B O N N E V I L L E   P O W E R   A D M I N I S T R A T I O N

Conservation Potential Assessment

2022 – 2043

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Acronyms and Abbreviations

aMW	Average Megawatt
BPA	Bonneville Power Administration
CBSA	Commercial Building Stock Assessment
CPA	Conservation Potential Assessment
CVR	Conservation Voltage Reduction
Council	Northwest Power and Conservation Council
DVR	Demand Voltage Reduction
EUL	Effective Useful Life
FMY	Future Meteorological Year
HSPF	Heating Seasonal Performance Factor
HVAC	Heating, Ventilation, and Air Conditioning
kW	Kilowatt
kWh	Kilowatt-hour
MW	Megawatt
MWh	Megawatt-hour
NEEA	Northwest Energy and Efficiency Alliance
O&M	Operations and Maintenance
RTF	Regional Technical Forum
RBSA	Residential Building Stock Assessment
SAE	Statistically Adjusted End Use
SEER	Seasonal Energy Efficiency Ratio
TAP	Technology/Activity/Practice
T&D	Transmission and Distribution
TMY	Typical Meteorological Year
TRC	Total Resource Cost Test
UCT	Utility Cost Test
UES	Unit Energy Savings
USDA	United States Department of Agriculture

Executive Summary

On behalf of the Bonneville Power Administration (BPA), Cadmus and Lighthouse Energy Consulting (the Cadmus/Lighthouse team) present the 2021 BPA Conservation Potential Assessment (CPA) report. This assessment produced estimates of the magnitude, timing, and costs of the achievable technical conservation potential within BPA's service territory—defined as all public power load of the utilities with Regional Dialogue contracts with BPA—over a 22-year period, from 2022 through 2043.

Background and Purpose

The primary purpose of this CPA was to produce estimates of achievable technical conservation potential and its associated costs for BPA's 2022 Resource Program. Since its 2018 Resource Program enhancements, BPA assesses conservation potential in line with other available supply- and demand-side resources. Available amounts of conservation are input into the Resource Program's optimization model, which then compares and selects resources bases on need, availability, and cost. This ensures all potential conservation is included and evaluated against competing alternatives in the optimization selection process. Resource Program outcomes inform BPA's Energy Efficiency Action Plan, which outlines near-term objectives for BPA's energy efficiency programs.

In early 2022, the Northwest Power and Conservation Council (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. In addition to estimating region-wide potential, the Council has also developed a BPA scenario in which it estimates conservation potential for BPA's service territory. The Power Plan is also a primary input into BPA's Energy Efficiency Action Plan.

Assessment Objectives and Methodological Approach

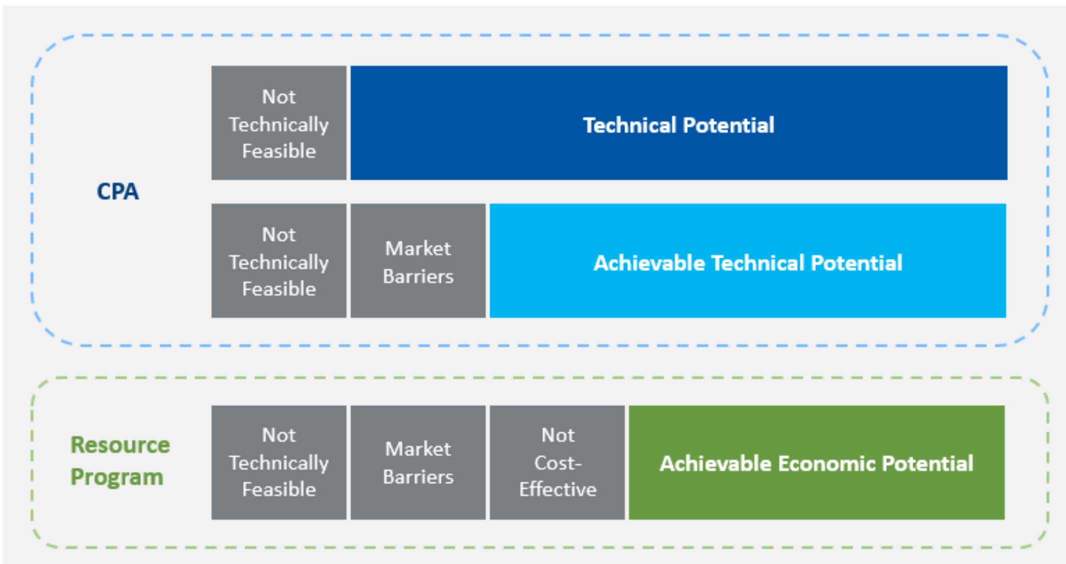
The Cadmus/Lighthouse team's primary objective was to develop the conservation supply curves to inform BPA's 2022 Resource Program optimization modeling. The supply curves document the achievable technical potential and its associated costs, and the Resource Program modeling identifies which measures are part of a resource mix that balances cost and risk. The CPA involved quantifying two of the three types of potential commonly identified in conservation potential studies. The three types of potential are defined below and illustrated in Figure 1.

Technical potential (identified in this study) assumes that all technically feasible resource opportunities may be captured, regardless of their costs or other market barriers. It represents the total conservation potential in BPA's service territory, accounting only for technical constraints.

Achievable technical potential (identified in this study) is the portion of technical potential that is assumed to be achievable during the study's forecast period. Achievable technical potential includes assumptions about the maximum possible adoption as well as the pace of annual achievements.

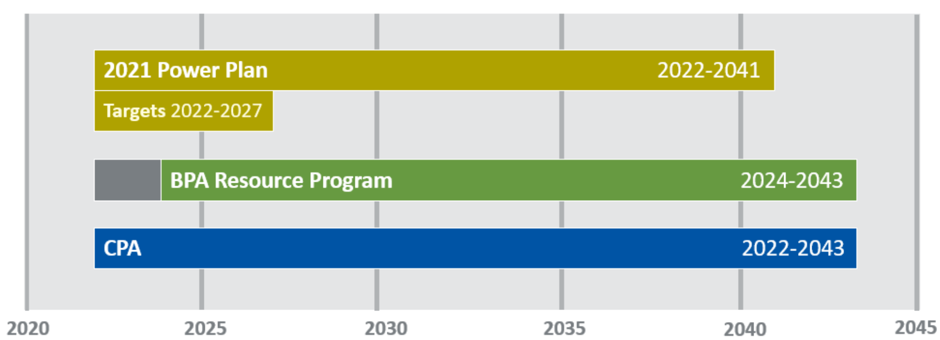
Achievable economic potential (not included in this study) is the portion of achievable technical portion determined to be cost effective by economic optimization modeling or comparing measure costs and benefits with alternative resource options. For BPA, the achievable economic potential is determined by the optimization modeling in the Resource Program, in which bundles of conservation measures are selected based on cost and savings. The cumulative potential for these selected measures or bundles constitutes BPA's achievable economic potential.

Figure 1. 2021 CPA and Types of Conservation Potential



The Cadmus/Lighthouse team quantified the achievable technical potential over a 22-year study period, starting in 2022 and ending in 2043. Using this this range allowed the study to cover both the 2022 to 2041 horizon included in the 2021 Power Plan (for comparison purposes), as well as the 2024 to 2043 period considered in BPA's 2022 Resource Program. Figure 2 illustrates how these two timelines relate.

Figure 2. Study Timeline



Note: The figure shows fiscal years.

Since this assessment focused on the achievable technical potential developed for BPA's Resource Program, the results in this report primarily focus on the period covered by the 2022 Resource Program, 2024 through 2043.

For this study, the Cadmus/Lighthouse team used methods that were largely consistent with the Council's draft 2021 Power Plan, while incorporating up-to-date assumptions and BPA-specific data from regional stock assessments, BPA's Power Customers, and financial assumptions. The primary exception to this is the use of measure savings based on Typical Meteorological Year (TMY) weather data instead of the Future Meteorological Year (FMY) weather used in the 2021 Power Plan.

Examples of BPA-specific data include saturations from the Northwest Energy and Efficiency Alliance's (NEEA) fourth regional Commercial Building Stock Assessment (CBSA), units forecasts derived from BPA and utility customer data, and various financial assumptions (such as discount rates and avoided costs) developed in collaboration with BPA staff. In addition, the Cadmus/Lighthouse team used the latest costs and savings estimates for energy conservation measures approved by the Regional Technical Forum (RTF) as of January 2021. This methodology and approach are consistent with that used in BPA's 2018 CPA.

Scope of the Analysis

For this study, the Cadmus/Lighthouse team analyzed conservation potential in five sectors and the associated building types:

- **Residential:** Single-family, multifamily, and manufactured homes
- **Commercial:** Eighteen commercial segments, such as offices and retail space
- **Industrial:** Energy-intensive manufacturing and (primarily) process-driven customers
- **Agricultural:** Measures applicable to primarily dairy and irrigation segments
- **Utility Distribution:** Utility distribution system's efficiency improvements

For each sector, the Cadmus/Lighthouse team characterized the savings, per-unit costs, and applicability of commercially available energy conservation measures. The team considered measures that provide savings to nearly every end use in each sector and modeled different applications of each measure, including normal replacement on burnout, retrofit, and new construction:

- ***Natural replacement (lost opportunity) measures*** are assumed to be installed when the equipment it replaces reaches the end of its effective useful life (EUL). Examples are appliances, such as clothes washers and refrigerators, and HVAC equipment, such as heat pumps and chillers.
- ***New construction (lost opportunity) measures*** are installed in newly constructed homes and buildings. Building energy codes affect the baselines for new construction measures, and the timing of these savings is constrained by new construction rates.
- ***Retrofit (discretionary) measures*** encompass upgrades to existing equipment or buildings and can theoretically be completed at any time over the study forecast period. Unlike natural replacement measures, the timing of retrofit savings is not subject to turnover rates. Examples of retrofit measures include weatherization and HVAC controls.

Study Limitations

Conservation potential studies require complex analyses based on large amounts of data from multiple sources. Estimates are inherently limited by the quality of that data and by the complexity of the analytic procedures used. While the Cadmus/Lighthouse team made every effort to use only the best and most recent data available, it recognizes the uncertainties inherent in the data, especially those obtained through statistical sampling.

For this study, the team used BPA-specific primary data only when that data could produce estimates of acceptable statistical rigor. In addition, while the measure list for this study is based on the measures included in the Council's 2021 Power Plan and includes most commercially available measures, it is not exhaustive. The team recognizes that new technologies continue to emerge, and while not currently commercially viable or vetted, these technologies could produce additional savings over the 22-year study period.

2021 Conservation Potential Results and Discussion

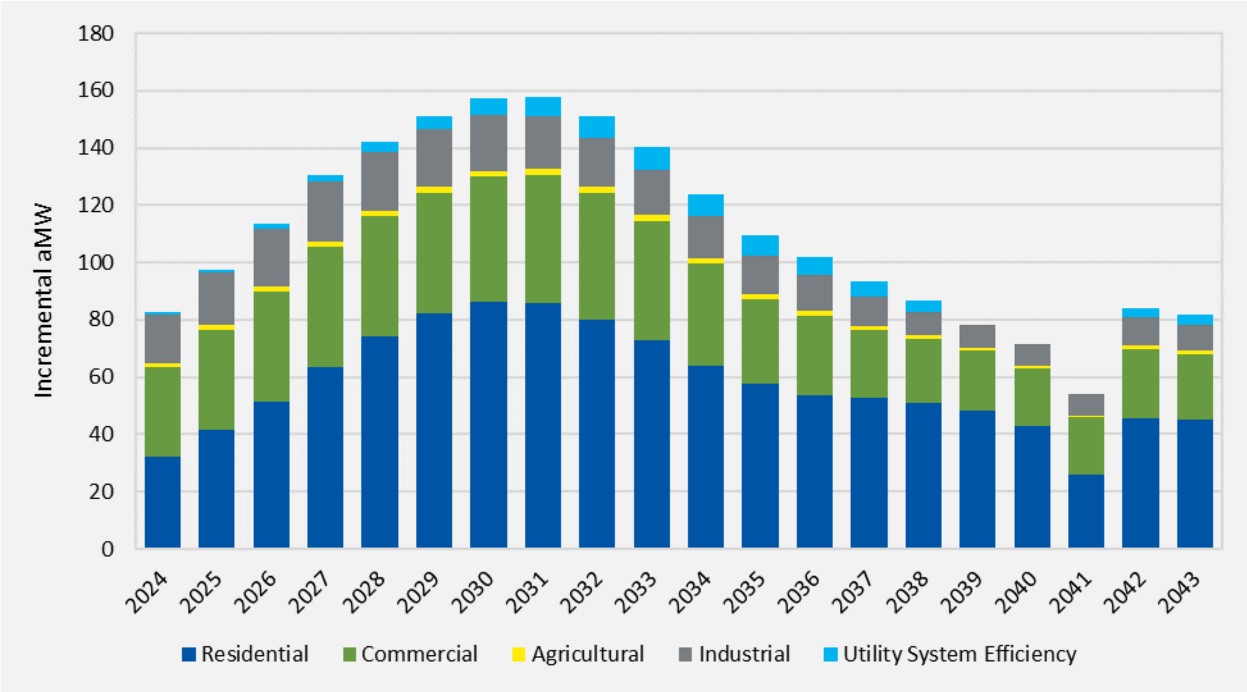
The Cadmus/Lighthouse team identified 717 aMW and 2,207 aMW of achievable technical potential over the 6- and 20-year time periods, respectively, that align with the 2022 Resource Program analysis period. The residential sector accounts for nearly half of this potential, while the commercial and industrial sectors make up the majority of the remaining potential. Table 1 shows the cumulative 6- and 20-year achievable technical potential by sector. This and all subsequent tables present savings at the busbar.

Table 1. Achievable Technical Potential by Sector

BPA Sector	Cumulative Achievable Technical Potential (aMW)	
	6-Year (2024 to 2029)	20-Year (2024 to 2043)
Residential	345	1,155
Commercial	231	654
Agricultural	10	30
Industrial	117	288
Utility System Efficiency	15	80
Total	**717**	**2,207**

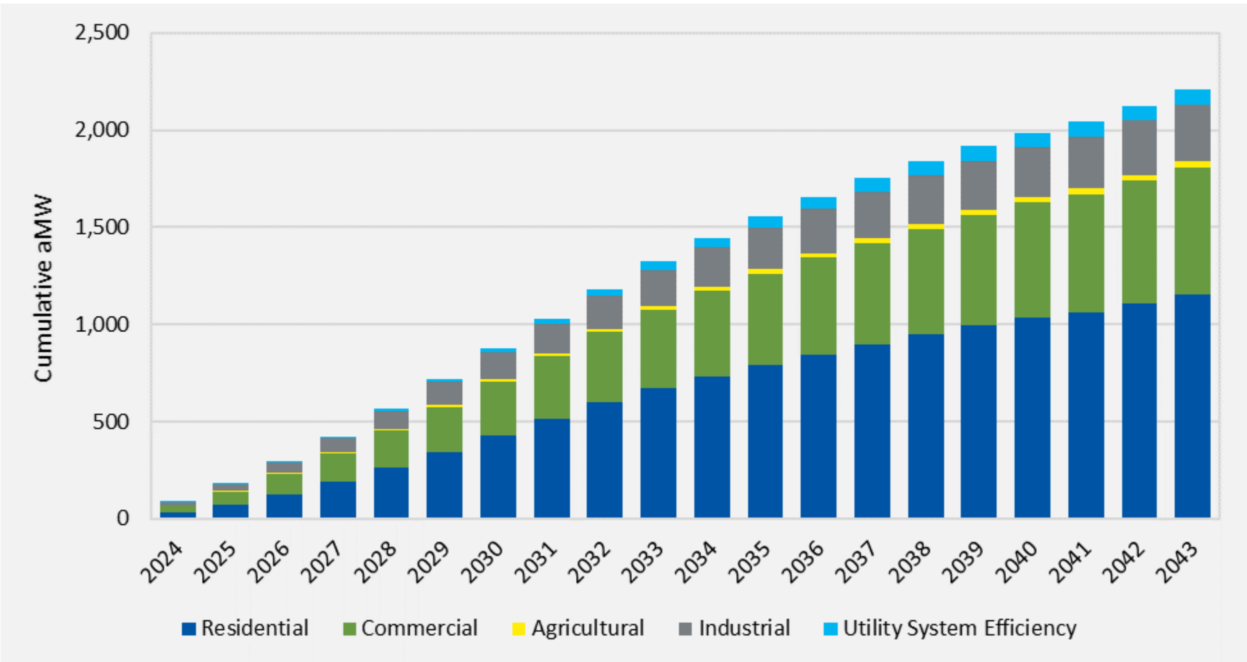
The Cadmus/Lighthouse team applied measure-specific ramp rates to determine incremental (annual) and cumulative savings in each year of the study. The assumed ramp rates are the same as those used in the 2021 Power Plan, adjusted to account for this study's 22-year time period. Specifically, lost opportunity measure ramp rates were extended at their final values, which are often at or near 100% for final two years of the study (2042 and 2043). Discretionary measures used the 2021 Power Plan ramp rates but included additional potential in the final two years to reflect that additional savings were available in these years. Figure 3 illustrates annual incremental achievable technical potential, and Figure 4 illustrates annual cumulative achievable potential. The potential starts at approximately 80 aMW in 2024 and increases to nearly 160 aMW as the projected annual adoption of energy efficiency measures increases. After 2031, the annual potential begins to decline as the amount of remaining available opportunities diminishes and projected annual achievements slows.

Figure 3. Incremental Achievable Technical Potential Forecast



Note: Annual **incremental** achievable potential represents the annual energy savings from measures installed in each year. This also includes normal replacement of the measure on burnout. Measures with an EUL of less than 20 years are assumed to be re-installed at the end of their EUL.

Figure 4. Cumulative Achievable Technical Potential Forecast



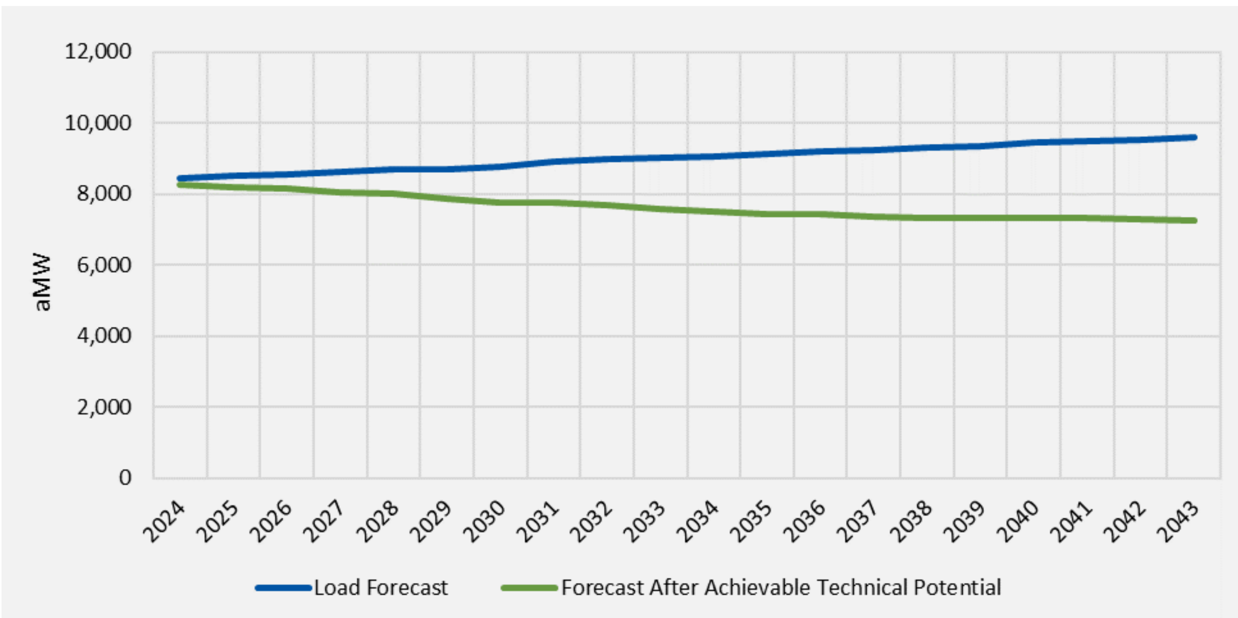
Note: Annual **cumulative** savings represent the total annual energy savings from measures installed in each year and all previous years.

The cumulative achievable technical energy conservation potential is equivalent to approximately 8% of BPA's forecasted load in 2029 and 23% of forecasted load in 2043. In other words, acquiring all the achievable technical potential savings identified in this study would lower BPA's forecasted 2043 load by 23%, as shown in Table 2 and Figure 5. Capturing all the economic potential, which for BPA will be determined during the Resource Program optimization modeling, will result in a smaller reduction to BPA's load forecast.

Table 2. Cumulative Achievable Technical Potential as a Percentage of BPA Load

BPA Sector	6-Year (2024 to 2029) Cumulative Achievable Technical Potential		20-Year (2024 to 2043) Cumulative Achievable Technical Potential	
	aMW	% of Baseline	aMW	% of Baseline
All	717	8.2%	2,207	23.0%

Figure 5. Load Forecast Adjusted for Achievable Technical Potential

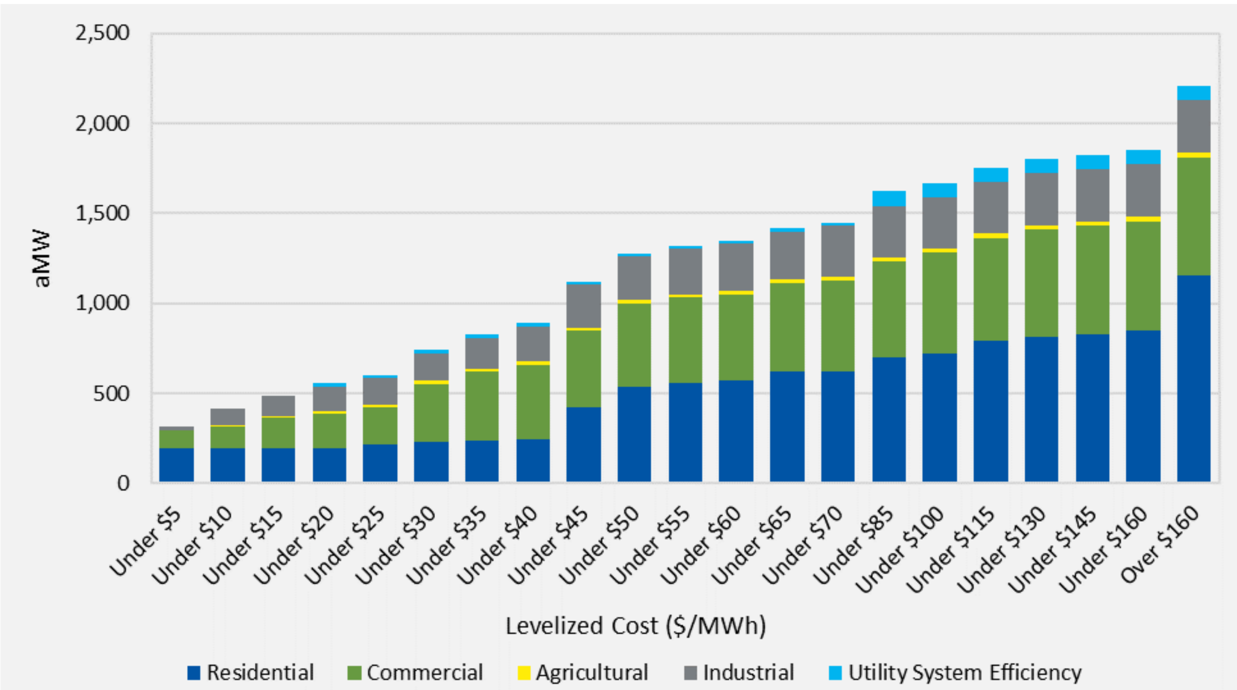


As part of this study, the Cadmus/Lighthouse team developed estimates of the per-unit levelized cost of savings ($/MWh) for each measure, based on the measure's *net* total resource cost (TRC).[1] This information, in conjunction with each measure's incremental savings, produces points for a conservation supply curve, illustrated in Figure 6. BPA's Resource Program uses this information to determine the cost-effective amount of conservation. As the figure shows, approximately 825 aMW (or

1 Net TRC levelized costs reflect most of the quantifiable costs and benefits that can be attributed to the energy conservation measure. Costs include the incremental capital, administrative, operations and maintenance (O&M), and avoided periodic replacements, and are levelized over the 22-year study. Benefits include avoided transmission, non-energy benefits, and natural gas. Levelized costs do not include benefits from avoided distribution capacity costs.

37% of the total 2,207 aMW) is expected to be available at a levelized cost of $35 per MWh or less. Figure 6 shows the cumulative achievable technical potential by sector that is available at different levelized cost points over the 2024-2043 period that aligns with the Resource Program analysis period. Each sector contributes varying amounts at different cost thresholds. For example, the residential sector has a small amount of potential in the Under $5 bin, but little additional potential is added to this until you reach the higher cost bins, starting around $45 per MWh. The potential added at the $45 and $50 per MWh cost thresholds includes potential from residential circulator pumps, heat pump dryers, Tier 4 heat pump water heaters, some weatherization measures, and certain smart thermostat measures.

Figure 6. Supply Curve of Achievable Technical Potential by Sector



Key Findings

The Cadmus/Lighthouse team identified several significant shifts in the potential in this CPA from BPA's previous CPA and recent program history. More efficient baselines, including state-specific product standards, have resulted in reduced or eliminated potential in several categories. Low avoided costs, including low market prices and low values for transmission and distribution capacity, will likely result in significant shifts in the economic potential identified through BPA's Resource Program optimization modeling. New measures not included in BPA's previous CPA offset these changes, but the potential is in low-volume measures not commonly found in recent energy efficiency programs.

Figure 7 shows how the achievable technical potential aligns with recent BPA programmatic achievement as reported in the RTF's 2019 Regional Conservation Progress Report. This includes both BPA- and utility self-funded savings, excluding momentum and market transformation. At the writing of this report, data for 2020 and 2021 were not available. Figure 7 includes all achievable technical potential without any economic screen applied. If the achievable technical potential is limited to just those measures with a levelized cost under $50 per megawatt-hour, it would decrease by nearly half. This is shown in Figure 8.

Figure 7. Comparison of Achievable Technical Potential to Past BPA Achievement

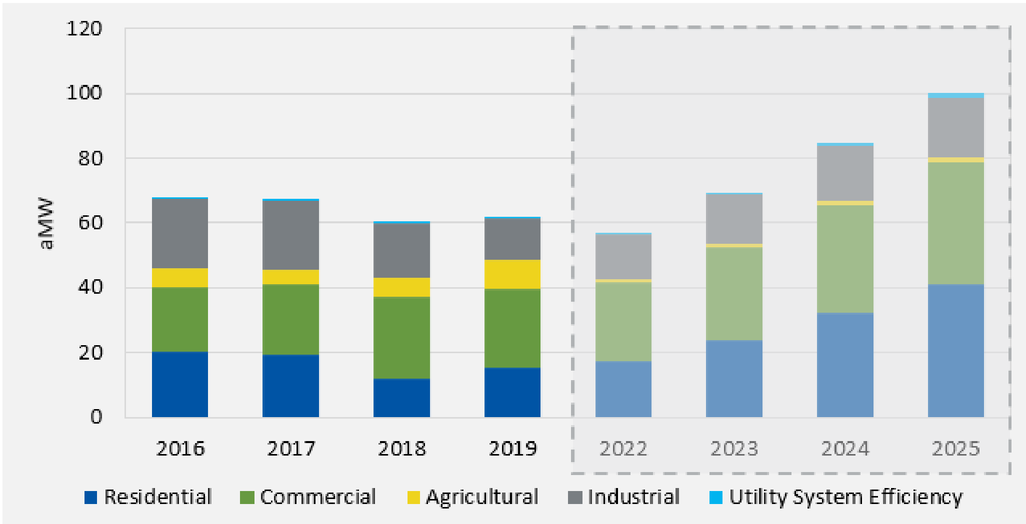
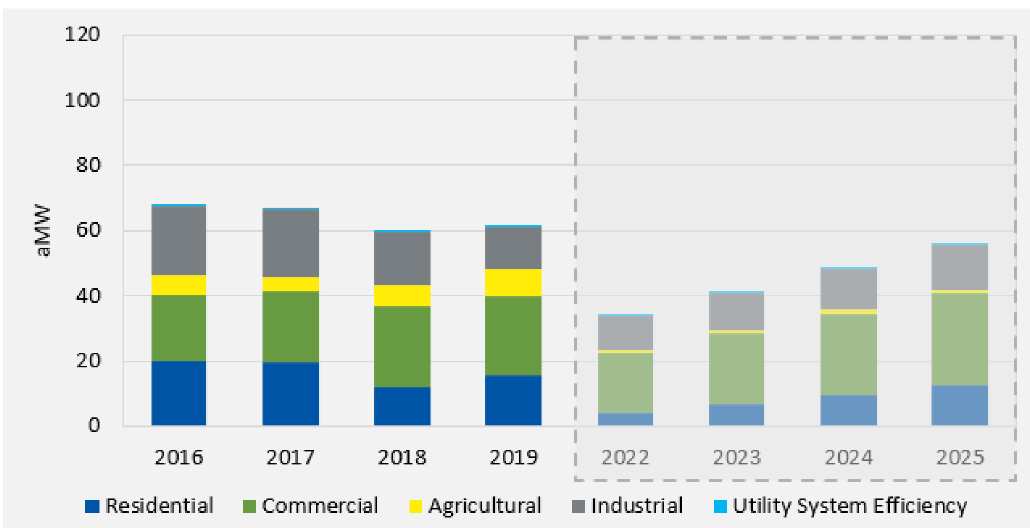


Figure 8. Comparison of Achievable Technical Potential Under $50 per MWh to Past BPA Achievement



The following sections highlight some of the key findings in each sector. The *Detailed Results and Discussion* contains more information on these results.

Residential	The amount of lighting potential identified in the 2021 BPA CPA decreased from the last CPA because of increasing baselines. The baselines were driven by the market saturation of LEDs and standards for many screw-in lamp types in Washington state. There is potential available in integrated LED fixtures, but it is subject to the same baseline efficiency improvements. The potential in the water heating end use was also greatly impacted by the removal of showerheads. This measure was deactivated by the RTF because of insufficient data to validate savings. They also now fall under a state standard in Washington. The reversion to TMY-based measure savings for weatherization added significant potential compared to the 2021 Power Plan.
Commercial	Lighting continues to make up a sizeable portion of the commercial potential, although it is still subject to rising market baselines. New measures for motor-driven systems, including air compressors, pumps, and fans, have added potential, but these measures are driven by equipment turnover cycles and are therefore acquired more slowly.
Agricultural	The agricultural sector has the smallest potential of any sector. While several new measures were added, it was not enough to overcome declines in the per-unit savings estimates in key irrigation measures.
Industrial	Like the commercial sector, new measures for motor-driven systems and efficient motors have added to the available potential in the industrial sector.
Utility System Efficiency	The BPA CPA used the Council's updated methodology to quantify the potential associated with conservation voltage reduction (CVR). The overall potential in this area is still small overall.

Comparison to BPA's 2018 CPA

BPA's 2018 CPA identified potential achievable technical potential from 2020 to 2039. To allow for a more meaningful comparison to the 2018 BPA CPA results, the 6-year and 20-year 2021 BPA CPA values, shown in Table 3, reflect the start year of 2024.

Table 3. Comparison of 2021 BPA CPA to 2018 BPA CPA

Study	6-Year Cumulative Achievable Technical Potential		20-Year Cumulative Achievable Technical Potential	
	aMW	% of Baseline	aMW	% of Baseline
2021 CPA	717	8.2%	2,207	23.0%
2018 CPA	675	7.1%	1,812	18.4%

Note: 6- and 20-year table values for the 2021 CPA correspond to 2024 through 2029 and 2043, respectively.

Several key differences led to the change in achievable technical potential between the two BPA CPAs:

- The 2018 BPA CPA was based on the Council's Seventh Power Plan, with significant RTF updates since they were available at the time of the analysis. The 2021 BPA CPA was based on the Council's 2021 Power Plan and had some RTF updates, mainly around residential lighting and FMY impacted measures to revert to a TMY-based analysis. A new tier of heat pump water heaters was added for residential sector.
- The 2018 BPA CPA represents a start year of 2020; therefore, the corresponding ramp rates from the Council's Seventh Power Plan start in the fifth year of the ramp, whereas the 2021 BPA CPA starts in the third year (2024) of the 2021 Power Plan ramps.
- The 2021 Power Plan maximum achievability factor now varies between 85% and 100% depending on whether the measure is subject to future codes or standards. The 2018 BPA CPA used a maximum achievability factor of 85% across the board.

Table 4 shows additional granularity for the 2018 and 2021 BPA CPA results by sector.

Table 4. Comparison of 2021 BPA CPA to 2018 BPA CPA by Sector

BPA Sector	2018 BPA CPA Cumulative Achievable Technical Potential (aMW)		2021 BPA CPA Cumulative Achievable Technical Potential (aMW)	
	6-Year (2020 to 2025)	20-Year (2020 to 2039)	6-Year (2024 to 2029)	20-Year (2024 to 2043)
Residential	292	920	345	1,155
Commercial	235	542	231	654
Agricultural	17	39	10	30
Industrial	121	243	117	288
Utility System Efficiency	10	67	15	80
Total	**675**	**1,812**	**717**	**2,207**

Note: Years shown represent the years of the Resource Program.

Comparison to Draft 2021 Power Plan

The Council's draft BPA 2021 Power Plan identified achievable technical potential from 2022 to 2041. As such, Table 5 shows the 6-year and 20-year values with a start year of 2022 to allow a more meaningful comparison to the 2021 Power Plan.

Table 5. Comparison of 2021 BPA CPA to Council's Draft BPA 2021 Power Plan

Study	6-Year Cumulative Achievable Technical Potential		20-Year Cumulative Achievable Technical Potential	
	aMW	% of Baseline	aMW	% of Baseline
2021 CPA	550	8.2%	2,167	22.9%
Council's Draft BPA 2021 Power Plan	508	5.9%	1,971	20.8%

Note: 6- and 20-year table values for the Council's draft BPA 2021 Power Plan and the 2021 BPA CPA correspond to 2022 through 2027 and 2041, respectively

Several key differences led to the change in achievable technical potential between the Council's draft BPA 2021 Power Plan and the 2021 BPA CPA:

- The Council's draft BPA 2021 Power Plan results reflect the same measure sources as the draft 2021 Power Plan workbooks. While these workbooks were the basis for 2021 BPA CPA, the Cadmus/Lighthouse team made minor RTF updates where updated RTF measure characterization inputs were relatively easy to incorporate into the Council's existing workbooks.
- The Council's draft BPA 2021 Power Plan results reflect climate change driven FMY inputs whereas the 2021 BPA CPA results removed these climate change impacts to reflect TMY inputs. These adjustments were made either from updating to RTF workbook results or removing the FMY adjustment factor from measure characterization calculations.
- The number of residential buildings, commercial square feet, industrial sales, and other forecast updates were made to the Council's draft BPA 2021 Power Plan. These were based on the most recent available data provided by BPA.
- The latest NEEA CBSA 4 results were not fully incorporated into the Council's draft BPA 2021 Power Plan measure characterization or supply curves. Where possible, without significant workbook revisions, the latest CBSA results were incorporated into 2021 BPA CPA commercial results.

Table 6 shows additional granularity for the Council's draft BPA 2021 Power Plan and 2021 BPA CPA results by sector.

Table 6. Comparison of 2021 BPA CPA to Council's Draft BPA 2021 Power Plan by Sector

BPA Sector	Council's Draft 2021 Power Plan Cumulative Achievable Technical Potential (aMW)		2021 BPA CPA Cumulative Achievable Technical Potential (aMW)	
	6-Year (2022 to 2027)	20-Year (2022 to 2041)	6-Year (2022 to 2027)	20-Year (2022 to 2041)
Residential	200	955	230	1,106
Commercial	197	660	199	659
Agricultural	7	27	9	30
Industrial	97	261	105	299
Utility System Efficiency	7	69	7	74
Total	**508**	**1,971**	**550**	**2,167**

Note: 6- and 20-year table values for the Council's draft BPA 2021 Power Plan and the 2021 BPA CPA correspond to 2022 through 2027 and 2041, respectively.

Methodology

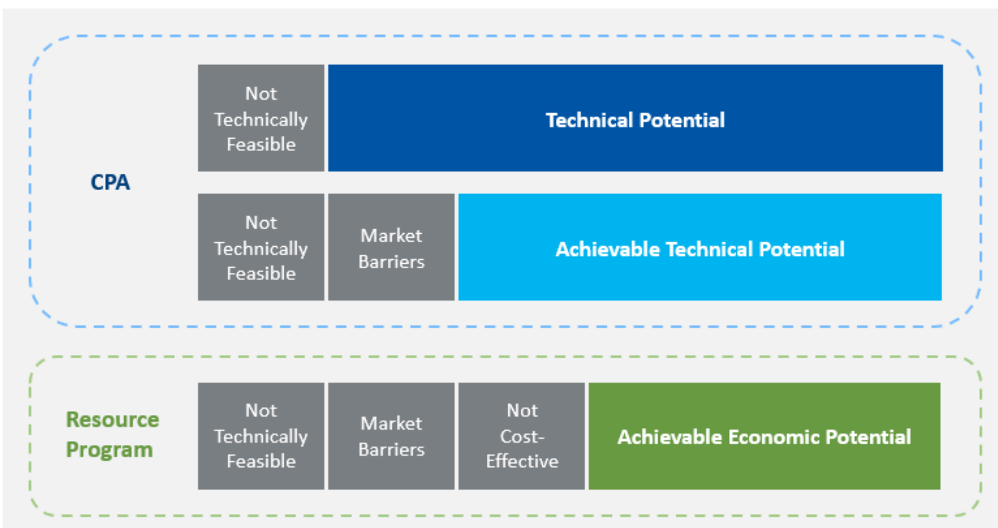
For the CPA, the Cadmus/Lighthouse team based its methods and models on those employed by the Council to develop the 2021 Power Plan. Specifically, the team developed conservation potential supply curve workbooks that replicate the calculations used for the 2021 Power Plan and incorporate BPA-specific market data (e.g., saturations, fuel shares, applicability factors, sector customers and loads) and planning assumptions (economic inputs and ramp rates). The overall goal was to provide the Resource Program with the most up-to-date estimates of conservation potential using the best data available, including any changes since the completion of the draft 2021 Power Plan supply curves.

The following sections describe the calculations for technical and achievable technical potential, identify the data sources for components of these calculations, and discuss key global assumptions.

Definitions of Potential

As shown in Figure 9, the CPA involved quantifying two of the three types of potential commonly identified in conservation potential studies—technical potential and achievable technical potential.

Figure 9. 2021 CPA and Types of Conservation Potential



The three types of potential are defined below.

Technical potential assumes that all technically feasible resource opportunities may be captured, regardless of their costs or other market barriers. It represents the total conservation potential in a service territory, after accounting for only technical constraints.

Achievable technical potential is the portion of technical potential that might be assumed achievable during the study forecast horizon, regardless of the acquisition mechanism. For example, savings may be acquired through utility programs, improved codes and standards, or market transformation.

Achievable economic potential is the portion of achievable technical potential determined to be cost effective. In this CPA, this will be done through the Resource Program's optimization modeling, which will select either bundles or individual conservation potential measures based on their cost and savings.

The team's primary objective for the assessment was to develop the conservation supply curves to inform BPA's Resource Program optimization modeling. The supply curves document the achievable technical potential, and the Resource Program optimization modeling will identify which measures are part of a resource mix that balanced cost and risk (Figure 9).

Comparison of Methodology to 2021 Power Plan

To conduct this study, the team built upon on the analysis and methods in the Council's draft 2021 Power Plan for the BPA scenario, while incorporating up-to-date measure assumptions and additional BPA-specific market data where possible. Table 7 identifies key components of the study and how they relate to the 2021 Power Plan. The column headers *Consistent with 2021 Power Plan* and *Modified from 2021 Power Plan* reflect approaches, assumptions, or data taken as-is from the 2021 Power Plan or modified slightly. Further discussion of each key component follows Table 7.

Table 7. Comparison of Data Sources and Methods

Key Components	Consistent with 2021 Power Plan	Modified from 2021 Power Plan	New Data/Approach
Potential Calculation Methodology	✓		
2021 Power Plan Measure List	✓		
New/Revised Regional Technical Forum (RTF) Measures			✓
Measure Savings		✓	
Codes and Standards		✓	
Load Forecast			✓
Market Data			✓
Economic/Financial Data		✓	

Potential Calculation Methodology: The Cadmus/Lighthouse team used the same methodology to calculate potential as the Council's 2021 Power Plan and developed analytical workbooks that follow the same structure as the 2021 Power Plan supply curve workbooks. While the general methods were the same, the team changed inputs if newer or more granular BPA-specific data were available.

2021 Power Plan Measure List: The Cadmus/Lighthouse team started with the list of measures included in the 2021 Power Plan. However, after the completion of the Plan's draft supply curve files, the RTF updated some unit energy savings (UES) measures. The team updated 2021 Power Plan measures with changes approved by the RTF at the December 8, 2020 meeting.

Measure Savings: The Cadmus/Lighthouse team used the 2021 Power Plan's BPA scenario supply curve files as the starting point for this analysis and modified the measure UES estimates to reflect the recent RTF updates, as well as align with climate change impacts incorporated in the Resource Program. The team used measure savings based on TMY data wherever possible instead of the FMY-based savings included in the 2021 Power Plan.

Codes and Standards: The 2021 Power Plan considered codes and standards adopted before January 2021. The team considered changes to code or standards subsequent to this date.

Load Forecast: BPA provided load forecast information to the Council for the 2021 Power Plan, which Council staff then modified. Since the Cadmus/Lighthouse team relied on a units approach to determine energy efficiency potential, it did not use the load forecast as a primary input in the analysis. Instead, it used BPA's econometric load forecast[2] and new statistically adjusted end-use (SAE) forecast as important points of comparison for estimates of conservation potential.

The Cadmus/Lighthouse team estimated the initial sector-specific stock counts (e.g., number of homes, commercial floor area) using a variety of data sources, including the 2021 Power Plan materials, BPA data, regional stock assessments, and census data. The team relied on BPA's sector-specific growth rates, based on BPA's overall load forecast and estimate of future climate change impacts.

Market Data: The Cadmus/Lighthouse team used recent market data from regional stock assessments, RTF research, and BPA's evaluation research to inform the CPA inputs. One of the primary changes from the 2021 Power Plan was the use of the 2020 Commercial Building Stock Assessment 4 (CBSA 4) data, which the Northwest Energy Efficiency Alliance made available after the completion of the draft 2021 Power Plan supply curves. The team collaborated with the Council on the development of data for these updates.

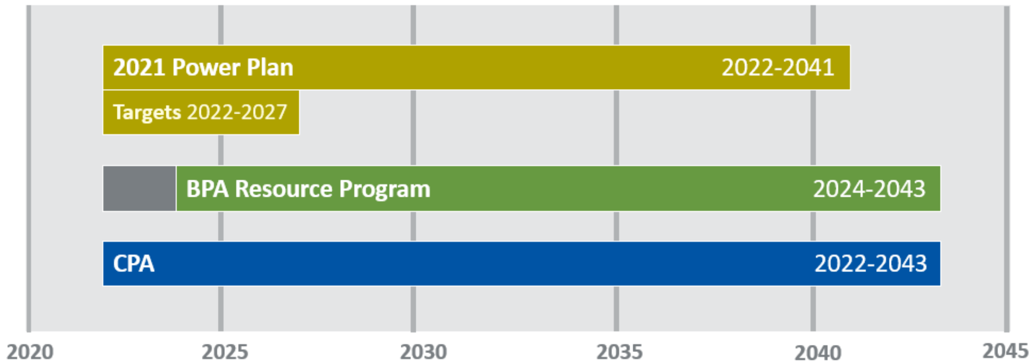
Economic and Financial Data: The Cadmus/Lighthouse team used updated economic and financial assumptions, such as discount rates, the base year for real dollars, and incentive levels to reflect BPA-specific values. For some assumptions, however, the team used the same values as the 2021 Power Plan (for instance, the team will apply a 20% administrative cost adder). *Appendix A* includes the economic and financial assumptions.

Study Timeframe

The Cadmus/Lighthouse team assessed conservation potential for the 22-year timeframe from 2022 through 2043, which covers the time periods for both the 2021 Power Plan and BPA's Resource Program. Figure 10 illustrates how these two timelines relate.

[2] BPA's econometric load forecast assumes average (1:2) weather and that loads continue unchanged past 2028.

Figure 10. Study Timeline



Note: The figure shows fiscal years.

Incorporating BPA's Load Forecast

As noted, the Cadmus/Lighthouse team used BPA's load forecasts as a point of comparison for estimates of conservation potential. The team compared aggregated estimates of conservation potential to BPA's forecasted loads to ensure they were reasonable and aligned with similar assessments. Typically, conservation potential assessments identify technical potential that is equivalent to between 20% and 40% of forecasted load. The team did not use BPA's load forecast as a direct input into conservation potential modeling.

BPA produces load forecasts for each of its customer utilities and is moving from an econometric approach to a SAE model. As of October 2020, BPA has developed SAE forecasts for approximately 25% of its customer utilities. BPA's econometric load forecast does not provide the granularity required for conservation potential modeling (i.e., these forecasts are not disaggregated by sector). While the SAE forecasts provide more granularity, complete data were not available for this study.

As such, the team developed initial total stock counts, prior to segmentation, for the residential, commercial, and agricultural sectors by applying ratios to the regional counts developed for the draft 2021 Power Plan. Beyond the initial year, the team incorporated sector-specific growth rates to project future growth in each sector. The team worked with BPA to ensure that these growth rates were consistent with BPA's overall load forecast and assumptions about climate change impacts within the study period. For the industrial and utility distribution sectors, BPA used information from both the Council and BPA to develop sector-level estimates. The team used different growth rates than the Council as BPA's load forecast does not assume the same level of climate change impacts as the 2021 Power Plan.

The Cadmus/Lighthouse team compared the treatment of standards in BPA's load forecast to the standards included in the analysis. BPA's SAE model assumes gradual improvement in end-use efficiency, which are partially driven by building energy codes and future equipment standards. The team's review of standards in the load forecast helped to ensure it did not double count their impact.

Steps for Estimating Potential

The Cadmus/Lighthouse team followed these series of steps in its approach:

- **Conduct Segmentation.** The team identified the regions, sectors, and segments for estimating conservation potential in the Council's 2021 Power Plan draft BPA scenario supply curves. This allowed the team to account for variation across different parts of BPA's service territory as well as different applications of conservation measures. See the *Segmentation* section below for more detail.
- **Update BPA-Specific Supply Curves.** The team updated the Council's 2021 Power Plan draft BPA scenario supply curves and the recently updated RTF UES measures. The latest RTF measure definition included updated clothes washers and excluded showerheads to align with the RTF's recent decision to deactivate this measure. See the *BPA-Specific Supply Curves* section for an overview of the components and data sources the team used to estimate measure savings, costs, applicability factors, and lifetimes, as well as baseline assumptions and the treatment of federal and state standards.
- **Develop Units Forecasts.** The team developed units forecasts that vary by sector and measure and reflect the number of units that could be installed for each measure. The *Units Forecasts* section presents the data sources and the approach the team used to forecast the number of units for each sector and measure.
- **Calculate Levelized Costs.** The Resource Program optimization modeling will require levelized costs to compare energy conservation to supply-side resources. The team used ProCost to estimate levelized costs from the Total Resource Cost (TRC)[3] and Utility Cost Test (UCT) perspectives. The *Calculation of Levelized Costs* section discusses the components and assumptions the team used to calculate the levelized costs.
- **Calculate Technical and Achievable Technical Potential**. The Cadmus/Lighthouse team developed technical potential forecasts using the sector-specific units forecasts and the measure data compiled from the prior steps. The team used a similar equation to develop achievable technical potential forecasts, plus additional maximum achievable factors and ramp rates to account for market barriers and ramping of conservation potential. See the *Calculation of Technical and Achievable Technical Potential* section for details.
- **Bundle Resource Program Inputs.** The team bundled forecasts of achievable technical potential by levelized costs and other measure characteristics (e.g., technology/activity/practice [TAP]) to enable BPA's Resource Program staff to model and compare conservation equally to other supply- and demand-side resources. See the *Resource Program Inputs* section for more information.

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[3] The Cadmus/Lighthouse team modified the TRC used in this analysis to be consistent with the Council's Northwest Resource Cost (NRC) test.

Segmentation

To segment BPA's service territory, the Cadmus/Lighthouse team used the same sectors, residential home types, commercial building types, and industry definitions included in the 2021 Power Plan—this allowed the team to use segment-specific costs and savings consistent with the Plan. The team started with the segmentation from Council's 2021 Power Plan BPA scenario supply curve workbooks and updated it with new and more specific BPA data wherever possible. BPA's territory includes of all BPA customer load regardless how that load is served; new large single loads have been excluded. More detail on the team's methodology for each sector is described in the *Units Forecast* section below.

There were, however, practical limits to the extent the Cadmus/Lighthouse team could segment BPA's service territory. The team developed many of the conservation measure inputs using primary data, such as the Northwest Energy Efficiency Alliance's CBSA 4 and the 2018 Residential Building Stock Assessment 2 (RBSA 2). When analyzing these data sets, the team ensured that sample sizes remained large enough to produce statistically robust estimates.

For weather-sensitive measures, the Cadmus/Lighthouse team considered the same three cooling zones and heating zones used in the 2021 Power Plan. Table 8 lists the different possible combinations of heating and cooling zones and shows the assumed heating degree days and cooling degree days for each combination. These definitions are based on the current RTF definitions.

Table 8. Climate Zones

Climate Zone	Heating Degree Days (Hourly Calculation)	Cooling Degree Days (Hourly Calculation)
Heating 1 - Cooling 1	<6,000	<300
Heating 1 - Cooling 2	<6,000	>300-949
Heating 1 - Cooling 3	<6,000	>950
Heating 2 - Cooling 1	6,000-7,499	<300
Heating 2 - Cooling 2	6,000-7,499	>300-949
Heating 2 - Cooling 3	6,000-7,499	>950
Heating 3 - Cooling 1	>7,500	<300
Heating 3 - Cooling 2	>7,500	>300-949
Heating 3 - Cooling 3	>7,500	>950

The team did not develop separate sector-level units forecasts for each climate zone. Instead, where a measure uses an average UES estimate (weighted by climate zone), the team calculated BPA-specific weights. Also, if a measure had different applicability factors across climate zones, the team developed BPA-specific values for each climate zone.

BPA-Specific Supply Curves

This section describes the approach to updating the BPA-specific supply curves developed by the Council for the 2021 Power Plan.

Overview and Components

In each sector, the Cadmus/Lighthouse team compiled energy efficiency datasets that include the unit energy savings, costs, measure lives, non-energy impacts, and applicability factors for each energy conservation measure. Specifically, these datasets included the following information for each measure permutation:

- **UES.** The team used the UES from the Council's 2021 Power Plan BPA scenario supply curve workbooks. Where applicable, the team updated these with any new information from the RTF. For measures where regional values are inputs into the derivation of UES values, the team updated calculations with BPA-specific data. BPA's current forecasts do not include the same level of climate change impacts as the Council in the near future. For example, BPA projects a slower rate of air conditioning adoption and is using the past 15 years of weather instead of the Council's modeling of future weather. Accordingly, for measures where the Council adjusted unit savings based on future climate change impacts, the team backed out these impacts where practical.
- **Costs and Non-Energy Impacts.** The team used cost data from the 2021 Power Plan workbooks. Where applicable, the team updated these with new information from the RTF.
- **Effective Useful Lives.** Effective useful life is the expected lifetime (in years) for an energy efficiency measure from the 2021 Power Plan. Where applicable, team updated these with new information from the RTF.
- **Applicability Factors.** Where possible, the team calculated new BPA-specific applicability factors using regional stock assessment data for each measure to ensure that units forecasts reflect the characteristics of BPA's service territory. The decision to make updates was based on whether a difference between BPA and regional estimates is meaningful and whether the data are sufficient to product a statistically-significant BPA-specific estimate.
- **End-Use Savings Percentage (industrial only).** The team relied on estimates included in the Council's 2021 Power Plan industrial tool.
- **Savings Shape.** The team used the same savings shapes and mapping of savings shapes to measures as the 2021 Power Plan.
- **BPA TAP Category.** The team mapped TAP categories to each measure to allow for TAP-level reporting. It was not possible to map each measure to each of the TAP categories due to differing granularities in measure definition and TAP categories.

Table 9 summarizes each component listed above and identifies the main sources.

Table 9. Conservation Measure Components and Sources

Component	Sources
Unit Energy Savings	2021 Power Plan and RTF
Costs and Non-Energy Impacts	2021 Power Plan and RTF
Effective Useful Lives	2021 Power Plan and RTF
Applicability Factors	RBSA 2; CBSA 4
End-Use Savings Percent	2021 Power Plan
Savings Shape	2021 Power Plan
BPA TAP Category	Cadmus/Lighthouse mapping using BPA's *UES Measure List Version 9.0*

Units Forecasts

This section describes how the Cadmus/Lighthouse team developed a forecast of BPA-specific units, beginning from the initial segmentation described above.

General Approach

The team developed a 22-year forecast (2022 through 2043) of the number of units that could feasibly be installed for each permutation of each energy efficiency measure in the 2021 Power Plan. This approach followed the Council's approach for each of the retrofit, natural replacement, and new construction measure installation types.[4]

The measure-specific units forecast the team used to estimate technical potential relied on four factors. Each factor is described below, along with how they were updated for this CPA.

Sector-units forecasts are estimates of the number of homes (residential) or amount of floor space (commercial), industrial load, or agricultural production. The team updated these with the results of the segmentation analysis described above. The team also applied growth rates developed collaboratively with BPA load's forecasting team to project growth over the 22-year study period. Additional detail on how the team developed the units forecast is discussed in the next section.

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4 Retrofit measures are applicable to opportunities where the baseline condition is generally always available. Weatherization measures are examples of retrofit measures. Natural replacement measures are measures that are generally only available when equipment has reached the end of its useful life. For example, homeowners are unlikely to replace a working water heater that is not at the end of its useful life. Similarly, new construction measures are only available when homes or commercial buildings are being constructed. Natural replacement and new construction measures are often referred to together as lost opportunity measures.

Unit density (units per sector unit) are estimates of the number of equipment units per sector unit (per home or per square foot) within BPA's service territory. The team calculated these using data from CBSA 4 and RBSA 2. This factor is generally only applicable to the residential and commercial sectors.

To account for the effects of climate change, the team assumed all households will having cooling equipment—either through heat pump, ductless heat pump, central air conditioning, or room air conditioners—by 2050, which is consistent with BPA's load forecast.

***Applicability factor (technical feasibility times baseline saturation of measure*)** is the product of the technical feasibility (the percentage of units that can feasibly receive the measure) and the base saturation of the measure (the percentage of eligible installations where the measure has not already been installed). The team used the Council's assumptions for these values.

Turnover rates (for natural replacement measures) are used to determine the percentage of units that can be installed in each year for natural replacement measures. Turnover rates equal one divided by the measure life. Because the team used the 2021 Power Plan values for measure life, the assumptions for turnover also followed the Power Plan.

Figure 11 illustrates the general equation the team used to determine the number of units for each measure over the study forecast horizon. By default, the turnover rate for retrofit and new construction measures will equal 100% as turnover was not accounted for in these permutations.

Figure 11. Units Forecasts Equation

Units forecasts relied heavily on data that represent BPA's service territory and not regional forecasts produced for the 2021 Power Plan regional scenario, as shown in Table 10. By using BPA-specific units forecast and the 2021 Power Plan's UES values, the team produced granular BPA-specific estimates while preserving consistency with 2021 Power Plan baselines.

Table 10. Units Forecasts Components and Data Sources

Component	Data Source	Specific to BPA's Service Territory?
Sector Units	BPA load forecasts; regional stock assessments; BPA utility customer data (when available)	Yes
Unit Density	BPA load forecasts; regional stock assessments; BPA utility customer data (when available)	Yes
Applicability Factor	Regional stock assessments; BPA utility customer data (where available)	Yes
Turnover Rate	2021 Power Plan supply curve workbooks	No; turnover rate is a function of measure life, which will be the same as those used in the 2021 Power Plan.

Units Forecast in Each Sector

This section outlines the Cadmus/Lighthouse team's method for developing units forecasts in each sector. Like the Council's analysis, this CPA considered energy efficiency first. Adoption of demand response measures will not drive any changes in the adoption of energy efficiency.

Residential

The team developed 22-year forecasts (2022 to 2043) of the number of single-family, multifamily low-rise, multifamily high-rise, and manufactured homes in BPA's service territory. The team derived separate forecasts for each segment. First, the team used U.S. Census Bureau American Community Survey data to determine the number of households (for each segment) in each zip code within BPA's service territory. Then, the team aggregated these data by segment and region to determine the share of households in BPA's service territory in 2022. To determine household projections beyond 2022, the team applied growth rates provided by BPA. The forecasts also incorporated the demolition rates used by the Council in the 2021 Power Plan. These demolition rates specify the share of existing units that were demolished and removed from the existing building stock.

Commercial

The team produced 22-year floor space (square feet) forecasts for each commercial segment. The approach started with the virtual catalogue developed for the CBSA 4, which the team used to determine BPA's share of regional floor area by building type. Like the residential sector, the commercial forecast incorporated growth rates provided by BPA and the demolition rate used by the Council in the 2021 Power Plan.

Industrial

In the industrial sector, the team produced energy (MWh) forecasts for the 22-year study horizon. The team used the initial load estimates developed by the Council, verifying and updating the values with updated information provided by BPA.

In the 2021 Power Plan, the Council included new measures that were based on an estimated regional share of national shipment data. For these measures, the team calculated BPA's share of Northwest regional values by calculating BPA's share of industrial loads. This follows the methodology used by the

Council in the BPA scenario. Industrial growth rates over the study period were based on load growth rates provided by BPA.

Agricultural

The team produced forecasts for the irrigation, area light, and dairy segments in the agriculture sector. Depending on the measure, the team either developed estimates for BPA's service territory directly from the 2017 Census of Agriculture or used BPA shares of the state-level estimates developed by the Council. The team developed the estimates using county- and zip-code level data from the 2017 USDA Census of Agriculture and a database of utility service territories by zip code that covered BPA's service territory, some of which extends beyond the Columbia basin. The team then applied growth rates provided by BPA to forecast these estimates through the 22-year study period.

Utility

For the utility sector, the team used the BPA-specific assignment of utilities used in the 2021 Power Plan. The Council calculated savings in this sector by estimating the quantity of distribution system equipment based on the loads of each utility.

Calculation of Levelized Costs

For each energy efficiency measure, the Cadmus/Lighthouse team calculated levelized cost of energy ($/MWh) from a TRC and UCT perspective. By determining the levelized cost for each measure, the team produced energy efficiency supply curves and measure bundles to include in BPA's Resource Program modeling. The calculation of levelized cost included all values considered in the 2021 Power Plan that were not accounted for in the Resource Program modeling. Table 11 summarizes the various components of the levelized cost and whether they are accounted for in the CPA-calculated levelized cost or Resource Program, and whether or not they are considered in the TRC or UCT perspective.

Table 11. Levelized Cost Components

Cost or Benefit	Component	Source/Value	Incorporated in CPA analysis or Resource Program?	TRC	UCT
Cost	Capital, Labor, and Incentives	Capital and labor vary by measures, and incentives are 60% of incremental measure cost; 2021 Power Plan and RTF	CPA	Yes	Yes, only portion covered by the utility and/or BPA in an incentive
	Annual Operations and Maintenance (O&M)	Varies by measure; 2021 Power Plan and RTF	CPA	Yes	Yes, only portion covered by the utility and/or BPA in an incentive
	Program Administration	20% of incremental measure costs	CPA	Yes	Yes
	Periodic Replacement	Varies by measure; 2021 Power Plan and RTF	CPA	Yes	No
	Other Fuel Costs	Varies by measure; 2021 Power Plan and RTF	CPA	Yes	No
	Non-Energy Impacts	Varies by measure; 2021 Power Plan and RTF	CPA	Yes	No
Benefit	Avoided Energy Costs	BPA Resource Program modeling	Resource Program	Yes	Yes
	Deferred Transmission and Distribution (T&D) Expansion	T: $1.50/kW-yr (2016 dollars) D: $6.85/kW-yr (2016 dollars)	CPA	Yes	Yes
	Regional Act Credit	10%	Resource Program	Yes	Yes
	Deferred Generation Capacity Investment	BPA Resource Program modeling	Resource Program	Yes	Yes
	Avoided Periodic Replacement	Varies by measure; 2021 Power Plan and RTF	CPA	Yes	No
	Other Fuel Benefits	Varies by measure; 2021 Power Plan and RTF	CPA	Yes	No
	Non-Energy Impacts	Varies by measure; 2021 Power Plan and RTF	CPA	Yes	No
	Risk Mitigation Credit	BPA Resource Program modeling	Resource Program	Yes	Yes

Capital, labor, O&M, periodic replacement, other fuel costs and/or benefits, and non-energy impacts were the same as the 2021 Power Plan. Program administration costs equaled 20% of incremental costs. BPA provided the deferred transmission benefits and the team aligned distribution system deferral benefits with draft 2021 Power Plan values. These values are applied to the capacity contributions of individual measures coincident with the assumed timing of peak demands. Savings included transmission and distribution line losses of 3.1% and 4.74%, respectively.

To calculate levelized costs, the team used ProCost to align with the Council's approach. The approach considered the costs required to sustain savings over a 20-year study horizon, which also aligns with the

20-year period considered for the Resource Program, and included re-installation costs for measures with a useful life under 20 years. The team provided levelized costs in real 2020 dollars and used a real discount rate of 2.12%

Calculation of Technical and Achievable Technical Potential

In calculating the technical and achievable potential, the Cadmus/Lighthouse team followed the Council's methodology. Because the Power Plan only cover 20 years, the team extended the ramp rates to cover the additional time period.

For new construction and lost opportunity measures, the team extended the existing ramp rates to cover the additional years covered by the Resource Program. Most of the Council's lost opportunity ramp rates trend to or reach 100% in the later years of the typical 20-year period. To cover the additional years, the team extrapolated these ramp rates.

Ramp rates for retrofit measures typically sum to 100% over the traditional 20-year study period. Since this CPA covers more than 20 years, the additional years do not provide an opportunity to acquire additional potential through the ramp rate. There is, however, an opportunity to acquire additional potential by achieving above and beyond the assumed maximum achievability.

The Cadmus/Lighthouse team assumed additional potential was available based on the Council's initial assumptions of maximum achievability, detailed below:

- For measures with the traditional maximum achievability of 85%, the team assumed that an additional 4.25% (i.e., 85% divided by 20 years) is available in each of the final years.
- For measures with maximum achievability set to 95%, the team assumed that an additional 2.5% is achieved in each of the final years.
- No adjustment were made for measures with maximum achievability factors of 100%.

Resource Program Inputs

The Cadmus/Lighthouse team developed conservation supply curves that will allow BPA's resource optimization model to identify the cost-effective level of conservation. BPA's optimization model, Aurora, requires hourly forecasts of conservation potential. To produce these hourly forecasts, the team applied hourly savings shapes to annual estimates of achievable technical potential for each measure. These savings shapes are the same as those used in the 2021 Power Plan (including generalized shapes that the team expanded to hourly shapes).

The format of inputs into the resource optimization model will be bundled by the following:

- Levelized cost bin (based on TRC and UCT levelized costs)
- Measure type (retrofit, natural replacement, or new construction)
- End-use group (HVAC, lighting, etc.)

BPA's Resource Program team is considering incorporating additional decision points into the analysis. Including the measure type in the Resource Program inputs will allow BPA to roll forward energy efficiency that was not selected in previous years to be selected later in the study period.

The Cadmus/Lighthouse team will provide savings potential identified for the 2022 to 2023 years as must-take resources, as these years will not be accounted for in the load forecast. Additionally, to align with the BPA load forecast, the team will work with BPA to identify the program savings from half of 2020 and all of 2021 that should also be included in the Resource Program baseline forecast.

Detailed Results and Discussion

This assessment included a comprehensive set of commercially available and vetted conservation measures. The Cadmus/Lighthouse team considered each of the measures included in the 2021 Power Plan, making updates to reflect recent RTF updates, different assumptions on climate change, and BPA-specific data as much as possible. The analysis considered the 22-year time period beginning in 2022 and ending in 2043. However, the results included in this section focus on the 20-year time period that aligns with the BPA's Resource Program, which begins in 2024.

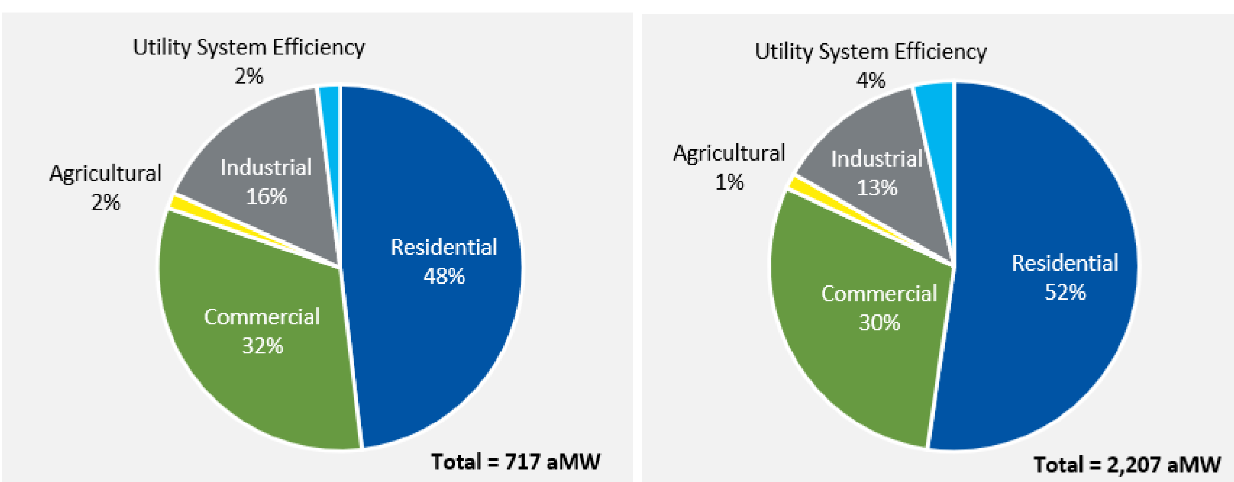
Table 12 illustrates the 6- and 20-year cumulative achievable technical potential for each sector. In total, the Cadmus/Lighthouse team identified 717 aMW and 2,207 aMW of cumulative achievable technical potential over the 6- and 20-year periods, respectively.

Table 12. 6- and 20-Year Cumulative Achievable Technical Potential by Sector

BPA Sector	Cumulative Achievable Technical Potential (aMW)	
	6-Year (2024 to 2029)	20-Year (2024 to 2043)
Residential	345	1,155
Commercial	231	654
Agricultural	10	30
Industrial	117	288
Utility System Efficiency	15	80
Total	**717**	**2,207**

The residential sector accounts for approximately one-half of the total achievable technical potential, with the remaining potential largely split between the commercial and industrial sectors. The utility and agricultural sectors comprise a small portion of the overall potential. Figure 12 illustrates the distribution of total achievable technical potential by sector.

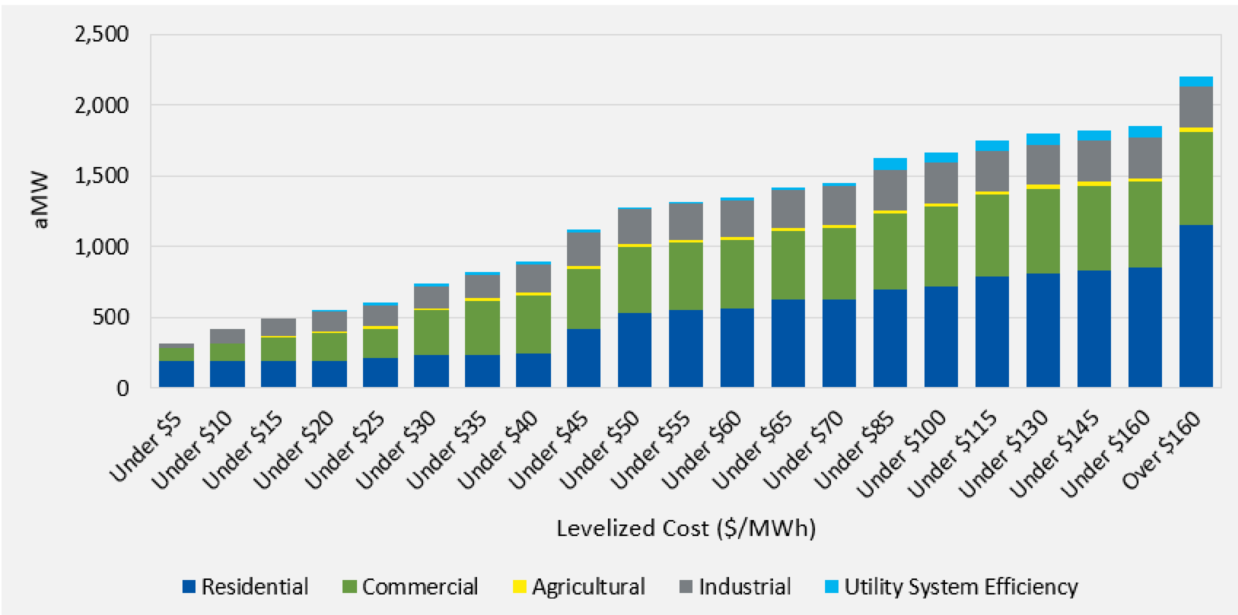
Figure 12. Shares of 6- and 20-Year Achievable Technical Potential by Sector



The distribution of achievable technical potential by sector, however, varies at different cost thresholds. Conservation potential in the commercial and industrial sectors is generally lower cost than in the residential sector. For instance, while the residential sector accounts for approximately one-half of the total achievable technical potential, for measures less than $50/MWh levelized, the residential sector only accounts for 42% of the total potential. The commercial and industrial sectors account for 36% and 19%, respectively, of the total potential. For measures less than $20/MWh, the residential sector only accounts for 35% of the total potential, while the commercial and industrial sectors account for 35% and 25%, respectively, of the total potential.

Generally, the residential sector has more savings from high-cost measures. Figure 13 shows the 20-year cumulative achievable potential by levelized cost and sector.

Figure 13. Achievable Technical Potential Supply Curve by Sector



The Cadmus/Lighthouse team applied ramp rates from the 2021 Power Plan and adjusted them for this study's 2022 to 2043 horizon to determine the incremental achievable technical potential in each year. For natural replacement measures, turnover rates also influence the amount of potential available in each year. The incremental potential begins at approximately 82 aMW in the first year of the Resource Program timeframe (2024) and then increases as the annual achievement is projected to increase, reaching a peak of 158 aMW in 2031. The annual potential then ramps down to 71 aMW in 2040 as the remaining available opportunities diminishes. The available potential drops in 2041 due to limits of maximum potential available but picks back up in 2042 and 2043 due to the additional potential available in the final two years of the 22-year study period.

Average incremental savings over the 20 years is approximately 110 aMW per year. Figure 14 shows incremental achievable technical potential by sector.

Figure 14. Incremental Achievable Technical Potential by Sector

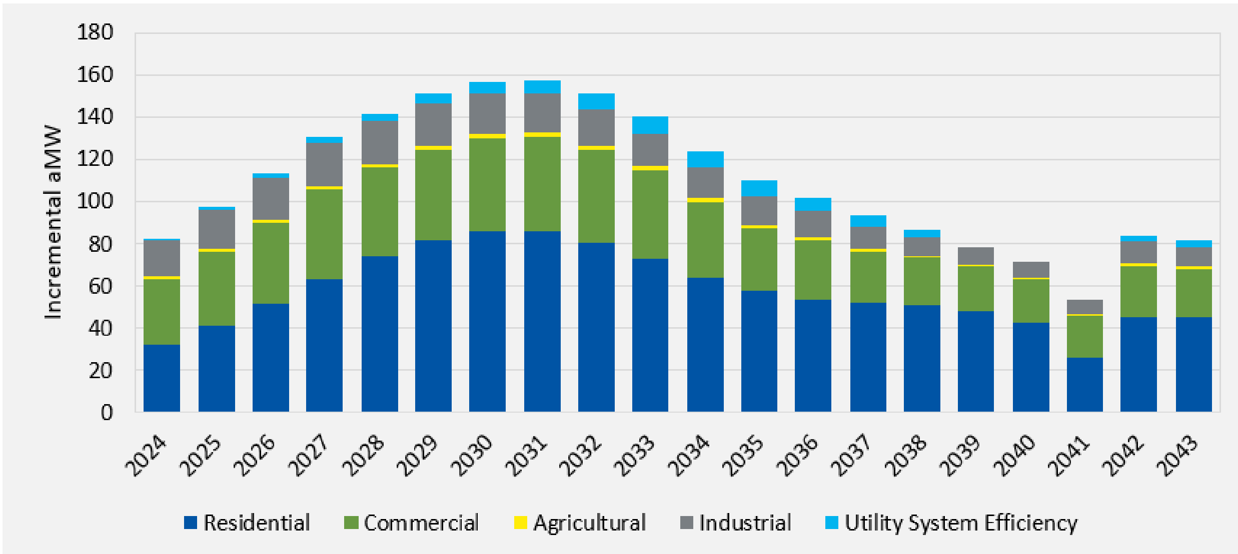
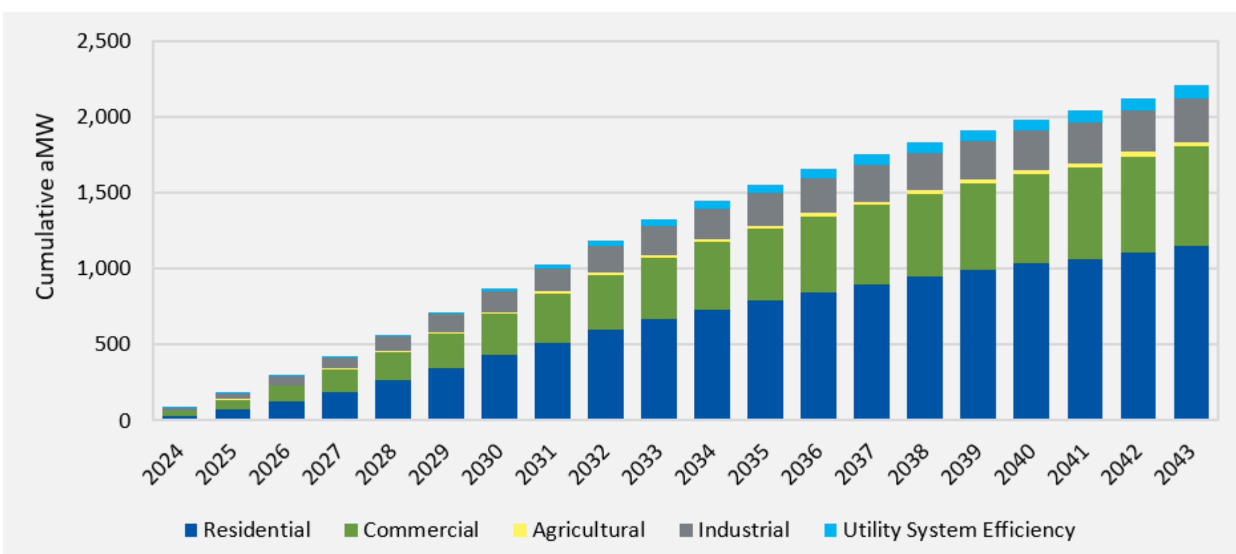


Figure 15 illustrates cumulative achievable technical potential in each year of the Resource Program study horizon. To avoid double-counting the cumulative impact on BPA's load, these estimates exclude the re-installation of energy conservation measures. In effect, once the measures are first installed, savings persist through the remainder of the study horizon. While incremental savings are often used for program planning because they allow planners to estimate the costs associated with energy conservation programs, cumulative savings are often used for resource planning because it represents the total expected reduction in load due to energy conservation. More savings occur within the first 10 years of the study horizon (60% of 20-year cumulative), while the acquisition of savings slows down in the last 10 years.

Figure 15. Cumulative Achievable Technical Potential by Sector



Subsequent sections provide detailed conservation potential results for each sector, including the following information:

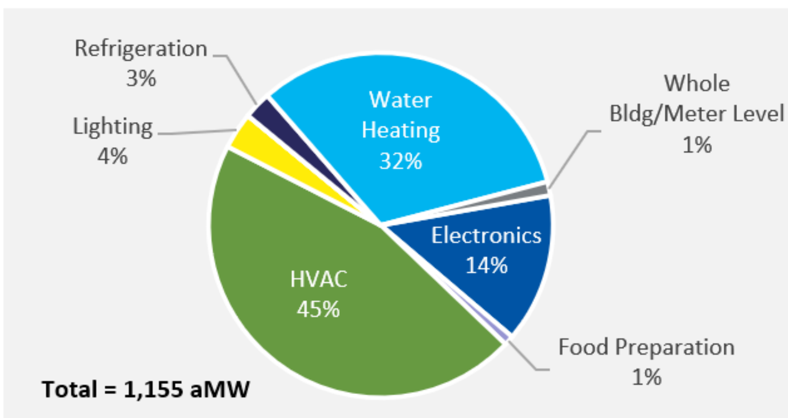
- The distribution of conservation potential by end use
- The total potential and cost for the highest-saving measures
- The sector-specific supply curve
- Factors that influence the potential and costs

Generally, 20-year cumulative achievable technical potential is presented in each section, unless indicated otherwise. All values reflect savings at the busbar.

Residential Sector

The Cadmus/Lighthouse team considered energy efficiency measures in the residential sector for all residential segments and measures in the 2021 Power Plan, except for showerheads (which will be deactivated from the RTF active measure list in the near future). Overall, the team identified 1,155 aMW of achievable technical conservation potential from 2024 through 2043. Most of these savings come from efficiency improvements to HVAC, water heating, and electronic end uses. Figure 16 shows the distribution of residential potential by end use from 2024 through 2043.

Figure 16. Share of 20-Year Residential Achievable Technical Potential by End Use



During analysis, where possible, the team made changes to the HVAC, weatherization, and water heater HVAC interaction savings to adjust calculations from the Council's assumed future meteorological year climate change assumptions to typical meteorological year impacts. These changes allowed the team to calculate achievable technical potential in a manner that aligns with the incorporation of climate change impacts into BPA's load forecast; they included either updating the Council's BPA workbooks to the latest RTF workbook measure characterization savings or removing the future meteorological year adjustment factor for heating and cooling impacts.

Table 13 shows the 6- and 20-year cumulative achievable technical potential in the residential sector, by end use and measure category. Within the residential sector, water heaters, HVAC systems, lighting, envelope improvements, and pumps and fans provide the most potential.

Table 13. Residential Achievable Technical Potential by BPA End Use and Category

BPA Sector	BPA End Use	BPA Category	Cumulative Achievable Technical Potential (aMW)	
			6-Year (2024 to 2029)	20-Year (2024 to 2043)
Residential	Electronics	Computer Technologies	3.9	6.3
Residential	Electronics	Entertainment	8.2	27.1
Residential	Electronics	Plug Load	11.6	128.0
Residential	Food Preparation	Cooking	0.7	10.7
Residential	HVAC	Envelope	93.0	184.1
Residential	HVAC	Heat Recovery	0.1	1.4
Residential	HVAC	HVAC System	133.4	339.1
Residential	Lighting	Lamps/Fixtures	8.8	39.6
Residential	Other	Other	0.0	0.0
Residential	Refrigeration	Freezers	6.7	29.7
Residential	Water Heating	Heat Recovery	0.0	0.8
Residential	Water Heating	Other	0.6	8.2
Residential	Water Heating	Pipe Insulation	0.6	1.3
Residential	Water Heating	Water Heaters	56.5	310.9
Residential	Water Heating	Water-Using Devices	16.3	52.9
Residential	Whole Bldg/Meter Level	Homes	4.3	14.9
		Total	**344.8**	**1,155.0**

Figure 17 illustrates the supply curve for the residential sector from 2024 through 2043.

Figure 17. Residential 20-Year Supply Curve by End Use

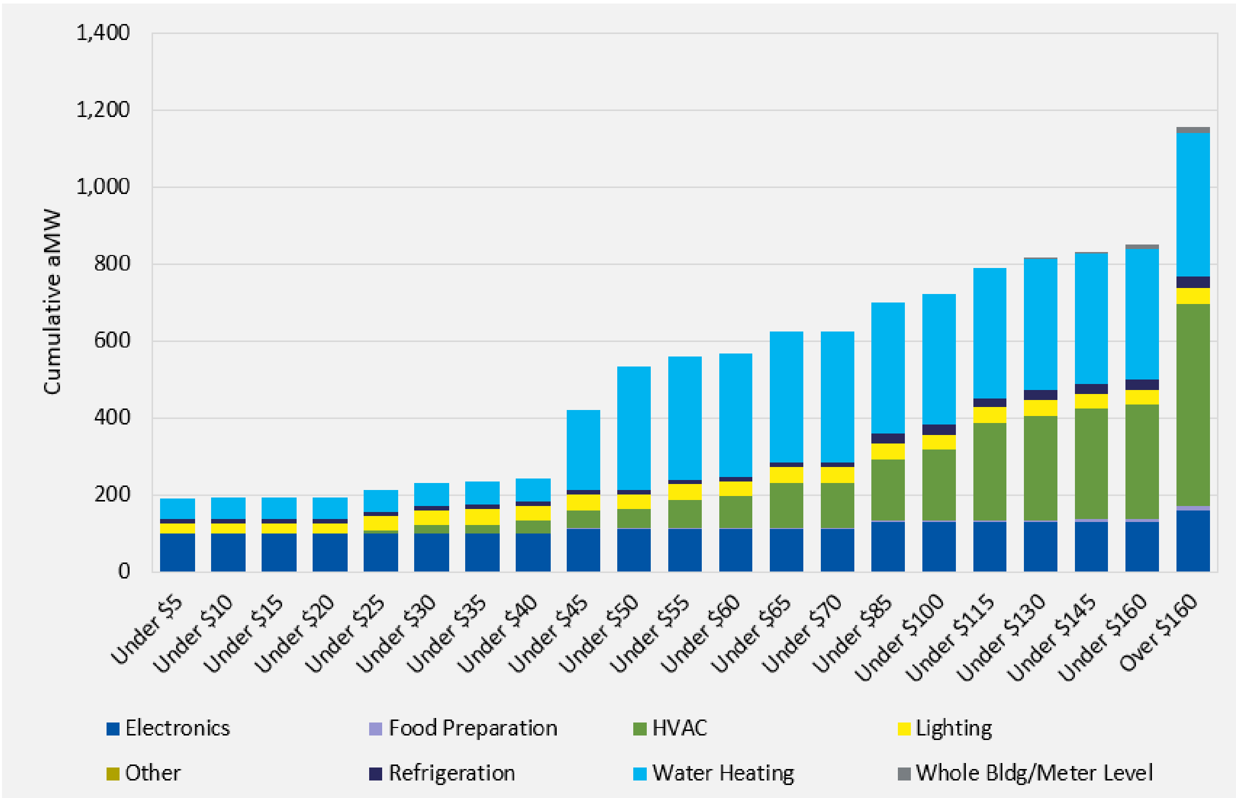


Table 14 shows the residential measure technologies contributing the most achievable technical potential by levelized cost ranges.

Table 14. Significant Residential Achievable Technical Potential by Levelized Cost Buckets

Measure Technology	2021 BPA CPA Cumulative Achievable Technical Potential (aMW)
	20-Year (2024 to 2043)
Levelized cost of $40/MWh or less	
Clothes Dryers	71
Lamps and Fixtures	40
Clothes Washers	31
Weatherization	29
Televisions	27

Measure Technology	2021 BPA CPA Cumulative Achievable Technical Potential (aMW)
	20-Year (2024 to 2043)
Levelized cost between $40 to $45/MWh	
Heat Pump Water Heater	150
Levelized cost between $45 to $160/MWh	
Heat Pump Water Heater	129
Air Source Heat Pumps	74
Weatherization	71
Ductless Heat Pumps	42
Thermostats	40
Levelized cost above $160/MWh	
Ductless Heat Pumps	78
Weatherization	57
Air Source Heat Pumps	52
Heat Pump Water Heaters	32

Key Differences in Residential 2021 BPA CPA and 2018 BPA CPA

Comparison of the 2021 BPA CPA residential potential, with a start year of 2024, to the 2018 BPA CPA, with a start year of 2020, shows the 6-year achievable technical potential increased by 18.2% and the 20-year potential increased by 25.5%. The main difference between the 20-year residential achievable technical potential is largely driven from the following changes to multiple measure categories:

- **Ductless Heat Pumps**. Ductless heat pump potential increased by 72 aMW, which was largely driven from the additional application to multifamily zonal baseboard applications.
- **Heat Pump Water Heaters**. Heat pump water heater potential increased by 56 aMW based on updates to the RTF workbook and changes to the 2021 Power Plan supply curve inputs, such as an increase in electric water heater saturations and an increase in the maximum achievability factor (from 85% to 100%).
- **Weatherization**. Weatherization potential increased by 34 aMW based on updates to the RTF workbooks for all three residential segments.
- **Air Source Heat Pumps**. Air source heat pump potential increased by 15 aMW based on the most recent RTF workbooks. The workbooks include the upgrade to a variable capacity heat pump with 12 heating seasonal performance factor (HSPF) and 18 seasonal energy efficiency ratio (SEER) unit, whereas the highest efficiency in the 2018 CPA was a 9 HSPF and 14 SEER system.
- **Lamps and Fixtures**. Residential lighting potential decreased by 22 aMW based on the Council's and RTF's adjustments to baseline market average wattages. These adjustments reduced overall savings and incremental costs relative to values utilized in the Seventh Power Plan or RTF files available during construction of the 2018 BPA CPA.

- **Showerheads**. Showerhead potential decreased by 22 aMW since the RTF deactivated this measure and the team removed it from this analysis.

Key Differences in Residential 2021 BPA CPA and Council's BPA 2021 Power Plan

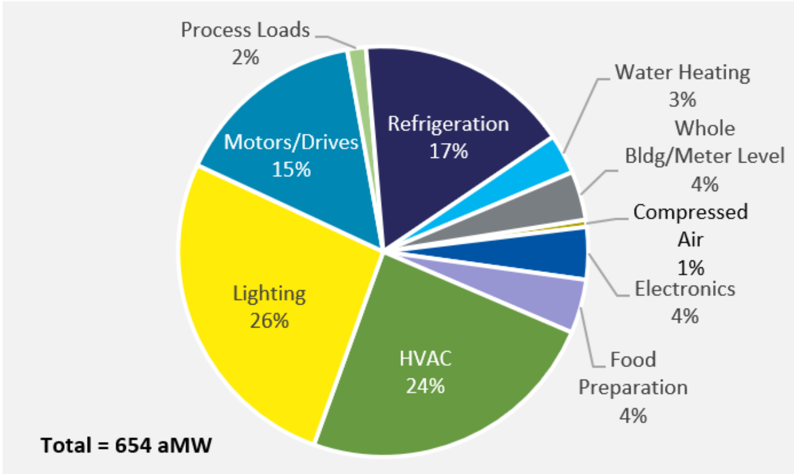
Comparison of the 2021 BPA CPA residential potential, with a start year of 2022, to the Council's BPA 2021 Power Plan, with a start year of 2022, shows the 6-year achievable technical potential increased 15.1% and the 20-year potential increased 15.8%. The main difference between the 20-year residential achievable technical potential is driven by multiple impacts to different measure categories:

- **Heat Pump Water Heaters**. Heat pump water heater potential increased by 112 aMW based on the most recent RTF workbook, which included Tier 4 units rather than Tier 3 units.
- **Weatherization.** Weatherization potential increased by 56 aMW from removing FMY assumptions by converting measures to the most recent RTF workbooks for each residential building type.
- **Air Source Heat Pumps.** Air source heat pump potential increased by 24 aMW based on the most recent RTF workbooks, which removed the FMY impacts applied by the Council.
- **Lamps and Fixtures**. Lighting potential increased by 6 aMW based on updates to specific iterations in the most recent RTF workbook and adjusted supply curve lamps and fixtures per home using BPA-specific RBSA analysis.
- **Clothes Washers**. Clothes washer potential decreased by 21 aMW based on the most recent RTF workbook and updates to the fuel share for water heater and dryers using BPA-specific RBSA data.
- **Heat Pump Dryers.** Dryer potential decreased by 19 aMW based on the most recent RTF workbook.
- **Showerheads.** Showerhead potential decreased by 11 aMW since the RTF deactivated this measure and the team removed it from this analysis.

Commercial Sector

As in the residential sector, the Cadmus/Lighthouse team considered energy efficiency measures in the commercial sector for all 2021 Power Plan commercial segments and measures, except for showerheads (which will be deactivated from the RTF active measure list in the near future). Overall, the team identified 654 aMW of achievable technical conservation potential from 2024 through 2043. Most of these savings come from efficiency improvements to lighting, HVAC, refrigeration, and motor and drive end uses. Figure 18 shows the distribution of commercial potential by end use from 2024 through 2043.

Figure 18. Share of 20-Year Commercial Achievable Technical Potential by End Use



Similar to the residential sector, the team adjusted the commercial sector HVAC, weatherization, and water heater HVAC interaction savings, where possible, to remove the Council's climate change impacts to measure savings.

Table 15 shows the 6- and 20-year cumulative achievable technical potential in the commercial sector, by end use and measure category. Within the commercial sector, lighting, refrigeration system controls, HVAC systems, envelope improvements, and pumps and fans provide the most potential.

Table 15. Commercial Achievable Technical Potential by BPA End Use and Category

BPA Sector	BPA End Use	BPA Category	Cumulative Achievable Technical Potential (aMW)	
			6-Year (2024 to 2029)	20-Year (2024 to 2043)
Commercial	Compressed Air	Compressed Air System Improvements	0.6	3.8
Commercial	Electronics	Computer Technologies	18.8	18.8
Commercial	Electronics	Plug Load	2.3	8.1
Commercial	Food Preparation	Cooking	7.6	27.8
Commercial	HVAC	Envelope	8.2	60.1
Commercial	HVAC	HVAC System Controls	7.4	12.5
Commercial	HVAC	HVAC System Improvements	19.8	84.6
Commercial	Lighting	Lamps/Ballasts/Fixtures	85.6	161.3
Commercial	Lighting	Signs and Signals	6.4	11.5
Commercial	Motors/Drives	Pumps and Fans	18.6	99.7
Commercial	Process Loads	Elevators	0.1	0.5
Commercial	Process Loads	Process Loads System Improvements	4.9	9.1
Commercial	Refrigeration	Packaged Refrigeration	1.9	7.3
Commercial	Refrigeration	Refrigeration System Controls	37.3	103.1
Commercial	Water Heating	Water Heaters	2.1	13.3
Commercial	Water Heating	Water Heating Controls	1.0	4.6
Commercial	Water Heating	Water Using Devices	0.7	2.5

BPA Sector	BPA End Use	BPA Category	Cumulative Achievable Technical Potential (aMW)	
			6-Year (2024 to 2029)	20-Year (2024 to 2043)
Commercial	Whole Bldg/Meter Level	Whole Bldg/Meter Level System Improvements	7.7	25.0
		Total	**230.8**	**653.7**

Figure 19 illustrates the supply curve for the commercial sector from 2024 through 2043.

Figure 19. Commercial 20-Year Supply Curve by End Use

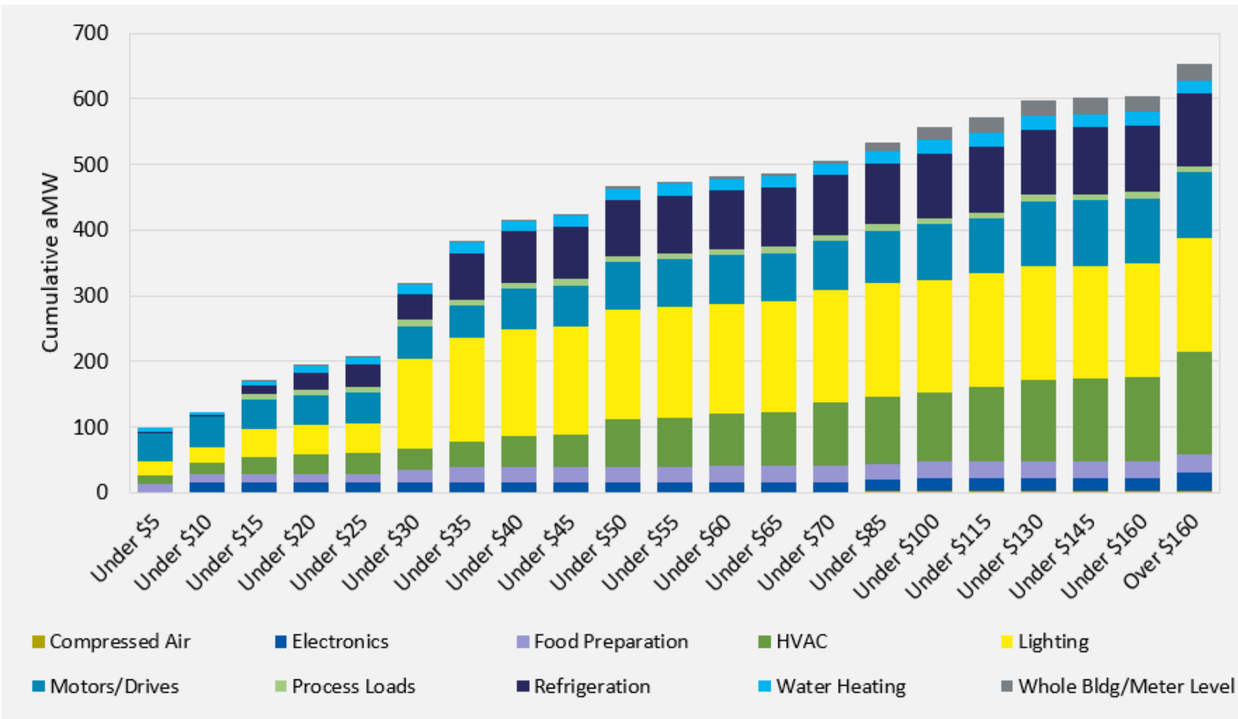


Table 16 shows the commercial measure technologies contributing the most achievable technical potential by levelized cost ranges.

Table 16. Significant Commercial Achievable Technical Potential by Levelized Cost Buckets

Measure Technology	2021 BPA CPA Cumulative Achievable Technical Potential (aMW)
	20-Year (2024 to 2043)
Levelized cost of $25/MWh or less	
Fan Upgrades and Controls	46
Refrigeration Improvements	31
Interior Lighting	29
Unitary Air Conditioning	15
Server and Power Supplies	15
Levelized cost between $25 to $45/MWh	
Interior Lighting	115
Refrigeration Improvements	42
Levelized cost between $45 to $100/MWh	
Very High-Efficiency Dedicated Outdoor Air System	32
Pump Upgrades and Controls	21
Refrigeration Improvements	19
Energy Management System	18
Levelized cost above $100/MWh	
Window Upgrades	32
Pump Upgrades and Controls	16

Key Differences in Commercial 2021 BPA CPA and 2018 BPA CPA

Comparison of the commercial 2021 BPA CPA, with a start year of 2024, to the 2018 BPA CPA, with a start year of 2020, shows the 6-year achievable technical potential decreased 1.9% and the 20-year potential increased 20.6%. The main difference between the 20-year commercial achievable technical potential is a driven to changes to multiple measure categories:

- **Pumps and Fan Improvements and Controls**. Pump and fan potential increased by 42 aMW based on the most recent RTF workbooks; where possible, the team used the Council's draft 2021 Plan BPA workbooks for this analysis.
- **Windows Upgrades**. Window potential increased by 40 aMW based on the 2021 Power Plan, which included triple pane windows and window film savings in addition to the secondary glazing measures already in the Seventh Power Plan.
- **HVAC Technologies**. HVAC end-use potential increased by 34 aMW based on the inclusion of additional HVAC technology applications including unitary air conditioners, chillers, package terminal heat pumps, and air source heat pumps.
- **Heat Pump Water Heaters**. Heat pump water heater potential increased by 12 aMW based the measures included in the 2021 Power Plan, which included application of heat pump water heaters to both residential-sized and commercial water heaters.

- **Lighting Improvements**. Lighting potential decreased by 19 aMW overall from the various lighting technologies. The largest decrease was seen in exterior lighting technologies which saw 40 aMW decrease relative to a 2018 BPA CPA potential of 49 aMW. This decrease was offset by the increase of interior lighting improvements and controls technologies which saw 22 aMW increase relative to the 2018 BPA CPA potential of 124 aMW. The remaining delta is the result of various other lighting technologies including parking garage lighting, streetlighting and exit signs. These changes are due to numerous input assumption changes in the 2021 Power Plan such as lumen per watt, baseline market average LED saturations, and technology distributions.

Key Differences in Commercial 2021 BPA CPA and Council's BPA 2021 Power Plan

Comparison of the commercial 2021 BPA CPA, with a start year of 2022, to the Council's BPA 2021 Power Plan, with a start year of 2022, shows the 6-year achievable technical potential increased 0.7% and the 20-year potential decreased 0.2%. The main difference between the 20-year commercial achievable technical potential is roughly an increase of 19 aMW to the BPA CPA measure iterations for refrigeration improvement measures. Similarly, numerous other technologies decreased 21 aMW. This decrease was largely driven by pump improvements, circulation pumps, energy management systems, heat pump water heaters, interior lighting, and unitary air conditioning equipment. The shift in potential between technologies was largely driven by the team incorporating CBSA into the supply curve analysis and also from incorporating recent RTF measure updates and removing FMY adjustment factors, where possible.

Industrial Sector

The Cadmus/Lighthouse team considered energy efficiency measures in the industrial sector for all 2021 Power Plan measures. Overall, the team identified 288 aMW of achievable technical conservation potential from 2024 through 2043. Most of these savings come from efficiency improvements to process loads, lighting, compressed air, and whole building and meter level end uses. Figure 20 shows the distribution of industrial potential by end use from 2024 through 2043.

Figure 20. Share of 20-Year Industrial Achievable Technical Potential by End Use

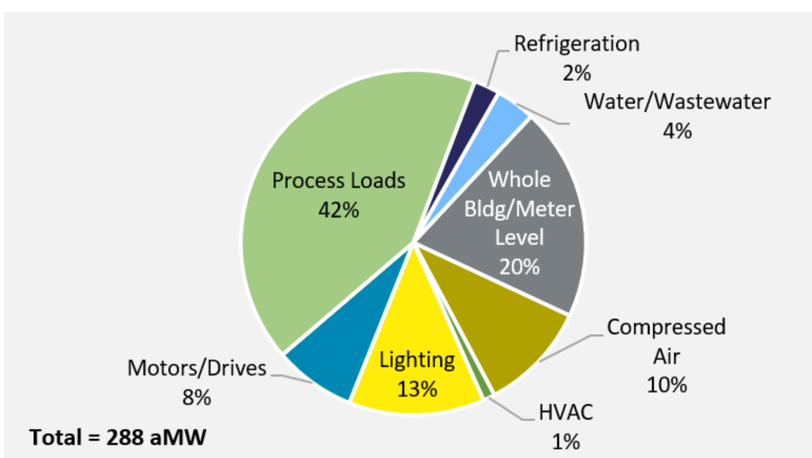


Table 17 shows the 6- and 20-year cumulative achievable technical potential in the industrial sector, by end use and measure category. Within the industrial sector, pumps and fans, whole building and meter level system improvements, lighting, compressed air system improvements, and motor controls provide the most potential.

Table 17. Industrial Achievable Technical Potential by BPA End Use and Category

BPA Sector	BPA End Use	BPA Category	Cumulative Achievable Technical Potential - aMW	
			6-Year (2024 to 2029)	20-Year (2024 to 2043)
Industrial	Compressed Air	Compressed Air System Improvements	12.2	29.7
Industrial	HVAC	HVAC System Improvements	2.1	3.2
Industrial	Lighting	Lamps/Ballasts/Fixtures	24.2	36.7
Industrial	Motors/Drives	Motors	3.3	22.1
Industrial	Process Loads	Process Loads System Improvements	7.7	20.4
Industrial	Process Loads	Pumps and Fans	27.8	100.9
Industrial	Process Loads	Wastewater System Improvements	0.0	0.0
Industrial	Refrigeration	Refrigeration System Improvements	4.6	7.1
Industrial	Water/Wastewater	Other	7.0	10.7
Industrial	Whole Bldg/Meter Level	Whole Bldg/Meter Level System Improvements	27.5	57.6
		Total	**116.5**	**288.3**

Figure 21 illustrates the supply curve for the industrial sector from 2024 through 2043.

Figure 21. Industrial 20-Year Supply Curve by End Use

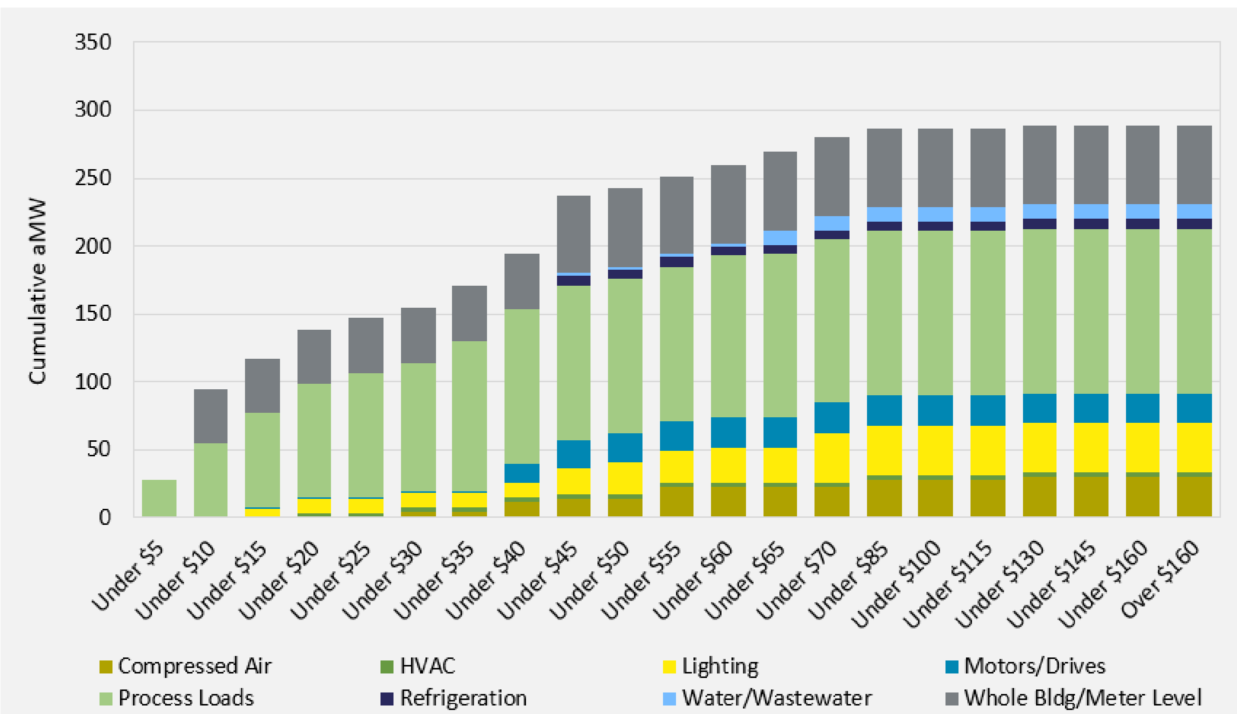


Table 18 shows the industrial measure technologies contributing the most achievable technical potential by levelized cost ranges.

Table 18. Significant Industrial Achievable Technical Potential by Levelized Cost Buckets

Measure Technology	2021 BPA CPA Cumulative Achievable Technical Potential - aMW
	20-Year (2024 to 2043)
Levelized cost of $5/MWh or less	
Fan Upgrades	23
Levelized cost between $5 to $25/MWh	
Energy Management System	40
Clean Water Pumps Upgrades	22
Pump Optimization	18
Fan Upgrades	15
Efficient Lighting	11
Levelized cost between $25 to $45/MWh	
Advanced Motor Upgrades	19
Energy Management System	17
Clean Water Pumps Upgrades	15
Levelized cost between $45 to $70/MWh	
Lighting Controls	11
Wastewater Improvements	9
Compressor Upgrades	9
Levelized cost above $70/MWh	
Compressor Upgrades	7

Key Differences in Industrial 2021 BPA CPA and 2018 BPA CPA

Comparison of the industrial 2021 BPA CPA, with a start year of 2024, to the 2018 BPA CPA, with a start year of 2020, shows the 6-year achievable technical potential decreased 3.8% and the 20-year potential increased 18.6%. The main difference between the 20-year industrial achievable technical potential is roughly an increase of 45 aMW due to new industrial measures added to the draft 2021 Power Plan, along with changes to the overall 2021 BPA industrial segment load forecast.

Key Differences in Industrial 2021 BPA CPA and Council's BPA 2021 Power Plan

Comparison of the industrial 2021 BPA CPA, with a start year of 2022, to the Council's BPA 2021 Power Plan, with a start year of 2022, shows the 6-year achievable technical potential increased 8.1% and the 20-year potential increased 14.4%. The main difference between the 20-year industrial achievable technical potential of 38 aMW is only driven by changes to the industrial load forecast. Segment-specific load changes between the Council's draft BPA 2021 Power Plan forecast loads is largely driven by potential variation in the following end-use technologies: process loads improvements, energy management systems, compressed air, water, and wastewater technologies.

Agricultural Sector

The Cadmus/Lighthouse team considered energy efficiency measures in the agricultural sector, primarily for irrigation and dairy farms. Overall, the team identified 30 aMW of achievable technical conservation potential from 2024 through 2043. Most of these savings come from efficiency improvements to irrigation systems. Figure 22 shows the distribution of agricultural potential by end use from 2024 through 2043.

Figure 22. Share of 20-Year Agricultural Achievable Technical Potential by End Use

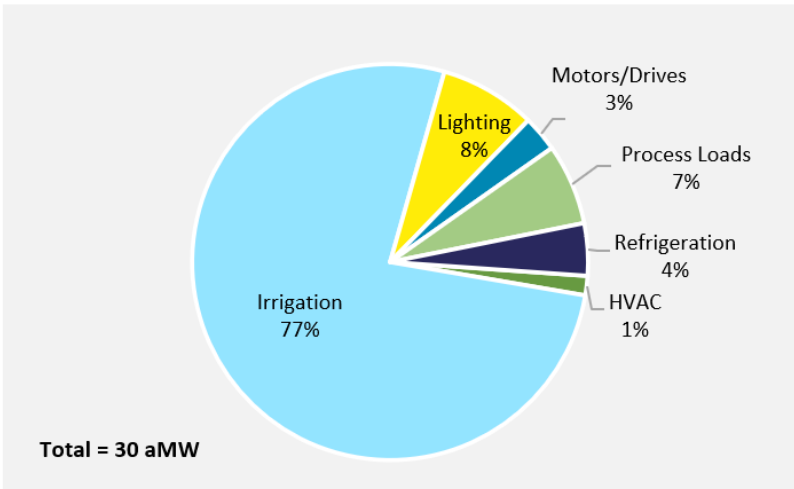


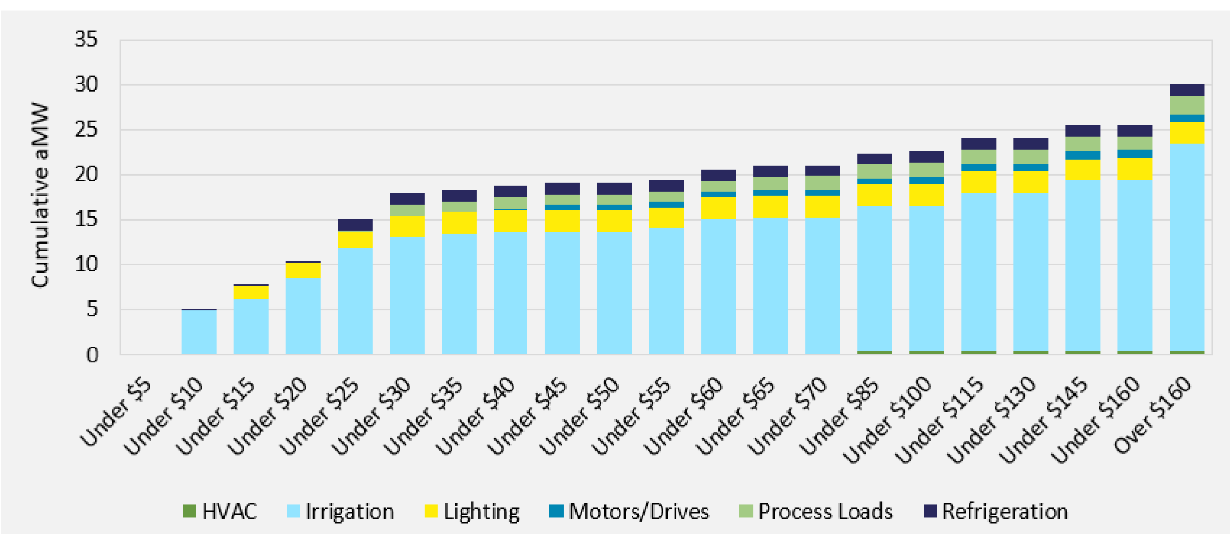
Table 19 shows the 6- and 20-year cumulative achievable technical potential in the agricultural sector, by end use and measure category. Within the irrigation end use, efficient irrigation pumps, sprinkler hardware replacements, and irrigation system improvements provide the most potential. This CPA included measures for fans in dairies, freeze-resistant stock tanks, and generator block heaters, but these did not contribute significantly to the overall potential.

Table 19. Agricultural Achievable Technical Potential by BPA End Use and Category

BPA Sector	BPA End Use	BPA Category	Cumulative Achievable Technical Potential - aMW	
			6-Year (2024 to 2029)	20-Year (2024 to 2043)
Agricultural	HVAC	HVAC System Improvements	0.1	0.5
Agricultural	Irrigation	Hardware	2.7	9.3
Agricultural	Irrigation	Irrigation System Improvements	1.1	4.9
Agricultural	Irrigation	Pumps and Fans	3.5	5.4
Agricultural	Irrigation	Water Management	0.6	3.4
Agricultural	Lighting	Lamps/Ballasts/Fixtures	0.9	2.4
Agricultural	Motors/Drives	Motors	0.4	0.7
Agricultural	Motors/Drives	Motors/Drives Controls	0.1	0.2
Agricultural	Motors/Drives	Pumps and Fans	0.0	0.0
Agricultural	Process Loads	Livestock Tanks	0.1	1.9
Agricultural	Process Loads	Process Loads System Improvements	0.1	0.1
Agricultural	Refrigeration	Dairy System Improvements	0.0	0.2
Agricultural	Refrigeration	Heat Recovery	0.2	0.7
Agricultural	Refrigeration	Other	0.1	0.4
		Total	**10.0**	**30.0**

Agricultural measures are generally low-cost, with most of the sector's savings coming from measures with a levelized cost of $30/MWh or less. Measures in this category include efficient pumps, lighting, irrigation system replacements, and certain irrigation hardware measures. The potential above $30/MWh includes variable rate irrigation, freeze-resistant stock tanks, and more expensive irrigation hardware measures. Figure 23 illustrates the supply curve for the agricultural sector from 2024 through 2043.

Figure 23. Agricultural 20-Year Supply Curve by End Use



Key Differences in Agricultural 2021 BPA CPA and 2018 BPA CPA

Comparison of the agricultural 2021 BPA CPA, with a start year of 2024, to the 2018 BPA CPA, with a start year of 2020, shows the 6-year achievable technical potential decreased 39.8% and the 20-year potential decreased 23.9%. The main difference between the 20-year agricultural achievable technical potential is roughly a decrease of 12 aMW due to changes to irrigation motor and control measures between the Seventh Power Plan and the draft 2021 Power Plan.

Key Differences in Agricultural 2021 CPA and Council's BPA 2021 Power Plan

Comparison of the agricultural 2021 BPA CPA, with a start year of 2022, to the Council's BPA 2021 Power Plan, with a start year of 2022, shows the 6-year achievable technical potential increased 31.9% and the 20-year potential increased 12.5%. In the agricultural sector, the BPA 2021 CPA identified approximately 3 aMW more achievable technical potential due to higher per-unit savings estimates for pump replacements based on updated information from the RTF.

Utility Sector

The Cadmus/Lighthouse team considered energy efficiency measures in the utility sector for all 2021 Power Plan measures. Overall, the team identified 80 aMW of achievable technical conservation potential from 2024 through 2043. All of these savings come from efficiency improvements to the utility distribution system. Figure 24 shows the distribution of the utility sector potential by end use from 2024 through 2043.

Figure 24. Share of 20-Year Utility Sector Achievable Technical Potential by End Use

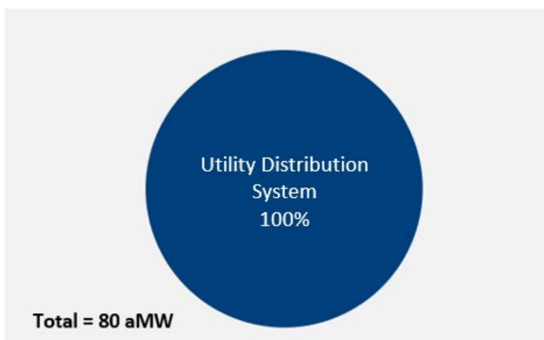


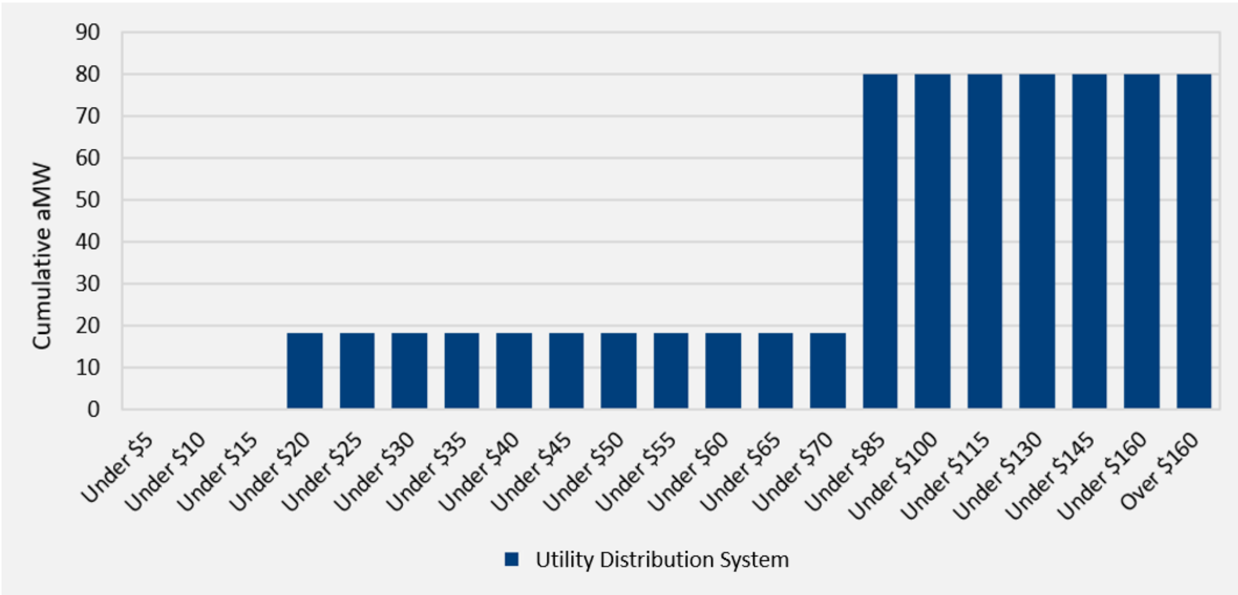
Table 20 lists the 6- and 20-year cumulative achievable technical potential in the utility sector, by end use and measure category. The utility sector only has two measures contributing to the overall potential: one with utility load management controls and a second with additional control technologies.

Table 20. Utility Sector Achievable Technical Potential by BPA End Use and Category

BPA Sector	BPA End Use	BPA Category	Cumulative Achievable Technical Potential (aMW)	
			6-Year (2024 to 2029)	20-Year (2024 to 2043)
Utility System Efficiency	Utility Distribution System	Voltage Management	14.6	80.1
		Total	**14.6**	**80.1**

Figure 25 illustrates the supply curve for the utility sector from 2024 through 2043.

Figure 25. Utility Sector 20-Year Supply Curve by End Use



As shown in the figure above the utility load management control measure has a levelized cost under $20/MWh with 18 aMW and the additional utility load control technology measure has a levelized cost under $85/MWh with 62 aMW.

Key Differences in Utility 2021 BPA CPA and 2018 BPA CPA

Comparison of the utility sector 2021 BPA CPA, with a start year of 2024, to the 2018 BPA CPA, with a start year of 2020, shows the 6-year achievable technical potential increased 40.5% and the 20-year potential increased 19.8%. The main difference between the 20-year utility sector achievable technical potential is an increase of roughly 13 aMW due to updates to the distribution system measures between the Seventh Power Plan and the draft 2021 Power Plan, along with changes to the overall 2021 BPA load forecast.

Key Differences in Utility 2021 BPA CPA and Council's BPA 2021 Power Plan

Comparison of the utility sector 2021 BPA CPA, with a start year of 2022, to the Council's BPA 2021 Power Plan, with a start year of 2022, shows the 6-year achievable technical potential decreased 3.8% and the 20-year potential increased 7.8%. The main difference between the 20-year utility sector achievable technical potential is roughly an increase of 5 aMW due to estimates of the additional potential to be acquired in the final two years of the study period.

Appendix A. Detailed Assumptions and Inputs

Table A-1. Units Forecast Assumptions and Inputs

Item/Topic	Decision and Notes
Post 2028	Assume loads continue. BPA's current contracts with its customers end in 2028. It is unknown what products BPA will offer and which customers will continue with BPA.
Extrapolation of forecast	Extrapolate units/load forecasts to cover time period needed for Resource Program.
Codes and standards	BPA uses same code and standards impact assumptions as the Council, so there is alignment in BPA and Council forecasts.
Inclusion of irrigation districts	Irrigation districts pump water to supply irrigators with water, not all of whom may power their irrigation pumps with BPA power. The irrigation energy efficiency measures and demand response products developed by the Council are not applicable to irrigation district loads. It is unclear how to quantify the remaining energy efficiency opportunities within these districts, and whether the pumps may overlap with the shipment data used by the Council for commercial and industrial pumps.
Loads served by BPA customer generation	All BPA customer loads, including those served by non-BPA generation, should be included. Note that the Council has updated their methodology.
New large single loads	Exclude all new large single loads from the CPA.
Residential segmentation	Use the American Community Survey data combined with utility zip code allocations to update housing allocations. A similar approach was used for the 2018 CPA, the outcomes of which were used in the 2021 Power Plan. This study will update that data.
Residential demolition rate	Use the demolition rates developed by the Council for the 2021 Power Plan.
Residential new construction growth	Use midpoint of range provided by BPA in March 2021 (0.8%).
Commercial segmentation	Use the methodology used for the 2021 Power Plan: the BPA share of floor area by building type in the 2019 CBSA Virtual Catalogue.
Commercial demolition rate	Use the demolition rates developed by the Council for the 2021 Power Plan.
Commercial new construction	Use midpoint of range provided by BPA in March 2021 (0.95%).
Industrial segmentation	Use the industrial segmentation provided by BPA.
Industrial growth rate	Use midpoint of range provided by BPA in March 2021 (0.55%).
Agricultural segmentation	Use the 2017 Census of Agriculture (the most recent available) to develop primary inputs or, depending on the measure, scale regional agricultural inputs. The 2021 Power Plan BPA scenario used similar data that were developed for BPA's 2018 CPA.
Agricultural growth	Use midpoint of range provided by BPA in March 2021 (0.1%).
Utility segmentation	Use the utility assignments and loads developed by the Council with feedback from BPA in the CVR supply curve.
Western Montana	Use a definition of western Montana that includes all of BPA's service territory. This approach aligns with what was done in the 2018 CPA, but differs from the approach taken by the Council in which only the portion of Montana that is part of the Columbia river basin is considered western Montana.

Table A-2. Climate Change Assumptions and Inputs

Item/Topic	Decision and Notes
AC saturation	Use BPA cooling saturation values. BPA assuming universal cooling (via heat pump, ductless heat pump, central AC, room AC) by 2050.
Measure savings adjustments	Modify measure savings to backout climate change impacts where possible, depending on the measure analysis. Some measures have straightforward adjustments to incorporate climate change, while others involve complex modeling. Options to adjust these measures may be limited.
Units/load forecast	For the base case, use sector-specific growth rates provided by BPA. Additional data to be developed based on selected scenarios.

Table A-3. Economic Assumptions and Inputs

Item/Topic	Decision and Notes
Dollar base year	Dollars should be in real 2020 dollars. Provided by BPA to align with Resource Program inputs.
Cost-effectiveness tests	Use TRC and UCT.
Incentive assumption (% of costs)	For TRC-perspective economic calculations, use the Council's assumptions on the split of measure and program costs. For the UCT-perspective economics, develop estimates of incentives based on BPA incentives for UES measures and average incentive rates for custom, lighting, and strategic energy management projects.
Carbon costs	Exclude from levelized cost calculations, but include ability to use an average cost in deliverables. Include in TRC-perspective benefit-cost ratio calculations.
Deferred transmission and distribution capacity benefits	Use BPA-specific values provided to Council via Council-developed calculator for transmission, 2021 Power Plan value for distribution. Transmission: $1.50/kW-yr. Distribution: $6.85/kW-yr, 2016$.
Discount rate	Use 2.12%. 2.12% was used previously. BPA has a 3.5% (nominal) "risk-free" discount rate. This agency-wide value has not been updated for 2021 analyses.
Transmission line losses	Use 3.10%. 0.404% was used previously.
Distribution line losses	Use 4.74%, which is the draft 2020 Power Plan regional value.
CPA Resource Program input file	Use fields as documented in June 2021 email conversation between BPA and Cadmus/Lighthouse.
Market prices	Market prices will be factored into the Resource Program.

Table A-4. Baseline Adjustments

Item/Topic	Decision and Notes
Cost period	Align 20-year levelized cost calculation with 20-year Resource Program timeframe. Levelized costs should be calculated in a similar manner to maintain apples-to-apples comparability.
Extension of ramp rates	Extend lost opportunity ramp rates by continuing final trajectory (typically to 100%). For retrofit, add 85% (divided by 20 years) in each of the final years for measures with a maximum achievability of 85%. For measures with 95% maximum achievability, add 2.5% to the final two years. Make no adjustment for measures with 100% achievability. The Council assumes maximum achievability rates over a 20-year power plan. By looking beyond 20 years, additional measures may be achieved.
2022 to 2023	The CPA will include savings from 2022 to 2023 as must-take resources or equivalent. Savings from half of 2020 and all of 2021 will also be provided as adjustments to the load. Cadmus/Lighthouse will be reliant upon BPA for savings projections for these years, since they are not in the CPA timeframe. Depending on the assumptions in the load forecast, additional adjustments may be necessary in what is provided to the Resource Program.

Table A-5. Energy Efficiency and Demand Response Interactions

Topic	Decision and Notes
Energy efficiency / demand response interaction	Take iterative approach. Assume energy efficiency measures below market energy prices will be adopted; use those to estimate impacts to demand response. Iterate if necessary to incorporate additional energy efficiency x demand response interactions.
CVR/DVR split	With BPA guidance, Cadmus/Lighthouse to assign separate market shares that are applicable to CVR and DVR.
Resource Program decision points	BPA will incorporate additional decision points into its analysis. Cadmus to share information on what potential can be carried forward into future years.

Appendix B. ProCost Parameters

The following tables represent the ProCost settings on the ProCost Excel worksheet ProData. In addition to these inputs, the team calculated customized levelized cost and benefit-cost ratios based on the outputs calculated by ProCost.

The team used the following version of ProCost and supporting workbook for this study:

- **Main ProCost Model:** ProCost_v4.0.06-BPA CPA
- **Supporting File:** MC_AND_LOADSHAPE_v4.0.06-BPA CPA

Table B-1 through Table B-6 summarize the ProCost settings used for the BPA CPA. Where appropriate, the team made changes from the Council's BPA 2021P ProCost setup, which are documented below each table.

Table B-1. ProCost Marginal Cost and Conservation Load Shape Parameters

Worksheet Type	Worksheet Reference
Marginal Elec Avoided Cost Input Worksheet	BPA Market Prices
Elec Savings Shape Input Worksheet	GLSShapes
Marginal Gas Avoided Cost Input Worksheet	2021P Gas
Gas Savings Shape Input Worksheet	GLSShapes
Marginal Elec CO2 per kWh Input Worksheet	CO2 lbs per kWh
Marginal Gas CO2 per therm Input Worksheet	CO2 lbs per therm
Marginal Avoided Cost CO2 Input Worksheet	Dollars per ton CO2
Peak Hours Definitions Input Worksheet	UtilityPeakHours

Changes from BPA setup: the Council's BPA 2021 Power Plan ProCost used a worksheet reference for "Marginal Elec Avoided Cost Input Worksheet" of "2021P Electric Mid". The market prices used in the BPA CPA were an average of all the market price scenarios developed for the 2021 Power Plan.

Table B-2. ProCost Run Parameters

Data Field	Data Entry
Run Type	Electric
Negative B/C Ratios	Off
Admin Cost @ Measure Application Level	On
Repeat Periodic Replacement	On
Limit Program Life to Measure Life	On

No Changes to any data entry value.

Table B-3. ProCost Program Parameters

Data Field	Data Entry
Program Life (yrs)	20
Program Start Date	2022
Present Value Time Zero	2022
Input Cost Reference Year	2016
Real Discount Rate	0.0212
Capital Real Escalation Rate	0
Admin Cost (as % of Initial Capital Cost)	20%
Regional Act Conservation Credit (%)	10%
Report Annual Carbon Saved for Year	2022

Changes from BPA set up: the Council's BPA 2021 Power Plan version of ProCost used a value of 0% for the "Regional Act Conservation Credit (%)." In the Council's work, the regional act credit is included in their Resource Portfolio Model.

Table B-4. ProCost Utility System Parameters

Data Field	Electric Data Entry	Gas Data Entry
Bulk System T&D Loss Factor	0.031	0.01
Bulk System T&D Credit ($/kw-yr)($/dailytherm-yr)	1.5	0
Bulk System T&D Credit - Applicable Peak Period (1,2, or both)	Peak Period 1 only	Peak Period 1 only
Bulk System T&D I2R Loss Component (%)	0.9	N/A
Local System Dist Loss Factor	0.047399348	0
Local System Dist Credit ($/kw-yr)($/dailytherm-yr)	6.85	0
Local System Dist Credit - Applicable Peak Period (1,2, or both)	Peak Period 1 only	Peak Period 1 only
Local System Dist I2R Loss Component (%)	0.7	N/A
Risk-Mitigation Credit (mills/kWh)(mills/therm) - Retro.	0	0
Risk-Mitigation Credit (mills/kWh)(mills/therm) - Lost Op.	0	0
Deferred Generation Capacity Credit - Same or Different Resources?	Same Resource	N/A
Deferred Generation Capacity Credit ($/bulk kW-year) - Peak 1	122.85	N/A
Deferred Generation Capacity Credit ($/bulk kW-year) - Peak 2	0	N/A

Changes from BPA setup: the Council's BPA 2021P ProCost used a electric data entry for "Bulk System T&D Credit - Applicable Peak Period (1,2, or both)" and "Local System Dist Credit - Applicable Peak Period (1,2, or both)" of "Peak Periods 1 and 2". Additionally, the electric data entry for "Deferred Generation Capacity Credit - Same or Different Resources?" of "None – No Credit" and the electric data entry for "Deferred Generation Capacity Credit ($/bulk kW-year) - Peak 1" of 0.

Table B-5. ProCost Deferred Generation Capacity – Same Resources

Data Field	Data Entry
Total Value ($/bulk kW-year)	122.85
% to Peak 1	1

Changes from BPA setup: the Council's BPA 2021P ProCost used the data entry for "Total Value ($/bulk kW-year)" of 115 and the data entry for "% to Peak 1" of 75%.

Table B-6. ProCost Deferred Generation Capacity – Different Resources

Data Field	Data Entry
Peak 1 Value ($/bulk kW-year)	115.00
Peak 2 Value ($/bulk kW-year)	25

No Changes to any data entry value.

Appendix C. Utility Cost Test

Introduction

In addition to considering the costs and benefits from a TRC perspective, this CPA also prepared results using a UCT approach, focusing on the benefits accrued and costs incurred by BPA. Costs and benefits associated with Bonneville Power Administration's customer utilities and their end-use customers were not considered in this approach. Other than this treatment of costs and benefits, all other assumptions were kept the same. Accordingly, the amount and timing of potential identified is the same as what was discussed above. The only difference is in the calculation of the levelized cost associated with each measure.

Methodology

As discussed above, the only methodological difference is the treatment of costs and benefits associated with each measure. The primary difference is in the treatment of measure costs. In the TRC perspective, all costs are included, including the costs borne by the end-use customer as well as any portion of the costs covered by BPA or utility incentives. In this part of the analysis, the team considered only the costs covered by BPA's incentives, along with any accompanying program administrative costs. To maintain parity in the treatment of costs and benefits, the team consider only the benefits accruing to BPA.

Table C-1 describes how the costs and benefits were treated in this UCT perspective.

Table C-1. Utility Cost Perspective Levelized Cost Components

Cost or Benefit	Component	Source/Value	Incorporated in CPA analysis or Resource Program?	UCT
Cost	Capital, Labor, and Incentives	Capital and labor vary by measures, incentives are 60% of incremental measure cost; 2021 Power Plan and RTF	CPA	Yes, only portion covered by BPA in an incentive
	Annual Operations and Maintenance (O&M)	Varies by measure; 2021 Power Plan and RTF	CPA	Yes, only portion covered by BPA in an incentive
	Program Administration	20% of incremental measure costs	CPA	Yes, only the portion covered by BPA
	Periodic Replacement	Varies by measure; 2021 Power Plan and RTF	CPA	No, assumed to be paid for by end-use customer
	Other Fuel Costs	Varies by measure; 2021 Power Plan and RTF	CPA	No
	Non-Energy Impacts	Varies by measure; 2021 Power Plan and RTF	CPA	No
Benefit	Avoided Energy Costs	BPA Resource Program modeling	Resource Program	Yes
	Deferred Transmission and Distribution (T&D) Expansion	T: $1.50/kW-yr (2016 dollars) D: $6.85/kW-yr (2016 dollars)	CPA	Only deferred transmission costs
	Regional Act Credit	10%	Resource Program	Yes

Cost or Benefit	Component	Source/Value	Incorporated in CPA analysis or Resource Program?	UCT
	Deferred Generation Capacity Investment	BPA Resource Program modeling	Resource Program	Yes
	Avoided Periodic Replacement	Varies by measure; 2021 Power Plan and RTF	CPA	No
	Other Fuel Benefits	Varies by measure; 2021 Power Plan and RTF	CPA	No
	Non-Energy Impacts	Varies by measure; 2021 Power Plan and RTF	CPA	No
	Risk Mitigation Credit	BPA Resource Program modeling	Resource Program	Yes

To identify the portion of the measure costs covered by BPA's incentive, the Cadmus/Lighthouse team analyzed BPA's Unit Energy Savings (UES) measure list, as well as the average incentive per kilowatt-hour paid to nonresidential custom, lighting, and strategic energy management projects. By mapping the typical BPA incentive to the measures included in this CPA, the team could estimate an approximate incentive for each measure.

Results

Figure C-1 shows the supply curve by sector using a BPA cost perspective in calculating the levelized cost. BPA has 1,473 aMW under a cost of $40/MWh, which is approximately two-thirds of the total achievable technical potential available, but this does not include any additional costs paid by BPA's customer utilities or end-use customers.

Figure C-1. UCT Supply Curve by Sector

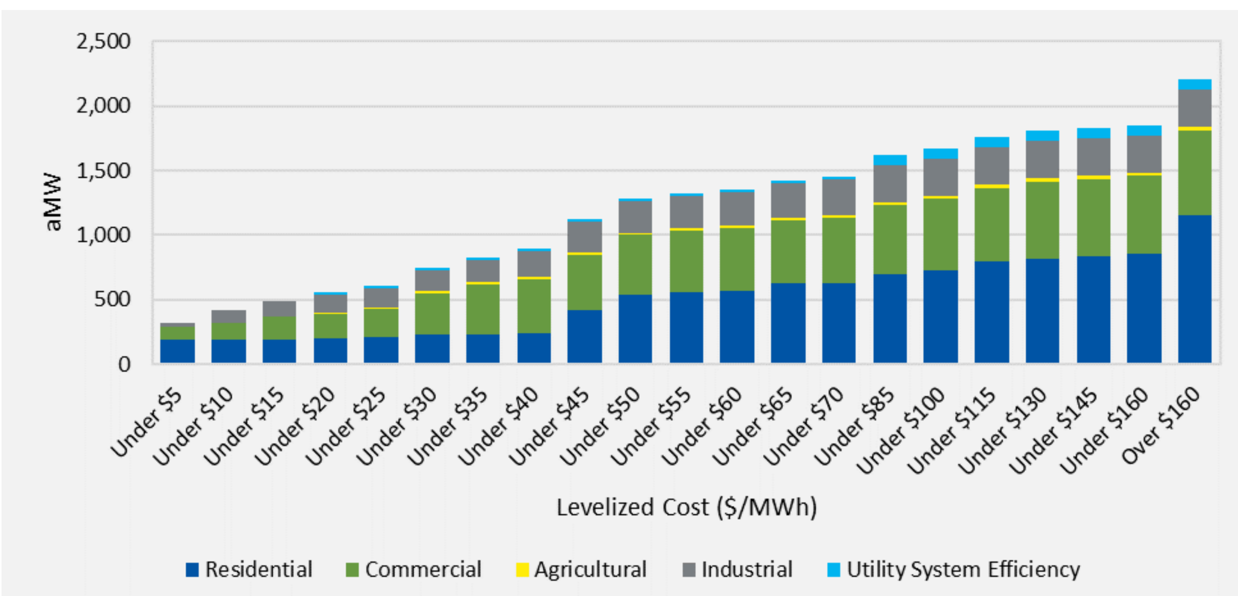
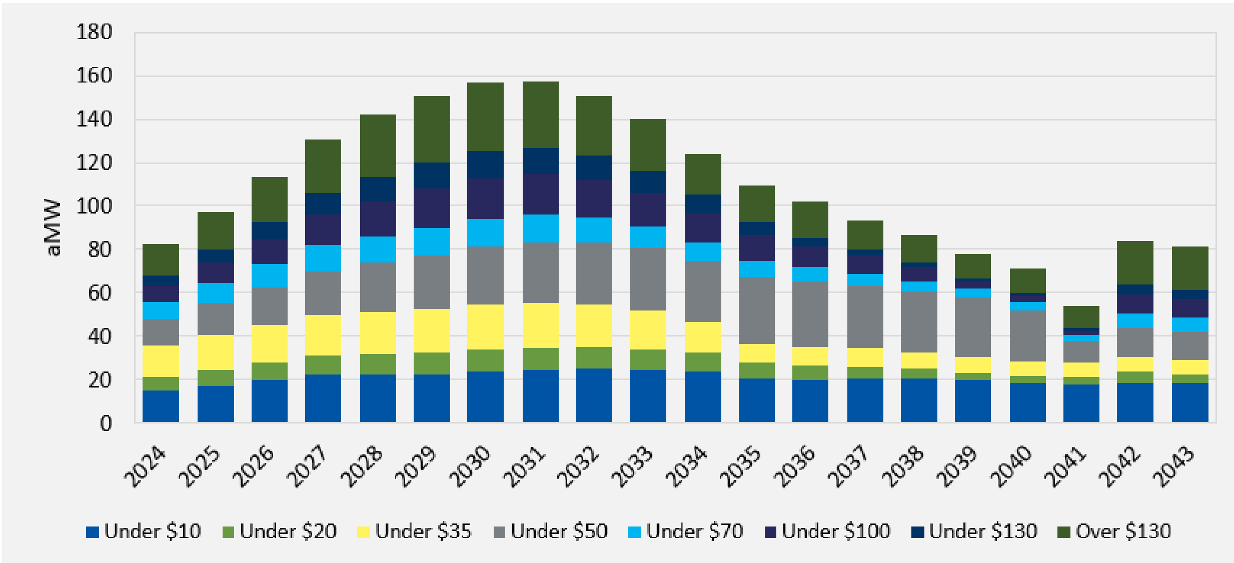


Figure C-2 shows the annual incremental potential by UCT cost bin.

Figure C-2. Annual Incremental Potential by UCT Cost Bin



As the costs considered in this portion of the analysis only those incurred by BPA, more potential is available at lower cost thresholds than in the TRC based analysis described in the main body of the report. However, the UCT is not commonly used for utility resource planning as the cost-effectiveness of measures can be modified by changing assumptions about incentives. This can lead to a situation where measures are cost-effective from a utility perspective, but the incentive dollars are used to encourage adoption of measures that may not be cost-effective from the perspective of customers participating.

Figure C-3 shows the top measure categories below a UCT-perspective levelized cost of $25/MWh. While there are 149 aMW of technical achievable potential under a TRC-perspective levelized cost of $25 per MWh, that increases to 241 aMW under a UCT-perspective levelized cost. The increases are driven by measure categories with additional potential under the $25 per MWh cost threshold as well as additional measures that fall under the threshold under the different UCT perspective.

Figure C-3. Top Measures by 6-Year Cumulative Potential Below $25/MWh (UCT Perspective)