

FACTORS AFFECTING ELECTRICITY CONSUMPTION IN THE U.S. (2010 - 2035)

IEE Report March 2013









Factors Affecting Electricity Consumption in the U.S. (2010–2035)

IEE Report

March 2013

Prepared by

Ingrid Rohmund David Costenaro Anthony Duer

EnerNOC Utility Solutions Consulting

Lisa Wood Adam Cooper

IEE

TABLE OF CONTENTS

EXECUTIVE SUMMARY	1
Scenarios	2
Results	
INTRODUCTION	7
CODES AND STANDARDS	9
IMPACT OF CODES AND STANDARDS ON U.S. ELECTRICITY CONSUMPTION	12
RESULTS BY SECTOR	18
Residential Sector	
Commercial Sector	20
Industrial Sector	22
SUMMARY	
RATEPAYER-FUNDED EFFICIENCY PROGRAMS	
RATEPAYER-FUNDED EE PROGRAM ANALYSIS APPROACH	25
ACCOUNTING FOR RATEPAYER-FUNDED CODES & STANDARDS EFFORTS	27
SUMMARY	
ELECTRIC TRANSPORTATION	29
LIGHT DUTY VEHICLE SCENARIOS	33
LIGHT DUTY SCENARIO RESULTS	34
TRANSPORTATION SCENARIOS	37
SUMMARY	39
CONCLUSION	42
APPENDIX A COMPARISON OF AEO 2009, 2010, 2011, AND 2012	A-1
APPENDIX B ASSUMPTIONS ABOUT BUILDING CODES AND APPLIANCE	
STANDARDS	B-1
APPENDIX C OVERVIEW OF MODELING APPROACH	C-1
APPENDIX D RATEPAYER-FUNDED EE PROGRAM ANNUAL IMPACTS	D- 1
APPENDIX E TRANSPORTATION SECTOR ANALYSIS APPROACH	E-1
APPENDIX F REFERENCES	F-1

EXECUTIVE SUMMARY

In the coming decades, many factors will affect electricity consumption in the United States. This report, prepared by EnerNOC Utility Solutions Consulting, examines the potential effects of three key factors on electricity consumption:

- 1. Improvements to building energy codes and appliance/equipment efficiency standards
- 2. Growth in ratepayer-funded electric efficiency (EE) programs including both utility programs and those administered by state or regional program administrators
- 3. Electrification of the transportation sector; primarily light duty vehicles and commercial light trucks.

Table 1 shows the impact of each of these factors on electricity consumption in 2025 and 2035 under two scenarios – a *moderate* scenario which is very plausible and under a more *aggressive* scenario – relative to the Reference Case from the Energy Information Administration's (EIA) Annual Energy Outlook 2012 (AEO 2012).¹

 Table 1: Factors Affecting Electricity Consumption in the U.S. in 2025 and 2035

	2010 Total Electricity Use (TWh)	2025 Total Electricity Use (TWh)	Percentage of Total Use	2035 Total Electricity Use (TWh)	Percentage of Total Use
Reference Case	3,730	4,099	100%	4,440	100%
Moderate Scenario					
Moderate Codes and Standards		-277	-6.8%	-420	-9.5%
Ratepayer Funded EE Programs*		-242	-5.9%	-249	-5.6%
Moderate Electric Transportation		16	0.4%	33	0.8%
TOTAL EFFECT		-504	-12.3%	-635	-14.3%
IEE MODERATE FORECAST		3,595		3,805	
Aggressive Scenario					
Aggressive Codes and Standards		-478	-11.7%	-769	-17.3%
Ratepayer Funded EE Programs*		-242	-5.9%	-249	-5.6%
Aggressive Electric Transportation		52	1.3%	147	3.3%
TOTAL EFFECT		-668	-16.3%	-871	-19.6%
IEE AGGRESSIVE FORECAST		3,431		3,569	

* To avoid double counting, ratepayer-funded EE programs exclude the effects of utility-administered codes and standards programs. In 2035, we project an overlap of 46 TWh, meaning that EE programs achieve an additional 46 TWh of savings related to codes and standards programs which is 15.8% of the ratepayer-funded EE Programs component.

¹ http://www.eia.gov/forecasts/archive/aeo12/index.cfm

SCENARIOS

Under the *moderate scenario*, today's most efficient appliances and equipment become the minimum standard, newly constructed buildings use 35 percent less energy, ratepayer-funded EE programs grow at current trends, and electric vehicles make up 2 percent of the registered vehicle stock by 2035. This scenario is very plausible.

The *aggressive scenario* expands on the assumptions made in the moderate scenario. By 2035, newly constructed buildings use 60 percent less energy, electric vehicles constitute 12 percent of the registered vehicle stock, and some appliance and equipment efficiency standards are pushed to engineering limits. Ratepayer-funded EE programs follow the same path as in the moderate scenario.

The effect of each factor is summarized below.

- As shown in Table 1, **building codes and equipment standards** have the largest impact among the factors examined with the potential to decrease electricity consumption by 420 Terawatt-hours (TWh) (9.5%) in 2035 under a moderate scenario and 769 TWh (17.3%) under an aggressive scenario.
 - The codes and standards *moderate* scenario decreases growth in consumption nearly 60% between 2010 and 2035 relative to the AEO reference forecast in 2010.
 - The codes and standards *aggressive* scenario completely eliminates growth in electricity consumption between 2010 and 2035. Over 70% of these savings comes from equipment standards, with the remainder ensuing from building codes phased into the building stock over time through new construction and major renovations.
- **Ratepayer-funded electric energy efficiency (EE) programs**, including both utility programs and those administered by state or regional program administrators decrease national electricity consumption. Following current trends, these programs reduce electricity consumption by 249 TWh (5.6%) by 2035.
 - O Some ratepayer-funded EE programs are beginning to include efforts to accelerate the development and enforcement of codes and standards. To avoid double-counting the codes and standards savings, we subtract the savings achieved due to codes and standards programs to get a net ratepayer-funded programs savings estimate. When unadjusted, ratepayer EE programs save an estimated 295 TWh (6.7%) in 2035.²

² At the national level the attribution of this overlap is moot as the net effect on U.S. electricity consumption remains the same. However, for participating utilities, the attribution of energy savings resulting from ratepayer-funded codes and standards programs is very important. In the face of increasing statewide and

- Electrification of the transportation sector has some impact on energy consumption in the U.S. Growth is mainly due to the progressive use of electric light duty and commercial vehicles in 2020 and beyond. Various policy and economic drivers as well as consumer demand will determine the ultimate levels of electric vehicle adoption, including: advances in battery technology, oil prices, and government mandates on fleet fuel efficiency (or CAFE) standards. However, under both scenarios, the electricity growth is modest. It should be noted that this analysis does not capture the electrification of non-road transportation equipment.
 - Under the *moderate* electric transportation scenario, where electric vehicles comprise 2 percent of the registered vehicle stock (5.3 million vehicles), electricity consumption increases by 33 TWh (0.8%) in 2035. Based on the AEO 2012 Reference Case.
 - Under the *aggressive* electric transportation scenario, where electric vehicles comprise 12 percent of the registered vehicle stock (30.4 million vehicles), electricity consumption increases by 147 TWh (3.3%) in 2035. Based on the Advanced Battery & High Oil (\$200/barrel in 2035) forecast.

Light Duty Electric Vehicle Stock by Scenario	2010	2015	2020	2025	2030	2035
Moderate Scenario: AEO 2012 Reference Case	20	230	900	1,960	3,430	5,330
Aggressive Scenario: Advanced Battery & High Oil						
(\$200/barrel in 2035)	20	1,117	5,354	11,069	19,295	30,400

RESULTS

Figure 1 shows the combined effect of all three factors, relative to the AEO 2012 reference forecast. As shown, under the *moderate* scenario, electricity consumption between 2010 and 2035 remains relatively flat –moving from 3,730 TWh in 2010 to 3,805 TWh in 2035. Under the *aggressive* scenario, electricity consumption declines between 2010 and 2035 – moving from 3,730 TWh in 2010 to 3,569 TWh in 2035.

utility-specific energy efficiency program performance targets, along with the rules and regulations that govern how energy savings are calculated, proper attribution of energy savings from codes and standards programs is a very real business concern for participating utilities.



Figure 1: Energy Use in the U.S., AEO 2012 Reference Case and IEE Scenarios (2010-2035)

Figure 2 and Figure 3 illustrate how the factors combine with the reference forecast to produce the net energy use projected in IEE's two scenarios. The purple section of each bar indicates energy use reduction from codes and standards relative to the AEO 2012 Reference Case, the red section represents energy use reductions from ratepayer funded programs, and, the green section indicates additional energy use from electric transportation.



Figure 2: Moderate Scenario – Combined Effect of Factors (2010-2035)

As shown in Figure 2, under the *moderate* scenario, codes and standards reduce electricity consumption by 420 TWh in 2035 (9.5 percent of AEO Reference Case), with roughly 70 percent of the savings coming from improvements to appliance and equipment standards. Continued support of ratepayer-funded EE programs over the forecast period saves an additional 249 TWh in 2035 (5.6 percent of AEO Reference Case). The gradual introduction of electric light duty vehicles (LDVs), commercial light trucks, and growth in transit rail increases electricity consumption by 33 TWh (less than 1 percent of AEO Reference Case).

Combined, these factors have a dampening effect on U.S. electricity consumption and midway through the forecast (2020-2025) total U.S. consumption flattens at a low of 3,590 TWh. Electricity consumption turns up between 2025 and 2035 due to projected economic growth and increased use of electricity as a fuel for the transportation sector. *In aggregate, under the moderate scenario, accounting for these three factors, IEE projects 2035 electricity consumption to be 3,805 TWh, a mere 75 TWh (2 percent) above 2010 levels and 14.3 percent less than the AEO Reference Case projection for 2035.*



Figure 3: Aggressive Scenario — Combined Effect of Factors (2010–2035)

As shown in Figure 3, under the *aggressive* scenario, codes and standards programs have a substantial impact on electricity consumption throughout the forecast period, reducing electricity consumption in 2035 by 769 TWh (17.3 percent of AEO Reference Case). Continued support of ratepayer-funded EE programs over the forecast period saves an additional 249 TWh in 2035. In this scenario, substantial battery technology breakthroughs and increasing oil prices result in greater consumer demand for electric light duty vehicles (LDVs) and commercial light trucks resulting in electricity consumption increasing by 147 TWh (3.3 percent of AEO Reference Case).

Combined, these factors have a substantial dampening effect on U.S. electricity consumption and in 2025 total U.S. consumption drops to a forecast low of 3,431 TWh. Rapid electrification of the transportation sector in the latter part of the forecast partially offsets the downward drivers, resulting in an end of forecast value of 3,569 TWh. *In aggregate, under the aggressive scenario, accounting for these three factors, IEE projects 2035 electricity consumption to be 3,569 TWh, which is 161 TWh (4 percent) below 2010 levels and 19.6 percent less than the AEO Reference Case projection for 2035.*

INTRODUCTION

In the coming decades, many factors will affect electricity consumption in the United States. This report examines the potential effects of three key factors on electricity consumption:

- Improvements to building energy codes and appliance/equipment efficiency standards
- Growth in ratepayer-funded electric efficiency (EE) programs including both utility programs and those administered by state or regional program administrators
- Electrification of the transportation sector; primarily light duty vehicles and commercial light trucks.

Our analysis begins with identification of a baseline forecast, which is the Reference Case from EIA's Annual Energy Outlook 2012 (AEO 2012).

AEO 2012 provides total U.S. electricity consumption in the residential, commercial, and industrial sectors from 2010 to 2035. According to AEO 2012, electricity use across all sectors increases from 3,730 TWh in 2010 to 4,440 TWh in 2035, an increase in consumption of 710 TWh (19.0% increase) over the 26-year period. This implies an annual growth rate of 0.7%.

Table 3 shows the AEO 2012 calibrated at the aggregate sector level.³

Market Sector	2010 Usage (TWh)	Share of Total	2025 Usage (TWh)	Share of Total	2035 Usage (TWh)	Share of Total
Residential	1,454	39.0%	1,546	37.7%	1,737	39.1%
Commercial	1,336	35.8%	1,525	37.2%	1,716	38.7%
Industrial	940	25.2%	1,027	25.1%	986	22.2%
Total	3,730	100.0%	4,099	100.0%	4,440	100.0%

 Table 3: Reference Electricity Consumption by Sector, 2010, 2025, and 2035

Source: LoadMAP model calibrated to AEO 2012 at aggregate level

IEE developed two scenarios—moderate and aggressive—and compared the results from these scenarios against AEO 2012 to develop an alternative perspective on how the U.S. will use electricity in 2035.

³ See Appendix C for information on the study approach and EnerNOC's LoadMAP tool.

Under the *moderate scenario*, today's most efficient appliances and equipment become the minimum standard, newly constructed buildings use 35 percent less energy, ratepayer-funded EE programs grow at current trends, and electric vehicles make up 2 percent of the registered vehicle stock by 2035. IEE believes this scenario is very plausible.

The *aggressive scenario* expands on the assumptions made in the moderate scenario. By 2035, newly constructed buildings use 60 percent less energy, electric vehicles constitute 12 percent of the registered vehicle stock, and some appliance and equipment efficiency standards are pushed to engineering limits. Ratepayer-funded EE programs follow the same path as in the moderate scenario.

IEE's moderate and aggressive forecasts present two different U.S. electricity consumption outlooks than what AEO 2012 projects. The following sections provide further details on each of the three factors—codes and standards, ratepayer EE programs, and electric transportation—that influence US electricity consumption through 2035. The methodology and major assumptions used to produce IEE's forecasts are provided in the appendices.

CODES AND STANDARDS

As part of a push toward a more energy-efficient U.S. economy, activity at federal and state levels indicates that building energy efficiency codes and appliance/equipment energy efficiency standards will increase in stringency over the next 25 years. In fact, recent years have seen a flurry of activity in appliance and equipment standards, and a number of new appliance standards have gone through the rulemaking process and are now officially on the books. Additionally, jurisdictions continue to adopt and implement more stringent building codes. This wave of activity has been incorporated into the AEO Reference case, best described as a 'current laws and regulations' case, prepared each year by the Energy Information Administration (EIA), causing significant downward pressure in forecasts relative to past editions of the AEO. Appendix A catalogues the decline in projected electricity consumption since AEO 2009.

The AEO serves as a starting point for policy analysis and depending on the specific codes and standards adopted, under an aggressive scenario, electricity savings could be as high as 17.3% (i.e., 769 TWh) of the AEO reference electricity forecast in 2035. *Savings of this magnitude will completely offset the anticipated growth in demand in the residential, commercial, and industrial sectors combined, reducing the need for additional power plants to serve these sectors.* The more likely moderate scenario anticipates savings of 9.5% in 2035 (i.e., 420 TWh). Average annual growth in the reference forecast is 0.7%, and IEE's moderate codes and standards scenario would reduce it to 0.3% per year.

This chapter is an update to Assessment of Electricity Savings in the U.S. Achievable through New Appliance/Equipment Efficiency Standards and Building Efficiency Codes (2010-2025), released by IEE in May 2011. IEE's 2011 report was based on the AEO 2011 reference forecast, and this report updates the analysis using the AEO 2012 reference forecast and updated assumptions to take a fresh look at savings achievable through the adoption of new building codes and appliance/equipment efficiency standards beyond those embedded in the AEO reference.⁴

⁴ AEO 2012 can be found at: <u>http://www.eia.gov/forecasts/aeo/</u>. See Appendix A for a comparison of AEO 2009 thru 2012.

The results presented here quantify the impact of future building codes and appliance/equipment efficiency standards on electricity consumption in the United States. New efficiency codes and standards have two basic components: new building energy codes and new or expanded appliance and equipment efficiency standards.

- Building codes focus on reducing energy consumption in newly-constructed buildings or those undergoing major renovation, making them less energy intensive than older buildings.
- Appliance and equipment efficiency standards entail mandated minimum efficiency levels for energy-using equipment, such as central air conditioners, lamps and ballasts, furnace fans, and residential white-goods appliances (e.g., refrigerators, dishwashers, clothes washers).
- Federal or state-level equipment standards result in lower electricity consumption levels for all units purchased, both in new construction and existing buildings.

Codes and standards affect baseline electricity use — the amount of consumption expected to occur *before* utility or other ratepayer-funded energy-efficiency programs become effective. New codes and standards that are adopted in a timely fashion shift the starting point and thus change the potential for savings from ratepayer-funded programs, which are discussed in a subsequent section of this report.

Because of uncertainty in the policy-making process, we developed two possible codes and standards scenarios for this paper — moderate and aggressive — intended to represent a range of possibilities in future legislative and regulatory actions surrounding codes and standards. The two scenarios reflect the input of the authors, as informed by professional experience, literature review, and discussion with experts.⁵ IEE's projections and underlying assumptions have not undergone a full life-cycle cost and payback analysis, or other preliminary analyses typically undertaken during a formal rulemaking process. This was not the intended purpose.

Rather, the moderate scenario defines a plausible range of possible future outcomes that IEE considers likely. The moderate scenario was developed by incrementally layering and expanding upon the minimum efficacy assumptions embedded in the AEO reference forecast and by expanding the scope of appliances and equipment that codes and standards address. The AEO reference case assumes that the prevailing code is fully complied with and IEE does not alter that

⁵ A list of references can be found in Appendix F. IEE received expert advice from Steve Nadel from the American Council for an Energy-Efficient Economy (ACEEE) and Steve Rosenstock from the Edison Electric Institute (EEI).

assumption in either scenario. Appendix B provides assumptions for the codes and standards changes modeled in this paper.

The moderate scenario includes standards for commercial IT equipment, home electronics, furnace fans, and commercial refrigeration equipment. We say that this scenario can be considered likely because it assumes standards requiring levels of efficiency that can be met by products already available in the marketplace, such as ENERGY STAR appliances. The aggressive scenario was developed by adding more aggressive efficiency assumptions onto those embedded in the moderate case. Some of the assumptions are quite aggressive and this scenario pushes the envelope. For example, the moderate case assumes that a new federal standard will raise the minimum SEER rating for a central air conditioner to 15, effective in 2022. Under the aggressive case, a new federal standard will raise the minimum SEER rating to 18, effective in 2022. The aggressive scenario also assumes a 2020 standard for residential and commercial general service lamps equivalent to 65 lumens per watt, significantly higher than the 50 lumen per watt mark contemplated in the moderate scenario and the 45 lumen per watt mark modeled in the reference case. As an aside, each of the lumen per watt standards can be met by CFL and LED lighting systems currently available in the market.

With regard to codes for residential buildings in the moderate scenario, it is assumed that IECC 2012, with estimated energy savings of 25% compared to IECC 2006, goes into effect in 2016, and IECC 2015, with energy saving of 35%, goes into effect in 2019. The aggressive case uses the same assumptions as the moderate scenario until 2024, when it is assumed that a new code, with energy savings of 60%, goes into effect.⁶ Again, the aggressive case pushes the envelope, with similar assumptions for commercial codes as well. Appendix Tables B-1 thru B-5 provides the detailed assumptions regarding codes and standards.

⁶ DOE's multi-year program plan projects slightly higher savings than these values. Adjusted values were used in this analysis to model the imperfect implementation of the building codes. In addition, the authors recognize that issues related to code enforcement and code compliance can create a lag between when codes become effective and when the associated energy savings are actually realized. The scenarios do not explicitly take into account this lag in savings realization, which could be addressed via more aggressive local enforcement and/or ratepayer-funded programs to promote code compliance.

IMPACT OF CODES AND STANDARDS ON U.S. ELECTRICITY CONSUMPTION

As described earlier, we quantified the impact of changes in codes and standards on electricity consumption under two scenarios — moderate and aggressive. Table 4 shows savings in 2025 from codes and standards ranging from 277 TWh (under the moderate scenario) to 478 TWh (under the aggressive scenario), which is equivalent to 6.8% and 11.7% of the AEO 2012 reference forecast in 2025, respectively. Note that standards dominate the savings, providing nearly three-quarters of the total energy savings in the moderate scenario and roughly 80% in the aggressive scenario.

By 2035, savings increase to 420 TWh or 9.5% of the reference case under the moderate scenario and 769 TWh or 17.3% of the reference case under the aggressive scenario. Standards still provide the largest share of the savings, although the relative contribution of building codes increases somewhat.

	2025		2035	
	Moderate	Aggressive	Moderate	Aggressive
	Scenario	Scenario	Scenario	Scenario
	(TWh)	(TWh)	(TWh)	(TWh)
AEO 2012 Reference Case (TWh)	4,099	4,099	4,440	4,440
Savings from Building Codes	75	95	123	205
Savings from Equipment Standards	202	384	297	564
Total Savings	277	478	420	769
IEE Scenario (TWh)	3,821	3,620	4,020	3,671
Savings (as a % of Reference)	6.8%	11.7%	9.5%	17.3%

Table 4: Summary of Codes and Standards Impacts in 2025 and 2035: Residential, Commercial and Industrial Sectors

In Figure 4, the bars represents the AEO 2012 reference forecast, which includes the impacts of existing codes and standards, naturally-occurring efficiency, and embedded energy efficiency. The lines represent the impact of codes and standards on electricity consumption under the two IEE scenarios. Projected codes and standards changes lead to a reduction in electricity consumption to 4,020 TWh in 2035 under the moderate scenario and 3,671 TWh under the aggressive scenario. The moderate scenario cuts forecasted electricity consumption by approximately 60% between 2010 and 2035 relative to the reference forecast. The aggressive scenario completely flattens electricity consumption growth between 2010 and 2035.



Figure 4: Impact of Codes and Standards on Total U.S. Electricity Consumption (TWh)

Figure 5 displays the energy consumption results under the reference case and the two scenarios in 2035 for each of the three market sectors: residential, commercial, and industrial. Figure 6 presents the savings by scenario and sector in 2035. In the moderate scenario, the residential sector accounts for slightly more than half of the total savings. In the aggressive scenario, the residential and commercial sectors contribute roughly equal shares. In both scenarios, industrial electricity savings from codes and standards are modest, contributing less than 15% of total savings.



Figure 5: Electricity Consumption Forecast by Scenario and Sector in 2035 (TWh)

Figure 6: Electricity Savings by Scenario and Sector in 2035 (TWh)



In Figure 7 we show end-use savings for each market sector and end use. Below we summarize the key results.

- In the residential sector, electronics show the largest potential for energy savings. The moderate scenario for computers assumes a standard that requires a 40% savings in 2016, while the aggressive scenario assumes 50% savings in 2016. Televisions are ripe for standards as well. In the moderate case, it is assumed that the Federal standard will align with the Tier 2 standard in California, requiring 50% savings in 2016. The aggressive scenario assumes a standard savings in 2016. The aggressive scenario assumes a standard savings in 2016.
- Residential lighting, in the moderate case, is impacted by a new standard for general service lamps that requires an efficacy of 50 lumens per watt (equivalent to current CFL lamps) in 2020. In the aggressive case, the 2020 standard calls for a minimum efficacy of 65 lumens per watt. As in the commercial sector, LED lamps meet this efficacy requirement.
- Residential white-goods appliance standards continue to provide significant energy savings.
- In the commercial sector, lighting dominates savings potential due to the assumption that the system efficacy requirements under the moderate scenario will be 65 lumens per watt. This can be met using all Super T8s in place of the combination of standard T8s and Super T8s that is present in the reference forecast. In the aggressive scenario, the system efficacy requirement will increase to 97 lumens per Watt in 2018, which can be met by LED lamps.
- Commercial office equipment has sizeable efficiency potential. In the moderate scenario, the current ENERGY STAR equivalent efficiency is mandated for servers by 2016, while in the aggressive case, the mandated efficiency level is 15% better than ENERGY STAR, also in 2016. For computers, the moderate and aggressive cases in 2016 respectively require efficiency levels 40% and 50% above the current ENERGY STAR.
- Commercial ventilation savings come from building codes, which are assumed to incorporate less energy-intensive air movement schemes into building design. Cooling savings also result from building codes and modest equipment standards.
- In the industrial sector, machine drives primarily motors and air compressors dominate potential energy savings as motors and air compressors transition to premium efficiency grade in the moderate case in 2015. The aggressive scenario tracks the moderate scenario until 2018 when super-premium grade becomes the standard.
- Lighting mirrors the requirements for fluorescent systems in the commercial sector and adds standards for HID lamps moving forward. The moderate case ratchets up to a 95 lumen per watt standard for HID lamps in 2020, while the aggressive case reaches this mark in 2015 and increases to 196 lumens per watt in 2020.

Table 5 shows a detailed breakout of the savings by end use, as well as by building codes versus appliance/equipment standards.



Figure 7: Savings by End Use and Scenario in 2035 (TWh)

		Moderate	Moderate	Moderate	Aggressive	Aggressive	Aggressive
		Building	Equipment	Scenario	Building	Equipment	Scenario
Sector	End Use	Codes	Standards	Total	Codes	Standards	Total
	Heating	5	1	6	10	2	11
	Water Heating	9	2	12	17	2	19
la	Miscellaneous	0	8	8	0	17	17
ent	Lighting	8	29	37	14	32	46
esid	Electronics	0	92	92	0	100	100
Ϋ́.	Cooling	21	20	41	38	52	90
	Appliances	0	27	27	0	56	56
	Residential Subtotal	44	180	223	78	261	339
	Heating	2	0	2	7	0	7
	Water Heating	3	0	3	4	0	4
	Ventilation	19	0	19	27	30	58
la	Refrigeration	0	5	5	0	18	18
lerc	Office Equipment	0	24	24	0	39	39
20	Miscellaneous	0	15	15	0	17	17
ő	Interior Lighting	32	27	60	47	76	123
	Exterior Lighting	3	0	3	4	10	14
	Cooling	10	4	14	24	11	35
	Commercial Subtotal	68	76	144	113	201	315
	Heating	2	0	2	2	0	2
	Ventilation	2	0	2	3	5	7
	Process	0	0	0	0	0	0
ial	Other	0	0	0	0	0	0
ustr	Machine Drive	0	37	37	0	71	71
pul	Interior Lighting	4	3	7	5	20	26
	Exterior Lighting	0	0	0	1	3	3
	Cooling	2	1	3	3	2	5
	Industrial Subtotal	11	41	52	14	101	115
	All Sector Total	123	297	420	205	564	769

 Table 5: Savings for Codes and Standards Separately by End Use and Scenario in 2035

Figure 8 separates savings between new construction (post 2010) and existing buildings for each of the sectors and the two scenarios. Building codes primarily affect new construction, but equipment efficiency standards apply to both new and existing buildings. In the residential sector, the existing stock of homes is larger than the new construction market, and slightly more than half of savings accrue from existing buildings. In the commercial sector, however, new construction dominates the savings, due to the large potential for building codes to produce

energy savings in new construction and major remodels, such as those that occur during tenant improvement projects. Residential and commercial buildings provide the largest savings in comparison to the industrial sector.



Figure 8: Electricity Savings by Building Vintage and Sector in 2035

RESULTS BY SECTOR

Residential Sector

The impacts of future codes and standards in the residential sector are presented in Table 6. Under the moderate scenario, residential savings present the largest opportunity among all sectors. New electronics standards are responsible for the largest impact, at 92 TWh by 2035. Cooling is second, followed by lighting. Lighting savings are somewhat muted due to strong pursuits and additional standards in the reference forecast that are applied to incandescent (general service), reflector, and linear fluorescent lamps after 2020. For the aggressive scenario, the relative results are similar, with electronics showing the largest savings (100 TWh) followed by cooling, appliances, and then lighting.

	AEO 2012	Moderate Scenario		Aggressive Scenario	
	Reference Case	Savings	Savings	Savings	Savings
End Use	(TWh)	(TWh)	(%)	(TWh)	(%)
Appliances	307	27	8.9%	56	18.4%
Cooling	377	41	10.8%	90	23.7%
Electronics*	238	92	38.6%	100	42.1%
Lighting	137	37	27.0%	46	33.5%
Miscellaneous*	416	8	2.0%	17	4.0%
Water Heating	161	12	7.3%	19	11.8%
Heating	101	6	6.1%	11	11.4%
Residential Total	1,737	223	12.9%	339	19.5%

Table 6: Residential Sector — Savings by End Use and Scenario in 2035

* Electronics and miscellaneous end uses are currently not subject to any standards.

In the reference forecast, residential usage is projected to increase from 1,454 TWh to 1,737 TWh between 2010 and 2035, equivalent to 19.5% growth. As shown in Figure 9, the moderate scenario reduces the growth over the same time period to only 4.1%, while the aggressive scenario yields a decrease in usage of 3.9% relative to the 2010 reference residential energy consumption of 1,454 TWh.

Figure 9: Residential Sector — Impact of Codes and Standards on Electricity Consumption (TWh)



Commercial Sector

As shown in Table 7, under the moderate scenario, electricity savings in the commercial sector are substantial, both in absolute terms (144 TWh) and as a percentage of the reference forecast (8.4% in 2035). This is largely due to the assumed standards in the area of commercial interior and exterior lighting, contributing 63 of the total 144 TWh of savings in this scenario. Under the aggressive scenario lighting savings grow to 137 TWh as more stringent standards, equivalent to LED lamps, are incorporated. Aggressive assumptions about power management in office equipment lead to sizeable savings for this end use. Furthermore, building code changes influence savings in building shell measures and HVAC systems.

The commercial sector reference forecast shows the largest increase in electricity consumption of the three sectors. In absolute terms, usage increases by 28.5% between 2010 and 2035. As shown in Figure 10, the impact of the moderate scenario reduces the growth rate in the forecast substantially so that usage increases by just 17.7% over the 26-year horizon relative to the AEO

reference case commercial electricity consumption of 1,336 TWh in 2010. In the case of the aggressive scenario, growth drops to 4.9% versus the AEO reference case in 2010.

Endlise	AEO 2012	Moderate	e Scenario	Aggressive Scenario		
Ella Ose	(TWh)	Savings (TWh)	Savings (%)	Savings (TWh)	Savings (%)	
Cooling	161	14	8.9%	35	21.8%	
Exterior Lighting	28	3	10.6%	14	49.5%	
Interior Lighting	306	60	19.5%	123	40.2%	
Miscellaneous	660	15	2.3%	17	2.7%	
Office Equipment	202	24	11.7%	39	19.2%	
Refrigeration	110	5	4.8%	18	16.5%	
Ventilation	179	19	10.6%	58	32.4%	
Water Heating	25	3	10.5%	4	15.3%	
Heating	47	2	4.3%	7	15.7%	
Commercial Total	1,716	144	8.4%	315	18.3%	

Table 7: Commercial Sector – Savings by End Use and Scenario in 2035

* Miscellaneous and office equipment are currently not subject to any standards.

Figure 10: Commercial Sector – Impact of Codes and Standards on Electricity Consumption (TWh)



Industrial Sector

Electricity consumption in the industrial sector is dominated by machine drive (primarily motors and air compressors) and process equipment, while uses related to the building envelope and construction practices represent a smaller share of industrial energy use. Therefore, the impact of aggressive building energy codes is very limited. However, building codes are a factor nonetheless and are captured in the HVAC and lighting impacts shown in Table 8. In addition, both scenarios assume improvements in motor efficiency, which contribute approximately 37 TWh to the industrial impact in the moderate scenario and 71 TWh in the aggressive scenario. While the improvement in efficiency is often only a few percent, the abundance of machine drives in industrial applications leads to significant savings from this standard. This is especially evident in the aggressive scenario, which is represented by both premium efficiency and super-premium efficiency motors as opposed to the NEMA standard equipment.

Endline	AEO 2012	Moderate	Scenario	Aggressive Scenario		
End Ose	(TWh)	Savings (TWh)	Savings (%)	Savings (TWh)	Savings (%)	
Cooling	34	3	9.6%	5	14.9%	
Exterior Lighting	6	0	7.1%	3	53.2%	
Interior Lighting	60	7	12.0%	26	43.2%	
Machine Drive	488	37	7.6%	71	14.6%	
Other	71	0	0.1%	0	0.1%	
Process	276	-	0.0%	-	0.0%	
Ventilation	27	2	7.3%	7	27.3%	
Heating	24	2	8.0%	2	10.2%	
Industrial Total	986	52	5.3%	115	11.7%	

Table 8: Industrial Sector – Savings by End Use and Scenario in 2035

Figure 11shows that the reference forecast in the industrial sector, although declining slightly in the final decade, still increases 4.9% over the 26-year horizon. *The moderate codes and standards scenario decreases usage during that time period by 0.6% relative to the 2010 reference industrial electricity consumption of 940 TWh. For the aggressive scenario case, usage decreases by 7.3% versus the 2010 reference.*

Figure 11: Industrial Sector — Impact of Codes and Standards on Electricity Consumption (TWh)



SUMMARY

As part of a push toward a more energy-efficient U.S. economy, activity at federal and state levels indicates that building efficiency codes and equipment efficiency standards are likely to become more stringent over the forecast period. As shown in Figure 11, depending on the specific codes and standards adopted, under an aggressive scenario, electricity savings could be as high as 769 TWh which is 17.3% of the AEO reference forecast in 2035. The more likely moderate scenario anticipates savings of 420 TWh or 9.5% of the AEO reference forecast in 2035. Savings resulting from codes and standards will offset some (moderator scenario) or all (aggressive scenario) of the anticipated growth in electricity consumption in the combined residential, commercial, and industrial sectors.

RATEPAYER-FUNDED EFFICIENCY PROGRAMS

In most states, electric utilities or other entities have developed programs to deliver energy efficiency (EE) programs and associated savings. These EE programs generally are ratepayer-funded, through mechanisms such as a line item public benefits charge, to offset expenditures such as the purchase price of energy efficient products, consumer education and information activities which support market transformation, and behavior-based programs. In 2010, approximately 85 percent of the dollars allocated to ratepayer-funded efficiency programs were administered by the utility that provides electric service to the customer, with the remaining dollars administered by an independent or state entity. To assess the impact of these ratepayer-funded programs on future electricity use, we developed a forecast of savings and costs based on historical program data as well as trends and forecasts in the different states and regions.

Some ratepayer-funded programs are beginning to focus their funding and efforts on the strengthening and adoption of codes and standards. Arguably, changes to codes and standards are a cost-effective means to achieve persistent savings. Indeed, changes in building codes and equipment standards may make it increasingly challenging to achieve energy savings through traditional ratepayer-funded energy efficiency programs, particularly those that target individual appliances and equipment, since new codes and standards reap some of the "low-hanging fruit". In response, utility programs may need to turn to measures with higher costs per kWh of energy or kW of demand shifted/saved. On the other hand, as the importance of codes and standards grows, utilities and program implementers are finding new opportunities to partner with government bodies, trade allies, and industry partners to increase effectiveness of new building codes and equipment standards — in many cases gaining credit for some of the savings toward meeting their efficiency goals, creating a win-win situation.⁷

To avoid double counting between the codes and standards savings (C&S) developed in the previous chapter and any ratepayer-funded codes and standards activities, we identify the impacts due to ratepayer-funded C&S programs and remove them from the EE program tally. At the national level the attribution of this overlap is moot as the net effect on U.S. electricity consumption remains the same. However, for participating utilities, the attribution of energy

⁷ For additional information on this topic, please see IEE whitepaper, "Integrating Codes and Standards into Electric Utility Energy Efficiency Portfolios" (August 2011).

savings resulting from ratepayer-funded codes and standards programs is very important. In the face of increasing statewide and utility-specific energy efficiency program performance targets, along with the rules and regulations that govern how energy savings are calculated, proper attribution of energy savings from codes and standards programs is a very real business concern for participating utilities.

RATEPAYER-FUNDED EE PROGRAM ANALYSIS APPROACH

Savings from programs are assumed to be correlated with the level of program spending and the cost per kWh saved. Therefore the first step in the analysis was to develop a projection of program spending over the forecast horizon. Table 9 provides historic ratepayer-funded electric efficiency program budgets, which ranged from \$2.723 million in 2007 to \$6.812 million in 2011. Using anticipated trends in policy and state and utility spending, a 2009 report by Lawrence Berkeley National Laboratory (LBNL) projects that this spending will rise to \$12.4 billion in 2020. Assuming a linear trend, we projected spending to rise to \$23.8 billion in 2035 in nominal dollars.

Actual Budgets						
Year	Total	Utility	Non-Utility			
2007	\$2,723	\$2,414	\$309			
2008	\$3,165	\$2,704	\$461			
2009	\$4,370	\$3,796	\$574			
2010	\$5,433	\$4,790	\$643			
2011	\$6,812	\$5,750	\$1,062			
	Foreca	st Budgets				
Year	Total	No	tes			
2020	\$12,400	LBNL Hig	gh Case			
2025	\$16,408	Proje	ction			
2030	\$20,146	Proje	ction			
2035	\$23.884	Proie	ction			

Table 9: U.S. Ratepayer-Funded Electric Efficiency Budgets (\$ Millions)

Sources: IEE Brief, Summary of Ratepayer-Funded Electric Efficiency Impacts, Budgets and Expenditures (2010-2011), January 2012 and The Shifting landscape of Ratepayer-Funded Energy Efficiency in the U.S. LBNL – 2258E. October 2009.

The productivity of EE programs, in terms of dollars spent per incremental kWh saved provides a metric for projecting achievable savings from programs as a function of program expenditures. This data can be obtained from the EIA's Form 861. Because the cost per kWh metric is in terms of incremental kWh savings installed in a given year, we made an assumption about the persistence of measure effects beyond the year of installation. We assumed that on average measures have a ten-year life, thus savings persist for ten years after the measure is installed.⁸

At the time of this analysis, the EIA data for cost per kWh saved were only available from 2007 to 2010. We project the 2010 value into future years using two assumptions.

- First, because the budget projections discussed above are in terms of nominal dollars, we assume annual growth in cost per kWh saved of 2.92% to account for inflation. This inflation rate is based on the 2010–2035 growth of the Consumer Price Index as projected in the AEO 2012.
- Second, we assume a further rate of change in the cost of EE savings. Several factors will contribute to an increase in these costs over time, as past and existing programs are already garnering the most easily achieved savings and incremental efficiency technologies are becoming more sophisticated and costly. This will likely be mitigated by increases in market transformation, customer momentum, and improved delivery methods. However, to provide a conservative estimate, this analysis assumes that the increasing cost factors will outweigh the decreasing cost factors, projecting an additional 1% annual growth in the cost of EE savings.

Table 10 shows the lifetime costs per kWh saved will rise from \$0.031 in 2010 to \$0.082 by 2035 in nominal dollars.

Year	Lifetime Cost per kWh (\$)	Annual Budget (\$ millions)	Cumulative Savings (TWh)		
Forecasts					
2020	\$0.046	\$12,400	217		
2025	\$0.056	\$16,408	274		
2030	\$0.068	\$20,146	293		
2035	\$0.082	\$23,884	295		

Tabla	4 n .	lifatima	Cant	mar L/Mh	Annual	Dudaat	~~	Cumulativa		Cavinga
rable	IU:	Litetime	COST	Der Kvvn	Annua	Duquet.	. and	Cumulative	Electricity	Savinus
				P			,	•••••••	,	

Notes: Cumulative savings based on 10-year measure life with lifetime cost per kWh increasing at inflation plus 1 percent. Budget based on IEE Brief, Summary of Ratepayer-Funded Electric Efficiency Impacts, Budgets and Expenditures (2010-2011), January 2012 and The Shifting landscape of Ratepayer-Funded Energy Efficiency in the U.S. LBNL – 2258E. October 2009.

⁸ We realize that a much more detailed analysis could be performed but the intention here was to project an overall trend in ratepayer-funded EE budgets and associated savings.

Next, the trends in program budgets and the trends in costs to achieve savings were combined to project a stream of savings on a year-by-year basis. Cumulative savings are relative to the start of the IEE forecast period (2010) and accumulate from 2010. In summary, energy savings from ratepayer-funded electric efficiency programs are projected to be 274 TWh in 2025 and 295 TWh in 2035.

ACCOUNTING FOR RATEPAYER-FUNDED CODES & STANDARDS EFFORTS

The final step in the analysis was determining the proportion of savings within the ratepayerfunded programs generated by codes and standards activities. To do so, we use known and forecasted energy savings resulting from California's ratepayer-funded initiatives around codes and standards as a starting point for our national assessment. The 2011 California Statewide IOU Potential Study indicated that 9.7% of California program savings in 2010 derived from codes and standards-related program activities. Separately, the ACEEE 2012 State Efficiency Scorecard credits California with producing 25.4% of nationwide EE savings. The product of these two percentages, 9.7% and 25.4%, equals 2.5% and represents the percentage of nationwide EE savings in 2010 derived from California ratepayer-funded codes and standards activities. Table 11 shows a forecast of EE program savings associated with codes and standards programs out to 2035. Based on the California Potential Study we estimate that participating utilities will realize 21.1% of total portfolio savings from attributed codes and standards programs, effective in 2020. By 2035, we estimate that three-quarters of the utilities in the U.S. will support a codes and standards program, accounting for 15.8% of portfolio savings in the U.S.

Table	11:	EE	Savings	Derived	from	Ratepayer-Funded	Program	Codes	and	Standards
Activit	ties									

				% of National
	% of savings from		% of National EE from	Ratepayer funded
	C&S in Participating		C&S Participating	savings from C&S
Year	States	C&S Participating States	States	programs
2010	9.7%	CA	25.4%	2.5%
2020	21.1%	AZ, CA, MA, MN, OR, WA	46.1%	9.8%
2035	21.1%	75% of National EE	75.0%	15.8%

Sources: 2011 California Potential Study, IEE Whitepaper "Integrating Codes and Standards into Electric Utility Energy Efficiency Portfolios", August 2011, and ACEEE 2012 Scorecard.

Table 12 combines and summarizes the results of the analysis for selected years. As stated above, energy use reductions in 2035 are 295 TWh or 6.7% of the AEO reference forecast in 2035. Adjusting to avoid double counting the C&S savings, we remove 15.8% of savings because these are included in the codes and standards estimated savings in the previous chapter. This results in adjusted ratepayer-funded savings of 242 TWh in 2025 and 249 TWh in 2035 representing 5.6% of the reference forecast in 2035. Appendix D provides detailed year-by-year results.

SUMMARY

Table 12: EE Ratepayer-Funded Program Analysis Inputs and Forecasts (selected years)

	2025	2035
Total Spending (\$ million)	\$16,408	\$23,884
Total Savings (TWh)	274	295
Total Savings (% of reference forecast)	6.7%	6.7%
% From Codes & Standards programs	11.8%	15.8%
Net Savings, excluding C&S efforts (TWh)	242	249
Net Savings, excluding C&S efforts (% of reference forecast)	5.9%	5.6%
Lifetime Cost per kWh Saved	\$0.056	\$0.082

The AEO 2012 reference case already includes some level of embedded savings from recent ratepayer-funded energy efficiency programs. However, we do not attempt to break out the magnitude of these effects, as these savings are implicitly buried in equipment shipments data and new construction trends. We assume these effects are minor, and that our conservative assumptions are unlikely to result in overstating the EE savings from ratepayer-funded programs. Overall, we assume the EE embedded in the AEO 2012 reference case for 2035 is relatively small.

The ratepayer-funded program savings forecast in this report represent the entire nation, which is a distribution of individual contributors at different levels. Across the U.S., some utilities and some states lead the way reflecting regulatory environments that promote utility investments in energy efficiency programs.

ELECTRIC TRANSPORTATION

In 2010, the transportation sector comprised 29 percent of total national energy consumption in the U.S., making it the second largest consumer of energy, behind only the industrial sector. Fossil fuels currently make up about 99 percent of the fuel in transportation. However, the opportunity to implement efficient and cost-effective new electric technologies is large, and electrification is beginning to gain traction in a variety of transportation applications.

Our analysis is based on AEO 2012's Transportation Sector Reference Case for all fuels. This is distinct from the AEO 2012 Reference Case that we referred to in prior chapters which covered electricity use in the residential, commercial, and industrial sectors only. Table 13 shows total energy use and electric energy use in 2010 for each of the vehicle classes identified in the AEO. Light-duty vehicles (LDV)-consisting of automobiles, light trucks, and motorcycles-dominate total energy usage in the transportation sector (58.2%), followed by freight trucks and air transportation. Considering electric energy for transportation, however, light duty vehicles consume only 1% of electric energy, with intercity, transit, and commuter rail collectively accounting for 98.6% of electric transportation use today. For each of the vehicle types outlined in Table 13, we identify electrification opportunities in Table 14. LDVs represent the largest transportation electrification opportunity, because although LDVs dominate energy usage in the transportation sector, the penetration of electric LDVs is still small, as indicated in Table 13. The most common options for electric LDVs are all-electric vehicles (AEVs), which operate solely on battery power, such as the Nissan Leaf and Tesla S, and plug-in hybrid electric vehicles (PHEVs), which operate on both battery power and fossil-fuel, such as the Chevy Volt and Prius Plug-in. A typical AEV consumes 3,000 to 4,000 kWh per year, slightly more than an average central air-conditioner. A PHEV consumes between 20-50% of the electricity used by an AEV, with the remainder of its energy coming from gasoline.

Vehicle Type	2010 Energy Use All Fuels (TBTU)	% of All Energy	2010 Energy Use Electricity Only (GWh)	% of Electric Energy
Light-Duty Vehicle	16,056	58.2%	64	1.0%
Commercial Light Trucks	554	2.0%	19	0.3%
Transit Bus	106	0.4%	3	0.0%
School Bus	116	0.4%	3	0.0%
Military Use	765	2.8%	6	0.1%
Freight Trucks	4,822	17.5%	0	0.0%
Air Transportation	2,515	9.1%	0	0.0%
Domestic Shipping	218	0.8%	0	0.0%
International Shipping	861	3.1%	0	0.0%
Freight Rail	453	1.6%	0	0.0%
Intercity Bus	30	0.1%	0	0.0%
Intercity Rail	15	0.1%	448	6.7%
Transit Rail	15	0.1%	4,370	64.8%
Commuter Rail	18	0.1%	1,826	27.1%
Recreational Boats	254	0.9%	0	0.0%
Miscellaneous	787	2.9%	0	0.0%
Totals	27,586	100.0%	6,741	100.0%

Table 13: Transportation Sector Energy Consumption by Vehicle Type (2010)

Note: Highlighted values identify vehicles with electrification opportunities.

In addition to LDVs, electrification opportunities exist within the commercial light trucks, transit bus, school bus, military, freight trucks, air transportation, and domestic and international shipping vehicle types. In this paper, we identify LDVs, commercial light trucks, transit bus, school bus, and on-base military ground vehicles as vehicle types that can be fully electrified. Conversely, the electrification opportunity of freight trucks, air transportation, domestic and international shipping is restricted. These vehicles can be electrified to only a small degree due to physical and economic constraints. For example, the energy density required for shipping freight overseas and over rail exceeds the limits of current and foreseeable electric and battery technologies. These modes of transit are simply too heavy and require too much range for electrification of the primary drive systems. The same applies for aircraft when in flight. However, particular applications within these segments may offer efficiencies from electrification when idling. A jetliner idling at the gate which typically runs a small turbine on jet fuel to produce auxiliary power for lighting and air conditioning can reduce jet fuel use by connecting to the terminal's electric supply. Electrification of freight trucks at rest stops when idling/stopped is also a viable option. Domestic and international container ships can also be
powered by electricity while docked at the port. Appendix E shows our transportation electrification modeling strategy by vehicle type in greater detail.

Non-road transportation equipment at airports, seaports, mines, warehouses, intermodal facilities, and agriculture production sites also represent electrification opportunities, but this report primarily focuses on on-road transportation opportunities.

Vehicle Type	Description	Elect	rification Opportunity
Light-Duty Vehicle	Automobiles, Light Trucks, Motorcycles in both personal and commercial fleet usage	YES	Electrify primary vehicle drive
Commercial Light Trucks	Trucks from 8,501-10,000 lbs gross vehicle weight	YES	Electrify primary vehicle drive
Transit Bus	Buses with routes inside a single metropolitan area, traversing relatively short distances with more frequent stops	YES	Electrify primary vehicle drive
School Bus	Buses that carry students to and from educational facilities, frequent stops	YES	Electrify primary vehicle drive
Military Use	Mix of military ground, air, and sea vehicles	YES	Ground vehicles only, Electrify primary vehicle drive
Freight Trucks	Trucks greater than 10,000 lbs gross vehicle weight	YES	Utilize electric umbilical for auxiliary power when idling
Air Transportation	All air carriers of passenger and cargo, as well as general aviation and small aircraft	YES	Replace onboard mini turbine with electric umbilical for auxiliary power when idling at gate
Domestic Shipping	Water vessels with both departure and arrival at a U.S. port	YES	Shore power: shipyard auxiliary tether to prevent idling in Domestic Oceanliners
International Shipping	Water borne vessels with either a departure or an arrival at a U.S. port, but not both	YES	Shore power: shipyard auxiliary tether to prevent idling in International Oceanliners
Freight Rail	Locomotive drawn freight railroad cars	No	Range and weight requirements prohibitive
Intercity Bus	Buses with routes between metropolitan areas, traversing mostly highways with infrequent stops	No	Range and weight requirements prohibitive
Intercity Rail	Trains with routes between metropolitan areas, traversing relatively long distances with infrequent stops	No	None. Virtually all practicable electrifications complete.
Transit Rail	Trains with routes inside a single metropolitan area, traversing relatively short distances with more frequent stops	No	None. Virtually all practicable electrifications complete.
Commuter Rail	Trains with routes to and from a metropolitan area, traversing moderate distances with somewhat frequent stops	No	None. Virtually all practicable electrifications complete.
Recreational Boats	Personal boats and watercraft	No	Not applicable.
Miscellaneous	Alternative and miscellaneous uses of fuel substances: lubricants and transportation of natural gas	No	Not applicable.

Table 14: Transportation Electrification Opportunities

LIGHT DUTY VEHICLE SCENARIOS

LDVs represent a significant opportunity for electrification in the transportation sector. To assess electrified LDV potential, we considered a range of scenarios, including several assessed in the AEO, as described below.

- AEO 2012 Transportation Reference Case This scenario aligns with the AEO 2012 baseline assumptions for economic growth (2.5% annual GDP growth from 2010 through 2035), oil prices (light, sweet crude rises to \$145 per barrel in 2010 dollars in 2035), and technology development. It assumes that renewable fuel standards (RFS) targets will be met as soon as possible. The number of electric plug-in light-duty vehicles grows. However, ethanol-flex vehicles grow at a considerably higher rate. Fuel efficiency across all vehicle types is increasing as a result of Corporate Average Fuel Economy (CAFE) standards and technology improvements.
- *AEO CAFE Standards* This scenario reflects the U.S. Department of Energy's perspective on enactment of new, proposed LDV CAFE and greenhouse gas (GHG) emissions standards for years 2017–2025. Under this case, the number of electric vehicles is roughly double the Reference case.⁹
- High Oil (\$200/barrel in 2035) High oil prices, resulting from a combination of higher demand for petroleum and other liquid fuels in the non-OECD nations and lower global supply, stimulate the market for electric vehicles. Compared with the Reference case, GDP growth rates for China and India are higher (1.0% higher in 2012 and 0.3% higher in 2035). GDP growth rates for other non-OECD regions average about 0.5% above the Reference case. OPEC market share remains at about 40% throughout the projection, and non-OPEC petroleum production expands more slowly in the short- to middle-term relative to the Reference case. Light, sweet crude oil prices rise to \$200 per barrel (2010 dollars) in 2035.
- Center for Automotive Research (CAR) CAFE (54.5 MPG by 2025) Based on a 2011 report from the Center for Automotive Research (CAR), this scenario estimates manufacturer responses to technology improvements needed to meet CAFE standards for 2017–2025, based on discrete, least-cost analysis of potential improvements to vehicle components such as stop/start technology, light weighting, new spark-ignited engine technologies, and plug-in hybrids. As a result, in 2025, 10% of new light duty vehicle sales are electric drive (9.1% PHEV, 0.9% AEV). In 2035, 16.5% of new light duty vehicle sales are electric drive.
- Advanced Battery This scenario is based on the AEO High-Tech Battery case, but with strategic alterations developed by the project team. It assumes significant improvements in vehicle battery and non-battery system cost and performance that promote higher market penetrations of electric vehicles. Such improvements include enhanced battery chemistry to allow for faster and deeper charging, expansion of pubic charging infrastructure, and superior

⁹ The Environmental Protection Agency and National Highway Transportation Security Agency issued a proposed rule on CAFE and GHG standards in December, 2011 that had not been finalized when the AEO 2012 was released. <u>http://www.eia.gov/forecasts/aeo/sector_transportation_all.cfm#energyimpact</u>

battery energy density. Based on these improvements, the project team adjusted the AEO scenario by redistributing the electric vehicles to include 63% AEV's, some of which will have a 200-mile range. These assumptions better represent the battery advances than the original AEO scenario, which estimated AEV's at 52% of the electric LDV market and zero presence of 200-mile vehicles.

Advanced Battery & High Oil (\$200/barrel in 2035) — This scenario is a combination of two of the previously described scenarios: Advanced Battery and AEO High Oil Price. This scenario models a world affected by both high oil prices and rapid advancements in battery technology. The vehicle stock and new EV sales resulting from those two scenarios are summed, then multiplied by 0.90 to reflect that these sales would not be simply additive. A portion of the purchases driven by high oil prices would also occur under the drivers of advanced battery technology.

LIGHT DUTY SCENARIO RESULTS

Figure 12 and Table 15 show how the electric LDV stock develops over the forecast period. The AEO 2012 Transportation Reference Case is the most conservative scenario and electric LDV stock reaches 5.3 million in 2035 (approximately 2 percent of all registered LDVs on the road in the U.S.). The AEO CAFE and High Oil (\$200/barrel in 2035) scenarios forecast a higher penetration of electric LDVs , projecting 7.9 million and 9 million electric LDVs, respectively (equivalent to 2.9 and 3.3 percent of all registered LDVs on the road in the U.S.).

The Advanced Battery scenario shows substantial penetration of electric LDVs with 24.8 million vehicles on the road in 2035 (9.5 percent of all LDVs). This scenario shows the importance of the initial purchase price, and the value of having enhanced vehicle utility through range extension and reduced charge time. The CAR CAFE (54.5 MPG by 2025) scenario shows the highest penetration of electric LDVs with 35.4 million LDVs on the road in 2035 (14.7 percent of the vehicle stock). The final scenario, Advanced Battery & High Oil shows the second highest penetration with 30.4 million LDVs on the road in 2035 (11.9 percent of the vehicle stock).

Figure 12: Light Duty Electric Vehicle Stock: Forecast by Scenario (millions)



It is interesting to note that the High Oil scenario does not induce more consumers to purchase electric LDVs. One reason for the lack of response is because the increase in the price of oil (and its derivatives, motor grade gasoline and diesel) is gradually phased into the forecast; hence consumers do not experience a sudden and extreme price shock that would fundamentally alter their vehicle purchase decisions. Additionally, this scenario does not directly influence the initial purchase price of the electric LDV, a large barrier for many consumers.

Table 15: Light Duty Electric Vehicle Stock: Forecast by LDV Scenario (thousands)

Light Duty Electric Vehicle Stock by Scenario	2010	2015	2020	2025	2030	2035
AEO 2012 Reference Case	20	230	900	1,960	3,430	5,330
AEO CAFE Standards	20	230	1,050	3,240	5,680	7,910
High Oil (\$200/barrel in 2035)	20	570	2,130	4,040	6,420	9,030
Advanced Battery	20	839	3,711	8,079	15,560	24,800
CAR CAFE (54.5 MPG by 2025)	20	439	3,523	13,811	23,792	35,369
Advanced Battery & High Oil (\$200/barrel in 2035)	20	1,117	5,354	11,069	19,295	30,400

Figure 13 shows the impact of electric LDV penetration on electricity consumption in the transportation sector. The two main drivers of LDV electricity consumption over the forecast period are the accumulation of electric vehicles within the stock of registered vehicles and the electric drive range (i.e., battery size) of the vehicle. The AEO 2012 Transportation Reference Case scenario shows total electricity consumption of 13.1 TWh in 2035. The AEO CAFE and High Oil (\$200/barrel in 2035) scenarios project electricity consumption of 18.9 TWh and 29.3 TWh, respectively in 2035.

The CAR CAFE scenario projects the highest number of electric LDVs by 2035, 35.4 million, yet has only 52 TWh associated with these vehicles. In comparison, the Advanced Battery and High Oil scenario projects the largest increase in LDV electricity consumption with 87.8 TWh consumed in 2035 associated with 30.4 million LDVs. While the result may seem counterintuitive given a comparison of the electric vehicle stock across the two scenarios, it is because the Advanced Battery and High Oil scenario includes a higher share of AEVs, some with a 200-mile range, than the CAR CAFE scenario.





TRANSPORTATION SCENARIOS

We defined two electric transportation scenarios, moderate and aggressive, as defined below.

- The *moderate* electric transportation scenario includes:
 - The penetration of electric LDVs from the AEO 2012 Transportation Reference Case.
 - Electrification of commercial light trucks, transit bus, school bus, and military vehicle type stock at 50 percent the growth rate for electric LDVs in the AEO 2012 Transportation Reference Case. The battery and charging infrastructure technology used by these vehicles types is similar to electric LDVs.
 - Freight trucks, air transportation, and domestic and international shipping vehicle types displace 20 percent of their fossil fuel energy demands with auxiliary electric power while idled.
 - Transit and commuter rail electrification are based on the AEO 2012 Transportation Reference Case.
- The *aggressive* electric transportation scenario includes:
 - The penetration of electric LDVs from the Advanced Battery & High Oil (\$200/barrel in 2035) scenarios.
 - Electrification of commercial light trucks, transit bus, school bus, and military vehicle type stock at 50 percent the growth rate for electric LDVs in the Advanced Battery &High Oil (\$200/barrel in 2035) scenarios. The battery and charging infrastructure technology used by these vehicles types is similar to electric LDVs.
 - Freight trucks, air transportation, and domestic and international shipping vehicle types displace 50 percent of their fossil fuel energy demands with auxiliary electric power while idled.
 - Transit and commuter rail electrification are based on the AEO 2012 Transportation Reference Case.

Figure 14 shows electricity consumption under the moderate scenario by six transportation sector end uses. The "all other" category includes transit bus, school bus, freight trucks, air transportation, and domestic and international shipping vehicle types. The impact of the individual electric vehicle types that comprise the "all other" category are combined for this report. Under the moderate scenario, U.S. electricity consumption increases by 33 TWh in 2035. Electric LDVs, commercial light trucks, and commuter rail are the primary drivers for the increase with LDVs making up 13 of the 33 TWh, about 40 percent of the total.



Figure 14: Electricity Use in Transportation Sector – Moderate Scenario (TWh)

Figure 15 shows the aggressive scenario where battery advancements and rising oil prices induce consumers to purchase electric powered vehicles. Under the aggressive scenario, U.S. electricity consumption increases by 147 TWh in 2035. Electric LDVs account for 88 TWh, or nearly 60 percent, of the total, and commercial light trucks account for 26 TWh, or 18 percent of the total.





SUMMARY

Interpreting the IEE moderate and aggressive scenario results relative to the energy used in the transportation sector requires setting a reference point on context. A simple approach would be to establish an estimate of electricity consumption assuming that all vehicles with electrification opportunities are powered by electricity. Yet, this approach is not appropriate or realistic. For example, the simple conversion of total energy used by the vehicle types highlighted in Table 12 (from British Thermal Units (BTU) to kilowatt-hours (kWh)) would result in electricity consumption of 7,624 TWh. This is roughly twice the amount of electricity consumed by the residential, commercial, and industrial sector in the U.S. in 2010 according to the AEO 2012, making this estimate unrealistic. To put the results in context, IEE developed an a rough estimate of an upper bound on electrification potential in transportation based on available sources.

IEE's upper bound for electrification opportunities is based on assumptions from the Electrification Coalition's November 2009 report, "Electrification Roadmap, Revolutionizing Transportation and Achieving Energy Security". The Electrification Roadmap outlines a remarkable transformation of energy use in the transportation sector resulting in 150 million electric LDVs in operation in 2040, consuming 440 TWh per year. IEE combined this projection

with the fact that roughly 60 percent of energy used in the transportation sector is consumed by LDVs to set an upper bound for electrification opportunities in the vehicle types identified in Table 13 at 733 TWh (i.e., 440 TWh/0.60).

Using an estimated upper bound of electrification opportunities of 733 TWh, we examine the moderate and aggressive transportation scenario results. Figure 16 shows that the moderate scenario projects a relatively small increase in electricity consumption of 33 TWh, equal to 4.5 percent of the 733 TWh upper bound. Figure 17 shows that the aggressive scenario projects electricity consumption of 147 TWh, equal to 20 percent of the 733 TWh upper bound. These results demonstrate the wide range of potential outcomes associated with electrification within the transportation sector. To put this into a larger context, based on the AEO 2012 Reference Case for Residential, Commercial, and Industrial, electricity use is projected to increase by 710 TWh between 2010 and 2035 without electric transportation. Relative to the 710 TWh of increased electricity consumption, the aggressive electric transportation scenario resulting in 147 TWh is significant.

Figure 17: Moderate Scenario: Transportation Electrification Forecast vs. Opportunity in 2035 (TWh)



Figure 18: Aggressive Scenario: Transportation Electrification Forecast vs. Opportunity in 2035 (TWh)



CONCLUSION

The results presented in this paper provide two scenario views of U.S. electricity consumption through 2035 different than the AEO 2012 forecast. Combined, the three drivers—advancements in building energy codes and appliance/equipment efficiency standards, ratepayer-funded EE programs, and electric transportation—have a major impact on electricity consumption in the U.S., with building energy codes and appliance/equipment standards having the largest impact and electric transportation having the smallest impact under both scenarios.

Under the moderate scenario, today's most efficient appliances and equipment become the minimum standard, newly constructed buildings use 35 percent less energy, ratepayer-funded EE programs grow at current trends, and electric vehicles make up 2 percent of the registered vehicle stock by 2035. This scenario is very plausible.

The aggressive scenario expands on the assumptions made in the moderate scenario. By 2035, newly constructed buildings use 60 percent less energy, electric vehicles constitute 12 percent of the registered vehicle stock, and some appliance and equipment efficiency standards are pushed to engineering limits. Ratepayer-funded EE programs follow the same path as in the moderate scenario.

The effect of each factor is summarized below.

- Building codes and equipment standards have the largest impact among the factors examined, with the potential to decrease electricity consumption by 420 TWh (9.5%) in 2035 under a moderate scenario and 769 TWh (17.3%) under an aggressive scenario.
- **Ratepayer-funded electric energy efficiency (EE) programs**, including both utility programs and those administered by state or regional program administrators decrease national electricity consumption. Following current trends, these programs reduce electricity consumption by 295 TWh (6.7%) by 2035.
- Electrification of the transportation sector has some impact on energy consumption in the U.S. Growth is mainly due to the progressive use of electric light duty and commercial vehicles in 2020 and beyond. Various policy and economic drivers as well as consumer demand will determine the ultimate levels of electric vehicle adoption, including: advances in battery technology, oil prices, and government mandates on fleet fuel efficiency (or CAFE) standards. However, under both scenarios, the electricity growth is modest. It should be noted that this analysis does not capture the electrification of non-road transportation equipment.

Figure 19 shows the combined effect of all three factors, relative to the AEO 2012 reference forecast. As shown, under the *moderate* scenario, electricity consumption between 2010 and 2035 remains relatively flat, moving from 3,730 TWh in 2010 to 3,805 TWh in 2035. Under the *aggressive* scenario, electricity consumption declines between 2010 and 2035, moving from 3,730 TWh in 2010 to 3,569 TWh in 2035.



Figure 19: Energy Use in the U.S., Reference Case and IEE Scenarios (2010-2035)

Figure 20 and Figure 21 illustrate how the factors combine with the reference forecast to produce the net energy use projected in IEE's two scenarios. The purple section of each bar indicates energy use reduction from codes and standards relative to the AEO 2012 Reference Case, the red section represents energy use reductions from ratepayer funded programs, and, the green section indicates additional energy use from electric transportation.



Figure 20: Moderate Scenario – Combined Effect of Factors (2010-2035)

As shown in Figure 20, under the *moderate* scenario, codes and standards reduce electricity consumption by 420 TWh in 2035 (9.5 percent of AEO Reference Case), with roughly 70 percent of the savings coming from improvements to appliance and equipment standards. Continued support of ratepayer-funded EE programs over the forecast period saves an additional 249 TWh in 2035 (5.6 percent of AEO Reference Case). The gradual introduction of electric light duty vehicles (LDVs) and growth in transit rail increases electricity consumption by 33 TWh (less than 1 percent of AEO Reference Case).

Combined, these factors have a dampening effect on U.S. electricity consumption and midway through the forecast (2020-2025) total U.S. consumption flattens at a low of 3,590 TWh. Electricity consumption turns up between 2025 and 2035 due to projected economic growth and increased use of electricity as a fuel for the transportation sector. *In aggregate, under the moderate scenario, accounting for these three factors, IEE projects 2035 electricity consumption to be 3,805 TWh, a mere 75 TWh (2 percent) above 2010 levels and 14.3 percent less than the AEO Reference Case projection for 2035.*



Figure 21: Aggressive Scenario — Combined Effect of Factors (2010–2035)

As shown in Figure 21, under the *aggressive* scenario, codes and standards programs have a substantial impact on electricity consumption throughout the forecast period, reducing electricity consumption in 2035 by 769 TWh (17.3 percent of AEO Reference Case). Continued support of ratepayer-funded EE programs over the forecast period saves an additional 249 TWh in 2035. In this scenario, substantial battery technology breakthroughs and increasing oil prices result in greater consumer demand for electric light duty vehicles (LDVs) and commercial light trucks resulting in electricity consumption increasing by 147 TWh (3.3 percent of AEO Reference Case).

Combined, these factors have a substantial dampening effect on U.S. electricity consumption and in 2025 total U.S. consumption drops to a forecast low of 3,431 TWh. Rapid electrification of the transportation sector in the latter part of the forecast partially offsets the downward drivers, resulting in an end of forecast value of 3,569 TWh. *In aggregate, under the aggressive scenario, accounting for these three factors, IEE projects 2035 electricity consumption to be 3,569 TWh, which is 161 TWh (4 percent) below 2010 levels and 19.6 percent less than the AEO Reference Case projection for 2035.*

APPENDIX A COMPARISON OF AEO 2009, 2010, 2011, AND 2012

Table A-1 and Figure A-1 compare the reference forecasts for AEO 2009 (used for the original 2009 IEE White Paper) through AEO 2012 (used in this paper). Comparing the forecast energy use in 2030, the AEO 2012 forecast is 6.4% lower than the 2009 forecast. The AEO 2012 forecast includes the following assumptions:¹⁰

- Existing codes and standards as shown in Appendix B.
 - Both local and federal building codes
 - Appliance standards officially signed (National Appliance Energy Conservation Act and DOE review process)
 - Other energy-relevant legislation, including the Energy Improvement and Extension Act of 2008, the Energy Independence and Security Act of 2007(EISA), and the Energy Policy Act of 2005 (EPACT 2005)
 - The assumed standards for six categories of residential white-goods appliances from the consensus agreement reached by the American Council for an Energy-Efficient Economy (ACEEE), the Association of Home Appliance Manufacturers (AHAM), and the appliance manufacturers in the fall of 2010
 - Appliance and equipment standards approved through 2011
- International Energy Conservation Code (IECC) 2009 and the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) 90.1 2007 phased-in through 2018 and naturally occurring efficiency
 - Technological improvements in energy-consuming equipment
 - Conservation response to rising energy prices (based on usage elasticity)
 - Market trends toward "green" affecting both energy purchases and usage behaviors.
- Embedded demand-side management defined as future impacts of past programs and future trends in appliance and equipment purchases in the forecast period; these impacts yield from:
 - o Utility information and incentive programs

¹⁰ With the exception of some technical data on unit efficiency as a function of standards (e.g., EISA 2007), all of these factors are implicit in the National Energy Modeling System (NEMS) modeling framework, which is used to develop the AEO. In other words, they are manifested as they affect average energy usage values that form the core of the demand-side modules within NEMS (only in the residential and commercial sectors).

- State funding and regulatory mechanisms
- Funding for energy efficiency through the American Reinvestment and Recovery Act (ARRA)

Table A-1: Comparison of Annual Energy Outlook Forecasts for Residential,	Commercial,
and Industrial Sectors (TWh)	

	AEO	AEO	AEO	AEO	Difference	Difference	Difference
Year	2012	2011	2010	2009	2011-12	2010-12	2009-12
2010	3,743	3,684	3,610	3,730	1.6%	3.6%	0.3%
2015	3,745	3,751	3,862	3,912	-0.2%	-3.1%	-4.4%
2020	3,898	3,913	4,073	4,116	-0.4%	-4.5%	-5.6%
2025	4,077	4,074	4,262	4,335	0.1%	-4.5%	-6.3%
2030	4,241	4,244	4,457	4,511	-0.1%	-5.1%	-6.4%
2035	4,393	4,405	4,643	-			
% Increase (2008-2030)	17%	20%	29%				
Avg. annual growth rate	0.7%	0.8%	1.1%				

Figure A-1: AEO 2009 and AEO 2011 Forecasts for the Residential, Commercial and Industrial Sectors



APPENDIX B ASSUMPTIONS ABOUT BUILDING CODES AND APPLIANCE STANDARDS

The following tables provide detail on the codes and standards assumed under the moderate and aggressive codes and standards scenarios. Table B-1 presents the building code assumptions for the residential and commercial sectors. Table B-2 summarizes assumptions regarding the savings these building codes will provide under the moderate and aggressive scenarios for selected years. Tables B-3 through Table B-5 provide detailed assumptions about the appliance and equipment standards under the two scenarios in turn for the residential, commercial, and industrial sectors, including the level of savings the standards provide.



Figure B-1: Projected Building Codes Savings - Residential Sector

Figure B-2: Projected Building Codes Savings – Commercial Sector



Table B-1: Building Code Assumptions



Commercial	2010 2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Base Case	2 2007 AS	004 / SHRA	ASHR/ E 90.1	4E 9 L (10	0.1 /)% ph	ase	d-	2007 ASHRAE 90.1 (10%)																	
Moderate Case	2004 ASHRA 90.1	AE	200 ASHR (15%	7 AE 6)	20 ASI 90.1	010 HRAI (25%	E %)						2	2013	ASI	IRA	E 90	.1 (3	3%)						
Aggressive Case	2004 ASHRA 90.1	NE	200 ASHR (15%	7 AE 6)	20 ASI 90.1	010 HRAI (20%	E %)	201	.3 AS	SHR/	4E 9	0.1	(40%	6)				5	0% 9	Savi	ngs				

Table B-2: Building Code Assumptions

Residential Sector

End Uses	Scenario	Code	Savings %	Effective	Source
				Date	
	Paco Caco	IECC 2006/IECC 2009	15% by 2017	2018	EIA
Cooling, Space	Dase Case	IECC 2009	15%	2018	EIA
		IECC 2009	15%	2013	
	Moderate Case	IECC 2012	25%	2016	EEI/ACEEE/MYPP
Heating, Water		IECC 2015	35%	2019	ACEEE
Heating, Lighting		IECC 2009	15%	2013	
	Aggrossivo Caso	IECC 2012	25%	2016	EEI/ACEEE/MYPP
	Agglessive Case	IECC 2015	45%	2019	ACEEE
		NA	60%	2024	ACEEE/EEI

Commercial Sector

End Uses	Scenario	Code	Savings %	Effective Date	Source
	Pasa Casa	2004/2007 ASHRAE 90.1	10% by 2018	2018	EIA
Cooling, Space	Dase Case	2007 ASHRAE 90.1	10%	2018	EIA
		2007 ASHRAE 90.1	15%	2013	
	Moderate Case	2010 ASHRAE 90.1	25%	2015	EEI/MYPP
Heating, ventilation,		2013 ASHRAE 90.1	33%	2018	EEI/ACEEE
Water Heating,		2007 ASHRAE 90.1	15%	2013	
Lighting	Aggrossivo Coso	2010 ASHRAE 90.1	20%	2015	EEI/MYPP
	Aggressive Case	2013 ASHRAE 90.1	40%	2018	EEI/ACEEE
		NA	50%	2025	ACEEE/EEI

		Base level		2nd Standard (relat	elative to Base) 4th Standard (relative to Base)										
		1st Standard (re	elative to Base)	3rd Standard (relat	ive to Base)										
		2010 2011 2012 2013	2014 2015 2016 2016	2018 2019 2020 2021	²⁰²² ²⁰²³ ²⁰²³	2025 2026 2028 2029 2031 2033 2033 2033									
	Baseline	SEER 13			SEE	R 13/14									
Central AC	Moderate	SEER 13	SE	ER 14		SEER 15									
	Aggressive	SEER 13	SE	ER 14		SEER 18									
	Baseline	EER 9.8			EER 11.0										
Room AC	Moderate	EER 9.8	EER 1	1.0		EER 11.5									
	Aggressive	EER 9.8	EER J	11.0		EER 12.5									
	Baseline	SEER 13.0/HSPF 7.7	,		SEER 14	1.0/HSPF 8.0									
Heat Pump	Moderate	SEER 13.0/HSPF 7.7	SEER 14.0/HS	PF 8.0		SEER 15.0/HSPF 8.2									
	Aggressive	SEER 13.0/HSPF 7.7	SEER 14.0/HS	SEER 14.0/HSPF 8.0 SEER 16.0/HSPF 8.5											
Water Heater	Baseline	EF 0.90		EF 0.95											
(<55 gallons)	Moderate	EF 0.90	EF 0.	.95		EF 0.98									
(100 gallotto)	Aggressive	EF 0.90	EF 0.95	EF 0.95 EF 0.97											
Water Heater	Baseline	EF 0.90	.90 Heat Pump Water Heater												
(>55 gallons)	Moderate	EF 0.90			Heat Pump	o Water Heater									
(>35 gallol13)	Aggressive	EF 0.90			Heat Pump	o Water Heater									
	Baseline	Incandescent	Advanced Incandescent lumens/watt)	- tier 1 (20	Advanced Incandescent - tier 2 (45 lumens/watt)										
Incandescent Lamps	Moderate	Incandescent	Advanced Incandescent lumens/watt)	- tier 1 (20	Advanced Incandescent - tier 3 (50 lumens/watt)										
	Aggressive	Incandescent	Advanced Incandescent lumens/watt)	- tier 1 (20	65 lu	umens/watt (equivalent to current CFLs)									
Pofloctor	Baseline			In	candescent										
Lamps	Moderate	Incandescent Advanc	ed Incandescent (13 lume	ns/watt)		30 lumens/watt									
Lamps	Aggressive	Incandescent Advanc	ed Incandescent (13 lume	ns/watt)		45 lumens/watt									
Linear	Baseline	T12			Т8										
Eluoroccont	Moderate	Т	18	90 lumens/watt (can be met with Super T-8 lamps)											
Fluorescent	Aggressive	Т	6		97 lumens/wa	tt (equivalent to next-generation LED)									
	Baseline	NAECA Standard			25% sa	vings									
Refrigerator	Moderate	NAECA Standard	25% savings			30% savings									
	Aggressive	NAECA Standard	25% savings			40% savings									
	1				250/	vince									
i	Baseline	NAECA Standard			25% sa	vings									
Freezer	Baseline Moderate	NAECA Standard NAECA Standard	25% savings		25% sa	30% savings									

Table B-3: Residential Appliance and Equipment Standards Assumptions

		Base level 1st Standard (relative to	Base)	2nd Standard 3rd Standard	l (relativ (relativ	ve to Base) ve to Base)		4th Sta	andard	(relativ	ve to E	Base)							
		2010 2011 2011 2012	2013 2014 2015	²⁰¹⁶ 2017	2018 2019 2019	2021	²⁰²² ²⁰²³	2024 2025	2026	2027	2029	2030	2031	2032	2033 2033	2035				
	Baseline	355 kWh/yr	•	· · ·			307 kWh/yr (1	14% savin	igs)											
Dishwasher	Moderate	355 kWh/yr	307 kWh/yr (1	L4% savings)					280 kWI	h/yr										
	Aggressive	355 kWh/yr	307 kWh/yr (1	L4% savings)					280 kWI	h/yr										
Clather	Baseline	MEF 1.26 for top loa	ader	MEF 1.72					MEF 2	.0										
Clothes	Moderate	MEF 1.26 for top loa	ader	MEF 1.72					MEF 2	.4										
wasner	Aggressive	MEF 1.26 for top loa	ader	MEF 1.72					MEF 2	.8										
	Baseline	EF 3.01						EF 3.17												
Clothes Dryer	Moderate	EF 3.01		EF 3.	EF 3.17 15% savings															
	Aggressive	EF 3.01		EF 3.	17				Heat I	Pump Cl	othes D	ryer								
	Baseline					Con	ventional													
Range/Oven	Moderate		Conventional 13% savings																	
	Aggressive		Conventional Induction, Halogen Burners																	
	Baseline		Conventional																	
Microwave	Moderate	Conventional					Reduced S	tandby P	ower											
	Aggressive	Conv	ventional				Redu	iced Stan	dby Pov	wer + 15	% saving	gs								
	Baseline				0	onventio	nal/Energy St	ar												
Computer	Moderate	Conventional/Ene	rgy Star		40% sav	vings	nuly Energy St				50%	% saving	gs							
-	Aggressive	Conventional/Ene	ergy Star			Ŭ		50% sa	vings				<u> </u>							
	Baseline					onventio	nal/Energy St	ar												
Color TV	Moderate	Conventional/Fne	rgy Star			onventio	50% savi	ngs (CA 1	ier 2 Sta	andard)										
	Aggressive	Conventional/Ene	ergy Star				60% sav	ings (nev	w Energy	y Star)										
	Baseline		Conventional 13% savings Conventional Induction, Halogen Burners Conventional Conventional Conventional Reduced Standby Power Conventional Reduced Standby Power + 15% savings Conventional/Energy Star Conventional/Energy Star Conventional/Energy Star 50% savings Conventional/Energy Star S0% savings Conventional/Energy Star 50% savings (CA Tier 2 Standard) Conventional/Energy Star 60% savings (new Energy Star) Conventional 15% savings Conventional 15% savings																	
Set-Top Boxes	Moderate	Convent	ional					15%	savings	5										
	Aggressive	Convent	tional					30%	savings	5										
-	Baseline				20	08 Standa	ard per EISA 20	007												
External	Moderate	2008 Standard per EIS	A .				30%	savings												
Power Supply	Aggressive	2008 Standard per EIS/	4 30% sav	/ings				40%	6 saving	S										
Patton	Baseline		Interview Interview EF 3.01 EF 3.17 EF 3.01 EF 3.17 If a solution of the solutis of the solution of the solutis ol																	
Charger	Moderate	Convention	al					30% sa	vings											
Charger	Aggressive	Convention	al	30% savings					40% sav	ings										
	Baseline					Con	ventional													
Furnace Fan	Moderate	Convention	al					20% sa	vings											
	Aggressive	Convention	al	30%	% savings 40% savings															

Table B-3: Residential Appliance and Equipment Standards Assumptions (cont.)

		Base level	(relative to Base)	2nd S 3rd S	Standard (relative to Base) Standard (relative to Base)	4th Standard (relative to Base)											
		²⁰¹⁰ ²⁰¹¹ ²⁰¹²	2014 2014 2015 2016	2017 2018 2018 2019	² 020 2021 2022 2023 2024	2026 2027 2028 2029 2039 2033 2033 2033											
Packaged	Baseline	EPACT			EER 11.0/11.2												
Terminal	Moderate	EPACT	EER 11.0/11.2			EER 11.8											
AC/HP	Aggressive	EPACT	EER 11.0/11.2			EER 12.5											
Roof Top	Baseline				EER 11.0/11.2												
Units	Moderate	EER	11.0/11.2			EER 11.8											
onits	Aggressive	EER	11.0/11.2		EER 12.5												
	Baseline				EER 11.0/COP 3.3												
Heat Pump	Moderate	EER 1	0/COP 3.3		EE	R 11.5/COP 3.4											
	Aggressive	EER 1	.0/COP 3.3		EE	R 13.0/COP 3.6											
Air Handling	Baseline			Cor	Constant Air Volume/Variable Air Volume												
System	Moderate			Cor	istant Air Volume/Variable Air Volu	me											
oystem	Aggressive	Constant Air Volur	ne/Variable Air Volum	ie –	Vari	able Air Volume											
	Baseline	Incandescent	Advanced Incand (20 lumen	lescent - tier 1 s/watt)	ier 1 Advanced Incandescent - tier 2 (45 lumens/watt)												
Incandescent Lamps	Moderate	Incandescent	Advanced Incand (20 lumen	lescent - tier 1 s/watt)	Advanced Incandescent - tier 3 (50 lumens/watt)												
	Aggressive	Incandescent	Advanced Incand (20 lumen	lescent - tier 1 s/watt)	65 lumens	/watt (equivalent to current CFLs)											
Reflector	Baseline				Halogen (14.6 lumens/watt)												
Lamps	Moderate	Halogen Adv	anced Halogen (18 lur	nens/watt)		45 lumens/watt											
Lamps	Aggressive	Halogen Adv	anced Halogen (18 lur	nens/watt)		67 lumens/watt											
Linear	Baseline	T12			Т8												
Eluorescent	Moderate		T8		65 lumens/watt (ca	n be met using Super T-8 lamps)											
Hubresterre	Aggressive		T8 97 lumens/watt (next generation of LED lamps)														
High Intensity	Baseline				88 lumens/watt												
Discharge	Moderate		88 lumens/watt		95 lumens/watt												
Discharge	Aggressive	75 lumens/wa	t 95 lum	ens/watt	196 lumens/watt												
	Baseline				Conventional/Energy Star												
Computer	Moderate	Conventional/Er	ergy Star	40%	40% savings 50% savings												
	Aggressive	Conventional/Er	ergy Star		50% s	avings											

 Table B-4: Commercial Appliance and Equipment Standards Assumptions

		Base leve	el 🛛		2nd Standa	ard (relativ	ve to Base)	4th Standard (relative to Base)									
		1st Stand	ard (relative to	Base)	3rd Standa	rd (relativ	e to Base))										
		²⁰¹⁰ ²⁰¹¹ ²⁰¹²	2013 2014 2014 2015	²⁰¹⁶ 2017 2010	2019	²⁰² 1 2022	2023 2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
	Baseline		, , , ,			Conven	tional	/				1						
Server	Moderate	Conve	ntional				E	Energy S	Star									
	Aggressive	Conve	ntional	Energy Star + 15% savings														
	Baseline			Conventional														
Monitor	Moderate			Conventional														
	Aggressive		Conventional					Er	nergy S	otar								
	Baseline					Conven	tional											
Printer/Copier	Moderate					Conven	tional											
	Aggressive		Conventional	nal Energy Star														
Walk-in	Baseline			EISA 2007 Standard														
Refrigerator /	Moderate	EISA 2007	/ Standard	5% savings														
Freezer	Aggressive	EISA 2007	' Standard	15% savings 20% savings														
Decel in	Baseline		EPACT 2005 Standard															
Reach-In Defrigeration	Moderate	EPACT 200	5 Standard				1	15% sav	vings									
Kerngeration	Aggressive	EPACT 200	5 Standard	15% savings				20)% sav	ings								
Supermarket	Baseline	EPACT				2	5% savings											
and Other	Moderate	EPACT	25% savings				ŭ	30)% sav	ings								
Refrigeration	Aggressive	EPACT	25% savings				4	40% sav	vings									
Manallina	Baseline	FPACT				5	0% savings											
Vending	Moderate	EPACT				5	0% savings											
wachines	Aggressive	EPACT	50% savings					55	5% sav	ings								
	Baseline					2010 Sta	ndard											
Icemaker	Moderate	2010 St	tandard				1	15% sav	vings									
	Aggressive	2010 St	tandard		15% savin	gs						25%	saving	gs				
Low-V	Baseline					NEMA 2007	Standard											
Transformers	Moderate	NEMA 200	7 Standard				98.	.4% Effi	ciency									
mansionmers	Aggressive	NEMA 200	7 Standard	98.4% Efficiency 98.6% Efficiency														
	Baseline	62.3% Effic	ciency				70%	Efficien	cv									
Small Motors	Moderate	62.3% Effic	ciency	70	<u>% Efficiency</u>						80%	<u>6 Effic</u>	iency					
	Aggressive	62.3% Effic	ciency	70% Effic	ciency					80%	Effic	iency						
Commerial	Baseline	MEF 1.26					MEF 1.6	5										
Laundry	Moderate	MEF 1.26					MEF 1.6	5										
(Washers)	Aggressive	MEF 1.26	MEF 1.	1EF 1.6 MEF 2.4														

Table B-4: Commercial Appliance and Equipment Standards Assumptions (cont.)

		Base level 1st Standard (relative to	D Base) 2n 3rd	d Standard (rela d Standard (rela	tive to Base) tive to Base)	4th Standard (relative to Base)		
		2010 2011 2012 2013 2014 2014	2016 2017 2018	2020 2020 2021	2023 2023 2024 2025	2026 2027 2028 2029 2030 2033 2033 2033		
Motors	Baseline	EISA 2007 Standards						
WIOLOIS	Aggressive	EISA 2007 Standards	Premium	Super Premium Efficiency				
Packaged	Baseline	EPACT EER 11.0/11.2						
Terminal	Moderate	EPACT EER 11.0	/11.2	EER 11.8				
AC/HP	Aggressive	EPACT EER 11.0	/11.2		EER 12.5			
	Baseline	EER 11.0/11.2						
Roof Top Units	Moderate	EER 11.0/11.2		EER 11.8				
	Aggressive	EER 11.0/11.2		EER 12.5				
	Baseline	EER 11.0/COP 3.3						
Heat Pump	Moderate	EER 11.0/COP 3.3		EER 11.5/COP 3.4				
	Aggressive	EER 11.0/COP 3.3		EER 13.0/COP 3.6				
Air Handling	Baseline	Constant Air Volume/Variable Air Volume						
System	Moderate	Constant Air Volume/Variable Air Volume						
	Aggressive Constant Air Volume/Variable Air Volume Variable Air Volume							
Incandescent Lamps	Baseline	Incandescent Advance	d Incandescent - tier 1 20 lumens/watt)		Advanced Incandescent - tier 2 (45 lumens/watt)			
	Moderate	Incandescent Advanced Incandescer (20 lumens/wat		Advanced Incandescent - tier 3 (50 lumens/watt)		ncandescent - tier 3 (50 lumens/watt)		
	Aggressive	Incandescent Advance	ed Incandescent - tier 1 20 lumens/watt)	- tier 1 65 lumens/watt (equivalent to current CFLs)		s/watt (equivalent to current CFLs)		
Lincor	Baseline							
Linear	Moderate	T8		65 lumens/watt (can be met using Super T-8 lamps)				
riuorescent	Aggressive	Т8		97 lumens/watt (next generation of LED lamps)				
High Intensity	Baseline			88 lun	88 lumens/watt			
Discharge	Moderate	88 lumens/watt		95 lumens/watt				
	Aggressive	75 lumens/watt	95 lumens/watt	tt 196 lumens/watt				
Low-V &	Baseline	NEMA 2007 Standard						
Medium	Moderate	NEMA 2007 Standard	Standard		98.4% Efficiency			
Transformers	Aggressive	NEMA 2007 Standard	98.4% Efficie	ency	98.6% Efficiency			

APPENDIX C OVERVIEW OF MODELING APPROACH

To perform this analysis, the Load Management Analysis and Planning tool (LoadMAPTM), developed by Global Energy Partners, was utilized. LoadMAP was developed in 2007 and has been used for numerous studies of energy efficiency and demand response potential for utilities, state agencies, and other organizations. It has the following key features:

- Embodies the basic principles of rigorous end-use models (such as EPRI's REEPS and COMMEND) but in a more simplified, accessible form.
- Includes stock-accounting algorithms that treat older, less efficient appliance/equipment stock separately from newer, more efficient equipment. Equipment is replaced according to the measure life defined by the user.
- Isolates new construction from existing equipment and buildings and treats purchase decisions for new construction, replacement upon failure, early replacement, and non-owner acquisition separately.
- Uses a simple logic for appliance and equipment decisions. Some models embody decision models based on efficiency choice algorithms or diffusion models. While these have some merit, the model parameters are difficult to estimate or observe and sometimes produce anomalous results that require calibration or even overriding. LoadMAP allows the user to drive the appliance and equipment choices year by year directly in the model, which allows us to easily align with the AEO forecasts.
- Includes appliance and equipment models customized by end use. For example, the logic for lighting equipment is distinct from refrigerators and freezers.
- Accommodates various levels of segmentation. Analysis can be performed at the sector level (e.g., total residential) or for customized segments within sectors (e.g., housing type or income level).

For this analysis, model inputs consistent with the AEO 2012 forecast were developed and the forecast results were calibrated to AEO 2012 forecast results. To assess the two codes and standards scenarios, model inputs were modified according to the details provided in Appendix B. Additional details are available from EnerNOC upon request.

APPENDIX D RATEPAYER-FUNDED EE PROGRAM ANNUAL IMPACTS

Table D-1: Annual Impacts of Ratepayer-funded EE Programs

					Overlapping	
			Ratepayer-	% of National	Savings:	Ratepayer-
			Funded	Ratepayer-	Ratepayer	Funded Programs:
			Programs -	Funded	funded C&S	Excludes C&S
	Total Spending	Lifetime Cost	Cumulative	Savings from	programs	Program Efforts
Year	(\$ Millions)	per kWh (\$)	Savings (TWh)	C&S programs	(TWh)	(TWh)
2012	\$6,689	\$0.034	20	3.9%	1	19
2013	\$7,437	\$0.035	41	4.6%	2	39
2014	\$8,185	\$0.036	63	5.4%	3	60
2015	\$8,932	\$0.038	87	6.1%	5	82
2016	\$9,680	\$0.039	112	6.8%	8	104
2017	\$10,427	\$0.041	137	7.6%	10	127
2018	\$11,175	\$0.043	163	8.3%	14	150
2019	\$11,922	\$0.044	190	9.0%	17	173
2020	\$12,400	\$0.046	217	9.8%	21	196
2021	\$13,418	\$0.048	245	10.2%	25	220
2022	\$14,165	\$0.050	254	10.6%	27	227
2023	\$14,913	\$0.052	262	11.0%	29	233
2024	\$15,660	\$0.054	268	11.4%	31	238
2025	\$16,408	\$0.056	274	11.8%	32	242
2026	\$17,156	\$0.058	279	12.2%	34	245
2027	\$17,903	\$0.060	283	12.6%	36	248
2028	\$18,651	\$0.063	287	13.0%	37	250
2029	\$19,398	\$0.065	290	13.4%	39	251
2030	\$20,146	\$0.068	293	13.8%	40	252
2031	\$20,893	\$0.070	294	14.2%	42	252
2032	\$21,641	\$0.073	295	14.6%	43	252
2033	\$22,389	\$0.076	296	15.0%	44	251
2034	\$23,136	\$0.079	296	15.4%	46	250
2035	\$23,884	\$0.082	295	15.8%	47	249

APPENDIX E TRANSPORTATION SECTOR ANALYSIS APPROACH

	AEO 2012			
Vehicle Type	Reference	Moderate Scenario	Aggressive Scenario	
Light-Duty Vehicle	LDV Penetration Data	LDV data from Reference Case of AEO 2012 (13.1 TWh in 2035)	LDV data from High Tech Battery + High Oil (combination of two cases from AEO 2012) (87.8 TWh in 2035)	
Commercial Light Trucks	No electrification	Electrified Stock% = 0.50 x LDV's Electrified Stock%	Electrified Stock% = 0.50 x LDV's Electrified Stock%	
Transit Bus	No electrification	Electrified Stock% = 0.50 x LDV's Electrified Stock%	Electrified Stock% = 0.50 x LDV's Electrified Stock%	
School Bus	No electrification	Electrified Stock% = 0.50 x LDV's Electrified Stock%	Electrified Stock% = 0.50 x LDV's Electrified Stock%	
Military Use	No electrification	Electrified Stock% = 0.10 x LDV's Electrified Stock% (Ground vehicles only)	Electrified Stock% = 0.10 x LDV's Electrified Stock% (Ground vehicles only)	
Freight Trucks	No electrification	20% auxiliary power electrification	50% penetration of auxiliary power electrification	
Air Transportation	No electrification	20% auxiliary power electrification	50% penetration of auxiliary power electrification	
Domestic Shipping	No electrification	20% auxiliary power electrification	50% penetration of auxiliary power electrification	
International Shipping	No electrification	20% auxiliary power electrification	50% penetration of auxiliary power electrification	

Table E-1 Transportation Electrification Modeling Strategy

APPENDIX F REFERENCES

- AHAM, "Today's Energy Standards for Refrigerators Reflect Consensus by Advocates, Industry to Increase Appliance Efficiency," September 27, 2010 press release, http://www.aham.org/ht/a/GetDocumentAction/i/50432>.
- American Council for an Energy-Efficient Economy (ACEEE). "HR. 2454 Addresses Climate Change Through a Wide Variety of Energy Efficiency Measures." 1 June 2009. http://www.aceee.org/energy/national/HR2454_Estimate06-01.pdf>.
- American Council for an Energy-Efficient Economy, "Ka-BOOM! The Power of Appliance Standards, Opportunities for New Federal and Appliance and Equipment Standards", July 2009
- Appliance Standards Awareness Project: http://www.standardsasap.org/
- Electrification Coalition, "Electrification Roadmap: Revolutionizing Transportation and Achieving Energy Security", November 2009
- Energy Independence and Security Act of 2007. Pub. L. 110-140. 19 December 2007. Stat. 121.1492.
- Energy Information Administration, "Annual Energy Outlook 2012", June 2012, http://www.eia.doe.gov/forecasts/aeo/
- Energy Information Administration, "EIA Technology Forecast Updates Residential and Commercial Building Technologies – Reference Case, Second Edition (Revised)", Navigant Consulting, September 2007
- Energy Information Administration, "EIA Technology Forecast Updates Residential and Commercial Building Technologies – Reference Case", Navigant Consulting, September 2008
- Institute for Electric Efficiency, "Assessment of Electricity Savings in the U.S. Achievable through New Appliance/Equipment Efficiency Standards and Building Efficiency Codes (2010-2020)", December 2009.
- Institute for Electric Efficiency, "Integrating Codes and Standards Into Electric Utility Energy Efficiency Portfolios", August 2011.
- Institute for Electric Efficiency, "Summary of Ratepayer-Funded Electric Efficiency Impacts, Budgets and Expenditures (2010-2011)", January 2012.
- U.S. Department of Energy's Appliances and Commercial Equipment Standards Program: http://www1.eere.energy.gov/buildings/appliance_standards/index.html

U.S. Department of Energy, "Multi Year Program Plan – Building Regulatory Programs -Energy Efficiency and Renewable Energy, Building Technologies Program", October 2010

About IEE

IEE is an Institute of The Edison Foundation focused on advancing the adoption of innovative and efficient technologies among electric utilities and their technology partners that will transform the power grid. IEE promotes the sharing of information, ideas, and experiences among regulators, policymakers, technology companies, thought leaders, and the electric power industry. IEE also identifies policies that support the business case for adoption of cost-effective technologies. IEE's members are committed to an affordable, reliable, secure, and clean energy future.

IEE is goverened by a Management Committee of 23 electric industry Chief Executive Officers. IEE members are the investor-owned utilties who represent about 70% of the U.S. electric power industry. IEE has a permanent Advisory Committee of leaders from the regulatory community, federal and state governement agencies, and other informed stakeholders. IEE has a Strategy Committee of senior electric industry executives and 33 smart grid techology company partners.

Visit us at: www.edisonfoundation.net/IEE

For more information contact:

Adam Cooper

Research Manager IEE 701 Pennsylvania Avenue, N.W. Washington, D.C. 20004-2696 202.508.5551 acooper@edisonfoundation.net

