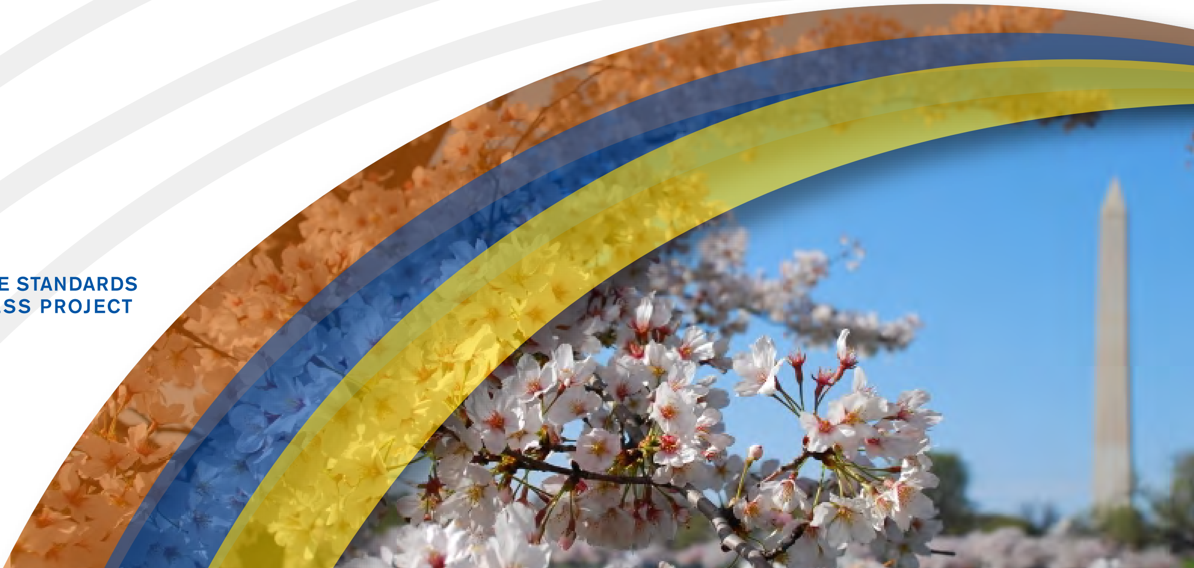
A POWERFUL PRIORITY:
HOW APPLIANCE STANDARDS CAN HELP MEET U.S. CLIMATE GOALS AND SAVE CONSUMERS MONEY

By Joanna Mauer and Andrew deLaski

RESEARCH REPORT
NOVEMBER 2020



ASAP | APPLIANCE STANDARDS AWARENESS PROJECT

ACEEE
American Council for an Energy-Efficient Economy

Contents

About the Authors

Joanna Mauer, technical advocacy manager of the Appliance Standards Awareness Project (ASAP), leads advocacy in a range of U.S. Department of Energy (DOE) regulatory proceedings for residential appliances and commercial equipment. She is the lead author of *Better Appliances: An Analysis of Performance, Features, and Price as Efficiency Has Improved* and *States Go First: How States Can Save Consumers Money, Reduce Energy and Water Waste, and Protect the Environment with New Appliance Standards*. Prior to joining ASAP, Joanna worked at the U.S. Environmental Protection Agency (EPA) and the Center for Integrative Environmental Research. She also served as a Peace Corps volunteer in the Dominican Republic. Joanna earned a master of public policy from the University of Maryland and a bachelor of science in civil and environmental engineering from Cornell University.

Andrew deLaski, ASAP's executive director, coordinates national advocacy efforts related to federal efficiency standards and advises state policymakers and advocates interested in state-level energy efficiency standards policy. He has coauthored and updated several national and state studies on savings potential from new appliance standards. He previously worked at the Consortium for Energy Efficiency and the State Public Interest Research Groups. Andrew earned a master of public policy from the University of Michigan and a bachelor of arts in economics from the University of Virginia.

Acknowledgments

This report was made possible through the generous support of the Tilia Fund and an anonymous donor. The authors gratefully acknowledge the external reviewers, internal reviewers, colleagues, and sponsors who supported this report. External expert reviewers included Alex Chase from 2050 Partners; Ben Evans from the Alliance to Save Energy; Pierre duVair and Nicholaus Struven from the California Energy Commission; Mel Hall-Crawford from the Consumer Federation of America; Steve Pantano from the Collaborative Labeling and Appliance Standards Program; Tim Ballo from Earthjustice; Rachel Levine and Eric Rubin from Energy Solutions; Charlie Harak from the National Consumer Law Center; Kevin Rose from National Grid; David Goldstein, Noah Horowitz, Lauren Urbanek, and Jackie Wong from the Natural Resources Defense Council; Dave Lis from Northeast Energy Efficiency Partnerships; Bing Liu and Louis Starr from the Northwest Energy Efficiency Alliance; Chris Corcoran from the New York State Energy Research and Development Authority; Rick Duke; Kathleen Hogan; Jim McMahon; and Roland Risser. External review and support do not imply affiliation or endorsement. Internal reviewers included Steven Nadel, Maggie Molina, Chris Perry, and Lowell Ungar from ACEEE, and Marianne DiMascio, Megan Geuss, and Kanchan Swaroop from ASAP. Last, we would like to thank Mary Robert Carter for managing the editing process, Mariel Wolfson for developmental editing, Keri Schreiner for copy editing, Roxanna Usher for proofreading, and Ben Somberg, Maxine Chikumbo, and Wendy Koch for their help in launching this report.

Suggested Citation

Mauer, J., and A. deLaski. 2020. *A Powerful Priority: How Appliance Standards Can Help Meet U.S. Climate Goals and Save Consumers Money*. Washington, DC: ACEEE; Boston: ASAP. aceee.org/research-report/a2001.

Executive Summary

KEY FINDINGS

- Updates to national appliance standards that could be completed within the next few years could reduce cumulative CO_2 emissions through 2050 by 1.5–2.9 billion metric tons, which is equivalent to the emissions of approximately 13–25 average-sized coal plants over that period.
- Potential annual utility bill savings for an average household are more than $100 in 2030, increasing to $230 in 2035 and nearly $350 in 2050.
- By 2050, peak electricity demand could be reduced by almost 90 gigawatts (GW), which is equivalent to about 13% of current total peak demand, allowing for faster decarbonization of the electric grid at a lower cost.
- New standards for residential water heaters, commercial and industrial fans, residential furnaces, and light bulbs could provide the greatest potential CO_2 reductions.

The path to net-zero-emissions buildings will include energy efficiency, decarbonizing the electric grid, and electrifying end uses such as space heating and water heating. Appliance standards are a key strategy within a suite of energy efficiency policies that could reduce U.S. CO_2 emissions by 50% by 2050.[1] Furthermore, appliance standards can allow for faster decarbonization of the electric grid at a lower cost and help ensure that electrification efforts do not overburden the grid, all while providing large savings for consumers and businesses.

Appliance standards are a tried and proven policy. Enacted by Congress over several decades on a bipartisan basis and periodically updated by the Department of Energy (DOE), they have driven huge declines in energy use. For example, since 1990, the average energy use of new refrigerators and central air conditioners has declined by 50%, and that of clothes washers by 70%. Cumulative consumer bill savings from existing standards will reach $2 trillion by 2030, with cumulative CO_2 reductions reaching nearly 8 billion metric tons (BMT).[2] Despite this tremendous progress, much more can be done.

For this report, we estimated potential savings from updated efficiency standards for 47 products. These standards could all be met using current technology and finalized in the next few years. We examined two scenarios—the Annual Energy Outlook (AEO) reference case and a low-carbon grid scenario—and found that updated standards could potentially

---

[1] S. Nadel and L. Ungar, *Halfway There: Energy Efficiency Can Cut Energy Use and Greenhouse Gas Emissions in Half by 2050* (Washington, DC: ACEEE, 2019).

[2] "Average Household Refrigerator Energy Use, Volume, and Price over Time," Appliance Standards Awareness Project, Accessed October 1, 2020, appliance-standards.org/sites/default/files/refrigerator_graph_Nov_2016.pdf; "Saving Energy and Money with Appliance and Equipment Standards in the United States," U.S. Department of Energy, October 2016, www.energy.gov/sites/prod/files/2016/10/f33/Appliance%20and%20Equipment%20Standards%20Fact%20Sheet-101416.pdf.

reduce annual CO_2 emissions by 57–105 million metric tons (MMT) per year by 2035 and 87–176 MMT/year by 2050. The potential cumulative CO_2 reductions through 2050 are 1.5–2.9 BMT, which is equivalent to the emissions of approximately 13–25 average-sized coal plants over that period.

For consumers and businesses, annual utility bill savings could reach $41 billion in 2035, increasing to $70 billion in 2050. Potential cumulative savings through 2050 are $1.1 trillion. The potential annual utility bill savings for an average household are more than $100 in 2030, increasing to $230 in 2035 and nearly $350 in 2050. The electricity savings from updated standards would translate to reductions in peak electricity demand of 47 GW in 2035 and 89 GW in 2050, which are equivalent to approximately 7% and 13% of current total peak demand, respectively. Reductions in peak demand can accelerate the retirement of fossil-fuel power plants, helping to meet electricity-sector decarbonization goals.

Figure ES1 shows the potential cumulative CO_2 reductions through 2050 for the top dozen products (and all others combined) based on the AEO reference case (left) and the low-carbon grid scenario (right). Updated standards for residential water heaters provide the greatest potential CO_2 reductions under both scenarios. Compared to the AEO reference case, the top dozen products under the low-carbon grid scenario include more products that save natural gas, including faucets, commercial water heaters, and commercial furnaces.

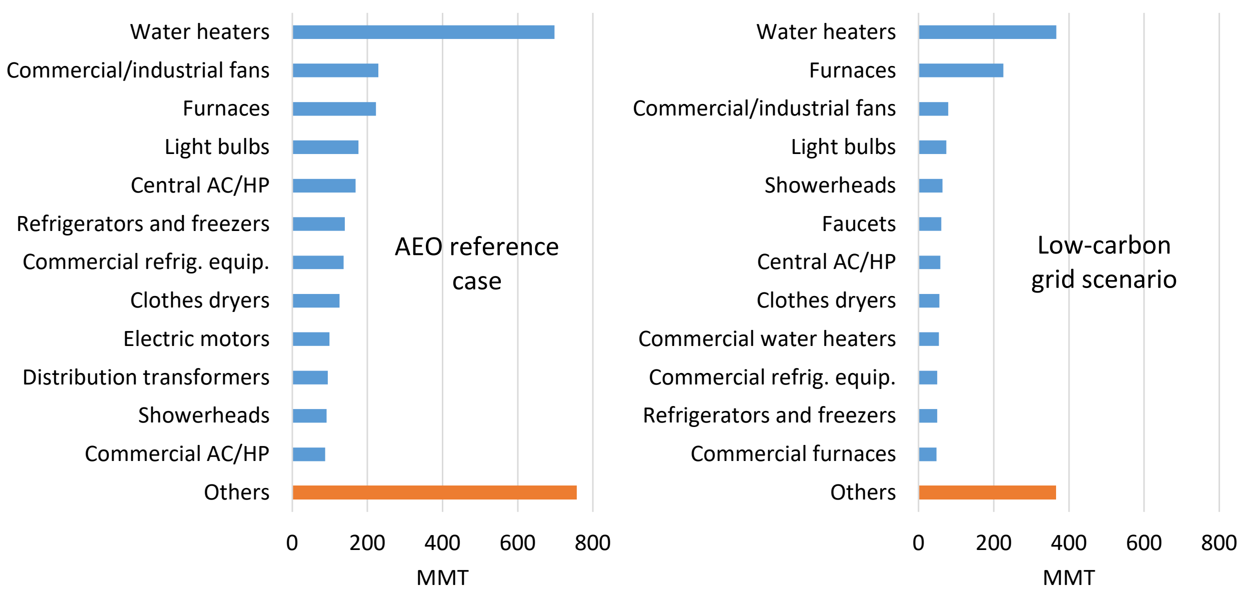


Figure ES1. Potential cumulative CO_2 reductions through 2050 for the top dozen products (and all others combined) based on the AEO reference case (left) and the low-carbon grid scenario (right)

Savings beyond these estimates could be achieved by adding new products (such as air purifiers, commercial light fixtures and lamps, computers, portable electric spas, and televisions) to the national appliance standards program and by broadening the scope of existing standards. Savings could be further increased by improving test procedures used to rate products' energy and water use to better represent actual usage.

Introduction

Limiting global warming to 1.5° C and minimizing the worst impacts of climate change will require reaching net-zero global CO_2 emissions by around 2050 (IPCC 2018). The path to net-zero-emissions buildings will include energy efficiency, decarbonizing the electric grid, and electrifying end uses such as space and water heating. Appliance standards are a key strategy within a suite of energy efficiency policies that could reduce U.S. CO_2 emissions by 50% by 2050 (Nadel and Ungar 2019). Furthermore, appliance standards can allow for faster decarbonization of the electric grid at a lower cost and help ensure that electrification efforts do not overburden the grid, all while providing large savings for consumers and businesses.

Appliance standards set minimum energy and/or water efficiency requirements for products such as refrigerators, clothes washers, water heaters, commercial air conditioners, and electric motors. Enacted by Congress over several decades on a bipartisan basis and periodically updated by the Department of Energy (DOE), they have driven huge declines in energy use. For example, since 1990, the average energy use of new refrigerators and central air conditioners has declined by 50%, while the energy use of clothes washers has declined by 70% (ASAP 2016; DOE 2016c). As products have become more efficient, performance has generally stayed the same or improved, manufacturers have continued to offer new product features to consumers, and, in many cases, prices have declined (Mauer et al. 2013).

We estimated that, in 2015, electricity and gas/heating oil savings from existing standards were equal to 13% and 4% of total electricity and gas/heating oil use, respectively (deLaski and Mauer 2017). These energy savings directly reduce CO_2 emissions. In addition, appliance standards lower electricity consumption, which reduces the required investment in clean energy, such as new wind and solar generation, to decarbonize the electric grid. Furthermore, as electrification efforts take off, appliance standards can help reduce the peak demand impacts of replacing existing gas- and oil-fired equipment with electric-powered appliances and equipment (such as heat pumps).

At the same time, appliance standards are already saving the average American family about $500 per year (deLaski and Mauer 2017); they also play a critical role in helping to ensure that savings from efficiency improvements reach the people who need them most. One in three U.S. households faces challenges in paying their energy bills or adequately heating and cooling their homes (EIA 2018b), and low-income, Black, Hispanic, and Native American households all face high energy burdens (Drehobl, Ross, and Ayala 2020). Additionally, one-quarter of all renters have extremely low incomes[1] (JCHS 2017). Because landlords have no incentive to purchase efficient appliances when the tenants pay the utility bills, renters are significantly less likely to have efficient appliances (Davis 2009). Appliance standards help to improve equity by reducing energy burdens and ensuring that all

[1] 30% or less of area medians.

products sold—including those purchased by landlords—meet a minimum level of efficiency.

As part of President Obama's 2013 Climate Action Plan, the administration set a goal of cumulatively reducing CO_2 emissions by 3 billion metric tons (BMT) by 2030 through efficiency standards (Executive Office of the President 2013). DOE met the carbon reduction goal by finalizing new or updated efficiency standards for more than 50 products, which will save consumers a total of $550 billion on their utility bills through 2030 (DOE 2017d). Taking into account all existing standards, cumulative utility bill savings will reach $2 trillion by 2030, and CO_2 reductions will reach nearly 8 BMT (DOE 2016c).

However, while tremendous progress has been made to improve appliance and equipment efficiency, huge opportunities to achieve additional emissions reductions and utility bill savings remain. In our 2016 report, *Next Generation Standards: How the National Energy Efficiency Standards Program Can Continue to Drive Energy, Economic, and Environmental Benefits*, we found that by 2050, updates to existing standards could reduce CO_2 emissions by 200 million metric tons (MMT) per year and save consumers and businesses $65 billion on their annual utility bills (deLaski et al. 2016).

Unfortunately, the Trump administration has failed to deliver any of these savings. Since the beginning of the Trump administration, DOE has not completed a single rulemaking to update appliance standards.[2] As of November 2020, DOE had missed 28 legal deadlines for reviewing appliance standards and 21 deadlines for updating test procedures (ASAP 2020). The administration has instead worked to undermine the appliance standards program by taking actions such as rolling back light bulb standards and revising the Process Rule[3] to make it more difficult for DOE to set standards. Appendix H lists and describes Trump administration actions that have undercut and harmed national efficiency standards; such actions should therefore be reversed.

In this report, we provide up-to-date estimates of the potential savings from appliance standards that could be adopted over the next few years. We also recommend new products that could be added to the national standards program to achieve additional savings. Finally, we provide recommendations for improving test procedures, which can help ensure that standards deliver the expected savings and enable additional savings.

---

[2] DOE published one rule in the Federal Register in 2017 and four in 2020, but these were all originally issued late in the Obama administration. After publishing one of the issued rules in 2017, the Trump administration withheld the others from official Federal Register publication. In late 2019, a federal court ruled that withholding the duly-issued rules had been illegal, and it ordered their Federal Register publication.

[3] The Process Rule describes the procedures, interpretations, and policies implemented by DOE in establishing new or amended efficiency standards.

Methodology for Estimating Potential Savings from Updated Standards

We estimated potential savings through 2050 from one round of updated standards for 47 products, almost all of which are currently subject to national efficiency standards.[4] [5] For two products in our analysis—circulator pumps[6] and commercial and industrial fans—there are currently no national standards. However, DOE initiated rulemakings for both products during the Obama administration and convened stakeholder working groups that developed consensus recommendations. For the remaining 45 products, the standard levels we evaluated represent updates to existing national standards.

> ***TECHNOLOGY EVOLUTION CONTINUES TO OPEN UP NEW SAVINGS OPPORTUNITIES***
>
> As part of each appliance standards rulemaking, DOE evaluates the maximum technologically feasible (max-tech) efficiency level based on all potential design options that are incorporated in commercially available products or working prototypes. However, technological progress ensures that max-tech is not a fixed level over time (McMahon 2012). For many products, there are models on the market with rated efficiencies that exceed the max-tech levels from the last DOE rulemaking. For example, for commercial refrigeration equipment, the max-tech levels in the 2014 DOE final rule for the most common refrigerators and freezers[7] represented energy savings of 19% and 9%, respectively, relative to the standard levels adopted, while the most-efficient models on the market today save more than 50% relative to those same standard levels. For commercial packaged air conditioners—that is, rooftop units, or RTUs—the max-tech level in the 2016 DOE final rule for large equipment[8] was 20.1 IEER,[9] while the most-efficient units on the market today have IEER levels above 22.

We estimated final rule dates and compliance dates for each of the potential standards based on statutory requirements for the timing of DOE reviews, and statutory lead times between publication of final rules and compliance dates, which are typically 3–5 years. For light bulbs (i.e., general service lamps, or *GSLs*), we assumed that DOE could reinstate the

---

[4] Existing DOE standards cover approximately 60 products. We excluded some products from our analysis because we lacked the information needed to estimate potential savings.

[5] By law, DOE must review each national appliance standard every six years and publish either a proposed rule to update the standard or a determination that no change is warranted (i.e., a "negative determination"). If DOE publishes a proposed update, a final rule is due two years later. Therefore, for many of the products in our analysis, DOE may issue multiple updated standards prior to 2050. For this report, however, we evaluated the potential savings from only a single update.

[6] Circulator pumps are commonly used as part of a domestic hot-water recirculation system or to circulate hot water provided by a boiler.

[7] Vertical closed solid, self-contained, medium temperature (VCS.SC.M) and vertical closed solid, self-contained, low temperature (VCS.SC.L).

[8] ≥135,000 Btu/h and <240,000 Btu/h.

[9] Integrated Energy Efficiency Ratio (IEER) is a measure of cooling efficiency, calculated as a weighted average of efficiency at four load points (25%, 50%, 75%, and 100% of full load).

standards with a compliance date of July 1, 2021.[10] For products with an existing DOE-published preliminary analysis and/or a proposed rule—that is, for furnaces, room air conditioners, and commercial water heaters—we assumed that the next administration could publish final rules in early 2022. We further assumed that the earliest that that administration could publish a final rule for any other products would be in early 2023. Except for GSLs, the estimated compliance dates range from 2025 to 2031.

For each product, we estimated potential savings from a new standard that could be met using current technology. For most products, we analyzed efficiency levels equivalent to the level of maximum technologically feasible, or *max-tech*, in DOE's most recent standards analysis. For three products (dehumidifiers, refrigerators, and room air conditioners), we analyzed efficiency levels equivalent to the ENERGY STAR Most Efficient 2020 levels, which are higher than the max-tech levels from the last DOE rulemakings for these products. For another six products—battery chargers, furnace fans, residential water heaters, automatic ice makers, commercial clothes washers, and commercial refrigeration equipment—we evaluated standard levels that can be met by existing models across a range of sizes/capacities and that exceed the last DOE rulemaking's max-tech levels. Finally, for the plumbing products (faucets, showerheads, toilets, and urinals), we analyzed efficiency levels equivalent to California's current standards. Tables D1 and D2 in Appendix D show the standard levels we evaluated for each of the products.

EMERGING TECHNOLOGIES

In this report, we estimated potential savings from updates to existing standards based on current technology. New technologies under development will likely enable significant additional savings beyond what we have estimated. For example, for clothes dryers, we evaluated savings from standard levels that would reduce energy use by 30%. Oak Ridge National Laboratory researchers are working with General Electric Appliances on an ultrasonic clothes dryer, which would use vibrations instead of heat to dry clothes. Ultrasonic clothes dryers are expected to be up to five times more efficient than conventional models while cutting drying time in half (DOE 2017c).

We are not necessarily endorsing the precise efficiency levels evaluated in this report for the next revision to each of the standards. By law, each new DOE standard must achieve the maximum improvement in energy efficiency that is technologically feasible and economically justified, and economic justification considers consumer and manufacturer impacts (42 US Code 6295(o)). In some cases, higher standards will make sense, while in others, lower ones may be appropriate. Nevertheless, given the historical record of technological progress for most products covered by standards, we believe that the standard

[10] Updated standards for light bulbs were scheduled to take effect January 1, 2020 and would have applied to a broader general service lamp (GSL) definition to cover all the common light bulbs used in homes. However, in 2019, the Trump administration rolled back the expanded definition for GSLs and blocked the updated standards from taking effect.

levels we evaluated provide a reasonable basis for estimating the savings potential of updates to existing standards.

We calculated CO_2 emissions reductions using average electricity carbon intensities for two scenarios: the 2020 Annual Energy Outlook (AEO) reference case, and a low-carbon grid scenario. To model the low-carbon grid scenario, we used the 2020 AEO carbon price scenario ($25 fee case).[11] We included the low-carbon grid scenario to show how the emissions reductions from improved efficiency standards change if significant decarbonization of the power sector is achieved in the coming decades. As figure 1 shows, in the AEO reference case, the carbon intensity of electricity declines by 28% between 2021 and 2050. In the low-carbon grid scenario, electricity carbon intensity decreases substantially between 2021 and 2030, and by 2050 is about 70% lower than in the reference case. We used these two scenarios to provide a range of the potential CO_2 reductions that would be achieved from standards that reduce electricity use.

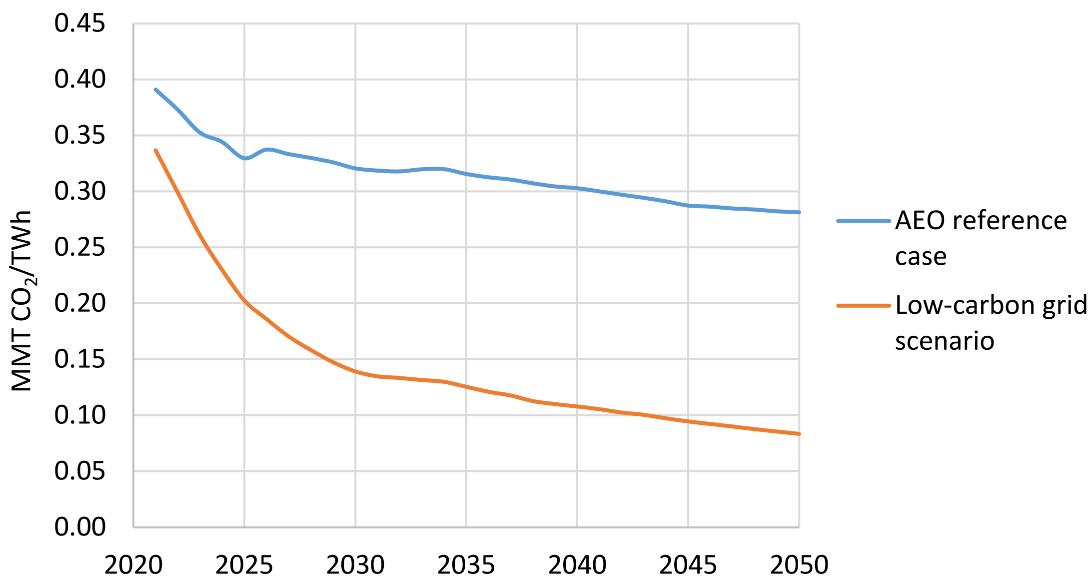


Figure 1. Annual electricity carbon intensity for the AEO reference case and the low-carbon grid scenario. *Source:* EIA 2020.

We calculated utility bill savings based on projected average electricity, natural gas, oil, and water and wastewater prices (EIA 2020; DOE 2016a), and we calculated peak demand reductions based on end-use load profiles (EPRI 2020; Wilson et al. 2014). We assumed that the electric grid's peak load occurs during the summer between 5 p.m. and 6 p.m.

We did not attempt to estimate the costs to meet the analyzed standard levels. For the products in our study, the most recent DOE analysis is up to a decade old, and in many cases the technology has changed significantly since it was analyzed. In addition, product

[11] The carbon price scenario ($25 fee case) assumes the implementation of an economy-wide carbon fee of $25 per metric ton of CO_2 beginning in 2021, with the fee increasing by 5% per year (in real dollars).

prices tend to decrease over time (Desroches et al. 2012). Therefore, we did not have data to reliably estimate current product costs. We also did not attempt to estimate potential economic savings beyond the direct utility bill savings from updated standards (e.g., from reduced peak electricity demand).

Finally, we did not attempt to incorporate the potential impacts of electrification. Electrification efforts could significantly change the fuel shares (electricity versus gas) used by new equipment for space heating, water heating, clothes drying, and cooking. An increase in sales of electric equipment would increase potential savings from updated standards for some products while decreasing savings for others. For example, for residential space heating, electrification would likely shift sales of gas furnaces to electric heat pumps. Under such a scenario, the potential savings from updated standards for gas furnaces would decrease while the potential savings from heat pump standards would increase.

Appendix D provides additional details about our methodology and assumptions.

Potential Carbon Reductions, Utility Bill Savings, and Peak Demand Reductions from Updated Efficiency Standards

We found that updates to national appliance standards could contribute substantially to reducing CO_2 emissions, while providing very large utility bill savings for consumers and businesses and significant peak demand reductions.

CARBON REDUCTIONS

As figure 2 shows, the potential CO_2 emissions reductions resulting from electricity, natural gas, and oil savings are substantial in both the low-carbon grid scenario and the AEO reference case. The annual emissions reductions increase over time as more of the existing stock of appliances and equipment is replaced with models meeting the new standard levels. The potential annual CO_2 reductions reach 57–105 MMT in 2035 and, by 2050, increase to 87–176 MMT. The CO_2 reductions from electricity savings are lower under the low-carbon grid scenario compared to the AEO reference case due to the electric grid's lower carbon intensity, while the CO_2 reductions from natural gas and oil savings are the same under both scenarios. The CO_2 reductions from gas and oil savings represent about 50% of the total cumulative reductions under the low-carbon grid scenario and about 25% of the total reductions under the AEO reference case.

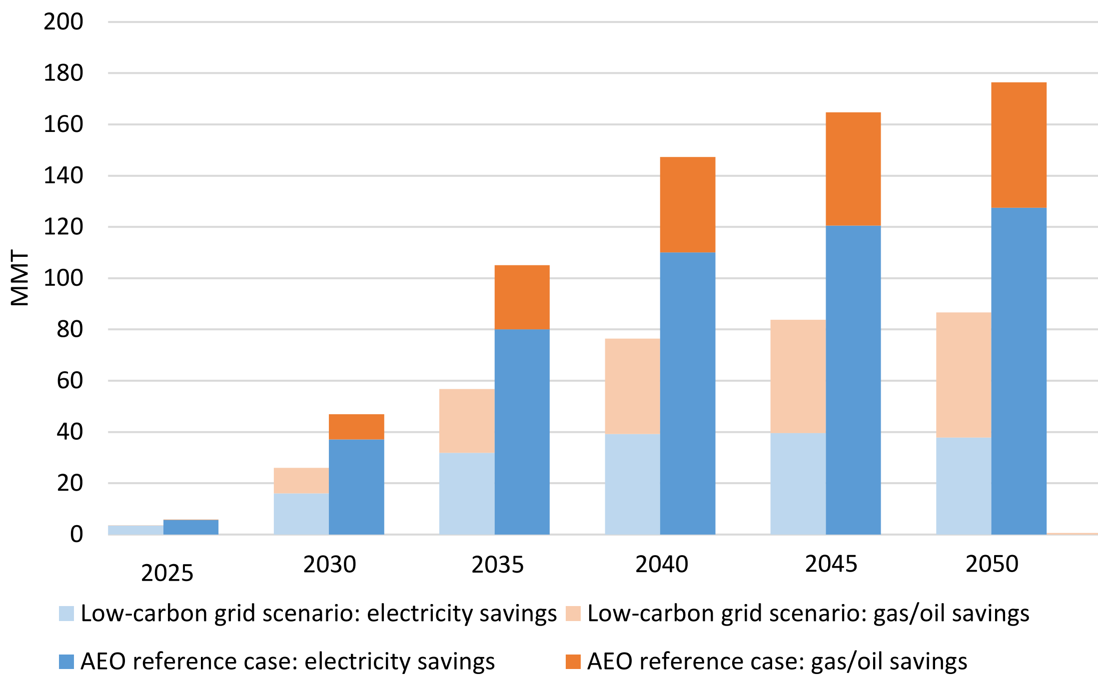


Figure 2. Potential annual CO_2 reductions from updated efficiency standards for the low-carbon grid scenario and the AEO reference case

In Appendix C, table C1 shows the values in figure 2 in tabular form.

Tables 1 and 2 show the potential annual CO_2 reductions in 2035 and 2050 and cumulative reductions through 2050 for the residential products and commercial and industrial products, respectively, for both the low-carbon grid scenario and the AEO reference case.[12] Table 3 shows the totals.[13] The total potential cumulative CO_2 reductions through 2050 are 1.5–2.9 BMT, which is equivalent to the emissions of approximately 13–25 average-sized coal plants over that period (EPA 2020c). The potential cumulative reductions are also equivalent to 3.5–7 months of current U.S. energy-related CO_2 emissions (EIA 2020).

[12] For residential and commercial boilers and furnaces and commercial water heaters, we accounted for the small increases in electricity use associated with higher efficiency levels for gas- and oil-fired equipment. Therefore, for these products, the CO_2 reductions under the low-carbon grid scenario are slightly larger compared to the AEO reference case because the impact of the increased electricity use is smaller in the low-carbon grid scenario.

[13] We accounted for the interaction effects among residential water heaters, clothes washers, dishwashers, faucets, and showerheads in calculating the total potential CO_2 reductions. The total potential reductions are thus smaller than the sum of the individual products.

Table 1. Potential annual CO_2 reductions in 2035 and 2050 and cumulative reductions through 2050 for residential products

	Annual CO_2 reductions in 2035 (MMT)		Annual CO_2 reductions in 2050 (MMT)		Cumulative CO_2 reductions through 2050 (MMT)	
Product	Low-carbon grid scenario	AEO reference case	Low-carbon grid scenario	AEO reference case	Low-carbon grid scenario	AEO reference case
Battery chargers	0.4	0.9	0.2	0.8	7.8	20.7
Boilers	0.9	0.9	2.9	2.9	33.0	32.2
Ceiling fans	0.6	1.4	0.7	2.3	13.9	39.7
Central air conditioners and heat pumps	2.0	5.1	3.7	12.6	57.8	168.6
Circulator pumps	0.4	1.0	0.3	1.1	7.7	21.8
Clothes dryers	2.2	4.6	2.8	7.0	55.3	126.1
Clothes washers	0.6	0.9	0.9	1.3	16.2	23.8
Cooking products	0.9	1.4	1.1	2.0	21.3	36.7
Dedicated-purpose pool pumps	0.5	1.2	0.3	1.0	7.9	22.0
Dehumidifiers	0.1	0.2	0.1	0.2	1.4	4.0
Direct heating equipment	0.1	0.1	0.2	0.2	3.4	3.4
Dishwashers	0.5	0.7	0.6	1.0	12.0	18.6
External power supplies	0.2	0.6	0.1	0.5	4.9	12.9
Faucets	3.0	4.2	2.8	4.2	60.3	86.4
Furnaces	6.7	6.6	17.0	16.8	225.3	222.9
Furnace fans	0.7	2.2	1.1	5.4	18.2	71.0
General service lamps	2.5	6.4	1.9	6.3	73.5	176.2
Microwave ovens	0.1	0.3	0.1	0.3	2.4	6.7
Miscellaneous refrigeration equipment	0.1	0.3	0.1	0.3	2.4	6.6
Pool heaters	0.4	0.6	0.5	0.9	9.9	15.6
Portable air conditioners	0.2	0.5	0.3	0.9	5.0	14.5
Refrigerators and freezers	2.0	5.0	2.4	8.1	49.4	139.6
Room air conditioners	0.9	2.3	0.6	2.1	17.0	46.4
Showerheads	3.1	4.4	3.0	4.4	63.6	91.1
Toilets	--	--	--	--	--	--
Uninterruptible power supplies	0.5	1.2	0.3	1.1	8.1	22.6
Water heaters	14.0	25.3	20.4	40.9	366.7	697.7

Table 2. Potential annual CO_2 reductions in 2035 and 2050 and cumulative reductions through 2050 for commercial and industrial products

	Annual CO_2 reductions in 2035 (MMT)		Annual CO_2 reductions in 2050 (MMT)		Cumulative CO_2 reductions through 2050 (MMT)	
Product	Low-carbon grid scenario	AEO reference case	Low-carbon grid scenario	AEO reference case	Low-carbon grid scenario	AEO reference case
Air compressors	0.2	0.6	0.5	1.6	7.5	22.2
Automatic ice makers	0.2	0.5	0.1	0.4	3.3	9.0
Beverage vending machines	0.04	0.1	0.04	0.1	0.8	2.3
Commercial boilers	0.8	0.8	2.6	2.6	29.0	28.9
Commercial clothes washers	0.2	0.2	0.2	0.3	3.9	5.0
Commercial furnaces	1.3	1.2	4.3	4.0	47.7	45.3
Commercial packaged air conditioners and heat pumps (RTUs)	1.0	2.5	2.2	7.4	29.9	87.7
Commercial refrigeration equipment	2.7	6.8	1.9	6.4	49.6	136.9
Commercial three-phase air conditioners and heat pumps	0.1	0.3	0.2	0.5	3.2	9.1
Commercial water heaters	2.2	2.2	2.8	2.7	53.8	53.5
Computer room air conditioners	0.3	0.9	0.4	1.2	8.2	23.0
Distribution transformers	1.2	3.1	2.1	7.0	33.0	94.5
Electric motors	1.5	3.7	1.6	5.4	35.3	99.3
Fans	2.8	6.9	5.5	18.5	78.7	228.9
Packaged terminal air conditioners and heat pumps	0.05	0.1	0.03	0.1	0.9	2.3
Pumps	0.3	0.8	0.3	1.0	6.8	19.2
Single-package vertical air conditioners and heat pumps	0.04	0.1	0.05	0.2	1.0	2.9
Small motors	0.2	0.5	0.1	0.4	3.2	9.0
Urinals	--	--	--	--	--	--
Water-source heat pumps	0.3	0.6	0.3	1.1	6.5	18.5

Table 3. Potential total annual CO_2 reductions in 2035 and 2050 and cumulative reductions through 2050

	Annual CO_2 reductions in 2035 (MMT)		Annual CO_2 reductions in 2050 (MMT)		Cumulative CO_2 reductions through 2050 (MMT)	
	Low-carbon grid scenario	AEO reference case	Low-carbon grid scenario	AEO reference case	Low-carbon grid scenario	AEO reference case
Residential total	41	73	62	115	1,093	1,980
Commercial/industrial total	15	32	25	61	402	898
Total	**57**	**105**	**87**	**176**	**1,496**	**2,878**

Appendix B shows CO_2 reductions for residential water heaters by product type. Appendix C shows annual CO_2 reductions in 2030 and 2040 by product and the totals.

Figure 3 shows the potential cumulative CO_2 reductions through 2050 for the top dozen products (and all others combined) based on the AEO reference case (left) and the low-carbon grid scenario (right).[16] Updated standards for residential water heaters provide the greatest potential CO_2 reductions under both scenarios.[17] Under the AEO reference case, other major energy-using products used in homes are also in the top dozen; these include furnaces, light bulbs, central air conditioners and heat pumps, refrigerators and freezers, clothes dryers, and showerheads.[18] Rounding out the top dozen are several major equipment types that are used in commercial buildings and factories—commercial and industrial fans; commercial refrigeration equipment; electric motors; and commercial packaged air conditioners and heat pumps (also known as *rooftop units*, or RTUs)—and distribution transformers, which handle virtually all the electricity consumed in the United States. While the other 35 products in our analysis each represent smaller potential CO_2 reductions, their combined potential is roughly equivalent to the savings from water heaters.

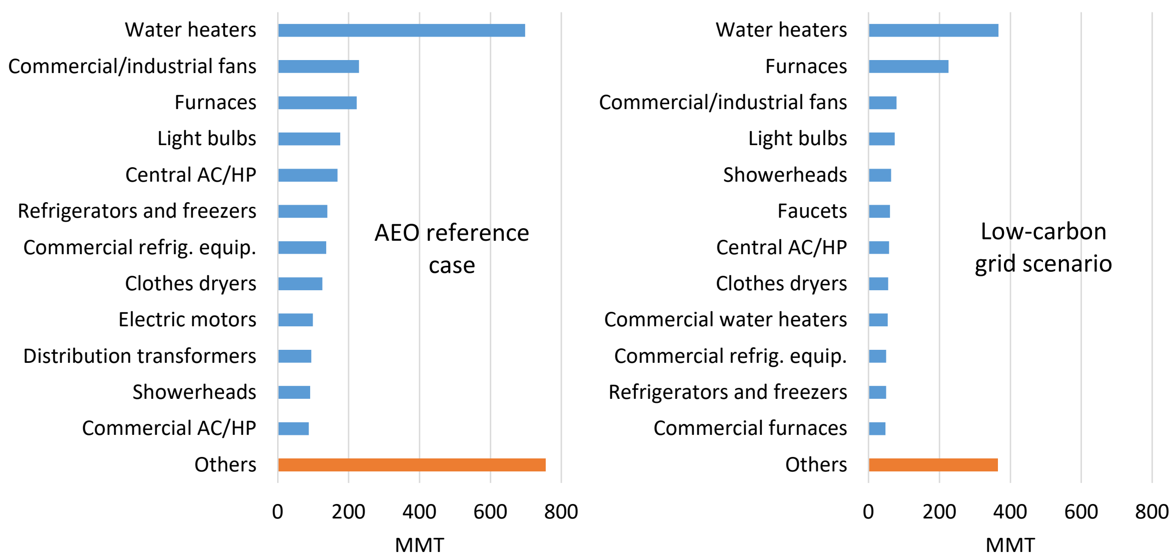


Figure 3. Potential cumulative CO_2 reductions through 2050 for the top dozen products (and all others combined) based on the AEO reference case (left) and the low-carbon grid scenario (right)

[16] The values in figure 3 do not include the interaction effects among residential water heaters, clothes washers, dishwashers, faucets, and showerheads.

[17] For residential water heaters, the CO_2 reductions from electricity savings represent 73% and 49% of the total potential cumulative CO_2 reductions under the AEO reference case and the low-carbon grid scenario, respectively.

[18] In addition to saving water, more-efficient showerheads save a significant amount of energy by reducing hot-water consumption.

Under the low-carbon grid scenario, the CO_2 reductions from electricity savings decrease relative to the AEO reference case, while the CO_2 reductions from natural gas and oil savings remain the same. The top dozen products under the low-carbon grid scenario thus include more products that save natural gas, including faucets, commercial water heaters, and commercial furnaces.

UTILITY BILL SAVINGS

Figure 4 shows the potential annual utility bill savings from updated efficiency standards, broken down into electricity bill savings, natural gas and oil bill savings, and water and wastewater bill savings. The potential annual savings for consumers and businesses are $41 billion in 2035, increasing to $70 billion by 2050, with electricity bill savings making up about 70% of the total.[19] Potential cumulative savings through 2050 are $1.1 trillion. Figure 4 also shows an average household's annual utility bill savings from improved standards: more than $100 in 2030, increasing to $230 in 2035 and nearly $350 in 2050. These savings are in addition to the $500 per year that an average household is already saving from existing standards (deLaski and Mauer 2017).

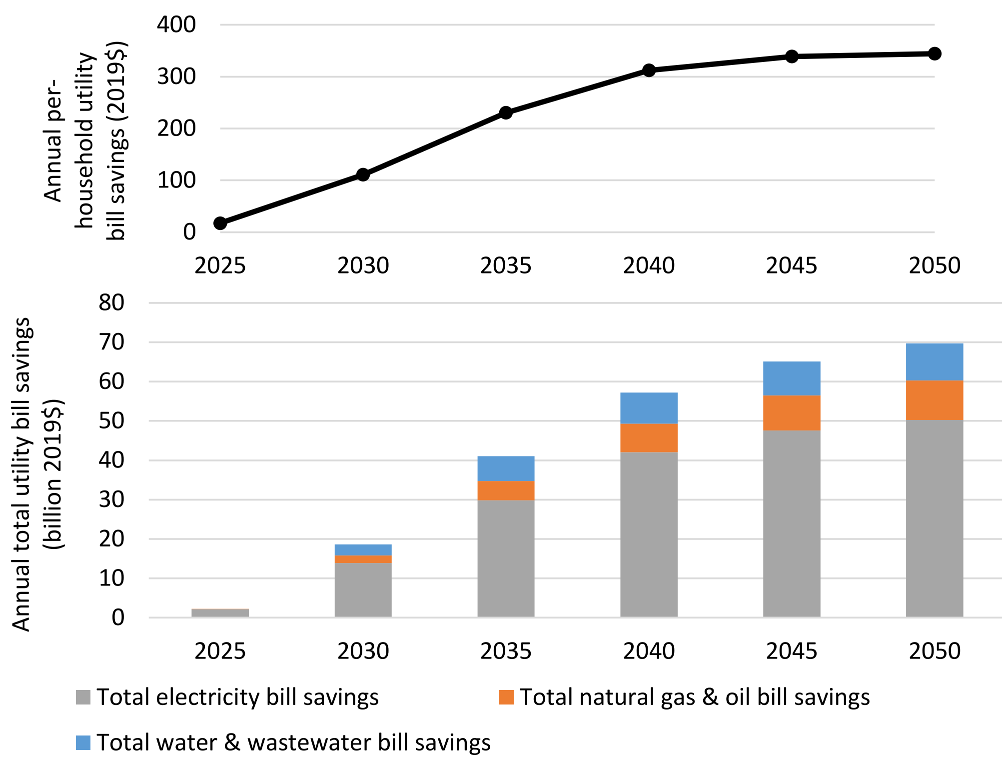


Figure 4. Potential annual total utility bill savings and average per-household utility bill savings from updated efficiency standards

[19] We calculated electricity bill savings using the AEO reference case. Total utility bill savings would be about 10% greater under the low-carbon grid scenario, which has higher electricity prices.

Figure 5 shows the breakdown of average per-household savings in 2035 and 2050.[20] The products that contribute the most to the per-household savings are water heaters, faucets, showerheads, light bulbs, central air conditioners and heat pumps, refrigerators and freezers, clothes dryers, and furnaces. Faucets and showerheads provide significant water and wastewater bill savings in addition to energy bill savings.

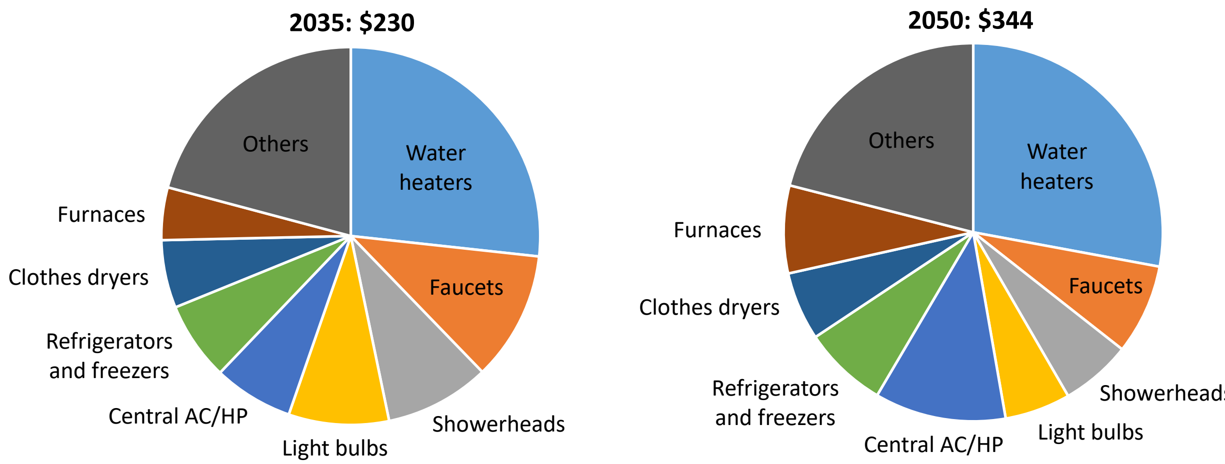


Figure 5. Breakdown of potential average per-household utility bill savings in 2035 and 2050 from updated efficiency standards

PEAK DEMAND REDUCTIONS

Figure 6 shows the potential annual peak electricity demand reductions from updated efficiency standards. Potential peak demand reductions are 47 gigawatts (GW) in 2035, increasing to 89 GW in 2050—equivalent to about 7% and 13% of current total peak demand, respectively (EIA 2019). These peak demand savings would allow for faster, cheaper decarbonization of the electric grid by allowing existing fossil-fuel power plants to be retired sooner and reducing the investment required in clean energy, such as new wind and solar generation. Delaying or avoiding marginal investments in new generation, as well as in storage, transmission, and distribution infrastructure, can help moderate electricity rates and save consumers money.

---

[20] The values in figure 5 incorporate the interaction effects among residential water heaters, clothes washers, dishwashers, faucets, and showerheads.

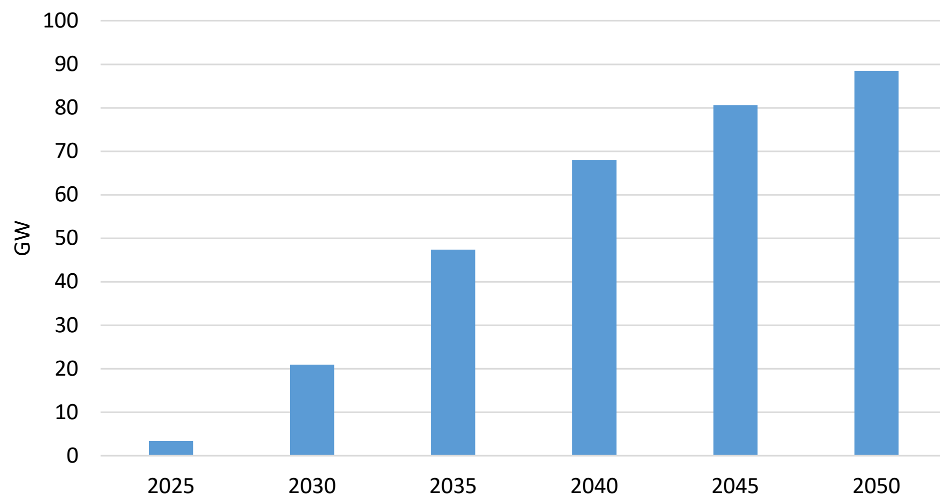


Figure 6. Potential annual peak demand reductions from updated efficiency standards

Figure 7 shows the products that would contribute the most to the peak demand reductions in 2035 and 2050.[21] Air conditioners provide the largest peak demand reductions since much of their operation coincides with peak demand periods. Products whose consumption is more evenly distributed over the year—such as electric water heaters, light bulbs, commercial and industrial fans, and residential and commercial refrigerators and freezers—also provide significant peak demand reductions due to their large potential electricity savings.

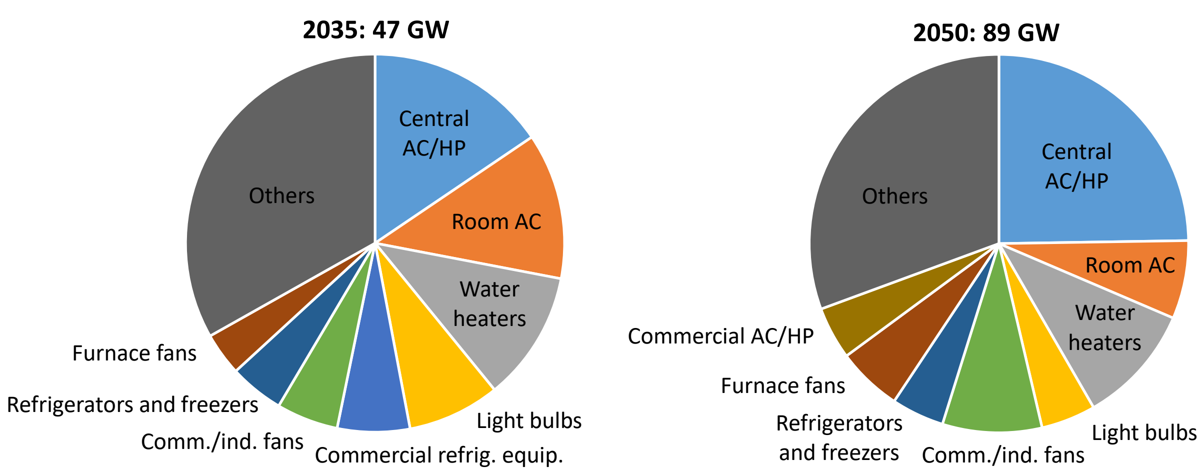


Figure 7. Breakdown of potential peak demand reductions in 2035 and 2050 from updated efficiency standards

[21] The values in figure 7 incorporate the interaction effects among residential water heaters, clothes washers, dishwashers, faucets, and showerheads.

Appendix A shows the potential annual energy, water, and utility bill savings and peak demand reductions in 2035 and 2050 and the cumulative primary energy, water, and utility bill savings through 2050 by product and the totals. Appendix B shows savings for residential water heaters by product type.

TOP OPPORTUNITIES FOR CARBON REDUCTIONS

The paragraphs below discuss the 15 products that represent the top opportunities for reducing CO_2 emissions based on the AEO reference case and/or the low-carbon grid scenario (see figure 3). The products are listed in order of potential cumulative CO_2 reductions through 2050 under the AEO reference case.

Water Heaters

Water heating represents about 14% of residential primary energy consumption (EIA 2020). Residential water heater efficiency is described by a metric called *uniform energy factor* (UEF), which represents a water heater's performance over a 24-hour period.[22] The current standards are 0.92 UEF for the most common electric storage water heaters and 0.64 UEF for the most common gas storage water heaters.[23] Heat pump technology can reduce electric water heater energy consumption by more than 60%, while condensing technology can reduce gas water heater energy consumption by more than 20%. We analyzed standard levels for electric and gas storage water heaters of 3.55 UEF and 0.83 UEF, respectively, which can be met by the most-efficient products currently on the market.

Commercial and Industrial Fans

Commercial and industrial fans are used in various applications, including commercial building HVAC systems, commercial kitchen exhaust systems, and agricultural ventilation. A fan's efficiency depends enormously on the specific application, and a fan with a very efficient design can perform very inefficiently in certain applications. Improved fan selection for a given application therefore represents the most significant opportunity for energy savings for fans. In 2011, DOE initiated a rulemaking for fans and, in 2015, convened a stakeholder working group that developed a set of consensus recommendations,[24] but DOE has yet to publish a proposed rule. We analyzed standard levels for fans that would require about 70% of existing fan selections to shift to more-efficient options for the given application.

Furnaces

Space heating represents approximately one-third of residential primary energy consumption, and approximately 40% of homes are heated using gas furnaces (EIA 2020, 2018a). Furnace efficiency is measured by an *annual fuel utilization efficiency* (AFUE) metric, which is the ratio of the furnace's annual heat output compared to the total energy

---

[22] Prior to 2015, the efficiency metric for water heaters was *energy factor* (EF).

[23] 50-gallon electric water heaters with a medium draw pattern, and 40-gallon gas water heaters with a high draw pattern.

[24] The consensus recommendations did not include recommended standard levels.

consumed. The current standard is 80 AFUE for the most common type of gas furnaces (non-weatherized). DOE has not made a meaningful update to the furnace standards since Congress established the first national standards in 1987.[25] Condensing technology can significantly improve furnace efficiency by extracting additional heat by condensing the water vapor in the flue gases; about half of all furnaces sold today use condensing technology (DOE 2016d). We analyzed a standard level of 98 AFUE, which can be met by the most-efficient condensing furnace models currently on the market.

General Service Lamps

Congress established the first standards for GSLs as part of the Energy Independence and Security Act (EISA) of 2007. The initial standards were phased in between 2012 and 2014; they required savings of 25–30% for the most common type of light bulb (the pear-shaped A-type lamps) relative to traditional incandescent bulbs. Updated standards were scheduled to take effect January 1, 2020. These standards, which could be met by light emitting diodes (LEDs) and compact fluorescent lamps (CFLs), would have achieved savings of about 65% relative to traditional incandescent bulbs. Further, in 2017, DOE expanded the GSL definition such that these updated standards would have applied to all common light bulbs used in homes, including reflector, candelabra, and globe lamps. However, in 2019, the Trump administration rolled back the expanded definition for GSLs and blocked the updated standards from taking effect. We evaluated the savings from reinstating the light bulb standards, including the expanded definition, with a compliance date of July 1, 2021.[26]

Central Air Conditioners and Heat Pumps

Space cooling represents about 10% of residential primary energy consumption, and about two-thirds of homes have central air-conditioning (EIA 2020, 2018a). The cooling efficiency of central air conditioners and heat pumps is described by a metric called *seasonal energy efficiency ratio* (SEER), which represents efficiency over a cooling season. The current standards are SEER 14 for all heat pumps and for most air conditioners installed in Southern states, and SEER 13 for most air conditioners installed in the North. New standards, which will take effect in 2023, will raise these levels to SEER 15 and SEER 14, respectively.[27] We analyzed standard levels of SEER 17 and SEER 19 for the most common air conditioners and heat pumps, respectively, which are the max-tech levels from the last DOE rulemaking.[28]

---

[25] A 2007 final rule, which took effect in 2015, updated the standard for non-weatherized gas furnaces from 78 AFUE to 80 AFUE, but 99% of furnace sales already met the higher level. A subsequent final rule published in 2011 would have required a 90 AFUE standard in northern states and maintained the 80 AFUE in southern states, but a lawsuit brought by gas industry plaintiffs resulted in vacatur on procedural grounds.

[26] Pending litigation could reinstate the light bulb standards (*New York v. DOE*, 2d Cir. No. 19-3652; *NRDC v. DOE*, 2d Cir. No. 20-699).

[27] The 2023 standards for cooling efficiency are based on a new metric, SEER 2, which has values that are slightly lower than the equivalent SEER values. The SEER 2 metric more accurately reflects the ducting conditions in homes.

[28] Most central air conditioners and heat pumps are split-system equipment, where the compressor and condenser are located outdoors, and the evaporator is indoors. For split-system air conditioners, we analyzed the max-tech level for coil-only units, which are sold without a supply fan (and typically are installed in homes with

These standard levels would reduce the energy consumption of central air conditioners and heat pumps by 10–15% relative to the 2023 standards and could be met using technologies such as staged and variable-speed compressors, improved heat exchangers, and more-efficient fans and fan motors.

Refrigerators and Freezers

Since the first national standards for refrigerators took effect in 1990, average refrigerator energy use has decreased by more than 50% (ASAP 2016). However, there are still opportunities to significantly reduce refrigerator and freezer energy use. We analyzed standard levels based on the ENERGY STAR Most Efficient 2020 specification, which represents energy savings of 20% and 15% for standard-size refrigerators and freezers, respectively, relative to the current standards.[29] Refrigerator and freezer efficiency can be improved using technologies such as variable-speed compressors and vacuum-insulated panels.

Electrification and Demand Flexibility

Roadmaps for deep carbon reductions include replacing gas- and oil-fired appliances such as water heaters and furnaces with efficient alternatives powered by clean electricity, and shifting electric appliances' demand to times when excess clean, renewable power is available (Gowrishankar and Levin 2017; Naimoli and Ladislaw 2020). To date, appliance standards have not been designed with these goals in mind. While increasing standards for gas products may shift some consumers to electric choices as relative product prices change, the effect is indirect. Future standards could require electric and gas products to meet the same requirements, potentially creating pathways to phase down fossil-fuel appliances. They could also include requirements that products include grid-flexibility features that enable them to respond to signals from the power grid. But the current legal framework for federal appliance standards—which dates from the 1970s and 1980s—may not be adequate for broad consideration of standards that address either electrification or demand flexibility. Thus, Congress might have to first amend the appliance standards law.

Commercial Refrigeration Equipment

Commercial refrigeration equipment includes the refrigerators and freezers used in supermarkets, convenience stores, restaurants, and commercial kitchens. We analyzed standard levels for this equipment based on levels that can be achieved by the most-efficient models currently on the market across a range of sizes. For the most common equipment categories, the standard levels would reduce energy consumption by 15–65% relative to the current standards. The efficiency of commercial refrigeration equipment can be improved

---

a furnace that already has a supply fan), since these represent the most common configuration sold. The max-tech levels for heat pumps are higher than those for air conditioners since heat pumps are typically sold with a supply fan and therefore can incorporate additional efficiency improvements.

[29] ENERGY STAR Most Efficient 2020 does not include a percentage savings requirement for top-mount refrigerator-freezers. We analyzed the same efficiency level (20% savings) for top-mounts as for other standard-size refrigerator-freezers. Those savings are equivalent to the efficiency level of the most-efficient top-mount model available as of April 2020.

using technologies such as improved heat exchangers, vacuum-insulated panels, and alternative refrigerants such as propane.

Clothes Dryers

Electric clothes dryers consume about as much energy as a typical refrigerator, clothes washer, and dishwasher combined (Horowitz et al. 2014). However, until recently, there had been little improvement in clothes dryer efficiency. The first ENERGY STAR specification for clothes dryers took effect on January 1, 2015 and requires a 20% reduction in energy use compared with conventional models (EPA 2015). ENERGY STAR also offered an Emerging Technology Award in 2014 for clothes dryers that provide savings of approximately 40% in their most efficient setting (EPA 2014). LG and Whirlpool both introduced heat pump clothes dryers in 2014 that meet the Emerging Technology Award specification. We assumed that clothes dryers meeting this specification would achieve savings of 30% on average in the field and analyzed standard levels for both electric and gas dryers that represent 30% savings relative to the current standards.

Electric Motors

Almost 70% of the electricity consumed in the industrial sector is used to power systems driven by electric motors (Scheihing et al. 2012), which commonly drive pumps, fans, compressors, mechanical processes, and material-handling equipment. The current standards, which took effect in 2016, apply to three-phase induction motors from 1 to 500 horsepower and are equivalent to the NEMA Premium[30] (or IE3) efficiency levels. We analyzed standard levels for electric motors that are roughly equivalent to the Super Premium (IE4) levels. These efficiency levels, which would reduce energy losses by about 15%, can be met by more-efficient conventional induction motors as well as by advanced motor technologies such as permanent magnet, switched reluctance, and synchronous reluctance motors.

Distribution Transformers

Distribution transformers reduce electricity voltage from the high voltage used in electricity distribution lines to the lower voltages used by equipment in homes, businesses, and factories. Since virtually all the electricity consumed in the United States passes through distribution transformers, even small improvements in transformer efficiency can yield large energy savings. Energy losses in transformers can be significantly reduced by using amorphous metal for the transformer steel core. We analyzed standards for distribution transformers based on amorphous metal, which would reduce energy losses by 40–70% relative to the current standards.

Showerheads

The national standards for showerheads have not been updated since 1992. The current standards require that showerheads use no more than 2.5 gallons per minute (gpm). California, Hawaii, and Washington adopted standards in recent years for showerheads that set the maximum flow rate at 1.8 gpm. We analyzed standards for showerheads that are

[30] NEMA Premium was established by the National Electrical Manufacturers Association.

equivalent to these state standards. In addition to saving water, more-efficient showerheads save a significant amount of energy by reducing hot-water consumption.

Commercial Packaged Air Conditioners and Heat Pumps

RTUs are typically used to cool small- to mid-sized commercial buildings such as schools, restaurants, big-box stores, and small office buildings. Many commercial packaged air conditioners also contain a gas heating section (i.e., a commercial furnace). An RTU's cooling efficiency is described by an *integrated energy efficiency ratio* (IEER) metric, which is calculated as a weighted average of efficiency at four load points (25%, 50%, 75%, and 100% of full load). Updated RTU standards that will take effect in 2023 will raise the IEER levels to 14.8, 14.2, and 13.2 for small, large, and very large air conditioners, respectively.[31] We analyzed standard levels of 21.5, 20.1, and 15.6 IEER for small, large, and very large air conditioners, respectively, which are the max-tech levels from the last DOE rulemaking and can be met by products currently on the market across the range of cooling capacities.

Faucets

As with showerheads, the national standards for faucets have not been updated since 1992. Current standards require that faucets use no more than 2.2 gpm. California, Hawaii, and Washington adopted standards in recent years that set the maximum flow rate at 1.2 gpm for lavatory faucets and 1.8 gpm for kitchen faucets.[32] We analyzed standards for faucets that are equivalent to these state standards. Like showerheads, in addition to saving water, more-efficient faucets save a significant amount of energy by reducing hot-water consumption.

Commercial Water Heaters

Commercial water heaters are used in places such as restaurants, hospitals, schools, and office buildings. DOE has not updated the standards for commercial water heaters in almost 20 years. Gas-fired commercial water heater efficiency is described by a *thermal efficiency* metric, and current minimum thermal efficiency levels are 80%. We analyzed standard levels for gas-fired commercial water heaters of 96–99% thermal efficiency, depending on the equipment type, which could be met using condensing technology.

Commercial Furnaces

Almost all commercial furnaces are part of RTUs. An RTU that includes a commercial furnace can provide both cooling and heating to a building. Commercial furnace efficiency is also described by a thermal efficiency metric. Updated standards for commercial furnaces that will take effect in 2023 will raise the thermal efficiency levels to 81% and 82% for gas- and oil-fired furnaces, respectively. As with residential furnaces, condensing technology can

---

[31] The IEER levels are for equipment with "electric resistance heating or no heating." The cooling capacity ranges are as follows: small equipment is ≥65,000 Btu/h and <135,000 Btu/h; large is ≥135,000 Btu/h and <240,000 Btu/h; and very large is ≥240,000 Btu/h and <760,000 Btu/h.

[32] Colorado and Vermont also adopted the same standards for kitchen faucets.

significantly improve the efficiency of commercial furnaces. We analyzed standard levels of 92% thermal efficiency for both gas- and oil-fired furnaces.

New Products That Could Add to Potential Savings

DOE has limited authority to set standards for new product categories. For consumer products, DOE may set standards for a new product if the average per-household annual energy consumption is at least 150 kWh and the aggregate national annual energy consumption is at least 4.2 TWh. For commercial and industrial equipment, DOE may set new standards for a list of specific equipment categories outlined in the Energy Policy and Conservation Act. While not an exhaustive list, the following paragraphs describe new products that could be added to the national standards program to deliver additional savings. We did not attempt to estimate the potential savings from setting standards for these products.

AIR PURIFIERS

Air purifiers (or room air cleaners) are portable units that remove fine particles, such as dust and pollen, from indoor air. Almost five million air purifiers are sold in the United States each year; as of 2019, only 43% of shipments met the ENERGY STAR specification (EPA 2020b). Air purifiers that do not meet the ENERGY STAR specification typically use more than 500 kWh per year on average (Xcel Energy 2015). ENERGY STAR Version 1.2 specifies a minimum Clean Air Delivery Rate (CADR) per watt (CADR/Watt) for dust of 2.0., while the most-efficient air purifiers certified to ENERGY STAR have CADR/Watt values of more than 10.0 (EPA 2011; EPA 2020a).

COMMERCIAL LIGHT FIXTURES AND LAMPS

Federal law authorizes DOE to establish standards for electric lights (42 US Code 6311). In the United States, most office spaces and many other commercial buildings are primarily lit by linear fluorescent light fixtures, typically using four-foot tubes. LED replacements are now widely available for fluorescent lighting fixtures and can provide significant savings. European Union standards that eliminate T8 fluorescent lamps become effective in 2023. European mercury regulations may accelerate this phaseout of fluorescent lamps to 2021 and extend to T5 lamps (Bennich and Scholand 2019).

EXPANDING SCOPE WITHIN CURRENTLY REGULATED PRODUCTS

In addition to setting standards for new products, additional savings could be achieved by expanding the scope within currently regulated product categories. For example, the current standards for motors apply only to polyphase induction motors and capacitor-start motors; they do not cover inefficient motor types (e.g., split phase and permanent split capacitor motors) or advanced, high-efficiency motor technologies such as permanent magnet, switched reluctance, and synchronous reluctance motors. Similarly, the current standards for commercial and industrial pumps apply only to clean water pumps, while other pump types (such as wastewater pumps) are not subject to any standards.

COMPUTERS AND MONITORS

Each year, U.S. consumers and businesses buy approximately 65 million desktop and portable computers and about 20 million monitors (Mauer, deLaski, and DiMascio 2017). California established the first efficiency standards for computers and monitors in 2016. Vermont, Washington, and Colorado subsequently adopted the California standards. The typical home desktop computer and monitor together use about 320 kWh per year, while portables (laptops, notebooks, and netbooks) use just 42 kWh (Urban et al. 2017). By applying some of the same energy-saving approaches used in portables to desktops, the energy consumption of desktops could be substantially reduced without compromising computer performance.

PORTABLE ELECTRIC SPAS

Portable electric spas are free-standing hot tubs that are electrically heated. More than five million U.S. households have portable electric spas (APSP 2016). Typical portable electric spas waste a significant amount of energy through heat loss when the spa is not being used. California adopted the first standards for portable electric spas in 2004, and updated California standards took effect in 2019. Several other states also have standards. The most-efficient spas use less than half the energy of a spa just meeting the current California standards (CEC 2020).

TELEVISIONS

Federal law authorizes DOE to establish standards for televisions (42 U.S. Code 6295(l)(3)), but DOE has never done so. In 2009, California set the first state-level television standards, which Connecticut and Oregon subsequently copied. Since then, ENERGY STAR has completed several revision cycles, with the latest version taking effect in 2019. Nearly every U.S. household has a television, with most households owning two or more. The primary television in a home uses about 200 kWh per year, and the average unit uses about 120 kWh per year (Urban et al. 2017). Existing energy-saving technology could reduce television energy use by about 10% (N. Horowitz, NRDC, pers. commun., 2020).

Recommendations for Improving Test Procedures

For many products, improving test procedures can be as important to achieving energy savings as setting new standards. In general, test procedure improvements focus on better reflecting how products actually perform in homes and businesses, which can help ensure that standards deliver the expected savings and enable significant additional savings.

AN EXAMPLE OF HOW TEST PROCEDURE CHANGES CAN DELIVER ADDITIONAL SAVINGS

Until recently, the test procedure for commercial rooftop air conditioners measured performance only at full load,[33] even though this equipment operates mostly at part load in the field. Measuring performance only at full load meant that the efficiency ratings did not provide an adequate relative ranking of efficiency. For example, two units with the same full-load efficiency rating might have significantly different part-load efficiency. In this case, the unit with improved part-load efficiency would have consumed less energy in the field, but the previous test procedure would not have reflected this benefit. In addition, by not capturing part-load performance, the test procedure failed to capture technologies that can provide significant energy savings—including staged and variable-speed compressors and fan speed control. The shift to a test procedure that captures part-load performance enabled the 2016 final rule for commercial rooftop air conditioners to capture very large additional savings through improved part-load performance. The new standards will save more energy than any other product standard that DOE has established.

While not an exhaustive list, Appendix G outlines examples of potential improvements to test procedures for individual products. The paragraphs below describe some cross-cutting test procedure recommendations. We did not attempt to estimate the potential savings from test procedure improvements.

CROSS-CUTTING RECOMMENDATIONS

Capturing a range of load points

Many test procedures measure performance at just a single load point, and yet the equipment operates at a wide range of load points in the field. For example, when measuring cooling efficiency, test procedures for some air-conditioning and heat pump equipment use EER, which measures performance only at full load. Similarly, the efficiency metrics for electric motors, small electric motors, and commercial boilers reflect only full-load performance, yet such equipment rarely operates at full load in actual use. Further, increases in efficiency at full-load conditions may not always yield comparable gains at part-load conditions. We recommend that DOE consider amendments to a range of test procedures to capture part-load performance.

Capturing the performance of air-conditioning equipment under varying loads

Current test procedures for air-conditioning equipment are based on steady-state performance, which does not reflect how equipment operates in the field. In actual use, single-speed air-conditioning equipment will cycle on and off to maintain the temperature in the space. However, the associated cycling losses are not captured by many test procedures, which are generally based on full-load tests (i.e., where the unit is running

[33] *Full load* refers to an air conditioner's maximum cooling capacity; full-load efficiency is measured at an outdoor ambient temperature of 95° F.

continuously). Even test procedures that do attempt to capture cycling losses, such as the test procedure for central air conditioners and heat pumps, do not reflect the actual cycling behavior of units under dynamic conditions. Furthermore, test procedures that are based on full-load performance do not capture the energy savings associated with variable-speed operation. Finally, current test procedures that attempt to capture the benefits of variable-speed equipment, such as the test procedure for central air conditioners and heat pumps, test the equipment at fixed compressor and fan speeds. This approach fails to capture the huge impact that a unit's control strategy can have on the actual efficiency of variable-speed equipment. We recommend that DOE evaluate load-based testing for air-conditioning equipment.

Capturing standby/off mode power consumption for commercial and industrial equipment

Many products use energy while in standby or off mode. While existing law requires DOE to incorporate standby- and off-mode power measurements in test procedures for residential products, most test procedures for commercial and industrial equipment do not capture this power consumption. We recommend that DOE develop methods to capture standby and off mode power consumption in future test procedure rulemakings for commercial and industrial equipment.

Capturing network mode

Manufacturers are increasingly offering products that can be connected to a local Wi-Fi network. Such products consume energy in network mode, which is not currently captured in the DOE test procedures. We recommend that DOE incorporate measurements of network mode power consumption in future test procedure rulemakings.

Addressing software and firmware updates post installation

Products that can be connected to the Internet are often able to receive software and firmware updates, which can affect energy use. It is critical that product efficiency ratings remain valid after such software or firmware updates; otherwise, a manufacturer could circumvent the standards by designing a product to perform very efficiently when tested, but then issue software or firmware updates that change that efficiency performance significantly. In such situations, the test procedure would be entirely unrepresentative of actual performance. We recommend that DOE test procedures specify that product efficiency ratings must remain valid following any software or firmware updates.

Conclusion

Appliance standards have driven substantial declines in energy use, but there are still huge opportunities to achieve additional savings. Updates to national appliance standards could reduce CO_2 emissions by 1.5–2.9 BMT cumulatively through 2050, which is equivalent to the emissions of approximately 13–25 average-sized coal plants over that period. The potential annual utility bill savings for an average household are more than $100 in 2030, increasing to $230 in 2035 and nearly $350 in 2050. The electricity savings from updated standards would translate to reductions in peak electricity demand of 47 GW in 2035 and 89 GW in 2050, which are equivalent to approximately 7% and 13% of current total peak demand, respectively. Residential water heaters, commercial and industrial fans, residential furnaces, and light bulbs represent the greatest potential CO_2 reductions, but potential savings from other products are also large. Additional savings could be achieved by adding new products to the national standards program and improving test procedures. After several years without progress, advancing new and updated standards has the potential to deliver very large CO_2 reductions, utility bill savings, and reductions in peak demand.

References

APSP (Association of Pool and Spa Professionals). 2016. *U.S. Swimming Pool and Hot Tub Market 2015*. Alexandria, VA: APSP.

ASAP (Appliance Standards Awareness Project). 2016. *Average Household Refrigerator Energy Use, Volume, and Price Over Time*. Boston: ASAP. appliance-standards.org/sites/default/files/refrigerator_graph_Nov_2016.pdf.

——. 2020. *Missed Deadlines for Appliance Standards*. Boston: ASAP. appliance-standards.org/sites/default/files/Missed_deadlines_as_of_November_2020.pdf.

Bennich, P., and M. Scholand. 2019. *Evidence of the Availability of Mercury-Free Alternative Products to Certain Fluorescent Lamps: Report to the Committee on the Restriction of Hazardous Substances.* Stockholm: Swedish Energy Agency; Washington, DC: CLASP (Collaborative Labeling and Appliance Standards Program). storage.googleapis.com/clasp-siteattachments/SEA-and-CLASP-analysis-of-RoHS-exemptions-for-fluorescent-lamps-v2a.pdf.

CEC (California Energy Commission). 2020. "MAEDbS (Modernized Appliance Efficiency Database System)." cacertappliances.energy.ca.gov/.

CLASP (Collaborative Labeling and Appliance Standards Program). 2019. "New TV Test Method Underpins World-Leading European Energy Policy." *CLASP Updates*, November 7. clasp.ngo/updates/2019/new-tv-test-method-underpins-world-leading-european-energy-policy.

Davis, L. 2009. *Evaluating the Slow Adoption of Energy Efficient Investments: Are Renters Less Likely to Have Energy Efficient Appliances?* Cambridge, MA: NBER (National Bureau of Economic Research). www.nber.org/papers/w16114.pdf.

deLaski, A., and J. Mauer. 2017. *Energy-Saving States of America: How Every State Benefits from National Appliance Standards*. Boston: ASAP; Washington, DC: ACEEE. appliance-standards.org/sites/default/files/Appliances%20standards%20white%20paper%202%202-14-17.pdf.

deLaski, A., J. Mauer, J. Amann, M. McGaraghan, B. Kundu, S. Kwatra, and J. McMahon. 2016. *Next Generation Standards: How the National Energy Efficiency Standards Program Can Continue to Drive Energy, Economic, and Environmental Benefits*. Washington, DC: ACEEE; Boston: ASAP. appliance-standards.org/sites/default/files/Next%20Gen%20Report%20Final_1.pdf.

Desroches, L., K. Garbesi, C. Kantner, R. Van Buskirk, and H. Yang. 2012. *Incorporating Experience Curves in Appliance Standards Analysis*. Prepared by Berkeley Lab. Washington, DC: DOE. www.osti.gov/servlets/purl/1047753.

DOE (Department of Energy). 2016a. *Final Rule National Impact Analysis (NIA) Spreadsheet*. Washington, DC: DOE. www.regulations.gov/document?D=EERE-2014-BT-STD-0021-0031.

——. 2016b. *Notice of Proposed Rulemaking Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: General Service Lamps*. Prepared by Navigant Consulting and Berkeley Lab. Washington, DC: DOE. www.regulations.gov/document?D=EERE-2013-BT-STD-0051-0042.

——. 2016c. *Saving Energy and Money with Appliance and Equipment Standards in the United States*. Washington, DC: DOE. www.energy.gov/sites/prod/files/2016/10/f33/Appliance%20and%20Equipment%20Standards%20Fact%20Sheet-101416.pdf.

——. 2016d. *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces*. Prepared by Navigant Consulting and Berkeley Lab. Washington, DC: DOE. www.regulations.gov/document?D=EERE-2014-BT-STD-0031-0217.

——. 2017a. *2015 U.S. Lighting Market Characterization*. Washington, DC: DOE. www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf.

——. 2017b. *Energy Conservation Program: General Service Incandescent Lamps and Other Incandescent Lamps Request for Data*. Washington, DC: DOE. www.regulations.gov/document?D=EERE-2017-BT-NOA-0052-0001.

——. 2017c. "No Heat? No Problem: This Ultrasonic Clothes Dryer Dries Clothes in Half the Time." www.energy.gov/eere/articles/no-heat-no-problem-ultrasonic-dryer-dries-clothes-half-time.

——. 2017d. *Secretary Ernest Moniz: Cabinet Exit Memo*. Washington, DC: DOE. obamawhitehouse.archives.gov/sites/whitehouse.gov/files/documents/DOE%20Exit%20Memo.pdf.

Drehobl, A., L. Ross, and R. Ayala. 2020. *How High Are Household Energy Burdens? An Assessment of National and Metropolitan Energy Burden Across the United States*. Washington, DC: ACEEE. www.aceee.org/sites/default/files/pdfs/u2006.pdf.

EIA (Energy Information Administration). 2016. "Carbon Dioxide Emissions Coefficients." www.eia.gov/environment/emissions/co2_vol_mass.php.

——. 2018a. "2015 RECS Survey Data." www.eia.gov/consumption/residential/data/2015/.

——. 2018b. "One in Three U.S. Households Faces a Challenge in Meeting Energy Needs." *Today in Energy*, September 19. www.eia.gov/todayinenergy/detail.php?id=37072.

——. 2019. "Heat Wave Results in Highest U.S. Electricity Demand since 2017." *Today in Energy*, August 1. www.eia.gov/todayinenergy/detail.php?id=40253.

——. 2020. *Annual Energy Outlook 2020*. Washington, DC: EIA. www.eia.gov/outlooks/aeo/.

EPA (Environmental Protection Agency). 2011. *ENERGY STAR® Program Requirements for Product Specification for Room Air Cleaners: Eligibility Criteria Version 1.2*. Washington, DC: EPA. www.energystar.gov/sites/default/files/Room_Air_Cleaners_Program_Requirements%20V1.2.pdf.

——. 2014. "2014 Emerging Technology Award: Advanced Clothes Dryers." www.energystar.gov/about/awards/energy-star-emerging-technology-award/2014-emerging-technology-award-advanced-clothes-dryers.

——. 2015. "Clothes Dryers." www.energystar.gov/products/appliances/clothes_dryers.

——. 2020a. "ENERGY STAR Certified Air Purifiers (Cleaners)." Accessed June. www.energystar.gov/productfinder/product/certified-room-air-cleaners/results.

——. 2020b. *ENERGY STAR® Unit Shipment and Market Penetration Report: Calendar Year 2019 Summary*. Washington, DC: EPA. www.energystar.gov/sites/default/files/asset/document/2019%20USD%20Summary%20Report.pdf.

——. 2020c. "Greenhouse Gases Equivalencies Calculator—Calculations and References." www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references.

EPRI (Electric Power Research Institute). 2020. "Load Shape Library 7.0." loadshape.epri.com/.

Executive Office of the President. 2013. *The President's Climate Action Plan*. Washington, DC: Executive Office of the President. obamawhitehouse.archives.gov/sites/default/files/image/president27sclimateactionplan.pdf.

Gowrishankar, V., and A. Levin. 2017. *America's Clean Energy Frontier: The Pathway to a Safer Climate Future*. New York: NRDC (Natural Resources Defense Council). www.nrdc.org/sites/default/files/americas-clean-energy-frontier-report.pdf.

Hannas, B., and L. Gilman. 2014. *Dryer Field Study*. Prepared by Ecotope, Inc. Portland: NEEA (Northwest Energy Efficiency Alliance). neea.org/resources/rbsa-laundry-study.

Horowitz, N., C. Calwell, D. Denkenberger, and B. Spak. 2014. *A Call to Action for More Efficient Clothes Dryers: U.S. Consumers Missing Out on $4 Billion in Annual Savings*. New York: NRDC. www.nrdc.org/sites/default/files/efficient-clothes-dryers-IB.pdf.

IPCC (Intergovernmental Panel on Climate Change). 2018. *Special Report: Global Warming of 1.5°C: Summary for Policymakers*. Geneva: World Meteorological Organization. www.ipcc.ch/sr15/chapter/spm/.

JCHS (Joint Center for Housing Studies of Harvard University). 2017. *America's Rental Housing 2017*. Cambridge, MA: JCHS. www.jchs.harvard.edu/sites/default/files/harvard_jchs_americas_rental_housing_2017_0.pdf.

Kantner, C., A. Alstone, M. Ganeshalingam, B. Gerke, and R. Hosbach. 2017. *Impact of the EISA 2007 Energy Efficiency Standard on General Service Lamps.* Prepared by Berkeley Lab. Washington, DC: DOE. eta.lbl.gov/sites/default/files/publications/lbnl-1007090-rev2.pdf.

Key, T. 2007. "Role of Renewable Energy and Implication of RPS in a Sustainable Electric Generation Portfolio." *NARUC Electricity Committee 2007 Annual Conference*. Washington, DC: NARUC (National Association of Regulatory Utility Commissioners). slideplayer.com/slide/8895523/.

Mauer, J., A. deLaski, and M. DiMascio. 2017. *States Go First: How States Can Save Consumers Money, Reduce Energy and Water Waste, and Protect the Environment with New Appliance Standards*. Boston: ASAP; Washington, DC: ACEEE. appliance-standards.org/sites/default/files/States%20Go%20First.pdf.

Mauer, J., A. deLaski, S. Nadel, A. Fryer, and R. Young. 2013. *Better Appliances: An Analysis of Performance, Features, and Price as Efficiency Has Improved*. Washington, DC: ACEEE; Boston: ASAP. appliance-standards.org/sites/default/files/Better_Appliances_Report.pdf.

McMahon, J. 2012. "Energy Efficiency Is a Renewable Resource." *Proceedings of the 2012 ACEEE Summer Study on Energy Efficiency in Buildings* 13: 227–35. Washington, DC: ACEEE. www.aceee.org/files/proceedings/2012/data/papers/0193-000411.pdf.

Nadel, S., and L. Ungar. 2019. *Halfway There: Energy Efficiency Can Cut Energy Use and Greenhouse Gas Emissions in Half by 2050*. Washington, DC: ACEEE. www.aceee.org/research-report/u1907.

Naimoli, S., and S. Ladislaw. 2020. *Climate Solutions Series: Decarbonizing the Electric Power Sector*. Washington, DC: CSIS (Center for Strategic and International Studies). csis-website-prod.s3.amazonaws.com/s3fs-public/publication/200512__Naimoli_Ladislaw_Climate_v3_WEB%20FINAL.pdf?9v3JsO0B4FnGnyO0QKeY41f0mwnJb9ra.

NEEA. 2020. *Comments Re: Test Procedures for Residential and Commercial Clothes Washers*. EERE-2016-BT-TP-0011, RIN 1904-AD95, July 6. Washington, DC: DOE. www.regulations.gov/document?D=EERE-2016-BT-TP-0011-0012.

NEEA (Northwest Energy Efficiency Alliance) and NPCC (Northwest Power and Conservation Council). 2015. *NEEA and NPCC Comments Re: DOE Request for Information Regarding Residential Clothes Dryer Standards*. Docket No. EERE–2014–BT–STD–0058, May 11. Washington, DC: DOE. www.regulations.gov/document?D=EERE-2014-BT-STD-0058-0014.

Scheihing, P., M. Rosenberg, M. Olszewski, C. Cockrill, and J. Oliver. 2012. *United States Industrial Motor-Driven Systems Market Assessment: Charting a Roadmap to Energy Savings for Industry*. Washington, DC: DOE. energy.gov/sites/prod/files/2014/05/f16/us_industrial_motor_driven.pdf.

Urban, B., K. Roth, M. Singh, and D. Howes. 2017. *Energy Consumption of Consumer Electronics in U.S. Homes in 2017: Final Report to the Consumer Technology Association*. Prepared by Fraunhofer USA. Arlington, VA: CTA (Consumer Technology Association). cdn.cta.tech/cta/media/media/advocacy/pdfs/energy-consumption-of-consumer-electronics-in-u-s-homes-in-2017-(fraunhofer-usa,-commissioned-by-cta,-december-2017).pdf.

Wilson, E., C. Engebrecht Metzger, S. Horowitz, and R. Hendron. 2014. *2014 Building America House Simulation Protocols*. Prepared by NREL (National Renewable Energy Laboratory). Washington, DC: DOE. www.energy.gov/sites/prod/files/2014/03/f13/house_simulation_protocols_2014.pdf.

Xcel Energy. 2015. *Retail Products Platform: Product Analysis*. Minneapolis: Xcel Energy. www.xcelenergy.com/staticfiles/xe/PDF/Regulatory/CO-Rates-and-Regs-DSM-Cadmus-RPP-Product-Analysis-August-2015.pdf

Appendix A: Energy, Water, and Utility Bill Savings and Peak Demand Reductions

Table A1. Potential annual energy, water, and utility bill savings and peak demand reductions in 2035 and 2050 for residential products

Product	Annual savings in 2035					Annual savings in 2050				
	Electricity (TWh)	Gas and oil (TBtu)	Water (billion gallons)	Utility bills (million 2019$)	Peak demand (MW)	Electricity (TWh)	Gas and oil (TBtu)	Water (billion gallons)	Utility bills (million 2019$)	Peak demand (MW)
Battery chargers	2.9	--	--	382	335	2.9	--	--	368	335
Boilers	(0.1)	15.9	--	204	(0.1)	(0.3)	52.6	--	733	(0.4)
Ceiling fans	4.5	--	--	585	877	8.3	--	--	1,037	1,614
Central air conditioners and heat pumps	16.1	--	--	2,099	7,351	44.7	--	--	5,596	21,903
Circulator pumps	3.0	--	--	375	4	4.0	--	--	480	5
Clothes dryers	12.8	10.8	--	1,789	1,558	21.6	18.2	--	2,922	2,624
Clothes washers	1.5	8.5	65.4	1,177	223	2.2	12.6	97.8	2,022	333
Cooking products	2.8	9.6	--	471	1,146	4.7	13.1	--	745	1,931
Dedicated-purpose pool pumps	3.7	--	--	481	422	3.7	--	--	463	422
Dehumidifiers	0.6	--	--	73	64	0.7	--	--	91	83
Direct heating equipment	--	2.1	--	23	--	--	4.1	--	49	--
Dishwashers	1.2	5.7	13.3	406	157	2.0	9.0	21.3	704	252
External power supplies	1.8	--	--	231	203	1.8	--	--	222	203
Faucets	6.4	40.7	183.0	3,790	631	6.8	42.9	192.6	4,508	664
Furnaces	(0.4)	127.4	--	1,387	(0.5)	(1.0)	322.2	--	3,745	(1)
Furnace fans	7.8	(5.1)	--	953	1,740	22.0	(14.5)	--	2,578	4,919
General service lamps	20.3	--	--	2,636	3,740	22.4	--	--	2,798	4,123
Microwave ovens	1.0	--	--	129	409	1.1	--	--	143	469
Miscellaneous refrigeration equipment	1.0	--	--	124	132	1.2	--	--	147	163
Pool heaters	1.1	5.4	--	208	130	1.7	7.1	--	297	193
Portable air conditioners	1.4	--	--	175	1,115	3.3	--	--	391	2,594
Refrigerators and freezers	15.9	--	--	2,068	2,208	28.7	--	--	3,593	3,985
Room air conditioners	7.4	--	--	913	5,925	7.4	--	--	877	5,925
Showerheads	6.8	43.0	132.1	3,168	666	7.2	45.2	139.1	3,709	701
Toilets	--	--	37.6	512	--	--	--	84.5	1,379	--
Uninterruptible power supplies	3.8	--	--	394	430	3.8	--	--	374	430
Water heaters	59.8	121.8	--	9,151	5,859	103.7	220.5	--	15,628	10,156

Table A2. Potential annual energy, water, and utility bill savings and peak demand reductions in 2035 and 2050 for commercial and industrial products

Product	Annual savings in 2035					Annual savings in 2050				
	Electricity (TWh)	Gas and oil (TBtu)	Water (billion gallons)	Utility bills (million 2019$)	Peak demand (MW)	Electricity (TWh)	Gas and oil (TBtu)	Water (billion gallons)	Utility bills (million 2019$)	Peak demand (MW)
Air compressors	1.9	–	–	126	257	5.6	–	–	352	743
Automatic ice makers	1.4	–	–	146	194	1.4	–	–	138	194
Beverage vending machines	0.3	–	–	29	39	0.5	–	–	43	61
Commercial boilers	(0.0)	14.3	–	132	(0.01)	(0.0)	47.4	–	468	(0.04)
Commercial clothes washers	0.3	2.7	16.6	278	41	0.3	3.1	18.7	362	47
Commercial furnaces	(0.3)	24.7	–	176	(0.4)	(1.1)	81.6	–	629	(1.3)
Commercial packaged air conditioners and heat pumps (RTUs)	8.0	–	–	814	1,204	26.4	–	–	2,551	3,984
Commercial refrigeration equipment	21.6	–	–	2,197	2,931	22.7	–	–	2,191	3,085
Commercial three-phase air conditioners and heat pumps	1.0	–	–	102	486	1.9	–	–	188	946
Commercial water heaters	(0.1)	41.9	–	346	(7)	(0.1)	52.2	–	457	(9)
Computer room air conditioners	2.8	–	–	284	1,357	4.4	–	–	425	2,142
Distribution transformers	9.7	–	–	985	1,104	24.9	–	–	2,406	2,848
Electric motors	11.7	–	–	1,012	1,566	19.3	–	–	1,589	2,578
Fans	22.0	–	–	2,057	2,501	65.9	–	–	5,867	7,502
Packaged terminal air conditioners and heat pumps	0.4	–	–	38	153	0.4	–	–	36	153
Pumps	2.4	–	–	192	321	3.7	–	–	281	489
Single-package vertical air conditioners and heat pumps	0.4	–	–	36	144	0.6	–	–	54	228
Small motors	1.5	–	–	127	206	1.5	–	–	122	206
Urinals	–	–	17.1	234	–	–	–	21.7	354	–
Water-source heat pumps	2.0	–	–	204	821	4.0	–	–	387	1,642

Table A3. Potential total annual energy, water, and utility bill savings and peak demand reductions in 2035 and 2050

	Annual savings in 2035					Annual savings in 2050				
	Electricity (TWh)	Gas and oil (TBtu)	Water (billion gallons)	Utility bills (million 2019$)	Peak demand (MW)	Electricity (TWh)	Gas and oil (TBtu)	Water (billion gallons)	Utility bills (million 2019$)	Peak demand (MW)
Residential total	167	362	431	31,527	34,066	271	687	535	50,801	61,668
Commercial/industrial total	87	84	34	9,513	13,319	182	184	40	18,898	26,839
Total	**254**	**446**	**465**	**41,039**	**47,385**	**453**	**871**	**576**	**69,699**	**88,507**

Table A4. Potential cumulative energy, water, and utility bill savings for residential products

Product	Cumulative savings through 2050 Primary energy (quads)	Water (billion gallons)	Utility bills (billion 2019$)
Battery chargers	0.6	–	8.8
Boilers	0.6	–	7.9
Ceiling fans	1.2	–	17.1
Central air conditioners and heat pumps	5.0	–	72.8
Circulator pumps	0.6	–	8.8
Clothes dryers	3.5	–	50.6
Clothes washers	0.6	1,750	33.4
Cooking products	0.9	–	13.0
Dedicated-purpose pool pumps	0.6	–	9.4
Dehumidifiers	0.1	–	1.7
Direct heating equipment	0.1	–	0.7
Dishwashers	0.5	371	11.7
External power supplies	0.4	–	5.4
Faucets	2.1	3,853	83.4
Furnaces	4.2	–	47.9
Furnace fans	2.2	–	32.7
General service lamps	5.1	–	73.1
Microwave ovens	0.2	–	2.9
Miscellaneous refrigeration equipment	0.2	–	2.8
Pool heaters	0.4	–	5.3
Portable air conditioners	0.4	–	5.9
Refrigerators and freezers	4.1	–	59.9
Room air conditioners	1.4	–	18.8
Showerheads	2.2	2,781	69.3
Toilets	--	1,152	17.1
Uninterruptible power supplies	0.7	–	7.7
Water heaters	18.6	–	259.9

Table A5. Potential cumulative energy, water, and utility bill savings for commercial and industrial products

Product	Cumulative savings through 2050 Primary energy (quads)	Water (billion gallons)	Utility bills (billion 2019$)
Air compressors	0.7	--	4.8
Automatic ice makers	0.3	--	3.0
Beverage vending machines	0.1	--	0.8
Commercial boilers	0.5	--	5.1
Commercial clothes washers	0.1	368	6.5
Commercial furnaces	0.8	--	6.8
Commercial packaged air conditioners and heat pumps (RTUs)	2.6	--	29.4
Commercial refrigeration equipment	4.0	--	45.4
Commercial three-phase air conditioners and heat pumps	0.3	--	3.0
Commercial water heaters	1.0	--	8.5
Computer room air conditioners	0.7	--	7.7
Distribution transformers	2.8	--	31.6
Electric motors	2.9	--	28.1
Fans	6.8	--	70.7
Packaged terminal air conditioners and heat pumps	0.1	--	0.8
Pumps	0.6	--	5.0
Single-package vertical air conditioners and heat pumps	0.1	--	1.0
Small motors	0.3	--	2.4
Urinals	--	412	6.0
Water-source heat pumps	0.5	--	6.2

Table A6. Potential total cumulative energy and water savings

	Cumulative savings through 2050 Primary energy (quads)[34]	Water (billion gallons)	Utility bills (billion 2019$)
Residential total	52	9,907	856
Commercial/industrial total	25	779	273
Total	**77**	**10,686**	**1,129**

[34] We calculated primary energy savings using average heat rates based on the AEO reference case. Total cumulative energy savings would be about 4% lower using heat rates based on the low-carbon grid scenario.

Appendix B. Water Heater Savings

Table B1. Potential annual energy and utility bill savings and peak demand reductions in 2035 and 2050 for residential water heaters

	Annual savings in 2035				Annual savings in 2050			
	Electricity (TWh)	Gas and oil (TBtu)	Utility bills (million 2019$)	Peak demand (MW)	Electricity (TWh)	Gas and oil (TBtu)	Utility bills (million 2019$)	Peak demand (MW)
Gas-fired storage	–	111.6	1,259	–	–	193.5	2,322	–
Electric storage	59.8	–	7,776	5,859	103.7	–	12,979	10,156
Oil-fired storage	–	0.1	3	–	–	0.2	6	–
Gas-fired instantaneous	–	10.0	113	–	–	26.8	321	–
Total	59.8	121.8	9,151	5,859	103.7	220.5	15,628	10,156

Table B2. Potential cumulative energy and utility bill savings for residential water heaters

	Cumulative savings through 2050	
	Primary energy (quads)	Utility bills (billion 2019$)
Gas-fired storage	3.2	36.9
Electric storage	15.1	218.9
Oil-fired storage	0.0	0.1
Gas-fired instantaneous	0.3	4.0
Total	18.6	259.9

Table B3. Potential annual CO_2 reductions in 2035 and 2050 and cumulative reductions through 2050 for residential water heaters

	Annual CO_2 reductions in 2035 (MMT)		Annual CO_2 reductions in 2050 (MMT)		Cumulative CO_2 reductions through 2050 (MMT)	
Product	Low-carbon grid scenario	AEO reference case	Low-carbon grid scenario	AEO reference case	Low-carbon grid scenario	AEO reference case
Gas-fired storage	5.9	5.9	10.3	10.3	169.5	169.5
Electric storage	7.5	18.9	8.6	29.2	178.4	509.5
Oil-fired storage	0.0	0.0	0.0	0.0	0.3	0.3
Gas-fired instantaneous	0.5	0.5	1.4	1.4	18.5	18.5
Total	14.0	25.3	20.4	40.9	366.7	697.7

Appendix C: Total Annual CO_2 Reductions by Year and CO_2 Reductions by Product in 2030 and 2040

Table C1. Potential annual CO_2 reductions from electricity savings and gas and oil savings

	Low-carbon grid scenario			AEO reference case		
Year	Annual CO_2 reductions from electricity savings (MMT)	Annual CO_2 reductions from gas and oil savings (MMT)	Total Annual CO_2 reductions (MMT)	Annual CO_2 reductions from electricity savings (MMT)	Annual CO_2 reductions from gas and oil savings (MMT)	Total Annual CO_2 reductions (MMT)
2025	3.5	0.1	3.6	5.7	0.1	5.8
2030	16.1	9.9	26.0	37.1	9.9	46.9
2035	31.8	25.0	56.8	80.1	25.0	105.1
2040	39.2	37.2	76.4	110.1	37.2	147.3
2045	39.6	44.2	83.8	120.5	44.2	164.7
2050	37.8	48.9	86.7	127.5	48.9	176.4

Table C2. Potential annual CO_2 reductions in 2030 and 2040 for residential products

	Annual CO_2 reductions in 2030 (MMT)		Annual CO_2 reductions in 2040 (MMT)	
Product	Low-carbon grid scenario	AEO reference case	Low-carbon grid scenario	AEO reference case
Battery chargers	0.4	0.9	0.3	0.9
Boilers	0.2	0.2	1.6	1.5
Ceiling fans	0.2	0.5	0.8	2.3
Central air conditioners and heat pumps	0.5	1.2	3.1	8.7
Circulator pumps	0.1	0.3	0.4	1.2
Clothes dryers	1.1	2.2	3.0	6.8
Clothes washers	0.3	0.4	0.9	1.3
Cooking products	0.4	0.7	1.2	2.0
Dedicated-purpose pool pumps	0.2	0.5	0.4	1.1
Dehumidifiers	0.0	0.1	0.1	0.2
Direct heating equipment	0.04	0.04	0.2	0.2
Dishwashers	0.2	0.3	0.7	1.0
External power supplies	0.2	0.6	0.2	0.5
Faucets	1.4	2.0	3.0	4.3
Furnaces	2.8	2.7	10.7	10.6
Furnace fans	0.3	0.7	0.9	3.5
General service lamps	2.7	6.2	2.3	6.3
Microwave ovens	0.1	0.2	0.1	0.3
Miscellaneous refrigeration equipment	0.1	0.1	0.1	0.4

Product	Annual CO_2 reductions in 2030 (MMT) Low-carbon grid scenario	Annual CO_2 reductions in 2030 (MMT) AEO reference case	Annual CO_2 reductions in 2040 (MMT) Low-carbon grid scenario	Annual CO_2 reductions in 2040 (MMT) AEO reference case
Pool heaters	0.1	0.2	0.6	0.9
Portable air conditioners	0.0	0.0	0.3	0.9
Refrigerators and freezers	1.1	2.6	2.5	7.1
Room air conditioners	0.5	1.3	0.8	2.2
Showerheads	1.5	2.1	3.2	4.6
Toilets	--	--	--	--
Uninterruptible power supplies	0.21	0.5	0.4	1.1
Water heaters	4.9	8.5	21.5	41.0

Table C3. Potential annual CO_2 reductions in 2030 and 2040 for commercial and industrial products

Product	Annual CO_2 reductions in 2030 (MMT) Low-carbon grid scenario	Annual CO_2 reductions in 2030 (MMT) AEO reference case	Annual CO_2 reductions in 2040 (MMT) Low-carbon grid scenario	Annual CO_2 reductions in 2040 (MMT) AEO reference case
Air compressors	0.0	0.0	0.4	1.2
Automatic ice makers	0.1	0.2	0.2	0.4
Beverage vending machines	0.02	0.04	0.05	0.1
Commercial boilers	0.2	0.2	1.4	1.4
Commercial clothes washers	0.1	0.1	0.2	0.3
Commercial furnaces	0.3	0.3	2.3	2.1
Commercial packaged air conditioners and heat pumps (RTUs)	0.3	0.6	1.5	4.3
Commercial refrigeration equipment	1.4	3.3	2.4	6.9
Commercial three-phase air conditioners and heat pumps	0.1	0.2	0.2	0.5
Commercial water heaters	1.2	1.2	2.8	2.7
Computer room air conditioners	0.2	0.4	0.5	1.3
Distribution transformers	0.6	1.5	1.6	4.5
Electric motors	0.8	1.8	1.9	5.4
Fans	1.0	2.3	3.9	11.1
Packaged terminal air conditioners and heat pumps	0.03	0.1	0.04	0.1
Pumps	0.1	0.3	0.4	1.1
Single-package vertical air conditioners and heat pumps	0.02	0.1	0.1	0.2
Small motors	0.1	0.2	0.2	0.5
Urinals	--	--	--	--
Water-source heat pumps	0.1	0.3	0.3	0.9

Table C4. Potential total annual CO_2 reductions in 2030 and 2040

	Annual CO_2 reductions in 2030 (MMT)		Annual CO_2 reductions in 2040 (MMT)	
	Low-carbon grid scenario	AEO reference case	Low-carbon grid scenario	AEO reference case
Residential total	19	34	56	102
Commercial/industrial total	7	13	20	45
Total	**26**	**47**	**76**	**147**

Appendix D: Methodology and Assumptions

Tables D1 and D2 show the standard levels we assumed in our analysis for residential products and commercial and industrial products, respectively, for the most important product categories. Where the assumed standard level is listed as percentage savings, the savings are relative to a product just meeting the current standards unless otherwise noted.[35]

Table D1. Assumed standard levels for residential products[36]

Product	Assumed standard level
Battery chargers	75–95% savings
Boilers	Gas-fired, hot water: 96% AFUE Oil-fired, hot water: 91% AFUE
Ceiling fans	Standard: 44% savings Hugger: 41% savings
Central air conditioners and heat pumps	Split-system AC <30,000 Btu/h: 17 SEER Split-system AC ≥30,000 Btu/h: 16.5 SEER Single-package AC: 17.5 SEER Split-system HP <45,000 Btu/h: 19 SEER, 9.9 HSPF Split-system HP ≥45,000 Btu/h: 17.5 SEER, 9.4 HSPF Single-package HP: 15 SEER, 8.2 HSPF
Circulator pumps	68–75% savings relative to base-case efficiency distribution
Clothes dryers	30% savings
Clothes washers	Top loading: 2.04 IMEF, 4.1 IWF Front loading: 2.46 IMEF, 3.4 IWF
Cooking products	Electric coil cooktops: 4% savings Electric smooth cooktops: 30% savings Gas cooktops: 34% savings Standard electric and gas ovens: 30% savings Self-clean electric and gas ovens: 20% savings
Dedicated-purpose pool pumps	Standard-size, self-priming pool filter pump, 1 HP: 12% savings Standard-size, self-priming pool filter pump, 3 HP: 18% savings Standard-size, non-self-priming pool filter pump: 71% savings Pressure cleaner booster pump: 27% savings
Dehumidifiers	≤25 pints/day: 1.70 IEF >25 and ≤50 pints/day: 1.90 IEF >50 pints/day: 3.40 IEF
Direct heating equipment	Gas wall fan: 80% AFUE Gas wall gravity: 70% AFUE Gas floor: 58% AFUE Gas room: 83% AFUE

[35] With the exception of cooking products, for which the percentage savings are relative to the least-efficient products currently available since there are no efficiency performance standards for cooking products.

[36] For most of the products for which the assumed standard level is listed as percentage savings, the current standards are defined as an equation. HSPF is heating seasonal performance factor; IMEF is integrated modified energy factor; IWF is integrated water factor; IEF is integrated energy factor; lpw is lumens per watt; CEER is combined energy efficiency ratio; gpf is gallons per flush.

Product	Assumed standard level
Dishwashers	225 kWh
External power supplies	Single-voltage, AC-DC, basic voltage: 2.5 W: 74.8% efficiency, 0.039 W no-load power 18 W: 91.1% efficiency, 0.039 W no-load power 60 W: 92.2% efficiency, 0.05 W no-load power 120 W: 93.5% efficiency, 0.089 W no-load power
Faucets	Residential lavatory: 1.2 gpm Kitchen: 1.8 gpm
Furnaces	Non-weatherized gas: 98% AFUE Mobile home gas: 96% AFUE
Furnace fans	Non-weatherized gas furnace, non-condensing: 32% savings Non-weatherized gas furnace, condensing: 35% savings
General service lamps	65 lpw
Microwave ovens	Countertop: 0.02 W standby Over-the-range: 0.04 W standby
Miscellaneous refrigeration equipment	Compact, free-standing: 54% savings
Pool heaters	Gas-fired: 95% efficiency Electric: 563% efficiency
Portable air conditioners	32% savings
Refrigerators and freezers	Standard-size refrigerators: 20% savings Standard-size freezers: 15% savings Compact refrigerators: 25% savings Compact freezers: 20% savings
Room air conditioners	W/o reverse cycle, with louvered sides, <6,000 Btu/h: 13.8 CEER W/o reverse cycle, with louvered sides, 6,000-7,999 Btu/h: 13.6 CEER
Showerheads	1.8 gpm
Toilets	1.28 gpf
Uninterruptible power supplies	Voltage and frequency dependent: 62% savings Voltage independent: 56% savings Voltage and frequency independent: 35% savings
Water heaters	Gas-fired storage: 0.83 UEF Electric storage: 3.55 UEF Oil-fired storage: 0.68 UEF Gas-fired instantaneous: 0.97 UEF

Table D2. Assumed standard levels for commercial and industrial products[37]

Product	Assumed standard level
Air compressors	9–11% savings
Automatic ice makers	Ice-making head: 20% savings Remote condensing: 20% savings Self-contained: 30% savings
Beverage vending machines	Class A: 35% savings Class B: 43% savings
Commercial boilers	Gas-fired, hot-water, small: 99% TE Gas-fired, hot-water, large: 97% CE
Commercial clothes washers	Top loading: 2.2 MEF, 4.5 IWF Front loading: 2.98 MEF, 3.8 IWF
Commercial furnaces	Gas-fired: 92% TE Oil-fired: 92% TE
Commercial packaged air conditioners and heat pumps (RTUs)	≥65,000 and <135,000 Btu/h AC: 21.5 IEER ≥135,000 and <240,000 Btu/h AC: 20.1 IEER ≥240,000 and <760,000 Btu/h AC: 15.6 IEER
Commercial refrigeration equipment	5–65% savings
Commercial three-phase air conditioners and heat pumps	AC: 19 SEER HP: 18 SEER
Commercial water heaters	Commercial gas-fired storage: 99% TE Residential-duty gas-fired storage: 97% TE Gas-fired instantaneous tankless: 96% TE Gas-fired instantaneous hot-water supply boiler: 96% TE
Computer room air conditioners	Air-cooled <65,000 Btu/h: 3.00 SCOP Air-cooled ≥65,000 and <240,000 Btu/h: 3.10 SCOP Air-cooled ≥240,000 and <760,000 Btu/h: 2.90 SCOP
Distribution transformers	Liquid-immersed: 99.47–99.73% efficiency Low-voltage dry-type: 99.44–99.58% efficiency Medium-voltage dry-type: 99.45–99.67% efficiency
Electric motors	IE4
Fans	Ducted: 0.86 efficiency target Unducted: 0.82 efficiency target
Packaged terminal air conditioners and heat pumps	<7,000 Btu/h: 13.8 EER ≥7,000 and ≤15,000 Btu/h: 13.1 EER >15,000 Btu/h: 11.0 EER
Pumps	70% efficiency percentile
Single-package vertical air conditioners and heat pumps	<65,000 Btu/h: 12.3 EER ≥65,000 and <135,000 Btu/h: 11.5 EER
Small motors	Polyphase, 1 HP, 4 poles: 87.7% efficiency Capacitor-start, ¾ HP, 4 poles: 86.7% efficiency
Urinals	0.125 gpf
Water-source heat pumps	<17,000 Btu/h: 18.1 EER ≥17,000 and <65,000 Btu/h: 21.6 EER ≥65,000 and <135,000 Btu/h: 17.2 EER

[37] TE is thermal efficiency; CE is combustion efficiency; SCOP is sensible coefficient of performance.

Our general methodology for estimating savings is based on product sales; the exception is for general service lamps (Appendix F describes our methodology for GSLs). To estimate annual electricity, natural gas, oil, and water savings, we used estimates of current annual shipments, per-unit energy and/or water savings, and average product lifetimes. We calculated per-unit savings relative to the average energy and/or water use in the base case, taking into account the estimated market distribution of efficiencies. We estimated each product's base-case average efficiency based on data from the most recent DOE rulemaking, data on the market penetration of ENERGY STAR products, and/or the average efficiency of available models certified to DOE. When we estimated a product's base-case average efficiency based on the average efficiency of available models, it is likely a conservative assumption since lower-efficiency products are typically sold in higher volumes (i.e., in most cases, the average efficiency of available models is likely higher than the shipment-weighted average efficiency).

To simplify the analysis, we assumed that both annual shipments and the distribution of efficiency levels in the base case remain constant over the analysis period. In reality, shipments and base-case efficiency tend to increase over time. Thus, we implicitly assumed that these two factors cancel each other out.

To calculate savings in each year through 2050, we used the following equation:

> *Annual savings = Number of installed units meeting new standard * Per-unit savings relative to the base-case efficiency distribution*

where the number of installed units meeting the new standard is

- Before stock turnover: *Annual shipments * (Number of years after compliance date + 0.5)*
- After stock turnover: *Annual shipments * Average product lifetime*

To calculate the number of installed units meeting the new standard before stock turnover, we accounted for products being purchased throughout the year. Thus, in any given year, we counted only one-half year of savings from products purchased in that year.

Tables D3 and D4 show our assumptions for compliance date, annual shipments, average lifetime, and per-unit savings relative to the base-case efficiency distribution for residential products and commercial and industrial products, respectively; as we noted earlier, GSLs have separate assumptions (see Appendix F).

Table D3. Assumptions for compliance date, annual shipments, average lifetime, and per-unit savings for residential products

Product	Compliance date	Annual shipments (million)	Average lifetime (years)	Per-unit savings relative to base-case efficiency distribution	Units
Battery chargers	2026	535.9	3.7	1.5	kWh
Boilers	2029	0.4	–	–	–
Gas	2029	0.3	26.2	6.9	MMBtu
Electricity	2029	–	–	(44)	kWh
Oil	2029	0.1	24.3	4.2	MMBtu
Electricity	2029	–	–	(29)	kWh
Ceiling fans	2028	21.1	13.8	28	kWh
Central air conditioners and heat	2029	7.6	–	–	–
Air Conditioners	2029	4.8	21.2	236	kWh
Heat Pumps	2029	2.8	15.3	479	kWh
Circulator pumps	2028	1.8	10.0	225	kWh
Clothes dryers	2026	8.5	–	–	–
Electric	2026	6.7	16.0	202	kWh
Gas	2026	1.8	16.0	0.6	MMBtu
Clothes washers	2026	10.1	–	–	–
Top loaders	2026	4.4	14.2	–	–
Electricity	2026	–	–	28	kWh
Gas	2026	–	–	0.2	MMBtu
Water	2026	–	–	1,375	gallons
Front loaders	2026	5.6	14.2	–	–
Electricity	2026	–	–	5	kWh
Gas	2026	–	–	0.04	MMBtu
Water	2026	–	–	145	gallons
Cooking products	2026	19.0	–	–	–
Cooktops	2026	9.1	–	–	–
Electric	2026	5.8	16.0	19	kWh
Gas	2026	3.3	13.0	0.2	MMBtu
Ovens	2026	9.8	–	–	–
Electric	2026	6.7	16.0	27	kWh
Gas	2026	3.1	13.0	0.1	MMBtu
Dedicated-purpose pool pumps	2028	1.4	6.5	410	kWh
Dehumidifiers	2027	2.0	11.1	33	kWh
Direct heating equipment	2028	0.1	15.0	1.9	MMBtu
Dishwashers	2026	7.5	15.2	–	–
Electricity	2026	–	–	17	kWh
Gas	2026	–	–	0.1	MMBtu
Water	2026	–	–	188	gallons
External power supplies	2025	282.1	4.6	1.4	kWh
Faucets	2026	45.1	–	–	–
Residential lavatory	2026	29.9	10.0	–	–
Electricity	2026	–	–	5	kWh
Gas	2026	–	–	0.03	MMBtu
Water	2026	–	–	147	gallons
Kitchen	2026	15.3	10.0	–	–
Electricity	2026	–	–	34	kWh

Gas	2026	–	–	0.2	MMBtu
Water	2026	–	–	974	gallons
Furnaces	2027	3.4	21.5	–	–
Gas	2027	–	–	4.4	MMBtu
Electricity	2027	–	–	(13)	kWh
Furnace fans	2028	3.5	21.2	–	–
Electricity	2028	–	–	147	kWh
Gas	2028	–	–	(0.2)	MMBtu
Microwave ovens	2026	14.0	10.9	7	kWh
Miscellaneous refrigeration equipment	2027	1.6	10.5	71	kWh
Pool heaters	2028	0.3	–	–	–
Gas-fired	2028	0.2	10.0	4.0	MMBtu
Electric	2028	0.1	11.2	1,705	kWh
Portable air conditioners	2031	1.4	–	–	–
Residential	2031	1.2	10.5	194	kWh
Commercial	2031	0.2	10.5	487	kWh
Refrigerators and freezers	2026	20.1	–	–	–
Standard-size refrigerators	2026	13.3	17.4	103	kWh
Standard-size freezers	2026	2.8	22.3	58	kWh
Compact refrigerators	2026	3.4	5.6	62	kWh
Compact freezers	2026	0.7	7.5	56	kWh
Room air conditioners	2025	8.8	–	–	–
Residential	2025	7.7	10.3	73	kWh
Commercial	2025	1.1	10.3	140	kWh
Showerheads	2026	16.3	–	–	–
Electricity	2026	–	–	44	kWh
Gas	2026	–	–	0.3	MMBtu
Water	2026	–	–	851	gallons
Toilets	2026	16.2	–	–	–
Residential	2026	12.7	25.0	232	gallons
Commercial	2026	3.5	12.0	288	gallons
Uninterruptible power supplies	2028	9.9	–	–	–
Residential	2028	1.0	6.1	62	kWh
Commercial	2028	9.0	6.1	62	kWh
Water heaters	2028	11.2	–	–	–
Gas-fired storage	2028	4.4	13.0	3.4	MMBtu
Electric storage	2028	5.3	13.0	1,498	kWh
Oil-fired storage	2028	0.0	13.0	0.5	MMBtu
Gas-fired instantaneous	2028	1.4	20.0	0.9	MMBtu

Table D4. Assumptions for compliance date, annual shipments, average lifetime, and per-unit savings for commercial and industrial products

Product	Compliance date	Annual shipments (million)	Average lifetime (years)	Per-unit savings relative to base-case efficiency distribution	Units
Air compressors	2031	0.03	–	–	–
Commercial	2031	0.001	12.9	5,946	kWh
Industrial	2031	0.03	13.0	16,256	kWh
Automatic ice makers	2026	0.2	8.5	880	kWh
Beverage vending machines	2027	0.1	13.4	515	kWh
Commercial boilers	2029	0.03	–	–	–
Gas-fired	2029	0.03	24.8	72	MMBtu
Electricity	2029	–	24.8	(39)	kWh
Oil-fired	2029	0.004	24.8	40	MMBtu
Electricity	2029	–	24.8	(141)	kWh
Commercial clothes washers	2026	0.2	10.7	–	–
Electricity	2026	–	–	150	kWh
Gas	2026	–	–	1.5	MMBtu
Water	2026	–	–	9,142	gallons
Commercial furnaces	2029	0.2	–	–	–
Gas-fired	2029	0.2	23.0	16.8	MMBtu
Electricity	2029	–	–	(221)	kWh
Oil-fired	2029	0.003	23.0	9.0	MMBtu
Electricity	2029	–	–	(246)	kWh
Commercial packaged air conditioners and heat pumps	2029	0.29	–	–	–
Air Conditioners	2029	0.27	22.6	4,167	kWh
Heat Pumps	2029	0.03	21.9	4,333	kWh
Commercial refrigeration equipment	2026	1.6	10.0	1,419	kWh
Commercial three-phase air conditioners and heat pumps	2026	0.3	18.5	410	kWh
Commercial water heaters	2025	0.1	13.1	–	–
Gas	2025	–	–	27.6	MMBtu
Electricity	2025	–	–	(42)	kWh
Computer room air conditioners	2026	0.02	15.0	14,557	kWh
Distribution transformers	2026	0.1*	32.0	11,914*	kWh
Electric motors	2026	7.3	15.6	169	kWh
Fans	2028	1.5	27.6	1,954	kWh
Packaged terminal air conditioners and heat pumps	2026	0.5	–	–	–
Air conditioners	2026	0.3	8.0	78	kWh
Heat pumps	2026	0.2	8.0	105	kWh
Pumps	2027	0.4	13.0	666	kWh
Single-package vertical air conditioners and heat pumps	2026	0.07	–	–	–
Air conditioners	2026	0.05	15.0	440	kWh
Heat pumps	2026	0.02	15.0	730	kWh
Small motors	2028	4.8	7.4	44	kWh
Urinals	2026	0.9	12.0	2,088	gallons
Water-source heat pumps	2026	0.2	19.0	963	kWh

***For distribution transformers, the annual sales are in units of million megavolt-amperes (MVA) and the per-unit savings are kWh/MVA.**

We calculated CO_2 emissions reductions by multiplying annual electricity, natural gas, and oil savings by respective average CO_2 emissions factors. Table D5 shows the CO_2 emissions factors used over the analysis period (EIA 2020, 2016).

Table D5. Assumptions for CO_2 emissions factors

	2025	2030	2035	2040	2045	2050
Electricity (MMT/TWh)						
Low-carbon grid scenario	0.202	0.139	0.125	0.108	0.095	0.083
AEO reference case	0.330	0.321	0.316	0.303	0.287	0.281
Natural gas (MMT/quad)	53.1	53.1	53.1	53.1	53.1	53.1
Fuel oil (MMT/quad)	73.2	73.2	73.2	73.2	73.2	73.2

We calculated utility bill savings by multiplying annual electricity, natural gas, oil, and water savings by respective average prices. Table D6 shows the energy and water and wastewater prices used over the analysis period (EIA 2020; DOE 2016a).

Table D6. Assumptions for electricity, natural gas, fuel oil, and water and wastewater prices

	2025	2030	2035	2040	2045	2050
Electricity price (2019$/kWh)						
Residential	0.129	0.131	0.130	0.128	0.127	0.125
Commercial	0.104	0.104	0.102	0.100	0.098	0.096
Industrial	0.066	0.066	0.065	0.064	0.063	0.063
Natural gas price (2019$/MMBtu)						
Residential	10.19	10.98	11.27	11.48	11.69	12.00
Commercial	7.72	8.25	8.41	8.52	8.66	8.89
Fuel oil price (2019$/MMBtu)						
Residential	23.71	24.76	25.95	26.79	28.06	28.94
Commercial	18.84	20.23	21.49	22.36	23.67	24.60
Water and wastewater price (2019$/thous. gal.)	11.83	12.73	13.63	14.53	15.43	16.33

We calculated peak demand reductions using factors specific to various end uses that represent the peak load relative to the average load.[38] We assumed that the peak load on the electric grid occurs during the summer between 5 p.m. and 6 p.m. For most products, we used load profiles from the Electric Power Research Institute (EPRI). For end uses for which EPRI provides regional data, we calculated weighted averages of the peak load and the average load based on electricity consumption in each North American Electric Reliability Corporation (NERC) region (EPRI 2020; Key 2007). For ceiling fans and cooking products,

[38] We calculated average load as annual electricity savings divided by 8,760 hours.

we used load profiles from the 2014 Building America House Simulation Protocols (Wilson et al. 2014). Table D7 shows the national peak load factors used for each of the 16 end uses.

We applied the peak load factor for residential central air-conditioning to furnace fans in cooling mode, portable air conditioners, and room air conditioners, as well as to central air conditioners and to heat pumps in cooling mode. We applied the peak load factor for residential water heating to the electricity savings from faucets and showerheads in addition to water heaters. We applied the peak load factor for industrial machine drives to air compressors, motors, and pumps. We applied the peak load factor for ranges and ovens to microwave ovens and other cooking products. Finally, we assumed a flat load profile (i.e., a peak load factor of 1.00) for battery chargers, dedicated-purpose pool pumps, dehumidifiers, external power supplies, furnace fans in constant circulation and standby mode, electric pool heaters, uninterruptible power supplies, and distribution transformers.

Table D7. Assumptions for peak load factors by end use

End use	Peak load factor
Residential central air-conditioning	7.78
Residential clothes dryers	1.06
Residential clothes washers	1.33
Residential dishwashers	1.12
Residential heating	0.01
Residential lighting	1.62
Residential refrigerators	1.22
Residential water heating	0.86
Commercial cooling	4.26
Commercial heating	0.01
Commercial refrigeration	1.19
Commercial ventilation	1.00
Commercial water heating	0.94
Industrial machine drives	1.17
Ceiling fans	1.71
Ranges and ovens	3.60

For RTUs and central air conditioners and heat pumps, the cooling efficiency metrics (IEER and SEER, respectively) are seasonal efficiency metrics that largely reflect part-load performance. Therefore, to calculate the peak demand reductions for these products, we accounted for the smaller percentage savings during peak demand periods compared to the average savings over the year. Specifically, we adjusted the peak load factors based on the percentage savings at full load (measured by EER[39]) relative to the percentage savings at

[39] EER (Energy Efficiency Ratio) is a measure of full-load efficiency at an outdoor temperature of 95°F.

part load (measured by IEER or SEER). Based on the relationship between full-load efficiency and part-load efficiency of models in the Air-Conditioning, Heating, & Refrigeration Institute (AHRI) directory, we calculated percentage savings at full-load relative to the percentage savings at part load of 78% and 40% for central air conditioners and heat pumps, respectively, and 32% and 25% for commercial packaged air conditioners and heat pumps, respectively. We then multiplied these adjustment factors by the peak load factors in table D7 for residential central air-conditioning and commercial cooling.

We calculated total primary energy savings (quads) by summing primary electricity, natural gas, and oil savings. We used average heat rates based on the AEO reference case to convert site electricity savings to primary energy savings. Table D8 shows the heat rates we used over the analysis period (EIA 2020).

Table D8. Assumptions for heat rates

	2025	2030	2035	2040	2045	2050
Heat rate (Btu/kWh)	9,273	9,079	8,945	8,813	8,748	8,687

Our estimates for products that save hot water (clothes washers, dishwashers, faucets, and showerheads) assume water heater efficiency levels based on water heaters sold today. However, in calculating total potential savings, we accounted for the interaction effects among residential water heaters, clothes washers, dishwashers, faucets, and showerheads. If the standards for water heaters are improved, the energy savings from adopting standards for clothes washers, dishwashers, faucets, and showerheads would be lower due to improved water heater efficiency. Similarly, if the standards for products that use hot water are improved, the savings from water heaters would be lower due to reduced household hot-water consumption.

Finally, for the water-using products in this analysis, we included only the direct energy savings from reduced water heating. Water also includes significant embedded energy due to pumping and treatment, and this embedded energy may account for as much as 3.5% of national energy use (Griffiths-Sattenspiel and Wilson 2009). However, we did not attempt to estimate those additional energy savings for this report.

Appendix E: Sources for Product Assumptions

Table E1. Sources for product assumptions for residential products

Product	Sources
Battery chargers	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Battery Chargers* (Washington, DC: DOE, 2016). www.regulations.gov/document?D=EERE-2008-BT-STD-0005-0257. DOE, *Compliance Certification Database*. (Washington, DC: DOE, 2020). www.regulations.doe.gov/certification-data/#q=Product_Group_s%3A*. Accessed April 10, 2020.
Boilers	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Boilers* (Washington, DC: DOE, 2015). www.regulations.gov/#!documentDetail;D=EERE-2012-BT-STD-0047-0070. DOE, *Final Rule Analytical Tools: Residential Boilers National Impact Analysis (NIA) Spreadsheet- AFUE*. (Washington, DC: DOE, 2015). www.regulations.gov/document?D=EERE-2012-BT-STD-0047-0072.
Ceiling fans	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Ceiling Fans* (Washington, DC: DOE, 2016). www.regulations.gov/document?D=EERE-2012-BT-STD-0045-0149. DOE, *Ceiling Fans Final Rule National Impact Analysis (NIA) Spreadsheets* (Washington, DC: DOE, 2016). www.regulations.gov/document?D=EERE-2012-BT-STD-0045-0147.
Central air conditioners and heat pumps	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products: Residential Central Air Conditioners and Heat Pumps* (Washington, DC: DOE, 2016). www.regulations.gov/document?D=EERE-2014-BT-STD-0048-0098. DOE, *Final Rule Analytical Spreadsheets: National Impact Analysis (NIA)*. www.regulations.gov/document?D=EERE-2014-BT-STD-0048-0099.
Circulator pumps	DOE, 2016-11-03 - 04 Working Group Presentation: Circulator Pumps Appliance Standards and Rulemaking Federal Advisory Committee (ASRAC) Working Group, Ninth Meeting; Economic Analyses Post-Meeting (Washington, DC: DOE, 2016). www.regulations.gov/document?D=EERE-2016-BT-STD-0004-0078. DOE, *2016-07-12 -13 Working Group Meeting Presentation: Circulator Pumps Appliance Standards and Rulemaking Federal Advisory Committee (ASRAC) Working Group Fifth Meeting (Post-Meeting)* (Washington, DC: DOE, 2016). www.regulations.gov/document?D=EERE-2016-BT-STD-0004-0041.
Clothes dryers	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Clothes Dryers and Room Air Conditioners* (Washington, DC: DOE, 2011). DOE, *2011-04-18 Residential Clothes Dryers National Impact Analysis* (Washington, DC: DOE, 2011). www.regulations.gov/#!documentDetail;D=EERE-2007-BT-STD-0010-0053. DOE, *Energy Conservation Program: Test Procedures for Residential Clothes Dryers: Proposed Rule* (Washington, DC: DOE, 2013). www.regulations.gov/#!documentDetail;D=EERE-2011-BT-TP-0054-0006. DOE, *ENERGY STAR Unit Shipment and Market Penetration Report: Calendar Year 2018 Summary* (Washington, DC: EPA, 2018). www.energystar.gov/sites/default/files/asset/document/2018%20Unit%20Shipment%20Data%20Summary%20Report%20.pdf. EPA, *Clothes Dryers* (Washington, DC: EPA, 2020). www.energystar.gov/products/appliances/clothes_dryers. EPA, *2014 Emerging Technology Award: Advanced Clothes Dryers* (Washington, DC: EPA, 2014). www.energystar.gov/about/awards/energy-star-emerging-technology-award/2014-emerging-technology-award-advanced-clothes-dryers.

Product	Sources
Clothes washers	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Clothes Washers* (Washington, DC: DOE, 2012). www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0019-0047. DOE, *2012-05 National Impact Analysis* (Washington, DC: DOE, 2012). www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0019-0046. DOE, *Compliance Certification Database*. (Washington, DC: DOE, 2020). www.regulations.doe.gov/certification-data/#q=Product_Group_s%3A*. Accessed April 10, 2020.
Cooking products	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Conventional Cooking Products* (Washington, DC: DOE, 2016). www.regulations.gov/document?D=EERE-2014-BT-STD-0005-0052. DOE, *2016 SNOPR Analytical Tools: National Impact Analysis (NIA) Spreadsheet* (Washington, DC: DOE, 2016). www.regulations.gov/document?D=EERE-2014-BT-STD-0005-0050.
Dedicated-purpose pool pumps	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Dedicated-Purpose Pool Pumps* (Washington, DC: DOE, 2016). www.regulations.gov/document?D=EERE-2015-BT-STD-0008-0105. DOE, *2016 Final Rule Spreadsheet: National Impact Analysis (NIA)*. www.regulations.gov/document?D=EERE-2015-BT-STD-0008-0107.
Dehumidifiers	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Dehumidifiers* (Washington, DC: DOE, 2016). www.regulations.gov/document?D=EERE-2012-BT-STD-0027-0046. DOE, *Final Rule Analytical Tools: National Impact Analysis (NIA) Spreadsheet* (Washington, DC: DOE, 2016). www.regulations.gov/document?D=EERE-2012-BT-STD-0027-0048. DOE, *Compliance Certification Database*. (Washington, DC: DOE, 2020). www.regulations.doe.gov/certification-data/#q=Product_Group_s%3A*. Accessed April 10, 2020. EPA, *Most Efficient 2020: Recognition Criteria: Dehumidifiers* (Washington, DC: EPA, 2020). www.energystar.gov/sites/default/files/Dehumidifier%20ENERGY%20STAR%20Most%20Efficient%202020%20Final%20Criteria.pdf.
Direct heating equipment	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Water Heaters, Direct Heating Equipment, and Pool Heaters* (Washington, DC: DOE, 2010). www.regulations.gov/#!documentDetail;D=EERE-2006-STD-0129-0149. DOE, *2010-03-23 National Impact Analysis DHE* (Washington, DC: DOE, 2010). www.regulations.gov/document?D=EERE-2006-STD-0129-0148.
Dishwashers	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Dishwashers* (Washington, DC: DOE, 2016). www.regulations.gov/document?D=EERE-2014-BT-STD-0021-0029. DOE, *Final Rule National Impact Analysis (NIA) Spreadsheet* (Washington, DC, DOE: 2016). www.regulations.gov/document?D=EERE-2014-BT-STD-0021-0031. DOE, *Compliance Certification Database*. (Washington, DC: DOE, 2020). www.regulations.doe.gov/certification-data/#q=Product_Group_s%3A*. Accessed April 10, 2020.

Product	Sources
External power supplies	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: External Power Supplies* (Washington, DC: DOE, 2014). www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0005-0217.
Faucets	California Investor-Owned Utilities. *Faucets: Codes and Standards Enhancement (CASE) Initiative for PY 2013: Title 20 Standards Development: Analysis of Standards Proposal for Residential Faucets and Faucet Accessories*, 2013. efiling.energy.ca.gov/GetDocument.aspx?tn=71768&DocumentContentId=8103. CEC. *Staff Analysis of Water Efficiency Standards for Toilets, Urinals, and Faucets* (Sacramento, CA: CEC), 2015). efiling.energy.ca.gov/GetDocument.aspx?tn=203718&DocumentContentId=11538. EIA, *Residential Energy Consumption Survey (RECS): 2015 RECS Survey Data* (Washington, DC: EIA, 2018). www.eia.gov/consumption/residential/data/2015/. DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Water Heaters, Direct Heating Equipment, and Pool Heaters* (Washington, DC: DOE, 2010). www.regulations.gov/#!documentDetail;D=EERE-2006-STD-0129-0149. DOE, *Compliance Certification Database*. (Washington, DC: DOE, 2020). www.regulations.doe.gov/certification-data/#q=Product_Group_s%3A*. Accessed April 10, 2020.
Furnaces	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces* (Washington, DC: DOE, 2016). www.regulations.gov/document?D=EERE-2014-BT-STD-0031-0217. DOE, *2016-08-30 SNOPR Analytical Tools: Residential Furnaces National Impact Analysis* (Washington, DC: DOE, 2016). www.regulations.gov/document?D=EERE-2014-BT-STD-0031-0213.
Furnace fans	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnace Fans* (Washington, DC: DOE, 2014). www.regulations.gov/#!documentDetail;D=EERE-2010-BT-STD-0011-0111. DOE, *Final Rule National Impact Analysis Spreadsheet* (Washington, DC: DOE, 2014). www.regulations.gov/#!documentDetail;D=EERE-2010-BT-STD-0011-0116. DOE, *2014-04-17 Final Rule Life Cycle Cost Spreadsheet*. (Washington, DC: DOE. 2014). www.regulations.gov/document?D=EERE-2010-BT-STD-0011-0114. DOE, *Compliance Certification Database*. (Washington, DC: DOE, 2020). www.regulations.doe.gov/certification-data/#q=Product_Group_s%3A*. Accessed April 10, 2020.
Microwave ovens	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Microwave Ovens: Stand-By Power* (Washington, DC: DOE, 2013). www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0048-0021. DOE, *National Impact Analysis for Microwave Ovens* (Washington, DC: DOE, 2013). www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0048-0024. DOE, *Compliance Certification Database*. (Washington, DC: DOE, 2020). www.regulations.doe.gov/certification-data/#q=Product_Group_s%3A*. Accessed April 10, 2020.

Product	Sources
Miscellaneous refrigeration equipment	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Miscellaneous Refrigeration Products* (Washington, DC: DOE, 2016). www.regulations.gov/document?D=EERE-2011-BT-STD-0043-0118. DOE, *Direct Final Rule (DFR) Analytical Spreadsheets: National Impact Analysis (NIA)*. www.regulations.gov/document?D=EERE-2011-BT-STD-0043-0115. DOE, *Compliance Certification Database*. (Washington, DC: DOE, 2020). www.regulations.doe.gov/certification-data/#q=Product_Group_s%3A*. Accessed April 10, 2020.
Pool heaters	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Water Heaters, Direct Heating Equipment, and Pool Heaters* (Washington, DC: DOE, 2010). www.regulations.gov/#!documentDetail;D=EERE-2006-STD-0129-0149. DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Pool Heaters* (Washington, DC: DOE, 2015). www.regulations.gov/document?D=EERE-2015-BT-STD-0003-0009. DOE *2010-03-23 National Impact Analysis Pool Heaters* (Washington, DC: DOE, 2010). www.regulations.gov/document?D=EERE-2006-STD-0129-0148. DOE, *2015-10-15 Analytical Tools: Preliminary National Impact Analysis (NIA) Spreadsheet* (Washington, DC: DOE, 2015). www.regulations.gov/document?D=EERE-2015-BT-STD-0003-0011. DOE, *Compliance Certification Database*. (Washington, DC: DOE, 2020). www.regulations.doe.gov/certification-data/#q=Product_Group_s%3A*. Accessed April 10, 2020.
Portable air conditioners	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Portable Air Conditioners* (Washington, DC: DOE, 2016). www.regulations.gov/document?D=EERE-2013-BT-STD-0033-0047. DOE, *Final Rule Spreadsheet: National Impact Analysis (NIA)* (Washington, DC: DOE, 2016). www.regulations.gov/document?D=EERE-2013-BT-STD-0033-0048.
Refrigerators and freezers	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Refrigerators, Refrigerator-Freezers, and Freezers* (Washington, DC: DOE, 2011). www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0012-0128. DOE, *2011-08-30 Analytical Tools: National Impact Analysis for Residential Refrigerators, Refrigerator-Freezers, and Freezers Final Rule* (Washington, DC: DOE, 2011). www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0012-0130. DOE, *Compliance Certification Database*. (Washington, DC: DOE, 2020). www.regulations.doe.gov/certification-data/#q=Product_Group_s%3A*. Accessed April 10, 2020. EPA, *Most Efficient 2020: Recognition Criteria: Refrigerator-Freezers and Freezers* (Washington, DC: EPA, 2020). www.energystar.gov/sites/default/files/Refrigerator-Freezer%20and%20Freezer%20ENERGY%20STAR%20Most%20Efficient%202020%20Final%20Criteria.pdf.

Product	Sources
Room air conditioners	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Clothes Dryers and Room Air Conditioners* (Washington, DC: DOE, 2011). www.regulations.gov/#!documentDetail;D=EERE-2007-BT-STD-0010-0053. DOE, *Compliance Certification Database*. (Washington, DC: DOE, 2020). www.regulations.doe.gov/certification-data/#q=Product_Group_s%3A*. Accessed April 10, 2020. EPA, *Most Efficient 2020: Recognition Criteria: Room Air Conditioners* (Washington, DC: EPA, 2020). www.energystar.gov/sites/default/files/Room%20Air%20Conditioner%20ENERGY%20STAR%20Most%20Efficient%202020%20Final%20Criteria.pdf.
Showerheads	California Investor-Owned Utilities, *Showerheads: Codes and Standards Enhancement (CASE) Initiative for PY 2015: Title 20 Standards Development: Analysis of Standards Proposal for Showerheads*, 2015. efiling.energy.ca.gov/GetDocument.aspx?tn=205606&DocumentContentId=11922. CEC, *Staff Analysis of Water Efficiency Standards for Showerheads* (Sacramento, CA: CEC, 2015). efiling.energy.ca.gov/GetDocument.aspx?tn=205654&DocumentContentId=11944. EIA, *Residential Energy Consumption Survey (RECS): 2015 RECS Survey Data* (Washington, DC: EIA, 2018). www.eia.gov/consumption/residential/data/2015/. DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Water Heaters, Direct Heating Equipment, and Pool Heaters* (Washington, DC: DOE, 2010). www.regulations.gov/#!documentDetail;D=EERE-2006-STD-0129-0149. DOE, *Compliance Certification Database*. (Washington, DC: DOE, 2020). www.regulations.doe.gov/certification-data/#q=Product_Group_s%3A*. Accessed April 10, 2020.
Toilets	California Investor-Owned Utilities, *Toilets and Urinals Water Efficiency: Codes and Standards Enhancement (CASE) Initiative for PY 2013: Title 20 Standards Development: Analysis of Standards Proposal for Toilets and Urinals Water Efficiency*, 2013. efiling.energy.ca.gov/GetDocument.aspx?tn=71765&DocumentContentId=8087. CEC. *Staff Analysis of Water Efficiency Standards for Toilets, Urinals, and Faucets* (Sacramento, CA: CEC, 2015). efiling.energy.ca.gov/GetDocument.aspx?tn=203718&DocumentContentId=11538. DOE, *Compliance Certification Database*. (Washington, DC: DOE, 2020). www.regulations.doe.gov/certification-data/#q=Product_Group_s%3A*. Accessed April 10, 2020.
Uninterruptible power supplies	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Uninterruptible Power Supplies* (Washington, DC: DOE, 2016). www.regulations.gov/document?D=EERE-2016-BT-STD-0022-0023. DOE, *UPS Final Rule National Impact Analysis* (Washington, DC: DOE, 2016). www.regulations.gov/document?D=EERE-2016-BT-STD-0022-0025.

Product	Sources
Water heaters	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Water Heaters, Direct Heating Equipment, and Pool Heaters* (Washington, DC: DOE, 2010). www.regulations.gov/#!documentDetail;D=EERE-2006-STD-0129-0149. DOE, *2010-03-23 National Impact Analysis Water Heaters* (Washington, DC: DOE, 2010). www.regulations.gov/#!documentDetail;D=EERE-2006-STD-0129-0148. DOE, *Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters* (Washington, DC: DOE, 2016). www.regulations.gov/document?D=EERE-2015-BT-TP-0007-0042. DOE, *Compliance Certification Database*. (Washington, DC: DOE, 2020). www.regulations.doe.gov/certification-data/#q=Product_Group_s%3A*. Accessed April 10, 2020.

Table E2. Sources for product assumptions for commercial and industrial products

Product	Sources
Air compressors	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Air Compressors* (Washington, DC: DOE, 2016). www.regulations.gov/document?D=EERE-2013-BT-STD-0040-0082. DOE, *Final Rule Analytical Spreadsheets: National Impact Analysis (NIA)* (Washington, DC: DOE, 2016). www.regulations.gov/document?D=EERE-2013-BT-STD-0040-0084.
Automatic ice makers	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Automatic Commercial Ice Makers* (Washington, DC: DOE, 2014). www.regulations.gov/#!documentDetail;D=EERE-2010-BT-STD-0037-0136. DOE, *Compliance Certification Database*. (Washington, DC: DOE, 2020). www.regulations.doe.gov/certification-data/#q=Product_Group_s%3A*. Accessed April 10, 2020.
Beverage vending machines	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Refrigerated Bottled or Canned Beverage Vending Machines* (Washington, DC: DOE, 2015). www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0022-0067. DOE, *Final Rule Beverage Vending Machine Spreadsheet: National Impact Analysis (NIA)* (Washington, DC: DOE, 2015). www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0022-0069. DOE, *Compliance Certification Database*. (Washington, DC: DOE, 2020). www.regulations.doe.gov/certification-data/#q=Product_Group_s%3A*. Accessed April 10, 2020.
Commercial boilers	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Packaged Boilers* (Washington, DC: DOE, 2016). www.regulations.gov/document?D=EERE-2013-BT-STD-0030-0083. DOE, *Final Rule Spreadsheet: Commercial Packaged Boiler National Impact Analysis (NIA)* (Washington, DC: DOE, 2016). www.regulations.gov/document?D=EERE-2013-BT-STD-0030-0087.

Product	Sources
Commercial clothes washers	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Clothes Washers* (Washington, DC: DOE, 2014). www.regulations.gov/#!documentDetail;D=EERE-2012-BT-STD-0020-0036. DOE, *Final Rule National Impact Analysis Spreadsheet (FR_CCW__NIA_2014_09)* (Washington, DC: DOE, 2014). www.regulations.gov/#!documentDetail;D=EERE-2012-BT-STD-0020-0034. DOE, *Compliance Certification Database*. (Washington, DC: DOE, 2020). www.regulations.doe.gov/certification-data/#q=Product_Group_s%3A*. Accessed April 10, 2020.
Commercial furnaces	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Warm Air Furnaces* (Washington, DC: DOE, 2015). www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0021-0050. DOE, *2015-12-14 Direct Final Rule National Impact Analysis (NIA) Spreadsheet* (Washington, DC: DOE, 2015). www.regulations.gov/document?D=EERE-2013-BT-STD-0021-0052.
Commercial packaged air conditioners and heat pumps	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Small, Large, and Very Large Commercial Package Air Conditioning and Heating Equipment* (Washington, DC: DOE, 2015). www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0007-0105. DOE, *Direct Final Rule National Impact Analysis Spreadsheet* (Washington, DC: DOE, 2015). www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0007-0107.
Commercial refrigeration equipment	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Refrigeration Equipment* (Washington, DC: DOE, 2014). www.regulations.gov/#!documentDetail;D=EERE-2010-BT-STD-0003-0102. DOE, *Compliance Certification Database*. (Washington, DC: DOE, 2020). www.regulations.doe.gov/certification-data/#q=Product_Group_s%3A*. Accessed April 10, 2020.
Commercial three-phase air conditioners and heat pumps	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: ASHRAE Equipment* (Washington, DC: DOE, 2015). www.regulations.gov/#!documentDetail;D=EERE-2014-BT-STD-0015-0043.
Commercial water heaters	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Water Heating Equipment* (Washington, DC: DOE, 2016). www.regulations.gov/#!documentDetail;D=EERE-2014-BT-STD-0042-0016.
Computer room air conditioners	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: ASHRAE Equipment* (Washington, DC: DOE, 2012). www.regulations.gov/document?D=EERE-2011-BT-STD-0029-0039.
Distribution transformers	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Distribution Transformers* (Washington, DC: DOE, 2013). www.regulations.gov/#!documentDetail;D=EERE-2010-BT-STD-0048-0760. DOE, *Final Rule: National Impacts Analysis Spreadsheet* (Washington, DC: DOE, 2013). www.regulations.gov/#!documentDetail;D=EERE-2010-BT-STD-0048-0765.

Product	Sources
Electric motors	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Electric Motors* (Washington, DC: DOE, 2014). www.regulations.gov/#!documentDetail;D=EERE-2010-BT-STD-0027-0108. DOE, *Final Rule. National Impact Analysis Design AB Spreadsheet* (Washington, DC: DOE, 2014). www.regulations.gov/#!documentDetail;D=EERE-2010-BT-STD-0027-0112. DOE, *Final Rule. National Impact Analysis Brake Spreadsheet* (Washington, DC: DOE, 2014). www.regulations.gov/#!documentDetail;D=EERE-2010-BT-STD-0027-0111.
Fans	DOE, *2016 NODA Life-Cycle Cost (LCC) and Payback Period (PBP) Analyses Spreadsheet* (Washington, DC: DOE, 2016). www.regulations.gov/document?D=EERE-2013-BT-STD-0006-0190. DOE, 2016 NODA National Impact Analysis (NIA) Spreadsheet (Washington, DC: DOE, 2016). www.regulations.gov/document?D=EERE-2013-BT-STD-0006-0192.
Packaged terminal air conditioners and heat pumps	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Packaged Terminal Air Conditioners and Heat Pumps* (Washington, DC: DOE, 2015). www.regulations.gov/#!documentDetail;D=EERE-2012-BT-STD-0029-0040. DOE, *Final Rule Spreadsheet: National Impact Analysis (NIA)* (Washington, DC: DOE, 2015). www.regulations.gov/#!documentDetail;D=EERE-2012-BT-STD-0029-0043. DOE, *Compliance Certification Database*. (Washington, DC: DOE, 2020). www.regulations.doe.gov/certification-data/#q=Product_Group_s%3A*. Accessed April 10, 2020.
Pumps	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Pumps* (Washington, DC: DOE, 2015). www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0031-0056.
Single-package vertical air conditioners and heat pumps	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Single Package Vertical Units* (Washington, DC: DOE, 2015). www.regulations.gov/#!documentDetail;D=EERE-2012-BT-STD-0041-0027. DOE, *Compliance Certification Database*. (Washington, DC: DOE, 2020). www.regulations.doe.gov/certification-data/#q=Product_Group_s%3A*. Accessed April 10, 2020.
Small motors	DOE, *Final Rule Technical Support Document (TSD): Energy Efficiency Program for Commercial and Industrial Equipment: Small Electric Motors* (Washington, DC: DOE, 2010). www.regulations.gov/document?D=EERE-2007-BT-STD-0007-0054.
Urinals	California Investor-Owned Utilities, *Toilets and Urinals Water Efficiency: Codes and Standards Enhancement (CASE) Initiative for PY 2013: Title 20 Standards Development: Analysis of Standards Proposal for Toilets and Urinals Water Efficiency*, 2013. efiling.energy.ca.gov/GetDocument.aspx?tn=71765&DocumentContentId=8087. CEC, *Staff Analysis of Water Efficiency Standards for Toilets, Urinals, and Faucets*, 2015. efiling.energy.ca.gov/GetDocument.aspx?tn=203718&DocumentContentId=11538. DOE, *Compliance Certification Database*. (Washington, DC: DOE, 2020). www.regulations.doe.gov/certification-data/#q=Product_Group_s%3A*. Accessed April 10, 2020.

Product	Sources
Water-source heat pumps	DOE, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: ASHRAE Equipment* (Washington, DC: DOE, 2015). www.regulations.gov/#!documentDetail;D=EERE-2014-BT-STD-0015-0043.

Appendix F: Methodology for General Service Lamps

For GSLs, we estimated savings for the lamps covered by the original Energy Independence and Security Act (EISA) 2007 standards, which are A-type medium screw base lamps, as well as for the four lamp types covered by the 2017 expanded definition—that is, reflector, multifaceted reflector (MR), decorative,[40] and miscellaneous A-type lamps.

Because more than 95% of A-type lamps are used in the residential sector (DOE 2017a), we calculated savings for A-type lamps only for that sector. We also assumed that all decorative and miscellaneous A-type lamps, 96% of reflector lamps, and 77% of MR lamps are used in the residential sector based on DOE's 2015 *U.S. Lighting Market Characterization* (LMC) (DOE 2017a).

To calculate the stock of each lamp type in each year, we started with estimates of the 2015 stock for A-type lamps (table F1) and the expanded definition lamps (table F2).[41]

Table F1. 2015 stock of A-type lamps by lamp type

Lamp type	Lamps (million)	% of total
Conventional incandescent	777	22%
Halogen	693	20%
CFL	1,814	51%
LED	240	7%
Total	3,524	100%

Source: DOE 2017a

Table F2. 2015 stock of expanded definition lamps by lamp category and lamp type

	Incandescent		LED		Total lamps (million)
Lamp category	Lamps (million)	% of total	Lamps (million)	% of total	
Reflector	648	81%	150	19%	798
Decorative	944	100%	0	0%	944
MR	74	86%	12	14%	86
Misc. A-type	83	100%	0	0%	83

Incandescent lamps include conventional incandescents and halogens. *Sources*: DOE 2017a, 2017b.

For the base case for the residential sector, we assumed that, as of 2020, 25% of sales of A-type, reflector, and MR lamps would be incandescents,[42] and 75% would be LEDs. For

---

[40] Decorative lamps include globe lamps.

[41] For simplicity, we excluded CFLs from our analysis for the expanded definition lamp types.

[42] We use *incandescent* here to refer to both conventional incandescent lamps and halogen lamps.

decorative and miscellaneous A-type lamps, for which the LED market share has not increased as fast as for the other lamp categories, we assumed an even split of sales between incandescents and LEDs. (Because the average lifetime of LEDs is much longer than that of incandescents, these splits in market share result in stock penetrations of incandescents that are much lower than their market share. For example, for A-type lamps, the stock of incandescents is less than 5% beginning in 2022.) For the standards case, we assumed a 100% market share for LEDs beginning in July 2021. For lamps used in the commercial sector, we assumed that, as of 2020, 100% of sales would be LEDs.

We calculated the number of lamps of each lamp type being replaced each year based on the stock in the previous year and the average lamp lifetime. We also accounted for lamp shipments going to new construction based on the U.S. Energy Information Administration’s (EIA’s) projections of the average annual growth in residential and commercial floor space (EIA 2020). We calculated the stock of each lamp type in each future year as the sum of replacement shipments, shipments to new construction, and lamps not being replaced (i.e., installed lamps that did not burn out in the previous year). We calculated total annual energy use in each year based on the stock of each lamp type and the per-unit energy use.

Table F3 shows our assumptions for each lamp category and lamp type, including average wattage, lifetime, and per-unit annual energy use.

Table F3. Assumed average wattage, lifetime, and per-unit annual energy use by lamp category and lamp type

Lamp category and lamp type	Average wattage (W)	Average lifetime (years)	Average per-unit annual energy use (kWh)
A-type			
Halogen	45.2	1.5	37.9
CFL	13.7	6.4	11.5
LED	10.5	19.3	8.8
Reflector			
Residential			
Incandescent	65	2.5	66.9
LED	8.5	13	8.6
Commercial			
Incandescent	65	0.5	229.0
LED	8.5	4.4	26.6
MR			
Residential			
Halogen	50	4.2	51.4
LED	6.5	19.0	5.6
Commercial			
Halogen	50	1.4	176.0
LED	6.5	8.5	18.5
Decorative			
Incandescent	50	5.6	38.6
LED	5	18.5	3.4
Misc. A-type			
Incandescent	72	1.5	61.2
LED	11	16.0	9.5

Sources: DOE 2017a, 2016b; Kantner et al. 2017.

Finally, we calculated annual energy savings in each year based on the difference in total annual energy use in the base case and the standards case.

Appendix G: Examples of Product-Specific Test Procedure Improvements

Table G1 summarizes examples of potential product-specific test procedure improvements. We then provide additional details below.

Table G1. Summary of examples of product-specific test procedure improvements

Product	Test procedure improvements
Central air conditioners and heat pumps	Consider adopting a load-based test procedure
Clothes dryers	Add a smaller load to the test procedure and consider testing on more than just the "normal" cycle
Clothes washers	Amend the test procedure to better reflect the energy used for drying and shift to a metric based on pounds of clothes washed
Commercial packaged air conditioners and heat pumps (RTUs)	Amend the test procedure to better capture fan energy use
Computers	Consider adopting a test procedure that captures software operation and short-idle
Electric motors	Amend the test procedure to capture multiple load points, and consider ways to capture the benefits of speed control
Refrigerators and freezers	Consider adopting an IEC[43] test procedure, which better reflects real-world conditions
Televisions	Amend the test procedure to reflect current technology, standby power use due to internet connectivity, and the persistence of energy-saving settings

Central air conditioners and heat pumps

The current test procedure for central air conditioners and heat pumps reflects steady-state performance, which does not capture how equipment performs in the field under varying loads. In particular, the current test procedure does not capture the control strategies used with variable-speed equipment, which can significantly impact real-world efficiency. We recommend that DOE consider a load-based test procedure for central air conditioners, which would both better reflect how all equipment performs in the field and encourage manufacturers to develop improved control strategies.

Clothes dryers

The current test procedure for clothes dryers includes a single load size (8.45 lbs.) and tests products on only the "normal" cycle. The Northwest Energy Efficiency Alliance (NEEA) found that more than one-third of loads are 5 lbs. or less and that load size significantly

[43] International Electrotechnical Commission.

impacts clothes dryer efficiency (Hannas and Gilman 2014; NEEA and NPCC 2015). In addition, with hybrid heat pumps, which are becoming more common, energy use on the "normal" cycle could be significantly less than on a different cycle that uses more electric resistance heat. We recommend that DOE add a smaller load to the test procedure and consider testing on more than just the "normal" cycle.

Clothes washers

The current test procedure for clothes washers captures machine energy, water heating energy, and the energy required by the clothes dryer to remove the remaining moisture in the clothes (in addition to low-power-mode energy consumption). Clothes dryer energy is the largest component of energy use. However, for many machines, the current test procedure may be significantly underestimating the energy required to remove the moisture in the clothes because the test measures the clothes' remaining moisture content (RMC) using only the "cold" wash temperature and the maximum load size. NEEA testing found that clothes come out of the washer wetter with smaller load sizes or when the "warm" wash temperature is selected (NEEA 2020). In addition, the current efficiency metric's structure is biased toward large-capacity washers. We recommend that DOE amend the test procedure to calculate a weighted-average value for RMC based on all the test cycles and shift to a metric based on pounds of clothes washed.

Commercial packaged air conditioners and heat pumps

The current test procedure for RTUs assumes unrealistically low external static pressures and does not capture fan energy use in ventilation mode or heating mode. The test thus significantly underestimates fan energy consumption and does not provide an accurate relative ranking of products. We recommend that DOE adopt an amended test procedure that better captures fan energy use.

Computers

DOE currently lacks a regulatory test procedure for computers. In addition, the test procedure used for ENERGY STAR does not reflect how users typically use computers (i.e., with many applications open at once) nor does it capture current technological approaches for saving energy. Computers can significantly reduce energy consumption by going into low-power states measured in the milliseconds (e.g., between keystrokes), but the current test does not reflect this capability. The European Union and the Canadian Standards Association have begun work on more representative test procedures. We recommend that DOE review the latest work on international test procedures and consider adopting a new test procedure for computers.

Electric motors

The current test procedure for electric motors is based on performance at full load. However, motors typically operate at loads that are significantly less than full load, and motor loading varies across individual applications. Furthermore, motors with speed control can provide very large energy savings in many applications, but the current test does not capture speed control's energy-saving benefits. We recommend that DOE amend the test procedure to capture efficiency at multiple load points and consider modifications that would account for speed control.

Refrigerators and freezers

The current test procedure for refrigerators and freezers is conducted at an ambient temperature of 90˚F without door openings, which does not represent typical usage conditions and may not adequately represent the performance of refrigerators with variable-speed compressors. An international test procedure (IEC 62552:2015) includes two steady-state tests at ambient temperatures of 61˚F and 90˚F and a "load processing efficiency" test that places water loads in the refrigerator and freezer compartments and measures the energy required to return the unit to stable operating conditions. We recommend that DOE evaluate and consider adopting the International Electrotechnical Commission (IEC) test procedure.

Televisions

The current test procedure for televisions relies on an outdated test clip that does not reflect current technology such as ultra-high definition (UHD) and high dynamic resolution (HDR). The Collaborative Labeling and Appliance Standards Program has developed an updated test clip that has been adopted by the European Commission (CLASP 2019). Further, television energy use depends significantly on the picture settings that consumers select. The current test procedure requires energy measurement as shipped, but products may prompt consumers to change to settings—such as "vivid" or "sports"—that consume higher amounts of energy and do not default back to the standard mode. We recommend that DOE evaluate the IEC's latest work on television test procedures and consider updating the federal test procedure.

Appendix H: Reversing Policies that Undercut the National Appliance Efficiency Standards Program

Under the Trump administration, the number of missed legal deadlines for reviewing and potentially upgrading efficiency standards ballooned from 4 to 28. A new administration should prioritize work to catch up on overdue standards. The Trump administration also completed several rules that have undercut existing standards or made future, cost-effective standards harder to achieve. The paragraphs below describe rules and policies that should be reversed.

REINSTATE LIGHT BULB STANDARDS

In two rules published in September and December 2019, the Trump administration narrowed and then blocked new light bulb standards slated to take effect on January 1, 2020. A coalition of 17 state and city attorneys general and environmental and consumer groups sued.[44] These standards would have shifted the U.S. market for commonly used light bulbs to highly efficient light emitting diodes (LEDs). Although the market is trending to LEDs, this standard remains one of the top appliance standards savings opportunities. Because the inefficient, incandescent light bulbs that would be eliminated by this standard burn out quickly, this standard would rapidly shift nearly all sockets that still have an incandescent bulb to LEDs. We recommend that the new administration move expeditiously to implement the light bulb standards.

REPEAL OR SIGNIFICANTLY MODIFY THE PROCESS RULE

In a final rule published in February 2020, the Trump administration rewrote the agency's internal rules governing how it considers and develops new standards (DOE 2020f). The revised process established multiple new hurdles and constraints that will make future cost-effective standards harder to complete. These include undue deference to industry-developed test procedures and model standards developed by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE); requirements to complete a "coverage" regulatory proceeding (triggering preemption of state authority) prior to considering standards for newly regulated products; minimum savings thresholds that put some standards off limits, even if they are attainable at zero or very low cost; and requirements that DOE restart the regulatory process whenever it expands rulemaking scope or identifies a needed change to a test procedure (ASAP et al. 2019a). Unlike previous agency processes, DOE has made the new one legally binding, increasing the likelihood of legal challenges to future rules. A further modification to the new Process Rule published in August 2020 will alter how DOE selects standards, potentially directing DOE to select lower standard levels than required by statute (DOE 2020e; ASAP et al. 2020). DOE should repeal the revised Process Rule or modify it significantly.

REPEAL THE GAS PRODUCTS INTERPRETIVE RULE

---

[44] *New York v. DOE*, 2d Cir. No. 19-3652; *NRDC v. DOE*, 2d Cir. No. 20-699.

In response to a petition from the gas industry, DOE proposed an interpretive rule in July 2019 and a modified supplemental proposed rule in September 2020 that effectively puts meaningful future standards for products that use natural gas off-limits (DOE 2019a, 2020d; ASAP et al. 2019c). Reversing previously settled DOE policy, the new rule would require DOE to create separate product classes for non-condensing gas space- and water-heating products or, alternatively, to achieve the same outcome by creating separate classes based on exhaust vent type. Previously, DOE had evaluated condensing technology as a pathway for improving efficiency. Because condensing technology is the single most important energy-saving technology for most gas appliances, the proposed interpretive rule would put nearly all the potential savings from improved standards for gas appliances off limits. DOE should repeal this interpretive rule if it has been completed.

REPEAL "SHORT-CYCLE" DISHWASHER, CLOTHES WASHER, AND CLOTHES DRYER RULES

In response to a petition from the Competitive Enterprise Institute, DOE established a separate product class for dishwashers that have a "normal" wash cycle of 60 minutes or less (DOE 2020b). The final rule exempts products with this short "normal" cycle from existing standards and indicates that DOE will initiate a rulemaking to establish standards for them which could be weaker than existing dishwasher standards. Manufacturers, opposed to the rule, argued that nearly 90% of current models already have a short cycle (AHAM 2019). Efficiency advocates and the attorneys general of 14 states and cities added that the rule would violate the appliance standards law's anti-backsliding clause (ASAP et al. 2019d; Attorneys General 2019). In August 2020, DOE issued a similar proposal for clothes washers and dryers (DOE 2020a). DOE should repeal the dishwasher short-cycle product class rule and any other completed short-cycle product class rule.

REPEAL AUTOMATIC INTERIM TEST PROCEDURE WAIVER RULE

The test procedure waiver process accommodates situations in which a particular product cannot be tested under the normal procedure. In 2019, DOE proposed a rule that would automatically grant manufacturer applications for interim test procedure waivers if not acted upon by DOE within 30 days (DOE 2019b). Test procedures can be complicated, however, and reviews typically take significantly longer than 30 days. Granting waivers without DOE review would invite abuse of the process, effectively allowing manufacturers an opportunity to write their own test procedures (ASAP et al. 2019b). Many manufacturers and efficiency advocates raised concerns with or opposed the proposed interim test procedure rule; DOE should repeal it if it has been published.

RE-INSTITUTE THE PRIOR DEFINITION OF "SHOWERHEAD"

In August 2020, DOE issued a proposed test procedure rule that would modify the definition of *showerhead* (DOE 2020c). This rule would create a new regulatory definition that would allow any one showerhead to contain multiple nozzles, each of which could use up to the flow rate permitted by existing federal standards (2.5 gpm). A previous final test procedure rule issued in 2013 had made clear that flow rate applies to the overall showerhead, not individual nozzles or components. Congress enacted the 2.5 gpm standard in 1992, and it has never been strengthened. If DOE has completed a rule redefining showerhead in this manner, it should repeal it.

Appendix H References

AHAM (Association of Home Appliance Manufacturers). 2019. *AHAM Comments on DOE's Proposal to Grant Petition for Rulemaking on Dishwasher Product Classes*. Docket No. EERE-2018-BT-STD-0005, RIN 1904-AE35, October 16. Washington, DC: DOE (Department of Energy). www.regulations.gov/document?D=EERE-2018-BT-STD-0005-3188.

ASAP (Appliance Standards Awareness Project), ACEEE, CEC (California Energy Commission), CFA (Consumer Federation of America), NRDC (Natural Resources Defense Council), NEEP (Northeast Energy Efficiency Partnerships), and NEEA (Northwest Energy Efficiency Alliance). 2019a. *Comments of ASAP, ACEEE, CEC, CFA, NRDC, NEEP, and NEEA Re: Proposed Procedures for Use in New or Revised Energy Conservation Standards and Test Procedures for Consumer Products and Commercial/Industrial Equipment*. Docket No. EERE–2017–BT–STD–0062, RIN 1904–AD38, May 6. Washington, DC: DOE. appliance-standards.org/sites/default/files/Process%20Rule%20NOPR%20comments.pdf.

——. 2019b. *Comments of ASAP, ACEEE, CFA, NCLC, NEEP, and NEEA Re: Notice of Proposed Rulemaking on the Test Procedure Interim Waiver Process*. Docket No. EERE–2019–BT–NOA–0011, August 6. Washington, DC: DOE. appliance-standards.org/sites/default/files/Test_Procedure_Waiver_NOPR_Comments.pdf.

——. 2019c. *Comments of ASAP, ASE, ACEEE, CFA, and NCLC Re: Energy Conservation Standards for Residential Furnaces and Commercial Water Heaters*. Docket No. EERE-2018-BT-STD-0018, September 9. Washington, DC: DOE. appliance-standards.org/sites/default/files/Comments_gas_industry_interpetive_rule.pdf.

——. 2019d. *Comments of ASAP, CFA, NCLC, and NRDC Re: Proposed Rule Granting a Petition for Rulemaking for Dishwashers*. Docket No. EERE–2018–BT–STD–0005, RIN 1904–AE35, October 16. Washington, DC: DOE. appliance-standards.org/sites/default/files/Dishwasher_Petition_Proposed_Rule_Comments_0.pdf.

——. 2020. *Comments of ASAP, ACEEE, CEC, CFA, NRDC, NEEP, and NEEA Re: Proposed Procedures for Evaluating Statutory Factors for Use in New or Revised Energy Conservation Standards*. Docket. No. EERE–2017–BT–STD-0062, RIN 1904-AE84, March 16. Washington, DC: DOE. appliance-standards.org/sites/default/files/Process_Rule_SNOPR_Comments.pdf.

Attorneys General. 2019. *Comments of Attorneys General of California, Connecticut, Illinois, Maine, Maryland, Massachusetts, Minnesota, New Jersey, New York, Oregon, Vermont, Washington, and the District of Columbia, and the City of New York*. Docket No. EERE-2018-BT-STD-0005, RIN 1904-AE35, October 16. Washington, DC: DOE. www.regulations.gov/document?D=EERE-2018-BT-STD-0005-3136.

DOE. 2019a. *Energy Conservation Program for Appliance Standards: Energy Conservation Standards for Residential Furnaces and Commercial Water Heaters*. EERE-2018-BT-STD-0018-

0065, July 11. Washington, DC: DOE. www.regulations.gov/document?D=EERE-2018-BT-STD-0018-0065.

——. 2019b. *Test Procedure Interim Waiver Process*. EERE-2019-BT-NOA-0011-0001, RIN 1904-AE24, May 1. Washington, DC: DOE. www.regulations.gov/document?D=EERE-2019-BT-NOA-0011-0001.

——. 2020a. *Energy Conservation Program: Energy Conservation Standards for Clothes Washers and Dryers*. EERE–2020–BT–STD–0001, RIN 1904–AE86, August 13. Washington DC: DOE. www.regulations.gov/document?D=EERE-2020-BT-STD-0001-0001.

——. 2020b. *Energy Conservation Program: Establishment of a New Product Class for Residential Dishwashers*. EERE-2018-BT-STD-0005, October 30. Washington, DC: DOE. www.regulations.gov/document?D=EERE-2018-BT-STD-0005-3221.

——. 2020c. *Energy Conservation Program: Test Procedure for Showerheads*. EERE-2020-BT-TP-0002, August 13. Washington, DC: DOE. www.regulations.gov/document?D=EERE-2020-BT-TP-0002-0001.

——. 2020d. *Energy Conservation Program for Appliance Standards: Energy Conservation Standards for Residential Furnaces and Commercial Water Heaters.* EERE-2018-BT-STD-0018-0097, September 24. Washington DC: DOE. www.regulations.gov/document?D=EERE-2018-BT-STD-0018-0097.

——. 2020e. *Energy Conservation Program for Appliance Standards: Procedures for Evaluating Statutory Factors for Use in New or Revised Energy Conservation Standards*. EERE-2017-BT-STD-0062-0176, August 19. Washington DC: DOE. www.regulations.gov/document?D=EERE-2017-BT-STD-0062-0176.

——. 2020f. *Energy Conservation Program for Appliance Standards: Procedures for Use in New or Revised Energy Conservation Standards and Test Procedures for Consumer Products and Commercial/Industrial Equipment*. EERE-2017-BT-STD-0062-0163, February 14. Washington, DC: DOE. www.regulations.gov/document?D=EERE-2017-BT-STD-0062-0163.