Seattle City Light

2022 Conservation Potential Assessment—Volume I

August 3, 2021
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Definition of Terms

aMW	Average Megawatt
AC	Air Conditioning
ACS	American Community Survey
BPA	Bonneville Power Administration
CBECS	Commercial Buildings Energy Consumption Survey
CBSA	Commercial Building Stock Assessment
CETA	Clean Energy Transformation Act
CEE	Consortium for Energy Efficiency
CFL	Compact Fluorescent Lamp
CEAP	Clean Energy Action Plan
CEIP	Clean Energy Implementation Plan
Council	Northwest Power and Conservation Council
CPA	Conservation Potential Assessment
CRI	Color Rendering Index
DHW	Domestic hot water
DHP	Ductless heat pump
DSR	Demand-side response
ECM	Energy Conservation Measure
ECM	Electronically Commutated Motor
EISA	Energy Independence and Security Act of 2007
EUI	Energy Use Intensity
EUL	Effective Useful Life
GPM	Gallons Per Minute
HVAC	Heating Ventilation and Air Conditioning
I-937	Initiative 937
IRP	Integrated Resource Plan
kW	Kilowatt
kWh	Kilowatt-hour

LED	Light-emitting diode
MW	Megawatt
MWh	Megawatt-hour
NEEA	Northwest Energy Efficiency Alliance
O&M	Operations and Maintenance
PACT	Program administrator cost test
RBSA	Residential Building Stock Assessment
RCW	Revised Code of Washington
REC	Renewable Energy Credit
RTF	Regional Technical Forum
RUL	Remaining Useful Life
SEER	Seasonal Energy Efficiency Ratio
T&D	Transmission and Distribution
TRC	Total Resource Cost
TSPR	Total System Performance Ratio
UCT	Utility Cost Test
UEC	Unit Energy Consumption
UES	Unit Energy Savings
WAC	Washington Administrative Code

Acknowledgements

The authors would like to thank the Seattle City Light staff who provided invaluable guidance and support, especially Kali Hollenhorst, Jennifer Finnigan, Emma Johnson, Joe Fernandi, John Rudolph, Aliza Seelig, Villamor Gamponia, Paul Nissley, and Saul Villareal. The study required a compilation of a large amount of data from many sources, including several departments at City Light.

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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 in its service territory over the next 20 years, beginning in 2022. This study, as part of City Light's Integrated Resource Planning (IRP) process, is intended to identify cost-effective potential from the perspectives of energy efficiency and demand response within City Light's major customer sectors: residential, commercial, and industrial.[1] The results of this assessment will also help inform City Light's future programs. The study period aligns with the timeline for City Light's 2022 IRP and provides direct inputs into its IRP.

This study accomplishes the following objectives:

- Fulfills statutory requirements of Chapter 194-37 of the Washington Administrative Code (WAC), Energy Independence Act. The WAC requires that City Light identify all achievable, cost-effective, conservation potential for the upcoming ten years.[2] City Light's public biennial conservation target should be no less than the *pro rata* share of conservation potential over the first ten years. The study estimates will inform City Light's targets for the 2022-2023 biennium.
- Supports City Light's compliance of Washington State's Clean Energy Transformation Act (CETA), passed as Senate Bill 5116 in April 2019, to inform City Light's energy efficiency and demand response short- and long-term targets.[3] In addition, this study will inform City Light's near-term interim targets for its Clean Energy Implementation Plan (CEIP) as required by CETA. CETA sets additional requirements for City Light, such as including the social cost of carbon in avoided energy costs. This study, more broadly, supports City Light's Clean Energy Action Plan (CEAP), a ten-year action plan described in the 2020 IRP Progress Report to meet CETA requirements.
- Develops up-to-date estimates of energy conservation measure (ECM) datasets for the residential, commercial, and industrial market sectors using measures consistent with the Northwest Power and Conservation Council's (Council) draft 2021 Power Plan, the Regional Technical Forum (RTF), and other data sources.
- Provides inputs into City Light's IRP. Completed every two years, City Light's IRP determines the mixture of supply-side and demand-side resources required over the next 20 years to meet customer demand and looks ahead to how City Light plans to meet the 2045 100 percent

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[1] This study did not estimate street lighting potential as all streetlights have been converted to LED.

[2] Washington State Legislature. *Energy Independence Act*. Washington Administrative Code Chapter 194-37.

[3] CETA requires proposing interim targets for meeting the standard under RCW 19.405.040(1) during the years prior to 2030 and between 2030 and 2045. This study estimates potential over 20 years (2022-2041) and does not directly estimate potential through 2045. Through the IRP process, City Light's projects their long-term targets out to 2045.

non-emitting standard of CETA. The IRP requires a thorough analysis of conservation potential to properly assess the reliability, cost, risk, and environmental impact of different resource portfolios for power generation as well as other demand-side resources that are not part of the CPA.

This study relies on City Light-specific data, compiled from City Light's oversample of the 2017 Northwest Energy Efficiency Alliance (NEEA) Residential Building Stock Assessment (RBSA),[4] the 2019 Commercial Building Stock Assessment (CBSA),[5] and other regional data sources. This study uses a methodology consistent with the Council's draft 2021 Power Plan supply curve workbooks, as of December 2020.[6] It incorporates savings and costs for all ECMs in the Council's draft 2021 Power Plan workbooks and the active unit energy savings (UES) workbooks from the RTF.[7] The *Detailed Methodology* section of this report describes the sources and data used in greater detail.

This study also estimates demand response potential to align with the Council's demand response methodology and to provide City Light the data it needs to meet Washington State's CETA requirements. The demand response potential can be found in Appendix E.

1.2. Scope of Analysis

This study analyzed three sectors—residential, commercial, and industrial—and, where applicable, Cadmus considered multiple market segments, construction vintages (new and existing), and end-uses:

- Residential: Eight segments including standard-income single-family and multifamily homes (including low-rise, mid-rise, and high-rise) and low-income single-family and multifamily homes (including low-rise, mid-rise, and high-rise)[8]
- Commercial: 20 major commercial segments (including offices, retail, and other segments)
- Industrial: Energy-intensive manufacturing and primarily process-driven customers

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[4] Northwest Energy Efficiency Alliance. *2017 Residential Building Stock Assessment*.

[5] Northwest Energy Efficiency Alliance. *2019 Commercial Building Stock Assessment*.

[6] In early 2022, the Council is expected to finalize the region's eighth Power Plan (the 2021 Power Plan). This is a regional plan that provides guidance on which resources can help ensure a reliable and economical regional power system from 2022 to 2041. The Council develops supply curves covering a variety of supply- and demand-side resources, considers how to best meet the region's power needs across a range of future scenarios, balancing cost and risk, and develops a draft plan and gathers public input before releasing the final version.

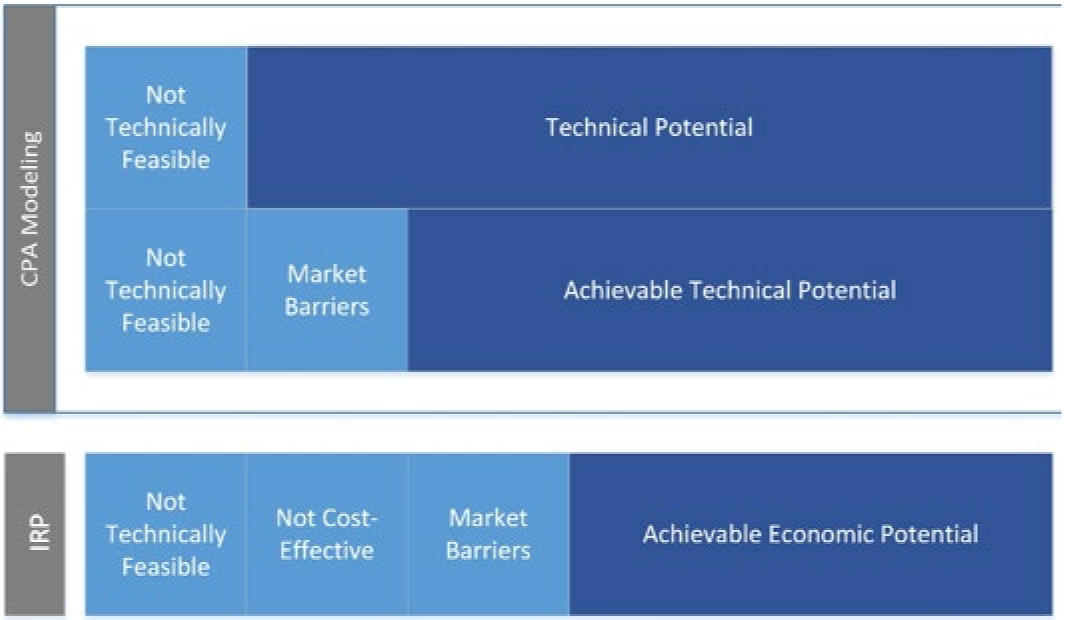
[7] RCW 19.285.040 requires CPAs to use methodologies consistent with those used by the Council's most recent regional power plan.

[8] Cadmus disaggregated residential households into low-income and standard-income segments based on income qualification in the City Light Utility Discount Program. Thus, only customers with a household income of less than 70 percent of the state median income, by household size, were considered low-income.

For each sector, Cadmus developed a baseline end-use load forecast that assumed no new future programmatic conservation. The baseline forecast largely captured 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 codes and standards and naturally occurring savings.

Consistent with the WAC requirements, this study considers two types of energy efficiency potential, as shown in Figure 1.1. City Light determined a third potential—achievable economic—through the IRP's optimization modeling.

Figure 1.1. Types of Energy Efficiency Potential



The three types of potential are described as follows:

- **Technical potential** assumes that all technically feasible resource opportunities may be captured, regardless of their costs or other market barriers. It represents the total energy efficiency potential in City Light's service territory, after accounting for purely technical constraints.
- **Achievable technical potential** is the portion of technical potential assumed to be achievable during the study's forecast, regardless of the acquisition mechanism. For example, savings may be acquired through utility programs, improved codes and standards, and market transformation.
- **Achievable economic potential** is the portion of achievable technical portion determined to be cost-effective by the IRP's optimization modeling, in which either bundles or individual energy efficiency measures are selected based on cost and savings. The cumulative potential for these selected bundles constitutes achievable economic potential.

This is a divergence from prior CPAs where Cadmus provided the estimates for achievable economic potential based on screening individual measures for cost-effectiveness under a total resource cost (TRC) test.[9] For the 2022 CPA, City Light used their IRP optimization model to select measures based on the levelized cost.

To be consistent with WAC requirements of relying on cost-effective energy efficiency for this 2022 CPA, Cadmus bundled the resulting forecasts of achievable technical potential by levelized costs bin for City Light's IRP modeling team. The IRP modeling team then determined the amount of cost-effective energy efficiency that could be considered as a resource within the IRP. Details of the IRP process and the final selection of measures considered as part of the IRP optimization model can be found in the *Development of Conservation IRP Inputs* section of this report and in Appendix D (Measure Details).

1.3. Summary of Results

The study found 125 average megawatts (aMW) of achievable technical potential in the first ten years (cumulative in 2031) in City Light's service territory.[10] To inform CEIP energy efficiency targets, Cadmus calculated two-year and four-year cumulative achievable technical potential. In the first two years, cumulative achievable technical potential equals 28 aMW, and in the first four year cumulative achievable technical potential is 53 aMW.

Furthermore, City Light used its IRP optimization model to select measures based on the levelized TRC. Overall, the cumulative 20-year achievable economic potential is 106 aMW, with 77 aMW acquired in the first ten years. The *pro rata* share (20 percent of 10-year achievable economic potential), which represents City Light's minimum biennial target, equals 15 aMW. All estimates of potential in this report are presented at the generator, meaning they include line losses.[11]

1.3.1. Technical Potential

Table 1.1 shows the cumulative technical potential for each sector in 2041. Overall, the study identified 233 aMW of technically feasible conservation potential by 2041—the equivalent of 19 percent of forecasted baseline sales. Study results are presented as a percentage of forecasted baseline sales, which provides a useful benchmark for comparison against City Light's previous CPAs and the Council's draft 2021 Power Plan. The commercial, residential, and industrial sectors account for 56 percent, 39 percent, and 5 percent of the 20-year technical potential, respectively.

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[9] Cadmus conducted both the 2020 CPA and the 2022 CPA.

[10] An average megawatt (aMW) refers to a unit of measure that represent one million watts (MW) delivered continuously 24 hours a day for each day of the year (e.g., 8,760 hours). A detailed description of MW and aMW can be found on the Council's website: https://www.nwcouncil.org/reports/columbia-river-history/megawatt

[11] For illustrative purposes, City Light estimates line losses to be 5.5 percent, so the minimum biennial target at the customer site is 14 aMW.

Table 1.1. Cumulative Technical Potential by Sector (2022-2041)

Sector	Baseline Sales–20-Year (aMW)	Technical Potential–20-Year (aMW)	Technical Potential as % of Baseline Sales
Residential	461	90	20%
Commercial	667	131	20%
Industrial	91	12	13%
Total	**1,219**	**233**	**19%**

1.3.2. Achievable Technical Potential

Table 1.2 shows the cumulative achievable technical potential for each sector in 2041. Overall, the study identified 196 aMW of technically feasible achievable potential by 2041—the equivalent of 16 percent of forecasted baseline sales. The commercial, residential, and industrial sectors account for 59 percent, 36 percent, and 5 percent of the cumulative achievable technical potential, respectively.

Table 1.2. Cumulative Achievable Technical Potential by Sector (2022-2041)

Sector	Baseline Sales–20-Year (aMW)	Achievable Technical Potential–20-Year (aMW)	Achievable Technical Potential as % of Baseline Sales
Residential	461	70	15%
Commercial	667	116	17%
Industrial	91	10	11%
Total	**1,219**	**196**	**16%**

Table 1.3 provides two-year, four-year, and ten-year cumulative achievable technical potential by sector. The commercial sector provides the majority of the cumulative achievable technical potential. This is due in part to the commercial sector's higher baseline sales compared to the residential and industrial sectors as well as the reduction in potential for residential screw-base lighting compared to prior assessments, thereby shifting the potential to the commercial sector.

Table 1.3. Cumulative Achievable Technical Potential by Sector and Time Period

Sector	Achievable Technical Potential – aMW				
	2-Year (2022-2023)	4-Year (2022-2025)	10-Year (2022-2031)	20-Year (2022-2041)	20% of 10-Year Potential
Residential	6	12	32	70	6
Commercial	20	37	85	116	17
Industrial	2	4	9	10	2
Total	**28**	**53**	**125**	**196**	**25**

Table 1.4 provides the winter and summer technical and achievable technical capacity savings from energy efficiency by sector in 2041 in megawatts (MW). Capacity savings represent the maximum demand for each season. The commercial sector accounts for the majority of the total cumulative winter and summer capacity achievable technical potential. The residential sector accounts for nearly 46 percent of the winter capacity achievable technical potential but only 25 percent of the summer capacity achievable technical potential, which reflects the relatively higher saturation of residential electric space heating loads compared with residential cooling loads.

Table 1.4. Cumulative Winter and Summer Capacity (MW) Savings by Sector (2022-2041)

Sector	Technical Potential		Achievable Technical Potential	
	Winter MW	Summer MW	Winter MW	Summer MW
Residential	158	81	124	63
Commercial	154	199	135	175
Industrial	13	13	11	11
Total	**325**	**294**	**270**	**249**

Table 1.5 provides the two-,four-,and ten-year summer and winter capacity savings by sector. In the first ten years of the study period, the cumulative winter achievable technical capacity savings are 167 MW, 62 percent of the 20-year cumulative winter achievable technical capacity savings. The cumulative summer achievable technical capacity savings are 165 MW, 66 percent of the 20-year cumulative summer achievable technical capacity savings.

Table 1.5. Cumulative Winter and Summer Capacity (MW) Savings by Sector and Time Period

Sector	Cumulative Winter Achievable Technical Potential (MW)			Cumulative Summer Achievable Technical Potential (MW)		
	2-Year (2022-2023)	4-Year (2022-2025)	10-Year (2022-2031)	2-Year (2022-2023)	4-Year (2022-2025)	10-Year (2022-2031)
Residential	10	22	59	5	10	26
Commercial	23	43	98	31	57	129
Industrial	2	4	9	2	4	10
Total	**35**	**69**	**167**	**38**	**71**	**165**

1.3.3. Technical and Achievable Technical Comparison to the 2020 CPA

The 2022 CPA identified 233 aMW of cumulative, 20-year technical potential, compared to 282 aMW in the 2020 CPA, as shown in Table 1.6. The 17 percent decrease in cumulative, final year technical potential is due to the following major drivers:

- Cadmus made updates to the residential baseline forecast that assume a shift in heating and cooling equipment to more efficient heat pumps over time based on City Light's assumptions about market adoption. For example, Cadmus increased new construction, single-family heat pump saturations from 15 percent in the base year to 30 percent in the final year to align with City Light's load forecasting assumptions.

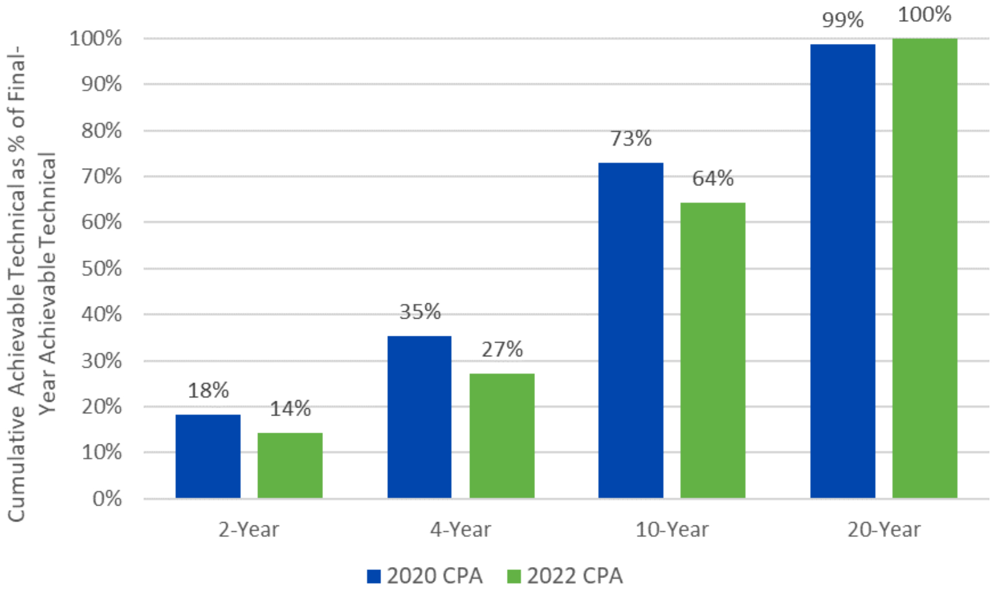
- The study accounted for an increase in LED lighting saturation and state standards in Washington (HB 1444). The state standards require general service lamps to meet or exceed a lamp efficacy of 45 lumens per watt, similar to the federal Energy Independence and Security Act of 2007 (EISA) backstop provision. Additional details can be found in *Additional Codes and Standards Considerations* section of this report.
- Cadmus assumed a higher saturation of more efficient lighting for standard-income residential customers compared to the 2020 CPA. As a result, less lighting savings can be achieved (e.g., more homes already have efficient LED lighting),.
- Commercial lighting measure potential decreased by 50 percent compared to the Seventh Power Plan, in part, due to the higher saturation of existing LED lamp and fixture applications in the commercial sector.
- Cadmus included additional industrial measures from the draft 2021 Power Plan, requested by City Light.

Table 1.6. Cumulative Technical Potential Comparison by Sector

Sector	2022 CPA			2020 CPA		
	Baseline Sales—20 Year (aMW)	Technical Potential—20 Year (aMW)	Technical Potential as % of Baseline Sales	Baseline Sales—21 Year (aMW)	Technical Potential—21 Year (aMW)	Technical Potential as % of Baseline Sales
Residential	461	90	20%	440	100	23%
Commercial	667	131	20%	693	173	25%
Industrial	91	12	13%	88	9	10%
Total	**1,219**	**233**	**19%**	**1,221**	**282**	**23%**

This report's *Comparison to 2020 CPA* section discusses each factor in detail. Figure 1.2 illustrates that the 2020 CPA realized a higher proportion of total achievable technical potential in the initial years of the study.

Figure 1.2. Cumulative Achievable Technical Potential as a Percentage of Total Achievable Technical Potential



Cadmus used the draft 2021 Power Plan ramp rates in the 2022 CPA rather than the Seventh Power Plan ramp rates (released in February 2016) that were used in the 2020 CPA. The change in sources for ramp rate data leads to a decrease in potential in the initial years of the study relative to the final year. Because the Seventh Power Plan ramp rates ranged from 2016 to 2035, for the 2020 CPA, Cadmus took the ramp rate beginning in 2020 and extrapolated maximum saturation to extend from 2035 to the final year of the study (2040). This methodology is described in more detail in the *Achievable Technical Potential and Ramping* section of this report.

The 2022 CPA used the ramp rates from the draft 2021 Power Plan supply curve workbooks (as of December 2020), which have ramp rates for the 2022 to 2041 period. Therefore, the first year of the study aligns with the first year of the CPA—no extrapolation was needed. This leads to less realized potential in the initial years of the study. It is worth noting, as part of this study, Cadmus worked with City Light to determine the appropriate Council ramp rates so that City Light's program measures align better with historical program acquisition as well as with local and state policies promoting energy efficiency.

Even with these adjustments, the annual rate of adoption is lower in the early years of this study compared to the prior CPA. However, this study still "frontloads" the savings with the earlier part of the study with the ten-year estimate representing over 60 percent of the total 20-year achievable technical potential. Ramp rates are explained in more detail in the *About Measure Ramp Rates* section of this report.

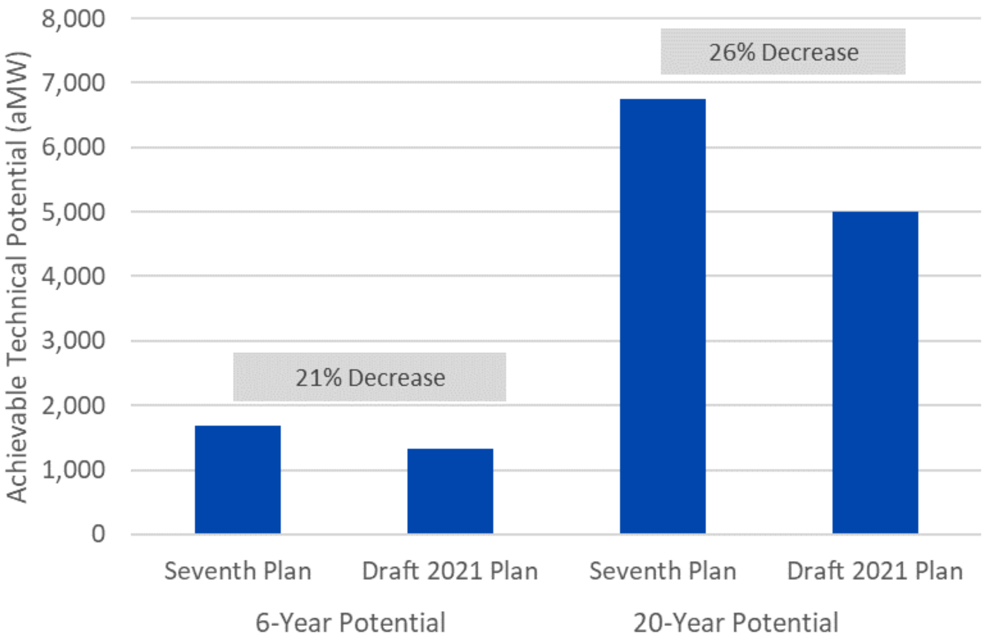
The industrial sector in the 2022 CPA included new measures based on the draft 2021 Power Plan, such as HVAC measures, forklift battery chargers, and new savings methodology for compressors, fans, pumps, and other motor-driven systems. City Light also requested the inclusion of measures such as industrial generator block heaters, retro-commissioning, and welder system upgrades. These additions and changes in methodology increased the potential in the industrial sector compared to the prior CPA. Additional detail of this comparison can be found in the *Industrial Sector Changes*

The industrial sector in the 2022 CPA included new measures based on the draft 2021 Power Plan, such as HVAC measures, forklift battery chargers, and new methodology for compressors, fans, pumps, and other motor-driven systems. City Light also requested the addition of measures such as industrial generator block heaters, retro-commissioning, and welder system upgrades. These additions and changes in methodology increased the potential in the industrial sector compared to the prior CPA.

Achievable Technical Potential and Ramping

Further differences in the achievable technical and technical potential between the 2020 CPA and the 2022 CPA are tied to the change in source of the underlying data, from using the Seventh Power Plan to using the draft 2021 Power Plan. Both studies are consistent with Council as the primary resource for residential, commercial, and industrial measures impacts. The 2022 CPA transitioned from the Council's Seventh Power Plan (February 2016) to the draft 2021 Power Plan. These updates impacted measure consumption or savings values for individual measures. As demonstrated in Figure 1.3, the potential in the first six years and the 20-year achievable technical potential from the draft 2021 Power Plan are 21 percent and 26 percent less than the corresponding Seventh Power Plan values, respectively.

Figure 1.3. Draft 2021 Power Plan and Seventh Power Plan Regional Cumulative Achievable Technical Potential

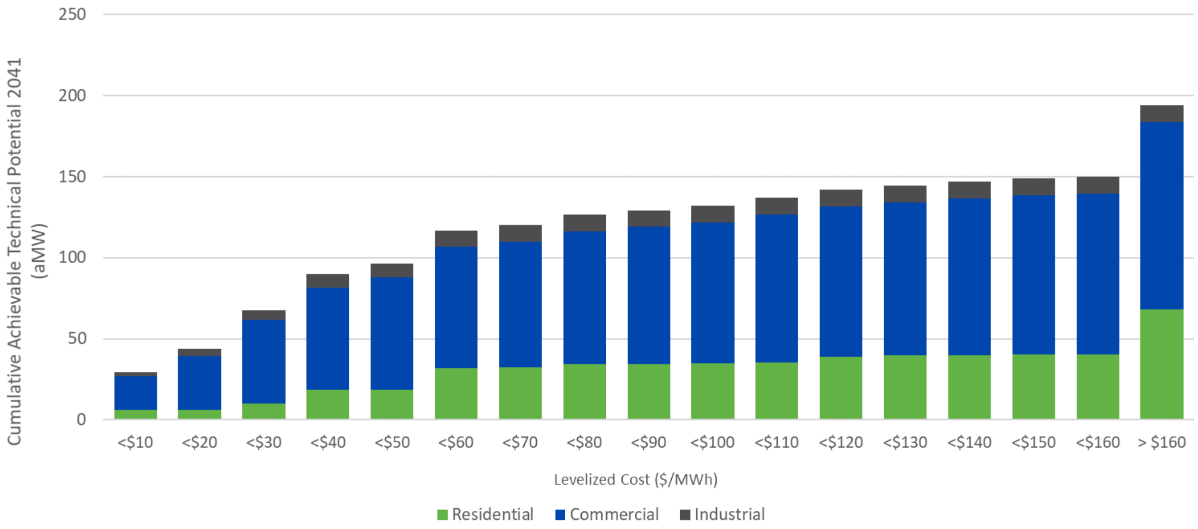


Note: Draft 2021 Power Plan data was last updated on June 16, 2020, and may not represent final planning values.

1.3.4. Incorporating Conservation into City Light's IRP

Cadmus summarized the achievable technical potential for energy efficiency, described above, by the levelized cost groups (bins) of conserved energy by customer class for inclusion in City Light's IRP framework. These costs have been calculated over a 20-year program life—the *Development of Conservation IRP Inputs* section provides additional detail on the levelized cost methodology. Figure 1.4 shows that 67 aMW, or 34 percent, of the cumulative, 2041 achievable technical potential has a levelized cost of less than or equal to $30 per MWh. Additionally, the figure shows that 24 percent of the total achievable technical potential has a levelized cost of greater than $160 per MWh.

Figure 1.4. Electric Supply Curve – Cumulative 20-Year Achievable Technical Potential (Levelized Cost Bins)



There is less energy efficiency potential available in the lower levelized cost bins compared to the prior CPA. This directly corresponds with the Council's draft 2021 Power Plan data, where the measure acquisition costs are higher compared to the Seventh Power Plan.

1.3.5. Achievable Economic Potential

After incorporating the achievable technical levelized cost of conserved energy bins, City Light's IRP model identified an optimal amount of annual conservation. Bundling resources into a number of distinct cost groups allowed the portfolio optimization model to select the combination of conservation cost bundles by sector that provided City Light with the least-cost portfolio alongside renewable resources while also achieving resource adequacy targets, I-937 requirements, City Light's greenhouse gas neutrality goals, and the requirements of the Clean Energy Transformation Act of Washington. By integrating conservation choices alongside renewable supply options into the portfolio optimization model, City Light can capture the different value streams from all resources within the same analytical framework.

The resulting IRP analysis selected 106 aMW of achievable economic potential at an optimal levelized cost for each sector, as shown in Table 1.7. Cumulative, 20-year achievable economic potential accounted for

9 percent of the total baseline sales in 2041. The commercial sector had the greatest achievable economic potential relative to baseline sales, accounting for 12 percent of the baseline sales for the commercial sector in 2041. This was followed by the industrial sector cumulative achievable economic potential, which accounted for 11 percent of the industrial 2041 baseline sales. Finally, the residential sector cumulative achievable economic potential made up 4 percent of the 2041 residential baseline sales.

The IRP portfolio optimization model differentiated the levelized TRC by sector so the model can select the specific energy efficiency cost bins for each sector that best fit City Light's portfolio and minimize the overall costs. This also recognizes that the conservation supply curves for each sector have different shapes, limits, and elasticities. As shown in Table 1.7, the achievable economic potential represents the levelized TRC of $40 or less per MWh for residential, $70 or less per MWh for commercial, and all levelized cost bins for industrial.

Table 1.7. Cumulative Achievable Economic Potential by Sector (2022-2041)

Sector	Levelized TRC ($/MWh)	Baseline Sales—20 Year (aMW)	20-Year Achievable Economic Potential (aMW)	Achievable Economic Potential as % of Baseline Sales
Residential	≤$40	461	18	4%
Commercial	≤$70	667	77	12%
Industrial	All Bins	91	10	11%
Total		**1,219**	**106**	**9%**

Table 1.8 provides the two-, four-, ten-, and 20-year cumulative achievable economic potential estimates by sector. Eighteen percent of the total 20-year achievable economic is achieved in the first two years, and 73 percent is achieved in the first ten years.

Table 1.8. Cumulative Achievable Economic Potential by Sector and Time Period

Sector	Achievable Economic Potential – aMW				
	2-Year (2022-2023)	4-Year (2022-2025)	10-Year (2022-2031)	20-Year (2022-2041)	20% of 10-Year Potential
Residential	2.90	5.22	11.16	17.91	2.23
Commercial	13.85	25.98	57.08	77.48	11.42
Industrial	1.99	4.03	8.65	10.44	1.73
Total	**18.74**	**35.23**	**76.89**	**105.83**	**15.38**

Table 1.9 provides achievable economic potential estimates of the two-,four-,and ten-year summer and winter capacity savings by sector.

Table 1.9. Cumulative Achievable Economic Winter and Summer Capacity (MW) Savings by Sector and Time Period

Sector	Cumulative Winter Achievable Technical Potential (MW)			Cumulative Summer Achievable Technical Potential (MW)		
	2-Year (2022-2023)	4-Year (2022-2025)	10-Year (2022-2031)	2-Year (2022-2023)	4-Year (2022-2025)	10-Year (2022-2031)
Residential	4	8	16	3	5	12
Commercial	16	31	68	20	37	80
Industrial	2	4	9	2	4	10
Total	**23**	**43**	**93**	**25**	**47**	**102**

1.4. Organization of this Report

This report presents the study's findings in two volumes. Volume I—this document—presents the methodologies and findings. Volume II contains the appendices and provides detailed study results, supplemental materials, and summaries of demand response potential.

Volume I includes the following sections:

- *Methodology Overview* provides an overview of the methodology Cadmus and City Light used to estimate technical, achievable technical, and achievable economic potential.
- *Baseline Forecast* 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 top-saving measures in each sector.
- *Comparison to 2020 CPA* shows how this study's results (the 2022 CPA) compare to City Light's prior CPA.
- *Detailed Methodology* describes Cadmus' combined top-down/bottom-up modeling approach.
- *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 ECMs, deriving from this estimates of conservation potential. This section discusses how Cadmus adapted measure data from the draft 2021 Power Plan, the RTF, RBSA, CBSA, and other sources for this study.
- *Estimating Conservation Potential* discusses assumptions and underlying equations used to calculate technical and achievable technical potential.
- *Development of Conservation IRP Inputs* details the 2022 CPA methodology of determining cost-effective conservation supply curves as an input for City Light's IRP optimization model to identify the achievable economic potential.

- *City Light's IRP Portfolio Framework* provides an overview of the methodology from the City Light economic screening process to determine the cost-effective conservation potential for the Energy Independence Act and the CEIP.

Volume II includes the following sections:

- Appendix A. Washington Initiative 937 (I-937) Compliance Documentation
- Appendix B. Baseline Data
- Appendix C. Detailed Assumptions and Energy Efficiency Potential
- Appendix D. Measure Details[12]
- Appendix E. Demand Response

Volume III includes detailed inputs, assumptions, and scenarios of City Light's IRP optimization modeling.

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[12] Appendix D includes sector, end-use group, and measure level results by technical, achievable technical, and IRP selected potential (achievable economic potential).

2. Methodology Overview

Estimating conservation potential draws upon a sequential analysis of various energy conservation measures (ECMs) in terms of technical feasibility (technical potential), expected market acceptance, and the normal barriers that could impede measure implementation (achievable technical potential).

Cadmus' assessment took the following primary steps:

- Development of the baseline forecast involved determining the 20-year future energy consumption by sector, market segment, and end-use. This study calibrated the base year (2022) to City Light's sector level, corporate load forecast produced in 2020. Baseline forecasts in this report include estimated impacts of market-driven efficiency, codes and standards, and City Light's estimates of the impacts of COVID-19 on commercial and residential energy usage. Cadmus worked with the City Light load forecast team to determine the impacts of market-driven efficiency and codes and standards.
- Estimates of technical potential are based on incremental difference between the baseline load forecast and an alternative forecast reflecting the technical impacts of specific energy efficiency measures.
- Estimates of achievable technical potential are calculated by applying ramp rates and achievability percentages to technical potential, described in greater detail in this section.

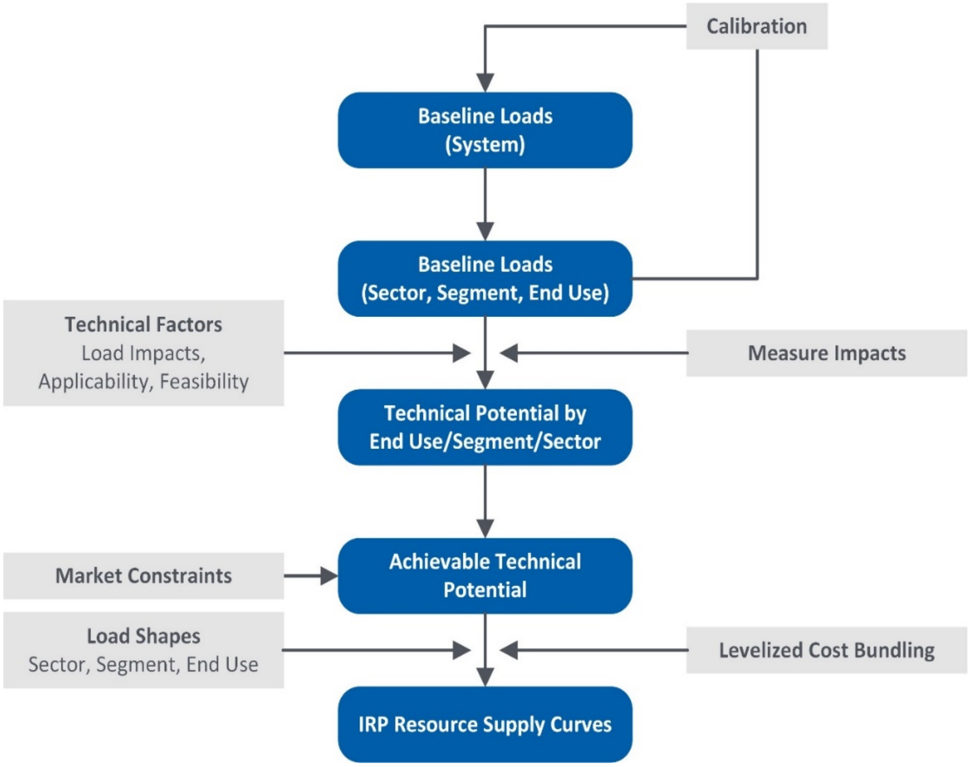
This approach offered two advantages:

- Savings estimates were driven by a baseline forecast that is consistent with the assumptions used in City Light's adopted 2020 corporate load forecast.
- The approach maintained consistency among all assumptions underlying the baseline and alternative forecasts—technical and achievable technical potential. The alternative forecasts changed relevant inputs at the end-use level to reflect ECM impacts. Because 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. Cadmus then disaggregated this load forecast into its constituent customer sectors, customer segments, and end-use components.

The bottom-up component estimates electric consumptions for each major building end-use and applies potential technical impacts of various ECMs to each end-use. This bottom-up analysis includes assumption on end-use equipment saturations, fuel shares, ECM technical feasibility, ECM cost, and engineering estimates of ECM unit energy consumption and savings. A detailed description of the methodology can be found in the *Detailed Methodology* section.

Figure 2.1. General Methodology for Assessment of Conservation Potential



In the final step, Cadmus developed energy efficiency supply curves so City Light's IRP portfolio optimization model could identify the amount of cost-effectiveness for energy efficiency. The portfolio optimization model required hourly forecasts of electric energy efficiency potential. To produce these hourly forecasts, Cadmus applied hourly end-use load profiles to annual estimates of achievable technical potential for each measure. These profiles are similar to the shapes the Council used in its draft 2021 Power Plan supply curves and as the RTF used in its UES measure workbooks.

2.1. Considerations and Limitations

This study provides insights into which measures City Light could offer in future programs and is intended to inform program targets. The following are other considerations about the design of this potential study that may cause future program plans to differ from study results:

- The baseline demand forecasts is based on the 2020 adopted City Light's Corporate Forecast. It includes assumptions about the impacts of COVID-19 on commercial and residential energy usage that, by default, impact the related energy efficiency potential. Due to the lack of data and knowledge about the future impacts of the pandemic, it is possible that the near-term demand and potential available has more uncertainty than in normal times.
- This potential study uses broad assumptions about the adoption of energy efficiency measures. Program design, however, requires a more detailed examination of historic participation and incentive levels on a measure-by-measure basis. The study can inform planning for measures City

Light has not historically offered, or can focus program design on areas with remaining amounts of potential identified in this study.

- This potential study does not consider program implementation barriers. Though it includes a robust, comprehensive set of efficiency measures, it does not examine if these measures can be delivered through incentive programs or what incentive rate is appropriate. Many programs require strong trade ally networks or must overcome market barriers to succeed.
- This potential study cannot predict market changes over time. Though it accounts for changes in codes and standards as they are enacted today, the study cannot predict future changes in policies, pending codes and standards, and which new technologies may become commercially available. For example, past potential studies may not have accurately predicted the speed and magnitude of recent adoption of LED technology. City Light programs are not static and have the flexibility to address changes in the marketplace, whereas the potential study estimates potential using information collected at a single point in time.
- Due to timing constraints, City Light did not fully evaluate climate change impacts in its baseline load forecast that was used for the 2022 CPA. City Light's current forecast does not include the same level of climate change-induced impacts as does the Council. As a result, this study does not directly reflect possible changes in consumption patterns resulting from climate change. However, City Light's 2022 IRP portfolio optimization model did assess alterative scenarios that incorporate climate change impacts.
- This potential study does not attempt to forecast or otherwise predict future changes in energy efficiency measure costs. The study includes Council and RTF incremental energy efficiency measure costs, including equipment, labor, and operations and maintenance, but it does not attempt to forecast changes to these costs during the course of the study (except where Council makes adjustments). For example, changes in incremental costs may impact some emerging technologies, which may then impact both the speed of adoption and the levelized cost of that measure (impacting the IRP levelized cost bundles).
- Commercial end-use consumption relies on NEEA's CBSA data supplemented by U.S. Energy Information Administration's Commercial Buildings Energy Consumption Survey (CBECS). However, these data may not reflect the type of commercial facilities in City Light's territory and may have an inherent level of uncertainty. On May 28, 2021, the Council's Conservation Resources Advisory Committee reiterated that additional research for the region is needed to develop more reliable energy use intensity data for commercial buildings. In addition, Seattle contains a number of large multifamily buildings with insufficient primary data (such as baseline stock characteristics). For example, this potential study assessed the impacts of the 2018 Seattle Energy Code and incorporated the code as best as possible. Data were limited on the natural gas fuel shares of equipment in multifamily construction and, therefore, it was difficult to correctly estimate the impact of this 2018 code. As a result, this potential study has limited insight to inform the remaining potential in this segment and requires further research.

- This study uses City Light's nonresidential database to identify sales and the number of customers for each commercial market segment. City Light last updated this database in 2016. Though still realitively recent, this database does not incorperate changes in customer building use or any new construction activity within the past five years. An update to these data will be the basis for segmentation of the commercial sector and will improve future CPA potential characterization analysis.

Though these considerations and limitations impact the CPA, it is worth noting that Chapter 194-37 of the WAC requires City Light to complete and update a CPA every two years. City Light can then address some of these considerations over time and mitigate short- and mid-term uncertainties by continually revising CPA assumptions to reflect charges in the market.

3. Baseline Forecast

3.1. Scope of Analysis

Assessing conservation potential starts with development of baseline end-use load forecasts over a 20-year (2022 to 2041) planning horizon. These forecasts are calibrated to City Light's corporate load forecast in the base year (2022). They are not adjusted for future programmatic conservation, but they do account for enacted equipment standards and building energy codes. This potential study separately considers residential, commercial, and industrial sectors in the baseline forecast.

In each sector-level assessment, the study further distinguishes building segments, facility types, and their respective, applicable end-uses. The analysis addressed the following:

- Sixteen residential segments of existing and new construction:
    - Single-family, single-family low-income
    - Multifamily low-rise, multifamily low-rise low-income, multifamily mid-rise, multifamily mid-rise low-income, multifamily high-rise, multifamily high-rise low-income[13]
- Forty commercial segments, which include new and existing construction for 20 standard commercial segments
- Eight industrial segments (existing construction only)

Cadmus and City Light's load forecast team worked together to develop a baseline forecast that aligned with City Light's 2020 adopted corporate load forecast. To achieve this, Cadmus modified the residential baseline forecast to include assumptions about electrification and market-driven equipment adoption (e.g., changing heat pump and cooling equipment saturations over time). These changes are detailed in the following section as well as in the *Detailed Methodology* section.

Figure 3.1 shows the distribution of projected sales by sector in 2041. The commercial sector will account for roughly 55 percent of projected sales, while the residential and industrial sectors will account for 38 percent and 7 percent, respectively.

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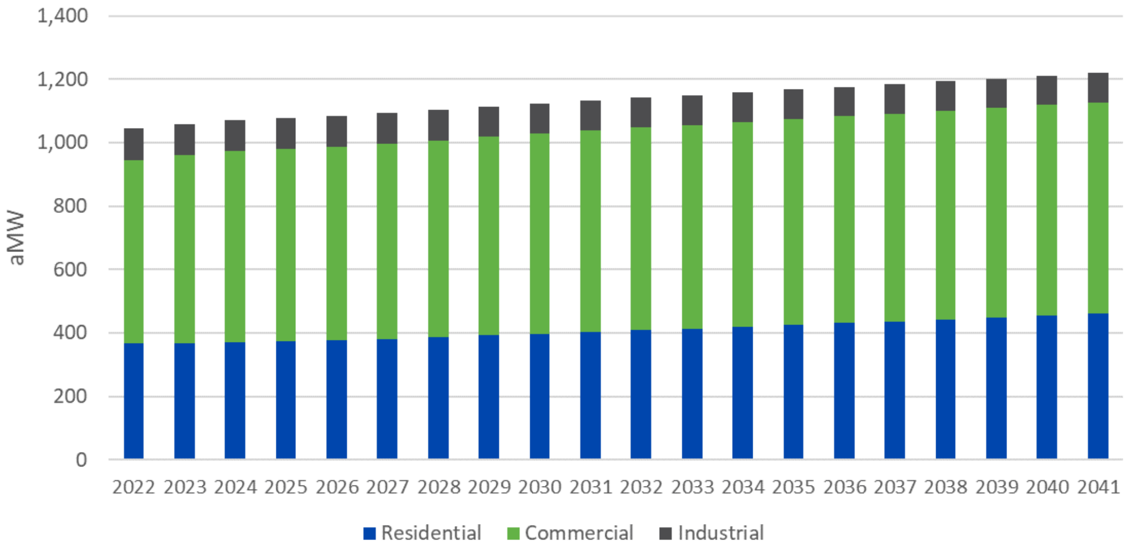
[13] Multifamily low-rise is defined as multifamily buildings with one to three floors; mid-rise is defined as buildings with four to six floors; and high-rise is defined as buildings with more than six floors. Multifamily common area is treated within the commercial sector.

Figure 3.1. Annual Baseline Sales by Sector (2022-2041)



3.2. Residential

Cadmus considered eight residential segments with 34 end-uses. Table 3.1 lists the residential segment and end-uses considered as well as the broad end-use groups used in this study. Overall, the residential sector accounted for approximately 38 percent of total baseline sales.

City Light produces separate forecasts of single-family, multifamily low-rise, multifamily mid-rise, and multifamily high-rise households. Cadmus used City Light's residential household forecast in the baseline forecast. Cadmus disaggregated these households into low-income and standard-income segments based on income qualification in the City Light Utility Discount Program.[14] Thus, only customers with a household income of less than 70 percent of the state median income, by household size, were considered low-income.

Cadmus relied on five-year American Community Survey (ACS) household income reports to determine the proportion of customers considered low-income for each residential building type. Cadmus combined residential household forecasts, estimates of end-use saturations, fuel shares, efficiency shares, and end-use consumption to produce a sales forecast through 2041. This approach is described in the *Developing Baseline Forecasts* section below.

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[14] City of Seattle, Seattle Public Utilities. "Utility Discount Program." Accessed June 2021. https://www.seattle.gov/utilities/your-services/discounts-and-incentives/utility-discount-program

Table 3.1. Residential Segment and End-Uses

Segments	End-Use Group	End-Use	
Single-Family Multifamily – High-Rise Multifamily – Mid-Rise Multifamily – Low-Rise Single-Family Low-Income Multifamily – High-Rise Low-Income Multifamily – Mid-Rise Low-Income Multifamily – Low-Rise Low-Income	Appliances	Cooking Oven Dryer	Freezer Refrigerator
	Electric Vehicles	Electric Vehicles	
	Cooling	Cool Central Cool Room Computer – Desktop Computer – Laptop DVD Player Home Audio System	Microwave Monitor Multifunction Device Plug Load Other Printer Set Top Box Television
	Electronics		
	Exterior Lighting	Lighting Exterior Standard	
	Heating	Circulation – Domestic Hot Water (DHW) Circulation – Hydronic Heating Heat Central	Heat Pump Heat Room Ventilation - Air
	Interior Lighting	Lighting Interior Linear Fluorescent Lighting Interior Specialty Lighting Interior Standard	
	Miscellaneous	Air Purifier Other	Waste Water Pool Pump
	Water Heating	Water Heat GT 55 Gal Water Heat LE 55 Gal	

Figure 3.2 shows residential sales by segment for each year of the study. City Light projects more than 80,000 new housing units will be built by 2041. New multifamily units account for about 80 percent of new residential construction, so multifamily sector baseline sales are expected to increase at a faster rate than single-family, as shown in Table 3.2.

Figure 3.2. Annual Residential Baseline Sales by Segment (2022-2041)

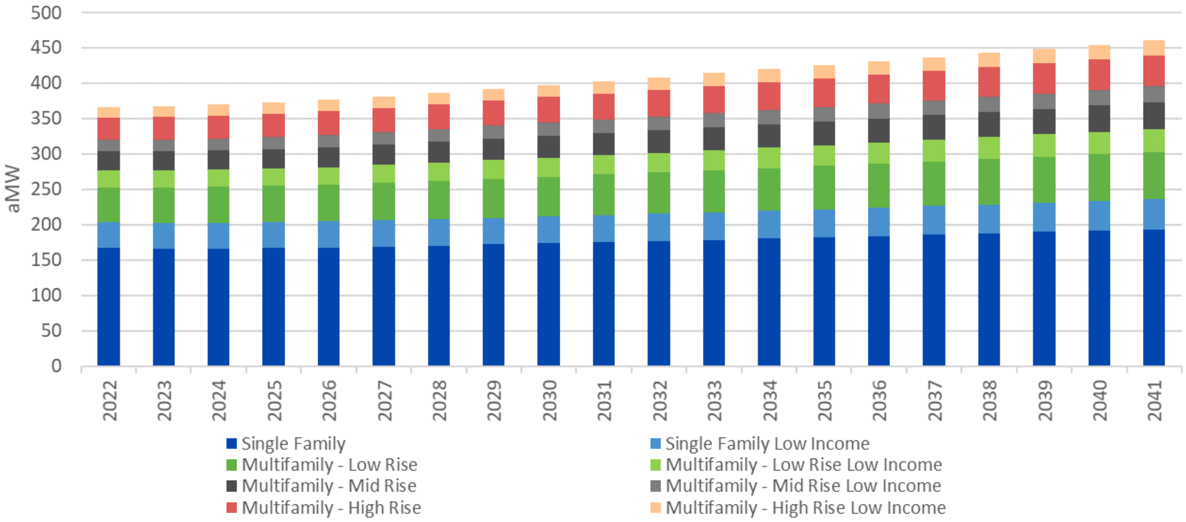

Table 3.2. Residential Baseline Sales and Housing Units by Segment

Sector	Sales (aMW)		Housing Units	
	2022	2041	2022	2041
Single-Family	167	194	164,352	177,532
Single-Family Low-Income	37	42	35,836	38,710
Multifamily – Low-Rise	49	67	60,983	79,711
Multifamily – Low-Rise Low-Income	24	32	29,155	38,109
Multifamily – Mid-Rise	27	37	37,320	48,782
Multifamily – Mid-Rise Low-Income	16	23	22,772	29,765
Multifamily – High-Rise	32	44	43,783	57,229
Multifamily – High-Rise Low-Income	15	21	20,601	26,928
Total	**366**	**461**	**414,803**	**496,765**

In the base year (2022), Cadmus calibrated baseline forecasts to City Light's load forecast, ensuring that the study's starting point aligned with the starting point of City Light's forecasts. Cadmus then produced a residential forecast.

Figure 3.3 shows the residential baseline forecast by end-use. Overall, City Light's residential forecast increases by approximately 26 percent over the 20-year horizon. This is primarily due to an increased customer forecast, the addition of new load from electric vehicles, and assumptions for the greater saturation of electric heat pumps as a result of electrification. The figure also shows that heating and appliances are the top two consuming end-use groups, accounting for a combined 57 percent of residential consumption. The next three highest forecasted end-use groups were electronics (13.8 percent), water heating (13.6 percent), and electric vehicles (8 percent).

Figure 3.3. Annual Residential Baseline Forecast by End-Use Group (2022-2041)

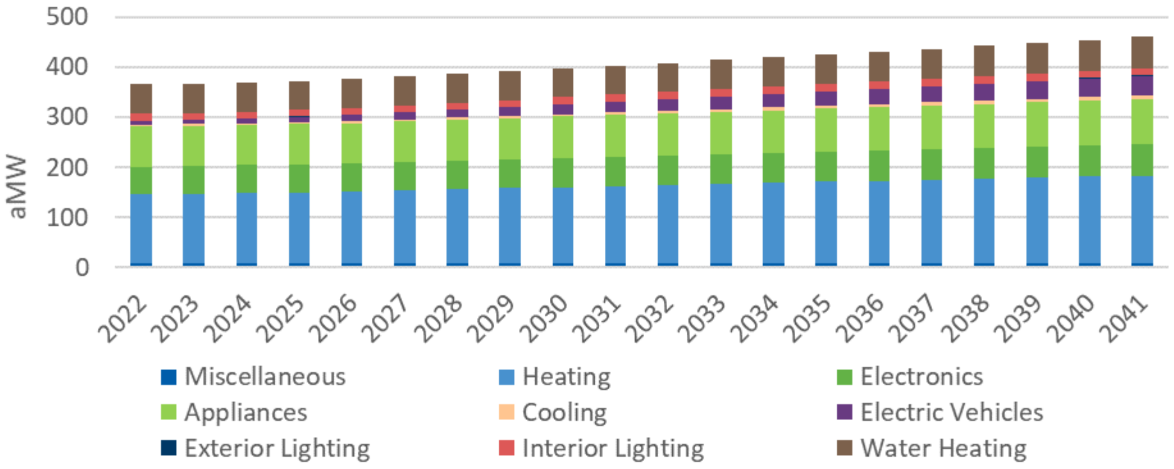

Table 3.3 shows the assumed average electric consumption per household for each residential segment in 2041. Differences in average consumption for each segment drive either differences in end-use consumption, saturations, fuel shares,[15] or any combination of differences. Appendix B includes detailed baseline data for the residential sector.

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[15] Fuel shares refers to the percentage of end-use equipment that is electric for end-uses where customers have at least the option of electricity or another fuel. Residential end-uses where multiple fuels are an option include central furnace space heat, water heating, cooking, and dryers. For example, single-family has a higher share of natural gas space heating compared to multifamily. Therefore, multifamily electric space heating end-use baseline sales show a higher per-home value.

Table 3.3. Per Household Baseline Sales (kWh/Home) by Sector and End-Use Group – 2041

End Use	Single-Family	Multifamily – Low-Rise	Multifamily – Mid-Rise	Multifamily – High-Rise
Miscellaneous	200	119	98	98
Heating	2,862	3,347	3,157	3,222
Electronics	1,550	824	773	773
Appliances	2,080	1,050	1,285	1,285
Cooling	89	173	147	147
Electric Vehicles	757	618	618	618
Exterior Lighting	59	1	1	1
Interior Lighting	403	145	138	137
Water Heating	1,561	1,117	487	487
Total	9,562	7,394	6,704	6,769

Note: Low-income kwh/home values are equivalent to the standard-income.

Table 3.4 shows the electric end-use group distributions of the baseline consumption in 2041 by building type. For each of the building types, heating makes up greater than 25 percent of the building type consumption in 2041 and is the end-use group with the largest consumption.

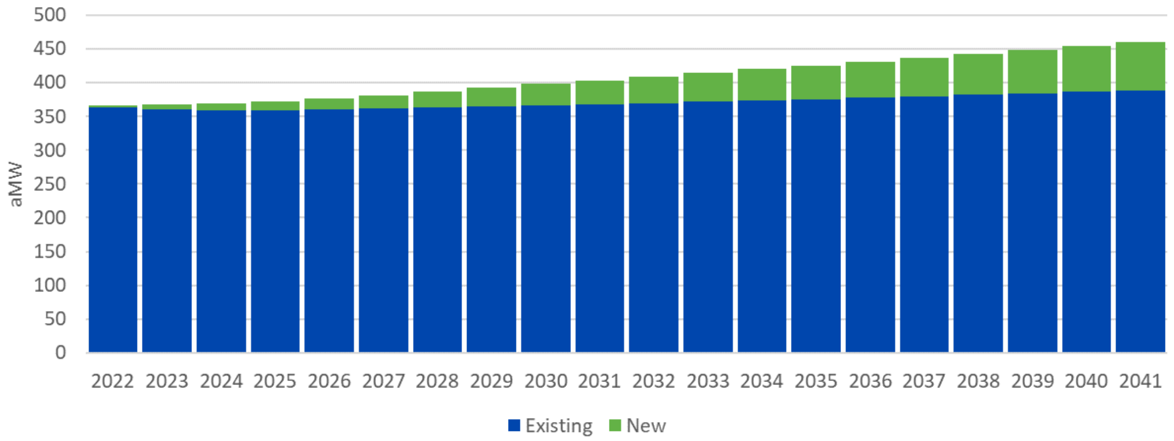
Table 3.4. Residential Consumption End-Use Group Distributions by Segment – 2041

End-Use Group	Single-Family	Multifamily – Low-Rise	Multifamily – Mid-Rise	Multifamily – High-Rise
Miscellaneous	2%	2%	1%	1%
Heating	30%	45%	47%	48%
Electronics	16%	11%	12%	11%
Appliances	22%	14%	19%	19%
Cooling	1%	2%	2%	2%
Electric Vehicles	8%	8%	9%	9%
Exterior Lighting	1%	0.01%	0.01%	0.01%
Interior Lighting	4%	2%	2%	2%
Water Heating	16%	15%	7%	7%

Note: Low-income percentage distribution values are equivalent to the standard-income.

Figure 3.4 shows forecasted residential sales by construction vintage over the study horizon. Study results indicate approximately 16 percent of sales will derive from homes constructed after 2021 (new construction). Use per customer for existing homes will decrease over the 20-year study timeframe, partly due to more efficient equipment standards and other naturally occurring efficiency.

Figure 3.4. Annual Residential Baseline Sales by Construction Vintage (2022-2041)



3.3. Commercial

Cadmus considered 20 commercial building segments and 18 end-uses. Table 3.5 shows the commercial segments and end-uses considered in this study as well as the corresponding segment and end-use groups presented in this report. Cadmus chose commercial segments for consistency with the draft 2021 Power Plan with one exception. The multifamily common area was not a stand-alone segment in the draft 2021 Power Plan. Overall, the commercial sector accounts for 667 aMW, or 55 percent of total baseline sales in 2041.

Table 3.5. Commercial Segments and End-Uses

Segment Group	Segment
Assembly	Assembly
Data Center	Data Center
Hospital	Hospital
Large Grocery	Supermarket
Large Office	Large Office Medium Office
Lodging	Lodging
Multifamily Common Area	Multifamily Common Area
Miscellaneous	Other
Other Health	Residential Care
Restaurant	Restaurant
Retail	Large Retail Medium Retail Small Retail Extra Large Retail
School	School K-12
Small Grocery	Mini Mart
Small Office	Small Office
University	University
Warehouse	Warehouse

End-Use Group	End-Use
Cooking	Cooking
Cooling	Cool Chillers Cooling DX
Data Center	Data Center Servers
Heat Pump	Heat Pump (Air Source)
Heating	Space Heat
Lighting	Exterior Lighting Interior Lighting
Miscellaneous	Computer – Desktop Computer – Laptop Other[1] Plug Load Other Waste Water
Refrigeration	Refrigeration
Ventilation and Circulation	Ventilation and Circulation
Water Heat	Water Heat GT 55 Gal Water Heat LE 55 Gal

[1] Other end uses includes all undefined loads such as elevators, automatic doors, and process loads.

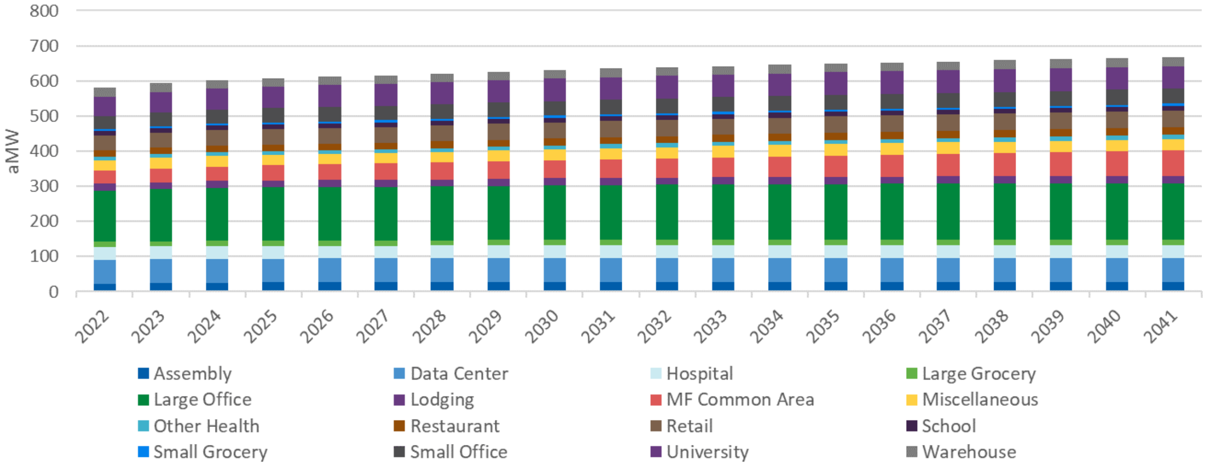
Cadmus used City Light's nonresidential database to identify sales and the number of customers for each commercial market segment. The database combined City Light's billing data with King County Assessor data, as well as other secondary data sources, to identify the customer segment and consumption for each nonresidential customer. These data served as the basis for Cadmus' segmentation of the commercial sector.

Cadmus also classified customers as commercial or industrial based on City Light's premise-level nonresidential customer database. Commercial customers are mapped to segments listed in Table 3.5. (Industrial customers are mapped to segments listed in Table 3.6, shown in the *Industrial* section below.)

To align with the City Light load forecast team's commercial building square footage, Cadmus adjusted the commercial building counts per segment, based on average square footage per building type from the 2020 CPA.

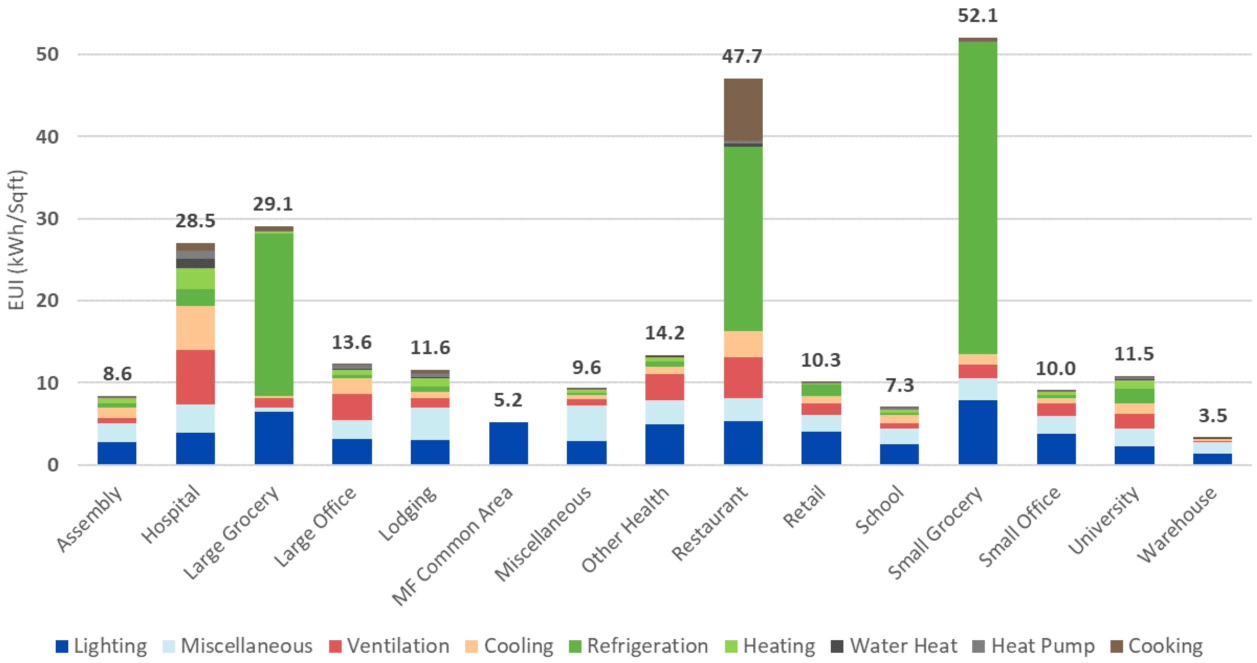
Figure 3.5 shows the distribution of baseline commercial energy consumption by segment for each year of the study. Large offices accounted for 24 percent of commercial baseline sales. Data center, multifamily common area, and university accounted for ten percent, 11 percent, and ten percent, respectively, of baseline sales. Together, these segments represent 55 percent of all commercial sector sales.

Figure 3.5. Annual Commercial Baseline Sales by Segment (2022-2041)



Cadmus developed the whole-building energy intensities (total kWh per building square feet) based on NEEA's CBSA IV. To develop the end-use intensities, Cadmus used CBSA, Energy Information Administration's Commercial Buildings Energy Consumption Survey (CBECS), and other Cadmus research. Further details is described in the *Derivation of End-Use Consumption* section below. Figure 3.6 shows energy intensities for each building type and end-use group.

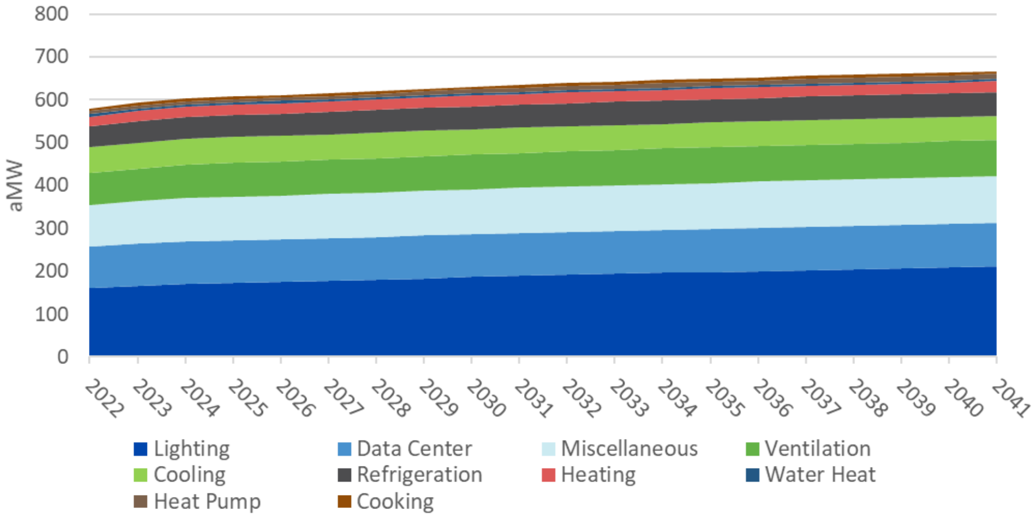
Figure 3.6. Commercial End-Use Group Intensities by Building Type – 2041



Note: The data center segment EUI of 181.5 kWh/sq ft is not included due to scaling. Additionally, all of the consumption for the data center segment appears in the data centers end-use group.

Figure 3.7 shows the commercial baseline forecast by end-use group. The forecast shows moderate load growth of commercial sales by roughly 0.7 percent on average per year over the study's horizon. The highest consuming end-use group was lighting, accounting for 32 percent of projected commercial consumption in 2041 (approximately the same percentage of overall end use as in 2022). Miscellaneous, data center, and ventilation end-use groups also account for a large share of consumption, at 16 percent, 15 percent, and 13 percent of projected commercial sales, respectively. Appendix B includes detailed baseline data for the commercial sector.

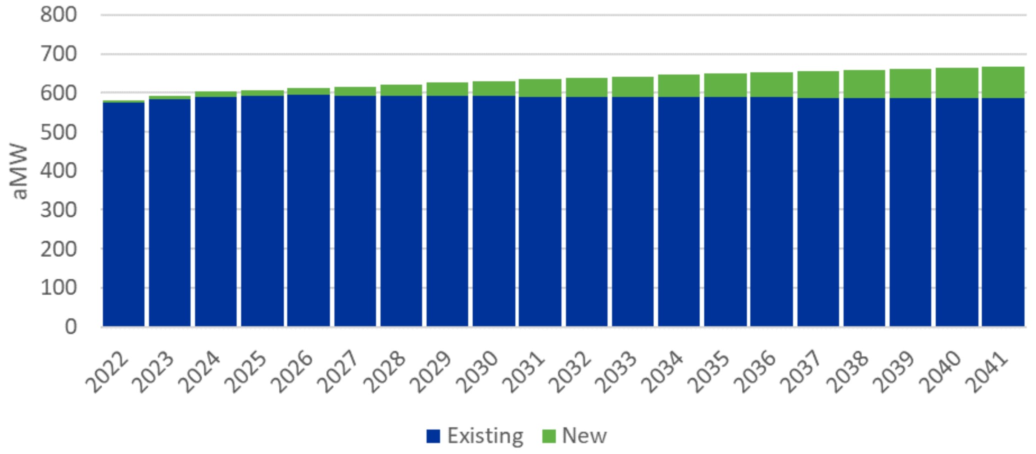
Figure 3.7. Annual Commercial Forecast by End-Use Group (2022-2041)



Note: The "miscellaneous" end-use group includes laptops (1.88 aMW of 2041 sales), desktops (28 aMW of 2041 sales), all other plug load (69.59 aMW of 2041 sales),and waste water (9.79 aMW of 2041 sales).

New commercial floorspace is a significant contributor to load growth in the commercial sector. By 2041, 12 percent of the forecasted load will come from buildings constructed after 2019. Figure 3.8 shows the commercial baseline forecast by construction vintage based on floor space.

Figure 3.8. Annual Commercial Forecast by Construction Vintage (2022-2041)



3.4. Industrial

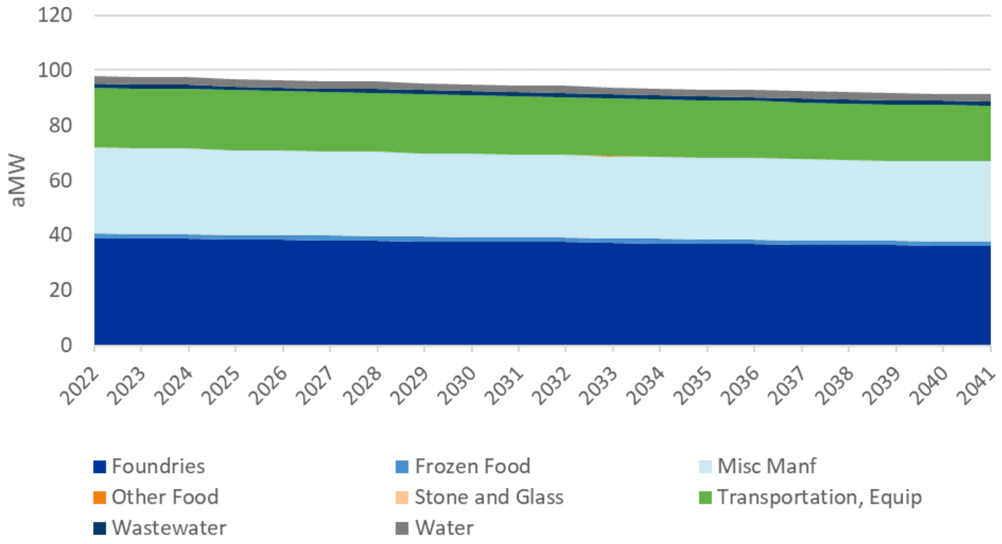
Cadmus disaggregated City Light's forecasted industrial sales into eight facility types/segments and 11 end-uses, as shown in Table 3.6. Overall, the industrial sector accounted for 91 aMW, or seven percent of City Light's overall forecasted baseline sales in 2041. The sector included about ten of City Light's largest customers with known industrial processes in addition to customers that contribute wastewater and water treatment loads.

Table 3.6. Industrial Segments and End-Uses

Segments	End-Uses
Foundries	Process Air Compressor
Frozen Food	Lighting
Miscellaneous Manufacturing	Fans
Other Food	Pumps
Stone and Glass	Motors Other
Transportation, Equipment	Process Other
Wastewater	Process Heat
Water	HVAC
	Other
	Process Electro Chemical
	Process Refrigeration

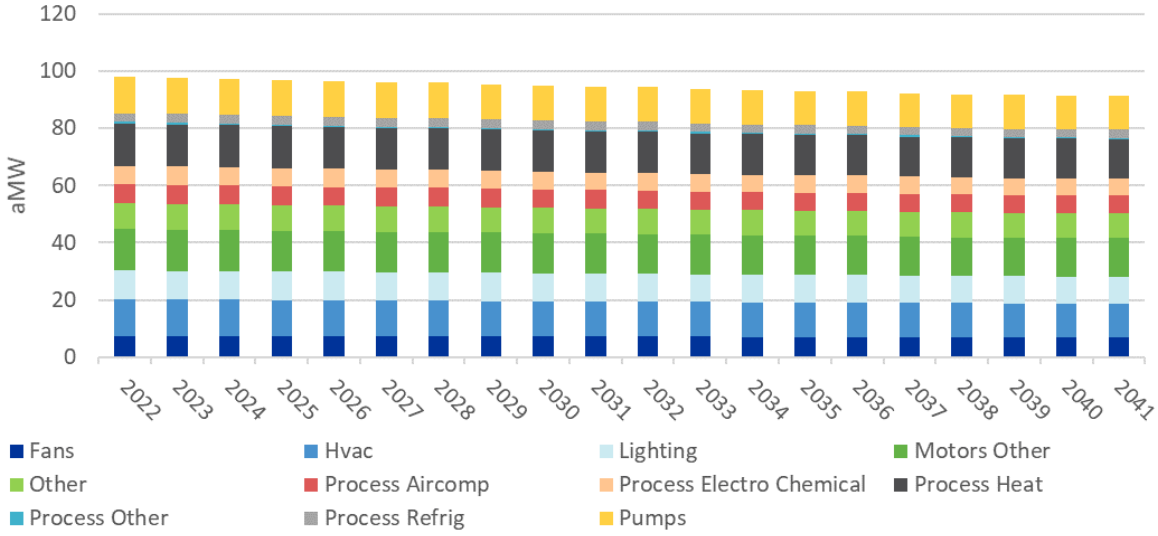
Like the commercial sector, Cadmus relied on City Light's nonresidential customer database to determine the distribution of baseline sales by segment. Figure 3.9 shows the distribution of industrial sales by segment in 2041. Foundries accounts for 40 percent of industrial baseline sales; the next largest segments are miscellaneous manufacturing (32 percent) and transportation equipment (22 percent).

Figure 3.9. Annual Industrial Baseline Sales by Segment (2022-2041)



Cadmus relied on end-use distributions provided in the draft 2021 Power Plan's industrial tool to disaggregate segment-specific consumption into end-uses. Figure 3.10 shows industrial baseline sales forecast by end-use.

Figure 3.10. Annual Industrial Baseline Sales by End-Use (2022-2041)



4. Energy Efficiency Potential

4.1. Overview

4.1.1. Scope of the Analysis

This potential study included a comprehensive set of conservation measures, including those assessed by the Council in the draft 2021 Power Plan and by the RTF. Cadmus began its analysis by assessing the technical potential of hundreds of unique conservation measures applicable to each sector, segment, and construction vintage (discussed in the *Baseline Forecast* section).

Cadmus considered over 7,111 permutations of conservation measures representing a wide range of technologies and applications. Permutations are defined as unique measure, sector, segment, end-use, construction vintage, and baseline combinations that have technical potential (i.e., no below-standard measures are included). For example, an ENERGY STAR air purifier for residential single-family new construction with a federal standard baseline is a different permutation than an ENERGY STAR purifier for residential single-family *existing* construction with a federal standard baseline. Table 4.1 lists the number conservation measures and permutations by sector considered in this study.

Table 4.1. Measures and Permutations

Sector	Measures	Permutations
Residential	228	1,454
Commercial	1,137	5,471
Industrial	34	186
Total	**1,399**	**7,111**

4.1.2. Summary of Results

Table 4.2 shows baseline sales and cumulative technical and achievable technical potential by sector. Study results indicate 233 aMW of technically feasible conservation potential—19 percent of baseline sales—will be available by 2041, and 84 percent (196 aMW) is considered achievable in 2041. The achievable technical potential corresponds to 16 percent of baseline sales. Technical and achievable technical potential are inclusive of future City Light-funded conservation. That is, the baseline consumption forecasts account for historical achieved and planned City Light-funded conservation prior to 2022. However, the estimated potential identified is inclusive of—not in addition to—forecasted program savings. In other words, the baseline forecast excludes future, planned energy efficiency program efforts but the savings estimates include energy efficiency program savings.

These results in this report account for line losses and represent cumulative energy savings at generator (unless specified).

Table 4.2. Cumulative Technical and Achievable Technical Potential by Sector (2022-2041)

Sector	Baseline Sales	Technical Potential		Achievable Technical Potential	
		aMW	Percent of Baseline	aMW	Percent of Baseline
Residential	461	90	20%	70	15%
Commercial	667	131	20%	116	17%
Industrial	91	12	13%	10	11%
Total	**1,219**	**233**	**19%**	**196**	**16%**

The commercial sector, representing 55 percent of baseline energy use, accounts for approximately 59 percent of cumulative achievable technical potential in 2041, as shown in Figure 4.1. The residential and industrial sectors account for 36 percent and 5 percent, respectively.

Figure 4.1. Cumulative Achievable Technical Potential by Sector (2022-2041)

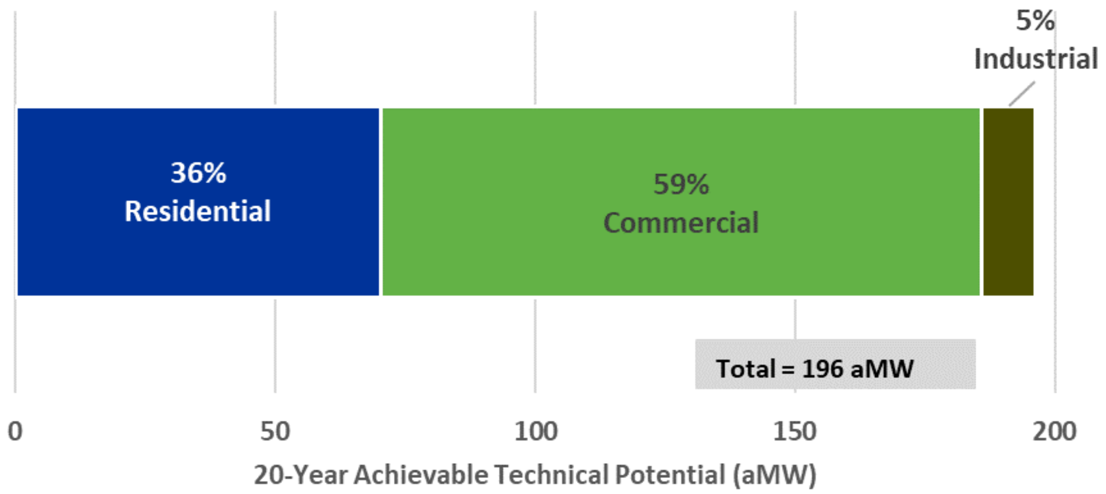


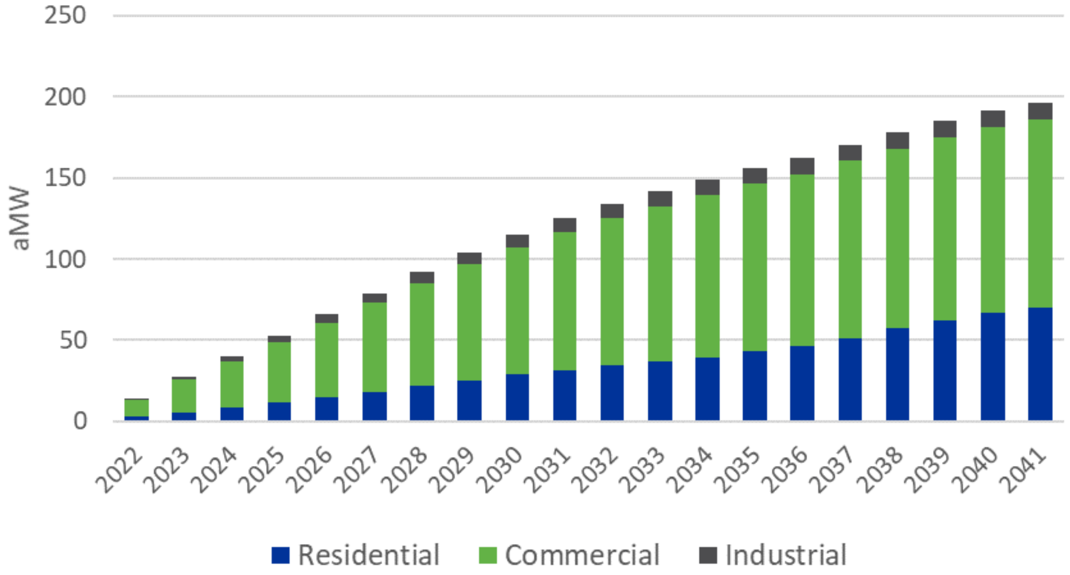
Table 4.3 shows cumulative two-year, four-year, ten-year, and 20-year achievable technical potential by sector, as well as 20 percent of the ten-year achievable technical potential.

Table 4.3. Cumulative Achievable Technical Potential by Sector and Time Period

Sector	Achievable Technical Potential – aMW				
	2-Year (2022-2023)	4-Year (2022-2025)	10-Year (2022-2031)	20-Year (2022-2041)	20% of 10-Year Potential
Residential	6	12	32	70	6
Commercial	20	37	85	116	17
Industrial	2	4	9	10	2
Total	**28**	**53**	**125**	**196**	**25**

Figure 4.2 presents the cumulative achievable technical potential across the study horizon.

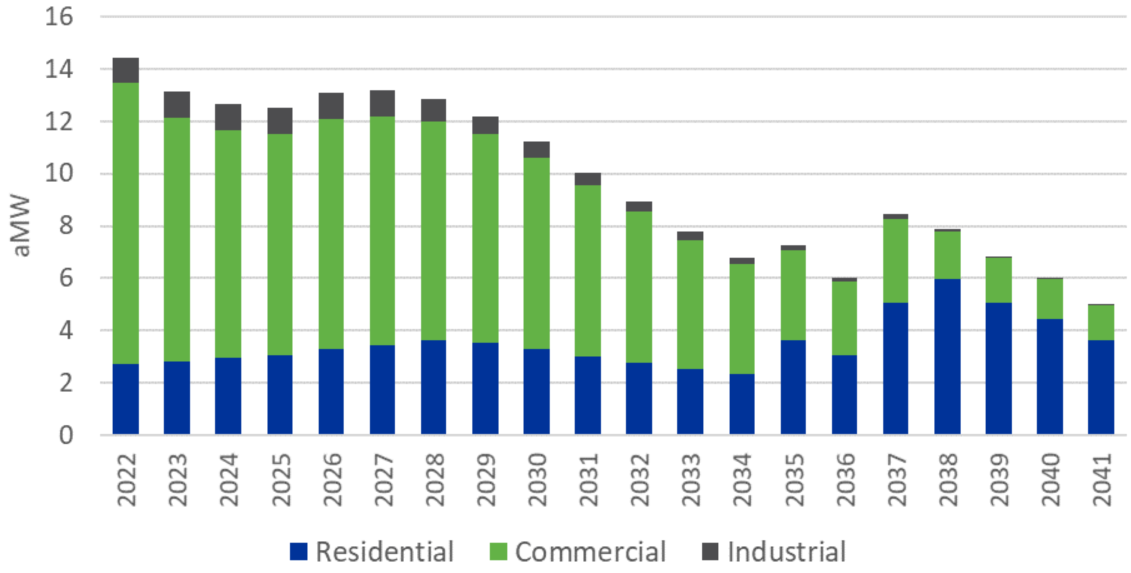
Figure 4.2. Cumulative Achievable Technical Potential by Sector (2022-2041)



Approximately 27 percent of cumulative 20-year achievable potential is acquired in the first four years, and 64 percent of cumulative 20-year achievable potential is acquired in the first ten years. This acquisition rate is based on the acquisition rate from the draft 2021 Power Plan along with acceleration adoption for measures that City Light has historically offered through programs to better align with local and state policies promoting energy efficiency. The *About Measure Ramp Rates* section of this report provides more information on how Cadmus performed this calculation.

Cadmus determined incremental achievable technical potential in each year of the study horizon, using the rate at which equipment naturally turns over and measure-specific ramp rates. Figure 4.3 shows incremental achievable potential. The increase in savings in 2037 is the result of the ramp rates applied and the 15-year measure life for many heating measures. For example, in 2037, residential zonal heating systems, initially installed in 2022, need to be replaced since the technology has a 15-year measure life. A proportion, based on the ramp rate in the year of replacement (2037), is replaced by ductless heat pumps. Since ductless heat pumps are such a high-saving measure, there is a large increase in residential incremental achievable potential in 2037.

Figure 4.3. Annual Incremental Achievable Technical Potential (2022-2041)



The conservation supply curve in Figure 4.4 shows cumulative achievable potential in $10/MWh levelized cost increments. The study found that 60 percent (117 aMW) of the cumulative 2041 achievable technical potential can be acquired at less than or equal to $60/MWh.[16] The amount of available achievable technical potential levels off at less than or equal to $60/MWh, excluding high-cost measures (costing more than $160/MWh). The 2041 achievable technical potential with a levelized cost of greater than $160/MWh makes up 24 percent of cumulative achievable technical potential. Many of the costlier measures are for emerging equipment, heat pump conversion (e.g., electric resistance heating to heat pump), and weatherization in the residential and commercial sectors.

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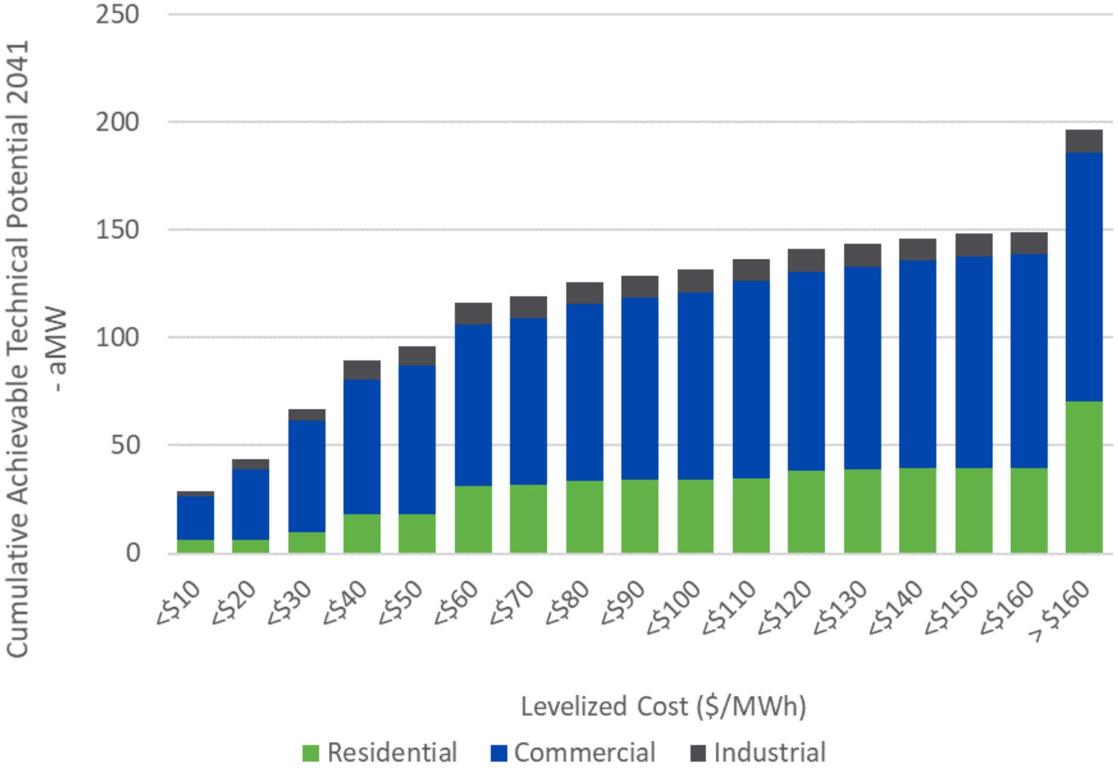
[16] The levelized cost bundle of less than or equal to $60/MWh represents an example value, and it has been identified as in between City Light's IRP optimization model selection for the residential ($40/MWh) and commercial ($70/MWh) sectors.

Figure 4.4. All Sectors Supply Curve — Cumulative Achievable Technical Potential in 2041 by Levelized Cost



Appendix D shows detailed measure-level results, including levelized costs and technical and achievable technical conservation potential for each measure. The remainder of this section provides detailed results by sector.

City Light's IRP selected an achievable economic potential of 106 aMW. Table 4.4 shows cumulative, 20-year achievable economic potential by sector and the maximum levelized cost for measure permutations in each sector. For example, all residential achievable economic potential can be obtained at a levelized cost of less than or equal to $40/MWh. Details of achievable economic potential methodology can be found in the *Achievable Economic Potential* section.

Table 4.4. Cumulative Achievable Economic Potential by Sector (2022-2041)

Sector	**Levelized TRC ($/MWh)**	**20-Year Achievable Economic Potential (aMW)**
Residential	≤$40	18
Commercial	≤$70	77
Industrial	All Bins	10
Total		**106**

4.2. Residential

Residential customers in City Light's service territory account for 38 percent of 2041 total baseline sales. This sector, made up of low- and standard-income single-family and multifamily customers, has a variety of sources for potential savings, including equipment efficiency upgrades (e.g., water heaters and appliances) and improvements to building shells (e.g., windows, insulation, and air sealing).

Based on resources in this assessment, Cadmus estimated residential, cumulative, achievable technical potential of 70 aMW over 20 years, which corresponds to 15 percent of the forecast residential load in 2041. Table 4.5 shows cumulative 20-year residential conservation potential by segment.

Table 4.5. Cumulative Residential Potential by Segment (2022-2041)

Segment	Baseline Sales	Cumulative 2041 – aMW			
		Technical Potential (TP)	TP % of Baseline	Achievable Technical Potential (AP)	AP % of TP
Single-Family	194	41	21%	31	77%
Single-Family Low-Income	42	9	21%	7	77%
Multifamily – Low-Rise	67	12	18%	10	80%
Multifamily – Low-Rise Low-Income	32	6	18%	5	80%
Multifamily – Mid-Rise	37	7	18%	5	78%
Multifamily – Mid-Rise Low-Income	23	4	18%	3	78%
Multifamily – High-Rise	44	8	18%	6	78%
Multifamily – High-Rise Low-Income	21	4	18%	3	78%
Total	**461**	**90**	**20%**	**70**	**78%**

As shown in Table 4.5 and Figure 4.5, single-family homes account for 55 percent (38 aMW) of total achievable technical potential, followed by multifamily low-rise (15 aMW), multifamily high-rise (9 aMW), and multifamily mid-rise (8 aMW). Total achievable technical potential for income-qualified customers is 18 aMW, or 25 percent. Each home type's proportion of baseline sales drives this distribution, but segment-specific end-use saturations and fuel shares have a role as well. Appendix B includes detailed data on saturations and fuel shares for each segment.[17] Appendix C includes detailed summary of achievable technical potential by segment and end use for each segment.

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[17] The scope of this study does not distinguish differences in end-use saturations and fuel shares among income classifications. Potential by income classification is defined by customer segmentation. (Potential results by segment, including income classification and end-use, can be found in Appendix C).

Figure 4.5. Residential Cumulative Achievable Technical Potential by Segment (2022-2041)

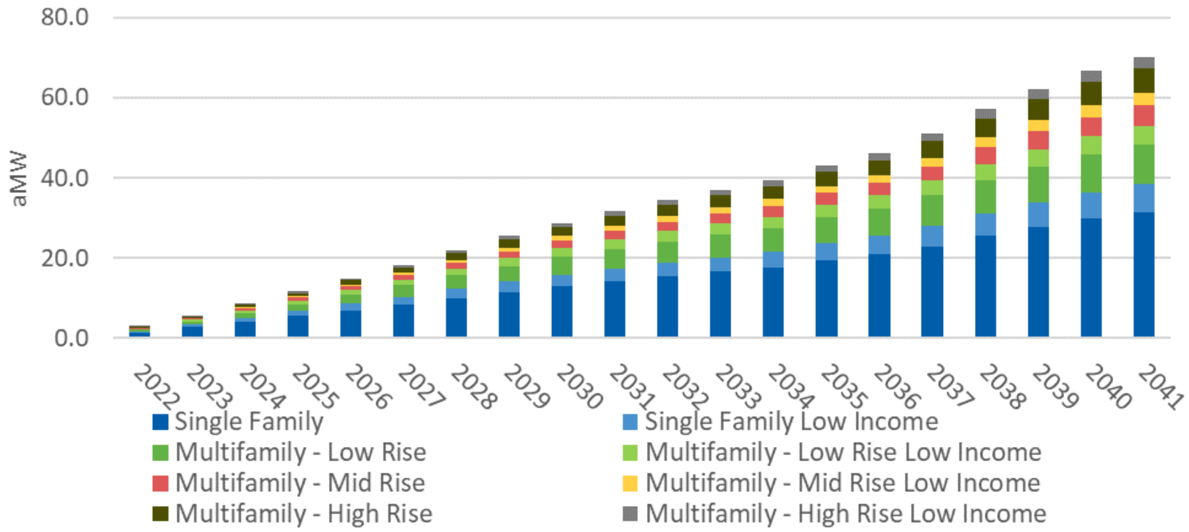


Figure 4.6 presents the cumulative achievable technical potential by construction type for the residential sector. Existing construction represents the majority of achievable technical potential, particularly in the early years of the study, accounting for 96 percent of the potential in the first two years (2022-2023). However, by the final year of the study period (2041), new construction accounts for 18 percent of the total cumulative residential achievable technical potential. This is because of the increase in new construction, from roughly 4,000 buildings in 2022 to over 86,000 buildings constructed between 2022 and 2041.

Figure 4.6. Residential Cumulative Achievable Technical Potential by Construction Type (2022-2041)

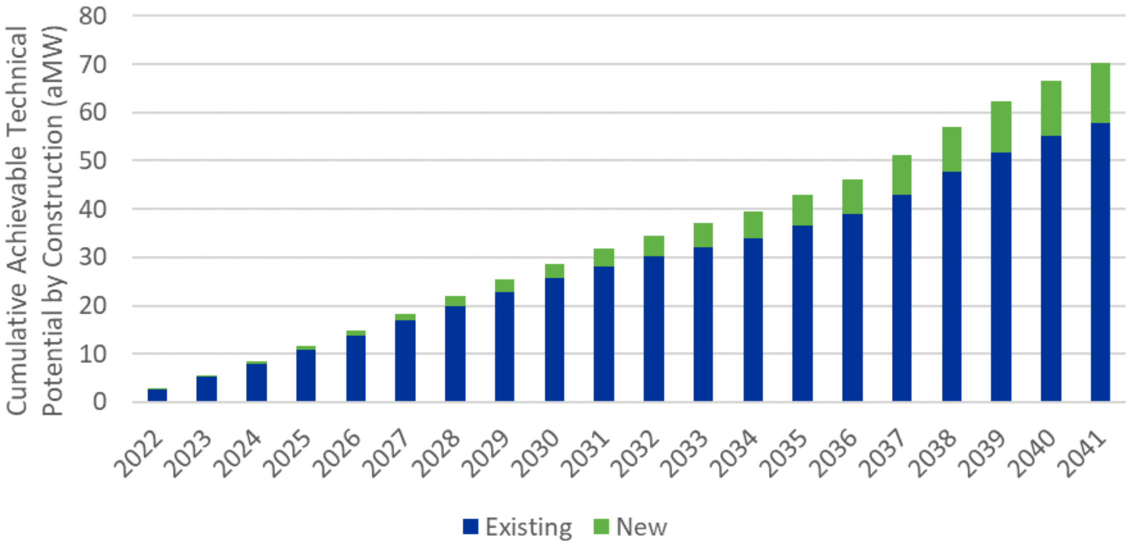


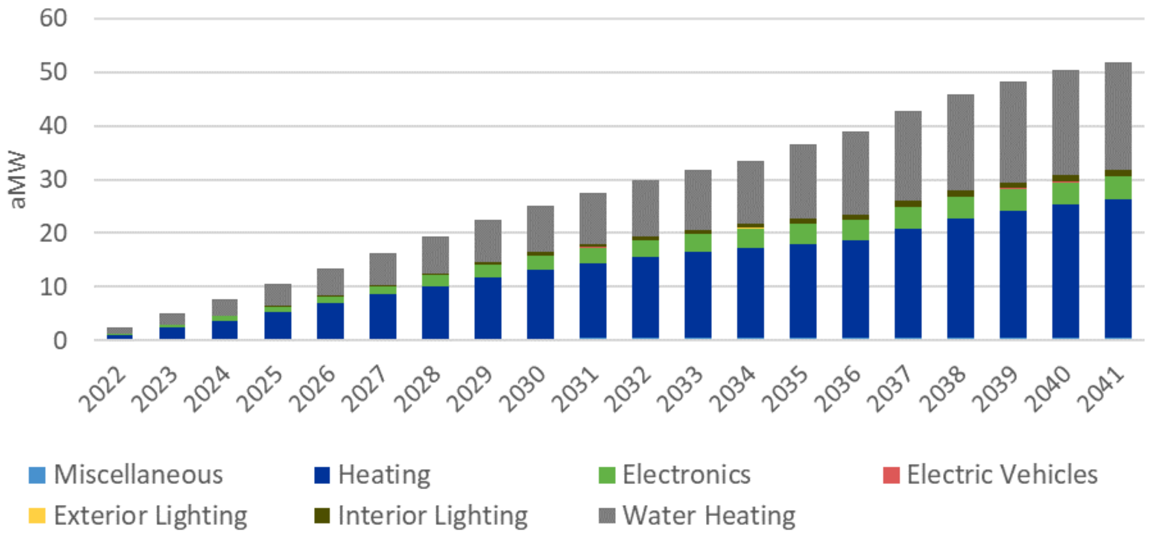
Table 4.6 shows the residential baseline sales, technical, and achievable technical potential by end-use group. Heating savings make up the greatest proportion of cumulative achievable technical potential at 37 percent. Water heating measures contribute 29 percent of the total achievable technical potential, followed by appliance measures at 25 percent. Overall, 78 percent of the technical potential is considered achievable based on adoption patterns from the draft 2021 Power Plan and adjusted for City Light's historical program success.

Table 4.6. Cumulative Residential Potential by End-Use Group (2022-2041)

End Use	Baseline Sales	Cumulative 2041 - aMW			
		Technical Potential (TP)	TP % of Baseline	Achievable Technical Potential (AP)	AP % of TP
Miscellaneous	8	1	7%	1	87%
Heating	175	32	18%	26	80%
Electronics	64	4	7%	4	94%
Appliances	89	26	29%	18	69%
Cooling	7	1	11%	1	81%
Electric Vehicles	38	0.2	1%	0.2	94%
Exterior Lighting	1	<0.01	2%	<0.01	85%
Interior Lighting	14	1	9%	1	86%
Water Heating	63	25	39%	20	82%
Total	**461**	**90**	**20%**	**70**	**78%**

Incremental and cumulative potential over the 20-year study horizon varies by end-use group due to the application of ramp rates. These ramp rates were assigned to each measure based on factors such as availability, existing program activity, and market trends. Cadmus used the same ramp rates for each measure, as assigned by the Council in the draft 2021 Power Plan, with some adjustments as discussed in the *Achievable Technical Potential and Ramping* section. Figure 4.7 shows cumulative residential achievable potential.

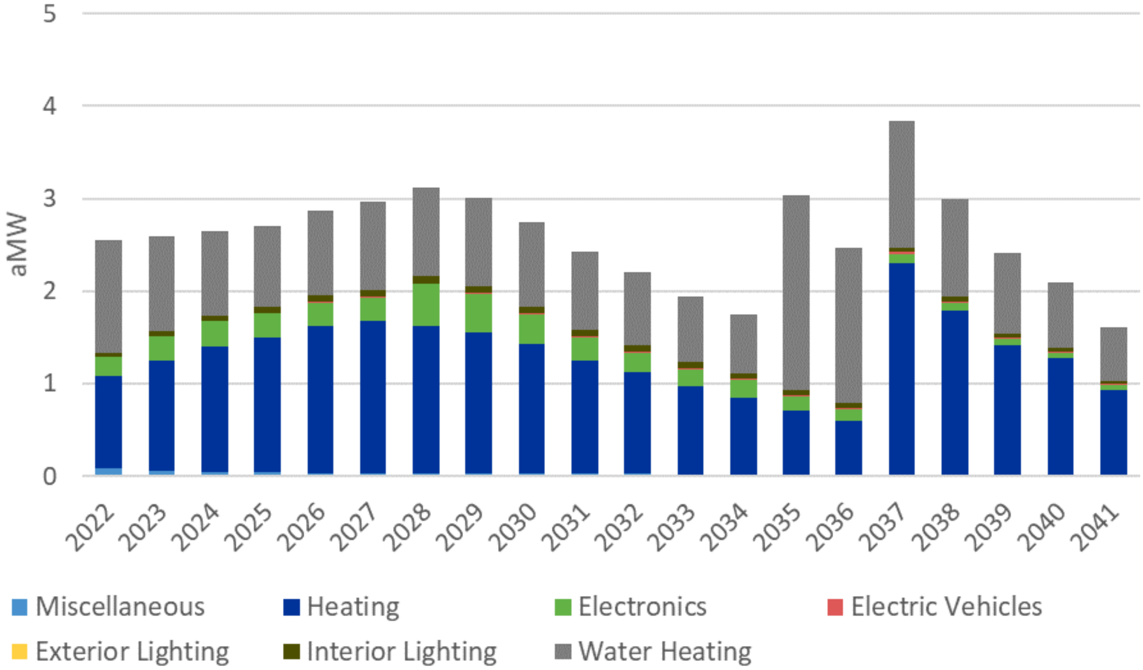
Figure 4.7. Residential Cumulative Achievable Technical Potential (2022-2041)



Note: In 2041, exterior lighting and electric vehicles makes up 0.03 percent and 0.27 percent of residential cumulative achievable technical potential, respectively.

Figure 4.8 shows incremental residential achievable potential. Measure ramp rates and effective useful lives (only for equipment replacement measures) determine the timing of these savings. The increase in heating savings in 2037 is the result of the replacement of a high proportion of zonal heating measures with ductless heat pumps after their 15-year measure life expires.

Figure 4.8. Residential Incremental Achievable Technical Potential (2022-2041)



Note: On average, exterior lighting and electric vehicles makes up 0.03 percent and 0.27 percent of annual residential incremental achievable technical potential, respectively.

Table 4.7 lists the 15 highest-saving residential measures, which make up 77 percent of the total residential achievable technical potential. The table also includes the weighted average levelized costs for these measures,[18] which represent the economic equipment and administrative costs while still accounting for energy and non-energy benefits. The measure with the highest cumulative achievable technical potential—multifamily ductless heat pumps—also has a levelized cost of $297 per MWh. Other measures identified with high savings are heat pump dryers, efficient (hybrid) heat pump water heaters, and refrigerators and freezers CEE (Consortium for Energy Efficiency) Tier 3. Of the highest-savings measures, the least costly are ENERGY STAR printers, wall insulation, and CEE Tier 3 refrigerators and freezers.

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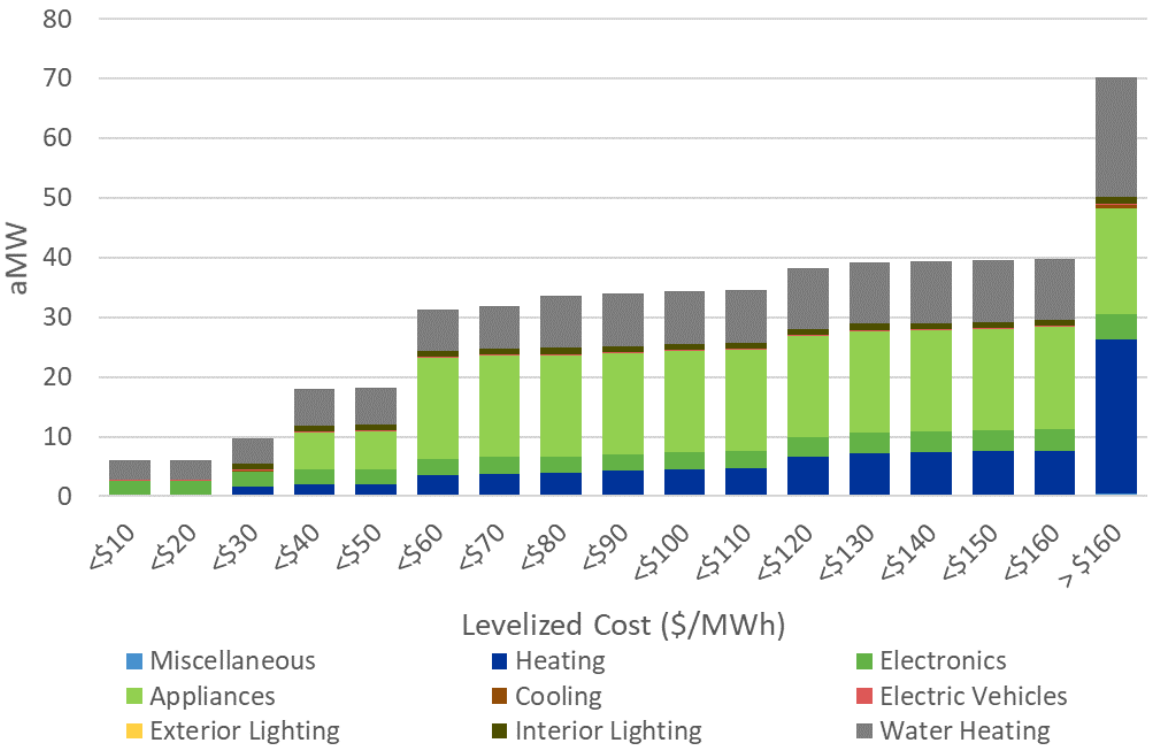
[18] The levelized cost value represents a weighted average across all iterations, including segment and end-use. As a result, permutations of a measure may have a low levelized cost while other permutations may have a high levelized cost.

Table 4.7. Top-Saving Residential Measures

Measure Name	Cumulative Achievable Technical Potential – aMW				Percent of Total (20-Year)	Weighted Average Levelized TRC ($/MWh)
	2-Year	4-Year	10-Year	20-Year		
Multifamily Ductless Heat Pump Upgrade	0.50	1.43	4.98	11.40	16%	$297.08
Heat Pump Dryer	0.02	0.09	1.00	10.61	15%	$56.43
Heat Pump Water Heater – Tier 4	0.30	0.82	2.79	7.70	11%	$367.54
Refrigerator and Refrigerator-Freezer – CEE Tier 3	0.28	0.73	2.34	6.04	9%	$39.64
Heat Pump Water Heater – Tier 3	0.14	0.38	1.18	3.13	4%	$60.09
Office Printer – ENERGY STAR	0.30	0.62	1.55	1.94	3%	-$4.90
Single Family Weatherization – Insulate Wall – R0 to R11 – Heating Zone 1	0.41	0.82	1.64	1.87	3%	$133.46
Front Load Washer CEE Tier 2 and Electric DHW Electric Dryer	0.60	0.92	1.48	1.86	3%	$119.28
Solar Hot Water - Solar Zone 1	0.00	0.02	0.23	1.78	3%	$1,034.36
HVAC Upgrade – Heat Pump Upgrade to 12 HSPF/18 Seasonal Energy Efficiency Ratio (SEER) - Heating and Cooling Zone 1	0.01	0.06	0.40	1.54	2%	$1,810.16
Wall Insulation - R0 to R11 - Heating Zone 1	0.33	0.66	1.33	1.51	2%	$28.86
Top Load Washer CEE Tier 1 and Electric DHW Electric Dryer	0.42	0.64	1.03	1.29	2%	$90.31
Zonal to Ductless Heat Pump	0.09	0.23	0.41	1.19	2%	$215.74
Single Family Showerhead Aerator 1.50 Gallons Per Minute (GPM)	0.40	0.60	0.93	1.09	2%	$40.64
Residential Thermostatic Shower Restriction Valve	0.01	0.05	0.51	1.00	1%	$185.71

Overall, 16 percent of residential conservation potential is achievable within the first four years, and 45 percent is achievable in the first ten years. Figure 4.9 shows 20-year cumulative residential potential by levelized cost (in $10/MWh increments).

Figure 4.9. Residential Supply Curve — Cumulative Achievable Technical Potential in 2041 by Levelized Cost



Forty-three percent of the residential achievable technical potential is from measures with a levelized cost of over $160/MWh. This is partly because the highest savings measure—multifamily ductless heat pump upgrades (MF DHP Upgrades)—has a levelized cost greater than $160/MWh.

City Light's IRP selected an economic achievable potential of 18 aMW for the residential sector. Figure 4.9 shows the cumulative, 20-year achievable economic potential for the residential sector by end-use group. The two end-use groups that have the greatest achievable economic potential are appliances and water heating. Collectively, appliance and water heating achievable economic potential is 68 percent of the total residential 20-year, cumulative achievable economic potential.

Figure 4.10. Residential Cumulative Achievable Economic Potential in 2041 by End-Use Group

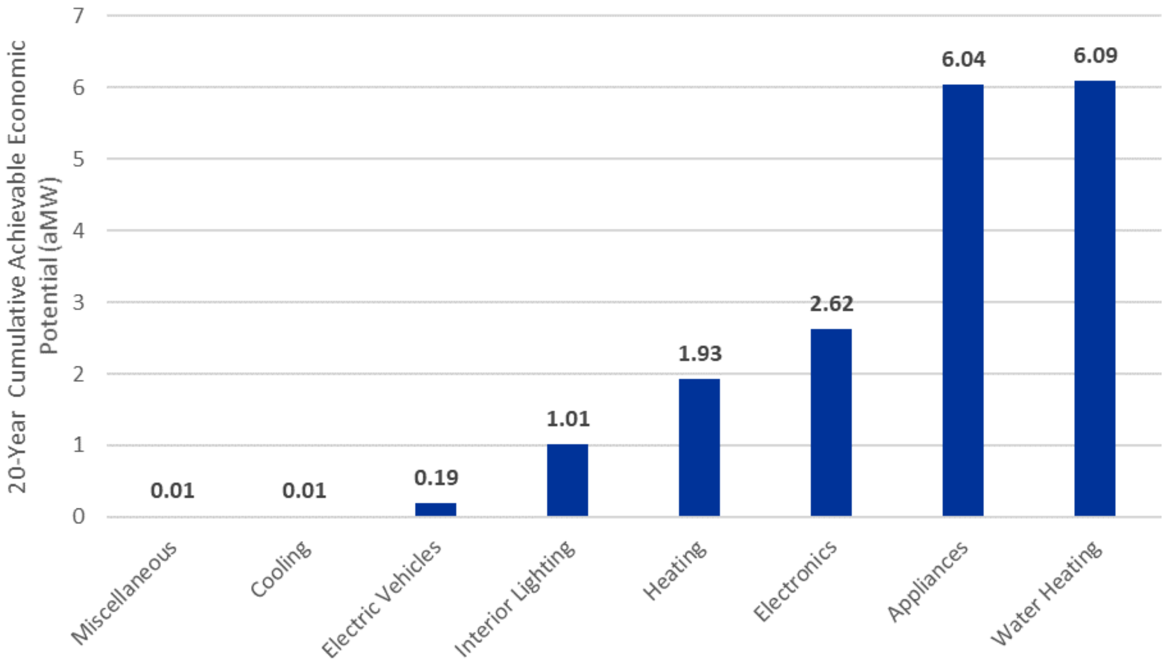


Table 4.8 lists the 15 highest saving IRP selected residential measures. The measure permutations included in the table all have a levelized cost of less than or equal to $40/MWh and make up 21 percent of the cumulative, 20-year achievable technical potential for the residential sector.

Table 4.8. Top-Saving Residential Measures Selected by IRP

Measure Name	Cumulative Achievable Economic Potential (aMW) – Less than or Equal to $40/MWh				Percent of Cumulative 20-Year Achievable Technical Potential
	2-Year	4-Year	10-Year	20-Year	
Refrigerator and Refrigerator-Freezer – CEE Tier 3	0.28	0.73	2.34	6.04	9%
Office Printer – ENERGY STAR	0.30	0.62	1.55	1.94	2%
Front Load CEE Tier 2 Washer with Electric DHW Electric Dryer	0.56	0.86	1.38	1.73	2%
Wall Insulation - R0 to R11 - Heating Zone 1	0.32	0.64	1.29	1.46	2%
Top Load Washer CEE Tier 1 with Electric DHW Electric Dryer	0.39	0.59	0.96	1.20	1%
Single Family Showerhead Aerator 1.50 GPM	0.37	0.55	0.87	1.01	1%
Linear Fluorescent Lamp – TLED	0.09	0.20	0.56	1.00	1%
Heat Pump Water Heater – Tier 3	0.04	0.10	0.30	0.81	1%
Multifamily Showerhead Aerator 1.50 GPM	0.18	0.28	0.45	0.57	1%
Home Audio System – ENERGY STAR	0.01	0.02	0.19	0.38	0.4%
Single Family Bathroom Aerator	0.09	0.13	0.21	0.24	0.3%
Ultra-High Definition TV – ENERGY STAR	0.00	0.01	0.11	0.22	0.2%
Electric Vehicle Supply Equipment Level 2 Networked Charger	0.00	0.00	0.04	0.19	0.2%
Single Family Kitchen Aerator	0.06	0.09	0.13	0.16	0.2%
Floor Insulation - R0 to R19 - Heating Zone 1	0.03	0.07	0.13	0.15	0.2%

4.3. Commercial

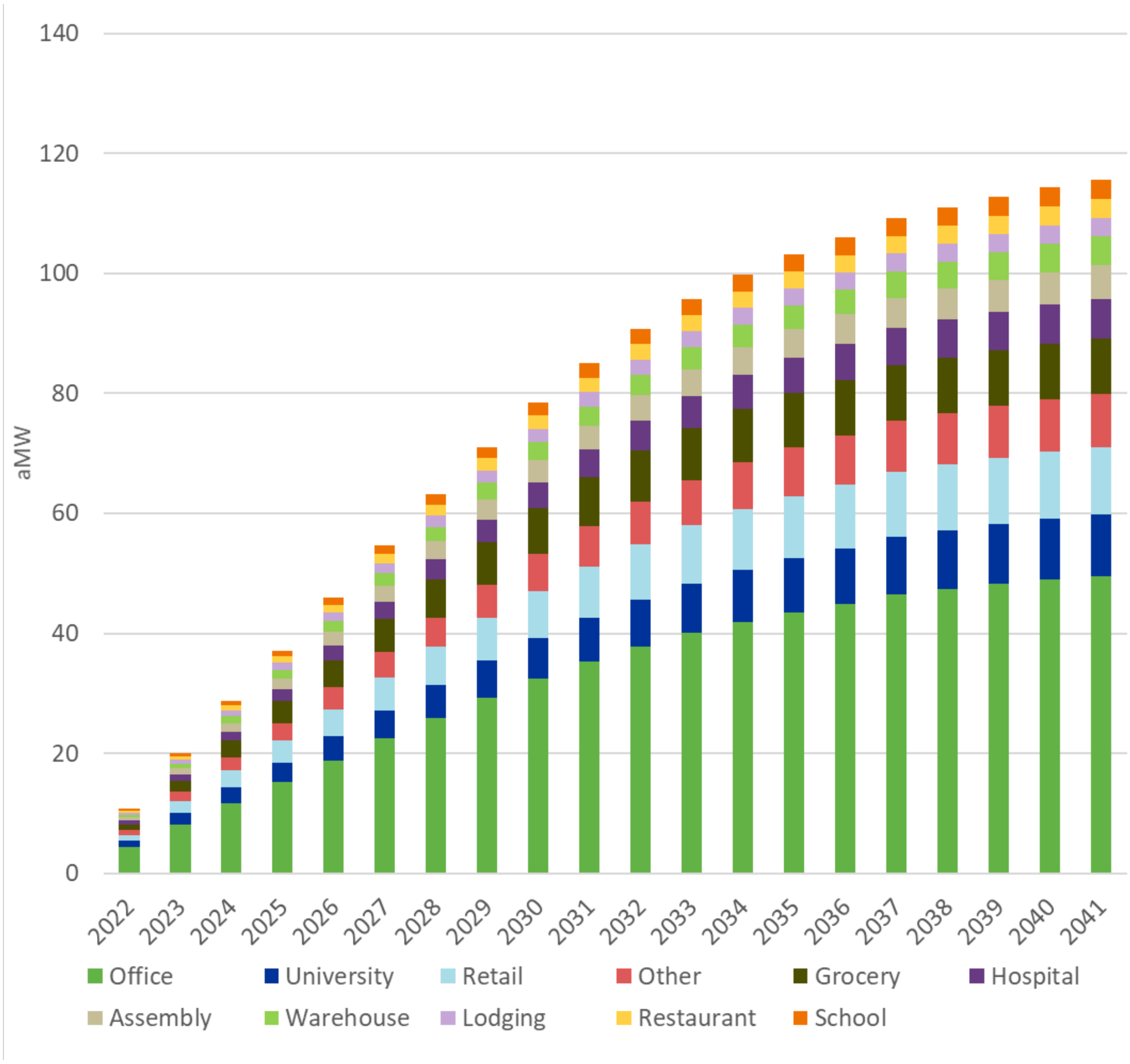
City Light’s commercial sector accounts for 55 percent of its baseline sales in 2041 and 59 percent of total achievable technical potential. Cadmus estimated potential for the 20 commercial segments listed above in Table 3.5 (grouped into 16 segments for this report). Table 4.9 summarizes 20-year cumulative technical and achievable technical potential by commercial segment.

Table 4.9. Cumulative Commercial Potential by Segment (2022-2041)

Segment	Baseline Sales	Cumulative 2041 – aMW			
		Technical Potential (TP)	TP % of Baseline	Achievable Technical Potential (AP)	AP % of TP
Assembly	28	6	23%	6	88%
Data Center	67	0.3	0.5%	0.3	85%
Hospital	38	8	20%	7	85%
Large Grocery	16	9	56%	8	89%
Large Office	160	41	25%	36	89%
Lodging	21	4	17%	3	89%
Multifamily Common Area	71	0	0%	0	0%
Miscellaneous	33	7	22%	7	91%
Other Health	11	2	18%	2	90%
Restaurant	21	4	16%	3	87%
Retail	47	13	26%	11	90%
School	14	4	28%	3	85%
Small Grocery	7	2	23%	1	89%
Small Office	42	15	35%	13	89%
University	65	12	19%	10	83%
Warehouse	25	5	22%	5	88%
Total	**667**	**131**	**20%**	**116**	**88%**

Approximately 31 percent of 20-year commercial achievable technical potential is from the large office segment, as shown in Figure 4.10. Together, large and small offices account for 43 percent of commercial achievable technical potential. The large grocery segment has the highest technical potential savings relative to baseline sales due to the high potential associated with refrigeration equipment.

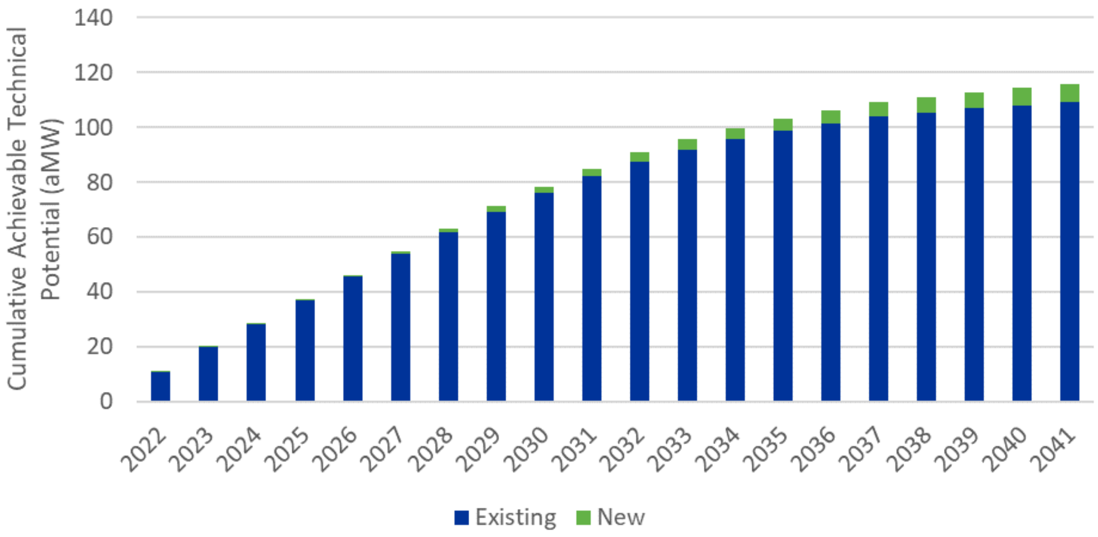
Figure 4.11. Cumulative Commercial Achievable Technical Potential by Segment (2022-2041)



Note: Other segment includes data centers, multifamily common area, miscellaneous, and other health.

Figure 4.11 presents the cumulative achievable technical potential by construction vintage for the commercial sector. Existing construction represents the majority of achievable technical potential, particularly in the early years of the study, accounting for 98.9 percent of the potential in the first two years (2022-2023).

Figure 4.12. Cumulative Commercial Achievable Technical Potential by Construction Type (2022-2041)



Across each of these segments, lighting accounts for 33 percent of total achievable technical potential. Table 4.10 shows 20-year cumulative commercial potential by end use.

Table 4.10. Cumulative Commercial Potential by End-Use Group (2022-2041)

End Use	Baseline Sales	Cumulative 2041 – aMW			
		Technical Potential (TP)	TP % of Baseline	Achievable Potential (AP)	AP % of TP
Cooking	7	1	9%	1	85%
Cooling	57	23	40%	19	82%
Data Center	101	5	5%	4	89%
Heat Pump	12	4	36%	4	84%
Heating	25	8	30%	6	85%
Lighting	211	42	20%	38	91%
Miscellaneous	109	5	4%	4	88%
Refrigeration	56	18	32%	16	89%
Ventilation	85	25	30%	23	91%
Water Heating	5	2	32%	1	74%
Total	**667**	**131**	**20%**	**116**	**88%**

Note: The heat pump end-use group includes air source heat pumps and related retrofit measures. This differs from heat pump water heaters, which are included in the water heating end-use group. Heating end-use group refers to non-heat pump electric space heating equipment (e.g., electric resistance heating). Cooling end-use group refers to cooling direct expansion, chiller equipment, and related retrofit measures.

One-third of commercial achievable potential comes from interior lighting equipment upgrades, exterior lighting equipment upgrades, and controls. Lighting's 20-year technical potential is equivalent to an 18 percent reduction in baseline lighting consumption. Overall, 91 percent of lighting technical potential is considered achievable based on the maximum achievable potential assumed in the draft 2021 Power Plan.

Compared to the residential sector, a larger proportion of the achievable technical potential is realized in the first ten years of the study, with 73 percent of the 20-year cumulative achievable technical potential in the first ten years and 32 percent in the first four years. Figure 4.12 and Figure 4.13 show cumulative and incremental achievable potential for the commercial sector, respectively. There is a slight bump in incremental achievable technical potential in 2037, due to the replacement of high-savings measures that have a measure life of 15 years.

Figure 4.13. Commercial Cumulative Achievable Technical Potential (2022-2041)

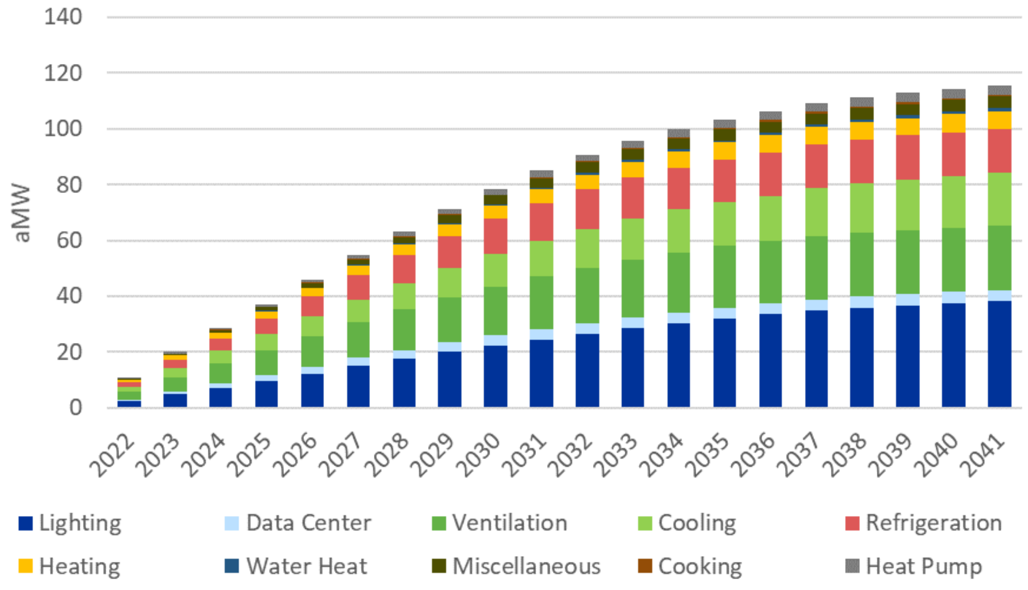


Figure 4.14. Commercial Incremental Achievable Technical Potential (2022-2041)

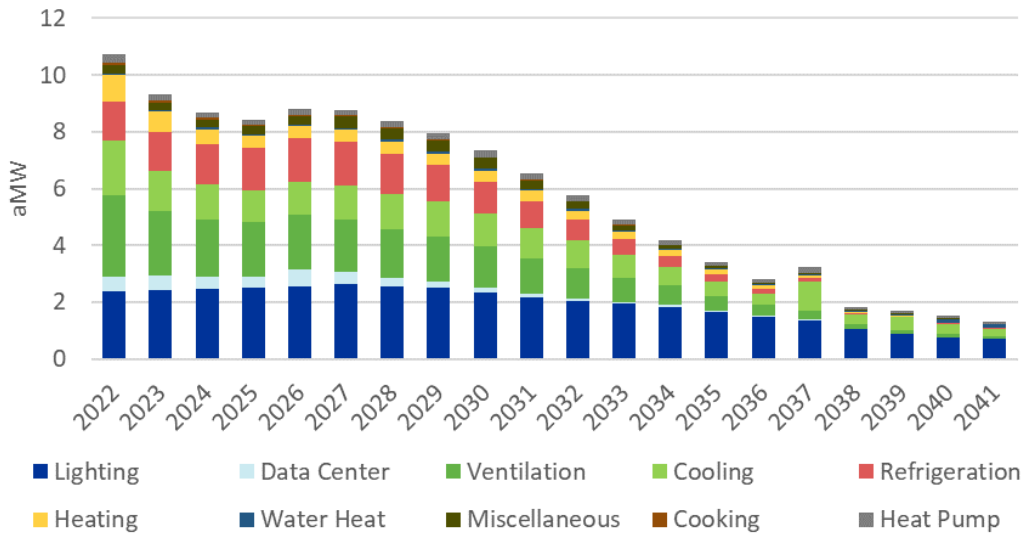


Table 4.11 shows the top 15 commercial measures and their average levelized costs,[19] sorted by 20-year achievable technical potential. Together, these measures represent 34 percent of the commercial cumulative 2041 achievable technical potential. The highest-saving measure is HVAC retro-commissioning with over 5 aMW, or four percent, of achievable technical potential. Depending on the application, this measure can also be costly and may not be considered economic with a weighted average levelized TRC of $160 per MWh.

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[19] The levelized cost value represents a weighted average across all iterations, including segment and end-use. As a result, permutations of a measure may have a low levelized cost while other permutations may have a high levelized cost.

Table 4.11. Top-Saving Commercial Measurers

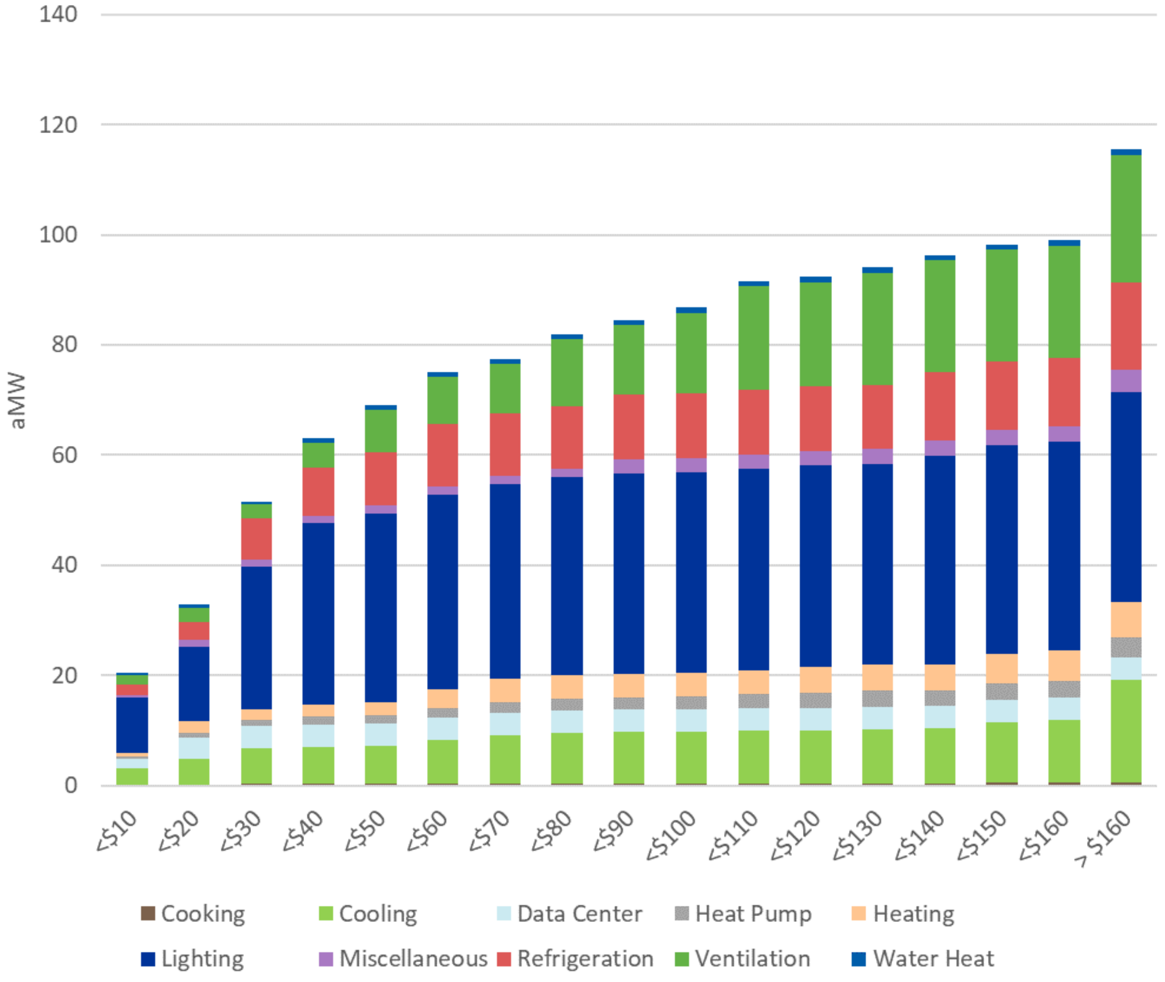
Measure Name	Cumulative Achievable Technical Potential - aMW				Percent of Total (20-Year)	Weighted Average Levelized TRC ($/MWh)
	2-Year	4-Year	10-Year	20-Year		
HVAC Retro-commissioning	1.95	2.94	4.54	5.16	4%	$159.97
Building Automation System Upgrades	1.81	2.74	4.29	4.96	4%	$11.87
Strategic Energy Management (SEM)	0.06	0.26	2.50	4.59	4%	$189.09
Large Office Linear Fixture from Linear Fluorescent Tube to LED Panel Control	0.23	0.58	1.81	3.31	3%	$23.70
New Refrigerated Case	0.71	1.41	2.84	3.22	3%	$25.94
Fans (Retrofit) Commercial System Upgrade	0.51	1.01	2.03	2.31	2%	$44.47
Thin Triple Windows Large Office	0.03	0.12	1.13	2.03	2%	$116.81
Server – Virtualization	0.44	0.87	1.75	1.99	2%	$15.36
Medium Office Linear Fixture from Linear Fluorescent Tube to LED Panel Control	0.13	0.32	0.99	1.81	2%	$23.51
Circulation Pumps Space Heating Commercial Electronically Commutated Motor (ECM) + Advanced Speed Controls	0.68	1.02	1.58	1.80	2%	$93.84
Server - ENERGY STAR	0.42	0.79	1.69	1.78	2%	$1.39
Packaged AC (Air-Cooled) >= 240,000 Btu/h and < 760,000 Btu/h - Above Code	0.05	0.18	0.69	1.74	2%	$12.56
Packaged AC (Air-Cooled) >= 135,000 Btu/h and < 240,000 Btu/h - Above Code	0.05	0.18	0.68	1.73	1%	$214.33
Circulation Pumps Water Heating Commercial ECM + Advanced Run Hour Controls	0.65	0.97	1.50	1.71	1%	$74.74
Large Commercial Refrigerators	0.16	0.39	1.38	1.65	1%	$355.41

Note: The average levelized TRC value represents a weighted average across all iterations, including segment and end-use. As a result, permutations of a measure may have a low levelized cost while other permutations may have high levelized cost.

Approximately 73 percent of 20-year commercial achievable technical potential falls within the first ten years of the study horizon. Much of the commercial retrofit potential for existing buildings becomes exhausted within the first ten years.

Figure 4.14 shows that the commercial levelized cost distributions for the achievable technical potential are similar to the residential sector. However, 14 percent of the realized achievable technical savings has costs greater than $160/MWh. This is primarily because HVAC retro-commissioning and weatherization measures such as thin triple window replacements are costly but offer large savings opportunities.

Figure 4.15. Commercial Supply Curve — Cumulative Achievable Technical Potential in 2041 by Levelized Cost



Note: The cooking end use has 0.12 aMW at ≤$10/MWh, 0.21 aMW at ≤$20/MWh, 0.38 aMW at ≤$30/MWh, 0.40 aMW at ≤$90/MWh, 0.43 aMW at ≤$100/MWh, 0.53 aMW at ≤$150/MWh.

City Light's IRP selected an achievable economic potential for the commercial sector of 77 aMW. Figure 4.15 shows the cumulative, 20-year achievable economic potential for the commercial sector by end-use group. Lighting achievable economic potential makes up 46 percent of the commercial achievable economic potential, followed by refrigeration (15 percent) and ventilation (12 percent).

Figure 4.16. Commercial Cumulative Achievable Economic Potential in 2041 by End-Use Group

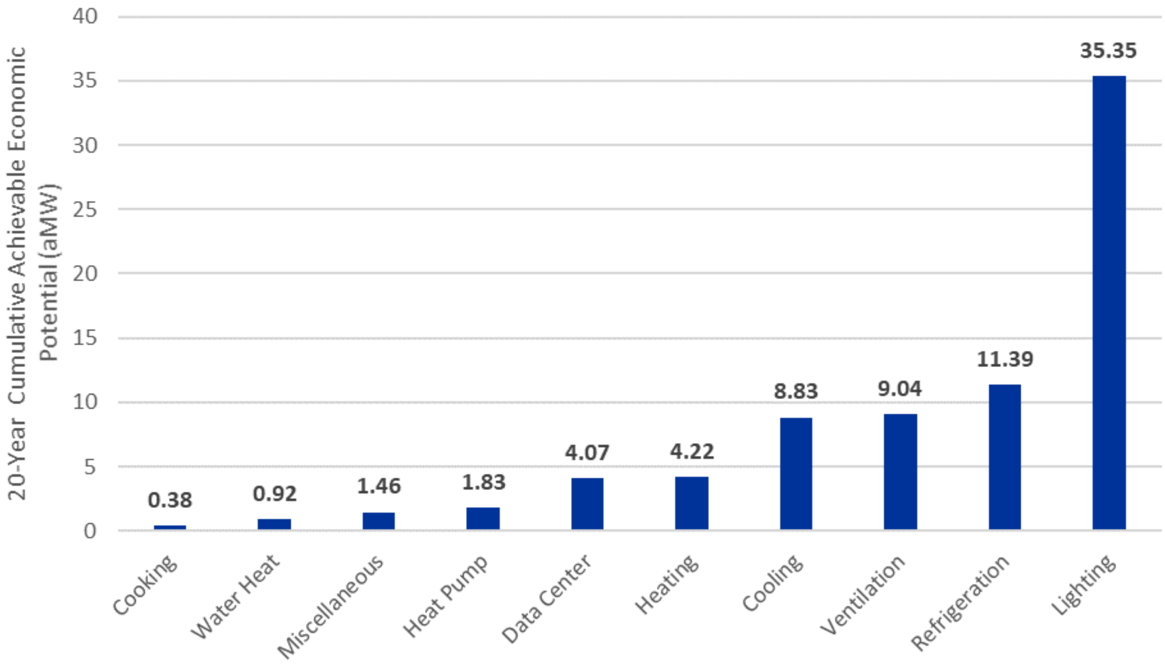


Table 4.12 lists the 15 highest saving IRP selected commercial measures. The commercial achievable economic measure permutations selected all have a levelized cost of less than or equal to $70/MWh, and their associated cumulative achievable economic potential makes up 26 percent of the commercial, cumulative 2041 achievable technical potential.

Table 4.12. Top-Saving Commercial Measures Selected by IRP

Measure Name	Cumulative Achievable Economic Potential (aMW) – Less than or Equal to $70/MWh				Percent of Cumulative 20-Year Achievable Technical Potential
	2-Year	4-Year	10-Year	20-Year	
Building Automation System Upgrades	1.65	2.49	3.91	4.53	4%
Large Office Linear Fixture from Linear Fluorescent Tube to LED Panel Control	0.23	0.58	1.81	3.31	3%
New Refrigerated Case	0.71	1.41	2.84	3.22	3%
HVAC Retro-commissioning	1.02	1.54	2.38	2.70	2%
Fans (Retrofit) Commercial System Upgrade	0.51	1.01	2.03	2.31	2%
Server – Virtualization	0.44	0.87	1.75	1.99	2%
Medium Office Linear Fixture from Linear Fluorescent Tube to LED Panel Control	0.13	0.32	0.99	1.81	2%
Server - ENERGY STAR	0.42	0.79	1.69	1.78	2%
Packaged AC (Air-Cooled) >= 240,000 Btu/h and < 760,000 Btu/h - Above Code	0.05	0.18	0.69	1.74	2%
Strategic Energy Management	0.02	0.10	0.93	1.66	1%
Small Office Linear Fixture from Linear Fluorescent Tube to LED Panel Control	0.07	0.18	0.57	1.22	1%
Retrofit Add Refrigerated Case Door	0.23	0.47	0.94	1.07	1%
Exterior Lighting - Parking Lot to LED from High Pressure Sodium 250W	0.13	0.28	0.76	1.06	1%
Economizer - Outside Air	0.39	0.59	0.91	1.03	1%
Other Building Type Linear Fixture from Linear Fluorescent Tube to LED Panel Control	0.08	0.21	0.64	1.03	1%

4.4. Industrial

Cadmus estimated conservation potential for the industrial sector using the Council's draft 2021 Power Plan analysis tool. The conservation potential addressed eight industrial segments in City Light's service territory, based on allocations developed from City Light's nonresidential database. The assessment identified approximately 10 aMW of achievable technical potential by 2041.

Table 4.13 shows cumulative industrial potential by segment in 2041.

Table 4.13. Cumulative Industrial Potential by Segment (2022-2041)

Segment	Baseline Sales	Cumulative 2041 – aMW			
		Technical Potential (TP)	TP % of Baseline	Achievable Potential (AP)	AP % of TP
Foundries	36	5	15%	5	86%
Frozen Food	2	0.3	17%	0.2	85%
Miscellaneous. Manufacturing	29	1	5%	1	86%
Other Food	0	<0.1	17%	<0.1	86%
Transportation Equipment	20	4	21%	4	85%
Wastewater	2	0.2	10%	0.1	85%
Water	3	1	27%	1	85%
Total	**91**	**12**	**13%**	**10**	**86%**

Note: Miscellaneous Manufacturing represents all undefined industrial segments with City Light's customer database. Other Food represents all non-frozen food manufacturing that may include specialty food manufacturing, fruit and vegetable preserving, bakeries and tortilla manufacturing, animal food manufacturing, etc.

Figure 4.15 shows industrial cumulative achievable technical potential by segment and year. The distribution of industrial achievable technical potential by segment follows a similar distribution to the baseline sales. Foundries account for 5 aMW, the largest percentage of 20-year industrial achievable technical potential, followed by transportation equipment, which makes up 4 aMW of total achievable technical potential.

Figure 4.17. Cumulative Industrial Achievable Technical Potential by Segment (2022-2041)

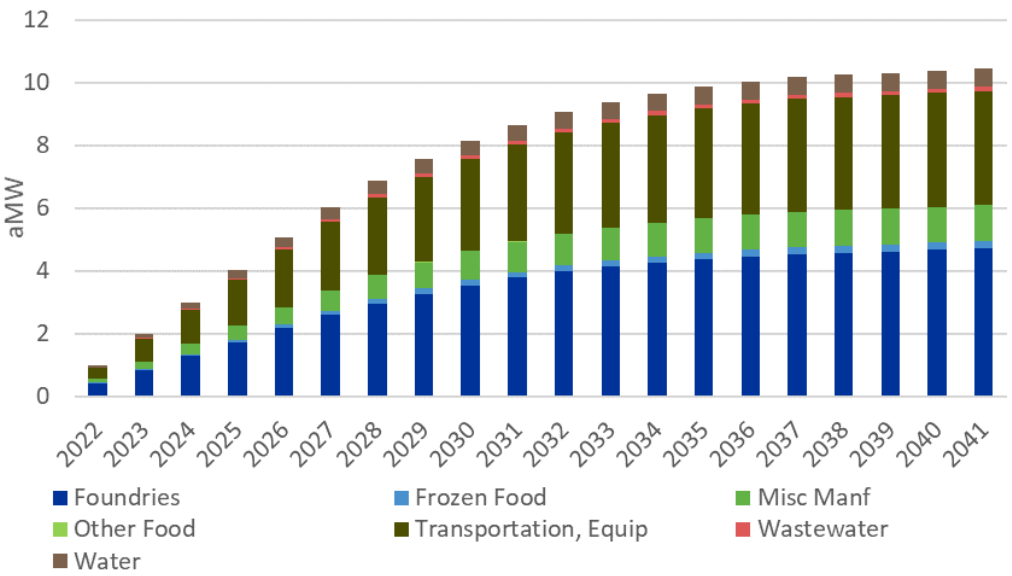


Table 4.14 shows 20-year potential by industrial end use. The four highest end-uses of industrial achievable technical potential are for lighting (32 percent), fans (15 percent), pumps (15 percent), and process air compressor (12 percent).

Table 4.14. Cumulative Industrial Potential by End-Use (2022-2041)

End Use	Baseline Sales	Cumulative 2041 – aMW			
		Technical Potential (TP)	TP % of Baseline	Achievable Potential (AP)	AP % of TP
Fans	7	2	27%	2	85%
HVAC	12	1	10%	1	85%
Lighting	9	4	42%	3	85%
Motors Other	13	1	5%	1	85%
Other	9	1	10%	1	85%
Process Air Compressor	6	1	21%	1	92%
Process Electro Chemical	6	0.4	6%	0.3	85%
Process Heat	14	0	0%	0	0%
Process Other	0.5	0	0%	0	0%
Process Refrigeration	3	0.1	5%	0.1	85%
Pumps	12	2	16%	2	85%
Total	**91**	**12**	**13%**	**10**	**86%**

Figure 4.16 and Figure 4.17 show cumulative and incremental, achievable technical potential over the 20-year study horizon, respectively.

Figure 4.18. Industrial Cumulative Achievable Technical Potential (2022-2041)

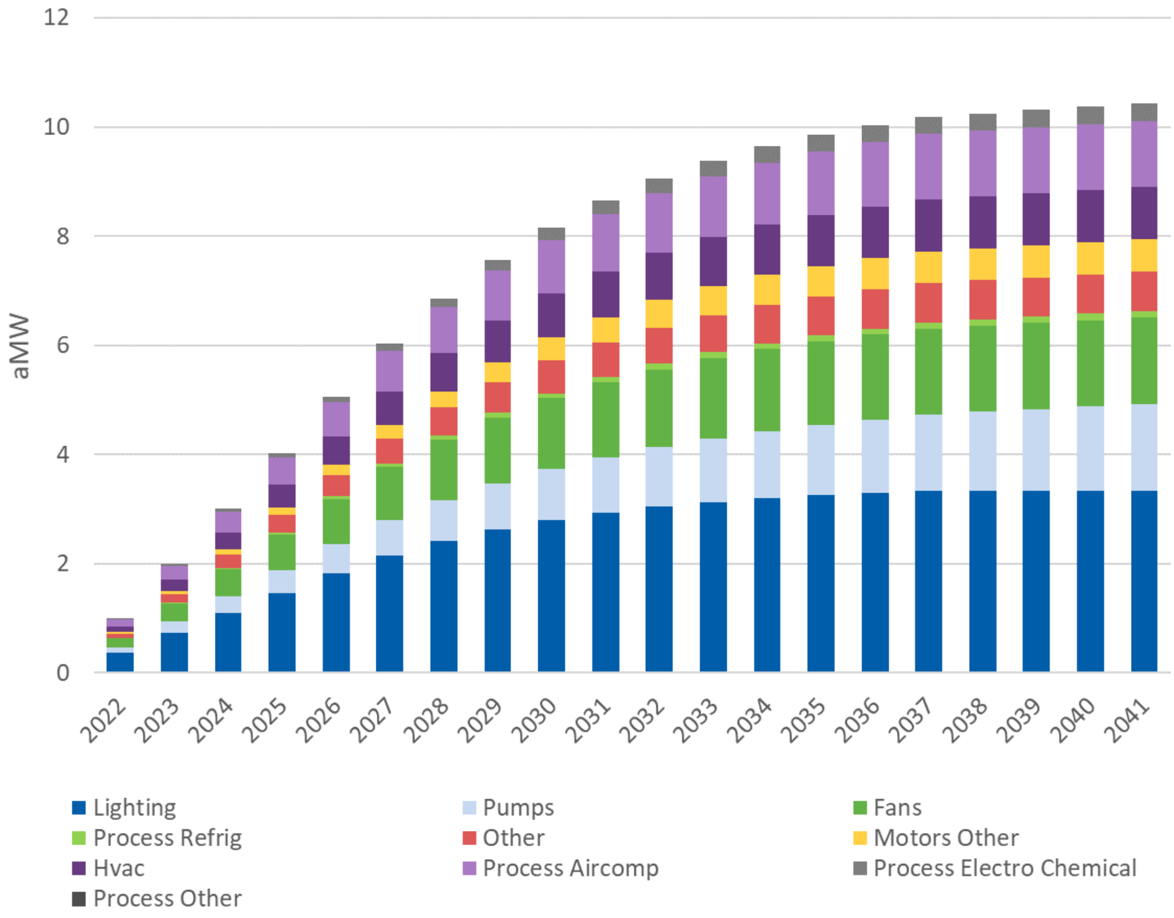


Figure 4.19. Industrial Incremental Achievable Technical Potential (2022-2041)

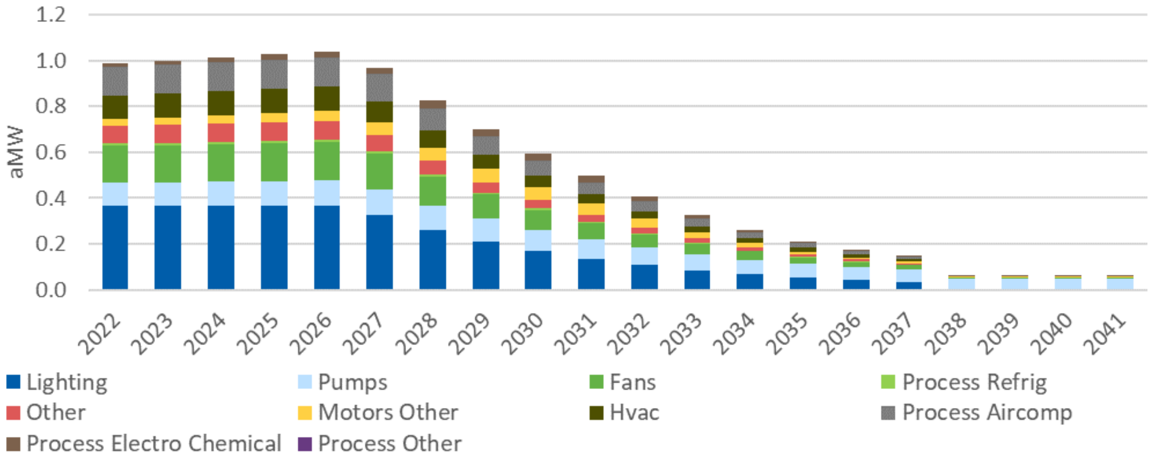


Table 4.15 shows the top-saving industrial measures and their weighted average levelized costs; collectively, these represent 79 percent of industrial 20-year cumulative, achievable technical potential.

Table 4.15. Top-Saving Industrial Measures

Measure Name	Cumulative Achievable Technical Potential – aMW				Percent of Total (20-Year)	Weighted Average Levelized TRC ($/MWh)
	2-Year	4-Year	10-Year	20-Year		
Lighting Controls	0.19	0.37	0.74	0.84	8%	$39.81
HVAC	0.18	0.36	0.73	0.83	8%	$15.35
Pump Optimization	0.07	0.14	0.35	0.70	7%	$2.14
Energy Management (SEM)	0.07	0.16	0.58	0.69	7%	$21.68
Fan Equipment Upgrade	0.15	0.30	0.59	0.67	6%	$0.00
High Bay Lighting 2 Shift	0.14	0.27	0.55	0.62	6%	$34.01
Wastewater	0.13	0.25	0.51	0.58	6%	$55.85
Air Compressor Equipment	0.13	0.25	0.51	0.58	6%	$62.71
High Bay Lighting 1 Shift	0.12	0.24	0.48	0.55	5%	$39.43
Efficient Lighting 2 Shift	0.11	0.21	0.43	0.49	5%	$10.34
Efficient Lighting 1 Shift	0.09	0.18	0.36	0.41	4%	$12.61
Fan Optimization	0.08	0.17	0.34	0.38	4%	$36.90
Energy Management 2 (SEM)	0.03	0.07	0.17	0.33	3%	$44.67
Air Compressor Variable Speed	0.06	0.13	0.25	0.29	3%	$56.67
Advanced Motors - Material Processing	0.03	0.06	0.23	0.28	3%	$9.02

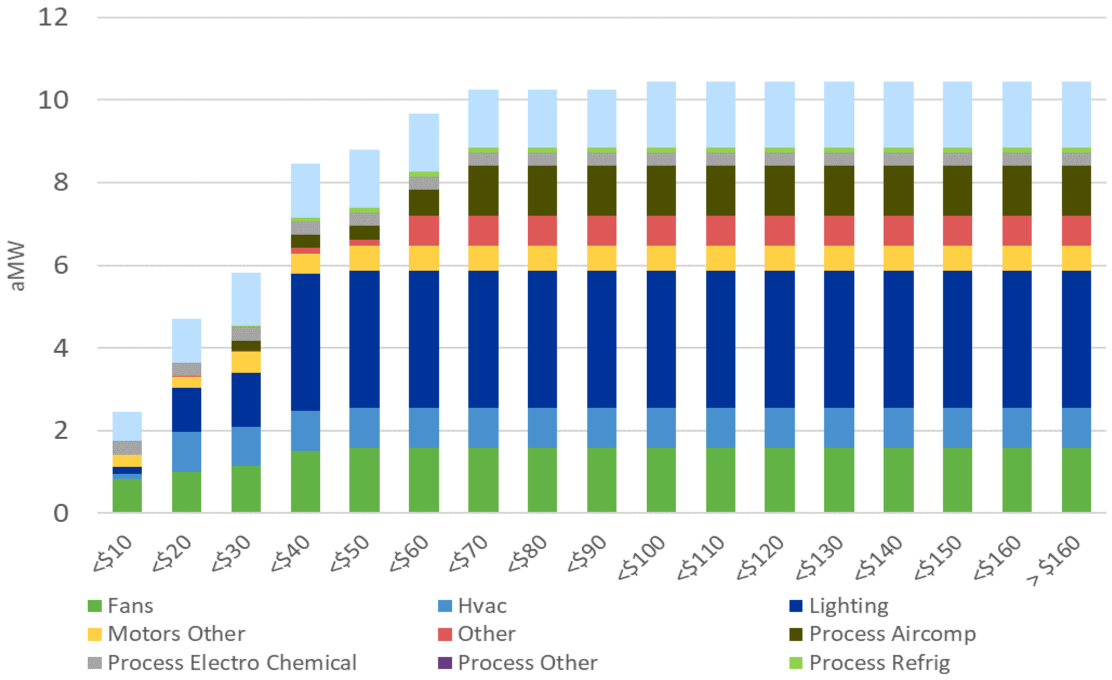
Note: The average levelized TRC value represents a weighted average across all iterations, including segment and end-use. As a result, permutations of a measure may have a low levelized cost while other permutations may have high levelized cost.

Note: The Council separated the Energy Management (SEM) measures into two tiers level 1 and level 2. Energy Management (SEM) 2 represents 50 percent more savings but assumes double the cost.

Note: The Fan Equipment Upgrade net expenses (costs and benefits) were less than zero. The resulting levelized TRC was shown as $0.00 ($/MWh) and can be considered cost effective, Consistent with the Council's approach to the industrial sector, Cadmus modeled all industrial measures as retrofits and did not distinguish between new and existing construction. After applying ramp rates, approximately 83 percent of 20-year achievable technical potential is realized within the first ten years.

Industrial measures are generally low cost, so the industrial achievable technical potential by levelized cost distribution does not suffer from the same peak at greater than $160/MWh as the residential and commercial sectors do. In fact, all 10 aMW of industrial potential can be achieved at a levelized cost of less than or equal to $100/MWh. Figure 4.18 shows cumulative achievable economic potential in 2041 for different levelized cost thresholds.

Figure 4.20. Industrial Supply Curve — Cumulative Achievable Technical Potential in 2041 by Levelized Cost



City Light’s IRP selected all industrial measures for inclusion in the achievable economic potential portfolio. Therefore, the 20-year, cumulative achievable economic potential for the industrial sector is 10 aMW at a levelized cost of less than or equal to $160/MWh. For this sector, the achievable economic potential is equivalent to the achievable technical potential, because all of the achievable technical potential is considered economically feasible at the levelized cost threshold. Therefore, the achievable economic potential by end-use can be found in Table 4.14 and the 15 highest savings measures is equal to the achievable technical potential in Table 4.15, above.

5. Comparison to 2020 CPA

5.1. Overview

Overall, the 2022 CPA identified lower final year cumulative technical potential and achievable technical potential than the 2020 CPA. This section compares results from the two assessments and explains the reasons for the change.

The 2022 study focused on final year cumulative estimates of technical potential and incremental estimates of achievable technical potential. Cadmus defines the final year cumulative technical potential as the total aMW of savings that are considered technically feasible to achieve over the study horizon. For the 2022 CPA, that horizon is 2022-2041, and for the 2020 CPA, that horizon is 2020-2040.

5.2. Technical Potential

The 2022 CPA identified 233 aMW of technical potential, compared to 282 aMW in the 2020 CPA. The 17 percent decrease in cumulative, final year technical potential is heavily influenced by the transition from the Seventh Power Plan to the draft 2021 Power Plan, which is the primary resource for residential and commercial measures. Table 5.1 compares cumulative technical potential, by sector, from the 2020 and 2022 CPAs.

Table 5.1. Technical Cumulative Potential Comparison

Sector	2022 CPA			2020 CPA			Percent Change in Technical Potential
	Baseline Sales – 20-Year (aMW)	Technical Potential – 20-Year (aMW)	Technical Potential as % of Baseline Sales	Baseline Sales – 21-Year (aMW)	Technical Potential – 21-Year (aMW)	Technical Potential as % of Baseline Sales	
Residential	461	90	20%	440	100	23%	-10%
Commercial	667	131	20%	693	173	25%	-24%
Industrial	91	12	13%	88	9	10%	43%
Total	**1,219**	**233**	**19%**	**1,221**	**282**	**23%**	**-17%**

The following sections detail the changes between 2022 CPA and the 2020 CPA .

5.2.1. Residential Sector Changes

The residential sector potential decreased 100 aMW of technical potential in the final year from the 2020 CPA to 90 aMW in the 2022 CPA. This is a 10 percent decrease that can be attributed to two major facts: first, the assumption that lighting, heating, and cooling market equipment is more efficient than in 2020 study; and second, the update in unit energy consumptions (UEC) and savings that align with the draft 2021 Power Plan.

Cadmus assumed a more efficient lighting baseline for standard-income residential customers compared to the 2020 CPA lighting baseline.[20] By increasing the efficiency of the lighting baseline, less lighting savings are achieved, because the incremental difference in consumption between the baseline and measure has decreased relative to the last CPA.

For example, more homes have LEDs in the 2022 CPA, resulting in less available lighting potential to install LEDs. In the 2022 CPA, all standard-income residential specialty and screw-base lighting measures are assumed to have an LED baseline. Thus, the market average baseline is more efficient than if the study had assumed an incandescent or halogen baseline (as was done in the 2020 CPA).

In addition to the lighting updates, Cadmus assumed an increase in efficient heating and cooling equipment over time based on City Light's assumptions about market adoption of efficient equipment. For example, Cadmus increased new construction, single-family heat pump saturations from 15 percent in the base year to 30 percent of homes in the final year to align with City Light's load forecasting assumptions (such as electrification conversion assumptions of non-electric heating equipment to electric heating equipment). Smaller impacts also contribute to the differences between CPAs. One smaller impact, but notable difference, relates to the increased adoption of electric vehicles in the 2022 CPA.

Table 5.2 provides a comparison of baseline sales and technical potential and the reasoning for the change.

Table 5.2. Residential Cumulative Technical Potential Comparison

Component	2022 CPA 20-Year (aMW)	2020 CPA 21-Year (aMW)	Percent Change	Reason for Change
Baseline Sales (aMW)	461	440	5%	Updated sales forecast from City Light with adjustments from HVAC equipment adoption
Technical Potential (aMW)	90	100	-13%	Transition to LED lighting baseline for standard-income customers; more efficient baseline, UEC updates in draft 2021 Power Plan
Technical Potential as % of Baseline	20%	23%	N/A	

Figure 5.1 compares the residential technical potential at the end-use group level. The blue bars indicate all end-use groups that saw a decrease in technical potential from the 2020 study to the 2022 study. As described above, the most significant decrease, of 8.4 aMW, comes from the transition to LEDs as the baseline throughout the study for standard-income residential customers. Other notable dips in potential are for heating and water heating due to differences in end-use group consumptions and savings estimates in the draft 2021 Power Plan compared to the Seventh Power Plan. Finally, the potential for appliances increases as the result of higher savings estimates in the draft 2021 Power Plan compared to the Seventh Power Plan for measures such as refrigerators, freezers, and dryers.

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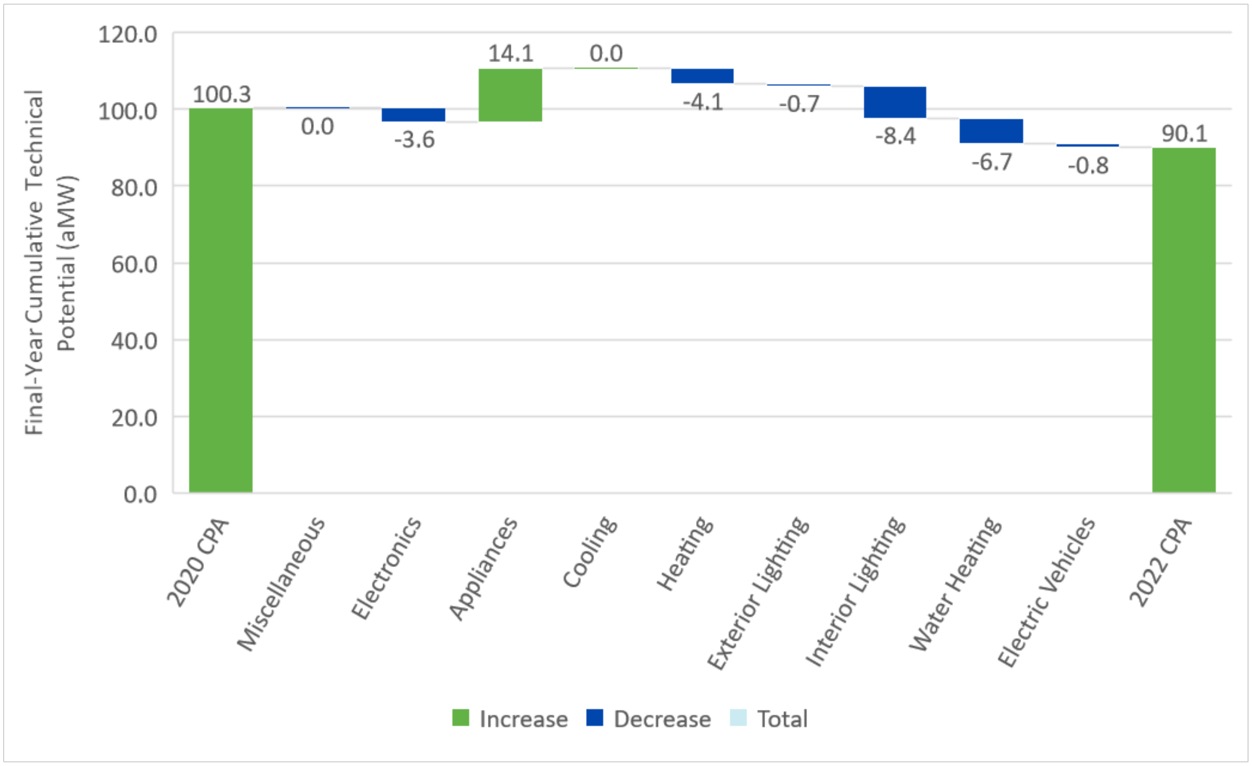
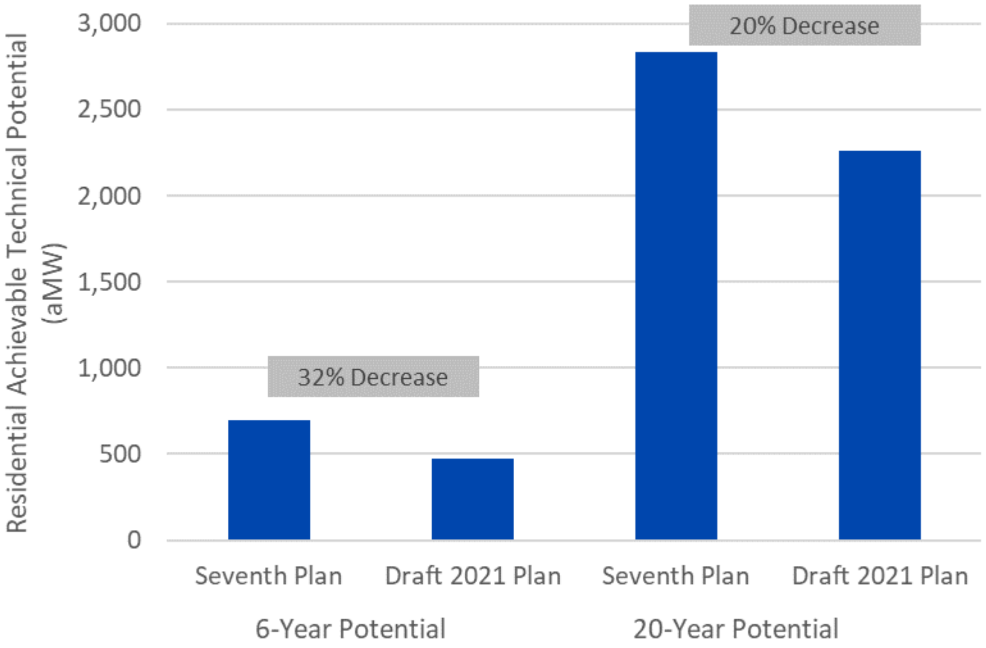
[20] Cadmus assumed income-qualified customers have remaining lighting potential that can be obtained through direct replacement of halogen baseline equipment.

Figure 5.1. Change in Cumulative Residential Technical Potential by End-Use Group



These residential changes from the prior 2020 CPA correlate to the changes from Seventh Power Plan to draft 2021 Power Plan. Though the draft 2021 Power Plan added 11 new measures, the overall achievable technical 20-year potential deceased by 20 percent, as shown in Figure 5.2. The short-term achievable technical potential is more pronounced and decreases by 32 percent compared to the Seventh Power Plan, in part due to differences in ramp rates. The largest driver is the decrease in residential lighting potential compared to the Seventh Power Plan, with a decrease of more than 80 percent of the regional lighting achievable technical potential.

Figure 5.2. Draft 2021 Power Plan and Seventh Power Plan Cumulative Residential Achievable Technical Potential (aMW)



Note: Draft 2021 Power Plan data last updated on 6/16/2020 and may not represent final planning values.

5.2.2. Commercial Sector Changes

The 2022 CPA identified lower final-year cumulative technical potential than the 2020 CPA. One notable change relates to a decrease in the baseline sales as a result from latest CBSA data (2019 dataset version IV) that informed building energy end-use group intensities compared to prior CBSA data (2014 dataset version III). This new CBSA data showed a much higher saturation of efficient lighting compared to the estimates within the 2020 CPA. The 2022 study incorporated the latest CBSA data that included new lighting saturation data. CBSA IV data showed a large shift towards LED lamps and fixtures compared to the prior CBSA III. Table 5.3 compares technical potential in the commercial sector for the two CPAs.

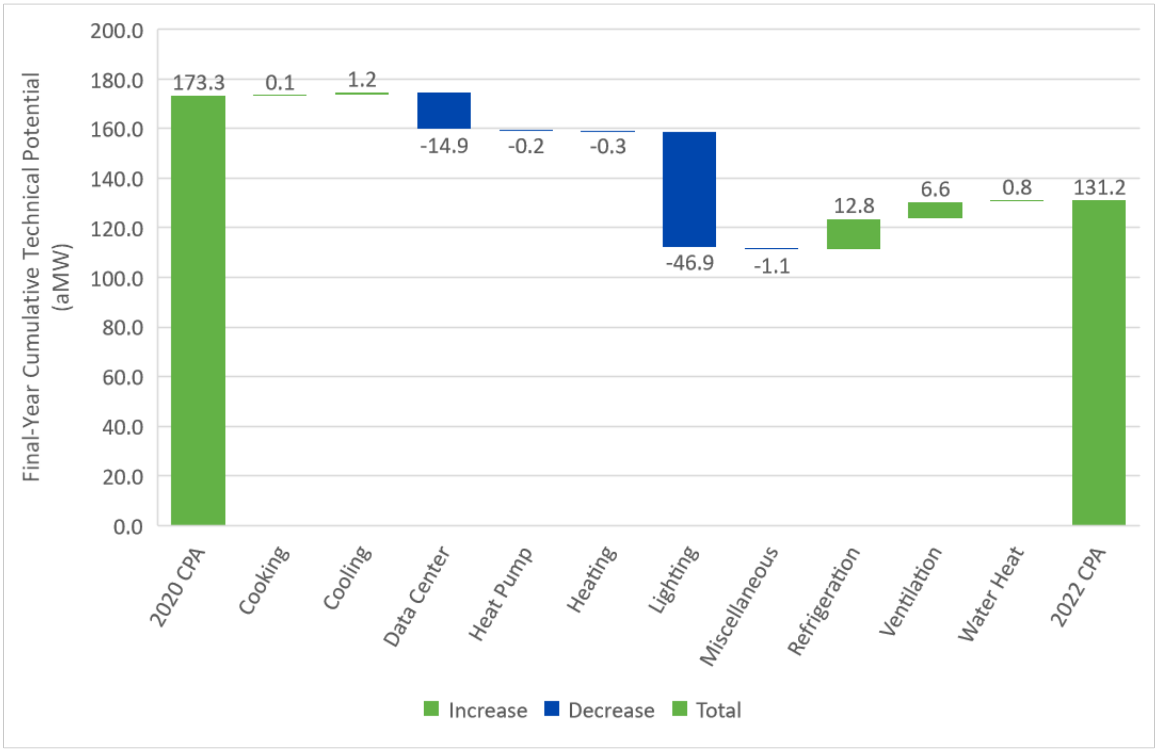
Table 5.3. Commercial Cumulative Technical Potential Comparison

Component	2022 CPA	2020 CPA	Percent Change	Reason for Change
Baseline Sales	667	693	-4%	Updated sales forecast with adjustments from CBSA IV
Technical Potential	131	173	-24%	More efficient lighting baseline; transition to draft 2021 Power Plan
Technical Potential as % of Baseline	20%	25%	N/A	

Figure 5.3 illustrates the change in commercial technical potential between the 2020 and 2022 CPAs by end-use group. End-use groups exhibiting decreased technical potential include lighting, data center,

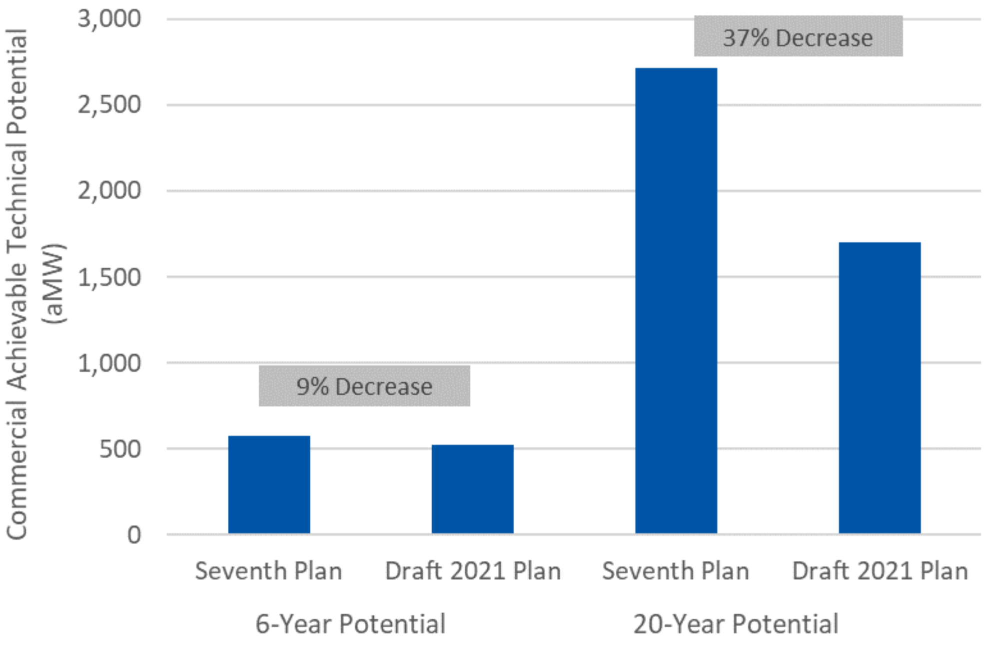
miscellaneous (laptops, showerhead, compressors, and washing machines), heating, and heat pump. The decrease in lighting potential alone makes up the difference between the 2020 and 2022 CPA technical potential.

Figure 5.3. Change in Commercial Cumulative Technical Potential by End-Use Group



Changes from Seventh Power Plan to draft 2021 Power Plan contribute to the notable differences in potential. Figure 5.4 shows the overall achievable technical 20-year potential deceased by 37 percent. Though the draft 2021 Power Plan added 12 new commercial measures, commercial lighting potential decreased by 50 percent compared to the Seventh Power Plan base. As noted above, this is due in part to the high saturation of existing LED lamp and fixture applications in the commercial sector CBSA data. In addition, the draft 2021 Power Plan looked at fewer data center measures. Working with City Light, Cadmus added several specific data center measures back into the CPA to help minimize the gap in potential as well as to align with City Light's historical program participation with data center upgrades.

Figure 5.4. Draft 2021 Power Plan and Seventh Power Plan Cumulative Commercial Achievable Technical Potential (aMW)



Note: Draft 2021 Power Plan data last updated on 6/16/2020 and may not represent final planning values.

5.2.3. Industrial Sector Changes

The industrial sector in the 2022 CPA included new measures based on the draft 2021 Power Plan, such as HVAC measures, forklift battery chargers, and new methodology for compressors, fans, pumps, and other motor-driven systems. City Light also requested the addition of measures such as industrial generator block heaters, retro-commissioning, and welder system upgrades. These additions and changes in methodology increased the potential in the industrial sector compared to the prior CPA.

5.3. Achievable Technical Potential and Ramping

As with assessments of technical potential, Cadmus identified lower, cumulative, achievable technical potential. Because 20-year cumulative achievable technical potential is a subset of technical potential, factors contributing to lower cumulative achievable technical potential are the same as those previously discussed for technical potential.

Figure 5.5 shows incremental achievable technical potential from the 2022 CPA, and Figure 5.6 shows incremental achievable technical potential from the 2020 CPA. Incremental achievable technical potential in the first two years of the 2022 CPA is about 34 percent lower than the first two years of the 2020 CPA.

Figure 5.5. Incremental Achievable Technical Potential—2022 CPA

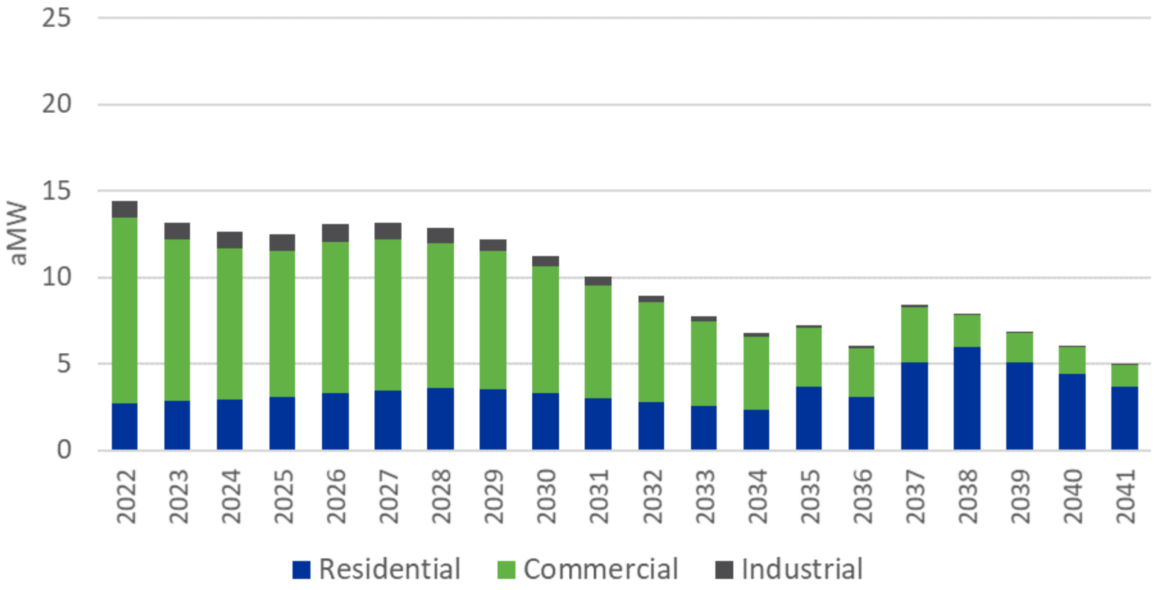


Figure 5.6. Incremental Achievable Technical Potential—2020 CPA

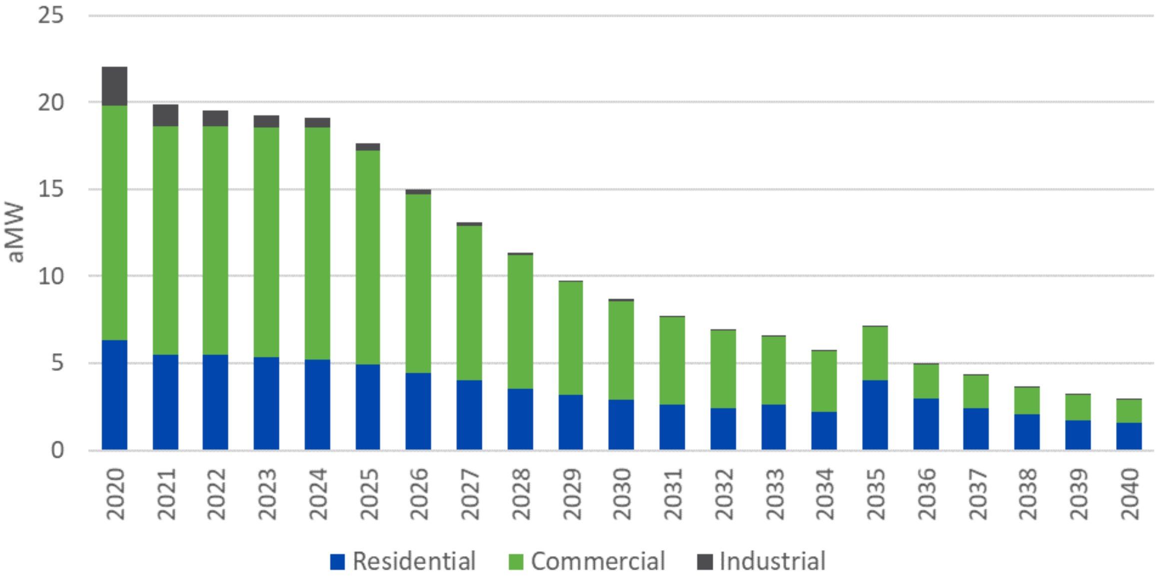


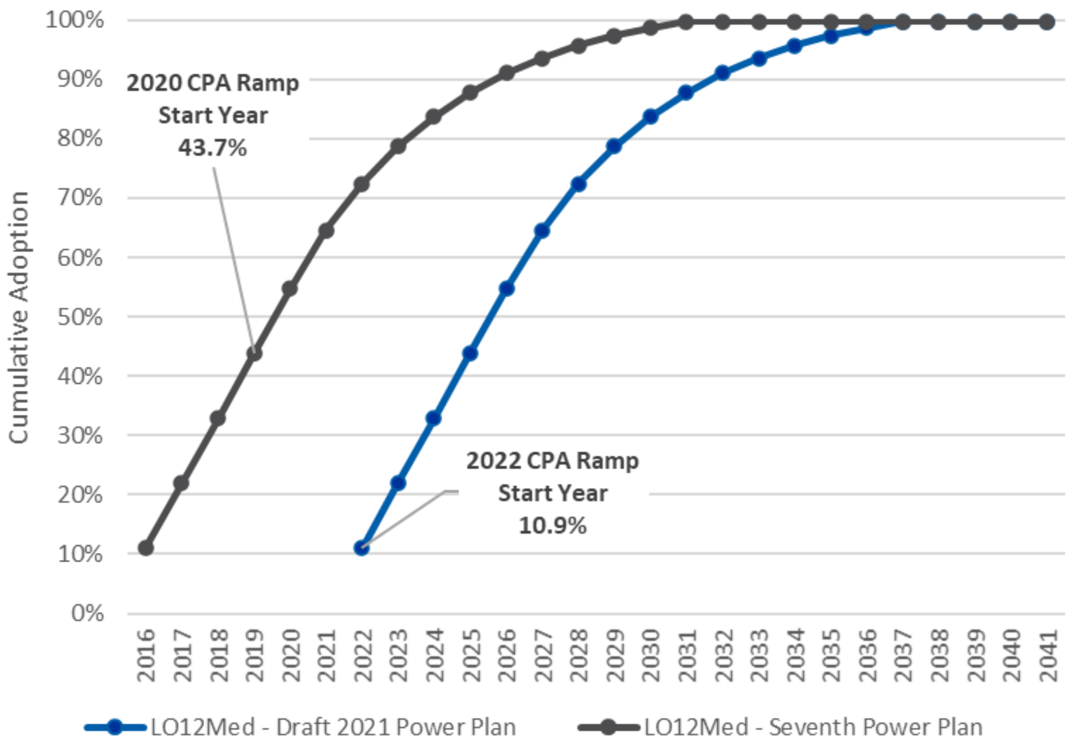
Figure 5.6 shows that the 2020 CPA determines that a higher proportion of total available potential will be realized in the study's early years than in the 2022 CPA. The two-year achievable potential in the 2020 CPA is equal to approximately 18 percent of the total 21-year achievable technical potential, whereas the two-year achievable potential in the 2022 CPA is equal to approximately 14 percent of the total 20-year achievable technical potential. This change is the result of two key factors—changes in ramp rate assumptions and the decrease in technical potential from the 2020 CPA to the 2022 CPA.

For the 2022 CPA, Cadmus used the draft 2021 Power Plan ramp rates rather than the Seventh Power Plan ramp rates (released in February 2016) used in the 2020 CPA. The change in the source of ramp rate data leads to a decrease in potential in the initial years of the study relative to the final year.

The Seventh Power Plan ramp rates ranged from 2016 to 2035. For the 2020 CPA, Cadmus took the ramp rate beginning in 2020 and extrapolated maximum saturation to extend from 2035 to the final year of the study (2040). For example, Figure 5.7 shows the ramp rate for multifamily ductless heat pumps used in the 2020 CPA and the 2022 CPA. The ramp rate is the LO12Med ramp rate, which indicates it is a lost opportunity ramp rate that reaches full saturation after 12 years and has a medium ramp-up speed. Using the Seventh Power Plan ramp rate, Cadmus started farther up on the curve, assuming an adoption rate of 44 percent in the first year and increasing until 100 percent adoption in 2031.

For the 2022 CPA, Cadmus used the ramp rates released from the draft 2021 Power Plan in 2020. The first year adoption is 11 percent and increases to 100 percent adoption in 2037. Therefore, though the adoption rate is the same in the final years of 2040 and 2041, the incremental adoption in the initial years of the study is drastically different. This leads to the differences in incremental potential in the initial years of the study between the 2020 and 2022 CPA.

Figure 5.7. Comparison of 2020 CPA and 2022 CPA Ramp Rates



5.4. IRP Achievable Economic Potential Comparison

The 2020 CPA achievable (economic) potential and the 2022 CPA IRP selected economic potential cannot be directly compared without acknowledging that the two studies use very different methodologies in determining what is consider "economic." The 2020 CPA followed an economic cost-effectiveness criteria, based on City Light's avoided supply costs for delivering electricity, whereas the 2022 CPA used the IRP optimization modeling to determine how much energy efficiency, as a resource, is cost-effective compared to other competing resources over the study horizon. Table 5.4 shows a comparison of the achievable (economic) potential between the two studies.

Table 5.4. Achievable Economic Cumulative Potential Comparison

Sector	2022 CPA			2020 CPA			Percent Change in Potential
	Baseline Sales – 20-Year (aMW)	Achievable Economic Potential – 20-Year (aMW)	Achievable Economic Potential as % of Baseline Sales	Baseline Sales – 21-Year (aMW)	Achievable Potential – 21-Year (aMW)	Achievable Potential as % of Baseline Sales	
Residential	461	18	4%	440	12	3%	53%
Commercial	667	77	12%	693	96	14%	-19%
Industrial	91	10	11%	88	4	5%	158%
Total	**1,219**	**105**	**9%**	**1,221**	**111**	**9%**	**-5%**

The 2022 CPA residential sector achievable economic potential increased by 53 percent, compared to the 2020 CPA. The 2022 CPA IRP selected appliance measures, such as refrigerators and freezers, whereas the 2020 CPA did not find these appliance measures cost-effective. In addition, the 2022 CPA IRP analysis selected more weatherization measures (impacting heating and cooling end-uses) compared to the 2020 CPA. These differences represent the majority of the change in achievable economic potential in the residential sector between the two studies.

The 2022 CPA commercial sector achievable economic potential decreased slightly, by 19 percent, compared to the 2020 CPA. Though there were increases in achievable economic potential in the refrigeration and ventilation end uses, the majority of change reflects the decrease in available lighting potential. The lighting end-use comparison between studies is described in the *Commercial Sector Changes* section above.

As described in the *Industrial Sector Changes* section, the industrial sector in the 2022 CPA included new measures that increased the achievable economic potential. In addition, 2022 CPA IRP portfolio optimization modeling selected all of the available industrial achievable technical potential. Slightly less than half of the technical potential in the 2020 CPA was determined to be cost-effective as achievable economic potential. These two factors represent the majority of the differences between the two studies.

6. Detailed Methodology

Cadmus' general methodology can be best described as a combined top-down/bottom-up approach. The top-down component began with the most current load forecast, adjusting for building codes, equipment efficiency standards, and market trends that are not accounted for through the forecast. Cadmus then disaggregated this load forecast into its constituent customer sectors, customer segments, and end-use components and projected out 20 years. The study calibrated the base year (2022) to City Light's sector-load forecasts produced in 2020.

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. The technical potential presents an alternative forecasts that reflects the technical impacts of specific energy efficiency measures. The achievable technical potential is then determined by applying ramp rates and achievability percentages to technical potential. The following section describes the CPA methodology in detail.

6.1. Developing Baseline Forecasts

City Light's sector-level sales and customer forecasts provided the basis for assessing energy efficiency potential. Prior to estimating potential, Cadmus 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 baseline forecasts was to determine the appropriate customer segments in each sector. Designations drew upon categories available in the study's key data sources—primarily City Light's nonresidential customer database (for the commercial and industrial sectors), and the U.S. Census Bureau's American Community Survey (for the residential sector)—then mapping the appropriate end-uses to relevant customer segments.

Upon determining appropriate customer segments and end-uses for each sector, Cadmus 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 used 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 (UPAi generally equals 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 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 $EUSE_{ij}$ across the end-uses and customer segments.

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 and drawing upon data available from the Energy Information Administration.[21]

6.1.1. Derivation of End-Use Consumption

End-use energy consumption estimates 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 used estimates on unit energy consumption (UEC), representing annual energy consumption associated with an end use and represented by a specific type of equipment (e.g., a central air conditioner or heat pump). The basis for the UEC values were derived from savings in the Council's draft 2021 Power Plan workbooks and savings analysis to calculate accurate consumption wherever possible for all efficiency levels of end-use technology. When Council workbooks did not exist for certain end-uses, Cadmus used results from NEEA's 2017 RBSA City Light oversample or conducted other research.

For the commercial sector, the study treated consumption estimates as end-use intensities that represented annual energy consumption per square foot served. To develop the end-use intensities, Cadmus developed electric energy intensities (total kWh per building square feet) based on NEEA's CBSA IV. Cadmus then benchmarked these electric energy intensities against various other data sources including CBSA III, historical forecasted and potential study data from City Light, and historical end-use intensities developed by the Council and NEEA.

To distribute the energy intensities Cadmus developed from the CBSA IV to end-use intensities for this potential study, Cadmus used assumptions specific to each building segment and each end-use:

- **Lighting.** The methodology for lighting end-use consisted of analyzing CBSA IV's lighting power density (lighting wattage per square foot) multiplied by the Council's interior lighting hours of use

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[21] U.S. Department of Energy, Energy Information Administration. 2010. *Manufacturing Energy Consumption Survey.*

by building type. Once lighting end-use intensity was calculated, Cadmus subtracted this portion of load from the total CBSA electric energy intensities (e.g., to estimate non-lighting intensities).

- **Non-lighting.** To distribute the remaining non-lighting CBSA electric energy intensities into end-uses, Cadmus used CBECS 2012 microdata to calculate percentages of end-use intensities across various end-use groups by building types as defined by the Council. Cadmus used the CBSA fuel shares and end-use saturations to adjust the distributions of CBECS end-use intensities to better represent City Light's commercial service territory. These finalized CBECS end-use intensities—adjusted with CBSA values where possible—were the basis for most of the end-use intensities in the commercial sector.
- **Computers and servers.** Cadmus developed energy intensities by building type for two end-uses—computers (desktops and laptops) and servers—using the CBECS number of units per square foot multiplied by unit consumption.
- **University.** The CBSA IV data lacked information on university building type, and the schools building type represented only K-12, as designated by the Council. Cadmus developed a more accurate electric energy intensity specific to university by calculating a ratio of the CBECS's university and school K-12 building types. Cadmus then used the CBSA school K-12 lighting power density and applied the Council's university lighting hours of use. Cadmus determined that the result was reasonable by benchmarking the university lighting end-use intensity developed for City Light against the ratio of CBECS University and School K-12 lighting loads.
- **Retail.** Low CBSA respondent counts and matching varying definitions of building type in Council and CBECS data caused concern, especially for the large and extra large retail building types, so Cadmus combined large and extra large retail building types for the CBSA electric energy intensities and lighting power density. Cadmus combined small and medium retail building types because it found counts and definitions were sufficient.

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

6.1.2. City Light Forecast Adjustments

Cadmus worked with the City Light load forecast team to adjust the baseline forecast to account for the impacts of COVID-19, increased market adoption of efficient, electric heating and cooling equipment, and to align this study's commercial and residential baseline forecasts with the City Light load forecasts.

Cadmus made the following adjustments to the heating and cooling residential forecasts using the 2018 Seattle City Code and City Light's electrification assumptions to account for changes in adoption patterns over time:

- Increased saturations of heat pumps in single-family and multifamily from the base year to 2041. City Light expects significant conversion to heat pumps for single-family homes traditionally heated by electric furnaces as well as the conversion of single-family homes traditionally heated by fuel oil.

- Decreased saturations for single-family and multifamily homes heated by electric furnaces and baseboard to account for increased heat pump conversion.
- Increase of UEC for all residential cooling measures to align more closely with City Light estimates.

The first two adjustments created a more efficient baseline, which means less potential for heating equipment than would have occurred if the baseline accounted only for changes in the federal standard. In this study, these adjustments are naturally occurring rather than having energy efficiency potential.

City Light's current forecast do not include the same level of climate change inducted impacts as does the Council. As described above, City Light projects different cooling loads instead of the Council's modelling of future weather. Accordingly, for measures where the Council adjusted unit savings based on future climate change impacts, Cadmus removed these future climate change impacts by using RTF workbooks assumptions instead, where feasible.

6.2. Measure Characterization

Because technical potential draws upon an alternative forecast, reflecting installations of all technically feasible measures, Cadmus chose the most robust set of appropriate ECMs. Cadmus measures by developing a comprehensive database of technical and market data for ECMs that applied to all end-uses in various market segments.

The database included the following measures:

- All measures in the Council's draft 2021 Power Plan conservation supply curve workbooks
- Active unit energy savings (UES) measures in the RTF
- Particular commercial technologies of interest to City Light, as identified and included for the study:
    - Airflow Management (Data Center)
    - Building Automation System Upgrades
    - Computer Room Air Conditioner
    - Cooling Towers
    - Economizer – Outside Air
    - Economizer – Water side
    - Freezer – Lab Grade
    - Heat Pump – Water Source
    - Heat Recovery Improvements
    - HVAC Retro-commissioning
    - LED Sign Lighting
    - Server – Virtualization
    - Water Heater Controls

Cadmus included only the Council and RTF measures applicable to sectors and market segments in City Light's service territory. For example, this study does not characterize measures for the agriculture sector or the residential manufactured home segment as these sectors are a small fraction of City Light's customer mix. Cadmus added measures if the RTF workbooks were not included in the Council's draft 2021 Power Plan or the RTF workbooks have been updated since the Council's draft 2021 Power Plan workbooks.

For the residential sector, these included the following:

- Freezer – Decommissioning
- New Construction Home
- Pool Pumps
- Refrigerator – Decommissioning
- Thermostat - Communicating Line Voltage
- Thermostat - Electronic Line Voltage
- Vehicle Engine Block Heater Control

In the commercial sector, additional RTF measures included the following:

- Demand Control Kitchen Ventilation
- Fan - VSD
- Pool Pumps
- Pump – VSD
- Walk-in - Evaporator Fan ECM Motor
- Weatherization – School

Cadmus classified the electric energy efficiency measures applicable to City Light's service territories into two categories:

- **High-efficiency equipment (lost opportunity) measures** directly affecting end-use equipment (e.g., high-efficiency domestic water heaters), which follow normal replacement patterns based on expected lifetimes.
- **Non-equipment (retrofit) measures** affecting 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, given that savings can be acquired at any point over the planning horizon.

Each measure type's relevant inputs include the following:

- **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 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:**
  - Percentage incomplete: the percentage of buildings where customers have not installed the measure, but where its installation is technically feasible. This equals 1.0 minus the measure's current saturation
  - 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 through the following:

- Northwest Energy Efficiency Alliance (NEEA) Commercial Building Stock Assessment (CBSA) IV, including Puget Sound Energy's oversample, where applicable[22]
- NEEA Residential Building Stock Assessment (RBSA) II with City Light's oversample
- The Northwest Power and Conservation Council's draft 2021 Power Plan conservation supply curve workbooks
- The Regional Technical Forum (RTF) unit energy savings (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, Cadmus developed the following hierarchy for costs and savings (and shown in Table 6.1):

1. The Council's draft 2021 Power Plan conservation supply curve workbooks, except in cases where a more recent version of RTF UES measure workbooks were submitted and not used in the Council's draft 2021 Power Plan
2. RTF UES measure workbooks
3. Secondary sources, such as American Council for an Energy-Efficient Economy work papers, Simple Energy and Enthalpy Model 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 percentage incomplete. This hierarchy differed slightly for residential and commercial measure lists.

RBSA Methodology

For residential estimates, Cadmus relied on City Light's oversample in NEEA's 2016 RBSA. If City Light's subset did not have a sufficient sample to achieve 90 percent confidence with a ±10 percent precision for a given estimate, estimates were derived from the sample of Puget Sound-area customers (e.g., City Light, Puget Sound Energy, Snohomish County Public Utility District, Tacoma Power) or for the broader Northwest, as found in the RBSA. If Cadmus could not calculate applicability factors from NEEA's RBSA, the study used applicability factors from the Council's draft 2021 Power Plan conservation supply curve workbooks. The resulting estimates reflected averages for the Northwest region and were not necessarily specific to City Light's service territory.

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[22] City Light did not have an oversample conducted as part of CBSA IV. To better represent the Seattle area (compared to regional values), Cadmus incorporated Puget Sound Energy's CBSA oversample data.

CBSA Methodology

For the commercial sector, Cadmus first used the subset of City Light's customers, including Puget Sound Energy's oversample, in NEEA's 2019 CBSA IV.

The original CBSA IV weights were constructed to represent the Council's regional building counts. To represent City Light's building counts, Cadmus reanalyzed the CBSA weights based on City Light's totals of building square footage for specific building type buckets. Cadmus included only the CBSA data and the Puget Sound Energy's oversample in the Council's defined climate heating zone 1. While reviewing whether to include urban sites only in these analyses, Cadmus found that, for the heating zone 1 subset, 92 percent of the buildings were urban and 95 percent of building square footage was urban. Due to the limited impact of rural for all sites in the heating zone 1 subset, Cadmus did not make any further adjustments in the overall analysis.

Once Cadmus finalized City Light's CBSA weights to match City Light's total building square footage by building type bucket, these weights were used for all CBSA analysis in this study. Where respondent counts were sufficient for specific CBSA analyses, Cadmus used building type names as defined by the Council to produce more granular results.

If NEEA's CBSA did not have sufficient data to estimate a particular value (for example, applicability factors) for a given measure, Cadmus relied on factors from the Council's draft 2021 Power Plan conservation supply curve workbooks.

Measure Data Sources

By data input, Table 6.1 lists the primary sources referenced in the study.

Table 6.1. Key Measure Data Sources

Data	Residential Source	Commercial Source	Industrial Source
Energy Savings	Draft 2021 Power Plan supply curve workbooks; RTF; Cadmus research	Draft 2021 Power Plan supply curve workbooks; RTF; Cadmus research	Draft 2021 Power Plan supply curve workbooks; RTF; Cadmus research
Equipment and Labor Costs	Draft 2021 Power Plan supply curve workbooks; RTF; Cadmus research	Draft 2021 Power Plan supply curve workbooks; RTF; Cadmus research	Draft 2021 Power Plan supply curve workbooks; RTF; Cadmus research
Measure Life	Draft 2021 Power Plan supply curve workbooks; RTF; Cadmus research	Draft 2021 Power Plan supply curve workbooks; RTF; Cadmus research	Draft 2021 Power Plan supply curve workbooks; RTF; Cadmus research
Technical Feasibility	NEEA RBSA; Cadmus research	NEEA CBSA; Cadmus research	Cadmus research; Industrial Council data
Percentage Incomplete	NEEA RBSA; City Lights program accomplishments; Cadmus research	NEEA CBSA; City Lights program accomplishments; Cadmus research	Cadmus research; Industrial Council data
Measure Interaction	Draft 2021 Power Plan supply curve workbooks; RTF; Cadmus research	Draft 2021 Power Plan supply curve workbooks; RTF; Cadmus research	Cadmus research

6.2.1. Incorporating Federal Standards, State and Local Codes and Policies

Cadmus' assessment accounted for changes in codes, standards, and policies over the planning horizon. These changes not only affected customers' energy-consumption patterns and behaviors, they also 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 reviewed all local codes, state codes, federal standards, and local and state policy initiatives that could impact this potential study. For the residential and commercial sectors, the potential study considered the local energy code (2018 Seattle Energy Code, 2018 Washington State Energy Code, and 2018 Revised Code of Washington) as well as current and pending federal standards. Cadmus also assessed if, how, and when Washington state and Seattle City legislation impact the potential study. This legislation included the Seattle's Energy Benchmarking Program (SMC 22.920), Clean Buildings' bill (E3SHB 1257), and the Clean Energy Transformation Act (194-40-330).

Cadmus reviewed the following codes, standards, and policy initiatives:

Federal standards. All technology standards for heating and cooling equipment, lighting, water heating, motors, and other appliances not covered in or superseded by state and local codes.[23]

2018 Seattle Energy Code. The code prohibits new commercial and multifamily buildings from using electric resistance or fossil fuels for space heating effective June 1, 2021, and electric resistance or fossil fuels for water heating effective January 1, 2022. All other code provisions take effect March 15, 2021.[24]

2018 Washington State Energy Code. The code provides requirements for residential and commercial new construction buildings, except in cases where the 2018 Seattle Energy Code supersedes Washington code. The effective date is February 1, 2021.[25]

Seattle's Energy Benchmarking Program (SMC 22.920). This program requires owners of commercial and multifamily buildings (20,000 square feet or larger) to track energy performance and annually report to the City of Seattle. Though in effect since 2016, full enforcement of the program began on January 1, 2021.[26]

2018 Revised Code of Washington (RCW 19.260.040). These codes set minimum efficiency standards to specific types of products including computers, monitors, showerheads, faucets, residential ventilation fans, general service lamps, air compressors, uninterruptible power supplies, water coolers, portable air conditioners, high color rendering index (CRI) fluorescent lamps, commercial dishwashers, steam cookers, hot food holding cabinets, and fryers. The effective dates vary by product with the 2018 RCW signed on July 28, 2019.[27]

Clean Buildings Bill (E3SHB 1257). The law requires the Washington State Department of Commerce to develop and implement an energy performance standard for the state's existing buildings, especially large

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[23] Office of Energy Efficiency & Renewable Energy. "Standards and Test Procedures." Accessed June 2021. https://www.energy.gov/eere/buildings/standards-and-test-procedures

[24] City of Seattle, Office of the City Clerk. February 1, 2021. "Council Bill No: CB 119993. An ordinance relating to Seattle's construction codes." http://seattle.legistar.com/LegislationDetail.aspx?ID=4763161&GUID=A4B94487-56DE-4EBD-9BBA-C332F6E0EE5D

[25] Washington State Building Code Council. Accessed June 2021. https://sbcc.wa.gov/

[26] City of Seattle, Office of Sustainability and Environment. "Energy Benchmarking." Accessed June 2021. https://www.seattle.gov/environment/climate-change/buildings-and-energy/energy-benchmarking#:~:text=Seattle's%20Energy%20Benchmarking%20Program%20(SMC,to%20the%20City%20of%20Seattle.&text=Compare%20your%20building's%20energy%20performance,started%20saving%20energy%20and%20money.

[27] Washington State Legislature. Revised Code of Washington. December 7, 2020. "RCW 19.260.050 Limit on sale or installation of products required to meet or exceed standards in RCW 19.260.040." https://app.leg.wa.gov/rcw/default.aspx?cite=19.260.050

commercial buildings (based on building square feet) and provide incentives to encourage efficiency improvements. Effective date is July 28, 2019, with the building compliance schedule set to begin on June 1, 2026. Early adopter incentive applications begin in July of 2021.[28]

Clean Energy Transformation Act (CETA) (194-40-330). This act applies to all electric utilities serving retail customers in Washington and sets specific milestones to reach the required 100 percent clean electricity supply. The first milestone is in 2022, when each utility must prepare and publish a clean energy implementation plan with its own targets for energy efficiency and renewable energy. [29]

6.2.1.1 Applying Federal Standards

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 6.1 provides a comprehensive list of equipment standards considered in the study. 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. However, Cadmus did not attempt to predict how energy standards might change in the future.

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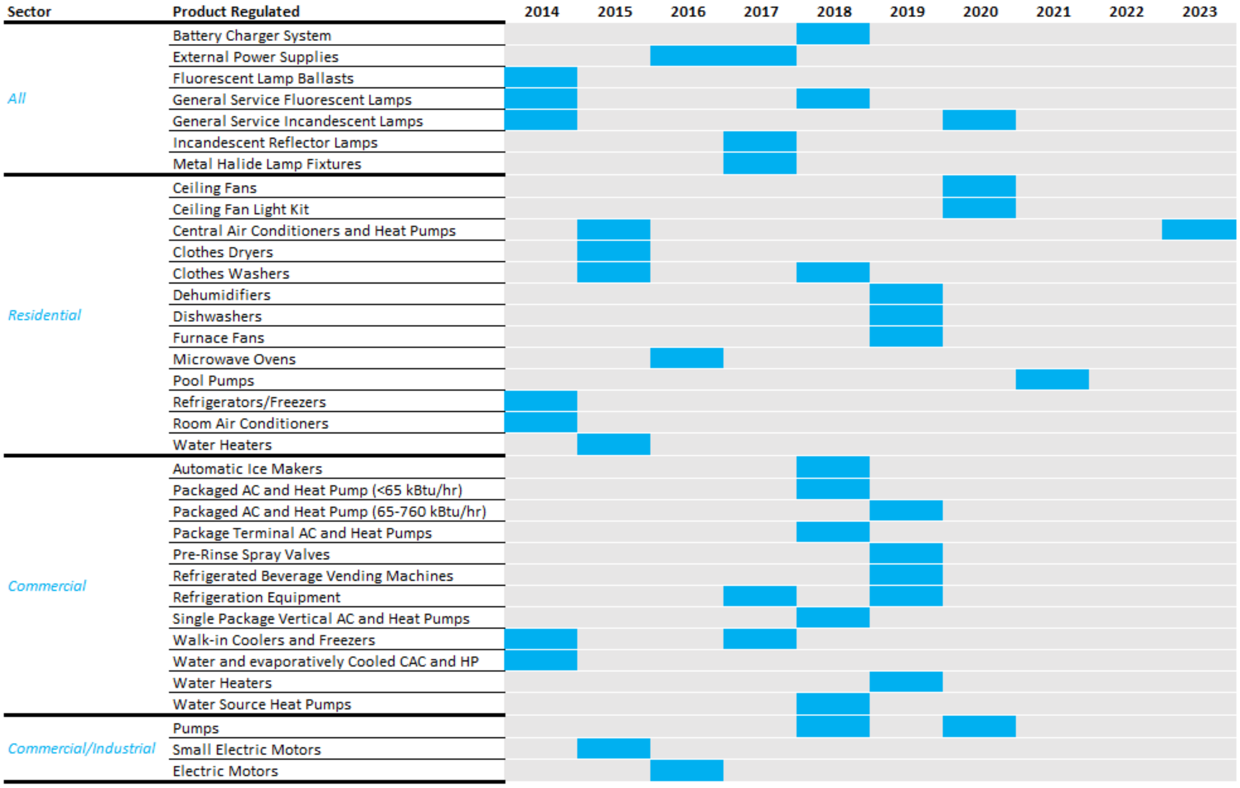
[28] Washington State Department of Commerce. “Clean Buildings.” Accessed June 2021. https://www.commerce.wa.gov/growing-the-economy/energy/buildings/

[29] Washington State Department of Commerce. “Clean Energy Transformation Act (CETA).” Accessed June 2021. https://www.commerce.wa.gov/growing-the-economy/energy/ceta/

Figure 6.1. Equipment Standards Considered



Sector	Product Regulated	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
All	Battery Charger System					■					
	External Power Supplies			■	■						
	Fluorescent Lamp Ballasts	■									
	General Service Fluorescent Lamps	■				■					
	General Service Incandescent Lamps	■						■			
	Incandescent Reflector Lamps				■						
	Metal Halide Lamp Fixtures				■						
Residential	Ceiling Fans							■			
	Ceiling Fan Light Kit							■			
	Central Air Conditioners and Heat Pumps		■								■
	Clothes Dryers		■								
	Clothes Washers		■			■					
	Dehumidifiers						■				
	Dishwashers						■				
	Furnace Fans						■				
	Microwave Ovens			■							
	Pool Pumps								■		
	Refrigerators/Freezers	■									
	Room Air Conditioners	■									
	Water Heaters		■								
Commercial	Automatic Ice Makers					■					
	Packaged AC and Heat Pump (<65 kBtu/hr)					■					
	Packaged AC and Heat Pump (65-760 kBtu/hr)						■				
	Package Terminal AC and Heat Pumps					■					
	Pre-Rinse Spray Valves						■				
	Refrigerated Beverage Vending Machines						■				
	Refrigeration Equipment				■		■				
	Single Package Vertical AC and Heat Pumps					■					
	Walk-in Coolers and Freezers	■			■						
	Water and evaporatively Cooled CAC and HP	■									
	Water Heaters						■				
	Water Source Heat Pumps					■					
Commercial/Industrial	Pumps					■		■			
	Small Electric Motors		■								
	Electric Motors			■							

6.2.1.2 Treatment of State and Local Codes and Initiatives

Cadmus identified each type of code (local or state) and/or initiative (local and state) that would impact the measures in the CPA. Cadmus sorted each impact into four main categories.

- **Measure applicability or savings adjustment.** Cadmus adjusted measure characterization inputs to account for local and state energy codes (2018 Washington State Energy Code and 2018 Revised Code of Washington). Where appropriate, Cadmus revised measure applicability, savings, and/or costs to reflect the impact of the code. For example, measures were removed entirely or over time (applicability set to zero) if code baselines were more efficient than the baseline data found in the RTF or Council workbooks (such as showerheads, fryers, steam cookers, and new construction homes).
- **Equipment saturation adjustment.** Cadmus adjusted equipment saturations by year to account for the 2018 Seattle Energy Code. In addition, Cadmus adjusted new construction commercial and large multifamily buildings space heating equipment saturations to align with this code (such as ductless heat pump and air source heat pumps). These adjustments were also accounted for in the baseline forecast, as described in the *City Light Forecast Adjustments* section.
- **Adoption ramp rate adjustment.** Cadmus accounted for initiatives and legislation that promote energy efficiency through customer incentives or penalties (Seattle's Energy Benchmarking Program and Clean Buildings bill). This also includes CETA in setting state-wide goals that require

City Light to set performance targets. These initiatives do not mandate an energy code or baseline for specific measures, rather they inherently speed up the rate of the adoption of energy efficiency through energy reduction requirements. City Light can also claim energy impacts through these initiatives; therefore, removing measures or adjusting baselines may not be appropriate within the context of the CPA. Cadmus reviewed and adjusted the prescribed ramp rates in the Council's draft 2021 Power Plan, where necessary, to address groups of measures that will be impacted. Changing the ramp rates (in most cases) will not impact the cumulative potential; rather it changes the timing of when the potential occurs. Cadmus adjusted ramp rates to measures currently in City Light's programs by increasing the allocated Council ramp rates up to the next tier (e.g., slow speed ramp moved to medium speed ramp).

- **No adjustment (already accounted for in the existing data).** Measures impacted by federal standards and in some cases by 2018 Revised Code of Washington, the Council's draft 2021 Power Plan workbooks, and Cadmus' equipment characterization are already accounted for as part of the initial development of the measure data.

6.2.1.3 Additional Codes and Standards Considerations

Cadmus identified two considerations that impact the characterization of this potential study. Starting with residential lighting, Cadmus reviewed the codes and standards as well as assessed the current situation related to LED lighting.

The Council's draft 2021 Power Plan and RTF residential lighting workbooks account for the Washington state code requirement (HB 1444) of the EISA backstop provision. Originally adopted from the federal standard, the EISA backstop provision requires higher-efficiency technologies (i.e., 45 lumens per watt or better). There are still pending legal challenges and, with the change in presidential administrations, uncertainty remains regarding if and how this standard will be reintroduced. For example, the Biden-Harris Administration, through the Department of Energy, has introduced a semiannual Unified Agenda of Federal Regulatory and Deregulatory Actions that includes possible amendments to EISA. Washington state did, however, adopt the EISA backstop provision. The savings in the draft 2021 Power Plan and RTF workbooks state a 45 lumens per watt baseline (for Washington only).

As a result, Cadmus developed a special case for residential lighting. After reviewing the Council and RTF workbooks, Cadmus concluded that the 45 lumens per watt baseline should be changed to an LED baseline for the CPA. Currently, there are no lighting technologies on the market that meet the 45 lumens per watt requirement other than CFLs or LEDs. Furthermore, major manufacturers have phased out production of CFLs. The market is rapidly adopting LEDs (according to the RBSA saturations and Council and RTF projections) and becoming the de facto baseline. Considering that LEDs are the only viable technology that meets Washington code, Cadmus used LEDs as the baseline for all standard-income applications but assessed potential for low-income homes. This adjustment to the lighting loads is effectively accounted for in City Light's baseline forecast and the CPA. The lighting impact by end-use can be found in Table 3.3 and Table 4.6, above.

Secondly, the 2018 Washington state energy code includes both residential and commercial new construction prescriptive and performance path requirement options. The CPA characterizes efficiency improvements on a measure basis that aligns with the prescriptive path. The performance path includes the HVAC total system performance ratio (HVAC TSPR) requirement. HVAC TSPR is defined as the ratio of the sum of a building's annual heating and cooling load compared to the sum of the annual carbon emissions from the energy consumption of the building's HVAC systems. The variability in the HVAC TSPR from building to building cannot be easily captured in the CPA. For this study, Cadmus followed the prescriptive requirements in the 2018 Washington state energy code.

6.2.2. Adapting Measures from the RTF and Draft 2021 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:** City Light relies on deemed savings estimates provided by the Bonneville Power Administration (BPA) that largely remain consistent with savings in RTF workbooks in demonstrating compliance with I-937 targets. Therefore, Cadmus sought to preserve these deemed savings in the potential study to avoid possible inconsistencies among 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 the RBSA and CBSA. Cadmus updated regional inputs with estimates, calculated either from City Light's oversample of CBSA and RBSA or from estimates affecting the broader Puget Sound area. This approach preserved consistency with Council methodologies while incorporating Seattle-specific data.

Cadmus' approach for adapting Council's and RTF's workbooks varied by sector, as described in the following sections.

6.2.2.1 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 Light's oversample of RBSA, adjusted for City Light's program accomplishments. If Cadmus could not develop a City Light-specific applicability factor from the RBSA, it 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 measure consumption and baseline consumption. For instance, for the heat pump water heater measure, Cadmus estimated the baseline consumption of an average market water heater and used the Council's deemed savings to calculate the consumption for a heat pump water heater. This approach preserved the deemed savings in Council workbooks.

- Savings for retrofit measures were calculated in percentage terms relative to the baseline end-use consumption but reflected the Council's and RTF's deemed values. For instance, if the Council's deemed savings were 1,000 kilowatt-hour (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 ten percent. Cadmus did not apply relative savings from the Council's workbooks to baseline end-use consumption because doing so would lead to per-unit estimates that differed from Council and RTF values.

Cadmus also accounted for interactive effects presented 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. Because installation of a heat pump water heater represents a single installation, Cadmus employed a stock accounting model, which combined interactive and primary end-use effects into one savings estimate. Though Cadmus recognizes this approach could lead to overstating or understating savings in an end use, in aggregate—across end-uses—savings matched the Council's deemed values.

Cadmus generally followed the same approach with the commercial sector; however, because of the mixture of lighting measures considered in the Council's draft 2021 Power Plan, Cadmus chose to model all commercial lighting measures as retrofits and none as equipment replacements. Savings and costs for these measures reflected this decision.

6.2.2.2 Industrial

Cadmus adapted measures from the Council's Industrial_Tool_2021P_v08 and IND_AllMeasures_2021P_V8 workbooks for inclusion in this study for the following key industrial measure inputs:

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

Cadmus mapped each Council industry type to industries found in City Light's service territory. These 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 6.2 shows the distribution of end-use consumption and the list of industries considered in this study.

Table 6.2. Distribution of End Use Consumption by Segment

Cadmus Segment	Process Air Compressor	Lighting	Fans	Pumps	Motors Other	Process Other	Process Heat	HVAC	Other	Process Electro-Chemical	Process Refrigeration
Foundries	7%	9%	10%	18%	15%	0%	21%	9%	5%	6%	0%
Frozen Food	4%	8%	4%	4%	12%	0%	4%	7%	1%	3%	53%
Misc. Manufacturing	7%	11%	7%	10%	16%	0%	11%	17%	9%	6%	6%
Other Food	12%	4%	2%	8%	11%	0%	0%	9%	8%	2%	44%
Transportation Equip	6%	20%	6%	8%	11%	0%	0%	28%	7%	14%	0%
Wastewater	0%	5%	30%	44%	15%	0%	0%	0%	6%	0%	0%
Water	12%	4%	0%	71%	0%	0%	0%	7%	6%	0%	0%
Stone and Glass	8%	5%	7%	13%	20%	2%	25%	6%	3%	2%	7%

To incorporate broader secondary data, Cadmus aggregated some Council end-uses into broader end-uses. Table 6.3 shows the mapping of Council end-uses to Cadmus end-uses.

Table 6.3. Council and Cadmus End-Uses

Council End-Use	Cadmus End-Use
Pumps	Pumps
Fans and Blowers	Fans
Compressed Air	Process Air Compressor
Material Handling	Process Electro Chemical
Material Processing	Motors Other
Low Temp Refer	Process Refrigeration
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

6.3. Estimating Conservation Potential

As discussed, Cadmus estimated two types of conservation potential, and City Light determined a third potential—achievable economic—through the IRP's optimization modeling, as shown in Figure 6.2.

Figure 6.2. Types of Conservation Potential

- **Technical potential** assumes that all technically feasible resource opportunities may be captured, regardless of their costs or other market barriers. It represents the total energy efficiency potential in City Light's service territory, after accounting for purely technical constraints.
- **Achievable technical potential** is the portion of technical potential assumed to be achievable during the study's forecast, regardless of the acquisition mechanism. For example, savings may be acquired through utility programs, improved codes and standards, and market transformation.
- **Achievable economic potential** is the portion of achievable technical portion determined to be cost-effective by the IRP's optimization modeling, in which either bundles or individual energy efficiency measures are selected based on cost and savings. The cumulative potential for these selected bundles constitutes achievable economic potential.

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

6.3.1. 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 installations of the highest-efficiency equipment that are commercially available. For example, this study examined CFL and LED general-service lighting in residential applications. In assessing technical potential, Cadmus 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 as installed in sockets ineligible for LEDs. This study treated competing non-equipment measures in the same way, assuming installation of the highest-saving measures where technically feasible.

In estimating technical potential, it is inappropriate to merely sum up savings from individual measure installations. Significant interactive effects can result from installations 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:

- **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 if the equipment had remained at a constant average efficiency. Similarly, savings realized by replacing equipment decrease upon installation of non-equipment measures.
- **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 shower head does not affect savings realized from installing a faucet aerator. Insulating hot water pipes, however, causes water heaters to operate more efficiently, thus reducing savings from either measure. This study accounted for such interactions by stacking interactive measures, iteratively reducing baseline consumption as measures were installed, thus lowering savings from subsequent measures.

Although, 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, annual incremental and cumulative potential could be estimated by sector, segment, construction vintage, end use, and measure.

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

6.3.2. Achievable Technical Potential

The achievable technical potential summarized in this report is a subset of the technical potential that accounts for market barriers. To subset the technical potential, Cadmus follows the approach of the Council and employs two factors:

- **Maximum achievability factors** represent the maximum proportion of technical potential that can be acquired over the study horizon.
- **Ramp rates** are annual percentages values representing the proportion of cumulative 20-year technical potential that can be acquired in a given year (discretionary measures) or the

proportion of technical annual potential that can be acquired in a given year (lost opportunity measures).

Achievable technical potential is the product of technical potential and both the maximum achievability factor and the ramp rate percentage. Cadmus assigned maximum achievability factors to measures based on the Council's draft 2021 Power Plan supply curves. Ramp rates are measure-specific and were based on the ramp rates developed for the Council's draft 2021 Power Plan supply curves but were accelerated based on the program accomplishments of City Light. The following sections provide additional detail about ramp rates.

6.3.2.1 About Measure Ramp Rates

The study applied measure ramp rates to lost opportunity and discretionary resources, although interpretation and application of these rates differed for each class, as described below. Measure ramp rates were based on the Council's draft 2021 Power Plan. As described above in *Treatment of State and Local Codes and Initiatives* section, Cadmus accounted for initiatives and legislation that promote energy efficiency through customer incentives or penalties (Seattle's Energy Benchmarking Program and Clean Buildings bill) by accelerating ramp rates for measures that are offered by City Light programs. These initiatives and legislation (including CETA) are viewed as mechanisms to speed up the rate of the adoption for energy efficiency.

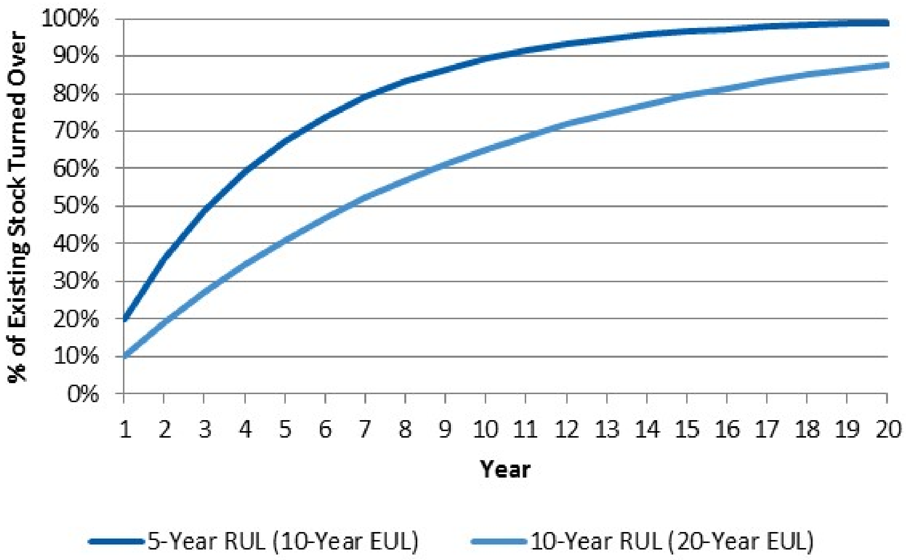
For measures not specified in the draft 2021 Power Plan, the study assigned a ramp rate considered appropriate for that technology— i.e., the same ramp rate as a similar measure in draft 2021 Power Plan or Seventh Power Plan.

Lost Opportunity Resources

Quantifying achievable technical 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 into 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. 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 equal—on average—one-half of the effective useful life (EUL). The fraction of equipment turning over each year would be a function of this RUL; thus, technical potential for lost opportunity measures would have an annual shape before applying ramp rates, as shown in Figure 6.3. The same concept applied to new construction, where resource acquisition opportunities became available only during home or building construction. In addition to showing an annual shape, Figure 6.3 demonstrates that amounts of equipment turning over during the study period were a function of the RUL: the shorter the RUL, the higher the percentage of equipment assumed to turn over.

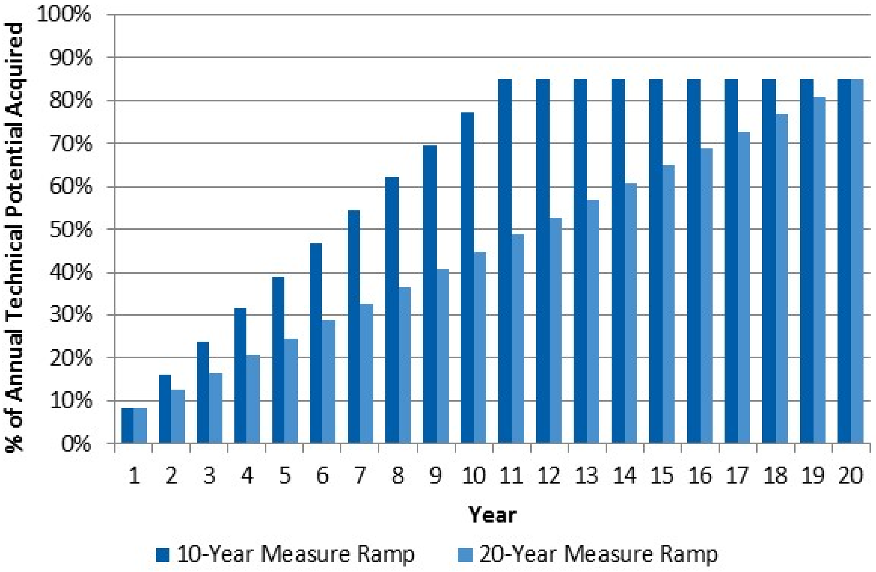
Figure 6.3. Existing Equipment Turnover for Varying Remaining Useful Life (RUL)



In addition to natural timing constraints of equipment turnover and new construction rates, Cadmus applied measure ramp rates to reflect other resource acquisition limitations (such as market availability over the study's horizon). These measure ramp rates had a maximum ranging from 60 percent to 100 percent, reflecting the Council's measure-specific assumptions about the percentage of technical potential could be achieved over a 20-year planning horizon.

Figure 6.4 shows a measure with a maximum achievable percentage of 85 percent that ramps up over ten years. This measures would reach full market maturity—85 percent of annual technical potential—by the end of that period, while another measure might take 20 years to reach full maturity. Measures that were ramped over 20 years in this CPA included some newer technologies, such as heat pump dryers, whereas measures that were ramped over a shorter time period included more mature and accepted technologies, such as various LED lighting technologies.

Figure 6.4. Examples of Lost Opportunity 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. In the early years of the study horizon, a gap occurs between assumed acquisition and the maximum achievability. These lost resources can be considered unavailable until the measure's EUL elapses. Therefore, depending on EUL and measure ramp rate assumptions, some potential may be pushed beyond the twentieth year, and the total lost opportunity, achievable economic potential may be less than the maximum achievable percentage of the technical potential.

Figure 6.5 shows a case for a measure with a five-year RUL/10-year EUL. The spike in achievable technical potential, starting in Year 11—after the measure's EUL—results from acquisition of opportunities missed at the beginning of the study period.

Figure 6.5. Example of Combined Effects of Resource Availability and Measure Ramping Based on 10-Year EUL

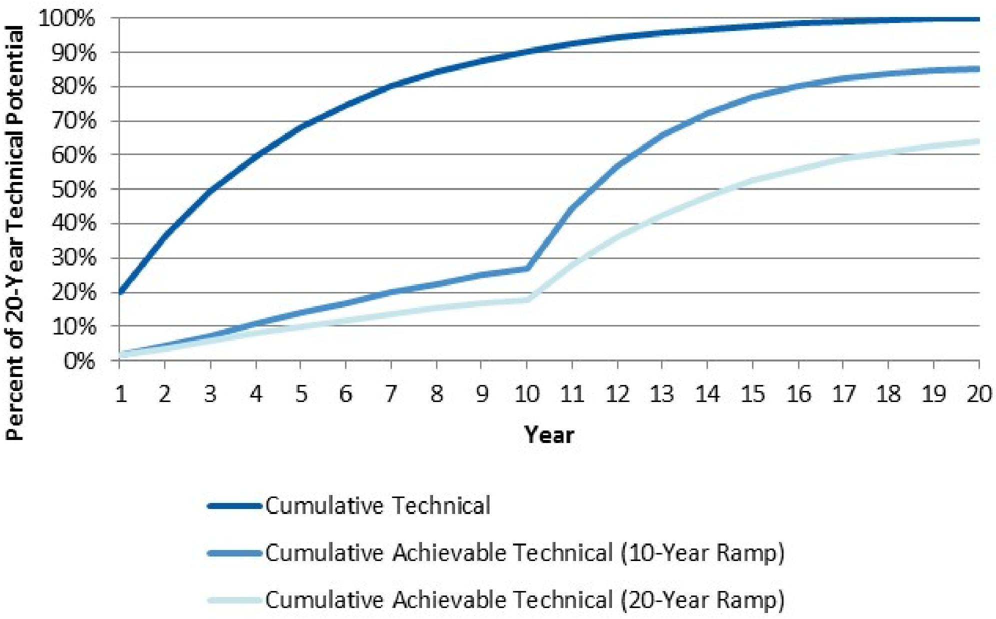


Table 6.4 illustrates this method, based on the same five-year RUL/10-year EUL measures on a 10-year ramp rate (the light blue line in Figure 6.5), assuming 1,000 inefficient units would be in place by Year 1. In the first ten years, lost opportunities would accumulate as the measure ramp-up rate caps the availability of high-efficiency equipment. Starting in the eleventh year, the opportunities lost during the previous ten years become available again. Table 6.4 also shows that this EUL and measure ramp rate combination results in 85 percent of technical potential achieved by the close of the study period.

As described, amounts of achievable 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 Table 6.4. Across all lost opportunity measures in this study, approximately 77 percent of technical potential appears achievable over the 20-year study period.

Table 6.4. Example of Lost Opportunity Treatment: 10-Year EUL Measure on a 10-Year Ramp

Year	Incremental Stock Equipment Turnover (Units)	Cumulative Stock Equipment Turnover (Units)	Measure Ramp Rate	Installed High-Efficiency Units	Missed Opportunities for Acquisition in Later Years (Units)	Missed Opportunities Acquired (Units)	Cumulative Units Installed	Cumulative Percent of Technical Achieved
1	200	200	9%	17	180	0	17	9%
2	160	360	16%	26	130	0	43	12%
3	128	488	24%	30	92	0	73	15%
4	102	590	31%	32	65	0	106	18%
5	82	672	39%	32	44	0	138	20%
6	66	738	47%	31	29	0	168	23%
7	52	790	54%	29	19	0	197	25%
8	42	832	62%	26	11	0	223	27%
9	34	866	70%	23	6	0	246	28%
10	27	893	77%	21	2	0	267	30%
11	21	914	85%	18	0	153	438	48%
12	17	931	85%	15	0	110	563	60%
13	14	945	85%	12	0	78	653	69%
14	11	956	85%	9	0	55	717	75%
15	9	965	85%	7	0	38	762	79%
16	7	972	85%	6	0	25	793	82%
17	6	977	85%	5	0	16	814	83%
18	5	982	85%	4	0	10	828	84%
19	4	986	85%	3	0	5	836	85%
20	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 that all achievable technical potential for discretionary resources could be acquired in the study’s first year. From a practical perspective, however, this outcome is realistically impossible due to infrastructure and budgetary constraints and customer considerations.

Furthermore, due to interactive effects between discretionary and lost opportunity resources, immediate acquisition distorts the potential for lost opportunity resources. For example, if one assumes that all homes would be weatherized in the program's first year, 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).

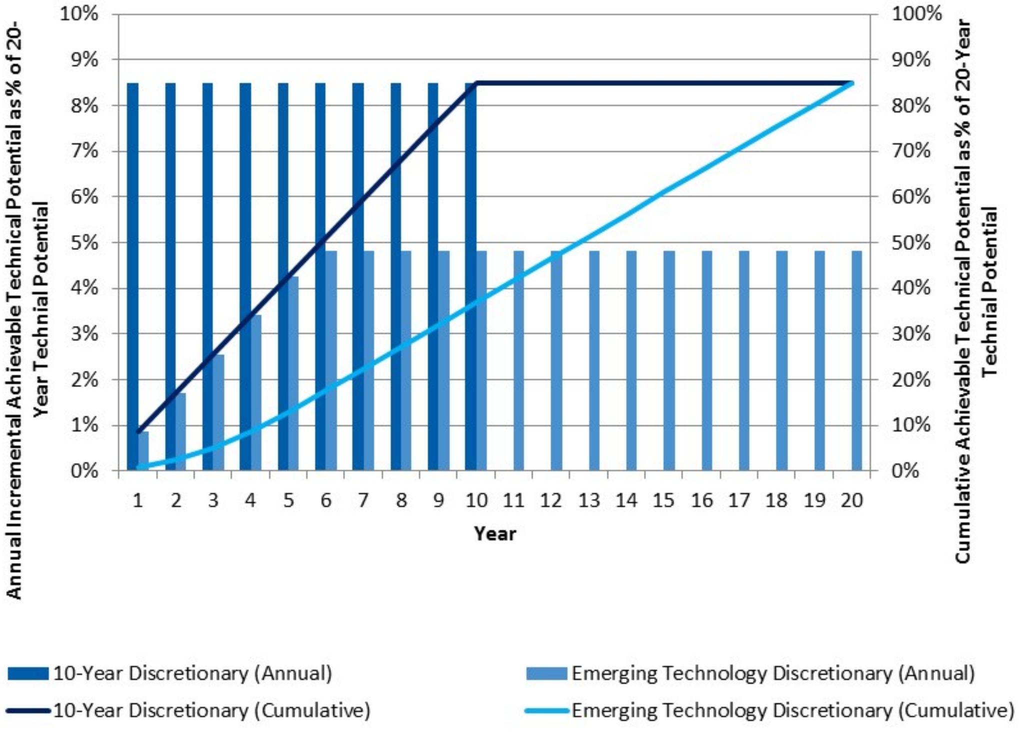
Consequently, the study addressed discretionary resources in two steps:

1. Developing a 20-year estimate of discretionary resource technical potential, assuming technically feasible measure installations would occur equally (at 5 percent of the total available) for each year of the study, avoiding the distortion of interactions between discretionary and lost opportunity resources 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 technical values.

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

Figure 6.6 shows incremental (bars) and cumulative (lines) acquisitions for two different discretionary ramp rates. A measure with an 85 percent maximum achievability on the 10-year discretionary ramp rate reaches full maturity in ten years, with market penetration increasing in equal increments each year. A measure with an 85 percent maximum achievability on the emerging technology discretionary ramp rate would take longer to reach full maturity, though also gaining 85 percent of the total technical potential. Ultimately, it would arrive at the same cumulative savings as the measure on the ten-year ramp rate.

Figure 6.6. Examples of Discretionary Measure Ramp Rates



6.3.3. Development of Conservation IRP Inputs

Cadmus worked with City Light to determine the format of inputs into the IRP model. Cadmus compiled energy efficiency potential into the levelized costs bundles shown in Table 6.5. Cadmus spread the annual savings estimates over 8760-hour load shapes to produce hourly bundles. The number and delineating values of the electric levelized cost bundles remain unchanged from the 2020 CPA.

Table 6.5. Electric Levelized Cost Bundle

Bundle	$/MWh
1	($9,999,999) to $10
2	$10 to $20
3	$20 to $30
4	$30 to $40
5	$40 to $50
6	$50 to $60
7	$60 to $70
8	$70 to $80
9	$80 to $90
10	$90 to $100
11	$100 to $110
12	$110 to $120
13	$120 to $130
14	$130 to $140
15	$140 to $150
16	$150 to $160
17	$160 to $9,999,999

Cadmus derived the levelized cost for each measure using the following formula.

$$\mathrm{LCOE} = \frac{\sum_{t=0}^{n} \frac{\mathrm{Expenses}_t}{(1+i)^t}}{\sum_{t=0}^{n} \frac{E_t}{(1+i)^t}}$$

Where:

LCOE = The levelized cost of conserved energy for a measure

$\mathrm{Expenses}_t$ = All net expenses in the year t for a measure using the costs and benefits outlined in Table 6.6

i = The discount rate

n = The lifetime of the analysis (20-years)

E_t = The energy conserved in year t

Cadmus grouped the achievable technical potential by levelized cost over the 20-year study horizon, allowing City Light's IRP model to select the optimal amount of energy efficiency potential, given various assumptions regarding future resource requirements and costs. The 20-year total resource levelized cost calculation incorporates numerous factors, which are consistent with the expense components shown in Table 6.6.

Table 6.6. Levelized Cost Components

Type	Component
Costs	Incremental Measure Equipment and Labor Cost
	Incremental Operations and Maintenance (O&M) Cost
	Administrative Adder
Benefits	Present Value of Non-Energy Benefits
	Present Value of Transmission and Distribution (T&D) Deferrals
	Secondary Energy Benefits
	10% Conservation Credit

The levelized cost calculation incorporates several factors:

- **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 EUL,[30] considered an annual reinstallation cost for the remainder of the 20-year period.[31]

- **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. Cadmus used the present value to adjust the levelized cost upward for measures with costs above baseline technologies and downward for measures that decreased O&M costs.
- **Administrative adder:** Cadmus assumed program administrative costs of 16 percent of incremental measure costs in the residential sector and 22 percent of incremental measure costs in the commercial and industrial sectors.
- **Non-energy benefits**: A reduction in levelized costs for measures that saved resources (such as water or detergent). For example, the value of reduced water consumption from installing a low-flow shower head would reduce that measure's levelized cost. Council and RTF workbooks provide measure level non-energy benefit assumptions.
- **10 percent conservation credit and transmission and distribution (T&D) deferrals:** Each are treated as reductions in levelized cost for electric measures. The addition of this credit, per the Northwest Power Act, was consistent with the Council methodology and effectively served as an adder to account for unquantified external benefits from conservation when compared to other resources.[32]
- **Secondary energy benefits:** A reduction in levelized costs for measures saving energy on secondary fuels. This treatment was necessitated by Cadmus' end-use approach to estimating technical potential. An example is R-60 ceiling insulation costs 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 produced for electric cooling systems, conditioned on the presence of a gas furnace, as a secondary benefit that reduced the measure's levelized cost. This adjustment affected only the measure's levelized costs; the R-60's magnitude of energy savings on the gas supply curve was not affected by considering secondary energy benefits.

The approach adopted in calculating a measure's levelized cost of conserved energy aligned with that of the Council, 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.

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

[31] 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.

[32] Northwest Power and Conservation Council. January 1, 2010. *Northwest Power Act.* https://www.nwcouncil.org/reports/northwest-power-act

For example, Figure 6.7 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 five years (Year 17 through Year 20) were treated differently, leveling measure costs over the measure's eight-year life and treating these as annual reinstallation costs.

Figure 6.7. Illustration of Capital and Reinstallation Cost Treatment

	Year																			
Component	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Initial Capital Cost	■																			
Reinstallation Cost									■								■	■	■	■

As with incremental measure costs, Cadmus considered O&M costs 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 decreased O&M costs.

6.3.4. Achievable Economic Potential

According to WAC 194-37-070, City Light must consider conservation potential estimates using avoided costs equal to a forecast of regional market prices. Regional market price forecasts, however, do not reflect all costs for City Light to meet future resource need. Therefore, in the 2022 CPA, to assess the value of conservation and develop the economic potential, City Light used its IRP framework. The 2020 IRP Progress Report provided the foundation for the analysis to evaluate the achievable economic potential on its conservation programs.[33] In past conservation potential assessments, City Light used a conservation screening methodology that was based on a high-level avoided cost from the most recent IRP. This new integrated methodology evaluates conservation potential alongside power supply and other demand-side resource choices to more discretely target the conservation attributes that meet City Light's resource needs. This methodology creates a more equivalent way of looking at supply and demand-side resources.

This new framework also supports development of cost-effective targets for meeting CETA and preparation of a CEIP every four years. With the current regulatory timeline for the CPA and CEIP and with the City Light's 2022 IRP process in progress, City Light also included eight different scenarios [see section Portfolio Optimization Modeling] to test the robustness of the conservation targets and considered feedback from its IRP Technical Advisory Group in setting the targets.

6.3.4.1 City Light's IRP Portfolio Framework

The IRP framework is a decision support system that develops an optimal resource strategy, given the current forecasts of supply-side and demand-side resource costs and future load and market conditions. By using this framework for the CPA, the benefit of the conservation path is determined by establishing an

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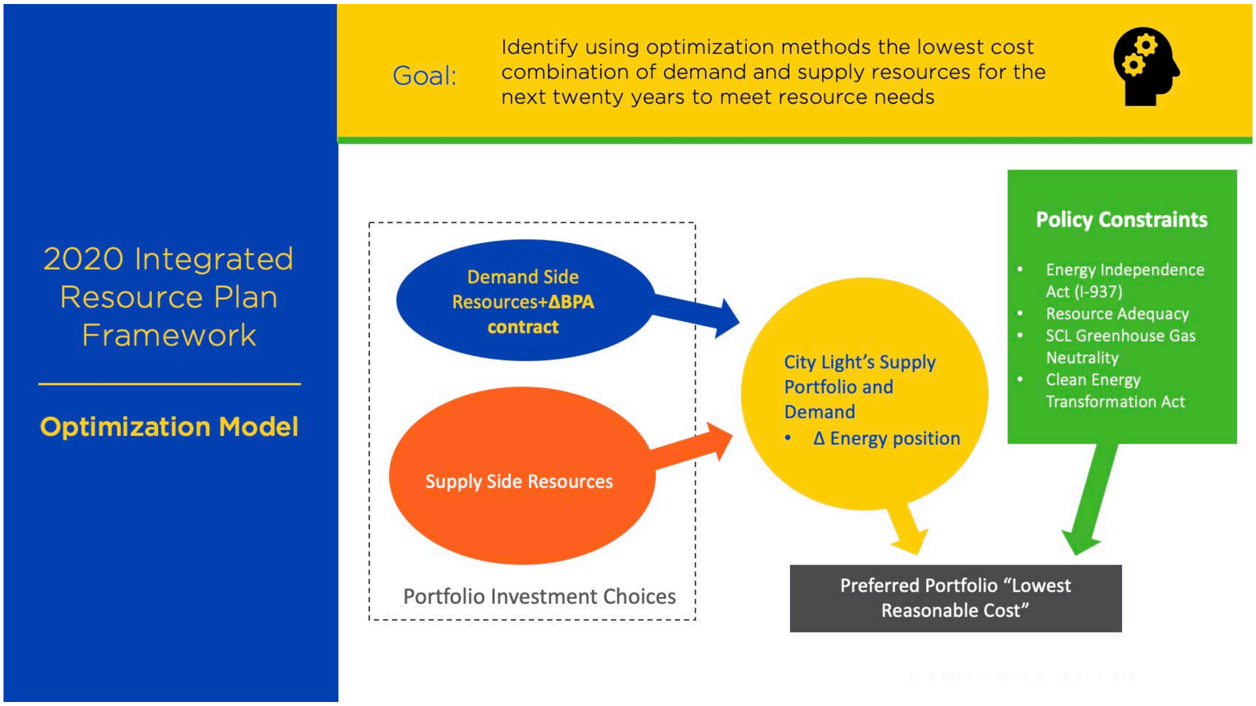
[33] City Light. *2020 Integrated Resources Plan Progress Report.* https://www.seattle.gov/Documents/Departments/CityLight/2020IRPProgessReport.pdf

optimal portfolio with conservation alongside resources that minimize the net present value (NPV) of City Light's total incremental portfolio cost. For the CPA, resources of all types are set up for analysis on an equivalent basis between 2022 to 2041. The model also uses end effects to capture CETA's requirements beyond the 20-year analysis and to make every portfolio equivalent. Each portfolio meets City Light's resource needs and compliance obligations. Figure 6.8 is a high-level overview of City Light's IRP framework.

Figure 6.8. High Level IRP Framework



The IRP framework captures several factors in selecting a resource strategy by methodically evaluating interactions between different options and policies. These interactions include the following:

- **City Light's Monthly Energy Resource Adequacy.** Resource adequacy is having sufficient generation, energy efficiency, storage, and demand-side resources to serve loads across a wide range of conditions.
- **Washington Energy Independence Act (I-937) compliance.**[34] In 2006, Washington voters approved Initiative 937 (I-937), which requires that major utilities invest in all cost-effective energy efficiency measures and sets targets for adding Northwest renewable energy as a percentage of load. Eligible renewable resources include water, wind, solar energy, geothermal energy, landfill gas, wave, ocean or tidal power, gas for sewage treatment plants, bio-diesel fuel, and biomass

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[34] Washington State Legislature. RCW 19.285. Energy Independence Act. https://apps.leg.wa.gov/rcw/default.aspx?cite=19.285

energy. In 2020, the renewable energy target increased to 15 percent of load, and this target does not increase beyond the current level. The law also includes provisions to keep costs affordable for utilities. Today, City Light can comply under the "no load growth" option.

- **Clean Energy Transformation Act (CETA) clean electricity compliance.[35]** Approved by the Washington Legislature in 2019, CETA provides electric utilities in Washington a clear mandate to phase out greenhouse gas emissions. CETA requires that utilities eliminate the use of coal-fired resources after December 31, 2025. Additionally, all electricity sold to customers must be greenhouse gas neutral starting January 1, 2030, and greenhouse gas free by 2045. To be greenhouse gas neutral, a utility must supply at least 80 percent of its load with a combination of renewable and non-emitting resources. Utilities may use alternative compliance options during the greenhouse gas neutral period for no more than 20 percent of load.
- **Greenhouse gases.** City Light applies the Social Cost of Greenhouse Gases when evaluating conservation programs, developing IRPs, and evaluating mid- to long-term resource options during resource acquisition.
    - **City Light's greenhouse gas neutrality policy.** Since 2005, City Light has accounted for the greenhouse gas emissions used to serve retail load and purchased offsets for those emissions to be greenhouse gas neutral.[36]
    - **Clean Energy Transformation Act's social cost of greenhouse gases requirement.** CETA establishes that a utility must incorporate a social cost of greenhouse gases in making resource decisions. CETA also sets a minimum cost that a utility must use from a technical study published in August 2016 by the Interagency Working Group on Social Cost of Greenhouse Gases. CETA also stipulates that a utility may use a higher cost if it can establish a reasonable basis for doing so.
- **Bonneville Power Administration (BPA) contract impacts.** Load and energy efficiency programs impact City Light's BPA power contract deliveries. As load declines, City Light receives less BPA power. The ability to add energy efficiency creates a choice for City Light and gives the utility some control over how much BPA power City Light receives. When a conservation path reduces City Light's BPA power deliveries, BPA's power costs are reduced and the change in BPA's contribution to resource adequacy is taken into account.
- **Hourly energy sales and energy purchases.** Conservation's impact on hourly demand and City Light's ability to reshape its existing hydro power resources to this change in load shape is taken into account in the IRP models. The models account for the hours when conservation makes City

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[35] Washington State Legislature. RCW 19.405. Washington Clean Energy Transformation Act. https://app.leg.wa.gov/RCW/default.aspx?cite=19.405

[36] Climate Registry summary of City Light's utility-specific emission factors: https://www.theclimateregistry.org/our-members/cris-public-reports/

Light more surplus and sells more power, and it also accounts for when conservation reduces City Light's market purchases.

Third-party system transmission costs. For City Light, new supply resources will interconnect with another utility's transmission system. In the IRP framework, these transmission costs include the cost of moving power across other utility's transmission systems. Current limitations on moving power from specific locations of the transmission system is also taken into account. Table 6.7 provides a high-level comparison of the 2020 CPA methodology to the 2022 CPA methodology and important factors driving the updated targets.

Table 6.7. Achievable (Economic) Potential Methodology Comparison

	2020 CPA Approach	**2022 CPA Approach**
Screening Method	**Compare levelized avoided cost to measure levelized cost**	**Compare NPV of benefits to NPV of measure/resource cost**
Calculation of Net Benefits (Value Components)		
Bonneville Power Administration	Application of Market Revenue, GHG costs, and BPA power costs without adjustment for change in hourly and monthly shapes and net energy position	Accounts for hourly changes in City Light energy position, reductions in GHG emissions consistent with CETA, and monthly changes to BPA power deliveries
Net Market Position		
GHG		
I-937 Need	Low cost renewable energy credit (REC) to meet I-937 requirements	Recognizes, by conservation measure groupings, the benefit in reducing I-937 (with multiple compliance options) and winter and summer resource adequacy when competitive with other resource options
Resource Adequacy Need	None	
Third-Party Transmission Costs	Flat annual BPA transmission rate	Conservation measures that are competitive with resources help reduce third-party transmission costs

The 2022 CPA approach is better able to recognize the identified resource needs from City Light's new load forecast and more up-to-date alternative resource costs. The result is a CPA target based on the evaluation of conservation's monthly and hourly shapes to more closely match City Light's resource needs. The new analysis also takes into account CETA compliance and BPA contract high water impacts.

Overall, this new approach provides a better way for City Light to weigh the tradeoffs of different levels of investment in conservation. The combination of these factors led to selection of conservation at different levelized costs levels in the 2022 CPA than used in the 2020 CPA.

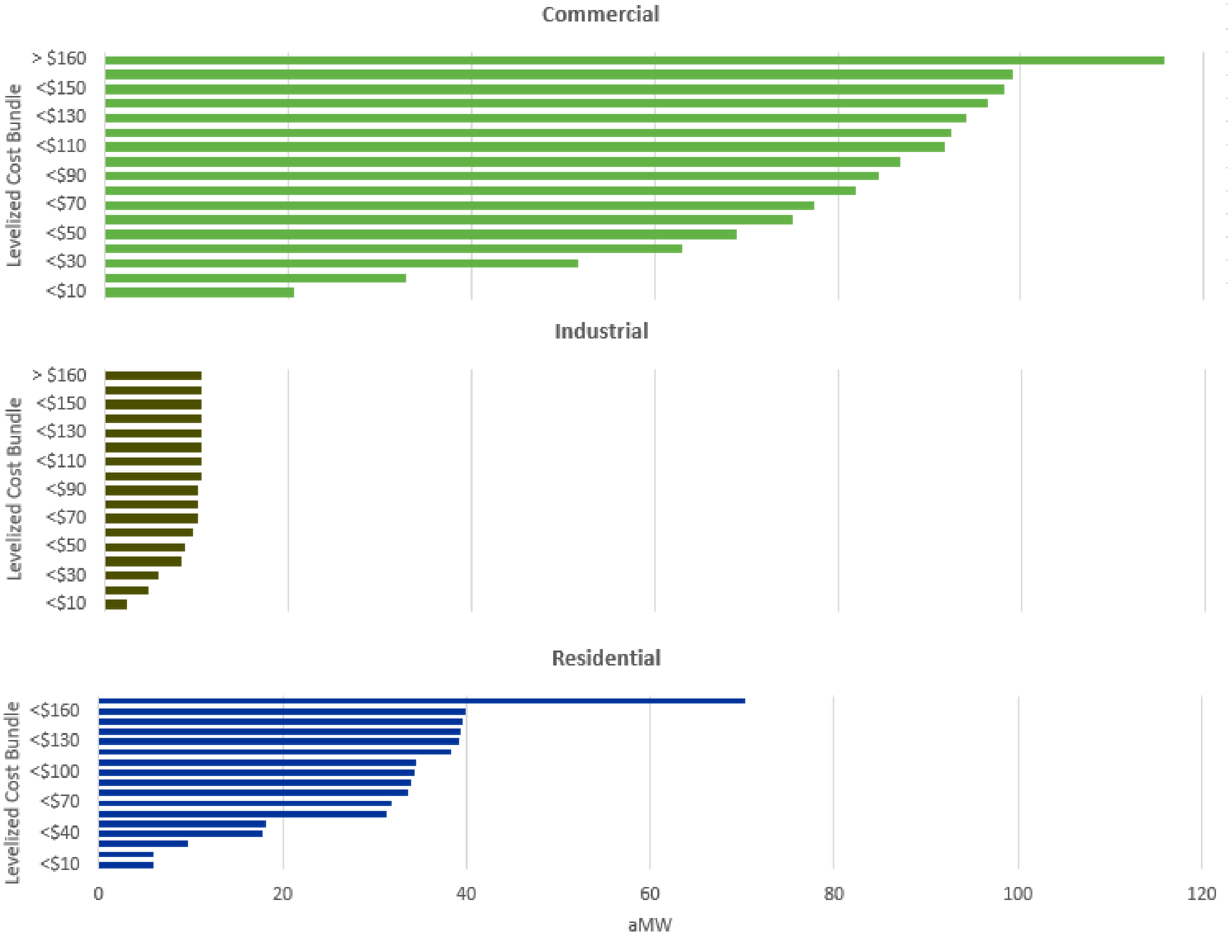
6.3.4.2 Conservation Resource Inputs into the IRP Framework

A main input into the IRP framework is the levelized costs bundles shown in Table 6.5. City Light created these bundles to minimize modeling run time. To evaluate all possible combinations of 17 levelized cost bundles for each of the three customer classes would have required optimization of the portfolio for approximately 5,000 combinations of conservation bundles. City Light further reduced the number of combinations to evaluate by combining cost bundles where the achievements did not significantly increase, even at higher levelized cost bundles.

Figure 6.9 illustrates where City Light combined cost bundles. For example, residential levelized cost bundles $10/MWh and $20/MWh were combined because the additional achievement with the higher cost bundle was negligible. This led to eight residential, seven industrial, and eleven commercial cost bundles for a total of 616 bundles that included the no-conservation savings option for each customer class. This led to shorter run times without sacrificing precision.

The figure also shows the elasticity of the conservation supply curves by customer class. The industrial supply curve becomes inelastic at $60/MWh, while the residential supply curve becomes inelastic above $70/MWh. The commercial supply curve shows the highest elasticity but reaches high inelasticity above $130/MWh. The inelasticity of conservation places a limit to the amount of conservation potential that can be relied upon to contribute to the portfolio.

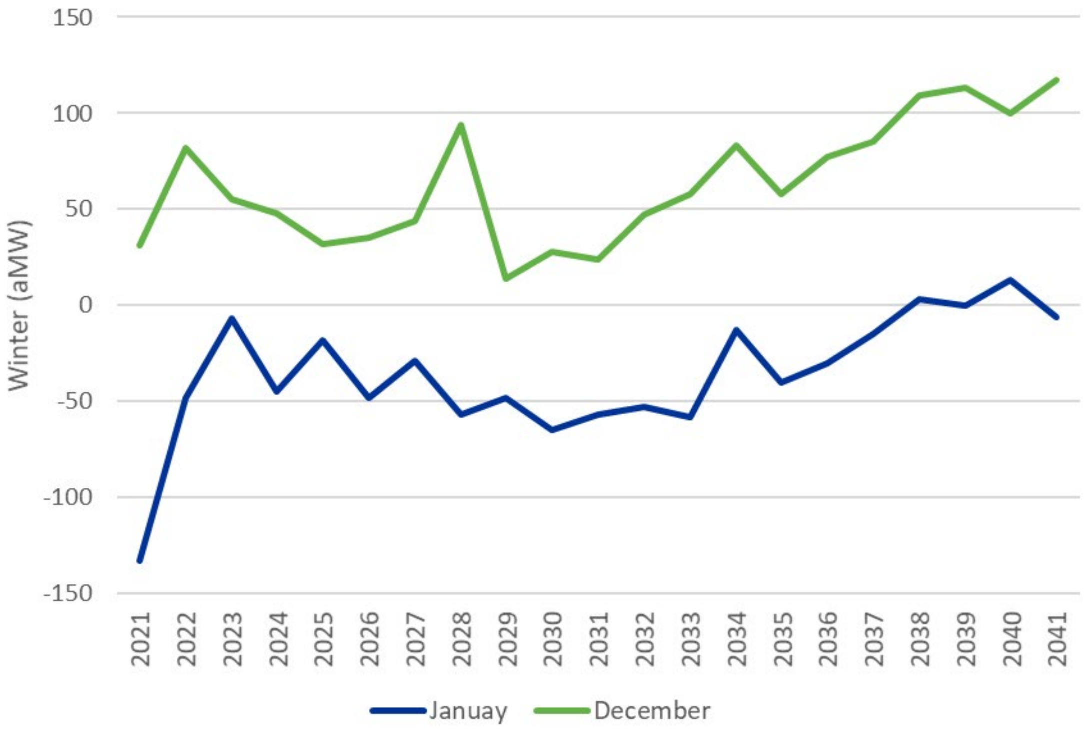
Figure 6.9. Conservation Supply Curves – 2041 Cumulative Savings



The adjusted cost bundles and energy savings are the starting point for input into the IRP framework. The hourly conservation inputs allow City Light to reflect the seasonal and hourly economic benefits of conservation to the hydro system and to the overall generation portfolio. For each conservation sector (residential, commercial, and industrial) being evaluated, City Light's IRP framework develops an energy resource adequacy contribution for meeting City Light's resource adequacy needs.[37] Once this contribution is established, City Light conducts its portfolio optimization modeling. Refer to Volume 3 of this report for more information on the IRP framework.

Figure 6.10 and Figure 6.11 show that City Light has winter and summer energy resource adequacy needs that must be met.[38]

Figure 6.10. Winter Resource Adequacy Needs (2021-2041)



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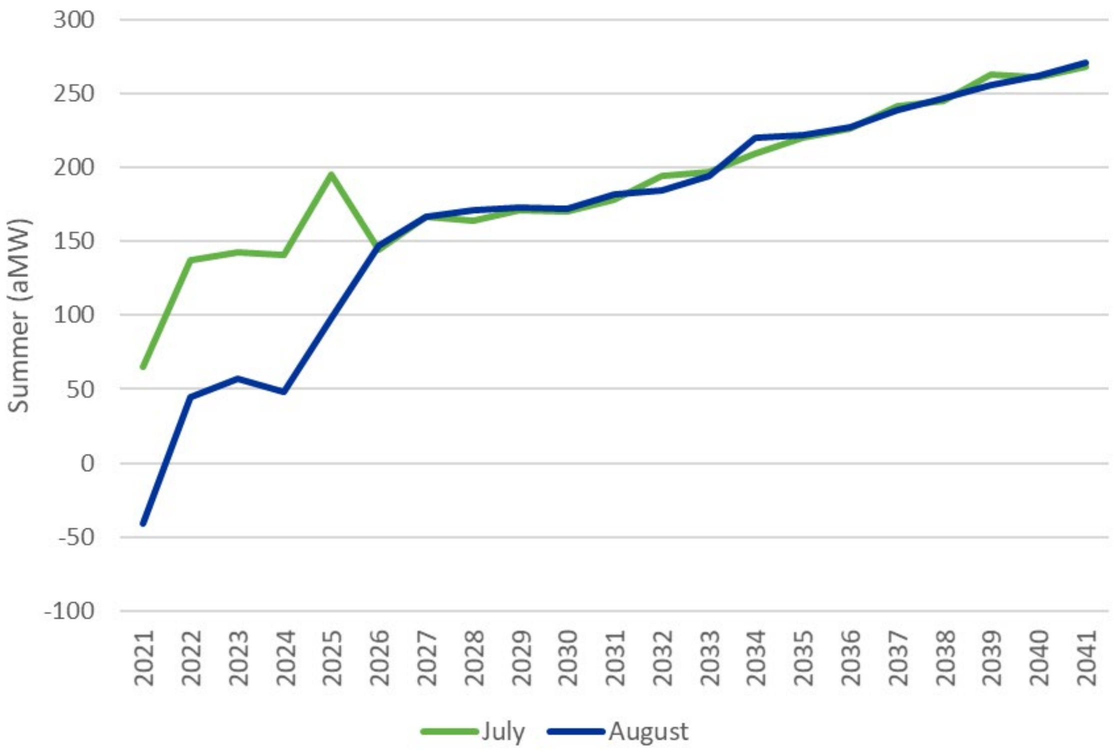
[37] City Light's Hydro Risk and Reliability Analyzer (HydRRA) is the tool that calculates energy resources adequacy needs and contributions.

[38] Resource adequacy needs are established using simulations of loads and resources in HydRRA, assuming no new supply and conservation resources, a market reliance of 200 aMW, and an achievement of an adequacy target of loss of load events (LOLEV) no greater than two every ten years.

Figure 6.11. Summer Resource Adequacy Needs (2021-2041)



In the 2020 CPA, City Light did not identify any resource adequacy needs. New to the 2022 CPA are City Light's resources adequacy needs, which were found using the new IRP Framework, as shown in Figure 6.10 and Figure 6.11. The load forecast used in the 2022 CPA, which includes additional electrification from new codes and faster EV growth, leads to winter resource adequacy needs.

Summer resource adequacy needs are also identified in the 2022 CPA, as shown in Figure 6.11. This is due to changing regional power supply and demand, which has reduced and altered the reliability of surplus energy available from the wholesale market when City Light's hydro supply is low and demand is high.[39]

Once these needs are identified, seasonal resource adequacy contributions of conservation by sector are developed for every year of the study.[40] Figure 6.12 and Figure 6.13 show the December and August resource adequacy contribution multipliers for conservation, respectively.

These multipliers indicate the energy contribution to resource adequacy relative to the monthly energy savings of each conservation bundle. For example, as shown in Figure 6.12 and Figure 6.13, approximately 1.0 aMW of commercial savings improves resource adequacy by 0.5 aMW in August 2030, while 1.0 aMW

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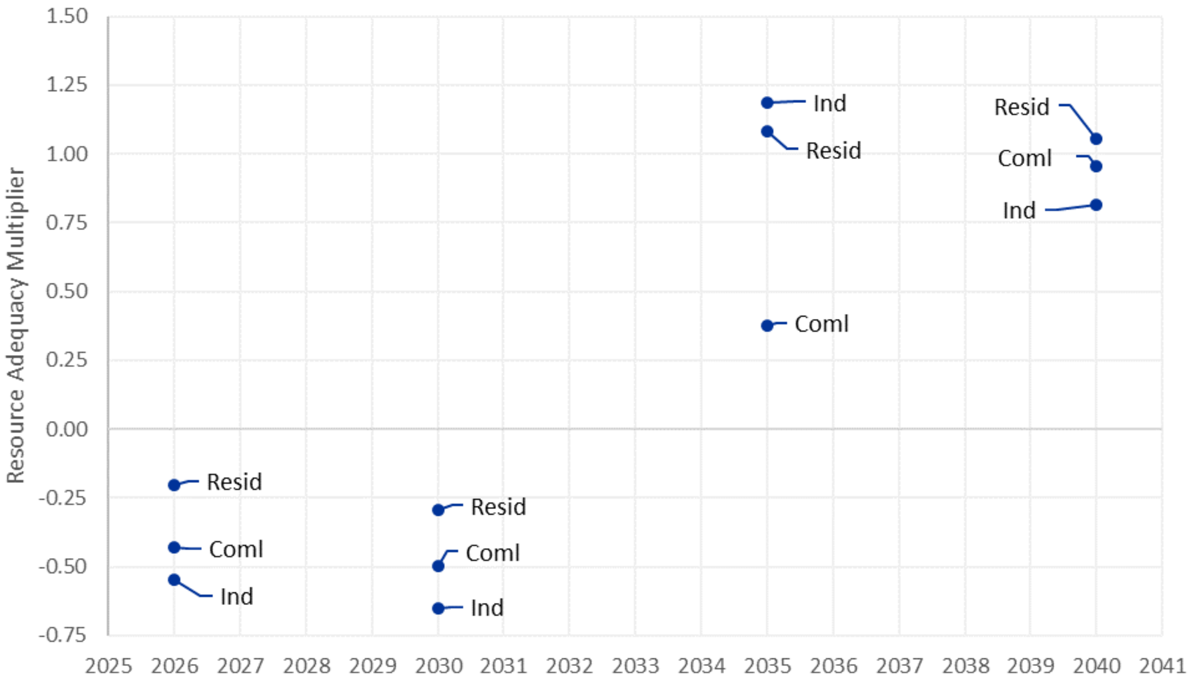
[39] City Light. *2020 Integrated Resources Plan Progress Report.* https://www.seattle.gov/Documents/Departments/CityLight/2020IRPProgessReport.pdf

[40] HydRRA is used to develop the seasonal and annual resource adequacy contributions of conservation by sector.

of commercial savings reduces the resource adequacy need for December 2030 by 0.5 aMW.[41] Conservation can reduce BPA power deliveries more in the winter than in the summer largely because of how the power deliveries are defined in the BPA contract.[42]

Figure 6.12. December Energy Resource Adequacy Contribution



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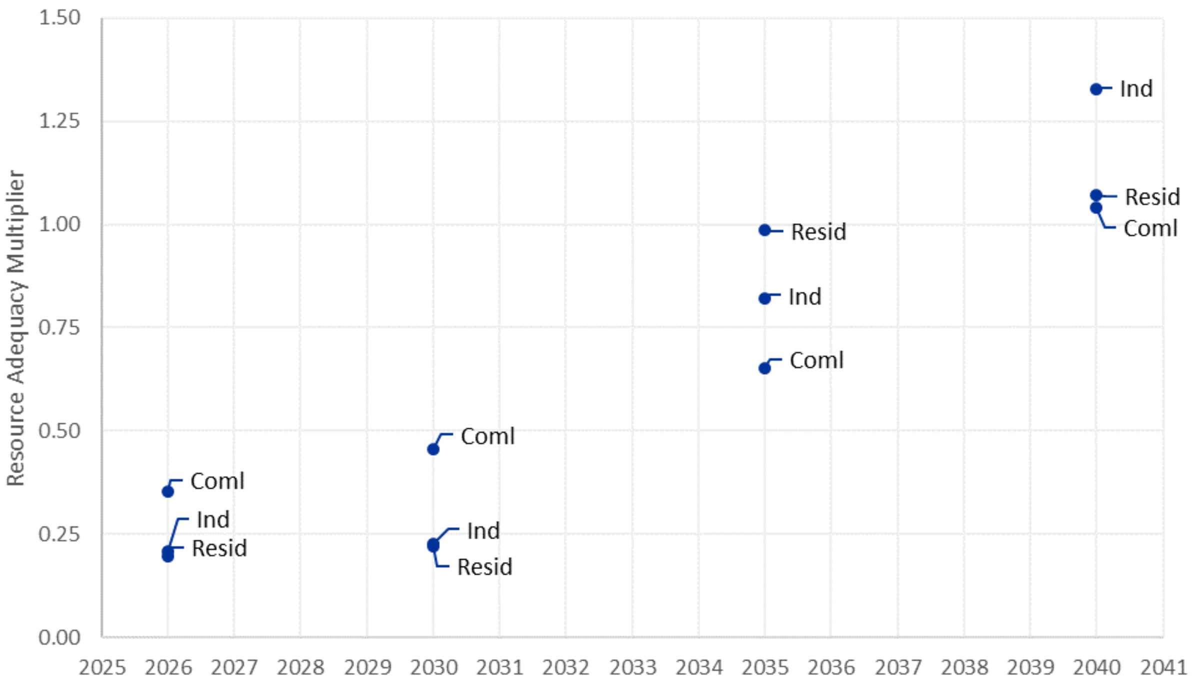
[41] The resource adequacy contribution is applied across all conservation measures within a particular bundle and sector.

[42] As an example, the resource adequacy contribution of conservation in the winter before 2035 is negative for two primary reasons. First, City Light's BPA annual energy entitlement is below the maximum annual contractual energy entitlement ("high water mark"). Second, because existing power deliveries are shaped more toward the winter, a load reduction means a bigger power delivery reduction in the winter compared to the summer. Once loads begin to increase in 2035, the difference between the annual entitlement and the maximum annual contractual energy entitlement becomes smaller, this leads to an increase in the resource adequacy contribution of conservation.

Figure 6.13. August Energy Resource Adequacy Contribution



6.3.4.3 Portfolio Optimization Modeling

The targets for 2022 CPA achievable economic conservation result from a systematic evaluation of the choices in supply-side and demand-side resources and are based on City Light's most recent estimates of load, resource costs, conservation savings, and future power market conditions. Technology and regulations are constantly evolving and the region's energy supply changes, so City Light obtained and included more up-to-date information about new resource costs and market conditions since its 2020 IRP Progress Report.

Nevertheless, because the future is unknown, City Light relied on more than one analysis. City Light reviewed a range of potential futures, or scenarios, to evaluate the factors that could change the targets for achievable economic potential.[43] Detailed information about the IRP's updated inputs, assumptions, and scenarios can be found in Volume III.

The IRP framework found that across all scenarios reviewed, five different conservation combinations rose to the top. Across the scenarios, the optimal result included all measures with a net levelized cost of $40/MWh and below for the residential sector, $70/MWh and below for the commercial sector, and $160/MWh and below for the industrial sector. Table 6.8 shows the scenarios that were evaluated and in which scenario the five conservation bundles listed were optimal.

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[43] In addition to good utility practice, WAC 194-070 requires City Light to test multiple scenarios.

Table 6.8. Scenarios – Cumulative Achievable Economic Potential Results by Sector and Time Period

Scenarios	Optimal Conservation Bundle By Levelized Cost and Sector	Achievable Economic Potential – aMW			
		2-Year (2022-2023)	4-Year (2022-2025)	10-Year (2022-2031)	20-Year (2022-2041)
1. Baseline 2. Resource Adequacy need delayed to 2030 3. Forced selection of low cost demand response options	Residential ≤ $40/MWh Commercial ≤ $70/MWh Industrial : All Bins	19	35	77	106
4. Use short-term REC purchases to meet I-937 5. No I-937 renewable energy requirement	Residential ≤ $20/MWh Commercial ≤ $50/MWh Industrial ≤ $60/MWh	15	28	63	85
6. No future winter Resource Adequacy needs	Residential ≤ $40/MWh Commercial ≤ $100/MWh Industrial ≤ $60/MWh	21	39	84	114
7. High Load 2030 to 2041	Residential ≤ $70/MWh Commercial ≤ $130/MWh Industrial : All Bins	22	41	93	136
8. High Load 2030 to 2041 and no RPS	Residential ≤ $70/MWh Commercial ≤ $100/MWh Industrial : All Bins	21	40	88	129

The analysis shows two-year targets that range from 30 percent lower to 4 percent higher than the 2020 CPA's two-year target of 21.3 aMW.

The eight scenarios show that City Light's conservation target can be sensitive to existing future conditions. Under some conditions, City Light's conservation targets are sensitive to I-937 compliance opportunities. For example, if City Light's current long-term load forecast is unchanged going forward and assuming I-937 can be met with renewable energy credits (RECs) that cost less than conservation, then the lower end of the range would be more desirable. Compared to the 2020 CPA, investments at the low end of the range still emphasize investment in higher-cost commercial and industrial measures but lower-cost residential measures. In other words, only residential measures with levelized costs of $20 and below should be considered part of the conservation portfolio when lower-cost RECs are assumed to be available in the future and are part of the compliance option.

Conversely, if load is 5 percent higher compared to the current forecast in 2030 and 11 percent higher in 2041, then City Light would benefit by investing in conservation near the top end of the range. This higher load growth has little impact on the conservation target relative to the baseline scenario because the achievable economic target for the baseline scenario is currently at the inelastic portion of the achievable economic conservation potential. The analysis also shows that, in the future, greater conservation investment and more demand response programs can be complementary. Demand response potential is outlined in Appendix E.

In summary, the optimal decision for economic conservation is an achievable economic target that recognizes the long-run benefit of conservation investments in supporting portfolio diversification.

With policies and new regulations aimed at mitigating the impacts of climate change, conservation continues to play a significant role in supporting a clean energy future and environmental equity.

Finally, though not the highest possible conservation level, the CPA target represents a robust strategy in the sense that it is chosen most frequently across various scenarios and performs well even in scenarios where it was not optimal.

Results from the 2022 CPA analysis are also being used to establish renewable energy, conservation, and demand response targets for City Light's 2022 Clean Energy Implementation Plan. Table 6.9 shows the optimal portfolio decisions for the 2022 CPA and the Clean Energy Implementation Plan. The portfolio is considered the most robust at this time; it represents the lowest reasonable cost and risk and was selected based on how it performed across the most scenarios. The table shows the projected new supply-side resources, changes in BPA power deliveries from the contractual high water mark, and the cumulative conservation savings. To keep the table simple, BPA and conservation savings are shown only for three representative years. City Light will continue to refine the long-term resource strategy in the 2022 IRP and through its work helping customers choose the resources that best meet their power needs.

Table 6.9. Optimal Portfolio Decisions

Portfolio Resource Change	Year	Capacity
Spot RECs	2024	5
Spot RECs	2025	24
OR Solar Addition	2026	100
Gorge Wind Addition	2026	25
SE WA Solar Addition	2026	300
Gorge Wind Addition	2027	50
SE WA Solar Addition	2030	25
SE WA Solar Addition	2032	25
BPA aMW below Max	2026, 2030	-75
BPA aMW below Max	2041	-31
Cumulative Conservation Savings aMW (2-Year)	2023	19
Cumulative Conservation Savings aMW (4-Year)	2025	35
Cumulative Conservation Savings aMW (20-Year)	2041	106

7. Glossary of Terms

These definitions draw heavily from the NAPEE Guide for Conducting Energy Efficiency Potential Studies and the State and Local Energy Efficiency Action Network.[44]

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

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

Conservation potential assessment: A quantitative analysis of the amount of energy savings that exists, proves cost-effective, or could potentially be realized through implementation of energy-efficient programs and policies.

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

Economic potential: Refers to the subset of technical potential that is economically cost-effective 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, this represents per-UEC consumption for a given end use, expressed in annual kWh per unit. (Also called unit energy consumption [UEC]).

End-use intensities: Used in the commercial and institution sectors, 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 service level to an 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 the median number of years that energy efficiency measures installed under a program remain in place and operable. EUL also is sometimes defined as the date at which 50 percent of installed units remain 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 (MWhs).

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

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

Measure: Installation of equipment, subsystems, or systems, or modifications of equipment, subsystems, systems, or operations on the customer side of the meter, designed 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.

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

Retrofit: An efficiency measure or efficiency program intended to encourage 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 reducing energy consumption (e.g., increased insulation, lighting occupancy controls, economizer ventilation systems).

Resource Adequacy*:* having sufficient resources, generation, energy efficiency, storage, and demand-side resources to serve loads across a wide range of conditions.

Technical potential: The theoretical maximum amount of energy use that could be displaced by efficiency, disregarding all non-engineering constraints (such as cost-effectiveness or 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 efficiency costs 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 impacts of efficiency initiatives on an administrator or an energy system. It compares administrator costs (e.g., incentives paid, staff labor, marketing, printing, data tracking, reporting) to accrued benefits, including avoided energy and demand supply costs. Also called the program administrator cost test (PACT).