Demand-Side Management Potential Study 2019-2038

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List of Acronyms

ACS: American Community Survey

B/C: Benefit-to-cost

CBECS: Commercial Building Energy Consumption Survey (Energy Information Agency)

CIS: Customer information system

EIA: Energy Information Agency

EUC: End-use consumption

EUL: Effective useful life

EUI: End-use intensities

GWh: Gigawatt hours

MECS: Manufacturing Energy Consumption Survey (Energy Information Agency)

MW: Megawatt

MWh: Megawatt hour

NAICS: North American Industrial Classification System

KU: Kentucky Utilities Company

LG&E: Louisville Gas and Electric Company

kWh: Kilowatt hour

RASS: Residential Appliance Saturation Survey

RECS: Residential Energy Consumption Survey (Energy Information Agency)

SIC: Standard industrial classification

TRC: Total resource cost test

UEC: Unit energy consumption, also referred to as end-use consumption

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Executive Summary

Overview

Cadmus conducted an independent study of the long-run technical, economic, and achievable potential of electric and natural gas energy efficiency for the residential and commercial sectors in the service territories of Louisville Gas and Electric Company (LG&E) and Kentucky Utilities Company (KU), hereafter referred to as the Company, from 2019 to 2038. The Company commissioned this study to inform the development of the 2019 and forward energy efficiency program portfolio and its next integrated resource plan. Although Cadmus focused this study primarily on electric efficiency, we also conducted a preliminary study of natural gas efficiency potential as an update to the analysis we performed for the Company's 2013 energy efficiency potential study.

Cadmus relied on secondary and primary data to conduct the analysis, which comprised the Company's most recent official load forecasts, long-term avoided costs (including annual energy and capacity values), system loss factors, and discount rate. Because the Company had already vetted these data, we did not validate them and used the data as provided. For critical technical and market information specific to the Company's service territory, we used phone surveys of LG&E and KU residential and commercial customers, along with the on-site audits of commercial customers conducted for the 2013 LG&E and KU potential study. We updated the market data collected for the 2013 potential study to account for the following information:

- The Company's demand-side management (DSM) program accomplishments from 2013 through 2016
- The impact of recently adopted building energy codes and federal equipment standards
- The natural adoption of efficient technology since 2013
- New energy efficiency measures, changes in measure costs, and up-to-date estimates of measure savings

Cadmus supplemented primary data with information from secondary sources.[1] Together, these data provided the foundation for estimating technical, economic, and achievable potential, defined as follows:

- ***Technical potential*** represents all technically feasible, energy efficiency measures being implemented, regardless of their costs or market barriers.
- ***Economic potential*** represents a subset of technical potential, consisting only of measures meeting cost-effectiveness criteria based on the Company's avoided supply costs for delivering

[1] Note that secondary sources are different from secondary data. Secondary sources provide information that was not directly gathered or compiled by Cadmus, but which we consider accurate. Examples of secondary sources are the U.S. Census Bureau and U.S. Energy Information Administration websites, where we obtained supplemental technical and market data.

electricity and natural gas and for avoided line losses. Cadmus determined the economic potential using a total resource cost (TRC) test, in which we compared the net benefits of energy efficiency measures with their costs.[2]

- ***Achievable potential*** represents the portion of economic potential assumed to be reasonably achievable in the course of the planning horizon, given budgetary constraints and market barriers that may impede customers' participation in utility programs. In this study, Cadmus examined survey results to assess consumers' willingness to adopt energy efficiency measures at three levels, depending on the fraction of the measure's incremental cost (0%, 50%, and 75%) covered by the Company's incentives.

To estimate technical potential, Cadmus used the industry-standard, bottom-up approach. This approach is consistent with energy efficiency studies by Cadmus and other consultants in various jurisdictions throughout the United States. We began with a comprehensive review of electric and natural gas energy efficiency measures applicable to each of the Company's sector and market segments. Using technical measure data and market characteristics, we determined the likely long-term saturations of each measure in specific sectors and market segments. This assessment resulted in a technical potential supply curve at the measure level, which we then screened for cost-effectiveness to determine the economic potential. With this study, we also established the achievable levels of energy efficiency potential by assessing customers' willingness to pay for energy efficiency measures, also derived from survey results.

This study does not include consideration of program potential, which is the portion of achievable potential that the Company may realize through DSM programs, and which accounts for the Company's spending on energy efficiency programs and for any program implementation barriers. Program potential also can provide the basis for the Company's DSM savings goals. Although estimates of achievable potential can inform the development of Company DSM programs, estimates of potential program savings must be produced outside the scope of this study.

Summary of Results

For this study, Cadmus quantified the amount of energy and demand the Company can save in its service territory from 2019 to 2038. The Company can achieve these savings by adopting proven, commercially available energy-efficient technologies while also accounting for the following factors:

- Changes in codes and standards (taking effect from 2019 to 2038)
- Technical feasibility and limitations (technical potential)

2 For a description of the method for calculating TRC, see: California Public Utilities Commission. *California Standard Practice Manual: Economic Analysis of Demand-Side Management Programs*. October 2001. Available online: http://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/Utilities_and_Industries/Energy_-_Electricity_and_Natural_Gas/CPUC_STANDARD_PRACTICE_MANUAL.pdf

- Cost-effectiveness (economic potential), using the TRC benefit/cost test
- Consumers' willingness to adopt energy efficiency measures (achievable potential)

Electric Energy Efficiency Potential

Summary of Key Findings

Cadmus identified the following key findings from our analysis of electric energy efficiency potential:

- ***New technologies contributed to higher technical and economic potential.*** Technical potential increased significantly because of new high-efficiency technologies for lighting, HVAC, dryers, and water heaters; however, most of these technologies are not cost-effective. LED lighting in the residential sector is now cost-effective and has significant savings potential. It is the highest-saving residential measure and accounts for nearly one-third of all achievable potential in the sector. Some measures that were considered in this study, but not in the 2013 assessment, which have high economic potential are energy feedback (i.e., home energy reports), 1.5 gallons per minute (gpm) showerheads, and LED linear fluorescent lighting (TLED) in the commercial sector.
- ***Naturally occurring conservation and DSM program accomplishments reduced economic potential.*** The Company's existing DSM programs, combined with the natural adoption of efficiency measures, has led to an increase in the saturation of cost-effective DSM measures over the last three years. This led to decreased estimates of technical, economic, and achievable energy efficiency potential. New federal equipment standards for water heaters, lighting, HVAC, and various appliances further reduced energy efficiency potential.
- ***Lower avoided costs reduced economic potential.*** Declines in the Company's avoided energy and capacity costs reduced the overall benefit for energy efficiency. This, in turn, decreased estimates of economic potential.

Detailed Results

The study results indicate a cumulative 7,072 gigawatt hours (GWh) of technically feasible, electric energy efficiency potential by 2038, the end of the 20-year study horizon, with approximately 1,988 GWh (28%) of these savings proving cost-effective (Table 1). The estimated amount of economic potential is equivalent to 9% of the Company's 2038 sales forecast.

Calculating economic potential is the first step in determining the amount of energy efficiency potential the Company should expect from its programmatic efforts. However, it does not represent the total amount the Company can expect to achieve because of well-documented market barriers, which is detailed in the Achievable Potential section.

Table 1. Technical and Economic Electric Energy Efficiency Potential – Energy (GWh)

Sector	Baseline Sales	Cumulative 2038		Percentage of Baseline		Economic as a Percentage of Technical
		Technical	Economic	Technical	Economic	
Residential	11,453	4,143	1,093	36%	10%	26%
Commercial	10,200	2,930	895	29%	9%	31%
Total	**21,652**	**7,072**	**1,988**	**33%**	**9%**	**28%**

Table 2 shows the technical and economic peak demand reduction potential. The 20-year cumulative technical potential is 2,069 MW and the 20-year cumulative economic potential is 303 MW, which is equivalent to 35% and 5% of baseline peak demand, respectively.

Table 2. Technical and Economic Electric Energy Efficiency Potential – Demand (MW)

Sector	Baseline Peak	Cumulative 2038		Percentage of Baseline		Economic as a Percentage of Technical
		Technical	Economic	Technical	Economic	
Residential	3,843	1,495	138	39%	4%	9%
Commercial	2,069	574	166	28%	8%	29%
Total	**5,912**	**2,069**	**303**	**35%**	**5%**	**15%**

Cadmus used the same approach to estimate achievable potential in this study as we used in the 2013 assessment. Because of uncertainties inherent in future markets for energy efficiency products and services (described in the Achievable Potential section), we did not attempt to develop a point estimate of achievable potential in this study. Rather, we developed a *range* of estimates, based on the fraction of economic potential we expect to be achievable, given customers' willingness to adopt energy efficiency measures.

We used primary data collected for the 2013 potential study, in which we had asked customers about their willingness to invest in energy efficiency if the Company subsidized the investment by paying 0%, 50%, or 75% of the energy efficiency measure's incremental cost. (Note that none of these incentive levels were related to the Company's avoided cost of energy or capacity.) We had designed the 2013 survey to learn which incentive levels would motivate customers to install energy efficiency measures.

Table 3 and Table 4 show the low, medium, and high levels of cumulative, electric energy efficiency potential the Company can expect to be achievable over the course of this study's 20-year horizon, for energy and demand, respectively.

Table 3. Achievable Electric Energy Efficiency Potential – Energy (GWh)

Sector	Baseline Sales	Cumulative 2038			Percentage of Baseline		
		Low	Medium	High	Low	Medium	High
Residential	11,453	477	635	710	4%	6%	6%
Commercial	10,200	387	620	689	4%	6%	7%
Total	**21,652**	**864**	**1,255**	**1,400**	**4.0%**	**5.8%**	**6.5%**

Table 4. Achievable Electric Energy Efficiency Potential – Demand (MW)

Sector	Baseline Sales	Cumulative 2038			Percentage of Baseline		
		Low	Medium	High	Low	Medium	High
Residential	3,843	51	74	83	1%	2%	2%
Commercial	2,069	69	112	125	3%	5%	6%
Total	**5,912**	**120**	**186**	**207**	**2.0%**	**3.1%**	**3.5%**

Results indicate a range of 864 GWh to 1,400 GWh of achievable electricity savings for energy, representing 4.0% and 6.5% of retail sales in 2038, respectively. These estimated savings have a medium value of 1,255 GWh, which represents 5.8% of the baseline sales. The achievable demand reduction indicates a range of 120 MW to 207 MW, representing 2.0% and 3.5% of baseline summer peak demand.

Figure 1 shows incremental achievable potential for the medium scenario in each year of the study horizon if the Company were to acquire discretionary (retrofit) savings evenly over the first 10 years of the study horizon. After 2028, incremental savings comes from lost opportunity (equipment replacement and new construction) measures.

Figure 1. Incremental Achievable Potential for Medium Achievable Scenario – 10-Year Retrofit Ramp

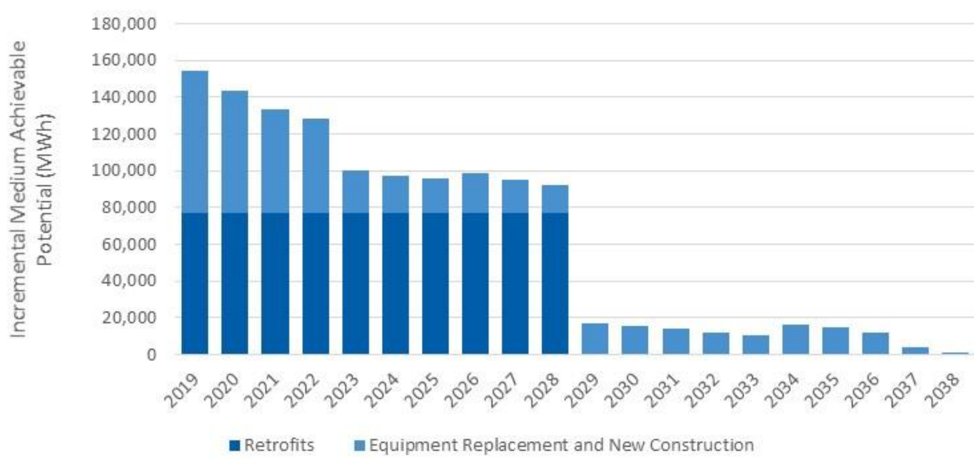


Figure 2 shows cumulative achievable potential for the medium scenario.

Figure 2. Cumulative Achievable Potential for Medium Achievable Scenario

Top-Saving Measures

Table 5 and Table 6 show the residential and commercial measures with the highest achievable potential, respectively. All measures passed the TRC benefit/cost test, and many are already provided through the Company's existing energy efficiency programs. In the residential sector, LED lighting for medium screw-base sockets accounts for 33% of the sector's achievable potential. Overall, standard and specialty LED bulbs account for 39% of the residential sector's achievable potential, which equals nearly 210,000 MWh of cumulative energy savings by 2038. Low-flow showerheads (those rated at 1.5 gpm) also have high achievable potential at a relatively low cost by offering significant efficiency gains over 2.2 gpm units that merely comply with federal standards.

Table 5. Top Residential Measures

Measure Name	Cumulative 2038 Achievable Potential (Medium) - MWh	Percentage of Total Achievable Potential
Lighting General Service Lamp - Premium Efficiency LED	176,728	33%
Low-Flow Showerhead	72,548	13%
Home Energy Reports	67,537	12%
Refrigerator - Removal of Secondary	40,551	7%
Lighting Specialty Lamp - Premium Efficiency LED	33,273	6%
Pool Pump - Two-Speed	27,448	5%
Programmable Thermostat	24,698	5%
Low-Flow Faucet Aerator - Kitchen	23,510	4%
Low-Flow Faucet Aerator - Bathroom	16,746	3%
Office Multifunction Device - ENERGY STAR®	16,585	3%

Occupancy sensor controls for lighting are the highest-saving cost-effective measure in the commercial sector. Although Cadmus considered this measure in our 2013 assessment of energy efficiency potential, recent program evaluations have identified savings that are much higher than previously assumed. For example, a Lawrence Berkley National Laboratory (LBNL) meta-study of occupancy sensor evaluations[3] found higher savings than assumed in Cadmus 2013 study. These studies included in the LBNL report identified occupancy sensor savings equivalent to nearly 20% of lighting usage for many applications (such as linear fluorescent, screw base, and high bay).

Table 6. Top Commercial Measures

Measure Name	Cumulative 2038 Achievable (Medium) - MWh	Percentage of Total Achievable Potential
Occupancy Sensor Control	171,640	33%
Daylighting Controls, Outdoors (Photocell)	41,882	8%
Motor - Pump and Fan System - Variable Speed Control	34,937	7%
Lighting Interior - Screw-Base LED - Above Standard	30,013	6%
Lighting Interior - Efficient Metal Halide - Above Standard	29,432	6%
Lighting Interior - TLED - Above Standard	27,666	5%
Direct/Indirect Evaporative Cooling, Pre-Cooling	17,629	3%
Lighting Package - Advanced Efficiency	15,536	3%
Case Replacement Low Temperature	14,911	3%
Exit Sign - Photoluminescent or Tritium	14,148	3%

[3] Lawrence Berkeley National Laboratory (Page, Erik). "A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings." September 2011. Available online: https://eetd.lbl.gov/sites/all/files/a_meta-analysis_of_energy_savings_from_lighting_controls_in_commercial_buildings_lbnl-5095e.pdf

Considerations and Limitations for Program Design

While this study provides insight into which measures the Company could offer in future programs, it is only meant to inform, not set, program targets. While this study identifies the level of cost-effective energy efficiency that the Company's customers could adopt over the next 20 years, it does not identify how much of that savings should be captured through programs—it does not estimate program potential. The Company has used the results of this potential study to guide the development of its energy efficiency program plans. However, program plans may differ from the results presented in this study for the following reasons:

- **Potential study estimates account for interactions between cost-effective measures**. When two interactive measures are installed (such as ceiling insulation and windows), the combined interactive savings are lower than the sum of the stand-alone savings for the two measures. This effect is sometimes referred to as "measure stacking." These interactive effects can produce lower estimates than planned savings because program plans may not include all of the measures considered within the potential study.
- **The potential study produced estimates of cumulative energy efficiency savings, while program planning produces incremental savings.** While for many measures, cumulative and incremental savings are the same, for measures with short lifetimes, cumulative savings can be much lower than the sum of incremental savings. A home energy reports measure may save 50,000 MWh per year, though the cumulative savings over 20 years is still only 50,000 MWh because customers must be re-enrolled each year.
- **The potential study uses broad assumptions about the adoption of energy efficiency measures with different incentive levels:** The different estimates of achievable potential are meant to be directional; i.e. given a certain increase/decrease in incentives, we would expect to see a corresponding increase/decrease in savings. This approach provides a realistic range of estimates, given a range of incentive levels. However, program design requires a more detailed look at historic participation and incentive levels on a measure-by-measure basis. The potential study can then be used to inform planning for measures the Company has not historically offered.
- **The potential study only considers cost-effective energy efficiency measures.** It does not consider the possible bundling of cost-effective and non-cost-effective measures. Some programs, however, can be designed so measures that are not cost-effective on their own can be delivered in cost-effective bundles.
- **The potential study does not consider program implementation barriers:** While it does account for customers' willingness-to-adopt efficiency measures, it does not examine whether these measures can be delivered through programs. Many programs require robust trade ally networks, or must overcome barriers such as split incentives, to succeed. This study does not account for such barriers.

Comparison to 2013 Potential Study

Technical Potential

Cadmus identified higher technical potential in this study than we found in our 2013 assessment. Overall, technical potential accounts for approximately 33% of baseline sales in this 2016 study, compared to 22% of baseline sales in the 2013 study (see Table 7).[4]

Table 7. Technical Potential Comparison

Sector	Technical Potential – 20-Year (GWh)		Technical Potential – Percentage of Baseline	
	2016 Study	2013 Study	2016 Study	2013 Study
Residential	4,143	3,689	36%	26%
Commercial	2,930	1,702	29%	17%
Total	**7,072**	**5,391**	**33%**	**22%**

New technologies contributed to a significant increase in technical potential in both sectors. To begin this project, Cadmus thoroughly reviewed the energy efficiency measures included in our 2013 assessment. We removed measures that have become a part of Kentucky's building energy code or federal equipment standards and added measures that have become commercially viable within the last three years.

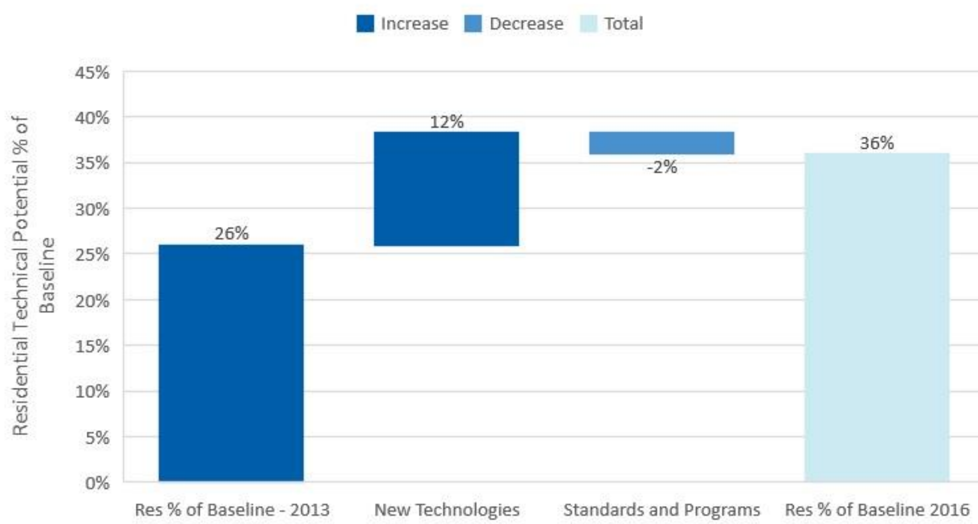
In the residential sector, examples of new technologies with high technical potential include enhanced efficiency central cooling and heat pumps (SEER 22+), heat pump dryers, and advanced weatherization. These, and other new technologies, could produce technically feasible savings equivalent to 12% of residential baseline sales. The introduction of these new technologies effectively increased residential technical potential by nearly 50%.

However, other factors contributed to a decrease in technical potential. Program accomplishments, the natural adoption of efficient equipment, and federal equipment standards increasing between 2013 and 2016 contributed to a reduction in residential sector technical potential. These factors increased the baseline saturation of efficient technology, which in turn reduced the technical potential for many measures. Combined, these three factors produced savings equivalent to approximately 2% of residential baseline sales.

Figure 3 shows how new technologies and the adoption of efficient technology (either through programs or outside programs) contributed to a net increase of technical potential equivalent to 10% of baseline residential sales.

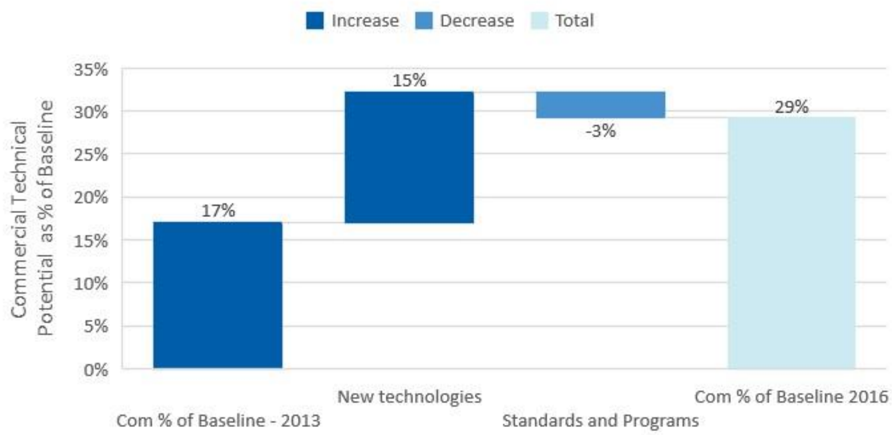
[4] Cadmus compared savings relative to baseline sales (as a percentage) from each study, as opposed to relative to absolute savings, because we relied on different baseline forecasts for the two studies. By comparing relative savings, not absolute savings, we avoid misidentifying differences due to changes in the reference case.

Figure 3. Residential Technical Potential – Changes from 2013 Study



New technologies and the adoption of efficient technologies contributed to a similar net increase in commercial sector technical potential. New lighting technologies, such as LED replacements for linear fluorescents and high-bay fixtures, contributed to a large increase in commercial technical potential. Specifically, linear TLED lighting, super-efficient cooling, and higher evaluated savings for occupancy sensors contributed to an increase in commercial technical potential equivalent to 15% of the sector's baseline sales. At the same time, increasing standards, the natural adoption of efficient technologies, and the Company's program accomplishment contributed to a reduction in technical potential equivalent to 3% of commercial baseline sales. Overall, commercial sector technical potential increased from 17% to 29% (as shown in Figure 4).

Figure 4. Commercial Technical Potential – Changes from 2013 Study



Economic Potential

Compared to the 2013 study, for this 2016 study Cadmus identified lower economic potential in the residential sector and higher economic potential in the commercial sector, although the overall economic potential in the two studies is similar. Lower avoided costs (both energy and capacity) decreased estimates of economic potential, while new commercially available cost-effective measures increased the economic potential back to a level similar to the 2013 study. Levelized avoided energy costs are nearly 20% lower compared to the 2013 study, and avoided capacity costs are $0 per kW compared to $100 per kW in the 2013 study (see Table 8).

Table 8. Avoided Cost Comparison

Component	2013 Study	2016 Study
Energy (20-year levelized)	Between $0.037/kWh and $0.046/kWh	Between $0.030/kWh and $0.037/kWh
Capacity	$100/kW per year	$0/kW per year

Table 9 shows a comparison of the economic potential from the 2013 and 2016 studies. Residential sector economic potential decreased from 12% of baseline sales to 10% because of naturally occurring conservation, program activity, and lower avoided costs. Commercial sector economic potential increased from 8% of baseline sales in the 2013 study to 9% in the 2016 study, mostly because of new commercially available cost-effective measures; lower avoided costs had less of an impact on the commercial sector than on the residential sector.

Table 9. Economic Potential Comparison

Sector	Economic Potential – 20-Year (GWh)		Economic Potential – Percentage of Baseline	
	2016 Study	2013 Study	2016 Study	2013 Study
Residential	1,093	1,716	10%	12%
Commercial	895	811	9%	8%
Total	**1,988**	**2,527**	**9%**	**10%**

Figure 5 shows the factors that contributed to the net decrease in residential economic potential. First, new cost-effective measures in the 2016 study, such as home energy reports and 1.5 gpm showerheads, contributed to an increase in economic potential equivalent to 1% of baseline sales. LED lighting for medium screw-base bulbs, which was not cost-effective in the 2013 assessment, is cost-effective in the 2016 study, and contributed to an increase in economic potential equivalent to 3% of baseline sales. Naturally occurring savings and program accomplishments produced a decrease in economic potential equivalent to 2% of baseline sales, and the Company's lower avoided energy and capacity costs reduced economic potential by an amount equivalent to 4% of baseline sales. After accounting for each of these factors, overall residential economic potential decreased from approximately 12% of baseline sales to 10%.

Figure 5. Residential Economic Potential – Changes from the 2013 Study

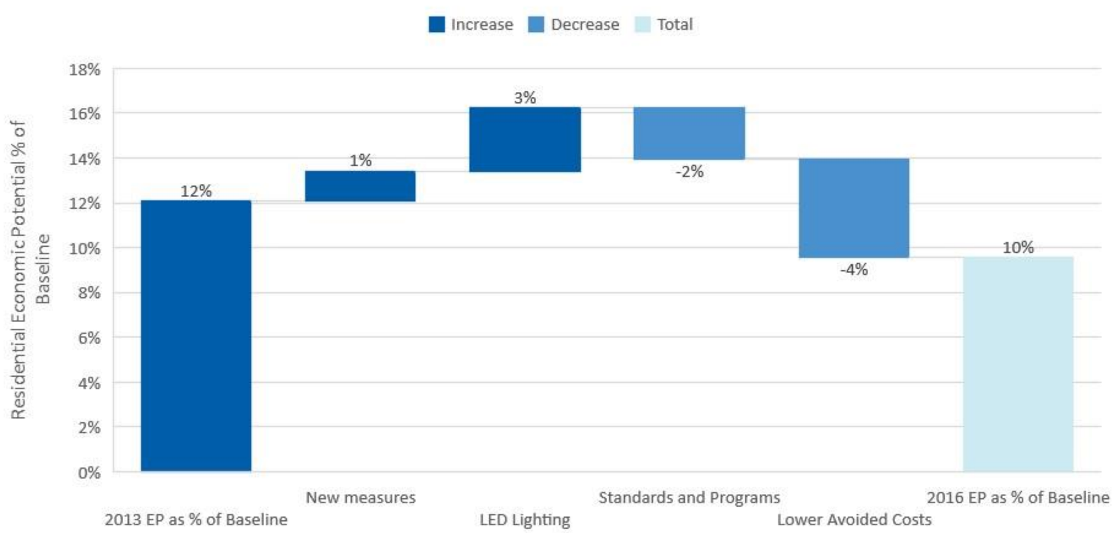
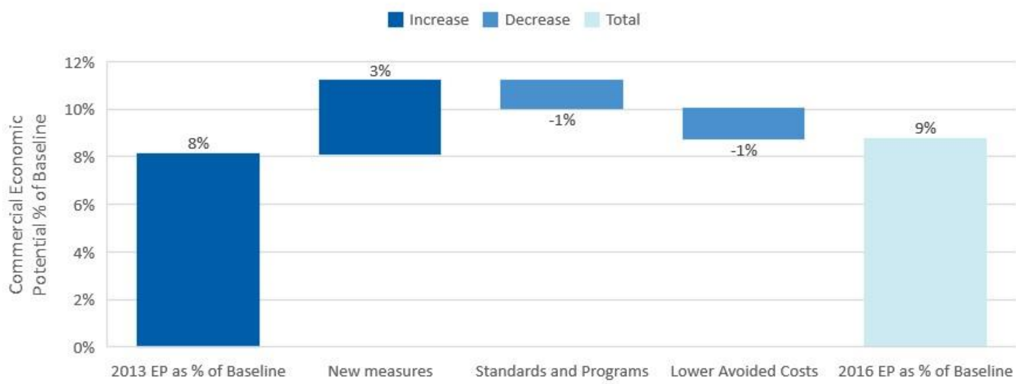


Figure 6 shows the factors that contributed to an increase in commercial sector economic potential, from being equivalent to 8% of baseline sales in the 2013 study to 9% of baseline sales in the 2016 study. New measures and new data on the savings for old measures contributed to an increase in economic potential equivalent to 3% of baseline sales. Increased standards and program accomplishments contributed to a decrease in economic potential equivalent to 1% of baseline sales, and lower avoided costs also contributed to a decrease equivalent to 1% of baseline sales.

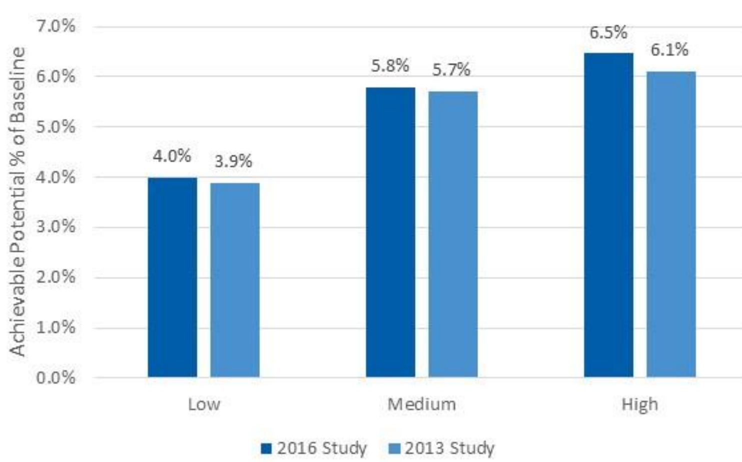
Figure 6. Commercial Economic Potential – Changes from 2013 Study



Achievable Potential

Estimates of achievable potential in this 2016 study are slightly higher than estimates from the 2013 study (shown in Figure 7). The 2013 study produced a range of achievable estimates that were equivalent to between 3.9% and 6.1% of baseline sales, while this study produced a range equivalent to between 4.0% and 6.5% of baseline sales.

Figure 7. Electric Achievable Potential – Comparison to the 2013 Study



Natural Gas Energy Efficiency Potential

2016 study results indicate that 11.7 million MCF of natural gas energy efficiency potential are technically feasible by 2038. Using avoided natural gas commodity costs to screen measures for cost-effectiveness, nearly one-third of this potential (or approximately 4 million MCF) will be economic. This level of cost-effective potential represents 15% of the Company's projected sales in 2038.

Table 10. Technical and Economic Natural Gas Energy Efficiency Potential (Cumulative 2038) by Sector (MCF)

Sector	Baseline Sales	Cumulative 2038		Percentage of Baseline		Economic as a Percentage of Technical
		Technical	Economic	Technical	Economic	
Residential	17,872,105	8,794,324	3,082,896	49%	17%	35%
Commercial	8,775,436	2,974,937	937,691	34%	11%	32%
Total	26,647,541	11,769,261	4,020,586	44%	15%	34%

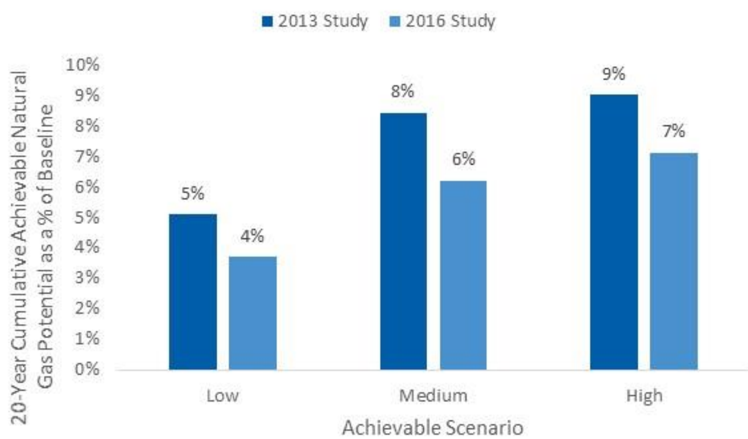
The study results suggest that between 0.98 million to 1.8 million MCF of natural gas savings are achievable over the 20-year planning period. These results indicate that the Company can expect a medium level (1.6 million MCF) of achievable potential, representing 6.2% of the Company's baseline sales forecast (as shown in Table 11).

Table 11. Achievable Natural Gas Energy Efficiency Potential (Cumulative 2038) by Sector (MCF)

Sector	Baseline Sales	Cumulative 2038			Percentage of Baseline		
		Low	Medium	High	Low	Medium	High
Residential	17,872,105	738,633	1,189,821	1,364,631	4.1%	6.7%	7.6%
Commercial	8,775,436	249,711	456,015	515,945	2.8%	5.2%	5.9%
Total	**26,647,541**	**988,344**	**1,645,836**	**1,880,577**	**3.7%**	**6.2%**	**7.1%**

Compared to the 2013 potential study, this study identified lower achievable natural gas potential in each scenario. The 2013 potential study produced a range of achievable natural gas potential equivalent to between 5% and 9% of baseline sales, while this study identified a range of 4% to 7% (Figure 8). Lower natural gas commodity prices, higher saturations of efficient natural gas technologies, and federal furnace and boiler standards all contributed to the drop in achievable natural gas potential.

Figure 8. Natural Gas Achievable Potential – Comparison to the 2013 Potential Study



Demand Response Potential

Cadmus considered five different demand response (DR) programs each for LG&E's and KU's service territories. For this assessment, Cadmus used three demand response options—direct load control (DLC), pricing, and load curtailment—across five programs:

- DLC: Residential and Commercial Demand Conservation Program
- DLC: Residential Wi-Fi Thermostat Option for Demand Conservation
- Pricing: Residential Time-of-Use (TOU)
- Pricing: Residential Critical Peak Pricing (CPP)
- Commercial Load Curtailment

The Company offers DLC, a Wi-Fi thermostat pilot, and curtailment through DSM programs. They also offer TOU rates outside of the DSM programs, but do not offer a residential CPP program. Cadmus modeled low and high participation scenarios for each DR program (except for critical peak pricing), and we report both summer and winter peak savings for each scenario (Table 12). The low scenarios are based on LG&E's and KU's existing programs. To determine the high scenarios, Cadmus considered program changes consistent with benchmarking similar programs at other utilities.

Table 12. Demand Reduction Analysis Scenarios

Program	Summer Peak		Winter Peak	
	Low	High	Low	High
Residential DLC	✓	✓	✓	✓
Commercial DLC	✓	✓	✓	✓
Wi-Fi Thermostat*	✓	✓	✓	✓
Time of Use	✓	✓	✓	✓
Curtailment	✓	✓	✓	✓
Critical Peak Pricing	✓		✓	

* Cadmus included the winter Wi-Fi smart thermostat participants in the winter residential DLC program, since device impacts were identical.

Cadmus employed a top-down approach to determining the achievable load reduction potential, in which we disaggregated system loads by sector, segment, and applicable end uses, then applied technical potential, program participation, and event participation.[5] Table 13 shows that the summer achievable load reduction for KU totals 70 MW in the low scenario and 176 MW in the high scenario (2% and 5% of summer peak, respectively). The winter achievable load reduction for KU totals 105 MW in the low scenario and 151 MW in the high scenario (6% and 9% of winter peak, respectively).

[5] Cadmus used the top-down approach for TOU, CPP, and curtailment, but estimated DLC programs using device-level impacts at the device level.

Table 13. KU Demand Reduction Potential Results

Program	Utility	Peak Season	Achievable Load Reduction in 2038*		Peak Reduction**		Levelized Cost per Year ($/kW-year)***	
			Low	High	Low	High	Low	High
Residential DLC	KU	Summer	32	96	1.0%	2.9%	$232	$75
Commercial DLC	KU	Summer	0	3	0.0%	0.1%	$278	$86
Wi-Fi Thermostat	KU	Summer	2	4	0.1%	0.1%	$79	$48
TOU	KU	Summer	9	33	0.3%	1.0%	$155	$88
Curtailment	KU	Summer	27	40	0.8%	1.2%	$55	$80
CPP	KU	Summer	27	N/A	0.8%	N/A	$98	N/A
Total+	**KU**	**Summer**	**70**	**176**	**2%**	**5%**		
DLC	KU	Winter	84	114	5.8%	7.9%	$87	$63
TOU	KU	Winter	3	10	0.1%	0.3%	$549	$314
Curtailment	KU	Winter	18	27	0.5%	0.8%	$69	$92
CPP	KU	Winter	8	N/A	0.6%	N/A	$206	N/A
Total+	**KU**	**Winter**	**105**	**151**	**6%**	**9%**		

* These values are at generation and include line losses.

** This represents achievable load reduction divided by the market basis (peak load) for residential and commercial loads during the top 40 hours (10 four-hour events).

*** Cadmus discounted future values using a 6.5% rate, and escalated program and technology costs for future years using a 1.9% rate of inflation.

Levelized costs reflect net present value costs divided by the potential demand savings over the 20-year study horizon. If the Company were to offer a new DR product, or expand an existing product, we expect the cost will be roughly equal to the $/kW-year levelized cost. Cadmus did not compare DR products to the Company's avoided capacity cost, nor did we assess whether an individual product is cost-effective.

+ Totals exclude CPP as it is an alternative to the TOU program, and the savings are not additive.

Table 14 shows that the summer achievable load reduction for LG&E totals 70 MW in the low scenario and 176 MW in the high scenario (2% and 6% of summer peak, respectively). The winter achievable load reduction for LG&E totals 108 MW in the low scenario and 147 MW in the high scenario (8% and 11% of winter peak, respectively).

Table 14. LG&E Demand Reduction Potential Results

Program	Utility	Peak Season	Achievable Load Reduction in 2038*		Peak Reduction**		Levelized Cost per Year ($/kW)***	
			Low	High	Low	High	Low	High
Residential DLC	LG&E	Summer	33	105	1.3%	4.2%	$223	$76
Commercial DLC	LG&E	Summer	0	0	0.0%	0.0%	$304	$140
Wi-Fi Thermostat	LG&E	Summer	2	4	0.1%	0.1%	$59	$44
TOU	LG&E	Summer	7	26	0.2%	0.8%	$200	$113
Curtailment	LG&E	Summer	28	41	0.8%	1.3%	$52	$77
CPP	LG&E	Summer	21	N/A	0.8%	N/A	$114	N/A
Total+	**LG&E**	**Summer**	**70**	**176**	**2%**	**6%**		
DLC	LG&E	Winter	78	106	7.1%	9.6%	$129	$94
TOU	LG&E	Winter	2	7	0.1%	0.2%	$766	$432
Curtailment	LG&E	Winter	22	34	0.7%	1.0%	$58	$82
CPP	LG&E	Winter	5	N/A	0.5%	N/A	$283	N/A
Total+	**LG&E**	**Winter**	**103**	**147**	**8%**	**11%**		

* These values are at generation and include line losses.

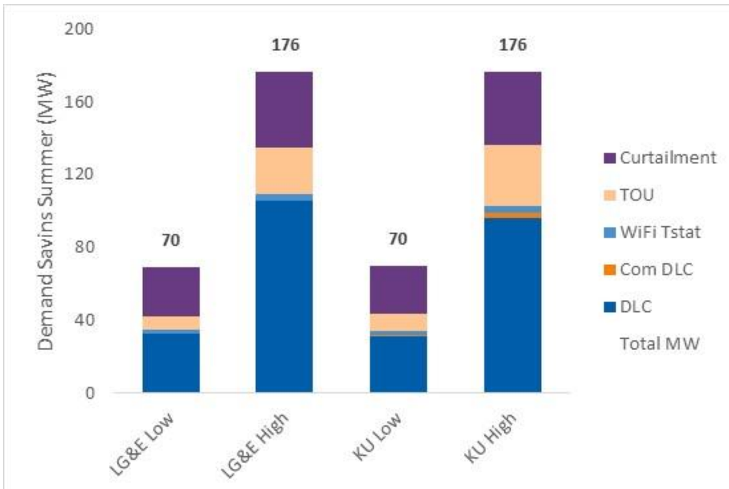
** This represents achievable load reduction divided by the market basis (peak load) for residential and commercial loads during the top 40 hours (10 four-hour events).

*** Cadmus discounted future values using a 6.5% rate, and escalated program and technology costs for future years using a 1.9% rate of inflation.

+ Totals exclude CPP as it is an alternative to the TOU program, and the savings are not additive.

The low scenarios are based on LG&E's and KU's existing programs. To determine the high scenarios, Cadmus considered program changes consistent with benchmarking similar programs at other utilities. As shown in Figure 9, the results indicate that each utility can achieve summer demand reductions equivalent to 176 MW under the high scenario, which results in a 6% summer peak load reduction for LG&E and a 5% summer peak load reduction for KU.

Figure 9. Demand Reduction Portfolio Results for Summer Peak



The low scenario aligns with LG&E- and KU-specific program data provided by the Company, impact and process evaluations, and DSM plan filings with the Public Service Commission.[6] For the high scenario program assumptions, Cadmus adjusted the low scenario to align with benchmarking for similar programs. The reduced percentage of system peak more than doubled under the KU high scenario (from 2% to 5%) and tripled under the LG&E high scenario (from 2% to 6%). Given the additional potential offered by the high scenario, Cadmus presents the following recommendations for the Company's existing demand reduction programs:

- ***Consider modifying the residential DLC program to Wi-Fi or advanced metering infrastructure (AMI) controlled thermostats.*** This shift would allow for increasing the control strategy from approximately 33% to between 40% and 50%, a typical percentage for cooling programs. Two-way communications can be used to identify nonresponsive devices (NRD), thus improving event participation beyond the existing 70%.
- ***Consider expanding the residential TOU program beyond the pilot size.*** Cadmus could not obtain the evaluated participation or results for the TOU program, and in 2018, AMI deployment plans are limited to 5,000 units for each territory. In our analysis, Cadmus assumed full AMI deployment by 2022 for both the high and low scenarios.
- ***Consider implementing a residential winter DLC pilot program***. This analysis indicated that there is significant potential for winter peak reduction in the low scenario, with a winter peak

6 Program-related data include program participation, event participation, device impacts, and program-related costs.

reduction of 6% for KU and 8% for LG&E. The Company could target Wi-Fi thermostat participants for the pilot, providing a more accurate estimate of demand impacts.

Organization of Report

This document presents methodologies and findings and includes the following four sections:

1. General Approach and Methodology, which provides an overview of the methodology Cadmus used to estimate technical, economic, and achievable potential.
2. Technical and Economic Potential, which presents the technical and economic potential available from energy efficiency resources.
3. Achievable Potential, which describes the basis for and results of estimating realistically achievable energy efficiency potential.
4. Demand Response, which summarizes the peak demand reduction potential from demand response strategies.

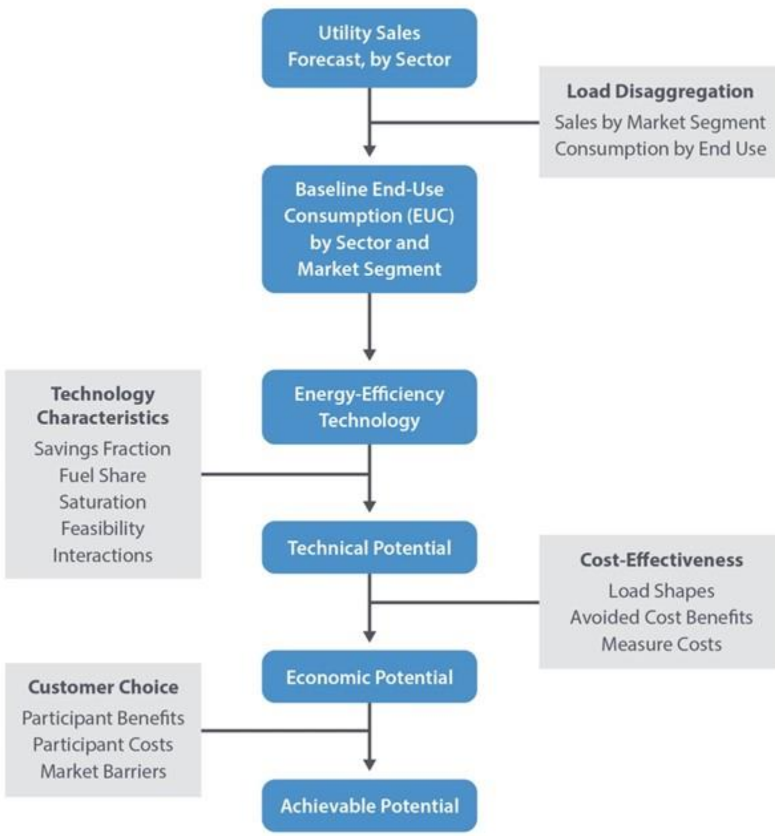
General Approach and Methodology

For this assessment, Cadmus relied on industry best practices, analytic rigor, and flexible and transparent tools to accurately estimate the potential for energy and capacity savings in the Company's service territory between 2019 and 2038. This section describes each step of our assessment process and summarizes the results.

General Approach

To estimate the technical, economic, and achievable energy efficiency potential, Cadmus drew upon standard industry practices. Figure 10 presents our general methodology and illustrates how we combined baseline and efficiency data to estimate savings for each type of potential.

Figure 10. General Methodology for Assessing Energy Efficiency Potentials



Cadmus calculated three types of potential: technical, economic, and achievable.

- ***Technical potential*** represents all technically feasible DSM measures being implemented, regardless of their costs or market barriers. For energy efficiency resources, there are three distinct classes of technical potential: retrofit opportunities in existing buildings, equipment replacements in existing buildings, and new construction. The first class, existing in current building stock, can be acquired at any point in the planning horizon, while end-use equipment turnover rates and new construction rates dictate the timing of the other two classes.
- ***Economic potential*** represents a subset of technical potential, consisting only of measures meeting the cost-effectiveness criteria based on the Company's avoided energy and capacity costs. For each energy efficiency measure, Cadmus structured the benefit/cost test as the ratio of the net present values (NPVs) of the measure's benefits and costs, and only deemed measures with a benefit/cost ratio of 1.0 or greater as cost-effective.
- ***Achievable potential*** represents the portion of economic potential that might be assumed as reasonably achievable in the course of the planning horizon, given market barriers that might impede customer participation in utility programs. Achievable potential can vary greatly based on program incentive structures, marketing efforts, energy costs, customer socio-economic characteristics, and other factors. In this study, Cadmus examined survey results to assess customers' willingness to adopt energy efficiency measures at three levels, based on the fraction of the measure's incremental cost covered by theoretical incentive levels: 0%, 50%, and 75%.

Although this study is meant to inform program design, we did not set program targets. Specifically, Cadmus did not estimate the fourth type of energy efficiency potential—program potential. Program potential reflects energy savings that a utility expects to achieve given certain spending levels and program design objectives. It requires a more detailed assessment of rebate levels, expenditures on marketing and administration, and the possible mixture of measures the Company can offer in its portfolio. Although study results are an excellent reference point for program development, they are based on some broad assumptions that may not apply to the Company's specific programs.

For example, estimates of achievable potential include all cost-effective energy efficiency measures and no measures that fail the TRC benefit/cost test. The Company may include measures that are not cost-effective in a portfolio as along as the portfolio-level TRC benefit/cost ratio exceeds 1.0. Because of this, the results from this study are a directional indicator of the energy efficiency potential available for the Company, and they identify areas and provide indicators of which energy efficiency measures have the most remaining energy efficiency potential savings, as well as areas that have limited remaining potential based on the current commercial available energy efficiency technologies.

Overview

To estimate energy efficiency potential, Cadmus conducted a sequential analysis of various energy efficiency measures in terms of technical feasibility (technical potential), cost-effectiveness (economic potential), and expected market acceptance, considering normal barriers that may impede measure implementation (achievable potential). The steps for this assessment were as follows:

1. ***Developing baseline forecast:*** Cadmus determined 20-year future energy consumption by fuel, sector, market segment, and end use. We calibrated the base year, 2016, to the Company's sector load forecasts. As previously described, baseline forecasts shown in this report include estimates of naturally occurring potential.
2. ***Estimating technical potential:*** Next, we estimated technical potential based on alternative forecasts that reflect technical impacts of specific energy efficiency measures.
3. ***Estimating economic potential:*** Then Cadmus estimated economic potential based on forecasts that reflect the technical impacts of cost-effective energy efficiency measures.
4. ***Estimating achievable potential:*** Last, we determined achievable potential, which we calculated by applying ramp rates and an achievability percentage to cost-effective measures (as detailed later in this section).

Developing Baseline Forecast

Collecting Baseline Data

Creating a baseline forecast required multiple data inputs to accurately characterize energy consumption in the Company's service area. These key inputs included:

- Sales and customer forecasts
- Major customer segments (e.g., residential dwelling types or commercial business types)
- End-use saturations
- Equipment saturations
- Fuel shares
- Efficiency shares (the percentage of equipment below, at, and above code)
- Annual end-use consumption estimates, by efficiency level

Data specific to the Company's service territory not only provided the basis for baseline calibration, but supported the estimation of technical potential. The Company also provided data on actual and forecasted sales and customers by sector. Table 15 identifies sources for key data.

Table 15. Baseline Forecast Data Sources

Input	Residential	Commercial
Customer and Load Forecasts	LG&E and KU actual	LG&E and KU actual
Percentage Sales or Customers by Building Type	LG&E and KU customer database, U.S. Census data	LG&E and KU customer database
End-Use Energy Consumption	Energy Information Administration (EIA's) 2012 Residential Energy Consumption Survey (RECS),* ENERGY STAR,** engineering calculations, building simulations	EIA's 2013 Commercial Buildings Energy Consumption Survey (CBECS),*** ENERGY STAR, engineering calculations, building simulations
Saturations and Fuel Shares	LG&E and KU saturation surveys, Cadmus' 2013 study, EIA's RECS, LG&E and KU energy efficiency program evaluations	LG&E and KU saturation surveys, Cadmus' 2013 study, EIA's CBECS, LG&E and KU energy efficiency program evaluations
Efficiency Shares	LG&E and KU saturation surveys, Cadmus' 2013 study, EIA's RECS, ENERGY STAR unit shipment reports[7]	LG&E and KU saturation surveys, Cadmus' 2013 study, EIA's CBECS, ENERGY STAR reports
Energy Efficiency Measures	Cadmus' 2013 study, LG&E and KU existing prescriptive programs and program evaluation data, regional technical reference manuals (TRMs),Cadmus' energy efficiency measure database, ENERGY STAR	Cadmus' 2013 study, LG&E and KU existing prescriptive programs and program evaluation data, regional TRMs, Cadmus' measure list, ENERGY STAR

* Energy Information Administration. "Residential Energy Consumption Survey." Available online: https://www.eia.gov/consumption/residential/

** ENERGY STAR Cost Savings Calculators. Available online: http://energy.gov/eere/femp/energy-and-cost-savings-calculators-energy-efficient-products

*** Energy Information Administration. "Commercial Buildings Energy Consumption Survey." Available online: https://www.eia.gov/consumption/commercial/

+ Regional TRMs may include sources such as the California Energy Commission Database for Energy Efficient Resources (http://www.deeresources.com/), Pennsylvania TRM (http://www.puc.state.pa.us/filing_resources/issues_laws_regulations/act_129_information/technical_reference_manual.aspx), or the Northeast TRM (http://www.neep.org/mid-atlantic-technical-reference-manual-v6)

Baseline Forecast of Sales and Customers

Cadmus ensured that the baseline end-use forecast was aligned with the Company's official forecasts. To accomplish this, we relied on the Company's residential and commercial customer forecasts to determine the number of homes and the amount of commercial floor space in each year of the study horizon. We also calibrated the final baseline energy forecasts to the Company's by adjusting the number of users per household in the residential sector and the use per square feet in the commercial

[7] EPA ENERGY STAR Unit Shipment Data. https://www.energystar.gov/index.cfm?c=partners.unit_shipment_data

sector. Also, we ensured that the rate classes included in each sector reflected the customers who pay into the Company's DSM programs, and therefore are eligible to participate. The Company provided data to allocate rate class level forecasts to nine different sectors. We excluded five of these sectors from this study—industrial, mine power, municipal pumping, street lighting, and wholesale municipal. The study's commercial sector includes large commercial, small commercial, and public authority customers. Table 16 shows the mapping of the Company's sector categories to the sectors used in this study.

Table 16. Sector Mapping

Company Sector Categories	2016 Study Sector
Industrial	-
Large Commercial	Commercial
Mine Power	-
Municipal Pumping	-
Public Authorities *	Commercial
Residential	Residential
Small Commercial	Commercial
Street Lights	-
Wholesale Municipal	-

* This sector excludes the Fort Knox and Louisville Water customers.

One key distinction between this study and the 2013 study is that the previous study did not include public authority customers, who account for the significant absolute increase in baseline sales and potential in the commercial sector. However, the inclusion of public authority customers did not increase the potential when expressed as a fraction of baseline sales.

End-Use Energy Consumption

The per-unit end-use energy consumption, sometimes referred to as unit energy consumption for a residential forecast and energy-use intensity for a commercial forecast, is a crucial input for end-use forecasts. Industry studies have derived this consumption using a variety of methods, including statistical methods (such as conditional demand modeling), physics-based building simulation models (such as the U.S. Department of Energy's EnergyPlus model), and simple algorithms (such as ENERGY STAR calculators). Specific sources for this study include:

- ***EIA 2012 RECS and 2013 CBECS:*** EIA's RECS and CBECS are national surveys of collected information about building characteristics and end-use saturations. In addition, EIA uses utility bills and end-use data to develop conditional demand models that produce estimates of end-use consumption for different climate zones. EIA's RECS and CBECS are generally reliable sources for end-use consumption because estimates are derived using robust statistical methods and actual use data.

- ***U.S. Environmental Protection Agency's (EPA) ENERGY STAR Calculators:*** EPA produces calculators that use simple engineering algorithms to estimate energy consumption for common non-weather-sensitive end uses such as refrigerators, clothes washers, and various home electronics. Because energy consumption for these end uses changes very little with climate, Cadmus only needed to make a few adjustments (if any) to these algorithms for this study.
- ***Engineering calculations:*** Cadmus produced additional use algorithms for non-weather-sensitive end uses without an ENERGY STAR calculator. We derived these algorithms from various regional TRMs, such as the Pennsylvania TRM, the Northeastern TRM, California's Database of Energy Efficiency Resources (DEER), or the Northwest Regional Technical Forum (RTF) workbooks.
- ***Cadmus building simulations, adjusted for Kentucky's climate:*** Cadmus maintains a library of end-use consumption estimates derived from various building simulation tools including eQUEST, EnergyPlus, REM/Rate, and the Simplified Energy Enthalpy Model. For weather-sensitive measures, we adjusted estimates to reflect Kentucky's climate.

Although the Company produces residential end-use forecasts, Cadmus relied on the sources listed above because the potential study requires higher resolution estimates. That is, while the Company's load forecast may provide use for a broad end use (such as a central air conditioner), the potential study requires details of the use for specific pieces of equipment (such as air conditioners of different efficiencies). Our calibration process aligned aggregated end-use consumption in Cadmus' models with end-use estimates in the Company's models.

Saturations and Fuel Shares

To produce a bottom-up end-use forecast, Cadmus first determined how many units of each end use are in a typical home. End-use saturations represent the average number of units in a home and fuel shares represent the proportion of those units that either use electricity versus natural gas. For instance, on average, a typical home has 0.9 clothes dryers (the saturation), and 85% of these units are electric (the fuel share).[8]

Cadmus relied on the following sources to estimate saturations and fuel shares:

- ***LG&E's and KU's most recent saturation surveys:*** LG&E and KU complete frequent residential end use surveys to inform load forecasts. Cadmus analyzed the Company's most recent surveys to produce fuel shares and saturations.
- ***Data from Cadmus' 2013 phone surveys and site visits at residences and businesses:*** For the 2013 study, Cadmus completed phone surveys with residential and commercial customers, as well as site assessments for commercial customers. We used these surveys to supplement

8 Saturations are less than 1.0 when some homes do not have the end use.

LG&E's and KU's existing saturation surveys with data that are difficult to collect over the phone (such as the cooling system type and size in commercial buildings).

- ***EIA's RECS/CBECS:*** The EIA RECS and CBECS include nearly comprehensive end-use data for residential and commercial buildings. While Cadmus prefers to use LG&E and KU-specific saturation surveys, EIA's RECS and CBECS can provide reliable regional estimates for end uses that cannot be characterized by the Company's saturation surveys.

Although many of these sources are roughly three years old, we did not need to adjust the saturations and fuel shares. While changes in end-use efficiency can occur over a short period of time (discussed in the next section), saturations and fuel shares stay relatively constant. Cadmus has reviewed multiple iterations of EIA's RECS and CBECS surveys, and found that saturations and fuel shares for the core end uses (such as for heating, cooling, water heating, various appliances, and plug load end uses) change little.

Efficiency Shares

Efficiency shares equal the current saturation of a specific type of equipment (of varying efficiency). Within an end use, these shares sum to 100%. For instance, the efficiency shares for a central air conditioning end use may be 50% SEER 13, 25% SEER 15, and 25% SEER 16. Sources for efficiency shares included:

- ***LG&E's and KU's most recent saturation surveys:*** Phone and mail surveys, such as LG&E's and KU's saturation survey, collect equipment age data that Cadmus used as a proxy for efficiency shares. Knowing the age of a unit of equipment, we were able to determine its minimum efficiency based on the federal government adopted equipment standards at that time.
- ***Data from Cadmus' 2013 phone surveys and site visits for residences and businesses:*** For our 2013 commercial site assessments, Cadmus collected efficiency information for major end uses (such as lighting, cooling, and water heating). In addition, in both our phone surveys and site assessments, we collected equipment age data, which we then used as a proxy for efficiency.
- ***EIA's RECS/CBECS:*** When Cadmus could not estimate efficiency shares using the two survey sources listed above, we filled in these gaps using EIA data.
- ***ENERGY STAR Unit Shipment Reports:*** The EPA has reported unit shipment data for all ENERGY STAR-rated equipment since 2003. These reports allowed Cadmus to estimate the current saturation of ENERGY STAR-rated equipment; these end uses include various appliances (such as refrigerators, freezers, and clothes washers) and home electronics (such as televisions, set top boxes, computers, and monitors).

Cadmus adjusted efficiency shares calculated from these sources to account for LG&E's and KU's energy efficiency program accomplishments, recent equipment standards, and the natural adoption of equipment more efficient than federal standards. Unlike saturations and fuel shares, efficiency shares can change significantly over a short period of time. For instance, the saturation of high-efficiency lighting (CFLs and LEDs) has increased significantly in many regions over the last three years, driven by low measure lives, declining equipment costs, and increasing federal standards. To account for these changes, Cadmus simulated the natural turnover of equipment for each end use over the last three years and estimated the new distribution of equipment after the installation of standard and above-standard units.

Preparing the Baseline Forecast

We derived the baseline forecast for each customer sector from the baseline data (described above) to obtain estimates of average consumption by market segment, construction vintage, and end use; then we summed this data to the sector level. Next, we calibrated the end-use and customer sector forecasts to the Company's official forecast to evaluate the accuracy of Cadmus' forecast and to ensure its consistency with the Company forecast. This approach offered the following key advantages:

- Cadmus derived savings estimates using a baseline calibrated to official sales forecasts, which required care to ensure that the underlying inputs and assumptions were reasonable and consistent with other known customer characteristics.
- We incorporated the effects of equipment standards and naturally occurring efficiency improvements resulting from usage reductions upon the retirements of lower-efficiency equipment and their replacement with higher-efficiency units. Ensuring that the baseline forecast accounted for these effects prevented potential estimates from being inflated by naturally occurring efficiency, thus double-counting the potential.
- We used the same assumptions underlying the baseline forecasts to develop the energy efficiency measure inputs, as well as estimates of technical potential, ensuring consistency.

Incorporating Impending Codes and Standards

The importance of accurately accounting for changes in codes and standards over the planning horizon cannot be overstated. Not only do these changes affect customers' energy consumption patterns and behaviors, but they determine which energy efficiency measures continue to produce savings over minimum requirements. In this study, Cadmus captured current efficiency requirements as well as those enacted, but not yet in effect.

For our analysis, Cadmus did not attempt to predict how energy codes and standards might change in the future; rather, we only factored in the enacted legislation, notably, the provisions of the 2007 Energy Independence and Security Act (EISA), known to take effect over the course of this analysis.

EISA includes a backstop provision, requiring still higher-efficiency technologies beginning in 2020. Capturing the effects of this legislation proved especially important, as residential lighting has had a large role in the Company's energy efficiency programs over the past several years.

Moreover, Cadmus explicitly accounted for several other pending federal codes and standards. For the residential sector, these include appliances, HVAC, and water heating standards. For the commercial sector, these include appliances, motors, water heating, HVAC, and lighting standards. Table 17 provides a comprehensive list of the standards we considered in this study.

Table 17. Federal Equipment Standards

Equipment Type	Existing (Baseline) Standard	New Standard	Date Effective*
Appliances			
Clothes washer (top loading)	Federal standard 2007	Federal standard 2015	March 7, 2015
Clothes washer (front loading)	Federal standard 2007	Federal standard 2018	January 1, 2018
Commercial refrigeration equipment (semi-vertical and vertical cases)	Federal standard 2012	Federal standard 2017	March 27, 2017
Dishwasher	Federal standard 2010	Federal standard 2013	May 30, 2013
Dryer	Federal standard 2011	Federal standard 2015	January 1, 2015
Freezer	Federal standard 2001	Federal standard 2014	September 15, 2014
Refrigerator	Federal standard 2001	Federal standard 2014	September 15, 2014
HVAC			
Central air conditioner	Federal standard 2006	Federal standard 2015 (no change for northern region)	July 1, 2016
Heat pump (air source)	Federal standard 2006	Federal standard 2015	January 1, 2015
Residential furnace fans	Existing conditions (no federal standard)	Federal standard 2019	July 3, 2019
Room air conditioners	Federal standard 2000	Federal standard 2014	June 1, 2014
Lighting			
Lighting general service lamp (EISA)	Existing conditions (no federal standard before EISA)	Federal standard 2014 (phased in over three years)	January 1, 2014
Lighting general service lamp (EISA backstop provision)	Existing conditions (no federal standard before EISA)	Federal standard 2020	January 1, 2020
Fluorescent linear lamps	Federal standard 2012	Federal standard 2018	January 26, 2018
Metal halide lamp fixtures	Federal standard 2009	Federal standard 2017	February 10, 2017
Motors			
Small electric motors	Federal standard 1987	Federal standard 2015	March 9, 2015
Water Heaters			
Water heater > 55 gallons	Federal standard 2004	Federal standard 2015	April 16, 2015
Water heater ≤ 55 gallons	Federal Standard 2004	Federal Standard 2015	April 16, 2015

* For the potential assessments, Cadmus assumed that standards taking effect mid-year will begin on January 1 of the following year.

To ensure accurate assessment of the remaining potential, Cadmus accounted for the effects of future standards. Drawing on a strict interpretation of the legislation, Cadmus assumed that affected equipment would be replaced with more efficient alternatives that meet the minimum federal standards (in other words, we assumed complete compliance with the standards).

Accounting for Naturally Occurring Efficiency

Cadmus' baseline forecast included naturally occurring efficiency—that is, reductions in energy use likely to occur from normal market forces (such as technological changes, energy price changes, market transformation efforts, and higher energy codes and standards). We accounted for naturally occurring efficiency in four ways:

1. For the potential associated with certain energy efficiency measures, we assumed a natural adoption rate, net of current saturation. For example, to determine total potential savings associated with ENERGY STAR appliances, we accounted for current adoption trends.
2. Cadmus accounted for gradual efficiency increases due to retiring older equipment in existing buildings, followed by replacement with units meeting or exceeding minimum standards at the time of replacement.
3. We accounted for pending improvements to equipment efficiency standards taking effect during the planning horizon (as discussed). We did not, however, forecast changes to standards not yet adopted.
4. Our estimates of energy consumption in new construction reflect the 2012 International Energy Conservation Code (IECC).[9] For this study, we assumed that all energy efficiency measures would meet or exceed the 2012 IECC, and, where applicable, we calculated energy savings using 2012 IECC as a baseline. For example, current building code requires R-38 ceiling insulation, so we calculated energy savings for all ceiling insulation measures in new construction with R-38 as the baseline. Consequently, we did not attribute savings to ceiling insulation levels below R-38 in new construction. (Note that building codes have the smallest impact of these four classes of naturally occurring efficiency, given that they only apply to new construction.)

Compiling Energy Efficiency Technology Data

Cadmus created a comprehensive list of electric and natural gas energy efficiency measures applicable to the Company's service territory. We included the following measures from our database:

- Measures included in Cadmus' 2013 study of DSM potential assessment
- All measures currently included in the Company's prescriptive programs
- Efficiency tiers from the Consortium for Energy Efficiency and ENERGY STAR
- Measures from Cadmus' extensive database that includes measures in regional or national databases (e.g., DEER) and TRMs
- Selected emerging technologies and particular technologies identified by the Company as relevant to the study.

The emerging technologies in this study included behavioral measures, CO_2 heat pump water heaters, and commercial active chilled beam cooling systems. We focused on emerging technologies approaching commercialization or those that may become cost-effective within the next five years.

[9] https://law.resource.org/pub/us/code/ibr/icc.iecc.2012.pdf

After creating a list of electric energy efficiency measures applicable to the Company's service territory, Cadmus classified measures into two categories:

1. High-efficiency equipment measures, which directly affect end-use equipment (e.g., high-efficiency central air conditioners), and follow normal replacement patterns, based on expected lifetimes.
2. Non-equipment measures, which affect end-use consumption without replacing end-use equipment (e.g., insulation). Such measures, which do not include timing constraints from equipment turnover (except for new construction), are considered discretionary, as savings can be acquired at any point over the planning horizon.

For this study, Cadmus assumed that all high-efficiency equipment measures are installed at the end of the existing equipment's remaining useful life. We did not assess energy efficiency potential for early replacement, because most measures will naturally be replaced within the study horizon, and long-run technical potential from early replacement measures will equal savings from replace-on-burnout measures. However, incremental costs for early replacement measures are much higher than for replace-on-burnout measures because they reflect the full measure cost, not incremental costs. The economic potential, therefore, depends on the allocation of early replacement and replace-on-burnout measures. Including these early replacement measures would contribute to estimates of technical and economic potential that are inconsistent with their definitions.[10]

Early replacement, however, can be considered in estimates of program potential. Short-run savings from early replacement measures may exceed savings from replace-on-burnout iterations because early replacement savings are calculated using a below-standard baseline. Because this study did not include an estimate of program potential, Cadmus excluded early replacement measures from the analysis.

The following are relevant inputs for equipment and non-equipment measures:

- Energy savings—average annual savings attributable to installing the measure, in absolute and/or percentage terms
- Equipment cost—full or incremental, depending on the nature of the measure and the application
- Labor cost—the expense of installing the measure
- Measure life—the expected life of measure equipment

[10] Cadmus did consider refrigerator, freezer, and room air conditioner recycling to estimate savings associated with the removal of below-standard secondary units. These measures, however, are not considered early replacement because they are not based on the secondary unit being replaced with an efficient unit.

The following are relevant inputs for non-equipment measures only:

- Technical feasibility—the percentage of buildings where customers can install this measure, accounting for physical constraints
- Percentage incomplete—the percentage of buildings where customers have not installed the measure, but where it could technically feasible be installed
- Measure competition—for mutually exclusive measures, the percentage of each measure likely installed (to avoid double-counting savings)
- Measure interaction—the end-use interactions between measures (e.g., a decrease in lighting power density causing heating loads to increase)

As shown in Table 18, Cadmus used a number of sources to characterize savings, costs, and measure lifetimes.

Table 18. Measure Characterization Data Sources

Input	Residential	Commercial
Energy savings	Cadmus' 2013 potential study and the Company's 2013 program evaluation, ENERGY STAR, other statewide TRMs, U.S. Department of Energy (DOE) Energy Efficiency and Renewable Energy (EERE) technical documents, RTF, Cadmus research	LG&E and KU 2013 potential study and 2013 program evaluation, CBECS 2013 microdata, ENERGY STAR, DEER*, other statewide TRMs, DOE/EERE, RTF, Cadmus research
Equipment and labor costs	National Residential Efficiency Measures Database,*** RSMeans,+ ENERGY STAR, DOE/EERE, DEER*, incremental cost studies, online retailers, Cadmus research	RSMeans, ENERGY STAR, DOE/EERE, DEER*, RTF, regional TRMs, incremental cost studies, online retailers, Cadmus research
Measure life	ENERGY STAR, DEER*, Cadmus research	ENERGY STAR, DEER*, Cadmus research
Technical feasibility	Cadmus research	Cadmus research
Percentage incomplete	Primary data collection phone surveys, LG&E and KU program accomplishments, EIA RECS, Cadmus research	Primary data collection phone surveys, LG&E and KU program accomplishments, Cadmus research

** U.S. Department of Energy Office of Energy Efficiency and Renewable Technology. http://energy.gov/eere/office-energy-efficiency-renewable-energy

* California Energy Commission. "Database for Energy Efficient Resources." Available online: http://www.deeresources.com/

*** National Renewable Energy Laboratory. "National Residential Efficiency Measures Database." Available online: http://www.nrel.gov/ap/retrofits/

+ RSMeans. "Cost Data." Available online: https://www.rsmeans.com/products/books/2016-cost-data-books.aspx

Energy Savings and Measure Interactions

For each energy efficiency measure, Cadmus estimates energy savings both as savings per unit (kWh or MCF) and savings as a percentage of end-use consumption. For these estimates, we accounted for the interaction of savings and use across end uses (e.g., cooling load will decrease when efficient lighting is installed because of the reduction of waste heat). We relied on a number of sources to develop savings estimates, including:

- ***The 2013 LG&E and KU residential and commercial energy efficiency potential study:*** Cadmus characterized measure savings for the 2013 potential study; most of these estimates are still valid because we developed them using standard protocols for estimating energy savings.
- ***LG&E's and KU's most recent program evaluations and program data:*** Program evaluations can inform estimates of energy savings. Many program evaluations either use engineering algorithms (such as those found in TRMs), billing analyses, or building simulations to estimate savings for energy efficiency measures. Evaluations of LG&E's and KU's existing programs are an excellent source of savings because they reflect actual measures installed in the Company's customers' homes and businesses.
- ***Other utility program evaluations:*** Cadmus benchmarked estimates against other utilities' program evaluations. We also referred to these when characterizing measures that LG&E and KU do not offer through existing prescriptive programs.
- ***The DOE Uniform Methods Project or other standard evaluation protocols:*** DOE's Uniform Methods Project defines standard calculations to estimate energy savings for a number of measures. Cadmus' savings calculations are consistent with such industry standards.
- ***ENERGY STAR calculators:*** EPA's ENERGY STAR calculators provide estimates of per-unit savings for a number of measures, including efficient appliances (refrigerators, freezers, clothes washers, etc.) and efficient home electronics (televisions, computers, monitors, etc.).
- ***Regional TRMs**:* TRMs from other states and regions such as Pennsylvania, California (DEER), and the Northwest provide formulas to estimate per-unit energy savings. When Cadmus used a regional TRM, we ensured that the calculations incorporated Kentucky-specific inputs.

Equipment, Labor, and Annual Operation and Maintenance Costs

Cadmus estimated the equipment, labor, and annual operation and maintenance O&M costs for each energy efficiency measure. We used these costs to calculate benefit/cost ratios and estimate potential program expenditures. Costs can change significantly over a short period of time; therefore, Cadmus reviewed each measure and determined whether the costs used in Cadmus' 2013 potential study are still relevant. In addition to data from the 2013 potential study, other cost data sources included:

- ***LG&E's and KU's most recent program evaluations and program data:*** Where available, Cadmus incorporated the Company's program data to produce cost estimates.
- ***National Renewable Energy Laboratory (NREL) National Residential Efficiency Measures Database:*** NREL maintains a detailed, up-to-date data set of measure costs for a number of energy efficiency measures.

- ***RSMeans:*** RSMeans provides construction cost data, including costs for a number of home retrofits (such as weatherization, windows, and other various shell upgrades). We used data from 2016 RSMeans, which is the most recent version.
- ***ENERGY STAR:*** EPA provides current equipment costs for a number of ENERGY STAR-rated units.
- ***DOE EERE technical support documents:*** The DOE EERE includes estimates of equipment and labor costs in their technical support documents for a number of different types of energy-efficient equipment
- ***Regional TRMs and incremental cost studies:*** TRMs often require incremental cost studies, which typically show both baseline and efficiency measure costs (labor, equipment, and O&M). States frequently update these studies to incorporate the most recent cost data. These studies include the measures most commonly offered through utility-sponsored energy efficiency programs.
- ***Online retailers:*** Cadmus staff continuously review the prices listed on manufacturer or retailer websites. While online retailers may not provide estimates of installation (labor) or annual O&M costs, they do provide reliable equipment costs.

Measure Life

Cadmus uses estimates of each measure's effective useful life (EUL) to calculate the lifetime NPV benefits and costs for each energy efficiency measure. Many of the data sources for measure savings and costs (described above) also provide estimates for measure lifetimes. We updated measure lives from Cadmus' 2013 potential assessment using the following sources:

- LG&E's and KU's most recent program evaluations and program data
- NREL National Residential Efficiency Measures Database
- EUL studies, which included the Northeast Energy Efficiency Partnership's 2007 EUL study[11] or EULs derived by the Association of Home Appliance Manufacturers
- ENERGY STAR
- DOE EERE technical support documents
- Regional TRMs

Technical Feasibility

Technical feasibility factors represent the percentage of homes or buildings where an energy efficiency measure could feasibly be installed. Technical limitations include equipment capability or space limitations. For example, solar water heaters cannot be feasibly installed in all buildings because some

[11] Northeast Energy Efficiency Partnership. "Load Shape Research and Data." Available online: http://www.neep.org/initiatives/emv-forum/forum-products#Loadshape Research and Data Catalog/

buildings do not have the required roof orientation and pitch. Cadmus updated technical feasibility factors from the 2013 assessment using the following sources:

- ***Stock assessments and surveys such as EIA's RECS and CBECS:*** These assessments include building characteristics that can inform estimates of technical feasibility. For instance, some floor insulation measures require a basement or a crawlspace, and Cadmus used EIA's RECS to determine the proportion of homes that have a basement or crawlspace and can, therefore, feasibly have this measure installed.
- ***Utility energy efficiency program evaluations:*** Some utility energy efficiency program evaluations include research to identify technical barriers to installing energy efficiency measures.
- ***Northwest Power Planning and Conservation Council Power Plans and other potential studies:*** Regional potential studies, such as the Northwest Power Planning and Conservation Council's Sixth and Seventh Power Plans, provide estimates of the technical feasibility for common energy efficiency measures.[12]
- ***Third-party research including the Federal Energy Management Program, DOE, or Toolbase.org:*** Various third-party measure characterization reports identify the technical limitations for energy efficiency measures. Cadmus used these assessments to estimate the proportion of homes or businesses where each measure can feasibly be installed.

Percentage Incomplete

Percentage incomplete factors represent the percentage of remaining homes or businesses that have yet to install an energy efficiency measure. This is equivalent to 100% minus the current saturation of the energy efficiency measure. Similar to efficiency shares, Cadmus updated percentage incomplete factors to account for LG&E's and KU's program accomplishments, building energy codes and standards, and the natural adoption of efficiency measures. Cadmus relied on the following sources to update these factors:

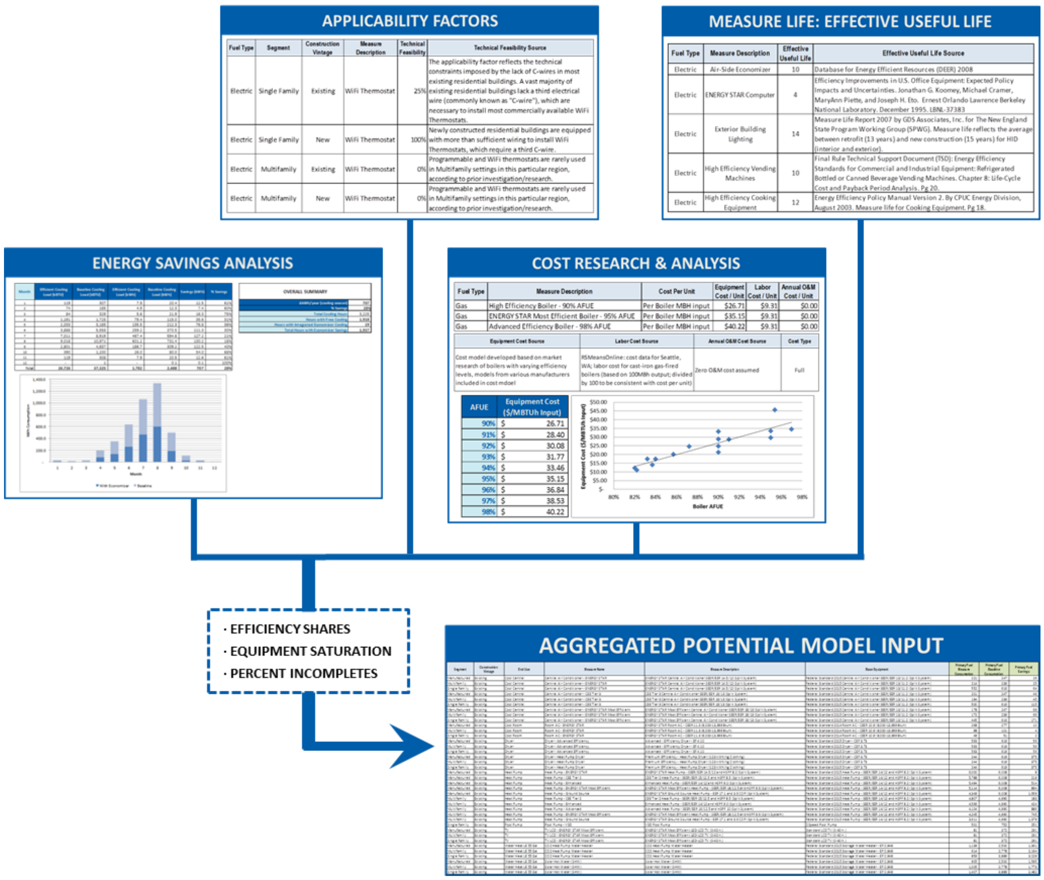
- LG&E's and KU's most recent program evaluations and program data
- Recent stock assessments and surveys such as EIA's RECS and CBECS
- ENERGY STAR reports
- DOE EERE technical support documents

Populating the Measure Databases

Cadmus characterized the underlying measure assumptions and analysis in Excel workbooks (by measure), with examples shown in Figure 11. These measure workbooks contain detailed saving calculations, cost research, EUL data, applicability factor values, and measure assumptions, as well as well-documented source descriptions. We aggregated all measure data into a final master input file for the potential model.

[12] Northwest Power and Conservation Council

Figure 11. Example of Measure Workbooks



Estimating Technical Potential

After Cadmus populated the measure database, we used the measure-level inputs to estimate technical potential over the planning horizon. We began this process by estimating savings from all measures included in the analysis, then aggregating the results to the end use, market segment, and sector levels.

For this approach, we began by characterizing individual measure savings, first in terms of the percentage of end-use consumption. For each non-equipment measure, we estimated absolute savings using the following basic relationship:

$$SAVE_{ijm} = EUI_{ije} * PCTSAV_{ijem} * APP_{ijem}$$

Where:

$SAVE_{ijm}$	=	Annual energy savings for measure *m* for end use *j* in customer segment *i*
EUI_{ije}	=	Calibrated annual end-use energy consumption for equipment *e* for end use *j* and customer segment *i*
$PCTSAV_{ijem}$	=	The percentage savings of measure *m,* relative to the base usage for the equipment configuration *ije*, accounting for interactions among measures, such as by calibrating lighting and HVAC to annual end-use energy consumption
APP_{ijem}	=	Measure applicability: a fraction representing a combination of the technical feasibility, existing measure saturation, end-use interaction, and any adjustments to account for competing measures

For example, for wall insulation saving 10% of space heating consumption, the final percentage of the end use saved would be 5%, assuming an overall applicability of 50%. This value represents the percentage of baseline consumption the measure saved in an average home.

To capture all applicable measures, Cadmus examined many instances where multiple measures affected a single end use. To avoid overestimating total savings in assessing cumulative impacts, we accounted for interactions among the various measures—a treatment known as measure stacking. The primary method to account for stacking effects is to establish a rolling, reduced baseline, then apply it sequentially to assessments of measures in the stack. The equations below illustrate this technique, applying measures 1, 2, and 3 to the same end use:

$$SAVE_{ij1} = EUI_{ije} * PCTSAV_{ije1} * APP_{ije1}$$

$$SAVE_{ij2} = (EUI_{ije} - SAVE_{ij1}) * PCTSAV_{ije2} * APP_{ije2}$$

$$SAVE_{ij3} = (EUI_{ije} - SAVE_{ij1} - SAVE_{ij2}) * PCTSAV_{ije3} * APP_{ije3}$$

After iterating all measures in a bundle, the final percentage of the reduced end-use consumption provided the sum of the individual measures' stacked savings, which we then divided by the original baseline consumption.

Estimating Economic Potential

Cadmus based our methodology for estimating economic potential on the methods described in the California Standard Practice Manual,[13] which establishes the procedures for economic evaluation from the perspectives of participants, the utility (or program administrator), total resource costs, society, and all ratepayers. Consistent with standard industry practice for the analysis of economic potential, Cadmus relied on the TRC test as the criterion for screening energy efficiency measures for cost-effectiveness.

[13] California Public Utilities Commission. "California Standard Practice Manual for Economic Analysis of Demand-Side Programs and Projects." 2002.

For each measure, we applied TRC by first calculating the measure benefits, as measured by the avoided long-run energy and capacity costs and avoided line losses, and comparing the result to the measure's costs. For equipment measures, we calculated costs based on the measure's incremental costs (compared with the cost of baseline technology). For retrofit measures, measure costs included the total installed cost of the measure. For this study, Cadmus considered a measure to be cost-effective if the NPV of its benefits exceeded the NPV of its costs as measured according to the TRC test, that is:

$$\frac{\text{TRC Benefits}}{\text{TRC Costs}} \geq 1$$

Where:

$$\text{TRC Benefits} = NPV\left(\sum_{year=1}^{measurelife}\left(\sum_{i}^{i=8760}(impact_i \times avoided\cos t_i)\right)\right)$$

$$\text{TRC Costs} = \text{NPV (incremental or total installed measure cost)}$$

Economic potential represents the savings from the subset of measures that passed the cost-effectiveness criterion according to the TRC test.

To calculate each measure's TRC test benefits, Cadmus used the following data:

- ***End-use load shapes***, or consumption patterns by costing period, applied to electric and natural gas measures, and capturing the time-differentiated value of energy savings to determine the amount of savings during peak periods.
- ***Line losses*** representing energy lost between the generator and the customer meter. Thus, energy and capacity savings at the customer meter are gross, capturing the true value of savings. Cadmus used electric line loss of 5.8% for LG&E, 6.2% for KU, and a natural gas line loss of 1.93%, as provided by the Company.
- ***Discount rate*** of 6.51% for both utilities.
- ***Utility avoided energy costs***, which are the Company's projections of time and seasonally differentiated electric energy and natural gas commodity costs.
- ***Utility avoided capacity costs***, or the Company's projections of the cost of supplying power during peak periods, estimated by the Company as $0 per kW per year for the base scenario, and additional scenarios with avoided capacity costs of $33, $68, and $100 per kW per year.

The line loss factor, discount rate, avoided energy costs, and avoided capacity costs were provided to Cadmus by the Company.

Based on the results from the cost-effectiveness analysis, and using the same method described in the Estimating Technical Potential section above, Cadmus developed a supply curve consisting of measures that passed the cost-effectiveness criterion from the TRC perspective.

Why Economic Potential Can Exceed Technical Potential for Individual Measures

Economic potential can exceed technical potential when a second measure that interacts with a given measure fails the benefit/cost screen. For instance, suppose a homeowner installs an efficient air conditioner that reduces their baseline cooling consumption from 1,000 kWh to 900 kWh. Then the homeowner installs a weatherization measure that saves 10% of the baseline cooling consumption. The technical potential for this weatherization measure would equal 90 kWh (900 x 10%). Now suppose the efficient air conditioner measure is not cost-effective—the homeowner's baseline consumption will remain at 1,000 kWh. If the weatherization measure is cost-effective, the 10% savings will yield economic potential equal to 100 kWh (1,000 x 10%). In this case, economic potential for the weatherization measure will exceed the technical potential.

Technical and Economic Potential

Scope of Analysis

Cadmus separately assessed technical potential and economic potential for electricity and natural gas in the residential and commercial sectors. Within each utility's sector-level assessment, we further distinguished among market segments or business types, vintage, and applicable end uses, as follows:

- Six residential segments (existing and new construction for single family, multifamily, and manufactured)[14]
- Twenty-two commercial segments (11 building types within existing and new construction)

Cadmus began the analysis by assessing the technical potential for 364 unique electric and 198 unique natural gas energy efficiency measures (shown in Table 19), representing a comprehensive set of electric and natural gas energy efficiency measures applicable to local climate and customer characteristics.

Table 19. Energy Efficiency Measure Counts

Sector	Unique Measures	Permutations by Utility, Market Segment, and Vintage
Electric		
Residential	141	2,248
Commercial	223	9,714
Natural Gas		
Residential	103	521
Commercial	95	2,102

Summary of Results

Electric Energy Efficiency Potential

Study results indicate 7,072 GWh of technically feasible electric energy efficiency potential by 2038, the end of the 20-year planning horizon, with approximately 1,988 GWh of these resources proving cost-effective (as shown in Table 20). The identified economic potential amounts to 9% of forecast load in 2038.

Cadmus estimated savings using forecasts of future consumption, absent utility program activities. While consumption forecasts account for the past savings each utility has acquired, we estimated potential inclusive of—not in addition to—current or forecasted program savings.

[14] Cadmus did not model manufactured homes for LG&E's service territory due to the small number of manufactured homes in Louisville. We did include manufactured homes in KU's service territory.

Table 20. Technical and Economic Electric Energy Efficiency Potential by Utility – Energy (GWh)

Sector	Baseline Sales 2038	Cumulative 2038		Percentage of Baseline		Economic as a Percentage of Technical
		Technical	Economic	Technical	Economic	
LGE						
Residential	5,012	1,752	472	35%	9%	27%
Commercial	4,627	1,237	359	27%	8%	29%
Subtotal	**9,639**	**2,989**	**831**	**31%**	**9%**	**28%**
KU						
Residential	6,440	2,390	621	37%	10%	26%
Commercial	5,573	1,693	536	30%	10%	32%
Subtotal	**12,013**	**4,083**	**1,157**	**34%**	**10%**	**28%**
Total						
Residential	11,453	4,143	1,093	36%	10%	26%
Commercial	10,200	2,930	895	29%	9%	31%
Total	**21,652**	**7,072**	**1,988**	**33%**	**9%**	**28%**

Table 21 shows technical and economic demand reduction for each utility and sector. Overall, technical potential is 2,069 MW of demand reduction by 2038, and economic potential is 303 MW. This is equivalent to 35% and 5% of baseline peak demand, respectively. Cadmus calculated demand reduction using the Company's 8760 end-use load shapes. We identified the Company's summer coincident peak hour and multiplied annual energy savings by the peak hour coincidence factor to determine demand reduction for each measure.

Table 21. Technical and Economic Electric Energy Efficiency Potential by Utility – Demand (MW)

Sector	Baseline Sales 2038	Cumulative 2038		Percentage of Baseline		Economic as a Percentage of Technical
		Technical	Economic	Technical	Economic	
LGE						
Residential	1,695	672	47	40%	3%	7%
Commercial	944	246	69	26%	7%	28%
Subtotal	**2,639**	**917**	**116**	**35%**	**4%**	**13%**
KU						
Residential	2,148	823	91	38%	4%	11%
Commercial	1,125	329	97	29%	9%	29%
Subtotal	**3,273**	**1,152**	**187**	**35%**	**6%**	**16%**
Total						
Residential	3,843	1,495	138	39%	4%	9%
Commercial	2,069	574	166	28%	8%	29%
Total	**5,912**	**2,069**	**303**	**35%**	**5%**	**15%**

Natural Gas Energy Efficiency Potential

Table 22 presents 2038 forecasted baseline sales and potential by sector. The study results indicate over 11.7 million MCF of technically feasible, natural gas energy efficiency potential by 2038. The identified economic potential of 4.0 million MCF amounts to 15% of forecast load in 2038.

Table 22. Technical and Economic Natural Gas Energy Efficiency Potential (MCF)

Sector	Baseline Sales	Cumulative 2038		Percentage of Baseline		Economic as a Percentage of Technical
		Technical	Economic	Technical	Economic	
Residential	17,872,105	8,794,324	3,082,896	49%	17%	35%
Commercial	8,775,436	2,974,937	937,691	34%	11%	32%
Subtotal	26,647,541	11,769,261	4,020,586	44%	15%	34%

The residential sector accounts for 75% of the total technical potential and 77% of the total economic potential. The commercial sector accounts for the remaining 25% and 23% of technical and economic potential, respectively.

Detailed Energy Efficiency Potentials

Electric Energy Efficiency

Residential Sector

The study results indicate that residential customers account for about 58% of forecasted electricity retail sales. The single family, manufactured, and multifamily potential savings measures included:

- Equipment efficiency upgrades (e.g., air conditioning, refrigerators)
- Improvements to building shells (e.g., insulation, windows, air sealing)
- Increases in lighting efficiency (e.g., CFLs, LED interior lighting)
- Behavioral measures, such as energy feedback

Table 23 is based on resources included in this assessment, showing the estimated residential sector electric economic potential of 1,093 GWh over 20 years, corresponding to a cumulative 10% reduction (9% for LG&E and 10% for KU) in 2038 residential usage.

Table 23. Residential Electric Energy Efficiency Potential by Utility – Energy (GWh)

Segment	Baseline Sales	Cumulative 2038		Percentage of Baseline	
		Technical	Economic	Technical	Economic
LG&E					
Single Family	4,231	1,505	414	36%	10%
Multifamily	782	248	57	32%	7%
Subtotal	**5,012**	**1,752**	**472**	**35%**	**9%**
KU					
Single Family	5,299	2,002	527	38%	10%
Multifamily	492	152	36	31%	7%
Manufactured	650	236	58	36%	9%
Subtotal	**6,440**	**2,390**	**621**	**37%**	**10%**
Total					
Single Family	9,530	3,506	942	37%	10%
Multifamily	1,273	400	93	31%	7%
Manufactured	650	236	58	36%	9%
Total	**11,453**	**4,143**	**1,093**	**36%**	**10%**

Table 24 shows residential sector technical and economic demand reduction potential for each segment. Economic potential is 138 MW by 2038, which is equivalent to 4% of baseline residential peak demand.

Table 24. Residential Electric Energy Efficiency Potential by Utility – Demand (MW)

Segment	Baseline Sales	Cumulative 2036		Percentage of Baseline	
		Technical	Economic	Technical	Economic
LG&E					
Single Family	1,511	606	42	40%	3%
Multifamily	184	65	5	36%	3%
Subtotal	**1,695**	**672**	**47**	**40%**	**3%**
KU					
Single Family	1,878	727	81	39%	4%
Multifamily	119	40	3	33%	3%
Manufactured	152	56	6	37%	4%
Subtotal	**2,148**	**823**	**91**	**38%**	**4%**
Total					
Single Family	3,389	1,334	122	39%	4%
Multifamily	303	105	9	35%	3%
Manufactured	152	56	6	37%	4%
Total	**3,843**	**1,495**	**138**	**39%**	**4%**

The single family segment accounts for 86% (Figure 12) of total residential sector potential energy savings (economic) and 89% of demand reduction (Figure 13).

Figure 12. Residential Sector Electric Economic Potential by Segment – Energy (GWh)

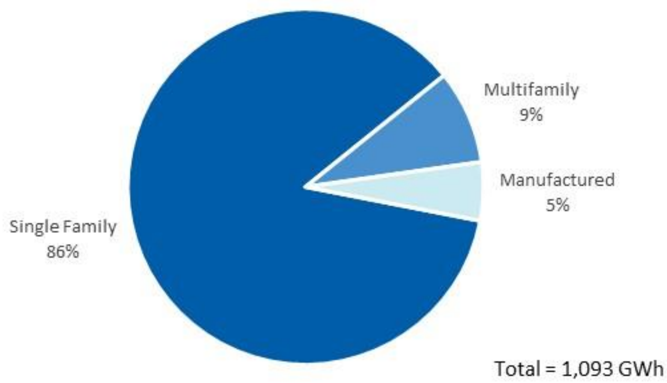


Figure 13. Residential Sector Electric Economic Potential by Segment – Demand (MW)

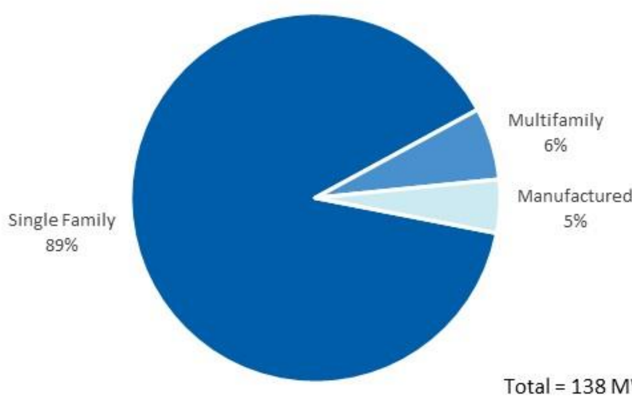


Figure 14 and Figure 15 show the distribution of residential sector economic potential (energy and demand, respectively) by end use group. Water heating measures account for 27% of total residential sector energy savings, but only 14% of demand reduction. Lighting accounts for 30% of energy savings and 10% of demand reduction. Cooling and heat pump measures produce the highest potential demand reduction (25% and 32% of total, respectively), but a smaller portion of energy savings (15% and 5% of total, respectively).

Figure 14. Residential Sector Electric Economic Potential by Measure Type – Energy (GWh)

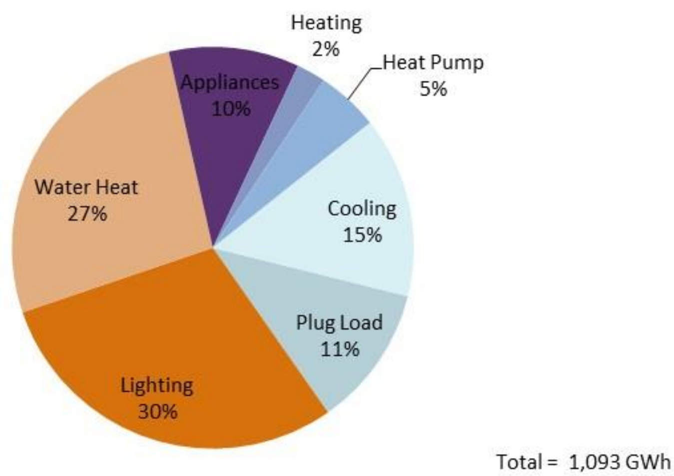


Figure 15. Residential Sector Electric Economic Potential by Measure Type – Demand (MW)

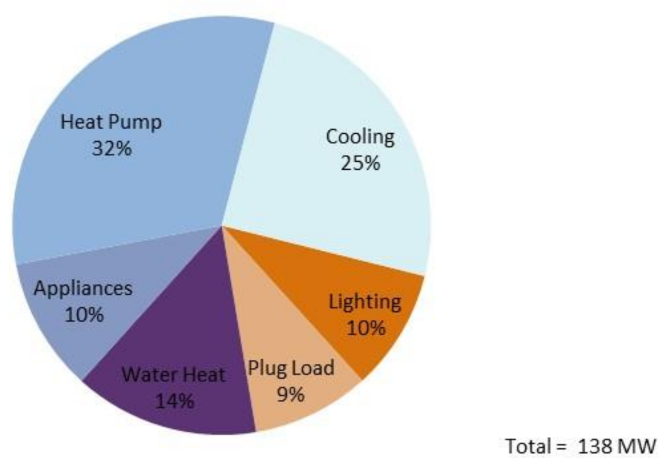


Table 25 and Table 26 show residential sector technical and economic potential by end use group for energy and demand, respectively.

Table 25. Residential Sector Electric Energy Efficiency Potential by End-Use Category – Energy (GWh)

End Use Group	Baseline Sales	Cumulative 2038		Percentage of Baseline	
		Technical	Economic	Technical	Economic
Plug Load	2,227	264	125	12%	6%
Cooking	155	9	0	6%	0%
Cooling	2,304	1,055	159	46%	7%
Appliances	1,361	652	115	48%	8%
Heating	1,578	662	26	42%	2%
Heat Pump	1,818	707	55	39%	3%
Lighting	890	281	323	32%	36%
Ventilation and Circulation	0.3	0.03	0.00	10%	0%
Water Heat	1,119	513	292	46%	26%
Total	**11,453**	**4,143**	**1,093**	**36%**	**10%**

Table 26. Residential Sector Electric Energy Efficiency Potential by End-Use Category – Demand (MW)

End Use Group	Baseline Sales	Cumulative 2038		Percentage of Baseline	
		Technical	Economic	Technical	Economic
Plug Load	228	27	13	12%	5%
Cooking	15	1	0	6%	0%
Cooling	1,853	769	34	42%	2%
Appliances	172	83	14	48%	8%
Heating	0.052	0.018	0.000	34%	0%
Heat Pump	1,463	569	44	39%	3%
Lighting	36	11	13	32%	36%
Ventilation and Circulation	< 1	< 1	0	10%	0%
Water Heat	76	35	20	46%	26%
Total	**3,843**	**1,495**	**138**	**39%**	**4%**

Table 27 shows the top saving measures, sorted by technical potential. Enhanced central air conditioners (SEER 20), above code wall insulation (R-13), ultrasonic dryers, and tier 2 windows (with a U-Value = 0.25) have high technical potential, but none of these measures are cost-effective.

Table 27. Top Saving Residential Measures – Sorted by Technical Potential

Measure Name	2038 (MWh)		Percentage of Total	
	Technical	Economic	Technical	Economic
Central Air Conditioner - Enhanced	449,820	0	11%	0%
Dryer - Ultrasonic Dryer	363,158	0	9%	0%
Wall Insulation (KY) - Maximum Feasible	313,985	0	8%	0%
Window (KY) - Tier 2 Above Code	272,680	0	7%	0%
Heat Pump - Air-Source Enhanced	181,175	0	4%	0%
Lighting General Service Lamp - Premium Efficiency LED	168,613	258,320	4%	24%
Home Energy Reports	130,825	153,959	3%	14%
Refrigerator - CEE Tier 3	122,188	0	3%	0%
CO2 Heat Pump Water Heater	108,426	0	3%	0%
Low-Flow Showerhead	108,039	177,708	3%	16%

Table 28 shows the highest-saving cost-effective residential measures. LED lighting accounts for approximately 24% of the residential sector's economic potential.

Table 28. Top Saving Residential Measures – Sorted by Economic Potential

Measure Name	2038 (MWh)		Percentage of Total	
	Technical	Economic*	Technical	Economic
Lighting General Service Lamp - Premium Efficiency LED	168,613	258,320	4%	24%
Low-Flow Showerhead	108,039	177,708	3%	16%
Home Energy Reports	130,825	153,959	3%	14%
Refrigerator - Removal of Secondary	77,953	101,378	2%	9%
Pool Pump - Two Speed	0	61,228	0%	6%
Lighting Specialty Lamp - Premium Efficiency LED	76,168	55,358	2%	5%
Low-Flow Faucet Aerator - Kitchen	32,220	52,554	1%	5%
Programmable Thermostat	22,704	51,455	1%	5%
Low-Flow Faucet Aerator - Bathroom	22,543	37,427	1%	3%
Office Multifunction Device - ENERGY STAR	37,350	37,350	1%	3%

*Economic potential exceeds technical potential for individual measures due to reduced interactive effects.

Commercial Sector

Based on resources included in this assessment, Table 29 shows the estimated electric economic potential in the commercial sector, as approximately 895 GWh over the 20-year planning horizon. This corresponds to a 9% reduction of forecasted 2038 commercial usage for the Company (8% for LG&E and 10% for KU).

Table 29. Commercial Sector Electric Energy Efficiency Potential by Utility – Energy (GWh)

Segment	Baseline Sales	Cumulative 2038		Percentage of Baseline		Economic as a Percentage of Technical
		Technical	Economic	Technical	Economic	
LGE	4,627	1,237	359	27%	8%	29%
KU	5,573	1,693	536	30%	10%	32%
Total	**10,200**	**2,930**	**895**	**29%**	**9%**	**31%**

The potential cost-effective reduction of peak demand in the commercial sector is 166 MW (cumulative by 2038; see Table 30). This is equivalent to an 8% reduction in the commercials sector's baseline peak demand.

Table 30. Commercial Sector Electric Energy Efficiency Potential by Utility – Demand (MW)

Company	Baseline Peak	Cumulative 2038		Percentage of Baseline		Economic as a Percentage of Technical
		Technical	Economic	Technical	Economic	
LGE	944	246	69	26%	7%	28%
KU	1,125	329	97	29%	9%	29%
Total	**2,069**	**574**	**166**	**28%**	**8%**	**29%**

Figure 16 and Figure 17 show the distribution of economic potential by market segment (for energy and demand, respectively).

Figure 16. Commercial Sector Electric Economic Potential by Segment – Energy

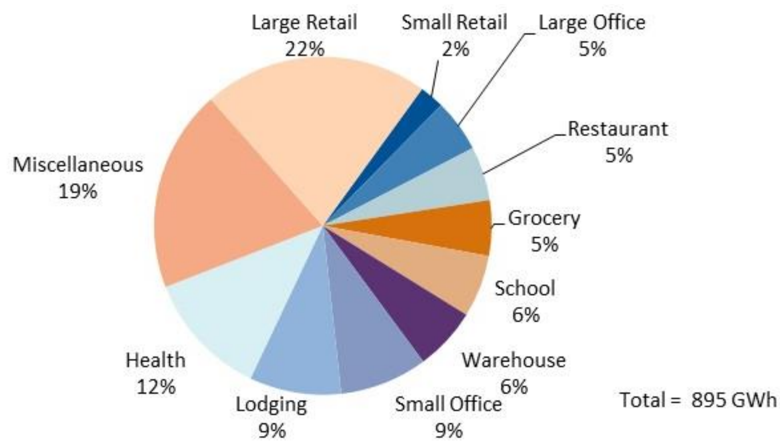


Figure 17. Commercial Sector Electric Economic Potential by Segment – Demand

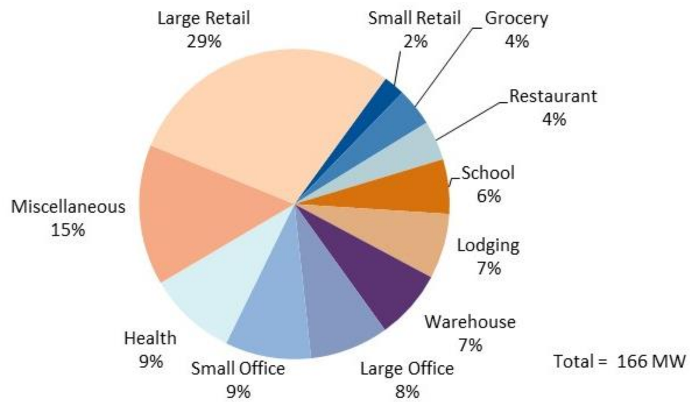


Figure 18 and Figure 19 show the distribution of economic potential in the commercial sector for energy and demand, respectively. Lighting accounts for nearly two-thirds (65%) of cost-effective energy savings and 46% of demand reduction. Cooling accounts for 29% of demand reduction, but only 10% of energy savings.

Figure 18. Commercial Sector Electric Economic Potential by End Use Group – Energy

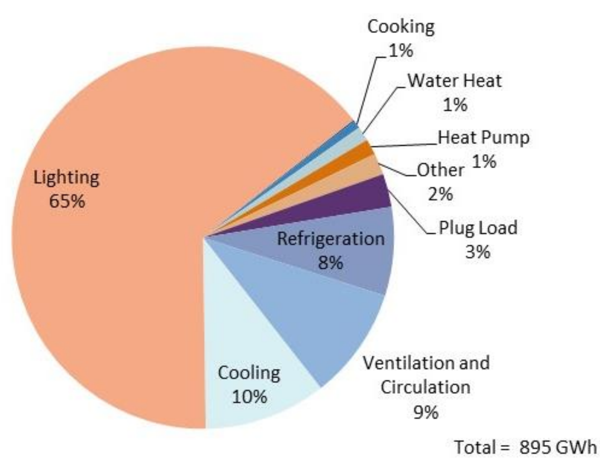


Figure 19. Commercial Sector Electric Energy Efficiency Potential by End-Use Category – Demand

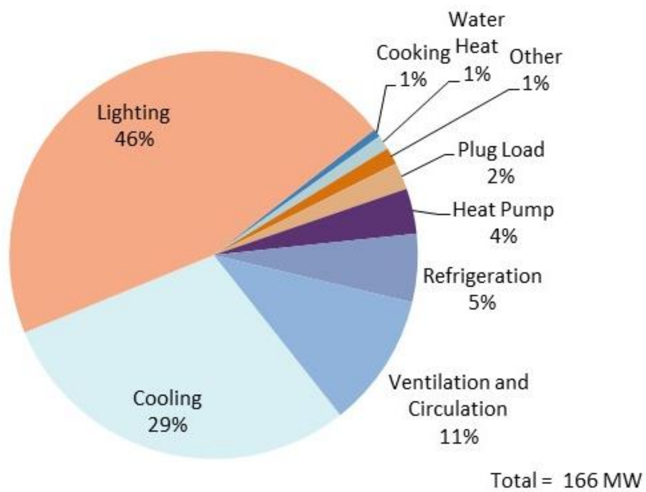


Table 31 and Table 32 show detailed commercial sector technical and economic potential for each end use group, for energy and demand, respectively.

Table 31. Commercial Electric Technical and Economic Potential by End use – Energy (GWh)

End Use	Baseline Sales	Cumulative 2038		Percentage of Baseline	
		Technical	Economic	Technical	Economic
Cooking	38	8	6	20%	15%
Cooling	1,029	345	93	34%	9%
Heat Pump	476	113	12	24%	3%
Heating	110	33	1	30%	1%
Lighting	4,435	1,798	579	41%	13%
Other	58	17	16	29%	28%
Plug Load	1,885	70	25	4%	1%
Refrigeration	1,005	347	67	35%	7%
Ventilation and Circulation	1,043	132	85	13%	8%
Water Heat	120	67	11	55%	9%
Total	**10,200**	**2,930**	**895**	**29%**	**9%**

Table 32. Commercial Electric Technical and Economic Potential by End use – Demand (MW)

End Use	Baseline Sales	Cumulative 2038		Percentage of Baseline	
		Technical	Economic	Technical	Economic
Cooking	6.5	1.4	1.1	22%	17%
Cooling	522	180	49	34%	9%
Heat Pump	231	58	6	25%	3%
Heating	0.05	0.01	0.00	31%	0%
Lighting	646	239	76	37%	12%
Other	8	2	2	29%	28%
Plug Load	289	10	4	3%	1%
Refrigeration	134	46	9	34%	7%
Ventilation and Circulation	212	28	18	13%	8%
Water Heat	20	11	2	55%	10%
Total	**2,069**	**574**	**166**	**28%**	**8%**

Table 33 lists commercial measures in order of cumulative technical potential. LED replacements for linear fluorescent lighting (TLEDs) have the highest technical potential—this measure accounts for 31% of technical potential in the commercial sector. However, this measure is rarely cost-effective. TLEDs only account for 7% of total economic potential.

Table 33. Top-Saving Commercial Electric Measures – Sorted by Technical Potential

Measure Name	2038 (MWh)		Percentage of Total	
	Technical	Economic*	Technical	Economic
Lighting Interior - TLED - Above Standard	900,442	62,128	31%	7%
LED Exterior Wall Pack	260,820	0	9%	0%
Occupancy Sensor Control	208,288	285,297	7%	32%
Lighting Interior - High Bay LED - Above Standard	109,118	0	4%	0%
Night Covers for Display Cases	96,068	0	3%	0%
Motor - Pump and Fan System - Variable Speed Control	76,486	69,769	3%	8%
Refrigeration Commissioning or Recommissioning	72,499	5,795	2%	1%
Daylighting Controls, Outdoors (Photocell)	70,168	69,422	2%	8%
Recommissioning	67,838	0	2%	0%
DX Package 240 to 760 kBtuh - Premium Efficiency	52,970	849	2%	0%

*Economic potential exceeds technical potential for individual measures due to reduced interactive effects.

Table 34 lists the highest saving cost-effective energy efficiency measures in the commercial sector.

Table 34. Top-Saving Commercial Electric Measures – Sorted by Economic Potential

Measure Name	2038 (MWh)		Percentage of Total	
	Technical	Economic	Technical	Economic
Occupancy Sensor Control	208,288	285,297	7%	32%
Motor - Pump and Fan System - Variable Speed Control	76,486	69,769	3%	8%
Daylighting Controls, Outdoors (Photocell)	70,168	69,422	2%	8%
Lighting Interior - TLED - Above Standard	900,442	62,128	31%	7%
Lighting Interior - Efficient Metal Halide - Above Standard	0	45,798	0%	5%
Lighting Interior - Screw-Base LED - Above Standard	43,728	44,575	1%	5%
Direct/Indirect Evaporative Cooling, Pre-Cooling	28,229	32,487	1%	4%
Case Replacement Low Temp	25,187	25,187	1%	3%
Lighting Package - Advanced Efficiency	37,646	24,461	1%	3%
Exit Sign - Photoluminescent or Tritium	23,480	23,662	1%	3%

Natural Gas

Residential Sector

Single family homes represent 90% of total economic residential potential, followed by multifamily homes. Multifamily homes represent a smaller share of natural gas potential largely due to a lower saturation of natural gas furnaces.

Table 35. Residential Sector Natural Gas Technical and Economic Potential by Segment (MCF)

Segment	Baseline Sales	Cumulative 2038		Percentage of Baseline		Economic as a Percentage of Technical
		Technical	Economic	Technical	Economic	
Single Family	16,160,909	8,131,286	2,829,161	50%	18%	35%
Multifamily	1,711,196	663,038	253,735	39%	15%	38%
Total	17,872,105	8,794,324	3,082,896	49%	17%	35%

Figure 20 presents distributions of natural gas economic potential by measure type. The largest portion of economic potential in the residential sector derives from measures impacting central furnaces (68%) followed by water heating (32%).

Figure 20. Residential Sector Economic Potential by End Use

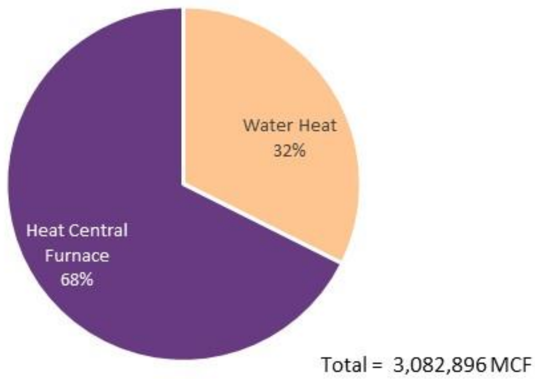


Table 36 provides technical and economic potential by end-use category. As shown, central gas furnaces offer significant technical potential—measures affecting this end use can could technically produce a 50% reduction in baseline usage and cost-effectively produce a 16% reduction in baseline usage. Water heating measures produce economic potential equivalent to roughly 26% of baseline water heating natural gas consumption.

Table 36. Residential Sector Natural Gas Technical and Economic Potential by End Use (MCF)

End Use Group	Baseline Sales	Cumulative 2038		Percentage of Baseline		Economic as a Percentage of Technical
		Technical	Economic	Technical	Economic	
Cooking Oven	1,191	234	0	20%	0%	0%
Cooking Range	3,354	0	0	0%	0%	-
Dryer	1,696	236	0	14%	0%	0%
Heat Central Furnace	132,809	66,955	20,844	50%	16%	31%
Pool Heat	1,848	291	0	16%	0%	0%
Water Heat	37,822	20,227	9,985	53%	26%	49%
Total	**178,721**	**87,943**	**30,829**	**49%**	**17%**	**35%**

Table 37 and Table 38 show the highest-savings residential natural gas measures, sorted by technical and economic potential, respectively.

Table 37. Top-Saving Residential Natural Gas Measures – Sorted by Technical Potential

Measure Name	2038 (MCF)		Percentage of Total	
	Technical	Economic*	Technical	Economic
Wall Insulation (KY) - Maximum Feasible	1,635,282	0	19%	0%
Window (KY) - Tier 2 Above Code	1,124,926	0	13%	0%
Furnace - Premium Efficiency 98% AFUE	1,109,798	1,814,667	13%	59%
Low-Flow Showerhead	495,838	729,417	6%	24%
Wi-Fi Thermostat	422,493	0	5%	0%
Floor Insulation (KY) - Above Code	406,199	0	5%	0%
Water Heater - ENERGY STAR Tankless	386,605	0	4%	0%
Ceiling Insulation (KY) - Code	365,512	0	4%	0%
Integrated Space Heating and Water Heating	345,428	0	4%	0%
Tune-Up - Boiler	326,164	0	4%	0%

*Economic potential can exceed technical for individual measures due to interactive effects. See the explanation in the *Why Economic Potential Can Exceed Technical Potential* of this report.

Table 38. Top-Saving Residential Natural Gas Measures – Sorted by Economic Potential

Measure Name	2038 (MCF)		Percentage of Total	
	Technical	Economic*	Technical	Economic
Furnace - Premium Efficiency 98% AFUE	1,109,798	1,814,667	13%	59%
Low-Flow Showerhead	495,838	729,417	6%	24%
Programmable Thermostat	98,742	269,771	1%	9%
Low-Flow Faucet Aerator - Kitchen	89,037	123,520	1%	4%
Low-Flow Faucet Aerator - Bathroom	73,071	101,393	1%	3%
Low-Flow Showerhead - Federal Standard 1994	24,884	36,570	0.3%	1%
Pipe Insulation - Water Heater	7,391	7,557	0.1%	0.2%

*Economic potential can exceed technical for individual measures due to interactive effects. See the explanation in the *Why Economic Potential Can Exceed Technical Potential* of this report.

Commercial Sector

As shown in Figure 21, miscellaneous buildings and health facilities represent the largest shares of natural gas economic potential in the commercial sector (26% and 20%, respectively). As with the commercial electric sector, the miscellaneous segment includes a combination of business segments that do not fit into the other categories, or that presented insufficient information to be classified.

Figure 21. Commercial Natural Gas Economic Potential by Segment

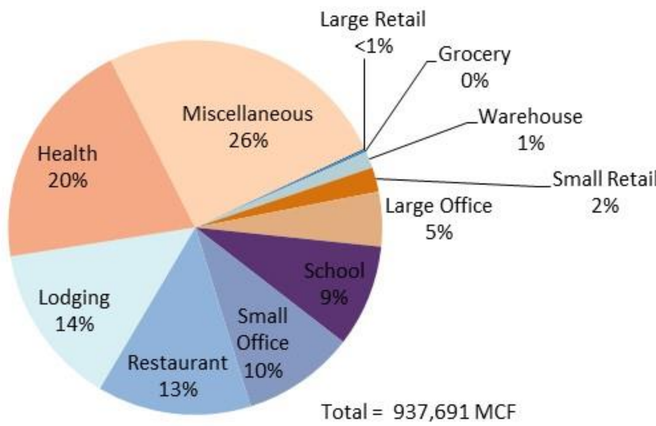


Table 39 shows the commercial sector's baseline sales, cumulative technical potential, and cumulative economic potential in 2038, for natural gas in each commercial segment.

Table 39. Commercial Sector Natural Gas Technical and Economic Potential by Segment (MCF)

Segment	Baseline Sales	Cumulative 2038		Percentage of Baseline		Economic as a Percentage of Technical
		Technical	Economic	Technical	Economic	
Grocery	17,963	5,985	1,853	33%	10%	31%
Health	1,205,237	417,390	187,680	35%	16%	45%
Large Office	245,617	103,757	44,242	42%	18%	43%
Large Retail	1,263,026	479,492	1,195	38%	0%	0%
Lodging	1,428,266	315,639	131,260	22%	9%	42%
Miscellaneous	2,231,711	798,988	239,223	36%	11%	30%
Restaurant	607,753	220,707	124,988	36%	21%	57%
School	750,630	275,588	82,715	37%	11%	30%
Small Office	715,792	252,132	91,252	35%	13%	36%
Small Retail	171,923	59,276	19,781	34%	12%	33%
Warehouse	137,518	45,984	13,501	33%	10%	29%
Total	8,775,436	2,974,937	937,691	34%	11%	32%

Figure 22 presents distributions of natural gas energy efficiency economic potential by measure type. The largest portion of economic potential in the commercial sector comes from the furnace end uses (56%), followed by water heating (27%). Boilers account for 10% of economic potential, and cooking accounts for the remaining 7% of economic potential.

Figure 22. Commercial Sector Natural Gas Economic Potential by End Use

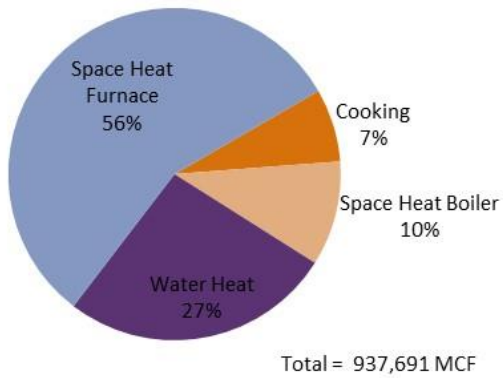


Table 40 shows the commercial sector's baseline sales, cumulative technical potential, and cumulative economic potential in 2038, for natural gas in each end use group.

Table 40. Commercial Sector Natural Gas Technical and Economic Potential by End Use (MCF)

End Use	Baseline Sales	Cumulative 2038		Percentage of Baseline		Economic as a Percentage of Technical
		Technical	Economic	Technical	Economic	
Cooking	627,255	131,130	66,681	21%	11%	51%
Space Heat Boiler	1,004,465	421,810	95,508	42%	10%	23%
Space Heat Furnace	5,103,328	2,052,102	527,684	40%	10%	26%
Water Heat	1,025,012	304,688	247,817	30%	24%	81%
Pool Heat	1,015,376	65,206	0	6%	0%	0%
Total	8,775,436	2,974,937	937,691	34%	11%	32%

Table 41 lists the energy efficiency measures with the highest natural gas technical potential in the commercial sector. Recommissioning accounts for 18% of total technical potential (over 500,000 MCF by 2038), however, this measure is not cost-effective. The second highest-saving measure—advanced efficiency furnaces—offers both high technically feasible and cost-effective savings. Generally, building shell measures, such as ceiling insulation and floor insulation, have high technical potential but low economic potential.

Table 41. Top-Saving Commercial Natural Gas Measures Sorted by Technical Potential

Measure Name	2038 (MCF)		Percentage of Total	
	Technical	Economic*	Technical	Economic
Recommissioning	531,020	0	18%	0%
Furnace < 225 kBtuh - Advanced Efficiency	354,397	385,890	12%	41%
Ceiling Insulation - Code	314,217	10,949	11%	1%
Direct Digital Control System-Installation	243,674	0	8%	0%
Floor Insulation - Non-Sla) - Code	201,085	8,654	7%	1%
Water Heater Less than 55 Gal - Condensing - High Efficiency	163,438	162,790	5.5%	17%
Automated Ventilation VFD Control (Occupancy Sensors/CO2 Sensors)	112,784	0	3.8%	0%
Tune-Up - Furnace Maintenance	100,696	50,168	3%	5%
Convert Constant Volume Air System to VAV	94,674	0	3%	0%
Wall Insulation - Code	75,697	0	3%	0%

*Economic potential can exceed technical for individual measures due to interactive effects. See the explanation in the *Why Economic Potential Can Exceed Technical Potential* of this report.

Table 42 lists the highest-saving cost-effective natural gas energy efficiency measures in the commercial sector. Highly efficient equipment, such as advanced efficiency furnaces and condensing water heaters, account for a significant share of total natural gas economic potential in the commercial sector. Equipment measures are generally cost-effective because their incremental costs are low, yet savings are relatively high. Retrofit measures, such as weatherization and controls measures, are generally not cost-effective due to relatively high incremental costs.

Table 42. Top-Saving Commercial Natural Gas Measures Sorted by Economic Potential

Measure Name	2038 (MCF)		Percentage of Total	
	Technical	Economic*	Technical	Economic
Furnace < 225 kBtuh - Advanced Efficiency	354,397	385,890	12%	41%
Water Heater less than 55 Gal - Condensing - High Efficiency	163,438	162,790	5%	17%
Boiler < 300 kBtuh - Advanced Efficiency	50,070	75,477	2%	8%
Tune-Up - Furnace Maintenance	100,696	50,168	3%	5%
Water Heater greater than 55 Gal - Tankless - ENERGY STAR	44,406	44,375	1%	5%
Steam Cooker	43,568	43,568	1.5%	5%
Infiltration Reduction	36,982	31,901	1.2%	3.4%
Dishwashing - Commercial - Low Temperature	24,507	24,663	1%	3%
Duct Insulation - Code	43,014	19,984	1%	2%
Fryer	19,726	19,726	1%	2%

*Economic potential can exceed technical for individual measures due to interactive effects. See the explanation in the *Why Economic Potential Can Exceed Technical Potential* of this report.

Avoided Cost Sensitivity

To assess how estimates of economic potential may change given increases to avoided costs, Cadmus produced three additional avoided cost scenarios. In this section, we compare the results of Cadmus' base scenario, in which we used avoided capacity costs of $0 per kW, to scenarios with avoided capacity costs of $33, $68, and $100 per kW. Table 43 shows 20-year cumulative economic potential for each avoided cost scenario. Changing avoided capacity costs from $0 per kW to $100 per kW increases economic potential from 9% of baseline sales to just under 15% of baseline sales. Higher avoided capacity costs produce more cost-effective measures, primarily in cooling end uses for which usage is largely coincident with the Company's peak.

Table 43. Economic Potential with Different Avoided Capacity Costs

Sector	Cumulative 2038 Economic Potential (GWh)			
	$0/kW	$33/kW	$68/kW	$100/kW
Residential	1,046	1,268	1,545	1,954
Commercial	895	1,031	1,133	1,225
Total	**1,941**	**2,299**	**2,678**	**3,179**
Percentage of Baseline				
Residential	9.1%	11.1%	13.5%	17.0%
Commercial	8.8%	10.1%	11.1%	12.0%
Total	**9.0%**	**10.6%**	**12.4%**	**14.7%**

Economic potential reflects the savings potential for *all measures that have a benefit/cost ratio greater than or equal to 1.0.* The relationship between avoided costs and economic potential is not linear, but stepwise. If, for example, a large number of high saving measures have a benefit/cost ratio slightly below 1.0, a small increase in avoided costs could result in a large increase in economic potential. However, if a large number of high saving measures have low benefit/cost ratios, even a large increase in avoided costs would have no impact on economic potential.

Achievable Potential

Achievable potential is the portion of economic potential that can be targeted and acquired through energy efficiency programs offered by the Company. Therefore, Cadmus measured achievable potential as a fraction (percentage) of economic potential. While estimating technical and economic potentials is fundamentally based on engineering and accounting endeavors, and industry standard practices and methodologies, achievable potential is more difficult to quantify and reliably predict, as it depends on many behavioral factors, which tend to change unpredictably over time.

Several factors account for the gap between economic and achievable potential, including customer awareness, perceptions of the value of energy efficiency, and the upfront costs for energy efficiency measures. In the case of new measures and programs, there are additional practical constraints regarding the availability of delivery infrastructure. These barriers have been well documented in energy efficiency literature.[15]

The Company can mitigate some of these market barriers through program design and delivery processes, while others barriers remain out of reach. For example, the Company can reduce first-cost barriers by providing financial incentives to lower the upfront costs and improve customer paybacks. However, since utility incentives only cover a portion of the incremental costs for most measures, incentives may not be sufficient to motivate a customer to adopt energy efficiency measures. This is particularly true for the commercial sector and for large equipment in the residential sector, where upfront costs tend to be high. Therefore, Cadmus determined which barriers the Company can overcome over the course of the planning horizon, and how much economic potential can be deemed reasonably achievable.

To assess the fraction of customers who would likely adopt an energy efficiency measure, Cadmus used telephone survey data from our 2013 study that included a battery of questions to elicit information about customers' willingness to adopt measures under different hypothetical incentive scenarios. For a number of measure types (e.g., heating, cooling, lighting, weatherization), we first asked survey respondents if they would adopt efficient measures if the Company did not provide an incentive—corresponding to the low achievable scenario. Then we asked if the customer would adopt the efficient measure if the Company covered 50% of the measure incremental cost (the cost to upgrade)—corresponding to the medium achievable scenario. Finally, we asked if a customer would adopt the efficient measure if the Company covered 75% of the measure incremental cost—corresponding to the high achievable scenario. Figure 23 and Figure 24 show residential and commercial customers' willingness to adopt efficient measures under the different incentive scenarios, respectively.

[15] See, for example: Golove, William H. and J. H. Eto. "Market Barriers to Energy Efficiency: A Critical Reappraisal of the Rationale for Public Policies to Promote Energy Efficiency." LBL-38059 UC-1322. March 1996.

Figure 23. Residential Customers' Willingness to Adopt by Measure Type

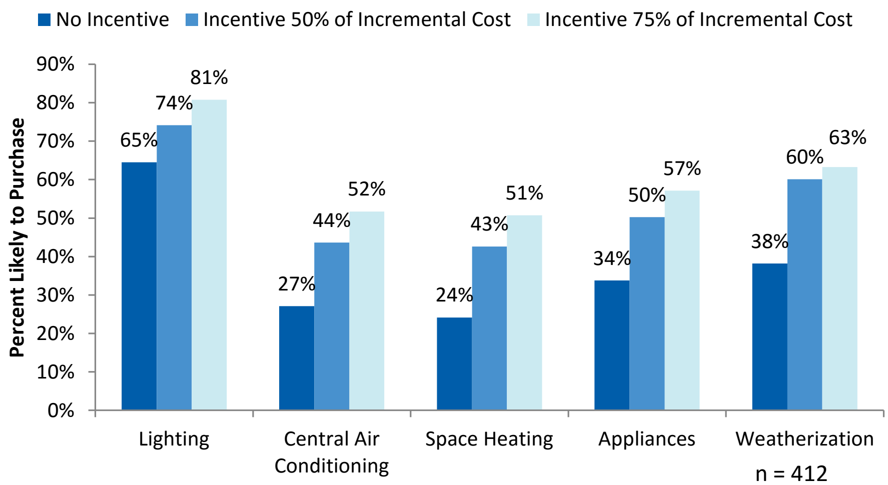
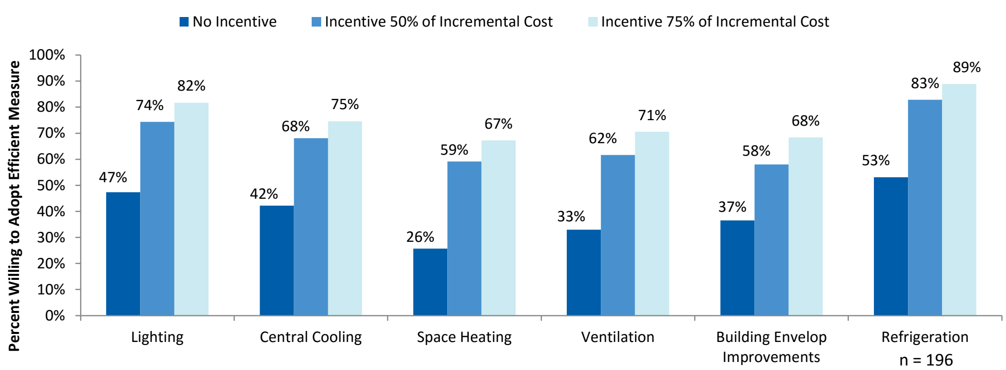


Figure 24. Commercial Customers' Willingness to Adopt by Measure Type



The results indicate a range of 864 GWh to 1,400 GWh of achievable electricity savings, representing, respectively, 4.0% and 6.5% of retail sales in 2038. The estimated savings have a medium value of 1,255 GWh, which represents 5.8% of the baseline sales (Table 44).

Table 44. Electric Achievable Energy Potential by Sector-Energy (GWh)

Sector	Baseline Sales	Cumulative 2038			Percentage of Baseline		
		Low	Medium	High	Low	Medium	High
LGE							
Residential	5,012	213	278	310	4.3%	5.5%	6.2%
Commercial	4,627	155	248	276	3.3%	5.4%	6.0%
Subtotal	**9,639**	**368**	**526**	**587**	**3.8%**	**5.5%**	**6.1%**
KU							
Residential	6,440	264	357	400	4.1%	5.5%	6.2%
Commercial	5,573	232	371	413	4.2%	6.7%	7.4%
Subtotal	**12,013**	**496**	**728**	**813**	**4.1%**	**6.1%**	**6.8%**
Total							
Residential	11,453	477	635	710	4.2%	5.5%	6.2%
Commercial	10,200	387	620	689	3.8%	6.1%	6.8%
Total	**21,652**	**864**	**1,255**	**1,400**	**4.0%**	**5.8%**	**6.5%**

Achievable demand reduction is between 120 MW and 207 MW, which is equivalent to a range of 2.0% to 3.5% of baseline peak demand (Table 45).

Table 45. Electric Achievable Energy Potential by Sector-Demand (MW)

Sector	Baseline Sales	Cumulative 2038			Percentage of Baseline		
		Low	Medium	High	Low	Medium	High
LGE							
Residential	1,695	18	26	29	1.1%	1.5%	1.7%
Commercial	944	29	47	52	3.1%	4.9%	5.5%
Subtotal	**2,639**	**47**	**72**	**81**	**1.8%**	**2.7%**	**3.1%**
KU							
Residential	2,148	32	48	54	1.5%	2.2%	2.5%
Commercial	1,125	40	65	73	3.6%	5.8%	6.5%
Subtotal	**3,273**	**73**	**113**	**127**	**2.2%**	**3.5%**	**3.9%**
Total							
Residential	3,843	51	74	83	1.3%	1.9%	2.2%
Commercial	2,069	69	112	125	3.3%	5.4%	6.0%
Total	**5,912**	**120**	**186**	**207**	**2.0%**	**3.1%**	**3.5%**

Demand Response

This section summarizes demand response potential assumptions and results for the residential and commercial sectors in LG&E and KU service territories. In conducting this analysis, Cadmus considered three types of demand response programs: DLC, pricing programs (including TOU and CPP), and commercial load curtailment.

Demand response objectives may be met through a broad array of programs, including price-based (such as time-varying rates or interruptible tariffs) and incentive-based (such as DLC) programs. Demand response programs can reduce peak demand during system emergencies or periods of extreme market prices, promote improved system reliability, and, in some cases, balance variable-load resources (particularly wind energy).

Focused on reducing a utility's short-term capacity needs, demand response programs rely on flexible loads, which may be curtailed or shifted during system emergencies or when marginal electricity costs exceed the costs to use demand response. These programs reduce peak demand, promote improved system reliability, and decrease supply costs. In some cases, the programs may defer investments in delivery and generation infrastructure.

In this assessment, Cadmus considered three demand response strategies (DLC, pricing, and load curtailment) across the five following programs:

- ***Demand Conservation Program.*** LG&E and KU offer a DLC program for residential and small commercial customers. During four-hour peak events, load control switches cycle air conditioning units off for approximately 33% of the time. Water heaters and pool pumps are fully curtailed during four-hour peak events.
- ***Wi-Fi thermostat option.*** LG&E and KU offer an existing Wi-Fi thermostat DLC program for residential customers. During peak events, the utility controls residential air conditioning loads. Customers must purchase and install an approved Wi-Fi-enabled smart thermostat. The Company controls Wi-Fi thermostats in partnership with a third-party vendor via the Internet during four-hour peak events, rather than through the radio or a paging infrastructure. Smart thermostats can increase temperature set points or cycle air conditioners to reduce load. Some smart thermostats can pre-cool a customer's home prior to an event, provided proper notice is given. Pre-cooling improves customer comfort and decreases event opt-out rates. Third parties typically implement smart thermostat programs, providing a customer web portal, licensing, and software hosting.
- ***Time-of-day energy rates.*** LG&E and KU currently offer a TOU program with a two-tiered rate schedule. TOU programs generally operate based on two- or three-tiered, time-differentiated tariff structures, in which there are fixed usage prices during different blocks of time (typically on- and off-peak prices, by season). The TOU rate design more closely reflects the marginal costs of generating and delivering power. Participation in the program requires AMI.

- ***CPP***. LG&E and KU currently do not offer a residential CPP program. These programs reduce system demand by encouraging customers to reduce their loads for a limited number of hours during peak load events. When CPP events occur, customers receive notice[16] and may curtail or shift energy use to a different time to avoid paying substantially higher retail rates. CPP programs integrate a pricing structure similar to a TOU program, though CPPs include a more extreme price signal during critical peak events.
- ***Load curtailment.*** LG&E and KU currently offer a commercial curtailment program. These programs require contractual arrangements between a utility and a third-party aggregator who administers the program and recruits commercial and industrial customers. The third-party aggregator typically guarantees a specific curtailment level to the utility during an event period by aggregating individual customer load-curtailment pledges.

Cadmus estimated market potential and the corresponding levelized cost per kW-year for each of these DR products. Levelized costs can show how a DR product relates to the Company's avoided capacity cost, as well as other DR products. However, this study does not conclude whether a given DR product is cost-effective.

Methodology

Overview

Cadmus conducted this demand response potential assessment in two stages: a research (benchmarking) stage and a data modeling stage. In the benchmarking stage, we researched typical program characteristics for demand response programs, reviewing several data sources to determine the appropriate program assumptions.

First, we reviewed the Federal Energy Regulatory Commission (FERC) 2012 *Assessment of Demand Response and Advanced Metering Staff Report*. We supplemented this with information from the following:

- Demand response program evaluations conducted for various utilities in North America
- DOE program reports
- Demand Response Research Center at the LBNL
- Oak Ridge National Laboratory
- California Measurement Advisory Council database
- Association for Demand Response and Smart Grid

Cadmus also used LG&E and KU demand conservation and commercial curtailment program data for program costs, event impacts, and participation (as available).

[16] Customer notifications can include the use of in-home-devices such as smart thermostats, energy dashboard displays, emails, and text messages.

For the data modeling stage, Cadmus employed two approaches: For pricing and curtailment programs, we relied on a proprietary demand response model, using a top-down approach. For the Demand Conservation Program and the Wi-Fi Smart Thermostat option, we relied on a bottom-up analysis. The following sections describe these approaches in greater detail.

Modeling Approach

Top-Down Model

Cadmus relied on a top-down model to estimate achievable load reduction for the TOU, CPP, and curtailment programs. We disaggregated system loads by sector, segment, and applicable end uses. We also applied program-specific assumptions (e.g., technical potential, program participation, event participation) to disaggregated loads at the end-use level. We used the following general steps to perform the analysis:

1. ***Define customer sectors, market segments, and applicable end uses.*** In estimating the load basis, Cadmus defined customer segments and applicable end uses, similar to those used in estimating energy efficiency potentials. We further disaggregated segment load shares into the end uses.
2. ***Compile utility specific, end-use loads for each sector.*** To establish reliable estimates of demand response potential, Cadmus required accurate characterizations of sector, segment, and end-use loads. LG&E and KU each provided system load profiles, as well as annual percentages of sales for each segment in their respective territories. Cadmus used the end-use load profiles provided for energy efficiency potential to estimate the contribution of each end-use load to system peak loads.
3. ***Estimate technical potential***. Next, Cadmus estimated the reduction in load possible for each end use by each specific demand response option. For pricing and curtailment options, we assumed a constant technical load reduction potential (i.e., the percentage of end-use load) for the study duration, specific to the residential and commercial market segments.
4. ***Estimate market potential***. Market potential accounts for customers' ability and willingness to participate in demand response, subject to their unique priorities, operating requirements, and economic (price) considerations. Cadmus derived market potential estimates by adjusting the technical potential for expected program participation rates and for expected event participation rates (the percentage of program participants that will participate in a particular demand response event). Cadmus used benchmarking data for both program participation and event participation rates.[17]
5. ***Estimate costs.*** Finally, we calculated the levelized cost (i.e., the cost per kW per year) of each program and option using estimates of program development, technology, incentives,

[17] We did not conduct a customer survey in 2016 to estimate program participation in any of the demand response programs.

administration, and communications costs drawn from LG&E and KU data (where available) and from benchmarking of similar programs.

Bottom-Up Model

Cadmus used a bottom-up model to estimate the achievable load reduction for the Demand Conservation and Wi-Fi Thermostat Option programs. The bottom-up model quantifies achievable load reduction for DLC programs as the product of five variables:

- Number of eligible customers
- Equipment saturation rates
- Program participation rates
- Expected per-unit (kW) impacts[18]
- Expected event participation rates

Cadmus used baseline customer forecasts (starting in 2016), in conjunction with equipment saturation rates from the energy efficiency potential study, to determine the number of eligible customers. The product of customer counts and equipment saturation rates determined eligible participation, as customers had to have the equipment required (air conditioners, electric water heaters, and pool pumps) to have loads controlled. We applied estimated program participation rates to the number of eligible customers to determine final program participation. Event participation represented the average number of program participants that actually participated when load control events were called. We assumed programs would have a portion of customers who opt out of an event or who have nonresponsive load control devices. The final program impact was the product of average event participation and average impacts per device.

Program Assumptions and Results

The following sections present program assumptions and analysis results. For each of the five programs, we provide brief program descriptions, followed by program assumptions and analysis results. Programs are presented in the preceding order, with residential results for the Demand Conservation Program presented prior to the Small Commercial Program.

LG&E and KU Demand Conservation Program

Modeled after existing LG&E and KU DLC programs for residential, residential multifamily, and small commercial customers, the Company controls residential and small commercial air conditioning, water heat, and pool pump loads using a one-way paging infrastructure. Peak events last four hours and can be called during June through September. LG&E and KU provided inputs for the analysis based on

[18] For the Demand Conservation Program, Cadmus used LG&E's and KU's evaluated impacts per air conditioning switch for low scenario impacts. For all other impacts, we relied on benchmarked values from similar programs.

evaluated impacts from the existing program for residential and commercial air conditioning devices.[19] Participants received a $20 incentive (i.e., $5 per month for each of the four peak months) plus a one-time $25 bonus incentive for each appliance enrolled.

Residential Demand Conservation Program Assumptions

Table 46 shows assumptions for the Residential DLC Program, with each low and high scenario variable listed along with the sources. For attrition, Cadmus derived the 1% high scenario assumption from a recent impact evaluation (Tetra Tech 2015), while the low scenario value reflects benchmarking of other similar programs. For the low scenario per-customer impacts for central air conditioning, we relied on draft evaluation results (Tetra Tech 2015). All other impacts are based on typical benchmarking values from similar programs.

Cadmus used current participation levels (device counts) provided by LG&E and KU as the assumptions for program participation. The low scenario program implementation costs per participant are based on an average of non-incentive costs from the 2011 and 2014 filings. The high scenario has increased program costs to reduce high levels of NRDs, as estimated by LG&E and KU for the program. We based the low scenario event participation on LG&E's and KU's estimates for NRDs, while we relied on the upper end of the range of values from similar programs for the high scenario.

For the winter peak, we assumed a 1.4 kW impact for central heating and heat pumps. We assumed water heating impacts to be the same, but excluded pool pumps from the winter peak analysis. The Demand Conservation Program's winter achievable load reduction includes Wi-Fi thermostat option participants. As winter assumptions were identical for the Demand Conservation Program and the Wi-Fi thermostat option, the programs did not require separation.

19 Tetra Tech. *Residential and Small Commercial Demand Conservation Impact Evaluation – DRAFT.* December 18, 2015.

Table 46. Residential Demand Conservation Program Study Assumptions

Inputs	High Scenario	Low Scenario	Sources or Assumptions
Annual Attrition	1.0%	5.0%	High scenario based on LG&E and KU program evaluation (which is similar to other switch-based programs: Missouri River Energy Services 1% (2014) and PacifiCorp 7% (2012). Benchmarked thermostat DLC programs ranged from 2% to 9%: (Colorado Springs Utilities 1.5% [2015], MRES 1% [2014], Rocky Mountain Power 2% [2010], Interstate Power and Light 3% [2014-2018], Con Edison 3.8% [2012], Avista Utilities 4%, Bonneville Power Administration [BPA] Kootenai Pilot 5%, and Xcel Energy Colorado 9% [2013]).
Per Customer Impacts	Central air conditioner single family: 1.0 kW Central air conditioner multifamily: 0.6 kW Water heat: 0.35 kW Pool pump: 1.91 kW Space heat: 1.4 kW	Central air conditioner single family: 0.45 kW Central air conditioner multifamily: 0.139 kW Water heat: 0.35 kWs Pool pump: 1.36 kW Space heat: 1.4 kW	LG&E and KU program estimated 0.45 kW single family and 0.139 kW multifamily. Benchmarking included: Xcel Energy single family 0.62 kW and multifamily 0.47 kW (2015), MRES 1.0 Kw (2014), Duke Energy Indiana1.0 kW to 1.5 kW (2015), Duke Energy Ohio 0.9 kW to 1.8 kW (2015), Duke Energy Carolinas 1.19 kW to 1.57 kW, PSO and OG&E 1.0 kW per air conditioner and 0.35 kW per water heater (2014), PacifiCorp 1.0 kW per air conditioner and 0.5 kW per water heater (2013), California Codes and Standards Program 1.1 kW to 2.3 kW per pool pump (2013), SDG&E 1.91 kW (2013), and SCE 1.36 kW (2008). Winter space heating impacts included: PSE 1.74 kW; BPA Kootenai 1.65 kW (including water heat; Xcel Energy Minnesota 1.42 kW.
Technology Cost	$150 per air conditioner $200 per water heat and pool pump	$150 per air conditioner $200 per water heat and pool pump	Based on LG&E and KU data. Similar programs had costs in the range of $140 to $280: MRES $200, PSO $200 plus $80 install, OG&E $200 plus $80 install, PacifiCorp $60 per switch plus $80 install.
Program Costs	$35 per participant	$30 per participant	Average non-incentive costs from LG&E and KU data. Accounted for program administrative costs and communications costs for load control devices.
Incentive (annual costs)	Central air conditioner single family: $25 Central air conditioner multifamily: $20 Water heat and pool pump: $10	Central air conditioner single family: $20 Central air conditioner multifamily: $8 Water heat and pool pump: $8	For low scenario Cadmus assumed LG&E and KU incentives; we increased by 25% for high scenario to drive higher participation. Other programs offered similar incentives, including: MRES $22 per customer (2014), Duke Energy Carolina $32 per customer (2015), Duke Energy Ohio and Duke Energy Indiana $32 to $67 per customer (2015); PSO and OG&E $25 per central air conditioner and $10 per water heat (both 2014), and PacifiCorp $20 per central air conditioner and $10 per water heat (2013).

Inputs	High Scenario	Low Scenario	Sources or Assumptions
Program Participation	29%	29%	LG&E and KU participant counts for single family was 141,057 and for multifamily was 35,696 based on evaluation disaggregated by end use and service territory. Similar programs ranged from PacifiCorp 12.5% (2013, reflecting California, Idaho, Oregon, Washington, and Wyoming) to PSO 30% (2014). A Brattle study (2012) found a range of 10% to 30%. Various programs' participation fell within this range.
Event Participation	95%	70%	LG&E and KU estimated that 30% of devices were NRD. Event participation in benchmarked programs was generally quite high, ranging from Duke Energy Indiana 79% (2015) to PacifiCorp 100% (when including NRDs; 2013). Event participation for most programs was above 90%: MRES 95% (2014), SDG&E 97% (2011), Duke Energy Carolinas 94% (2015), Duke Energy Indiana 79% (2015), Duke Energy Ohio 85% (2015), and OG&E 95% (2014).

Residential Demand Conservation Program Results

Table 47 shows the residential Demand Conservation Program's achievable load reduction for summer and winter peak. KU's low scenario summer potential is 32 MW, and the high scenario is 96 MW (1% and 3% of the summer peak, respectively). LG&E's low scenario summer potential totaled 33 MW, and the high scenario is 105 MW (1% and 4% of the summer peak, respectively). Winter achievable load reductions were higher than summer, with KU having a winter achievable potential of 84 MW and 114 MW for the low and high scenarios, and LG&E having a winter achievable potential of 78 MW and 106 MW for the low and high scenarios, respectively.

Table 47. Residential Demand Conservation Program Results

Utility	Peak Season	Achievable Load Reduction in 2038*		Percentage Peak Reduction**		Levelized Cost per Year ($/kW-year)***	
		Low	High	Low	High	Low	High
KU	Summer	32	96	1%	3%	$232	$75
	Winter	84	114	6%	8%	$87	$63
LG&E	Summer	33	105	1%	4%	$223	$76
	Winter	78	106	7%	10%	$129	$94

* This load reduction was at generation and includes line losses.
** To determine these values, Cadmus divided the achievable load reduction by the market basis (peak load) for both residential and commercial loads during the top 40 hours (10 four-hour events).
*** We discounted future values using a 6.5% rate, and escalated program and technology costs for future years using a 1.9% inflation rate.;
Levelized costs reflect net present value costs divided by the potential demand savings over the 20-year study horizon. If the Company were to offer a new DR product, or expand an existing product, we expect the cost will be roughly equal to the $/kW-year levelized cost. Cadmus did not compare DR products to the Company's avoided capacity cost, nor did we assess whether an individual product is cost-effective.

To determine the summer low scenario, Cadmus relied on LG&E's and KU's evaluated cooling demand impacts and event participation. The high scenario results indicated that an additional incremental summer load reduction of 65 MW for KU and 72 MW for LG&E is achievable. The two key drivers of the additional potential were the per-unit cooling demand impact and the event participation. LG&E and KU evaluated per-unit cooling impacts of 0.45 kW, compared to a typical 1.0 kW benchmarking value used in the high scenario. One factor contributing to the lower impact was LG&E and KU employing an approximately 33% control strategy, while most benchmarked programs use a 50% control strategy. Additionally, event participation was low compared to benchmarking, with LG&E and KU reporting that 30% of load control switches were NRDs. In the high scenario, Cadmus increased program costs and incentives to limit NRDs and to allow the Company to provide additional incentives to increase the control strategy to 50%.

Small Commercial Demand Conservation Program Assumptions

Table 48 shows assumptions for LG&E's and KU's Small Commercial Demand Conservation Program. The peak load control events and equipment cycling strategy were the same as for the residential program. For the low scenario, Cadmus used the average per-unit central air conditioner demand reduction from Tetra Tech's evaluation of the Company's Small Commercial Demand Conservation program. For the high scenario demand reduction, we used typical values from benchmarking. For the low scenario incentives and program costs, we used LG&E and KU program data.

In the high scenario, Cadmus raised incentive and program costs to align with increased program and event participation. We estimated program participation for the low scenario using LG&E's and KU's current device counts, and used a typical benchmarking value for the high scenario. We determined eligible participants by applying heat pump saturations to small office and small retail sector customer counts. Dividing the LG&E and KU switch counts evenly across residential and small commercial customer counts resulted in 10% program participation, which we used in the low scenario. For event participation in the low scenario, we used LG&E's and KU's estimate for NRDs; and for the high scenario we relied on typical benchmarking.

Table 48. Small Commercial Demand Conservation Program Potential Study Assumptions

Inputs	High Scenario	Low Scenario	Sources or Assumptions
Annual Attrition (%)	3.0%	3.0%	Based on LG&E's and KU's Small Commercial Demand Conservation program evaluation.
Per Customer Impacts (kW)	Central air conditioner: 1.3 kW Water heat: 0.35 kW	Central air conditioner: 0.43 kW Water heat: 0.35 kW	LG&E and KU evaluated savings were 0.43 kW per switch. Benchmarking of similar programs had a range of: 0.4 kW to 1.9 kW: PacifiCorp 1.25 kW per air conditioner and 0.5 kW per water heat (2012), Long Island Power Authority 1.35 kW (2002), Austin Energy 1.4 kW per air conditioner;, Xcel Energy 1.9 kW (2015; Brattle); CPS Energy 0.4 kW per air conditioner (Brattle); FERC 2 kW to 4 kW (2010).
Technology Cost	$150	$150	Based on LG&E and KU data. Similar programs had costs in the range of $140 to $280: MRES $200, PSO $200 plus $80 install, OG&E $200 plus $80 install, PacifiCorp $60 per switch plus $80 install, Xcel Energy $150 per customer (2015).
Program Costs	$60 per participant	$50 per participant	Average non-incentive costs from LG&E and KU data. Accounts for program administrative costs and communications costs for load control devices.
Incentive (annual costs)	$25 per switch	$20 per switch	Low scenario based on LG&E's and KU's impact memo provided to Cadmus in December 2015. High scenario adjusted upward to drive increased participation.
Program Participation	15%	10%	Low scenario allocates LG&E and KU devices counts based on customer counts and results in 10%, which aligns with benchmarking range of 5% to 30%: Texas 5%-10% (2012),

Inputs	High Scenario	Low Scenario	Sources or Assumptions
			PSO 20% (2014), OG&E 15% (2104), PacifiCorp 12.5% to 26% (2013).
Event Participation	95%	70%	LG&E and KU estimated that 30% of devices were NRD. Benchmarked event participation ranged from 90% to 100%: PSO 90% (2014), OG&E 90% (2014), PacifiCorp 100% (2013).

Small Commercial Demand Conservation Program Results

Table 49 shows results from Cadmus' assessment of the Small Commercial Demand Conservation Program's achievable load reduction for summer peak. KU's achievable summer potential is 0.5 MW (0.01% of load) for the low scenario and 2.6 MW (0.1% of summer peak) for the high scenario. LG&E's low scenario summer potential is 0.04 MW, with a high scenario summer potential of 0.1 MW (0.001% and 0.003% of the summer peak, respectively).

Table 49. Small Commercial Demand Conservation Program Results

Utility	Peak Season	Achievable Load Reduction in 2038*		Percentage Peak Reduction**		Levelized Cost per Year ($/kW)***	
		Low	High	Low	High	Low	High
KU	Summer	0.49	2.65	0.015%	0.081%	$278	$86
LG&E	Summer	0.04	0.10	0.001%	0.003%	$304	$140

* This load reduction was at generation and includes line losses.

** To determine these values, Cadmus divided the achievable load reduction the market basis (peak load) for both residential and commercial loads during the top 40 hours (10 four-hour events).

*** We discounted future values using a 6.5% rate, and escalated program and technology costs for future years using a 1.9% inflation rate.

Levelized costs reflect net present value costs divided by the potential demand savings over the 20-year study horizon. If the Company were to offer a new DR product, or expand an existing product, we expect the cost will be roughly equal to the $/kW-year levelized cost. Cadmus did not compare DR products to the Company's avoided capacity cost, nor did we assess whether an individual product is cost-effective.

The small commercial sector had a limited amount of eligible participants with residential-style central air conditioning systems in the small retail and small office segments. This limited customer eligibility results in small achievable potential compared to other programs with larger eligible customer bases. Similar to the residential DLC program, the high scenario includes additional program costs to increase event participation by decreasing NRDs. Cadmus also added additional incentives in the high scenario to increase the air conditioning control strategy to 50%.

Wi-Fi Thermostat Option for Demand Conservation

During four-hour peak events, LG&E and KU control participating residential air conditioning loads by controlling Wi-Fi smart thermostats. Customers must purchase and install an approved device to participate.[20] During peak events, smart thermostats will either increase the temperature set point or cycle the unit to reduce cooling loads. Participants receive a $20 incentive, consisting of $5 per month for each of the four peak months (June through September). In the current plan year, the Company is offering an additional, one-time program enrollment incentive of $25. This is reviewed on an annual basis.

Wi-Fi Thermostat Option Program Assumptions

Table 50 shows assumptions for the Smart Thermostat Program. We determined annual attrition in the high scenario from the draft program evaluation, and used benchmarking for the low scenario. For the low scenario customer demand reduction, Cadmus adjusted the average 0.45 kW impact from the Company's draft evaluation upward to 0.6 kW to reflect benchmarking and the estimated impact range from the program implementer. The high scenario impact of 1.0 kW was typical of benchmarked programs, and was consistent with the program implementer's estimated impact rage of 0.7 kW to 1.5 kW.

We assumed program participation of 1% of single family customers with air conditioning, based on the number of surveyed demand conservation participants who had purchased a programmable thermostat since enrolling (Tetra Tech 2015). Cadmus based the customer support and software hosting costs, along with vendor licensing costs, on benchmarking values from similar smart thermostat pilots. Marketing costs in the high scenario reflect continuing LG&E's and KU's additional incentive, currently offered to new participants.

[20] This program design is often referred to as Bring Your Own Device (BYOD).

Table 50. Wi-Fi Smart Thermostat Option Potential Study Assumptions

Inputs	High Scenario	Low Scenario	Sources or Assumptions
Annual Attrition	1%	5%	Benchmarking range of 2% to 9%: MRES 1%, Western utility 1.5% (2015), Rocky Mountain Power 2% (2010), IPL 3% (2014-2018 plan), Con Edison 3.8% (2012), Avista Utilities 4% (YEAR), BPA Kootenai 5% (pilot), Xcel Energy Colorado 9% (2013, pilot).
Per Customer Impacts	1.0 kW	0.6 kW	Cadmus adjusted LG&E and KU existing DLC program results of 0.45 kW upward to reflect benchmarking. Implementer (Energy Hub) estimated impacts in the range of 0.7 kW to 1.5 kW. DLC program benchmarking ranged from 1.5 kW to 0.62 KW: Duke Indiana 1.04 kW; MRES 1.0 kW (2014), Xcel Energy Minnesota 1.05 kW to 0.62 kW, Hoosier Indiana 0.995 kW (2013), Alliant Energy Iowa 0.75 kW (YEAR), Esource benchmarking report 1.53 kW to 0.75 kW per switch.
Customer Support and Software Hosting	$2.50 per participant	$3.25 per participant	Based on similar Western utility pilot program costs. Low scenario based on costs associated with less than 2,000 participants. Costs per participant decreased with increased participation.
Technology Vendor /Licensing	$30 per participant	$25 per participant	Based on a similar Western utility pilot Wi-Fi program costs, and consistent with Energy Hub estimates for software, licensing, and information technology setup of $25 to $35.
Technology Cost	$0 BYOD	$0 BYOD	A similar Western utility pilot program had cost of $145 for thermostat and $148 installation. Energy Hub provided Wi-Fi thermostats from $120 to $250 with installation costs from $100 to $200.
Marketing Cost	$25 per new participant	$0 per participant	LG&E and KU did not expect to have direct marketing expenses for the program. For the high scenario we used LG&E's and KU's $25 existing enrollment incentive as a proxy. Benchmarking ranged from $10 to $94 per new customer, depending on the program: Con Edison $10 (Cool New York pilot) and DLC thermostats are 3% of total program costs; Tennessee Valley Authority $50 (2011).
Incentive (annual costs)	$25	$20	LG&E's and KU's existing annual incentive was $20. Benchmarked thermostat incentives were: PG&E $25, Xcel Energy Colorado $50 towards purchase, $5 per event, Austin Energy BYOD $85, Con Edison $25. Benchmarked incentives for DLC switches were: PSE $50 for space heat and water heat, Con Edison $10 for room air conditioner and $25 for ResSmart, Entergy Arkansas $25 yearly for 50% cycle and $40 for 100% cycle (YEAR), TVA $55 (potential study), ESource benchmarking $5 to $32. Con Edison bring-your-own-device (BYOD) incentive of $85 for enrollment plus $25 additional rebate (ESource); Orange & Rockland BYOD incentive of $85 for enrollment and $25 for participation the following summer (ESource).

Inputs	High Scenario	Low Scenario	Sources or Assumptions
Eligible Load	100% - DLC participants	100% - DLC participants	Based on assumption that all central air conditioner and heat pump customers and associated loads were eligible for the program.
Program Participation (single family)	1%	1%	Participation was in addition to existing Demand Conservation Program and reflects the surveys with participants that purchased programmable thermostats. Benchmarking included: Xcel Energy Colorado CPA expanded BAU 50% (2014), Xcel Energy Minnesota 55%, Xcel Energy Colorado 38%; Duke Energy North Carolina 15%, NV Energy 16% (2013), Avista Utilities 11.5% (2013), FERC 10% to 30% (2010).
Event Participation	90%	75%	Benchmarking results were: CSU 8.5% opted out at least 1 hour (2005), NV Energy 10% to 13% NRD (YEAR), Company 20% (1990s), Xcel Energy Colorado 54% of tech impact when including opt-out and offline equipment (YEAR); San Diego Gas and Electric (SDGE) 56% overall, with 22% opt-out, 8% signal failure, 17% equipment not in use during event.

Wi-Fi Thermostat Option Program Results

Table 51 shows the Wi-Fi Thermostat Option Program's achievable load reductions for summer peak. Both LG&E and KU had low scenario potential of approximately 2 MW (0.06% of summer peak load) and the high scenario totaled 4 MW (0.1% of summer peak load). Cadmus did not model the winter peak impacts because we included 1% of program participants in the winter potential for the Demand Conservation Program.

Table 51. Wi-Fi Smart Thermostat Option Program Results

Utility	Peak Season	Achievable Load Reduction in 2038*		Percentage Peak Reduction**		Levelized Cost per Year ($/kW)***	
		Low	High	Low	High	Low	High
KU	Summer	2.0	4.0	0.06%	0.1%	$79	$48
LG&E	Summer	1.9	3.8	0.06%	0.1%	$59	$44

* This load reduction was at generation and includes line losses.

** To determine these values, Cadmus divided the achievable load reduction by the market basis (peak load) for residential and commercial loads during the top 40 hours (10 four-hour events).

*** We discounted future values using a 6.5% rate, and escalated program and technology costs for future years using a 1.9% inflation rate.

Levelized costs reflect net present value costs divided by the potential demand savings over the 20-year study horizon. If the Company were to offer a new DR product, or expand an existing product, we expect the cost will be roughly equal to the $/kW-year levelized cost. Cadmus did not compare DR products to the Company's avoided capacity cost, nor did we assess whether an individual product is cost-effective.

The low overall impact was a result of the 1% residential program participation. The program competed with the existing demand conservation program, which has a high level of participation. Additionally, participants were required to supply and install the devices, further limiting program participation. Similar benchmarked programs installed the thermostat for participants in a fully developed program and offered BYOD as an option. BYOD design can also be used for an initial pilot, with the utility then transitioning to provide higher incentives or provide devices in a larger program deployment. Given the program's low levelized cost, transitioning participation away from the demand conservation program to a Wi-Fi- or AMI-based, two-way, communicating thermostat program could present a viable option for the Company.

Residential Time of Day Pricing Program

TOU customers receive a discount on their normal retail rates during non-peak periods in exchange for paying predetermined, premium prices during peak periods. As the peak price has been set in advance, customers maintain some degree of certainty regarding participation costs. TOU participation generally increases when the rate structures lead to larger average bill savings for participating customers. Table 52 shows LG&E and KU pricing tiers, with LG&E having a peak to off-peak price ratio of 4.1 and KU having a ratio of 5.1. LG&E and KU's price ratios were similar to other programs Cadmus reviewed.

Table 52. LG&E and KU TOU Pricing Tiers

	LG&E	KU
Off-Peak $/kWh	$0.0557	$0.0538
On-Peak $/kWh	$0.2271	$0.2728
Price Ratio	**4.1**	**5.1**

Residential Time of Day Pricing Program Assumptions

Table 53 shows assumptions for the Residential TOU Program. Cadmus estimated low and high scenario technical potential using benchmarking from programs with similar peak to off-peak price ratios as those of LG&E and KU. We also based program participation on benchmarking, in addition to a recent price responsiveness survey for a similar TOU program.

Table 53. Residential TOU – Potential Study Assumptions

Inputs	High Scenario	Low Scenario	Sources or Assumptions
Annual Administrative Costs	15%	15%	Cadmus assumed an administrative adder of 15%.
Technology Cost (per new participant)	$210	$210	Benchmarking included: OG&E/PSO $350, TVA $180, PSE $515 including AMI costs. Benchmarking costs were similar to programs with only AMI, with AMI meter and communications estimates ranging from $165 to $220.
Marketing Cost (per new participant)	$30	$25	Cadmus based low scenario marketing costs on one-half full-time equivalent (FTE) of staff time, valued at $50/hour (fully loaded); for the high scenario we added 25% to reflect additional effort.
Incentives (annual costs per participant)	N/A	N/A	Though no customer incentives were offered, customers could have lower bills than on a standard rate.
Communication Costs (per customer per year)	N/A	N/A	Cadmus estimated AMI meter costs to include communications infrastructure.
Overhead: First Costs	$0	$0	This is a standard program development assumption, including necessary internal labor, research, and IT/billing system changes. Cadmus assumed this will be $0 as the TOU program is deployed.
Eligible Load	100%	100%	All residential customers are eligible.
Technical Potential	10%	7%	Benchmarking of summer programs included: Xcel Energy 7.4% (2015), PSO 8% (2014), SMUD 9% (2014), Nevada Energy 10.74% (2015), and OG&E 14%
Program Participation of Eligible Customers	15%	6%	Participation estimates aligned with recent Xcel Energy Minnesota (2015) price responsiveness survey and program benchmarking. Pilot programs had lower penetration as they were not fully deployed: FERC <1% of total residential meters,

Inputs	High Scenario	Low Scenario	Sources or Assumptions
			SMUD 5%, TVA 5%, OG&E 20%, PGE 2% increasing to 40% in 2028.
Event Participation	100%	100%	Event participation was captured in the average load impact.

Residential Time of Day Pricing Program Results

Table 54 shows the Residential Time of Day Pricing Program's achievable load reduction potentials for summer and winter peak. KU's low scenario summer potential is 9 MW, and the high scenario is 33 MW (0.3% and 1% of the summer peak, respectively). LG&E's low scenario summer potential is 7 MW, and the high scenario is 26 MW (0.2% and 0.8% of the summer peak load, respectively). KU's low scenario winter potential is 3 MW, and the high scenario is 10 MW (0.1% and 0.3% of the winter peak, respectively). LG&E's low scenario winter potential is 2 MW, and the high scenario is 7 MW (0.1% and 0.2% of the winter peak load, respectively).

Table 54. Residential Time of Day Pricing Program Results

Utility	Peak Season	Achievable Load Reduction in 2038*		Percentage Peak Reduction**		Levelized Cost per Year ($/kW)***	
		Low	High	Low	High	Low	High
KU	Summer	9	33	0.3%	1.0%	$155	$88
	Winter	3	10	0.1%	0.3%	$549	$314
LG&E	Summer	7	26	0.2%	0.8%	$200	$113
	Winter	2	7	0.1%	0.2%	$766	$432

* This load reduction was at generation and includes line losses.

** To determine these values, Cadmus divided the achievable load reduction by the market basis (peak load) for both residential and commercial loads during the top 40 hours (10 four-hour events).

*** We discounted future values using a 6.5% rate, and escalated program and technology costs for future years using a 1.9% inflation rate.

Levelized costs reflect net present value costs divided by the potential demand savings over the 20-year study horizon. If the Company were to offer a new DR product, or expand an existing product, we expect the cost will be roughly equal to the $/kW-year levelized cost. Cadmus did not compare DR products to the Company's avoided capacity cost, nor did we assess whether an individual product is cost-effective.

Most benchmarked programs showed increased program participation in later years similar to or higher than the high scenario's assumed participation. Initially, participation was limited by the current AMI deployment schedule of 5,000 meters by 2018. For this analysis, Cadmus assumed full AMI meter deployment by 2022. The Detailed Demand Response Results section of this report (specifically Figure 25 and Figure 30 for KU, and Figure 38 and Figure 39 for LG&E) shows program ramp estimates.

Levelized costs for the TOU program were higher than for other programs in this assessment, since $210 of AMI-related costs were attributed to the program.[21]

Residential Critical Peak Pricing

LG&E and KU do not currently offer CPP programs for the residential sector. While the Company TOU programs have been well established, they are now completing pilot phases for many dynamic pricing programs using AMI. With AMI, customers can view energy use data using a web portal or using technology such as in-home displays (IHDs). Most of the benchmarked pilot programs compared results of traditional CPP programs to programs that combine CPP-enabling technologies (e.g., IHDs, programmable communicating thermostats [PCTs]).

CPP with Programmable Communicating Thermostats Versus Without

The OG&E pilot results showed a 38% reduction in demand with PCTs and a 12% reduction without PCTs; the SMUD pilot showed a 26% reduction with an IHD and 22% without. OG&E moved to full implementation of its program, combining DLC (PCTs) with CPP, servings as an example of CPP and DLC programs merging.

Residential Critical Peak Pricing Program Assumptions

Cadmus conducted the CPP analysis as an alternative to the existing TOU program; as such, the results are not additive, but show an alternative to the TOU program, with the Company only implementing one program. Cadmus based all the CPP program assumptions (shown in Table 55) on values we identified through benchmarking.

Table 55. Residential CPP – Potential Study Assumptions

Inputs	Value	Sources or Assumptions
Annual Administrative Costs	15%	Cadmus assumed an administrative adder of 15%.
Technology Cost (per new participant)	$220	Cadmus estimated AMI meter costs as $220. Benchmarking results were: Ameren $165 (2012); FERC $226 for meter plus capital communications costs; PECO $210 (2013), eMeter.com $221 (2010).
Marketing Cost (per new participant)	$25	Cadmus based marketing costs on one-half hour of staff time, valued at $50/hour (fully-loaded).
Incentives (annual costs per participant)	N/A	There were no customer incentives; customers could have a lower bill than on a standard rate.
Communication Costs (per customer per year)	N/A	Cadmus estimated AMI meter costs to include communications infrastructure.
Overhead: First Costs	$100,000	Cadmus assumed one-half the standard cost, divided across LG&E and KU, as the Company already deployed the TOU program. The standard program development assumption—including necessary internal labor,

21 If we exclude AMI costs from the program, summer levelized costs fall below $20 per MW.

Inputs	Value	Sources or Assumptions
		research, and IT/billing system changes—for the TVA potential study was $400,000.
Eligible Load	100%	All residential customers would be eligible.
Technical Potential	12%	Benchmarked results for summer were: PGE 20% reduced for summer pilots without technology with range of 11% to 20%, Pepco DC 13% winter impact. Benchmarked results for winter were: PGE 20% with 4.4 price ratio and a 12% impact for TOU, Pepco DC 13%. Benchmarked results for summer programs without PCTs were: OGE 12%, Green Mountain Power 11% to 14%, TVA 17% (potential study), Sioux Valley 24%.
Program Participation (%)	10%	Pilot programs had lower penetration, as they were not fully deployed. Benchmarked results were: FERC <1%, SMUD 5%, OG&E 20%, PGE 2% increasing to 40% in 2028, TVA 5%.
Event Participation (%)	100%	Event participation was captured in the average load impact.

Residential Critical Peak Pricing Program Results

Table 56 shows the Residential CPP Program's achievable load reduction potential for summer and winter peak. KU's summer potential is 27 MW, and the winter potential is 8 MW (0.8% and 0.6% of the peak loads, respectively). LG&E's summer potential is 21 MW, and the winter achievable potential is 5 MW (0.8% and 0.5% of the peak loads, respectively).

Table 56. Residential CPP Program Results

Utility	Peak Season	Achievable Load Reduction in 2038*	Percentage Peak Reduction**	Levelized Cost per Year ($/kW)***
KU	Summer	27	0.8%	$98
	Winter	8	0.6%	$206
LG&E	Summer	21	0.8%	$114
	Winter	5	0.5%	$283

* This load reduction was at generation and includes line losses.

** To determine these values, Cadmus divided the achievable load reduction by the market basis (peak load) for both residential and commercial loads during the top 40 hours (10 four-hour events).

*** We discounted future values using a 6.5% rate, and escalated program and technology costs for future years using a 1.9% inflation rate.

Levelized costs reflect net present value costs divided by the potential demand savings over the 20-year study horizon. If the Company were to offer a new DR product, or expand an existing product, we expect the cost will be roughly equal to the $/kW-year levelized cost. Cadmus did not compare DR products to the Company's avoided capacity cost, nor did we assess whether an individual product is cost-effective.

Initially, program participation was limited by the current AMI deployment schedule of 5,000 meters by 2018. For this analysis, Cadmus assumed full AMI meter deployment by 2022. The Detailed Demand

Response Results section shows program ramp rates (specifically, this is Figure 31 for KU and Figure 40 for LG&E).

Load Curtailment Program

In load curtailment programs, there are established contractual arrangements between the utility, a third-party aggregator implementing the program, and utility nonresidential customers agreeing to curtail their operations (in whole or part) for a predetermined period when requested by the utility. In most cases for the benchmarked programs, the utility requires mandatory participation or liquidated damage payment for nonparticipation once customers enroll in the program; however, contract terms limited the number of curtailment requests—both in total and on a daily basis.

Generally, the Company did not pay customers for individual events, but provided compensation through a fixed annual amount per kW of pledged curtailable load or through a rate discount. Typically, the program contracts require customers to curtail their connected loads by a set percentage or to a predetermined level. Similar benchmarked programs often involve long-term contracts, with penalties for noncompliance ranging from simply dropping the customer from the program to more punitive actions, such as requiring the customer to repay the utility for the committed (but not curtailed) energy at market rates.

Load Curtailment Program Assumptions

Table 57 shows the assumptions for the Load Curtailment Program. Program implementation costs, such as new participant enablement costs, incentives, and vendor costs, are from LG&E's and KU's existing program data. Cadmus based all other program assumptions on benchmarking results.

Table 57. Load Curtailment Program – Potential Study Assumptions

Inputs	Value	Sources or Assumptions
Annual Administrative Costs	5%	Cadmus assumed an administrative adder of 5%.
Enablement per new participant	$13,000	The value matches the enablement per customer site for EnerNOC's Commercial Demand Conservation Program.
Incentives (annual costs per participating kW)	High scenario: $50 per kW Low scenario: $25 per kW	LG&E and KU customers received up to $25 per kW curtailed (incentives varied by actual kW reduction and number of events). Benchmarking results were: PSO $32 per kW and an additional 5% bonus to customers who participated in all events, CenterPoint Energy $35 per kW, Duke Energy $57 per kW, for many benchmarked programs, a customer-specific incentive was determined based on the amount of kW pledged to the program.
Overhead: First Costs	$0	Cadmus did not include this cost, as LG&E and KU have an existing program. The program startup fee from a third-party implementer for a similar program was typically $100,000.
Vendor Costs	$233,000 per year	This matches the EnerNOC annual subscription fee for the Commercial Demand Conservation Program plus a portfolio management fee.

Inputs	Value	Sources or Assumptions
Technical Potential for Load Shed	30%	Customers shed between 27% and 34% of load for day-of and day-ahead events, respectively (2010 and 2011 Statewide Aggregator Demand Response Programs: Final Report, Christensen Associates). LBNL data centers 12% (2012).
Program Participation	High scenario: 30% Low scenario: 20%	Customer surveys from benchmarked programs revealed that between 25% and 30% of customers are willing to participate in a curtailment program, given incentives levels of $30 and $50, respectively. Benchmarked participation rates from 4.5% for Mid-American Curtailment Program to 30% for Georgia Power and Indiana Michigan Power Company. Assessment of Industrial Load for Demand Response across the Western Interconnect varied by segment from 10-40% (Oak Ridge National Laboratory).
Event Participation	95%	Range of PJM and MidAm programs (90%-95%).
Participation Criteria (eligibility)	200 kW	Cadmus assumed a minimum demand of 200 kW as an eligibility criterion.

Commercial Load Curtailment Program Results

Table 58 shows the Commercial Load Curtailment Program achievable load reduction for summer and winter peak. KU's low scenario summer potential is 27 MW, and the high scenario summer potential is 40 MW (0.8% and 1.2% of summer peak, respectively). LG&E's low scenario summer potential is 27 MW, and the high scenario summer potential is 41 MW (0.8% and 1.3% of the summer peak, respectively). KU's low scenario winter potential is 18 MW, and the high scenario is 27 MW (0.5% and 0.8% of winter peak, respectively). LG&E's low scenario winter potential is 22 MW, and the high scenario winter potential totaled is 34 MW (0.7% and 1.0% of the winter peak, respectively).

Table 58. Commercial Load Curtailment Results

Utility	Peak Season	Achievable Load Reduction in 2038*		Percentage Peak Reduction**		Levelized Cost per Year ($/kW)***	
		Low	High	Low	High	Low	High
KU	Summer	27	40	0.8%	1.2%	$55	$80
	Winter	18	27	0.5%	0.8%	$69	$92
LG&E	Summer	27	41	0.8%	1.3%	$52	$77
	Winter	22	34	0.7%	1.0%	$58	$82

* This load reduction was at generation and includes line losses.
** To determine these values, Cadmus divided the achievable load reduction by the market basis (peak load) for both residential and commercial loads during the top 40 hours (10 four-hour events).
*** We discounted future values using a 6.5% rate, and escalated program and technology costs for future years using a 1.9% inflation rate.
Levelized costs reflect net present value costs divided by the potential demand savings over the 20-year study horizon. If the Company were to offer a new DR product, or expand an existing product, we expect the cost will be roughly equal to the $/kW-year levelized cost. Cadmus did not compare DR products to the Company's avoided capacity cost, nor did we assess whether an individual product is cost-effective.

The high scenario for summer peak, with program participation increasing by 20% to 30% compared to the low scenario, indicated additional achievable load reduction of 15 MW for KU and 14 MW for LG&E. While Cadmus doubled the high scenario incentives to increase participation, levelized costs were still reasonable, at $81 per kW and $78 per kW for KU and LG&E, respectively.

Conclusions and Recommendations

Cadmus' findings reveal that there is additional potential in the existing KU and LG&E DLC programs, as the high scenario results across the portfolio of demand response programs provides additional demand reduction of 353 MW for the Company, combined (as was shown above in Figure 9). The high scenario portfolios result in an estimated 5% summer peak load reduction for KU and a 6% summer peak load reduction for LG&E. Given the additional potential in the high scenario, we offer the following recommendations for the existing demand response programs:

- ***Consider modifying the residential DLC program to Wi-Fi- or AMI-controlled thermostats.*** This shift would allow the control strategy to increase from between 35% and 40% to 50%, a rate typical for cooling programs. Two-way communications can be used to identify NRD, improving event participation beyond the existing 70%.
- ***Consider expanding the residential TOU program beyond the pilot size.*** Currently evaluated participation or results were not available for the TOU program, and AMI deployment plans are limited to 5,000 units for each territory in 2018. In this analysis, Cadmus assumed full AMI deployment by 2022.
- ***Consider implementing a residential winter DLC pilot program.*** The analysis revealed significant potential for winter peak reduction in the low scenario, of 6% for KU and 8% for LG&E. The

Company could target Wi-Fi thermostat participants for the pilot, providing a more accurate estimate of the demand impacts.

- ***Consider combining the DLC program with a pricing program (TOU or CPP) or a peak time rebate.*** Programs that combine pricing with enabling technology have achieved better results than those that are implemented separately. Additionally, more utilities are considering peak-time rebates as an option to TOU or CPP programs.

Detailed Demand Response Results

KU Results by Year

Figure 25 through Figure 33 show achievable load reduction by year for KU demand response programs.

Figure 25. KU Residential DLC Summer Results by Year

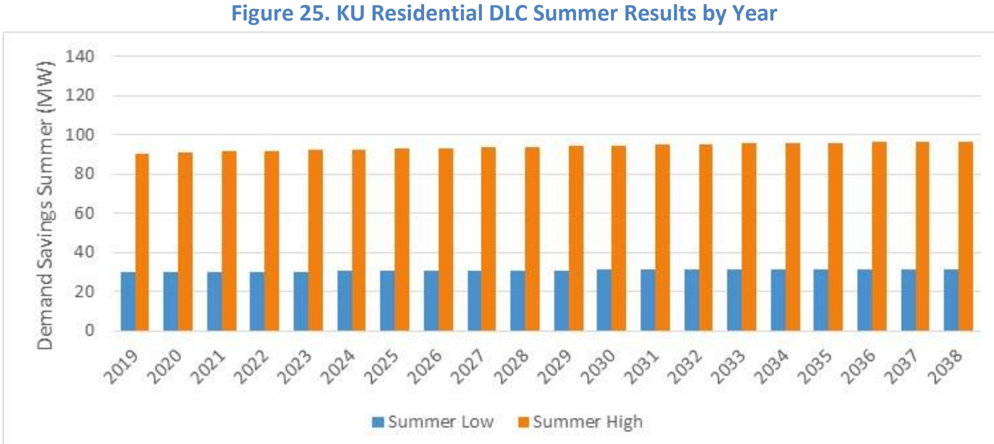


Figure 26. KU Residential DLC Winter Results by Year

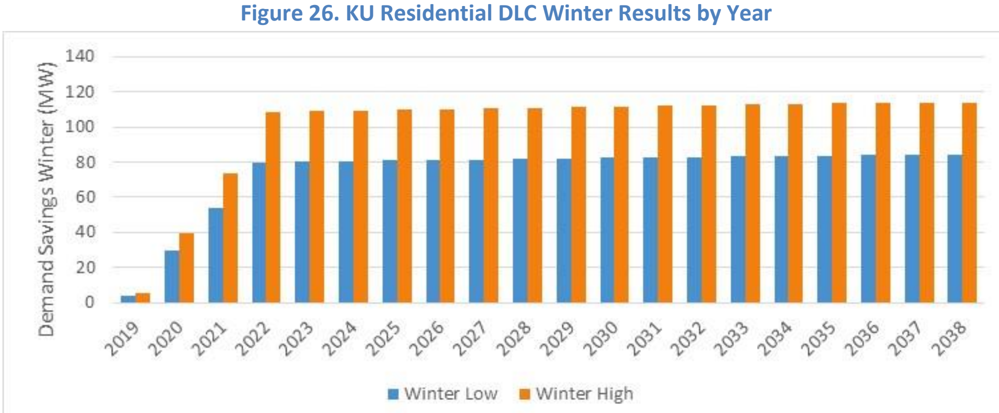


Figure 27. KU Commercial DLC Summer Results by Year

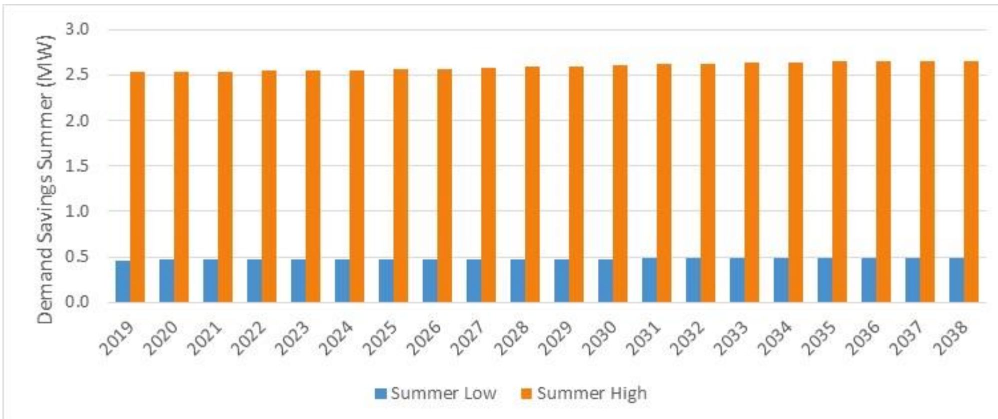


Figure 28. KU Residential Wi-Fi Smart Thermostat Summer Results by Year

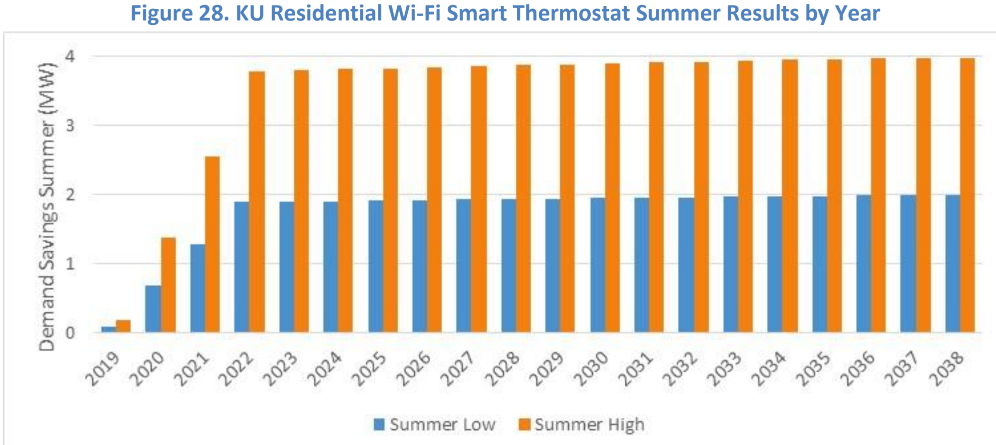


Figure 29. KU Residential TOU Summer Results by Year

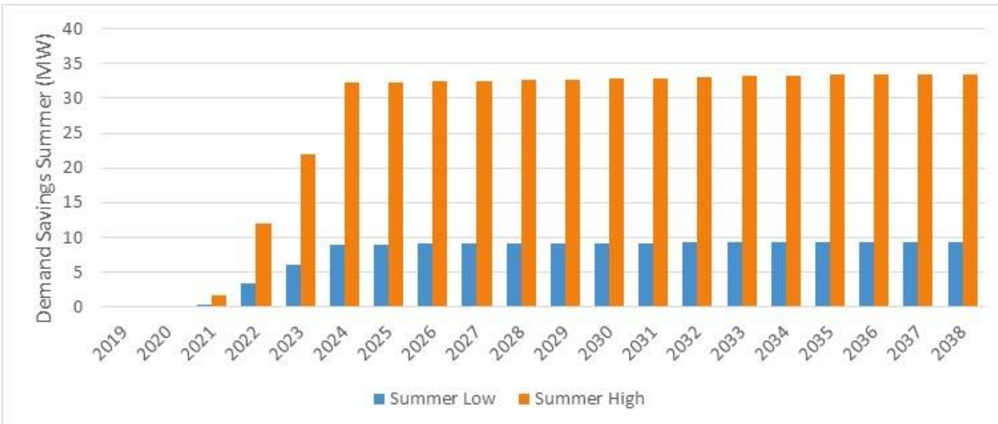


Figure 30. KU Residential TOU Winter Results by Year

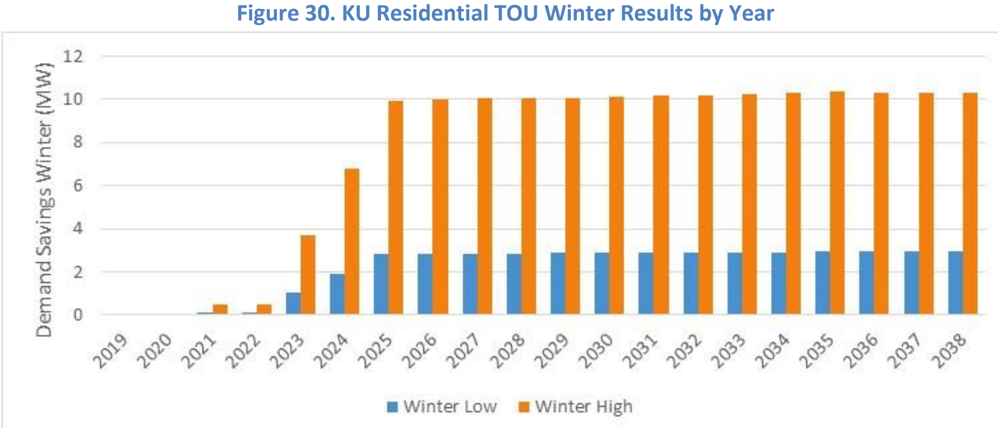


Figure 31. KU Residential CPP Summer and Winter Results by Year

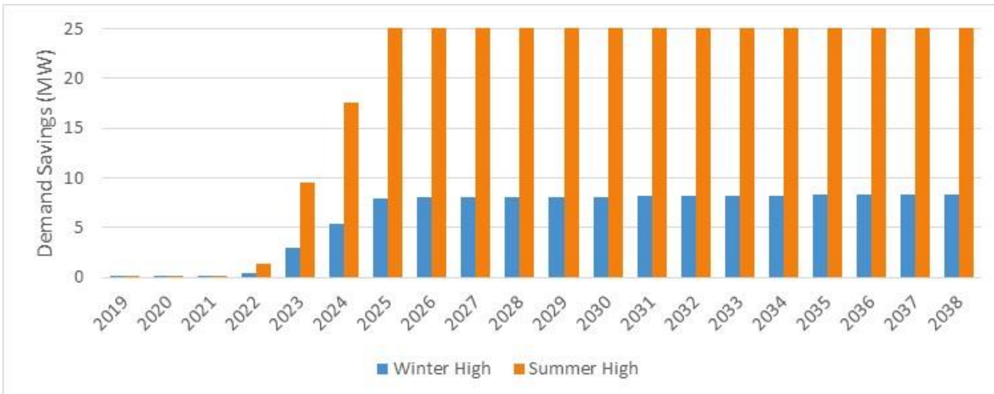


Figure 32. KU Commercial Curtailment Summer Results by Year

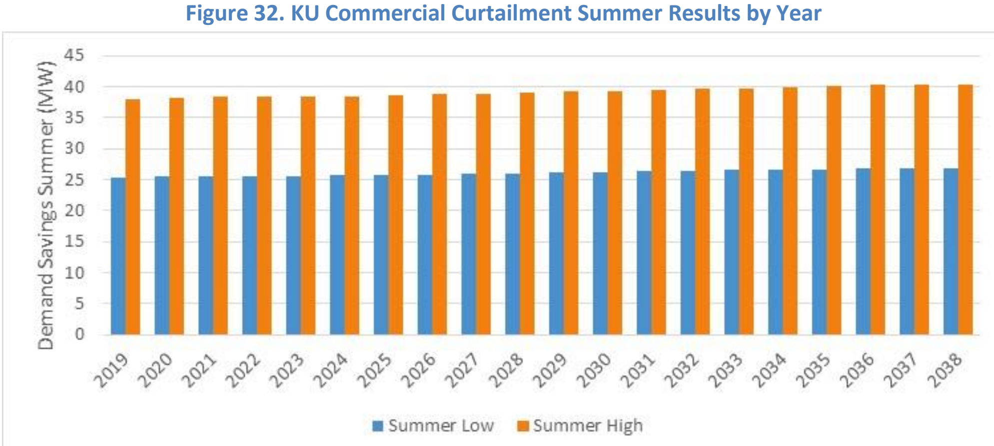
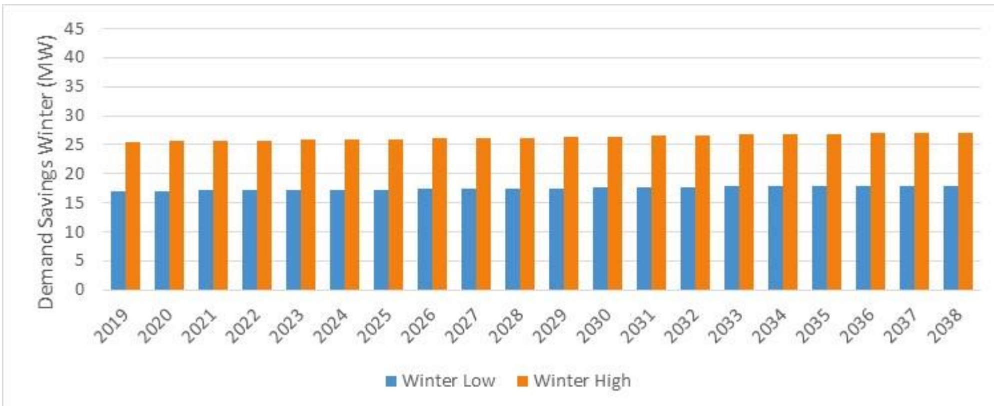


Figure 33. KU Commercial Curtailment Winter Results by Year



LG&E Results by Year

Figure 34 through Figure 42 show achievable load reduction by year for LG&E demand response programs.

Figure 34. LG&E Residential DLC Summer Results by Year

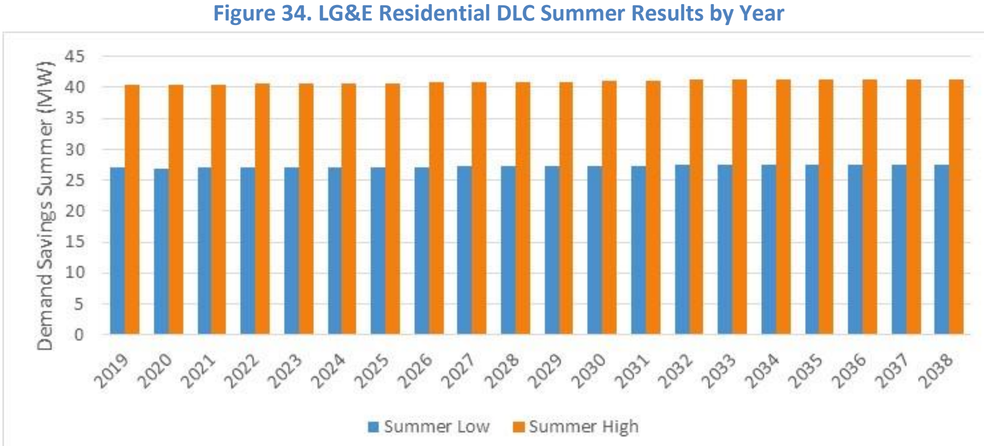


Figure 35. LG&E Residential DLC Winter Results by Year

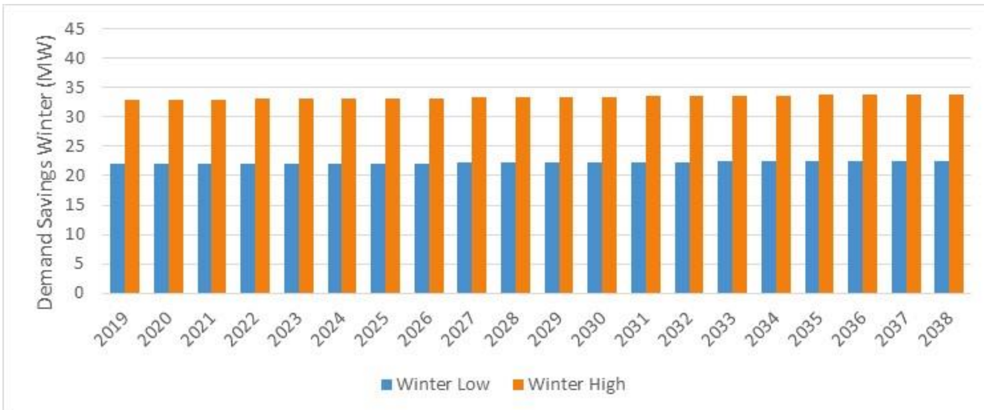


Figure 36. LG&E Commercial DLC Summer Results by Year

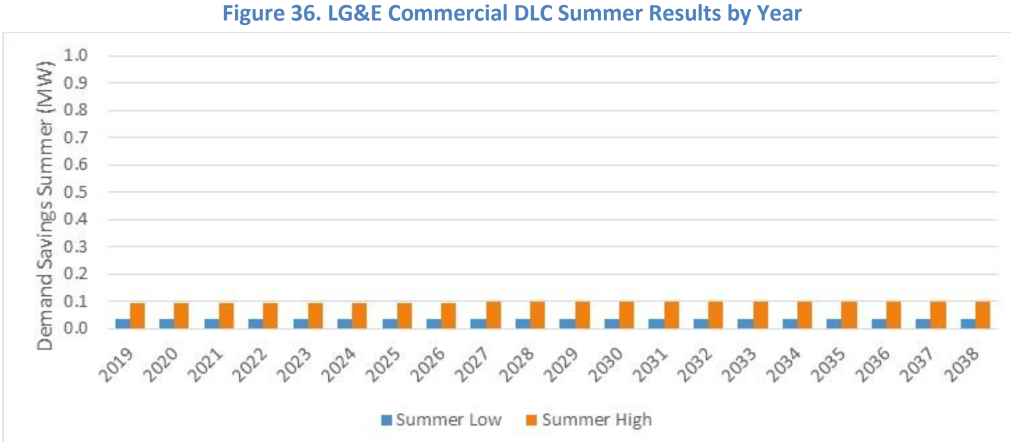


Figure 37. LG&E Residential Wi-Fi 33 Smart Thermostat Summer Results by Year

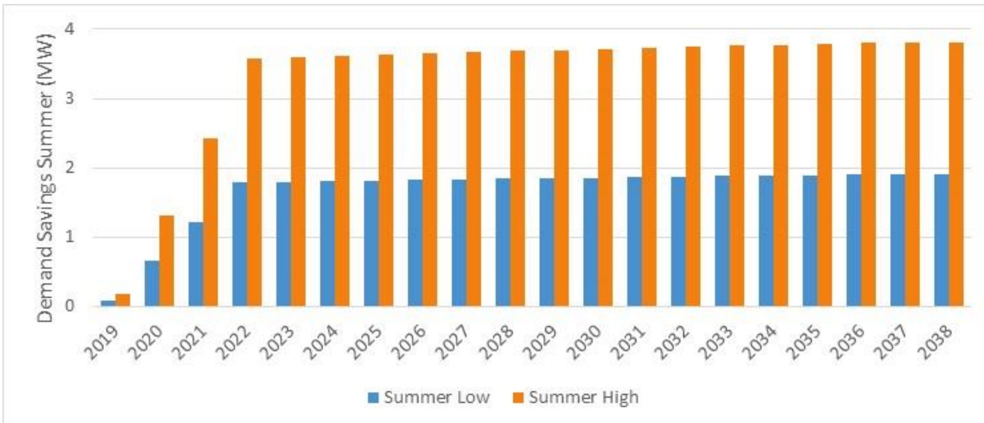


Figure 38. LG&E Residential TOU Summer Results by Year

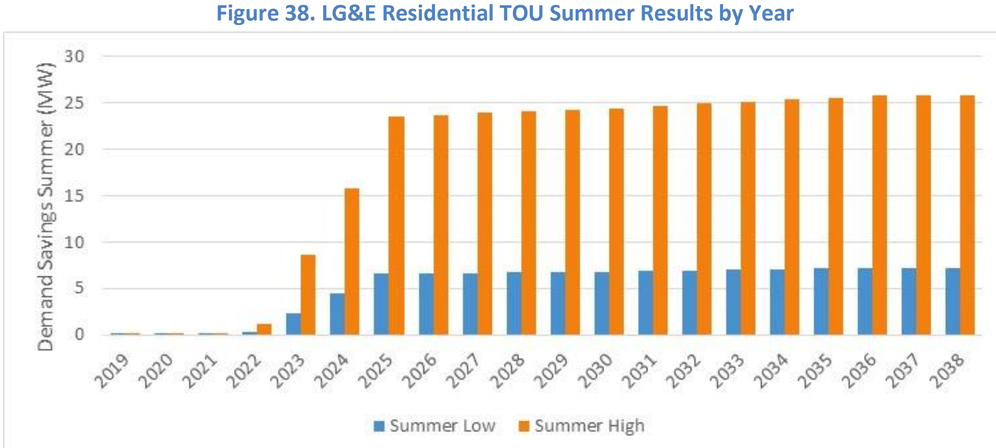


Figure 39. LG&E Residential TOU Winter Results by Year

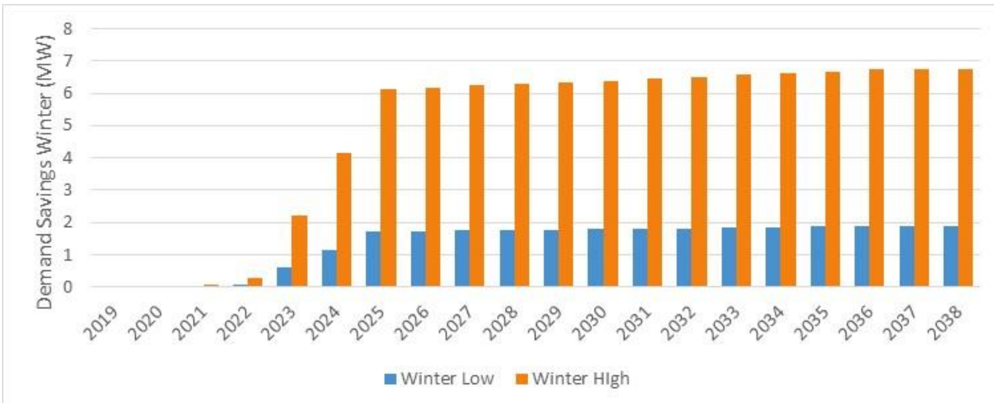


Figure 40. LG&E Residential CPP Summer and Winter Results by Year

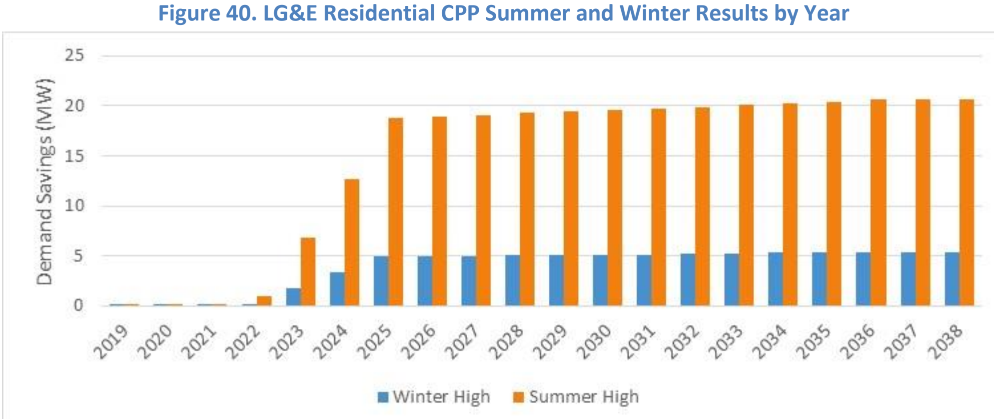


Figure 41. LG&E Commercial Curtailment Summer Results by Year

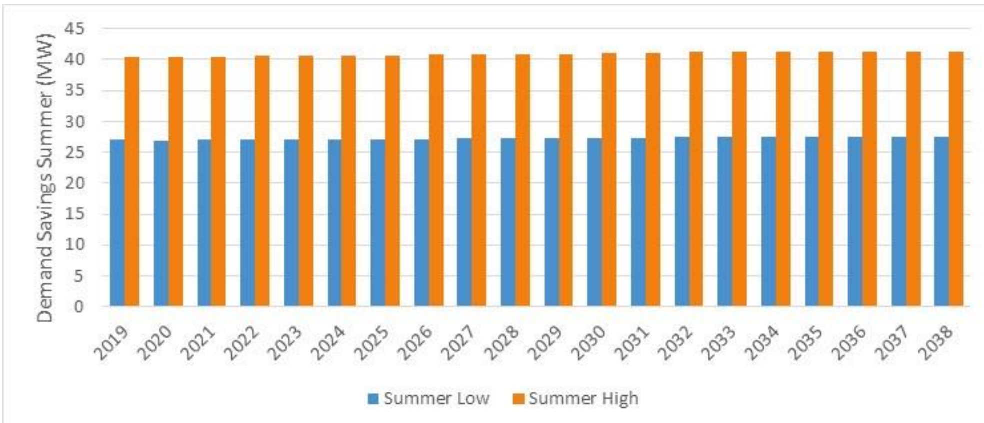
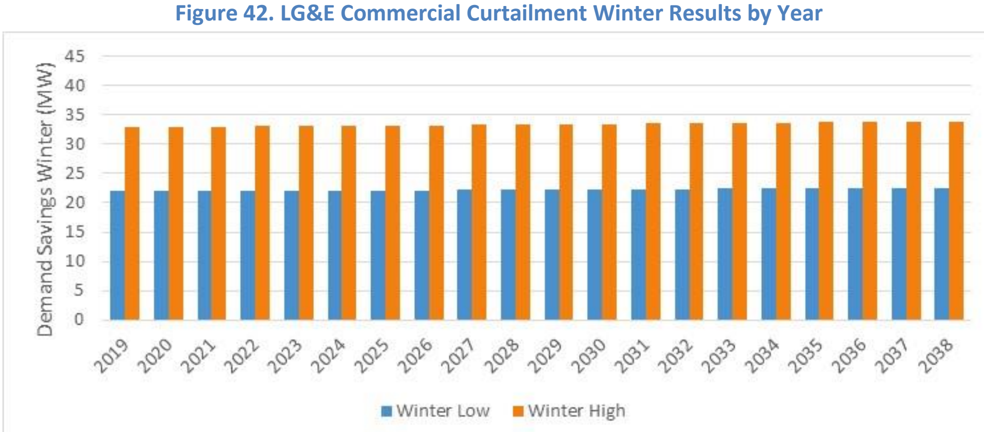


Figure 42. LG&E Commercial Curtailment Winter Results by Year



Glossary of Terms

GLOSSARY OF TERMS[22]

Benefit-cost ratio: The ratio (as determined by the Total Resource Cost test) of the discounted total benefits of the program to the discounted total costs over some specified time period.

Cost-effectiveness: A measure of the relevant economic effects resulting from the implementation of an energy efficiency measure. If the benefits of this selection outweigh its cost, the measure is said to be cost-effective.

Economic potential: Refers to the subset of the technical potential that is economically cost-effective as compared to conventional supply-side energy resources.

End use: A category of equipment or service that consumes energy (e.g., lighting, refrigeration, heating, process heat).

End Use Consumption: Used for the residential sector, the per unit energy consumption for a given end use, expressed in annual kWh per unit. Also referred to as unit energy consumption (UEC).

End-use intensities: Used in the commercial and institution sectors, the energy consumption per square foot for a given end use, expressed in annual kWh per square foot per unit.

Energy efficiency: The use of less energy to provide the same or an improved level of service to the energy consumer in an economically efficient way.

Effective useful life: An estimate of the duration of savings from a measure. EUL is estimated through various means, including median number of years that the energy efficiency measures installed under a program are still in place and operable. Also, EUL is sometimes defined as the date at which 50% of Installed units are still in place and operational.

Levelized cost: The result of a computational approach used to compare the cost of different projects or technologies. The stream of each project's net costs is discounted to a single year using a discount rate (creating a net present value) and divided by the project's expected lifetime output (megawatt-hours or MCF).

Lost opportunity: Refers to an efficiency measure or efficiency program that seeks to encourage the selection of higher-efficiency equipment or building practices than would typically be chosen at the time of a purchase or design decision.

[22] These definitions draw heavily from the NAPEE Guide for Conducting Energy Efficiency Potential Studies and the State and Local Energy Efficiency Action Network, 2012. *Energy Efficiency Program Impact Evaluation Guide*. Prepared by Steven R. Schiller, Schiller Consulting, Inc., www.seeaction.energy.gov

Achievable potential: The amount of energy use that efficiency can realistically be expected to displace assuming different incentive scenarios (e.g., providing end-users with payments for the entire incremental cost of more efficiency equipment).

Measure: Installation of equipment, subsystems, or systems, or modification of equipment, subsystems, systems, or operations on the customer side of the meter, in order to improve energy efficiency.

Portfolio: Either (a) a collection of similar programs addressing the same market, technology, or mechanisms or (b) the set of all programs conducted by one organization.

Potential study: A quantitative analysis of the amount of energy savings that either exists, is cost-effective, or could potentially be realized through the implementation of energy efficient programs and policies.

Program: A group of projects with similar characteristics and installed in similar applications.

Program potential: Energy efficiency potential possible given specific program funding levels and designs.

Retrofit: Refers to an efficiency measure or efficiency program that seeks to encourage the replacement of functional equipment before the end of its operating life with higher efficiency units (also called "early-retirement") or the installation of additional controls, equipment, or materials in existing facilities for purposes of reducing energy consumption (e.g., increased insulation, lighting occupancy controls, economizer ventilation systems).

Technical potential: The theoretical maximum amount of energy use that could be displaced by efficiency, disregarding all non-engineering constraints such as cost-effectiveness and the willingness of end-users to adopt the efficiency measures.

Total resource cost (TRC) test: A cost-effectiveness test that assesses the impacts of a portfolio of energy efficiency initiatives on the economy at large. The test compares the present value of costs of efficiency for all members of society (including costs to participants and program administrators) compared to the present value of benefits, including avoided energy supply and demand costs.

Utility cost test (UCT): A cost-effectiveness test that evaluates the impacts of the efficiency initiatives on the administrator or energy system. It compares the administrator costs (e.g. incentives paid, staff labor, marketing, printing, data tracking, and report) to accrued benefits, including avoided energy and demand supply costs. Also referred to as the Program Administrator Cost Test (PACT).