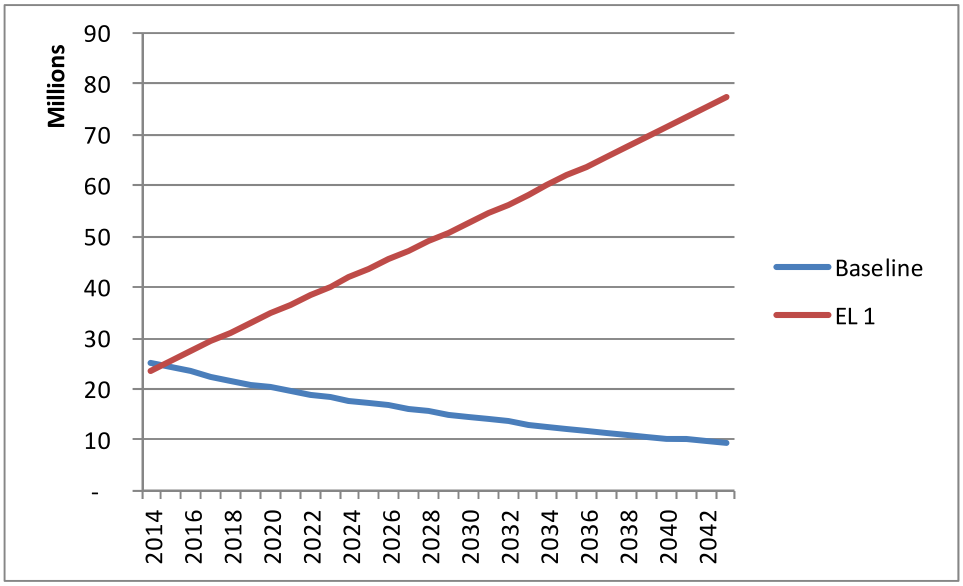

Figure 11.2.9 Product Class 5 – Sign Ballasts That Operate Four 8-Foot HO Lamps: Installed Ballast Stock (Base Case Existing Technologies)

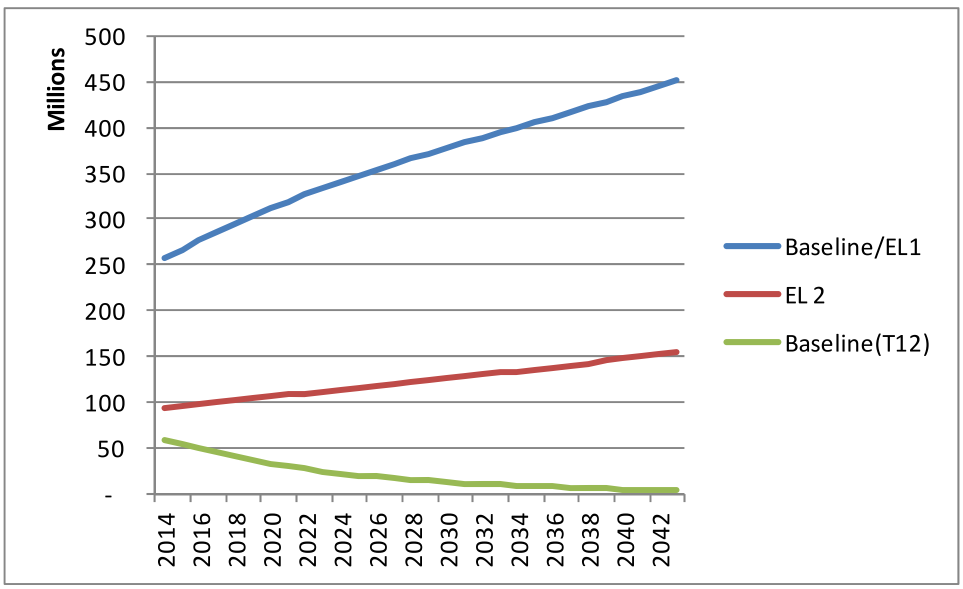

Figure 11.2.10 Product Class 6 – IS and RS Residential Ballasts That Operate Two 4-Foot MBP Lamps: Installed Ballast Stock (Base Case Existing Technologies)

11.2.2 Average Ballast Efficiency in the Stock

As discussed earlier, the average efficiency of ballast stocks can be an indication of the energy consumption, and is an important input to both the NPV and NES calculations. Figure 11.2.11 and Figure 11.2.12 present the average efficiency forecasts of ballast stocks (as represented by ballast efficiency) in the base case and standards case for both the existing technologies, shift and the emerging technologies, roll-up scenarios. Each figure presents the efficiencies at multiple TSLs.

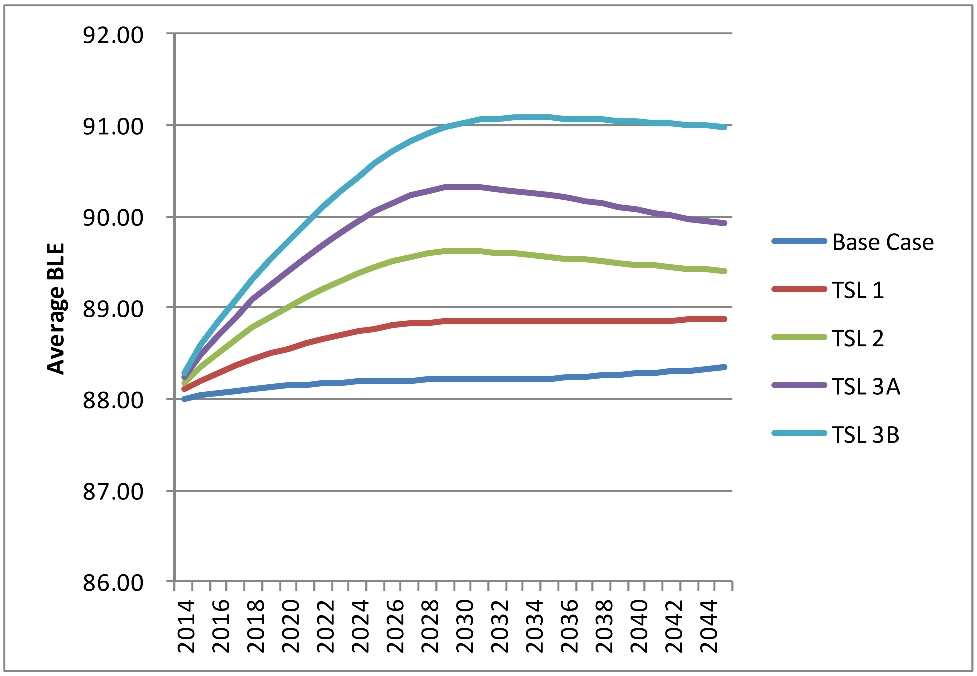

Figure 11.2.11 Average Ballast Efficiency in the Ballast Stock, Emerging Technologies, Roll-Up Scenario, 2014–2043

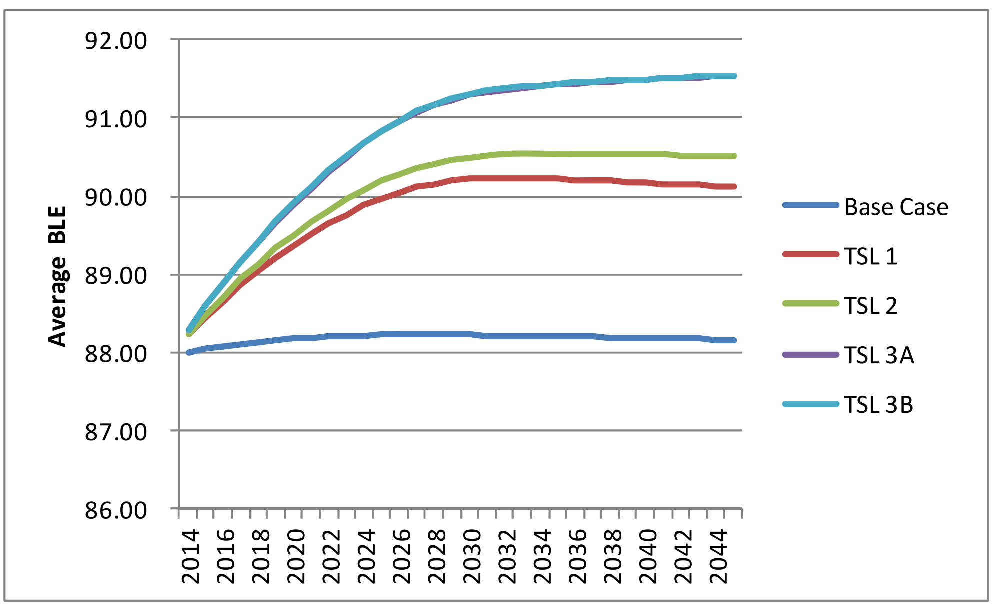

Figure 11.2.12 Average Ballast Efficiency in the Ballast Stock, Existing Technologies, Shift Scenario, 2014–2043

11.3 NATIONAL ENERGY SAVINGS

11.3.2 National Energy Savings Definition

DOE calculated annual national energy savings as the difference in energy consumption by lamp-and-ballast systems between the base case (without new standards) and the standards case (with new standards). Positive values of NES correspond to net energy savings following standards implementation; *i.e.*, national AEC with standards is less than AEC in the base case.

$$NES_t = (AEC_{t,base} - AEC_{t,std}) \times HVAC \times RR$$

Eq. 11.1

Where:

NES_t = national energy savings in year t,
AEC = annual national energy consumption each year (at the source) in quads,
$HVAC$= heating, ventilation, air conditioning (HVAC) factor,
RR = rebound factor, equal to one minus the rebound rate,
t = year in the forecast (*e.g.*, 2014 to 2043),
$base$ = base case, and
std = standards case.

Cumulative energy savings are the sum over a defined time period from the implementation of a standard forward (from 2014 to 2043) of the annual national energy savings multiplied by the HVAC interaction factor and rebound rate.

$$NES_{cum} = \sum_t NES_t$$

Eq. 11.2

Where:

NES_{cum} = cumulative national energy savings.

DOE calculated the AEC (in any year) by multiplying the number or stock of ballasts by the product of the annual unit energy consumption and the site-to-source conversion factor, shown by the following equation:

$$AEC_t = \sum_{bd} STOCK_{bdt} \times UEC_{bd} \times src\_conv_t$$

Eq. 11.3

Where:

bd = ballast ID number,
$STOCK_{bdt}$ = stock of ballasts for a given design surviving in the year for which DOE calculated AEC,

UEC_{bd} = unit energy consumption (kilowatt-hours (kWh) per year), and
src_conv_t = time-dependent conversion factor to convert from site energy (kWh) to source energy (quads, Btu/kWh).

11.3.3 National Energy Savings Inputs

Table 11.3.1 lists the inputs for the determination of NES.

Table 11.3.1 National Energy Saving Inputs

Input
Unit Energy Consumption (*UEC*)
Ballast Stock by Design (*STOCK*)
Site-to-Source Conversion Factor (*src_conv*)
Heating, Ventilation, Air Conditioning Factor (*HVAC*)
Rebound Rate (*RR*)

11.3.3.1 Unit Energy Consumption

DOE presented the per-unit UEC for each lamp-and-ballast system design in the energy use characterization (final rule TSD chapter 6). For the NES and NPV calculations, DOE used an average number of annual operating hours for each sector and ballast type in calculating the UEC of each lamp-and-ballast system design.

In response to the March 2010 preliminary TSD, California Utilities and the Northwest Energy Efficiency Alliance (NEEA) and Northeast Power Coordinating Council (NPCC) suggested that both individual ballast failure replacements and system installations for new construction/renovation could be normalized for light output at any given efficiency level. This could be accomplished through foreseeable ballast design options and/or lighting system modifications (*e.g.*, number of lamps, lamp type, or fixture reflector).[a] NEEA and NPCC contended that DOE could then simplify its analyses by applying normalized system input power throughout. (California Utilities, No. 30 at pp. 3–5;[b] NEEA and NPCC, No. 32 at pp. 6–7)

In its preliminary analysis, DOE used both rated and normalized system input power in determining the annual unit energy consumption for the NIA. As in the life-cycle cost (LCC) analysis, ballast shipments for failure replacements were assigned rated system input power, and this assumption was applied across the entire 30-year analysis period. DOE agrees that the lighting system modifications noted by the California Utilities can have the practical effect of normalizing light output for individual replacement systems. Therefore, DOE believes that normalized system input power provides a reasonable basis for estimating future energy savings

[a] The ballasts preliminary TSD is available at www1.eere.energy.gov/buildings/appliance_standards/residential/fluorescent_lamp_ballasts_ecs_prelim_tsd.html.
[b] A notation in this form provides a reference for information that is in the docket of DOE's rulemaking to develop energy conservation standards for fluorescent lamp ballasts (Docket No. EERE–2007–BT–STD–0016), which is maintained at www.regulations.gov. This notation indicates that the statement preceding the reference is document number 30 in the docket for the energy conservation standards rulemaking for fluorescent lamp ballasts, and appears at pages 3-5 of that document.

and used it to generate NIA results for the ballasts notice of proposed rulemaking (NOPR) and this final rule.

11.3.3.2 Ballast Stock

The ballast stock in a given year is the total number of ballasts shipped in prior years that survive up to the given year. The NES spreadsheet model keeps track of the ballasts shipped each year. DOE discusses forecasted shipments for the base case and all standards cases in chapter 10. To generate the shipments that eventually compose the ballast stock, the shipments analysis incorporates one set of base-case scenarios and one set of standards-case scenarios that can affect shipments. The base-case scenarios, existing and emerging technologies, dictate the penetration of other lighting technologies, and therefore affect the total volume of ballast shipments and installed stock. The standards-case scenarios are composed of the roll-up and shift scenarios. These scenarios dictate the inputs to the market-share apportionments, and therefore affect the breakdown of the installed stock by ballast design from 2014 to 2043.

These standards-case scenarios are compared to two separate base-case scenarios (existing and emerging technologies), resulting in four possible sets of results. The shift scenario generally results in higher energy savings than the roll-up scenario.

11.3.3.3 Site-to-Source Conversion Factors

The site-to-source conversion factor is the multiplier DOE used for converting site-energy consumption into primary or source energy consumption. For electricity, the conversion factors vary over time due to projected changes in generation sources (*i.e.*, the power plant types projected to provide electricity to the country). For this rulemaking, DOE calculated annual average site-to-source conversion factors based on the version of the National Energy Modeling Systems (NEMS) that corresponds to the Energy Information Administration's (EIA's) *Annual Energy Outlook 2010* (*AEO2010*). Table 11.3.2 presents site-to-source factors used in the NES spreadsheet model. The average conversion factors vary over time, due to projected changes in electricity generation sources.

Please note that DOE calculated two conversion factors for emerging technologies and existing technologies because these two scenarios have different energy savings patterns.

Table 11.3.2 Site-to-Source Conversion Factors

Year	Site-to-Source Conversion Factor for Existing Technologies *Btu/kWh*	Site-to-Source Conversion Factor for Emerging Technologies *Btu/kWh*
2014	19,354	17,282
2015	19,354	17,282
2016	19,354	14,912
2017	16,493	13,186
2018	15,736	13,441
2019	14,248	12,038
2020	13,221	11,108
2021	12,550	9,976
2022	13,659	10,690
2023	14,193	10,764
2024	13,302	10,791
2025	11,635	10,189
2026	10,492	9,873
2027	10,265	9,755
2028	9,400	8,985
2029	9,377	9,084
2030	9,265	9,187
2031	9,275	9,265
2032	9,207	9,289
2033	9,165	9,208
2034	8,960	9,358
2035	10,174	9,875
2036	10,174	9,875
2037	10,174	9,875
2038	10,174	9,875
2039	10,174	9,875
2040	10,174	9,875
2041	10,174	9,875
2042	10,174	9,875
2043	10,174	9,875

11.3.3.4 Interactions with Heating, Ventilation, and Air Conditioning Systems

Interactions with HVAC systems in the commercial and industrial sectors are represented by an HVAC factor, as given in Eq. 11.3. The HVAC factor reflects the extent to which the energy savings from more efficient equipment are offset by increased demands placed on heating and cooling equipment in the presence of more efficient equipment. Typically, this takes the form of increased efficiency being achieved through less energy wasted as heat, increasing the burden on HVAC equipment in winter months.

In the previous research (the 2000 Ballast Rule; 65 FR 56740; 10 CFR 430.23(m)(4)) DOE found that rebound rate is highly dependent on the composition of building stock. Updating the HVAC factor would be desirable, but in this rule higher level uncertainty with regard to energy savings comes from the emerging technologies influence. Therefore, an HVAC factor of 1 was used in energy savings calculations.

11.3.3.5 Rebound Rate

In its analysis, DOE considered the rebound effect that occurs after installation of energy efficient lighting equipment. Under economic theory, "rebound effect" refers to the tendency of a consumer to respond to the cost savings associated with more efficient equipment in a manner that actually leads to marginally greater product usage, thereby diminishing some portion of anticipated benefits related to improved efficiency. DOE examined a summary of the literature regarding the rebound effect in relation to lighting equipment.[1] Based on four studies, the summary estimated that for a 100-percent increase in energy efficiency, "take-back" or rebound values for residential lighting are between 5 and 12 percent of energy consumption savings. The summary estimated 0- to 2-percent rebound values for commercial and industrial lighting. Therefore, in the calculation of NES due to energy conservation standards on lighting, DOE calculated a rebound rate of 8.5 percent in the residential sector and 1 percent in the commercial and industrial sectors.

However, the take-back in energy consumption associated with the rebound effect provides consumers with increased value (*e.g.*, increased lighting hours, because the increased efficiency enables consumers to use their lighting equipment for longer periods). The impact on consumers is therefore the sum of the change in the cost of owning the lighting equipment (*i.e.*, LCC) and the increased value of more lighting hours. DOE has not been able to monetize this increase in consumer value in the LCC analysis. If it were able to monetize the increased value to consumers of the rebound effect, this value would be equal to or greater than the value of the foregone energy savings. For this analysis, DOE estimates that this value is equal to the monetary value of the energy savings that would have occurred without the rebound effect. Therefore, while the assumed rebound rate affects the calculated energy savings from amended standards, it does not affect the calculated monetary value of those savings.

11.4 NET PRESENT VALUE

11.4.1 Net Present Value Definition

The NPV is the value in the present of a time series of costs and savings. The NPV is calculated as follows:

$$NPV = PVS - PVC$$

Eq. 11.4

Where:

PVS = present value of operating cost savings, and
PVC = present value of increased total installed costs.

The *PVS* and *PVC* are determined according to the following expressions:

$$PVS = \sum OCS_t \times DF_t$$

Eq. 11.5

$$PVC = \sum TIC_t \times DF_t$$

Eq. 11.6

Where:

OCS = total annual operating cost savings,
TIC = total annual installed cost increases,
DF = discount factor, and
t = year (*PVS* and *PVC* are summed over 2014–2043).

DOE determined the contributions to *PVC* and *PVS* for each year from the effective date of the standard, 2014 to 2043, discounted for the NOPR analysis and final rule to 2011. DOE calculated costs and savings as the difference between a standards case (*i.e.*, with amended standards) and a base case (*i.e.*, without amended standards). DOE calculated a discount factor from the discount rate and the number of years between the "present" (*i.e.*, year to which the sum is being discounted) and the year in which the costs and savings occur. DOE calculated the NPV as the sum over time of the discounted net savings (which is equivalent to the approach shown in Eq. 11.4 through Eq. 11.6).

11.4.2 Net Present Value Inputs

Table 11.4.1 summarizes the inputs to the NPV calculation.

Table 11.4.1 Net Present Value Inputs

Input
Total Annual Installed Cost Increases (*TICt*)
Total Annual Operating Cost Savings (*OCSt*)
Discount Factor *(DF)*
Ballast Stock by Design *(STOCK)*
Ballast Shipments by Design *(SHIP)*

11.4.2.1 Total Annual Installed Cost Increases

DOE calculated the increase in total annual installed costs as the difference between the total annual installed costs in the standards case minus those in the base case. For each case, the total annual installed costs were equal to the product of the shipments and per-unit installed cost (summed over each ballast design).

$$TIC_t = \sum_{bd} SHIP_{bdt,std} \times (equipment\ \ price_{bd} + installing) - \sum_{bd} SHIP_{bdt,base} \times (equipment\ \ price_{bd} + installing)$$

Eq. 11.7

On February 22, 2011, DOE published a notice of data availability (NODA, 76 FR 9696) stating that DOE may consider improving regulatory analysis by addressing equipment price trends. Consistent with the NODA, DOE examined historical producer price indices (PPIs) for ballasts and found both positive and negative real price trends depending on the specific time period examined. Therefore, in the absence of a definitive trend, DOE assumed in its price forecasts for the final rule that the real prices of ballasts are constant in time and that ballast prices will trend the same way as prices in the economy as a whole. DOE is aware that there have been significant changes in both the regulatory environment and mix of ballast technologies that create analytical challenges for estimating longer-term product price trends from the product-specific PPI data. DOE performed price trends sensitivity calculations to examine the dependence of the analysis results on different analytical assumptions.

For this final rule, DOE also considered adjusting ballast prices using forecasted price indices (called deflators) used by EIA to develop the *AEO*. When adjusted for inflation, the deflator-based price indices decline from 100 in 2010 to approximately 50 in 2043, the effects of which are diminished significantly when discounting is taken into account. Deflator-based NPV results from the NIA were approximately 8 percent lower than NPV values based on constant real prices for ballasts. Given this minor difference in estimated NPV, and that DOE did not receive negative comments on its constant real price basis in the NOPR, DOE retained its constant real price approach for this final rule. A more detailed discussion of price trend modeling and calculations is provided in appendix 8A of the final rule TSD.

11.4.2.2 Total Annual Operating Cost Savings

As the LCC and payback period (PBP) analysis (final rule TSD chapter 8) describes, DOE calculated total annual operating costs based on national average electricity prices. DOE calculated total annual operating cost savings as the difference between total annual operating costs in the base case minus those in the standards case. (The components of annual operating cost for lamp-and-ballast systems that are different between the base case and the standards case are the cost of electricity consumption and relamping costs.)

$$OCS_t = \sum_{bd} STOCK_{bdt,base} \times (UEC_{bd,base} \times electricity\ price_t + relamping) - \sum_{bd} STOCK_{bdt,std} \times (UEC_{bd,std} \times electricity\ price_t + relamping)$$

Eq. 11.8

DOE used an average number of annual operating hours for each sector and ballast type in calculating the UEC of each lamp-and-ballast design.

DOE used national average commercial electricity prices for commercial sector 4-foot MBP, 8-foot slimline, and 4-foot T5 MiniBP SO systems. DOE used national average industrial prices for the 8-foot recessed double contact (RDC) HO and 4-foot T5 MiniBP HO systems. For 4-foot MBP systems in the residential sector, DOE used national average residential electricity prices for its analysis. DOE used *AEO2010* to establish all electricity prices.[2] Chapter 8 provides the electricity price forecasts DOE used to calculate the NPV.

11.4.2.3 Discount Factor

DOE multiplied monetary values in future years by the discount factor (DF) to calculate the present value. The following equation describes how to calculate the DF:

$$DF = 1/(1+r)^{(t-t_p)}$$

Eq. 11.9

Where:

r = discount rate,
t = year of the monetary value, and
t_p = year in which the present value is being determined.

DOE estimated national impacts with both a 3-percent and a 7-percent real discount rate as the average real rate of return on investments in the U.S. economy. These discount rates were used in accordance with the Office of Management and Budget's (OMB's) guidance to Federal agencies on the development of regulatory analysis, provided in OMB Circular A-4, section E, "Identifying and Measuring Benefits and Costs."[3] DOE defined the present year as 2011 for this final rule analysis.

11.5 NATIONAL ENERGY SAVINGS AND NET PRESENT VALUE RESULTS

The NES spreadsheet model provides estimates of the NES and NPV due to various TSLs. The inputs to the NES spreadsheet are discussed in sections 11.3.3 and 11.4.2. DOE generated the NES and NPV results using Microsoft Excel spreadsheets, accessible at www.eere.energy.gov/buildings/appliance_standards/residential/fluorescent_lamp_ballasts.html. Appendix 11A provides instructions for using the spreadsheets.

11.5.1 National Energy Savings and Net Present Value Input Summary

Table 11.5.1 summarizes the inputs to the NES spreadsheet model. A brief description of the data is given for each input.

Table 11.5.1. National Energy Saving and Net Present Value Inputs

Input Data	Data Description
Shipments	Annual shipments from the ballast shipment model. Historical shipments based on U.S. Census Bureau Current Industrial Reports data (final rule TSD chapter 10).
Stock of Ballasts	Established based on historical and projected ballast shipments, the service life of ballasts, penetration of emerging technologies, growth rate, and substitution among product classes.
Effective Date of Standard	2014.
Analysis Period	2014 to 2043.
Unit Energy Consumption (kWh/yr)	Established in the energy use characterization (final rule TSD chapter 6) by lamp-and-ballast design and sector.
Total Installed Cost	Established in the markups analysis (final rule TSD chapter 7) and the LCC analysis (final rule TSD chapter 8) by lamp-and-ballast designs.
Electricity Price Forecast	EIA forecasts (to 2035) from the *AEO2010* and extrapolation for beyond 2035 (final rule TSD chapter 8).
Electricity Site-to-Source Conversion	Conversion varies yearly and was generated by NEMS-BT (National Energy Modeling System–Building Technologies). Conversion factors beyond 2035 are extrapolated.
HVAC Interaction Savings	Negligible.
Rebound Effect	1% of total energy savings in the commercial sector. 8.5% of total energy savings in the residential sector.
Discount Rate	3% and 7% real.
Present Year	Future costs and savings are discounted to 2011.

11.5.2 National Energy Savings Results

The following section provides NES results for each TSL that DOE considered for ballasts. Results are cumulative to 2043 and are shown as primary energy savings measured in quads. As discussed earlier, DOE analyzed several shipment scenarios for ballasts. In this section DOE presents only upper and lower bound energy savings and NPV results (from the existing/shift and emerging/roll-up scenarios, respectively).

Table 11.5.2 and Table 11.5.3 show the NES results under the existing technologies, shift scenario, which reflects the upper bound of energy savings, and the emerging technologies, roll-up scenario, which reflects the lower bound, respectively. Due to a larger reduction in the installed stock of ballasts affected by standards, the emerging technologies base-case forecast results in lower energy savings than the existing technologies base-case forecast. Finally, because in the shift scenario more consumers move to higher efficiency lamp-and-ballast systems than in the roll-up scenario, the shift scenario results in higher energy savings than the roll-up scenario.

Table 11.5.2 Cumulative National Energy Savings for Ballasts Under the Existing, Shift Scenario (2014–2043)

TSL	Product Class	Undiscounted	Discounted at 3%	Discounted at 7%
1	IS and RS non-residential ballasts that operate			
	Two 4-foot MBP lamps	1.19	0.65	0.32
	Four 4-foot MPB lamps	0	0	0
	Two 8-foot slimline lamps	0	0	0
	PS ballasts that operate			
	Two 4-foot MBP lamps	0.27	0.17	0.10
	Four 4-foot MBP lamps	0.27	0.15	0.07
	Two 4-foot MiniBP SO lamps	0.43	0.23	0.11
	Two 4-foot MiniBP HO lamps	0.25	0.14	0.07
	Ballasts that operate			
	Two 8-foot HO lamps	0.04	0.04	0.03
	Sign ballasts that operate			
	Four 8-foot HO lamps	0.92	0.56	0.31
	IS and RS residential ballasts that operate			
	Two 4-foot MBP lamps	0.13	0.07	0.04
	Total (TSL 1)	3.50	2.00	1.07
2	IS and RS non-residential ballasts that operate			
	Two 4-foot MBP lamps	1.19	0.65	0.33
	Four 4-foot MPB lamps	0	0	0
	Two 8-foot slimline lamps	0.02	0.01	0.01
	PS ballasts that operate			
	Two 4-foot MBP lamps	0.27	0.17	0.10
	Four 4-foot MBP lamps	0.33	0.18	0.09
	Two 4-foot MiniBP SO lamps	0.78	0.41	0.19
	Two 4-foot MiniBP HO lamps	0.43	0.24	0.12
	Ballasts that operate			
	Two 8-foot HO lamps	0.04	0.04	0.03
	Sign ballasts that operate			
	Four 8-foot HO lamps	0.92	0.56	0.31
	IS and RS residential ballasts that operate			
	Two 4-foot MBP lamps	0.13	0.07	0.04
	Total (TSL 2)	4.10	2.32	1.22
3A	IS and RS non-residential ballasts that operate			
	Two 4-foot MBP lamps	1.44	0.79	0.39
	Four 4-foot MPB lamps	0.31	0.17	0.09
	Two 8-foot slimline lamps	0.02	0.01	0.01
	PS ballasts that operate			
	Two 4-foot MBP lamps	0.30	0.18	0.11
	Four 4-foot MBP lamps	0.33	0.18	0.09
	Two 4-foot MiniBP SO lamps	1.51	0.79	0.37
	Two 4-foot MiniBP HO lamps	0.56	0.31	0.16
	Ballasts that operate			
	Two 8-foot HO lamps	0.04	0.04	0.03
	Sign ballasts that operate			
	Four 8-foot HO lamps	0.92	0.56	0.31
	IS and RS residential ballasts that operate			

	Two 4-foot MBP lamps	0.13	0.07	0.04
	Total (TSL 3A)	5.55	3.10	1.60
3B	IS and RS non-residential ballasts that operate			
	Two 4-foot MBP lamps	1.44	0.79	0.39
	Four 4-foot MPB lamps	0.31	0.17	0.09
	Two 8-foot slimline lamps	0.02	0.01	0.01
	PS ballasts that operate			
	Two 4-foot MBP lamps	0.30	0.18	0.11
	Four 4-foot MBP lamps	0.33	0.18	0.09
	Two 4-foot MiniBP SO lamps	1.51	0.79	0.37
	Two 4-foot MiniBP HO lamps	0.56	0.31	0.16
	Ballasts that operate			
	Two 8-foot HO lamps	0.04	0.04	0.03
	Sign ballasts that operate			
	Four 8-foot HO lamps	0.92	0.56	0.31
	IS and RS residential ballasts that operate			
	Two 4-foot MBP lamps	0.13	0.08	0.04
	Total (TSL 3B)	5.56	3.10	1.60

Table 11.5.3 Cumulative National Energy Savings for Ballasts Under the Emerging, Roll-Up Scenario (2014–2043)

TSL	Product Class	Undiscounted	Discounted at 3%	Discounted at 7%
1	IS and RS non-residential ballasts that operate			
	Two 4-foot MBP lamps	0.001	0.001	0.0004
	Four 4-foot MPB lamps	0	0	0
	Two 8-foot slimline lamps	0	0	0
	PS ballasts that operate			
	Two 4-foot MBP lamps	0.13	0.09	0.06
	Four 4-foot MBP lamps	0.10	0.06	0.03
	Two 4-foot MiniBP SO lamps	0.16	0.10	0.06
	Two 4-foot MiniBP HO lamps	0.23	0.13	0.07
	Ballasts that operate			
	Two 8-foot HO lamps	0.04	0.03	0.03
	Sign ballasts that operate			
	Four 8-foot HO lamps	0.69	0.42	0.24
	IS and RS residential ballasts that operate			
	Two 4-foot MBP lamps	0.01	0.01	0.00
	Total (TSL 1)	1.36	0.84	0.49
2	IS and RS non-residential ballasts that operate			
	Two 4-foot MBP lamps	0.42	0.25	0.14
	Four 4-foot MPB lamps	0	0	0
	Two 8-foot slimline lamps	0.001	0.001	0.0004
	PS ballasts that operate			
	Two 4-foot MBP lamps	0.13	0.09	0.06
	Four 4-foot MBP lamps	0.13	0.08	0.04
	Two 4-foot MiniBP SO lamps	0.25	0.15	0.09
	Two 4-foot MiniBP HO lamps	0.39	0.21	0.11
	Ballasts that operate			
	Two 8-foot HO lamps	0.04	0.03	0.03
	Sign ballasts that operate			
	Four 8-foot HO lamps	0.69	0.42	0.24

	IS and RS residential ballasts that operate			
	Two 4-foot MBP lamps	0.01	0.01	0.003
	Total (TSL 2)	2.05	1.25	0.71
3A	IS and RS non-residential ballasts that operate			
	Two 4-foot MBP lamps	0.55	0.34	0.19
	Four 4-foot MPB lamps	0.12	0.08	0.04
	Two 8-foot slimline lamps	0.02	0.01	0.01
	PS ballasts that operate			
	Two 4-foot MBP lamps	0.14	0.10	0.07
	Four 4-foot MBP lamps	0.13	0.08	0.04
	Two 4-foot MiniBP SO lamps	0.51	0.30	0.17
	Two 4-foot MiniBP HO lamps	0.52	0.28	0.14
	Ballasts that operate			
	Two 8-foot HO lamps	0.04	0.03	0.03
	Sign ballasts that operate			
	Four 8-foot HO lamps	0.69	0.42	0.24
	IS and RS residential ballasts that operate			
	Two 4-foot MBP lamps	0.01	0.01	0.003
	Total (TSL 3A)	2.74	1.65	0.93
3B	IS and RS non-residential ballasts that operate			
	Two 4-foot MBP lamps	0.55	0.34	0.19
	Four 4-foot MPB lamps	0.12	0.08	0.04
	Two 8-foot slimline lamps	0.02	0.01	0.01
	PS ballasts that operate			
	Two 4-foot MBP lamps	0.14	0.10	0.07
	Four 4-foot MBP lamps	0.13	0.08	0.04
	Two 4-foot MiniBP SO lamps	0.51	0.30	0.17
	Two 4-foot MiniBP HO lamps	0.52	0.28	0.14
	Ballasts that operate			
	Two 8-foot HO lamps	0.04	0.03	0.03
	Sign ballasts that operate			
	Four 8-foot HO lamps	0.69	0.42	0.24
	IS and RS residential ballasts that operate			
	Two 4-foot MBP lamps	0.12	0.07	0.04
	Total (TSL 3B)	2.86	1.71	0.96

11.5.3 Net Present Value Analysis

The NPV calculation attempts to calculate the total monetary costs and benefits of the standard for all consumers of ballasts. This calculation relies primarily on two inputs: the NES calculations described in the previous section, which are translated into a decrease (or in some cases increase) in operating costs; and the increase (or in some cases decrease) in installed costs.

This section graphs both elements of NPV over time. Figure 11.5.1 through Figure 11.5.9 present the discounted annual total installed cost increases and annual operating cost savings at the national level using a 7-percent discount rate at TSL 3A. Both annual total installed cost increases and annual operating costs savings accumulate from 2014 to 2043. The figures also present the NPV, which is the difference between cumulative annual discounted operating cost savings and the cumulative annual discounted total installed cost increases.

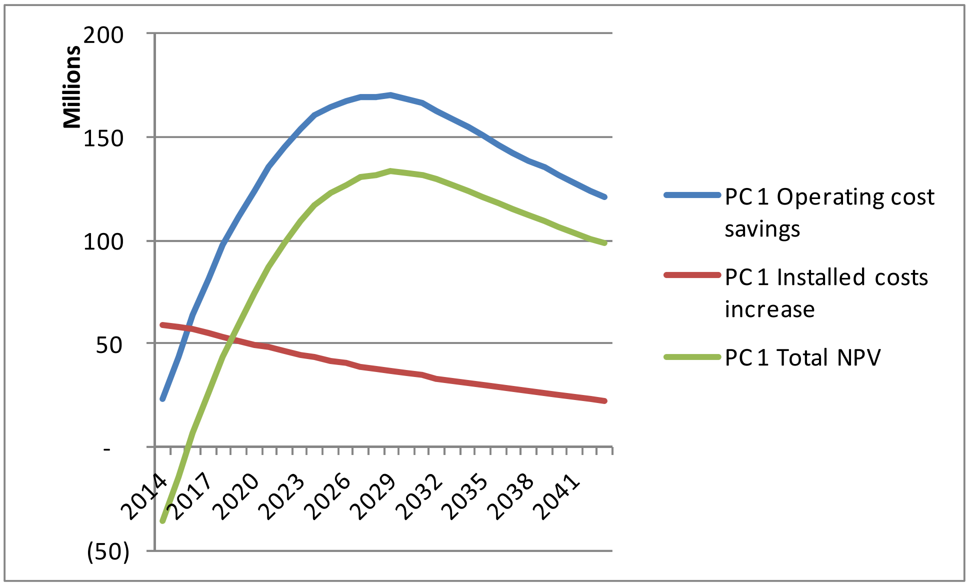

Figure 11.5.1 Product Class 1 – IS and RS Ballasts That Operate Two Non-residential 4-Foot MBP Lamps: National Annual Total Installed Equipment and Operating Cost Savings at TSL 3A (Existing Technologies, Shift Scenario) Discounted at 7 Percent per Year

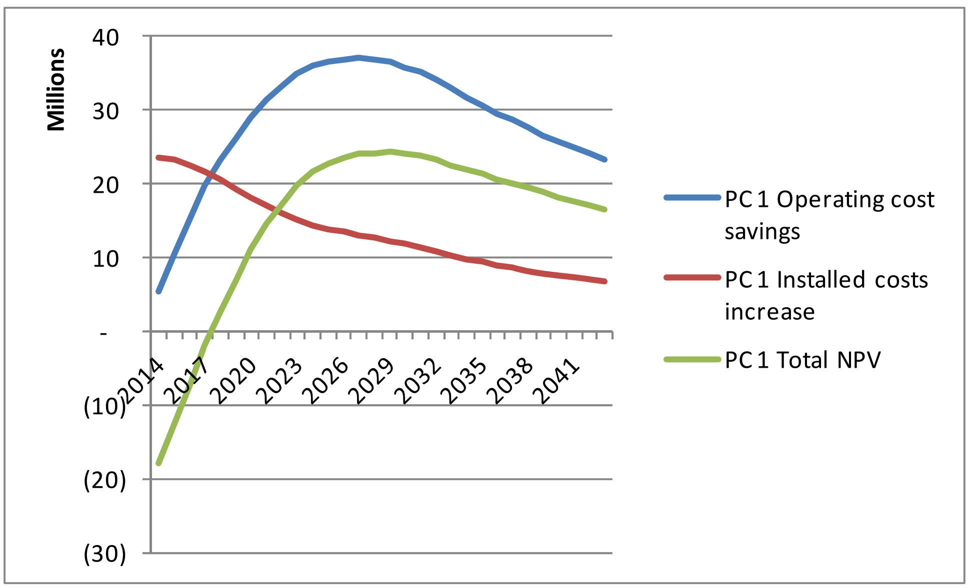

Figure 11.5.2 Product Class 1 – IS and RS Ballasts That Operate Four Non-residential 4-Foot MBP Lamps: National Annual Total Installed Equipment and Operating Cost Savings at TSL 3A (Existing Technologies, Shift Scenario) Discounted at 7 Percent per Year

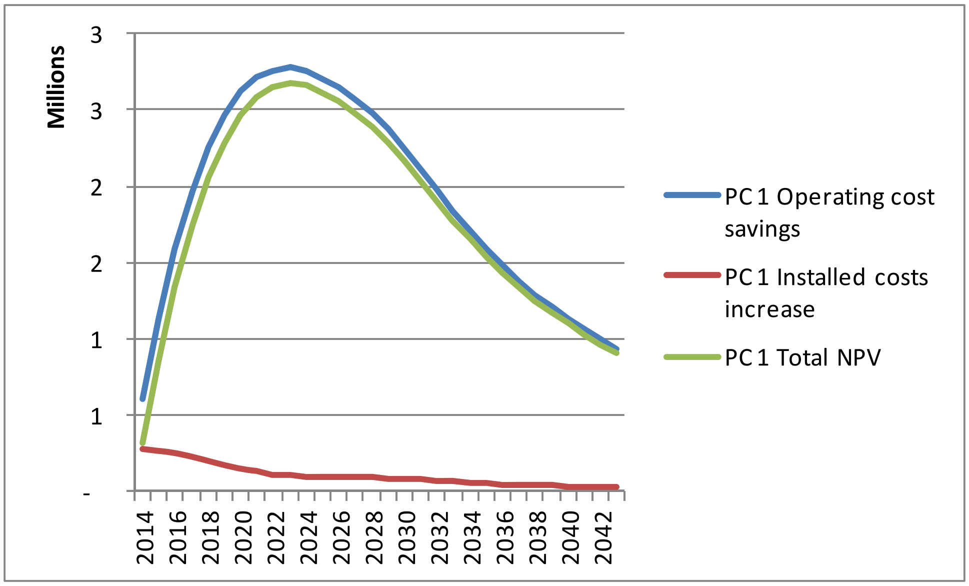

Figure 11.5.3 Product Class 1 – IS and RS Ballasts That Operate Two 8-Foot Slimline Lamps: National Annual Total Installed Equipment and Operating Cost Savings at TSL 3A (Existing Technologies, Shift Scenario) Discounted at 7 Percent per Year

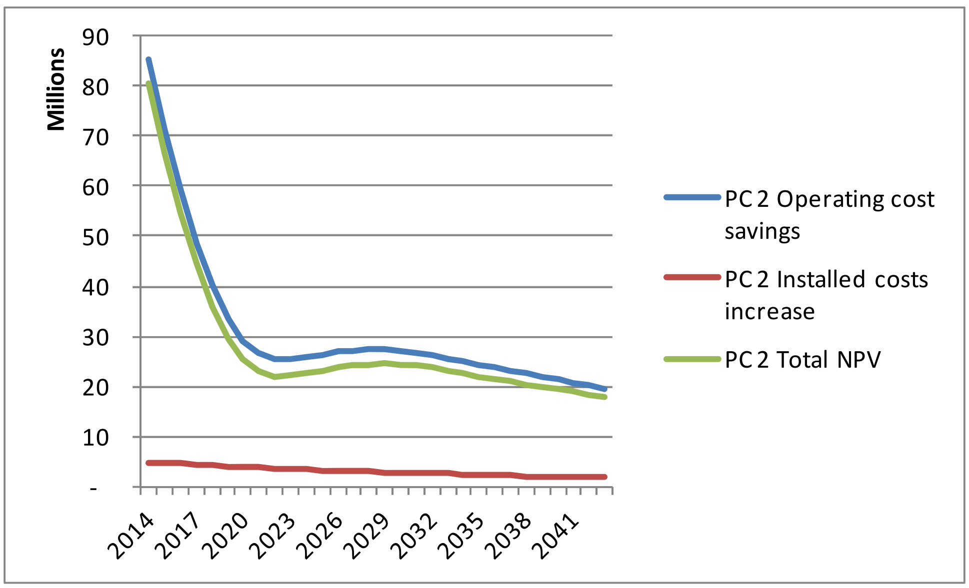

Figure 11.5.4 Product Class 2 – PS Ballasts That Operate Two Non-residential 4-Foot MBP Lamps: National Annual Total Installed Equipment and Operating Cost Savings at TSL 3A (Existing Technologies, Shift Scenario) Discounted at 7 Percent per Year

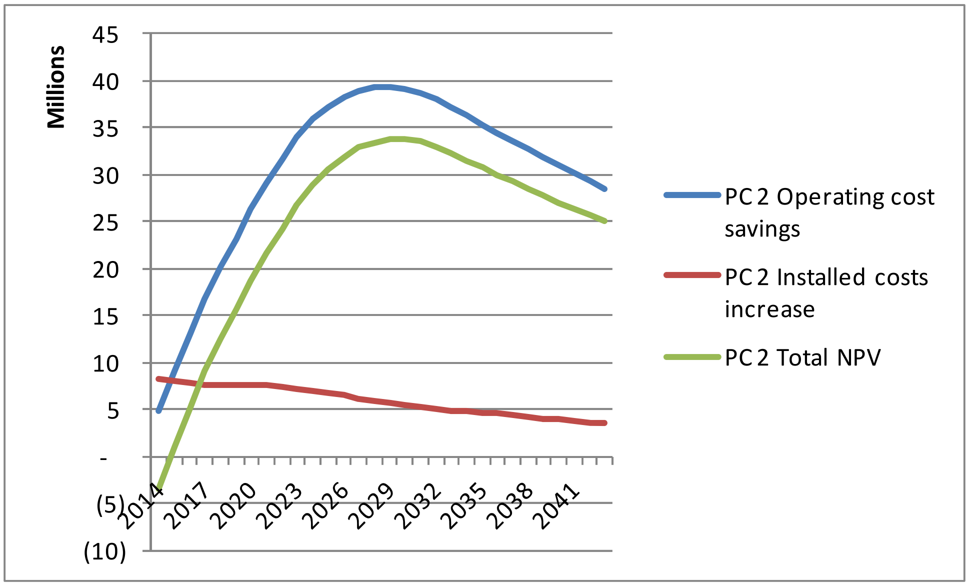

Figure 11.5.5 Product Class 2 – PS Ballasts That Operate Four Non-residential 4-Foot MBP Lamps: National Annual Total Installed Equipment and Operating Cost Savings at TSL 3A (Existing Technologies, Shift Scenario) Discounted at 7 Percent per Year

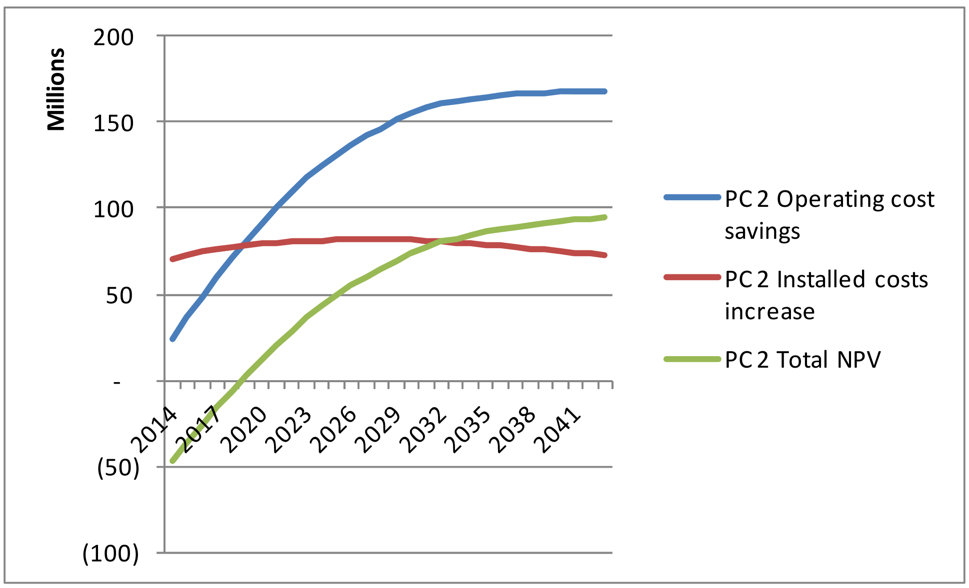

Figure 11.5.6 Product Class 2 – PS Ballasts That Operate Two Non-residential 4-Foot MiniBP SO Lamps: National Annual Total Installed Equipment and Operating Cost Savings at TSL 3A (Existing Technologies, Shift Scenario) Discounted at 7 Percent per Year

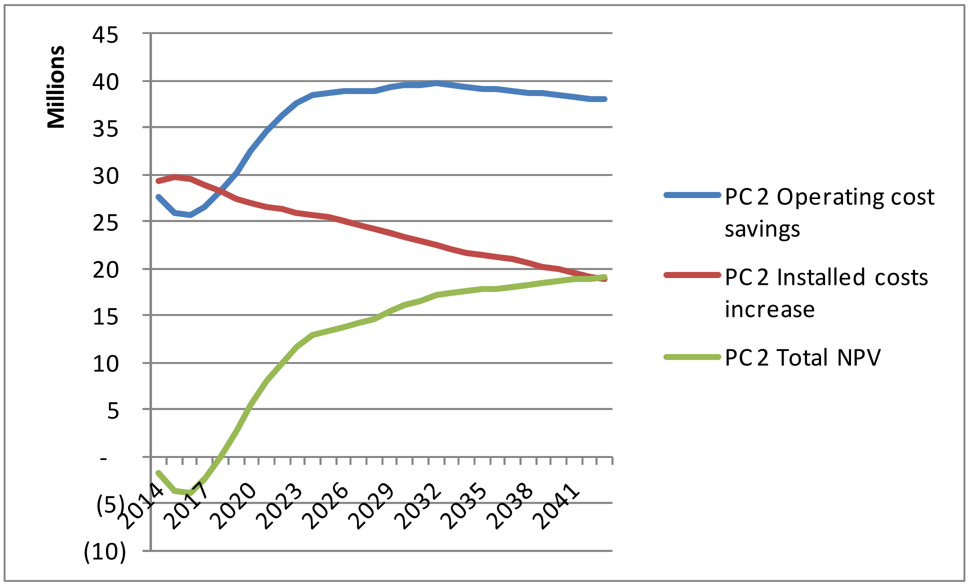

Figure 11.5.7 Product Class 2 – PS Ballasts That Operate Two Non-residential 4-Foot MiniBP HO Lamps: National Annual Total Installed Equipment and Operating Cost Savings at TSL 3A (Existing Technologies, Shift Scenario) Discounted at 7 Percent per Year

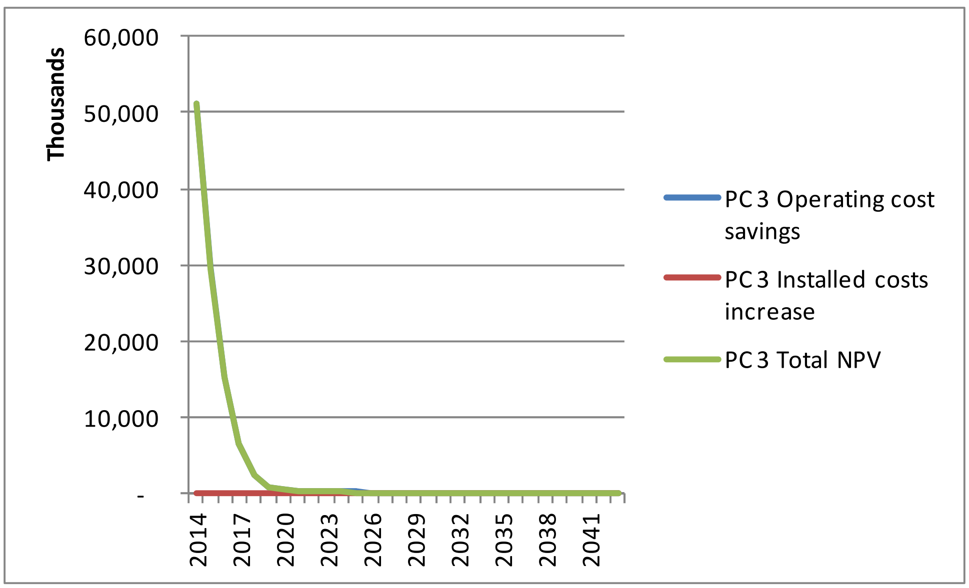

Figure 11.5.8 Product Class 3 – IS and RS Ballasts That Operate Two 8-Foot HO Lamps: National Annual Total Installed Equipment and Operating Cost Savings at TSL 3A (Existing Technologies, Shift Scenario) Discounted at 7 Percent per Year

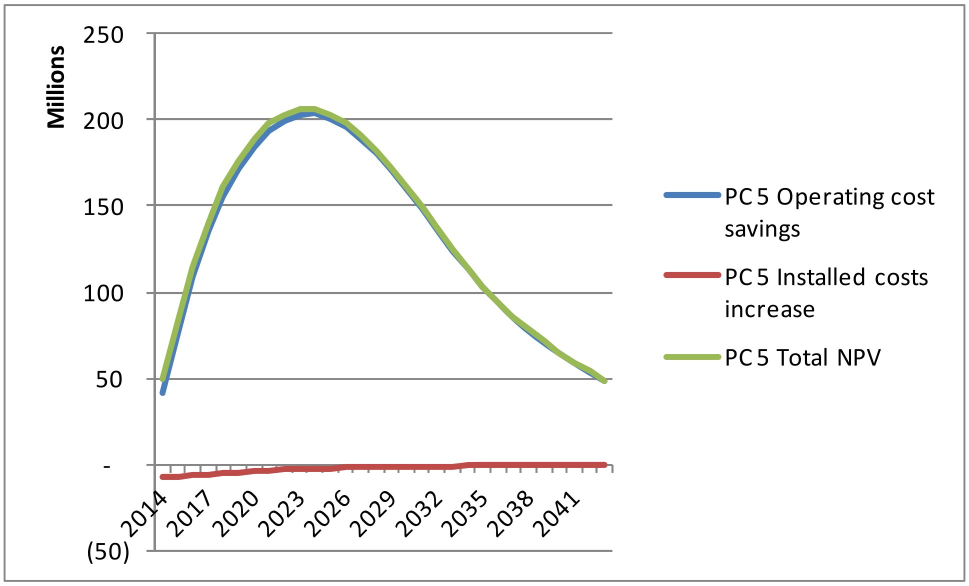

Figure 11.5.9 Product Class 5 – Sign Ballasts That Operate Four 8-foot HO Lamps: National Annual Total Installed Equipment and Operating Cost Savings at TSL 3A (Existing Technologies, Shift Scenario) Discounted at 7 Percent per Year

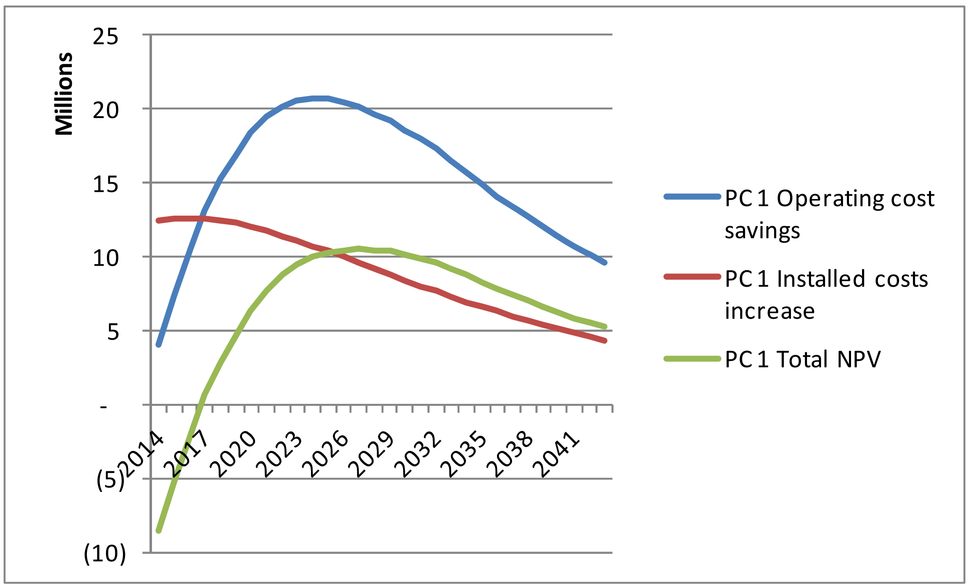

Figure 11.5.10 Product Class 6 – IS and RS Residential Ballasts That Operate Two 4-Foot MBP Lamps: National Annual Total Installed Equipment and Operating Cost Savings at TSL 3A (Existing Technologies, Shift Scenario) Discounted at 7 Percent per Year

In most cases the operating cost savings, installed costs increases, and NPV all trend toward zero over time, reflecting the impacts of discounting.

NPV results are cumulative and shown as the discounted value of these savings in dollar terms. DOE used national averages for key inputs, such as electricity pricing and sector-specific point values for operating hours, in calculating operating cost savings and installed cost increases. Thus, the NPV results are discrete point values rather than a distribution of values as in the LCC and PBP analyses.

The present value of increased total installed costs is the total installed cost increase (*i.e.*, the difference between the standards case and base case in a given year), discounted to the present, and summed over the time period in which DOE evaluated the impact of standards (*i.e.*, from the effective date of standards, 2014 to 2043).

Savings are decreases in operating costs associated with higher efficiency ballasts purchased in the standards case compared to the base case. DOE calculated total annual operating cost savings as the difference between total annual operating costs in the base case minus those in the standards case. Eq. 11.8 gives the total annual operating costs in each case.

In general, the NPV results at each TSL largely reflect the LCC savings at the corresponding efficiency levels. As discussed in the final rule TSD chapter 8 (LCC and PBP analyses), for most ballast purchasing events and most baseline ballast designs, increasing efficiency levels generally results in increased LCC savings. Due to the general cost-effectiveness of higher efficiency ballasts, the existing technologies base-case forecast (which increases the affected stock and shipments) and the shift scenario (which results in the shipment of more high-efficiency ballasts) represent the high-range scenario for NPV.

11.5.4 Net Present Value Results

Table 11.5.4 lists the NPV results, including the existing technologies, shift scenario, and the emerging technologies, roll-up scenario. NPV is presented at both 7- and 3-percent discount rates.

Table 11.5.4 Cumulative NPV Results for Ballasts Under the Existing Technologies, Shift Scenario and Emerging Technologies, Roll-up Scenarios (2014-2043)

Trial Standard Level	Product Class	Net Present Value *billion 2010$*			
		Existing Technologies, Shift		Emerging Technologies, Roll-up	
		7-Percent Discount Rate	3-Percent Discount Rate	7-Percent Discount Rate	3-Percent Discount Rate
1	IS and RS ballasts that operate:				
	Two 4-foot MBP lamps (commercial)	2.33	5.20	0.01	0.01
	Four 4-foot MBP lamps	0	0	0	0
	Two 8-foot slimline lamps	0	0	0	0
	PS ballasts that operate:				
	Two 4-foot MBP lamps	0.77	1.40	0.51	0.78
	Four 4-foot MBP lamps	0.61	1.35	0.30	0.58
	Two 4-foot MiniBP SO lamps	1.11	2.45	0.57	1.02
	Two 4-foot MiniBP HO lamps	0.42	0.88	0.42	0.88
	IS and RS ballasts that operate:				
	Two 8-foot HO lamps	0.11	0.12	0.10	0.12

	Sign ballasts that operate:				
	Four 8-foot HO lamps in outdoor signs	2.94	5.55	2.52	4.62
	IS and PS ballasts that operate:				
	Two 4-foot MBP lamps (residential)	0.22	0.49	0.16	0.27
	Total (TSL1)	8.52	17.43	4.59	8.28
2	IS and RS ballasts that operate:				
	Two 4-foot MBP lamps (commercial)	2.33	5.20	1.08	2.15
	Four 4-foot MBP lamps	0	0	0	0
	Two 8-foot slimline lamps	0.05	0.10	0.01	0.01
	PS ballasts that operate:				
	Two 4-foot MBP lamps	0.77	1.40	0.51	0.78
	Four 4-foot MBP lamps	0.73	1.61	0.37	0.72
	Two 4-foot MiniBP SO lamps	1.33	3.09	0.68	1.31
	Two 4-foot MiniBP HO lamps	0.42	0.94	0.43	0.94
	IS and RS ballasts that operate:				
	Two 8-foot HO lamps	0.11	0.13	0.11	0.13
	Sign ballasts that operate:				
	Four 8-foot HO lamps in outdoor signs	2.94	5.55	2.52	4.62
	IS and PS ballasts that operate:				
	Two 4-foot MBP lamps (residential)	0.22	0.49	0.16	0.27
	Total (TSL2)	8.91	18.50	5.85	10.92
3A	IS and RS ballasts that operate:				
	Two 4-foot MBP lamps (commercial)	2.83	6.31	1.44	2.86
	Four 4-foot MBP lamps	0.46	1.06	0.25	0.52
	Two 8-foot slimline lamps	0.05	0.10	0.05	0.10
	PS ballasts that operate:				
	Two 4-foot MBP lamps	0.84	1.54	0.56	0.87
	Four 4-foot MBP lamps	0.73	1.61	0.37	0.72
	Two 4-foot MiniBP SO lamps	1.52	3.89	0.85	1.87
	Two 4-foot MiniBP HO lamps	0.36	0.87	0.36	0.87
	IS and RS ballasts that operate:				
	Two 8-foot HO lamps	0.11	0.13	0.11	0.13
	Sign ballasts that operate:				
	Four 8-foot HO lamps in outdoor signs	2.94	5.55	2.52	4.62
	IS and PS ballasts that operate:				

	Two 4-foot MBP lamps (residential)	0.22	0.49	0.16	0.27
	Total (TSL3A)	10.06	21.55	6.67	12.84
3B	IS and RS ballasts that operate:				
	Two 4-foot MBP lamps (commercial)	2.83	6.31	1.44	2.86
	Four 4-foot MBP lamps	0.46	1.06	0.25	0.52
	Two 8-foot slimline lamps	0.05	0.10	0.05	0.10
	PS ballasts that operate:				
	Two 4-foot MBP lamps	0.84	1.54	0.56	0.87
	Four 4-foot MBP lamps	0.73	1.61	0.37	0.72
	Two 4-foot MiniBP SO lamps	1.52	3.89	0.85	1.87
	Two 4-foot MiniBP HO lamps	0.36	0.87	0.36	0.87
	IS and RS ballasts that operate:				
	Two 8-foot HO lamps	0.11	0.13	0.11	0.13
	Sign ballasts that operate:				
	Four 8-foot HO lamps in outdoor signs	2.94	5.55	2.52	4.62
	IS and PS ballasts that operate:				
	Two 4-foot MBP lamps (residential)	0.23	0.50	0.23	0.50
	Total (TSL3B)	10.06	21.56	6.73	13.07

11.6 ANNUALIZED NATIONAL COSTS AND BENEFITS

The benefits and costs of today's proposed standards, for products sold in 2014–2043, can be expressed in terms of annualized values. The annualized monetary values are the sum of (1) the annualized national economic value of the benefits from consumer operation of equipment that meet the proposed standards (consisting primarily of operating cost savings from using less energy, minus increases in equipment purchase and installation costs, which is another way of representing consumer NPV); and (2) the annualized monetary value of the benefits of emission reductions, including carbon dioxide (CO_2) emission reductions. The derivation of the monetary value of the benefits of emission reductions is described in chapter 17 of the final rule TSD. The value of the CO_2 reductions, otherwise known as the Social Cost of Carbon (SCC), is calculated using a range of values per metric ton of CO_2 developed by a recent interagency process. The derivation of the time series of SCC values is discussed in appendix 17A of the final rule TSD.

Although combining the values of operating savings and CO_2 reductions provides a useful perspective, two issues should be considered. First, the national operating cost savings are domestic U.S. consumer monetary savings that occur as a result of market transactions while the value of CO_2 reductions is based on a global value. Second, the assessments of operating cost savings and CO_2 savings are performed with different methods that use quite different time frames for analysis. The national operating cost savings is measured for the lifetime of products shipped in the 30-year analysis period. The SCC values, on the other hand, reflect the present value of future climate-related impacts resulting from the emission of 1 ton of carbon dioxide in each year. These impacts go well beyond 2100.

11.6.1 Calculation Method

DOE uses a two-step calculation process to convert each time-series of costs and benefits into annualized values. First, DOE calculates a present value in the "present" year used in discounting the NPV of total consumer costs and savings.[c] For this calculation, DOE uses discount rates of 3 and 7 percent for all costs and benefits except for the value of CO_2 reductions. For the latter, DOE uses the discount rate appropriate for each SCC time-series (see final rule TSD chapter 17 for discussion).

$$PV_x = \sum_{t=y_1,y_\mathrm{T}} \left(x(t) \cdot (1+r_x)^{y_\mathrm{NPV}-t}\right)$$

Eq. 11.10

Where:

$x(t)$= time-series under evaluation,
PV_x= present value of the time-series x,
y_1= first year in the analysis period,
y_T = last year in the analysis period,
y_NPV= year to which the NPV of consumers' costs and savings are being discounted, and
r_x = discount rate used to discount the annual values of time-series x to year y_NPV.

In the second step, DOE calculates, from the present values, the fixed annual payments over a 30-year period, starting in the first year of the analysis period (*i.e.*, the compliance year), which yields the same present values with discount rates of 3 and 7 percent. This requires projecting the present values in the "present" year ahead to the compliance year. The fixed annual payments are the annualized values.

$$Ann_{x,r} = PV_x \cdot f_{y_1-y_\mathrm{NPV},r} \cdot a_{30,r} = PV_x \cdot (1+r)^{y_1-y_\mathrm{NPV}} \cdot \frac{r\cdot(1+r)^{30}}{(1+r)^{30}-1}$$

Eq. 11.11

Where:

$Ann_{x,r}$= annualized value of the time-series x,
$f_{n,r}$ = factor to project a value n years ahead[d] with r discount rate, and
$a_{30,r}$ = factor to annualize present values over a 30-year period with r discount rate.

[c] For the value of emissions reductions, DOE uses a time series that corresponds to the time period used in calculating the operating cost savings (*i.e.*, through the final year in which products shipped are still operating).
[d] n is the number of years between the "present" year and the compliance year.

Although DOE calculates annualized values, this does not imply that the time-series of cost and benefits from which the annualized values were determined would be a steady stream of payments.

11.6.2 Results for the Adopted Standards

The direct final rule associated with this TSD states that DOE is adopting amended energy conservation standards for fluorescent lamp ballasts that correspond to TSL 3A. Estimates of annualized values for the proposed standards are shown in Table 11.6.1.

The low benefits and high benefits estimates are based on forecasted ballast shipments in the emerging technologies, roll-up scenario and the existing technologies, shift scenario, respectively. In addition, all estimates use incremental product costs that reflect constant prices (no learning rate) for product prices. See appendix 8B for discussion of the product price trends.

For the final rule, cumulative total NES and NPV values decreased compared to the NOPR analysis due in part to the increase in the market penetration of LEDs and dimming fluorescent lamp ballasts in the Emerging Technologies, Roll-up shipments scenario. However, annualized results did not decrease accordingly because in the NOPR annualized values (for both the existing and emerging technologies scenarios) were discounted to 2011. In this final rule (for annual impacts only) benefits were discounted to 2014 and then annualized. This increases annualized values by a factor of 1.23 for the 7% discount rate, and by a factor of 1.09 for the 3% discount rate.

Table 11.6.1 Annualized Benefits and Costs of New and Amended Standards for Ballasts Sold in 2014-2043*

	Discount Rate	Primary Estimate*	Low Estimate (Emerging Technologies, Roll-up Scenario)*	High Estimate (Existing Technologies, Shift Scenario)*
		Monetized *million 2010$/year*		
Benefits				
Operating Cost Savings	7%	1,189	886	1,492
	3%	1,344	934	1,754
CO_2 Reduction at $4.9/t**	5%	20	9	30
CO_2 Reduction at $22.3/t**	3%	92	41	143
CO_2 Reduction at $36.5/t**	2.5%	151	66	237
CO_2 Reduction at $67.6/t**	3%	280	124	435
NO_x Reduction at $2,537/t**	7%	2.2	1.3	3.0
	3%	2.4	1.6	3.2
Total†	7% plus CO_2 range	1,211 to 1,471	896 to 1,011	1,525 to 1,930
	7%	1,283	928	1,637
	3%	1,438	976	1,900
	3% plus CO_2 range	1,366 to 1,626	945 to 1,059	1,788 to 2,193
Costs				
Incremental Product Costs	7%	363	227	498
	3%	385	218	553
Total Net Benefits				
Total†	7% plus CO_2 range	848 to 1,108	669 to 784	1,027 to 1,432
	7%	920	700	1,139
	3%	1,053	758	1,347
	3% plus CO_2 range	981 to 1,241	727 to 842	1,235 to 1,640

* This table presents the annualized costs and benefits associated with fluorescent lamp ballasts shipped between 2014 and 2043. These results include benefits to consumers that accrue after 2043 from the ballasts purchased from 2014 to 2043. Costs incurred by manufacturers, some of which may be incurred prior to 2014 in preparation for the rule, are not directly included, but are indirectly included as part of incremental product costs.
** The CO_2 values represent global monetized values (in 2010$) of the social cost of CO_2 emissions in 2010 under several scenarios. The values of $4.9, $22.3, and $36.5 per metric ton are the averages of SCC distributions calculated using 5-percent, 3-percent, and 2.5-percent discount rates, respectively. The value of $67.6/t represents the 95^{th} percentile of the SCC distribution calculated using a 3-percent discount rate. The value for NO_x (in 2010$) is the average of the low and high values used in DOE's analysis.
† Total benefits for both the 3-percent and 7-percent cases are derived using the SCC value calculated at a 3-percent discount rate, which is $22.3/t in 2010 (in 2010$). In the rows labeled as "7% plus CO_2 range" and "3% plus CO_2 range," the operating cost and NO_x benefits are calculated using the labeled discount rate, and those values are added to the full range of CO_2 values.

Appendix 11B of this final rule TSD presents detailed RISC & OIRA Consolidated Information System (ROCIS) tables with annualized benefits and costs by product class for all TSLs considered in this final rule.

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CHAPTER 12. LIFE-CYCLE COST SUBGROUP ANALYSIS

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CHAPTER 12. LIFE-CYCLE COST SUBGROUP ANALYSIS

12.1 INTRODUCTION

The life-cycle cost (LCC) subgroup analysis evaluates impacts of standards on identifiable groups, such as different consumer populations or business types that may be disproportionately affected by any national energy conservation standard level. For this final rule, the U.S Department of Energy (DOE) analyzed the LCCs and payback periods (PBPs) for consumers that fall into such groups. The analysis determined whether any particular group of consumers would be adversely affected by any of the trial standard levels (TSLs).

DOE determined the impact on consumer subgroups using the LCC spreadsheet model. Chapter 8 of the final rule technical support document explains in detail the inputs to the model used in determining LCC impacts and PBPs.

This chapter describes the subgroup identification in further detail and gives the results of the LCC and PBP analyses for the considered subgroups.

12.2 SUBGROUPS DESCRIPTION

Using the LCC spreadsheet model, DOE determined the impact of the TSLs on the following consumer subgroups: low-income consumers, institutions of religious worship, and institutions that serve low-income populations. Representative ballast designs used in the industrial sector (*e.g.*, ballasts operating high output lamps) are not typically used by the identified subgroups, and were not included in the subgroup analysis.

12.2.1 Low-Income Consumers

To reflect conditions faced by low-income consumers, DOE adjusted electricity prices to represent rates paid by consumers living below the "poverty line." DOE defines low-income consumers using data from the U.S. Census Bureau,[1] as has been done in the Fluorescent and Incandescent Lamps Rule.[2] As defined in the Energy Information Administration's 2005 Residential Energy Consumption Survey (RECS),[3] the poverty line varies with household size, head of household age, and family income. RECS was updated in 2009, but these updates did not address lighting usage; therefore, DOE used RECS 2005 data (and corresponding census poverty threshold data for 2005) for this final rule.

Table 12.2.1 summarizes the income level baselines for selecting low-income households from the RECS sample. DOE also assumed that low-income consumers use residential ballasts only, and did not include commercial ballast designs in the LCC analysis for this subgroup.

Table 12.2.1 U.S. Census Bureau 2005 Definition of Low-Income Households

Household Size	Owner Age	Weighted-Average Threshold
1	65 and over	$9,367
1	64 and under	$10,160
2	65 and over	$11,815
2	64 and under	$13,145
3	Any	$15,577
4	Any	$19,971
5	Any	$23,613
6	Any	$26,683
7	Any	$30,249
8	Any	$33,610
9 or more	Any	$40,288

DOE discovered that residential low-income consumers faced electricity prices that were higher by 0.02 cents per kWh (in 2005 dollars) than the prices faced by consumers above the poverty line in 2005. In the subgroups analysis, DOE multiplied the national average residential electricity price of $0.1222 by 1.002 to arrive at the low-income residential electricity price of $0.1224. Because of the large diversity of low-income families in the residential sector, DOE does not expect to see differences in other inputs like operating hours, lamp types, or event response behaviors that vary significantly on average from the residential sector as a whole. Therefore, with the exception of electricity prices, DOE used the same inputs in the low-income consumer subgroup analysis as it used for the general residential sector population.

12.2.2 Institutions of Religious Worship

DOE found that institutions of religious worship operate for fewer hours per year than any other building type in the commercial sector according to the U.S. Lighting Market Characterization: Volume I[4] and 2003 Commercial Buildings Energy Consumption Survey[5] For institutions of religious worship, DOE assumed that this subgroup has lower annual operating hours than the commercial sector average used in the main LCC analysis. Specifically, DOE used 2,239 instead of the national average of 3,886 operating hours for the subgroup analysis. DOE also assumed that institutions of religious worship use commercial ballasts only, and did not include residential ballast designs in the LCC analysis for this subgroup. In general, because of the large diversity of institutions of religious worship in the commercial sector, DOE does not expect to see differences in other inputs like electricity prices or sales tax that vary significantly on average from the commercial sector as a whole. Therefore, with the exception of operating hours, DOE used the same inputs in the institutions of religious worship subgroup analysis as it used for the general commercial sector population.

12.2.3 Institutions that Serve Low-Income Populations

In the Fluorescent and Incandescent Lamps Rule, DOE performed research on institutions that serve low-income populations and found a wide variety of non-profit, for-profit, and governmental organizations.[1] Because of the large diversity of organizations in this sector, DOE does not expect to see operating hours, lamp types, or event response behaviors that vary significantly on average from the commercial sector as a whole. DOE, however, expects that the majority of organizations serving low-income populations are small non-profit groups. For this reason, DOE chose a subgroup scenario with a discount rate that is 3.8 percent higher than the average discount rate for the commercial sector (for a discount rate of 10.7 percent versus 6.9 percent). Complete details for calculating discount rates are given in chapter 8. DOE assumed that these institutions use commercial ballasts only, and did not include residential ballast designs in the LCC analysis for this subgroup.

12.3 LCC SUBGROUP RESULTS

Table 12.3.1 through Table 12.3.10 show the LCC impacts and PBPs for identified subgroups that purchase ballasts. In general, the results show higher installed prices and lower operating costs at higher ELs. However, this is not always the case. For example, ballasts operating 4-foot MiniBP SO lamps (Table 12.3.8) have higher operating costs at EL3 than at EL2. This is from the higher input power for EL3, which would result in increased energy use and costs despite its more efficient design. Negative PBP values indicate standards that reduce operating costs and installed costs. Entries of “N/A” indicate standard levels that do not reduce operating costs. In general, the average LCC savings for the identified sub-groups at the considered efficiency levels exhibited the same trends and relationships as the averages for all consumers.

Table 12.3.1 Product Class 1—Instant Start (IS) and Rapid Start (RS) Ballasts That Operate Two 4-Foot Medium Bipin (MBP) Lamps (Commercial, T12 Baseline): LCC and PBP Subgroup Results

Trial Standard Level	**Efficiency Level**	**Life-Cycle Cost** *2010$*			**Life-Cycle Cost Savings**			**Median Payback Period*** *years*
		Installed Cost	**Discounted Operating Cost**	**LCC**	**Average Savings** *2010$*	**Percent of Consumers that Experience**		
						Net Cost	**Net Benefit**	
Subgroup: Institutions of Religious Worship								
Event I: Replacement								
	Baseline	64	195	260				
1	1	57	178	235	25	0	100	-5.81
2	2	59	173	232	28	0	100	-2.89
3A, 3B	3	60	170	230	30	0	100	-2.26
Event II: New Construction / Renovation								
	Baseline	67	195	262				
1	1	59	176	235	27	0	100	-5.16
2	2	62	169	231	32	0	100	-2.48
3A, 3B	3	62	167	229	33	0	100	-2.06
Subgroup: Institutions Serving Low-Income Populations								
Event I: Replacement								
	Baseline	64	209	273				
1	1	57	191	247	26	0	100	-3.35
2	2	59	185	244	29	0	100	-1.66
3A, 3B	3	60	181	241	32	0	100	-1.30
Event II: New Construction / Renovation								
	Baseline	67	209	276				
1	1	59	188	247	28	0	100	-2.97
2	2	62	180	242	34	0	100	-1.43
3A, 3B	3	62	179	241	35	0	100	-1.19

* Negative PBP values indicate standards that reduce operating costs and installed costs.

Table 12.3.2 Product Class 1—IS and RS Ballasts That Operate Two 4-Foot MBP Lamps (Commercial, T8 Baseline): LCC and PBP Subgroup Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2010$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2010$*	Percent of Consumers that Experience		
						Net Cost	Net Benefit	
Subgroup: Institutions of Religious Worship								
Event I: Replacement								
1	Baseline / 1	56	178	234				
2	2	59	173	231	3	1	99	6.28
3A, 3B	3	59	170	229	6	0	100	4.96
Event II: New Construction / Renovation								
1	Baseline / 1	58	178	237				
2	2	61	171	232	5	0	100	4.79
3A, 3B	3	62	169	231	6	0	100	4.75
Subgroup: Institutions Serving Low-Income Populations								
Event I: Replacement								
1	Baseline / 1	56	191	246				
2	2	59	185	243	3	1	99	3.62
3A, 3B	3	59	181	240	6	0	100	2.86
Event II: New Construction / Renovation								
1	Baseline / 1	58	191	249				
2	2	61	183	244	5	0	100	2.76
3A, 3B	3	62	181	242	7	0	100	2.74

Table 12.3.3 Product Class 1—IS and RS Ballasts That Operate Four 4-Foot MBP Lamps: LCC and PBP Results: LCC and PBP Subgroup Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2010$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2010$*	Percent of Consumers that Experience		
						Net Cost	Net Benefit	
Subgroup: Institutions of Religious Worship								
Event I: Replacement								
1, 2	Baseline / 2	78	326	405				
3A, 3B	3	81	319	400	5	0	100	4.61
Event II: New Construction / Renovation								
1, 2	Baseline / 2	81	326	407				
3A, 3B	3	83	322	405	2	10	90	7.69
Subgroup: Institutions Serving Low-Income Populations								
Event I: Replacement								
1, 2	Baseline / 2	78	349	427				
3A, 3B	3	81	341	422	5	0	100	2.65
Event II: New Construction / Renovation								
1, 2	Baseline / 2	81	349	429				
3A, 3B	3	83	344	427	2	4	96	4.43

Table 12.3.4 Product Class 1—IS and RS Ballasts That Operate Two 8-Foot Slimline Lamps (T12 Baseline): LCC and PBP Subgroup Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2010$*			Life-Cycle Cost Savings			Median Payback Period* *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2010$*	Percent of Consumers that Experience		
						Net Cost	Net Benefit	
Subgroup: Institutions of Religious Worship								
Event I: Replacement								
1	Baseline / 1	90	362	452				
2	2	90	342	431	20	0	100	-0.20
3A, 3B	3	90	336	426	26	0	100	-0.01
Event II: New Construction / Renovation								
1	Baseline / 1	92	362	454				
2	2	92	348	441	14	0	100	-0.30
3A, 3B	3	92	344	436	18	0	100	-0.02
Subgroup: Institutions Serving Low-Income Populations								
Event I: Replacement								
1	Baseline / 1	90	387	477				
2	2	90	365	455	22	0	100	-0.12
3A, 3B	3	90	359	449	28	0	100	0.01
Event II: New Construction / Renovation								
1	Baseline / 1	92	387	479				
2	2	92	372	465	15	0	100	-0.17
3A, 3B	3	92	368	460	19	0	100	0.01

* Negative PBP values indicate standards that reduce operating costs and installed costs.

Table 12.3.5 Product Class 1—IS and RS Ballasts That Operate Two 8-Foot Slimline Lamps (T8 Baseline): LCC and PBP Subgroup Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2010$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2010$*	Percent of Consumers that Experience		
						Net Cost	Net Benefit	
Subgroup: Institutions of Religious Worship								
Event I: Replacement								
1, 2	Baseline / 2	90	342	432				
3A, 3B	3	91	336	427	5	0	100	0.80
Event II: New Construction / Renovation								
1, 2	Baseline / 2	93	342	434				
3A, 3B	3	93	337	430	4	0	100	1.05
Subgroup: Institutions Serving Low-Income Populations								
Event I: Replacement								
1, 2	Baseline / 2	90	365	456				
3A, 3B	3	91	359	450	6	0	100	0.46
Event II: New Construction / Renovation								
1, 2	Baseline / 2	93	365	458				
3A, 3B	3	93	361	454	4	0	100	0.61

Table 12.3.6 Product Class 2—Programmed Start (PS) Ballasts That Operate Two 4-Foot MBP Lamps: LCC and PBP Subgroup Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2010$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2010$*	Percent of Consumers that Experience		
						Net Cost	Net Benefit	
Subgroup: Institutions of Religious Worship								
Event I: Replacement								
	Baseline	59	149	208				
1, 2	2	60	139	199	9	0	100	1.90
3A, 3B	3	60	137	198	10	0	100	2.16
Event II: New Construction / Renovation								
	Baseline	61	149	210				
1, 2	2	62	139	201	9	0	100	1.89
3A, 3B	3	63	137	200	10	0	100	2.19
Subgroup: Institutions Serving Low-Income Populations								
Event I: Replacement								
	Baseline	59	163	222				
1, 2	2	60	152	212	10	0	100	1.09
3A, 3B	3	60	150	211	11	0	100	1.25
Event II: New Construction / Renovation								
	Baseline	61	163	225				
1, 2	2	62	152	215	10	0	100	1.09
3A, 3B	3	63	151	213	11	0	100	1.26

Table 12.3.7 Product Class 2—PS Ballasts That Operate Four 4-Foot MBP Lamps: LCC and PBP Subgroup Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2010$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2010$*	Percent of Consumers that Experience		
						Net Cost	Net Benefit	
Subgroup: Institutions of Religious Worship								
Event I: Replacement								
	Baseline	77	273	350				
1	1	81	272	352	-2	100	0	35.63
2, 3A, 3B	3	83	265	347	3	80	20	10.41
Event II: New Construction / Renovation								
	Baseline	79	273	353				
1	1	83	249	332	20	0	100	2.48
2, 3A, 3B	3	85	243	329	24	0	100	3.06
Subgroup: Institutions Serving Low-Income Populations								
Event I: Replacement								
	Baseline	77	299	376				
1	1	81	298	378	-2	100	0	20.50
2, 3A, 3B	3	83	290	373	4	19	81	6.00
Event II: New Construction / Renovation								
	Baseline	79	299	379				
1	1	83	273	356	22	0	100	1.43
2, 3A, 3B	3	85	267	352	27	0	100	1.76

Table 12.3.8 Product Class 2—PS Ballasts That Operate Two 4-Foot MiniBP Standard Output (SO) Lamps: LCC and PBP Subgroup Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2010$*			Life-Cycle Cost Savings			Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2010$*	Percent of Consumers that Experience		
						Net Cost	Net Benefit	
Subgroup: Institutions of Religious Worship								
Event I: Replacement								
	Baseline	64	212	276				
1	1	64	198	263	14	0	100	0.09
2	2	66	190	256	21	0	100	0.95
3A, 3B	3	70	199	270	7	1	99	6.63
Event II: New Construction / Renovation								
	Baseline	66	212	279				
1	1	67	198	265	14	0	100	0.09
2	2	68	197	265	14	0	100	1.35
3A, 3B	3	73	192	265	14	0	100	4.19
Subgroup: Institutions Serving Low-Income Populations								
Event I: Replacement								
	Baseline	64	227	291				
1	1	64	212	276	15	0	100	0.05
2	2	66	203	269	22	0	100	0.55
3A, 3B	3	70	213	284	7	2	98	3.82
Event II: New Construction / Renovation								
	Baseline	66	227	294				
1	1	67	212	279	15	0	100	0.05
2	2	68	210	278	15	0	100	0.78
3A, 3B	3	73	205	278	15	0	100	2.41

Table 12.3.9 Product Class 6—IS and RS Ballasts That Operate Two 4-Foot MBP Lamps (Residential, T12 Baseline): LCC and PBP Subgroup Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2010$*			Life-Cycle Cost Savings			Median Payback Period* *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2010$*	Percent of Consumers that Experience		
						Net Cost	Net Benefit	
Subgroup: Low-Income Consumers								
Event I: Replacement								
	Baseline	53	71	124				
1, 2, 3A	1	46	57	102	21	0	100	-5.46
3B	2	47	58	105	19	0	100	-4.92
Event II: New Construction / Renovation								
	Baseline	55	71	126				
1, 2, 3A	1	48	63	111	15	0	100	-9.45
3B	2	49	61	110	16	0	100	-6.35

* Negative PBP values indicate standards that reduce operating costs and installed costs.

Table 12.3.10 Product Class 6—IS and RS Ballasts That Operate Two 4-Foot MBP Lamps (Residential, T8 Baseline): LCC and PBP Subgroup Results

Trial Standard Level	Efficiency Level	Life-Cycle Cost *2010$*			Life-Cycle Cost Savings			Median Payback Period* *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2010$*	Percent of Consumers that Experience		
						Net Cost	Net Benefit	
Subgroup: Low-Income Consumers								
Event I: Replacement								
1, 2, 3A	Baseline/1	45	57	101				
3B	2	46	58	104	-2	100	0	N/A
Event II: New Construction / Renovation								
1, 2, 3A	Baseline/1	47	57	104				
3B	2	49	55	103	1	27	73	8.18

* Entries of “N/A” indicate standard levels that do not reduce operating costs.

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CHAPTER 13. MANUFACTURER IMPACT ANALYSIS

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CHAPTER 13. MANUFACTURER IMPACT ANALYSIS

13.1 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. 6313(a)(6)(B)(i)) The law also calls for an assessment of the impact of any lessening of competition as determined in writing by the Attorney General. *Id*. DOE conducted a manufacturer impact analysis (MIA) to estimate the financial impact of amended energy conservation standards on manufacturers of fluorescent lamp ballasts, 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 more stringent energy conservation standards for each product by comparing changes in INPV between a base case and the various trial standard levels (TSLs) in the standards case. The qualitative part of the MIA addresses product characteristics, manufacturer characteristics, market and product trends, as well as the impact of standards on subgroups of manufacturers.

13.2 METHODOLOGY

DOE conducted the MIA in three phases. Phase I, "Industry Profile," consisted of preparing an industry characterization for the fluorescent lamp ballasts industry, including data on market share, sales volumes and trends, pricing, employment, and financial structure. In Phase II, "Industry Cash Flow," DOE used the GRIM to assess the impacts of amended energy conservation standards on fluorescent lamp ballasts.

In Phase II, DOE created a GRIM for fluorescent lamp ballasts and an interview guide to gather information on the potential impacts on manufacturers. DOE presented the MIA results for fluorescent lamp ballasts based on a set of considered TSLs. These TSLs are described in Section 13.4.5 below.

In Phase III, "Subgroup Impact Analysis," DOE interviewed manufacturers representing more than 90 percent of fluorescent lamp ballast sales. Interviewees included large and small manufacturers with various market shares and market focus, providing a representative cross-section of the industries. During interviews, DOE discussed financial topics specific to each manufacturer and obtained each manufacturer's view of the industry. The interviews provided DOE with valuable information for evaluating the impacts of amended energy conservation standards on manufacturer cash flows, investment requirements, and employment.

13.2.1 Phase I: Industry Profile

In Phase I of the MIA, DOE prepared a profile of the fluorescent lamp ballast industry that built upon the market and technology assessment prepared for this rulemaking. (See chapter 3 of this Technical Support Document (TSD).) Before initiating the detailed impact studies, DOE collected information on the present and past structure and market characteristics of each industry. This information included market share data, product shipments, manufacturer markups, and the cost structure for various manufacturers. The industry profile includes: (1) further detail on the overall market and product characteristics; (2) estimated manufacturer market shares; (3) financial parameters such as net plant, property, and equipment; selling, general and administrative (SG&A) expenses; cost of goods sold, *etc.;* and (4) trends in the number of firms, market, and product characteristics. The industry profile included a top-down cost analysis of fluorescent lamp ballast 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 fluorescent lamp ballast industry, including Securities and Exchange Commission (SEC) 10–K reports,[1] Standard & Poor's (S&P) stock reports,[2] and corporate annual reports. DOE supplemented this public information with data released by privately held companies.

13.2.2 Phase II: Industry Cash-Flow Analysis and Interview Guides

Phase II focused on the financial impacts of potential amended energy conservation standards on manufacturers of fluorescent lamp ballasts. More stringent 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 fluorescent lamp ballasts. In performing these analyses, DOE used the financial values derived during Phase I and the shipment scenarios used in the national impact analysis (NIA). In Phase II, DOE performed these preliminary industry cash-flow analyses and prepared written guides for manufacturer interviews.

13.2.2.1 Industry Cash-Flow Analysis

The GRIM uses several factors to determine a series of annual cash flows from the announcement year of amended energy conservation standards until several years after the standards' compliance date. These factors include annual expected revenues, costs of sales, SG&A, taxes, and capital expenditures related to the amended standards. Inputs to the GRIM include manufacturing production costs, selling prices, and shipments forecasts developed in other analyses. DOE derived the manufacturing costs from the engineering analysis and information provided by the industry and estimated typical manufacturer markups from public financial reports and interviews with manufacturers. DOE developed alternative markup scenarios for the GRIM based on discussions with manufacturers. DOE's shipments analysis, presented in chapter 11 of this TSD, provided the basis for the shipment projections in the GRIM. The financial parameters were developed using publicly available manufacturer data and were revised with information submitted confidentially during manufacturer interviews. The GRIM results are compared to base case projections for the industry. The financial impact of amended energy conservation standards is the difference between the discounted annual cash flows in the base case and standards case at each TSL.

13.2.2.2 Interview Guides

During Phase III of the MIA, DOE interviewed manufacturers to gather information on the effects of amended energy conservation on revenues and finances, direct employment, capital assets, and industry competitiveness. Before the interviews, DOE distributed an interview guide for the fluorescent lamp ballast industry. The interview guide provided a starting point to identify relevant issues and help identify the impacts of amended energy conservation standards on individual manufacturers or subgroups of manufacturers. Most of the information DOE received from these meetings is protected by non-disclosure agreements and resides with DOE's contractors. Before each telephone interview or site visit, DOE provided company representatives with an interview guide that included the topics for which DOE sought input. The MIA interview topics included (1) test procedure follow-up; (2) preliminary analysis follow-up; (3) key issues to this rulemaking; (4) a company overview and organizational characteristics; (5) manufacturer markups and profitability; (6) shipment projections and market shares; (7) financial parameters; (8) conversion costs; (9) cumulative regulatory burden; (10) direct employment impact assessment; (11) manufacturing capacity and non-US sales; (12) impact on competition; and (13) impacts on small business. The interview guides are presented in appendix 13A.

13.2.3 Phase III: Subgroup Analysis

For its analysis, DOE presented the impacts on all product classes of fluorescent lamp ballasts as a whole. While conducting the MIA, DOE interviewed a representative cross-section of fluorescent lamp balllast manufacturers. The MIA interviews broadened the discussion to include business-related topics. DOE sought to obtain feedback from industry on the approaches used in the GRIMs and to isolate key issues and concerns. During interviews, DOE defined two manufacturer subgroups (small manufacturers and sign ballast manufacturers) that could be disproportionately impacted by amended energy conservation standards. These subgroups are described in detail below.

13.2.3.1 Manufacturing Interviews

The information gathered in Phase I and the cash-flow analysis performed in Phase II are supplemented with information gathered from manufacturer interviews in Phase III. 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.

DOE used these interviews to tailor the GRIM to reflect unique financial characteristics for fluorescent lamp ballast manufacturers. DOE contacted companies from its database of manufacturers and interviewed small and large companies, subsidiaries and independent firms, and public and private corporations to provide a representation of the industry. Interviews were scheduled well in advance to provide every opportunity for key individuals to be available for comment. Although a written response to the questionnaire was acceptable, DOE sought interactive interviews, which help clarify responses and identify additional issues. The resulting information provides valuable inputs to the GRIM developed for the product classes.

13.2.3.2 Revised Industry Cash-Flow Analysis

In Phase II of the MIA, DOE provided manufacturers with preliminary GRIM input financial figures for review and evaluation. During the interviews, DOE requested comments on the values it selected for the parameters. DOE revised its industry cash-flow models based on this feedback. Section 13.4.3 provides more information on how DOE calculated the parameters.

13.2.3.3 Manufacturer Subgroup Analysis

Using average cost assumptions to develop an industry cash flow estimate is not adequate for assessing differential impacts among manufacturer subgroups. Small manufacturers and other manufacturers with a cost structure significantly different from the industry average could be more negatively affected. DOE uses the results of the industry characterization to group manufacturers exhibiting similar characteristics. During the interviews, DOE discussed the potential subgroups and subgroup members it identified for the analysis. DOE asked manufacturers and other interested parties to suggest what subgroups or characteristics are the most appropriate to analyze. As described in section 13.2.3, DOE presents the industry impacts on fluorescent lamp ballasts as a whole because most of the product classes represent the same market served by the same manufacturers. However, as discussed below, DOE identified two additional manufacturer subgroups that warranted a separate impact analysis: small manufacturers and sign ballast manufacturers.

13.2.3.3.1 Small-Business Manufacturer Subgroup

DOE investigated whether small business manufacturers should be analyzed as a manufacturer subgroup. DOE used the Small Business Administration (SBA) small business size standards published on August 22, 2008, as amended, and the North American Industry Classification System (NAICS) code, presented in Table 13.2.1 , to determine whether any small entities would be affected by the rulemaking.[a] For the product classes under review, the SBA bases its small business definition on the total number of employees for a business, its subsidiaries, and its parent companies. An

[a] The size standards are available on the SBA's website at www.sba.gov/idc/groups/public/documents/sba_homepage/serv_sstd_tablepdf.pdf.

aggregated business entity with fewer employees than the listed limit is considered a small business.

Table 13.2.1 SBA and NAICS Classification of Small Businesses Potentially Affected by This Rulemaking

Industry Description	Revenue Limit	Employee Limit	NAICS
Power, Distribution and Specialty Transformer Manufacturing	N/A	750	335311

DOE used the National Electrical Manufacturers Association (NEMA)[3] member directory to identify manufacturers of fluorescent lamp ballasts. DOE asked interested parties and industry representatives if they were aware of other small business manufacturers. DOE also consulted product databases like the Consortium for Energy Efficiency (CEE)[4] and the California Energy Commission (CEC)[5] for potential manufacturers. DOE contacted select companies on its list, as necessary, to determine whether they met the SBA's definition of a small business manufacturer of covered fluorescent lamp ballasts. DOE screened out companies that did not offer products covered by this rulemaking, did not meet the definition of a "small business," or are foreign owned and operated.

During its research, DOE identified approximately ten companies which manufacture products covered by this rulemaking and qualify as small businesses per the applicable SBA definition. DOE contacted the small businesses to solicit feedback on the potential impacts of energy conservation standards. Two of the small businesses consented to being interviewed during the MIA interviews, and DOE received feedback from one additional small business through a survey response. In addition to posing the standard MIA interview questions, DOE solicited data from other manufacturers on differential impacts these companies might experience from amended energy conservation standards. Because DOE was not able to certify that the rulemaking would not have a significant economic impact on a substantial number of small entities, DOE has analyzed small manufacturers as a subgroup. The results of this subgroup analysis are presented in section 13.6.

13.2.3.3.1 Sign Ballast Manufacturer Subgroup

DOE investigated sign ballast manufacturers as a second subgroup. Unlike the traditional fluorescent lamp ballast market, which is dominated by four large manufacturers with high volume product lines, the sign ballast market is significantly more fragmented, with numerous small players providing products in low volumes to distinct markets. As such, DOE conducted a subgroup analysis for sign ballast manufacturers, the results of which are presented in section 13.6.

13.2.3.4 Manufacturing Capacity Impact

One significant outcome of amended energy conservation standards could be the obsolescence of existing manufacturing assets, including tooling and investment. The manufacturer interview guides have a series of questions to help identify impacts of amended standards on manufacturing capacity, specifically capacity utilization and plant location decisions in the United States and North America, with and without amended standards; the ability of manufacturers to upgrade or remodel existing facilities to accommodate the new requirements; the nature and value of any stranded assets; and estimates for any one-time changes to existing plant, property, and equipment (PPE). DOE's estimates of the one-time capital changes and stranded assets affect the cash flow estimates in the GRIM. These estimates can be found in section 13.4.8; DOE's discussion of the capacity impact can be found in section 13.7.2.

13.2.3.5 Employment Impact

The impact of amended energy conservation standards on employment is an important consideration in the rulemaking process. To assess how domestic direct employment patterns might be affected, the interviews explored current employment trends in the fluorescent lamp ballast industry. The interviews also solicited manufacturer views on changes in employment patterns that may result from more stringent standards. The employment impacts section of the interview guide focused on current employment levels associated with manufacturers at each production facility, expected future employment levels with and without amended energy conservation standards, and differences in workforce skills and issues related to the retraining of employees. The employment impacts are reported in section 13.7.1.

13.2.3.6 Cumulative Regulatory Burden

DOE seeks to mitigate the overlapping effects on manufacturers due to amended energy conservation standards and other regulatory actions affecting the same products. DOE analyzed the impact on manufacturers of multiple, product-specific regulatory actions. Based on its own research and discussions with manufacturers, DOE identified regulations relevant to fluorescent lamp ballast manufacturers, such as State regulations and other Federal regulations that impact other products made by the same manufacturers. Discussion of the cumulative regulatory burden can be found in section 13.7.3.

13.3 MANUFACTURER IMPACT ANALYSIS KEY ISSUES

Each MIA interview starts by asking: "What are the key issues for your company regarding the energy conservation standard rulemaking?" This question prompts manufacturers to identify the issues they feel DOE should explore and discuss further during the interview. The following sections describe the most significant issues identified by manufacturers. These summaries are provided in aggregate to protect manufacturer confidentiality.

13.3.1 Component Shortage

All manufacturers stated that an ongoing component shortage, which began in the fall of 2009, is a key concern for their industry. During the recent economic downturn, component suppliers scaled back production significantly. When demand recovered as the recession ended, electronics suppliers lacked the capacity to meet demand. Suppliers have been reluctant to add capacity for fear that the downturn has not actually ended; this reluctance has driven a prolonged shortage of ballast components. Electrolytic capacitors and transistors are key examples of components in relatively short supply, which come almost entirely from Asia.

The fact that these components are shared among many electronics industries has exacerbated the problem for the ballast industry. Because the selling price of a ballast is much lower than that of many other products demanding these components, such as televisions and cell phones, other industries, which are better able to absorb small component prices increases, are able to pay more for these components and thus receive priority over the ballast industry. Some of these competing industries also have greater scale to help justify prioritization from vendors. Additionally, component manufacturers are seeing their customers place duplicate orders with several suppliers (only to later cancel the orders with all but one supplier). This has led to component suppliers being skeptical that the demand for components is as great as manufacturers claim. As a result, suppliers currently cannot meet the full demand for several components used in the ballasts industry and many other electronics industries.

In turn, ballast manufacturers have been unable to have their orders filled with lead times they have been accustomed to. They have been forced to pay higher charges to rush parts in order to fill their own customers' orders. The shortage not only disrupted manufacturers' ability to fill ballast orders within historical lead times, but also hampered their R&D efforts as obtaining parts for product development is more difficult. Manufacturers predicted the component shortage would last at least into 2011.

Manufacturers were concerned that energy conservation standards for fluorescent lamp ballasts would exacerbate the component shortage. New and amended standards, particularly at the highest efficiency levels analyzed, would greatly increase the demand for highly efficient components, which are only available from a limited number of suppliers and are already in short supply. The more stringent the standards are set, the more severe the component shortage could be.

Manufacturers also stated that the component shortage has forced them to expand the number of suppliers they use, which could cause greater variation in production output. The component shortage has also impacted their profitability because manufacturers are paying more for components but have not yet been able to pass on these increased costs to consumers.

13.3.2 Market Erosion

Manufacturers stated that emerging technologies are penetrating the fluorescent lamp ballasts market. Several manufacturers worried that new and amended energy conservation standards for ballasts would force them to invest in a shrinking market. Depending on the pace of market penetration of emerging technologies—such as light-emitting diodes (LEDs)—these investments might never be recouped. Also, manufacturers were concerned that new and amended standards on ballasts could hasten the switch to emerging technologies by lowering the difference in their first-cost price. If the standard did increase the natural migration toward new technology, manufacturers said they would be less likely to make the substantial investments to modify ballasts production equipment for some of their product lines. (To address emerging technologies issues discussed by manufacturers, DOE included several shipment scenarios in both the NIA and the GRIM. See chapter 11 of this final rule TSD for a discussion of the shipment scenarios used in the respective analyses.)

13.3.3 Opportunity Cost of Investments

Manufacturers also stated that the financial burden of developing products to meet amended energy conservation standards has an opportunity cost due to the limited pool of capital and R&D dollars. Currently, manufacturers are reinvesting the lion's share of the cash flow from fluorescent lamp ballast operations into emerging technologies such as LEDs and control systems. Any investments incurred to meet amended ballast standards would therefore reflect foregone investments in these emerging technologies, which the industry believes offer both better prospects for market growth and greater potential for energy savings than traditional fixed–light-output fluorescent lamp ballasts. Compared to these emerging technologies, manufacturers stated that they have little room for efficiency improvements within their ballast product lines.

13.3.4 Maintaining Product Tiers

Several manufacturers stated that they would not want standards to be so stringent that they eliminate the ability to carry two efficiency tiers within a product class. Most manufacturers—and all major manufacturers—currently offer both standard-efficiency and high-efficiency product lines. The standard-efficiency product lines are typically lower cost and lower margin. These high-volume products provide economies of scale and, by establishing a market presence and brand, enhance manufacturers' ability to enter the more profitable retrofit and aftermarket sales. Meanwhile, the high-efficiency product lines allow manufacturers to bundle other features within these products, which allows them to up sell these products and often command a better margin. Utility rebates and other similar programs also play a large role in driving the purchase of higher efficiency ballasts.

If DOE set standards that did not leave room for a high-efficiency product to differentiate itself from a baseline product, manufacturers worry the new standard would commoditize these now-premium products. In turn, prices of the high-efficiency ballasts would fall to the level of what were formerly the lower-tier products, harming manufacturer profitability. Utility companies and other programs would have little incentive to offer rebates for these former upper-tier products, which would then be baseline units. Without rebate incentives, sales to the energy retrofit market could decrease greatly due to cost, which would diminish the potential for energy savings due to the standard.

13.3.5 Adequate Compliance Periods

A number of manufacturers expressed concern about the timing between the announcement of the standard and the effective date of the standard. Manufacturers stated that they need adequate time to develop products that meet the amended efficiency standards. Without enough development time, manufacturers may not have the resources to redesign and test all of their product lines before the required compliance date in 2014, which could result in lost sales opportunities in the market.

13.4 GRIM INPUTS AND ASSUMPTIONS

The GRIM serves as the main tool for assessing the impacts on industry due to amended energy conservation standards. DOE relies on several sources to obtain inputs for the GRIM. Data and assumptions from these sources are then fed into an accounting model that calculates the industry cash flow both with and without amended energy conservation standards.

13.4.1 Overview of the GRIM

The basic structure of the GRIM, illustrated in Figure 13.4.1 , is an annual cash flow analysis that uses manufacturer prices, manufacturing costs, shipments, and industry financial information as inputs, and accepts a set of regulatory conditions such as changes in costs, investments, and associated margins. The GRIM spreadsheet uses a number of inputs to arrive at a series of annual cash flows, beginning with the base year of the analysis, 2011, and continuing to 2043. The model calculates the INPV by summing the stream of annual discounted cash flows during this period and adding a discounted terminal value.[6]

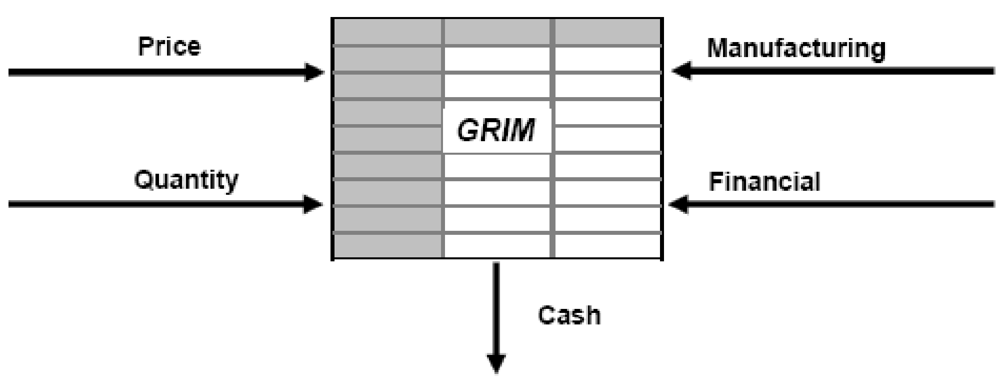

Figure 13.4.1 Using the GRIM to Calculate Cash Flow

The GRIM projects cash flows using standard accounting principles and compares changes in INPV between the base case and the standard-case scenario induced by amended energy conservation standards. The difference in INPV between the base case and the standard case(s) represents the estimated financial impact of the amended energy conservation standard on manufacturers. Appendix 13B provides more technical details and user information for the GRIM.

13.4.2 Sources for GRIM Inputs

The GRIM uses several different sources for data inputs in determining industry cash flow. These sources include corporate annual reports, company profiles, Census data, credit ratings, the shipments model, the engineering analysis, and the manufacturer interviews.

13.4.2.1 Corporate Annual Reports

Corporate annual reports to the SEC (SEC 10-Ks) provided many of the initial financial inputs to the GRIM. These reports exist for publicly held companies and are freely available to the general public. DOE developed initial financial inputs to the GRIM by examining the annual SEC 10-K reports filed by publicly-traded manufacturers that manufacture fluorescent lamp ballasts, among other products. Since these companies do not provide detailed information about their individual product lines, DOE used the financial information for the entire companies as its initial estimates of the financial parameters in the GRIM analysis. These figures were later revised using feedback from interviews to be representative of fluorescent lamp ballast manufacturing. DOE used corporate annual reports to derive the following initial inputs to the GRIM:

- Tax rate
- Working capital
- SG&A
- R&D
- Depreciation
- Capital expenditures
- Net PPE

13.4.2.2 Standard and Poor's Credit Ratings

S&P provides independent credit ratings, research, and financial information. DOE relied on S&P reports to determine the industry's average cost of debt when calculating the cost of capital.

13.4.2.3 Shipment Model

The GRIM used shipment projections derived from DOE's shipments model in the NIA. The model relied on historical shipments data for fluorescent lamp ballasts. Chapter 10 of the TSD describes the methodology and analytical model DOE used to forecast shipments.

13.4.2.4 Engineering Analysis

The engineering analysis establishes the relationship between manufacturer production cost (MPC) and energy efficiency for the products covered in this rulemaking.

DOE has adopted an efficiency level approach paired with reverse engineering cost estimates to develop cost-efficiency curves. DOE began its analysis by conducting industry research to determine representative product classes, select baseline ballasts, and select representative ballasts for further testing and analysis. Next DOE determined efficiency levels based on the design options associated with the specific ballasts studied and the maximum technologically feasible efficiency level. Lastly, DOE conducted a price analysis by generating a bill of materials (BOM) by tearing down representative ballasts and developing a cost model that converts the BOMs for each efficiency level into MPCs. By applying derived manufacturer markups to the MPC, DOE calculated the manufacturer selling price (MSP) and constructed industry cost-efficiency curves. In cases where DOE was not able to generate a BOM for representative ballasts, DOE estimated an MSP based on the relationship between teardown data, blue book prices, and manufacturer-supplied MSPs. See chapter 5 for a complete discussion of the engineering analysis.

13.4.2.5 Manufacturer Interviews

During the course of the MIA, DOE conducted interviews with a representative cross-section of manufacturers. DOE also interviewed manufacturers representing a significant portion of sales in every product class. During these discussions, DOE obtained information to determine and verify GRIM input assumptions in each industry. Key topics discussed during the interviews and reflected in the GRIM include:

- capital conversion costs (one-time investments in PPE);
- product conversion costs (one-time investments in research, product development, testing, and marketing);
- product cost structure, or the portion of the MPCs related to materials, labor, overhead, and depreciation costs;
- possible profitability impacts; and
- cost-efficiency curves calculated in the engineering analysis.

13.4.3 Financial Parameters

Table 13.4.1 below provides financial parameters for four public companies engaged in manufacturing and selling fluorescent lamp ballasts. The values listed are averages over a 6-year period (2002 to 2007).

Table 13.4.1 GRIM Financial Parameters Based on 2002–2007 Weighted Company Financial Data

Parameter	Weighted Average	Manufacturer			
		A	B	C	D
Tax Rate ***% of taxable income***	23.4	11.4	28.4	13.1	32.6
Working Capital ***% of revenues***	8.3	-29.4	17.9	11.9	16.4
SG&A ***% of revenues***	19.4	14.0	20.8	17.8	22.6
R&D ***% of revenues***	3.8	3.6	2.7	6.1	3.9
Depreciation ***% of revenues***	3.7	2.1	3.8	5.9	2.7
Capital Expenditures ***% of revenues***	4.2	3.0	4.6	6.4	2.3
Net PPE ***% of revenues***	14.6	18.2	14.1	13.5	13.7

During interviews, fluorescent lamp ballast manufacturers were asked to provide their own figures for the parameters listed in Table 13.4.1. Where applicable, DOE adjusted the parameters in the GRIM using this feedback and data from publicly traded companies to reflect manufacturing fluorescent lamp ballasts. Table 13.4.2 presents the revised parameters for fluorescent lamp ballast manufacturers.

Table 13.4.2 GRIM Revised Fluorescent Lamp Ballast Industry Financial Parameters

Parameter	Revised Estimate
Tax Rate ***% of taxable income***	31.8
Working Capital ***% of revenues***	8.3
SG&A ***% of revenues***	16.6
R&D ***% of revenues***	3.7
Depreciation ***% of revenues***	3.1
Capital Expenditures ***% of revenues***	3.2
Net PPE ***% of revenues***	11.4

13.4.4 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. DOE estimated the WACC for the fluorescent lamp ballast industry based on several representative companies, using the following formula:

WACC = After-Tax Cost of Debt x (Debt Ratio) + Cost of Equity x (Equity Ratio) Eq. 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. The capital asset pricing model (CAPM) provides one widely used means to estimate the cost of equity. According to the CAPM, the cost of equity (expected return) is:

Cost of Equity = Riskless Rate of Return + β x Risk Premium Eq. 2

where:

Riskless rate of return is the rate of return on a “safe” benchmark investment, typically considered the short-term Treasury Bill (T-Bill) yield.

Risk premium is the difference between the expected return on stocks and the riskless rate.

Beta (β) is the correlation between the movement in the price of the stock and that of the broader market. In this case, Beta equals one if the stock is perfectly correlated with the S&P 500 market index. A Beta lower than one means the stock is less volatile than the market index.

DOE determined that the industry average cost of equity for the fluorescent lamp ballast industry is 10.7 percent (Table 13.4.3).

Table 13.4.3 Cost of Equity Calculation

Parameter	**Industry-Weighted Average %**	**Manufacturer**			
		A	B	C	D
(1) Average Beta	1.29	1.65	1.24	1.48	0.92
(2) Yield on 10-Year T-Bill (1928-2009)	5.2	-	-	-	-
(3) Market Risk Premium (1928-2009)	6.0	-	-	-	-
Cost of Equity (2)+[(1)*(3)]	12.9	-	-	-	-
Equity/Total Capital	87.5	90.8	94.7	75.0	82.4

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 used this method to calculate the cost of debt for all four manufacturers by using S&P ratings and adding the relevant spread to the risk-free rate.

In practice, investors use a variety of different maturity Treasury bonds to estimate the risk-free rate. DOE used the 10-year Treasury bond return because it captures long-term inflation expectations and is less volatile than short-term rates. The risk free rate is estimated to be approximately 5.2 percent, which is the average 10-year Treasury bond return between 1928 and 2009.

For the cost of debt, S&P’s Credit Services provided the average spread of corporate bonds for the four public manufacturers. DOE added the industry-weighted average spread to the average T-Bill rate. Since proceeds from debt issuance are tax deductible, DOE adjusted the gross cost of debt by the industry average tax rate to determine the net cost of debt for the industry. Table 13.4.4 presents the derivation of the cost of debt and the capital structure of the industry (*i.e.* the debt ratio (debt/total capital)).

Table 13.4.4 Cost of Debt Calculation

Parameter	**Industry-Weighted Average %**	**Manufacturer**			
		A	B	C	D
S&P's Bond Rating	--	AA+	A-	A+	AA-
(1) Yield on 10-Year T-Bill (1928-2009)	5.2	-	-	-	-
(2) Gross Cost of Debt	8.1	7.2	8.7	7.9	7.7
(3) Tax Rate	23.4	11.4	28.4	13.1	32.6
Net Cost of Debt (2) x (1-(3))	6.2	-	-	-	-
Debt/Total Capital	12.5	9.2	5.3	25.0	17.6

Using public information for these four companies, the initial estimate for the fluorescent lamp ballast industry's WACC was approximately 10.2 percent. Subtracting an inflation rate of 3.1 percent between 1928 and 2009, the inflation-adjusted WACC and the initial estimate of the discount rate used in the straw-man GRIM is 7.1 percent. DOE also asked for feedback on the 7.1 percent discount during manufacturer interviews and used this feedback to determine that a 7.4 percent discount was an appropriate discount rate for use in the GRIM.

13.4.5 Trial Standard Levels

DOE developed TSLs for fluorescent lamp ballasts. Consistent with the engineering analysis, DOE analyzed five representative product classes based on ten representative ballasts. Table 13.4.5 show the TSLs for all product classes. DOE scaled the standards for the representative product classes to create standards for the product classes that were not directly analyzed (the 8-foot high-output (HO) programmed start (PS) and residential PS product classes), as set forth in chapter 5 of the TSD. Table 13.4.5 presents the efficiency level (EL) at each TSL used in the GRIM.

Table 13.4.5 Trial Standard Levels for Fluorescent Lamp Ballasts

Product Class	**TSL 1**	**TSL 2**	**TSL 3A**	**TSL 3B**
IS and RS ballasts (not classified as residential) that operate: 4-foot MBP lamps 2-foot U-shaped lamps 8-foot slimline lamps	EL1	EL2	EL3	EL3

Product Class	TSL 1	TSL 2	TSL 3A	TSL 3B
PS ballasts (not classified as residential) that operate: 4-foot MBP lamps 2-foot U-shaped lamps 4-foot MiniBP SO lamps 4-foot MiniBP HO lamps	EL1	EL2	EL3	EL3
IS and RS ballasts (not classified as sign ballasts) that operate: 8-foot HO lamps	EL1	EL2	EL2	EL3
PS ballasts (not classified as sign ballasts) that operate: 8-foot HO lamps	EL1	EL2	EL2	EL3
Sign ballasts that operate: 8-foot HO lamps	EL1	EL1	EL1	EL1
IS and RS residential ballasts that operate: 4-foot MBP lamps 2-foot U-shaped lamps 8-foot slimline lamps	EL1	EL1	EL1	EL2
PS residential ballasts that operate: 4-foot MBP lamps 2-foot U-shaped lamps	EL1	EL1	EL1	EL2

TSL 1, which would set energy conservation standards at EL1 for all product classes, would eliminate the majority of currently available 4-foot MBP T12 RS (commercial and residential), low-efficiency 4-foot MBP T8 PS, magnetic 8-foot HO, and magnetic sign ballasts. Based on these impacts, TSL 1 would likely cause a migration from 4-foot MBP T12 RS ballasts (both commercial and residential) to 4-foot MBP T8 IS ballasts. TSL 1 also prevents inefficient T5 standard output and high output ballasts from becoming prevalent in future years. DOE would not anticipate any impact of TSL 1 on consumers of 8-foot slimline ballasts.

TSL 2 would establish energy conservation standards at EL2 for the IS/RS, PS, and 8-foot HO IS/RS product classes. This level would likely eliminate low efficiency two-lamp 4-foot MBP T8 IS commercial ballasts and the least efficient T12 8-foot slimline ballasts, causing a migration toward high efficiency two lamp 4-foot MBP T8 IS ballasts and 8-foot T8 slimline ballasts. DOE does not anticipate any impact of TSL 2 on four-lamp 4-foot MBP T8 IS ballast consumers. For PS ballasts, high-efficiency 4-foot MBP T8 ballasts and high-efficiency T5 standard output and high output ballasts are required at TSL 2. For the 8-foot HO IS/RS product class, this level would likely result in the elimination of the majority of current T12 electronic ballasts, but can be met with T8 electronic ballasts. As with TSL 1, TSL 2 would continue to use EL1 for the residential IS/RS product class, eliminating currently available 4-foot MBP T12 RS ballasts, but allowing higher efficiency T8 residential ballasts. In addition, the sign ballast efficiency level remains unchanged from TSL1.

TSL 3A would establish energy conservation standards at the maximum technologically feasible level for all product classes except for residential and 8-foot HO IS/RS product classes. As with TSL 2, the 8-foot HO IS/RS product class at TSL 3A results in the elimination of current T12 electronic ballasts, but can be met with T8 electronic ballasts. Consistent with TSLs 1 and 2, TSL 3A also requires EL1 for the residential IS/RS product class. This TSL represents the most stringent efficiency requirements where a positive LCC savings for each representative product class is maintained.

TSL 3B represents the maximum technologically feasible level for all product classes. This level would establish energy conservation standards at EL1 for sign ballasts, EL2 for residential IS/RS product classes, and EL3 for the commercial IS/RS and PS, and 8-foot HO IS/RS product classes. TSL 3B represents the highest EL analyzed in all representative product classes and is the max tech TSL. Ballasts that meet TSL 3B represent the most efficient models tested by DOE in their respective representative product classes.

13.4.6 NIA Shipment Forecast

The GRIM estimates manufacturer revenues based on total-unit-shipment forecasts and the distribution of these values by efficiency level. Changes in the efficiency mix at each standard level are a key driver of manufacturer finances. For this analysis, the GRIM used the NIA shipments forecasts under two scenarios: existing technologies and emerging technologies. In the existing technologies scenario, no technologies outside of those covered by this rulemaking were analyzed for market penetration. However, DOE recognizes that rapidly emerging new lighting technologies could penetrate the fluorescent lighting market and significantly affect ballast shipment forecasts. Therefore, in the emerging technologies scenario, DOE calculated the market penetration of LED, ceramic metal halide (CMH), and dimming ballast systems through 2043, assessing each sector separately. DOE decreased the analyzed market size in each year in each sector by the amount that corresponded to the highest level of market penetration achieved by LED, CMH, or dimming ballast systems. The assumptions and methodology that drive these scenarios and the details specific to each are described in chapter 11 of the final rule TSD.

Only the shipments in 2011 and beyond have an impact on INPV because 2011 is the base year to which future cash flows are summed. Table 13.4.6 shows total shipments forecasted in the shipment analysis for fluorescent lamp ballasts in 2014 under each scenario. In order to aggregate shipments in the GRIM, DOE assigned each of the representative units to one of the five representative product classes shown in Table 13.4.5. DOE aggregated the shipments for all the scaled product classes under the corresponding representative product class and used the cost curve for the representative product class with which it is associated.

Table 13.4.6 Total Base Case NIA Shipments Forecast in 2014[b] under the Existing and Emerging Technologies Scenarios

Representative Product Class No.	Representative Unit	Total Industry Shipments (thousands)	
		Existing Technologies	Emerging Technologies
1	Two Lamp Normal BF 4ft MBP IS & RS	37,875	36,766
2	Two Lamp Normal BF 4ft MBP PS	5,613	5,448
1	Four Lamp Normal BF 4ft MBP IS & RS	15,602	15,145
2	Four Lamp Normal BF 4ft MBP PS	1,962	1,905
1	Two Lamp Normal BF 8ft SP Slimline	1,355	1,355
3	Two Lamp 8ft RDC HO IS & RS	70	70
2	Two Lamp Normal BF 4ft T5 MiniBP SO	14,372	13,946
2	Two Lamp 4ft T5 MiniBP HO	6,253	6,253
6	Two Lamp 4ft MBP IS & RS Residential	29,243	29,243
5	Four Lamp Sign Ballast	3,866	3,808

As part of the shipments analysis, DOE estimated the base-case shipment distribution by efficiency level for each representative ballast. In the standards case, DOE determined efficiency distributions for cases in which a potential standard applies for 2014 and beyond. DOE assumed that product efficiencies in the base case that did not meet the standard under consideration would move to meet the new standard in 2014 under two scenarios: roll-up and shift. The roll-up scenario represents the case in which all shipments in the base case that do not meet the new standard roll up to meet the new standard level. Consumers in the base case who purchase ballasts above the standard level are not affected as they are assumed to continue to purchase the same base-case ballast or lamp-and-ballast system in the standards case. In contrast, in a shift scenario, DOE assumes that any consumer may purchase a more efficient ballast. The shift scenario models a standards case in which all base-case consumer purchases are affected by the standard (regardless of whether their base-case efficiency is below the standard). As the standard level increases, market share migrates to, and accumulates at, the highest efficiency level because it represents "max tech" for each representative ballast type (*i.e.*, moving beyond it is impossible given available technology options). See chapter 11 of the final rule TSD for more information on the ballasts standards-case shipment scenarios.

[b] The compliance date for the fluorescent lamp ballast energy conservation standard is estimated to be October 2014.

13.4.7 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 more costly than baseline components. The changes in the MPCs of the analyzed products can affect the revenues, gross margins, and cash flow of the industry, making these product cost data key GRIM inputs for DOE's analysis.

To calculate MPCs at each efficiency level, DOE followed a two-step process. First, DOE derived MSPs for each analyzed product and efficiency level from blue book, online retail, and teardown-sourced prices as described in chapter 5 of the TSD. Next, DOE discounted these MSPs by the manufacturer markup to arrive at the MPCs. For all product classes, DOE used a 1.4 manufacturer markup based on manufacturer feedback. DOE also used confidential information from manufacturer interviews to verify its MPC estimates. In addition, DOE used teardown cost data to disaggregate the MPCs into material, labor, and overhead costs. DOE used a depreciation value for fluorescent lamp ballasts that is consistent with historical information in SEC 10-Ks. The remainder of total overhead was allocated to factory overhead.

As stated in section 13.4.6, DOE allocated shipments for the unanalyzed product classes to the product class for which the amended energy conservation standard is scaled. That way, the total revenue and INPV impacts for each representative product class is also representative of the INPV impacts on the unanalyzed product classes used to promulgate the amended energy conversation standards. Table 13.4.7 through Table 13.4.16 show the production cost estimates used in the GRIM for each representative unit.

Table 13.4.7 MPC Breakdown for Two Lamp Normal BF 4ft MBP IS & RS

EL (BLE)	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline (78.3)	0.53	5.11	0.11	0.26	6.01	1.40	8.41
EL 1 (86.0)	0.44	4.21	0.09	0.22	4.96	1.40	6.94
EL 2 (90.1)	0.56	5.37	0.12	0.27	6.32	1.40	8.85
EL 3 (91.1)	0.58	5.63	0.12	0.29	6.62	1.40	9.27

Table 13.4.8 MPC Breakdown for Two Lamp Normal BF 4ft MBP PS

EL (BLE)	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline (83.2)	0.53	5.09	0.11	0.26	5.99	1.40	8.39
EL 2 (89.9)	0.58	5.64	0.12	0.29	6.63	1.40	9.28
EL 3 (91.0)	0.60	5.82	0.13	0.30	6.85	1.40	9.59

Table 13.4.9 MPC Breakdown for Four Lamp Normal BF 4ft MBP IS & RS

EL (BLE)	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
EL 2 (91.0)	0.62	5.94	0.13	0.30	6.99	1.40	9.79
EL 3 (93.3)	0.73	7.06	0.15	0.36	8.31	1.40	11.63

Table 13.4.10 MPC Breakdown for Four Lamp Normal BF 4ft MBP PS

EL (BLE)	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline (81.9)	0.57	5.50	0.12	0.28	6.46	1.40	9.05
EL 1 (90.5)	0.74	7.19	0.16	0.37	8.46	1.40	11.84
EL 3 (92.8)	0.84	8.09	0.18	0.41	9.52	1.40	13.33

Table 13.4.11 MPC Breakdown for Two Lamp Normal BF 8ft SP Slimline

EL (BLE)	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
EL 1 (88.9)	0.56	5.37	0.12	0.27	6.31	1.40	8.84
EL 2 (91.6)	0.63	6.10	0.13	0.31	7.18	1.40	10.05
EL 3 (92.9)	0.65	6.25	0.14	0.32	7.35	1.40	10.29

Table 13.4.12 MPC Breakdown for Two Lamp 8ft RDC HO IS & RS

EL (BLE)	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline (73.9)	0.83	8.05	0.18	0.41	9.46	1.40	13.25
EL 1 (80.4)	0.60	5.80	0.13	0.30	6.82	1.40	9.55
EL 2 (91.7)	0.51	4.95	0.11	0.25	5.82	1.40	8.15
EL 3 (92.5)	0.69	6.71	0.15	0.34	7.89	1.40	11.05

Table 13.4.13 MPC Breakdown for Two Lamp Normal BF 4ft T5 MiniBP SO

EL (BLE)	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline (82.3)	0.68	6.55	0.14	0.33	7.70	1.40	10.78
EL 1 (88.7)	0.68	6.59	0.14	0.34	7.75	1.40	10.85
EL 2 (89.6)	0.75	7.24	0.16	0.37	8.51	1.40	11.92
EL 3 (92.0)	0.97	9.33	0.20	0.48	10.97	1.40	15.36

Table 13.4.14 MPC Breakdown for Two Lamp 4ft T5 MiniBP HO

EL (BLE)	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline (82.1)	0.60	5.84	0.13	0.30	6.86	1.40	9.61
EL 1 (90.6)	0.79	7.64	0.17	0.39	8.99	1.40	12.58
EL 2 (91.5)	0.92	8.93	0.19	0.46	10.50	1.40	14.70
EL 3 (92.3)	1.05	10.18	0.22	0.52	11.97	1.40	16.76

Table 13.4.15 MPC Breakdown for Two Lamp 4ft MBP IS & RS Residential

EL (BLE)	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline (77.7)	0.29	2.84	0.06	0.15	3.34	1.40	4.68
EL 1 (87.2)	0.24	2.29	0.05	0.12	2.69	1.40	3.77
EL 2 (90.0)	0.29	2.81	0.06	0.14	3.30	1.40	4.62

Table 13.4.16 MPC Breakdown for Four Lamp Sign Ballast

EL (BLE)	Labor $	Material $	Overhead $	Dep. $	MPC $	Mfr. Markup	MSP $
Baseline (74.6)	2.53	24.43	0.53	1.25	28.74	1.40	40.23
EL 1 (90.8)	2.24	21.61	0.47	1.10	25.41	1.40	35.58

13.4.8 Product and Capital Conversion Costs

New and amended energy conservation standards will cause manufacturers to incur conversion costs to bring their production facilities and product designs into compliance. 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, development, testing, marketing, and other non-capitalized costs necessary to make product designs comply with the new or amended energy conservation standard. Capital conversion costs are investments in property, plant, and equipment necessary to adapt or change existing production facilities such that new product designs can be fabricated and assembled. For the final rule, DOE converted the NOPR product and capital conversion costs to 2010$ from 2009$ using the producer price index (PPI) for the relevant industry. The PPI is disaggregated into each NAICS code. For fluorescent lamp ballasts, DOE updated the conversion costs using the specific PPI index under NAICS code 335311 – "Electric power and specialty transformer manufacturing" and series ID PCU3353113353115 – "Fluorescent lamp ballasts."

DOE's interviews with manufacturers revealed that the majority of the conversion costs manufacturers expect to incur at various TSLs derive from the need to develop new and improved circuit designs, rather than the purchase of new capital equipment. Due to the flexible nature of most ballast production equipment, manufacturers do not expect new or amended standards to strand a significant share of their production assets. As opposed to other more capital-intensive appliance industries, much of the cash outlay required to achieve higher efficiency levels would be expensed through research and development, engineering, and testing efforts.

DOE based its estimates of the product conversion costs that would be required to meet each TSL on information obtained from manufacturer interviews, the engineering analysis, the NIA shipment analysis, and market information about the number of models and stock-keeping units (SKUs) each major manufacturer supports. DOE estimated the product development costs manufacturers would incur for each model that would need to be converted in response to new or amended energy conservation standards based on the necessary engineering and testing resources required to redesign each model. The R&D resources required to reach the efficiency levels represented at each TSL varied according to whether models could be converted based on minor upgrades, redesigns based on existing topologies, or full redesigns. In addition to per-model R&D costs, DOE considered testing and validation costs for every SKU, which included internal testing, UL testing, additional certifications, pilot runs, and product training. DOE then multiplied these per-model and per-SKU estimates by the total number of ballast models and SKUs offered based on information from manufacturer catalogs and interviews to calculate the total potential costs each manufacturer could incur to redesign its products. Next, to assign these costs to particular representative product classes, DOE multiplied this total for each manufacturer by the percentage of models in each product class based on the NIA shipment analysis and manufacturer feedback. Lastly, to consider the models manufacturers offered that already met efficiency levels above baseline, DOE multiplied the total costs for each product class by the percentage of models DOE determined would need to be redesigned at each efficiency level based on data from the engineering analysis and manufacturer catalogs.

This methodology derived total product conversion cost estimates for most product classes and efficiency levels. For residential ballasts, however, DOE assumed a smaller redesign cost per model. According to manufacturer interviews, the residential ballast market does not support manufacturer attempts to differentiate through better designs, product variation, or additional value-added features. As such, suppliers, often Asian manufacturers selling directly to fixture manufacturers, make little attempt to compete on anything other than price. Interviews suggested suppliers would leverage R&D invested in the larger, more valuable commercial market, making minor design adjustments to meet minimum requirements of the residential market. For sign ballasts, DOE determined the number of magnetic models on the market based on manufacturer catalogs and estimated testing and redesign costs for each of these models.

As discussed above, DOE also estimated the capital conversion costs manufacturers would incur to comply with potential amended energy conservation standards represented by each TSL. During interviews, DOE asked manufacturers to estimate the capital expenditures required to expand the production of higher-efficiency products. These estimates included the required tooling and plant changes that would be necessary if product lines meeting the potential required efficiency level did not currently exist. Estimates for capital conversion costs varied greatly from manufacturer to manufacturer, as manufacturers anticipated different paths to compliance based on the modernity, flexibility, and level of automation of the equipment already existing in their factories. However, all manufacturers DOE interviewed indicated that capital costs would be relatively moderate compared to the required engineering effort. The modular nature of ballast production and the flexibility of the necessary production capital allows for significant equipment sharing across product lines. Based on interviews, DOE assumed that for most manufacturers, design changes would require moderate product conversion costs but would not require significant changes to existing production lines and equipment. It is therefore unlikely that most manufacturers would require high levels of capital expenditures compared to ordinary capital additions or existing net plants, property, and equipment (PPE).

To calculate its estimates of capital conversion costs, DOE aggregated its estimated capital costs for the major players in the industry rather than scaled up a "typical" manufacturer's expected conversion costs. Two considerations drove this choice in methodology. First, manufacturer feedback varied widely, making it impossible to characterize a "typical" manufacturer for conversion cost purposes. Second, the expected costs often depended upon the timing of the manufacturers' last redesign efforts and its strategy regarding the capital intensity of their plants and sourcing decisions. DOE estimated that some manufacturers would incur very minor capital expenditures per product class for testing equipment, even at max tech levels, as their factories' capital equipment would not require significant modification to produce higher-efficiency ballasts. For other manufacturers, DOE assumed greater investments would be necessary to upgrade lines for each product class with new wave solder equipment, reflow solder systems and surface mount device placement machines. The placement machines become increasingly important as ballasts become more complex with additional circuitry and components. DOE estimates capital conversion costs would rise most rapidly at high-efficiency levels not only because of the new production and testing equipment described above but also because manufacturers would need to expand capacity to account for lower throughput on high-efficiency lines.

For residential ballasts, DOE assumed the same magnitude of conversion costs as for commercial ballasts of the same starting method. While residential ballasts are generally not produced by the major four manufacturers, the Asian manufacturers who source them to domestic companies would be required to make similar modifications to their production lines in response to standards. For sign ballasts, DOE was unable to interview a representative sample of the industry. However, DOE recognizes that magnetic ballast lines have more capital exposure to changes in efficiency standards than electronic lines due to the change in technology. Because several manufacturers produce magnetic sign ballasts, DOE assumed new lines would be needed to convert magnetic products to electronic ballasts and scaled these line costs to the entire sign ballast market for this product class.

Finally, DOE estimated industry capital conversion costs for all analyzed product classes other than residential ballasts and sign ballasts by extrapolating the interviewed manufacturers' costs for each product class to account for the companies that DOE did not interview. DOE's estimates of the product and capital conversion costs for each representative product class can be found in Table 13.4.17 through Table 13.4.20 below.

Table 13.4.17 Product and Capital Conversion Costs for Product Class 1 (4-foot MBP IS and RS Commercial Ballasts and 8-foot SP Slimline Ballasts) by TSL

TSL (Efficiency Level)	**Product Conversion Costs** ***2010$ millions***	**Capital Conversion Costs** ***2010$ millions***
TSL 1 (EL 1)	1.9	0.3
TSL 2 (EL 2)	10.6	2.6
TSL 3A, TSL 3B (EL 3)	31.1	7.8

Table 13.4.18 Product and Capital Conversion Costs for Product Class 2 (PS Ballasts) by TSL

TSL (Efficiency Level)	**Product Conversion Costs** ***2010$ millions***	**Capital Conversion Costs** ***2010$ millions***
TSL 1 (EL 1)	0.8	4.7
TSL 2 (EL 2)	4.5	9.2
TSL 3A, TSL 3B (EL 3)	12.2	12.0

Table 13.4.19 Product and Capital Conversion Costs for Product Class 3 (8-foot HO IS and RS Ballasts) by TSL

TSL (Efficiency Level)	Product Conversion Costs *2010$ millions*	Capital Conversion Costs *2010$ millions*
TSL 1 (EL 1)	0.0	0.3
TSL 2, TSL 3A (EL 2)	0.1	2.1
TSL 3B (EL 3)	0.3	2.6

Table 13.4.20 Product and Capital Conversion Costs for Product Class 5 (Sign Ballasts) by TSL

TSL (Efficiency Level)	Product Conversion Costs *2010$ millions*	Capital Conversion Costs *2010$ millions*
TSL 1, TSL 2, TSL 3 (EL 1)	2.4	6.0

Table 13.4.21 Product and Capital Conversion Costs for Product Class 6 (4-foot MBP IS and RS Residential Ballasts) by TSL

TSL (Efficiency Level)	Product Conversion Costs *2010$ millions*	Capital Conversion Costs *2010$ millions*
TSL 1, TSL 2, TSL 3A (EL 1)	0.2	0.3
TSL 3B (EL 2)	2.4	0.9

13.4.9 Markup Scenarios

DOE used several standards case markup scenarios to represent the uncertainty about the impacts of amended energy conservation standards on prices and profitability. In the base case, DOE used the same baseline markups calculated in the engineering analysis for all product classes. In the standards case, DOE modeled two markup scenarios to represent the uncertainty about the potential impacts on prices and profitability following the implementation of amended energy conservation standards: (1) a preservation of operating profit markup scenario, and (2) a two-tier markup scenario. These scenarios lead to different markups values, which, when applied to the inputted MPCs, result in varying revenue and cash flow impacts.

13.4.9.1 Preservation of Operating Profit Markup Scenario

DOE implemented the preservation of operating profit markup scenario because manufacturers stated that they do not expect to be able to markup the full cost of production given the highly competitive market, in the standards case. The preservation of operating profit markup scenario assumes that manufacturers are able to maintain only the base-case total operating profit in absolute dollars in the standards case, despite higher product costs and investment. The base-case total operating profit is derived from marking up the cost of goods sold for each product by a flat percentage (the baseline markup, discussed in chapter 5 of the final rule TSD) to cover standard SG&A expenses, R&D expenses, and profit. To derive this percentage, DOE evaluated publicly available financial information for manufacturers of ballasts. DOE also requested feedback on this value during manufacturer interviews. DOE adjusted the manufacturer markups in the

GRIM at each TSL to yield approximately the same earnings before interest and taxes in the standards case in the year after the compliance date of the amended standards as in the base case. DOE assumed that the industry-wide impacts would occur under the new minimum efficiency levels. DOE altered the markups only for the minimally compliant products in this scenario, with margin impacts not occurring for products that already exceed the amended energy conservation standard. The preservation of operating profit markup scenario represents the upper bound of industry profitability following amended energy conservation standards. Under this scenario, while manufacturers are not able to earn additional operating profit on higher production costs and the investments required to comply with the amended energy conservation standard, they are able to maintain the same operating profit in the standards case as was earned in the base case.

Table 13.4.22 through Table 13.4.41 lists the representative ballast types DOE analyzed with the corresponding markups at each TSL under the preservation of operating profit markup scenario. Separate markups were calculated for each of the four shipment scenarios, but the markups did not vary within four digits between the emerging and existing technologies scenarios, so the roll-up and shift shipment scenario markups presented encompass both technology scenarios. It is worth noting that in cases where the average MPC decreases at a higher efficiency level, this scenario yields a higher markup at the new baseline than in the base case.

Table 13.4.22 Preservation of Operating Profit Markups for Two Lamp Normal BF 4ft MBP IS & RS (Roll-up Shipment Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (78.3)	1.4000	-	-	-	-
EL 1 (86.0)	1.4000	1.4001	-	-	-
EL 2 (90.1)	1.4000	1.4000	1.3789	-	-
EL 3 (91.1)	1.4000	1.4000	1.4000	1.3778	1.3778

Table 13.4.23 Preservation of Operating Profit Markups for Two Lamp Normal BF 4ft MBP IS & RS (Shift Shipment Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (78.3)	1.4000	-	-		-
EL 1 (86.0)	1.4000	1.3636	-		-
EL 2 (90.1)	1.4000	1.3636	1.3636	-	-
EL 3 (91.1)	1.4000	1.4000	1.4000	1.3778	1.3778

Table 13.4.24 Preservation of Operating Profit Markups for Two Lamp Normal BF 4ft MBP PS (Roll-up Shipment Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (83.2)	1.4000	-	-	-	-
EL 2 (89.9)	1.4000	1.3907	1.3907	-	-
EL 3 (91.0)	1.4000	1.4000	1.4000	1.3886	1.3886

Table 13.4.25 Preservation of Operating Profit Markups for Two Lamp Normal BF 4ft MBP PS (Shift Shipment Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (83.2)	1.4000	-	-	-	-
EL 2 (89.9)	1.4000	1.3827	1.3827	-	-
EL 3 (91.0)	1.4000	1.4000	1.4000	1.3886	1.3886

Table 13.4.26 Preservation of Operating Profit Markups for Four Lamp Normal BF 4ft MBP IS & RS (Roll-up Shipment Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
EL 2 (92.0)	1.4000	1.4000	1.4000	-	-
EL 3 (93.3)	1.4000	1.4000	1.4000	1.3830	1.3830

Table 13.4.27 Preservation of Operating Profit Markups for Four Lamp Normal BF 4ft MBP IS & RS (Shift Shipment Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
EL 2 (92.0)	1.4000	1.4000	1.4000	-	-
EL 3 (93.3)	1.4000	1.4000	1.4000	1.3830	1.3830

Table 13.4.28 Preservation of Operating Profit Markups for Four Lamp Normal BF 4ft MBP PS (Roll-up Shipment Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (81.9)	1.4000	-	-	-	-
EL 1 (90.5)	1.4000	1.3702	-	-	-
EL 3 (92.8)	1.4000	1.4000	1.3592	1.3592	1.3592

Table 13.4.29 Preservation of Operating Profit Markups for Four Lamp Normal BF 4ft MBP PS (Shift Shipment Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (81.9)	1.4000	-	-	-	-
EL 1 (90.5)	1.4000	1.3607	-	-	-
EL 3 (92.8)	1.4000	1.4000	1.3592	1.3592	1.3592

Table 13.4.30 Preservation of Operating Profit Markups for Two Lamp Normal BF 8ft SP Slimline (Roll-up Shipment Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
EL 1 (88.9)	1.4000	1.4000	-	-	-
EL 2 (91.6)	1.4000	1.4000	1.3990	-	-
EL 3 (92.9)	1.4000	1.4000	1.4000	1.3967	1.3967

Table 13.4.31 Preservation of Operating Profit Markups for Two Lamp Normal BF 8ft SP Slimline (Shift Shipment Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
EL 1 (88.9)	1.4000	1.4000	-	-	-
EL 2 (91.6)	1.4000	1.4000	1.3228	-	-
EL 3 (92.9)	1.4000	1.4000	1.4000	1.3967	1.3967

Table 13.4.32 Preservation of Operating Profit Markups for Two Lamp 8ft RDC HO IS & RS (Roll-up Shipment Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (73.9)	1.4000	-	-	-	-
EL 1 (80.4)	1.4000	1.4094	-	-	-
EL 2 (91.7)	1.4000	1.4000	1.4041	1.4041	-
EL 3 (92.5)	1.4000	1.4000	1.4000	1.4000	1.3640

Table 13.4.33 Preservation of Operating Profit Markups for Two Lamp 8ft RDC HO IS & RS (Shift Shipment Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (73.9)	1.4000	-	-	-	-
EL 1 (80.4)	1.4000	1.0139	-	-	-
EL 2 (91.7)	1.4000	1.0139	1.0075	1.0075	-
EL 3 (92.5)	1.4000	1.4000	1.4000	1.4000	1.3640

Table 13.4.34 Preservation of Operating Profit Markups for Two Lamp Normal BF 4ft T5 MiniBP SO (Roll-up Shipment Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (82.3)	1.4000	-	-	-	-
EL 1 (88.7)	1.4000	1.3998	-	-	-
EL 2 (89.6)	1.4000	1.4000	1.3873	-	-
EL 3 (92.0)	1.4000	1.4000	1.4000	1.3579	1.3579

Table 13.4.35 Preservation of Operating Profit Markups for Two Lamp Normal BF 4ft T5 MiniBP SO (Shift Shipment Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (82.3)	1.4000	-	-	-	-
EL 1 (88.7)	1.4000	1.3998	-	-	-
EL 2 (89.6)	1.4000	1.4000	1.3828	-	-
EL 3 (92.0)	1.4000	1.4000	1.4000	1.3579	1.3579

Table 13.4.36 Preservation of Operating Profit Markups for Two Lamp 4ft T5 MiniBP HO (Roll-up Shipment Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (82.1)	1.4000	-	-	-	-
EL 1 (90.6)	1.4000	1.3957	-	-	-
EL 2 (91.5)	1.4000	1.4000	1.3773	-	-
EL 3 (92.3)	1.4000	1.4000	1.4000	1.3636	1.3636

Table 13.4.37 Preservation of Operating Profit Markups for Two Lamp 4ft T5 MiniBP HO (Shift Shipment Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (82.1)	1.4000	-	-	-	-
EL 1 (90.6)	1.4000	1.3957	-	-	-
EL 2 (91.5)	1.4000	1.4000	1.3720	-	-
EL 3 (92.3)	1.4000	1.4000	1.4000	1.3636	1.3636

Table 13.4.38 Preservation of Operating Profit Markups for Two Lamp 4ft MBP IS & RS Residential (Roll-up Shipment Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (77.7)	1.4000	-	-	-	-
EL 1 (87.2)	1.4000	1.4020	1.4020	1.4020	-
EL 2 (90.0)	1.4000	1.4000	1.4000	1.4000	1.3800

Table 13.4.39 Preservation of Operating Profit Markups for Two Lamp 4ft MBP IS & RS Residential (Shift Shipment Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (77.7)	1.4000	-	-	-	-
EL 1 (87.2)	1.4000	1.3810	1.3810	1.3810	-
EL 2 (90.0)	1.4000	1.3810	1.3810	1.3810	1.3800

Table 13.4.40 Preservation of Operating Profit Markups for Four Lamp Sign Ballast (Roll-up Shipment Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (74.6)	1.4000	-	-	-	-
EL 1 (90.8)	1.4000	1.4069	1.4069	1.4069	1.4069

Table 13.4.41 Preservation of Operating Profit Markups for Four Lamp Sign Ballast (Shift Shipment Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (74.6)	1.4000	-	-	-	-
EL 1 (90.8)	1.4000	1.4069	1.4069	1.4069	1.4069

13.4.9.2 Two-Tier Markup Scenario

DOE also modeled a lower bound profitability scenario. During interviews, multiple manufacturers stated that they offer two tiers of product lines that are differentiated, in part, by efficiency level. The higher-efficiency tier typically earns a premium over the baseline efficiency tier. Several manufacturers suggested that the premium currently earned by the higher-efficiency tier would erode under new or amended standards due to the disappearance of the baseline efficiency tier, which would significantly harm profitability. Because of this pricing dynamic described by manufacturers and because of the pressure from luminaire manufacturers to commoditize the baseline efficiency tier, DOE also modeled a two-tier markup scenario. In this scenario, DOE assumed that the markup on fluorescent lamp ballasts varies according to two efficiency tiers in both the base case and the standards case. During the MIA interviews, manufacturers provided information on the range of typical efficiency levels in those two tiers and the change in profitability at each level. DOE used this information, retail prices derived in its product price determination, and industry average gross margins to estimate markups for fluorescent lamp ballasts under a two-tier pricing strategy in the base case. In the standards case, DOE modeled the situation in which portfolio reduction squeezes the margin of higher-efficiency products as they become the new baseline, presumably high-volume products. This scenario is consistent with information submitted during manufacturing interviews and responds to manufacturers' concern that DOE standards could severely disrupt profitability.

Table 13.4.42 through Table 13.4.61 lists the products DOE analyzed with the corresponding two-tier markups at each TSL.

Table 13.4.42 Two-Tier Markups for Two Lamp Normal BF 4ft MBP IS & RS (Existing Technologies Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (78.3)	1.3324	-	-	-	-
EL 1 (86.0)	1.3324	1.3324	-	-	-
EL 2 (90.1)	1.5374	1.5374	1.3324	-	-
EL 3 (91.1)	1.5374	1.5374	1.5374	1.3324	1.3324

Table 13.4.43 Two-Tier Markups for Two Lamp Normal BF 4ft MBP IS & RS (Emerging Technologies Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (78.3)	1.3258	-	-	-	-
EL 1 (86.0)	1.3258	1.3258	-	-	-
EL 2 (90.1)	1.5297	1.5297	1.3258	-	-
EL 3 (91.1)	1.5297	1.5297	1.5297	1.3258	1.3258

Table 13.4.44 Two-Tier Markups for Two Lamp Normal BF 4ft MBP PS (Existing Technologies Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (83.2)	1.3324	-	-	-	-
EL 2 (89.9)	1.5374	1.3324	1.3324	-	-
EL 3 (91.0)	1.5374	1.5374	1.5374	1.3324	1.3324

Table 13.4.45 Two-Tier Markups for Two Lamp Normal BF 4ft MBP PS (Emerging Technologies Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (83.2)	1.3258	-	-	-	-
EL 2 (89.9)	1.5297	1.3258	1.3258	-	-
EL 3 (91.0)	1.5297	1.5297	1.5297	1.3258	1.3258

Table 13.4.46 Two-Tier Markups for Four Lamp Normal BF 4ft MBP IS & RS (Existing Technologies Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
EL 2 (92.0)	1.3324	1.3324	1.3324	-	-
EL 3 (93.3)	1.5374	1.5374	1.5374	1.3324	1.3324

Table 13.4.47 Two-Tier Markups for Four Lamp Normal BF 4ft MBP IS & RS (Emerging Technologies Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
EL 2 (92.0)	1.3258	1.3258	1.3258	-	-
EL 3 (93.3)	1.5297	1.5297	1.5297	1.3258	1.3258

Table 13.4.48 Two-Tier Markups for Four Lamp Normal BF 4ft MBP PS (Existing Technologies Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (81.9)	1.3324	-	-	-	-
EL 1 (90.5)	1.3324	1.3324	-	-	-
EL 3 (92.8)	1.5374	1.5374	1.3324	1.3324	1.3324

Table 13.4.49 Two-Tier Markups for Four Lamp Normal BF 4ft MBP PS (Emerging Technologies Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (81.9)	1.3258	-	-	-	-
EL 1 (90.5)	1.3258	1.3258	-	-	-
EL 3 (92.8)	1.5297	1.5297	1.3258	1.3258	1.3258

Table 13.4.50 Two-Tier Markups for Two Lamp Normal BF 8ft SP Slimline (Existing Technologies Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
EL 1 (88.9)	1.3324	1.3324	-	-	-
EL 2 (91.6)	1.3324	1.3324	1.3324	-	-
EL 3 (92.9)	1.5374	1.5374	1.5374	1.3324	1.3324

Table 13.4.51 Two-Tier Markups for Two Lamp Normal BF 8ft SP Slimline (Emerging Technologies Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
EL 1 (88.9)	1.3258	1.3258	-	-	-
EL 2 (91.6)	1.3258	1.3258	1.3258	-	-
EL 3 (92.9)	1.5297	1.5297	1.5297	1.3258	1.3258

Table 13.4.52 Two-Tier Markups for Two Lamp 8ft RDC HO IS & RS (Existing Technologies Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (73.9)	1.3324	-	-	-	-
EL 1 (80.4)	1.3324	1.3324	-	-	-
EL 2 (91.7)	1.5374	1.5374	1.3324	1.3324	-
EL 3 (92.5)	1.5374	1.5374	1.5374	1.5374	1.3324

Table 13.4.53 Two-Tier Markups for Two Lamp 8ft RDC HO IS & RS (Emerging Technologies Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (73.9)	1.3258	-	-	-	-
EL 1 (80.4)	1.3258	1.3258	-	-	-
EL 2 (91.7)	1.5297	1.5297	1.3258	1.3258	-
EL 3 (92.5)	1.5297	1.5297	1.5297	1.5297	1.3258

Table 13.4.54 Two-Tier Markups for Two Lamp Normal BF 4ft T5 MiniBP SO (Existing Technologies Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (82.3)	1.3324	-	-	-	-
EL 1 (88.7)	1.3324	1.3324	-	-	-
EL 2 (89.6)	1.5374	1.5374	1.3324	-	-
EL 3 (92.0)	1.5374	1.5374	1.5374	1.3324	1.3324

Table 13.4.55 Two-Tier Markups for Two Lamp Normal BF 4ft T5 MiniBP SO (Emerging Technologies Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (82.3)	1.3258	-	-	-	-
EL 1 (88.7)	1.3258	1.3258	-	-	-
EL 2 (89.6)	1.5297	1.5297	1.3258	-	-
EL 3 (92.0)	1.5297	1.5297	1.5297	1.3258	1.3258

Table 13.4.56 Two-Tier Markups for Two Lamp 4ft T5 MiniBP HO (Existing Technologies Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (82.1)	1.3324	-	-	-	-
EL 1 (90.6)	1.3324	1.3324	-	-	-
EL 2 (91.5)	1.5374	1.5374	1.3324	-	-
EL 3 (92.3)	1.5374	1.5374	1.5374	1.3324	1.3324

Table 13.4.57 Two-Tier Markups for Two Lamp 4ft T5 MiniBP HO (Emerging Technologies Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (82.1)	1.3258	-	-	-	-
EL 1 (90.6)	1.3258	1.3258	-	-	-
EL 2 (91.5)	1.5297	1.5297	1.3258	-	-
EL 3 (92.3)	1.5297	1.5297	1.5297	1.3258	1.3258

Table 13.4.58 Two-Tier Markups for Two Lamp 4ft MBP IS & RS Residential (Existing Technologies Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (77.7)	1.3324	-	-	-	-
EL 1 (87.2)	1.3324	1.3324	1.3324	1.3324	-
EL 2 (90.0)	1.5374	1.5374	1.5374	1.5374	1.3324

Table 13.4.59 Two-Tier Markups for Two Lamp 4ft MBP IS & RS Residential (Emerging Technologies Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (77.7)	1.3258	-	-	-	-
EL 1 (87.2)	1.3258	1.3258	1.3258	1.3258	-
EL 2 (90.0)	1.5297	1.5297	1.5297	1.5297	1.3258

Table 13.4.60 Two-Tier Markups for Four Lamp Sign Ballast (Existing Technologies Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (74.6)	1.3324	-	-	-	-
EL 1 (90.8)	1.5374	1.3324	1.3324	1.3324	1.3324

Table 13.4.61 Two-Tier Markups for Four Lamp Sign Ballast (Emerging Technologies Scenario)

EL (BE)	Markups by TSL				
	Baseline	TSL 1	TSL 2	TSL 3A	TSL 3B
Baseline (74.6)	1.3258	-	-	-	-
EL 1 (90.8)	1.5297	1.3258	1.3258	1.3258	1.3258

13.5 INDUSTRY FINANCIAL IMPACTS

Using the inputs and scenarios described in the previous sections, the GRIM estimated indicators of financial impacts on the fluorescent lamp ballast industry. The following sections detail additional inputs and assumptions for fluorescent lamp ballasts. 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.

13.5.1 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 case. The INPV is different from DOE's net present value, which is applied to 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 fluorescent lamp ballasts GRIM estimates cash flows from 2011 to 2043. This timeframe models both the short-term impacts on the industry from the announcement of the standard until the compliance date (2011 until an estimated compliance date of October 2014) and a long-term assessment over the 30-year analysis period used in the NIA (2014 – 2043).

In the MIA, DOE compares the INPV of the base case (no amended energy conservation standards) to that of each TSL in the standards case. The difference between the base case and a standards case INPV is an estimate of the economic impacts that implementing that particular TSL would have on the industry. For the fluorescent lamp ballast industry, DOE examined the two markup scenarios described above: the preservation of operating profit markup and the two-tier markup. DOE also examined the existing and emerging technologies scenarios and the roll-up and shift shipment scenarios. This yields eight sets of INPV results for fluorescent lamp ballasts, bounded by the preservation of operating profit markup, existing technologies, and shift shipments combination and the two-tier markup, emerging technologies, and roll-up shipments combination. Table 13.5.1 through Table 13.5.8 provide the INPV estimates for the fluorescent lamp ballasts industry.

Table 13.5.1 Changes in Industry Net Present Value for Fluorescent Lamp Ballasts (Preservation of Operating Profit Markup, Roll-up Shipments, and Existing Technologies Scenarios)

	Units	**Base Case**	**Trial Standard Level**			
			1	**2**	**3A**	**3B**
INPV	*(2010$ millions)*	1,219	1,208	1,187	1,146	1,141
Change in INPV	*(2010$ millions)*	-	(10.7)	(32.1)	(73.1)	(77.6)
	(%)	-	-0.9%	-2.6%	-6.0%	-6.4%

*For tables in section 13.5.1, values in parenthesis indicate negative numbers

Table 13.5.2 Changes in Industry Net Present Value for Fluorescent Lamp Ballasts (Preservation of Operating Profit Markup, Roll-up Shipments, and Emerging Technologies Scenarios)

	Units	**Base Case**	**Trial Standard Level**			
			1	**2**	**3A**	**3B**
INPV	*(2010$ millions)*	733	721	702	671	667
Change in INPV	*(2010$ millions)*	-	(11.2)	(30.5)	(61.4)	(66.0)
	(%)	-	-1.5%	-4.2%	-8.4%	-9.0%

Table 13.5.3 Changes in Industry Net Present Value for Fluorescent Lamp Ballasts (Preservation of Operating Profit Markup, Shift Shipments, and Existing Technologies Scenarios)

	Units	**Base Case**	**Trial Standard Level**			
			1	**2**	**3A**	**3B**
INPV	*(2010$ millions)*	1,219	1,199	1,176	1,144	1,141
Change in INPV	*(2010$ millions)*	-	(19.6)	(42.4)	(74.5)	(77.6)
	(%)	-	-1.6%	-3.5%	-6.1%	-6.4%

Table 13.5.4 Changes in Industry Net Present Value for Fluorescent Lamp Ballasts (Preservation of Operating Profit Markup, Shift Shipments, and Emerging Technologies Scenarios)

	Units	Base Case	Trial Standard Level			
			1	2	3A	3B
INPV	*(2010$ millions)*	733	718	698	670	667
Change in INPV	*(2010$ millions)*	-	(14.9)	(34.1)	(62.8)	(66.0)
	(%)	-	-2.0%	-4.7%	-8.6%	-9.0%

Table 13.5.5 Changes in Industry Net Present Value for Fluorescent Lamp Ballasts (Two-Tier Markup, Roll-up Shipments, and Existing Technologies Scenarios)

	Units	Base Case	Trial Standard Level			
			1	2	3A	3B
INPV	*(2010$ millions)*	1,219	1,061	933	801	769
Change in INPV	*(2010$ millions)*	-	(157.7)	(285.4)	(417.6)	(449.7)
	(%)	-	-12.9%	-23.4%	-34.3%	-36.9%

Table 13.5.6 Changes in Industry Net Present Value for Fluorescent Lamp Ballasts (Two-Tier Markup, Roll-up Shipments, and Emerging Technologies Scenarios)

	Units	Base Case	Trial Standard Level			
			1	2	3A	3B
INPV	*(2010$ millions)*	733	616	545	464	431
Change in INPV	*(2010$ millions)*	-	(116.4)	(188.0)	(268.6)	(301.2)
	(%)	-	-15.9%	-25.7%	-36.7%	-41.1%

Table 13.5.7 Changes in Industry Net Present Value for Fluorescent Lamp Ballasts (Two-Tier Markup, Shift Shipments, and Existing Technologies Scenarios)

	Units	Base Case	Trial Standard Level			
			1	2	3A	3B
INPV	*(2010$ millions)*	1,219	1,492	1,241	914	769
Change in INPV	*(2010$ millions)*	-	273.5	22.2	(305.0)	(449.7)
	(%)	-	22.4%	1.8%	-25.0%	-36.9%

Table 13.5.8 Changes in Industry Net Present Value for Fluorescent Lamp Ballasts (Two-Tier Markup, Shift Shipments, and Emerging Technologies Scenarios)

	Units	Base Case	Trial Standard Level			
			1	2	3A	3B
INPV	*(2010$ millions)*	733	847	752	576	431
Change in INPV	*(2010$ millions)*	-	114.1	19.3	(157.1)	(301.2)
	(%)	-	15.6%	2.6%	-21.4%	-41.1%

13.5.2 Impacts on Annual Cash Flow

While INPV is useful for evaluating the long-term effects of amended energy conservation standards, short-term changes in cash flow are also important indicators of the industry's financial situation. For example, a large investment over one or two years could strain the industry's access to capital. Consequently, the sharp drop in financial performance could cause investors to flee, even though recovery may be possible. Thus, a short-term disturbance can have long-term effects that the INPV cannot capture. To get an idea of the behavior of annual free cash flows, Figure 13.5.1 through Figure 13.5.8 below present the annual free cash flows from 2011 through 2025 for the base case and different TSLs in the standards case.

Annual cash flows are discounted to the base year, 2011. Between 2011 and the 2014 compliance date of the amended energy conservation standard, cash flows are driven by the level of conversion costs and the proportion of these investments spent every year. After the standard announcement date (*i.e.*, the publication date of the final rule), industry cash flows begin to decline as companies use their financial resources to prepare for the amended energy conservation standard. The more stringent the amended energy conservation standard, the greater the impact on industry cash flows in the years leading up to the compliance date, as product conversion costs lower cash inflows from operations and capital conversion costs increase cash outflows for capital expenditures.

Free cash flow in the year the amended energy conservation standards take effect is driven by two competing factors. In addition to capital and product conversion costs, amended energy conservation standards could create stranded assets, *i.e.*, tooling and equipment that would have enjoyed longer use if the energy conservation standard had not made them obsolete. In this year, manufacturers write down the remaining book value of existing tooling and equipment whose value is affected by the amended energy conservation standard. This one-time write-down acts as a tax shield that alleviates decreases in cash flow from operations in the year of the write-down. In this year, there is also an increase in working capital that reduces cash flow from operations. A large increase in working capital is needed due to more costly production components and materials, higher inventory carrying to sell more expensive products, and higher accounts receivable for more expensive products. Depending on these two competing factors, cash flow can either be positively or negatively affected in the year the standard takes effect.

In the years following the compliance date of the standard, the impact on cash flow depends on the operating revenue. There is very little impact on cash flow from operations under the preservation of operating profit scenario because this scenario is calibrated to have the same operating income in the standards case at each TSL as the base case in the year after the standard takes effect. In this scenario, the industry value is impacted because production costs increase, but operating profit remains approximately equal to the base case which decreases profit margins as a percentage of revenue. Under the two-tier markup scenario, cash flow decreases at each TSL in the standards case compared to the base case because products are commoditized in the standards case and are unable to command as high of margins in the standards case as in the base case. The exception to this pattern under the two-tier markup scenario is at TSL 1 under the shift scenario because enough shipments shift to higher-priced units with higher margins to compensate for lower markups for minimally compliant products. Figure 13.5.1 through Figure 13.5.8 present the annual free cash flows for fluorescent lamp ballasts.

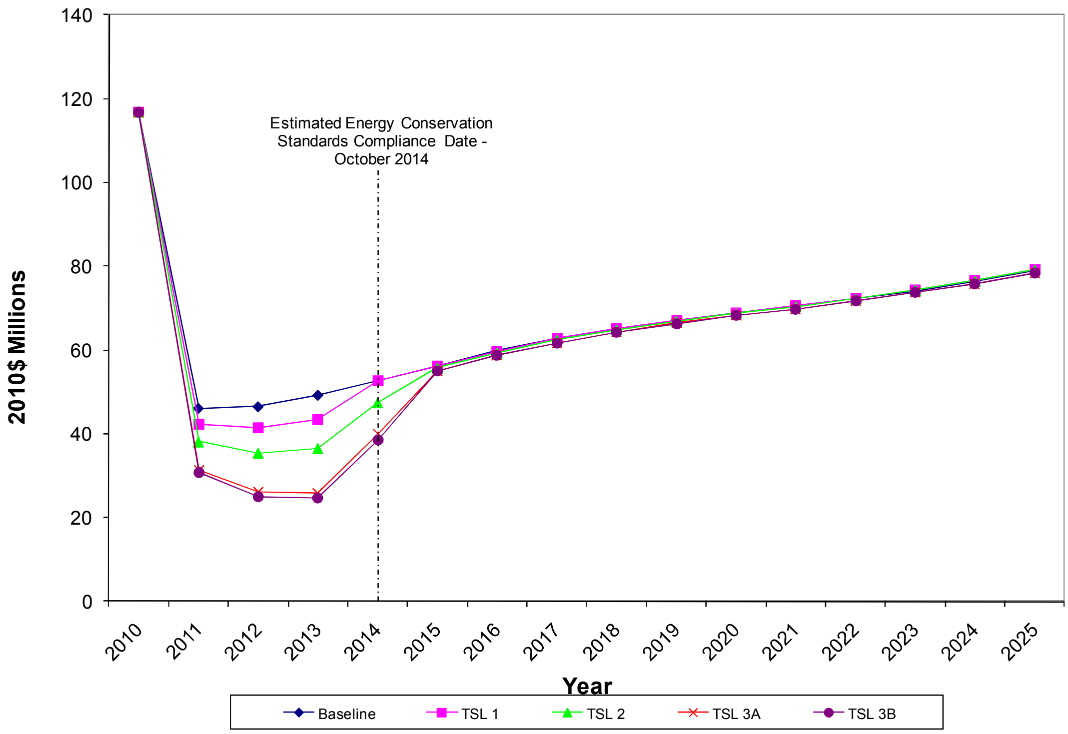

Figure 13.5.1 Annual Industry Free Cash Flows for Fluorescent Lamp Ballasts (Preservation of Operating Profit Markup, Roll-up Shipments, and Existing Technologies Scenarios)

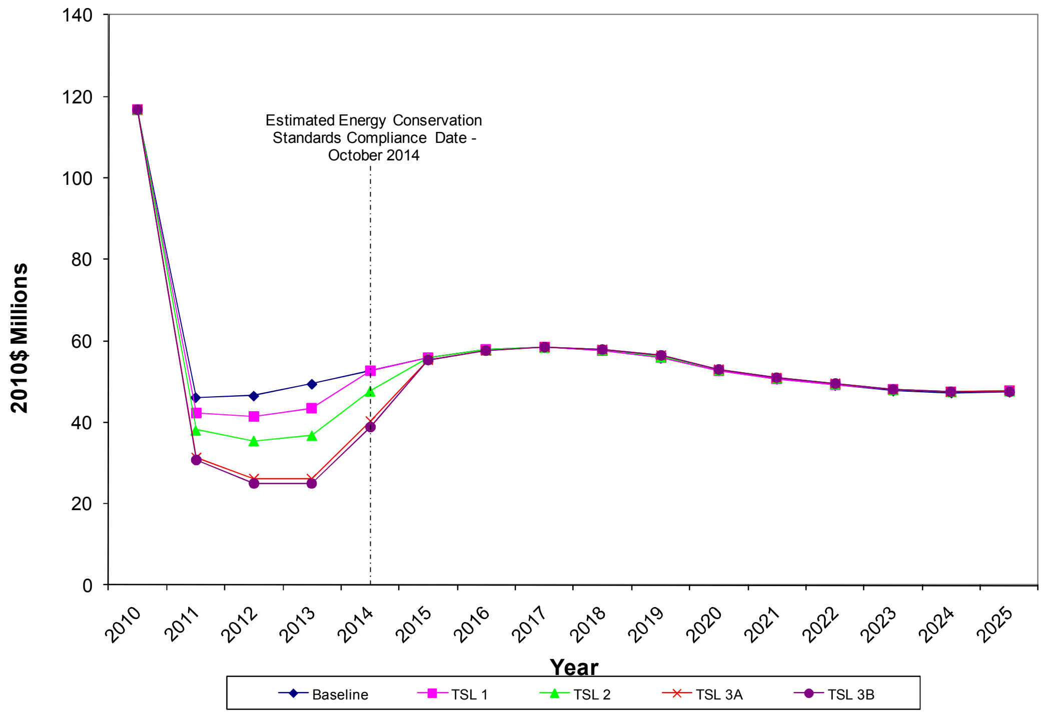

Figure 13.5.2 Annual Industry Free Cash Flows for Fluorescent Lamp Ballasts (Preservation of Operating Profit Markup, Roll-up Shipments, and Emerging Technologies Scenarios)

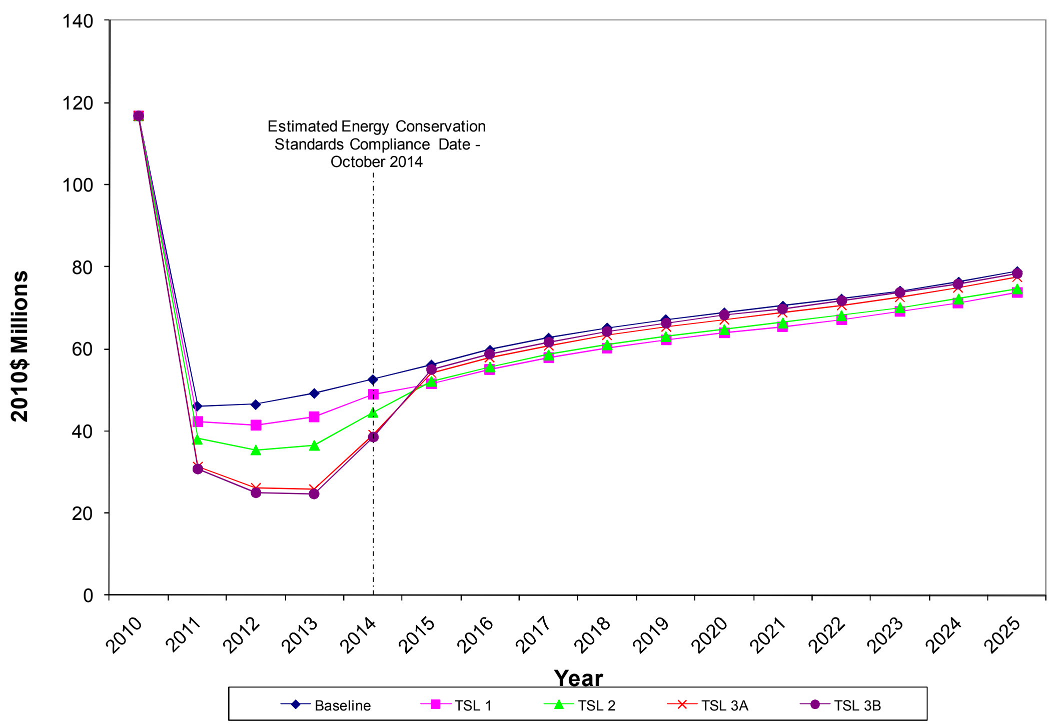

Figure 13.5.3 Annual Industry Free Cash Flows for Fluorescent Lamp Ballasts (Preservation of Operating Profit Markup, Shift Shipments, and Existing Technologies Scenarios)

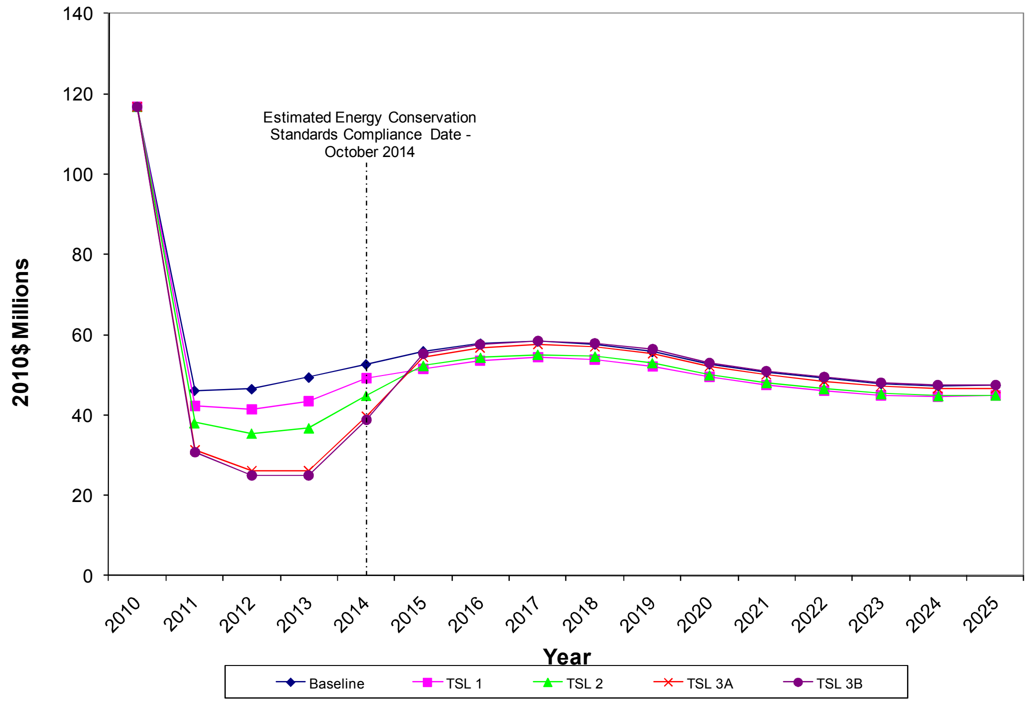

Figure 13.5.4 Annual Industry Free Cash Flows for Fluorescent Lamp Ballasts (Preservation of Operating Profit Markup, Shift Shipments, and Emerging Technologies Scenarios)

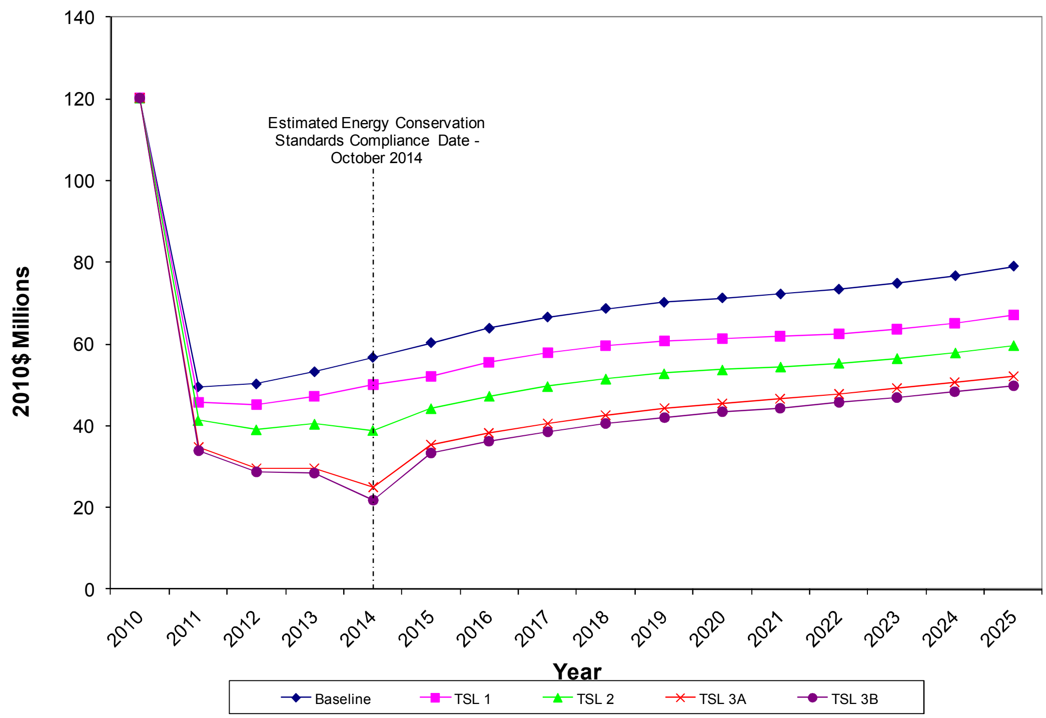

Figure 13.5.5 Annual Industry Free Cash Flows for Fluorescent Lamp Ballasts (Two-Tier Markup, Roll-up Shipments, and Existing Technologies Scenarios)

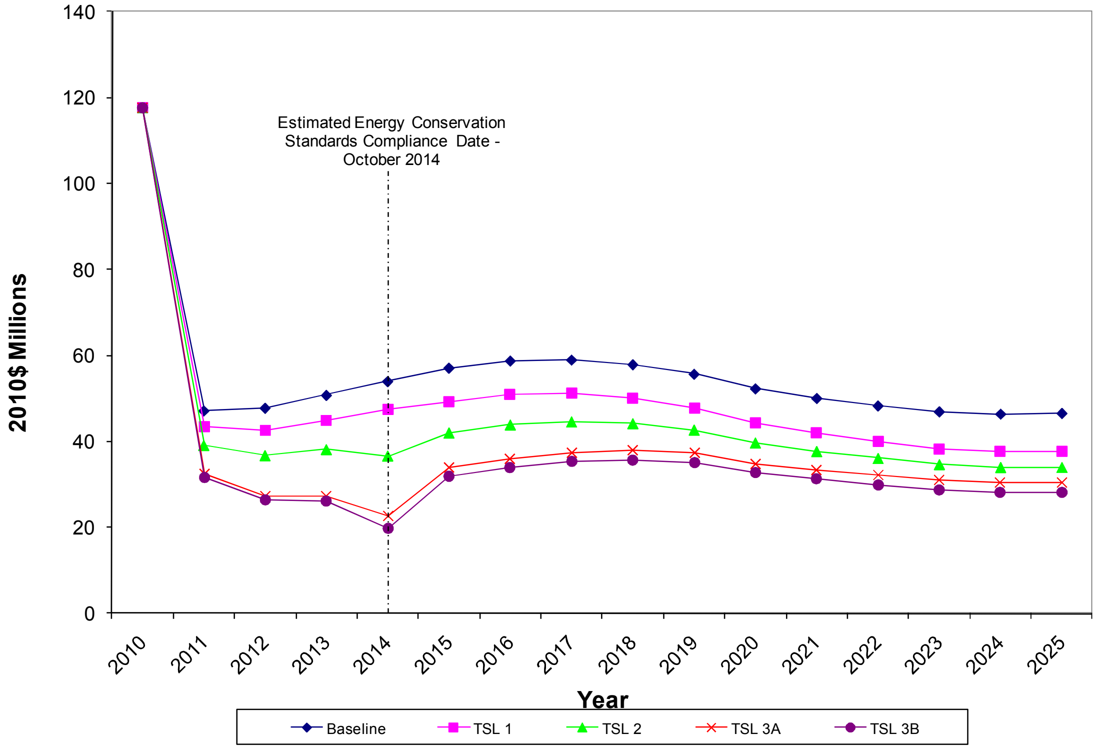

Figure 13.5.6 Annual Industry Free Cash Flows for Fluorescent Lamp Ballasts (Two-Tier Markup, Roll-up Shipments, and Emerging Technologies Scenarios)

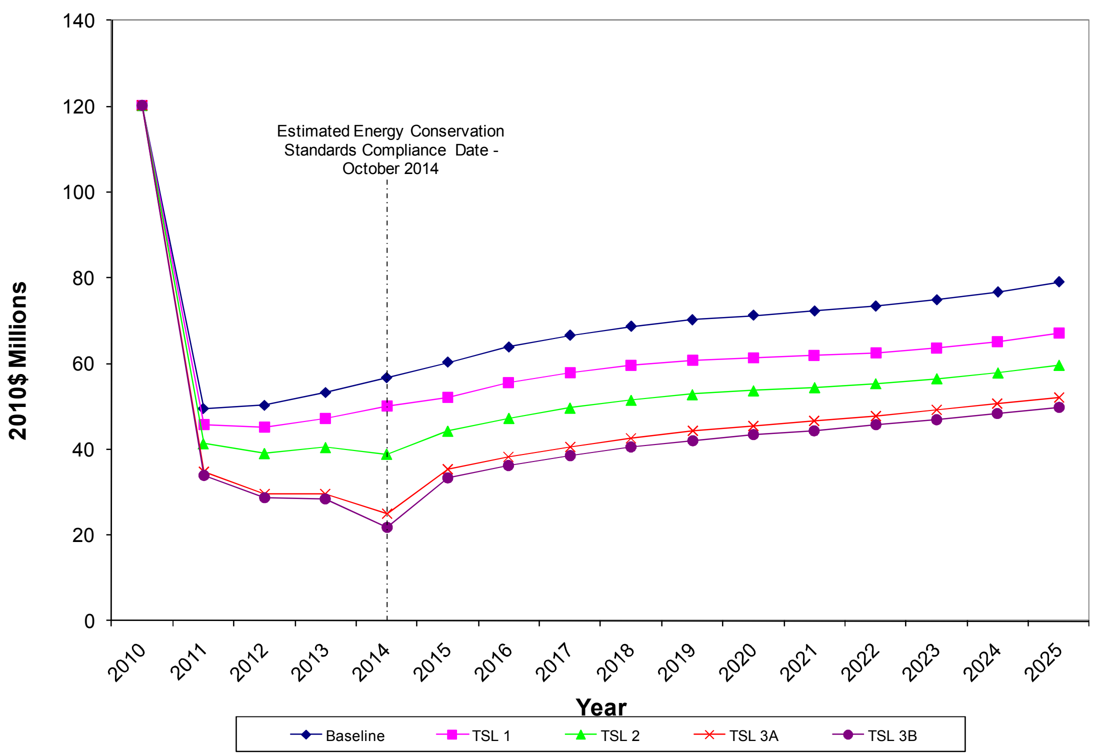

Figure 13.5.7 Annual Industry Free Cash Flows for Fluorescent Lamp Ballasts (Two-Tier Markup, Shift Shipments, and Existing Technologies Scenarios)

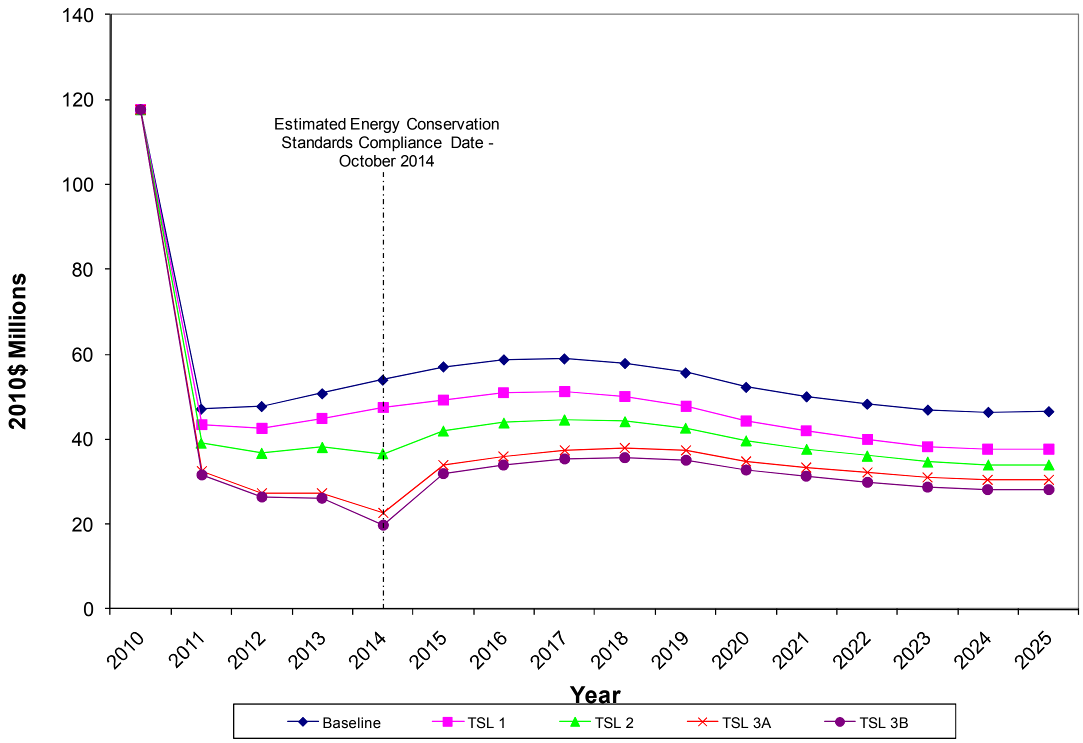

Figure 13.5.8 Annual Industry Free Cash Flows for Fluorescent Lamp Ballasts (Two-Tier Markup, Shift Shipments, and Emerging Technologies Scenarios)

13.6 IMPACTS ON MANUFACTURER SUBGROUPS

As described in section 13.2.3.3 above, DOE identified two subgroups of fluorescent lamp ballast manufacturers: small manufacturers and sign ballast manufacturers. The results of these subgroup analyses are described below.

13.6.1 Impacts on Small Business Manufacturers

13.6.1.1 Description and Estimated Number of Small Entities Regulated

DOE conducted a more focused inquiry of the companies that could be small business manufacturers of products covered by this rulemaking. During its market survey, DOE used all available public information to identify potential small manufacturers. DOE's research involved industry trade association membership directories (including NEMA), product databases (e.g., CEC and CEE databases), individual company websites, and market research tools (e.g., Dun and Bradstreet reports) to create a list of every company that manufactures or sells fluorescent lamp ballasts covered by this rulemaking. DOE also asked stakeholders and industry representatives if they were aware of any other small manufacturers during manufacturer interviews and at previous DOE public meetings. DOE contacted select companies on its list, as necessary, to determine whether they met the SBA's definition of a small business manufacturer of covered fluorescent lamp ballasts. DOE screened out companies that did not offer products covered by this rulemaking, did not meet the definition of a "small business," or are foreign owned and operated.

DOE initially identified at least 54 potential manufacturers of fluorescent lamp ballasts sold in the U.S. DOE reviewed publically available information on these 54 potential manufacturers and determined 30 were large manufacturers, were foreign owned, and/or operated or did not manufacture ballasts covered by this rulemaking. DOE then attempted to contact the remaining 24 companies that were potential small business manufacturers. Though many companies were unresponsive, DOE was able to determine that approximately 10 meet the SBA's definition of a small business and likely manufacture ballasts covered by this rulemaking.

Before issuing this final rule, DOE attempted to contact the small business manufacturers of fluorescent lamp ballasts it had identified. Two of the small businesses consented to being interviewed during the MIA interviews, and DOE received feedback from one additional small business through a survey response. DOE also obtained information about small business impacts while interviewing large manufacturers.

Four major manufacturers with non-domestic production supply the vast majority of the marketplace. None of the four major manufacturers is considered a small business. The remaining market share is held by foreign manufacturers and several smaller domestic companies with very small market shares. Even for these U.S.-operated firms, most production is outsourced to overseas vendors or captive overseas manufacturing facilities. Some very limited production takes place in the United States–mostly magnetic ballasts for specialty applications. DOE is unaware of any fluorescent lamp ballast companies, small or large, that produce only domestically. See chapter 3 of the final rule TSD for further details on the fluorescent lamp ballast market.

The four large manufacturers typically offer a much wider range of designs of covered ballasts than small manufacturers. Ballasts can be designed, or optimized, to operate different lamp lengths and numbers of lamps under various start methods, often in combination with various additional features. Large manufacturers typically offer many SKUs per product line to meet this wide range of potential specifications. Generally, one product family shares some fundamental characteristic (i.e., lamp diameter, number of lamps, etc.) and hosts a large number of SKUs that are manufactured with minor variations on the same product line. Some product lines, such as the 4-foot MBP IS ballast, are manufactured in high volumes, while other products may be produced in much lower volumes but can help manufacturers meet their customers' specific needs and provide higher margin opportunities. For their part, small manufacturers generally do not have the volume to support as wide a range of products.

Beyond variations in ballast types and features, the large manufacturers also offer multiple tiers of efficiency, typically including a baseline efficiency product and a high-efficiency product within the same family. On the other hand, some small manufacturers frequently only offer one efficiency level in a given product class to reduce the number of SKUs and parts they must maintain. This strategy is important to small-scale manufacturers because many product development costs (e.g., testing, certification, and marketing) are relatively fixed per product line.

Small manufacturers are able to compete in the fluorescent lamp ballast industry despite the dominance of the four major manufacturers due, in large part, to the fragmented nature of the fixture industry. The largest four fixture manufacturers comprise about 60 percent of the industry, while as many as 200 smaller fixture manufacturers have the remaining share. Many small ballast manufacturers have developed relationships with these small fixture manufacturers, whose production volumes may not be attractive to the larger players. The same structure applies to the electrical distributor market – while small ballast manufacturers often cannot compete for the business of the largest distributors, they are able to successfully target small distributors, often on a regional basis.

Lastly, like the major manufacturers, small manufacturers usually offer products in addition to those fluorescent lamp ballasts covered by this rulemaking, such as dimming ballasts, LED drivers, and compact fluorescent ballasts.

13.6.1.2 Description and Estimate of Compliance Requirements

At TSL3A, the level adopted in the final rule, DOE estimates capital conversion costs of $0.3 million and product conversion costs of $1.0 million for a typical small manufacturer, compared to capital and product conversion costs of $6.3 million and $9.7 million, respectively, for a typical large manufacturer. These costs and their impacts are described in detail below.

Those small manufacturers DOE interviewed did not expect increased capital conversion costs to be a major concern because most of them source all or the majority of their products from Asia. Those that source their products would likely not make the direct capital investments themselves. Small manufacturers experience the impact of sourcing their products through a higher cost of goods sold, and thus a lower operating margin, as compared to large manufacturers. The capital costs estimated are largely associated with those small manufacturers producing magnetic ballasts. DOE estimates capital costs of approximately $0.3 million for a typical small manufacturer at TSL 3A, based on the cost of converting magnetic production lines, such as sign ballasts, to electronic production lines.

Another challenge facing the industry is the component shortage discussed in section 13.3.1. As with large manufacturers, the component shortage is a significant issue for small manufacturers, but some small manufacturers stated that the shortage does not differentially impact them. At times, they actually can obtain components more easily than large manufacturers. Because their volumes are lower, they generally pay higher prices for parts than their larger competitors, which incentivizes suppliers to fill small manufacturers' orders relatively quickly. The lower-volume orders also allow small manufacturers to piggyback off the orders for certain components that are used throughout the consumer electronics industry.

While capital conversion costs were not a large concern to the small manufacturers DOE interviewed, product conversion costs could adversely impact small manufacturers at TSL 3A, the level adopted in the final rule. To estimate the differential impacts of the adopted standard on small manufacturers, DOE compared their cost of compliance with that of the major manufacturers. First, DOE examined the number of basic models and SKUs available from each manufacturer to determine an estimate for overall compliance costs. The number of basic models and SKUs attributed to each manufacturer is based on information obtained during manufacturer interviews and an examination of the different models advertised by each on company websites. DOE assumed that the product conversion costs required to redesign basic models and test and certify all SKUs to meet the standard levels presented in today's final rule would be lower per model and per SKU for small manufacturers, as detailed below. (A full description of DOE's methodology for developing product conversion costs is found in section 0 above.) The table below compares the estimated product conversion costs of a typical small manufacturer as a percentage of annual R&D expense to those of a typical large manufacturer.

Table 13.6.1 Comparison of a Typical Small and Large Manufacturer's Product Conversion Costs to Annual R&D Expense

	Large Manufacturer		Small Manufacturer	
	Product Conversion Costs for a Typical Large Manufacturer (2010$ millions)	Product Conversion Costs as a Percentage of Annual R&D Expense	Product Conversion Costs for a Typical Small Manufacturer (2010$ millions)	Product Conversion Costs as a Percentage of Annual R&D Expense
Baseline	$0.00	0%	$0.00	0%
TSL 1	$1.41	16%	$0.14	38%
TSL 2	$6.15	71%	$0.63	163%
TSL 3A	$9.68	111%	$0.99	257%
TSL 3B	$12.53	144%	$1.28	333%

Based on discussions with manufacturers, DOE estimated that the cost to fully redesign every ballast model for large manufacturers is approximately $120,000 per model and the cost to test and certify every SKU is approximately $20,000 per SKU. A typical major manufacturer offers approximately 80 basic covered models and 300 SKUs. Based on DOE's GRIM analysis, a typical major manufacturer has an annual R&D expense of $8.7 million. Because not all products would need to be redesigned at TSL 3A, DOE estimates $9.7 million in product conversion costs for a typical major manufacturer at TSL 3A (compared to $15.6 million if all products had to be fully redesigned), which represents 111 percent of its annual R&D expense. This means that a typical major manufacturer could redesign its products in just over a year if it were to devote its entire R&D budget for fluorescent lamp ballasts to product redesign and could retain the engineering resources.

DOE's research indicated that a typical small manufacturer offers approximately 50 basic covered models and 100 SKUs. However, based on manufacturer interviews, DOE does not believe that small manufacturers would incur the same level of costs per model and SKU as large manufacturers. Small manufacturers would not be as likely to redesign models in-house as large manufacturers. Instead, they would source and rebrand products from overseas manufacturers who supply their ballasts. As a result, DOE assumed a lower R&D investment, in absolute dollars, per model. Because their products are effectively sourced, DOE projects smaller manufacturers would face a higher level of cost of goods sold (i.e., a higher MPC). Therefore, in a competitive environment, small manufacturers would earn a lower markup than their larger peers and consequently operate at lower margins. Small manufacturers would also have to test and certify every SKU they offer, but they would not conduct the same extent of pilot runs and internal testing as large manufacturers because less production takes place in internal factories. As such, DOE estimates that small manufacturers' testing and certification costs are expected to be $10,000 per SKU for UL and other certifications. Thus, the product conversion costs for a typical small manufacturer could total $1.6 million. Because not all products would need to be fully redesigned at TSL 3A, however, DOE estimates product conversion costs of $1.0 million at TSL 3A. Based on scaling GRIM results to an average small-manufacturer market share of 1.0 percent, DOE assumed that a small manufacturer has an annual R&D expense of $0.4 million, so the estimated product conversion costs at TSL 3A would represent 257 percent of its annual R&D expense. This means that a typical small manufacturer could redesign its products within the three year compliance period if it were to devote its entire R&D budget for fluorescent lamp ballasts to product redesign and could retain the engineering resources.

Although the conversion costs required can be considered substantial for all companies, the impacts could be relatively greater for a typical small manufacturer because of much lower production volumes and the relatively fixed nature of the R&D resources required per model. The table below compares the total conversion costs of a typical small manufacturer as a percentage of annual revenue and earnings before taxes and interest (EBIT) to those of a typical large manufacturer.

Table 13.6.2 Comparison of a Typical Small and Large Manufacturer's Total Conversion Costs to Annual Revenue and EBIT

	Large Manufacturer			Small Manufacturer		
	Total Conversion Costs for a Typical Large Mfr. (2010$ millions)	Total Conversion Costs as a Percentage of Annual Revenue	Total Conversion Costs as a Percentage of Annual EBIT	Total Conversion Costs for a Typical Small Mfr. (2010$ millions)	Total Conversion Costs as a Percentage of Annual Revenue	Total Conversion Costs as a Percentage of Annual EBIT
Baseline	$0.00	0%	0%	$0.00	0%	0%
TSL 1	$3.99	2%	21%	$0.26	2%	37%
TSL 2	$10.68	5%	55%	$0.83	8%	119%
TSL 3A	$16.02	7%	82%	$1.27	12%	182%
TSL 3B	$19.14	8%	99%	$1.58	15%	226%

As seen in the table above, the impacts for a typical small manufacturer are relatively greater than for a large manufacturer at TSL 3A. Total conversion costs represent 182 percent of annual EBIT for a typical small manufacturer compared to 82 percent of annual EBIT for a typical large manufacturer. DOE believes these estimates reflect a worst-case scenario because they assume small manufacturers would redesign all proprietary models immediately, and not take advantage of the industry's supply chain dynamics or take other steps to mitigate the impacts. DOE anticipates, however, that small manufacturers would take several steps to mitigate the costs required to meet new and amended energy conservation standards.

At TSL 3A, it is more likely that ballast manufacturers would temporarily reduce the number of SKUs they offer as in-house designs to keep their product conversion costs at manageable levels in the years preceding the compliance date. As noted previously, the typical small manufacturer business model is not predicated on the supply of a wide range of models and specifications. Small manufacturers frequently either focus on a few niche markets or on customers seeking only basic, low-cost solutions. They therefore can satisfy the needs of their customers with a smaller product portfolio than large manufacturers who often compete on brand reputation and the ability to offer a full product offering. As such, DOE believes that under the adopted standards small businesses would likely selectively upgrade existing product lines to offer products that are in high demand or offer strategic advantage. Small manufacturers could then spread out further investments over a longer time period by upgrading some product lines prior to the compliance date while sourcing others until resources allow—and the market supports—in-house design. Furthermore, while the initial redesign costs are relatively large, the estimates assume small manufacturers would bring compliant ballasts to market in concert with large manufacturers. There is a possibility some small manufacturers would conserve resources by waiting to upgrade certain products until new compliant baseline designs become available or their in-house development is less resource-intensive. The commonality of many consumer electronics components, designs, and products fosters considerable sharing of experience throughout the electronics supply chain, particularly when unrestricted by proprietary technologies. DOE did not find any intellectual property restrictions that would prevent small manufacturers from making the technologies necessary to meet today's adopted levels.

13.6.2 Impacts on Sign Ballast Manufacturers

DOE is not presenting results under the two-tier markup scenario for sign ballasts because it did not observe this two-tier effect in the sign ballast market. Electronic ballasts at EL1 neither command a higher price nor a higher markup in the base case. Additionally, roll-up and shift scenarios do not have separate impacts for sign ballasts because there are no higher ELs above the new baseline to which products could potentially shift in the standards case. As such, the tables below present the cash-flow analysis results under the preservation of operating profit markup and roll-up shipment scenarios with existing or emerging technologies for sign ballast manufacturers.

Table 13.6.3 Manufacturer Impact Analysis for Sign Ballasts – Preservation of Operating Profit Markup, Existing Technologies, and Roll-up Shipment Scenario

	Units	Base Case	Trial Standard Level			
			1	2	3A	3B
INPV	(2010$ millions)	142	138	138	138	138
Change in INPV	(2010$ millions)	-	(4.2)	(4.2)	(4.2)	(4.2)
	(%)	-	-2.9%	-2.9%	-2.9%	-2.9%
Product Conversion Costs	(2010$ millions)	-	2	2	2	2
Capital Conversion Costs	(2010$ millions)	-	6	6	6	6
Total Conversion Costs	(2010$ millions)	-	8	8	8	8

Table 13.6.4 Manufacturer Impact Analysis for Sign Ballasts – Preservation of Operating Profit Markup, Emerging Technologies, and Roll-up Shipment Scenario

	Units	Base Case	Trial Standard Level			
			1	2	3A	3B
INPV	(2010$ millions)	116	111	111	111	111
Change in INPV	(2010$ millions)	-	(5.1)	(5.1)	(5.1)	(5.1)
	(%)	-	-4.4%	-4.4%	-4.4%	-4.4%
Product Conversion Costs	(2010$ millions)	-	2	2	2	2
Capital Conversion Costs	(2010$ millions)	-	6	6	6	6
Total Conversion Costs	(2010$ millions)	-	8	8	8	8

For the sign ballast product class, DOE analyzed only one efficiency level; thus, the results are the same at each TSL. TSLs 1 through 3B represent EL1 for the sign ballast product class. At TSLs 1 through 3B, DOE estimates impacts on INPV to range from -$4.2 million to -$5.1 million, or a change in INPV of -2.9 percent to -4.4 percent. At these levels, industry free cash flow is estimated to decrease by approximately 38 percent to $4.9 million, compared to the base-case value of $7.9 million in the year leading up to the energy conservation standards.

As shown by the results, DOE expects sign ballast manufacturers overall to face small negative impacts under TSLs 1 through 3B. DOE estimates that 64 percent of the sign ballast product class shipments would meet EL1 in the base case. Many manufacturers already produce electronic sign ballasts, which is the design option represented by EL1. Many other manufacturers, however, produce only magnetic T12 sign ballasts and therefore would face significant capital exposure in moving from magnetic to electronic ballasts to meet TSLs 1 through 3B. For that reason, DOE estimates relatively high capital conversion costs of $6 million for sign ballast manufacturers. Product redesign and testing costs are expected to total $2 million for sign ballasts.

Unlike most product classes, sign ballasts are expected to decrease rather than increase in price moving from baseline to EL1 by a shipment-weighted average decrease in MPC of over 4 percent. This is because electronic ballasts are a cheaper alternative to magnetic ballasts, even though the industry has not yet fully moved toward electronic production. During interviews, manufacturers stated that consumers were reluctant to convert to electronic ballasts even though there were no technical barriers to doing so. Under the preservation of operating profit markup scenario, however, manufacturers are able to maintain the base-case operating profit for the year following the compliance date of new and amended standards despite lower production costs, so the average markup increases slightly to 1.41 to account for the decrease in MPC. Despite this markup increase, revenue is lower at TSLs 1 through 3B than in the base-case because of the lower average unit price and the $8 million in conversion costs. When the preservation of operating profit markup is combined with the existing technologies scenario rather than the emerging technologies scenario, the impact of this maximized revenue per unit is greatest because it is applied to a larger total quantity of shipments.

13.7 OTHER IMPACTS

13.7.1 Employment

DOE typically presents modeled quantitative estimates of the potential changes in production employment that could result from new and amended energy conservation standards. However, for this rulemaking, DOE determined that none of the major manufacturers, which comprise more than 90 percent of the market, have domestic fluorescent lamp ballast production. Although a few niche manufacturers have relatively limited domestic production, based on interviews, DOE has identified very few domestic production employees in the United States Because many niche manufacturers did not respond to interview requests or submit comments on domestic employment impacts, DOE is unable to fully quantify domestic production employment impacts. Therefore, while DOE qualitatively discusses potential employment impacts below, DOE did not model direct employment impacts explicitly because the results would not be meaningful given the very low number of domestic production employees.

Based on interviews, DOE projects that significant direct employment impacts would occur only in the event that one or more businesses exit the market due to new standards. Discussions with manufacturers indicated that, at the highest efficiency levels (TSL 3A and TSL 3B), some small manufacturers will be faced with the decision of whether or not to make the investments necessary to remain in the market based on their current technical capabilities. In general, however, DOE projects that TSL 3A, the level adopted in today's final rule, will not have significant adverse impacts on domestic employment because achieving these levels is within the expertise of most manufacturers, including small manufacturers, due to the lack of intellectual property restrictions and similarity of products among manufacturers.

In summary, given the low number of production employees and the low likelihood that manufacturers would exit the market at the efficiency levels adopted in today's final rule, DOE does not expect a significant impact on direct employment following new and amended energy conservation standards. DOE notes that the employment impacts discussed here are independent of the employment impacts from the broader U.S. economy, which are documented in chapter 15, Employment Impact Analysis, of the final rule TSD.

13.7.2 Production Capacity

Manufacturers stated that new and amended energy conservation standards could harm manufacturing capacity due to the current component shortage discussed in section 13.3.1 above. At present, manufacturers are struggling to produce enough fluorescent lamp ballasts to meet demand because of a worldwide shortage of electrical components. The components most affected by this shortage are premium high-efficiency parts, for which demand would increase even more following new and amended energy conservation standards. In the near term this increased demand might exacerbate the component shortage, thereby impacting manufacturing capacity. While DOE recognizes that the component shortage is currently a significant issue for manufacturers, DOE projects it to be a relatively short-term phenomenon to which component suppliers will ultimately adjust. According to manufacturers, suppliers have the ability to ramp up production to meet ballast component demand by the compliance date of new and amended standards, but those suppliers have hesitated to invest in additional capacity due to economic uncertainty and skepticism about the sustainability of demand. The state of the macroeconomic environment through 2014 will likely affect the duration of the component shortage. Mandatory standards, however, could create more certainty for suppliers about the eventual demand for these components. Additionally, the components at issue are not new technologies; rather, they have simply not historically been demanded in large quantities by ballast manufacturers.

13.7.3 Cumulative Regulatory Burden

While any one regulation may not impose a significant burden on manufacturers, the combined effects of several impending regulations may have serious consequences for some manufacturers, groups of manufacturers, or an entire industry. Assessing the impact of a single regulation may overlook this cumulative regulatory burden. For the cumulative regulatory burden analysis, DOE looks at other significant product-specific regulations that could affect fluorescent lamp ballast manufacturers that will take effect 3 years before or after the compliance date of amended energy conservation standards for these products.[c] In addition to the amended energy conservation regulations on fluorescent lamp ballasts, several other Federal regulations apply to these products and other equipment produced by the same manufacturers. While the cumulative regulatory burden focuses on the impacts on manufacturers of other Federal requirements, DOE also

[c] The compliance date for fluorescent lamp ballasts products is 3 years from the date of publication of the final rule (approximately October 2014).

has described a number of other regulations in section 0 because it recognizes that these regulations also impact the products covered by this rulemaking.

Companies that produce a wide range of regulated products may be faced with more capital and product development expenditures than competitors with a narrower scope of products. Regulatory burdens can prompt companies to exit the market or reduce their product offerings, potentially reducing competition. Smaller companies in particular can be disproportionately affected by regulatory costs since these companies have lower sales volumes over which they can amortize the costs of meeting new regulations. A standard is not economically justified if it contributes to an unacceptable level of cumulative regulatory burden.

13.7.3.1 DOE Regulations for Other Products Produced by Fluorescent Lamp Ballast Manufacturers

In addition to the amended energy conservation standards on fluorescent lamp ballasts, several other Federal regulations and pending regulations apply to other products produced by the same manufacturers. DOE recognizes that each regulation can significantly affect a manufacturer's financial operations. Multiple regulations affecting the same manufacturer can quickly strain manufacturers' profits and possibly cause an exit from the market. Table 13.7.1 lists the other DOE energy conservation standards that could also affect manufacturers of fluorescent lamp ballasts in the 3 years leading up to and after the compliance date of amended energy conservation standards for these products.

Table 13.7.1 Other DOE and Federal Actions Affecting the Fluorescent Lamp Ballast Industry

Regulation	Approximate Compliance Date*	Number of Impacted Companies from the Market and Technology Assessment (MTA) (See Chapter 3)	Estimated Total Industry Conversion Costs
Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps	2012	1	$17.3 million (2007$)[d]
Ranges and Ovens	2012	1	$22.6 million (2006$)[e]
General Service Fluorescent Lamps and Incandescent Reflector Lamps	2012	10	$363.1 million (2008$)[f]
Dehumidifiers	2012	1	N/A†††
Commercial Clothes Washers	2013	1	$20.4 million (2008$)[g]
Direct Heating Equipment	2013	1	$5.39 million (2009$)[h]
Battery Chargers and External Power Supplies	2013*	1	N/A[††]
Residential Refrigerators and Freezers	2014	1	$1,243 million (2009$)[i]
Room Air Conditioners	2014	1	$171 million (2009$)[j]

[d] Estimated industry conversion expenses were published in the TSD for the October 2008 packaged terminal air conditioners and packaged terminal heat pumps final rule. 73 FR 58772. The TSD for the 2008 packaged terminal air conditioners and packaged terminal heat pumps final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/commercial/ptacs_pthps_final_tsd.html.
[e] Estimated industry conversion expenses were published in the TSD for the April 2009 residential cooking products final rule. 74 FR 16040. The TSD for the 2009 residential cooking products final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/residential/cooking_products_final_rule_tsd.html.
[f] Estimated industry conversion expenses were published in the TSD for the July 2009 general service fluorescent lamps and incandescent reflector lamps final rule. 74 FR 34080. The TSD for the 2009 lamps final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/residential/incandescent_lamps_standards_final_rule_tsd.html.
[g] Estimated industry conversion expenses were published in the TSD for the January 2010 commercial clothes washers final rule. 75 FR 1122. The TSD for the 2010 commercial clothes washers final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/commercial/clothes_washers_ecs_final_rule_tsd.html
[h] Estimated industry conversion expenses were published in the TSD for the April 2010 heating products final rule. 75 FR 20112. The TSD for the 2010 heating products final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/residential/heating_products_fr_tsd.html.
[i] Estimated industry conversion expenses were published in the TSD for the September 2011 residential refrigerators and freezers final rule. 76 FR 57516. The TSD for the 2011 residential refrigerators and freezers final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf.

Microwave Ovens	2014*	2	N/A††
Eliptical Reflector (ER), Bulge Reflector (BR), and Small Diameter Incandescent Reflector Lamps	2014*	3	N/A††
Residential Clothes Dryers	2015	1	$95 million (2009$)[k]
Metal Halide Lamp Fixtures	2015*	16	N/A††
Residential Clothes Washers	2015*	1	N/A††
Residential Water Heaters	2015	1	$95.9 million (2009$)[l]
Commercial Electric Motors	2015*	1	N/A††
Commercial Distribution Transformers	2016*	2	N/A††
High-Intensity Discharge Lamps	2017*	8	N/A††

*The dates listed are an approximation. The exact dates are pending final DOE action.
†† For energy conservation standards for rulemakings awaiting DOE final action, DOE does not have a finalized estimated total industry conversion cost.
††† For minimum performance requirements prescribed by the Energy Independence and Security Act of 2007 (EISA 2007), DOE did not estimate total industry conversion costs because an MIA was not completed as part of a rulemaking. Pub. L. 110-140. EISA 2007 made numerous amendments to the Energy Policy and Conservation Act (EPCA) of 1975, Pub. L. 94-163, (42 U.S.C. 6291–6309), which established an energy conservation program for major household appliances and industrial and commercial equipment.

One DOE regulation of significant concern to manufacturers of fluorescent lamp ballasts is the 2009 Lamps rule. The 2009 Lamps rule amended energy conservation standards for general service fluorescent lamps (GSFLs) and incandescent reflector lamps (IRLs). DOE estimates $361.3 million in conversion costs for GSFL and IRL manufacturers in response to the 2009 Lamps rule. Because many manufacturers of fluorescent lamp ballasts also manufacture large volumes of GSFL and IRL, these companies will incur a significant portion of the product and capital conversion costs for the 2009 Lamps rule. The engineering and capital investments necessary for fluorescent lamp ballasts will likely compete with company resources available for the 2009 Lamps rule.

[j] Estimated industry conversion expenses were published in the TSD for the April 2011 room air conditioners and clothes dryers final rule. 76 FR 22454. The TSD for the 2011 room air conditioners and clothes dryers final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_clothes_dryers_room_ac_direct_final_rule_tsd.html.

[k] Estimated industry conversion expenses were published in the TSD for the April 2011 room air conditioners and clothes dryers final rule. 76 FR 22454. The TSD for the 2011 room air conditioners and clothes dryers final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_clothes_dryers_room_ac_direct_final_rule_tsd.html.

[l] Estimated industry conversion expenses were published in the TSD for the April 2010 heating products final rule. 75 FR 20112. The TSD for the 2010 heating products final rule can be found at http://www1.eere.energy.gov/buildings/appliance_standards/residential/heating_products_fr_tsd.html.

13.7.3.2 Other Federal Regulations

EISA 2007 Requirements

EISA 2007 contained minimum energy conservation standards for general service incandescent lamps (GSIL) and contained reporting requirements for certain types of lamps (Pub. L. 110-140). The EISA 2007 requirements prescribe separate energy conservation standards and minimum rated lifetimes for GSIL and modified spectrum GSIL, with effective dates ranging from January 1, 2012 to January 1, 2014. The phased-in standards for these two types of lamps are shown in Table 13.7.2 and Table 13.7.3 below.

Table 13.7.2 EISA 2007 GSIL Standards

Rated Lumen Ranges	Maximum Rate Wattage	Minimum Rate Lifetime	Effective Date
1490 – 2600	72	1,000 hours	1/1/2012
1050 – 1489	53	1,000 hours	1/1/2013
750 – 1049	43	1,000 hours	1/1/2014
310 – 749	29	1,000 hours	1/1/2014

Table 13.7.3 EISA 2007 Modified Spectrum GSIL Standards

Rated Lumen Ranges	Maximum Rate Wattage	Minimum Rate Lifetime	Effective Date
1118 – 1950	72	1,000 hours	1/1/2012
788 – 1117	53	1,000 hours	1/1/2013
563 – 787	43	1,000 hours	1/1/2014
232 – 562	29	1,000 hours	1/1/2014

Many of the major manufacturers of fluorescent lamp ballasts also manufacture large volumes of GSIL. Consequently, these companies will also incur capital and product conversion investments to comply with the GSIL minimum energy conservation standards. The GSIL investments could also compete with fluorescent lamp ballasts for company resources. In addition, the capital costs to comply with EISA 2007 could potentially limit the funding available for fluorescent lamp ballast conversions because these investments will compete for the same sources of capital.

DOE does not have an estimate for the total conversion costs that manufacturers of fluorescent lamp ballasts would incur to comply with the EISA 2007 requirements for GSIL because an MIA was not completed for the legislatively determined energy conservation standards.

Finally, EISA 2007 requires NEMA to report yearly sales volumes for rough service, vibration service, 2601 – 3300 lumen general service, 3-way, and shatter-resistant lamps from 2010 to 2025. NEMA is also required to submit historical shipments for these five types of lamps for DOE to construct a shipment model. These five types of lamps could be regulated by DOE if the actual sales volume of that type of lamp exceeds the volume predicted in DOE's model by 100 percent or more in any given year (42 U.S.C. 6295(l)(4)).

13.7.3.3 Other Regulations That Could Impact Fluorescent Lamp Ballast Manufacturers

While the cumulative regulatory burden focuses on the impacts on manufacturers of other Federal requirements, in this section DOE has described a number of other regulations below that could also impact the fluorescent lamp ballasts covered by this rulemaking.

State Energy Conservation Standards

The CEC specifies appliance standards that are applicable as state law to the sale of appliances in California. Recent standards set minimum ballast efficacy factor requirements for ballasts that operate one and two F34T12 lamps, two F96T12/ES lamps, and two F96T12HO/ES lamps. The standards apply to fluorescent lamp ballasts manufactured on or after July 1, 2009; sold by the manufacturer on or after October 1, 2009; or incorporated into a luminaire by a luminaire manufacturer on or after July 1, 2010.[m]

International Toxic Materials Regulations

Fluorescent lamp ballast manufacturers that sell products outside of the United States are subject to several international toxic materials regulations. In the European Union (EU), products are subject to the Restriction of Hazardous Substances Directive (RoHS). This regulation bans the sale of new equipment in the EU that contains more than agreed levels of lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyl (PBB) and polybrominated diphenyl ethers (PBDE) flame retardants. Manufacturers do not have a lengthy history using lead-free solder and expressed concerns regarding the reliability of the material based on the experience of European as well as U.S. suppliers compliant with RoHS. Manufacturers commented that lead-free solder is harder and more brittle, and it is still unknown whether exposure to long term thermal expansion and contraction could lead to additional solder joint cracking and, ultimately, ballast malfunctioning. While no current Federal U.S. regulation impacts the use of lead-solder in ballasts, NEMA has issued a call to action for its members to be RoHS-compliant in 2010.

Anti-Arcing Protection Requirements

The provisions contained in ANSI/UL1598 Standard Third Edition require that luminaires be constructed using UL Type CC rated (anti-arcing) ballasts or high temperature Circle I rated lampholders in original equipment manufacturer (OEM)

[m] California Energy Commission. *2009 Appliance Efficiency Regulations*. 2009. <http://www.energy.ca.gov/2009publications/CEC-400-2009-013/CEC-400-2009-013.PDF >.

fixtures and UL-marked retrofit kits. While ballast manufacturers are not required to offer Type CC-rated ballasts since fixture manufacturers could use Circle I lampholders to prevent arcing and meet UL specifications, offering Type CC-rated ballasts does create a regulatory burden for ballast manufacturers. Type CC rating requires control circuitry to implement, and these circuits consume system power, which decreases overall ballast electrical efficiency.

Electromagnetic Interference (EMI) Requirements

Currently, in the U.S. and Canada, electronic fluorescent ballasts are tested only for conducted emission and are required to comply with Federal Communications Commission (FCC) Part 18, Subpart C, Class A for industrial and commercial applications, or Class B for residential applications. The burden of proof for existing EMI tests rests with the luminaire manufacturers. These requirements are not as rigorous as the CISPR 15 requirements effective in Europe which require more filtering stages, but manufacturers could be required to comply with the model European EMI regulation in the future, which would result in design changes that could decrease efficiency or increase the cost to meet a given efficiency level.

End-of-Life (EOL) Requirements

T5 ballasts are required to have EOL protection systems that detect characteristic electrical signals of a lamp in distress and activate control functions in the ballast to limit energy supplied to the lamp. This protection prevents fire hazards resulting from melted sockets and cracked glass near the lamp base caused by overheating. Compliance with EOL requirements has added cost and design complexity to these systems. In the future, T8 and T12 ballasts could also require EOL protection, which could add cost and decrease efficiency, but DOE does not expect EOL protection to be required for T8 and T12 ballasts in the United States as required in Europe due to significant differences between the lamps used in the United States and Europe.

13.8 CONCLUSION

The following section summarizes the impacts for the scenarios DOE believes are most likely to capture the range of impacts on fluorescent lamp ballast manufacturers as a result of amended energy conservation standards. DOE also notes that while these scenarios bound the range of most plausible impacts on manufacturers, there potentially could be circumstances which cause manufacturers to experience impacts outside of this range.

TSL 1 is EL1 for all five representative product classes. At TSL 1, DOE estimates impacts on INPV to range from -$19.6 million to -$116.4 million, or a change in INPV of -1.6 percent to -15.9 percent. At this level, industry free cash flow[n] is estimated to

[n] Industry free cash flow is the operating cash flow minus capital expenditures.

decrease by approximately 12 percent to $43.4 million, compared to the base-case value of $49.3 million in the year leading up to the energy conservation standards.

The INPV impacts at TSL 1 are relatively minor, in part because the vast majority of shipments already meet EL1. DOE estimates that in 2014, the year in which compliance with the new and amended standards will be required, over 99 percent of the IS/RS product class shipments, 73 percent of the PS product class shipments, 98 percent of the 8-foot HO IS/RS product class shipments, 64 percent of the sign ballast product class shipments, and 96 percent of the residential IS/RS product class shipments would meet EL1 or higher in the base case. The majority of shipments at baseline efficiency levels that would need to be converted at TSL 1 are 2-lamp and 4-lamp 4ft MBP PS ballasts, 4-lamp sign ballasts, and 2-lamp 4-foot MBP IS/RS residential ballasts.

Because most fluorescent lamp ballast shipments already meet the efficiency levels analyzed at TSL 1, DOE expects conversion costs to be small compared to the industry value. DOE estimates product conversion costs of $5 million due to the research, development, testing, and certification costs needed to upgrade product lines that do not meet TSL 1. For capital conversion costs, DOE estimates $11 million for the industry, largely driven by the cost of converting all magnetic sign ballast production lines to electronic sign ballast production lines.

Under the preservation of operating profit markup scenario, impacts on manufacturers are marginally negative because, while manufacturers earn the same operating profit as is earned in the base case for 2015 (the year following the compliance date of amended standards), they face $17 million in conversion costs. INPV impacts on manufacturers are not as significant under this scenario as in other scenarios because most shipments already meet TSL 1 and the shift shipment scenario moves products beyond the eliminated baseline to higher-price (and higher gross profit) levels. This results in a shipment-weighted average MPC increase of 6 percent applied to a growing market over the analysis period.

Shipments under the existing technologies scenario are nearly three and a half times greater than shipments under the emerging technologies scenario by the end of the analysis period. At TSL 1, the moderate price increase applied to a large quantity of shipments lessens the impact of the minor conversion costs estimated at TSL 1, resulting in slightly negative impacts at TSL 1 under the preservation of operating profit markup scenario.

Under the two-tier markup scenario, manufacturers are not able to fully pass on additional costs to consumers and are not guaranteed base-case operating profit levels. Rather, products that once earned a higher-than-average markup at EL1 become commoditized once baseline products are eliminated at TSL 1. Thus, the average markup drops below the base-case average markup (which is equal to the flat manufacturer markup of 1.4). Because shipments above the baseline do not shift to higher efficiencies with greater costs under the roll-up scenario, the shipment-weighted average MPC does not significantly increase. A lower average markup of 1.38 and $17 million in conversion costs results in more negative impacts at TSL 1 under the two-tier markup scenario.

These impacts increase on a percentage basis under the emerging technologies scenario relative to the existing technologies scenario because the base-case INPV against which changes are compared is nearly 40 percent lower.

TSL 2 represents EL1 for the sign ballast and residential IS/RS product classes. For the IS/RS, PS, and 8-foot HO IS/RS product classes, TSL 2 represents EL2. At TSL 2, DOE estimates impacts on INPV to range from -$42.4 million to -$188.0 million, or a change in INPV of -3.5 percent to -25.7 percent. At this level, industry free cash flow is estimated to decrease by approximately 26 percent to $36.6 million, compared to the base-case value of $49.3 million in the year leading up to the energy conservation standards.

Because the sign ballast and residential IS/RS product classes remain at EL1 at TSL 2, the additional impacts at TSL 2 relative to TSL 1 result only from increasing the IS/RS, PS, and 8-foot HO IS/RS product classes to EL2. At TSL 2, DOE estimates that 63 percent of the IS/RS product class shipments, 19 percent of the PS product class shipments, and 89 percent of the 8-foot HO IS/RS product class shipments would meet EL2 or higher in the base case. Since the 8-foot HO IS/RS product class represents only 0.1 percent of the fluorescent lamp ballast market, the vast majority of impacts at TSL 2 relative to TSL 1 result from changes in the IS/RS and PS product classes.

At TSL 2, conversion costs remain small compared to the industry value. Product conversion costs increase to $18 million due to the increase in the number of product lines within the IS/RS and PS product classes that would need to be redesigned at TSL 2. Capital conversion costs grow to $20 million at TSL 2 because manufacturers would need to invest in additional testing equipment and convert some production lines.

Under the preservation of operating profit markup scenario, INPV impacts are negative because manufacturers are not able to fully pass on higher product costs to consumers. The shipment-weighted average MPC increases by 9 percent compared to the baseline MPC, but this increase does not generate enough cash flow to outweigh the $38 million in conversion costs at TSL 2, resulting in a -3.5 percent change in INPV at TSL 2 compared to the base case.

Under the two-tier markup scenario, more products are commoditized to a lower markup at TSL 2. The impact of this lower average markup of 1.36 outweighs the impact of a 6 percent increase in shipment-weighted average MPC, resulting in a negative change in INPV at TSL 2. The $38 million in conversion costs further erodes profitability, and the lower base case INPV against which the change in INPV is compared under the emerging technologies scenario increases INPV impacts on a percentage basis.

TSL 3A is EL1 for the sign ballasts and residential IS/RS product classes, EL2 for the 8-foot HO IS/RS product class, and EL3 for the IS/RS and PS product classes. At TSL 3A, DOE estimates impacts on INPV to range from -$74.5 million to -$268.6 million, or a change in INPV of -6.1 percent to -36.7 percent. At this level, industry free cash flow is estimated to decrease by approximately 48 percent to $25.8 million, compared to the base-case value of $49.3 million in the year leading up to the energy conservation standards.

Because the sign ballast and residential IS/RS product classes remain at EL1 and the 8-foot HO IS/RS product class remains at EL2 for TSL 3A, the additional impacts at TSL 3A relative to TSL 2 result only from increasing the IS/RS and PS product classes to EL3. At TSL 3A, DOE estimates that 21 percent of the IS/RS product class shipments and 7 percent of the PS product class shipments would meet the efficiency levels contained in TSL 3A or higher in the base case.

At TSL 3A, product conversion costs increase to $46 million because a far more product lines within the IS/RS, and PS product classes would need to be redesigned at TSL 3A than TSL 2. Capital conversion costs rise to $28 million at TSL 3A because manufacturers would need to invest in equipment such as surface-mount device placement machinery and solder machines to convert production lines for the manufacturing of more efficient ballasts.

Under the preservation of operating profit markup scenario, INPV decreases by 6.1 percent at TSL 3A compared to the base case. The shipment-weighted average MPC increases by 17 percent, but manufacturers are not able to pass on the full amount of these higher costs to consumers. This MPC increase is outweighed by the $74 million in conversion costs at TSL 3A.

Under the two-tier markup scenario, at TSL 3A, products are commoditized to a lower markup to an even greater extent than under the preservation of operating profit markup scenario. The impact of this lower average markup of 1.33 outweighs the impact of a 15 percent increase in shipment-weighted average MPC, resulting in a negative change in INPV at TSL 3A compared to TSL 2. Profitability is further reduced by the $74 million in conversion costs and the lower base-case INPV over which change in INPV is compared under the emerging technologies scenario.

TSL 3B is EL1 for the sign ballast product class, EL2 for the residential IS/RS product class, and EL3 for the IS/RS, PS, and 8-foot HO IS/RS product classes. At TSL 3B, DOE estimates impacts on INPV to range from -$77.6 million to -$301.2 million, or a change in INPV of -6.4 percent to -41.1 percent. At this level, industry free cash flow is estimated to decrease by approximately 50 percent to $24.7 million, compared to the base-case value of $49.3 million in the year leading up to the energy conservation standards.

Because the sign ballast product class remains at EL1 and the IS/RS and PS product classes are at EL3 for TSL 3B, the additional impacts at TSL 3B relative to TSL 3A result only from increasing the 8-foot HO IS/RS product class to EL3 and the residential IS/RS product class to EL2. At TSL 3B, DOE estimates that 2 percent of the 8-foot HO IS/RS product class shipments and 23 percent of the residential IS/RS product class shipments would meet the efficiency levels contained in TSL 3B in the base case.

At TSL 3B, conversion costs are slightly greater compared to TSL 3A. Product and capital conversion costs increase to $48 million and $29 million, respectively, because more product lines would need to be redesigned and upgraded at TSL 3B.

Under the preservation of operating profit markup scenario, INPV decreases by 6.4 percent at TSL 3B compared to the base case, which is slightly greater than the percentage impact at TSL 3A. The shipment-weighted average MPC increases by over 17 percent, but manufacturers are not able to pass on the full amount of these higher costs to consumers. This slight MPC increase is outweighed by the $78 million in conversion costs at TSL 3B.

Under the two-tier markup scenario, at TSL 3B, products are commoditized to a lower markup to the greatest extent of any TSL analyzed. The impact of this lower average markup of 1.33 outweighs the impact of a 17 percent increase in shipment-weighted average MPC, resulting in a negative change in INPV at TSL 3B compared to TSL 3A. Profitability is further reduced by the $78 million in conversion costs and the lower base-case INPV over which change in INPV is compared under the emerging technologies scenario.

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CHAPTER 14. UTILITY IMPACT ANALYSIS

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CHAPTER 14. UTILITY IMPACT ANALYSIS

14.1 INTRODUCTION

The utility impact analysis estimates the change in the forecasted power generation capacity of the nation that would be expected to result from the adoption of new and amended efficacy efficiency standards. The U.S. Department of Energy (DOE) used a version of the Energy Information Administration's (EIA's) National Energy Modeling System (NEMS) for this analysis. NEMS, which is publicly available, is a large, multi-sectoral, partial equilibrium model of the U.S. energy sector. EIA uses NEMS to produce its *Annual Energy Outlook* (*AEO*),[1] a widely recognized baseline energy forecast for the United States. The version of NEMS used for appliance standards analysis is called NEMS-Building Technologies (NEMS-BT) and is based on *AEO2010* with minor modifications. The NEMS-BT offers a sophisticated picture of the effect of standards, since it accounts for the interactions between the various energy supply and demand sectors and the economy as a whole.

The utility impact analysis reports the changes in installed capacity and generation, by fuel type, that result from the adoption of new and amended efficacy standards at each trial standard level (TSL), as well as changes in electricity consumption.

14.2 METHODOLOGY

To estimate the effects of the adopted standards on the electric utility industry, DOE used NEMS-BT to provide key inputs to the analysis. EIA approves the use of the name NEMS only to describe an official version of the model with no modifications to the modeling code or data. Because this analysis entails some minor code modifications and the model is run under multiple policy scenarios that are variations on EIA assumptions, DOE refers to it as NEMS-BT.

For fluorescent lamp ballasts, the analysis consisted of forecasted differences between the base and standards cases for electricity generation, installed capacity, and electricity sales. The NEMS-BT model provides reference case load shapes for several end uses, including lighting applications.

For electrical end uses, NEMS-BT uses predicted growth in demand for each end use to project the total electric system load growth for each region, which in turn predicts the necessary additions to electrical generation capacity. NEMS-BT also accounts for the implementation of energy conservation standards by decrementing the appropriate reference case load shape. DOE determines the size of the decrement the same way it calculates national energy savings except that it uses site energy without converting it into source energy.

The use of NEMS-BT for the utility impact analysis offers several advantages. As the official DOE energy forecasting model, NEMS-BT relies on a set of transparent assumptions that have received wide exposure and commentary. NEMS-BT allows an estimate of the interactions between the various energy supply and demand sectors and the economy as a whole.

DOE conducted the utility impact analysis as a variant of the *AEO2010*, applying the same basic set of assumptions.[a] For example, the utility analysis uses the operating characteristics (*e.g.*, energy conversion efficacy, emissions rates) of future electricity generating plants.

The model uses predicted growth in demand for each end use to project total electric system load growth for each region, which in turn is used to predict necessary additions to electrical generation capacity.

The terminal year of the NEMS-BT model is 2035, impacts beyond which are typically assumed constant. As with the *AEO* reference case in general, the implicit premise is that the regulatory environment does not deviate from the current known situation during the extrapolation period. Only changes that have been announced with date-certain introduction are included in NEMS-BT.

14.3 RESULTS

Results of the utility impact analysis include changes in electricity sales, installed capacity, and generation for each TSL in 5-year forecasted increments extrapolated to 2043. DOE provides result for two boundary scenarios: (1) existing technologies, shift; and (2) emerging technologies, roll. Results are for all TSLs presented in 5-year increments to year 2035 for the reference case. Beyond 2035, an extrapolation to 2043 for each TSL is represented by a simple replication of the year 2035 results.

The results for the reference case are shown in Table 14.3.1. A separate set of TSLs are modeled for both the existing technologies, shift scenario and the emerging technologies, roll scenario as the high and low range estimates, respectively. For additional discussion of the formulation of these scenarios, see final rule TSD chapter 10.

The NEMS-BT results, including the difference from the reference case results, are presented in Table 14.3.2 through Table 14.3.9. These tables also present the results across the two scenarios.

New and amended fluorescent lamp ballast efficacy standards result in decreases to electricity consumption for all TSLs compared to the reference case under both scenarios. Power generation capacity is affected to a greater extent due to the larger decreases to electricity consumption

[a] DOE used the *AEO2010*-based NEMS-BT model in both its NOPR and final rule analyses. DOE published a notice of data availability (NODA) on August 24, 2011 to address ballast test data and engineering analysis issues, and seek public comment (see www1.eere.energy.gov/buildings/appliance_standards/residential/notice_of_data_availability.html). The comment period on the NODA closed on September 14, 2011, and DOE was required by consent decree to publish the final amended standards for fluorescent lamp ballasts by October 28, 2011. (*State of New York, et al. v. Bodman et al.*, 05 Civ. 7807 (LAP) and *Natural Resources Defense Council, et al. v. Bodman, et al.*, 05 Civ. 7808 (LAP) (Nov. 3, 2006), as amended on June 20, 2011.) The additional time required for DOE to consider the comments and information submitted by interested parties did not allow sufficient time for DOE to update the final rule analyses using *AEO2011*. DOE has determined, however, that the *AEO2011* 30-year annual growth rates for energy consumption (electric power) and electricity generating capacity are almost identical to those in *AEO2010*, and DOE does not expect utility impact analysis results to vary significantly using *AEO2010* and *AEO2011*.

associated with their adoption. Power generation capacity is reduced by between 1.6 GW (for TSL 1 under the emerging technologies, roll scenario) and 6.7 GW (for TSL 3B under the existing technologies, shift scenario).

Table 14.3.1 Reference Case Forecast: Electricity Consumption, Electricity Generation, and Electricity Capacity

NEMS-BT Results	2005*	2010	2015	2020	2025	2030	2035
*Total Electricity Consumption***							
Electricity Sales (TWh)	3,660	3,617	3,870	4,083	4,274	4,475	4,660
Total U.S. Electricity Generation§							
Coal (TWh)	2,013	1,828	2,039	2,095	2,147	2,215	2,304
Petroleum (TWh)	122	122	122	122	122	122	122
Gas (TWh)	765	765	765	765	765	765	765
Nuclear (TWh)	782	782	782	782	782	782	782
Renewables (TWh)	369	369	369	369	369	369	369
Total (TWh)	4,052	3,866	4,078	4,133	4,185	4,253	4,343
Installed Generating Capacity							
Fossil Steam (GW)§§	431	432	411	407	407	410	415
Combined Cycle (GW)	170	197	201	201	209	234	244
Combustion Turbines (GW)	130	138	133	136	148	156	175
Nuclear (GW)	100	102	105	111	111	111	113
Renewables (GW)	115	146	176	177	179	182	191
Total (GW)	946	1,015	1,026	1,032	1,054	1,093	1,138

*Values for 2005 are reported by NEMS-BT, but are very close to the historical values shown in various tables in *AEO2010*.
**Comparable to Table A8 of *AEO2010*, Electricity Supply, Disposition, Prices, and Emissions. Includes generation from electricity-only, combined heat and power, and end-use generators.
§Comparable to Table A9 of *AEO2010*, Electricity Generating Capacity.
§§Includes coal steam and other fossil fuel steam plants.

Table 14.3.2 Utility Impacts for Emerging Technologies, Roll-up Scenario from TSL 1

NEMS-BT Results	Difference from Reference Case						
						Extrapolation	
	2015	2020	2025	2030	2035	2040	2043
Total Electricity Consumption							
Electricity Sales (TWh)	-0.83	-2.54	-3.74	-4.43	-4.62	-4.62	-4.62
Total U.S. Electricity Generation							
Coal (TWh)	-0.28	-0.71	-0.76	-0.44	0.25	0.25	0.25
Petroleum (TWh)	-0.01	-0.01	-0.01	-0.01	0.01	0.01	0.01
Gas (TWh)	-0.13	-0.49	-0.92	-1.40	-1.94	-1.94	-1.94
Nuclear (TWh)	0.06	0.10	0.02	-0.18	-0.52	-0.52	-0.52
Renewables (TWh)	-0.50	-1.52	-2.23	-2.62	-2.69	-2.69	-2.69
Total (TWh)	-0.86	-2.64	-3.90	-4.65	-4.88	-4.88	-4.88
Installed Generating Capacity							
Fossil Steam (GW)	-0.02	-0.06	-0.06	-0.04	0.02	0.02	0.02
Combined Cycle (GW)	-0.04	-0.14	-0.25	-0.37	-0.48	-0.48	-0.48
Combustion Turbines (GW)	-0.13	-0.36	-0.45	-0.40	-0.22	-0.22	-0.22
Nuclear (GW)	0.01	0.01	0.00	-0.03	-0.07	-0.07	-0.07
Renewables (GW)	-0.14	-0.42	-0.59	-0.65	-0.62	-0.62	-0.62
Total (GW)	-0.32	-0.96	-1.34	-1.48	-1.37	-1.37	-1.37

Table 14.3.3 Utility Impacts for Emerging Technologies, Roll-up Scenario from TSL 2

NEMS-BT Results	Difference from Reference Case						
						Extrapolation	
	2015	**2020**	**2025**	**2030**	**2035**	**2040**	**2043**
Total Electricity Consumption							
Electricity Sales (TWh)	-1.32	-4.04	-5.95	-7.06	-7.36	-7.36	-7.36
Total U.S. Electricity Generation							
Coal (TWh)	-0.44	-1.13	-1.22	-0.71	0.41	0.41	0.41
Petroleum (TWh)	-0.01	-0.02	-0.02	-0.01	0.01	0.01	0.01
Gas (TWh)	-0.21	-0.79	-1.46	-2.22	-3.08	-3.08	-3.08
Nuclear (TWh)	0.09	0.17	0.04	-0.29	-0.83	-0.83	-0.83
Renewables (TWh)	-0.80	-2.43	-3.55	-4.17	-4.28	-4.28	-4.28
Total (TWh)	-1.36	-4.20	-6.21	-7.40	-7.77	-7.77	-7.77
Installed Generating Capacity							
Fossil Steam (GW)	-0.04	-0.09	-0.10	-0.06	0.03	0.03	0.03
Combined Cycle (GW)	-0.06	-0.22	-0.40	-0.58	-0.76	-0.76	-0.76
Combustion Turbines (GW)	-0.21	-0.57	-0.72	-0.64	-0.36	-0.36	-0.36
Nuclear (GW)	0.01	0.02	0.01	-0.04	-0.11	-0.11	-0.11
Renewables (GW)	-0.22	-0.66	-0.93	-1.03	-0.98	-0.98	-0.98
Total (GW)	-0.52	-1.53	-2.14	-2.36	-2.18	-2.18	-2.18

Table 14.3.4 Utility Impacts for Emerging Technologies, Roll-up Scenario from TSL 3A

NEMS-BT Results	Difference from Reference Case						
						Extrapolation	
	2015	**2020**	**2025**	**2030**	**2035**	**2040**	**2043**
Total Electricity Consumption							
Electricity Sales (TWh)	-1.81	-5.55	-8.17	-9.69	-10.10	-10.10	-10.10
Total U.S. Electricity Generation							
Coal (TWh)	-0.61	-1.55	-1.67	-0.97	0.56	0.56	0.56
Petroleum (TWh)	-0.01	-0.03	-0.03	-0.01	0.02	0.02	0.02
Gas (TWh)	-0.28	-1.08	-2.00	-3.05	-4.23	-4.23	-4.23
Nuclear (TWh)	0.12	0.23	0.05	-0.40	-1.14	-1.14	-1.14
Renewables (TWh)	-1.09	-3.33	-4.88	-5.73	-5.88	-5.88	-5.88
Total (TWh)	-1.87	-5.76	-8.52	-10.16	-10.67	-10.67	-10.67
Installed Generating Capacity							
Fossil Steam (GW)	-0.05	-0.12	-0.13	-0.08	0.04	0.04	0.04
Combined Cycle (GW)	-0.08	-0.31	-0.55	-0.80	-1.04	-1.04	-1.04
Combustion Turbines (GW)	-0.28	-0.78	-0.98	-0.88	-0.49	-0.49	-0.49
Nuclear (GW)	0.02	0.03	0.01	-0.05	-0.16	-0.16	-0.16
Renewables (GW)	-0.31	-0.91	-1.28	-1.42	-1.35	-1.35	-1.35
Total (GW)	-0.71	-2.09	-2.94	-3.23	-2.99	-2.99	-2.99

Table 14.3.5 Utility Impacts for Emerging Technologies, Roll-up Scenario from TSL 3B

NEMS-BT Results	Difference from Reference Case						
						Extrapolation	
	2015	**2020**	**2025**	**2030**	**2035**	**2040**	**2043**
Total Electricity Consumption							
Electricity Sales (TWh)	-1.90	-5.83	-8.59	-10.19	-10.61	-10.61	-10.61
Total U.S. Electricity Generation							
Coal (TWh)	-0.64	-1.63	-1.76	-1.02	0.59	0.59	0.59
Petroleum (TWh)	-0.01	-0.03	-0.03	-0.01	0.02	0.02	0.02
Gas (TWh)	-0.30	-1.13	-2.10	-3.21	-4.45	-4.45	-4.45
Nuclear (TWh)	0.13	0.24	0.06	-0.42	-1.19	-1.19	-1.19
Renewables (TWh)	-1.15	-3.50	-5.13	-6.02	-6.18	-6.18	-6.18
Total (TWh)	-1.97	-6.05	-8.96	-10.68	-11.22	-11.22	-11.22
Installed Generating Capacity							
Fossil Steam (GW)	-0.05	-0.13	-0.14	-0.08	0.05	0.05	0.05
Combined Cycle (GW)	-0.09	-0.32	-0.57	-0.84	-1.09	-1.09	-1.09
Combustion Turbines (GW)	-0.30	-0.82	-1.03	-0.93	-0.51	-0.51	-0.51
Nuclear (GW)	0.02	0.03	0.01	-0.06	-0.17	-0.17	-0.17
Renewables (GW)	-0.32	-0.96	-1.35	-1.49	-1.42	-1.42	-1.42
Total (GW)	-0.74	-2.20	-3.09	-3.40	-3.14	-3.14	-3.14

Table 14.3.6 Utility Impacts for Existing Technologies, Shift Scenario from TSL 1

NEMS-BT Results	Difference from Reference Case						
						Extrapolation	
	2015	**2020**	**2025**	**2030**	**2035**	**2040**	**2043**
Total Electricity Consumption							
Electricity Sales (TWh)	-1.50	-5.04	-8.25	-11.14	-13.71	-13.71	-13.71
Total U.S. Electricity Generation							
Coal (TWh)	-0.60	-1.62	-2.00	-1.71	-0.77	-0.77	-0.77
Petroleum (TWh)	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Gas (TWh)	0.44	0.61	-0.54	-3.01	-6.81	-6.81	-6.81
Nuclear (TWh)	0.08	0.15	0.04	-0.26	-0.74	-0.74	-0.74
Renewables (TWh)	-1.50	-4.42	-6.12	-6.61	-5.89	-5.89	-5.89
Total (TWh)	-1.58	-5.28	-8.62	-11.60	-14.22	-14.22	-14.22
Installed Generating Capacity							
Fossil Steam (GW)	-0.07	-0.18	-0.23	-0.20	-0.12	-0.12	-0.12
Combined Cycle (GW)	-0.06	-0.29	-0.64	-1.12	-1.59	-1.59	-1.59
Combustion Turbines (GW)	-0.26	-0.71	-0.90	-0.81	-0.48	-0.48	-0.48
Nuclear (GW)	0.01	0.02	0.01	-0.04	-0.11	-0.11	-0.11
Renewables (GW)	-0.42	-1.20	-1.64	-1.71	-1.52	-1.52	-1.52
Total (GW)	-0.78	-2.36	-3.39	-3.88	-3.81	-3.81	-3.81

Table 14.3.7 Utility Impacts for Existing Technologies, Shift Scenario from TSL 2

NEMS-BT Results	Difference from Reference Case						
						Extrapolation	
	2015	**2020**	**2025**	**2030**	**2035**	**2040**	**2043**
Total Electricity Consumption							
Electricity Sales (TWh)	-1.80	-6.02	-9.86	-13.31	-16.37	-16.37	-16.37
Total U.S. Electricity Generation							
Coal (TWh)	-0.71	-1.94	-2.38	-2.04	-0.92	-0.92	-0.92
Petroleum (TWh)	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Gas (TWh)	0.53	0.73	-0.64	-3.60	-8.14	-8.14	-8.14
Nuclear (TWh)	0.10	0.18	0.05	-0.31	-0.88	-0.88	-0.88
Renewables (TWh)	-1.80	-5.28	-7.31	-7.90	-7.04	-7.04	-7.04
Total (TWh)	-1.89	-6.31	-10.30	-13.86	-16.99	-16.99	-16.99
Installed Generating Capacity							
Fossil Steam (GW)	-0.08	-0.22	-0.27	-0.24	-0.14	-0.14	-0.14
Combined Cycle (GW)	-0.07	-0.34	-0.76	-1.34	-1.90	-1.90	-1.90
Combustion Turbines (GW)	-0.31	-0.85	-1.07	-0.97	-0.58	-0.58	-0.58
Nuclear (GW)	0.01	0.02	0.01	-0.04	-0.13	-0.13	-0.13
Renewables (GW)	-0.50	-1.44	-1.95	-2.04	-1.81	-1.81	-1.81
Total (GW)	-0.94	-2.82	-4.05	-4.63	-4.56	-4.56	-4.56

Table 14.3.8 Utility Impacts for Existing Technologies, Shift Scenario from TSL 3A

NEMS-BT Results	Difference from Reference Case						
						Extrapolation	
	2015	**2020**	**2025**	**2030**	**2035**	**2040**	**2043**
Total Electricity Consumption							
Electricity Sales (TWh)	-2.50	-8.39	-13.73	-18.54	-22.82	-22.82	-22.82
Total U.S. Electricity Generation							
Coal (TWh)	-0.99	-2.70	-3.32	-2.85	-1.28	-1.28	-1.28
Petroleum (TWh)	0.00	-0.01	-0.01	-0.02	-0.02	-0.02	-0.02
Gas (TWh)	0.73	1.02	-0.90	-5.02	-11.34	-11.34	-11.34
Nuclear (TWh)	0.13	0.26	0.07	-0.43	-1.23	-1.23	-1.23
Renewables (TWh)	-2.50	-7.35	-10.19	-11.01	-9.81	-9.81	-9.81
Total (TWh)	-2.63	-8.79	-14.35	-19.31	-23.67	-23.67	-23.67
Installed Generating Capacity							
Fossil Steam (GW)	-0.11	-0.30	-0.38	-0.34	-0.20	-0.20	-0.20
Combined Cycle (GW)	-0.09	-0.48	-1.06	-1.86	-2.64	-2.64	-2.64
Combustion Turbines (GW)	-0.43	-1.18	-1.49	-1.35	-0.80	-0.80	-0.80
Nuclear (GW)	0.02	0.03	0.01	-0.06	-0.18	-0.18	-0.18
Renewables (GW)	-0.69	-2.01	-2.72	-2.84	-2.52	-2.52	-2.52
Total (GW)	-1.30	-3.93	-5.65	-6.45	-6.35	-6.35	-6.35

Table 14.3.9 Utility Impacts for Existing Technologies, Shift Scenario from TSL 3B

NEMS-BT Results	Difference from Reference Case						
						Extrapolation	
	2015	**2020**	**2025**	**2030**	**2035**	**2040**	**2043**
Total Electricity Consumption							
Electricity Sales (TWh)	-2.50	-8.39	-13.74	-18.55	-22.82	-22.82	-22.82
Total U.S. Electricity Generation							
Coal (TWh)	-0.99	-2.70	-3.32	-2.85	-1.28	-1.28	-1.28
Petroleum (TWh)	0.00	-0.01	-0.01	-0.02	-0.02	-0.02	-0.02
Gas (TWh)	0.73	1.02	-0.90	-5.02	-11.34	-11.34	-11.34
Nuclear (TWh)	0.13	0.26	0.07	-0.43	-1.23	-1.23	-1.23
Renewables (TWh)	-2.51	-7.36	-10.19	-11.01	-9.81	-9.81	-9.81
Total (TWh)	-2.63	-8.79	-14.36	-19.32	-23.68	-23.68	-23.68
Installed Generating Capacity							
Fossil Steam (GW)	-0.11	-0.30	-0.38	-0.34	-0.20	-0.20	-0.20
Combined Cycle (GW)	-0.09	-0.48	-1.07	-1.86	-2.64	-2.64	-2.64
Combustion Turbines (GW)	-0.43	-1.18	-1.49	-1.35	-0.80	-0.80	-0.80
Nuclear (GW)	0.02	0.03	0.01	-0.06	-0.18	-0.18	-0.18
Renewables (GW)	-0.69	-2.01	-2.72	-2.85	-2.52	-2.52	-2.52
Total (GW)	-1.31	-3.93	-5.65	-6.45	-6.35	-6.35	-6.35

14.4 SUMMARY OF UTILITY IMPACT ANALYSIS

The following tables summarize the utility impact results for all fluorescent lamp ballast TSLs in the final year of the analysis period, 2043. Table 14.4.1 presents the reduction in total U.S. electricity generation in 2043 for both the existing technologies, shift scenario and the emerging technologies, roll-up scenario. Table 14.4.2 presents the reduction in total U.S. electric generating capacity in 2043 for both the existing technologies, shift scenario and the emerging technologies, roll-up scenario.

Table 14.4.1 Reduction in Total U.S. Electricity Generation (TWh) in 2043 for Ballasts TSLs

Analyzed Scenario/ TWh	TSL 1	TSL 2	TSL 3A	TSL 3B
Existing Technologies, Shift Scenario	14.2	17.0	23.7	23.7
Emerging Technologies, Roll-up Scenario	4.9	7.8	10.7	11.2

Table 14.4.2 Reduction in Electric Generating Capacity (GW) in 2043 for Ballasts TSLs

Analyzed Scenario/ GW	TSL 1	TSL 2	TSL 3A	TSL 3B
Existing Technologies, Shift Scenario	3.8	4.6	6.3	6.4
Emerging Technologies, Roll-up Scenario	1.4	2.2	3.0	3.1

14.5 IMPACT OF STANDARDS ON ELECTRICITY PRICES AND ASSOCIATED BENEFITS FOR CONSUMERS

For this rule, DOE used NEMS-BT to assess the impacts of the reduced need for new electric power plants and infrastructure projected to result from adopted standards. In NEMS-BT, changes in power generation infrastructure affect utility revenue requirements, which in turn affect electricity prices. Using the framework of the utility impact analysis, DOE analyzed the potential impact on electricity prices resulting from the adopted standards on fluorescent lamp ballasts. Associated benefits for all electricity users in all sectors of the economy were then derived from these price impacts.

In addition, utilities may avoid building additional power plants due to reduced demand. Table 14.5.1 presents overnight capital cost per kilowatt-hour from NEMS input file from *AEO 2010*. These are capital costs of a project as if it could be constructed overnight and do not include the interest cost of funds used during construction. Depending on the power plant type, costs vary significantly. Furthermore, uncertainties about regulations of CO_2 emissions, technological progress affecting clean energy sources, commodity prices as well as other uncertainties affect the power plant mix in the economy. DOE continues to investigate how capital costs of avoided capacity could be integrated into the analysis.

Table 14.5.1 Overnight Capital Costs per Kilowatt-hour by Power Plant Type

Power Plant Type	**Size** *MW*	**Overnight Capital Cost in 2010 (AEO 2010)** *$2010/kW*
Scrubbed Pulverized Coal	600	3,258
Integrated Gas Comb Cycle	550	3,764
Int. Gas Comb Cycle w/ Sequestration	380	5,372
Gas/Oil Steam Turbine	300	2,739
Existing Combustion Turbine	160	600
Conv Combustion Turbine	160	1,023
Adv Combustion Turbine	230	968
Existing Gas/Oil Comb Cycle	250	808
Conv Gas/Oil Comb Cycle	250	1,469
Adv Gas/Oil Comb Cycle	400	1,406
Adv CC w/Sequestration	400	2,697
Fuel Cells	10	7,437
Conventional Nuclear	1,350	9,837
Advanced Nuclear	1,350	5,186
Biomass (Wood)	80	5,351
Geothermal	50	4,475
Municipal Solid Waste	30	3,809
Hydroelectric	500	2,652
Pumped Storage	250	5,831
Other Storage	1	393
Wind	50	2,880
Wind Offshore	100	5,475
Solar Thermal	100	7,521
Photovoltaic	5	9,215
Distributed Generation-Base	2	2,091
Distributed Generation-Peak	1	2,510

14.5.1 Impact on Electricity Prices

DOE analyzed energy price impacts using NEMS-BT in a manner similar to that described in section 14.2. The price changes result from the lower demand for electricity that is expected to reduce the requirement for higher cost generation capacity in the electric utility sector.

DOE analyzed the electricity price effect for the adopted TSL 3A for the fluorescent lamp ballasts energy conservation standard. Figure 14.5.1 shows the annual change in average U.S. price for electricity, relative to the AEO2010 reference case, projected to result from the adopted standard for the existing technologies, shift scenario. Figure 14.5.2 depicts the emerging technologies, roll-up scenario. The price reduction averages 0.01 cents per kilowatt-hour (in 2010$) for both scenarios.

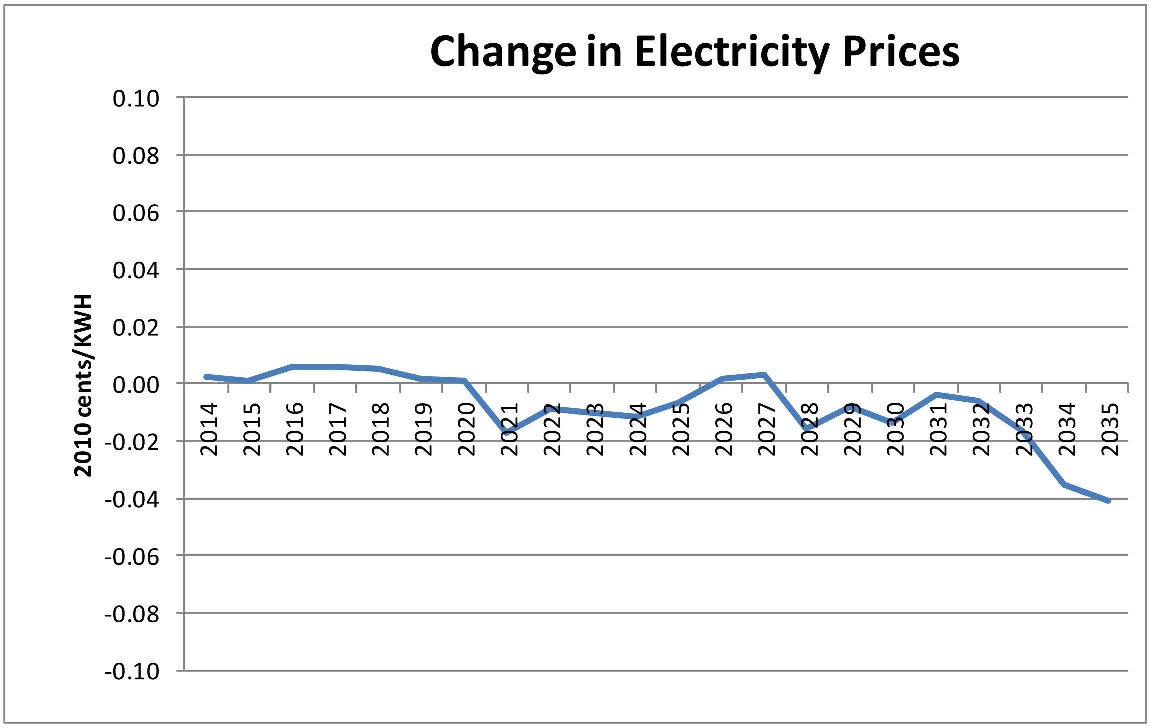

Figure 14.5.1 Effect of Adopted Ballast Energy Conservation Standards on Average U.S. Electricity Price (All Users) for the Existing Technologies, Shift Scenario

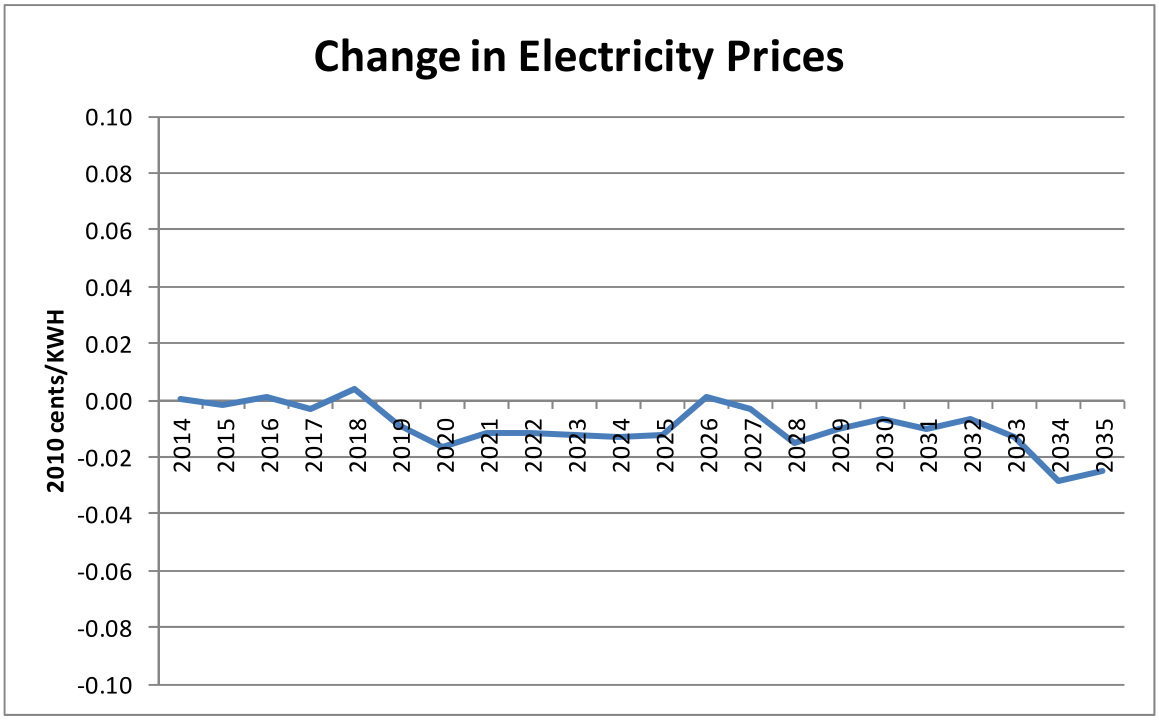

Figure 14.5.2 Effect of Adopted Ballast Energy Conservation Standards on Average U.S. Electricity Price (All Users) for the Emerging Technologies, Roll-up Scenario

14.5.2 Impact of Changes in Electricity Price on Electricity Users

Using the estimated electricity price impacts, DOE calculated the nominal savings in total electricity expenditures in each year by multiplying the annual change in the average user price for electricity by the total annual U.S. electricity consumption forecast by NEMS-BT, adjusted for the impact of the standards. The amended standards would continue to reduce demand for electricity after 2035 (which is the last year in the NEMS forecast). DOE's estimate for 2036–2043 (the period used to estimate the net present value (NPV) of the national consumer benefits from amended standards) multiplied the average electricity price reduction in 2015–2035 by estimated total annual electricity consumption in 2036–2043.[b] DOE then discounted the stream of reduced expenditures to calculate an NPV.

Table 14.5.2 shows the calculated NPV of the economy-wide savings in electricity expenditures for the adopted standard at 3-percent and 7-percent discount rates. The need to extrapolate price effects and electricity consumption beyond 2035 suggests that one should interpret the post-2035 results as a rough indication of the benefits to electricity users in the post-2035 period.

[b] The estimation of electricity consumption after 2035 uses the average annual growth rate in 2031–2035 of total U.S. electricity consumption forecasted by NEMS. This forecast includes the impact of the standards.

Table 14.5.2 Cumulative NPV of the Economy-Wide Savings in Electricity in Expenditures Due to the Projected Decline in Electricity Prices Resulting from the Adopted Standards for Fluorescent Lamp Ballasts

Discount Rate	Emerging Technologies, Roll-up	Existing Technologies, Shift
	billion 2010$	
3 percent	2.0	1.7
7 percent	3.9	3.9

*Impacts for units sold from 2014 to 2043

14.5.3 Discussion of Savings in Electricity Expenditures

Although the aggregate benefits for all electricity users are potentially large, there may be negative effects on those involved in electricity supply. ,An assessment of impacts on those involved in electricity supply from reduction in electricity demand associated with energy conservation standards, however, is beyond the scope of this rulemaking.

In considering the potential benefits to electricity users, DOE takes under advisement the information 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”). Specifically, at page 38, Circular A-4 instructs that transfers should be excluded from the estimates of the benefits and costs of a regulation. DOE is continuing to investigate the extent to which change in electricity prices projected to result from standards represents a net gain to society.

REFERENCES

1. U.S. Department of Energy–Energy Information Administration. *Annual Energy Outlook 2010*. 2010. (Last accessed February 27, 2011.) <www.eia.gov/oiaf/archive/aeo10/index.html>

CHAPTER 15. EMPLOYMENT IMPACT ANALYSIS

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15.1 INTRODUCTION

The U.S. Department of Energy's (DOE) employment impact analysis is designed to estimate indirect national job creation or elimination resulting from adopted standards, due to reallocation of the associated expenditures for purchasing and operating fluorescent lamp ballasts (hereafter referred to as "ballasts"). DOE conducted this analysis as part of this final rule.

15.2 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 ballasts, including the retail price plus sales tax, and increase installation costs.

Using an input/output econometric model of the U.S. economy, this analysis estimated the short-term effect of these expenditure impacts on net economic output and employment. DOE intends this analysis to quantify the indirect employment impacts of these expenditure changes. It evaluated direct employment impacts at manufacturers' facilities in the manufacturer impact analysis (see final rule technical support document (TSD) chapter 13).

DOE notes that ImSET (Impact of Sector Energy Technologies) 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. Since input/output models do not allow prices to bring markets into equilibrium, they are best used for short-run analysis. We 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.

15.3 METHODOLOGY

DOE based its analysis on an input/output model of the U.S. economy that estimates the effects of standards on major sectors of the economy related to buildings and the net impact of standards on jobs. The Pacific Northwest National Laboratory developed the model, ImSET 3.1.1[2] 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 appliances. The increased cost of appliances leads to higher employment in the appliance manufacturing sectors and lower employment in other economic sectors. Second, commercial firm and residential spending are redirected from utilities toward firms that supply production inputs. Third, electric utility sector investment funds are released for use in other sectors of the economy. When consumers use less energy, electric utilities experience relative reductions in demand which leads to reductions in utility sector investment and employment.

DOE also notes that the employment impacts estimated with ImSET for the entire economy differ from the employment impacts in the ballast manufacturing sector estimated in the final rule TSD chapter 13 using the Government Regulatory Impact Model (GRIM). The methodologies used and the sectors analyzed in the ImSET and GRIM models are different.

15.4 SHORT-TERM RESULTS

The results in this section refer to impacts of ballast standards relative to the base case. DOE disaggregated the impact of standards on employment into three component effects: increased capital investment costs, decreased energy and water costs, and changes in operations and maintenance costs. DOE presents the summary impact.

Conceptually, one can consider the impact of the rule in its first year on three aggregate sectors, the ballast production sector, the energy generation sector, and the general consumer good sector (as mentioned above ImSET's calculations are made at a much more disaggregate level). By raising energy efficiency, the rule generally increases the purchase price of ballasts, this increase in expenditures causes an increase in employment in this sector. At the same time, the improvements in energy efficiency reduce consumer expenditures on electricity. The reduction in electricity demand causes a reduction in employment in that sector. Finally, based on the net impact of increased expenditures on ballasts and reduced expenditures on electricity, consumer expenditures on everything else are either positively or negatively affected, increasing or reducing jobs in that sector accordingly. The model also captures any indirect jobs created or lost by changes in consumption due to changes in employment (as more workers are hired they consume more goods, which generates more employment; the converse is true for workers laid off). Table 15.4.1 presents the modeled net employment impact from the rule in 2015 and 2020.

Table 15.4.1 Net National Short-Term Change in Employment (number of jobs)*

Analysis Period Year	Trial Standard Level	Net National Change in Jobs	
		Existing Technologies, Shift	Emerging Technologies, Roll- up
2015	1	150	170
	2	120	150
	3A	70	90
	3B	70	90
2020	1	640	390
	2	620	500
	3A	680	580
	3B	680	620

* Compliance date of standard levels is 2014.

15.5 LONG-TERM RESULTS

Due to the short payback period of energy efficiency improvements mandated by this rule, over the long term we expect the energy savings to consumers to increasingly dominate the increase in appliance costs, resulting in increased aggregate savings to consumers. As a result, we expect demand for electricity to decline over time and demand for other goods to increase. Since the electricity generation sector is relatively capital intensive compared to the consumer goods sector, the net effect will be an increase in labor demand. In equilibrium, this should lead to upward pressure on wages and a shift in employment away from electricity generation towards consumer goods. Note that in long-run equilibrium there is no net effect on total employment since wages adjust to bring the labor market into equilibrium. Nonetheless, even to the extent that markets are slow to adjust, we anticipate that net labor market impacts will be negligible over time due to the small magnitude of the short-term effects presented in Table 15.4.1. The ImSET model projections, assuming no price or wage effects until 2020, are included in the second column of Table 15.4.1.

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CHAPTER 16. ENVIRONMENTAL ASSESSMENT

16.1 INTRODUCTION

Pursuant to the National Environmental Policy Act of 1969 and the requirements of DOE Order 451.1B: NEPA Compliance Program, the U.S. Department of Energy (DOE) has prepared an environmental assessment (EA) of the impacts of the new and amended standards for ballasts in this final rule. DOE found that the environmental effects associated with the standards for ballasts were not significant. Therefore, DOE is issuing a Finding of No Significant Impact (FONSI), pursuant to NEPA, the regulations of the Council on Environmental Quality (40 CFR parts 1500–1508), and DOE's regulations for compliance with NEPA (10 CFR part 1021). The FONSI is available in the docket for this rulemaking.

This chapter describes potential environmental effects that may result from new energy conservation standards for fluorescent lamp ballasts (FLB or ballasts). DOE's adopted energy conservation standards are not site-specific, and would apply to all 50 states and U.S. territories. Therefore, none of the standards would impact land uses, cause any direct disturbance to the land, or directly affect biological resources in any one area.

For this final rule, all of the trial standard levels (TSLs) are expected to reduce energy use in comparison to the base case. These changes in energy use are the primary drivers in analyzing environmental effects. The estimates of energy savings that serve as inputs to the environmental impacts analysis can be found in the utility impact analysis in chapter 14 of this final rule technical support document (TSD).

The primary impact of the TSLs is on air emissions resulting from power plant operations. Therefore, much of this chapter describes the air emissions analysis, and the latter part of the chapter describes potential impacts to other environmental resources.

16.2 AIR EMISSIONS ANALYSIS

A primary focus of the environmental analysis is the impact on air emissions of new energy conservation standards for ballasts. The outcomes of the environmental analysis are largely driven by changes in power plant types and quantities of electricity generated under each of the alternatives. Changes in electricity generation are described in the utility impact analysis in chapter 14 of this final rule TSD.

16.2.1 Air Emissions Descriptions

For each of the TSLs, DOE calculated total power-sector emissions based on output from the National Energy Modeling System-Building Technologies (NEMS-BT) model (see final rule TSD chapter 14 for a description of the model). This analysis considers three pollutants: sulfur dioxide (SO_2), nitrogen oxides (NO_x), and mercury (Hg). An air pollutant is any substance in the air that can cause harm to humans or the environment. Pollutants may be natural or man-made (*i.e.*, anthropogenic) and may take the form of solid particles (*i.e.*, particulates or particulate matter), liquid droplets, or gases.[a] This analysis also considers carbon dioxide (CO_2).

Sulfur Dioxide. Sulfur dioxide, or SO_2, belongs to the family of sulfur oxide gases (SO_x). These gases dissolve easily in water. Sulfur is prevalent in all raw materials, including crude oil, coal, and ore that contains common metals like aluminum, copper, zinc, lead, and iron. SO_x gases are formed when fuel containing sulfur, such as coal and oil, is burned, and when gasoline is extracted from oil or metals are extracted from ore. SO_2 dissolves in water vapor to form acid, and interacts with other gases and particles in the air to form sulfates and other products that can be harmful to people and their environment.[1]

SO_2 emissions from affected electricity generating units (EGUs) are subject to nationwide and regional emissions cap-and-trade programs, and DOE has preliminarily determined that these programs create uncertainty about the standards' impact on SO_2 emissions. The attainment of the emissions caps is flexible among EGUs and is enforced through the use of emissions allowances and tradable permits. Under existing EPA regulations, any excess SO_2 emission 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. However, if the standard resulted in a permanent increase in the quantity of unused emission allowances, there would be an overall reduction in SO_2 emissions from the standards. While there remains some uncertainty about the ultimate effects of efficiency standards on SO_2 emissions covered by the existing cap-and-trade system, the NEMS-BT modeling system that DOE uses to forecast emissions reductions currently indicates that no physical reductions in power sector emissions would occur for SO_2.

Nitrogen Oxides. Nitrogen oxides, or NO_x, is the generic term for a group of highly reactive gases, all of which contain nitrogen and oxygen in varying amounts. Many of the nitrogen oxides are colorless and odorless. However, one common pollutant, nitrogen dioxide (NO_2), along with particles in the air, can often be seen as a reddish-brown layer over many urban areas. NO_2 is the specific form of NO_x reported in this document. NO_x is one of the main ingredients involved in the formation of ground-level ozone, which can trigger serious respiratory problems. It can contribute to the formation of acid rain, and can impair visibility in areas such as national parks. NO_x also contributes to the formation of fine particles that can impair human health.[2]

Nitrogen oxides form when fossil fuel is burned at high temperatures, as in a combustion process. The primary manmade sources of NO_x are motor vehicles; electric utilities; and other industrial, commercial, and residential sources that burn fossil fuels. NO_x can also be formed naturally. Electric utilities account for about 22 percent of NO_x emissions in the United States.[3]

The Clean Air Interstate Rule (CAIR) (discussed further in section 16.2.2) established a cap on NO_x emissions in 28 eastern states and the District of Columbia. All these states and D.C. have elected to reduce their NO_x emissions by participating in cap-and-trade programs for EGUs. Therefore, energy conservation standards for ballasts may have little or no physical effect on

[a] More information on air pollution characteristics and regulations is available on the U.S. Environmental Protection Agency (EPA) website at www.epa.gov.

these emissions in the 28 eastern states and D.C. for the same reasons that they may have little or no physical effect on SO_2 emissions.

DOE is using NEMS-BT to estimate NO_x emissions reductions from possible standards in the states where emissions were not capped under CAIR.

Mercury. Coal-fired power plants emit mercury, or Hg, found in coal during the burning process. While coal-fired power plants are the largest remaining source of human-generated Hg emissions in the United States, they contribute very little to the global Hg pool or to contamination of U.S. waters.[4] U.S. coal-fired power plants emit Hg in three different forms: oxidized Hg (likely to deposit within the United States); elemental Hg, which can travel thousands of miles before depositing to land and water; and Hg that is in particulate form. Atmospheric Hg is then deposited on land, lakes, rivers, and estuaries through rain, snow, and dry deposition. Once there, it can transform into methylmercury and accumulate in fish tissue through bioaccumulation.

Americans are exposed to methylmercury primarily by eating contaminated fish. Because the developing fetus is the most sensitive to the toxic effects of methylmercury, women of childbearing age are regarded as the population of greatest concern. Children exposed to methylmercury before birth may be at increased risk of poor performance on neurobehavioral tasks, such as those measuring attention, fine motor function, language skills, visual-spatial abilities, and verbal memory.[4]

Carbon Dioxide. Carbon dioxide, or CO_2, is not a criteria pollutant (see below), but it is of interest because of its classification as a greenhouse gas (GHG). GHGs trap the sun's radiation inside the Earth's atmosphere and either occur naturally in the atmosphere or result from human activities. Naturally occurring GHGs include water vapor, CO_2, methane (CH_4), nitrous oxide (N_2O), and ozone (O_3). Human activities, however, add to the levels of most of these naturally occurring gases. For example, CO_2 is emitted to the atmosphere when solid waste, fossil fuels (oil, natural gas, and coal), wood, and wood products are burned. In 2007, over 90 percent of anthropogenic CO_2 emissions resulted from burning fossil fuels.[5]

Concentrations of CO_2 in the atmosphere are naturally regulated by numerous processes, collectively known as the "carbon cycle." The movement of carbon between the atmosphere and the land and oceans is dominated by natural processes, such as plant photosynthesis. While these natural processes can absorb some of the anthropogenic CO_2 emissions produced each year, billions of metric tons (MT) are added to the atmosphere annually. In 2007, CO_2 emissions from electricity generation accounted for 39 percent of total U.S. GHG emissions.[5]

Particulate Matter. Particulate matter, or PM, also known as particle pollution, is a complex mixture of extremely small particles and liquid droplets. Particle pollution is made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles.

PM impacts are of concern due to human exposures that can impact health. Particle pollution—especially fine particles—contains microscopic solids or liquid droplets that are so small that they can get deep into the lungs and cause serious health problems. Numerous scientific studies have linked particle pollution exposure to a variety of problems, including increased respiratory symptoms, such as irritation of the airways, coughing, or difficulty breathing, for example; decreased lung function; aggravated asthma; development of chronic bronchitis; irregular heartbeat; nonfatal heart attacks; and premature death in people with heart or lung disease.

DOE acknowledges that PM exposure can impact human health. Power plant emissions can have either direct or indirect impacts on PM. A portion of the pollutants emitted by a power plant are in the form of particulates as they leave the smoke stack. These are direct, or primary, PM emissions. However, the great majority of PM emissions associated with power plants are in the form of secondary sulfates, which are produced at a significant distance from power plants by complex atmospheric chemical reactions that often involve the gaseous (non-particulate) emissions of power plants, mainly SO_2 and NO_x. The quantity of the secondary sulfates produced is determined by a very complex set of factors, including the atmospheric quantities of SO_2 and NO_x, and other atmospheric constituents and conditions. Because these highly complex chemical reactions produce PM comprised of different constituents from different sources, EPA does not distinguish direct PM emissions from power plants from the secondary sulfate particulates in its ambient air quality requirements, PM monitoring of ambient air quality, or PM emissions inventories. For these reasons, it is not currently possible to determine how the new standard impacts either direct or indirect PM emissions. Therefore, DOE did not assess the impact of these standards on PM emissions. Further, as described previously, it is uncertain whether efficiency standards will result in a net decrease in power plant emissions of SO_2 and NO_x, since those pollutants are now largely regulated by cap-and-trade systems.

16.2.2 Air Quality Regulation

The Clean Air Act Amendments of 1990 list 188 toxic air pollutants that EPA is required to control.[6] EPA has set national air quality standards for six common pollutants (also referred to as "criteria" pollutants), two of which are SO_2 and NO_x. Also, the Clean Air Act Amendments of 1990 gave EPA the authority to control acidification and to require operators of electric power plants to reduce emissions of SO_2 and NO_x. Title IV of the 1990 amendments established a cap-and-trade program for SO_2 intended to help control acid rain.[6] This cap-and-trade program serves as a model for more recent programs with similar features.

In 2005, EPA issued the CAIR under sections 110 and 111 of the Clean Air Act (40 CFR parts 51, 96, and 97).[b] 70 FR 25162–25405 (May 12, 2005). CAIR limited emissions from 28 eastern states and D.C. by capping emissions and creating an allowance-based trading program. Although CAIR was remanded to EPA by the U.S. Court of Appeals for the District of Columbia Circuit (D.C. Circuit) (see *North Carolina v. EPA*, 550 F.3d 1176 (D.C. Cir. 2008)), it remained in effect temporarily, consistent with the D.C. Circuit's earlier opinion in *North Carolina v. EPA*, 531 F.3d 896 (D.C. Cir. 2008). On July 6, 2010, EPA issued the Transport Rule proposal, a replacement for CAIR, 75 FR 45210 (Aug. 2, 2010), and on July 6, 2011, EPA issued the final Transport Rule, titled "Federal Implementation Plans: Interstate Transport of Fine Particulate

[b] See www.epa.gov/cleanairinterstaterule/.

Matter and Ozone and Correction of SIP Approvals," but commonly referred to as the Cross-State Air Pollution Rule or the Transport Rule. 76 FR 48208 (Aug. 8, 2011).[c]

With respect to Hg emissions, in 2005, EPA issued the final rule titled "Standards of Performance for New and Existing Stationary Sources: Electric Steam Generating Units," under sections 110 and 111 of the Clean Air Act (40 CFR parts 60, 63, 72, and 75). This rule, called the Clean Air Mercury Rule (CAMR), was closely related to the CAIR and established standards of performance for Hg emissions from new and existing coal-fired electric utility steam generating units. The CAMR regulated Hg emissions from coal-fired power plants.

On February 8, 2008, the U.S. Court of Appeals for the D.C. Circuit issued its decision in *State of New Jersey, et al. v. Environmental Protection Agency*, 517 F.3d 574, 583 (D.C. Cir. 2008), in which the Court, among other actions, vacated the CAMR referenced above.

16.2.3 Global Climate Change

Climate change has evolved into a matter of global concern because it is expected to have widespread, adverse effects on natural resources and systems. A growing body of evidence points to anthropogenic sources of GHGs, such as CO_2, as major contributors to climate change. Because this final rule will likely decrease CO_2 emission rates from the fossil fuel sector in the United States, DOE here examines the impacts and causes of climate change and then the potential impact of the rule on CO_2 emissions and global warming.

Impacts of Climate Change on the Environment. Climate is usually defined as the average weather, over a period ranging from months to many years. Climate change refers to a change in the state of the climate, which is identifiable through changes in the mean and/or the variability of its properties (*e.g.*, temperature or precipitation) over an extended period, typically decades or longer.[7]

The World Meteorological Organization and United Nations Environment Programme (UNEP) established the Intergovernmental Panel on Climate Change (IPCC) to provide an objective source of information about climate change. According to the IPCC Fourth Assessment Report (IPCC Report), published in 2007, climate change is consistent with observed changes to the world's natural systems; the IPCC expects these changes to continue.

Changes that are consistent with warming include warming of the world's oceans to a depth of 3,000 meters; global average sea level rise at an average rate of 1.8 mm per year from 1961 to 2003; loss of annual average Arctic sea ice at a rate of 2.7 percent per decade; changes in wind patterns that affect extra-tropical storm tracks and temperature patterns; increases in intense precipitation in some parts of the world, as well as increased drought and more frequent heat waves in many locations worldwide; and numerous ecological changes.

Looking forward, the IPCC describes continued global warming of about 0.2 °C per decade for the next two decades under a wide range of emission scenarios for CO_2, other GHGs,

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[c] DOE's discussion and conclusions about NO_x emissions assume the implementation of CAIR and associated trading schemes and do not take into account the recently issued Transport Rule. In future rulemakings, DOE will adjust its relevant models to assume the implementation of the Transport Rule.

and aerosols. After that period, the rate of increase is less certain. The IPCC Report describes increases in average global temperatures of about 1.1 to 6.4 °C at the end of the century relative to today. These increases vary depending on the model and emissions scenarios.

The IPCC Report describes incremental impacts associated with the rise in temperature. At ranges of incremental increases to the global average temperature, IPCC reports, with either high or very high confidence, that there is likely to be an increasing degree of impacts such as coral reef bleaching, loss of wildlife habitat, loss to specific ecosystems, and negative yield impacts for major cereal crops in the tropics, but also projects that there likely will be some beneficial impacts on crop yields in temperate regions.

Causes of Climate Change. The IPCC Report states that the world has warmed by about 0.74 °C in the last 100 years. The report finds that most of the temperature increase since the mid-20th century is very likely due to the increase in anthropogenic concentrations of CO_2 and other long-lived GHGs such as methane and NO_x in the atmosphere, rather than from natural causes.

Increasing the CO_2 concentration partially blocks the Earth's re-radiation of captured solar energy in the infrared band, inhibits the radiant cooling of the Earth, and thereby alters the energy balance of the planet, which gradually increases its average temperature. The IPCC Report estimates that CO_2 currently makes up about 77 percent of the total CO_2-equivalent[d] global warming potential in GHGs emitted from human activities, with the vast majority (74 percent) of the CO_2 attributable to fossil fuel use.[8] For the future, the IPCC Report describes a wide range of GHG emissions scenarios, but under each scenario CO_2 would continue to comprise above 70 percent of the total global warming potential.

Stabilization of CO_2 Concentrations. Unlike many traditional air pollutants, CO_2 mixes thoroughly in the entire atmosphere and is long-lived. The residence time of CO_2 in the atmosphere is long compared to the emission processes. Therefore, the global cumulative emissions of CO_2 over long periods determine CO_2 concentrations because it takes hundreds of years for natural processes to remove the CO_2. Globally, 49 billion MT of CO_2-equivalent of anthropogenic GHGs are emitted every year. Of this annual total, fossil fuels contribute about 29 billion MT of CO_2.[9,e]

Researchers have focused on considering atmospheric CO_2 concentrations that likely will result in some level of global climate stabilization, and the emission rates associated with achieving the "stabilizing" concentrations by particular dates. They associate these stabilized CO_2 concentrations with temperature increases that plateau in a defined range. For example, at the low end, the IPCC Report scenarios target a CO_2 stabilized concentrations range between 350 and 400 ppm (essentially today's value)—because of climate inertia, concentrations in this

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[d] GHGs differ in their warming influence (radiative forcing) on a global climate system due to their different radiative properties and lifetimes in the atmosphere. These warming influences may be expressed through a common metric based on the radiative forcing of CO_2, *i.e.*, CO_2-equivalent. CO_2-equivalent emission is the amount of CO_2 emission that would cause the same time integrated radiative forcing, over a given time horizon, as an emitted amount of other long-lived GHG or mixture of GHGs.
[e] Other non-fossil fuel contributors include CO_2 emissions from deforestation and decay from agriculture biomass; agricultural and industrial emissions of methane; and emissions of nitrous oxide and fluorocarbons.

low-end range would still result in temperatures projected to increase 2.0 to 2.4 °C above pre-industrial levels[10] (about 1.3 to 1.7 °C above today's levels). To achieve concentrations between 350 and 400 ppm, the IPCC scenarios present that there would have to be a rapid downward trend in total annual global emissions of GHGs to levels that are 50 to 85 percent below today's annual emission rates by no later than 2050. Since it is assumed that there would continue to be growth in global population and substantial increases in economic production, the scenarios identify required reductions in GHG emissions intensity (emissions per unit of output) of more than 90 percent. However, even at these rates, the scenarios project some warming and some climate change due to already accumulated CO_2 and GHGs in the atmosphere.[10]

The Beneficial Impact of the Rule on CO_2 Emissions. It is anticipated that the rule will reduce energy-related CO_2 emissions, particularly those associated with energy use in buildings. The U.S. Energy Information Administration (EIA) reports in its *2010 Annual Energy Outlook* (*AEO2010*)[11] that U.S. annual energy-related emissions of CO_2 in 2007 were about 6.0 billion MT, of which 1.2 billion tons were attributed to the residential buildings sector (including related energy-using products such as residential furnaces and central air conditioner products.) Most of the GHG emissions attributed to residential buildings are emitted from fossil-fuel fired power plants that generate electricity used in this sector. In the *AEO2010* Reference Case, EIA projected that annual energy-related CO_2 emissions would grow from 5.7 billion MT in 2015 to 6.3 billion MT in 2035, an increase of 10 percent (see *AEO2010*), while residential emissions would grow to from 1.2 billion MT to 1.3 billion MT, an increase of 12 percent.

The estimated cumulative CO_2 emission reductions from the adopted FLB conservation standards (shown as a range of alternative TSLs) during the 30-year analysis period are indicated in Table 16.2.1. The estimated CO_2 emission reductions from electricity generation are calculated using the NEMS-BT model.

Table 16.2.1 Reduction in Cumulative Energy-Related Emissions of CO_2 from 2014 through 2043 from Ballast Energy Conservation Standards

Trial Standard Level	Cumulative Reduction in CO_2 Emissions (2014 through 2043) *million MT*	
	Existing Technologies, Shift	Emerging Technologies, Roll-up
1	64	13
2	76	20
3A	106	27
3B	106	29

The Incremental Impact of the Rule on Climate Change. It is difficult to correlate specific emission rates with atmospheric concentrations of CO_2 and specific atmospheric concentrations with future temperatures because the IPCC Report describes a clear lag in the climate system between any given concentration of CO_2 (even if maintained for long periods) and the subsequent average worldwide and regional temperature, precipitation, and extreme weather regimes. For example, a major determinant of climate response is "equilibrium climate sensitivity," a measure of the climate system response to sustained radioactive forcing. It is defined as the global average surface warming following a doubling of CO_2 concentrations. The IPCC Report describes its estimated, numeric value as about 3 °C, but the likely range of that value is 2 to 4.5 °C, with cloud feedbacks being the largest source of uncertainty. Further, as illustrated above, the IPCC Report scenarios for stabilization rates are presented in terms of a range of concentrations, which then correlates to a range of temperature changes. Thus, climate sensitivity is a key uncertainty for CO_2 mitigation scenarios that aim to meet specific temperature levels.

Because of how complex global climate systems are, it is difficult to know when and to what extent particular CO_2 emissions reductions will impact global warming. However, as Table 16.2.1 indicates, the rule is expected to reduce CO_2 emissions associated with energy use in buildings.

16.2.4 Analytical Methods for Air Emissions

Coal-fired electric generation is the single largest source of electricity in the United States. Because the mix of coals used significantly affects the emissions produced, the model includes a detailed representation of coal supply. The model considers the rank of the coal as well as the sulfur contents of the fuel used when determining optimal dispatch.[12]

Within the NEMS-BT model, planning options for achieving emissions restrictions in the Clean Air Act Amendments include installing pollution control equipment on existing power plants and building new power plants with low emission rates. These methods for reducing emissions are compared to dispatching options such as fuel switching and allowance trading. Environmental regulations also affect capacity expansion decisions. For instance, new plants are not allocated SO_2 emissions allowances according to the Clean Air Act Amendments. Consequently, the decision to build a particular capacity type must consider the cost (if any) of obtaining sufficient allowances. This could involve purchasing allowances or over complying at an existing unit.

DOE's analysis assumes the presence of nationwide emission caps on SO_2 and caps on NO_x emissions in the 28 states covered by the CAIR.[f] The NEMS-BT modeling system that DOE uses to forecast emission reductions currently indicates that no physical reductions in power sector emissions would occur for SO_2. However, in contrast to the NEMS-BT modeling forecasts that SO_2 emissions will remain at the cap, during the years 2007 and 2008, SO_2 emissions were below the trading cap. The difference between the emissions levels that NEMS-BT forecasts and those that EPA forecasts is an indicator of the uncertainties associated with long-range energy sector forecasts. Because of such uncertainties, DOE is unable to estimate the economic and physical benefit from SO_2 emissions reductions at this time.

With respect to Hg, in the absence of CAMR or other trading program, a DOE standard would likely reduce Hg emissions and DOE uses NEMS-BT to estimate these emission reductions. However, DOE continues to review the impact of rules that reduce energy use on Hg emissions, and may revise its assessment of Hg emission reductions in future rulemakings.

[f] As stated above, EPA issued the final Transport Rule on July 6, 2011. The Transport Rule replaces CAIR. DOE's discussion and conclusions about NO_x emissions assume the implementation of CAIR and associated trading schemes and do not take into account the very recently issued Transport Rule. In future rulemakings, DOE will adjust its relevant models to assume the implementation of the Transport Rule.

As noted in chapter 14, NEMS-BT model forecasts end in year 2035. Rather than extrapolate beyond this year, DOE assumes that emissions impacts beyond 2035 are equal to the impacts in 2035.

16.2.5 Effects on Power Plant Emissions

Table 16.2.2 shows NEMS-BT Reference Case power plant emissions in selected years and Table 16.2.3 show the estimated changes in power plant emissions of CO_2, NO_x, and Hg in selected years for each of the TSLs. Values for CO_2 are given in metric tons, while values for NO_x and Hg are given in short tons.

Table 16.2.2 Power Sector Emissions Forecast, Reference Case

NEMS-BT Results	2010	2015	2020	2025	2030	2035
CO_2 (million metric tons)	2,218	2,279	2,344	2,433	2,538	2,635
NO_x (thousand tons)	2.2	2.1	2.0	2.0	2.1	2.1
Mercury (tons)	40.6	30.7	30.4	30.3	30.8	30.6

Table 16.2.3 Power Sector Emissions Impacts Forecasts for Ballast TSLs, Existing Technologies, Shift Scenario*

NEMS-BT Results:	Difference from Reference Case						
						Extrapolation	
	2015	2020	2025	2030	2035	2040	2043
Trial Standard Level 1							
CO_2 (Million metric tons/year)	-0.41	-1.30	-2.03	-2.58	-2.96	-2.96	-2.96
NOx (Thousand tons/year)	-0.23	-0.68	-0.93	-1.00	-0.87	-0.87	-0.87
Hg (tons/year)	-0.01	-0.04	-0.05	-0.04	-0.02	-0.02	-0.02
Trial Standard Level 2							
CO_2 (Million metric tons/year)	-0.49	-1.56	-2.42	-3.08	-3.54	-3.54	-3.54
NOx (Thousand tons/year)	-0.28	-0.81	-1.11	-1.19	-1.04	-1.04	-1.04
Hg (tons/year)	-0.02	-0.05	-0.06	-0.05	-0.02	-0.02	-0.02
Trial Standard Level 3a							
CO_2 (Million metric tons/year)	-0.68	-2.17	-3.37	-4.30	-4.93	-4.93	-4.93
NOx (Thousand tons/year)	-0.38	-1.12	-1.55	-1.66	-1.45	-1.45	-1.45
Hg (tons/year)	-0.02	-0.06	-0.08	-0.07	-0.03	-0.03	-0.03
Trial Standard Level 3b							
CO_2 (Million metric tons/year)	-0.68	-2.17	-3.37	-4.30	-4.93	-4.93	-4.93
NOx (Thousand tons/year)	-0.38	-1.13	-1.55	-1.66	-1.45	-1.45	-1.45
Hg (tons/year)	-0.02	-0.06	-0.08	-0.07	-0.03	-0.03	-0.03

* CO_2 results are in metric tons, NO_x and Hg results are in short tons.

Table 16.2.4 Power Sector Emissions Impacts Forecasts for Ballast TSLs, Emerging Technologies, Roll Scenario

NEMS-BT Results:	Difference from Reference Case						
						Extrapolation	
	2015	**2020**	**2025**	**2030**	**2035**	**2040**	**2043**
Trial Standard Level 1							
CO_2 (Million metric tons/year)	-0.35	-0.92	-1.02	-0.66	0.16	0.16	0.16
NOx (Thousand tons/year)	-0.03	-0.11	-0.23	-0.38	-0.57	-0.57	-0.57
Hg (tons/year)	-0.01	-0.02	-0.02	-0.01	0.01	0.01	0.01
Trial Standard Level 2							
CO_2 (Million metric tons/year)	-0.56	-1.46	-1.62	-1.05	0.26	0.26	0.26
NOx (Thousand tons/year)	-0.04	-0.18	-0.37	-0.61	-0.91	-0.91	-0.91
Hg (tons/year)	-0.01	-0.03	-0.03	-0.02	0.01	0.01	0.01
Trial Standard Level 3a							
CO_2 (Million metric tons/year)	-0.78	-2.01	-2.23	-1.44	0.36	0.36	0.36
NOx (Thousand tons/year)	-0.05	-0.24	-0.50	-0.84	-1.24	-1.24	-1.24
Hg (tons/year)	-0.01	-0.04	-0.04	-0.02	0.01	0.01	0.01
Trial Standard Level 3b							
CO_2 (Million metric tons/year)	-0.82	-2.11	-2.34	-1.51	0.38	0.38	0.38
NOx (Thousand tons/year)	-0.06	-0.26	-0.53	-0.88	-1.31	-1.31	-1.31
Hg (tons/year)	-0.02	-0.04	-0.04	-0.02	0.01	0.01	0.01

16.2.6 Effects on Upstream Fuel-Cycle Emissions

Upstream fuel-cycle emissions refer to the emissions associated with the amount of energy used in the upstream production and downstream use of electricity, including energy used at the power plant.[13] Upstream processes include the mining of coal or extraction of natural gas, physical preparatory and cleaning processes, and transportation to the power plant. NEMS-BT does a thorough accounting of emissions at the power plant due to downstream energy use, but does not account for upstream emissions (*i.e.*, emissions from energy losses during coal and natural gas production). Thus, this analysis reports only power plant emissions.

However, previous DOE environmental assessment documents have developed approximate estimates of effects on upstream fuel-cycle emissions. These emissions factors provide a sense of the possible magnitude of upstream effects. These upstream emissions would be in addition to emissions from direct combustion.

Relative to the entire fuel cycle, estimates based on the work of Dr. Mark DeLuchi, and reported in earlier DOE environmental assessment documents, find that an amount approximately equal to 8 percent, by mass, of emissions (including SO_2) from coal production are due to mining, preparation that includes cleaning the coal, and transportation from the mine to the power plant.[14] Transportation emissions include emissions from the fuel used by the mode of transportation that moves the coal from the mine to the power plant. In addition, based on Dr. DeLuchi's work, DOE estimated that approximately 14 percent of emissions from natural gas production result from upstream processes.

Emission factor estimates and corresponding percentages of contributions of upstream emissions from coal and natural gas production, relative to power plant emissions, are shown in Table 16.2.5 for CO_2 and NO_x. The percentages provide a means to estimate upstream emission savings based on changes in emissions from power plants. This approach does not address Hg emissions.

Table 16.2.5 Estimated Upstream Emissions of Air Pollutants as a Percentage of Direct Power Plant Combustion Emissions

Pollutant	Percent of Coal Combustion Emissions	Percent of Natural Gas Combustion Emissions
CO_2	2.7	11.9
NO_x	5.8	40

16.3 WETLAND, ENDANGERED AND THREATENED SPECIES, AND CULTURAL RESOURCES

Because ballasts are not water-consuming products, more efficient products would not reduce the amount of water discharged into the waste stream. As a result, the adopted energy conservation standards do not have the effect of improving the quality of wetlands or the threatened or endangered species that reside in these wetlands. This action is also not expected to impact cultural resources such as historical or archaeological sites.

16.4 SOCIOECONOMIC IMPACTS

DOE's analysis has shown that, for the average consumer, the increase in the first cost of purchasing more efficient ballasts at the new standard levels is, in most cases, completely offset by a reduction in the life-cycle cost (LCC) of owning more efficient products. In other words, despite the increase in the first cost, the consumer will pay less in operating costs over the life of the product. The complete LCC analysis and its conclusions are presented in chapter 8 of the final rule TSD.

For subgroups of low-income and other consumers who purchase regulated ballasts, DOE determined that the average LCC impact of the standards is similar to that for the full sample of consumers. Therefore, DOE concludes that the adopted standards would have no significant adverse socioeconomic impact. For a complete discussion on the LCC impacts on consumer subgroups, see chapter 12 of the final rule TSD.

16.5 ENVIRONMENTAL JUSTICE IMPACTS

In view of Executive Order 12898 of February 11, 1994, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," DOE examined the effect of the energy conservation standards on low-income households. As described in the LCC subgroup analysis in chapter 11 of the final rule TSD, DOE found that there were no disproportionately high and adverse human health or environmental effects on low-income populations that would result from the adopted energy conservation standards.

16.6 NOISE AND AESTHETICS

Improvements in efficiency of ballasts are expected to result from changes in the choice of design features. These changes are described in chapter 5 of the final rule TSD. These design changes are not expected to change noise levels in comparison to products in today's market.

Ballasts that are currently manufactured in the existing market that already meet new standard efficiency levels are no louder than less efficient products. Changes to product design to improve the efficiency levels are not expected to adversely affect the aesthetics of the products.

16.7 SUMMARY OF ENVIRONMENTAL IMPACTS

Table 16.7.1 summarizes the estimated emissions impacts for each of the TSLs for ballasts under both low and high shipments scenarios. It shows cumulative changes in emissions for CO_2, NO_x, and Hg for 2015 through 2044 for each of the ballast TSLs. Cumulative CO_2, NO_x, and Hg emissions are reduced compared to the reference case for all TSLs.

Upstream fuel cycle emissions of CO_2 and NO_x are described but not quantified in section 16.2.5. The text describes potential reductions in fuel cycle emissions as percentage of decreases in power plant emissions. This approach suggests that upstream fuel cycle emissions would decrease and provides a sense of the magnitude of effects; however, DOE does not report actual estimates of the effects.

For subgroups of low-income and other consumers that purchase ballasts, DOE determined that the average LCC impact of the standards is similar to that for the full sample of consumers. Therefore, DOE concludes that the adopted new standards would have no significant adverse socioeconomic impact.

No impacts are anticipated in the areas of environmental justice, wetlands, endangered and threatened species, cultural resources, or noise and aesthetics.

Table 16.7.1 Cumulative Emissions Reductions Under Ballast TSLs*

Trial Standard Level	Cumulative Reduction in Emissions (2014 through 2043)					
	Existing Technologies, Shift			Emerging Technologies, Roll-Up		
	CO_2 *million-MT*	NO_X *thousand tons*	Hg *tons*	CO_2 *million-MT*	NO_X *thousand tons*	Hg *tons*
1	64	23	0.88	13	10	0.18
2	76	28	1.05	20	16	0.29
3A	106	39	1.47	27	22	0.40
3B	106	39	1.47	29	23	0.42

* Values for CO_2 are in metric tons; values for NO_x and Hg are in short tons.

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CHAPTER 17. MONETIZATION OF EMISSION REDUCTIONS BENEFITS

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CHAPTER 17. MONETIZATION OF EMISSION REDUCTIONS BENEFITS

17.1 INTRODUCTION

As part of its assessment of energy conservation standards for fluorescent lamp ballasts (FLB or ballasts), DOE estimated the monetary benefits likely to result from the reduced emissions of carbon dioxide (CO_2) and nitrogen oxides (NO_x) that are expected to result from each of the trial standard levels (TSLs) considered. In order to make this calculation similar to the calculation of the net present value of consumer benefit, DOE considered the reduced emissions expected to result over the lifetime of products shipped in the forecast period for each TSL. This chapter summarizes the basis for the monetary values used for each of these emissions and presents the benefits estimates considered.

17.2 MONETIZING CARBON DIOXIDE EMISSIONS

17.2.1 Social Cost of Carbon

Under section 1(b) of Executive Order 12866, "Regulatory Planning and Review," 58 FR 51735 (Oct. 4, 1993), 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 social cost of carbon (SCC) estimates presented here is to allow Federal 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 consider public comments, explore the technical literature in relevant fields, and discuss key model inputs and assumptions. The main objective of this process was to develop a range of SCC values using a defensible set of input assumptions grounded in the existing scientific and economic literatures. In this way, key uncertainties and model differences transparently and consistently inform the range of SCC estimates used in the rulemaking process.

The SCC is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. It is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services. Estimates of the SCC are provided in dollars per metric ton of carbon dioxide.

When attempting to assess the incremental economic impacts of carbon dioxide emissions, the analyst faces a number of serious challenges. A recent report from the National 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 serious limits of both quantification and monetization, SCC estimates can be useful in estimating the social benefits of reducing carbon dioxide emissions. Consistent with the directive quoted above, the purpose of the SCC estimates presented here is to make it possible for agencies to incorporate the social benefits from reducing carbon dioxide emissions into cost-benefit analyses of regulatory actions that have small, or "marginal," impacts on cumulative global emissions. Most Federal regulatory actions can be expected to have marginal impacts on global emissions.

For such policies, the 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. For policies that have a large (non-marginal) impact on global cumulative emissions, there is a separate question of whether the SCC is an appropriate tool for calculating the benefits of reduced emissions. DOE does not attempt to answer that question here.

It is important to emphasize that the interagency process is committed to updating these estimates as the science and economic understanding of climate change and its impacts on society improves over time. Specifically, the interagency group has set a preliminary goal of revisiting the SCC values within two years or at such time as substantially updated models become available, and to continue to support research in this area. In the meantime, the interagency group will continue to explore the issues raised by this analysis and consider public comments as part of the ongoing interagency process.

17.2.2 Social Cost of Carbon Values Used in Past Regulatory Analyses

To date, economic analyses for Federal regulations have used a wide range of values to estimate the benefits associated with reducing CO_2 emissions. In the final model year 2011 Corporate Average Fuel Economy (CAFE) Rule, the U.S. Department of Transportation (DOT) used both a "domestic" SCC value of $2 per ton of CO_2 and a "global" SCC value of $33 per ton of CO_2 for 2007 emission reductions (in 2007$), increasing both values at 2.4 percent per year.[a,2] DOT also included a sensitivity analysis at $80 per ton of CO_2. A domestic SCC value is meant to reflect the value of damages in the United States resulting from a unit change in CO_2 emissions, while a global SCC value is meant to reflect the value of damages worldwide.

[a] Throughout this section, references to tons of CO_2 refer to metric tons.

A 2008 regulation proposed by DOT assumed a domestic SCC value of $7 per ton of CO_2 (in 2006$) for 2011 emission reductions (with a range of $0 to $14 for sensitivity analysis), also increasing at 2.4 percent per year.[3] A regulation for packaged terminal air conditioners and packaged terminal heat pumps finalized by DOE in October 2008 used a domestic SCC range of $0 to $20 per ton of CO_2 for 2007 emission reductions (in 2007$). 73 FR 58772, 58814 (Oct. 7, 2008). In addition, the U.S. Environmental Protection Agency's (EPA's) 2008 Advance Notice of Proposed Rulemaking for Greenhouse Gases identified what it described as "very preliminary" SCC estimates subject to revision. 73 FR 44354 (July 30, 2008). EPA's global mean values were $68 and $40 per ton CO_2 for discount rates of approximately 2 percent and 3 percent, respectively (in 2006$ for 2007 emissions).

In 2009, an interagency process was initiated to offer a preliminary assessment of how best to quantify the benefits from reducing carbon dioxide emissions. To ensure consistency in how benefits are evaluated across agencies, the Administration sought to develop a transparent and defensible method, specifically designed for the rulemaking process, to quantify avoided climate change damages from reduced CO_2 emissions. The interagency group did not undertake any original analysis. Instead, it combined SCC estimates from the existing literature to use as interim values until a more comprehensive analysis could be conducted. The outcome of the preliminary assessment by the interagency group was a set of five interim values: global SCC estimates for 2007 (in 2006$) of $55, $33, $19, $10, and $5 per ton of CO_2.

These interim values represent the first sustained interagency effort within the U.S. government to develop an SCC for use in regulatory analysis. The results of this preliminary effort were presented in several proposed and final rules and were offered for public comment in connection with proposed rules, including the joint EPA-DOT fuel economy and CO_2 tailpipe emission proposed rules. See CAFÉ Rule for Passenger Cars and Light Trucks Draft EIS and Final EIS.2[,3]

17.2.3 Current Approach and Key Assumptions

Since the release of the interim values, the interagency group reconvened on a regular basis to generate improved SCC estimates, which were considered for this final rule. Specifically, the group considered public comments and further explored the technical literature in relevant fields. The interagency group relied on three integrated assessment models commonly used to estimate the SCC: the FUND, DICE, and PAGE models (described in appendix 17A of the final rule TSD). These models are frequently cited in the peer-reviewed literature and were used in the last assessment of the Intergovernmental Panel on Climate Change (IPCC). 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.

The interagency group selected four SCC values for use in regulatory analyses. Three values are based on the average SCC from three integrated assessment models, at discount rates of 2.5, 3, and 5 percent. The fourth value, which represents the 95th percentile SCC estimate across all three models at a 3-percent discount rate, is included to represent higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. For emissions (or emission reductions) that occur in later years, these values grow in real terms over time, as depicted in Table 17.2.1. 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,[b] although preference is given to consideration of the global benefits of reducing CO_2 emissions.

Table 17.2.1 Social Cost of CO_2, 2010–2050 (in 2007$ dollars per metric ton)

	Discount Rate			
	5% Avg	**3% Avg**	**2.5% Avg**	**3% 95th**
2010	4.7	21.4	35.1	64.9
2015	5.7	23.8	38.4	72.8
2020	6.8	26.3	41.7	80.7
2025	8.2	29.6	45.9	90.4
2030	9.7	32.8	50.0	100.0
2035	11.2	36.0	54.2	109.7
2040	12.7	39.2	58.4	119.3
2045	14.2	42.1	61.7	127.8
2050	15.7	44.9	65.0	136.2

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.

DOE recognizes the uncertainties embedded in the estimates of the SCC used for cost-benefit analyses. As such, DOE and others in the U.S. Government intend to periodically review and reconsider those estimates to reflect increasing knowledge of the science and economics of climate impacts, as well as improvements in modeling. In this context, statements recognizing the limitations of the analysis and calling for further research take on exceptional significance.

In summary, in considering the potential global benefits resulting from reduced CO_2 emissions, DOE used the most recent values identified by the interagency process, adjusted to

[b] 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.

2010$ using the gross domestic product price deflator. For each of the four cases specified, the values used for emissions in 2010 were $4.9, $22.3, $36.5, and $67.6 per metric ton avoided (values expressed in 2010$). To monetize the CO_2 emissions reductions expected to result from new standards for ballasts, DOE used the values identified in Table A1 of the "Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866," which is reprinted in appendix 17A of this TSD, appropriately adjusted to 2010$.[c] To calculate a present value of the stream of monetary values, DOE discounted the values in each of the four cases using the discount rates that had been used to obtain the SCC values in each case.

17.3 VALUATION OF OTHER EMISSIONS REDUCTIONS

DOE considered the potential monetary benefit of reduced NO_x emissions from the TSLs it considered. As noted in chapter 16, new or amended energy conservation standards would reduce NO_x emissions in those 22 states that are not affected by the Clean Air Interstate Rule, in addition to the reduction in site NO_x emissions nationwide. DOE estimated the monetized value of NO_x emissions reductions resulting from each of the TSLs considered based on environmental damage estimates from the literature. Available estimates suggest a very wide range of monetary values, ranging from $370 per ton to $3,800 per ton of NO_x from stationary sources, measured in 2001$ (equivalent to a range of $450 to $4,623 per ton in 2010$).[d] In accordance with Office of Budget and Management guidance, DOE conducted two calculations of the monetary benefits using each of the above values used for NO_x, one using a real discount rate of 3 percent and another using a real discount rate of 7 percent.[4]

DOE is aware of multiple agency efforts to determine the appropriate range of values used in evaluating the potential economic benefits of reduced Hg emissions. DOE has decided to await further guidance regarding consistent valuation and reporting of Hg emissions before it once again monetizes Hg in its rulemakings.

17.4 RESULTS

Table 17.4.1 and Table 17.4.2 present the global values of CO_2 emissions reductions for each considered TSL. DOE calculated domestic values as a range from 7 percent to 23 percent of the global values, and these results are presented in Table 17.4.3 and Table 17.4.4.

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[c] Table A1 presents SCC values through 2050. For DOE's calculation, it derived values after 2050 using the 3-percent per year escalation rate used by the interagency group.
[d] For additional information, refer to U.S. Office of Management and Budget, Office of Information and Regulatory Affairs, "2006 Report to Congress on the Costs and Benefits of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities," Washington, D.C.

Table 17.4.1 Estimates of Global Present Value of CO_2 Emissions Reduction in 2014-2043 Under Trial Standard Levels for Ballasts (Existing Technologies, Shift Scenario)

TSL	Million 2010$			
	5% discount rate, average*	3% discount rate, average*	2.5% discount rate, average*	3% discount rate, 95th percentile*
1	242	1,206	2,030	3,680
2	290	1,441	2,425	4,396
3A	404	2,008	3,379	6,125
3B	404	2,009	3,380	6,127

***** Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution.

Table 17.4.2 Estimates of Global Present Value of CO_2 Emissions Reduction in 2014-2043 Under Trial Standard Levels for Ballasts (Emerging Technologies, Roll-Up Scenario)

TSL	Million 2010$			
	5% discount rate, average*	3% discount rate, average*	2.5% discount rate, average*	3% discount rate, 95th percentile*
1	56	261	432	799
2	90	416	688	1,272
3A	123	571	944	1,746
3B	130	600	993	1,836

* Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution.

Table 17.4.3 Estimates of Domestic Present Value of CO_2 Emissions Reduction in 2014 - 2043 Under Trial Standard Levels for Ballasts (Existing Technologies, Shift Scenario)

TSL	Million 2010$			
	5% discount rate, average*	3% discount rate, average*	2.5% discount rate, average*	3% discount rate, 95th percentile*
1	17 to 56	84 to 277	142 to 467	258 to 846
2	20 to 67	101 to 331	170 to 558	308 to 1011
3A	28 to 93	141 to 462	237 to 777	429 to 1409
3B	28 to 93	141 to 462	237 to 777	429 to 1409

* Domestic values are presented as a range between 7% and 23% of the global values.
****** Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution.

Table 17.4.4 Estimates of Domestic Present Value of CO_2 Emissions Reduction in 2014-2043 Under Trial Standard Levels for Ballasts (Emerging Technologies, Roll Scenario)

TSL	*Million 2010$*			
	5% discount rate, average*	**3% discount rate, average***	**2.5% discount rate, average***	**3% discount rate, 95th percentile***
1	4 to 13	18 to 60	30 to 99	56 to 184
2	6 to 21	29 to 96	48 to 158	89 to 293
3A	9 to 28	40 to 131	66 to 217	122 to 402
3B	9 to 30	42 to 130	69 to 228	128 to 422

Table 17.4.5 and Table 17.4.6 present the cumulative monetary value of the economic benefits associated with NO_x emissions reductions for each TSL, calculated using 7-percent and three-percent discount rates.

Table 17.4.5 Estimates of Present Value of NO_x Emissions Reduction Under Trial Standard Levels for Ballasts (Existing Technologies, Shift Scenario)

TSL	*Million 2010$*	
	3% discount rate	**7% discount rate**
1	6 to 63	3 to 34
2	7 to 75	4 to 40
3A	10 to 105	5 to 56
3B	10 to 105	5 to 56

Table 17.4.6 Estimates of Present Value of NO_x Emissions Reduction Under Trial Standard Levels for Ballasts (Emerging Technologies, Roll-Up Scenario)

TSL	*Million 2010$*	
	3% discount rate	**7% discount rate**
1	2 to 24	1 to 11
2	4 to 38	2 to 18
3A	5 to 53	2 to 24
3B	5 to 55	2 to 26

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CHAPTER 18. REGULATORY IMPACT ANALYSIS

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CHAPTER 18. REGULATORY IMPACT ANALYSIS

18.1 INTRODUCTION

The U.S. Department of Energy (DOE) has determined that energy conservation standards for fluorescent lamp ballasts (hereafter referred to as "ballasts") constitute an "economically significant regulatory action" under Executive Order (E.O.) 12866, Regulatory Planning and Review. 58 FR 51735, 51735. (Oct. 4, 1993). Under 10 CFR part 430, subpart C, appendix A, section III.12, DOE committed to evaluating non-regulatory alternatives to adopted standards by performing a regulatory impact analysis (RIA). 61 FR 36981, 36978 (July 15, 1996). This RIA, which DOE has prepared pursuant to E.O. 12866, evaluates potential non-regulatory alternatives, comparing the costs and benefits of each to those of the adopted standards. 58 FR 51735, 51741. As noted in E.O. 12866, this RIA is subject to review by the Office of Management and Budget's Office of Information and Regulatory Affairs. 58 FR 51735, 51740.

For this final rule, DOE identified five major, non-regulatory alternatives to standards as representing feasible policy options to achieve potentially similar improvements in ballast energy efficiency:

- Consumer Rebates
- Consumer Tax Credits
- Manufacturer Tax Credits
- Voluntary Energy Efficiency Programs
- Bulk Government Purchases

DOE evaluated each alternative (plus the base case alternative of No New Regulatory Action) that applies to the ballasts covered by this final rule in terms of its ability to achieve significant energy savings at a reasonable cost, and compared the effectiveness of each alternative to that of the adopted standards. The following sections discuss the analysis method used, the non-regulatory alternatives considered, and the energy savings calculated.

18.2 METHODOLOGY

This section describes the method DOE used to analyze the energy savings and cost effectiveness of the six non-regulatory policy alternatives for the identified ballasts. This section also describes the assumptions underlying the analysis.

DOE used integrated national impact analysis-regulatory impact analysis (NIA-RIA) spreadsheet models to calculate the national energy savings (NES) and net present value (NPV) associated with each non-regulatory policy alternative. Chapter 11 of the final rule technical support document (TSD) describes the NIA spreadsheet models.

DOE quantified the effect of each alternative on the purchase of products that meet *target levels*, which are defined as the efficiency levels in the adopted standards. After establishing the quantitative assumptions underlying each alternative, DOE appropriately revised inputs to the NIA-RIA spreadsheet models. The primary model input revised was market shares of products meeting target efficiency levels. The shipments of products for any given year reflect a distribution of efficiency levels. DOE assumed that the adopted standards would affect 100 percent of the shipments of products that did not meet target levels in the base 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.

Increasing a product's efficiency often increases its average installed cost but generally decreases its operating costs because energy consumption declines. DOE therefore calculated an NPV for each non-regulatory alternative in the same way it did for the adopted standards. Because DOE assumed that consumers would re-pay credits and rebates in some way (such as by paying 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, given in quadrillion British thermal units (quads), describes the cumulative national primary energy savings for products bought during the period from the effective date of the policy (2014) through the end of the analysis period (2043).

- Net present value represents the value in 2010$ (discounted to 2011)[a] of net monetary savings from products bought during the period from the effective date of the policy (2014) through the end of the analysis period (2043).

- DOE calculated the NPV as the difference between the present value of installed product cost and operating expenditures in the base case and the present value of those costs in each policy case. DOE calculated operating expenses (including energy costs) for the life of the product.

DOE quantified the market penetration of each alternative, *i.e.*, what percent of consumers below the target efficacy level would migrate to the higher efficacy product, and revised its inputs to the NIA-RIA spreadsheet models. With these modifications, DOE calculated the NES and NPV of each non-regulatory alternative and compared it to that of the adopted standards, which correspond with trial standard level (TSL) 3A.

DOE's analyses indicated that the adopted standards at TSL 3A would save a significant amount of energy—with cumulative NES estimated at 2.7–5.6 quads over 30 years (2014 through 2043). The corresponding cumulative NPV of total consumer costs and savings of the adopted standards for ballasts, in 2010$, ranges from $6.7 billion (at a 7-percent discount rate) to $21.6 billion (at a 3-percent discount rate).

DOE calculated the impacts of each regulatory policy separately from those of the other policies. In actual practice, certain policies are often most effective when implemented in combination to provide incentives, such as consumer and manufacturer credits. DOE attempted

[a] The final rule for ballasts is expected to be published in 2011.

to make conservative assumptions to avoid double-counting policy impacts. Therefore, the policy impacts reported below are not additive; the combined impact of several or all of the policies may not be inferred from adding the results together.

18.3 NON-REGULATORY POLICIES

The following subsections describe DOE's analysis of the impacts of the six non-regulatory policy alternatives to chosen standards for ballasts. (Because the alternative of No New Regulatory Action has no energy or NPV impacts, essentially representing the NIA base case, DOE did not perform additional analysis for that alternative.) DOE developed estimates of the market penetration of high-efficiency products with each of the non-regulatory policy alternatives and compared them to the NIA base case.

18.3.1 No New Regulatory Action Base Case

The base case is the one in which no new regulatory action is taken with regard to the energy efficiency of ballasts, as described in the final rule TSD chapter 11. The base case provides the basis of comparison for all other policies. By definition, no new regulatory action yields zero energy savings and an NPV of zero dollars.

18.3.2 Consumer Rebates

Consumer rebates cover a portion of the difference in incremental product price between products meeting baseline efficacy levels and those meeting higher efficacy levels, resulting in a higher percentage of consumers purchasing more efficacious models and decreased aggregated energy use compared to the base case. For ballasts, DOE assumed a rebate that paid 70 percent of the incremental product price, based on its research for the 2009 Lamps Rule,[1] focusing on existing utility rebate programs for replacing a T12 system with a T8 system or upgrading an existing T8 system to a more efficacious T8 system.

DOE's previous research (for the 2000 Ballast Rule[2]) showed that, for the rebate amount that was equal to the full incremental cost, consumer response rate was about 25 percent. For a rebate worth 70 percent of the incremental cost, DOE assumed a response rate of 18 percent, and estimated a corresponding shift of 18 percent in market shares toward more efficient products, with no change in total shipments.

Although the rebate program reduces the total installed cost to the customer, it is financed by tax revenues. Therefore, from a societal perspective, the installed cost at any efficiency level does *not* change with the rebate program; rather, part of the cost is transferred from the consumer to taxpayers as a whole. Consequently, DOE assumed that equipment costs in the rebates scenario were identical to the NIA base case.

DOE assumed that rebates would remain in effect for the duration of the analysis period.

18.3.3 Consumer Tax Credits

Consumer tax credits are considered a viable non-regulatory market transformation program, as shown by the inclusion of Federal consumer tax credits in the Energy Policy Act of

2005 (EPAct 2005; Pub L. No. 109-58, 119 Stat 1026 (2005)) for various residential appliances. From a consumer perspective, the most important difference between rebate and tax credit programs is that a rebate can be obtained quickly, whereas receipt of tax credits is delayed until income taxes are filed or a tax refund is provided by the Internal Revenue Service (IRS).

As with consumer rebates, DOE assumed that consumer tax credits paid 70 percent of the incremental product price, but estimated a different response rate. The delay in reimbursement makes tax credits less attractive than rebates; consequently, DOE estimated a response rate that is 60 percent of that for rebate programs (per the 2000 Ballast Rule), or 11 percent.

From a societal perspective, tax credits (like rebates) do not change the installed cost of the equipment, but rather transfer a portion of the cost from the consumer to taxpayers as a whole. DOE, therefore, assumed that equipment costs in the consumer tax credits scenario were identical to the NIA base case.

18.3.4 Manufacturer Tax Credits

Manufacturer tax credits are considered a viable non-regulatory market transformation program, as shown by the inclusion of Federal tax credits in EPAct 2005 for manufacturers of residential appliances. Those manufacturer tax credits were in effect for models produced in 2006 and 2007 and reinstated under the American Recovery and Reinvestment Act (ARRA) for 2009 and 2010. DOE was unable to locate data from the IRS or other sources on manufacturer response to the Federal credits. Similar to consumer tax credits, manufacturer tax credits would effectively result in lower product prices for consumers by an amount that covers part of the incremental price difference between products meeting baseline efficiency levels and those meeting targeted efficiency levels.

DOE assumed that this incentive policy would help reimburse manufacturers for retooling costs. Because these tax credits would go to manufacturers instead of consumers, DOE assumed that manufacturers would pass the reduced costs on to consumers. Only these “direct price effects” would be visible to the consumer, with the tax credit program itself visible only to affected manufacturers. The impact of manufacturer tax credits is differentiated into direct price effects, which arise from the consumer cost savings, and “announcement effects” that establish credibility of a particular technology by its inclusion in an incentive program. DOE assumed that these effects split the overall response rate equally.[3]

Therefore, the response rate for manufacturer tax credits is assumed to be half of that for consumer tax credits, or 5.5 percent. As discussed above, DOE assumed that total installed costs will remain unchanged from the NIA base case, with no change in total shipments.

18.3.5 Voluntary Energy Efficiency Programs

DOE estimated the impact of a voluntary energy efficiency program based on its research for the 2009 Lamps Rule, in which it reviewed the historical and projected market transformation performance of past and current ENERGY STAR® programs. In 1991, the Environmental Protection Agency (EPA) introduced Green Lights, a voluntary (non-regulatory) program to reduce air pollution by promoting energy efficient lighting. Companies that participated in this program installed energy efficient lighting where it proved to be cost-effective (as long as lighting quality was not diminished). In return, the EPA provided technical assistance and public recognition. In a similar effort, the EPA launched ENERGY STAR in 1992 as a voluntary labeling program to help consumers identify the most energy efficient products on the market. In 1996, Green Lights became a part of the ENERGY STAR program.[4]

To determine how a lighting market would respond to a voluntary energy program, DOE analyzed the success of the Green Lights program in the 1990s. One of the significant results of the Green Lights program was observed in the fluorescent ballast market. Electronic ballasts are, on average, more efficient than magnetic ballasts. As such, as a result of the Green Lights initiative, electronic ballasts began to enter the market in increasing numbers. The study that analyzed the impact of public programs on fluorescent ballast shipments concluded that of all the electronic ballasts shipped between 1986 and 2000, about 45 percent were due to a public program.[5] To estimate how the market would change over the analysis period for this rule, DOE took 45 percent of the higher-efficiency ballast shipments and divided it by the sum of those shipments plus the total ballast shipments. The 55 percent of higher-efficiency ballast shipments that did not occur as a result of a public program were not included in the denominator, since consumers who bought these ballasts were considered to already be using energy-efficient technologies. DOE concluded that 13 percent of the market would shift to more efficient products as a result of a voluntary energy efficiency program. This percentage was applied across all baselines and efficiency levels.

DOE assumed that the impact of this policy would be to permanently transform the market so that the increased market penetration seen in the first year of the program would be maintained throughout the forecast period.

18.3.6 Bulk Government Purchases

In this policy alternative, “bulk government purchases” refers to programs that encourage Federal, State, and local governments to purchase products meeting applicable energy conservation standards. The motivations for this policy are that (1) aggregating public sector demand could provide a market signal to manufacturers and vendors that some of their largest customers seek suppliers with products that meet efficiency targets at competitive prices; and (2) this could induce “market pull” impacts through the effects of manufacturers and vendors achieving economies of scale for high-efficiency products.

Similar to previous analysis, DOE used floor space data from the 2003 Commercial Buildings Energy Consumption Survey (CBECS 2003)[6] to derive the proportion of government-owned floor space to total commercial floor space (including malls), which is 23.7 percent. DOE assumed that floor space owned by government was proportional to ballast sales. DOE then added a 1.4 percent market-pull impact to arrive at a conservative 25.1 percent market penetration rate.[7] This percentage was used for commercial and industrial ballasts across all TSLs. Bulk government purchases will not affect the residential market. DOE assumed that the impact of this policy would be to permanently transform the market so that the increased market penetration seen in the first year of the program would be maintained throughout the forecast period.

18.4 SUMMARY OF RESULTS FOR NON-REGULATORY ALTERNATIVES

Table 18.4.1 and Table 18.4.2 show the NES and NPV for the non-regulatory alternatives analyzed. The case in which no regulatory action is taken with regard to ballasts constitutes the base case (or "No Action") scenario and since energy savings and NPV are zero by definition it not included in the table. For comparison, the tables include the results of the NES and NPV for TSL 3A associated with the adopted energy conservation standard. Energy savings are expressed in quads in terms of primary or source energy, which includes generation and transmission losses from electricity utility sector. The NES and NPVs shown in the tables are computed only for the roll-up scenario for both existing and emerging technologies. This scenario better reflects market behavior than the shift scenario because only consumers below the target efficiency levels are affected. This is the same target group that non-regulatory alternatives aim to influence.

Table 18.4.1 Cumulative NES of Non-Regulatory Alternatives Compared to the Adopted Standards for Ballasts

Policy Alternatives	National Energy Savings *Quads*	
	Emerging Technologies	Existing Technologies
Consumer Rebates	1.13	1.74
Consumer Tax Credits	0.61	0.99
Manufacturer Tax Credits	0.48	0.77
Voluntary Energy Efficiency Programs	0.67	1.09
Bulk Government Purchases	0.95	1.57
Adopted Standards (TSL 3A)	2.74	5.55

Table 18.4.2 Cumulative NPV of Non-Regulatory Alternatives Compared to the Adopted Standards for Ballasts

Policy Alternatives	NPV *billion 2010$*			
	Existing Technologies		Emerging Technologies	
	7% Discount	3% Discount	7% Discount	3% Discount
Consumer Rebates	4.37	8.65	3.40	6.17
Consumer Tax Credits	2.15	4.41	1.57	2.92
Manufacturer Tax Credits	1.65	3.39	1.21	2.25
Voluntary Energy Efficiency Programs	2.36	4.84	1.72	3.21
Bulk Government Purchases	3.43	7.01	2.49	4.66
Adopted Standards (TSL 3A)	10.06	21.55	6.67	12.84

As shown above, none of the policy alternatives DOE examined would save as much energy as and have a lower NPV than the adopted standards level of TSL 3A. Also, several alternatives would require legislation, such as commercial customer or Federal tax credits, because there is currently no authority to carry out those alternatives.

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APPENDIX 8B. ESTIMATION OF POTENTIAL EQUIPMENT PRICE TRENDS FOR FLUORESCENT BALLASTS

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APPENDIX 8B. ESTIMATION OF POTENTIAL EQUIPMENT PRICE TRENDS FOR FLUORESCENT LAMP BALLASTS

8B.1 INTRODUCTION

In developing the adopted standards for fluorescent lamp ballasts (hereafter referred to as ballasts), DOE assumed that the manufacturer costs and retail prices of products meeting various efficiency levels remain fixed, in real terms, after 2010 (the year for which the engineering analysis estimated costs) and throughout the period of the analysis. In its notice of data availability (NODA) published on February 22, 2011 (76 FR 9696), DOE stated that it may consider improving its analyses by addressing equipment price trends. Consistent with the NODA, DOE examined two alternative price forecasting methods for ballasts:

- Deriving and applying an experience curve function; and
- Applying *Annual Energy Outlook (AEO)* price index projections (deflators).

DOE presented its experience curve method as part of the notice of proposed rulemaking (NOPR) for ballasts, published on April 11, 2011 (76 FR 20090). In developing the experience curve function, DOE found that price data exhibited mixed trends and were inconclusive. Therefore, without a definitive trend, DOE decided against using the experience curve method and instead assumed in its price forecasts that the real prices of ballasts are constant in time. DOE requested comment on its constant real price forecasting method in the NOPR, but received no specific feedback in the public meeting or written comments.

For this final rule, DOE considered but ultimately decided against adjusting ballast prices using forecasted price indices (called deflators) used by the Energy Information Administration (EIA) to develop the *AEO2010*. When adjusted for inflation, the deflator-based price indices decline from 100 in 2010 to approximately 54 in 2043, the effects of which are diminished significantly when discounting is taken into account. Deflator-based net present value (NPV) results from the national impacts analysis (NIA) were approximately 9 percent higher than NPV values based on constant real prices for ballasts. Given this minor difference in estimated NPV, and that DOE did not receive negative comments on its current constant real price basis in the NOPR, DOE retained its constant real price approach for this final rule.

The following sections discuss DOE's experience curve method (evaluated for the NOPR) and deflator-based price forecasting method (evaluated for this final rule).

8B.2 EXPERIENCE CURVES

Economic literature and historical data suggest that the real costs of many products may trend downward over time according to "learning" or "experience" curves. A draft paper, "Using the Experience Curve Approach for Appliance Price Forecasting," available at www1.eere.energy.gov/buildings/appliance_standards/supplemental_info_equipment_price_forecasting.html, provides a summary of the data and literature currently available to DOE that is relevant to price forecasts for selected appliances and equipment.

In typical learning curve formulations, the learning rate parameter is derived using two historical data series: cumulative production and price (or cost). DOE examined historical price trend for ballasts using the Bureau of Labor Statistics' (BLS) Producer Price Index (PPI). The PPI data for ballasts is available for 1982–2009 and is used to represent aggregate prices. Inflation-adjusted price indices were calculated by dividing the PPI series by the gross domestic product deflator for the same years. Figure 8B.2.1 shows an apparent downward price trend from 1982 to 2004; however, the price trends upward from 2004 to 2008. DOE implemented an efficiency standard for ballasts in 2005 that substantially changed the number of ballasts available on the market and their prices at that time.

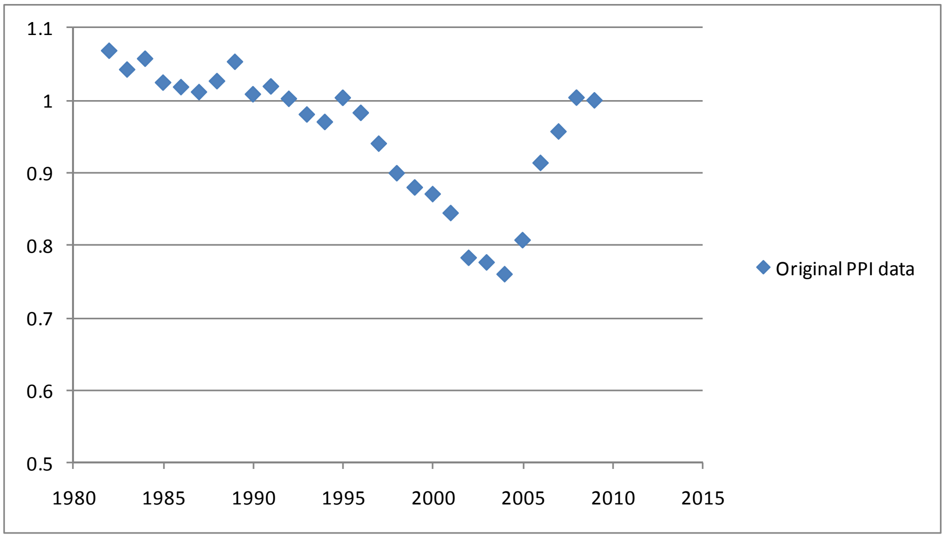

Figure 8B.2.1 Historical PPI Data for Ballasts

To perform an experience curve fit, DOE assembled a time-series of annual shipments for 1990–2005 for ballasts (for calculating cumulative production) from the Census Bureau.[a] Shipments prior to 1990 were extrapolated backward based on a linear trend to the estimated start of commercial production in 1940. DOE adjusted historical shipments data to include non-NEMA manufacturers. Projected shipments after 2005 were obtained from the base case estimation made for the NIA (see chapter 10 of this final rule TSD). These figures were adjusted to include ballasts not covered by the current rulemaking. For ballasts, DOE developed two base case shipments scenarios addressing the uncertainty about market penetration of light emitting diode (LED) technologies into the ballast market. Therefore, DOE developed two separate sets of future lighting product prices. The existing technologies scenario corresponds to no LED penetration, while the emerging technologies scenario depicts aggressive LED penetration.

To estimate potential product price trends, DOE performed a log linear regression on the ballast price index versus cumulative shipments. To model the 2005 shift in market structure, DOE also included a dummy variable in the model to account for the effect of the 2000 Ballast Rule on ballast prices: the variable is equal to 0 before 2005 (the year 2000 Ballast Rule went into effect) and equal to 1.0 for 2005 and after. The resulting model assumes that experience

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[a] U.S. Census Bureau, *Current Industrial Reports, Fluorescent Lamp Ballasts: 2005*. July 2006. Washington, D.C. <http://www.census.gov/industry/1/mq335c055.pdf>.

curve price trend applies to the entire ballast market with the effect of a market shift being a simple shift to a proportionally more expensive ballast type.

The modeled trend predicted a drop of 24 percent in real price compared to prices in the economy as a whole in the existing technologies scenario. In the emerging technologies scenario, the model forecasts that ballast prices would drop 19 percent compared to the 2010 real price values.

8B.3 *AEO* FORECASTED PRICE INDICES (DEFLATORS)

DOE has access to the forecasted price indices used by EIA in its National Energy Modeling System (NEMS) to develop the *AEO*. The price index projections used in the NEMS model are chained price indices called deflators, and are available through 2035. For this final rule, DOE considered the most relevant (*i.e.*, narrow) category that includes ballasts, specifically the "*Chained price index—other nondurable goods except drugs and tobacco*." This index could be made "real" using GDP deflator, projected for the purposes of *AEO2010* as well. DOE extrapolated deflators beyond 2035 to include the remaining years in the analysis period (through 2043).The results of this derivation are presented in Table 8B.3.1.

Table 8B.3.1 Price Factors for Ballasts Based on *AEO2010* Price Deflators

Year	Ballast Price Factor
2010	1.00
2011	0.99
2012	0.98
2013	0.97
2014	0.95
2015	0.93
2016	0.91
2017	0.89
2018	0.87
2019	0.85
2020	0.83
2021	0.82
2022	0.80
2023	0.79
2024	0.77
2025	0.76
2026	0.74
2027	0.73
2028	0.72
2029	0.70
2030	0.69
2031	0.68
2032	0.66
2033	0.65
2034	0.64
2035	0.62
2036	0.61
2037	0.60
2038	0.59
2039	0.58
2040	0.57
2041	0.56
2042	0.55
2043	0.54

Unlike the experience curve method described above, the *AEO* deflator approach does not directly consider cumulative production and shipments. Therefore, DOE applied the ballast price factors in Table 8B.3.1 to both the existing technologies and the emerging technologies scenarios in the NIA. The ballast price factors decline by more than 40 percent over the NIA analysis period; however, their effect on the cumulative NPV resulting from new and amended standards is greatly diminished by discounting. Deflator-based net present value (NPV) results from the national impacts analysis (NIA) were approximately 9 percent higher than NPV values based on constant real prices for ballasts.

APPENDIX 11B. RISC & OIRA CONSOLIDATED INFORMATION SYSTEM (ROCIS) TABLES

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11B.1 INTRODUCTION

The net present value (NPV) of the monetized benefits associated with emissions reductions can be viewed as a complement to the NPV of the customer savings calculated for each trial standard level (TSL) considered in this final rule for fluorescent lamp ballasts (FLB or ballasts). In Table 11B.1.1 through Table 11B.1.16, the top half of the table presents the NPV values that would result if the U.S. Department of Energy (DOE) were to add the estimates of the potential economic benefits resulting from reduced carbon dioxide (CO_2) and nitrogen oxides (NO_x) emissions in each of four valuation scenarios to the NPV of customer savings calculated for each TSL considered in this final rule, at both a 7-percent and 3-percent discount rate.

Although combining the values of operating savings and CO_2 reductions provides a useful perspective, two issues should be considered. First, the national operating savings are domestic U.S. consumer monetary savings that occur as a result of market transactions while the value of CO_2 reductions is based on a global value. Second, the assessments of operating cost savings and CO_2 savings are performed with different methods that use quite different time frames for analysis. The national operating cost savings is measured for the lifetime of products shipped in the 30-year analysis period. The SCC values, on the other hand, reflect the present value of future climate-related impacts resulting from the emission of one ton of carbon dioxide in each year. These impacts go well beyond 2100.

The benefits and costs of today's considered standard levels, for products sold in 2014–2043, can also be expressed in terms of annualized values. The annualized monetary values shown in Table 11B.1.1through Table 11B.1.16 present the sum of (1) the annualized national economic value, expressed in 2010 dollars (2010$), of the benefits from customer operation of products that meet the considered standard levels (consisting primarily of operating cost savings from using less energy, minus increases in equipment purchase and installation costs, which is another way of representing customer NPV); and (2) the annualized monetary value of the benefits of emission reductions, including CO_2 emission reductions. These results tables address all TSLs, equipment classes, and shipment scenarios. *Please note that zero values indicate product types with zero energy savings and associated consumer costs or benefits at a particular TSL, i.e., the corresponding efficiency level is a baseline design.*

Table 11B.1.1 Annualized Benefits and Costs of Considered Standard Levels for Ballasts for 2014–2043 Analysis Period (TSL 1, Existing Technologies, Shift Scenario, 3-Percent Discount Rate)

Fluorescent Light Ballasts	PC 1			PC 2				PC 3	PC 5	PC 6		
(Existing technologies, 3% discount rate)	1,3	4	8,9	2	5	10	11	6,7	14	12,13	**Total**	**Units**
Energy Savings Undiscounted (Cumulative to 2043)	1.186	0.000	0.000	0.267	0.271	0.432	0.246	0.041	0.919	0.129	3.491	*quad*
Energy Savings Discounted at 3% (Cumulative to 2043)	0.650	0.000	0.000	0.166	0.147	0.229	0.139	0.037	0.556	0.073	1.997	*quad*
Discounted Incr. Equipment Cost	1.783	0.000	0.000	0.128	0.222	0.013	0.124	0.000	-0.114	0.490	2.647	*billion $*
Discounted Oper. Cost Savings	6.979	0.000	0.000	1.532	1.571	2.458	1.001	0.125	5.432	0.982	20.081	*billion $*
NPV	5.196	0.000	0.000	1.404	1.348	2.446	0.878	0.125	5.546	0.492	17.434	*billion $*
Social Cost of Emissions (2014-2043)												
CO2 savings	21.626	0.000	0.000	4.862	4.939	7.875	4.489	0.750	16.747	2.359	63.647	*Mton*
Monetary values of CO2 savings												
At $4.9/ton in 2010$ (5% discount rate)	82.374	0.000	0.000	18.518	18.814	29.995	17.100	2.859	63.790	8.987	242.437	*million $*
At $22.3/ton in 2010$ (3% discount rate)	409.918	0.000	0.000	92.152	93.622	149.262	85.095	14.225	317.437	44.722	1206.433	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	689.785	0.000	0.000	155.068	157.541	251.169	143.194	23.937	534.165	75.256	2030.113	*million $*
At $67.6/ton in 2010$ (3% discount rate)	1250.311	0.000	0.000	281.077	285.560	455.271	259.554	43.389	968.232	136.409	3679.802	*million $*
NOx savings	7.962	0.000	0.000	1.790	1.818	2.899	1.653	0.276	6.166	0.869	23.433	*kton*
Monetary values of NOx savings (3% discount rate)												
At $451/ton in 2010$	2.085	0.000	0.000	0.469	0.476	0.759	0.433	0.072	1.615	0.228	6.137	*million $*
At $2543/ton in 2010$	11.752	0.000	0.000	2.642	2.684	4.279	2.440	0.408	9.100	1.282	34.587	*million $*
At $4635/ton in 2010$	21.418	0.000	0.000	4.815	4.892	7.799	4.446	0.743	16.586	2.337	63.036	*million $*
Monetary values of NOx savings (7% discount rate)												
At $451/ton in 2010$	1.115	0.000	0.000	0.251	0.255	0.406	0.231	0.039	0.863	0.122	3.281	*million $*
At $2543/ton in 2010$	6.283	0.000	0.000	1.412	1.435	2.288	1.304	0.218	4.865	0.685	18.491	*million $*
At $4635/ton in 2010$	11.451	0.000	0.000	2.574	2.615	4.170	2.377	0.397	8.868	1.249	33.702	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO2, $2543/ton NOx)												
(NOx at 3% discount rate)	5.617	0.000	0.000	1.499	1.445	2.599	0.965	0.139	5.873	0.538	18.675	*billion $*
(NOx at 7% discount rate)	5.612	0.000	0.000	1.497	1.443	2.597	0.964	0.139	5.869	0.537	18.659	*billion $*
Annualized Values												
Incr. Equipment Cost	0.099	0.000	0.000	0.007	0.012	0.001	0.007	0.000	-0.006	0.027	0.148	*billion $*
Oper. Cost Savings	0.389	0.000	0.000	0.085	0.088	0.137	0.056	0.007	0.303	0.055	1.120	*billion $*
NPV	0.290	0.000	0.000	0.078	0.075	0.136	0.049	0.007	0.309	0.027	0.972	*billion $*
Social Cost of Emissions												
Monetary values of CO2 savings												
At $4.9/ton in 2010$ (5% discount rate)	6.203	0.000	0.000	1.395	1.417	2.259	1.288	0.215	4.804	0.677	18.257	*million $*
At $22.3/ton in 2010$ (3% discount rate)	29.138	0.000	0.000	6.550	6.655	10.610	6.049	1.011	22.565	3.179	85.757	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	48.322	0.000	0.000	10.863	11.036	17.595	10.031	1.677	37.420	5.272	142.216	*million $*
At $67.6/ton in 2010$ (3% discount rate)	88.876	0.000	0.000	19.980	20.299	32.362	18.450	3.084	68.825	9.696	261.573	*million $*
Monetary values of NOx savings (3% discount rate)												
At $451/ton in 2010$	0.116	0.000	0.000	0.026	0.027	0.042	0.024	0.004	0.090	0.013	0.342	*million $*
At $2543/ton in 2010$	0.655	0.000	0.000	0.147	0.150	0.239	0.136	0.023	0.507	0.071	1.928	*million $*
At $4635/ton in 2010$	1.194	0.000	0.000	0.268	0.273	0.435	0.248	0.041	0.925	0.130	3.514	*million $*
Monetary values of NOx savings (7% discount rate)												
At $451/ton in 2010$	0.110	0.000	0.000	0.025	0.025	0.040	0.023	0.004	0.085	0.012	0.324	*million $*
At $2543/ton in 2010$	0.620	0.000	0.000	0.139	0.142	0.226	0.129	0.022	0.480	0.068	1.826	*million $*
At $4635/ton in 2010$	1.130	0.000	0.000	0.254	0.258	0.412	0.235	0.039	0.875	0.123	3.327	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO2, $2543/ton NOx)												
(NOx at 3% discount rate)	0.319	0.000	0.000	0.085	0.082	0.147	0.055	0.008	0.332	0.031	1.060	*billion $*
(NOx at 7% discount rate)	0.319	0.000	0.000	0.085	0.082	0.147	0.055	0.008	0.332	0.031	1.060	*billion $*

Table 11B.1.2 Annualized Benefits and Costs of Considered Standard Levels for Ballasts for 2014–2043 Analysis Period (TSL 2, Existing Technologies, Shift Scenario, 3-Percent Discount Rate)

Fluorescent Light Ballasts	PC 1			PC 2				PC 3	PC 5	PC 6		
(Existing technologies, 3% discount rate)	1,3	4	8,9	2	5	10	11	6,7	14	12,13	**Total**	**Units**
Energy Savings Undiscounted (Cumulative to 2043)	1.187	0.000	0.018	0.267	0.334	0.778	0.427	0.041	0.919	0.129	4.099	*quad*
Energy Savings Discounted at 3% (Cumulative to 2043)	0.651	0.000	0.010	0.166	0.181	0.409	0.237	0.037	0.556	0.073	2.320	*quad*
Discounted Incr. Equipment Cost	1.784	0.000	0.005	0.128	0.329	1.348	0.808	0.000	-0.114	0.490	4.780	*billion $*
Discounted Oper. Cost Savings	6.983	0.000	0.107	1.532	1.936	4.435	1.744	0.126	5.432	0.982	23.278	*billion $*
NPV	5.199	0.000	0.102	1.404	1.607	3.086	0.936	0.125	5.546	0.492	18.498	*billion $*
Social Cost of Emissions (2014-2043)												
CO_2 savings	22.019	0.000	0.326	4.947	6.195	14.427	7.913	0.764	17.040	2.401	76.030	*Mton*
Monetary values of CO_2 savings												
At $4.9/ton in 2010$ (5% discount rate)	83.871	0.000	1.242	18.843	23.597	54.952	30.140	2.909	64.908	9.145	289.605	*million $*
At $22.3/ton in 2010$ (3% discount rate)	417.365	0.000	6.181	93.767	117.424	273.456	149.983	14.474	323.001	45.506	1441.157	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	702.317	0.000	10.402	157.785	197.594	460.156	252.383	24.356	543.526	76.575	2425.093	*million $*
At $67.6/ton in 2010$ (3% discount rate)	1273.026	0.000	18.854	286.003	358.160	834.082	457.472	44.147	985.201	138.800	4395.746	*million $*
NOx savings	8.107	0.000	0.120	1.821	2.281	5.311	2.913	0.281	6.274	0.884	27.992	*kton*
Monetary values of NOx savings (3% discount rate)												
At $451/ton in 2010$	2.123	0.000	0.031	0.477	0.597	1.391	0.763	0.074	1.643	0.232	7.332	*million $*
At $2543/ton in 2010$	11.965	0.000	0.177	2.688	3.366	7.840	4.300	0.415	9.260	1.305	41.316	*million $*
At $4635/ton in 2010$	21.807	0.000	0.323	4.899	6.135	14.288	7.837	0.756	16.877	2.378	75.300	*million $*
Monetary values of NOx savings (7% discount rate)												
At $451/ton in 2010$	1.135	0.000	0.017	0.255	0.319	0.744	0.408	0.039	0.879	0.124	3.920	*million $*
At $2543/ton in 2010$	6.397	0.000	0.095	1.437	1.800	4.191	2.299	0.222	4.951	0.697	22.089	*million $*
At $4635/ton in 2010$	11.659	0.000	0.173	2.619	3.280	7.639	4.190	0.404	9.023	1.271	40.259	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO2, $2543/ton NOx)												
(NOx at 3% discount rate)	5.629	0.000	0.109	1.500	1.728	3.368	1.090	0.140	5.879	0.539	19.981	*billion $*
(NOx at 7% discount rate)	5.623	0.000	0.108	1.499	1.726	3.364	1.088	0.140	5.874	0.538	19.961	*billion $*
Annualized Values												
Incr. Equipment Cost	0.099	0.000	0.000	0.007	0.018	0.075	0.045	0.000	-0.006	0.027	0.266	*billion $*
Oper. Cost Savings	0.389	0.000	0.006	0.085	0.108	0.247	0.097	0.007	0.303	0.055	1.298	*billion $*
NPV	0.290	0.000	0.006	0.078	0.090	0.172	0.052	0.007	0.309	0.027	1.031	*billion $*
Social Cost of Emissions												
Monetary values of CO_2 savings												
At $4.9/ton in 2010$ (5% discount rate)	6.316	0.000	0.094	1.419	1.777	4.138	2.270	0.219	4.888	0.689	21.809	*million $*
At $22.3/ton in 2010$ (3% discount rate)	29.668	0.000	0.439	6.665	8.347	19.438	10.661	1.029	22.960	3.235	102.442	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	49.200	0.000	0.729	11.053	13.842	32.235	17.680	1.706	38.076	5.364	169.886	*million $*
At $67.6/ton in 2010$ (3% discount rate)	90.491	0.000	1.340	20.330	25.459	59.289	32.519	3.138	70.032	9.866	312.465	*million $*
Monetary values of NOx savings (3% discount rate)												
At $451/ton in 2010$	0.118	0.000	0.002	0.027	0.033	0.078	0.043	0.004	0.092	0.013	0.409	*million $*
At $2543/ton in 2010$	0.667	0.000	0.010	0.150	0.188	0.437	0.240	0.023	0.516	0.073	2.303	*million $*
At $4635/ton in 2010$	1.216	0.000	0.018	0.273	0.342	0.797	0.437	0.042	0.941	0.133	4.198	*million $*
Monetary values of NOx savings (7% discount rate)												
At $451/ton in 2010$	0.112	0.000	0.002	0.025	0.032	0.073	0.040	0.004	0.087	0.012	0.387	*million $*
At $2543/ton in 2010$	0.632	0.000	0.009	0.142	0.178	0.414	0.227	0.022	0.489	0.069	2.181	*million $*
At $4635/ton in 2010$	1.151	0.000	0.017	0.259	0.324	0.754	0.414	0.040	0.891	0.125	3.974	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO2, $2543/ton NOx)												
(NOx at 3% discount rate)	0.320	0.000	0.006	0.085	0.098	0.192	0.063	0.008	0.333	0.031	1.136	*billion $*
(NOx at 7% discount rate)	0.320	0.000	0.006	0.085	0.098	0.192	0.063	0.008	0.333	0.031	1.136	*billion $*

Table 11B.1.3 Annualized Benefits and Costs of Considered Standard Levels for Ballasts for 2014–2043 Analysis Period (TSL 3A, Existing Technologies, Shift Scenario, 3-Percent Discount Rate)

Fluorescent Light Ballasts	PC 1			PC 2				PC 3	PC 5	PC 6		
(Existing technologies, 3% discount rate)	1,3	4	8,9	2	5	10	11	6,7	14	12,13	Total	Units
Energy Savings Undiscounted (Cumulative to 2043)	1.438	0.306	0.018	0.298	0.334	1.515	0.556	0.041	0.919	0.129	5.554	*quad*
Energy Savings Discounted at 3% (Cumulative to 2043)	0.788	0.170	0.011	0.183	0.181	0.792	0.307	0.037	0.556	0.073	3.098	*quad*
Discounted Incr. Equipment Cost	2.149	0.722	0.005	0.167	0.329	4.758	1.407	0.000	-0.114	0.490	9.914	*billion $*
Discounted Oper. Cost Savings	8.459	1.781	0.110	1.712	1.936	8.649	2.278	0.126	5.432	0.982	31.465	*billion $*
NPV	6.311	1.059	0.105	1.544	1.607	3.890	0.872	0.125	5.546	0.492	21.551	*billion $*
Social Cost of Emissions (2014-2043)												
CO_2 savings	27.429	5.840	0.344	5.679	6.369	28.894	10.607	0.785	17.521	2.468	105.937	*Mton*
Monetary values of CO_2 savings												
At $4.9/ton in 2010$ (5% discount rate)	104.479	22.245	1.309	21.633	24.262	110.061	40.402	2.991	66.738	9.402	403.520	*million $*
At $22.3/ton in 2010$ (3% discount rate)	519.915	110.695	6.514	107.652	120.734	547.692	201.049	14.882	332.106	46.789	2008.030	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	874.882	186.272	10.962	181.151	203.164	921.624	338.314	25.042	558.848	78.733	3378.991	*million $*
At $67.6/ton in 2010$ (3% discount rate)	1585.819	337.638	19.870	328.355	368.257	1670.544	613.231	45.392	1012.973	142.712	6124.791	*million $*
NO_x savings	10.098	2.150	0.127	2.091	2.345	10.638	3.905	0.289	6.451	0.909	39.002	*kton*
Monetary values of NO_x savings (3% discount rate)												
At $451/ton in 2010$	2.645	0.563	0.033	0.548	0.614	2.786	1.023	0.076	1.690	0.238	10.215	*million $*
At $2543/ton in 2010$	14.905	3.173	0.187	3.086	3.461	15.702	5.764	0.427	9.521	1.341	57.567	*million $*
At $4635/ton in 2010$	27.165	5.784	0.340	5.625	6.308	28.617	10.505	0.778	17.352	2.445	104.919	*million $*
Monetary values of NO_x savings (7% discount rate)												
At $451/ton in 2010$	1.414	0.301	0.018	0.293	0.328	1.490	0.547	0.040	0.903	0.127	5.462	*million $*
At $2543/ton in 2010$	7.969	1.697	0.100	1.650	1.851	8.395	3.082	0.228	5.090	0.717	30.778	*million $*
At $4635/ton in 2010$	14.524	3.092	0.182	3.007	3.373	15.300	5.616	0.416	9.277	1.307	56.094	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO_2, $2543/ton NO_x)												
(NO_x at 3% discount rate)	6.845	1.173	0.111	1.655	1.731	4.454	1.078	0.141	5.888	0.540	23.617	*billion $*
(NO_x at 7% discount rate)	6.838	1.172	0.111	1.654	1.729	4.446	1.076	0.141	5.884	0.539	23.590	*billion $*
Annualized Values												
Incr. Equipment Cost	0.120	0.040	0.000	0.009	0.018	0.265	0.078	0.000	-0.006	0.027	0.553	*billion $*
Oper. Cost Savings	0.472	0.099	0.006	0.095	0.108	0.482	0.127	0.007	0.303	0.055	1.754	*billion $*
NPV	0.352	0.059	0.006	0.086	0.090	0.217	0.049	0.007	0.309	0.027	1.201	*billion $*
Social Cost of Emissions												
Monetary values of CO_2 savings												
At $4.9/ton in 2010$ (5% discount rate)	7.868	1.675	0.099	1.629	1.827	8.288	3.042	0.225	5.026	0.708	30.387	*million $*
At $22.3/ton in 2010$ (3% discount rate)	36.957	7.869	0.463	7.652	8.582	38.932	14.291	1.058	23.607	3.326	142.738	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	61.288	13.049	0.768	12.690	14.232	64.563	23.700	1.754	39.149	5.516	236.709	*million $*
At $67.6/ton in 2010$ (3% discount rate)	112.726	24.000	1.412	23.341	26.177	118.748	43.591	3.227	72.006	10.144	435.371	*million $*
Monetary values of NO_x savings (3% discount rate)												
At $451/ton in 2010$	0.147	0.031	0.002	0.031	0.034	0.155	0.057	0.004	0.094	0.013	0.570	*million $*
At $2543/ton in 2010$	0.831	0.177	0.010	0.172	0.193	0.875	0.321	0.024	0.531	0.075	3.209	*million $*
At $4635/ton in 2010$	1.514	0.322	0.019	0.314	0.352	1.595	0.586	0.043	0.967	0.136	5.849	*million $*
Monetary values of NO_x savings (7% discount rate)												
At $451/ton in 2010$	0.140	0.030	0.002	0.029	0.032	0.147	0.054	0.004	0.089	0.013	0.539	*million $*
At $2543/ton in 2010$	0.787	0.167	0.010	0.163	0.183	0.829	0.304	0.023	0.503	0.071	3.038	*million $*
At $4635/ton in 2010$	1.434	0.305	0.018	0.297	0.333	1.510	0.554	0.041	0.916	0.129	5.538	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO_2, $2543/ton NO_x)												
(NO_x at 3% discount rate)	0.390	0.067	0.006	0.094	0.098	0.257	0.063	0.008	0.333	0.031	1.347	*billion $*
(NO_x at 7% discount rate)	0.390	0.067	0.006	0.094	0.098	0.257	0.063	0.008	0.333	0.031	1.347	*billion $*

Table 11B.1.4 Annualized Benefits and Costs of Considered Standard Levels for Ballasts for 2014–2043 Analysis Period (TSL 3B, Existing Technologies, Shift Scenario, 3-Percent Discount Rate)

Fluorescent Light Ballasts	PC 1			PC 2				PC 3	PC 5	PC 6		
(Existing technologies, 3% discount rate)	1,3	4	8,9	2	5	10	11	6,7	14	12,13	Total	Units
Energy Savings Undiscounted (Cumulative to 2043)	1.438	0.306	0.018	0.298	0.334	1.515	0.556	0.041	0.919	0.133	5.557	*quad*
Energy Savings Discounted at 3% (Cumulative to 2043)	0.788	0.170	0.011	0.183	0.181	0.792	0.307	0.037	0.556	0.075	3.100	*quad*
Discounted Incr. Equipment Cost	2.149	0.722	0.005	0.167	0.329	4.758	1.407	0.001	-0.114	0.504	9.928	*billion $*
Discounted Oper. Cost Savings	8.459	1.781	0.110	1.712	1.936	8.649	2.278	0.126	5.432	1.004	31.487	*billion $*
NPV	6.311	1.059	0.105	1.544	1.607	3.890	0.872	0.125	5.546	0.500	21.560	*billion $*
Social Cost of Emissions (2014-2043)												
CO2 savings	27.424	5.839	0.344	5.678	6.368	28.889	10.605	0.786	17.517	2.528	105.977	*Mton*
Monetary values of CO2 savings												
At $4.9/ton in 2010$ (5% discount rate)	104.458	22.240	1.309	21.629	24.257	110.039	40.394	2.992	66.725	9.628	403.672	*million $*
At $22.3/ton in 2010$ (3% discount rate)	519.815	110.674	6.513	107.631	120.711	547.586	201.011	14.891	332.042	47.914	2008.787	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	874.713	186.236	10.960	181.116	203.124	921.445	338.248	25.057	558.740	80.626	3380.265	*million $*
At $67.6/ton in 2010$ (3% discount rate)	1585.513	337.573	19.866	328.292	368.185	1670.221	613.112	45.419	1012.778	146.143	6127.101	*million $*
NOx savings	10.096	2.150	0.127	2.091	2.345	10.636	3.904	0.289	6.449	0.931	39.017	*kton*
Monetary values of NOx savings (3% discount rate)												
At $451/ton in 2010$	2.644	0.563	0.033	0.548	0.614	2.786	1.023	0.076	1.690	0.244	10.220	*million $*
At $2543/ton in 2010$	14.902	3.173	0.187	3.086	3.461	15.698	5.763	0.427	9.525	1.374	57.594	*million $*
At $4635/ton in 2010$	27.160	5.783	0.340	5.624	6.307	28.611	10.503	0.778	17.359	2.503	104.969	*million $*
Monetary values of NOx savings (7% discount rate)												
At $451/ton in 2010$	1.414	0.301	0.018	0.293	0.328	1.489	0.547	0.041	0.904	0.130	5.464	*million $*
At $2543/ton in 2010$	7.967	1.696	0.100	1.650	1.850	8.393	3.081	0.228	5.092	0.734	30.792	*million $*
At $4635/ton in 2010$	14.521	3.092	0.182	3.007	3.372	15.297	5.615	0.416	9.281	1.338	56.120	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO2, $2543/ton NOx)												
(NOx at 3% discount rate)	6.845	1.173	0.111	1.655	1.731	4.454	1.078	0.141	5.888	0.550	23.626	*billion $*
(NOx at 7% discount rate)	6.838	1.172	0.111	1.654	1.729	4.446	1.076	0.141	5.883	0.549	23.599	*billion $*
Annualized Values												
Incr. Equipment Cost	0.120	0.040	0.000	0.009	0.018	0.265	0.078	0.000	-0.006	0.028	0.553	*billion $*
Oper. Cost Savings	0.472	0.099	0.006	0.095	0.108	0.482	0.127	0.007	0.303	0.056	1.755	*billion $*
NPV	0.352	0.059	0.006	0.086	0.090	0.217	0.049	0.007	0.309	0.028	1.202	*billion $*
Social Cost of Emissions												
Monetary values of CO2 savings												
At $4.9/ton in 2010$ (5% discount rate)	7.866	1.675	0.099	1.629	1.827	8.287	3.042	0.225	5.025	0.725	30.399	*million $*
At $22.3/ton in 2010$ (3% discount rate)	36.950	7.867	0.463	7.651	8.581	38.924	14.289	1.058	23.603	3.406	142.792	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	61.276	13.046	0.768	12.688	14.230	64.550	23.695	1.755	39.142	5.648	236.799	*million $*
At $67.6/ton in 2010$ (3% discount rate)	112.704	23.996	1.412	23.336	26.172	118.725	43.582	3.229	71.992	10.388	435.536	*million $*
Monetary values of NOx savings (3% discount rate)												
At $451/ton in 2010$	0.147	0.031	0.002	0.031	0.034	0.155	0.057	0.004	0.094	0.014	0.570	*million $*
At $2543/ton in 2010$	0.831	0.177	0.010	0.172	0.193	0.875	0.321	0.024	0.531	0.077	3.211	*million $*
At $4635/ton in 2010$	1.514	0.322	0.019	0.314	0.352	1.595	0.586	0.043	0.968	0.140	5.852	*million $*
Monetary values of NOx savings (7% discount rate)												
At $451/ton in 2010$	0.140	0.030	0.002	0.029	0.032	0.147	0.054	0.004	0.089	0.013	0.539	*million $*
At $2543/ton in 2010$	0.787	0.167	0.010	0.163	0.183	0.829	0.304	0.023	0.503	0.073	3.040	*million $*
At $4635/ton in 2010$	1.434	0.305	0.018	0.297	0.333	1.510	0.554	0.041	0.916	0.132	5.540	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO2, $2543/ton NOx)												
(NOx at 3% discount rate)	0.390	0.067	0.006	0.094	0.098	0.257	0.063	0.008	0.333	0.031	1.348	*billion $*
(NOx at 7% discount rate)	0.390	0.067	0.006	0.094	0.098	0.257	0.063	0.008	0.333	0.031	1.348	*billion $*

Table 11B.1.5 Annualized Benefits and Costs of Considered Standard Levels for Ballasts for 2014–2043 Analysis Period (TSL 1, Existing Technologies, Shift Scenario, 7-Percent Discount Rate)

Fluorescent Light Ballasts	PC 1			PC 2				PC 3	PC 5	PC 6		
(Existing technologies, 7% discount rate)	1,3	4	8,9	2	5	10	11	6,7	14	12,13	**Total**	**Units**
Energy Savings Undiscounted (Cumulative to 2043)	1.186	0.000	0.000	0.267	0.271	0.432	0.246	0.041	0.919	0.129	3.491	*quad*
Energy Savings Discounted at 7% (Cumulative to 2043)	0.325	0.000	0.000	0.101	0.073	0.111	0.074	0.032	0.314	0.038	1.066	*quad*
Discounted Incr. Equipment Cost	0.956	0.000	0.000	0.069	0.118	0.006	0.061	0.000	-0.073	0.266	1.403	*billion $*
Discounted Oper. Cost Savings	3.286	0.000	0.000	0.843	0.732	1.113	0.485	0.107	2.870	0.489	9.925	*billion $*
NPV	2.330	0.000	0.000	0.775	0.614	1.107	0.424	0.107	2.943	0.223	8.522	*billion $*
Social Cost of Emissions (2014-2043)												
CO_2 savings	21.626	0.000	0.000	4.862	4.939	7.875	4.489	0.750	16.747	2.359	63.647	*Mton*
Monetary values of CO_2 savings												
At $4.9/ton in 2010$ (5% discount rate)	82.374	0.000	0.000	18.518	18.814	29.995	17.100	2.859	63.790	8.987	242.437	*million $*
At $22.3/ton in 2010$ (3% discount rate)	409.918	0.000	0.000	92.152	93.622	149.262	85.095	14.225	317.437	44.722	1206.433	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	689.785	0.000	0.000	155.068	157.541	251.169	143.194	23.937	534.165	75.256	2030.113	*million $*
At $67.6/ton in 2010$ (3% discount rate)	1250.311	0.000	0.000	281.077	285.560	455.271	259.554	43.389	968.232	136.409	3679.802	*million $*
NO_x savings	7.962	0.000	0.000	1.790	1.818	2.899	1.653	0.276	6.166	0.869	23.433	*kton*
Monetary values of NO_x savings (3% discount rate)												
At $451/ton in 2010$	2.085	0.000	0.000	0.469	0.476	0.759	0.433	0.072	1.615	0.228	6.137	*million $*
At $2543/ton in 2010$	11.752	0.000	0.000	2.642	2.684	4.279	2.440	0.408	9.100	1.282	34.587	*million $*
At $4635/ton in 2010$	21.418	0.000	0.000	4.815	4.892	7.799	4.446	0.743	16.586	2.337	63.036	*million $*
Monetary values of NO_x savings (7% discount rate)												
At $451/ton in 2010$	1.115	0.000	0.000	0.251	0.255	0.406	0.231	0.039	0.863	0.122	3.281	*million $*
At $2543/ton in 2010$	6.283	0.000	0.000	1.412	1.435	2.288	1.304	0.218	4.865	0.685	18.491	*million $*
At $4635/ton in 2010$	11.451	0.000	0.000	2.574	2.615	4.170	2.377	0.397	8.868	1.249	33.702	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO_2, $2543/ton NO_x)												
(NO_x at 3% discount rate)	2.751	0.000	0.000	0.869	0.710	1.261	0.511	0.121	3.270	0.269	9.763	*billion $*
(NO_x at 7% discount rate)	2.746	0.000	0.000	0.868	0.709	1.259	0.510	0.121	3.266	0.269	9.747	*billion $*
Annualized Values												
Incr. Equipment Cost	0.094	0.000	0.000	0.007	0.012	0.001	0.006	0.000	-0.007	0.026	0.138	*billion $*
Oper. Cost Savings	0.324	0.000	0.000	0.083	0.072	0.110	0.048	0.011	0.283	0.048	0.980	*billion $*
NPV	0.230	0.000	0.000	0.076	0.061	0.109	0.042	0.011	0.291	0.022	0.841	*billion $*
Social Cost of Emissions												
Monetary values of CO_2 savings												
At $4.9/ton in 2010$ (5% discount rate)	6.203	0.000	0.000	1.395	1.417	2.259	1.288	0.215	4.804	0.677	18.257	*million $*
At $22.3/ton in 2010$ (3% discount rate)	29.138	0.000	0.000	6.550	6.655	10.610	6.049	1.011	22.565	3.179	85.757	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	48.322	0.000	0.000	10.863	11.036	17.595	10.031	1.677	37.420	5.272	142.216	*million $*
At $67.6/ton in 2010$ (3% discount rate)	88.876	0.000	0.000	19.980	20.299	32.362	18.450	3.084	68.825	9.696	261.573	*million $*
Monetary values of NO_x savings (3% discount rate)												
At $451/ton in 2010$	0.116	0.000	0.000	0.026	0.027	0.042	0.024	0.004	0.090	0.013	0.342	*million $*
At $2543/ton in 2010$	0.655	0.000	0.000	0.147	0.150	0.239	0.136	0.023	0.507	0.071	1.928	*million $*
At $4635/ton in 2010$	1.194	0.000	0.000	0.268	0.273	0.435	0.248	0.041	0.925	0.130	3.514	*million $*
Monetary values of NO_x savings (7% discount rate)												
At $451/ton in 2010$	0.110	0.000	0.000	0.025	0.025	0.040	0.023	0.004	0.085	0.012	0.324	*million $*
At $2543/ton in 2010$	0.620	0.000	0.000	0.139	0.142	0.226	0.129	0.022	0.480	0.068	1.826	*million $*
At $4635/ton in 2010$	1.130	0.000	0.000	0.254	0.258	0.412	0.235	0.039	0.875	0.123	3.327	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO_2, $2543/ton NO_x)												
(NO_x at 3% discount rate)	0.260	0.000	0.000	0.083	0.067	0.120	0.048	0.012	0.314	0.025	0.929	*billion $*
(NO_x at 7% discount rate)	0.260	0.000	0.000	0.083	0.067	0.120	0.048	0.012	0.314	0.025	0.929	*billion $*

Table 11B.1.6 Annualized Benefits and Costs of Considered Standard Levels for Ballasts for 2014–2043 Analysis Period (TSL 2, Existing Technologies, Shift Scenario, 7-Percent Discount Rate)

Fluorescent Light Ballasts	PC 1			PC 2				PC 3	PC 5	PC 6		
(Existing technologies, 7% discount rate)	1,3	4	8,9	2	5	10	11	6,7	14	12,13	**Total**	**Units**
Energy Savings Undiscounted (Cumulative to 2043)	1.187	0.000	0.018	0.267	0.334	0.778	0.427	0.041	0.919	0.129	4.099	*quad*
Energy Savings Discounted at 7% (Cumulative to 2043)	0.325	0.000	0.006	0.101	0.090	0.194	0.122	0.032	0.314	0.038	1.221	*quad*
Discounted Incr. Equipment Cost	0.957	0.000	0.003	0.069	0.175	0.658	0.410	0.000	-0.073	0.266	2.464	*billion $*
Discounted Oper. Cost Savings	3.288	0.000	0.055	0.843	0.902	1.985	0.830	0.107	2.870	0.489	11.371	*billion $*
NPV	2.332	0.000	0.052	0.775	0.728	1.327	0.419	0.107	2.943	0.223	8.907	*billion $*
Social Cost of Emissions (2014-2043)												
CO2 savings	22.019	0.000	0.326	4.947	6.195	14.427	7.913	0.764	17.040	2.401	76.030	*Mton*
Monetary values of CO2 savings												
At $4.9/ton in 2010$ (5% discount rate)	83.871	0.000	1.242	18.843	23.597	54.952	30.140	2.909	64.908	9.145	289.605	*million $*
At $22.3/ton in 2010$ (3% discount rate)	417.365	0.000	6.181	93.767	117.424	273.456	149.983	14.474	323.001	45.506	1441.157	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	702.317	0.000	10.402	157.785	197.594	460.156	252.383	24.356	543.526	76.575	2425.093	*million $*
At $67.6/ton in 2010$ (3% discount rate)	1273.026	0.000	18.854	286.003	358.160	834.082	457.472	44.147	985.201	138.800	4395.746	*million $*
NOx savings	8.107	0.000	0.120	1.821	2.281	5.311	2.913	0.281	6.274	0.884	27.992	*kton*
Monetary values of NOx savings (3% discount rate)												
At $451/ton in 2010$	2.123	0.000	0.031	0.477	0.597	1.391	0.763	0.074	1.643	0.232	7.332	*million $*
At $2543/ton in 2010$	11.965	0.000	0.177	2.688	3.366	7.840	4.300	0.415	9.260	1.305	41.316	*million $*
At $4635/ton in 2010$	21.807	0.000	0.323	4.899	6.135	14.288	7.837	0.756	16.877	2.378	75.300	*million $*
Monetary values of NOx savings (7% discount rate)												
At $451/ton in 2010$	1.135	0.000	0.017	0.255	0.319	0.744	0.408	0.039	0.879	0.124	3.920	*million $*
At $2543/ton in 2010$	6.397	0.000	0.095	1.437	1.800	4.191	2.299	0.222	4.951	0.697	22.089	*million $*
At $4635/ton in 2010$	11.659	0.000	0.173	2.619	3.280	7.639	4.190	0.404	9.023	1.271	40.259	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO2, $2543/ton NOx)												
(NOx at 3% discount rate)	2.761	0.000	0.059	0.871	0.848	1.609	0.574	0.122	3.276	0.270	10.389	*billion $*
(NOx at 7% discount rate)	2.756	0.000	0.059	0.870	0.847	1.605	0.572	0.122	3.271	0.269	10.370	*billion $*
Annualized Values												
Incr. Equipment Cost	0.094	0.000	0.000	0.007	0.017	0.065	0.041	0.000	-0.007	0.026	0.243	*billion $*
Oper. Cost Savings	0.325	0.000	0.005	0.083	0.089	0.196	0.082	0.011	0.283	0.048	1.123	*billion $*
NPV	0.230	0.000	0.005	0.076	0.072	0.131	0.041	0.011	0.291	0.022	0.879	*billion $*
Social Cost of Emissions												
Monetary values of CO2 savings												
At $4.9/ton in 2010$ (5% discount rate)	6.316	0.000	0.094	1.419	1.777	4.138	2.270	0.219	4.888	0.689	21.809	*million $*
At $22.3/ton in 2010$ (3% discount rate)	29.668	0.000	0.439	6.665	8.347	19.438	10.661	1.029	22.960	3.235	102.442	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	49.200	0.000	0.729	11.053	13.842	32.235	17.680	1.706	38.076	5.364	169.886	*million $*
At $67.6/ton in 2010$ (3% discount rate)	90.491	0.000	1.340	20.330	25.459	59.289	32.519	3.138	70.032	9.866	312.465	*million $*
Monetary values of NOx savings (3% discount rate)												
At $451/ton in 2010$	0.118	0.000	0.002	0.027	0.033	0.078	0.043	0.004	0.092	0.013	0.409	*million $*
At $2543/ton in 2010$	0.667	0.000	0.010	0.150	0.188	0.437	0.240	0.023	0.516	0.073	2.303	*million $*
At $4635/ton in 2010$	1.216	0.000	0.018	0.273	0.342	0.797	0.437	0.042	0.941	0.133	4.198	*million $*
Monetary values of NOx savings (7% discount rate)												
At $451/ton in 2010$	0.112	0.000	0.002	0.025	0.032	0.073	0.040	0.004	0.087	0.012	0.387	*million $*
At $2543/ton in 2010$	0.632	0.000	0.009	0.142	0.178	0.414	0.227	0.022	0.489	0.069	2.181	*million $*
At $4635/ton in 2010$	1.151	0.000	0.017	0.259	0.324	0.754	0.414	0.040	0.891	0.125	3.974	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO2, $2543/ton NOx)												
(NOx at 3% discount rate)	0.261	0.000	0.006	0.083	0.080	0.151	0.052	0.012	0.314	0.025	0.984	*billion $*
(NOx at 7% discount rate)	0.261	0.000	0.006	0.083	0.080	0.151	0.052	0.012	0.314	0.025	0.984	*billion $*

Table 11B.1.7 Annualized Benefits and Costs of Considered Standard Levels for Ballasts for 2014–2043 Analysis Period (TSL 3A, Existing Technologies, Shift Scenario, 7-Percent Discount Rate)

Fluorescent Light Ballasts	PC 1			PC 2				PC 3	PC 5	PC 6		
(Existing technologies, 7% discount rate)	1,3	4	8,9	2	5	10	11	6,7	14	12,13	**Total**	**Units**
Energy Savings Undiscounted (Cumulative to 2043)	1.438	0.306	0.018	0.298	0.334	1.515	0.556	0.041	0.919	0.129	5.554	*quad*
Energy Savings Discounted at 7% (Cumulative to 2043)	0.393	0.087	0.006	0.109	0.090	0.372	0.157	0.032	0.314	0.038	1.597	*quad*
Discounted Incr. Equipment Cost	1.151	0.398	0.003	0.090	0.175	2.322	0.716	0.000	-0.073	0.266	5.048	*billion $*
Discounted Oper. Cost Savings	3.980	0.854	0.057	0.928	0.902	3.844	1.078	0.107	2.870	0.489	15.109	*billion $*
NPV	2.829	0.456	0.054	0.838	0.728	1.521	0.362	0.107	2.943	0.223	10.062	*billion $*
Social Cost of Emissions (2014-2043)												
CO2 savings	27.429	5.840	0.344	5.679	6.369	28.894	10.607	0.785	17.521	2.468	105.937	*Mton*
Monetary values of CO2 savings												
At $4.9/ton in 2010$ (5% discount rate)	104.479	22.245	1.309	21.633	24.262	110.061	40.402	2.991	66.738	9.402	403.520	*million $*
At $22.3/ton in 2010$ (3% discount rate)	519.915	110.695	6.514	107.652	120.734	547.692	201.049	14.882	332.106	46.789	2008.030	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	874.882	186.272	10.962	181.151	203.164	921.624	338.314	25.042	558.848	78.733	3378.991	*million $*
At $67.6/ton in 2010$ (3% discount rate)	1585.819	337.638	19.870	328.355	368.257	1670.544	613.231	45.392	1012.973	142.712	6124.791	*million $*
NOx savings	10.098	2.150	0.127	2.091	2.345	10.638	3.905	0.289	6.451	0.909	39.002	*kton*
Monetary values of NOx savings (3% discount rate)												
At $451/ton in 2010$	2.645	0.563	0.033	0.548	0.614	2.786	1.023	0.076	1.690	0.238	10.215	*million $*
At $2543/ton in 2010$	14.905	3.173	0.187	3.086	3.461	15.702	5.764	0.427	9.521	1.341	57.567	*million $*
At $4635/ton in 2010$	27.165	5.784	0.340	5.625	6.308	28.617	10.505	0.778	17.352	2.445	104.919	*million $*
Monetary values of NOx savings (7% discount rate)												
At $451/ton in 2010$	1.414	0.301	0.018	0.293	0.328	1.490	0.547	0.040	0.903	0.127	5.462	*million $*
At $2543/ton in 2010$	7.969	1.697	0.100	1.650	1.851	8.395	3.082	0.228	5.090	0.717	30.778	*million $*
At $4635/ton in 2010$	14.524	3.092	0.182	3.007	3.373	15.300	5.616	0.416	9.277	1.307	56.094	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO2, $2543/ton NOx)												
(NOx at 3% discount rate)	3.364	0.570	0.060	0.949	0.852	2.085	0.569	0.122	3.285	0.271	12.127	*billion $*
(NOx at 7% discount rate)	3.357	0.569	0.060	0.947	0.850	2.078	0.566	0.122	3.280	0.271	12.100	*billion $*
Annualized Values												
Incr. Equipment Cost	0.114	0.039	0.000	0.009	0.017	0.229	0.071	0.000	-0.007	0.026	0.498	*billion $*
Oper. Cost Savings	0.393	0.084	0.006	0.092	0.089	0.379	0.106	0.011	0.283	0.048	1.492	*billion $*
NPV	0.279	0.045	0.005	0.083	0.072	0.150	0.036	0.011	0.291	0.022	0.993	*billion $*
Social Cost of Emissions												
Monetary values of CO2 savings												
At $4.9/ton in 2010$ (5% discount rate)	7.868	1.675	0.099	1.629	1.827	8.288	3.042	0.225	5.026	0.708	30.387	*million $*
At $22.3/ton in 2010$ (3% discount rate)	36.957	7.869	0.463	7.652	8.582	38.932	14.291	1.058	23.607	3.326	142.738	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	61.288	13.049	0.768	12.690	14.232	64.563	23.700	1.754	39.149	5.516	236.709	*million $*
At $67.6/ton in 2010$ (3% discount rate)	112.726	24.000	1.412	23.341	26.177	118.748	43.591	3.227	72.006	10.144	435.371	*million $*
Monetary values of NOx savings (3% discount rate)												
At $451/ton in 2010$	0.147	0.031	0.002	0.031	0.034	0.155	0.057	0.004	0.094	0.013	0.570	*million $*
At $2543/ton in 2010$	0.831	0.177	0.010	0.172	0.193	0.875	0.321	0.024	0.531	0.075	3.209	*million $*
At $4635/ton in 2010$	1.514	0.322	0.019	0.314	0.352	1.595	0.586	0.043	0.967	0.136	5.849	*million $*
Monetary values of NOx savings (7% discount rate)												
At $451/ton in 2010$	0.140	0.030	0.002	0.029	0.032	0.147	0.054	0.004	0.089	0.013	0.539	*million $*
At $2543/ton in 2010$	0.787	0.167	0.010	0.163	0.183	0.829	0.304	0.023	0.503	0.071	3.038	*million $*
At $4635/ton in 2010$	1.434	0.305	0.018	0.297	0.333	1.510	0.554	0.041	0.916	0.129	5.538	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO2, $2543/ton NOx)												
(NOx at 3% discount rate)	0.317	0.053	0.006	0.091	0.081	0.190	0.050	0.012	0.315	0.025	1.139	*billion $*
(NOx at 7% discount rate)	0.317	0.053	0.006	0.091	0.081	0.190	0.050	0.012	0.315	0.025	1.139	*billion $*

Table 11B.1.8 Annualized Benefits and Costs of Considered Standard Levels for Ballasts for 2014–2043 Analysis Period (TSL 3B, Existing Technologies, Shift Scenario, 7-Percent Discount Rate)

Fluorescent Light Ballasts	PC 1			PC 2				PC 3	PC 5	PC 6		
(Existing technologies, 7% discount rate)	1,3	4	8,9	2	5	10	11	6,7	14	12,13	Total	Units
Energy Savings Undiscounted (Cumulative to 2043)	1.438	0.306	0.018	0.298	0.334	1.515	0.556	0.041	0.919	0.133	5.557	*quad*
Energy Savings Discounted at 7% (Cumulative to 2043)	0.393	0.087	0.006	0.109	0.090	0.372	0.157	0.032	0.314	0.039	1.599	*quad*
Discounted Incr. Equipment Cost	1.151	0.398	0.003	0.090	0.175	2.322	0.716	0.000	-0.073	0.275	5.057	*billion $*
Discounted Oper. Cost Savings	3.980	0.854	0.057	0.928	0.902	3.844	1.078	0.108	2.870	0.501	15.121	*billion $*
NPV	2.829	0.456	0.054	0.838	0.728	1.521	0.362	0.107	2.943	0.226	10.064	*billion $*
Social Cost of Emissions (2014-2043)												
CO2 savings	27.424	5.839	0.344	5.678	6.368	28.889	10.605	0.786	17.517	2.528	105.977	*Mton*
Monetary values of CO2 savings												
At $4.9/ton in 2010$ (5% discount rate)	104.458	22.240	1.309	21.629	24.257	110.039	40.394	2.992	66.725	9.628	403.672	*million $*
At $22.3/ton in 2010$ (3% discount rate)	519.815	110.674	6.513	107.631	120.711	547.586	201.011	14.891	332.042	47.914	2008.787	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	874.713	186.236	10.960	181.116	203.124	921.445	338.248	25.057	558.740	80.626	3380.265	*million $*
At $67.6/ton in 2010$ (3% discount rate)	1585.513	337.573	19.866	328.292	368.185	1670.221	613.112	45.419	1012.778	146.143	6127.101	*million $*
NOx savings	10.096	2.150	0.127	2.091	2.345	10.636	3.904	0.289	6.449	0.931	39.017	*kton*
Monetary values of NOx savings (3% discount rate)												
At $451/ton in 2010$	2.644	0.563	0.033	0.548	0.614	2.786	1.023	0.076	1.690	0.244	10.220	*million $*
At $2543/ton in 2010$	14.902	3.173	0.187	3.086	3.461	15.698	5.763	0.427	9.525	1.374	57.594	*million $*
At $4635/ton in 2010$	27.160	5.783	0.340	5.624	6.307	28.611	10.503	0.778	17.359	2.503	104.969	*million $*
Monetary values of NOx savings (7% discount rate)												
At $451/ton in 2010$	1.414	0.301	0.018	0.293	0.328	1.489	0.547	0.041	0.904	0.130	5.464	*million $*
At $2543/ton in 2010$	7.967	1.696	0.100	1.650	1.850	8.393	3.081	0.228	5.092	0.734	30.792	*million $*
At $4635/ton in 2010$	14.521	3.092	0.182	3.007	3.372	15.297	5.615	0.416	9.281	1.338	56.120	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO2, $2543/ton NOx)												
(NOx at 3% discount rate)	3.364	0.570	0.060	0.949	0.852	2.085	0.569	0.122	3.285	0.275	12.131	*billion $*
(NOx at 7% discount rate)	3.357	0.569	0.060	0.947	0.850	2.077	0.566	0.122	3.280	0.275	12.104	*billion $*
Annualized Values												
Incr. Equipment Cost	0.114	0.039	0.000	0.009	0.017	0.229	0.071	0.000	-0.007	0.027	0.499	*billion $*
Oper. Cost Savings	0.393	0.084	0.006	0.092	0.089	0.379	0.106	0.011	0.283	0.049	1.493	*billion $*
NPV	0.279	0.045	0.005	0.083	0.072	0.150	0.036	0.011	0.291	0.022	0.994	*billion $*
Social Cost of Emissions												
Monetary values of CO2 savings												
At $4.9/ton in 2010$ (5% discount rate)	7.866	1.675	0.099	1.629	1.827	8.287	3.042	0.225	5.025	0.725	30.399	*million $*
At $22.3/ton in 2010$ (3% discount rate)	36.950	7.867	0.463	7.651	8.581	38.924	14.289	1.058	23.603	3.406	142.792	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	61.276	13.046	0.768	12.688	14.230	64.550	23.695	1.755	39.142	5.648	236.799	*million $*
At $67.6/ton in 2010$ (3% discount rate)	112.704	23.996	1.412	23.336	26.172	118.725	43.582	3.229	71.992	10.388	435.536	*million $*
Monetary values of NOx savings (3% discount rate)												
At $451/ton in 2010$	0.147	0.031	0.002	0.031	0.034	0.155	0.057	0.004	0.094	0.014	0.570	*million $*
At $2543/ton in 2010$	0.831	0.177	0.010	0.172	0.193	0.875	0.321	0.024	0.531	0.077	3.211	*million $*
At $4635/ton in 2010$	1.514	0.322	0.019	0.314	0.352	1.595	0.586	0.043	0.968	0.140	5.852	*million $*
Monetary values of NOx savings (7% discount rate)												
At $451/ton in 2010$	0.140	0.030	0.002	0.029	0.032	0.147	0.054	0.004	0.089	0.013	0.539	*million $*
At $2543/ton in 2010$	0.787	0.167	0.010	0.163	0.183	0.829	0.304	0.023	0.503	0.073	3.040	*million $*
At $4635/ton in 2010$	1.434	0.305	0.018	0.297	0.333	1.510	0.554	0.041	0.916	0.132	5.540	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO2, $2543/ton NOx)												
(NOx at 3% discount rate)	0.317	0.053	0.006	0.091	0.081	0.190	0.050	0.012	0.315	0.026	1.140	*billion $*
(NOx at 7% discount rate)	0.317	0.053	0.006	0.091	0.081	0.190	0.050	0.012	0.315	0.026	1.139	*billion $*

Table 11B.1.9 Annualized Benefits and Costs of Considered Standard Levels for Ballasts for 2014–2043 Analysis Period (TSL 1, Emerging Technologies, Roll Up Scenario, 3-Percent Discount Rate)

Fluorescent Light Ballasts	**PC 1**			**PC 2**				**PC 3**	**PC 5**	**PC 6**		
(Emerging technologies, 3% discount rate)	1,3	4	8,9	2	5	10	11	6,7	14	12,13	**Total**	**Units**
Energy Savings Undiscounted (Cumulative to 2043)	0.001	0.000	0.000	0.126	0.101	0.160	0.231	0.035	0.695	0.009	1.358	*quad*
Energy Savings Discounted at 3% (Cumulative to 2043)	0.001	0.000	0.000	0.090	0.060	0.099	0.128	0.032	0.424	0.006	0.838	*quad*
Discounted Incr. Equipment Cost	-0.002	0.000	0.000	0.041	0.076	0.004	0.124	0.000	-0.093	-0.085	0.064	*billion $*
Discounted Oper. Cost Savings	0.008	0.000	0.000	0.823	0.655	1.029	1.001	0.120	4.525	0.181	8.341	*billion $*
NPV	0.010	0.000	0.000	0.781	0.579	1.025	0.878	0.120	4.619	0.266	8.277	*billion $*
Social Cost of Emissions (2014-2043)												
CO_2 savings	0.008	0.000	0.000	1.159	0.930	1.475	2.121	0.326	6.390	0.084	12.493	*Mton*
Monetary values of CO_2 savings												
At $4.9/ton in 2010$ (5% discount rate)	0.036	0.000	0.000	5.230	4.199	6.656	9.570	1.473	28.839	0.379	56.381	*million $*
At $22.3/ton in 2010$ (3% discount rate)	0.164	0.000	0.000	24.223	19.448	30.827	44.324	6.823	133.571	1.753	261.132	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	0.272	0.000	0.000	40.082	32.180	51.009	73.342	11.289	221.018	2.901	432.092	*million $*
At $67.6/ton in 2010$ (3% discount rate)	0.503	0.000	0.000	74.116	59.504	94.321	135.618	20.875	408.690	5.364	798.991	*million $*
NO_x savings	0.006	0.000	0.000	0.925	0.743	1.177	1.693	0.261	5.102	0.067	9.974	*kton*
Monetary values of NO_x savings (3% discount rate)												
At $451/ton in 2010$	0.001	0.000	0.000	0.218	0.175	0.277	0.399	0.061	1.201	0.016	2.348	*million $*
At $2543/ton in 2010$	0.008	0.000	0.000	1.227	0.985	1.562	2.246	0.346	6.769	0.089	13.233	*million $*
At $4635/ton in 2010$	0.015	0.000	0.000	2.237	1.796	2.847	4.094	0.630	12.336	0.162	24.117	*million $*
Monetary values of NO_x savings (7% discount rate)												
At $451/ton in 2010$	0.001	0.000	0.000	0.100	0.081	0.128	0.184	0.028	0.553	0.007	1.082	*million $*
At $2543/ton in 2010$	0.004	0.000	0.000	0.566	0.454	0.720	1.035	0.159	3.119	0.041	6.097	*million $*
At $4635/ton in 2010$	0.007	0.000	0.000	1.031	0.828	1.312	1.886	0.290	5.684	0.075	11.112	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO_2, $2543/ton NO_x)												
(NO_x at 3% discount rate)	0.010	0.000	0.000	0.807	0.599	1.057	0.924	0.127	4.759	0.268	8.552	*billion $*
(NO_x at 7% discount rate)	0.010	0.000	0.000	0.806	0.599	1.056	0.923	0.127	4.755	0.268	8.545	*billion $*
Annualized Values												
Incr. Equipment Cost	0.000	0.000	0.000	0.002	0.004	0.000	0.007	0.000	-0.005	-0.005	0.004	*billion $*
Oper. Cost Savings	0.000	0.000	0.000	0.046	0.036	0.057	0.056	0.007	0.252	0.010	0.465	*billion $*
NPV	0.001	0.000	0.000	0.044	0.032	0.057	0.049	0.007	0.257	0.015	0.461	*billion $*
Social Cost of Emissions												
Monetary values of CO_2 savings												
At $4.9/ton in 2010$ (5% discount rate)	0.003	0.000	0.000	0.394	0.316	0.501	0.721	0.111	2.172	0.029	4.246	*million $*
At $22.3/ton in 2010$ (3% discount rate)	0.012	0.000	0.000	1.722	1.382	2.191	3.151	0.485	9.495	0.125	18.562	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	0.019	0.000	0.000	2.808	2.254	3.573	5.138	0.791	15.483	0.203	30.269	*million $*
At $67.6/ton in 2010$ (3% discount rate)	0.036	0.000	0.000	5.268	4.230	6.705	9.640	1.484	29.051	0.381	56.795	*million $*
Monetary values of NO_x savings (3% discount rate)												
At $451/ton in 2010$	0.000	0.000	0.000	0.012	0.010	0.015	0.022	0.003	0.067	0.001	0.131	*million $*
At $2543/ton in 2010$	0.000	0.000	0.000	0.068	0.055	0.087	0.125	0.019	0.377	0.005	0.738	*million $*
At $4635/ton in 2010$	0.001	0.000	0.000	0.125	0.100	0.159	0.228	0.035	0.688	0.009	1.345	*million $*
Monetary values of NO_x savings (7% discount rate)												
At $451/ton in 2010$	0.000	0.000	0.000	0.010	0.008	0.013	0.018	0.003	0.055	0.001	0.107	*million $*
At $2543/ton in 2010$	0.000	0.000	0.000	0.056	0.045	0.071	0.102	0.016	0.308	0.004	0.602	*million $*
At $4635/ton in 2010$	0.001	0.000	0.000	0.102	0.082	0.129	0.186	0.029	0.561	0.007	1.097	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO_2, $2543/ton NO_x)												
(NO_x at 3% discount rate)	0.001	0.000	0.000	0.045	0.034	0.059	0.052	0.007	0.267	0.015	0.481	*billion $*
(NO_x at 7% discount rate)	0.001	0.000	0.000	0.045	0.034	0.059	0.052	0.007	0.267	0.015	0.481	*billion $*

Table 11B.1.10 Annualized Benefits and Costs of Considered Standard Levels for Ballasts for 2014–2043 Analysis Period (TSL 2, Emerging Technologies, Roll Up Scenario, 3-Percent Discount Rate)

Fluorescent Light Ballasts	PC 1			PC 2				PC 3	PC 5	PC 6		
(Emerging technologies, 3% discount rate)	1,3	4	8,9	2	5	10	11	6,7	14	12,13	Total	Units
Energy Savings Undiscounted (Cumulative to 2043)	0.417	0.000	0.001	0.126	0.131	0.254	0.386	0.035	0.695	0.009	2.054	*quad*
Energy Savings Discounted at 3% (Cumulative to 2043)	0.252	0.000	0.001	0.090	0.078	0.153	0.211	0.032	0.424	0.006	1.245	*quad*
Discounted Incr. Equipment Cost	0.604	0.000	0.000	0.041	0.124	0.318	0.740	0.000	-0.093	-0.085	1.649	*billion $*
Discounted Oper. Cost Savings	2.751	0.000	0.012	0.823	0.847	1.626	1.683	0.125	4.525	0.181	12.573	*billion $*
NPV	2.147	0.000	0.012	0.781	0.722	1.308	0.944	0.126	4.619	0.266	10.924	*billion $*
Social Cost of Emissions (2014-2043)												
CO_2 savings	4.036	0.000	0.008	1.221	1.268	2.459	3.740	0.344	6.730	0.088	19.893	*Mton*
Monetary values of CO_2 savings												
At $4.9/ton in 2010$ (5% discount rate)	18.215	0.000	0.037	5.508	5.720	11.097	16.877	1.551	30.373	0.399	89.777	*million $*
At $22.3/ton in 2010$ (3% discount rate)	84.363	0.000	0.170	25.512	26.494	51.396	78.166	7.184	140.675	1.846	415.806	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	139.594	0.000	0.281	42.214	43.840	85.045	129.340	11.887	232.774	3.055	688.027	*million $*
At $67.6/ton in 2010$ (3% discount rate)	258.126	0.000	0.519	78.058	81.066	157.258	239.165	21.980	430.427	5.649	1272.247	*million $*
NO_x savings	3.222	0.000	0.006	0.974	1.012	1.963	2.986	0.274	5.373	0.071	15.882	*kton*
Monetary values of NO_x savings (3% discount rate)												
At $451/ton in 2010$	0.759	0.000	0.002	0.229	0.238	0.462	0.703	0.065	1.265	0.017	3.739	*million $*
At $2543/ton in 2010$	4.275	0.000	0.009	1.293	1.343	2.604	3.961	0.364	7.129	0.094	21.071	*million $*
At $4635/ton in 2010$	7.791	0.000	0.016	2.356	2.447	4.747	7.219	0.663	12.992	0.171	38.402	*million $*
Monetary values of NO_x savings (7% discount rate)												
At $451/ton in 2010$	0.350	0.000	0.001	0.106	0.110	0.213	0.324	0.030	0.583	0.008	1.723	*million $*
At $2543/ton in 2010$	1.970	0.000	0.004	0.596	0.619	1.200	1.825	0.168	3.284	0.043	9.708	*million $*
At $4635/ton in 2010$	3.590	0.000	0.007	1.086	1.127	2.187	3.326	0.306	5.986	0.079	17.693	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO_2, $2543/ton NO_x)												
(NO_x at 3% discount rate)	2.235	0.000	0.012	0.808	0.750	1.362	1.026	0.133	4.767	0.268	11.361	*billion $*
(NO_x at 7% discount rate)	2.233	0.000	0.012	0.807	0.749	1.361	1.024	0.133	4.763	0.268	11.349	*billion $*
Annualized Values												
Incr. Equipment Cost	0.034	0.000	0.000	0.002	0.007	0.018	0.041	0.000	-0.005	-0.005	0.092	*billion $*
Oper. Cost Savings	0.153	0.000	0.001	0.046	0.047	0.091	0.094	0.007	0.252	0.010	0.701	*billion $*
NPV	0.120	0.000	0.001	0.044	0.040	0.073	0.053	0.007	0.257	0.015	0.609	*billion $*
Social Cost of Emissions												
Monetary values of CO_2 savings												
At $4.9/ton in 2010$ (5% discount rate)	1.372	0.000	0.003	0.415	0.431	0.836	1.271	0.117	2.287	0.030	6.761	*million $*
At $22.3/ton in 2010$ (3% discount rate)	5.997	0.000	0.012	1.813	1.883	3.653	5.556	0.511	10.000	0.131	29.557	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	9.779	0.000	0.020	2.957	3.071	5.958	9.061	0.833	16.307	0.214	48.199	*million $*
At $67.6/ton in 2010$ (3% discount rate)	18.348	0.000	0.037	5.549	5.762	11.178	17.001	1.562	30.596	0.402	90.436	*million $*
Monetary values of NO_x savings (3% discount rate)												
At $451/ton in 2010$	0.042	0.000	0.000	0.013	0.013	0.026	0.039	0.004	0.071	0.001	0.208	*million $*
At $2543/ton in 2010$	0.238	0.000	0.000	0.072	0.075	0.145	0.221	0.020	0.397	0.005	1.175	*million $*
At $4635/ton in 2010$	0.434	0.000	0.001	0.131	0.136	0.265	0.402	0.037	0.724	0.010	2.141	*million $*
Monetary values of NO_x savings (7% discount rate)												
At $451/ton in 2010$	0.035	0.000	0.000	0.010	0.011	0.021	0.032	0.003	0.058	0.001	0.170	*million $*
At $2543/ton in 2010$	0.194	0.000	0.000	0.059	0.061	0.118	0.180	0.017	0.324	0.004	0.958	*million $*
At $4635/ton in 2010$	0.354	0.000	0.001	0.107	0.111	0.216	0.328	0.030	0.591	0.008	1.747	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO_2, $2543/ton NO_x)												
(NO_x at 3% discount rate)	0.126	0.000	0.001	0.045	0.042	0.077	0.058	0.008	0.268	0.015	0.640	*billion $*
(NO_x at 7% discount rate)	0.126	0.000	0.001	0.045	0.042	0.077	0.058	0.008	0.268	0.015	0.640	*billion $*

Table 11B.1.11 Annualized Benefits and Costs of Considered Standard Levels for Ballasts for 2014–2043 Analysis Period (TSL 3A, Emerging Technologies, Roll Up Scenario, 3-Percent Discount Rate)

Fluorescent Light Ballasts	PC 1			PC 2				PC 3	PC 5	PC 6		
(Emerging technologies, 3% discount rate)	1,3	4	8,9	2	5	10	11	6,7	14	12,13	Total	Units
Energy Savings Undiscounted (Cumulative to 2043)	0.554	0.124	0.017	0.143	0.131	0.512	0.522	0.036	0.695	0.009	2.742	*quad*
Energy Savings Discounted at 3% (Cumulative to 2043)	0.335	0.076	0.010	0.100	0.078	0.302	0.284	0.032	0.424	0.006	1.647	*quad*
Discounted Incr. Equipment Cost	0.796	0.287	0.005	0.062	0.124	1.405	1.407	0.000	-0.093	-0.085	3.908	*billion $*
Discounted Oper. Cost Savings	3.657	0.812	0.110	0.934	0.847	3.279	2.278	0.126	4.525	0.181	16.748	*billion $*
NPV	2.861	0.525	0.105	0.872	0.722	1.874	0.872	0.125	4.619	0.266	12.840	*billion $*
Social Cost of Emissions (2014-2043)												
CO2 savings	5.513	1.237	0.166	1.425	1.303	5.102	5.198	0.356	6.920	0.091	27.309	*Mton*
Monetary values of CO2 savings												
At $4.9/ton in 2010$ (5% discount rate)	24.880	5.581	0.747	6.430	5.881	23.024	23.457	1.605	31.228	0.410	123.242	*million $*
At $22.3/ton in 2010$ (3% discount rate)	115.231	25.849	3.460	29.782	27.240	106.637	108.640	7.432	144.633	1.898	570.802	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	190.671	42.772	5.725	49.280	45.073	176.451	179.765	12.297	239.323	3.141	944.498	*million $*
At $67.6/ton in 2010$ (3% discount rate)	352.573	79.091	10.586	91.124	83.346	326.279	332.408	22.739	442.537	5.808	1746.493	*million $*
NOx savings	4.401	0.987	0.132	1.138	1.040	4.073	4.150	0.284	5.524	0.073	21.802	*kton*
Monetary values of NOx savings (3% discount rate)												
At $451/ton in 2010$	1.036	0.232	0.031	0.268	0.245	0.959	0.977	0.067	1.301	0.017	5.133	*million $*
At $2543/ton in 2010$	5.839	1.310	0.175	1.509	1.380	5.404	5.505	0.377	7.329	0.096	28.925	*million $*
At $4635/ton in 2010$	10.642	2.387	0.320	2.751	2.516	9.849	10.034	0.686	13.358	0.175	52.717	*million $*
Monetary values of NOx savings (7% discount rate)												
At $451/ton in 2010$	0.477	0.107	0.014	0.123	0.113	0.442	0.450	0.031	0.599	0.008	2.365	*million $*
At $2543/ton in 2010$	2.690	0.604	0.081	0.695	0.636	2.490	2.536	0.174	3.377	0.044	13.327	*million $*
At $4635/ton in 2010$	4.903	1.100	0.147	1.267	1.159	4.538	4.623	0.316	6.154	0.081	24.289	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO2, $2543/ton NOx)												
(NOx at 3% discount rate)	2.982	0.552	0.108	0.903	0.751	1.986	0.986	0.133	4.771	0.268	13.440	*billion $*
(NOx at 7% discount rate)	2.979	0.551	0.108	0.902	0.750	1.983	0.983	0.133	4.767	0.268	13.424	*billion $*
Annualized Values												
Incr. Equipment Cost	0.044	0.016	0.000	0.003	0.007	0.078	0.078	0.000	-0.005	-0.005	0.218	*billion $*
Oper. Cost Savings	0.204	0.045	0.006	0.052	0.047	0.183	0.127	0.007	0.252	0.010	0.934	*billion $*
NPV	0.159	0.029	0.006	0.049	0.040	0.104	0.049	0.007	0.257	0.015	0.716	*billion $*
Social Cost of Emissions												
Monetary values of CO2 savings												
At $4.9/ton in 2010$ (5% discount rate)	1.874	0.420	0.056	0.484	0.443	1.734	1.766	0.121	2.352	0.031	9.281	*million $*
At $22.3/ton in 2010$ (3% discount rate)	8.191	1.837	0.246	2.117	1.936	7.580	7.723	0.528	10.281	0.135	40.575	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	13.357	2.996	0.401	3.452	3.158	12.361	12.593	0.861	16.765	0.220	66.165	*million $*
At $67.6/ton in 2010$ (3% discount rate)	25.062	5.622	0.753	6.477	5.925	23.193	23.629	1.616	31.457	0.413	124.147	*million $*
Monetary values of NOx savings (3% discount rate)												
At $451/ton in 2010$	0.058	0.013	0.002	0.015	0.014	0.053	0.054	0.004	0.073	0.001	0.286	*million $*
At $2543/ton in 2010$	0.326	0.073	0.010	0.084	0.077	0.301	0.307	0.021	0.409	0.005	1.613	*million $*
At $4635/ton in 2010$	0.593	0.133	0.018	0.153	0.140	0.549	0.559	0.038	0.745	0.010	2.939	*million $*
Monetary values of NOx savings (7% discount rate)												
At $451/ton in 2010$	0.047	0.011	0.001	0.012	0.011	0.044	0.044	0.003	0.059	0.001	0.233	*million $*
At $2543/ton in 2010$	0.266	0.060	0.008	0.069	0.063	0.246	0.250	0.017	0.333	0.004	1.316	*million $*
At $4635/ton in 2010$	0.484	0.109	0.015	0.125	0.114	0.448	0.456	0.031	0.608	0.008	2.398	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO2, $2543/ton NOx)												
(NOx at 3% discount rate)	0.168	0.031	0.006	0.051	0.042	0.112	0.057	0.008	0.268	0.015	0.758	*billion $*
(NOx at 7% discount rate)	0.168	0.031	0.006	0.051	0.042	0.112	0.057	0.008	0.268	0.015	0.758	*billion $*

Table 11B.1.12 Annualized Benefits and Costs of Considered Standard Levels for Ballasts for 2014–2043 Analysis Period (TSL 3B, Emerging Technologies, Roll Up Scenario, 3-Percent Discount Rate)

Fluorescent Light Ballasts	PC 1			PC 2				PC 3	PC 5	PC 6		
(Emerging technologies, 3% discount rate)	1,3	4	8,9	2	5	10	11	6,7	14	12,13	Total	Units
Energy Savings Undiscounted (Cumulative to 2043)	0.554	0.124	0.017	0.143	0.131	0.512	0.522	0.036	0.695	0.124	2.857	*quad*
Energy Savings Discounted at 3% (Cumulative to 2043)	0.335	0.076	0.010	0.100	0.078	0.302	0.284	0.032	0.424	0.069	1.710	*quad*
Discounted Incr. Equipment Cost	0.796	0.287	0.005	0.062	0.124	1.405	1.407	0.001	-0.093	0.504	4.497	*billion $*
Discounted Oper. Cost Savings	3.657	0.812	0.110	0.934	0.847	3.279	2.278	0.126	4.525	1.004	17.572	*billion $*
NPV	2.861	0.525	0.105	0.872	0.722	1.874	0.872	0.125	4.619	0.500	13.075	*billion $*
Social Cost of Emissions (2014-2043)												
CO2 savings	5.562	1.248	0.167	1.438	1.315	5.147	5.244	0.359	6.981	1.242	28.702	*Mton*
Monetary values of CO2 savings												
At $4.9/ton in 2010$ (5% discount rate)	25.101	5.631	0.754	6.487	5.934	23.229	23.665	1.620	31.505	5.604	129.530	*million $*
At $22.3/ton in 2010$ (3% discount rate)	116.255	26.079	3.491	30.047	27.482	107.585	109.606	7.504	145.919	25.957	599.925	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	192.366	43.152	5.776	49.718	45.474	178.020	181.364	12.416	241.450	42.950	992.687	*million $*
At $67.6/ton in 2010$ (3% discount rate)	355.708	79.794	10.681	91.934	84.087	329.180	335.364	22.959	446.471	79.420	1835.599	*million $*
NOx savings	4.440	0.996	0.133	1.148	1.050	4.109	4.186	0.287	5.573	0.991	22.914	*kton*
Monetary values of NOx savings (3% discount rate)												
At $451/ton in 2010$	1.045	0.235	0.031	0.270	0.247	0.967	0.986	0.067	1.312	0.233	5.395	*million $*
At $2543/ton in 2010$	5.891	1.322	0.177	1.523	1.393	5.452	5.554	0.380	7.394	1.315	30.401	*million $*
At $4635/ton in 2010$	10.737	2.409	0.322	2.775	2.538	9.936	10.123	0.693	13.476	2.397	55.407	*million $*
Monetary values of NOx savings (7% discount rate)												
At $451/ton in 2010$	0.482	0.108	0.014	0.124	0.114	0.446	0.454	0.031	0.605	0.108	2.485	*million $*
At $2543/ton in 2010$	2.714	0.609	0.081	0.702	0.642	2.512	2.559	0.175	3.407	0.606	14.007	*million $*
At $4635/ton in 2010$	4.947	1.110	0.149	1.279	1.169	4.578	4.664	0.319	6.209	1.105	25.528	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO2, $2543/ton NOx)												
(NOx at 3% discount rate)	2.983	0.552	0.108	0.903	0.751	1.987	0.987	0.133	4.772	0.528	13.705	*billion $*
(NOx at 7% discount rate)	2.980	0.552	0.108	0.903	0.750	1.984	0.984	0.133	4.768	0.527	13.688	*billion $*
Annualized Values												
Incr. Equipment Cost	0.044	0.016	0.000	0.003	0.007	0.078	0.078	0.000	-0.005	0.028	0.251	*billion $*
Oper. Cost Savings	0.204	0.045	0.006	0.052	0.047	0.183	0.127	0.007	0.252	0.056	0.980	*billion $*
NPV	0.159	0.029	0.006	0.049	0.040	0.104	0.049	0.007	0.257	0.028	0.729	*billion $*
Social Cost of Emissions												
Monetary values of CO2 savings												
At $4.9/ton in 2010$ (5% discount rate)	1.890	0.424	0.057	0.489	0.447	1.749	1.782	0.122	2.373	0.422	9.754	*million $*
At $22.3/ton in 2010$ (3% discount rate)	8.264	1.854	0.248	2.136	1.954	7.648	7.791	0.533	10.372	1.845	42.645	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	13.476	3.023	0.405	3.483	3.186	12.471	12.705	0.870	16.914	3.009	69.541	*million $*
At $67.6/ton in 2010$ (3% discount rate)	25.285	5.672	0.759	6.535	5.977	23.399	23.839	1.632	31.737	5.645	130.481	*million $*
Monetary values of NOx savings (3% discount rate)												
At $451/ton in 2010$	0.058	0.013	0.002	0.015	0.014	0.054	0.055	0.004	0.073	0.013	0.301	*million $*
At $2543/ton in 2010$	0.328	0.074	0.010	0.085	0.078	0.304	0.310	0.021	0.412	0.073	1.695	*million $*
At $4635/ton in 2010$	0.599	0.134	0.018	0.155	0.142	0.554	0.564	0.039	0.751	0.134	3.089	*million $*
Monetary values of NOx savings (7% discount rate)												
At $451/ton in 2010$	0.048	0.011	0.001	0.012	0.011	0.044	0.045	0.003	0.060	0.011	0.245	*million $*
At $2543/ton in 2010$	0.268	0.060	0.008	0.069	0.063	0.248	0.253	0.017	0.336	0.060	1.383	*million $*
At $4635/ton in 2010$	0.488	0.110	0.015	0.126	0.115	0.452	0.460	0.032	0.613	0.109	2.520	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO2, $2543/ton NOx)												
(NOx at 3% discount rate)	0.168	0.031	0.006	0.051	0.042	0.112	0.057	0.008	0.268	0.030	0.773	*billion $*
(NOx at 7% discount rate)	0.168	0.031	0.006	0.051	0.042	0.112	0.057	0.008	0.268	0.030	0.773	*billion $*

Table 11B.1.13 Annualized Benefits and Costs of Considered Standard Levels for Ballasts for 2014–2043 Analysis Period (TSL 1, Emerging Technologies, Roll Up Scenario, 7-Percent Discount Rate)

Fluorescent Light Ballasts	PC 1			PC 2				PC 3	PC 5	PC 6		
(Emerging technologies, 7% discount rate)	1,3	4	8,9	2	5	10	11	6,7	14	12,13	Total	Units
Energy Savings Undiscounted (Cumulative to 2043)	0.001	0.000	0.000	0.126	0.101	0.160	0.231	0.035	0.695	0.009	1.358	*quad*
Energy Savings Discounted at 7% (Cumulative to 2043)	0.000	0.000	0.000	0.063	0.033	0.058	0.066	0.027	0.240	0.003	0.492	*quad*
Discounted Incr. Equipment Cost	-0.002	0.000	0.000	0.027	0.049	0.002	0.061	0.000	-0.062	-0.060	0.015	*billion $*
Discounted Oper. Cost Savings	0.005	0.000	0.000	0.542	0.345	0.568	0.485	0.103	2.455	0.101	4.603	*billion $*
NPV	0.007	0.000	0.000	0.514	0.297	0.565	0.424	0.103	2.517	0.161	4.588	*billion $*
Social Cost of Emissions (2014-2043)												
CO2 savings	0.008	0.000	0.000	1.159	0.930	1.475	2.121	0.326	6.390	0.084	12.493	*Mton*
Monetary values of CO2 savings												
At $4.9/ton in 2010$ (5% discount rate)	0.036	0.000	0.000	5.230	4.199	6.656	9.570	1.473	28.839	0.379	56.381	*million $*
At $22.3/ton in 2010$ (3% discount rate)	0.164	0.000	0.000	24.223	19.448	30.827	44.324	6.823	133.571	1.753	261.132	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	0.272	0.000	0.000	40.082	32.180	51.009	73.342	11.289	221.018	2.901	432.092	*million $*
At $67.6/ton in 2010$ (3% discount rate)	0.503	0.000	0.000	74.116	59.504	94.321	135.618	20.875	408.690	5.364	798.991	*million $*
NOx savings	0.006	0.000	0.000	0.925	0.743	1.177	1.693	0.261	5.102	0.067	9.974	*kton*
Monetary values of NOx savings (3% discount rate)												
At $451/ton in 2010$	0.001	0.000	0.000	0.218	0.175	0.277	0.399	0.061	1.201	0.016	2.348	*million $*
At $2543/ton in 2010$	0.008	0.000	0.000	1.227	0.985	1.562	2.246	0.346	6.769	0.089	13.233	*million $*
At $4635/ton in 2010$	0.015	0.000	0.000	2.237	1.796	2.847	4.094	0.630	12.336	0.162	24.117	*million $*
Monetary values of NOx savings (7% discount rate)												
At $451/ton in 2010$	0.001	0.000	0.000	0.100	0.081	0.128	0.184	0.028	0.553	0.007	1.082	*million $*
At $2543/ton in 2010$	0.004	0.000	0.000	0.566	0.454	0.720	1.035	0.159	3.119	0.041	6.097	*million $*
At $4635/ton in 2010$	0.007	0.000	0.000	1.031	0.828	1.312	1.886	0.290	5.684	0.075	11.112	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO2, $2543/ton NOx)												
(NOx at 3% discount rate)	0.007	0.000	0.000	0.540	0.317	0.598	0.470	0.110	2.657	0.163	4.863	*billion $*
(NOx at 7% discount rate)	0.007	0.000	0.000	0.539	0.316	0.597	0.469	0.110	2.653	0.163	4.856	*billion $*
Annualized Values												
Incr. Equipment Cost	0.000	0.000	0.000	0.003	0.005	0.000	0.006	0.000	-0.006	-0.006	0.001	*billion $*
Oper. Cost Savings	0.000	0.000	0.000	0.053	0.034	0.056	0.048	0.010	0.242	0.010	0.454	*billion $*
NPV	0.001	0.000	0.000	0.051	0.029	0.056	0.042	0.010	0.248	0.016	0.453	*billion $*
Social Cost of Emissions												
Monetary values of CO2 savings												
At $4.9/ton in 2010$ (5% discount rate)	0.003	0.000	0.000	0.394	0.316	0.501	0.721	0.111	2.172	0.029	4.246	*million $*
At $22.3/ton in 2010$ (3% discount rate)	0.012	0.000	0.000	1.722	1.382	2.191	3.151	0.485	9.495	0.125	18.562	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	0.019	0.000	0.000	2.808	2.254	3.573	5.138	0.791	15.483	0.203	30.269	*million $*
At $67.6/ton in 2010$ (3% discount rate)	0.036	0.000	0.000	5.268	4.230	6.705	9.640	1.484	29.051	0.381	56.795	*million $*
Monetary values of NOx savings (3% discount rate)												
At $451/ton in 2010$	0.000	0.000	0.000	0.012	0.010	0.015	0.022	0.003	0.067	0.001	0.131	*million $*
At $2543/ton in 2010$	0.000	0.000	0.000	0.068	0.055	0.087	0.125	0.019	0.377	0.005	0.738	*million $*
At $4635/ton in 2010$	0.001	0.000	0.000	0.125	0.100	0.159	0.228	0.035	0.688	0.009	1.345	*million $*
Monetary values of NOx savings (7% discount rate)												
At $451/ton in 2010$	0.000	0.000	0.000	0.010	0.008	0.013	0.018	0.003	0.055	0.001	0.107	*million $*
At $2543/ton in 2010$	0.000	0.000	0.000	0.056	0.045	0.071	0.102	0.016	0.308	0.004	0.602	*million $*
At $4635/ton in 2010$	0.001	0.000	0.000	0.102	0.082	0.129	0.186	0.029	0.561	0.007	1.097	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO2, $2543/ton NOx)												
(NOx at 3% discount rate)	0.001	0.000	0.000	0.053	0.031	0.058	0.045	0.011	0.258	0.016	0.472	*billion $*
(NOx at 7% discount rate)	0.001	0.000	0.000	0.053	0.031	0.058	0.045	0.011	0.258	0.016	0.472	*billion $*

Table 11B.1.14 Annualized Benefits and Costs of Considered Standard Levels for Ballasts for 2014–2043 Analysis Period (TSL 2, Emerging Technologies, Roll Up Scenario, 7-Percent Discount Rate)

Fluorescent Light Ballasts	PC 1			PC 2				PC 3	PC 5	PC 6		
(Emerging technologies, 7% discount rate)	1,3	4	8,9	2	5	10	11	6,7	14	12,13	**Total**	**Units**
Energy Savings Undiscounted (Cumulative to 2043)	0.417	0.000	0.001	0.126	0.131	0.254	0.386	0.035	0.695	0.009	2.054	*quad*
Energy Savings Discounted at 7% (Cumulative to 2043)	0.141	0.000	0.000	0.063	0.043	0.087	0.107	0.027	0.240	0.003	0.712	*quad*
Discounted Incr. Equipment Cost	0.398	0.000	0.000	0.027	0.080	0.196	0.375	0.000	-0.062	-0.060	0.954	*billion $*
Discounted Oper. Cost Savings	1.477	0.000	0.007	0.542	0.447	0.872	0.801	0.107	2.455	0.101	6.808	*billion $*
NPV	1.079	0.000	0.007	0.514	0.367	0.676	0.426	0.107	2.517	0.161	5.855	*billion $*
Social Cost of Emissions (2014-2043)												
CO2 savings	4.036	0.000	0.008	1.221	1.268	2.459	3.740	0.344	6.730	0.088	19.893	*Mton*
Monetary values of CO2 savings												
At $4.9/ton in 2010$ (5% discount rate)	18.215	0.000	0.037	5.508	5.720	11.097	16.877	1.551	30.373	0.399	89.777	*million $*
At $22.3/ton in 2010$ (3% discount rate)	84.363	0.000	0.170	25.512	26.494	51.396	78.166	7.184	140.675	1.846	415.806	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	139.594	0.000	0.281	42.214	43.840	85.045	129.340	11.887	232.774	3.055	688.027	*million $*
At $67.6/ton in 2010$ (3% discount rate)	258.126	0.000	0.519	78.058	81.066	157.258	239.165	21.980	430.427	5.649	1272.247	*million $*
NOx savings	3.222	0.000	0.006	0.974	1.012	1.963	2.986	0.274	5.373	0.071	15.882	*kton*
Monetary values of NOx savings (3% discount rate)												
At $451/ton in 2010$	0.759	0.000	0.002	0.229	0.238	0.462	0.703	0.065	1.265	0.017	3.739	*million $*
At $2543/ton in 2010$	4.275	0.000	0.009	1.293	1.343	2.604	3.961	0.364	7.129	0.094	21.071	*million $*
At $4635/ton in 2010$	7.791	0.000	0.016	2.356	2.447	4.747	7.219	0.663	12.992	0.171	38.402	*million $*
Monetary values of NOx savings (7% discount rate)												
At $451/ton in 2010$	0.350	0.000	0.001	0.106	0.110	0.213	0.324	0.030	0.583	0.008	1.723	*million $*
At $2543/ton in 2010$	1.970	0.000	0.004	0.596	0.619	1.200	1.825	0.168	3.284	0.043	9.708	*million $*
At $4635/ton in 2010$	3.590	0.000	0.007	1.086	1.127	2.187	3.326	0.306	5.986	0.079	17.693	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO2, $2543/ton NOx)												
(NOx at 3% discount rate)	1.168	0.000	0.007	0.541	0.394	0.730	0.508	0.115	2.664	0.163	6.292	*billion $*
(NOx at 7% discount rate)	1.165	0.000	0.007	0.541	0.394	0.729	0.506	0.115	2.661	0.163	6.280	*billion $*
Annualized Values												
Incr. Equipment Cost	0.039	0.000	0.000	0.003	0.008	0.019	0.037	0.000	-0.006	-0.006	0.094	*billion $*
Oper. Cost Savings	0.146	0.000	0.001	0.053	0.044	0.086	0.079	0.011	0.242	0.010	0.672	*billion $*
NPV	0.107	0.000	0.001	0.051	0.036	0.067	0.042	0.011	0.248	0.016	0.578	*billion $*
Social Cost of Emissions												
Monetary values of CO2 savings												
At $4.9/ton in 2010$ (5% discount rate)	1.372	0.000	0.003	0.415	0.431	0.836	1.271	0.117	2.287	0.030	6.761	*million $*
At $22.3/ton in 2010$ (3% discount rate)	5.997	0.000	0.012	1.813	1.883	3.653	5.556	0.511	10.000	0.131	29.557	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	9.779	0.000	0.020	2.957	3.071	5.958	9.061	0.833	16.307	0.214	48.199	*million $*
At $67.6/ton in 2010$ (3% discount rate)	18.348	0.000	0.037	5.549	5.762	11.178	17.001	1.562	30.596	0.402	90.436	*million $*
Monetary values of NOx savings (3% discount rate)												
At $451/ton in 2010$	0.042	0.000	0.000	0.013	0.013	0.026	0.039	0.004	0.071	0.001	0.208	*million $*
At $2543/ton in 2010$	0.238	0.000	0.000	0.072	0.075	0.145	0.221	0.020	0.397	0.005	1.175	*million $*
At $4635/ton in 2010$	0.434	0.000	0.001	0.131	0.136	0.265	0.402	0.037	0.724	0.010	2.141	*million $*
Monetary values of NOx savings (7% discount rate)												
At $451/ton in 2010$	0.035	0.000	0.000	0.010	0.011	0.021	0.032	0.003	0.058	0.001	0.170	*million $*
At $2543/ton in 2010$	0.194	0.000	0.000	0.059	0.061	0.118	0.180	0.017	0.324	0.004	0.958	*million $*
At $4635/ton in 2010$	0.354	0.000	0.001	0.107	0.111	0.216	0.328	0.030	0.591	0.008	1.747	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO2, $2543/ton NOx)												
(NOx at 3% discount rate)	0.113	0.000	0.001	0.053	0.038	0.071	0.048	0.011	0.259	0.016	0.609	*billion $*
(NOx at 7% discount rate)	0.113	0.000	0.001	0.053	0.038	0.071	0.048	0.011	0.259	0.016	0.609	*billion $*

Table 11B.1.15 Annualized Benefits and Costs of Considered Standard Levels for Ballasts for 2014–2043 Analysis Period (TSL 3A, Emerging Technologies, Roll Up Scenario, 7-Percent Discount Rate)

Fluorescent Light Ballasts	PC 1			PC 2				PC 3	PC 5	PC 6		
(Emerging technologies, 7% discount rate)	1,3	4	8,9	2	5	10	11	6,7	14	12,13	Total	Units
Energy Savings Undiscounted (Cumulative to 2043)	0.554	0.124	0.017	0.143	0.131	0.512	0.522	0.036	0.695	0.009	2.742	*quad*
Energy Savings Discounted at 7% (Cumulative to 2043)	0.189	0.043	0.005	0.069	0.043	0.166	0.142	0.028	0.240	0.003	0.929	*quad*
Discounted Incr. Equipment Cost	0.525	0.193	0.003	0.041	0.080	0.866	0.716	0.000	-0.062	-0.060	2.303	*billion $*
Discounted Oper. Cost Savings	1.967	0.443	0.057	0.602	0.447	1.716	1.078	0.107	2.455	0.101	8.973	*billion $*
NPV	1.442	0.250	0.054	0.561	0.367	0.849	0.362	0.107	2.517	0.161	6.670	*billion $*
Social Cost of Emissions (2014-2043)												
CO2 savings	5.513	1.237	0.166	1.425	1.303	5.102	5.198	0.356	6.920	0.091	27.309	*Mton*
Monetary values of CO2 savings												
At $4.9/ton in 2010$ (5% discount rate)	24.880	5.581	0.747	6.430	5.881	23.024	23.457	1.605	31.228	0.410	123.242	*million $*
At $22.3/ton in 2010$ (3% discount rate)	115.231	25.849	3.460	29.782	27.240	106.637	108.640	7.432	144.633	1.898	570.802	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	190.671	42.772	5.725	49.280	45.073	176.451	179.765	12.297	239.323	3.141	944.498	*million $*
At $67.6/ton in 2010$ (3% discount rate)	352.573	79.091	10.586	91.124	83.346	326.279	332.408	22.739	442.537	5.808	1746.493	*million $*
NOx savings	4.401	0.987	0.132	1.138	1.040	4.073	4.150	0.284	5.524	0.073	21.802	*kton*
Monetary values of NOx savings (3% discount rate)												
At $451/ton in 2010$	1.036	0.232	0.031	0.268	0.245	0.959	0.977	0.067	1.301	0.017	5.133	*million $*
At $2543/ton in 2010$	5.839	1.310	0.175	1.509	1.380	5.404	5.505	0.377	7.329	0.096	28.925	*million $*
At $4635/ton in 2010$	10.642	2.387	0.320	2.751	2.516	9.849	10.034	0.686	13.358	0.175	52.717	*million $*
Monetary values of NOx savings (7% discount rate)												
At $451/ton in 2010$	0.477	0.107	0.014	0.123	0.113	0.442	0.450	0.031	0.599	0.008	2.365	*million $*
At $2543/ton in 2010$	2.690	0.604	0.081	0.695	0.636	2.490	2.536	0.174	3.377	0.044	13.327	*million $*
At $4635/ton in 2010$	4.903	1.100	0.147	1.267	1.159	4.538	4.623	0.316	6.154	0.081	24.289	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO2, $2543/ton NOx)												
(NOx at 3% discount rate)	1.563	0.277	0.057	0.592	0.395	0.961	0.476	0.115	2.669	0.163	7.270	*billion $*
(NOx at 7% discount rate)	1.560	0.277	0.057	0.591	0.394	0.958	0.473	0.115	2.665	0.163	7.254	*billion $*
Annualized Values												
Incr. Equipment Cost	0.052	0.019	0.000	0.004	0.008	0.086	0.071	0.000	-0.006	-0.006	0.227	*billion $*
Oper. Cost Savings	0.194	0.044	0.006	0.059	0.044	0.169	0.106	0.011	0.242	0.010	0.886	*billion $*
NPV	0.142	0.025	0.005	0.055	0.036	0.084	0.036	0.011	0.248	0.016	0.658	*billion $*
Social Cost of Emissions												
Monetary values of CO2 savings												
At $4.9/ton in 2010$ (5% discount rate)	1.874	0.420	0.056	0.484	0.443	1.734	1.766	0.121	2.352	0.031	9.281	*million $*
At $22.3/ton in 2010$ (3% discount rate)	8.191	1.837	0.246	2.117	1.936	7.580	7.723	0.528	10.281	0.135	40.575	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	13.357	2.996	0.401	3.452	3.158	12.361	12.593	0.861	16.765	0.220	66.165	*million $*
At $67.6/ton in 2010$ (3% discount rate)	25.062	5.622	0.753	6.477	5.925	23.193	23.629	1.616	31.457	0.413	124.147	*million $*
Monetary values of NOx savings (3% discount rate)												
At $451/ton in 2010$	0.058	0.013	0.002	0.015	0.014	0.053	0.054	0.004	0.073	0.001	0.286	*million $*
At $2543/ton in 2010$	0.326	0.073	0.010	0.084	0.077	0.301	0.307	0.021	0.409	0.005	1.613	*million $*
At $4635/ton in 2010$	0.593	0.133	0.018	0.153	0.140	0.549	0.559	0.038	0.745	0.010	2.939	*million $*
Monetary values of NOx savings (7% discount rate)												
At $451/ton in 2010$	0.047	0.011	0.001	0.012	0.011	0.044	0.044	0.003	0.059	0.001	0.233	*million $*
At $2543/ton in 2010$	0.266	0.060	0.008	0.069	0.063	0.246	0.250	0.017	0.333	0.004	1.316	*million $*
At $4635/ton in 2010$	0.484	0.109	0.015	0.125	0.114	0.448	0.456	0.031	0.608	0.008	2.398	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO2, $2543/ton NOx)												
(NOx at 3% discount rate)	0.151	0.027	0.006	0.058	0.038	0.092	0.044	0.011	0.259	0.016	0.701	*billion $*
(NOx at 7% discount rate)	0.151	0.027	0.006	0.058	0.038	0.092	0.044	0.011	0.259	0.016	0.700	*billion $*

Table 11B.1.16 Annualized Benefits and Costs of Considered Standard Levels for Ballasts for 2014–2043 Analysis Period (TSL 3B, Emerging Technologies, Roll Up Scenario, 7-Percent Discount Rate)

Fluorescent Light Ballasts	PC 1			PC 2				PC 3	PC 5	PC 6		
(Emerging technologies, 7% discount rate)	1,3	4	8,9	2	5	10	11	6,7	14	12,13	Total	Units
Energy Savings Undiscounted (Cumulative to 2043)	0.554	0.124	0.017	0.143	0.131	0.512	0.522	0.036	0.695	0.124	2.857	*quad*
Energy Savings Discounted at 7% (Cumulative to 2043)	0.189	0.043	0.005	0.069	0.043	0.166	0.142	0.028	0.240	0.035	0.961	*quad*
Discounted Incr. Equipment Cost	0.525	0.193	0.003	0.041	0.080	0.866	0.716	0.000	-0.062	0.275	2.639	*billion $*
Discounted Oper. Cost Savings	1.967	0.443	0.057	0.602	0.447	1.716	1.078	0.108	2.455	0.501	9.373	*billion $*
NPV	1.442	0.250	0.054	0.561	0.367	0.849	0.362	0.107	2.517	0.226	6.734	*billion $*
Social Cost of Emissions (2014-2043)												
CO2 savings	5.562	1.248	0.167	1.438	1.315	5.147	5.244	0.359	6.981	1.242	28.702	*Mton*
Monetary values of CO2 savings												
At $4.9/ton in 2010$ (5% discount rate)	25.101	5.631	0.754	6.487	5.934	23.229	23.665	1.620	31.505	5.604	129.530	*million $*
At $22.3/ton in 2010$ (3% discount rate)	116.255	26.079	3.491	30.047	27.482	107.585	109.606	7.504	145.919	25.957	599.925	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	192.366	43.152	5.776	49.718	45.474	178.020	181.364	12.416	241.450	42.950	992.687	*million $*
At $67.6/ton in 2010$ (3% discount rate)	355.708	79.794	10.681	91.934	84.087	329.180	335.364	22.959	446.471	79.420	1835.599	*million $*
NOx savings	4.440	0.996	0.133	1.148	1.050	4.109	4.186	0.287	5.573	0.991	22.914	*kton*
Monetary values of NOx savings (3% discount rate)												
At $451/ton in 2010$	1.045	0.235	0.031	0.270	0.247	0.967	0.986	0.067	1.312	0.233	5.395	*million $*
At $2543/ton in 2010$	5.891	1.322	0.177	1.523	1.393	5.452	5.554	0.380	7.394	1.315	30.401	*million $*
At $4635/ton in 2010$	10.737	2.409	0.322	2.775	2.538	9.936	10.123	0.693	13.476	2.397	55.407	*million $*
Monetary values of NOx savings (7% discount rate)												
At $451/ton in 2010$	0.482	0.108	0.014	0.124	0.114	0.446	0.454	0.031	0.605	0.108	2.485	*million $*
At $2543/ton in 2010$	2.714	0.609	0.081	0.702	0.642	2.512	2.559	0.175	3.407	0.606	14.007	*million $*
At $4635/ton in 2010$	4.947	1.110	0.149	1.279	1.169	4.578	4.664	0.319	6.209	1.105	25.528	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO2, $2543/ton NOx)												
(NOx at 3% discount rate)	1.564	0.277	0.057	0.592	0.395	0.962	0.477	0.115	2.670	0.253	7.365	*billion $*
(NOx at 7% discount rate)	1.561	0.277	0.057	0.592	0.395	0.959	0.474	0.115	2.666	0.252	7.348	*billion $*
Annualized Values												
Incr. Equipment Cost	0.052	0.019	0.000	0.004	0.008	0.086	0.071	0.000	-0.006	0.027	0.260	*billion $*
Oper. Cost Savings	0.194	0.044	0.006	0.059	0.044	0.169	0.106	0.011	0.242	0.049	0.925	*billion $*
NPV	0.142	0.025	0.005	0.055	0.036	0.084	0.036	0.011	0.248	0.022	0.665	*billion $*
Social Cost of Emissions												
Monetary values of CO2 savings												
At $4.9/ton in 2010$ (5% discount rate)	1.890	0.424	0.057	0.489	0.447	1.749	1.782	0.122	2.373	0.422	9.754	*million $*
At $22.3/ton in 2010$ (3% discount rate)	8.264	1.854	0.248	2.136	1.954	7.648	7.791	0.533	10.372	1.845	42.645	*million $*
At $36.5/ton in 2010$ (2.5% discount rate)	13.476	3.023	0.405	3.483	3.186	12.471	12.705	0.870	16.914	3.009	69.541	*million $*
At $67.6/ton in 2010$ (3% discount rate)	25.285	5.672	0.759	6.535	5.977	23.399	23.839	1.632	31.737	5.645	130.481	*million $*
Monetary values of NOx savings (3% discount rate)												
At $451/ton in 2010$	0.058	0.013	0.002	0.015	0.014	0.054	0.055	0.004	0.073	0.013	0.301	*million $*
At $2543/ton in 2010$	0.328	0.074	0.010	0.085	0.078	0.304	0.310	0.021	0.412	0.073	1.695	*million $*
At $4635/ton in 2010$	0.599	0.134	0.018	0.155	0.142	0.554	0.564	0.039	0.751	0.134	3.089	*million $*
Monetary values of NOx savings (7% discount rate)												
At $451/ton in 2010$	0.048	0.011	0.001	0.012	0.011	0.044	0.045	0.003	0.060	0.011	0.245	*million $*
At $2543/ton in 2010$	0.268	0.060	0.008	0.069	0.063	0.248	0.253	0.017	0.336	0.060	1.383	*million $*
At $4635/ton in 2010$	0.488	0.110	0.015	0.126	0.115	0.452	0.460	0.032	0.613	0.109	2.520	*million $*
NPV including Social Cost of Emissions												
(refers to: $22.3/ton CO2, $2543/ton NOx)												
(NOx at 3% discount rate)	0.151	0.027	0.006	0.058	0.038	0.092	0.044	0.011	0.259	0.024	0.709	*billion $*
(NOx at 7% discount rate)	0.151	0.027	0.006	0.058	0.038	0.092	0.044	0.011	0.259	0.024	0.709	*billion $*