Seattle City Light

December 2015

2016 Conservation Potential Assessment

Seattle City Light is dedicated to exceeding our customers' expectations in producing and delivering environmentally responsible, safe, low-cost and reliable power.

Larry Weis, General Manager and CEO

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Definition of Terms

aMW	Average Megawatt
AC	Air Conditioning
ACS	American Community Survey
B/C	Benefit-Cost
C&I	Commercial and Industrial
C&S	Codes and Standards
CAC	Central Air Conditioning
CBECS	Commercial Building Energy Consumption Survey
CBSA	Commercial Building Stock Assessment
CFL	Compact Fluorescent Lamp
CPA	Conservation Potential Assessment
Council	Northwest Power and Conservation Council
DEER	Database of Energy Efficient Resources
DOE	Department of Energy
DSM	Demand-side Management
ECM	Energy Conservation Measure
EIA	Energy Information Administration
EISA	Energy Independence and Security Act of 2007
EPA	Environmental Protection Agency
EUIs	Energy Use Intensities
EUL	Effective Useful Life
HVAC	Heating Ventilation and Air Conditioning
I-937	Initiative 937
IRP	Integrated Resource Plan
kW	Kilowatt
kWh	Kilowatt-hour
LCOE	Levelized Cost of Energy
LED	Light-emitting Diode
MW	Megawatt
MWh	Megawatt-hour
NEEA	Northwest Energy Efficiency Alliance

NPV	Net Present Value
O&M	Operations and Maintenance
PV	Present Value
RCW	Revised Code of Washington
REC	Renewable Energy Credit
RECS	Residential Energy Consumption Survey
RTF	Regional Technical Forum
RUL	Remaining Useful Life
SCL	Seattle City Light
SEEM	Simple Energy and Enthalpy Model
SWH	Solar Water Heating
T&D	Transmission and Distribution
TRC	Total Resource Cost
UCT	Utility Cost Test
UEC	Unit Energy Consumption
UES	Unit Energy Savings
WAC	Washington Administrative Code
WH	Water Heating
WHF	Waste Heat Factor

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1. Executive Summary

1.1. Overview

Seattle City Light (City Light) engaged Cadmus to complete a conservation potential assessment (CPA) to produce rigorous estimates of the magnitude, timing, and costs of conservation resources within City Light's service territory over the next 20 years, beginning in 2016. This study identifies all cost-effective conservation potential in each of City Light's major customer sectors, including residential, commercial, industrial, and street lighting. The study accomplishes the following objectives:

1. Fulfills statutory requirements of Chapter 194-37 of the Washington Administrative Code (WAC), Energy Independence. This WAC requires City Light to identify all achievable, cost-effective, conservation potential for the upcoming 10 years.[1] City Light's public biennial conservation target should be no less than the pro rata share of conservation potential over the first 10 years. Study estimates will inform City Light's targets for the 2016–2017 biennium.
2. Provides inputs into City Light's Integrated Resource Plan (IRP). Completed every two years, City Light's IRP determines the mixture of supply-side and conservation resources required over the next 20 years to meet customer demand. The IRP requires a thorough analysis of conservation potential to properly assess the reliability, cost, risk, and environmental impacts of different power generation resource portfolios.

This study relies on City Light-specific data, compiled from City Light's oversample of the Residential Building Stock Assessment (RBSA), Commercial Building Stock Assessment (CBSA), and other regional data sources. This study uses a methodology consistent with the Northwest Power and Conservation Council's (the Council) 7th Power Plan and incorporates savings and costs for all energy conservation measures (ECMs) in the Council's draft 7th Power Plan workbook and active Regional Technical Forum (RTF) unit energy savings (UES) workbooks.[2]

1.2. Scope of Analysis

This study includes analysis of four sectors. Within most of these sectors, Cadmus considered multiple market segments, construction vintages (new and existing), and end uses. Specifically, the analysis addressed the following sectors:

- **Residential:** Single-family and three types of multifamily homes (low-rise, mid-rise, and high-rise).
- **Commercial:** Eighteen major commercial segments, including offices, retail, and other segments. The commercial sector includes enterprise data centers.

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1 Washington State Legislature. Energy Independence Act, Washington Administrative Code Chapter 194-37. Last updated March 6, 2015. http://apps.leg.wa.gov/WAC/default.aspx?cite=194-37&full=true#194-37-080

2 RCW 19.285.040 requires CPAs to use methodologies consistent with those used by the Council's most recent regional power plan. While the 7th Power Plan has not been adopted as of the completion of this study, the Council has released the final 7th Power Plan supply curve workbooks. These workbooks provide the most up-to-date analysis of ECMs, accounting for recent changes in codes and standards and in market changes.

- **Industrial:** Energy-intensive manufacturing and primarily process-driven customers.
- **Street Lighting:** City-owned street lighting.

For each sector, Cadmus developed a baseline end-use load forecast that assumes no new future programmatic conservation. The baseline forecast largely captures savings from building energy codes, equipment standards, and other naturally occurring market forces. Cadmus calculated energy efficiency potential estimates by assessing the impact of each ECM on this baseline forecast. Therefore, conservation potential estimates presented in this report represent savings *beyond* naturally occurring savings.

This study considers three types of energy efficiency potential:

- **Technical potential** includes all technically feasible conservation measures, regardless of costs and market barriers. This is the theoretical upper bound of available conservation potential, estimated after accounting for technical constraints. The Methodology section of this report includes a description of the data sources Cadmus used to estimate these technical constraints for individual measures.
- **Economic potential** represents a subset of technical potential, consisting only of measures meeting cost-effectiveness criteria based on City Light's avoided supply costs for delivering electricity. Adherent to WAC 194-37-070, Cadmus uses the Total Resource Cost (TRC) to identify cost-effective measures using a method consistent with the Council. The Economic Potential section of this report includes a detailed description of costs and benefits considered.
- **Achievable economic potential** represents the portion of economic potential that might be reasonably achievable in the course of the 20-year study horizon, given the possibility of market barriers impeding customer adoption. Ramp rates, defined as the acquisition rates for specific technologies, determine the amount of economic potential considered achievable on an annual basis, beginning in 2016. The Achievable Economic Potential section includes discussion of Cadmus' approach to estimating achievable potential.

1.3. Summary of Results

1.3.1. Achievable Economic Potential

Study results indicate a 10-year achievable conservation potential within City Light's service territory of 128.1 aMW (cumulative in 2025). For the 2016–2017 biennium, City Light is establishing a conservation target of 25.6 aMW, or the equivalent of 20% of the cumulative, 10-year conservation potential. Table 1.1 summarizes achievable conservation potential for each sector—all values include line losses (at generator).

TABLE 1.1 CUMULATIVE ACHIEVABLE POTENTIAL BY SECTOR				
Sector	**Achievable Economic Potential - aMW**			
	Two-Year (2016-2017)	**10-Year (2016-2025)**	**20-Year (2016-2035)**	**20% of 10-Year Potential**
Residential	5.9	36.5	48.6	7.3
Commercial	10.3	82.2	145.9	16.4
Industrial	1.7	7.1	8.8	1.4
Street Lighting	2.2	2.2	2.2	0.4
Total	**20.1**	**128.1**	**205.4**	**25.6**

The commercial sector accounts for approximately 71% of cumulative, 20-year achievable potential, while the residential and industrial sectors account for roughly 24% and 4% of the 20-year potential, respectively. The street lighting sector accounts for approximately 1% of cumulative achievable potential. The Energy Efficiency Potential section of this report provides detailed estimates of achievable economic potential for each sector.

Figure 1.1 shows incremental achievable potential over the study horizon. Approximately 63% of the 20-year conservation potential is achieved within the first 10 years, partly due to the mixture of measures with high conservation potential. Cadmus determined the acquisition rate of incremental achievable potential by each measure's ramp rate, applying ramp rates developed by the Council for the 7th Power Plan, and modified the application of these ramp rates based on Seattle's historic conservation achievements.

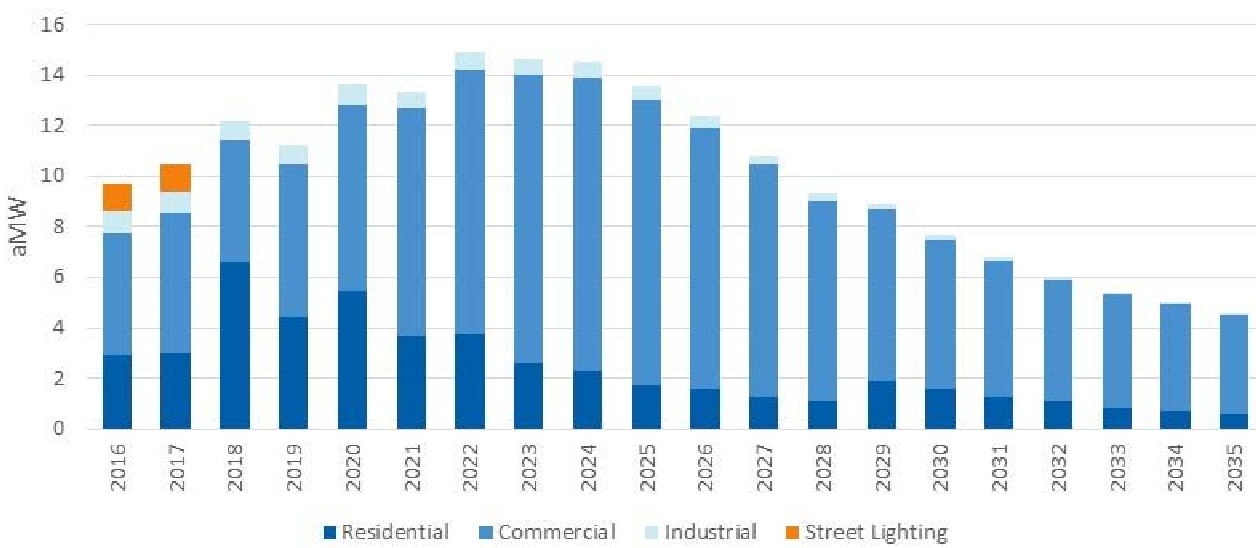

Figure 1.1 Incremental Achievable Economic Potential

Lighting measures in both the residential and commercial sectors account for a large portion of savings, and many of these measures have relatively aggressive ramp rates, which are based on the availability of measures and utilities' program accomplishments. The Achievable Economic Potential section includes discussions of Cadmus' application of ramp rates to determine incremental achievable potential, and the Energy Efficiency Potential section includes descriptions of top-saving measures in each sector.

Figure 1.2 shows the amount of achievable potential at different, levelized cost thresholds. Levelized costs represent the present value of the incremental measure cost (including reinstallations over the course of the study horizon) divided by the net present value of energy savings over the study horizon.[3] Levelized costs of conserved energy often are used to compare the cost of conservation to supply-side resources.

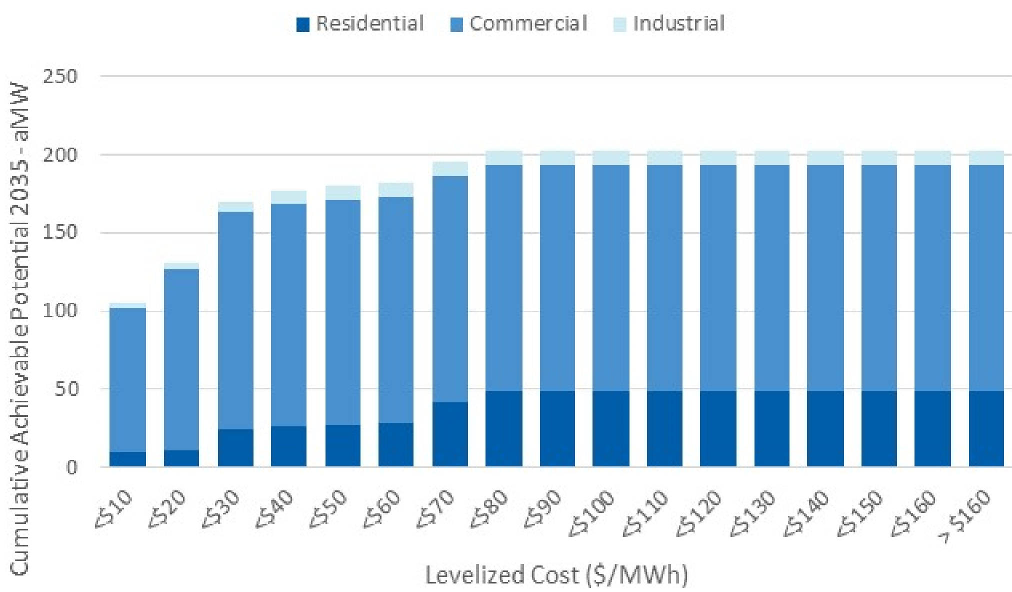

Figure 1.2 Conservation Supply Curves

Potential conservation remains a low-cost resource: study results indicate roughly 100 aMW of conservation is achievable at a cost of less than $10/MWh. This roughly accounts for 50% of the 20-year cumulative achievable potential. Approximately 88% of the 20-year cumulative achievable potential costs less than $40/MWh, levelized.

1.3.2. Technical and Economic Potential

1.3.2.1. Technical Potential

Table 1.2 shows the cumulative technical potential for each sector in 2035. Overall, study results identify 362 aMW of technically feasible conservation potential by 2035, which is equivalent to 27% of forecasted baseline sales.

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3 The Economic Potential section of this report includes a detailed discussion of the levelized cost calculation, including the methodology and components.

TABLE 1.2 TECHNICAL POTENTIAL			
Sector	**Baseline Sales - 20 Year (aMW)**	**Technical Potential - 20 Year (aMW)**	**Technical Potential as % of Baseline Sales**
Residential	370	121	33%
Commercial	740	226	31%
Industrial	208	12	6%
Street Lighting	10	2	22%
Total	**1,328**	**362**	**27%**

The commercial, residential, and industrial sectors account for 63%, 34%, and 3%, respectively, of 20-year technical potential, while street lighting accounts for approximately 1%.

1.3.2.2. Economic Potential

Cadmus developed two estimates of economic potential to reflect different avoided cost forecasts. Per WAC 194-37-070, City Light must consider estimates of conservation potential using avoided costs equal to a forecast of regional market prices. Regional market price forecasts, however, do not necessarily reflect costs associated with City Light's preferred portfolio of generation resources selected in City Light's previous IRP. To assess the impact of avoided cost uncertainty, Cadmus prepared estimates of economic and achievable potential using the following two avoided cost forecasts:

- **Market**: These avoided costs, based on market prices, assume the marginal generating unit is a conventional combined cycle turbine. Twenty-year levelized avoided costs for this scenario equal approximately $41/MWh.
- **IRP**: These avoided costs assume City Light builds a "blended" renewable resource in 2022. The "blended" renewable resource reflects a mixture of wind, cogeneration, and solar PV selected in City Light's preferred portfolio from the 2012 IRP. Twenty-year levelized avoided costs for this scenario equal approximately $63/MWh.

Both scenarios include adders for renewable energy credits, carbon offsets, and a 10% conservation credit.[4] Each scenario also accounts for forecasts of avoided transmission and distribution (T&D) costs. As City Light is not capacity constrained, these scenarios do not include costs associated with adding generation capacity. Figure 1.3 shows avoided cost forecasts for each scenario.

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[4] The Northwest Power Act requires the Bonneville Power Administration to provide a 10% benefit to conservation over other sources of electric generation. Northwest Power Act, Section 3(4)(D), 94 Stat. 2699.

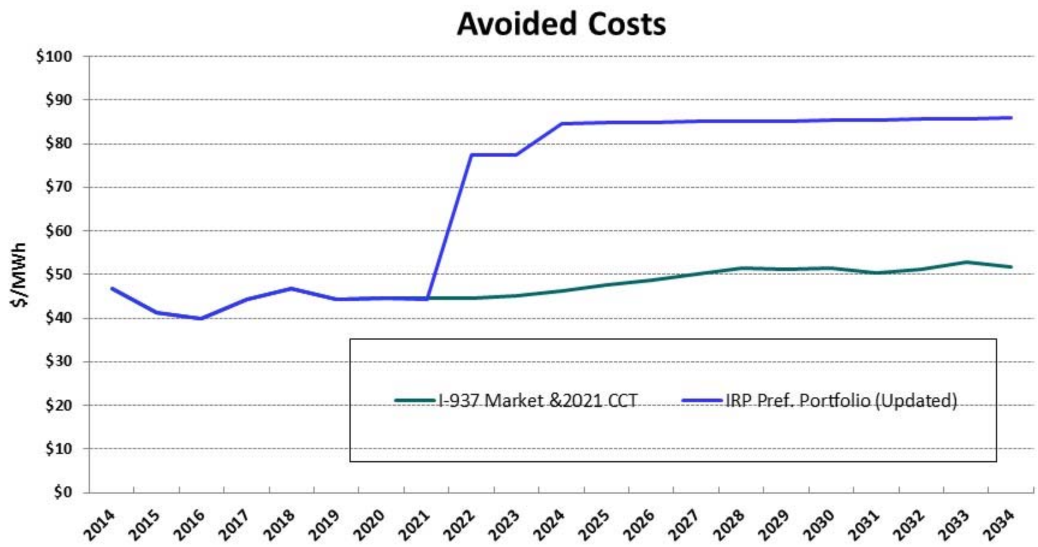

Figure 1.3 Avoided Cost Forecasts

Table 1.3 summarizes cumulative economic potential in 2035 for each avoided cost scenario. Higher avoided costs have a larger impact in the residential sector, compared to the commercial and industrial (C&I) sectors. This partly results from a lower proportion of cost-effective residential savings in the market price avoided-cost scenario. Using market price avoided costs, approximately 35% of technical potential proves cost-effective in the residential sector, compared to 79% and 69% in the commercial and industrial sectors, respectively.

TABLE 1.3 ECONOMIC POTENTIAL – MARKET AND IRP SCENARIOS

Sector	Market Avoided Costs			IRP Avoided Costs		
	Economic Potential - 20 Year (MWh)	EP as % of Baseline Sales	EP as % of Technical Potential	Economic Potential - 20 Year (MWh)	EP as % of Baseline Sales	EP as % of Technical Potential
Residential	42	11%	35%	59	16%	49%
Commercial	179	24%	79%	186	25%	82%
Industrial	8	4%	69%	10	5%	84%
Street Lighting	2	22%	100%	2	22%	100%
Total	**231**	**17%**	**64%**	**257**	**19%**	**71%**

With avoided costs from City Light's IRP preferred scenario, approximately 49% of technical potential proves cost-effective (a 41% increase) in the residential sector, compared to 82% in the commercial sector (a 4% increase) and 84% in the industrial sector (a 22% increase). Figure 1.4 shows the cumulative economic potential for each scenario in 2035 relative to forecasted baseline sales, by sector.

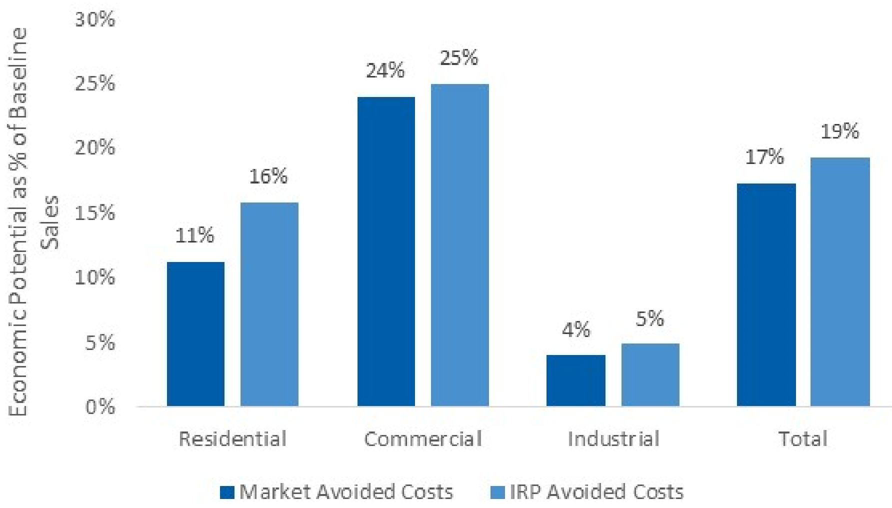

Figure 1.4 Economic Potential as a Fraction of Baseline Sales – 2035 Cumulative

Estimates of achievable potential and City Light's conservation target are based on the IRP avoided cost scenario. WAC 194-070 requires City Light to test multiple scenarios and to incorporate risk into estimates of achievable potential. By using the higher IRP avoided-cost scenario instead of a scenario based on avoided costs that reflect market prices, Cadmus accounts for risk associated with market price forecasts.

1.3.3. Comparison with the 2013 Conservation Potential Assessment

The 2016 Conservation Potential Assessment (CPA) differs from the 2013 CPA in several key ways—some global and some sector-specific; these differences affect estimates of conservation potential. Table 1.4 shows cumulative 20-year technical, economic, and achievable potential, expressed as a fraction of baseline sales, from the 2016 CPA and the 2013 CPA.

TABLE 1.4 CUMULATIVE 20-YEAR POTENTIAL AS A FRACTION OF BASELINE SALES—2016 AND 2013 CPAS						
Sector	**Technical Potential—20-Year MWh as a % of Baseline**		**Economic Potential—20-Year MWh as a % of Baseline**		**Achievable Potential—20-Year MWh as a % of Baseline**	
	2016 CPA	**2013 CPA**	**2016 CPA**	**2013 CPA**	**2016 CPA**	**2013 CPA**
Residential	33%	38%	16%	23%	13%	15%
Commercial	31%	30%	25%	24%	20%	19%
Industrial	6%	13%	5%	10%	4%	8%
Street Lighting	22%	44%	22%	42%	22%	42%
Total	**27%**	**31%**	**19%**	**23%**	**15%**	**17%**

The following key changes account for differences in estimated potential for the 2016 and 2013 CPAs:

- **Residential:** The 2016 CPA indicates lower residential technical, economic, and achievable potential as a fraction of baseline sales than those indicated in the 2013 CPA. This largely results from reduced savings potential for home electronics measures. While efficient home electronics accounted for 22% of economic potential in the 2013 CPA, the end-use group only accounts for 7% of economic potential in the 2016 CPA. Compared to the 2013 CPA, the 2016 CPA found a higher proportion of home electronics are already efficient, which contributed to lower savings potential.
- **Commercial:** The 2016 CPA indicates commercial potential as a fraction of baseline sales comparable to the 2013 CPA. The 2016 CPA potential savings, however, derive from a different mixture of measures than those used in the 2013 CPA. For example, water-heating measures accounted for 11% of the 20-year economic potential in the 2013 CPA; in the 2016 CPA, they account for roughly 2% of economic potential. This decrease is due to lower assumed savings for tank type water heaters and reduced water heater baseline consumption.
- **Industrial:** The 2016 CPA indicates significantly lower industrial achievable economic potential as a fraction of baseline sales (4%) than does the 2013 CPA (8%). This primarily results from program accomplishments. City Light achieved approximately 30,000 MWh savings in the industrial sector from 2013 through 2014 and expects projects completed in 2015 will contribute an additional 10,000 MWh savings. This 40,000 MWh savings is equivalent to approximately 40% of the estimated 20-year industrial potential identified in the 2013 CPA.
- **Street Lighting:** The 2016 CPA indicates street lighting potential roughly 50% lower than estimated potential in the 2013 CPA. This decrease in potential results from the City of Seattle’s recent accomplishments.

While the 2013 and 2016 CPAs provide estimates of potential relative to baseline sales, the 2016 CPA indicates lower absolute estimates of technical and economic potential. This primarily results from City Light’s lower residential and commercial baseline forecasts. Table 1.5 summarizes 20-year, cumulative, technical potential and baseline sales in the 2016 and 2013 CPAs.

TABLE 1.5 20-YEAR TECHNICAL POTENTIAL—2016 AND 2013 CPAS

Sector	2016 CPA			2013 CPA		
	Baseline Sales - 20 Year	Technical Potential - 20 Year	TP as % Baseline Sales	Baseline Sales - 20 Year	Technical Potential - 20 Year	TP as % Baseline Sales
Residential	372	121	33%	408	157	38%
Commercial	740	226	31%	880	268	30%
Industrial	208	12	6%	152	20	13%
Street Lighting	10	2	22%	10	4	44%
Total	**1,330**	**362**	**27%**	**1,450**	**450**	**31%**

In the 2016 CPA, 20-year baseline residential and commercial sales are 8% and 16% lower, respectively, than in the 2013 CPA. Overall, the 2016 CPA 20-year baselines are approximately 8% lower than in the 2013 CPA. . The decrease in baseline consumption reflects City Light's most recent load forecast and significantly affects estimates of technical potential —20-year technical potential is nearly 20% lower in the 2016 CPA than in the 2013 CPA. Much of this decrease stems from the drop in baseline forecasts—for instance, commercial technical potential as a fraction of baseline sales is roughly the same in the 2013 and 2016 assessments, but the absolute technical potential is approximately 16% lower in the 2016 assessment (the same as the decrease in the baseline forecast).

A lower portion of technical potential results from cost-effective ECMs in the 2016 CPA, compared to the 2013 CPA. Table 1.6 summarizes 20-year cumulative economic potential for the market price scenario in the 2016 and the 2013 CPAs.[5]

[5] Table 1.6 compares estimates for the market price scenario instead of the IRP scenario, as the 2013 CPA reported estimates of economic and achievable potential for the market price scenario. Use of IRP-preferred avoided costs as the primary avoided cost scenario is a key change for the 2015 CPA.

TABLE 1.6 20-YEAR CUMULATIVE ECONOMIC POTENTIAL—2016 AND 2013 CPAS

Sector	2016 CPA—Market Avoided Costs			2013 CPA		
	Economic Potential - 20 Year (MWh)	EP as % of Baseline Sales	EP as % of Technical Potential	Economic Potential - 20 Year (MWh)	EP as % of Baseline Sales	EP as % of Technical Potential
Residential	42	11%	35%	95	23%	61%
Commercial	179	24%	79%	216	24%	81%
Industrial	8	4%	69%	15	10%	75%
Street Lighting	2	22%	100%	4	42%	96%
Total	**231**	**17%**	**64%**	**330**	**23%**	**73%**

The market price avoided cost scenario produces economic potential equivalent to 64% of technical potential in the 2016 CPA, compared to 73% in the 2013 CPA. The drop in economic potential primarily occurs in the residential sector, where economic potential represents 35% of technical potential, compared to 61% in the 2013 CPA. This decrease does not result from a change in avoided costs; rather it is driven primarily by the different mixture of top-saving measures in the residential sector.

The Comparison with the 2013 Conservation Potential Assessment section of this report includes a sector-by-sector comparison to City Light's last CPA.

1.4. Organization of this Report

This report presents the study's finding in two volumes. Volume I (this document) presents the methodologies and findings, and Volume II contains the appendices and provides detailed study results and supplemental materials.

Volume I includes the following sections:

- **Methodology** provides an overview of the methodology Cadmus used to estimate technical, economic, and achievable economic potential. This section includes discussion of Cadmus' approach to the following:
  - **Developing Baseline Forecasts** provides an overview of Cadmus' approach to produce baseline end use forecasts for each sector.
  - **Measure Characterization** describes Cadmus' approach for developing a database of energy conservation measures, from which we derived estimates of conservation potential. This section discusses how Cadmus adapted measure data from the draft 7th Power Plan, RTF, and other sources for this study.
  - **Estimating Conservation Potential** discusses assumptions and the underlying equations used to calculate technical, economic, and achievable economic potential.
- **Baseline Forecasts** provides detailed sector-level results for Cadmus' baseline end use forecasts.
- **Energy Efficiency Potential** provides detailed sector, segment, and end use specific estimates of conservation potential, as well as discussion of the top-saving measures in each sector.

Volume II includes the following sections:

- Appendix A: Washington Initiative 937 (I-937) Compliance Documentation
- Appendix B: Crosswalk with the Northwest Power and Conservation Council's Draft 7th Power Plan
- Appendix C: Baseline Data
- Appendix D: Energy Efficiency Measure Descriptions
- Appendix E: Detailed Assumptions and Energy Efficiency Potential
- Appendix F: Measure Details
- Appendix G: Indoor Agriculture Methodology
- Appendix H: Comparison to Draft 7th Power Plan

2. Methodology

2.1. Overview of Methodology

Estimating conservation potential draws upon a sequential analysis of various ECMs in terms of technical feasibility (technical potential), cost-effectiveness (economic potential), and expected market acceptance, considering normal barriers possibly impeding measure implementation (achievable economic potential).

Cadmus' assessment took the following primary steps:

- ***Baseline forecasting:*** Determining 20-year future energy consumption by sector, market segment, and end use. The study calibrated the base year, 2015, to City Light's sector load forecasts. Baseline forecasts presented in this report include Cadmus' estimated impacts of naturally occurring potential.[6]
- ***Estimation of technical potential:*** Estimating technical potential, based on alternative forecasts that reflect technical impacts of specific energy efficiency measures.
- ***Estimation of economic potential:*** Estimating economic potential, based on alternative forecasts that reflect technical impacts of cost-effective ECMs.
- ***Estimation of achievable economic potential:*** Achievable economic potential, calculated by applying ramp rates and an achievability percentage to the economic potential (as this section describes in detail).

This approach offered two advantages:

- First, savings estimates would be driven by a baseline calibrated to City Light's forecasted sales (2015 through 2035). Other approaches may simply generate the total potential by summing estimated impacts of individual measures, which can result in total savings estimates representing unrealistically high or low baseline sales percentages.
- Second, the approach maintained consistency among all assumptions underlying the baseline and alternative (technical, economic, and achievable technical) forecasts. The alternative forecasts changed relevant inputs at the end-use level to reflect ECM impacts. As estimated savings represented the difference between baseline and alternative forecasts, they could be directly attributed to specific changes made to analysis inputs.

Cadmus' general methodology can be best described as a combined "top-down/bottom-up" approach. As shown in Figure 2.1, the top-down component began with the most current load forecast, adjusting for building codes, equipment efficiency standards, and market trends the forecast did not account for, and then disaggregated this into its constituent customer sector, customer segment, and end-use components. The bottom-up component considered potential technical impacts of various ECMs and practices on each end use. Impacts could then be estimated, based on engineering calculations and accounting for fuel shares, current market saturations, technical feasibility, and costs.

6 Cadmus' baseline forecast accounted for codes and standards not embedded in City Light's load forecast. Due to these adjustments, 2035 baseline sales presented in this report may not match City Light's official load forecast.

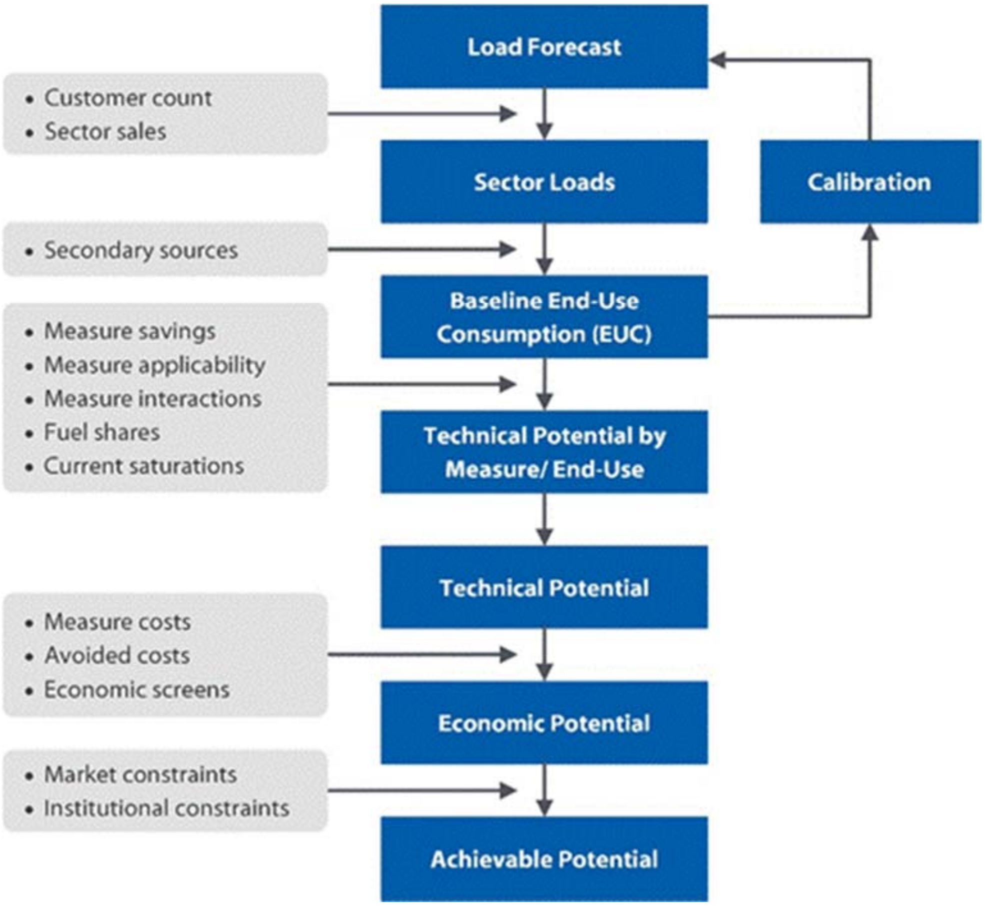

Figure 2.1 General Methodology for Assessment of Conservation Potential

2.2. Developing Baseline Forecasts

City Light's sector-level sales and customer forecasts provided the basis for assessing energy efficiency potential. Prior to estimating potential, the study disaggregated sector-level load forecasts by customer segment (business, dwelling, or facility types), building vintage (existing structures and new construction), and end uses (all applicable end uses in each customer sector and segment).

The first step in developing the baseline forecasts determined the appropriate customer segments within each sector. Designations drew upon categories available in some key data sources used in the study, primarily City Light's nonresidential customer database for the C&I sectors and the U.S. Census Bureau's American Community Survey for the residential sector, followed by mapping appropriate end uses to relevant customer segments.

Once appropriate customer segments and end uses had been determined for each sector, the study produced the baseline end-use forecasts, based on integration of current and forecasted customer counts with key market and equipment usage data. For the commercial and residential sectors, calculating total baseline annual consumption for each end use in each customer segment using the following equation:

$$EUSE_{ij} = \Sigma_e\ ACCTS_i * UPA_i * SAT_{ij} * FSH_{ij} * ESH_{ije} * EUI_{ije}$$

Where:

$EUSE_{ij}$ =	total energy consumption for end use *j* in customer segment *i*
$ACCTS_i$ =	the number of accounts/customers in customer segment *i*
UPA_i =	units per account in customer segment *i* (UPA_i generally equaling the average square feet per customer in commercial segments, and 1.0 in residential dwellings, assessed at the whole-home level)
SAT_{ij} =	the share of customers in customer segment *i* with end use *j*
FSH_{ij} =	the share of end use *j* of customer segment *i* served by electricity
ESH_{ije} =	the market share of efficiency level *e* in equipment for customer segment and end use *ij*
EUI_{ije} =	end-use intensity: energy consumption per unit (per square foot for commercial) for the electric equipment configuration *ije*

For each sector, total annual consumption could be determined as the sum of *EUSEij* across the end uses and customer segments. Ensuring accuracy of the baseline forecasts depended on the calibration of end-use model estimates of total consumption to City Light's forecasted sales from 2015 through 2035.

Consistent with other conservation potential studies, and commensurate with industrial end-use consumption data (which varied widely in quality), allocating the industrial sector's loads to end uses in various segments drew upon data available from the DOE's Energy Information Administration.[7] Street lighting loads were allocated based on City Light's data regarding the number of fixtures present in their service territory.

2.2.1. Derivation of End-Use Consumption

Estimates of end-use energy consumption by segment, end use, and efficiency level (EUI_{ije}) provided one of the most important components in developing a baseline forecast.

In the residential sector, the study based estimates on unit energy consumption, representing annual energy consumption associated with an end use (represented by a specific type of equipment, such as a central air conditioner or heat pump).

For the commercial sector, the study treated consumption estimates as end-use intensities, representing annual energy consumption per square foot served. The accuracy of these estimates proved critical: they had to account for weather and other factors, described below, driving the differences between various segments.

For the industrial sector, end-use energy consumption represented total annual industry consumption by end use, as allocated by the secondary data described above.

7 U.S. Department of Energy, Energy Information Administration. *Manufacturing Energy Consumption Survey*. 2006.

2.3. Measure Characterization

As technical potential drew upon an alternative forecast, reflecting installation of all technically feasible measures, selecting appropriate ECMs to include in this study posed a central concern. To alleviate that concern and to arrive at the most robust set of appropriate measures, Cadmus developed a comprehensive database of technical and market data for ECMs; these applied to all end uses in various market segments. This database included the following measures:

- All measures included in the Council's Draft 7th Northwest Power Plan conservation supply curve workbooks;[8]
- Active RTF UES Measures;[9] and
- Particular technologies City Lights identified as relevant to the study, such as enterprise data centers, indoor agriculture and street lighting measures.

Cadmus only included Council and RTF measures applicable to sectors and market segments within City Light's service territory. For example, the study did not characterize measures for the agriculture sector or for the residential manufactured home segment as these represented a small fraction of City Light's customer mix.

Cadmus also excluded measures previously included in the Council's 6th Power Plan but explicitly excluded from the 7th Power Plan, as shown by the residential and commercial measures in Table 2.1.

TABLE 2.1 EXCLUDED MEASURES

Residential	Efficient electric water heater tank
Residential	TVs
Residential	Set-top boxes
Commercial	HVAC controls commissioning & optimization
Commercial	Sign lighting
Commercial	Roof insulation on re-roof

Source: Conservation Resources Advisory Committee meeting. Conservation Supply Curve Development and Issues. Presented by Charlie Grist, Tina Jayaweera and Kevin Smit. October 3, 2014. Available online at: http://www.nwcouncil.org/media/7147288/Res-Ag-CRAC-100314_final.pdf; http://wwwnwcouncil.org/media/7147807/Com-Ind-CRAC-100314_final.pdf

The approach excluded efficient residential electric water heaters, ENERGY STAR televisions, and ENERGY set-top boxes due to high levels of naturally occurring savings. In the commercial sector, the new strategic energy management measure incorporated HVAC controls commissioning and optimization, solid-state lighting captured sign lighting, and roof insulation produced limited cost-effective savings.

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8 Conservation Supply Curve Workbooks. Available online at: https://www.nwcouncil.org/energy/powerplan/7/technical. Accessed April 8, 2015.

9 RTF UES Measures. Available online at: http://rtf.nwcouncil.org/measures/Default.asp. Accessed April 8, 2015.

Cadmus added measures not included in the 7th Power Plan , but for which the RTF developed UES workbooks For the residential sector, these included the following:

- ENERGY STAR room air conditioners
- LED holiday lights
- Residential refrigerator and freezer decommissioning
- Interior fluorescent high-performance T8 lamps

In the commercial sector, additional RTF measures included:

- Commercial refrigerator and freezer decommissioning
- Efficient commercial ice makers

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

- ***High-efficiency equipment measures.*** These measures directly affect end-use equipment (e.g., high-efficiency domestic water heaters), which follow normal replacement patterns based on expected lifetimes.

- ***Non-equipment (retrofit) measures.*** These measures affect end-use consumption without replacing end-use equipment (e.g., insulation). Such measures do not include timing constraints from equipment turnover (except for new construction) and should be considered discretionary as savings can be acquired at any point over the planning horizon.

Relevant inputs follow for each measure type.

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, accounting for differences in labor rates by region, urban versus rural areas, and other variables.
- ***Technical feasibility:*** the percentage of buildings where customers can install this measure, accounting for physical constraints.
- ***Measure life*****:** the expected life of the measure equipment.

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 is technically feasible to install. This equals 1.0 minus the current saturation of the measure.
- ***Measure competition*****:** for mutually exclusive measures, accounting for the percentage of each measure likely installed (to avoid double-counting savings).
- ***Measure interaction*****:** accounting for end-use interactions (e.g., a decrease in lighting power density causing heating loads to increase).

Cadmus derived these inputs from various sources, though primarily from the following:

- Northwest Energy Efficiency Alliance's (NEEA) CBSA, including City Lights' oversample;
- NEEA's RBSA;
- The Council's 7th Power Plan supply curve workbooks; and
- The RTF's UES measure workbooks.

For many equipment and non-equipment inputs, Cadmus reviewed a variety of sources. To determine which source to use for this study, we developed the following hierarchy for costs and savings:

- The Council's 7th Power Plan supply curve workbooks;
- RTF UES measure workbooks;
- The Council's 6th Power Plan supply curve workbooks; and
- Various secondary sources, such as American Council for an Energy-Efficient Economy work papers, SEEM building simulations, or various technical reference manuals.

Cadmus also developed a hierarchy to determine the source for various applicability factors, such as the technical feasibility and the percent incomplete. This hierarchy differed slightly for residential and commercial measure lists. Generally, the study sought to achieve 90% confidence ± 10% precision for each estimate.

For residential estimates, Cadmus relied on City Lights' oversample within NEEA's RBSA. If the City Lights subset included an insufficient sample to achieve 90% confidence ±10% precision for a given estimate, we derived estimates from the sample of Puget Sound-area customers (e.g., City Light, Puget Sound Energy, Snohomish Public Utility District, and Tacoma Power) found in the RBSA. If we could not calculate applicability factors from NEEA's RBSA, we used applicability factors included in the Council's 7th Power Plan workbooks. These estimates reflected averages for the Northwest region and were not necessarily specific to City Lights' service territory.

For the commercial sector, Cadmus first used the subset of City Lights customers, including City Lights' and the Bonneville Power Administration's oversample in NEEA's CBSA. If NEEA's CBSA had an insufficient number of customers to achieve estimates with 80% confidence ± 20% precision for a given building type, Cadmus developed estimates from the sample of urban buildings within the regional CBSA data. If NEEA's CBSA did not include sufficient data to estimate an applicability factor for a given measure, Cadmus relied on factors included in the Council's 7th Power Plan supply curve workbooks.

Table 2.2 lists the primary sources referenced in this study, per data input.

TABLE 2.2 KEY MEASURE DATA SOURCES

Data	Residential Source	Commercial Source	Industrial Source
Energy savings	7th Power Plan supply curve workbooks; RTF; 6th Power Plan supply curve workbooks; Cadmus research	7th Power Plan supply curve workbooks; RTF; 6th Power Plan supply curve workbooks; Cadmus research	7th Power Plan supply curve workbooks; RTF; 6th Power Plan supply curve workbooks; DOE Industrial Assessment Center database; Cadmus research
Equipment and labor costs	7th Power Plan supply curve workbooks; RTF; 6th Power Plan supply curve workbooks; Cadmus research	7th Power Plan supply curve workbooks; RTF; 6th Power Plan supply curve workbooks; Cadmus research	7th Power Plan supply curve workbooks; RTF; 6th Power Plan supply curve workbooks; DOE's Industrial Assessment Center database; Cadmus research
Measure life	7th Power Plan supply curve workbooks; RTF; 6th Power Plan supply curve workbooks; Cadmus research	7th Power Plan supply curve workbooks; RTF; 6th Power Plan supply curve workbooks; Cadmus research	7th Power Plan supply curve workbooks; RTF; 6th Power Plan supply curve workbooks; DOE's Industrial Assessment Center database; Cadmus research
Technical feasibility	NEEA RBSA; Cadmus research	NEEA CBSA; Cadmus research	Cadmus research; Industrial Council data; NEEA Industrial Facilities Site Assessment (IFSA)
Percent incomplete	NEEA RBSA; City Lights program accomplishments; Cadmus research	NEEA CBSA; City Lights program accomplishments; Cadmus research	Cadmus research; Industrial Council data; NEEA IFSA
Measure interaction	7th Power Plan supply curve workbooks; RTF; 6th Power Plan supply curve workbooks; Cadmus research	7th Power Plan supply curve workbooks; RTF; 6th Power Plan supply curve workbooks; Cadmus research	Cadmus research

Specific sources for individual measures can be found in the "source" columns of the accompanying workbooks.

2.3.1. Incorporating Codes and Standards

Cadmus' assessment accounted for changes in codes and standards over the planning horizon. These changes affected customers' energy-consumption patterns and behaviors, but determined which energy efficiency measures would continue to produce savings over minimum requirements. Cadmus captured current efficiency requirements, including those enacted but not yet in effect.

Cadmus did not attempt to predict how energy codes and standards might change in the future. Rather, the study only factored in legislation that had already been enacted—notably, the Energy Independence and Security Act (EISA) provisions slated to take effect over the course of the analysis. EISA requires that general service lighting become approximately 30% more efficient than current incandescent technology, with standards phased in by wattage from 2012 to 2014. In addition, EISA includes a backstop provision that requires even higher-efficiency technologies beginning in 2020.

Cadmus explicitly accounted for several other pending federal codes and standards. For the residential sector, these included appliance, HVAC, and water-heating standards. For the commercial sector, these included appliance, HVAC, lighting, motor, and water-heating standards. Figure 2.2 provides a comprehensive list of equipment standards considered in this study. [10] Bars indicate the year in which a new equipment standard will be enacted—some products will be subject to multiple standards over the planning horizon.

To ensure accurate assessment of the remaining potential, Cadmus accounted for the effects of future standards. Based on a strict interpretation of the legislation, we assumed customers would replace affected equipment with more efficient alternatives that would meet minimum federal standards. In other words, we assumed complete compliance.

Cadmus reviewed the 2012 City of Seattle Building Energy Code to determine which measures would apply to new construction and which measures would be naturally captured by the code.[11] The following measures (or groups of measures) were not applicable to residential new construction due to code:

- Wall insulation (R11)
- Floor insulation (R30)
- Attic Insulation (R49)
- Windows (CL30)
- CFM50 Infiltration Reduction
- Pipe Insulation (R4)
- Programmable thermostats

For equipment measures, Cadmus assumed “below standard” permutations did not apply to new construction. For weather-sensitive end uses, Cadmus estimated end-use consumption for both new and existing construction using SEEM 9.4 building simulations—new construction reflected a modeled home built to code. Due to codes, end-use consumption for new construction was lower than for existing construction.

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[10] All applicable standards enacted prior to 2014 have been accounted for, such as the 2013 commercial clothes washer standard, the 2012 lighting general service fluorescent lamp standard, the 2012 lighting incandescent reflector lamp standard, the 2012 dehumidifier standard, the 2012 cooking oven and range standard, the 2010 icemaker standard, and the 2010 electric motor standard.

[11] Seattle Residential 2012 Building Energy Code. Available online: http://www.seattle.gov/dpd/cs/groups/pan/@pan/documents/web_informational/p2235336.pdf

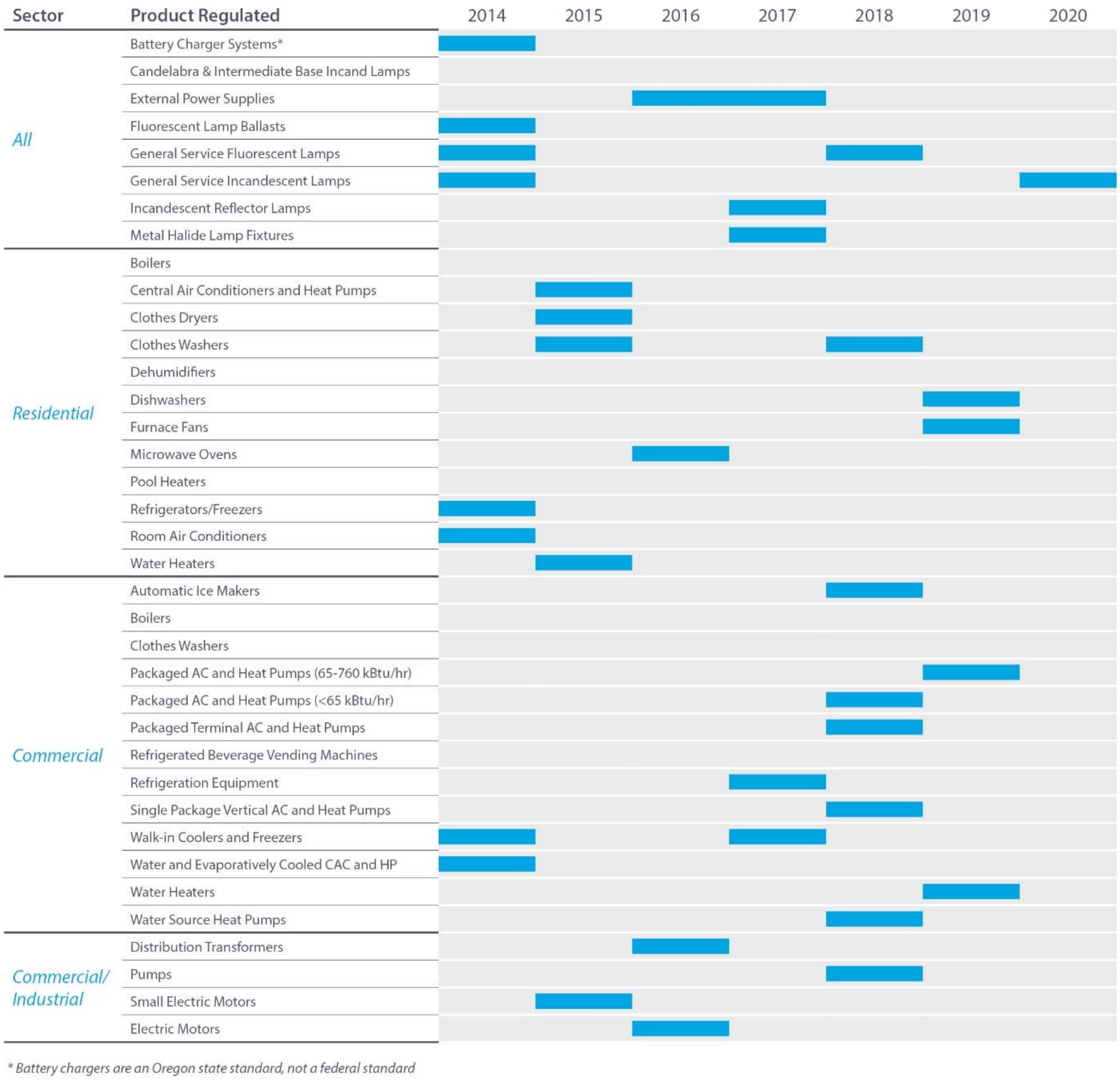

Figure 2.2 Equipment Standards Considered

2.3.2. Adapting Measures from the RTF and 7th Power Plan

To ensure consistency with methodologies employed by the Council and to fulfill requirements of WAC 194-37-070, Cadmus relied on ECM workbooks developed by the RTF and the Council to estimate measure savings, costs, and interactions. In adapting these ECMs for this study, Cadmus adhered to the following principles:

- **Deemed ECM savings in RTF or Council Workbooks must be preserved:** As City Light relies on deemed savings estimates provided by BPA that largely remain consistent with savings in RTF workbooks to demonstrate compliance with I-937 targets, Cadmus sought to preserve these deemed savings in the potential study. Doing so avoided possible inconsistencies between estimates of potential, targets, and reported savings.

- **Use inputs specific to City Light's service territory**: Some Council and RTF workbooks relied on regional estimates of saturations, equipment characteristics, and building characteristics derived from RBSA and CBSA. Cadmus updated regional inputs with estimates calculated from either City Lights' oversample of CBSA and RBSA or on estimates from the broader Puget Sound region. This approach preserved consistency with Council methodologies, while incorporating Seattle-specific data

Cadmus' approach for adapting Council and 7th Plan workbooks varied by sector, as described in the following sections.

2.3.2.1. Residential and Commercial

Cadmus reviewed each residential Council workbook and extracted savings, costs, and measure lives for inclusion in this study. Applicability factors (such as the current saturation of an ECM) largely derived from City Lights' oversample of RBSA, adjusted for City Lights program accomplishments. If Cadmus could not develop a City Lights-specific applicability factor from RBSA, we used the Council's regional value. In addition to extracting key measure characteristics, Cadmus identified each measure as an equipment replacement measure or a retrofit measure. Key distinctions between these two types of measures included the following:

- **Savings for equipment replacement measures** were calculated as the difference between the measure consumption and baseline consumption. For instance, concerning the heat pump water heater measure, Cadmus estimated the baseline consumption of an average market water heater and used deemed Council savings to calculate the consumption for a heat pump water heater. This approach preserved deemed savings found in Council workbooks.
- **Savings for retrofit measures** were calculated in percentage terms relative to the baseline end-use consumption, yet reflected deemed Council and RTF values. For instance, if the Council deemed savings of 1,000 kWh per home for a given retrofit measure and Cadmus estimated the baseline consumption for the end use to which this measure was applicable as 10,000 kWh, relative savings for the measure were 10%. Cadmus did not apply relative savings from the Council's workbooks to baseline end-use consumption; doing so would lead to per-unit estimates that differed from Council and RTF values.

Cadmus also accounted for interactive effects included in Council and RTF workbooks. For instance, the Council estimated water heating, heating, and cooling savings for residential heat pump water heaters (with the heating and cooling savings as the interactive savings). As installation of a heat pump water heater represented a single installation, and Cadmus employed a stock accounting model, which combined interactive and primary end-use effects into one savings estimate. Though we recognized this approach could lead to overstating or understating savings in a particular end use, in aggregate (across end uses), savings matched deemed Council values.

Cadmus generally followed the same approach with the commercial sector, though, due to the mixture of measures considered in the 7th Power Plan, we chose to model all commercial measures as retrofits and none as equipment replacements. While many commercial measures represent equipment improvements, commercial building operators often replace these before the end of their effective useful life. Savings and costs for these measures reflected this decision.

2.3.2.2. Industrial

Cadmus adapted measures from the Council's "Industrial_tool_7thPlan_v05p" workbook for inclusion in this study; the workbook defined values for the following key industrial measure inputs:

- Measure savings (expressed as end-use % savings)
- Measure costs (expressed in dollar per kWh saved)
- Measure lifetimes (expressed in years)
- Measure applicability (%)

Cadmus mapped each Council industry type to industries found in City Lights' service territory. These industries included: foundries, miscellaneous manufacturing, stone and glass, transportation equipment manufacturing, other food, frozen food, water, and wastewater. Cadmus identified applicable end uses using the Council's assumed distribution of end-use consumption in each industry. Table 2.3 shows the distribution of end-use consumption and the list of industries considered in this study.

TABLE 2.3 DISTRIBUTION OF END USE CONSUMPTION BY SEGMENT

Cadmus Segment	Process Aircomp	Lighting	Fans	Pumps	Motors Other	Process Other	Process Heat	HVAC	Other	Process Electro Chemical	Process Refrig
Foundries	7%	9%	10%	18%	6%	0%	21%	9%	1%	6%	14%
Frozen Food	4%	9%	4%	8%	16%	0%	4%	8%	6%	3%	39%
Other Food	6%	5%	28%	5%	16%	0%	0%	1%	6%	19%	15%
Transportation, Equip	6%	15%	6%	8%	14%	0%	11%	19%	12%	4%	5%
Misc. Manufacturing	7%	11%	7%	10%	16%	0%	12%	17%	9%	5%	5%
Water	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%
Wastewater	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%
Stone and Glass	9%	5%	8%	14%	22%	3%	22%	6%	3%	0%	7%

To incorporate broader secondary data, Cadmus aggregated some Council end uses into broader end uses. Table 2.4 shows the mapping of Council end uses to Cadmus end uses.

TABLE 2.4 COUNCIL AND CADMUS END USES

Council End Use	Cadmus End Use
Pumps	Pumps
Fans and Blowers	Fans
Compressed Air	Process Aircomp
Material Handling	Process Electro Chemical
Material Processing	Motors Other
Low Temp Refer	Process Refrig
Med Temp Refer	Process Refrig
Pollution Control	Other
Other Motors	Motors Other
Drying and Curing	Process Heat
Heat Treating	Process Heat
Heating	Process Heat
Melting and Casting	Process Heat
HVAC	HVAC
Lighting	Lighting
Other	Other

2.4. Estimating Conservation Potential

As discussed, Cadmus estimated three types of conservation potential, as shown in Figure 2.3.

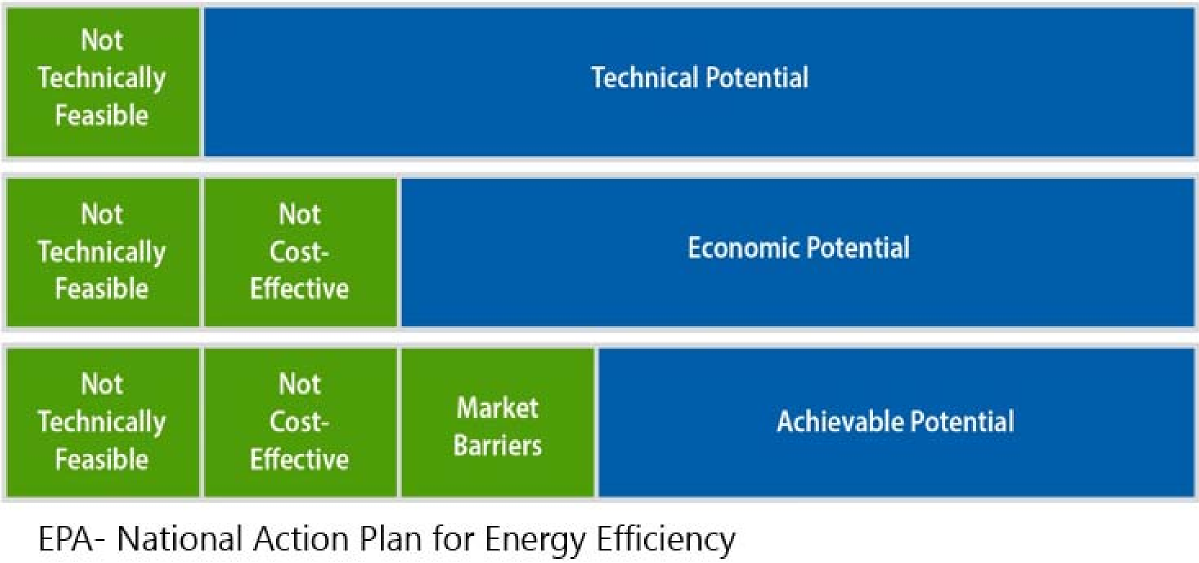

Figure 2.3 Types of Conservation Potential

The following sections describe Cadmus' approach to estimating each type of potential.

2.4.1. Technical Potential

Technical potential includes all technically feasible ECMs, regardless of costs or market barriers. Technical potential divides into two classes: discretionary (retrofit) and lost-opportunity (new construction and replacement of equipment on burnout).

Another important aspect in assessing technical potential is, wherever possible, to assume installation of the highest-efficiency equipment. For example, this study examined CFL and LED general service lighting in residential applications and, in assessing technical potential, assumed that, as equipment fails or new homes are built, customers will install LED lighting wherever technically feasible, regardless of cost. Where applicable, CFLs would be assumed installed in sockets ineligible for LEDs. Competing non-equipment measures were treated the same way, assuming installation of the highest-saving measures where technically feasible.

In estimating technical potential, one cannot merely sum up savings from individual measure installations, as significant interactive effects can result from the installation of complementary measures. For example, upgrading a heat pump in a home where insulation measures have already been installed can produce fewer savings than upgrades in an uninsulated home. Analysis of technical potential accounts for two types of interactions:

1. **Interactions between equipment and non-equipment measures:** As equipment burns out, technical potential assumes it will be replaced with higher-efficiency equipment, reducing average consumption across all customers. Reduced consumption causes non-equipment measures to save less than they would have, had equipment remained at a constant average efficiency. Similarly, savings realized by replacing equipment decrease upon installation of non-equipment measures.

2. **Interactions between non-equipment measures:** Two non-equipment measures applying to the same end use may not affect each other's savings. For example, installing a low-flow showerhead does not affect savings realized from installing a faucet aerator. Insulating hot water pipes, however, would cause water heaters to operate more efficiently, thus reducing savings from either measure. This assessment accounted for such interactions by "stacking" interactive measures—iteratively reducing baseline consumption as measures were installed, thus lowering savings from subsequent measures.

While theoretically, all retrofit opportunities in existing construction (often called "discretionary" resources) could be acquired in the study's first year, this would skew the potential for equipment measures and provide an inaccurate picture of measure-level potential. Therefore, the study assumed these opportunities would be realized in equal, annual amounts, over the 20-year planning horizon. By applying this assumption, natural equipment turnover rates, and other adjustments described above, the annual incremental and cumulative potential could be estimated by sector, segment, construction vintage, end use, and measure.

This study's estimates of technical potential drew upon best-practice research methods and standard analytic techniques in the utility industry. Such techniques remained consistent with conceptual approaches and methodologies used by other planning entities, such as those of the Council in developing regional energy-efficiency potential, and remained consistent with methods used in City Light's previous CPAs.

2.4.2. Economic Potential

Economic Potential represents a subset of technical potential, consisting only of measures meeting cost-effectiveness criteria based on City Light's avoided supply costs for delivering electricity. Adherent to WAC 194-37-070, Cadmus used the TRC to identify cost-effective measures in a manner consistent with the Council. Table 2.5 summarizes costs and benefits considered in the calculation of B/C ratios

TABLE 2.5 TRC BENEFITS AND COSTS

Type	Component
Costs	Incremental Measure Equipment and Labor Cost
	Incremental O&M Cost*
	Administrative Adder
Benefits	Avoided supply ($/kWh)
	Present Value of Non-Energy Benefits
	Present Value of T&D Deferrals ($/kW)
	10% Conservation Credit
	Secondary Energy Benefits

**Some measures may have a reduction in O&M costs, which is effectively treated as a benefit in the levelized cost calculation.*

- ***Incremental Measure Cost.*** This study considered costs required to sustain savings over a 20-year horizon, including reinstallation costs for measures with useful lives less than 20 years. If a measure's useful life extended beyond the end of the 20-year study, Cadmus incorporated an end effect that treated the measure's cost over its effective useful life (EUL)[12] as an annual reinstallation cost for the remainder of the 20-year period.[13]
- ***Incremental operations and maintenance (O&M) costs or benefits.*** As with incremental measure costs, O&M costs were considered annually over the 20-year horizon. The present value was used to adjust the levelized cost upward for measures with costs above baseline technologies and downward for measures that decrease O&M costs.
- ***Administrative adder.*** Cadmus assumed program administrative costs of 19% in the residential sector and 22% for the commercial and industrial sectors. This was based on City Light's actual 2012 program expenditures
- ***Non-energy benefits*** were treated as a reduction in levelized costs for measures that saved resources, such as water or detergent. For example, the value of reduced water consumption due to installation of a low-flow showerhead would reduce the levelized cost of that measure.
- ***The regional 10% conservation credit, capacity benefits during City Light's system peak, and T&D deferrals*** were similarly treated as reductions in levelized cost for electric measures. The addition of this credit, per the Northwest Power Act, was consistent with Council methodology and effectively served as an adder to account for unquantified external benefits of conservation when compared to other resources.[14]
- ***Secondary energy benefits*** were treated as a reduction in levelized costs for measures that saved energy on secondary fuels. This treatment was necessitated by Cadmus' end-use approach to estimating technical potential. For example, consider the cost for of R-60 ceiling insulation for a home with a gas furnace and an electric cooling system. For the gas furnace end use, Cadmus classified energy savings that R-60 insulation produces for electric cooling systems, conditioned on the presence of a gas furnace, as a secondary benefit that reduced the levelized cost of the measure. This adjustment only affected the measure's levelized costs; the magnitude of energy savings for the R-60 measure on the gas supply curve was not affected by considering secondary energy benefits.

2.4.2.1. About Levelized Costs of Conserved Energy

In addition to benefit-cost ratios, the levelized cost of conserved energy had to be determined to characterize each measure-in-conservation supply curves. Where possible, the study aligned its approach for calculating levelized costs for each measure to the Council's levelized-cost methodology—levelized costs include all costs and benefits described above.

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[12] This refers to levelizing over the measure's useful life, equivalent to spreading incremental measure costs over its EUL in equal payments, assuming a discount rate of SCL's weighted average cost of capital.

[13] This method is applied to measures with a useful life of greater than 20 years and those with a useful life extending beyond the 20th year at the time of reinstallation.

[14] Northwest Power & Conservation Council. *Northwest Power Act*. Available online: http://www.nwcouncil.org/library/poweract/default.htm.

The approach to calculating a measure's levelized cost of conserved energy aligned with that of the Council's, considering the costs required to sustain savings over a 20-year study horizon, including reinstallation costs for measures with useful lives less than 20 years. If a measure's useful life extended beyond the end of the 20-year study, Cadmus incorporated an end effect, treating the measure's levelized cost over its useful life as an annual reinstallation cost for the remainder of the 20-year period.[15] For example, Table 2.6 shows the timing of initial and reinstallation costs for a measure with an eight-year lifetime, in context with the 20-year study. As a measure's lifetime in this study ends after the study horizon, the final four years (Year 17 through Year 20) were treated differently, levelizing measure costs over its eight-year life and treating these as annual reinstallation costs.

TABLE 2.6 ILLUSTRATION OF CAPITAL AND REINSTALLATION COST TREATMENT

Component	Year																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Residential	■																			
Commercial									■								End Effect			

As with incremental measure costs, O&M costs were considered annually over the 20-year horizon. The present value was used to adjust the levelized cost upward for measures with costs above baseline technologies and downward for measures that decrease O&M costs.

15 This method applied to measures with a useful life greater than 20 years and those with useful lives extending beyond the 20th year at the time of reinstallation.

2.4.3. Achievable Economic Potential

Achievable economic potential can be defined as the portion of technical potential expected to be reasonably achievable in the course of a planning horizon. The quantity of energy efficiency potential realistically achievable depends on several factors, including the customers' willingness to participate in energy efficiency programs (partially as a function of incentive levels), retail energy rates, and a host of market barriers historically impeding adoption of energy efficiency measures and practices by consumers.[16] These barriers tend to vary, depending on the customer sector, local energy market conditions, and other, hard-to-quantify factors.

Assessing achievable technical potential, however, adopts a central tenet that assumes it is ultimately a function of the customers' willingness and ability to adopt energy efficiency measures; this information can be best ascertained through direct elicitations from potential participants.

Though methods for estimating achievable technical potential vary across potential assessment efforts, two dominant approaches appear to be most widely utilized:

1. The first approach assumes a hypothesized relationship between incentive levels and market penetration of energy efficiency programs. This achievable potential generally can be defined as that achieved solely through utility incentive programs, and often it is based on an incentive level at 50% of the incremental cost.
2. The second approach generally relies on a fixed percentage of technical potential, based on past experiences with similar programs. In the Northwest, for example, the Council has historically assumed that, by the end of the 20-year assessment horizon, 85% of the economic potential could be achieved, including savings from utility programs, market transformation, and changes in codes and standards.

Consistent with the Council, this study used option two, assuming up to 85% of economic potential could be acquired over the 20-year planning horizon. In addition to applying a fixed percentage, this assessment incorporated ramp rates to estimate annual achievable technical potential.

Developing sound utility IRPs requires knowledge of alternative resource options and reliable information on the long-run resource potential of achievable technologies. CPAs principally seek to develop reasonably reliable estimates of the magnitude, costs, and timing of resources likely available over the planning horizon's course; they do not, however, provide guidance as to *how* or by *what means* identified resources might be acquired. For example, identified potential for electrical equipment or building shell measures might be attained through utility incentives, legislative action instituting more stringent efficiency codes and standards, or other means.

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16 Consumers' apparent unwillingness to invest in energy efficiency has been attributed to certain energy efficiency market barriers. A rich body of literature exists concerning the "market barriers to energy efficiency." In one such study, market barriers identified fell into five broad classes of market imperfections, thought to inhibit energy-efficiency investments: (1) misplaced or split incentives; (2) high upfront costs and a lack of access to capital; (3) a lack of information and uncertainty concerning the benefits, costs, and risks of energy-efficiency investments; (4) investment decisions guided by convention and custom; and (5) time and "hassle" factors. For a discussion of these barriers, see: William H. Golove and Joseph H. Eto. "Market Barriers to Energy Efficiency: A Critical Reappraisal of the Rationale for Public Policies to Promote Energy." Lawrence Berkeley National Laboratory, University of California, Berkeley, California. LBL-38059. March 1996.

2.4.3.1. About Measure Ramp Rates

The study applied measure ramp rates to lost opportunity and discretionary resources, though interpretation and application of these rates differed for each class (as described below). Measure ramp rates generally matched those proposed for the Council's 7th Power Plan. For measures not specified in the 7th Power Plan, the study assigned a ramp rate considered appropriate for that technology (i.e., the same ramp rate as a similar measure in 6th Power Plan or 7th Power Plan).

Lost Opportunity Resources

Quantifying achievable economic potential for lost opportunity resources in each year required determining amounts technically available through new construction and natural equipment turnover. New construction rates drew directly from City Light's customer forecast. The study developed equipment turnover rates by dividing units in each year by the measure life. For example, if 100 units initially had a 10-year life, one-tenth of units (10) would be replaced. In the following year, 90 units would remain, and one-tenth of these (9) would be replaced, and so on over the study's course.

As the mix of existing equipment stock ages, the remaining useful life (RUL) would be, on average, one-half of the EUL.[17] The fraction of equipment turning over each year would be a function of this RUL; thus, the economic potential for lost opportunity measures would have an annual shape before application of any ramp rates, as shown in Figure 2.4. The same concept applied to new construction, where resource acquisition opportunities only become available during home or building construction. In addition to showing an annual shape, Figure 2.4 demonstrates amounts of equipment turning over during the study period as a RUL function: the shorter the RUL, the higher the percentage of equipment assumed to turn over.

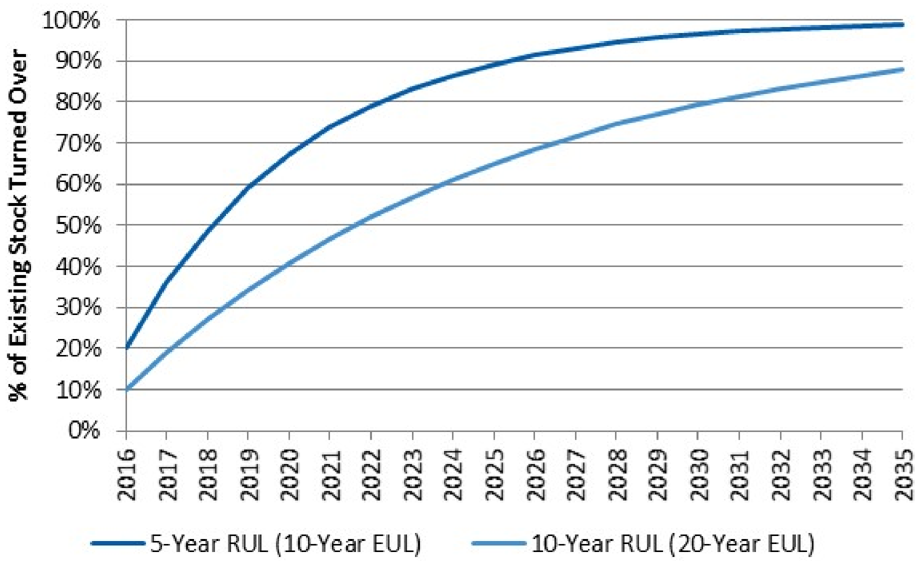

Figure 2.4 Existing Equipment Turnover for Varying RULs

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17 EULs represented median lifetimes, defined as the year that one-half of measures installed remained in place and operable and one-half did not, as defined by the RTF: http://www.nwcouncil.org/energy/rtf/subcommittees/measurelife/RTF%20Measure%20Useful%20Life%20Guidelines%20Final%202012%200515.pdf

In addition to natural timing constraints imposed by equipment turnover and new construction rates, Cadmus applied measure ramp rates to reflect other resource acquisition limitations over the study horizon, such as market availability. These measure ramp rates had a maximum value of 85%, reflecting the Council's assumption that, on average across all measures, up to 85% of technical potential could be achieved over a 20-year planning horizon. As illustrated by Figure 2.5, a measure that ramps up over 10 years would reach full market maturity (85% of annual technical potential) by the end of that period, whereas another measure might take 20 years to reach full maturity.

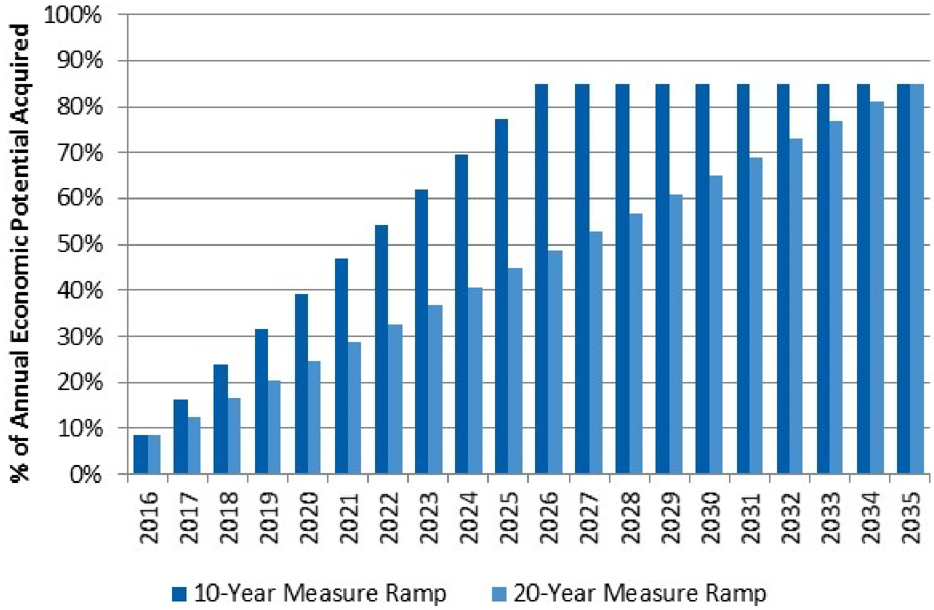

Figure 2.5 Examples of Lost Opportunity Measure Ramp Rates

To calculate annual achievable technical potential for each lost opportunity measure, Cadmus multiplied technical resource availability and measure ramping effects together, consistent with the Council's methodology. Particularly in the early years of the study horizon, a gap occurs between assumed acquisition and the 85% maximum achievability. These "lost" resources can be assumed not available until the measure's EUL elapses. Therefore, depending on EUL and measure ramp rate assumptions, some potential may be pushed beyond the 20th year, and the total lost opportunity achievable economic potential may be less than 85% of economic potential.

Figure 2.6 shows a case for a measure with a five-year RUL/10-year EUL. The spike in achievable technical potential starting in year 2023 (after the measure's EUL) results from acquisition of opportunities missed at the beginning of the study period.

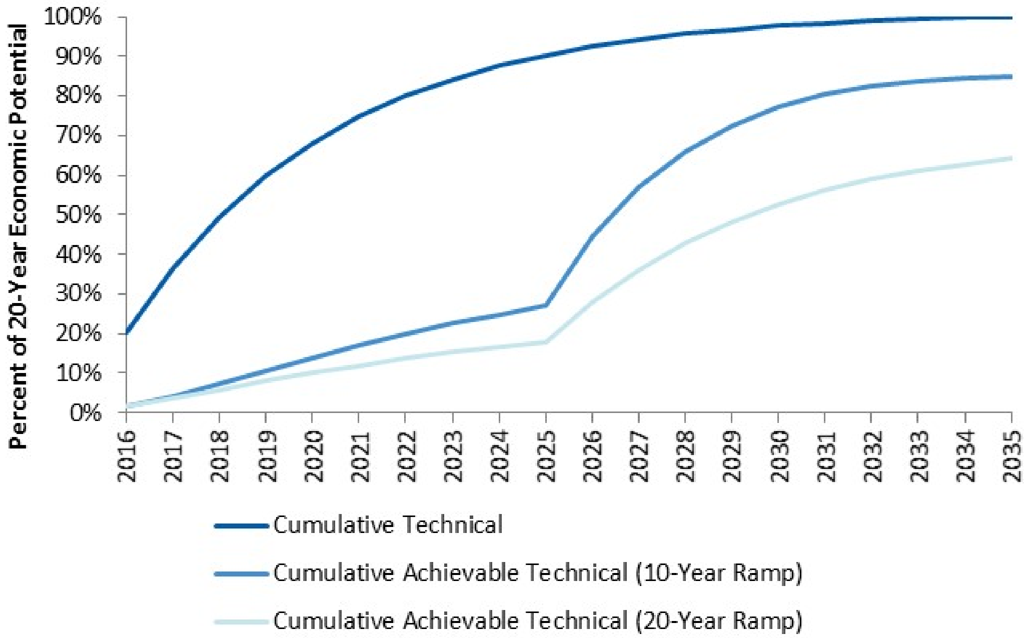

Figure 2.6 Example of Combined Effects of Technical Resource Availability and Measure Ramping Based on 10-Year EUL

Table 2.7 below, illustrates this method, based on the same five-year RUL/10-year EUL measure on a 10-year ramp rate (the light blue line in Figure 2.6), assuming 1,000 inefficient units would be in place by 2012. In the first 10 years (2013 through 2022), lost opportunities accumulate as the measure ramp-up rate caps availability of high-efficiency equipment. Starting in 2023 (the 11th year), opportunities lost 10 years prior become available again. Table 2.7 also shows this EUL and measure ramp rate combination results in 85% of technical potential achieved by the study period's close.

As described, amounts of achievable technical potential are a function of the EUL and measure ramp rate. The same 10-year EUL measure, on a slower 20-year ramp rate, would achieve less of its 20-year technical potential (also shown in Figure 2.6). Across all lost opportunity measures included in this study, approximately 72% of technical potential appears achievable over the 20-year study period, a finding consistent with the Council's assumption that less than 85% of lost opportunity resources can be achieved.[18]

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[18] A Retrospective Look at the Council's Conservation Planning Assumptions. April 2007. http://www.nwcouncil.org/library/2007/2007-13.htm

TABLE 2.7 EXAMPLE OF LOST OPPORTUNITY TREATMENT: 10-YEAR EUL MEASURE ON A 10-YEAR RAMP RATE

Year	Incremental Stock Equipment Turnover (Units)	Cumulative Stock Equipment Turnover (Units)	Measure Ramp Rate	Installed High Efficiency Units	Missed Oppor-tunities for Acquisition in Later Years (Units)	Missed Oppor-tunities Acquired (Units)	Cumulative Units Installed	Cumulative Percent of Technical Achieved
2016	200	200	9%	17	180	0	17	9%
2017	160	360	16%	26	130	0	43	12%
2018	128	488	24%	30	92	0	73	15%
2019	102	590	31%	32	65	0	106	18%
2020	82	672	39%	32	44	0	138	20%
2021	66	738	47%	31	29	0	168	23%
2022	52	790	54%	29	19	0	197	25%
2023	42	832	62%	26	11	0	223	27%
2024	34	866	70%	23	6	0	246	28%
2025	27	893	77%	21	2	0	267	30%
2026	21	914	85%	18	0	153	438	48%
2027	17	931	85%	15	0	110	563	60%
2028	14	945	85%	12	0	78	653	69%
2029	11	956	85%	9	0	55	717	75%
2030	9	965	85%	7	0	38	762	79%
2031	7	972	85%	6	0	25	793	82%
2032	6	977	85%	5	0	16	814	83%
2033	5	982	85%	4	0	10	828	84%
2034	4	986	85%	3	0	5	836	85%
2035	3	988	85%	2	0	2	840	85%

Discretionary Resources

Discretionary resources differ from lost opportunity resources due to their acquisition availability at any point within the study horizon. From a theoretical perspective, this suggests all achievable economic potential for discretionary resources could be acquired in the study's first year, though, from a practical perspective, this outcome is realistically impossible due to infrastructure and budgetary constraints and to customer considerations.

Further, due to interactive effects between discretionary and lost opportunity resources, immediate acquisition would distort the potential for lost opportunity resources. For example, if one assumes all homes would be weatherized in the first year of a program, potentially available high-efficiency HVAC equipment would decrease significantly (i.e., a high-efficiency heat pump would save less energy in a fully weatherized home).

Consequently, the study addressed discretionary resources in two steps:

1. Developing a 20-year estimate of discretionary resource economic potential, assuming technically feasible and cost-effective measure installations would occur equally (at 5% of the total available) for each year of the study, and avoiding distortion of interactions between discretionary and lost opportunity resources, as previously described.
2. Overlaying a measure ramp rate to specify the timing of achievable discretionary resource potential, thus transforming a 20-year cumulative technical value into annual, incremental, achievable values.

The discretionary measure ramp rates specify only the timing of resource acquisition and do not affect the portion of the 20-year economic potential achievable over the study period.

Figure 2.7 shows incremental (bars) and cumulative (lines) acquisitions for two different discretionary ramp rates. A measure on the 10-year discretionary ramp rate reaches full maturity (85% of its total economic potential) in 10 years, with market penetration increasing in equal increments each year. A measure on the emerging technology discretionary ramp rate would take longer to reach full maturity (also 85% of total economic potential), but ultimately it would arrive at the same cumulative savings as the measure on the 10-year ramp rate.

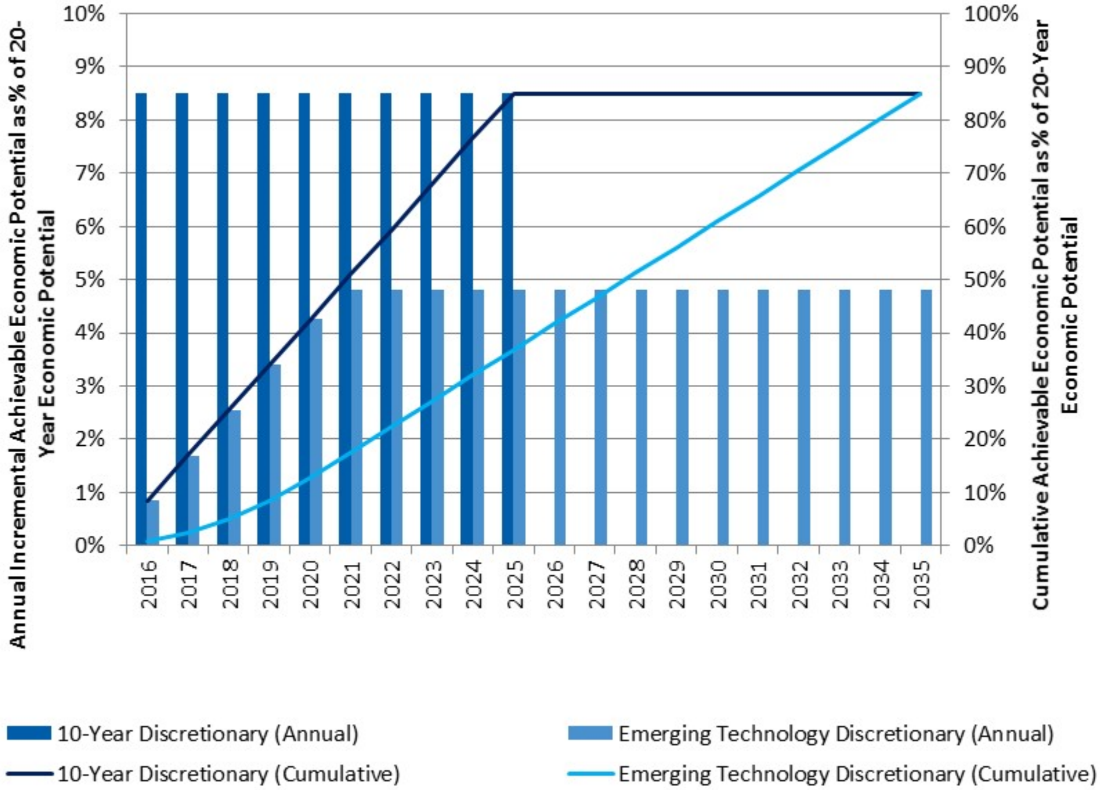

Figure 2.7 Examples of Discretionary Measure Ramp Rates

3. Baseline Forecasts

3.1. Scope of the Analysis

Assessing conservation potential starts with the development of baseline end use load forecasts over a 20-year (2016 to 2035) planning horizon. These forecasts are calibrated to City Light's econometric load forecasts, they are not adjusted for future programmatic conservation, but they do account for enacted equipment standards and building energy codes. The study separately considers residential, commercial, industrial, and street lighting sectors.

Within each sector-level assessment, the study further distinguished customer segments or facility types, and their respective applicable end uses. The analysis addressed:

- **Eight residential segments** (existing and new construction for single family, multifamily low-rise, multifamily mid-rise, and multifamily high-rise). Multifamily low-rise is defined as multifamily buildings with one to three floors, mid-rise is defined as buildings with four to six floors, and high-rise is defined as buildings with greater than six floors.
- **Forty-three commercial segments**. This includes new and existing construction for nineteen standard commercial segments, as well as three indoor agriculture segments, and enterprise data centers. Cadmus considered one vintage for indoor agriculture segments and enterprise data centers.
- **Eight industrial segments** (existing construction only).
- One segment for **street lighting**

Figure 3.1 shows the distribution of projected sales in 2035 by sector. The commercial sector will account for roughly 56% of projected sales, while the residential, industrial, and street lighting sectors account for 28%, 15%, and 1%, respectively.

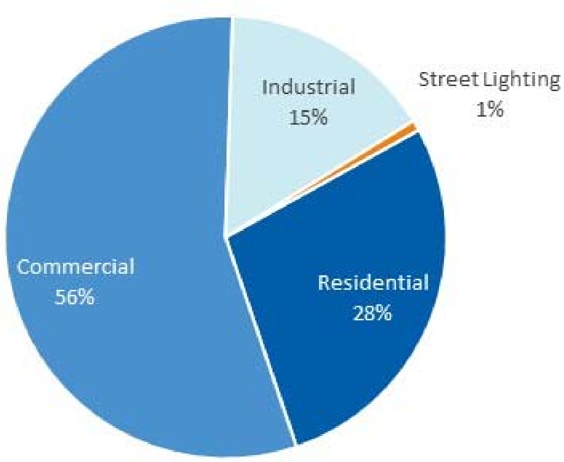

Figure 3.1 Baseline Sales by Sector - 2035

3.2. Residential

Cadmus considered four residential segments and 34 end uses within these segments. Table 3.1 lists each residential segment and end uses considered, as well as the broad end use groups used in this report. Overall the residential sector accounts for approximately 28% of total baseline sales.

TABLE 3.1 RESIDENTIAL SEGMENT AND END USES

Segments	End Use Group	End Use
Single Family	Appliances	Cooking Oven
Multifamily - High Rise	Appliances	Cooking Range
Multifamily - Mid Rise	Appliances	Dryer
Multifamily - Low Rise	Appliances	Freezer
	Appliances	Refrigerator
	Cooling	Cool Central
	Cooling	Cool Room
	Electronics	Computer - Desktop
	Electronics	Computer - Laptop
	Electronics	Copier
	Electronics	DVD
	Electronics	Home Audio System
	Electronics	Microwave
	Electronics	Monitor
	Electronics	Multifunction Device
	Electronics	Plug Load Other
	Electronics	Printer
	Electronics	Set Top Box
	Electronics	Television
	Electronics	Television Bigscreen
	Exterior Lighting	Lighting Exterior
	Heating	Heat Central
	Heating	Heat Pump
	Heating	Heat Room
	Heating	Ventilation and Circulation
	Interior Lighting	Lighting Interior Linear Fluorescent
	Interior Lighting	Lighting Interior Specialty

TABLE 3.1 RESIDENTIAL SEGMENT AND END USES		
Segments	**End Use Group**	**End Use**
	Interior Lighting	Lighting Interior Standard
	Miscellaneous	Air Purifier
	Miscellaneous	Other
	Miscellaneous	Waste Water
	Miscellaneous	Pool Pump
	Water Heating	Water Heat GT 55 Gal
	Water Heating	Water Heat LE 55 Gal

City Light produces separate forecasts of single family and multifamily households. Cadmus' used City Light's forecast of single family households directly in the baseline forecast. Cadmus disaggregated multifamily household forecasts based on the distribution of the estimated number of households for the following multifamily segments:

- Multifamily low-rise: Up to 3 floors.
- Multifamily mid-rise: 4 to 6 floors.
- Multifamily high-rise: over 6 floors.

We relied on 3-year American Community Survey (ACS) estimates of the number of households for each multifamily segment to determine the distribution used to disaggregate City Light's multifamily forecast. Using the approach described in the Developing Baseline Forecasts section, Cadmus combined residential household forecasts, estimates of end use saturations, fuel shares, efficiency shares, and end use consumption to produce a sales forecast through 2035. Figure 3.2 and Figure 3.3 show the distribution of residential sales in 2035 by segment and end use, respectively. The single family segment accounts for 57% of residential baseline sales in 2035. This segment accounts for nearly 50% of City Light's forecasted households, and has a higher overall consumption per household than multifamily segments.

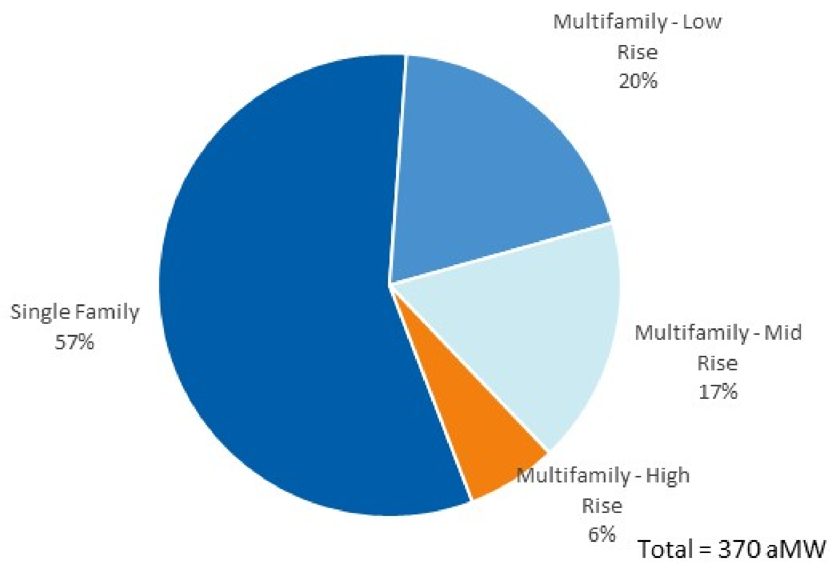

Figure 3.2 Residential Baseline Sales by Segment - 2035

Figure 3.3 shows heating and electronics are the top two consuming end uses and account for nearly one-half (46%) of residential consumption. The next three highest forecasted uses are water heating (18%), appliances (16%), and interior lighting (15%), which altogether account for 50% of residential consumption.

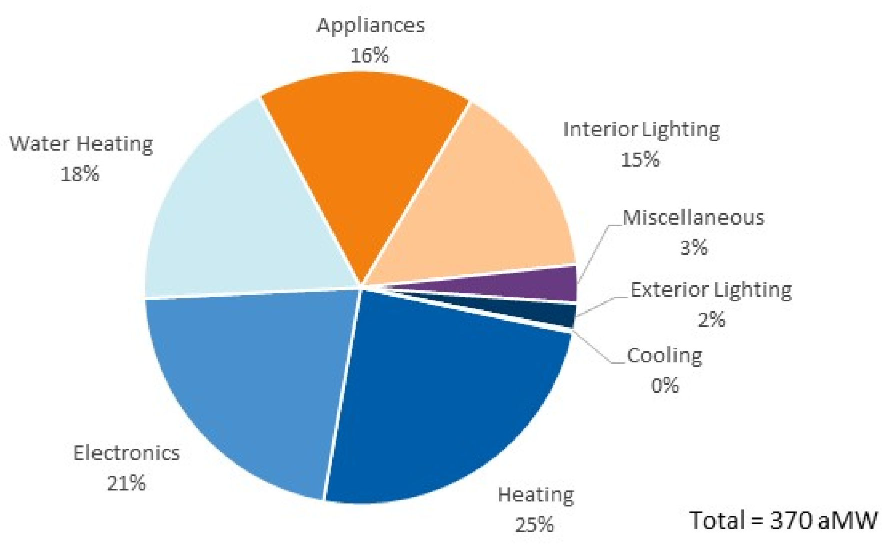

Figure 3.3 Residential Baseline Sales by End Use - 2035

Table 3.2 and Figure 3.4 show the assumed average consumption per household for each residential segment. Differences in average consumption for each segment are driven by either (or any combination of) differences in end use consumption, saturations, or fuel shares. Appendix C includes detailed baseline data for the residential sector.

TABLE 3.2 PER HOUSEHOLD BASELINE SALES (KWH/HOME) – 2035

End Use	Single Family	Multifamily - Low Rise	Multifamily - Mid Rise	Multifamily - High Rise
Heating	1,808	1,592	1,690	1,465
Electronics	1,799	1,217	1,195	1,186
Water Heating	1,512	1,278	1,085	161
Appliances	1,396	794	927	1,053
Interior Lighting	1,083	801	1,234	912
Miscellaneous	271	165	141	27
Exterior Lighting	254	32	34	12
Cooling	15	2	9	36
Total	**8,138**	**5,881**	**6,316**	**4,852**

Single family homes, on average, consume an estimated 8,138 kWh per home, with heating, electronics, water heating, and appliances accounting for the majority of consumption. Single family per home consumption exceeds each multifamily segment because these homes tend to have higher conditioned floor space. On average, single family homes have 1,882 square feet of conditioned floor area, while multifamily low, medium, and high-rise homes have an average of 660, 801, and 724 square feet of conditioned floor space. Compared to single family homes, heating and appliances account for a higher proportion of total consumption in multifamily homes.

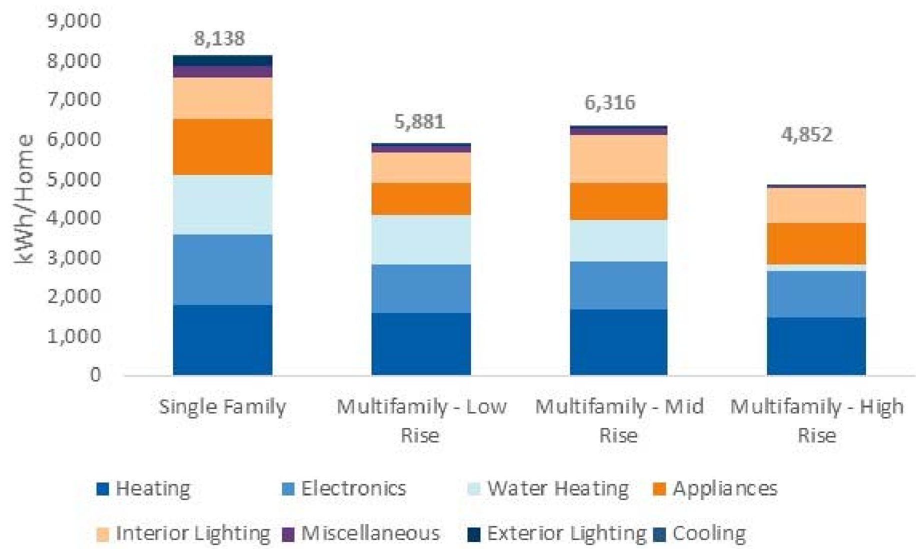

Figure 3.4 Residential Baseline Consumption Per Household – 2035

Cadmus calibrated baseline forecasts to City Light's econometric load forecasts—this ensured assumed load growth in the CPA is based on forecasted load in City Light's integrated resource plan. Cadmus adjusted then produced a residential forecast that explicitly accounts for federal lighting standards enacted under the Energy Independence and Security Act (EISA) of 2007, as this standard has little impact on City Light's sales history and it is not explicitly accounted for in City Light's econometric forecast. After including federal equipment standards, Cadmus' residential baseline load forecast is slightly lower than City Light's forecast. Figure 3.5 shows the residential baseline forecast by end use. Overall, City Light's residential forecast declines by approximately 8% over the 20-year horizon. This is due to a declining use per customer in City Light's load forecast.

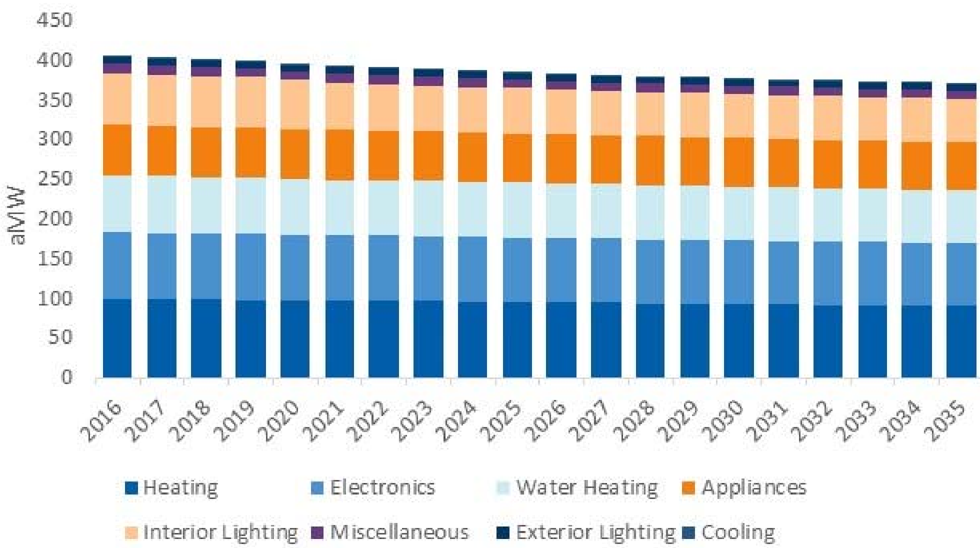

Figure 3.5 Residential Baseline Forecast by End Use

Figure 3.6 shows forecasted residential sales by construction vintage over the study horizon. Study results indicate approximately 12% of sales will be from homes constructed after 2015 (new construction). Use per customer for existing homes decreases by nearly 19% over the 20-year study timeframe—this decline in use per customer is partly driven by equipment standards and other naturally occurring efficiency.

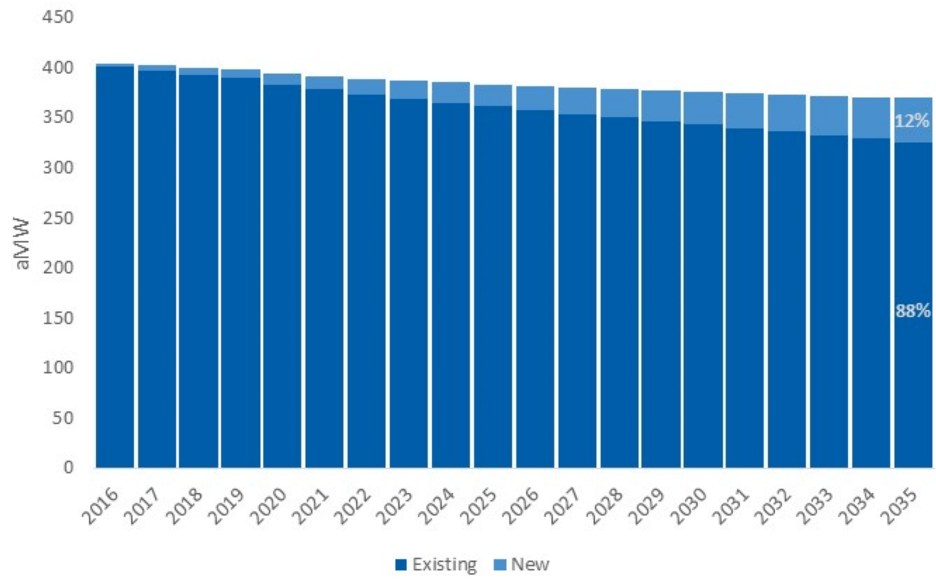

Figure 3.6 Residential Baseline Forecast by Construction Vintage

3.3. Commercial

Cadmus considered 23 commercial segments and up to 15 end uses within these segments. Table 3.3 shows each commercial segment and end use considered in this study, as well as the broad segment and end use groups used in this report. Segments are largely based on those included in the Council's draft 7th Power Plan. However, Cadmus added additional segments including enterprise data centers and three indoor agriculture segments (tier 1, tier 2, and tier 3), which are based on the size of the facility. Overall, the commercial sector accounts for 740 aMW, or 55% of total baseline sales in 2035.

TABLE 3.3 COMMERCIAL SEGMENTS AND END USES

Segments		End Uses	
Segment Group	**Segment**	**End Use Group**	**End Use**
Assembly	Assembly	Cooking	Cooking
Data Center	Enterprise Data Centers	Cooling	Cool Central
Hospital	Hospital	Data Center	Data Center
Indoor Agriculture	Indoor Agriculture - Production Facility Tier 1	Heat Pump	Heat Pump
Indoor Agriculture	Indoor Agriculture - Production Facility Tier 2	Heating	Heat Central
Indoor Agriculture	Indoor Agriculture - Production Facility Tier 3	Lighting	Exterior Lighting
Large Grocery	Supermarket	Lighting	Interior Lighting
Large Office	Large Office	Miscellaneous	Compressed Air

TABLE 3.3 COMMERCIAL SEGMENTS AND END USES			
Segments		**End Uses**	
Segment Group	**Segment**	**End Use Group**	**End Use**
Large Office	Medium Office	Miscellaneous	Other
Lodging	Lodging	Miscellaneous	Plug Load Other
MF Common Area	Multifamily Common Area	Miscellaneous	Waste Water
Miscellaneous	Other	Refrigeration	Refrigeration
Other Health	Residential Care	Ventilation	Ventilation
Restaurant	Restaurant	Water Heat	Water Heat GT 55 Gal
Retail	Large Retail	Water Heat	Water Heat LE 55 Gal
Retail	Medium Retail		
Retail	Small Retail		
Retail	Extra Large Retail		
School	School K-12		
Small Grocery	Mini Mart		
Small Office	Small Office		
University	University		
Warehouse	Warehouse		

Cadmus used City Light's non-residential database to identify the sales and number of customers for each commercial market segment. The database combines City Light's billing data with data from the King County assessor, as well as other secondary sources, to identify the customer segment, floor space, and consumption for each non-residential customer—this data was the basis for Cadmus' commercial sector segmentation. In addition, Cadmus classified customers as either commercial or industrial based on the segment identified in City Light's database. Commercial customers included those identified as one of the segments listed in Table 3.3, while industrial customers mapped to one of the segment listed in Table 3.4.

Cadmus chose commercial segments for consistency with the draft 7th Power Plan, with the exception of multifamily common area, which is not a stand-alone segment in the 7th Power Plan.

Figure 3.7 shows the distribution of baseline commercial consumption by segment in 2035.

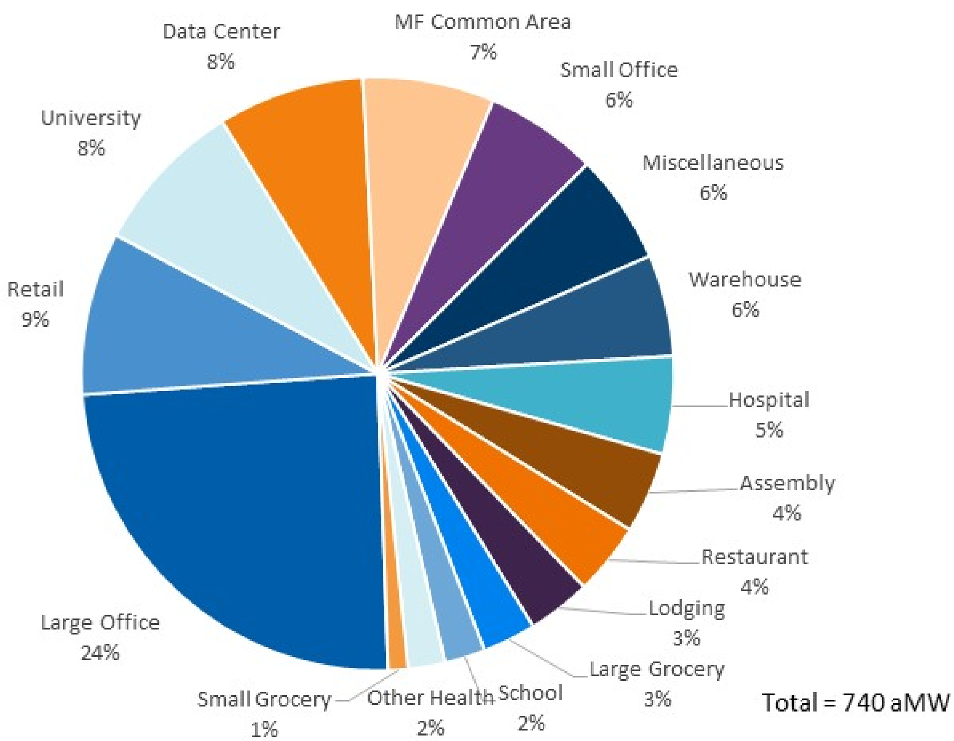

Figure 3.7 Baseline Sales by Segment - 2035

Large offices account for nearly one quarter (24%) of commercial baseline sales. Retail, universities, and data centers account for 9%, 8%, and 8% of baseline sales, respectively. Collectively, these segments represent nearly one-half (49%) of all commercial sector sales. Data center sales only represent consumption in enterprise data centers, and does not include consumption from embedded data centers within other segments (such as offices and universities).

Cadmus developed whole-building energy intensities using consumption and floor space estimates from City Light's non-residential customer database. We further disaggregated these energy intensities into end use intensities—end use intensities were based on end use saturations and fuel shares derived from City Light's CBSA oversample and eQUEST building simulations. Specifically, Cadmus determined the expected distribution of end use consumption for each building type based on City Light-specific saturations and building simulations, and disaggregated energy intensities (derived from City Light's customer data) using these distributions. Figure 3.8 shows energy intensities for each building type and

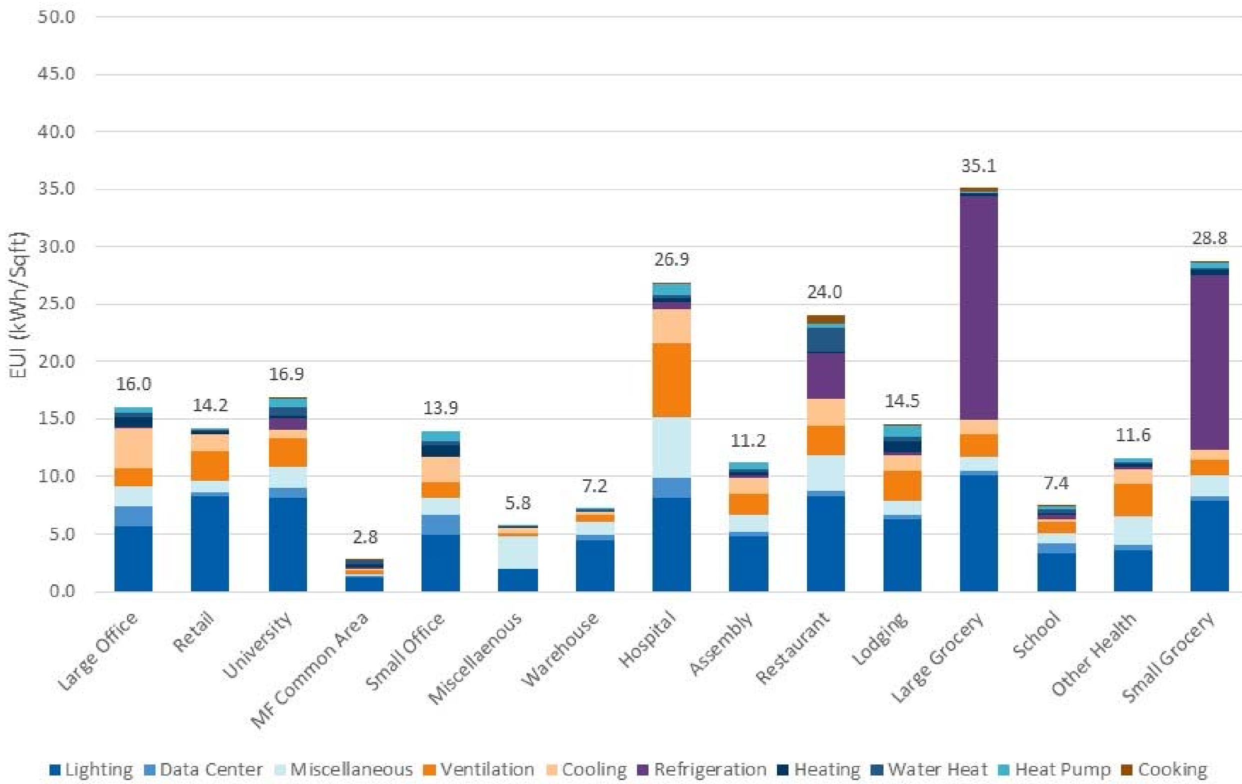

Figure 3.8 Commercial EUIs by Building Type

Figure 3.9 shows the overall distribution of commercial baseline sales by end use. The highest consuming end use is lighting, which accounts for 38% of projected commercial consumption in 2035. Data centers, ventilation, and cooling end uses also account for a large share of consumption, representing 12%, 12%, and 11% of projected commercial sales, respectively.

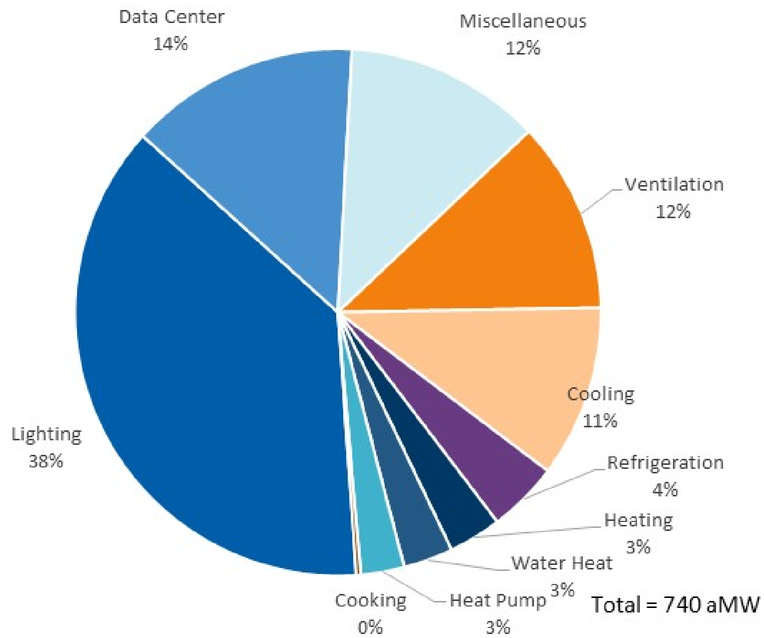

Figure 3.9 Baseline Sales by End Use – 2035

Cadmus' commercial baseline forecasts includes moderate load growth—commercial sales increase by roughly 1% per year over the study horizon. Figure 3.10 shows the commercial baseline forecast by end use.

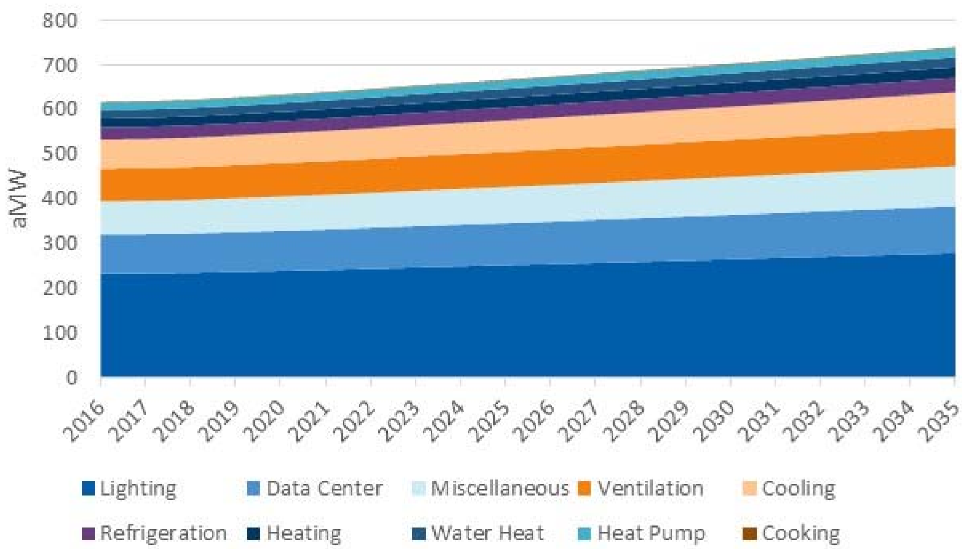

Figure 3.10 Commercial Forecast by End Use

Much of commercial load growth is in the “new” construction vintage. By 2035, 17% of forecasted load is from buildings constructed after 2016. Figure 3.11 shows the commercial baseline forecast by construction vintage.

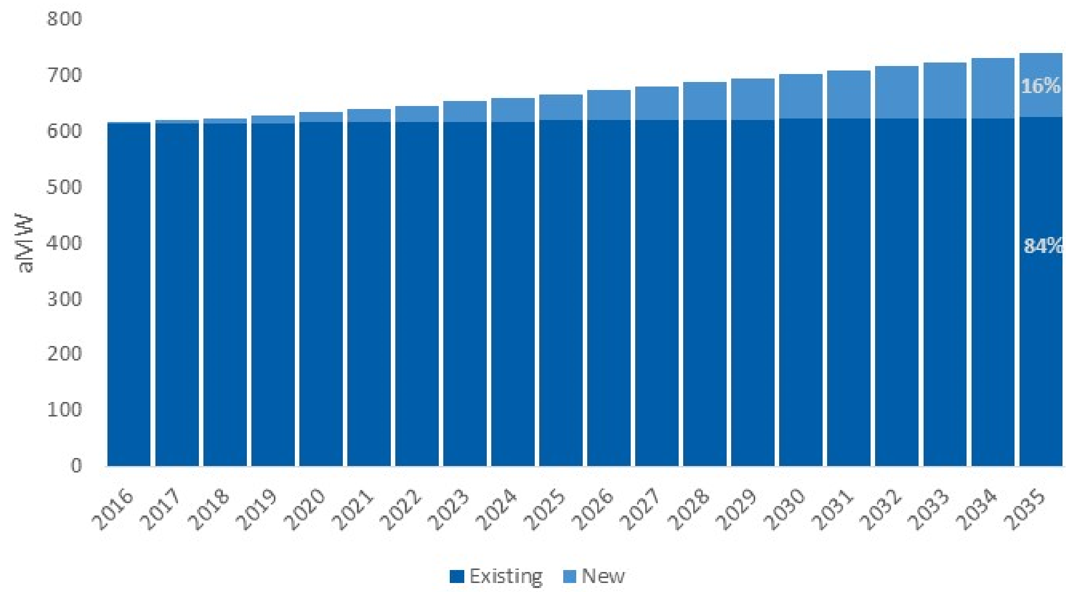

Figure 3.11 Commercial Forecast by Construction Vintage

3.4. Industrial

Cadmus disaggregated City Light’s forecasted industrial sales into eight facility types (segments) and ten end uses (Table 3.4). Overall, the industrial sector accounts for 208 aMW, or 15% of City Light’s overall forecasted baseline sales in 2035.

TABLE 3.4 INDUSTRIAL SEGMENTS AND END USES	
Segment Group	**Segment**
Frozen Food	HVAC
Miscellaneous Manufacturing	Lighting
Other Food	Motors Other
Stone and Glass	Other
Transportation, Equipment	Process Air Compressors
Wastewater	Process Electro Chemical
Water	Process Heat
	Process Other
	Process Refrigeration
	Pumps

Similar to the commercial sector, Cadmus relied on City Light's non-residential customer database to determine the distribution of baseline industrial sales by segment. These segments are largely consistent with the 2013 CPA—the primary difference is the 2016 CPA considers water and wastewater segments separately (instead of in a combined "Utilities" segment). Cadmus changed segment names slightly to ensure consistency with the segments considered in the 7th Power Plan. Figure 3.12 shows the distribution of industrial sales by segment in 2035. Foundries account for nearly one-third (31%) of industrial baseline sales. The next largest segments are miscellaneous manufacturing (22%), stone and glass (19%), and transportation equipment manufacturing (18%). Altogether, these segments account for 90% of baseline sales in 2035.

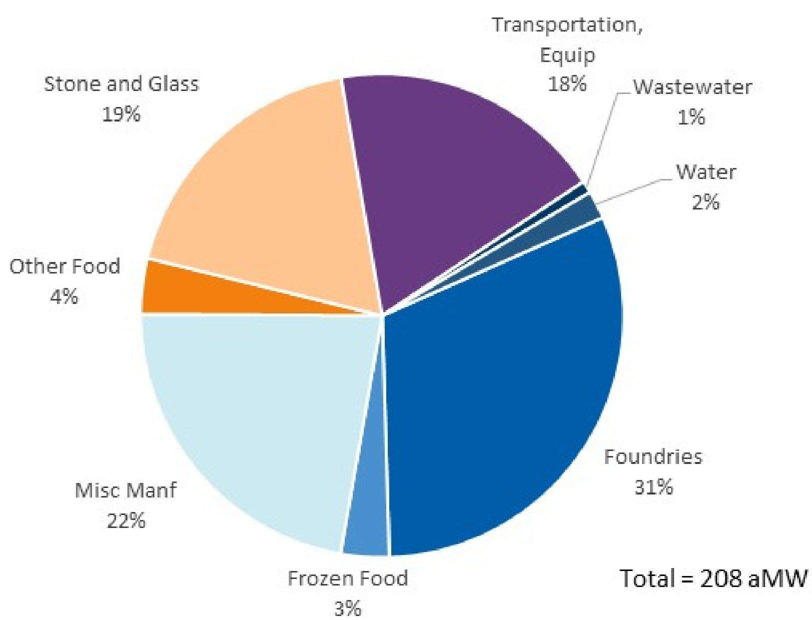

Figure 3.12 Industrial Baseline Sales by Segment – 2035

Cadmus relied on end use distributions provided in the Council's 7th Plan industrial tool to disaggregate segment-specific consumption into end uses. Table 2.3 includes end use distributions for each segment, and Figure 3.13 shows the overall distribution of industrial baseline sales in 2035 by end use.

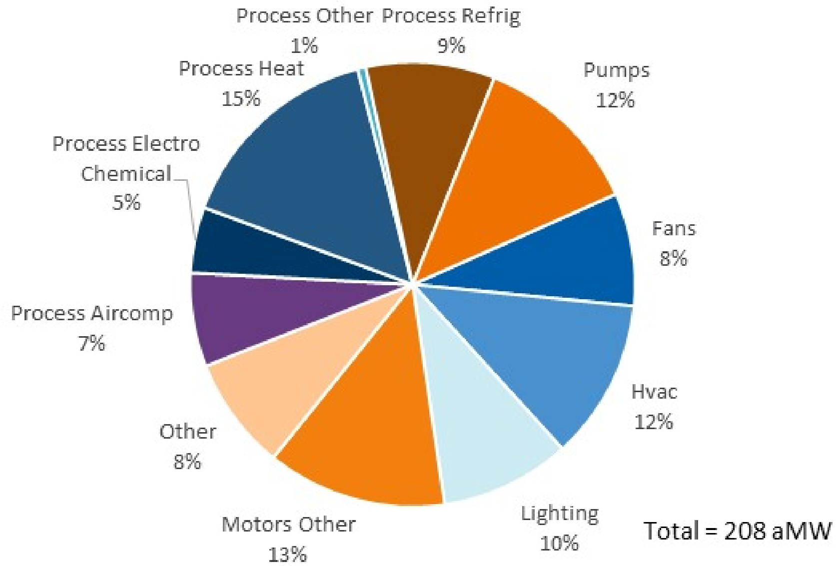

Figure 3.13 Industrial Baseline Sales by End Use - 2035

Industrial load growth is moderate over the study horizon, amounting to approximately a 1% annual average growth rate over the study horizon. Figure 3.14 shows the industrial forecast by segment.

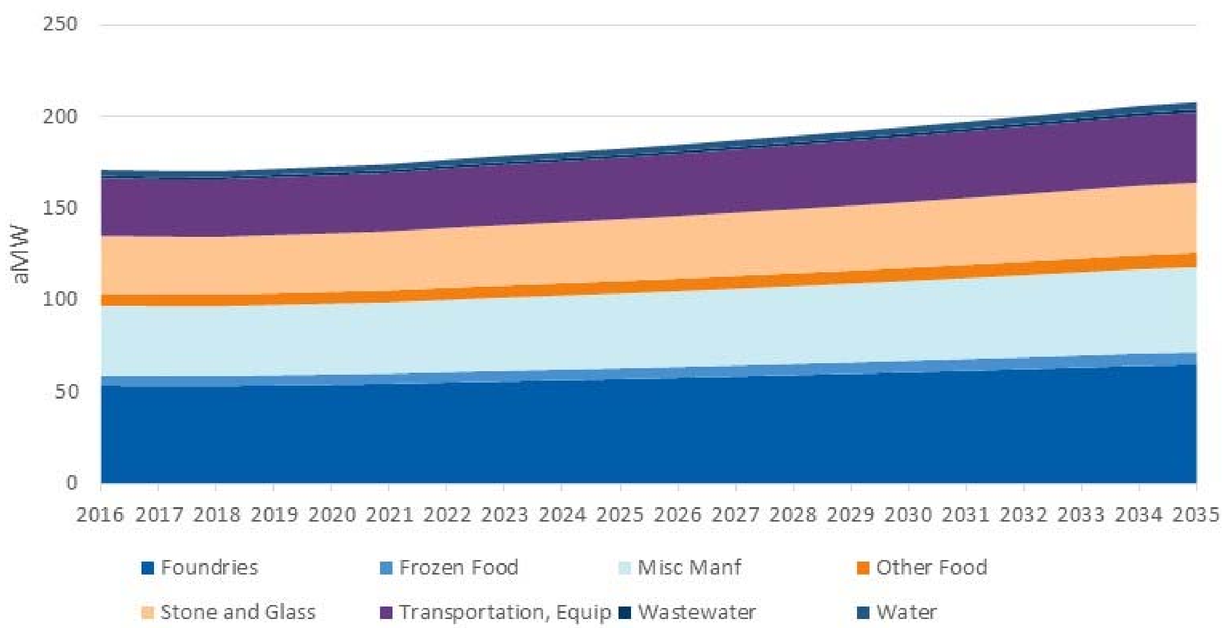

Figure 3.14 Industrial Baseline Forecast

4. Energy Efficiency Potential

4.1. Overview

4.1.1. Scope of the Analysis

This study included a comprehensive set of conservation measures, incorporating measures assessed by the Council in its draft 7th Power Plan and the RTF. Analysis began by assessing the technical potential of hundreds of unique conservation measures. These measures were considered for each applicable sector, segment, and construction vintage discussed in the Baseline Forecasts section. In total Cadmus considered over 4,400 permutations of conservation measures. Table 4.1 lists the counts and number of permutations of conservation measures considered in this study.

TABLE 4.1 MEASURE COUNTS AND PERMUTATIONS

Sector	Unique Count[a]	Permutations
Residential	234	887
Commercial	1,311	3,130
Industrial	39	379
Street Lighting	6	24
Total	**1,590**	**4,420**

[a] Measure counts for some sectors include segment-specific permutations, thus, measure counts are higher than what is typically seen in CPAs.

4.1.2. Summary of Results

Table 4.2 shows baseline sales and cumulative potential by sector.[19] Study results indicate 362 aMW of technically feasible conservation potential (27% of baseline sales) by 2035, the end of the 20-year study horizon, with an estimated 257 aMW (19% of baseline sales) that is both cost-effective and technically feasible (this is economic potential). Cumulative achievable economic potential equals 205 aMW in 2035 (15% of baseline sales). These results account for line losses and represent cumulative energy savings at generator.

These savings draw upon forecasts of future consumption, absent future City Light conservation program activities. While these consumption forecasts accounted for past City Light-funded conservation, the identified estimated potential is inclusive of (not in addition to) forecasted program savings. As discussed, the 2035 forecast may differ from City Light's official sales forecast due to the treatment of standards and the assignment of commercial and industrial sales.

[19] Economic potential and achievable economics potential reflect the IRP avoided cost scenario.

TABLE 4.2 TECHNICAL, ECONOMIC, AND ACHIEVABLE POTENTIAL BY SECTOR – 2035							
Sector	Baseline Sales	Technical Potential		Economic Potential - IRP		Achievable Potential	
		aMW	Percent of Baseline	aMW	Percent of Baseline	aMW	Percent of Baseline
Residential	370	121	33%	59	16%	49	13%
Commercial	740	226	31%	186	25%	146	20%
Industrial	208	12	6%	10	5%	9	4%
Street Lighting	10	2	22%	2	22%	2	22%
Total	**1,328**	**362**	**27%**	**257**	**19%**	**205**	**15%**

The commercial sector, which represents 56% of baseline energy use, accounts for approximately 71% of achievable economic conservation potential. The residential, industrial sectors account for 24%, 4%, and 1%, respectively (Figure 4.1). While the residential sector's share of baseline energy consumption is slightly higher than its share of achievable economic potential, the industrial sector's share of total achievable economic potential (5%) is much lower than its share of baseline energy consumption (15%). This is not surprising, as City Light has aggressive pursued and planned for industrial efficiency projects over the last two years.

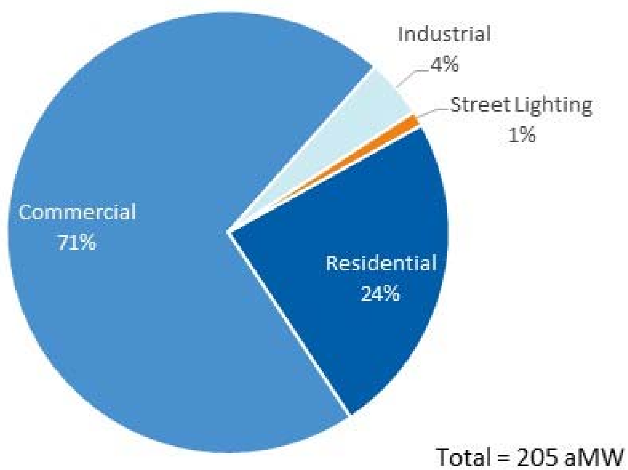

Figure 4.1 Achievable Economic Potential by Sector - 2035

Incremental achievable potential in each year of the study horizon is determined by the rate at which equipment naturally turns over and measure specific ramp rates (as discussed in the *About Measure Ramp Rates* section of this report). Table 4.3 shows cumulative two-year, ten-year, and 20-year achievable potential by sector, as well as 20% of the ten-year achievable potential, which is equivalent to City Light's pro-rata share of ten-year potential for the 2016-2017 biennium.

TABLE 4.3 ACHIEVABLE POTENTIAL BY SECTOR

Sector	Achievable Economic Potential – MWh			
	Two Year (2016-2017)	Ten Year (2016-2025)	20 Year (2016-2035)	20% of Ten-Year Potential
Residential	5.9	36.5	48.6	7.3
Commercial	10.3	82.2	145.9	16.4
Industrial	1.7	7.1	8.8	1.4
Street Lighting	2.2	2.2	2.2	0.4
Total	**20.1**	**128.1**	**205.4**	**25.6**

Pro-rata 10-year achievable economic potential is approximately 25% higher than cumulative achievable potential in 2017. This is because ramp rates gradually increase the incremental savings for most measures over the first 10 years of the study. Figure 4.2 and Figure 4.3 show cumulative and incremental achievable economic potential, by sector, over the study's 20-year horizon.

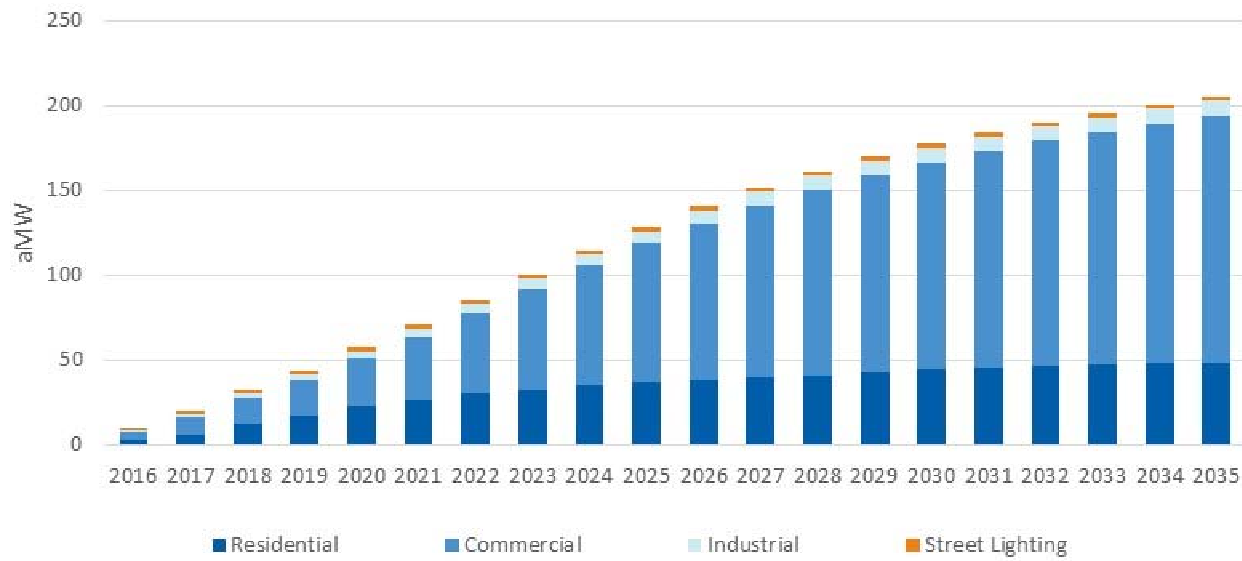

Figure 4.2 Cumulative Achievable Economic Potential

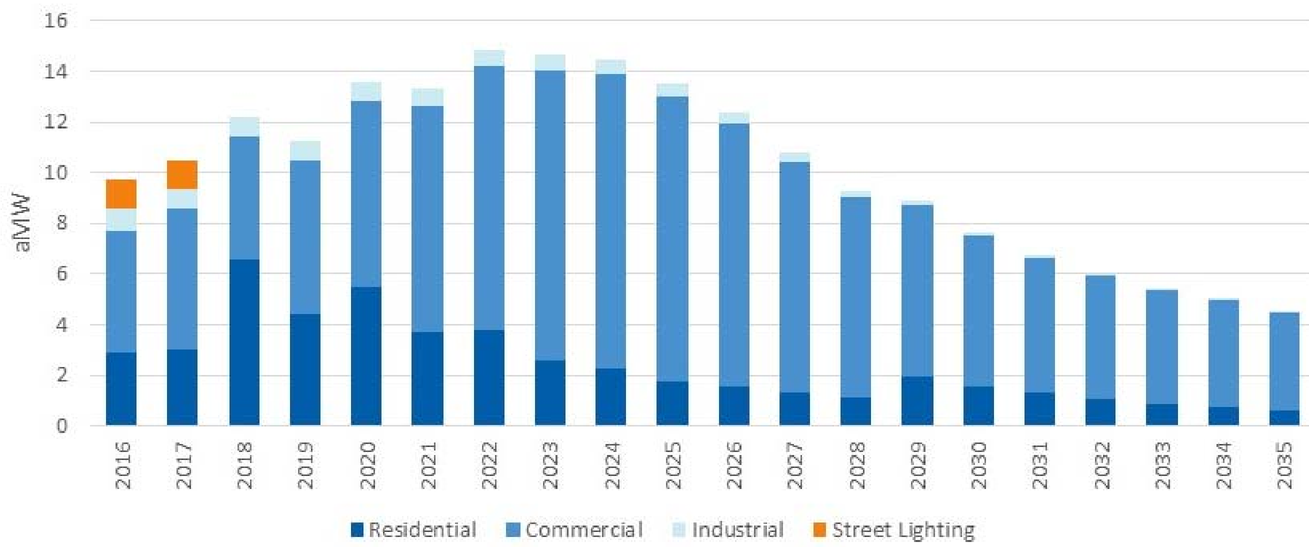

Figure 4.3 Incremental Achievable Economic Potential

Approximately 28% of 20-year achievable potential is acquired in the first five years and 63% of 20-year achievable potential is acquired in the first ten years. This acquisition rate reflects the mixture of measures for which there are high savings potential and is aligned with City Light's prior program accomplishments. Residential lighting, for instance, accounts for a large portion of five year potential due to a short baseline measure life (2 years) and a relatively fast ramp rate. The spikes in residential achievable economic potential shown in Figure 4.3 are due to the interaction between measure ramp rates and a short baseline measure life for lighting— refer to the *About Measure Ramp Rates* section of this report for more information on how Cadmus performs this calculation.

Study results indicate that conservation is a low cost resource, with roughly 177 aMW of achievable economic potential at a cost of less than $40/MWh levelized-- this represents nearly 88% of total cumulative 20-year achievable potential. The conservation supply curve in Figure 4.4 shows cumulative achievable potential in $10/MWh levelized cost increments.

Figure 4.4 Supply Curve – Achievable Economic Potential (All Sectors)

Cadmus identified cost-effective conservation potential up to $80/MWh—cost-effective measures with relatively high levelized costs tend to either have long measure lives or significant deferred transmission and distribution benefits. Appendix F shows detailed measure-level results, including levelized costs and both technical and achievable economic conservation potential for each measure. The remainder of this section provides detailed results by sector.

4.1.3. Comparison with the 2013 Conservation Potential Assessment

The 2016 Conservation Potential Assessment (CPA) differs from the 2013 CPA in several key ways—some global and some sector-specific; these differences affect estimates of conservation potential. Table 4.4 shows cumulative, 20-year, technical, economic, and achievable potential, expressed as a fraction of baseline sales, from the 2016 CPA and the 2013 CPA.

TABLE 4.4 CUMULATIVE 20-YEAR POTENTIAL AS A FRACTION OF BASELINE SALES – 2016 AND 2013 CPAS						
Sector	**Technical Potential—20-Year MWh as a % of Baseline**		**Economic Potential—20-Year MWh as a % of Baseline**		**Achievable Potential—20-Year MWh as a % of Baseline**	
	2016 CPA	**2013 CPA**	**2016 CPA**	**2013 CPA**	**2016 CPA**	**2013 CPA**
Residential	33%	38%	16%	23%	13%	15%
Commercial	31%	30%	25%	24%	20%	19%
Industrial	6%	13%	5%	10%	4%	8%
Street Lighting	22%	44%	22%	42%	22%	42%
Total	**27%**	**31%**	**19%**	**23%**	**15%**	**17%**

The following key changes account for differences in estimated potential for the 2016 and 2013 CPAs:

- **Residential:** The 2016 CPA indicates lower residential technical, economic, and achievable potential as a fraction of baseline sales than those indicated in the 2013 CPA. This largely results from reduced savings potential for home electronics measures. While efficient home electronics accounted for 22% of economic potential in the 2013 CPA, the end-use group only accounts for 7% of economic potential in the 2016 CPA. Compared to the 2013 CPA, the 2016 CPA found a higher proportion of home electronics are already efficient, which contributed to lower savings potential
- **Commercial:** The 2016 CPA indicates commercial potential as a fraction of baseline sales comparable to the 2013 CPA. The 2016 CPA potential savings, however, derive from a different mixture of measures that those used in the 2013 CPA. For example, water-heating measures accounted for 11% of the 20-year economic potential in the 2013 CPA; in the 2016 CPA, they account for roughly 2% of economic potential. This decrease is due to lower assumed savings for tank type water heaters and reduced water heater baseline consumption.
- **Industrial:** The 2015 CPA indicates significantly lower industrial achievable economic potential as a fraction of baseline sales (4%) than does the 2013 CPA (8%). This primarily results from program accomplishments. City Light achieved approximately 30,000 MWh savings in the industrial sector from 2013 through 2014, and expects projects completed in 2015 will contribute an additional 10,000 MWh savings. This 40,000 MWh is equivalent to approximately 40% of the estimated 20-year industrial potential identified in the 2013 CPA.
- **Street Lighting:** The 2016 CPA indicates street lighting potential roughly 50% lower than estimated potential in the 2013 CPA. This decrease in potential results from the City of Seattle's recent accomplishments.

While the 2013 and 2016 CPAs provide estimates of potential relative to baseline sales, the 2016 CPA indicates lower absolute estimates of technical and economic potential. This primarily results from City Light's lower residential and commercial baseline forecasts. Table 4.5 summarizes 20-year, cumulative, technical potential and baseline sales in the 2016 and 2013 CPAs.

TABLE 4.5 20-YEAR TECHNICAL POTENTIAL – 2016 AND 2013 CPAS

Sector	2016 CPA			2013 CPA		
	Baseline Sales - 20 Year	Technical Potential - 20 Year	Technical Potential as % of Baseline Sales	Baseline Sales - 20 Year	Technical Potential - 20 Year	Technical Potential as % of Baseline Sales
Residential	372	121	33%	408	157	38%
Commercial	740	226	31%	880	268	30%
Industrial	208	12	6%	152	20	13%
Street Lighting	10	2	22%	10	4	44%
Total	**1,330**	**362**	**27%**	**1,450**	**450**	**31%**

In the 2016 CPA, 20-year baseline residential and commercial sales are 8% and 16% lower (respectively) than in the 2013 CPA. Overall, the 2016 CPA 20-year baselines are approximately 8% lower than in the 2013 CPA. This reflects City Light's most recent load forecast. The decrease in baseline consumption significantly affects estimates of technical potential, with overall, 20-year technical potential nearly 20% lower in the 2016 CPA than in the 2013 CPA. Much of this decrease stems from the drop in baseline forecasts—for instance, commercial technical potential as a fraction of baseline sales is roughly the same in the 2013 and 2016 assessments, but the absolute technical potential is approximately 16% lower in the 2016 assessment (the same as the decrease in the baseline forecast).

A lower portion of technical potential results from cost-effective ECMs in the 2016 CPA, compared to the 2013 CPA. Table 4.6 summarizes 20-year, cumulative economic potential for the market price scenario in the 2016 and the 2013 CPAs.[20]

20

TABLE 4.6 20-YEAR CUMULATIVE ECONOMIC POTENTIAL – 2016 AND 2013 CPAS						
Sector	2016 CPA—Market Avoided Costs			2013 CPA		
	Economic Potential - 20 Year (aMW)	EP as % of Baseline Sales	Economic as a % of Technical Potential	Economic Potential - 20 Year (aMW)	Economic Potential as % of Baseline Sales	Economic Potential as % of Baseline Sales
Residential	42	11%	35%	95	23%	61%
Commercial	179	24%	79%	216	24%	81%
Industrial	8	4%	69%	15	10%	75%
Street Lighting	2	22%	100%	4	42%	96%
Total	**231**	**17%**	**64%**	**330**	**23%**	**73%**

The market price avoided cost scenario produces economic potential equivalent to 64% of technical potential in the 2016 CPA, compared to 73% in the 2013 CPA. The drop in economic potential primarily occurs in the residential sector, where economic potential represents 35% of technical potential, compared to 61% in the 2013 CPA. This decrease does not result from a change in avoided costs; rather it is driven primarily by the different mixture of top-saving measures in the residential sector.

TABLE 1.6 20-YEAR CUMULATIVE ECONOMIC POTENTIAL—2016 AND 2013 CPAS						
Sector	2016 CPA—Market Avoided Costs			2013 CPA		
	Economic Potential - 20 Year (MWh)	EP as % of Baseline Sales	EP as % of Technical Potential	Economic Potential - 20 Year (MWh)	EP as % of Baseline Sales	EP as % of Technical Potential
Residential	42	11%	35%	95	23%	61%
Commercial	179	24%	79%	216	24%	81%
Industrial	8	4%	69%	15	10%	75%
Street Lighting	2	22%	100%	4	42%	96%
Total	**231**	**17%**	**64%**	**330**	**23%**	**73%**

compares estimates for the market price scenario instead of the IRP scenario, as the 2013 CPA reported estimates of economic and achievable potential for the market price scenario. Use of IRP-preferred avoided costs as the primary avoided cost scenario is a key change for the 2015 CPA.

4.1.4. General Differences

Several broad changes affected the overall 2016 CPA results, including the following:

- **Additional sectors and resources:** City Light provided conservation potential estimates for street lighting, enterprise data centers, and Nucor cogeneration. Enterprise data center potential is incorporated in the commercial sector, and Nucor cogeneration is incorporated in the industrial sector. Cadmus also developed estimates of conservation potential for existing and projected indoor agriculture facilities.
- **Avoided costs**: City Light develops two avoided cost forecasts:
  - "Market" avoided costs, equaling a forecast of regional market prices; and[21]
  - "IRP" avoided cost forecast, based on City Light's preferred portfolio from the last IRP cycle.

  These avoided costs include construction of new renewable generation in 2022, and include CO_2 offsets, avoided T&D (which Cadmus models as an avoided capacity cost), and a 10% conservation credit. Market avoided costs are approximately 4.1 cents/kWh on a 20-year levelized basis, and IRP avoided costs are approximately 6.2 cents/ kWh on a 20-year levelized basis.

  Cadmus' estimates of economic potential use "IRP" avoided costs, as these reflect City Light's most likely planning scenario. The 2013 assessment used avoided costs for the market scenario.

- **Administrative costs**: The 2013 CPA used a blanket 20% administrative cost adder for all sectors. The 2016 CPA uses sector-specific administrative cost adders, derived from City Light's program tracking data. The residential and C&I administrative cost adders equal 11% and 22%, respectively. The weighted average administrative cost adder approximately equals 18%.
- **Inclusion of 7th Power Plan Measures**: Residential, commercial, and industrial measures are based on 7th Power Plan and on active RTF measures. Many of these measures include updated market baselines which reduced per unit savings for many measures. In addition, Cadmus largely excluded measures removed from the 7th Power Plan (such as many weatherization measures for new construction) as these are captured by codes and standards.
- **Accelerated achievable conservation:** For each measure, Cadmus applied ramp rates consistent with those used in the Council's Draft 7th Power Plan. Due to the application of these ramp rates and the different mixture of high-saving measures, Cadmus found a higher portion of 20-year potential will be achieved in the first 10 years of the study horizon than that estimated in the 2013 CPA. Specifically, 10-year achievable potential is approximately 63% of 20-year achievable potential in the 2016 CPA, compared to 47% in the 2013 CPA.

4.1.5. Residential

The following three factors produced lower estimates of residential conservation potential:

- **Updated baselines**: Cadmus' measure baselines reflect the current saturation of efficient technology and both current and upcoming federal equipment standards. These factors largely contributed to reduced savings potential. Savings expressed as a percentage of baseline sales decrease for nearly every residential end use. Figure 4.5 compares 20-year savings, expressed as a fraction of baseline sales, between in the 2016 CPA to the 2013 CPA.

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21 WAC 194-37-070c requires utilities to set avoided costs equal to regional market prices.

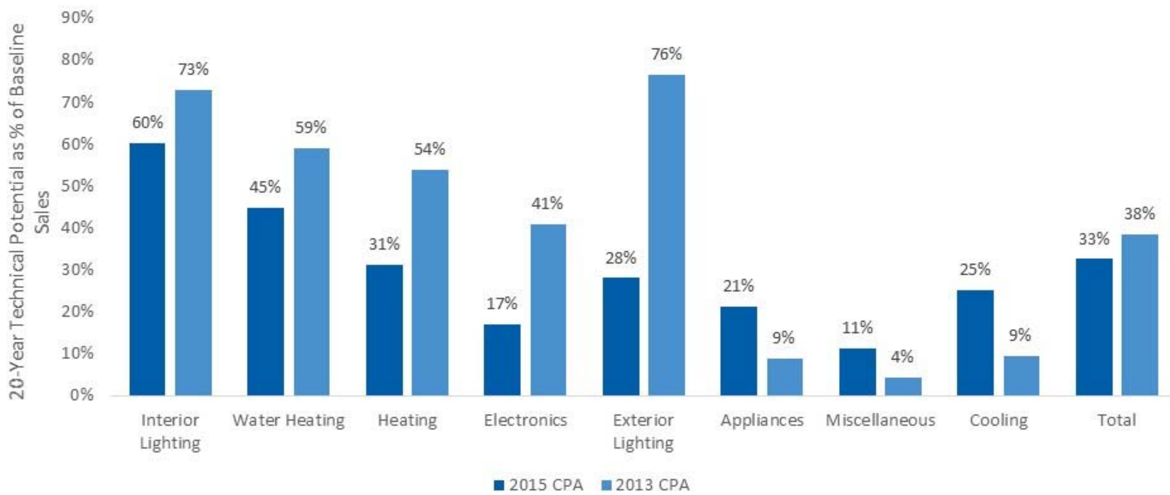

Figure 4.5 Residential Technical Potential as a Percent of Baseline Sales by End Use

Some end-use groups, such as appliances, show increased potential, relative to baseline sales. For example, higher appliance savings result from emerging technologies, such as heat pump dryers.

- **Baseline forecast**: City Light's residential load forecast is approximately 9% lower in the 20th year of the 2016 CPA study horizon (2035) than in the 20th year of the 2013 CPA study horizon (2033). Cadmus calibrated baseline load forecasts to City Light's forecast, resulting in lower baseline load forecasts and, consequently, lower estimates of energy efficiency potential.
- **Home electronics**: Efficient home electronics measures account for 9% of residential achievable economic potential in the 2016 CPA, compared to 22% in the 2013 CPA. Cadmus relied on the U.S. Environmental Protection Agency's ENERGY STAR market share reports and other secondary sources to determine the baseline saturation of ENERGY STAR home electronics. End uses with high savings potential in the 2013 CPA, such as televisions and set-top-boxes, offer minimal savings potential in the 2016 CPA due to high baseline saturations.

4.1.6. Commercial

The following two factors drove changes in commercial conservation potential:

- **Baseline end-use consumption:** Cadmus developed new baseline end-use forecasts, based on the following:
    - Whole-building energy intensities, derived from City Light's nonresidential customer database;
    - End-use saturations, derived from City Light's CBSA oversample; and
    - End-use energy use intensities, derived from building simulations and secondary sources.

  The characterization of end-use consumption resulted in a higher share of consumption attributed to lighting and a lower share attributed to "other" end uses, which includes data centers, office equipment, cooking, and low-consuming miscellaneous end uses (such as air compressors). Figure 4.6 shows the distribution of commercial baseline consumption by end use in the 20th year.

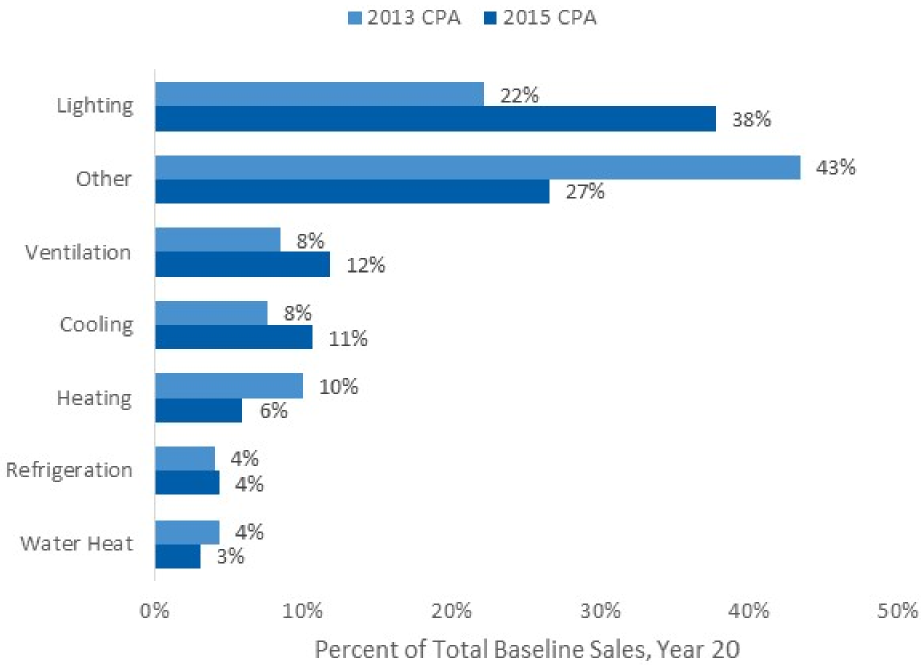

Figure 4.6 Distribution of Commercial Baseline End-Use Consumption

Higher lighting consumption presents implications for energy efficiency potential estimates. While lighting's technical potential as a fraction of baseline sales decreased due to updated baseline saturations and federal standards (48% in the 2016 CPA, compared to 72% in the 2013 CPA), the two studies produced roughly the same absolute lighting savings potential due to higher overall baseline lighting consumption.

- **Water Heating Potential**: Cadmus found significantly lower potential for the water heating end use in the 2016 CPA, compared to the 2013 CPA. Water heating measures, including efficient equipment and retrofits to existing equipment (e.g., efficient spray valves, showerheads, aerators), account for 2% of economic potential in the 2016 CPA, compared to 11% in the 2013 CPA. U.S. Department of Energy (DOE) rulemaking (requiring electric water heaters with a tank size greater than 55 gallons to achieve an energy factor of at least 2.057) contributed to this decrease in potential. Cadmus also incorporated updated baseline saturations of efficient aerators, showerheads, and pre-rinse spray valves.

4.1.7. Industrial

The following two items largely explain the decrease in industrial sector potential:

- **Program accomplishments:** City Light's industrial program accomplishments for 2013 through 2014 represented a large fraction of industrial, achievable potential identified in the 2013 CPA. The 2013 CPA identified approximately 106,000 MWh of achievable energy efficiency potential over the planning horizon. Since 2013, City Light has achieved approximately 30,000 MWh in savings through industrial programs, with an additional 10,000 MWh projected for 2015. Cadmus estimated approximately 63,000 MWh of 20-year, industrial, achievable potential, an amount nearly identical to 2013 savings, adjusted for program accomplishments. It should be noted, however, that the study produced an industrial baseline forecast roughly 24% higher in the 20th year, compared to the 2013 CPA. Thus, program accomplishments do not account for the entire difference in industrial savings potential.

- **Interactions:** Cadmus accounted for interactions between measures affecting the same end use by adjusting baseline consumption as measures installed. This approach avoided overstating potential savings. Cadmus' estimated industrial potential with and without interactions and found interactions accounted for approximately a 10% reduction in technical potential.

4.2. Residential – Detailed Results

Residential customers in City Light's service territory account for 28% of total baseline sales. The sector, which is divided into single family, multifamily low-rise, multifamily mid-rise, and multifamily high-rise homes, present of variety of potential savings sources, including equipment efficiency upgrades (e.g. water heaters and appliances), improvements to building shells (e.g. windows, insulation, and air sealing), and increases in lighting efficiency.

Based on resources included in this assessment, Cadmus estimated residential cumulative achievable potential of 49 aMW over 20 years, corresponding to nearly a 13% reduction in baseline sales by 2035. Table 4.7 shows cumulative 20-year residential conservation potential by segment.

TABLE 4.7 RESIDENTIAL POTENTIAL BY SEGMENT

Sector	Baseline Sales	Cumulative 2035 - aMW						
		Technical Potential (TP)	TP % of Baseline	Economic Potential (EP)	EP % of Baseline	EP % of TP	Achievable Potential (AP)	AP % of EP
Single Family	211	68	32%	36	17%	53%	29	81%
Multifamily - High Rise	23	5	22%	3	15%	66%	3	84%
Multifamily - Mid Rise	64	17	26%	9	14%	56%	8	85%
Multifamily - Low Rise	72	32	44%	10	14%	32%	9	85%
Total	**370**	**121**	**33%**	**59**	**16%**	**49%**	**49**	**82%**

As shown in Table 4.7 and Figure 4.7, single family homes account for 60% (29 aMW) of total achievable economic potential, followed by multifamily low-rise (9 aMW), multifamily mid-rise (8 aMW), and multifamily high-rise (3 aMW). Each home type's proportion of baseline sales drive this distribution, but segment-specific end use saturations and fuel shares have a role as well. Appendix A includes detailed data on saturations and fuel shares for each segment.

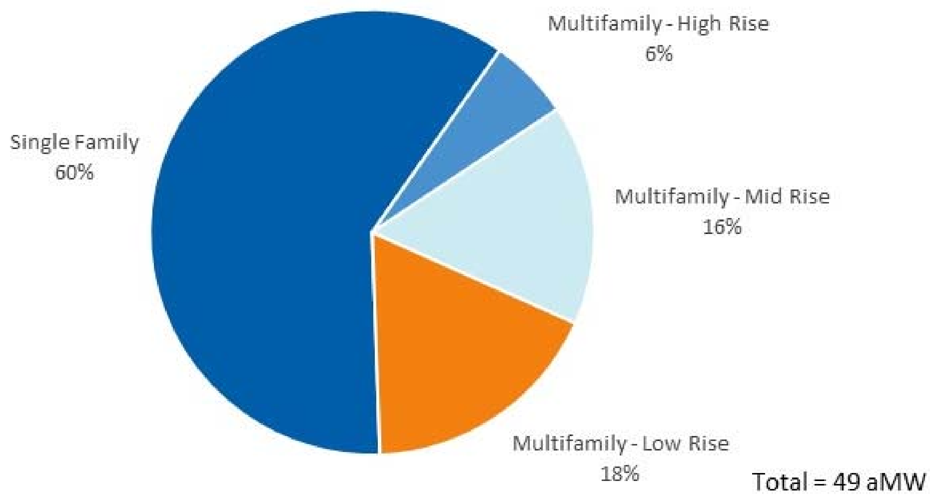

Figure 4.7 Residential Achievable Economic Potential by Segment - 2035

Interior lighting accounts for over one-half (51%) of total cumulative achievable economic potential by end use (as shown in Table 4.8 and Figure 4.8)—this savings is nearly entirely from the installation of LED lighting in standard and specialty fixtures. Efficient upgrades to linear fluorescent fixtures in homes accounts for a small portion of total residential lighting savings.

TABLE 4.8 RESIDENTIAL POTENTIAL BY END USE

Sector	Baseline Sales	Cumulative 2035 - aMW						
		Technical Potential (TP)	TP % of Baseline	Economic Potential (EP)	EP % of Baseline	EP % of TP	Achievable Potential (AP)	AP % of EP[a]
Interior Lighting	55	33	60%	29	53%	88%	25	85%
Water Heating	67	30	45%	16	24%	53%	13	83%
Heating	90	28	31%	6	7%	23%	4	66%
Electronics	79	13	17%	5	6%	37%	4	85%
Exterior Lighting	7	2	28%	2	28%	100%	2	85%
Appliances	60	13	22%	0	1%	3%	0	86%
Miscellaneous	11	1	11%	0	2%	19%	0	85%
Cooling	1	0	25%	0	6%	23%	0	84%
Total	**370**	**121**	**33%**	**59**	**16%**	**49%**	**49**	**82%**

[a] Some measures do not reach the maximum achievability of 85% due to the application of ramp rates. These measures tend to have long measure lives, such as efficient heat pumps (which is accounted for in the heating end use) or efficient water heaters.

Water heating savings includes both upgrades to efficient equipment, such as heat pump water heaters for unit less than 55 gallons, and the installation of water-saving measures, such as high efficiency aerators and showerheads. Clothes washer savings are also accounted for in the water heating end use, as most energy savings comes from reduced hot water use.

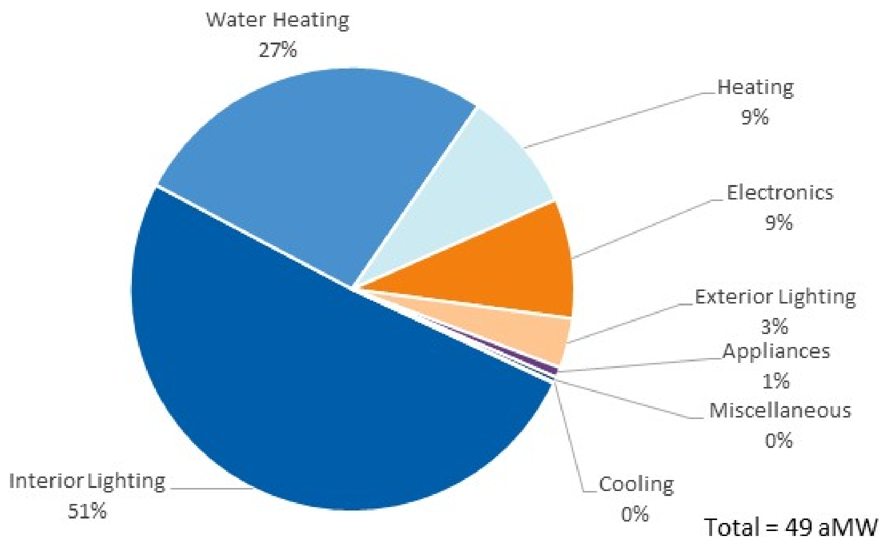

Figure 4.8 Residential Achievable Economic Potential by End Use - 2035

Incremental and cumulative potential over the 20-year study horizon varies by end use due the application of ramp rates—ramp rates were assigned to each measure based on a number of factors, including availability, existing program activity, and market trends. Cadmus used the same ramp rates for each measure as assigned by the Council in the draft 7th Power Plan. Figure 4.9 and Figure 4.10 show cumulative and incremental residential achievable potential, respectively.

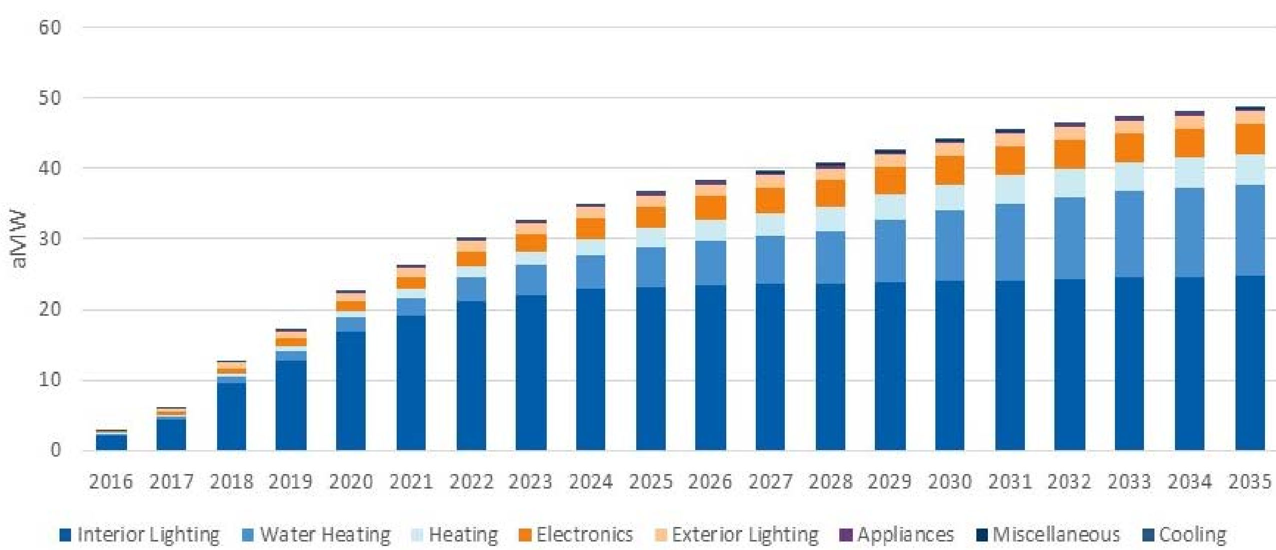

Figure 4.9 Residential Cumulative Achievable Economic Potential

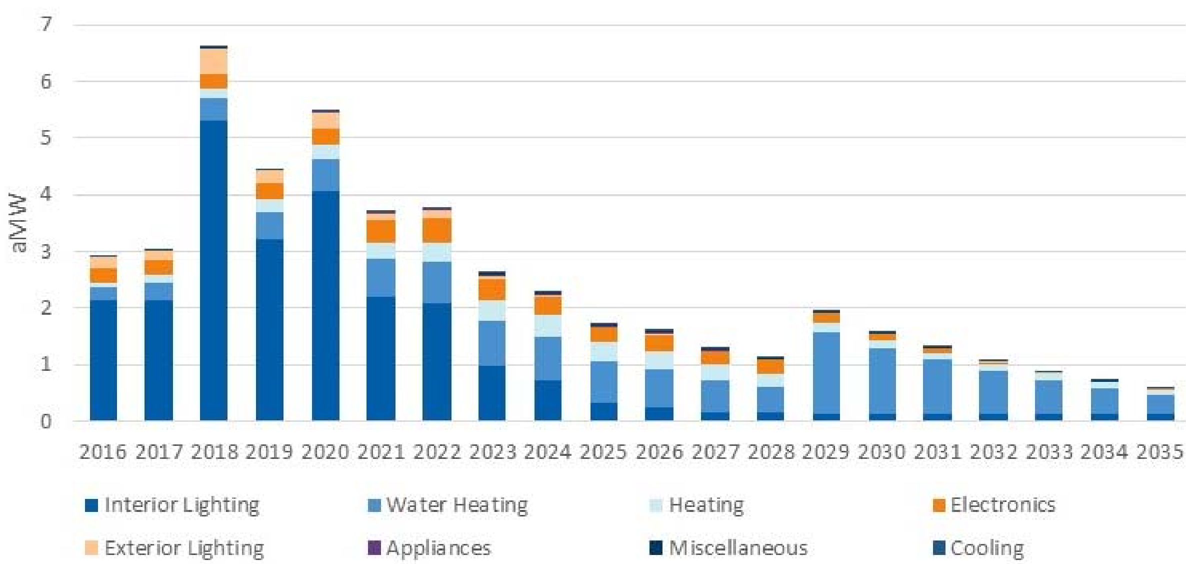

Figure 4.10 Residential Incremental Achievable Economic Potential

Measure ramp rates and effective useful lives (for equipment replacement measures only), determine the timing of savings shown in . The spike in lighting savings in 2018 and 2020 is due to the interaction between lighting ramp rates and the relatively short baseline measure life for standard and specialty lighting measures (2 years). Specifically, LED bulbs that were not installed in 2016 due to the application of a ramp rate are largely available for installation in 2018. A similar effect explains the increase in water heater savings in 2029, as water heaters have a baseline measure life of 13 years.

Overall, most (79%) of residential conservation potential is achievable within the first ten years. Approximately 51% of 20-year residential achievable economic potential comes in the first five years, and 70% of this five year potential comes from interior lighting. The rapid acquisition of lighting savings is consistent with research that points to a transformation in the lighting market—CFL sales have declined in recent years, while the availability of LED bulbs (measured by the percentage of total bulbs stocked) has roughly doubled. CFL prices in the region have slightly increased, while LED prices continue to decrease.[22]

Figure 4.11 shows 20-year cumulative residential potential by levelized cost (in $10/MWh increments).

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22 DNV GL "2014-2015 Northwest Residential Lighting Long-Term Market Tracking Study" *Northwest Energy Efficiency Alliance*, August 20, 2015. http://neea.org/docs/default-source/reports/northwest-residential-lighting-long-term-market-tracking-study.pdf?sfvrsn=4

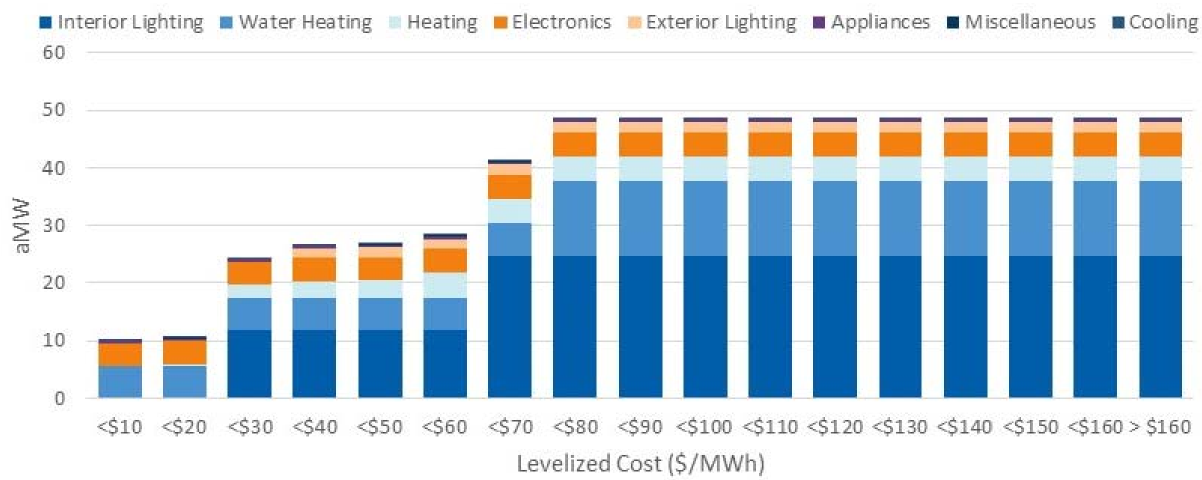

Figure 4.11 Residential Supply Curve

Nearly 55% of total residential achievable economic potential comes from measures with a levelized cost of conserved energy of $40/MWh or less. Few measures have levelized costs above $70/MWh—these are generally measures within the heating end use that have long measure lives and benefits that span multiple end uses.

LED lighting for standard screw base and specialty fixtures are the top two saving residential measures, respectively. Table 4.9 lists the top 15 saving residential measures.

TABLE 4.9 TOP-SAVING RESIDENTIAL MEASURES

Measure Name	Achievable Economic Potential - aMW			Percent of Total (20-Year)
	2-Year	10 - year	20 -Year	
LED Interior General Purpose Bulb	2.19	12.24	12.92	27%
LED - Specialty	2.09	10.93	11.77	24%
Heat Pump Water Heater - Tier 1	0.14	1.88	7.35	15%
SF Showerhead Replace_1_50gpm_Any Shower_ AnyWH	0.20	1.78	2.38	5%
MF Showerhead Replace_1_50gpm_Any Shower_ AnyWH	0.18	1.60	2.13	4%
Home Energy Reports	0.45	1.80	2.04	4%
Motor - ECM	0.03	0.69	1.77	4%
LED - Exterior	0.35	1.66	1.76	4%
Bathroom Aerator	0.01	0.38	1.19	2%
Set Top Box - ENERGY STAR	0.03	0.65	1.06	2%
Wall Insulation	0.08	0.73	0.88	2%
TV LCD - ENERGY STAR	0.02	0.49	0.81	2%
Floor Insulation	0.08	0.67	0.81	2%
SF CC&S + HZ1	0.00	0.18	0.35	1%
Freezer Decommissioning and Recycling	0.03	0.26	0.33	1%

Lighting and water heating measures including LED light bulbs, heat pump water heaters, and low flow showerheads are the top five saving residential measures. These measures collectively account for 75% of 20-year cumulative residential achievable economic potential. It is important to note that Table 4.9 *only* includes measures pass the benefit-cost screen. Solar water heaters, for instance, have the highest technical potential of any measures, however, they are not cost-effective from a TRC perspective.

4.3. Commercial

City Light's commercial sector accounts for 56% of City Light's baseline sales in 2035, and 71% of total achievable economic potential. The commercial sector makes up a higher proportion of potential (compared to its share of baseline sales) because commercial measures are generally more cost-effective and have more savings potential than measures found in other sectors. Cadmus estimated potential for the 23 commercial segments included in Table 3.3 (which we grouped into 17 segments for this report). Table 4.10 summarizes 20-year cumulative technical, economic, and achievable economic potential and summarizes the distribution of achievable economic potential by commercial segment.

TABLE 4.10 COMMERCIAL POTENTIAL BY SEGMENT

Segment	Baseline Sales	Cumulative 2035 - aMW						
		Technical Potential (TP)	TP % of Baseline	Economic Potential (EP)	EP % of Baseline	EP % of TP	Achievable Potential (AP)	AP % of EP
Assembly	33	11	34%	10	29%	87%	7	76%
Data Center	59	4	6%	4	6%	100%	4	100%
Hospital	39	8	21%	7	19%	91%	6	84%
Large Grocery	22	9	42%	8	37%	89%	7	85%
Large Office	181	60	33%	44	25%	74%	34	77%
Lodging	26	6	23%	5	19%	86%	4	80%
MF Common Area	53	25	48%	23	43%	90%	18	77%
Miscellaneous	44	13	29%	12	26%	90%	9	81%
Other Health	15	6	37%	5	34%	91%	4	85%
Restaurant	29	9	30%	8	27%	89%	7	84%
Retail	66	22	33%	19	29%	89%	15	77%
School	16	7	42%	5	33%	78%	4	72%
Small Grocery	8	3	42%	3	37%	89%	3	85%
Small Office	45	14	30%	10	23%	75%	8	72%
University	62	17	28%	14	22%	79%	11	78%
Warehouse	41	10	24%	8	20%	81%	6	70%
Indoor Agriculture	N/A	3	N/A	1	N/A	31%	1	84%
Total	**740**	**226**	**31%**	**186**	**25%**	**82%**	**146**	**78%**

Nearly one-quarter (24%) of 20-year commercial achievable potential is within the large office segment (Figure 4.12). Collectively, large and small offices account for 29% of commercial achievable economic potential. The multifamily common area segment has the highest savings relative to baseline sales due to high savings potential for interior, exterior, and parking lighting upgrades. Overall, a high portion of commercial technical potential is cost-effective (economic)—depending on the segment, economic potential is between 74% and 91% of technical potential for all segments except for indoor agriculture and data centers.[23]

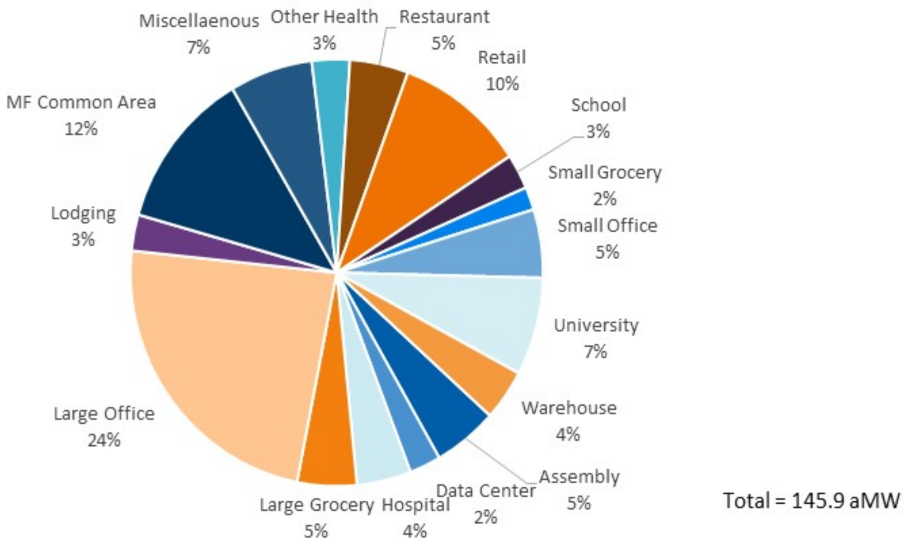

Figure 4.12 Commercial Achievable Potential by Segment - 2035

Across each of these segments, lighting accounts for a high portion of total achievable economic potential. Table 4.11 shows 20-year cumulative commercial potential by end use and Figure 4.13 shows the distribution of 20-year achievable economic potential by end use.

23 Excluding indoor agriculture and enterprise data centers. Indoor agriculture economic potential is roughly 31% of technical. Cadmus' estimates of savings potential for Enterprise Data Centers are based on City Light program expectations. Hence, 100% of technical potential is economic and 100% of economic potential is achievable.

TABLE 4.11 COMMERCIAL POTENTIAL BY END USE

Segment	Baseline Sales	Cumulative 2035 - aMW						
		Technical Potential (TP)	TP % of Baseline	Economic Potential (EP)	EP % of Baseline	EP % of TP	Achievable Potential (AP)	AP % of EP
Cooking	2	1	42%	1	36%	86%	1	84%
Cooling	78	23	30%	11	14%	46%	9	82%
Data Center	105	22	21%	21	20%	97%	19	87%
Heat Pump	20	3	15%	1	3%	20%	0	85%
Heating	24	9	36%	6	24%	66%	4	78%
Lighting	280	136	49%	121	43%	90%	91	75%
Miscellaneous	89	9	10%	4	4%	39%	3	84%
Refrigeration	32	6	19%	5	16%	86%	5	86%
Ventilation	87	14	16%	13	15%	93%	11	84%
Water Heat	23	3	15%	3	15%	99%	3	86%
Total	**740**	**226**	**31%**	**186**	**25%**	**82%**	**146**	**78%**

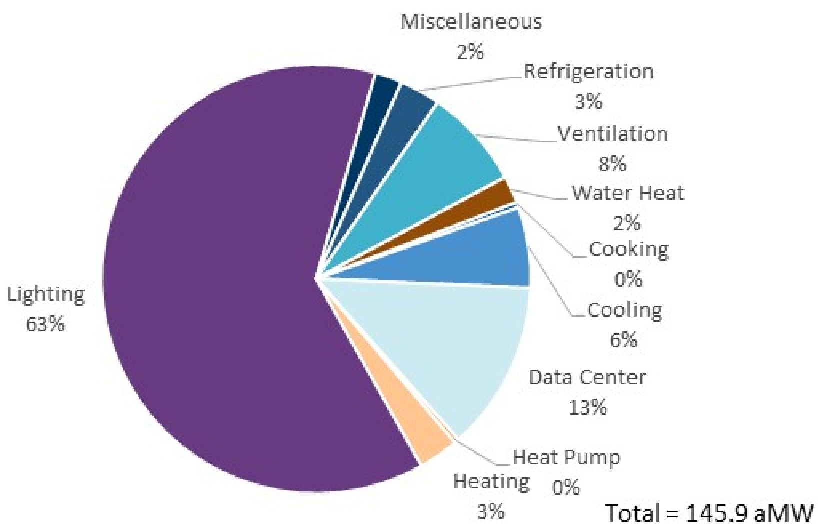

Figure 4.13 Commercial Achievable Economic Potential by End Use - 2035

Nearly two-thirds (63%) of commercial achievable potential comes from interior lighting equipment upgrades, exterior lighting equipment upgrades, and controls. Lighting 20-year technical potential is equivalent to a 49% reduction in baseline lighting consumption. Overall, 90% of lighting technical potential is cost-effective. Only 75% of lighting potential is achievable over the study horizon due because a high portion of savings for the end use comes from natural replacement measures (which do not always reach 85% achievability, depending on the measure's lifetime and ramp rate).

Similar to the residential sector, a large portion commercial potential is achieved within the first ten years of the study horizon. Figure 4.14 and Figure 4.15 show cumulative and incremental achievable potential for the commercial sector, respectively.

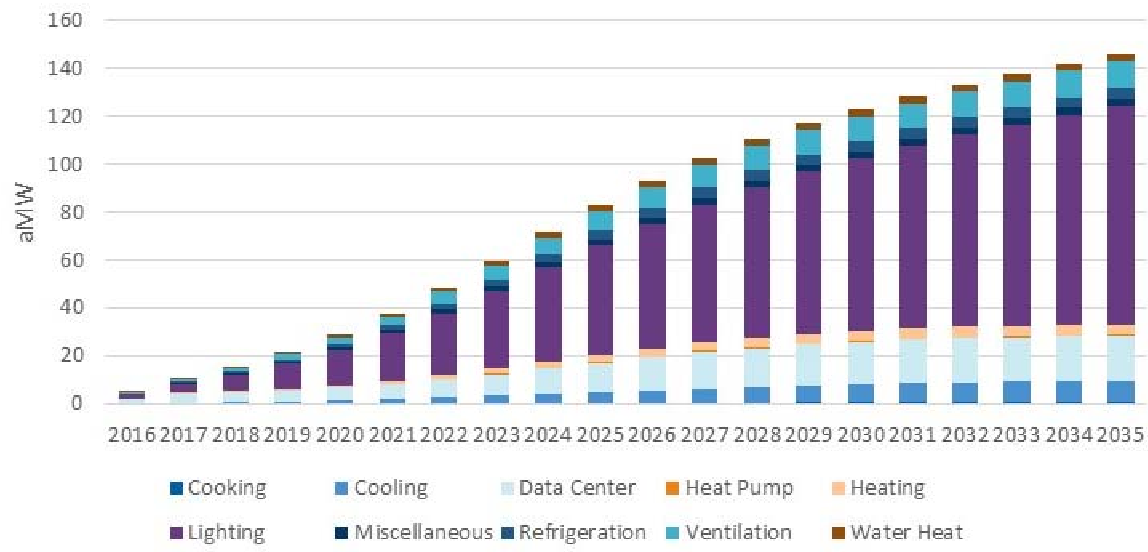

Figure 4.14 Commercial Cumulative Achievable Economic Potential

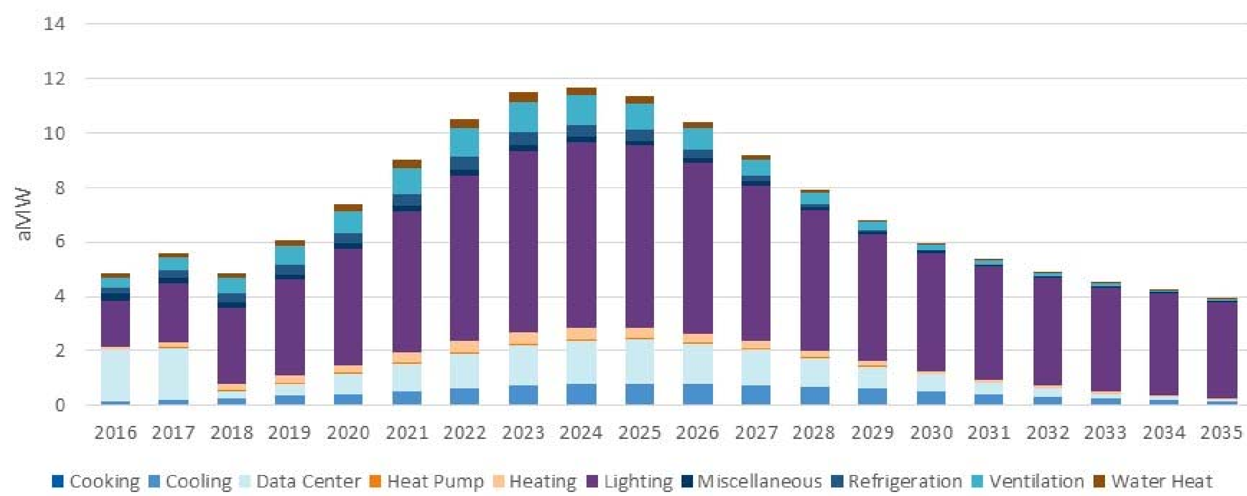

Figure 4.15 Commercial Incremental Achievable Economic Potential

Approximately 57% of 20-year commercial achievable economic potential is within the first 10 years of the study horizon. Incremental savings decreases in 2018, compared to 2016 and 2017 because these first two years include planned savings from enterprise data centers. Much of the commercial retrofit potential for existing building is exhausted within the first ten years—most savings within the last ten years of the study horizon come from the natural turnover and replacement of inefficient lighting fixtures with LEDs.

Commercial savings is not only abundant, but cheap. Figure 4.16 shows the cumulative 2035 achievable economic for the commercial sector by end use and levelized cost.

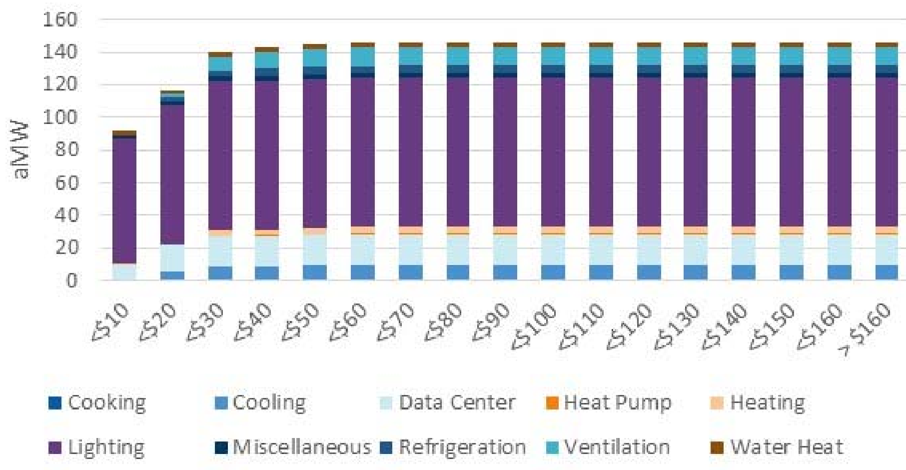

Figure 4.16 Commercial Supply Curve by End Use

Approximately 63% of cumulative achievable economic potential by 2035 costs less than $10/MWh from a TRC perspective—84% of this savings comes from lighting measures. While LED technologies are still more expensive than their incandescent, halogen, and fluorescent counterparts, the technology often has a much longer measure life, which means by installing it, future replacements of the baseline technology are deferred. For some measures, these deferred replacement costs exceed the incremental measure cost, which produces negative levelized costs.

Lighting, data center, and HVAC measures have significant conservation potential. Table 4.12 shows the top fifteen commercial measures, sorted by 20-year achievable economic potential.

TABLE 4.12 TOP-SAVING COMMERCIAL MEASURES

Measure Name	Achievable Economic Potential - aMW			Percent of Total (20-Year)
	2-Year	10-Year	20-Year	
LED - Linear Fluorescent	0.57	12.64	36.31	25%
LED - Other	1.17	10.25	12.35	8%
ECM VAV	1.02	9.13	11.71	8%
LED - Recessed Can	0.26	4.25	10.80	7%
Exterior Lighting: Façade - LED	0.76	6.94	9.48	6%
Server virtualization/consolidation	0.10	4.03	7.04	5%
LED - Highbay	0.19	2.65	6.07	4%
Advanced Rooftop Controller	0.03	1.53	4.44	3%
LED - Display or Track	0.27	2.74	4.34	3%

TABLE 4.12 TOP-SAVING COMMERCIAL MEASURES

Measure Name	Achievable Economic Potential - aMW			Percent of Total (20-Year)
	2-Year	10-Year	20-Year	
Enterprise Data Centers	3.58	3.58	3.58	2%
Demand Controlled Ventilation	0.29	2.54	3.06	2%
Showerheads	0.27	2.33	2.80	2%
Linear Fluorescent RDX - Linear Fluorescent	0.02	0.73	2.51	2%
Exterior Lighting: Walkway - LED	0.19	1.72	2.32	2%
Grocery Retrocommissioning	0.21	1.86	2.25	2%
Total	**8.93**	**66.91**	**119.04**	**82%**

LED tube replacements of linear fluorescent lighting is the highest saving measure, accounting for 36.3 aMW by 2035 (25% of total commercial potential). LED lighting for “Other” applications, which includes ceiling mounted, wall sconce, table lamps, and other miscellaneous fixtures is the second highest saving measure and also accounts for 8% of 20-year cumulative achievable economic energy potential.

Data centers also have significant savings potential—server virtualization and consolidation in embedded data centers is the sixth highest saving commercial measure with 7 aMW of achievable economic potential by 2035 (5% of total).

4.4. Industrial

Cadmus estimated conservation potential for the industrial sector using the draft Council 7th Power Plan analysis tool. Cadmus also included estimates of known potential combined heat and power projects, which were provided by City Light. We assessed conservational potential for eight industrial segments in City Light’s service territory, which were based on allocations developed from City Light’s non-residential database. The assessment identified approximately 8.8 aMW of achievable economic potential by 2035. Table 4.13 shows cumulative industrial potential by segment in 2035 and Figure 4.17 shows the distribution of industrial achievable economic potential by segment.

TABLE 4.13 INDUSTRIAL POTENTIAL BY SEGMENT

Segment	Baseline Sales	Cumulative 2035 - aMW						
		Technical Potential (TP)	TP % of Baseline	Economic Potential (EP)	EP % of Baseline	EP % of TP	Achievable Potential (AP)	AP % of EP
Foundries	64.9	2.6	4%	2.4	4%	94%	2.1	89%
Frozen Food	6.7	1.3	19%	1.0	15%	77%	0.8	85%
Miscellaneous Manufacturing	46.4	3.1	7%	2.5	5%	81%	2.2	85%
Other Food	7.7	1.2	16%	0.9	11%	71%	0.7	85%
Stone and Glass	38.3	1.7	4%	1.4	4%	83%	1.2	85%
Transportation, Equip	38.2	1.5	4%	1.2	3%	80%	1.0	85%
Wastewater	1.7	0.1	8%	0.1	8%	100%	0.1	86%
Water	3.9	0.7	18%	0.7	18%	100%	0.6	86%
Total	**207.9**	**12.2**	**6%**	**10.2**	**5%**	**84%**	**8.8**	**86%**

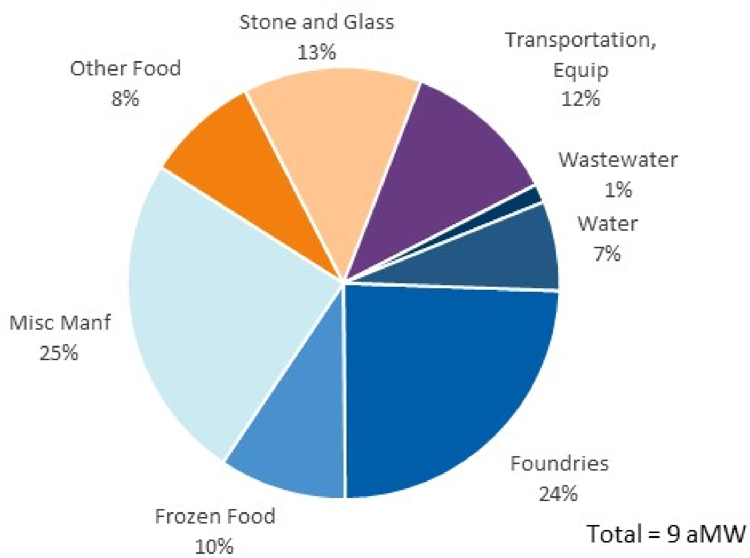

Figure 4.17 Industrial Achievable Economic Potential by Segment

The distribution of industrial achievable economic potential by segment is similar to the distribution of baseline sales. Foundries account for 26% of 20-year industrial achievable economic potential (2.1

aMW). This segment has higher potential than other segments both because it represents a large portion of baseline sales and it includes a potential combined heat and power project.[24]

Table 4.14 shows 20-year potential by industrial end use and Figure 4.18 shows the distribution of industrial achievable economic potential by end use.

TABLE 4.14 INDUSTRIAL POTENTIAL BY END USE

Segment	Baseline Sales	Cumulative 2035 - aMW						
		Technical Potential (TP)	TP % of Baseline	Economic Potential (EP)	EP % of Baseline	EP % of TP	Achievable Potential (AP)	AP % of EP
Fans	17.1	2.5	15%	1.5	9%	61%	1.3	85%
Hvac	24.3	0.7	3%	0.7	3%	102%	0.6	85%
Lighting	19.7	2.2	11%	2.2	11%	100%	1.9	85%
Motors Other	27.2	1.0	4%	0.8	3%	83%	0.7	84%
Other	17.1	0.8	5%	0.8	5%	100%	0.7	86%
Process Aircomp	14.2	0.9	7%	0.6	5%	69%	0.5	85%
Process Electro Chemical	9.9	0.2	2%	0.2	2%	100%	0.1	85%
Process Heat	32.0	0.0	0%	0.0	0%	N/A	0.0	N/A
Process Other	1.2	0.0	3%	0.0	3%	100%	0.0	84%
Process Refrig	19.5	1.2	6%	1.0	5%	82%	0.8	85%
Pumps	25.7	2.0	8%	1.7	6%	83%	1.4	85%
Cogeneration	N/A	0.6	N/A	0.6	N/A	100%	0.6	100%
Total	**207.9**	**12.2**	**6%**	**10.2**	**5%**	**84%**	**8.8**	**86%**

24 Achievable potential exceeds 85% of economic potential in the foundries sector due to this combined heat and power project (for which 100% of the potential is achievable).

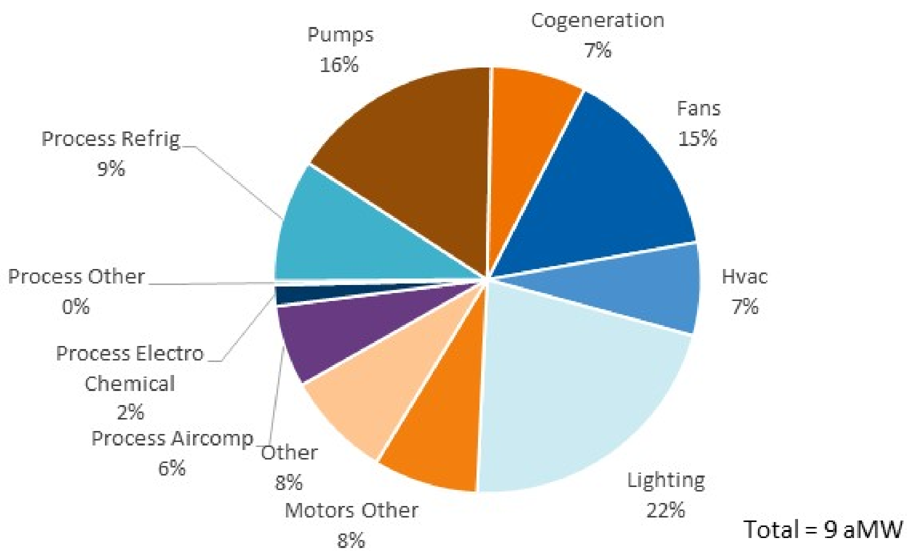

Figure 4.18 Industrial Achievable Economic Potential by End Use

Twenty-two percent of industrial achievable economic potential comes from lighting measures, followed by fans (15%), pumps (16%), and process refrigeration (9%).

Figure 4.19 and Figure 4.20 show cumulative and incremental achievable economic potential over the 20-year study horizon, respectively.

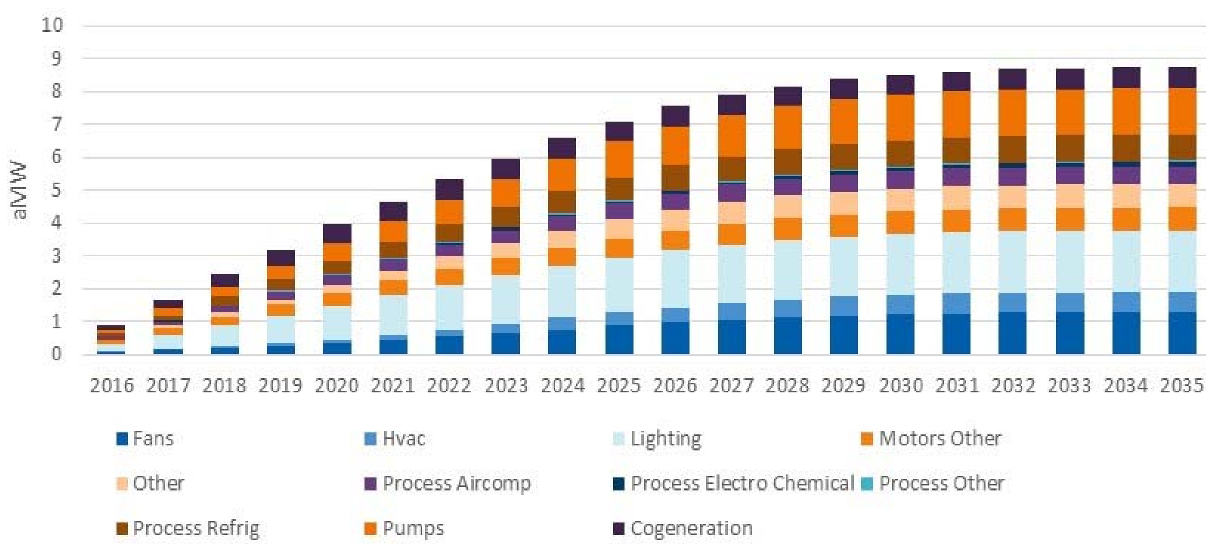

Figure 4.19 Industrial Cumulative Achievable Economic Potential

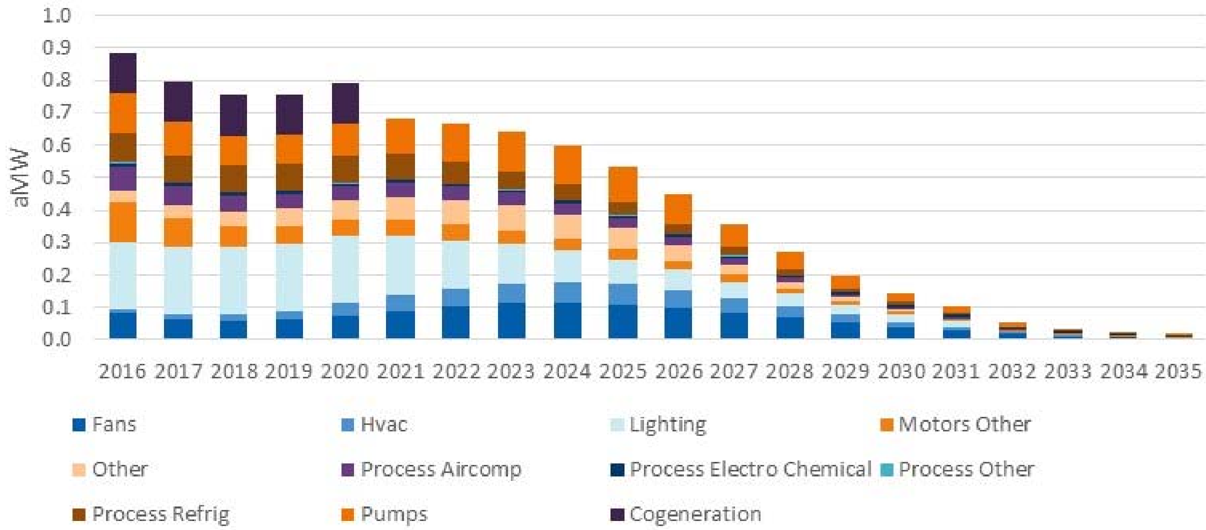

Figure 4.20 Industrial Incremental Achievable Economic Potential

Consistent with the Council's approach to the industrial sector, Cadmus modeled all industrial measures as retrofit, and did not distinguish between new and existing construction. After applying ramp rates, approximately 81% of 20-year achievable economic potential is realized within the first ten years.

Industrial measures are generally low cost—82% of technical potential is cost-effective, and all measures that contribute to achievable potential have a levelized cost of $50/MWh or lower. Figure 4.21 shows cumulative achievable economic potential in 2035 for different levelized cost thresholds.

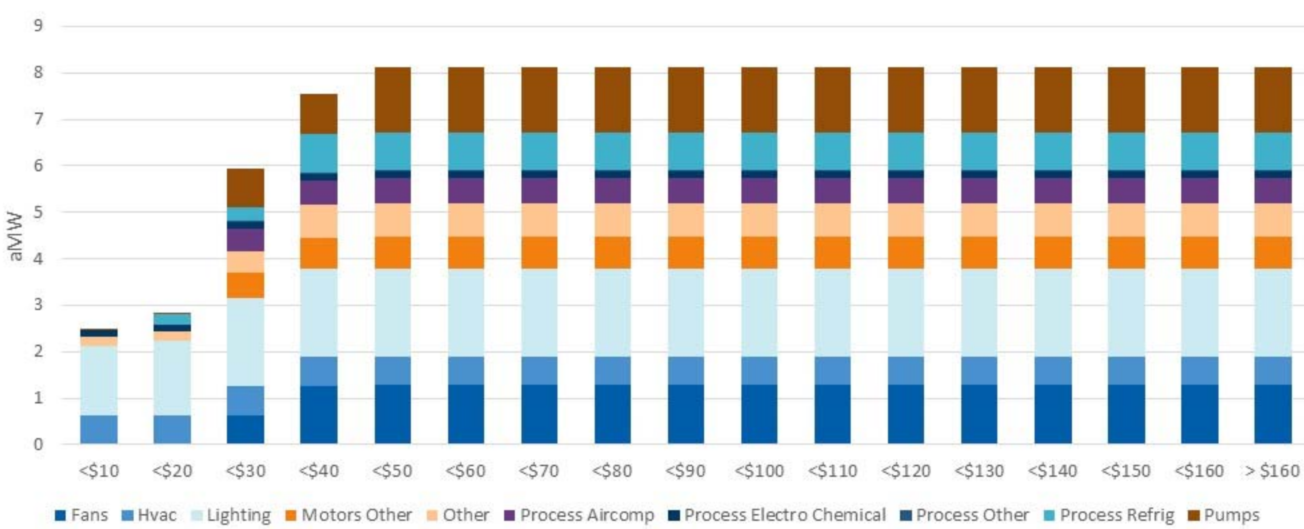

Figure 4.21 Industrial Supply Curve – Cumulative Achievable Economic Potential in 2035 by Levelized Cost

Table 4.15 shows the top 15 saving industrial measures—collectively, these represent 85% of 20-year cumulative achievable economic potential

TABLE 4.15 TOP-SAVING INDUSTRIAL MEASURES

Measure Name	Achievable Economic Potential - aMW			Percent of Total (20-Year)
	2-Year	10-year	20-Year	
Plant Energy Management	0.64	1.49	1.68	19%
HighBay Lighting 3 Shift	0.15	0.59	0.67	8%
Efficient Lighting 3 Shift	0.14	0.57	0.65	7%
Cogeneration	0.25	0.63	0.63	7%
Fan Equipment Upgrade	0.01	0.30	0.53	6%
Pump Equipment Upgrade	0.05	0.43	0.51	6%
Energy Project Management	0.04	0.36	0.43	5%
Food: Cooling and Storage	0.08	0.34	0.38	4%
Pump Energy Management	0.01	0.22	0.38	4%
Fan Energy Management	0.00	0.17	0.30	3%
Optimize Municipal Sewage; 1 to 10 MGD Design Capacity	0.02	0.21	0.26	3%
Clean Room: Chiller Optimize	0.02	0.20	0.24	3%
Clean Room: Change Filter Strategy	0.00	0.13	0.23	3%
Food: Refrig Storage Tuneup	0.05	0.19	0.21	2%
Optimize Municipal Sewage; >10 MGD Design Capacity	0.02	0.16	0.20	2%

Plant energy management is the highest saving cost-effective industrial measure, accumulating 1.68 aMW of savings by 2035, which represents 19% of total industrial achievable economic potential.

4.5. Street Lighting

City Light provided counts of remaining arterial high pressure sodium to LED conversions for arterial street lights, which will be completed in 2016 and 2017. Planned conversions include

- 200W High Pressure Sodium (HPS) to 135W LED
- 250W High Pressure Sodium (HPS) to 135W LED
- 400W High Pressure Sodium (HPS) to 135W LED
- 400W High Pressure Sodium (HPS) to 270W LED

Cadmus calculated savings for each conversion using methods consistent with the 7th Power Plan—this includes an efficacy adjustment to account for 2017 high pressure sodium standards. Table 4.16 shows savings potential for each conversion type.

TABLE 4.16 ACHIEVABLE ECONOMIC STREET LIGHTING POTENTIAL BY TECHNOLOGY			
Measure Name	**Baseline Description**	**aMW**	
		2016	**2016**
135W LED	200W HPS	0.05	0.05
135W LED	250W HPS	0.41	0.41
135W LED	400W HPS	0.04	0.04
270W LED	400W HPS	0.61	0.61
Total		**1.11**	**1.11**

Seattle will complete conversions across four distinct zones, which include:[25]

- Zone 1 – 160th St. to Brandon St.
- Zone 2 – Brandon St. to Denny Way
- Zone 3 – Denny Way to 145th St.
- Zone 4 – 145th St. to 205th St.

Table 4.17 shows LED street lighting potential for each zone.

TABLE 4.17 ACHIEVABLE ECONOMIC STREET LIGHTING POTENTIAL BY ZONE		
Segment	**aMW**	
	2016	**2016**
Street Lighting - Zone 1	0.33	0.33
Street Lighting - Zone 2	0.39	0.39
Street Lighting - Zone 3	0.19	0.19
Street Lighting - Zone 4	0.20	0.20
Total	**1.11**	**1.11**

25 "LED Street Lights" Seattle City Light. http://www.seattle.gov/light/streetlight/led/

5. Glossary of Terms

GLOSSARY OF TERMS[26]

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).

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.

Achievable potential: The amount of energy use that efficiency can realistically be expected to displace.

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.

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[26] 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

Conservation Potential Assessment: 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.

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).