Executive Summary

The Energy Policy and Conservation Act of 1975, as amended by the Energy Independence and Security Act of 2007 (EISA 2007), requires that the Secretary of Energy "shall prohibit the sale" of any general service lamp (GSL) that does not meet a minimum efficacy of 45 lumens per watt (lm/W) if the U.S. Department of Energy (DOE) fails to complete a rulemaking regarding GSLs in accordance with certain statutory criteria. This is referred to as the EISA 2007 backstop requirement. In these actions, DOE is finalizing its interpretation that the EISA 2007 backstop has been triggered and revising the definition of the term GSL to include certain lamps that were either previously excluded or not explicitly mentioned in the EISA 2007 definition, based on its statutory authority. In this report, DOE estimates the impacts of the EISA 2007 backstop in regard to annualized national economic costs and benefits to consumers for all GSLs in the revised definition.

Consistent with analysis of the GSL backstop, DOE projects the energy use, purchase price, and operating cost of representative lamps purchased during a 30-year analysis period, 2022-2051, for cases in which the revised GSL definition does and does not take effect in 2022. DOE first considered the purchase price and energy use of those commercially-available GSLs that would be prohibited under implementation of the EISA 2007 backstop and those more efficacious GSLs that would continue to be available. DOE then developed a shipments model to project GSL shipments for the cases in which the revised GSL definition does and does not take effect. Shipments are estimated using a stock turnover model and market shares are estimated using a consumer-choice model sensitive to first cost, energy savings, lamp lifetime, the presence of mercury, and ability to dim. The shipments analysis also considers the impact of price learning on product price. Based on the shipments projections, DOE calculated the national consumer economic impacts of the revised GSL definition and the 45 lm/W backstop, by comparing the total installed product costs and operating costs in the backstop case to the case in which the backstop does not take effect.

DOE analyzed the reduction in several greenhouse gases and other pollutants that would result from the EISA 2007 backstop using emissions intensity factors representing the marginal impacts of the change in electricity consumption associated with the backstop. DOE estimated the monetary benefits from the reduction in emissions of CO_2, N_2O, CH_4, NO_x and SO_2 that are expected to result from a 45 lm/W efficacy requirement. The monetized value of the CO_2, N_2O, and CH_4 reduction is calculated using interim estimates published in 2021 developed by an Interagency Working Group on the Social Cost of Greenhouse Gases (IWG). The monetized value of health benefits from the reduction of NO_x and SO_2 emissions is estimated based on analysis conducted by the US Environmental Protection Agency (EPA). DOE has determined that the estimates from the IWG's 2021 TSD are based upon sound analysis and provide well founded estimates for DOE's analysis of the impacts of the reductions of emissions anticipated from the rule.

The time-series of costs and benefits are converted into annualized values based on the present value in 2022. The present value is calculated using discount rates of 3 and 7 percent for consumer costs, benefits, NO_x, and SO_2 reduction benefits and case-specific discount rates for the value of the greenhouse gas emissions (CO_2, N_2O, and CH_4) reduction benefits.

High and low benefits scenarios are analyzed using inputs from the High and Low Economic growth variants of DOE's Annual Energy Outlook 2021 Reference case and different price learning rates for lamps with light emitting diodes (LEDs).

Annualized consumer costs and benefits attributable to the implementation of the 45 lm/W backstop are shown in Table ES - 1. Table ES - 2 presents the social value of emissions reductions calculated using four discount rates in the calculation of total and net benefits. Table ES - 3 shows the total annualized costs and benefits. The total benefits in Table ES - 3 include the consumer operating cost savings from Table ES - 1 and the emissions reduction benefits from Table ES - 2. For presentational purposes, the climate benefits in Table ES – 3 are associated with the average SC-GHG at a 3 percent discount rate are shown, but the Department does not have a single central SC-GHG point estimate, and it emphasizes the importance of considering the benefits calculated using all four SC-GHG estimates.

Table ES - 1. Summary of Annualized Consumer Benefits and Costs, 2022-2051

	Primary Estimate	Low-Net-Benefits Estimate	High-Net-Benefits Estimate
	Annualized (million 2020$/year)		
Consumer Operating Cost Savings			
7% discount rate	2,864.5	2,725.3	3,010.0
3% discount rate	2,955.1	2,788.0	3,128.8
Incremental Product Costs			
7% discount rate	177.6	180.3	173.0
3% discount rate	148.9	150.9	145.0
Net Consumer Benefits			
7% discount rate	2,686.9	2,545.0	2,837.0
3% discount rate	2,806.2	2,637.0	2,983.8

Note: This analysis presents costs and benefits assuming compliance beginning in 2022. As DOE has explained, DOE will release enforcement guidance simultaneously with this rulemaking. If significant compliance behavior changes result from enforcement discretion, both benefits and costs could be reduced for the relevant years, although DOE expects the net benefits will not be significantly changed.

Table ES - 2. Summary of Annualized Social Value of Emissions Reductions, 2022-2051

	Primary Estimate	Low-Net-Benefits Estimate	High-Net-Benefits Estimate
	Annualized (million 2020$/year)		
GHG Benefits			
5% discount rate, average	204.4	197.7	209.4
3% discount rate, average	591.0	571.1	606.0
2.5% discount rate, average	832.7	804.4	854.0
3% discount rate, 95th perc	1761.0	1701.5	1806.0
NOx Benefits (as PM2.5 and ozone)			
7% discount rate	658.1	638.4	672.9
3% discount rate	759.2	733.7	778.4
SO2 Benefits (as PM2.5)			
7% discount rate	302.8	294.0	309.4
3% discount rate	341.3	330.1	349.8

Note: Health benefits in this table are calculated by multiplying emissions by benefit-per-ton estimates for a given discount rate in Table 8. All fine particles are assumed to have equivalent health effects. The benefit-per-ton method does not take into account seasonal variations in energy usage and PM formation. NOx health benefits may be under or over-estimated due to limits on NOx emissions in effect for some states under the Cross-State Air-Pollution Rule. The monetized co-benefits incorporate the conversion from precursor emissions to ambient fine particles.

Table ES - 3. Summary of Total Monetized Costs and Benefits, 2022-2051

	Million 2020$/year		
	Primary Estimate	**Low-Net-Benefits Estimate**	**High-Net-Benefits Estimate**
3% discount rate			
Consumer Operating Cost Savings	2,955.1	2,788.0	3,128.8
Climate Benefits*	591.0	571.1	606.0
Health Benefits**	1,100.5	1,063.8	1,128.2
Total Benefits†	4,646.6	4,422.9	4,863.0
Consumer Incremental Product Costs‡	148.9	150.9	145.0
Net Benefits	4,497.7	4,272.0	4,718.1
7% discount rate			
Consumer Operating Cost Savings	2,864.5	2,725.3	3,010.0
Climate Benefits* (3% discount rate)	591.0	571.1	606.0
Health Benefits**	960.8	932.4	982.3
Total Benefits†	4,416.4	4,228.8	4,598.4
Consumer Incremental Product Costs‡	177.6	180.3	173.0
Net Benefits	4,238.8	4,048.5	4,425.3

Note: This table presents the costs and benefits associated with all GSLs shipped in 2022−2051. These results include benefits to consumers which accrue after 2051 from the products shipped in 2022−2051.
* Climate benefits are calculated using four different estimates of the social cost of carbon (SC-CO2), methane (SC-CH4), and nitrous oxide (SC-N2O) (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate). Together these represent the global social cost of greenhouse gases (SC-GHG). For presentational purposes of this table, the climate benefits associated with the average SC-GHG at a 3 percent discount rate are shown, but the Department does not have a single central SC-GHG point estimate.
** Health benefits are calculated using benefit-per-ton values for NO_X and SO_2. DOE is currently only monetizing (for SO_2 and NO_X) $PM_{2.5}$ precursor health benefits and (for NO_X) ozone precursor health benefits, but will continue to assess the ability to monetize other effects such as health benefits from reductions in direct $PM_{2.5}$ emissions. The health benefits are presented at real discount rates of 3 and 7 percent. See section 2.7.c of this document for more details.
† Total and net benefits include consumer, climate, and health benefits. For presentation purposes, total and net benefits for both the 3-percent and 7-percent cases are presented using the average SC-GHG with 3-percent discount rate, but the Department does not have a single central SC-GHG point estimate. DOE emphasizes the importance and value of considering the benefits calculated using all four SC-GHG estimates. On March 16, 2022, the Fifth Circuit Court of Appeals (No. 22-30087) granted the federal government's emergency motion for stay pending appeal of the February 11, 2022, preliminary injunction issued in Louisiana v. Biden, No. 21-cv-1074-JDC-KK (W.D. La.). As a result of the Fifth Circuit's order, the preliminary injunction is no longer in effect, pending resolution of the federal government's appeal of that injunction or a further court order. Among other things, the preliminary injunction enjoined the defendants in that case from "adopting, employing, treating as binding, or relying upon" the interim estimates of the social cost of greenhouse gases—which were issued by the Interagency Working Group on the Social Cost of Greenhouse Gases on February 26, 2021—to monetize the benefits of reducing greenhouse gas emissions. In the absence of further intervening court orders, DOE will revert to its approach prior to the injunction and present monetized benefits where appropriate and permissible under law.
‡ Costs include incremental equipment costs as well as installation costs.

1. Introduction

Beginning with the Energy Policy and Conservation Act of 1975 (EPCA), a series of congressional acts have directed the U.S. Department of Energy (DOE) to establish minimum energy conservation standards for a variety of consumer products and commercial and industrial equipment. These products include certain varieties of compact electric lamps, commonly referred to as light bulbs. In particular, the Energy Independence and Security Act of 2007 (EISA 2007) amended EPCA to expand coverage to include general service lamps (GSLs), defined by statute as including general service incandescent lamps (GSILs), compact fluorescent lamps (CFLs), general service light-emitting diode (LED) or organic LED (OLED) lamps, and "any other lamps that the Secretary [of Energy] determines are used to satisfy lighting applications traditionally served by general service incandescent lamps", with certain exclusions (*Energy Independence and Security Act of 2007*, 2007; *U.S. Code Title 42—The Public Health and Welfare*, 2010). In addition to expanding coverage, EISA 2007 set a series of energy efficiency standards for GSILs that took effect between 2012 and 2014.

In addition to setting standards for GSILs, EISA 2007 directed DOE to undertake an energy conservation standards rulemaking for GSLs, to be completed by January 1, 2017. If the rulemaking was not completed in accordance with certain statutory provisions, or if the rulemaking did not produce savings greater than or equal to the savings from a minimum efficacy standard of 45 lumens per watt (lm/W), a statutory provision (referred to as the backstop requirement) directed the Secretary of Energy to prohibit the sale of any GSL that does not meet a minimum efficacy of 45 lm/W, beginning January 1, 2020.

In two definition final rules published on January 19, 2017, DOE revised the GSL definition to include additional lamp types, under its authority within the EISA 2007 definition to determine other lamp types that are used to satisfy lighting applications traditionally served by GSILs (Title 42, Section 6291(30)(BB)(i)(IV) of the U.S. code), as well as its authority to determine whether the exemptions for certain incandescent lamps should be maintained or discontinued based, in part, on exempted lamp sales collected by the Secretary from manufacturers pursuant to Title 42, Section 6295(i)(6)(A)(i)(II) (U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy, 2017a, 2017b). DOE clarified in the January 2017 definition final rules that the definition of a general service lamp is a lamp that (1) has an American National Standards Institute (ANSI) base, (2) is able to operate at a voltage of 12 volts or 24 volts, at or between 100 to 130 volts, at or between 220 to 240 volts, or at 277 volts, (3) has an initial lumen output greater than or equal to 310 lumens and less than or equal to 3300 lumens, (4) is not a light fixture, (5) is not an LED downlight retrofit kit, and (6) is used in general lighting applications[1] (U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy, 2017a, 2017b). DOE clarified that certain exclusions exist, including the exclusion of high intensity discharge lamps and general service fluorescent lamps, the latter of which are covered by a separate set of standards[2]. DOE also determined that exclusions from the GSL definition specified by EISA 2007 for certain incandescent lamp types should be discontinued, including reflector lamps, rough service lamps, shatter-resistant lamps, three-way incandescent lamps, vibration service lamps, and lamps of certain shapes[3], per its authority under EISA 2007 to determine whether the exemptions for certain incandescent lamps should be maintained or discontinued.

Prior to the effective date, DOE withdrew the revised definition of GSL in a final rule published on September 5, 2019, reinstating the statutory definition of a GSL as the regulatory definition (U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy, 2019a). On December 27, 2019, DOE also determined that the statutory backstop had not been imposed (U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy, 2019b).

However, upon further review and consideration, DOE proposed to interpret the EISA 2007 backstop as having been triggered, because an energy conservation standards rulemaking for GSLs was not completed in accordance with the specified statutory provisions in EISA 2007. (U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy, 2021a) DOE also proposed to revise the definition of the term GSL to adopt the definition originally set forth in the January 2017 definition final rules (U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy, 2021b).

In these actions, DOE is finalizing its interpretation that the EISA 2007 backstop has been triggered, with an implementation date in 2022, and finalizing a revised definition of the term GSL as proposed in an August 19, 2021 notice of proposed rulemaking (August 2021 NOPR) and originally set forth in the January 2017 definition final rules (U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy, 2021b). Based on the estimates of stock[4] from the 2015 Lighting Market Characterization (LMC 2015), the proposed definition increases the number of lamps defined as a GSL by approximately 2 billion, from 3.8 billion lamps to 5.8

[1] The GSL definition differs slightly for modified spectrum GSILs and non-integrated lamps (*i.e.*, GSLs that require an external ballast, driver, or voltage transformer). See U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy, 2017a, 2017b for full details.

[2] A full list of exclusions is included in a footnote in section 2.1.

[3] Throughout this TSD, DOE refers to lamps by their base type and/or shape. For illustrations of lamp shapes and base types, see http://www.lightopedia.com/bulb-shapes-sizes and http://www.lightopedia.com/bases-filament-types.

[4] The stock is the total quantity of GSLs in the U.S. (in homes, businesses, etc.).

billion lamps, compared to the December 2019 definition final rule (Navigant Consulting, Inc., 2017).[5]

The lighting market is currently undergoing a transition to LED technologies as more products become available and the prices of these products continue to drop. During this transition period incandescent products continue to be sold. Since incandescent technologies cannot meet the 45 lm/W minimum efficacy required by the EISA 2007 backstop, the backstop and the expansion of the GSL definition will result in a more rapid and complete transition to LED technology following imposition of the backstop than would have occurred otherwise, yielding energy savings compared to a scenario in which the EISA backstop provision does not take effect and the definition of GSL remains the same as the statutory definition.

Previously, when DOE proposed to reinterpret the EISA 2007 backstop as having been triggered, a Lawrence Berkeley National Lab (LBNL) report estimated the annualized national economic costs and benefits to consumers associated with the application of the EISA 2007 backstop in 2022 to all GSLs that would meet the expanded GSL definition (Kantner et al., 2021). This paper also details the methodology and data inputs used to estimate the annualized national economic costs and benefits to consumers associated with the application of the EISA 2007 backstop in 2022 to all GSLs in DOE's revised definition of GSLs, including updates to certain inputs, and summarizes the results of that analysis.

2. Methodology

To estimate the annualized U.S. national economic costs and benefits to consumers associated with improved energy efficiency for GSLs, following the revision of the GSL definition and the implementation of the EISA 2007 backstop in 2022, DOE considered shipments of such lamps over a 30-year period (2022-2051). Specifically, DOE estimated annualized monetized values of consumer operating cost savings, incremental product costs, climate benefits from reductions in greenhouse gas emissions, and health benefits from reduction in NO_X and SO_2. In what follows, these values are referred to collectively as the *impact of the backstop*. To calculate this impact, DOE compared the projected total national consumer costs and emissions in two cases: (1) a base case that assumes that the market for lamps under examination will follow recent forecasts, and (2) a backstop case that assumes that any GSL with an efficacy less than 45 lumens per watt is prohibited from being sold in 2022 or thereafter.

To estimate the impact of the backstop, in each case, the energy use, purchase price, and operating cost of GSLs purchased during the 30-year analysis period must be modeled. To

---

[5] DOE assumed lamps categorized as "General Purpose-A-Shape", "General Purpose – Pin", "General Purpose Screw" or "General Purpose" in the 2015 LMC represented GSLs as defined in the December 2019 final rule. DOE assumed the stock of lamps included in the recently proposed definition includes lamps from the December 2019 final rule and any lamps categorized as "Decorative" or "Reflector" as well as linear LED lamps.

accomplish this, the lamps were divided into product categories according to their characteristics and typical applications. A limited number of representative lamps for each product category were developed, including lamp options that would and would not meet a 45 lm/W efficiency standard. These representative lamps are used as a proxy for the more diverse set of lamps available to consumers on the real-world market; simplifying the market in this way allows a tractable model to be constructed while still yielding a representative estimate of energy consumption and consumer costs. DOE estimated the annual energy consumption associated with each representative lamp based on operating hours, lamp wattage, and the reduction in energy consumption expected from the use of lighting controls. DOE also estimated a simple payback period for each of the representative lamps relative to the baseline lamp in each category.

Shipments (representing consumer purchases in each year) and national stock (total installed units) for each representative lamp were estimated for each year in the analysis period. By considering the energy consumption of each lamp in the installed stock, DOE computed the total annual national energy consumption for each case. Together with projections of electricity prices, this also yielded an estimate of annual consumer operating costs in each case. Similarly, the total consumer costs associated with lamp purchases were estimated for each case. Total operating cost savings and incremental product purchase and installation costs in the backstop case relative to the base case were annualized to estimate annualized net consumer benefits resulting from the EISA 2007 backstop. Emissions reductions were estimated by applying emissions factors to any estimated energy savings between cases. DOE estimated monetary health benefits, from the projected reduction in NO_X and SO_2, and monetary climate benefits, from the reduction in greenhouse gas emissions, expected to result from the implementation of the backstop and the revision of the GSL definition.

The following sections discuss in more detail each step in the analysis. Section 2.1 describes the scope of lamps analyzed and how the analyzed lamp types are categorized; section 2.2 describes the representative lamps used in the analysis; section 2.3 describes the hours of use, energy use, lifetime, and payback period for each of our representative lamps; section 2.4 describes the initial estimates for shipments and installed stock for each lamp category, and the stock turnover model and projected efficiency distribution used to estimate shipments in each year; section 2.5 describes the calculation of the national energy savings; and section 2.6 describes the calculation of the annualized national consumer costs and benefits; and section 2.7 describes the calculation of emissions reductions and their monetization.

2.1 Lamp Scope and Categorization

The scope of lamps under consideration in this analysis is the lamps that meet the definition of a GSL finalized in this action. This includes the set of eight types of medium screw-base (MSB) lamps for which the exemptions from the EISA 2007 GSL definition are discontinued by this action: reflector lamps, rough service lamps, shatter-resistant lamps, three-way lamps, vibration service lamps, T-shape lamps of 40 Watts or less or length of 10 inches or more, and B, BA, CA, F, G16-1/2, G25, G30, S, M-14 lamps of 40 Watts or less. In addition, this includes any lamp that (1) has an ANSI base, (2) is able to operate at a voltage of 12 volts or 24 volts, at or between 100 to 130 volts, at or between 220 to 240 volts, or at 277 volts, (3) has an initial lumen output greater than or equal to 310 lumens and less than or equal to 3300 lumens, (4) is not a light fixture, (5) is not an LED downlight retrofit kit, and (6) is used in general lighting applications was determined to be used to satisfy lighting applications traditionally served by general service incandescent lamps, with certain exceptions.[6,7] Among the most common lamps within this broad definition are A-type (pear-shaped) lamps, candle-shaped lamps, and reflector lamps.[8]

For the analyses discussed in this report, GSLs were grouped into categories based on whether they require an external ballast, driver, or voltage transformer to operate and whether they produce directional or omnidirectional light, attributes that affect both efficacy and application. This resulted in three initial categories: integrated omnidirectional lamps, integrated directional lamps, and non-integrated directional lamps. Non-integrated omnidirectional lamps were not considered in this analysis as there are no lamps on the market with efficacy below 45 lm/W in this category, and thus lamps in this category would not be directly impacted by the EISA 2007 backstop. Similarly, within the analyzed categories, lamp types for which there is not a direct substitute on the market with efficacy below 45 lm/W, such as linear LED lamps, were not analyzed as they would not be directly impacted by the EISA 2007 backstop.

The integrated omnidirectional lamp category was further split into two categories for our analysis, A-type lamps and non-A-type lamps, to account for differences in product offerings (such as the availability of traditional incandescent lamp options) as well as typical

---

6 General service lamps do not include: Appliance lamps; Black light lamps; Bug lamps; Colored lamps; G shape lamps with a diameter of 5 inches or more; General service fluorescent lamps; High intensity discharge lamps; Infrared lamps; J, JC, JCD, JCS, JCV, JCX, JD, JS, and JT shape lamps that do not have Edison screw bases; Lamps that have a wedge base or prefocus base; Left-hand thread lamps; Marine lamps; Marine signal service lamps; Mine service lamps; MR shape lamps that have a first number symbol equal to 16 (diameter equal to 2 inches), operate at 12 volts, and have a lumen output greater than or equal to 800; Other fluorescent lamps; Plant light lamps; R20 short lamps; Reflector lamps that have a first number symbol less than 16 (diameter less than 2 inches) and that do not have E26/E24, E26d, E26/50x39, E26/53x39, E29/28, E29/53x39, E39, E39d, EP39, or EX39 bases; S shape or G shape lamps that have a first number symbol less than or equal to 12.5 (diameter less than or equal to 1.5625 inches); Sign service lamps; Silver bowl lamps; Showcase lamps; Specialty MR lamps; T shape lamps that have a first number symbol less than or equal to 8 (diameter less than or equal to 1 inch), nominal overall length less than 12 inches, and that are not compact fluorescent lamps; Traffic signal lamps.

7 As noted previously, the GSL definition differs slightly for modified spectrum GSILs and non-integrated lamps (*i.e.*, GSLs that require an external ballast, driver, or voltage transformer). See U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy, 2021 for full details.

8 These lamp types represent a significant majority of GSLs in the national stock, as discussed in Kantner et al., 2017.

characteristics and applications. The integrated omnidirectional A-type lamp category is dominated by the most common type of light bulb: medium screw-base A-type lamps found in a wide variety of applications. The integrated omnidirectional non-A-type lamp category includes candle-shape lamps with candelabra screw bases often found in chandeliers, pendants, and sconces, as well as globe shape lamps often found in bathrooms. The integrated directional lamp category includes various reflector lamps that are commonly used in recessed cylindrical ceiling fixtures (commonly known as "cans"). The non-integrated directional lamp category includes pin-based multi-faceted reflector (MR) lamps commonly used in track lighting. See Table 1 for a summary of the analyzed lamp categories, including defining characteristics, typical applications, and example lamps.

Table 1. Lamp Categorization

Lamp Category	Defining Characteristics	Typical Application	Example Lamp	
Integrated Omnidirectional A-type	Pear-shape; operates without an external ballast/driver/transformer; omnidirectional light output.	Various	A19 shape, MSB	
Integrated Omnidirectional non-A-type	Not pear-shaped; operates without external ballast/driver/ transformer; omnidirectional light output. Includes candle- and globe-shaped lamps, as well as other shapes.	Chandelier, sconce, pendant	B11 shape, E12 base	
Integrated Directional	Reflector shape; operates without an external ballast/driver/transformer; directional light output	Recessed ceiling fixture	PAR38 shape, MSB	
Non-integrated Directional	Reflector shape; operates with an external ballast/driver/transformer; directional light output	Track lighting	MR16 shape, GU5.3 base	

2.2 Representative Lamps

As mentioned earlier, for each lamp category, the analysis considered a simplified market made up of a limited set of representative lamp options, which span the range of relevant features (technologies and efficiency levels) that will be impacted by the backstop. Each modeled lamp option is meant to serve as a proxy representing a number of similar lamp options available to consumers. For each category, a set of typical lamp properties was chosen and then representative lamp options having these properties for each of the common lighting technologies (traditional incandescent, halogen incandescent, CFL, or LED) in use within each category were constructed.

In selecting representative lamp options for the analysis, it was required that each of the options (1) be advertised as dimmable, (2) have a color-rendering index (CRI) of 80 or greater, and (3) have a correlated color temperature (CCT) of approximately 2700 K, as these are typical properties of these lamp types. For integrated omnidirectional A-type lamps, integrated directional lamps and non-integrated directional lamps, a database of commercially available lamps was consulted to select lamp options meeting these criteria with typical values for lumen output, lifetime, and CRI within each available technology and spanning the range of lamp efficacies on the market, following DOE's methodology in lighting rulemakings for GSLs and GSILs (U.S. Department of Energy, 2019a, 2016). Publicly available retail prices were reviewed and used to estimate prices for the representative lamps. The price for each of the representative lamp options was calculated based on the average price of similar lamp models.

A similar process as described above was performed for identifying the incandescent integrated omnidirectional non-A-type lamp options. LED integrated omnidirectional non-A-type lamps were not available in the dataset used to develop the other representative lamps. For LED non-A-type lamp options, an analysis of online product offerings was performed and a similar price-efficacy relationship was found for non-A-type LED lamps as A-type lamps. Based on this result, a set of non-A-type LED lamps analogous to the A-type LED lamp options were developed. The most common lumen output for non-A-type lamps in our dataset was 450 lumens. For each A-type LED lamp option, the wattage and efficacy were scaled to the expected value for a 450 lumen non-A-type LED lamp, at the same price and rated lifetime as the 800 lumen A-type option. Non-A-type CFL lamps were not included as options for this lamp category based on limited product offerings found on major retail websites, indicating a lack of consumer interest.

Table 2 presents the properties of all the representative lamps used in the analyses. Prices listed for the representative lamp options in Table 2 are for the year 2020 and include sales tax. Future price projections are discussed in section 2.4.d.

Table 2. Representative Lamp Options and Properties

Lamp Option	Technology	Wattage	Initial Lumens	Rated Lifetime (Hours)	Efficacy (lm/W)	Price per Lamp (2020$)
Integrated Omnidirectional A-Type						
1	Halogen	43.0	750	1,000	17.4	1.48
2	CFL	15.0	900	10,000	60.0	3.20
3	CFL	14.0	900	10,000	64.3	3.34
4	CFL	13.0	900	10,000	69.2	3.48
5	LED	10.0	800	15,000	80.0	3.41
6	LED	10.0	800	25,000	80.0	4.65
7	LED	9.0	800	15,000	88.9	4.18
8	LED	9.0	800	25,000	88.9	5.69
9	LED	8.0	800	15,000	100.0	4.95
10	LED	7.0	800	15,000	114.3	5.71
11	LED	6.5	810	15,000	124.6	6.09
Integrated Omnidirectional Non-A-Type						
1	Incandescent	60.0	535	1,500	8.9	1.02
2	LED	7.0	450	15,000	64.0	3.41
3	LED	7.0	450	25,000	64.0	4.65
4	LED	6.1	450	15,000	73.0	4.18
5	LED	6.1	450	25,000	73.0	5.69
6	LED	5.3	450	15,000	84.0	4.95
7	LED	4.6	450	15,000	99.0	5.71
8	LED	4.1	450	15,000	109.0	6.09
Integrated Directional						
1	Halogen	60.0	1,070	1,500	17.8	7.51
2	CFL	23.0	1,100	10,000	47.8	16.93
3	LED	17.0	1,200	25,000	70.6	13.49
4	LED	16.0	1,200	25,000	75.0	12.49
5	LED	15.0	1,200	25,000	80.0	11.52
6	LED	14.0	1,200	25,000	85.7	10.42
7	LED	12.5	1,200	25,000	96.0	8.52
Non-Integrated Directional						
1	Halogen	50.0	500	2,000	10.0	5.09
2	LED	8.0	500	25,000	62.5	10.15
3	LED	7.0	500	25,000	71.4	11.19
4	LED	6.5	500	25,000	76.9	12.10
5	LED	6.0	500	25,000	83.3	12.97

2.3 Hours of Use, Energy Consumption, Lifetime, and Payback Period

Two key inputs for estimating the impact of the backstop on the lamps in the expanded scope are the annual energy consumption and service lifetime of the representative lamps. These depend on properties intrinsic to the lamp design as well as on consumer usage patterns, such as the daily hours of use (HOU) and the frequency and degree to which lamps are dimmed. DOE estimated sector-specific annual energy consumption because HOU are typically much longer in the commercial sector.

To estimate HOU for integrated omnidirectional A-type lamps in the residential sector, DOE used the national-average of 2.3 hours/day developed for such lamps as part of DOE's 2016 GSL NOPR analysis, which considered a number of field metering studies conducted across the U.S. (U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy, 2016, Chap. 7). For integrated omnidirectional non-A-type lamps, integrated directional lamps, and non-integrated directional lamps, DOE estimated average HOU by scaling from the national average HOU for integrated omnidirectional A-type lamps. DOE developed scaling factors for omnidirectional non-A-type lamps, integrated directional lamps, and non-integrated directional lamps using the distribution of room types that particular lamp types (*e.g.*, candelabra-base lamps, globe-shaped lamps, integrated reflectors or MRs) are typically installed in and the HOU associated with those room types, relative to the distribution of room types and associated HOU for integrated omnidirectional A-type lamps. DOE relied on a study in California performed for the public utilities commission (KEMA, Inc., 2010) (henceforth the CPUC study) to estimate the distribution by room type for each lamp type. The hours of use associated with those room types were estimated using data from the Northwest Energy Efficiency Alliance's (NEEA) 2014 Residential Building Stock Assessment Metering Study (Ecotope Inc., 2014).

For the commercial sector, weighted-average daily HOU can be estimated for integrated omnidirectional A-type lamps based on data from the 2015 LMC (Navigant Consulting, Inc., 2017). DOE did not have sufficiently representative data to estimate different HOU for the lamp types considered in this analysis, so DOE assumed the same average daily HOU for all lamp types in the commercial sector. Table 3 lists the average daily HOU used in this analysis for each product category.

Table 3. Average Daily Hours of Use by Lamp Type and Sector

	Residential	**Commercial**
Integrated Omnidirectional A-Type	2.3	11.5
Integrated Omnidirectional Non-A-Type	2.6	11.5
Integrated Directional	2.9	11.5
Non-Integrated Directional	2.9	11.5

A lamp's unit energy consumption (UEC) is determined by its operating wattage, hours of use, and the effects of lighting controls, if any. Lighting controls can affect energy use by reducing the operating wattage (*e.g.*, dimmers) or the hours of use (*e.g.*, occupancy sensors). For the residential sector, DOE assumed any reduction in hours of use from lighting controls is already implicitly accounted for in field metering studies of hours of use, but took into account the reduction in energy consumption as a result of dimming. A meta-study of lighting controls in commercial applications found a 30% reduction in energy use for systems that utilize lighting controls, such as dimmers, compared to systems that do not (Williams et al., 2012). Similar data do not appear to exist, at present, for the effects of lighting controls in the residential sector and so DOE assumed the same 30% energy reduction for lamps operating with dimmers in the residential sector.

In the residential sector, DOE also assumed that for each lamp category the fraction of lamps installed on dimmers will remain constant at its 2015 level, which was estimated using the fraction of the corresponding lamp type installed in each room type from the CPUC study and the fraction of dimming controls by room type reported in DOE's 2015 LMC (Navigant Consulting, Inc., 2017). The fraction of Integrated Omnidirectional A-Type, Integrated Omnidirectional Non-A-Type and Integrated and Non-Integrated Directional lamps in the residential sector is 9%, 14% and 10%, respectively.

To determine the fraction of lamps operated with lighting controls in the commercial sector in each year of the analysis period, DOE used the trend from the 2016 GSL NOPR, which assumes an increasing utilization of controls over time, arising from updated building codes that are increasingly specifying lighting controls in commercial construction and renovation (U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy, 2016, App. 10C). For any increase in the fraction of lamps operated with controls in the commercial sector, DOE assumed a 30% reduction in energy savings, consistent with the study of commercial lighting controls mentioned previously.

The average annual UEC calculated for each representative lamp in 2022 is listed in Table 4.

The final attribute of the representative lamp options needed as an input to the analysis is the probability of lamp retirement (owing to lamp failure or other reasons) as a function of lamp age. For each lamp option DOE modeled the probability of lamp retirement as a function of lamp age following the methodology from DOE's 2016 GSL NOPR for CFL and LED lamps and the methodology from the 2019 GSIL Final Determination for incandescent and halogen lamps (U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy, 2019c, App. 8C, 2016, App. 8E). The methodology for all lamp types employs a Weibull distribution based on the lamp's rated lifetime, sector-specific HOU distributions, on-time cycle length (for residential CFLs), and the presence of controls (for incandescent and halogen lamps). Moreover, in keeping with the reference scenarios from the 2016 GSL NOPR and 2019 GSIL Final

Determination, DOE truncated the resulting survival function using another Weibull model with a median lifetime of 20 years to help ensure that LED lamps do not have unrealistically long lifetimes.[9] The median service lifetime, in years, is the lamp year that has a survival probability of 50%. The service lifetime for all lamp options is listed in Table 4.

[9] The 20-year median is intended to be representative of typical renovation or retrofit time scales.

Table 4. Service Lifetime, Unit Energy Consumption in 2022, and Simple Payback Period for All Lamp Options

Lamp Option	Technology	Residential: Median Service Lifetime (years)	Residential: Annual UEC (kWh/yr)	Residential: Simple Payback Period** (years)	Commercial: Median Service Lifetime (years)	Commercial: Annual UEC* (kWh/yr)	Commercial: Simple Payback Period** (years)
Integrated Omnidirectional A-Type							
1	Halogen	1.9	35.0	--	0.5	168.8	--
2	CFL	11.0	12.2	0.5	3.2	58.9	0.1
3	CFL	11.0	11.4	0.5	3.2	55.0	0.2
4	CFL	11.0	10.6	0.5	3.2	51.0	0.2
5	LED	18.2	8.1	0.5	4.7	39.3	0.1
6	LED	19.1	8.1	0.8	7.9	39.3	0.2
7	LED	18.2	7.3	0.6	4.7	35.3	0.2
8	LED	19.1	7.3	1.0	7.9	35.3	0.3
9	LED	18.2	6.5	0.8	4.7	31.4	0.2
10	LED	18.2	5.7	1.0	4.7	27.5	0.3
11	LED	18.2	5.3	1.0	4.7	25.5	0.3
Integrated Omnidirectional Non-A-Type							
1	Incandescent	2.1	54.3	--	0.6	233.8	--
2	LED	17.8	6.3	0.3	4.8	27.3	0.1
3	LED	18.9	6.3	0.5	7.9	27.3	0.2
4	LED	17.8	5.5	0.4	4.8	23.8	0.1
5	LED	18.9	5.5	0.6	7.9	23.8	0.2
6	LED	17.8	4.8	0.5	4.8	20.6	0.2
7	LED	17.8	4.2	0.6	4.8	17.9	0.2
8	LED	17.8	3.7	0.7	4.8	16.0	0.2
Integrated Directional							
1	Halogen	3.2	61.2	--	0.6	235.1	--
2	CFL	9.9	23.5	1.7	3.2	90.1	0.6
3	LED	18.7	17.3	0.9	7.9	66.6	0.3
4	LED	18.7	16.3	0.7	7.9	62.7	0.3
5	LED	18.7	15.3	0.6	7.9	58.8	0.2
6	LED	18.7	14.3	0.4	7.9	54.9	0.2
7	LED	18.7	12.7	0.1	7.9	49.0	0.1
Non-Integrated Directional							
1	Halogen	2.2	51.0	--	0.9	195.0	--
2	LED	18.7	8.2	0.8	7.9	31.2	0.3
3	LED	18.7	7.1	0.9	7.9	27.3	0.3
4	LED	18.7	6.6	1.0	7.9	25.4	0.4
5	LED	18.7	6.1	1.2	7.9	23.4	0.4

* Commercial UEC indicates the energy that would be consumed by a lamp over the course of a full year, even if the median service lifetime is less than a year.

** The simple payback period is calculated relative to the baseline lamp in each lamp category. The calculation assumes the lamps are operated for a full year and does not take into account replacements costs for lamps with different lifetimes.

To help put the estimated service lifetime in context, Table 4 also includes an estimate of the simple payback period. The simple payback period is the amount of time it takes consumers to recover any higher purchase price of more energy-efficient lamps through lower operating costs, without accounting for changes in operating costs over time or the time value of money. DOE used the annual UEC values in Table 4 and the lamp prices in Table 2 to calculate the simple payback period for each representative lamp, relative to the lamp category's baseline lamp. Consistent with the approach in the 2016 GSL NOPR analysis, DOE used sector-specific electricity prices using 2020 electricity price data from the Edison Electric Institute (EEI) and electricity price trends from Annual Energy Outlook (AEO) 2021 to calculate operating costs (Edison Electric Institute, 2020; U.S. Energy Information Administration, 2021). The simple payback period calculation assumes the lamps are operated for a full year and does not account for the additional cost of any needed replacement lamps when comparing lamps with different lifetimes.

2.4 Stock and Shipments

DOE developed a shipments model to estimate the consumer purchases of each representative lamp in each year of the analysis period in the base case (i.e., the case in which the backstop is not implemented) and the backstop case over a 30-year period from 2022-2051. The model starts from initial estimates of the historical shipments of lamps in each category, as well as the present-day stock, and it projects these estimates forward using a stock-turnover modeling methodology. In this section, DOE summarizes the methods for estimating the historical shipments and stock and for projecting these quantities over the analysis period.

a. Historical Shipments and Stock Estimates

Historical shipments estimates for each lamp category by technology were estimated based on publicly-available sources including shipments information published in public comments provided by the National Electrical Manufacturer's Association (NEMA) in response to the February 2019 GSL Definitional NOPR (NEMA, 2019) and the 2017 General Service Incandescent Lamp (GSIL) Notice of Data Availability (NEMA, 2017) and NEMA's online shipments indices[10]. From these sources, DOE developed a historical time series for integrated omnidirectional A-type and non-A-type lamps of all technologies, incandescent integrated directional lamps, and incandescent non-integrated directional lamps. Historic shipments for LED integrated directional and LED non-integrated directional lamps were estimated assuming shipments of each lamp type would follow a Bass diffusion curve (Bass, 1969), using parameter estimates from DOE's GSIL Final Determination (U.S. Department of Energy, 2019a), and that the projected stock associated with the shipments would match the 2018 stock value reported in the DOE's Adoption of LEDs in Common Applications report for that lamp category (Guidehouse, Inc., 2020). Historic shipments for CFL integrated directional lamps were estimated using a simple stock turnover method utilizing estimates for installed stock from the

[10] Available at https://www.nema.org/analytics/lamp-indices (Last accessed on September 8, 2021)

DOE's 2015 Lighting Market Characterization report (Navigant Consulting, Inc., 2017) and average lifetimes of typical incandescent and CFL integrated directional lamps (based on the lifetime distributions described in section 2.3). DOE assumed no historic shipments of CFL non-integrated directional or integrated omnidirectional non-A-type lamps based on limited product availability for those lamps.

b. Stock Turnover Model

To project the stock of lamps into the future DOE used a stock turnover model similar to that used in DOE's 2016 GSL NOPR analysis to estimate future demand for lamps by lamp category. This model calculates shipments in each year of the analysis based on demand for replacements of retired lamps (*i.e.*, lamps that failed or were replaced in renovation) and for lamps to be installed in new construction. DOE's 2016 GSL NOPR analysis describes the governing equations of the stock turnover model in detail (U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy, 2019c, 2016, Chap. 9). Broadly speaking, the shipments model projects future shipments by estimating the demand for new lamps in each year, for use in new construction and in replacement of retired lamps.

The demand for retirement replacements is given by computing the number of shipments in past vintages that are retired in a given year. The demand for lamps in new construction is driven by growth in total floor space, which is taken to be 1.0% in the commercial and residential sectors based on the floor space and housing stock forecasts in DOE's Annual Energy Outlook. (U.S. Energy Information Administration, 2021)

The stock turnover model also accounts for the reduction in demand due to the adoption of integral LED luminaires into lighting applications traditionally served by GSLs, both prior to and during the analysis period. In each year, an increasing portion of demand is assumed to be met by integral LED luminaires. DOE modelled the growth of integral LED luminaires as a Bass diffusion curve with a maximum market share of 15% of shipments demand, following the approach from the 2016 GSL NOPR.[11]

c. Market-Share Model

DOE used an econometric consumer-choice model to project the market share for lamp options in each lamp category over time in both the base case and the backstop case. The consumer-choice model allocates market share amongst available lamp options in each lamp category based on each representative unit's characteristics. Similar to the methodology employed by DOE in the GSL and GSIL energy conservation rulemakings, DOE used a conditional logit model with consumer sensitivities to lamp price, median lamp lifetime, energy savings, presence

[11] As noted in Chapter 9 of the 2016 GSL NOPR TSD, the fraction of the market that will eventually shift to integral LED luminaires is uncertain. The 15% estimate is based on input from lighting manufacturers and industry experts.

of mercury, and ability to dim[12,13] (for example, see Chapter 9 of the 2016 GSL NOPR TSD or the 2019 GSIL Final Determination TSD) (U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy, 2019c, 2016, Chap. 9). The model is calibrated with historical market share data.[14] A simplifying assumption of the model is that lamp efficacies and wattages exist only at the discrete levels defined by the lamp options listed in section 2.3. In each year of the shipments projection period, the consumer-choice model assigns a share of new purchases.

The market-share module also incorporates a limit on the diffusion of LED technology into the market using the widely accepted Bass adoption model. Specifically, the Bass adoption model includes a parameter, referred to here as MP_{max}, which controls the maximum market penetration that is achievable by a new technology[15]. MP_{max} can take on values between 0 and 1 (inclusive). In this analysis, then, the quantity $(1 - MP_{max})$ represents the fraction of consumers that will continue to purchase traditional incandescent or halogen lamps even as LED options become more cost effective. This 'holdout' fraction limits the maximum proportion of the stock that is achievable for LED lamps in the absence of the EISA 2007 backstop, since it implies that a certain fraction of consumers (representing a certain fraction of the stock) will consider only traditional incandescent or halogen lamps unless those lamp options are not available to them due to the backstop.

NEMA sales data from 2019-2021 for integrated omnidirectional A-type lamps suggest that the market share for LED lamps has plateaued at approximately 80% of A-type shipments. Based on this observation, DOE adopted $MP_{max} = 0.8$ for integrated omnidirectional A-type lamps. The current penetration of LED technologies in other lamp categories lags behind that of integrated omnidirectional A-type lamps. For all other lamp categories, DOE assumed an MP_{max} that corresponds to a stock holdout fraction of 25%, similar to the assumption made in a previous study (Kantner et al., 2017). This holdout fraction may reflect market failures such as consumer biases in projecting benefits or costs of energy efficiency improvements, imperfect information, bounded rationality, and split-incentive/principal-agent problems (Spurlock and Houde, 2016). Additionally, a significant fraction of consumers appear to purchase products based solely on their retail price, without taking into account their energy efficiency and operating costs at all

---

[12] CFLs have historically displayed poor dimming functionality in comparison to other technologies making CFLs less desirable.

[13] Note that preferences for warm versus cool tones were not accounted for because the representative lamps are selected to have the same color temperature.

[14] Data do not exist to support modeling consumer preference specifically related to bulb appearance, but to the degree that there might be differences in appearance based on lamp technology, consumer preference for appearance should be implicitly accounted for since the model is calibrated to historic market share data.

[15] The Bass adoption model also incorporates parameters representing external and internal influence, derived from fitting the LED market share for A-type lamps from the December 2019 GSIL Final Determination (U.S. Department of Energy, 2019b).

(Houde, 2018). Note, that DOE only applies a non-unity MP_{max} in the residential sector. DOE's 2015 LMC report generally finds a higher penetration of LED technologies in the commercial sector in 2015, relative to the residential sector, indicating that commercial consumers are less likely to be 'holdouts' (Navigant Consulting, Inc., 2017). Thus, for the commercial sector, DOE set $MP_{max} = 1$ for LED technologies.

To allocate market share among lamps in the backstop case, DOE assumed that, starting in 2022 only lamp options with an efficacy above 45 lm/W are available for purchase, since they are the only option remaining that meets the minimum efficacy requirement for each lamp category. Thus, all lamps are CFLs or LEDs starting in 2022 in the backstop case.

d. Lamp Price Learning

Prices for LEDs have been shown to decrease in a manner that is consistent with a learning curve (Gerke et al., 2014). Learning curves reflect systematic decreases in manufacturing costs resulting from cumulative production experience. (Wright, 1936; Yelle, 1979) Typically these manifest as a decline in consumer price and are represented as a power-law function dependent on the cumulative shipments to market of a particular technology. As described in the previous section, lamp price is a key input to the consumer-choice model which apportions market share to each lamp option. To estimate future prices of the lamps, DOE used a standard price-learning model which relates the price of a given technology to its cumulative production, as represented by total cumulative shipments.

For LED lamps, DOE used a learning parameter which corresponds to an 18% decrease in price for each doubling in cumulative shipments, consistent with the historic price learning rate observed by a study of the evolution of LED lamp prices (Gerke et al., 2015). Because LED lamps are a relatively young technology, their cumulative shipments increase relatively rapidly and hence they undergo a substantial price decline of 27.5% during the analysis period. DOE assumed that incandescent and CFL technologies do not undergo price learning in the analysis period due to the long history of these lamps in the market.

2.5 National Energy Savings

National energy savings (NES) from the implementation of the backstop is a critical input into estimating the annualized operating cost savings and avoided greenhouse gas emissions. NES is the difference in the total national energy consumption in the base case and the backstop case. To calculate the national annual energy consumption (AEC) in each year for each case, DOE multiplies the stock of lamps of each type in that year by the average annual UEC for that lamp type, and sum over all lamp types. The difference in national AEC between the cases yields energy savings at the site of consumption (i.e., the reduction in energy consumption in homes and buildings, as would be reflected in a utility bill).

The lamp options presented in Table 2 are meant to represent typical products in each lamp category, but do not necessarily reflect the entire range or products within the full distribution of lumen outputs of that category. DOE adjusted the energy use of the representative units for the integrated omnidirectional A-type category to account for the full distribution of GSL lumen outputs (i.e., 310 – 3300 lumens) based on data provided by the National Resource Defense Council in comments (NRDC, 2015) in response to DOE's December 2014 GSL Preliminary Analysis (U.S. Department of Energy, 2014).

Site energy savings are then converted to a reduction in primary energy consumption at the source of generation (i.e., reduction in energy consumption at the power plant), measured in quadrillion BTUs (quads), by applying a site-to-power-plant conversion factor in each year of the analysis period. The site-to-power plant conversion factors are developed using projections from AEO 2021 (U.S. Energy Information Administration, 2021) and the methodology described in the 2016 GSL NOPR TSD (U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy, 2016, Chap. 10). DOE also accounts for the full-fuel-cycle (FFC) energy use of lamps—which includes the energy required to extract, refine, and deliver primary fuel sources—following the methodology described in appendix 10B of the GSL NOPR TSD (U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy, 2016, App. 10B). DOE accounts for the energy used over the full lifetime of all lamps shipped during the 30-year analysis period. For long-lived lamps and lamps shipped late in the analysis period, this means tracking energy consumption through 2090, the year in which the last lamp shipped during the analysis period is assumed to be retired. As in DOE's 2016 GSL NOPR analysis, DOE accounts for the ingrowth of lighting controls in the commercial sector as discussed in section 2.3 (U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy, 2016, Chap. 10).

Federal rulemaking assessments of potential energy savings associated with more efficient appliances typically consider a rebound effect, which reflects the idea that as appliances become more efficient, the reduced operating costs will lead consumers to use their appliance more often. In the context of this analysis, a rebound effect would reduce the estimated national energy savings attributed to the implementation of the backstop due to either increased HOU or increased lumen density (i.e., lamps per square foot) in the backstop case. As in DOE's 2016 GSL NOPR and 2019 GSIL Final Determination, however, DOE assumed no rebound effect (U.S. Department of Energy, 2016; U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy, 2019b). DOE also notes that a series of LMC reports suggest no evidence of an increase in overall operating hours for GSLs accompanying the increase in the overall efficiency of GSLs in the installed stock between 2001 and 2015 (Navigant Consulting, Inc., 2017; Navigant Consulting, Inc., 2012; Navigant Consulting, Inc., 2002).

2.6 Annualized National Consumer Costs and Benefits

Annualized national consumer costs and benefits are calculated from the time series of increased consumer first costs and operating cost savings attributed to the implementation of the backstop. Cumulative national costs and benefits are summed over the years of operation for lamps shipped during the 30-year analysis period and discounted to year 2021 using discount rates of 3% and 7%. These discount rates are used because they are consistent with standard DOE practice (U.S. Department of Energy, 2016). Annualized values are derived by calculating the fixed annual value over a 30-year period, starting in 2022, that yields the same present value as the cumulative value.

The total first cost in a given year is the product of the installed price of a lamp option and the shipments of that option, summed over all lamp options. The installed price of a lamp is the purchase price of the lamp in a given year, taking into account price trends, and including nationally-representative average sales tax and installation cost, if any. DOE assumed that lamps installed in the residential sector had zero installation costs and lamps in the commercial sector have a per lamp installation cost of $1.57 based on Bureau of Labor Statistics hourly wage data (U.S. Department of Labor–Bureau of Labor Statistics., 2019), assuming it takes five minutes to replace a failed lamp.

The total operating cost in each year is the product of the sector-specific average annual energy consumption, for all lamp options in the installed stock, and the sector-specific cost of electricity, summed over sectors. Electricity prices and price trends come from the EEI and AEO 2021 as discussed in section 2.3.

In addition to the reference inputs, DOE also analyzed high and low benefits scenarios that use inputs from variants of the AEO 2021 Reference case. For the high benefits scenario, DOE used the AEO 2021 High Economic Growth scenario, which has a higher energy price trend relative to the Reference case. In order to consider a broad range of potential benefits resulting from the implementation of the EISA 2007 backstop DOE also assumed a lower price learning rate in the high benefits scenario. The lower learning rate in this scenario slows down the adoption of more efficacious lamp options in the base case, increasing the available energy savings attributable to the implementation of the backstop. For the low benefits scenario, DOE used the AEO 2021 Low Economic Growth scenario, which has a lower energy price trend relative to the Reference case, as well as a higher price learning rate. The higher learning rate in this scenario increases the adoption of more efficacious lamp options in the base case, decreasing the available energy savings attributable to the implementation of the backstop. Higher and lower learning rates are taken from the 95% confidence interval on the learning parameter relating cumulative LED A-type shipments and the corresponding price (see section 2.4.d).

2.7 Emissions Reduction and Monetization

a. Emissions Reduction

DOE calculated the reduction in greenhouse gases and other pollutants due to the implementation of the backstop in 2022 considering contributions from two components. The first component estimates the effect of the reduction in national energy use due to the backstop on power sector emissions of CO_2, NO_x, Hg, and SO_2. The second component estimates the impacts of potential standards on emissions of two additional greenhouse gases, CH_4 and N_2O, as well as the reductions to emissions of other gases due to "upstream" activities in the fuel production chain. These upstream activities comprise extraction, processing, and transporting fuels to the site of combustion. The associated emissions are referred to as upstream emissions and they include "fugitive" emissions (direct leakage to the atmosphere) of CH_4 and CO_2.

The estimated emissions reduction is computed from the energy savings in each year of the analysis by applying a multiplier representing the projected average carbon intensity per unit of electricity delivered. These multipliers were developed by DOE for its energy efficiency rulemakings, and are based on the projected mix of electricity generators on the grid. The methodology is based on results published for the Annual Energy Outlook (AEO) prepared by the Energy Information Administration, including a set of side cases that implement a variety of efficiency-related policies. The methodology is described in the report "Utility Sector Impacts of Reduced Electricity Demand" (Coughlin, 2019, 2014).

b. Social Cost of Greenhouse Gases

For the purpose of complying with the requirements of Executive Order 12866, DOE estimated the monetized benefits from the reduced emissions of CO_2, CH_4, and N_2O. These estimates represent the monetary value of the net harm to society associated with a marginal increase in emissions of these pollutants in a given year, or the benefit of avoiding that increase. These estimates are intended to include (but are not limited to) climate-change-related changes in net agricultural productivity, human health, property damages from increased flood risk, disruption of energy systems, risk of conflict, environmental migration, and the value of ecosystem services.

On March 16, 2022, the Fifth Circuit Court of Appeals (No. 22-30087) granted the federal government's emergency motion for stay pending appeal of the February 11, 2022, preliminary injunction issued in Louisiana v. Biden, No. 21-cv-1074-JDC-KK (W.D. La.). As a result of the Fifth Circuit's order, the preliminary injunction is no longer in effect, pending resolution of the federal government's appeal of that injunction or a further court order. Among other things, the preliminary injunction enjoined the defendants in that case from "adopting, employing, treating as binding, or relying upon" the interim estimates of the social cost of greenhouse gases—which were issued by the Interagency Working Group on the Social Cost of Greenhouse Gases on February 26, 2021—to monetize the benefits of reducing greenhouse gas emissions. In the absence of further intervening court orders, DOE will revert to its approach prior to the injunction and present monetized benefits where appropriate and permissible under law.

For the purpose of complying with the requirements of Executive Order 12866, DOE estimates the monetized benefits of the reductions in emissions of CO2, CH4, and N2O by using a measure of the social cost ("SC") of each pollutant (e.g., SC-GHGs). These estimates represent the monetary value of the net harm to society associated with a marginal increase in emissions of these pollutants in a given year, or the benefit of avoiding that increase. These estimates are intended to include (but are not limited to) climate-change-related changes in net agricultural productivity, human health, property damages from increased flood risk, disruption of energy systems, risk of conflict, environmental migration, and the value of ecosystem services. DOE exercises its own judgment in presenting monetized climate benefits as recommended by applicable Executive Orders and guidance, and DOE would reach the same conclusion presented in this notice in the absence of the social cost of greenhouse gases, including the February 2021 Interim Estimates presented by the Interagency Working Group on the Social Cost of Greenhouse Gases.

DOE estimated the global social benefits of CO_2, CH_4, and N_2O reductions (i.e., SC-GHGs) using the estimates presented in the Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990 published in February 2021 by the Interagency Working Group on the Social Cost of Greenhouse Gases (IWG) (IWG, 2021).[16] The SC-GHGs is the monetary value of the net harm to society associated with a marginal increase in emissions in a given year, or the benefit of avoiding that increase. In principle, SC-GHGs includes the value of all climate change impacts, including (but not limited to) changes in net agricultural productivity, human health effects, property damage from increased flood risk and natural disasters, disruption of energy systems, risk of conflict, environmental migration, and the value of ecosystem services. The SC-GHGs therefore, reflects the societal value of reducing emissions of the gas in question by one metric ton. The SC-GHGs is the theoretically appropriate value to use in conducting benefit-cost analyses of policies that affect CO_2, N_2O and CH_4 emissions. As a member of the IWG involved in the development of the February 2021 SC-GHG TSD), the DOE agrees that the interim SC-GHG estimates represent the most appropriate estimate of the SC-GHG until revised estimates have been developed reflecting the latest, peer-reviewed science.

The SC-GHGs estimates are presented here were developed over many years, using transparent process, peer-reviewed methodologies, the best science available at the time of that process, and

[16] *See* Interagency Working Group on Social Cost of Greenhouse Gases, *Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide. Interim Estimates Under Executive Order 13990*, Washington, D.C., February 2021. Available at: *www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf* (last accessed March 17, 2021).

with input from the public. Specifically, in 2009, an interagency working group (IWG) that included the DOE and other executive branch agencies and offices was established to ensure that agencies were using the best available science and to promote consistency in the social cost of carbon (SC-CO_2) values used across agencies. The IWG published SC-CO_2 estimates in 2010 that were developed from an ensemble of three widely cited integrated assessment models (IAMs) that estimate global climate damages using highly aggregated representations of climate processes and the global economy combined into a single modeling framework. The three IAMs were run using a common set of input assumptions in each model for future population, economic, and CO_2 emissions growth, as well as equilibrium climate sensitivity (ECS) – a measure of the globally averaged temperature response to increased atmospheric CO_2 concentrations. These estimates were updated in 2013 based on new versions of each IAM. In August 2016 the IWG published estimates of the social cost of methane (SC-CH_4) and nitrous oxide (SC-N_2O) using methodologies that are consistent with the methodology underlying the SC-CO_2 estimates. The modeling approach that extends the IWG SC-CO_2 methodology to non-CO_2 GHGs has undergone multiple stages of peer review. The SC-CH_4 and SC-N_2O estimates were developed by Marten et al. (2015) and underwent a standard double-blind peer review process prior to journal publication. In 2015, as part of the response to public comments received to a 2013 solicitation for comments on the SC-CO_2 estimates, the IWG announced a National Academies of Sciences, Engineering, and Medicine review of the SC-CO_2 estimates to offer advice on how to approach future updates to ensure that the estimates continue to reflect the best available science and methodologies. In January 2017, the National Academies released their final report, Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide, and recommended specific criteria for future updates to the SC-CO_2 estimates, a modeling framework to satisfy the specified criteria, and both near-term updates and longer-term research needs pertaining to various components of the estimation process (National Academies, 2017). Shortly thereafter, in March 2017, President Trump issued Executive Order 13783, which disbanded the IWG, withdrew the previous TSDs, and directed agencies to ensure SC-CO_2 estimates used in regulatory analyses are consistent with the guidance contained in OMB's Circular A-4, "including with respect to the consideration of domestic versus international impacts and the consideration of appropriate discount rates" (EO 13783, Section 5(c)).

On January 20, 2021, President Biden issued Executive Order 13990, which re-established the IWG and directed it to ensure that the U.S. Government's estimates of the social cost of carbon and other greenhouse gases reflect the best available science and the recommendations of the National Academies (2017). The IWG was tasked with first reviewing the SC-GHG estimates currently used in Federal analyses and publishing interim estimates within 30 days of the EO that reflect the full impact of GHG emissions, including by taking global damages into account. The interim SC-GHG estimates published in February 2021, specifically the SC-CH_4 estimates, are used here to estimate the climate benefits for this rulemaking. The EO instructs the IWG to undertake a fuller update of the SC-GHG estimates by January 2022 that takes into consideration the advice of the National Academies (2017) and other recent scientific literature.

The February 2021 SC-GHG TSD provides a complete discussion of the IWG's initial review conducted under EO 13990. In particular, the IWG found that the SC-GHG estimates used under EO 13783 fail to reflect the full impact of GHG emissions in multiple ways. First, the IWG found that a global perspective is essential for SC-GHG estimates because it fully captures climate impacts that affect the United States and which have been omitted from prior U.S.-specific estimates due to methodological constraints. Examples of omitted effects include direct effects on U.S. citizens, assets, and investments located abroad, supply chains, and tourism, and spillover pathways such as economic and political destabilization and global migration. In addition, assessing the benefits of U.S. GHG mitigation activities requires consideration of how those actions may affect mitigation activities by other countries, as those international mitigation actions will provide a benefit to U.S. citizens and residents by mitigating climate impacts that affect U.S. citizens and residents. If the United States does not consider impacts on other countries, it is difficult to convince other countries to consider the impacts of their emissions on the United States. As a member of the IWG involved in the development of the February 2021 SC-GHG TSD, DOE agrees with this assessment and, therefore, in this final rule DOE centers attention on a global measure of SC-GHG. This approach is the same as that taken in DOE regulatory analyses from 2012 through 2016. Prior to that, in 2008 DOE presented Social Cost of Carbon (SCC) estimates based on values the Intergovernmental Panel on Climate Change (IPCC) identified in literature at that time. As noted in the February 2021 SC-GHG TSD, the IWG will continue to review developments in the literature, including more robust methodologies for estimating a U.S.-specific SC-GHG value, and explore ways to better inform the public of the full range of carbon impacts. As a member of the IWG, DOE will continue to follow developments in the literature pertaining to this issue.

While the IWG works to assess how best to incorporate the latest, peer reviewed science to develop an updated set of SC-GHG estimates, it set the interim estimates to be the most recent estimates developed by the IWG prior to the group being disbanded in 2017. The estimates rely on the same models and harmonized inputs and are calculated using a range of discount rates. As explained in the February 2021 SC-GHG TSD, the IWG has recommended that agencies revert to the same set of four values drawn from the SC-GHG distributions based on three discount rates as were used in regulatory analyses between 2010 and 2016 and subject to public comment. For each discount rate, the IWG combined the distributions across models and socioeconomic emissions scenarios (applying equal weight to each) and then selected a set of four values recommended for use in benefit-cost analyses: an average value resulting from the model runs for each of three discount rates (2.5 percent, 3 percent, and 5 percent), plus a fourth value, selected as the 95th percentile of estimates based on a 3 percent discount rate. The fourth value was included to provide information on potentially higher-than-expected economic impacts from climate change. As explained in the February 2021 SC-GHG TSD, and DOE agrees, this update reflects the immediate need to have an operational SC-GHG for use in regulatory benefit-cost analyses and other applications that was developed using a transparent process, peer-reviewed methodologies, and the science available at the time of that process. Those estimates were subject to public comment in the context of dozens of proposed rulemakings as well as in a dedicated public comment period in 2013.

DOE's derivations of the SC-CO_2, SC-N_2O, and SC-CH_4 values used for this analysis are discussed in the following sections, and the results of DOE's analyses estimating the benefits of the reductions in emissions of these pollutants are presented in section 3.

Social Cost of Carbon

The SC-CO_2 values used for this analysis were generated using the values presented in the 2021 update from the IWG's February 2021 TSD. Table 5 shows the updated sets of annual SC-CO_2 estimates from the latest interagency update from 2020 to 2050. For purposes of capturing the uncertainties involved in regulatory impact analysis, DOE has determined it is appropriate to include all four sets of SC-CO_2 values, as recommended by the IWG.

Table 5. Interim Social Cost of CO_2 Values from 2021 Interagency Update, 2020–2050 (2020$ per Metric Ton of CO_2)

	Discount Rate and Statistics			
Emissions Year	**5%, Average**	**3%, Average**	**2.5%, Average**	**3%, 95th**
2020	14	51	76	152
2021	15	52	78	155
2022	15	53	79	159
2023	16	54	80	162
2024	16	55	82	166
2025	17	56	83	169
2026	17	57	84	173
2027	18	59	86	176
2028	18	60	87	180
2029	19	61	88	183
2030	19	62	89	187
2031	20	63	91	191
2032	21	64	92	194
2033	21	65	94	198
2034	22	66	95	202
2035	22	67	96	206
2036	23	69	98	210
2037	23	70	99	213
2038	24	71	100	217
2039	25	72	102	221
2040	25	73	103	225
2041	26	74	104	228
2042	26	75	106	232
2043	27	77	107	235
2044	28	78	108	239
2045	28	79	110	242
2046	29	80	111	246
2047	30	81	112	249
2048	30	82	114	253
2049	31	84	115	256
2050	32	85	116	260

In calculating the potential global benefits resulting from reduced CO_2 emissions, DOE used the values from the 2021 interagency report, adjusted to 2020$ using the implicit price deflator for gross domestic product (GDP) from the Bureau of Economic Analysis. For each of the four sets of SC-CO_2 cases specified, the values for emissions in 2020 were $14, $51, $76, and $152 per metric ton avoided (values expressed in 2020$). DOE derived values from 2051 to 2070 based on estimates published by EPA.[17] These estimates are based on methods, assumptions, and parameters identical to the 2020-2050 estimates published by the IWG. DOE derived values after 2070 based on the trend in 2060-2070 in each of the four cases.

DOE multiplied the CO_2 emissions reduction estimated for each year by the SC-CO_2 value for that year in each of the four cases. To calculate a present value of the stream of monetary values, DOE discounted the values in each of the four cases using the specific discount rate that had been used to obtain the SC-CO_2 values in each case.

Social Cost of Methane and Nitrous Oxide

The SC-CH_4 and SC-N_2O values used for this analysis were generated using the values presented in the 2021 update from the IWG. Table 6 and Table 7 show the full set of annual values for SC-CH_4 and SC-N_2O estimates from the latest interagency update. To capture the uncertainties involved in regulatory impact analysis, DOE has determined it is appropriate to include all four sets of SC-CH_4 and SC- N_2O values, as recommended by the IWG.

[17] See EPA, *Revised 2023 and Later Model Year Light-Duty Vehicle GHG Emissions Standards: Regulatory Impact Analysis*, Washington, D.C., December 2021. Available at: *www.epa.gov/system/files/documents/2021-12/420r21028.pdf* (last accessed April 15, 2022).

Table 6. Interim Social Cost of CH_4 Values from 2021 Interagency Update, Interagency Update, 2020–2050 (2020$ per Metric Ton of CH_4)

	Discount Rate and Statistics			
Emissions Year	**5%, Average**	**3%, Average**	**2.5%, Average**	**3%, 95th**
2020	670	1500	2000	3900
2021	690	1500	2000	4000
2022	720	1600	2100	4200
2023	750	1600	2100	4300
2024	770	1700	2200	4400
2025	800	1700	2200	4500
2026	830	1800	2300	4700
2027	860	1800	2300	4800
2028	880	1900	2400	4900
2029	910	1900	2500	5100
2030	940	2000	2500	5200
2031	970	2000	2600	5300
2032	1000	2100	2600	5500
2033	1000	2100	2700	5700
2034	1100	2200	2800	5800
2035	1100	2200	2800	6000
2036	1100	2300	2900	6100
2037	1200	2300	3000	6300
2038	1200	2400	3000	6400
2039	1200	2500	3100	6600
2040	1300	2500	3100	6700
2041	1300	2600	3200	6900
2042	1400	2600	3300	7000
2043	1400	2700	3300	7200
2044	1400	2700	3400	7300
2045	1500	2800	3500	7500
2046	1500	2800	3500	7600
2047	1500	2900	3600	7700
2048	1600	3000	3700	7900
2049	1600	3000	3700	8000
2050	1700	3100	3800	8200

Table 7. Interim Social Cost of N_2O Values from 2021 Interagency Update, Interagency Update, 2020–2050 (2020$ per Metric Ton of N_2O)

	Discount Rate and Statistics			
Emissions Year	**5%, Average**	**3%, Average**	**2.5%, Average**	**3%, 95th**
2020	5800	18000	27000	48000
2021	6000	19000	28000	49000
2022	6200	19000	28000	51000
2023	6400	20000	29000	52000
2024	6600	20000	29000	53000
2025	6800	21000	30000	54000
2026	7000	21000	30000	56000
2027	7200	21000	31000	57000
2028	7400	22000	32000	58000
2029	7600	22000	32000	59000
2030	7800	23000	33000	60000
2031	8000	23000	33000	62000
2032	8300	24000	34000	63000
2033	8500	24000	35000	64000
2034	8800	25000	35000	66000
2035	9000	25000	36000	67000
2036	9300	26000	36000	68000
2037	9500	26000	37000	70000
2038	9800	27000	38000	71000
2039	10000	27000	38000	73000
2040	10000	28000	39000	74000
2041	11000	28000	39000	75000
2042	11000	29000	40000	77000
2043	11000	29000	41000	78000
2044	11000	30000	41000	80000
2045	12000	30000	42000	81000
2046	12000	31000	43000	82000
2047	12000	31000	43000	84000
2048	13000	32000	44000	85000
2049	13000	32000	45000	87000
2050	13000	33000	45000	88000

DOE multiplied the CH_4 and N_2O emissions reduction estimated for each year by the SC-CH_4 and SC-N_2O estimates for that year in each of the cases. To calculate a present value of the stream of monetary values, DOE discounted the values in each of the cases using the specific discount rate that had been used to obtain the SC-CH_4 and SC-N_2O estimates in each case.

c. Social Cost of NO_X and SO_2

DOE estimated the monetized value of NO_X and SO_2 emissions reductions from electricity generation using the latest benefit per ton estimates for that sector from the EPA's Benefits Mapping and Analysis Program (U.S. Environmental Protection Agency, 2022). DOE used EPA's values for PM2.5-related benefits associated with NO_X and SO_2 and for ozone-related benefits associated with NO_X for 2025, 2030, and 2040, calculated with discount rates of 3 percent and 7 percent. DOE used linear interpolation to define values for the years not given in the 2025 to 2040 period; for years beyond 2040, the values are held constant. The benefits of reduced SO_2 and NO_X emissions are collectively referred to as health benefits, though the figures here reflect only benefits that currently can be monetized and so excludes potentially important unquantified health benefits, such as from direct PM2.5 exposures.[18]

Table 8. Summary of the Total monetized dollar value (mortality and morbidity) per ton of PM2.5 precursor reduced by Electricity Generating Units (EGU) (2016$)

Pollutant	Discount Rate	2025	2030
NO_x (as PM2.5)	3%	6,400	7,100
	7%	5,700	6,390
SO_2 (as PM2.5)	3%	73,000	82,000
	7%	65,700	73,800

Note: These values represent a national average $/ton of total emissions for electricity generating units (EGU) as shown in EPA's 2021 *Technical Support Document:* Estimating the Benefit per Ton of Reducing Directly-Emitted PM2.5, PM2.5 Precursors and Ozone Precursors from 21 Sectors *(https://www.epa.gov/system/files/documents/2021-10/source-apportionment-tsd-oct-2021_0.pdf)*. EPA modeled health benefits for the EGU sector at the state level, which are available here https://www.epa.gov/benmap/estimating-benefit-ton-reducing-pm25-precursors-21-sectors.

3. Results

In this section, DOE presents the estimated annualized national consumer costs and net benefits resulting from the implementation of EISA 2007 backstop in 2022, applied to lamps in the revised GSL definition. There are two categories of potential impacts from the expanded definition of GSLs: 1) expanding the scope of lamps subject to the EISA 2007 energy efficiency standards for GSILs; and 2) expanding the scope of lamps subject to implementation of the EISA 2007 backstop. For purposes of this analysis, DOE assumed minimal impact from #1 above due to coordination of the GSL definition and GSL backstop effective dates. Thus, this analysis focuses on the effects of #2.

In a LBNL report, the effects of implementing the EISA 2007 backstop were analyzed, under the assumption that all lamps within the revised GSL definition would need to meet a 45 lm/W

[18] *See also* Table 5, https://www.epa.gov/system/files/documents/2021-10/source-apportionment-tsd-oct-2021_0.pdf, for a list of unquantified effects, such as metabolic, cancer, and nervous system effects.

efficacy requirement beginning in 2022 (Kantner et al., 2021). That analysis included, but did not disaggregate, the effects of the backstop on the lamps that would be considered GSLs under this regulatory action. This analysis presents the impact of the backstop disaggregated into the impact on lamps explicitly in the statutory definition and the impact on lamps within the expanded definition, as well as the overall impact of the backstop on all GSLs in the revised definition.The effect of the implementation of the backstop on the subset of lamps in the expanded portion of the revised GSL definition is a subset of the overall impact of implementing the GSL backstop on the all lamps in the revised GSL definition, and should not be double-counted.

The following sections present the emission reduction results, the climate and health benefits, annualized national consumer operating cost savings, incremental product costs, and net benefits, as well as the benefits resulting from emissions reductions arising from those lamps shipped to market over a 30-year analysis period, for an analytical case in which the backstop takes effect as compared to a base case in which the backstop does not take effect.

In the backstop case, all lamp demand for new construction and replacements following implementation of the backstop is assumed to be fulfilled by lamps with an efficacy of at least 45 lm/W, yielding a substantial reduction in energy consumption and an associated savings in energy costs relative to the base case. DOE estimates national FFC energy savings of 5.7 quads from the implementation of a 45 lm/W backstop on all lamps within the GSL definition. Since the LED lamps have significantly longer lifetime than the incandescent lamps they replace, there is also a significant reduction in overall lamp shipments, which offsets higher prices for more efficacious lamps to a significant extent, resulting in a relatively low increase in incremental product costs.

3.1 Emission Reduction Results

Table 9 shows the annual emissions reductions from the implementation of the backstop to all GSLs in the revised definition. Table 10 shows the cumulative emissions reductions over the lifetime of shipments of all GSLs in the revised definition from 2022-2051.

Table 9. Time Series of Emissions Reduction for all GSLs, 2022-2051

Emissions Year	CO_2 (million metric tons)	SO_2 (thousand tons)	NO_x (thousand tons)	Hg (tons)	CH_4 (thousand tons)	N_2O (thousand tons)
2022	5.6	2.8	7.1	0.02	28.0	0.1
2023	8.6	4.3	10.7	0.02	42.2	0.1
2024	9.1	4.3	11.6	0.03	47.7	0.1
2025	9.0	4.2	11.8	0.02	50.6	0.1
2026	8.9	4.1	11.6	0.02	51.3	0.1
2027	8.5	3.9	11.2	0.02	50.1	0.1
2028	8.1	3.8	10.7	0.02	48.0	0.1
2029	7.8	3.6	10.3	0.02	46.4	0.1
2030	7.5	3.4	10.0	0.02	44.7	0.1
2031	7.2	3.2	9.7	0.02	43.7	0.1
2032	7.0	3.0	9.4	0.02	42.8	0.1
2033	6.9	3.0	9.3	0.02	42.2	0.1
2034	6.8	2.9	9.2	0.02	42.0	0.1
2035	6.7	2.9	9.0	0.02	41.5	0.1
2036	6.8	3.0	9.1	0.02	42.0	0.1
2037	6.8	3.0	9.2	0.02	42.9	0.1
2038	6.9	3.1	9.3	0.02	44.2	0.1
2039	7.1	3.2	9.6	0.02	45.6	0.1
2040	7.2	3.3	9.9	0.02	47.1	0.1
2041	7.3	3.3	10.0	0.02	48.0	0.1
2042	7.4	3.4	10.2	0.02	49.0	0.1
2043	7.4	3.4	10.3	0.02	49.8	0.1
2044	7.4	3.3	10.4	0.02	50.1	0.1
2045	7.3	3.3	10.3	0.02	49.9	0.1
2046	7.1	3.2	10.1	0.02	49.3	0.1
2047	7.0	3.2	10.0	0.02	48.7	0.1
2048	6.9	3.2	9.8	0.02	48.3	0.1
2049	6.8	3.1	9.7	0.02	47.8	0.1
2050	6.7	3.0	9.6	0.02	47.5	0.1
Cumulative Reduction (all years)*	221.9	100.8	299.9	0.6	1385.7	2.6

* Includes cumulative impact of the backstop on all GSLs shipped between 2022-2051.

Table 10. Summary of Total Emissions Reduction for all GSLs, 2022-2051

	Power Sector Emissions Reduction	Upstream Emissions Reduction	FFC Emissions Reduction
CO_2 (million metric tons)	207.8	14.1	221.9
SO_2 (thousand tons)	99.6	1.2	100.8
NO_x (thousand tons)	92.2	207.7	299.9
Hg (tons)	0.6	0.0	0.6
CH_4 (thousand tons)	17.6	1,368.1	1,385.7
N_2O (thousand tons)	2.5	0.1	2.6

3.2 Climate and Health Benefits

Table 11 and Table 12 present climate and health benefits estimated for the implementation for the backstop to all GSLs in the revised definition. The benefits of reduced CO_2, CH_4, and N_2O emissions are collectively referred to as climate benefits. The benefits of reduced NO_x and SO_2 emissions are collectively referred to as health benefits.

The annual values reflect the benefits from reduced emissions in each year. The associated benefits accrue over very many years in the case of GHG emissions, and over several years in the case of NO_x and SO_2 emissions. The time stream of benefits has been discounted to estimate the benefit-per-ton values for each year, but the total benefits associated with each emissions year are not discounted in these tables. The cumulative present value does reflect discounting at the noted discount rates.

Table 11. Estimated Monetized Climate Benefits from Reduction in GHG Emissions (billions 2020$)

Calendar Year	Discount Rate and Statistic			
	5% Average	3% Average	2.5% Average	3% 95th percentile
2022	0.11	0.34	0.50	1.00
2025	0.19	0.59	0.85	1.74
2030	0.18	0.54	0.77	1.61
2035	0.19	0.54	0.75	1.60
2040	0.24	0.64	0.88	1.91
2045	0.27	0.70	0.95	2.10
2050	0.28	0.70	0.95	2.10
Cumulative Present Value (all years)*	3.30	11.93	17.86	35.55
Annualized (all years)*	0.20	0.59	0.83	1.76

Notes: The present value of reduced GHG emissions is calculated differently than other benefits. The same discount rate used to discount the value of damages from future emissions (SC-GHGs at 5, 3, 2.5 percent) is used to calculate the present value of SC-GHGs for internal consistency. Annual benefits shown are undiscounted values.
* Includes cumulative impact of the backstop on all GSLs shipped between 2022 2051.

Table 12. Estimated Monetized Health Benefits from Changes in NO_x and SO_2 Emissions 2022 – 2050 (billions of 2020$)

Emissions Year	NO_x (as $PM_{2.5}$ and Ozone)		SO_2	
	3% discount rate	7 % discount rate	3% discount rate	7 % discount rate
2022	0.45	0.40	0.24	0.21
2023	0.68	0.61	0.36	0.33
2024	0.74	0.66	0.37	0.33
2025	0.74	0.67	0.36	0.32
2026	0.75	0.67	0.36	0.32
2027	0.73	0.66	0.35	0.31
2028	0.72	0.64	0.34	0.31
2029	0.71	0.63	0.33	0.30
2030	0.70	0.63	0.32	0.28
2031	0.70	0.63	0.30	0.27
2032	0.70	0.63	0.30	0.27
2033	0.70	0.63	0.30	0.27
2034	0.71	0.63	0.30	0.27
2035	0.71	0.64	0.30	0.27
2036	0.72	0.65	0.31	0.28
2037	0.75	0.67	0.33	0.29

Emissions Year	NO_x (as $PM_{2.5}$ and Ozone)		SO_2	
	3% discount rate	7 % discount rate	3% discount rate	7 % discount rate
2038	0.78	0.70	0.34	0.30
2039	0.81	0.73	0.35	0.32
2040	0.85	0.76	0.37	0.33
2041	0.86	0.77	0.38	0.34
2042	0.88	0.79	0.38	0.34
2043	0.89	0.80	0.38	0.34
2044	0.89	0.80	0.38	0.34
2045	0.89	0.80	0.37	0.34
2046	0.88	0.79	0.37	0.33
2047	0.86	0.77	0.36	0.33
2048	0.85	0.76	0.36	0.32
2049	0.84	0.75	0.36	0.32
2050	0.83	0.74	0.35	0.31
Cumulative Present Value (all years)*	15.33	8.74	6.89	4.02
Annualized (all years)*	0.76	0.66	0.34	0.30

Notes: Health benefits in this table are calculated by multiplying emissions by benefit-per-ton estimates for a given discount rate. For illustrative purposes, DOE only provide national estimates, but may update to finer regional disaggregation in the future. All fine particles are assumed to have equivalent health effects. The benefit-per-ton method does not take into account seasonal variations in energy usage and PM formation. NO_x health benefits may be under or over-estimated due to limits on NO_x emissions in effect for some states under the Cross-State Air Pollution Rule. All estimates were calculated using a benefits-per-ton approach. The monetized co-benefits incorporate the conversion from precursor emissions to ambient fine particles.
* Includes cumulative impact of the backstop on all GSLs shipped between 2022-2051.

3.3 Annualized Costs, Benefits, and Net Benefits

Table 13 summarizes the estimated annualized consumer costs and benefits.

Table 13. Summary of Annualized Consumer Benefits and Costs for all GSLs 2022-2051

	Primary Estimate	Low-Net-Benefits Estimate	High-Net-Benefits Estimate
	Annualized (million 2020$/year)		
Consumer Operating Cost Savings			
7% discount rate	2,864.5	2,725.3	3,010.0
3% discount rate	2,955.1	2,788.0	3,128.8
Incremental Product Costs			
7% discount rate	177.6	180.3	173.0
3% discount rate	148.9	150.9	145.0
Net Consumer Benefits			
7% discount rate	2,686.9	2,545.0	2,837.0
3% discount rate	2,806.2	2,637.1	2,983.8

Note: This analysis presents costs and benefits assuming compliance beginning in 2022. As DOE has explained, DOE will release enforcement guidance simultaneously with this rulemaking. If significant compliance behavior changes result from enforcement discretion, both benefits and costs could be reduced for the relevant years, although DOE expects the net benefits will not be significantly changed.

As discussed in section 2.5, DOE also converted site energy savings to FFC energy savings at the generation source by accounting for energy savings from generation, transmission and distribution, and primary fuel extraction, refinement, and delivery. Table 14 presents annualized monetized social value for avoided emissions. Table 15 shows the total monetized costs and benefits.

Table 14. Summary of Annualized Social Value of Emissions Reductions for all GSLs, 2022-2051

	Primary Estimate	Low-Net-Benefits Estimate	High-Net-Benefits Estimate
	Annualized (million 2020$/year)		
GHG Benefits			
5% discount rate, average	204.4	197.7	209.4
3% discount rate, average	591.0	571.1	606.0
2.5% discount rate, average	832.7	804.4	854.0
3% discount rate, 95th perc	1761.0	1701.5	1806.0
NO_x Benefits			
7% discount rate	658.1	638.4	672.9
3% discount rate	759.2	733.7	778.4
SO_2 Benefits			
7% discount rate	302.8	294.0	309.4
3% discount rate	341.3	330.1	349.8

Note: Health benefits in this table are calculated by multiplying emissions by benefit-per-ton estimates for a given discount rate in Table 8. All fine particles are assumed to have equivalent health effects. The benefit-per-ton method does not take into account seasonal variations in energy usage and PM formation. NOx health benefits may be under or over-estimated due to limits on NOx emissions in effect for some states under the Cross-State Air-Pollution Rule. The monetized co-benefits incorporate the conversion from precursor emissions to ambient fine particles

Table 15. Summary Total Annualized Monetized Costs and Benefits for all GSLs, 2022-2051

	Million 2020$/year		
	Primary Estimate	**Low-Net-Benefits Estimate**	**High-Net-Benefits Estimate**
3% discount rate			
Consumer Operating Cost Savings	2,955.1	2,788.0	3,128.8
Climate Benefits*	591.0	571.1	606.0
Health Benefits**	1,100.5	1,063.8	1,128.2
Total Benefits†	4,646.6	4,422.9	4,863.0
Consumer Incremental Product Costs‡	148.9	150.9	145.0
Net Benefits	4,497.7	4,272.0	4,718.1
7% discount rate			
Consumer Operating Cost Savings	2,864.5	2,725.3	3,010.0
Climate Benefits* (3% discount rate)	591.0	571.1	606.0
Health Benefits**	960.8	932.4	982.3
Total Benefits†	4,416.4	4,228.8	4,598.4
Consumer Incremental Product Costs‡	177.6	180.3	173.0
Net Benefits	4,238.8	4,048.5	4,425.3

Note: This table presents the costs and benefits associated with all GSLs shipped in 2022−2051. These results include benefits to consumers which accrue after 2051 from the products shipped in 2022−2051.

* Climate benefits are calculated using four different estimates of the social cost of carbon (SC-CO2), methane (SC-CH4), and nitrous oxide (SC-N2O) (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate). Together these represent the global social cost of greenhouse gases (SC-GHG). For presentational purposes of this table, the climate benefits associated with the average SC-GHG at a 3 percent discount rate are shown, but the Department does not have a single central SC-GHG point estimate.

** Health benefits are calculated using benefit-per-ton values for NO_X and SO_2. DOE is currently only monetizing (for SO_2 and NO_X) $PM_{2.5}$ precursor health benefits and (for NO_X) ozone precursor health benefits, but will continue to assess the ability to monetize other effects such as health benefits from reductions in direct $PM_{2.5}$ emissions. The health benefits are presented at real discount rates of 3 and 7 percent. See section 2.7.c of this document for more details.

† Total and net benefits include consumer, climate, and health benefits. For presentation purposes, total and net benefits for both the 3-percent and 7-percent cases are presented using the average SC-GHG with 3-percent discount rate, but the Department does not have a single central SC-GHG point estimate. DOE emphasizes the importance and value of considering the benefits calculated using all four SC-GHG estimates. On March 16, 2022, the Fifth Circuit Court of Appeals (No. 22-30087) granted the federal government's emergency motion for stay pending appeal of the February 11, 2022, preliminary injunction issued in Louisiana v. Biden, No. 21-cv-1074-JDC-KK (W.D. La.). As a result of the Fifth Circuit's order, the preliminary injunction is no longer in effect, pending resolution of the federal government's appeal of that injunction or a further court order. Among other things, the preliminary injunction enjoined the defendants in that case from "adopting, employing, treating as binding, or relying upon" the interim estimates of the social cost of greenhouse gases—which were issued by the Interagency Working Group on the Social Cost of Greenhouse Gases on February 26, 2021—to monetize the benefits of reducing greenhouse gas emissions. In the absence of further intervening court orders, DOE will revert to its approach prior to the injunction and present monetized benefits where appropriate and permissible under law.

‡ Costs include incremental equipment costs as well as installation costs.

Despite the expected widespread adoption of LEDs in the base case, expanding the definition of GSLs nevertheless yields large impacts in conjunction with implementation of the GSL backstop. DOE estimates annualized net consumer benefits of $2.7 billion at a 7% discount rate and $2.8 billion per year at a 3% discount rate. Including the social value of emission reductions, DOE estimates annualized net benefits of $4.2 billion at 7% and $4.4 billion at 3%.

These results can be disaggregated into the costs and benefits associated with lamps explicitly in the statutory definition and lamps in the expanded GSL definition. Table 16 through Table 18 show the costs and benefits associated with the implementation of the backstop for lamps explicitly in the statutory GSL definition and Table 19 through Table 21 show the costs and benefits of implementing the backstop for GSLs in the expanded definition. Note that for GSLs explicitly in the statutory definition, the incremental product costs in Table 16 and Table 18 are negative because the longer lamp lifetimes of LED lamps result in fewer lamp purchases in the backstop case relative to the base case. The fewer lamps purchased outweigh an increase in product costs in considering the total incremental product costs over 30 years of shipments.

Table 16. Summary of Annualized Costs and Benefits for GSLs Explicitly in the Statutory Definition, 2022-2051

	Primary Estimate	**Low-Net-Benefits Estimate**	**High-Net-Benefits Estimate**
	Annualized (million 2020$/year)		
Consumer Operating Cost Savings			
7% discount rate	687.3	652.8	723.1
3% discount rate	653.1	616.8	691.2
Incremental Product Costs			
7% discount rate	-28.1	-29.9	-26.5
3% discount rate	-32.8	-35.0	-30.6
Net Consumer Benefits			
7% discount rate	715.4	682.7	749.5
3% discount rate	685.9	651.9	721.8

Table 17. Summary of Annualized Monetized Social Value of Emissions Reductions for GSLs Explicitly in the Statutory Definition, 2022-2051

	Primary Estimate	Low-Net-Benefits Estimate	High-Net-Benefits Estimate
	Annualized (million 2020$/year)		
GHG Benefits			
5% discount rate, average	47.6	45.8	49.0
3% discount rate, average	133.5	128.5	137.4
2.5% discount rate, average	186.5	179.4	192.1
3% discount rate, 95th perc	398.2	383.2	410.1
NOx Benefits (as PM2.5 and ozone)			
7% discount rate	164.5	159.0	168.9
3% discount rate	175.0	168.5	180.2
SO2 Benefits (as PM2.5)			
7% discount rate	75.2	72.7	77.2
3% discount rate	78.3	75.4	80.6

Note: Health benefits in this table are calculated by multiplying emissions by benefit-per-ton estimates for a given discount rate in Table 8. All fine particles are assumed to have equivalent health effects. The benefit-per-ton method does not take into account seasonal variations in energy usage and PM formation. NO_x health benefits may be under or over-estimated due to limits on NO_x emissions in effect for some states under the Cross-State Air Pollution Rule. The monetized co-benefits incorporate the conversion from precursor emissions to ambient fine particles.

Table 18. Summary of Total Annualized Costs and Benefits for GSLs Explicitly in the Statutory Definition, 2022-2051

	Million 2020$/year		
	Primary Estimate	**Low-Net-Benefits Estimate**	**High-Net-Benefits Estimate**
3% discount rate			
Consumer Operating Cost Savings	653.1	616.8	691.2
Climate Benefits*	133.5	128.5	137.4
Health Benefits**	253.4	244.0	260.8
Total Benefits†	1,040.0	989.3	1,089.5
Consumer Incremental Product Costs‡	-32.8	-35.0	-30.6
Net Benefits	1,072.7	1,024.3	1,120.1
7% discount rate			
Consumer Operating Cost Savings	687.3	652.8	723.1
Climate Benefits* (3% discount rate)	133.5	128.5	137.4
Health Benefits**	239.8	231.7	246.1
Total Benefits†	1,060.5	1,013.0	1,106.6
Consumer Incremental Product Costs‡	-28.1	-29.9	-26.5
Net Benefits	1,088.7	1,042.9	1,133.1

Note: This table presents the costs and benefits associated with GSLs explicitly in the statutory definition shipped in 2022−2051. These results include benefits to consumers which accrue after 2051 from the products shipped in 2022−2051.
* Climate benefits are calculated using four different estimates of the social cost of carbon (SC-CO2), methane (SC-CH4), and nitrous oxide (SC-N2O) (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate). Together these represent the global social cost of greenhouse gases (SC-GHG). For presentational purposes of this table, the climate benefits associated with the average SC-GHG at a 3 percent discount rate are shown, but the Department does not have a single central SC-GHG point estimate.
** Health benefits are calculated using benefit-per-ton values for NO_X and SO_2. DOE is currently only monetizing (for SO_2 and NO_X) $PM_{2.5}$ precursor health benefits and (for NO_X) ozone precursor health benefits, but will continue to assess the ability to monetize other effects such as health benefits from reductions in direct $PM_{2.5}$ emissions. The health benefits are presented at real discount rates of 3 and 7 percent. See section 2.7.c of this document for more details.
† Total and net benefits include consumer, climate, and health benefits. For presentation purposes, total and net benefits for both the 3-percent and 7-percent cases are presented using the average SC-GHG with 3-percent discount rate, but the Department does not have a single central SC-GHG point estimate. DOE emphasizes the importance and value of considering the benefits calculated using all four SC-GHG estimates. On March 16, 2022, the Fifth Circuit Court of Appeals (No. 22-30087) granted the federal government's emergency motion for stay pending appeal of the February 11, 2022, preliminary injunction issued in Louisiana v. Biden, No. 21-cv-1074-JDC-KK (W.D. La.). As a result of the Fifth Circuit's order, the preliminary injunction is no longer in effect, pending resolution of the federal government's appeal of that injunction or a further court order. Among other things, the preliminary injunction enjoined the defendants in that case from "adopting, employing, treating as binding, or relying upon" the interim estimates of the social cost of greenhouse gases—which were issued by the Interagency Working Group on the Social Cost of Greenhouse Gases on February 26, 2021—to monetize the benefits of reducing greenhouse gas emissions. In the absence of further intervening court orders, DOE will revert to its approach prior to the injunction and present monetized benefits where appropriate and permissible under law.
‡ Costs include incremental equipment costs as well as installation costs.

Table 19. Summary of Total Annualized Costs and Benefits for GSLs in the Expanded Definition, 2022-2051

	Primary Estimate	Low-Net-Benefits Estimate	High-Net-Benefits Estimate
	Annualized (million 2020$/year)		
Consumer Operating Cost Savings			
7% discount rate	2,177.3	2,072.5	2,287.0
3% discount rate	2,302.0	2,171.2	2,437.6
Incremental Product Costs			
7% discount rate	205.8	210.2	199.5
3% discount rate	181.7	186.0	175.5
Net Consumer Benefits			
7% discount rate	1,971.5	1,862.4	2,087.5
3% discount rate	2,120.3	1,985.2	2,262.0

Table 20. Summary of Annualized Monetized Social Value of Emissions Reductions for GSLs in the Expanded Definition, 2022-2051

	Primary Estimate	Low-Net-Benefits Estimate	High-Net-Benefits Estimate
	Annualized (million 2020$/year)		
GHG Benefits			
5% discount rate, average	156.8	151.9	160.5
3% discount rate, average	457.5	442.6	468.6
2.5% discount rate, average	646.2	625.0	662.0
3% discount rate, 95th perc	1,362.8	1,318.3	1,395.9
NOx Benefits (as PM2.5 and ozone)			
7% discount rate	493.5	479.4	504.0
3% discount rate	584.1	565.2	598.2
SO2 Benefits (as PM2.5)			
7% discount rate	227.6	221.2	232.2
3% discount rate	263.0	254.7	269.2

Note: Health benefits in this table are calculated by multiplying emissions by benefit-per-ton estimates for a given discount rate in Table 8. All fine particles are assumed to have equivalent health effects. The benefit-per-ton method does not take into account seasonal variations in energy usage and PM formation. NOx health benefits may be under or over-estimated due to limits on NOx emissions in effect for some states under the Cross-State Air-Pollution Rule. The monetized co-benefits incorporate the conversion from precursor emissions to ambient fine particles.

Table 21. Summary of Total Monetized Costs and Benefits for GSLs in the Expanded Definition, 2022-2051

	Million 2020$/year		
	Primary Estimate	**Low-Net-Benefits Estimate**	**High-Net-Benefits Estimate**
3% discount rate			
Consumer Operating Cost Savings	2,302.0	2,171.2	2,437.6
Climate Benefits*	457.5	442.6	468.6
Health Benefits**	847.1	819.9	867.4
Total Benefits†	3,606.7	3,433.6	3,773.5
Consumer Incremental Product Costs‡	181.7	186.0	175.5
Net Benefits	3,424.9	3,247.7	3,598.0
7% discount rate			
Consumer Operating Cost Savings	2,177.3	2,072.5	2,287.0
Climate Benefits* (3% discount rate)	457.5	442.6	468.6
Health Benefits**	721.1	700.6	736.2
Total Benefits†	3,355.9	3,215.8	3,491.8
Consumer Incremental Product Costs‡	205.8	210.2	199.5
Net Benefits	3,150.1	3,005.6	3,292.2

Note: This table presents the costs and benefits associated with GSLs in the expanded definition shipped in 2022−2051. These results include benefits to consumers which accrue after 2051 from the products shipped in 2022−2051.
* Climate benefits are calculated using four different estimates of the social cost of carbon (SC-CO2), methane (SC-CH4), and nitrous oxide (SC-N2O) (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate). Together these represent the global social cost of greenhouse gases (SC-GHG). For presentational purposes of this table, the climate benefits associated with the average SC-GHG at a 3 percent discount rate are shown, but the Department does not have a single central SC-GHG point estimate.
** Health benefits are calculated using benefit-per-ton values for NO_X and SO_2. DOE is currently only monetizing (for SO_2 and NO_X) $PM_{2.5}$ precursor health benefits and (for NO_X) ozone precursor health benefits, but will continue to assess the ability to monetize other effects such as health benefits from reductions in direct $PM_{2.5}$ emissions. The health benefits are presented at real discount rates of 3 and 7 percent. See section 2.7.c of this document for more details.
† Total and net benefits include consumer, climate, and health benefits. For presentation purposes, total and net benefits for both the 3-percent and 7-percent cases are presented using the average SC-GHG with 3-percent discount rate, but the Department does not have a single central SC-GHG point estimate. DOE emphasizes the importance and value of considering the benefits calculated using all four SC-GHG estimates. On March 16, 2022, the Fifth Circuit Court of Appeals (No. 22-30087) granted the federal government's emergency motion for stay pending appeal of the February 11, 2022, preliminary injunction issued in Louisiana v. Biden, No. 21-cv-1074-JDC-KK (W.D. La.). As a result of the Fifth Circuit's order, the preliminary injunction is no longer in effect, pending resolution of the federal government's appeal of that injunction or a further court order. Among other things, the preliminary injunction enjoined the defendants in that case from "adopting, employing, treating as binding, or relying upon" the interim estimates of the social cost of greenhouse gases—which were issued by the Interagency Working Group on the Social Cost of Greenhouse Gases on February 26, 2021—to monetize the benefits of reducing greenhouse gas emissions. In the absence of further intervening court orders, DOE will revert to its approach prior to the injunction and present monetized benefits where appropriate and permissible under law.
‡ Costs include incremental equipment costs as well as installation costs.

3.4 Cumulative Costs, Benefits, and Net Benefits

Table 22 through Table 24 present the cumulative costs, benefits, and net benefits for all GSLs shipped between 2022-2051. Disaggregated results for GSLs explicitly in the statutory definition can be found in Table 25 through Table 27 and results for GSLs in the expanded definition in Table 28 through Table 30. This analysis presents costs and benefits assuming compliance beginning in 2022. As DOE has explained, DOE will release enforcement guidance simultaneously with this rulemaking. If significant compliance behavior changes result from enforcement discretion, both benefits and costs could be reduced for the relevant years, although DOE expects the net benefits will not be significantly changed.

Table 22. Summary of Cumulative Consumer Costs and Benefits for All GSLs, 2022-2051

	Billions 2020$
Consumer Operating Cost Savings	
7% discount rate	38.0
3% discount rate	59.7
Incremental Product Costs	
7% discount rate	2.4
3% discount rate	3.0
Net Consumer Benefits	
7% discount rate	35.7
3% discount rate	56.7

Table 23. Summary of Cumulative Monetized Social Value of Emissions Reductions for All GSLs, 2022-2051

	Billions 2020$
GHG Benefits	
5% discount rate, average	3.3
3% discount rate, average	11.9
2.5% discount rate, average	17.9
3% discount rate, 95th perc	35.6
NOx Benefits (as PM2.5 and ozone)	
7% discount rate	8.7
3% discount rate	15.3
SO_2 Benefits (as PM2.5)	
7% discount rate	4.0
3% discount rate	6.9

Note: Health benefits in this table are calculated by multiplying emissions by benefit-per-ton estimates for a given discount rate in Table 8. All fine particles are assumed to have equivalent health effects. The benefit-per-ton method does not take into account seasonal variations in energy usage and PM formation. NOx health benefits may be under or over-estimated due to limits on NOx emissions in effect for some states under the Cross-State Air-Pollution Rule. The monetized co-benefits incorporate the conversion from precursor emissions to ambient fine particles.

Table 24. Summary of Cumulative Total Monetized Costs and Benefits for All GSLs, 2022-2051

	Billion 2020$
3% discount rate	
Consumer Operating Cost Savings	59.7
Climate Benefits*	11.9
Health Benefits**	22.2
Total Benefits†	93.8
Consumer Incremental Product Costs‡	3.0
Net Benefits	90.8
7% discount rate	
Consumer Operating Cost Savings	38.0
Climate Benefits* (3% discount rate)	11.9
Health Benefits**	12.8
Total Benefits†	62.7
Consumer Incremental Product Costs‡	2.4
Net Benefits	60.4

Note: This table presents the costs and benefits associated with product name shipped in 2022−2051. These results include benefits to consumers which accrue after 2051 from the products shipped in 2022−2051.
* Climate benefits are calculated using four different estimates of the SC-GHG. For presentational purposes of this table, the climate benefits associated with the average SC-GHG at a 3 percent discount rate are shown, but the Department does not have a single central SC-GHG point estimate, and it emphasizes the importance of considering the benefits calculated using all four SC-GHG estimates.
** Health benefits are calculated using benefit-per-ton values for NO_X and SO_2. The benefits are based on the low estimates of the monetized value. DOE is currently only monetizing PM2.5 and (for NO_X) ozone precursor health benefits, but will continue to assess the ability to monetize other effects such as health benefits from reductions in direct PM2.5 emissions.
† Total benefits for both the 3-percent and 7-percent cases are presented using the average SC-GHG with 3-percent discount rate, but the Department does not have a single central SC-GHG point estimate. DOE emphasizes the importance and value of considering the benefits calculated using all four SC-GHG estimates. On March 16, 2022, the Fifth Circuit Court of Appeals (No. 22-30087) granted the federal government's emergency motion for stay pending appeal of the February 11, 2022, preliminary injunction issued in Louisiana v. Biden, No. 21-cv-1074-JDC-KK (W.D. La.). As a result of the Fifth Circuit's order, the preliminary injunction is no longer in effect, pending resolution of the federal government's appeal of that injunction or a further court order. Among other things, the preliminary injunction enjoined the defendants in that case from "adopting, employing, treating as binding, or relying upon" the interim estimates of the social cost of greenhouse gases—which were issued by the Interagency Working Group on the Social Cost of Greenhouse Gases on February 26, 2021—to monetize the benefits of reducing greenhouse gas emissions. In the absence of further intervening court orders, DOE will revert to its approach prior to the injunction and present monetized benefits where appropriate and permissible under law.
‡ Costs include incremental equipment costs as well as installation costs.

Table 25. Summary of Cumulative Consumer Costs and Benefits for GSLs Explicitly in the Statutory Definition, 2022-2051

	Billions 2020$
Consumer Operating Cost Savings	
7% discount rate	9.1
3% discount rate	13.2
Incremental Product Costs	
7% discount rate	-0.4
3% discount rate	-0.7
Net Consumer Benefits	
7% discount rate	9.5
3% discount rate	13.8

Table 26. Summary of Cumulative Monetized Social Value of Emissions Reductions for GSLs Explicitly in the Statutory Definition, 2022-2051

	Billions 2020$
GHG Benefits	
5% discount rate, average	0.8
3% discount rate, average	2.7
2.5% discount rate, average	4.0
3% discount rate, 95th perc	8.0
NOx Benefits (as PM2.5 and ozone)	
7% discount rate	2.2
3% discount rate	3.5
SO_2 Benefits (as PM2.5)	
7% discount rate	1.0
3% discount rate	1.6

Note: Health benefits in this table are calculated by multiplying emissions by benefit-per-ton estimates for a given discount rate in Table 8. All fine particles are assumed to have equivalent health effects. The benefit-per-ton method does not take into account seasonal variations in energy usage and PM formation. NOx health benefits may be under or over-estimated due to limits on NOx emissions in effect for some states under the Cross-State Air-Pollution Rule. The monetized co-benefits incorporate the conversion from precursor emissions to ambient fine particles.

Table 27. Summary of Cumulative Total Monetized Costs and Benefits for GSLs Explicitly in the Statutory Definition, 2022-2051

	Billion 2020$
3% discount rate	
Consumer Operating Cost Savings	13.2
Climate Benefits*	2.7
Health Benefits**	5.1
Total Benefits†	21.0
Consumer Incremental Product Costs‡	-0.7
Net Benefits	21.7
7% discount rate	
Consumer Operating Cost Savings	9.1
Climate Benefits* (3% discount rate)	2.7
Health Benefits**	3.2
Total Benefits†	15.0
Consumer Incremental Product Costs‡	-0.4
Net Benefits	15.4

Note: This table presents the costs and benefits associated with GSLs explicitly in statutory definition shipped in 2022−2051. These results include benefits to consumers which accrue after 2051 from the products shipped in 2022−2051.

* Climate benefits are calculated using four different estimates of the SC-GHG. For presentational purposes of this table, the climate benefits associated with the average SC-GHG at a 3 percent discount rate are shown, but the Department does not have a single central SC-GHG point estimate, and it emphasizes the importance of considering the benefits calculated using all four SC-GHG estimates.

** Health benefits are calculated using benefit-per-ton values for NO_X and SO_2. The benefits are based on the low estimates of the monetized value. DOE is currently only monetizing PM2.5 and (for NO_X) ozone precursor health benefits, but will continue to assess the ability to monetize other effects such as health benefits from reductions in direct PM2.5 emissions.

† Total benefits for both the 3-percent and 7-percent cases are presented using the average SC-GHG with 3-percent discount rate, but the Department does not have a single central SC-GHG point estimate. DOE emphasizes the importance and value of considering the benefits calculated using all four SC-GHG estimates. On March 16, 2022, the Fifth Circuit Court of Appeals (No. 22-30087) granted the federal government's emergency motion for stay pending appeal of the February 11, 2022, preliminary injunction issued in Louisiana v. Biden, No. 21-cv-1074-JDC-KK (W.D. La.). As a result of the Fifth Circuit's order, the preliminary injunction is no longer in effect, pending resolution of the federal government's appeal of that injunction or a further court order. Among other things, the preliminary injunction enjoined the defendants in that case from "adopting, employing, treating as binding, or relying upon" the interim estimates of the social cost of greenhouse gases—which were issued by the Interagency Working Group on the Social Cost of Greenhouse Gases on February 26, 2021—to monetize the benefits of reducing greenhouse gas emissions. In the absence of further intervening court orders, DOE will revert to its approach prior to the injunction and present monetized benefits where appropriate and permissible under law.

‡ Costs include incremental equipment costs as well as installation costs.

Table 28. Summary of Cumulative Consumer Costs and Benefits for GSLs in the Expanded Definition, 2022-2051

	Billions 2020$
Consumer Operating Cost Savings	
7% discount rate	28.9
3% discount rate	46.5
Incremental Product Costs	
7% discount rate	2.7
3% discount rate	3.7
Net Consumer Benefits	
7% discount rate	26.2
3% discount rate	42.8

Table 29. Summary of Cumulative Monetized Social Value of Emissions Reductions for GSLs in the Expanded Definition, 2022-2051

	Billions 2020$
GHG Benefits	
5% discount rate, average	2.5
3% discount rate, average	9.2
2.5% discount rate, average	13.9
3% discount rate, 95th perc	27.5
NOx Benefits (as PM2.5 and ozone)	
7% discount rate	6.6
3% discount rate	11.8
SO_2 Benefits (as PM2.5)	
7% discount rate	3.0
3% discount rate	5.3

Note: Health benefits in this table are calculated by multiplying emissions by benefit-per-ton estimates for a given discount rate in Table 8. All fine particles are assumed to have equivalent health effects. The benefit-per-ton method does not take into account seasonal variations in energy usage and PM formation. NOx health benefits may be under or over-estimated due to limits on NOx emissions in effect for some states under the Cross-State Air-Pollution Rule. The monetized co-benefits incorporate the conversion from precursor emissions to ambient fine particles.

Table 30. Summary of Cumulative Total Monetized Costs and Benefits for GSLs in the Expanded Definition, 2022-2051

	Billion 2020$
3% discount rate	
Consumer Operating Cost Savings	46.5
Climate Benefits*	9.2
Health Benefits**	17.1
Total Benefits†	72.8
Consumer Incremental Product Costs‡	3.7
Net Benefits	69.1
7% discount rate	
Consumer Operating Cost Savings	28.9
Climate Benefits* (3% discount rate)	9.2
Health Benefits**	9.6
Total Benefits†	47.7
Consumer Incremental Product Costs‡	2.7
Net Benefits	45.0

Note: This table presents the costs and benefits associated with GSLs in the expanded definition shipped in 2022−2051. These results include benefits to consumers which accrue after 2051 from the products shipped in 2022−2051.
* Climate benefits are calculated using four different estimates of the SC-. For presentational purposes of this table, the climate benefits associated with the average SC-GHG at a 3 percent discount rate are shown, but the Department does not have a single central SC-GHG point estimate, and it emphasizes the importance of considering the benefits calculated using all four SC-GHG estimates.
** Health benefits are calculated using benefit-per-ton values for NO_X and SO_2. The benefits are based on the low estimates of the monetized value. DOE is currently only monetizing PM2.5 and (for NO_X) ozone precursor health benefits, but will continue to assess the ability to monetize other effects such as health benefits from reductions in direct PM2.5 emissions.
† Total benefits for both the 3-percent and 7-percent cases are presented using the average SC-GHG with 3-percent discount rate, but the Department does not have a single central SC-GHG point estimate. DOE emphasizes the importance and value of considering the benefits calculated using all four SC-GHG estimates. On March 16, 2022, the Fifth Circuit Court of Appeals (No. 22-30087) granted the federal government's emergency motion for stay pending appeal of the February 11, 2022, preliminary injunction issued in Louisiana v. Biden, No. 21-cv-1074-JDC-KK (W.D. La.). As a result of the Fifth Circuit's order, the preliminary injunction is no longer in effect, pending resolution of the federal government's appeal of that injunction or a further court order. Among other things, the preliminary injunction enjoined the defendants in that case from "adopting, employing, treating as binding, or relying upon" the interim estimates of the social cost of greenhouse gases—which were issued by the Interagency Working Group on the Social Cost of Greenhouse Gases on February 26, 2021—to monetize the benefits of reducing greenhouse gas emissions. In the absence of further intervening court orders, DOE will revert to its approach prior to the injunction and present monetized benefits where appropriate and permissible under law.
‡ Costs include incremental equipment costs as well as installation costs.

4. References

Bass, F.M., 1969. A New Product Growth Model for Consumer Durables. Management Science 15, 215–227. https://doi.org/10.1287/mnsc.15.5.215
Coughlin, K., 2013. Projections of Full-Fuel-Cycle Energy and Emissions Metrics (No. LBNL-6025E). Lawrence Berkeley National Laboratory, Berkeley, CA.
Ecotope Inc., 2014. Residential Building Stock Assessment: Metering Study (No. E14-283). Northwest Energy Efficiency Alliance, Seattle, WA.
Edison Electric Institute, 2020. Typical Bills and Average Rates Report. Winter 2020, Summer 2020, Washington, D.C.
Energy Independence and Security Act of 2007, 2007.
Gerke, B.F., Ngo, A.T., Alstone, A.L., Fisseha, K.S., 2014. The Evolving Price of Household LED Lamps: Recent Trends and Historical Comparisons for the US Market (LBNL Report No. LBNL-6854E). Lawrence Berkeley National Laboratory, Berkeley, CA.
Gerke, B.F., Ngo, A.T., Fisseha, K.S., 2015. Recent Price Trends and Learning Curves for Household LED Lamps from a Regression Analysis of Internet Retail Data (No. LBNL-184075). Lawrence Berkeley National Laboratory, Berkeley, CA.
Guidehouse, Inc., 2020. Adoption of Light-Emitting Diodes in Common Lighting Applications. U.S. Department of Energy - Office of Energy Efficiency & Renewable Energy, Washington, D.C.
Houde, S., 2018. How consumers respond to product certification and the value of energy information. The RAND Journal of Economics 49, 453–477. https://doi.org/10.1111/1756-2171.12231
Kantner, C.L.S., Alstone, A.L., Ganeshalingam, M., Gerke, B.F., Hosbach, R., 2017. Impact of the EISA 2007 Energy Efficiency Standard on General Service Lamps (No. LBNL-1007090). Lawrence Berkeley National Laboratory, Berkeley, CA.
Kantner, C.L.S., Ganeshalingam, M., Hosbach, R., Zavodivker, L., 2021. Impact of the EISA 2007 Backstop Requirement on General Service Lamps (No. LBNL-2001438). Lawrence Berkeley National Laboratory, Berkeley, CA.
KEMA, Inc., 2010. Final Evaluation Report: Upstream Lighting Program: Volume 2 (No. CPU0015.02). California Public Utilities Commission, Energy Division, Sacramento, CA.
Navigant Consulting, Inc., 2017. 2015 U.S. Lighting Market Characterization (No. DOE/EE-1719). U.S. Department of Energy, Washington, D.C.
NEMA, 2019. NEMA comments DOE GSL Definitional NOPR [WWW Document]. URL https://www.regulations.gov/document?D=EERE-2018-BT-STD-0010-0329 (accessed 9.3.19).
NEMA, 2017. NEMA Comment response to the published Notification of data availability (NODA); request for information (RFI) [WWW Document]. URL https://www.regulations.gov/document/EERE-2017-BT-NOA-0052-0004 (accessed 9.8.21).
Spurlock, C.A., Houde, S., 2016. Minimum Energy Efficiency Standards for Appliances: Old and New Economic Rationales. Economics of Energy & Environmental Policy Volume 5.
U.S. Code Title 42—The Public Health and Welfare, 2010. , 42 U.S. Code 6291(30)(BB).
U.S. Department of Energy, 2019a. Energy Conservation Program: Energy Conservation Standards for General Service Incandescent Lamps: Final Rule, Federal Register.
U.S. Department of Energy, 2019b. Energy Conservation Program: Energy Conservation

Standards for General Service Incandescent Lamps: Final Rule, Federal Register.
U.S. Department of Energy, 2016. Energy Conservation Program: Energy Conservation Standards for General Service Lamps: Notice of Proposed Rulemaking and Announcement of Public Meeting, Federal Register.
U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy, 2021a. Energy Conservation Program: Backstop Requirement for General Service Lamps; Notification of Proposed Rule; Request for Comment, Federal Register.
U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy, 2021b. Energy Conservation Program: Definitions for General Service Lamps: Notice of Proposed Rulemaking and Announcement of Public Meeting, Federal Register.
U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy, 2019a. Energy Conservation Program: Definition for General Service Lamps: Final Rules; Withdrawal, Federal Register.
U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy, 2019b. Energy Conservation Program: Energy Conservation Standards for General Service Incandescent Lamps: Final Determination, Federal Register.
U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy, 2019c. Final Determination Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: General Service Incandescent Lamps.
U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy, 2017a. Energy Conservation Program: Energy Conservation Standards for General Service Lamps: Final Rule 82 Fed. Reg., 7276–7322.
U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy, 2017b. Energy Conservation Program: Energy Conservation Standards for General Service Lamps: Final Rule 82 Fed. Reg., 7322–7333.
U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy, 2016. Notice of Proposed Rulemaking Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: General Service Lamps. Washington, D.C.
U.S. Energy Information Administration, 2021. Annual Energy Outlook 2021 with Projections to 2050. Washington, D.C.
U.S. Environmental Protection Agency, 2022. Estimating the Benefit per Ton of Reducing Directly-Emitted PM2.5, PM2.5 Precursors and Ozone Precursors from 21 Sectors [WWW Document]. URL https://www.epa.gov/benmap/estimating-benefit-ton-reducing-directly-emitted-pm25-pm25-precursors-and-ozone-precursors (accessed 2.1.22).
Williams, A., Atkinson, B., Garbesi, K., Page, E., Rubinstein, F., 2012. Lighting Controls in Commercial Buildings. LEUKOS 8, 161–180. https://doi.org/10.1582/LEUKOS.2012.08.03.001
Wright, T.P., 1936. Factors affecting the cost of airplanes. Journal of Aeronautical Sciences 3, 122–128.
Yelle, L.E., 1979. The Learning Curve: Historical Review and Comprehensive Survey. Decision Sciences 10, 302–328. https://doi.org/10.1111/j.1540-5915.1979.tb00026.x

Appendix A. Emissions Intensity Factors

In this appendix DOE describes the methodology developed to calculate the emission intensity factors used to estimate emission reductions from the implementation of the backstop. The methodology is the same as the one used by DOE to estimate emissions reductions in energy conservation standards rulemakings using the most recent available version of EIA's AEO.

Power sector marginal emissions factors are calculated by looking at the difference, over the full analysis period, in fuel consumption and emissions across a variety of cases published with the AEO 2021. The analysis produces a set of emissions intensity factors that quantify the reduction in emissions of a given pollutant per unit reduction of fuel used in electricity generation for each of the primary fossil fuel types (coal, natural gas and oil). These factors are combined with estimates of the fraction of generation allocated to each fuel type, also calculated from AEO 2021 data, for the residential and commercial sector. Total power-sector emissions reductions are estimated by multiplying the intensity factors times the energy savings. Table A - 1 shows the time series of emissions intensity factors used in this analysis for the residential and commercial sectors in 5-year increments.

Table A - 1. Power Sector Emissions Factors in Million Short Tons per Quad Site Electricity Use

Sector	Pollutant	2025	2030	2035	2040	2045	2050
Residential	**CO_2**	4.63×10^{2}	4.12×10^{2}	3.78×10^{2}	3.60×10^{2}	3.43×10^{2}	3.29×10^{2}
	NOX	2.01×10^{-1}	1.73×10^{-1}	1.52×10^{-1}	1.39×10^{-1}	1.29×10^{-1}	1.22×10^{-1}
	SO_2	2.04×10^{-1}	1.77×10^{-1}	1.58×10^{-1}	1.57×10^{-1}	1.50×10^{-1}	1.44×10^{-1}
	Hg	1.19×10^{-6}	1.12×10^{-6}	1.01×10^{-6}	9.61×10^{-7}	9.06×10^{-7}	8.57×10^{-7}
	CH_4	3.65×10^{-2}	3.28×10^{-2}	2.97×10^{-2}	2.72×10^{-2}	2.50×10^{-2}	2.37×10^{-2}
	N_20	5.16×10^{-3}	4.64×10^{-3}	4.20×10^{-3}	3.83×10^{-3}	3.51×10^{-3}	3.32×10^{-3}
Commercial	**CO_2**	4.29×10^{2}	3.80×10^{2}	3.50×10^{2}	3.34×10^{2}	3.20×10^{2}	3.07×10^{2}
	NOX	1.80×10^{-1}	1.54×10^{-1}	1.36×10^{-1}	1.25×10^{-1}	1.15×10^{-1}	1.09×10^{-1}
	SO_2	1.70×10^{-1}	1.47×10^{-1}	1.30×10^{-1}	1.30×10^{-1}	1.23×10^{-1}	1.18×10^{-1}
	Hg	9.77×10^{-7}	9.15×10^{-7}	8.28×10^{-7}	7.85×10^{-7}	7.38×10^{-7}	6.97×10^{-7}
	CH_4	3.11×10^{-2}	2.78×10^{-2}	2.51×10^{-2}	2.30×10^{-2}	2.12×10^{-2}	2.00×10^{-2}
	N_20	4.36×10^{-3}	3.90×10^{-3}	3.52×10^{-3}	3.21×10^{-3}	2.94×10^{-3}	2.78×10^{-3}

Estimates for upstream emissions intensity factors uses an full-fuel cycle (FFC) accounting approach (Coughlin, 2013) and includes contributions from fuel combustion during extraction, processing and transportation of fuel, and "fugitive" emissions (direct leakage to the atmosphere) of CH_4 and CO_2. When demand for a particular fuel is reduced, there is a corresponding reduction in the upstream activities associated with production of that fuel (mining, refining etc.) These upstream activities also consume energy and therefore produce combustion emissions. The FFC accounting estimates the total consumption of electricity, natural gas and petroleum-based fuels in these upstream activities. The relevant combustion emissions factors are then applied to this fuel use to determine the total upstream emissions intensities from combustion, per unit of fuel delivered to the consumer. Table A - 2 shows the time series of upstream emissions factors used in this analysis in 5-year increments.

Table A - 2. Electricity Upstream Emissions Intensity Factors

Pollutant	Unit	2025	2030	2035	2040	2045	2050
CO_2	kg/MWh	26.1	24.3	23.0	22.8	23.0	22.3
NOX	g/MWh	344.7	322.4	307.7	305.6	310.7	302.3
SO_2	g/MWh	2.2	2.0	1.7	1.6	1.5	1.4
HG	g/MWh	4.0×10^{-6}	4.3×10^{-6}	3.6×10^{-6}	3.3×10^{-6}	2.9×10^{-6}	2.6×10^{-6}
CH_4	g/MWh	2222.2	2117.6	2021.1	2038.6	2055.2	2024.2
N_20	g/MWh	0.145	0.134	0.123	0.113	0.106	0.100