Guidehouse

2021 Energy Efficiency Potential and Goals Study - DRAFT

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Table of Contents

List of Tables

List of Figures

List of Equations

Executive Summary

Guidehouse and its partners, Tierra Resource Consultants, LLC and Jai J Mitchell Analytics (collectively known as the Guidehouse team), prepared this study (2021 Potential and Goals Study or 2021 Study) for the California Public Utilities Commission (CPUC).

This study develops estimates of energy and demand savings potential in the service territories of California's major investor-owned utilities (IOUs) during the post-2021 energy efficiency (EE) rolling portfolio planning cycle. This report includes results for Pacific Gas and Electric (PG&E), Southern California Edison (SCE), San Diego Gas & Electric (SDG&E), and Southern California Gas (SCG). A key component of the 2021 Study is the Potential and Goals Model (PG Model). This model provides a single platform to conduct robust quantitative scenario analysis to examine the complex interactions among various inputs and policy drivers for the full EE portfolio.

Background and Approach

The 2021 Study is a major update to the previous potential and goals study completed in 2019 (2019 Study[1]). During the 2 years since the 2019 Study was completed, several market and policy changes have taken place. These changes are reflected in the 2021 Study (see Study Enhancements on next page). The project kicked off in spring 2020 and was followed by a series of stakeholder workshops held through January 2021. These workshops helped to shape and guide the direction of the work presented in this report.

Study Objectives

The 2021 Study supports several CPUC objectives:

- Informs the CPUC as it proceeds to adopt updated EE goals for the IOUs.
- Serves as one of several sources of guidance to the IOUs and other program administrators in portfolio planning.
- Identifies new EE savings opportunities.
- Provides forecasting inputs to support the procurement and planning efforts of California's principal energy agencies including the CPUC, California Energy Commission (CEC), and California Independent System Operator (CAISO).
- Provides forecasting inputs to support the analysis and accounting of EE contributions to Senate Bill (SB) 350 targets.[2] SB 350 targets a doubling of EE by 2030.
- Explores the optimization of EE resources through the Integrated Resource Plan (IRP) process.

The 2021 Study forecast period spans from 2022 to 2032 and focuses on current and potential drivers of energy savings in IOU service areas.

Consistent with previous CPUC potential studies and common industry practice, the 2021 Study final output is an achievable potential analysis. Achievable potential is a calculation of EE savings based on specific incentive levels, program delivery methods, assumptions about

[1] Guidehouse (as Navigant). 2019 *Energy Efficiency Potential and Goals Study*. July 2019.
[2] https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201520160SB350

existing CPUC policies, market influences, and barriers. Achievable potential has historically been used by the CPUC to inform the goalsetting process.

This 2021 Study forecasts the potential energy savings from various EE programs as well as codes and standards (C&S) advocacy efforts for the following customer sectors: residential, commercial, agriculture, industrial, and mining. The 2021 Study does not set IOU goals, nor does it make any recommendations as to how to set goals. Rather, it informs the CPUC's goal setting process.

Study Enhancements

As a result of recent policy changes, CPUC staff direction, and stakeholder input, the 2021 Study includes a few notable methodological enhancements relative to the 2019 Study. These enhancements include the following:

- **Primary data collection:** Two new primary data collection efforts feed into the 2021 Study. Previous potential and goals studies did not collect any primary data and largely relied on secondary datasets and assumptions vetted with stakeholders. These two new research studies aimed to fill gaps previously identified by stakeholders:
    - **California Energy Efficiency Market Adoption Characteristics Study**[3] (referred to as the Market Adoption Study throughout this report). The Market Adoption Study surveyed single-family households, multifamily property managers or owners, and commercial facilities to provide data on their decision-making process to improve adoption forecasting in the 2021 Study. Previous studies forecasted adoption of EE technologies using simple factors like lifetime cost or payback period. The survey data informed the PG model algorithms to incorporate both financial and non-financial indicators in customer decision making.
    - **Industrial/Agriculture Market Saturation Study**[4] (referred to as the Industrial and Agriculture Market Study throughout this report). Most previous data sources for the industrial and agriculture measure characterization were not California-specific. The 2021 PG study used the Industrial and Agriculture Market Study's new California-specific data for forecasting.
- **Fuel substitution:** Changes to CPUC's policy in 2019 allowed fuel substitution (replacing equipment utilizing one regulated fuel with equipment utilizing another regulated fuel, for example, substituting gas equipment for electric equipment). into EE program portfolios.[5] The 2021 Study, for the first time, incorporated fuel substitution measures into the study.
- **Demand response (DR) integration:** The study performed sensitivities which endeavored to assess the impacts of integrating the benefits and costs of DR for DR-enabled EE technologies. Integrating DR benefits and costs allows the model to better simulate the market dynamics of technologies that provide multiple benefit streams.

[3] See Attachment 1 to this report, California Energy Efficiency Market Adoption Characteristics Study.

[4] See Attachment 2 to this report, Industrial and Agricultural Market Saturation Study.

[5] CPUC. *Decision Modifying The Energy Efficiency Three-Prong Test Related to Fuel Substitution*, 2019.

- **Total system benefit (TSB) analysis:** The study features a new output to value achievable potential, TSB.[6] TSB provides the monetary value for the utility life cycle benefit based on the avoided costs of offsetting any new generation, transmission and distribution, carbon, or fuel costs. Data from the CPUC's Avoided Cost Calculators provide key inputs to this analysis.
- **IRP optimization:** This activity explored and refined the methods of incorporating demand side resources into the IRP by examining how EE compares to supply side resources.
- **COVID-19 pandemic sensitivity:** The Guidehouse team developed sensitivity analysis to address the effects of the pandemic on achievable potential.

Scenarios

The 2021 Study considers multiple scenarios to explore market response and how potential might change based on several alternative assumptions. This study considers scenarios built primarily around policies and program decisions that are within the sphere of influence of the CPUC and its stakeholders collectively. Table ES-1 summarizes the various scenarios considered for the 2021 Study. Scenario 1 is the most comparable to the 2019 Study scenario that was used to inform the current IOU goals.

Scenario 4 is the result of the IRP optimization analysis, which inherently assesses cost-effectiveness via competition with other resources. The main scenario for the IRP model was run using its 38 MMT target with reference battery costs which is the more aggressive scenario modeled within the CPUC's reference system plans.[7] Additional scenarios and details on the IRP analysis are contained in the IRP Optimization section of this executive summary.

Table ES-1. Summary of Scenarios for EE Potential

Levers → Scenario ↓	C-E Test	C-E Threshold	Incentive Levels Capped*	Program Engagement‡	Include Financing ?
1: TRC Low	TRC	1.0	50%	Reference	No
2: TRC Reference§	TRC	0.85	50%	Reference	No
3: TRC High	TRC	0.85	75%	Aggressive	Yes
4: IRP Optimized	N/A†	N/A†	50%	Reference	No

TRC = Total Resource Cost Test; C-E = cost-effectiveness.
*Incentives are set based on a $/kWh and $/therms basis consistent with existing IOU programs; incentives are capped at 50% or 75% of incremental cost depending on the scenario.
† A cost-effectiveness screen is not required for IRP analysis as the IRP model itself inherently determine what is cost-effective via competition of supply and demand side resources.
‡Program engagement refers to the level of marketing awareness and effectiveness, as well as, the level of aggressiveness of the behavior, retrocommissioning and operational efficiency (BROs) program participation.
§ An additional scenario (not listed in this table) is a sensitivity of the TRC Reference with demand response costs and benefits included. The report includes findings of this analysis.
Source: Guidehouse

[6] TSB is not necessarily a new metric because it is the same as the present value of the total resource cost (TRC) benefits for EE measures only.
[7] Decision 20-03-028. "2019-2020 Electric Resource Portfolios to Inform Integrated Resource Plans And Transmission Planning"

Impactful Data Updates and Policy Changes

Table ES-2 highlights key 2021 Study data updates and policy changes and how each change affects overall results.

Table ES-2. Key Changes Relative to 2019 Study

Category	Update Relative to Previous Study	Directional Impact Relative to Previous Study	
Lighting Savings	The 2021 Study includes new data showing higher efficiency light emitting diodes (LEDs) can provide energy efficiency (EE) savings above the standard LED baseline in the commercial sector.	↑	Significant increase in lighting savings across all investor-owned utilities (IOUs) in the commercial sector.
Behavior, Retrocommissioning, and Operational (BROs) Interventions	Used more recent program evaluation results to inform the forecast.	↑	Gas savings increased across all scenarios, electric savings increased in some scenarios while remaining consistent to the 2019 Study in the conservative case. The increased savings is primarily from home energy reports (HERs).
Whole Building Interventions	Updated program data and new construction building codes, which provided refreshed inputs for whole building initiatives.	↓	Savings generally decreased across the commercial and residential sectors for gas and electric.
Cost-Effectiveness	A combination of using 2020 avoided costs and revised measure inputs resulted in some measures no longer being cost-effective in early years.	↓	Decreases in savings observed for appliance/plug loads and commercial refrigeration. In 2026 and beyond avoided costs increase allowing more measures to become cost-effective, albeit with low impact.
Market Adoption Multi-Attribute Analysis	The 2021 Study considers a broader set of customer preferences on economic and non-economic factors when modeling technology adoption.	↑↓	Revised data affects different measures different ways. Measures that provide non-EE benefits to customers see increased adoption. Measures with low non-EE benefits and higher hassle see decreased adoption.
Industrial/ Agriculture Sectors	Incorporated primary data collected in a new market study for these two sectors.	↑↓	Revised market data results in a higher forecast of electric savings from these sectors but shows decreased gas savings.
EE-DR Integration	CPUC staff directed the Guidehouse team to consider the costs and benefits of DR-enabled technologies along with their EE benefits.	↑	Accounting for DR benefits and costs overall would result in about a 5% increase in EE potential in the applicable end uses (lighting, appliances, water heating, HVAC).
Fuel Substitution	CPUC policy allows fuel substitution measures to be included in EE programs.	↑	The model shows very limited uptake of fuel substitution measures in this first assessment, though it does contribute to additional savings.

Source: Guidehouse

Results

The 2021 Study provides a rich dataset of results, the details of which can be found on the CPUC's 2021 Potential and Goals website.[8] The report presents results by program type:

- **EE equipment:** EE traditionally incentivized by IOU programs are modeled in the study. This specifically excludes fuel substitution.
- **Fuel substitution:** Fuel substitution equipment replaced gas appliances with electric appliances. It will indicate gas savings and simultaneously an increase in electric consumption. The potential study calculates impacts on electric and gas consumption that result from fuel substitution.
- **Behavior, retrocommissioning, and operational efficiency (BROs):** These programs are based on customer changes that may not rely on any new equipment installations.
- **Codes and standards:** Savings captured by C&S are based on the evaluated IOU advocacy for the development of new C&S and level of adoption in the marketplace.
- **Low income:** The potential for gas and electricity savings for participants of the Energy Savings Assistance (ESA) program.

Total Achievable Potential

Table ES-3 shows the achievable potential results for each program type (incentive programs, fuel substitution, and BROs) for each of the scenarios listed in Table ES-1. Table ES-3 also includes the 2019 Study scenario that was used by the CPUC to inform previous goals as a comparison. The 2019 Study did not include any fuel substitution or calculate TSB. The IRP Optimized scenario does not include fuel substitution, nor does it include any gas savings. To provide a single fuel metric for comparison purposes, fuel substitution includes an alternate calculation where gas savings are converted into electric savings. Finally, as explained further in the Integrated Resource Plan Optimization section, TSB output from Scenario 4 is not comparable to the other scenarios because system benefits from gas savings are not included.

Table ES-3. 2022 Net First-Year Incremental Savings by Scenario (Statewide)

Savings Metric	Program Type	2019 Goals	1: TRC Low	2: TRC Ref.	3: TRC High	4: IRP Optimized
Electric Energy (GWh/Year)	Fuel Substitution	-	-0.01	-3.29	-3.59	-
	BROs	443	502	502	604	419
	EE Equipment	378	295	334	345	90
	Total	**821**	**797**	**832**	**945**	**510**
Converted Electric Energy (GWh/Year)	Fuel Substitution	-	0.12	18.13	19.90	-
	BROs	443	502	502	604	419
	EE Equipment	378	295	334	345	90
	Total	**821**	**797**	**854**	**968**	**510**

[8] https://www.cpuc.ca.gov/General.aspx?id=6442464362

Savings Metric	Program Type	2019 Goals	1: TRC Low	2: TRC Ref.	3: TRC High	4: IRP Optimized
Electric Demand (MW)	Fuel Substitution	-	-	-	-	-
	BROs	83.1	112.9	112.9	132.9	99.9
	EE Equipment	80.0	72.5	86.2	89.0	20.5
	Total	**163**	**185**	**199**	**222**	**120.4**
Gas Energy (MMTherms/ Year)	Fuel Substitution	-	0.00	0.73	0.80	-
	BROs	17.4	21.1	21.1	27.0	-
	EE Equipment	16.7	11.1	13.6	14.3	-
	Total	**34.2**	**32.2**	**35.4**	**42.1**	**-**
TSB ($ Millions)	Fuel Substitution	-	$0.03	$3.90	$4.30	-
	BROs	-	$124	$124	$151	$145
	EE Equipment	-	$551	$622	$644	$85
	Total	**-**	**$675**	**$750**	**$799**	**$230**

Source: Guidehouse

The following are notable takeaways from the savings results:

- In all scenarios, electric and gas savings from EE equipment decrease relative to the previous goals. Total demand savings in the non-IRP scenarios are larger than the previous goals. This is primarily driven by an increase in demand savings from BROs (35%-60% larger than the previous goals). BROs savings forecasts are based on recent impact evaluation studies that show increased demand savings than those data available in the 2019 Study.
- In non-IRP scenarios, the reduction in first-year electric and gas savings from EE equipment is counterbalanced by increases in BROs savings. In these scenarios, BROs savings are similar to or larger than the previous goals due to updated HERs evaluation reports for the residential sector published by the CPUC; these reports showed higher customer participation rates than what was assumed in the 2019 Study.
- While all non-IRP scenarios showed a decrease in EE equipment electricity savings, some scenarios show an increase in EE equipment demand savings. EE equipment demand savings range from a 10% decrease to a 10% increase relative to previous goals. This due to revised input data for EE equipment showing higher demand savings per unit and the mix of measures adopted in the 2021 Study versus the 2019 Study.
- The IRP (Scenario 4) selected about 35%-45% less energy EE savings in 2022 than the other scenarios based on the IRP model's selection of optimal bundles.
- Fuel substitution's impact on electricity use is minimal in all scenarios. While fuel substitution leads to an increase in electric load it is balanced (and exceeded) by gas savings from the replaced equipment. Table ES-3 shows an alternate statement of potential where gas savings from fuel substitution are converted into electric energy savings credit in units of kWh.[9] After making this conversion, fuel substitution seems more substantial in the results, though is still small in magnitude. Fuel substitution was

[9] Uses calculations found in Fuel Substitution Technical Guidance Document v.1.1, https://www.cpuc.ca.gov/General.aspx?id=6442463306.

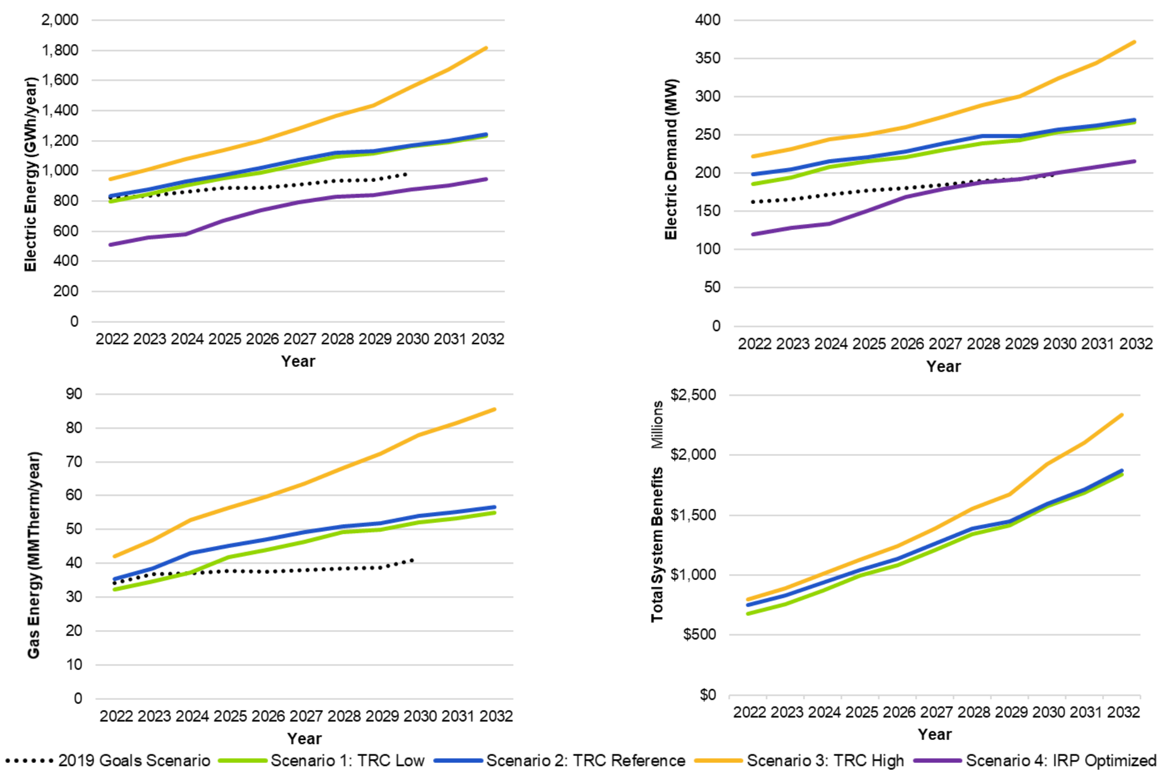
not considered in the IRP (Scenario 4). Per CPUC guidance, fuel substitution does not count for or against peak demand savings goals and are therefore zero in this study.[10]

The following are notable takeaways from the TSB results:

- As opposed to electric and gas savings, BROs amount to a much smaller proportion of TSB. This is due to short effective useful life (EUL) of BROs savings relative to EE equipment. TSB represents the benefits that accrue over the life of the intervention—because EE equipment tends to have a long useful life, it is the key driver for TSB.
- Fuel substitution has a negligible impact on TSB. Although fuel substitution savings in Scenarios 2-3 are small, their contribution to TSB is even smaller as a proportion of the whole. This is because positive benefits due to reduced gas consumption are largely offset by increased electric supply cost (which negatively impacts TSB).

Figure ES-1 shows the 11-year forecast for first-year net electric, peak demand, and gas achievable potential for EE equipment, fuel substitution, and BROs combined. After the first few years all non-IRP scenarios tend to separate from the previous goals and increase over time. The larger increase in Scenario 3 is due to aggressive assumptions about BROs programs. The TSB does not include the previous goals or IRP scenario for comparison purposes. The TSB follows the same trends as the savings.

Figure ES-1. Net First-Year Incremental Savings by Scenario (Statewide)



Source: Guidehouse

[10] California Public Utilities Commission (CPUC), Energy Division. 2019. *Fuel Substitution Technical Guidance, Version 1.1*. October 31. 2019

Sensitivity Analysis to COVID-19 Pandemic

The impacts of the COVID-19 pandemic on the California economy are far-reaching and not something the 2021 Study can ignore. The default scenario results presented are rooted in data developed pre-pandemic. The Guidehouse team developed separate COVID-19 sensitivity scenarios to estimate the impacts of the pandemic, which manifested in two ways in the model:

1. Reducing commercial building stocks due to business closures and increasing number of households eligible for low income programs due to lowered household income.
2. Adjustments that represent altered sensitivity of costs and barriers in consumer purchasing decision processes.

These impacts are not modeled as permanent shifts but rather as temporary deviations that assume full recovery to pre-pandemic levels by 2026. Table ES-4 provides the results the COVID-19 sensitivities' impacts on Scenario 2.

Table ES-4. Scenario 2 Comparison After Adjusting for COVID-19 Impacts

Unit	Sensitivity	2022	2023	2024	2025
GWh	No COVID-19	832.4	874.6	927.3	971.4
	COVID-19	825.8	869.7	924.4	971.1
	% Difference	0.8%	0.6%	0.3%	0.0%
MW	No COVID-19	199.1	204.7	215.2	221.4
	COVID-19	197.8	203.7	214.6	221.3
	% Difference	0.6%	0.5%	0.3%	0.0%
MMTherms	No COVID-19	35.4	38.6	43.1	45.3
	COVID-19	35.0	38.3	43.0	45.3
	% Difference	1.0%	0.7%	0.3%	0.0%
Total System Benefit ($ Millions)	No COVID-19	$750	$828	$938	$1,045
	COVID-19	$737	$817	$931	$1,043
	% Difference	1.7%	1.2%	0.7%	0.2%

Source: Guidehouse

Integrated Resource Plan Optimization

The 2021 Study worked to complement the traditional EE forecast (Scenarios 1-3) with an IRP-based analysis (Scenario 4) to observe how EE competes with other demand and supply side resources. The IRP integration analysis optimized electric EE savings (not including fuel substitution) from equipment rebate measures and BROs programs through the CPUC's IRP model RESOLVE, developed by E3. Savings from C&S and low income programs remained as baseline (load-modifying) resources in this analysis.[11] The biggest differences between Scenarios 1-3 and the Scenario 4: IRP Optimized scenario are that for the IRP analysis:

- The primary metric for assessing cost-effectiveness in the modeling process is the levelized cost of energy as it compares to other available resources.

[11] C&S development are largely outside the control of the IOUs. They are not procured the same way as other demand side resources. Low income programs are subject to a different set of regulations than all other demand side resources. They must be offered to IOU customers and are not subject to a cost-effectiveness test.

- There is added emphasis on hourly savings as RESOLVE optimizes based not only on cost but also by meeting electric resource needs at specific hours of the day and year.

The Guidehouse team used the PG Model to develop supply curves to represent the EE resources that feed into the CPUC's IRP model, RESOLVE. The EE supply curve consists of 30 different bundles of EE technologies that are grouped together based on their savings and cost characteristics. The RESOLVE model selects which measure bundles should optimally be adopted in each year of the optimization. The team translated this information into annual savings forecasts based on the selected bundles and further calculated TSB.

One consequence of the methodology for IRP integration is that bundle aggregation may result in a large spread of levelized costs as measures were grouped. The Guidehouse team calculated the weighted average levelized cost each bundle. The measure bundle simplification may result in grouping some lower cost measures that may have been cost-effective when not combined with higher cost measures. Notable findings on the adopted bundles are listed as follows.

- The IRP selected a higher proportion of BROs compared to EE equipment. This is partly because BROs, on average, have a lower levelized cost. All sectors have BROs savings selected by the IRP scenario.
- In the residential sector, in addition to BROs, the IRP selects whole building programs as optimal. Residential lighting, HVAC, and appliances/plug loads are not selected at all (Scenarios 1-3 do have savings in these areas).
- In the commercial sector, food service and appliance/plug loads are not selected as optimal (Scenarios 1-3 do have savings in these areas). HVAC is selected in 2027 and beyond, and lighting (a large saver in Scenarios 1-3) is selected in 2023 and beyond.

The IRP only analyzes electric potential and excludes gas benefits. Scenario 4 is comparable to Scenarios 1-3 when examining electric savings results. However, when examining costs and benefits, Scenario 4 is not directly comparable to Scenarios 1-3. For example, in 2022, the TSB for Scenario 4 is $230 million compared to Scenario 2 at $750 million.

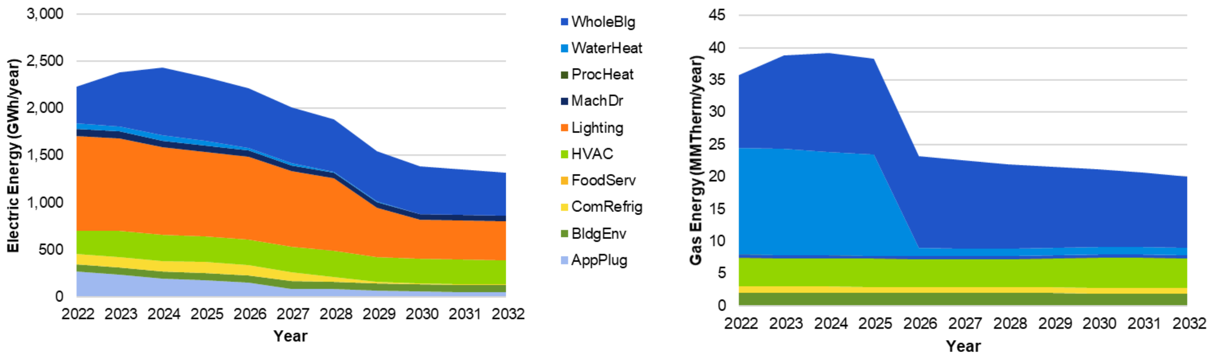
Additional IRP scenarios of 46 MMT, 30 MMT, and high storage cost sensitivities were analyzed and are discussed in the full report. In total six, IRP scenarios/sensitivities were analyzed.

Codes and Standards Savings

C&S savings do not vary across each scenario and tend to be larger than the magnitude of savings from any other source. Thus, they are presented as a single set of results separate from EE equipment, fuel substitution equipment, and BROs savings. Incremental annual savings from C&S that have been passed into law and C&S that are reasonably expected to be passed into law are illustrated in Figure ES-2.

This study is informed by draft results from the latest CPUC impact evaluation of C&S. As a result of using this updated information, electric savings from C&S have increased relative to those estimated in the 2019 Study. Meanwhile, gas savings are largely the same for early years, though they exhibit a steep decline in 2026. Incremental savings decrease in the outer years as the market impacted by a code or standard has completely turned over and savings from the retrofit market are no longer counted. The steep decline in gas savings in 2026 is due to this same effect. However, this steep decline is far more prominent as multiple high efficiency water fixture measures achieve complete stock turnover at the same time.

Figure ES-2. C&S Savings (Including Interactive Effects)

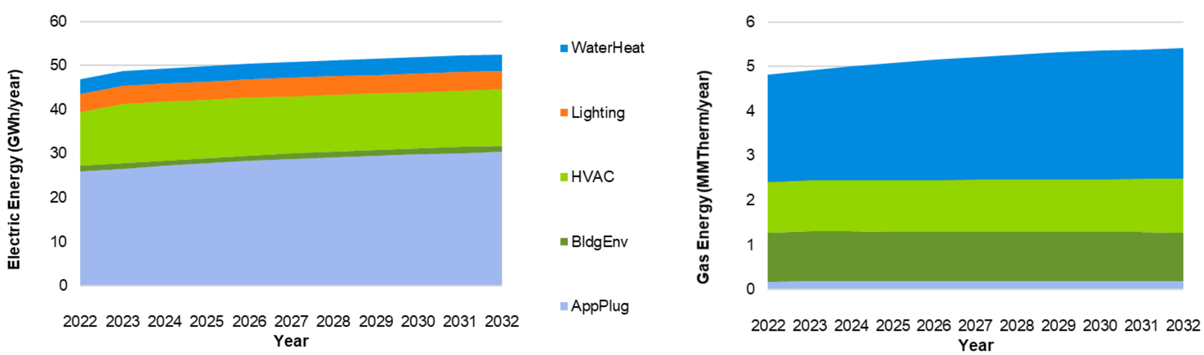


Source: Guidehouse

Low Income Savings

Low Income savings were excluded from the IOUs' previous EE-adopted goals because they were covered by a different CPUC proceeding.[12] Nonetheless, the 2021 Study forecasts low income potential to support goals assessment the low income proceeding. Figure ES-3 provides the low income electric and gas savings by end use. Additional details can be found in Attachment 3.

Figure ES-3. Low Income Savings by End Use



Source: Guidehouse

[12] Decision 19-08-034 (August 15, 2019) specifically excluded low income from the IOU goals (Figure 3, page 23). http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M311/K540/311540642.PDF

1. Introduction

1.1 Context of the Potential and Goals Study

Guidehouse and its partners, Tierra Resource Consultants, LLC and Jai J Mitchell Analytics (collectively known as the Guidehouse team), prepared this study (2021 Potential and Goals Study or 2021 Study) for the California Public Utilities Commission (CPUC). The purpose of this study is to develop estimates of energy and demand savings potential in the service territories of California's major investor-owned utilities (IOUs) during the post-2021 energy efficiency (EE) rolling portfolio planning cycle. This report includes results for Pacific Gas and Electric (PG&E), Southern California Edison (SCE), San Diego Gas & Electric (SDG&E), and Southern California Gas (SCG). A key component of the 2021 Study is the Potential and Goals Model (PG Model), which provides a single platform to conduct robust quantitative scenario analysis that reflects the complex interactions among various inputs and policy drivers.

The 2021 Study is the sixth consecutive potential study conducted by the Guidehouse (formerly Navigant) team on behalf of the CPUC. The last study published was the 2019 Study, which informed goals for 2020 and beyond.[13]

The 2021 Study supports multiple related efforts:

- Informs the CPUC as it proceeds to adopt goals and targets, providing guidance for the next IOU EE portfolios. The potential study is a framework that assesses savings reasonably expected to occur by IOU-funded programs based on certain policies and expectations of market uptake.
- The California Energy Commission (CEC) then uses the CPUC-adopted goals to develop its forecast of additional achievable energy efficiency potential (AAEE). Furthermore, the data becomes an input to SB 350 scenario analysis which targets a doubling of the AAEE by 2030.[14]
- Explores forecasting potential using Integrated Resource Planning (IRP) tools. This study also includes analysis that explores the optimization of some EE resources through the IRP. The Guidehouse team delivered EE supply curves to the IRP model and subsequently analyzed results to compare to the core study's achievable potential calculation.
- Guides the IOUs and other program administrators in portfolio planning. Although the PG Model cannot be the sole source of data for program administrator program planning activities, it can provide critical guidance for the program administrators as they develop their plans for the 2022 and beyond portfolio planning period.
- Provides forecasting inputs to support the procurement and planning efforts of California's principal energy agencies including the CPUC, CEC, and California Independent System Operator (CAISO).The study and the goals subsequently set by CPUC provides California's principal energy agencies with the tools and resources necessary to develop outputs in a manner that is most appropriate for their planning and procurement needs.

[13] Navigant, 2019 *Energy Efficiency Potential and Goals Study*, July 2019.

[14] https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201520160SB350

The 2021 Study builds on and significantly enhances the 2019 Study (key areas that were updated are discussed further in Section 1.3). The project kicked off in March 2020, and the draft workplan was presented to stakeholders on April 16, 2020. The 2021 Study workplan was directly informed by workshops hosted by the CPUC in October 2019 to review approaches for assessing EE potential and goals.[15] The October 2019 workshops included the following presentation topics and opportunities for stakeholder discussion and comment:

- EE-demand response (DR) integration
- Industrial and agriculture achievable potential analysis
- Community choice aggregator/regional energy network load disaggregation and location modeling
- Fuel substitution analysis
- Statewide and third-party program considerations
- Resource planning integration
- New ideas for assessing EE technical and achievable potential

The study period spans from 2022 to 2032 based on the direction provided by the CPUC. The study focuses on current and potential drivers of energy savings in IOU service areas. Analysis of EE savings in publicly owned utility service territories is not part of the scope of this effort.

1.2 Types of Potential

Consistent with the 2019 Study and common industry practice, the 2021 Study forecasts EE potential at three levels for rebate programs:

- **Technical potential:** Technical potential is defined as the amount of energy savings that would be possible if the highest level of efficiency within a group of competing measures for all technically applicable opportunities to improve EE were taken. Technical potential in existing buildings represents the replacement of applicable equipment-based technologies with the highest level of efficiency available, regardless of the cost of the replacement. Technical potential in new construction buildings represents installation of the highest level of efficiency at the time of construction. Technical potential in this study is undefined for codes and standards (C&S), whole building, and behavior, retrocommissioning (RCx), and operational efficiency (BROs) programs.[16]
- **Economic potential:** Using the results of the technical potential analysis, the economic potential is calculated as the total EE potential available when limited to only measures that pass a specific measure-level cost-effectiveness threshold.[17] Economic potential is a subset of technical potential. Economic potential may contain lower efficiency measures compared to those included in the Technical Potential. This would be the case

[15] Information about these workshops are available here: https://www.cpuc.ca.gov/General.aspx?id=6442464362

[16] Any statement on technical potential for C&S (a mandatory program) would completely overlap and negate savings potential from voluntary rebate programs. Thus, we do not attempt to calculate Technical Potential for C&S. Whole building savings are excluded from technical potential because its savings would double count with individual rebated technologies. BROs technical potential is out of scope of this study because it is highly uncertain if a technical potential for BROs would be additive to a technical potential for rebate programs.

[17] The model can use different metrics of cost-effectiveness as defined by the California Standard Practice Manual. This includes the total resource cost (TRC) and the program administrator cost (PAC) tests.

if the highest efficiency measure representing the technical potential is not cost-effective within a group of competing measures. Economic potential may be a fraction of technical potential as the economic screen is applied separately to new construction versus existing buildings. Economic potential is undefined for C&S, whole building, BROs, and low income programs.[18]

- **Achievable potential:** The final output of the potential study is an achievable potential analysis, which calculates the EE savings that could be expected in response to specific levels of incentives and assumptions about existing CPUC policies, market influences, and barriers. Some studies also refer to this as market potential. Achievable potential is a subset of economic potential but may include additional measures beyond what are included in the economic potential. Achievable potential allows any measure that is cost-effective to be adopted within a group of competing measures. Achievable potential is used to inform the utilities' EE goals, as determined by the CPUC. Achievable potential is primarily reported as a net savings value (CPUC shifted to setting goals based on net savings in 2017), though gross values are also produced by the PG Model.

Achievable potential is represented in the 2021 Study several different ways; each way is based on the same data and assumptions, though each serve separate needs and provide necessary perspectives.

- **Incremental first-year net savings** represent the annual energy and demand savings achieved by the set of measures and BROs programs in the first year the measure is implemented. It does not consider the additional savings the measure will produce over the life of the equipment. A view of incremental savings is necessary to understand what additional savings an individual year of EE programs will produce.
- **Cumulative savings** represent the total savings from EE program efforts from measures installed since 2022 (including the current program year) and that are still active in the current year. It includes the decay of savings as measures reach the end of their useful lives and the continuation of savings as customers re-install high efficiency equipment that has reached the end of its effective useful life (EUL). Cumulative savings also account for the timing effects of C&S that become effective after measure installation.
- **Total system benefit (TSB)** represents the total benefit that a measure provides to the electric and natural gas systems. It includes the total avoided cost benefits less any increase in supply costs as exhibited in Equation 1-1. There are two forms of increased supply costs. One is for interactive effects such as increased heating load due to decreased heat gain from more efficient lighting. The other is for the new electricity consumption due to fuel substitution of natural gas technologies with electric technologies. TSB is not necessarily a new metric since it is the same as the present value of the TRC benefits for energy efficiency measures only, in other words, TSB equals net avoided cost benefits (energy and capacity) for energy efficiency measures.

[18] While technical potential is calculated for low income programs, estimating the cost-effectiveness of these measures and their economic potential was out of scope of this study.

Equation 1-1. Total System Benefit

$$\begin{aligned} Total\ System\ Benefit \\ &= Net\ Avoided\ Cost\ Benefits\ (Energy\ and\ Capacity) \\ &- Increased\ Supply\ Cost \end{aligned}$$

Many variables drive the calculation of achievable potential. These include assumptions about the way efficient products and services are marketed and delivered, the level of customer awareness of EE, and customer willingness to install efficient equipment or operate equipment in ways that are more efficient. The Guidehouse team used the best available current market knowledge to calibrate achievable potential for voluntary rebate programs. This effort has been supplemented for the first time in this study using the two data collection studies for market adoption and industrial and agriculture market characterization.

1.3 Scope of this Study

This 2021 Study forecasts the above-described types of potential energy savings from the EE programs and C&S across all customer sectors: residential, low income,[19] commercial, agriculture, industrial, and mining. This study does not set IOU goals, nor does it make recommendations as to how to set goals. Rather, it informs the CPUC's goal setting process.

Key scope items in 2021 Study include the following:

- **Primary data collection:** Two studies collected new data to feed into the EE potential forecast. Historically, the potential and goals study did not collect any primary data and largely relied on secondary datasets and assumptions vetted with stakeholders. These two new research studies aimed to fill gaps identified by stakeholders in the October 2019 workshops:
    - **California Energy Efficiency Market Adoption Characteristics Study**[20] (referred to as the Market Adoption Study throughout this report). The Market Adoption Study surveyed single-family households, multifamily property managers or owners, and commercial facilities to provide insight on their decision-making process to adopting EE or fuel substitution equipment or participating in DR programs. The survey asked about payback period (price differential between equipment costs, incentives, and the use of financing), nonfinancial aspects of measure adoption, and impacts due to the COVID-19 pandemic. The results of the study were used to better characterize adoption rates in the 2021 Study for the EE, fuel substitution, and integrated EE-DR measures considered. Historically, the PG Model calculated customers' willingness to adopt EE technologies using simple factors like lifetime cost or payback period. Other potential studies in other jurisdictions have even used Delphi panels to provide opinions on technology adoption rates. However, true customer purchase decision behavior is not solely based on financial indicators, nor can the complexities of the decision for each unique measure be captured via a Delphi panel. This study gathered and analyzed survey data to inform the PG Model willingness to adopt algorithms to incorporate both financial and nonfinancial indicators in customer decision making. This study leveraged

[19] The details of the low income analysis are provided in Attachment 3, 2021 Low Income Program Energy Efficiency Potential Study.

[20] See Attachment 1 to this report, California Energy Efficiency Market Adoption Characteristics Study.

behavioral science research to identify nonfinancial indicators that include the customer's perception of a technology's environmental impacts, social status/statement signaling, hassle (or lack thereof) of installation, and aesthetics or features unrelated to energy use as key datapoints to model customer willingness to adopt. The PG Model used the analyzed survey results as key inputs to forecast residential and commercial customers' technology adoption and EE savings potential.

  - **Industrial/Agriculture Market Saturation Study**[21] (referred to as the Industrial and Agriculture Market Study throughout this report). Most previous data sources for the industrial and agriculture measure characterization were not California-specific and focused on top activity in the programs to date. The Industrial and Agriculture Market Study was designed to develop new California-specific data to rely upon for forecasting. The study identified the top segments to prioritize and EE opportunities within those segments. The study included interviews and a literature review to help quantify the EE savings and saturation data for three technologies each in six different segments. This data supplemented the technical potential calculations for the industrial and agriculture sectors. The study also provided qualitative inputs to the achievable potential analysis.

- **Enhanced potential forecast methodologies:** The core effort to forecast EE potential includes developing a model and producing scenario results. This forecast accounted for new topics such as fuel substitution and the co-benefits of EE-DR integration:
  - **Fuel substitution:** The CPUC passed a decision on fuel substitution instituted by the fuel substitution test (FST) in 2019.[22] With this test and other state initiatives, the 2021 Study incorporated fuel substitution measures into the measure list including space heating, water heating, and cooking, and updated the modeling methods to allow EE technologies to compete with the fuel substitution alternatives. Additionally, costs and savings need to be assigned to the correct entity. See Section 2.1.2 for methodology, Section 3.3 and Appendix B for data sources and characterization, and Section 0 for analysis results.
  - **EE-DR integration:** The study assessed the impacts of integrating the co-benefits and costs of DR for DR-enabled EE technologies. The analysis required including and differentiating the cost and benefit streams associated with DR. The Guidehouse team collaborated with the Lawrence Berkeley National Laboratory (Berkeley Lab) DR Potential Study team to select measures and characterize them within the EE potential study framework.[23] Some measures became cost-effective as a result of the DR benefit. Additionally, market adoption activity increased as the financial attractiveness improved. See Section 2.1.3 for methodology, Section 3.4 and Appendix I for data and analysis, and Section **Error! Reference source not found.** for results.

- **Total system benefit (TSB) analysis:** The TSB is a metric to show the relative value of each measure compared to each other measure independent of its measure cost, program cost, or fuel type. While previous studies included calculations of benefits (in

[21] See Attachment 2 to this report, Industrial/Agricultural Market Saturation Study.

[22] California Public Utilities Commission. *Decision Modifying The Energy Efficiency Three-Prong Test Related to Fuel Substitution*. 2019.

[23] Berkeley Lab. *2025 California Demand Response Potential Study – Charting California's Demand Response Future: Final Report on Phase 2 Results*; Energy Technologies Area, Berkeley Lab, March 2017. https://buildings.lbl.gov/publications/2025-california-demand-response

avoided costs) from rebate programs in their datasets, this Study calculates TSB for both rebate programs and BROs and displays the TSB results prominently alongside fuel-specific savings outputs as an additional metric. The TSB provides the monetary value for the utility lifecycle benefit based on the avoided costs of offsetting any new generation, transmission and distribution (T&D), carbon, or fuel costs.

- **Refresh measure data:** The study used the Database for Energy Efficient Resources (DEER) and workpapers as the primary data sources for refreshing input assumptions for measures. Old measures no longer in programs were removed while new measures were added. Specifically, in the commercial sector, high efficacy LEDs (those above baseline LEDs) were added. The new LED option is a high proportion of new commercial incentive program savings. Also, prior to the 2021 Study the Guidehouse team only characterized measures to the IOU-specific level of disaggregation. To account for potential differences in savings resulting in impacts to cost-effectiveness, the team developed three weather zones in each utility territory to reflect the cost-effective potential and savings analysis for climate-sensitive measures.
- **Refresh cost-effectiveness inputs and outputs:** This study uses 2020 avoided costs to assess the cost-effectiveness and benefits generated by IOU programs. Current avoided costs compared to those used in the 2019 study are lower in 2020-2025 but higher in 2026 and beyond. This study also increases the types of benefit and cost outputs being provided to stakeholders, including more detail on the cost-effectiveness of individual measures and the total benefits, total costs, and total system benefits of programs.
- **Low income analysis:** The method for analyzing low income potential is based on existing and potential measures for the Energy Savings Assistance (ESA) program. The low income program potential uses researcher-defined adoption curves based on historical participation rates and planned adoption trends for measures as well as customer characteristics. Previous potential and goals studies explored different approaches.
- **IRP integration:** As part of the 2017 Study,[24] Guidehouse developed methodologies and data sources and conducted a preliminary analysis for optimization of some EE into the CPUC's IRP.[25] The overarching objective of that report was to develop a proof of concept and serve as an input to a staff proposal for how some EE can be integrated into future IRP modeling efforts in California. The 2021 Study worked to complement the traditional EE forecast with an IRP-based analysis to observe how some EE competes with other demand and supply-side resources. The purpose of this activity was to continue to refine the methods of incorporating demand side resources into the IRP and examine how EE compares to supply side resources.
- **COVID-19 pandemic sensitivity:** While not in the original workplan, the Guidehouse team developed sensitivity analysis for the scenarios using specific adjustments to address the impacts of the pandemic on the baseline consumption and market adoption behavior.

[24] Navigant. *Energy Efficiency Potential and Goals Study for 2018 and Beyond.* September 2017 and Navigant. *IRP Technical Analysis: Considerations for Integrating Energy Efficiency into California's Integrated Resource Plan.* September 2018. https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442464366

[25] Only some and not all EE is included in the optimization analysis. The analysis fully optimizes some EE instead of using it as a load modifier, as it has historically been integrated. Reliable, claimed BROs and incentive programs are included. Low income and codes and standards are included as load modifiers.

The following items are not in the scope of this report, though they may be examined in subsequent analysis at the direction of CPUC staff:

- **Streetlighting potential.** This study does not include street lighting because of the increased market saturation of LED lighting. There is very little potential left worth quantifying.
- **Locational disaggregation.** This study produces results at the IOU level of geographic granularity. It does not provide further granularity at the climate zone or county level or for the service territories of regional energy networks (RENs) or community choice aggregators (CCAs). Upon CPUC direction, a REN/CCA disaggregation analysis of the study results will be published in a separate report.
- **Financing modeling updates.** The 2021 Study continues to use the methodology and data inputs from the 2019 Study on the impacts of financing on EE adoption. While additional studies have been conducted in the past 2 years that provide additional information, the 2021 Study prioritized the updates described earlier in this section over revising its analysis of financing programs.
- **Top-down forecasting pilot:** A separate effort is exploring forecasting EE potential using an alternate modeling approach from what was traditionally used in the goal setting process. Top-down forecasting studies look at the topline consumption values to breakdown the savings potential. Whereas, the potential and goals study calculates potential from the bottom-up by technology. Stakeholder feedback from the October 2019 workshops was the impetus of this activity. This effort will be published in a separate report.

1.4 Stakeholder Engagement

The Guidehouse team engaged with stakeholders through multiple public workshops, in part supported by the Demand Analysis Working Group.[26] All meeting materials are available on the CPUC website, https://www.cpuc.ca.gov/General.aspx?id=6442464362. These workshops were used to request data, collect feedback on scope, discuss methodology, and discuss key assumptions. Table 1-1 provides the schedule of meetings that were held. After each meeting, stakeholders were provided a period in which they could submit informal comments to the Guidehouse team and CPUC. The team reviewed all comments received and incorporated appropriate edits or changes into the study. The 2021 Study work included many more stakeholder workshops than in previous periods. The increased effort stemmed from the expanded scope and new modeling approaches included in the 2021 Study.

Table 1-1. Stakeholder Meeting Schedule

Date	Topics of Discussion
April 16, 2020	2021 Potential and Goals Study Workplan
June 2, 2020	Measure Characterization and Data Collection Studies
July 21, 2020	Modeling Adoption
October 8, 2020	Market Studies, BROs, and Low Income
November 5, 2020	Achievable Potential Scenarios and Calibration
November 23, 2020	Low Income Sector Workplan*

[26] http://demandanalysisworkinggroup.org/

Date	Topics of Discussion
January 20, 2021	Top-Down Study, COVID Impacts, and Reporting

*Target audience for this webinar was the low income working group.
Source: Guidehouse

1.5 Contents of this Report

This report documents the data sources for and results of the 2021 Study.

- **Section 2** provides an overview of the methodology for each key area of the study.
- **Section 3** details the input data used for each key area of the study. It describes the data sources and process taken to incorporate the data into the PG Model.
- **Section 4** provides the study's results on a statewide basis.
- **Section 5** focuses only on the IRP integration analysis.
- **The appendices** provide additional details on key topic areas. Areas include the fuel substitution methodology, the BROs methodology and input assumptions, the EE-DR integration analysis method, and the IRP analysis method.

Aside from this report, the following supporting deliverables are available to the public via the CPUC's website:[27]

- **2021 PG Results Viewer:** A tool that allows readers to dynamically explore the results of the study, including all scenarios.
- **2021 PG MICS:** A spreadsheet version of the Measure Input Characterization System documenting all final values for all rebated technologies forecast in the model.
- **2021 PG BROs Inputs:** A spreadsheet version of all measure-level inputs for BROs measures.
- **2021 PG Measure Level Results Database:** A spreadsheet of technical, economic, and achievable potential for each measure in each sector, end use, and utility. The database also includes measure level C&S results, BROs results, and cost-effectiveness test results.
- **2021 PG Model File:** An Analytica-based file that contains the PG Model used to create the results of this study.
- **2021 PG Model Users Guide:** Document that helps advanced users who want to open and run the PG Model file in Analytica.
- **2021 Low Income Potential Measure Level Results Database.** A spreadsheet of technical and achievable potential for each measure by utility. The database also includes the full potential and potential limited by the low income policy and procedure manual (please see Attachment 3 for more details).

[27] https://www.cpuc.ca.gov/General.aspx?id=6442464362

2. Study Methodology

The primary purpose of the 2021 Study is to provide the CPUC with information and analytical tools to engage in goal setting for the IOU EE portfolios. The study itself informs the CPUC's goal setting process but does not establish goals.

The 2021 Study forecasts potential energy savings from a variety of sources within six distinct customer sectors: residential, low income, commercial, agriculture, industrial, and mining. Street lighting is not included in the 2021 Study because of its low remaining potential. These sectors are also used in the CEC's Integrated Energy Policy Report (IEPR) forecast. Within some or all sectors, sources of savings include the following:

- **Incentive programs:** Incentive programs make up discrete categories of characterization that are further described in this report.
    - **Rebated technologies:** Discrete mass market technologies incentivized and provided to IOU customers in the residential, commercial, industrial, agriculture, and mining sectors. These sectors are modeled using individual measures for specific applications.
    - **Whole building approaches:** In the case of whole building initiatives, the Guidehouse team characterized retrofitting the entire home or building or constructing a new home or building to a higher-than-code efficiency level. The specific technologies used to achieve the higher level are not characterized individually because the exact technologies used to achieve the higher efficiency level may vary from building to building. Whole building initiatives are modeled for the residential and commercial sectors.
    - **Custom measures and emerging technologies:** This study defines custom measures as improvements to processes specific to the industrial and agriculture sectors. The measures themselves are not individually defined as a discrete technology but could be defined in site-specific analysis rather, they represent a wide array of niche technologies. Similarly, emerging technologies are represented as a wide array of technologies and are not individually defined.
- **BROs:** For this study, the Guidehouse team defines behavior-based initiatives as those providing information about energy use and conservation actions rather than financial incentives, equipment, or services. Savings from BROs are modeled as incremental impacts of behavior and operational changes beyond equipment changes.
- **C&S:** Codes regulate building design, requiring builders to incorporate high efficiency measures. Standards set minimum efficiency levels for newly manufactured appliances. Savings are forecast from C&S that went into effect starting in 2006.
- **Financing:** Financing has the potential to break through several market barriers that have limited the widespread market adoption of cost-effective EE measures. The PG Model estimates the effects of introducing EE financing on achievable potential and how shifting assumptions about financing affect the potential energy savings.
- **Residential low income:** The 2021 Study conducts a bottom-up forecast of savings from the residential low income sector. This analysis uses low income-specific market characterization data and measure list, sourced through IOU ESA program applications and savings reports, with additional measures added from expert opinion and

professional judgment. The study uses adoption calculations different from the residential sector. More details are available in Attachment 3 of this report.

The rest of this section discusses the 2021 Study methodology.

2.1 Modeling Methods

Table 2-1 summarizes the modeling approach for each savings source. Each approach is discussed in more detail in the subsequent subsections.

Table 2-1. Overview of Modeling and Calibration Approach

Savings Source	Summary of Modeling Approach	Summary of Calibration Approach	Methodology Change Relative to 2019 Study
Rebated technologies: Multi-attribute analysis	Bass diffusion forecast competes equipment against each other using multi-attribute analysis for below code, at code, fuel substitution (if applicable), and above code technologies.	Calibrated to historical program activity and market saturation data, as appropriate.	Multi-attribute analysis in this study vs. only considering willingness to participate based on payback period.
Rebated technologies: fuel substitution	Compete fuel substitution equipment with EE equipment using the same fuel as the baseline equipment.	No specific calibration because this savings source did not exist in historic portfolios. Same calibrated parameters as used for EE are applied to fuel substitution.	Fuel substitution analysis for program eligibility (using the FST) and fuel-neutral comparison for competition groups. Allocation of savings and costs must be attributed to the proper fuel utility.
Rebated technologies: EE-DR integration	Sensitivity analysis that includes savings that co-benefit from EE-DR measures.	No specific calibration because this savings source did not exist in historic portfolios. Same calibrated parameters as used for EE are applied to EE-DR	EE-DR co-benefits for economic screening and customer adoption.
Whole building packages	Bass diffusion forecast competes below code, at code, and above code technologies against each other.	Calibrated to historical program savings.	None.

Savings Source	Summary of Modeling Approach	Summary of Calibration Approach	Methodology Change Relative to 2019 Study
Industrial/ agriculture custom measures and emerging technologies	Trend forecast based on recent IOU custom project savings in these sectors. Emerging technologies ramp up based on standard market penetration trends.	Forecast is anchored in IOU program history and thus are inherently calibrated to current market conditions.	None.
BROs	Interventions are limited to the applicable customers and markets. For applicable markets, Guidehouse assumptions are made regarding reasonable penetration rates.	Starting penetration rates are based on current program penetration rates, as applicable.	None.
C&S	Model replicates the algorithms of the CPUC's Integrated Standards Savings Model (ISSM).	Calibration not needed because evaluated results and IOU claims are directly used.	None.
Financing	Financing is applied to rebated technologies and whole building approaches. It reduces upfront barriers, increasing consumer adoption, and supplements Bass diffusion modeling framework.	No program data to calibrate to.	None.
Residential low income	Adoption curves based on measure type and historical and planned implementation. (Discussed in greater detail in Attachment 3).	Calibrated to historical accomplishments in 2019 for low income programs.	Moved away from the bass diffusion model used in the 2019 Study to prescriptive adoption curves.

Source: Guidehouse

2.1.1 Rebated EE Technologies

Rebated technologies make up the majority of historical program spending and lifetime savings claims. They are a core part of the forecast. The Guidehouse team's approach of using a bass diffusion model to model rebated technologies has not changed since the 2019 Study. However, additional features were included in the 2021 Study. This updated methodology is documented in this section.

2.1.1.1 Types of Technologies

The 2021 Study forecasts the adoption of more than 150 representative EE technologies. The Guidehouse team aggregates and reviews the measures in DEER and workpapers, CEDARS, and other industry sources. The team filters the list down to set of measures that are eligible in programs and may contribute savings. Measures may have multiple variations for climate zone, building type, and configurations. The study typically calculates an average across the variations (considering weights, as appropriate) for a representative baseline and efficient equipment in the characterization. This process distills thousands of unique technologies into a more manageable set of representative technologies that can be characterized and modeled within the timeline and budget afforded to this study.

Each measure can be classified into one of several broad measure types. Each measure type is treated differently when calculating cost-effectiveness, calculating energy savings relative to the baseline, and modeling consumer decisions and market adoption. These differences are discussed throughout this section. The types of measure installations are outlined below:

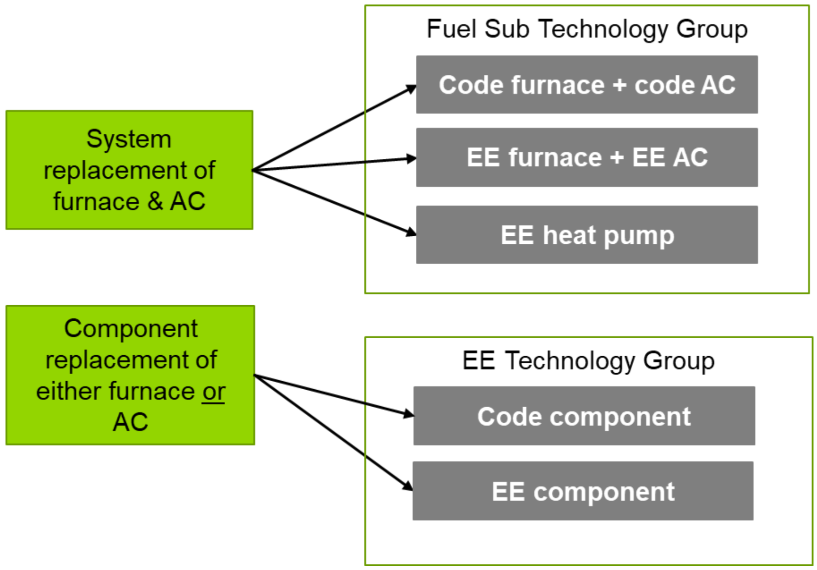
- **New Construction (NEW):** Equipment installed in a newly constructed building. In this situation, energy savings calculations are always relative to code.
- **Installation in existing buildings:**
    - **Normal replacement (NR) (i.e., replace on burnout [ROB]):** New equipment needs to be installed to replace equipment that has reached the end of its useful life, has failed, or is no longer functional. Upon failure, normal replacement equipment is generally not repaired by the customer and is instead replaced with a new piece of equipment. Appliance standards are applicable to some types of normal replacement equipment and apply to all new purchases.
    - **Retrofit (RET) – add-on equipment:** New equipment installed onto an existing system, either as an additional, integrated component or to replace a component of the existing system. In either case, the primary purpose of the add-on measure is to improve the overall efficiency of the system. These measures cannot operate on their own as standalone equipment and are not required to operate the existing equipment or building. Codes or standards may be applicable to some types of add-on measures by setting minimum efficiency levels of newly installed equipment, but the codes or standards do not require the measure to be installed.
    - **Retrofit (RET) – accelerated replacement:** Equipment that will be replaced before it fails. These EE equipment are installed to replace previously existing equipment that has either not failed or is past the end of its EUL but is not compromising use of the building (such as insulation and water fixtures). Many of these installations are subject to building code, but upgrades are not always required by code until a major building renovation (and even then, some may not be required).

2.1.1.2 Technology Groups, Efficiency Levels, and Competition

Within each technology type, multiple groups of technologies are formed and characterized. A technology group consists of multiple levels of efficiency of the same technology. Technologies within a technology group compete for installations. A technology group is a set of technologies that compete with each other, sometimes called a competition group. Figure 2-1 provides an example of technology groups. The individual technologies characterized within each group are designed to capture varied efficiency levels including below code units, at code units, and one or more levels of high efficiency units, and (where appropriate) fuel substitution technologies (discussed further in Section 2.1.2) and (where appropriate) DR-enabled technologies (discussed further in Section 2.1.3). For technology groups with fuel substitution levels, the fuel substitution involves replacing a gas baseline technology with an electric efficient technology. The electric technology competes with high efficiency gas technologies.

In determining which technologies to include in a group, the Guidehouse team considered possible future code levels and popular efficiency levels historically rebated by IOU programs.

Figure 2-1. Technology Group Examples – Fuel Substitution and Energy Efficiency



Source: Guidehouse

Table 2-2. Example of Technologies within a Technology Group – Non-Fuel Substitution

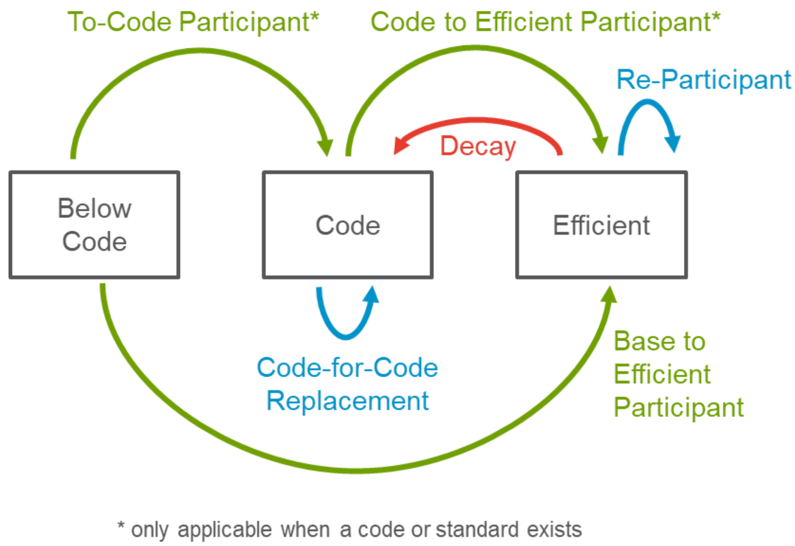
Technology Group	Technology	Description
Floor Insulation Retrofit	R0 Floor Insulation	Average Below Code Efficiency Level
	R19 Floor Insulation	Code Efficiency Level
	R30 Floor Insulation	High Efficiency Level

Source: Guidehouse

Where the Guidehouse team is aware of an upcoming code change for a certain technology, the team adjusted the code baseline from the year of the code change onward. The code efficiency level in Table 2-2 refers to the level that complies with code as of 2019. For higher efficiency levels that will be future code levels, the characterization included an input for the year that the higher level becomes the code. Then, for that year and thereafter, the model treats that higher level as the code efficiency level, and previous code level(s) become below code efficiency level(s) for purposes of the analysis.

The model simulates the flow of equipment stock across the different technologies within a technology group. Flow of stock occurs when the customer owning the equipment reaches a decision point to replace the equipment with a new unit. The decisions available to the customer in the model depend on the type of technology category the equipment in question falls in (discussed in Section 2.1.1.1). Figure 2-2 illustrates the replacement options a customer is faced with. The model allows customers to upgrade to higher efficiency equipment or downgrade from high efficiency equipment to at code-level equipment. With each replacement a unit energy savings, cost, and cost-effectiveness value is associated with the decision.

Figure 2-2. Stock Flow within a Technology Group



Source: Guidehouse

2.1.1.3 Technical and Economic Potential

Technical potential is defined as the amount of energy savings that would be possible if the highest level of efficiency for all technically applicable opportunities to improve EE (including fuel substitution) were taken, including retrofit add-on or retrofit accelerated replacement measures, normal replacement measures, and new construction measures. Technical potential can be reported in two forms: instantaneous and annualized. The following considerations are factored into the team's calculation of technical potential:

- Technical potential assumes all eligible customers within a technology group adopt the highest level of efficiency (or that which saves more source energy in the case of fuel substitution) available within the technology group.
- Total technical potential is the sum of all individual technical potential within each technology group excluding whole building packages and BROs. Whole building packages are excluded from the technical potential because including them would be duplicative with the technical potential for individual measures. Highly efficient new building or retrofitted building will have no additional opportunity for individual EE technologies to be installed. Technical potential for BROs is undefined in this study.

Using the results of the technical potential analysis, the **economic potential** is calculated as the total EE potential available when limited to only cost-effective measures. All components of economic potential are a subset of technical potential. In addition to the above considerations in modeling technical potential, the following considerations are factored into the team's calculation of economic potential:

- Economic potential assumes all eligible customers within a technology group adopt the highest cost-effective level of efficiency available within the technology group. The most efficient technology within the group may not be cost-effective.

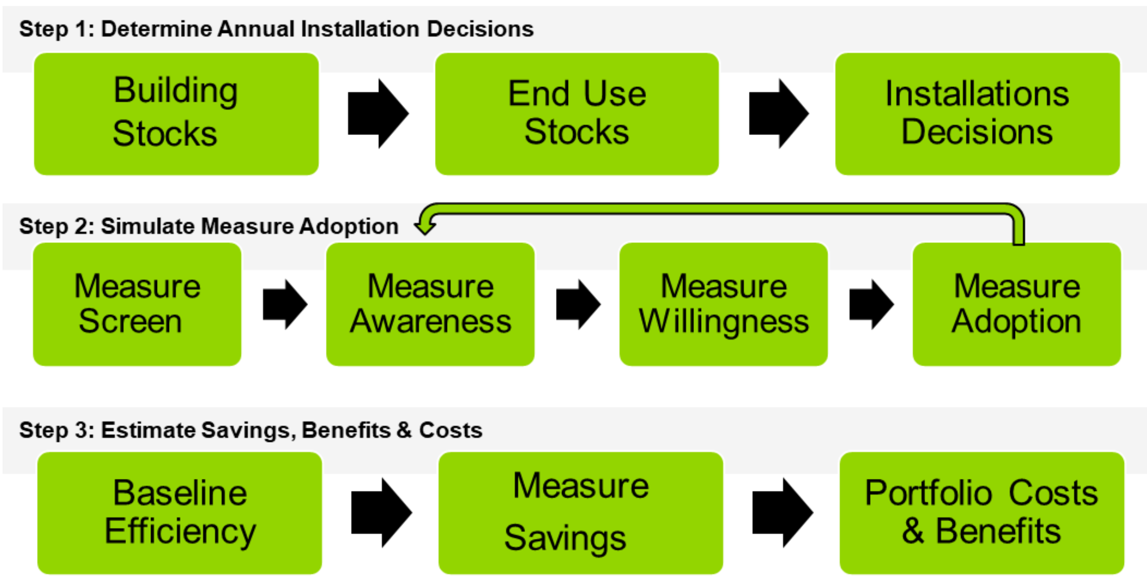
- Various cost-effectiveness screens can be applied (previously discussed in Section 1.2); thus, economic potential can vary by scenario. Meanwhile, technical potential does not vary by scenario.

Appendix I describes the cost-effectiveness analysis and the steps the 2021 Study team took to calculate results. The appendix also describes the 2021 Study work to align with the Cost-Effectiveness Tool (CET) methodology and inputs.[28]

2.1.1.4 Achievable Potential

To estimate the achievable potential for rebated technologies, the model employs a three-step process, which is generally illustrated in Figure 2-3 and described in detail after the figure.

Figure 2-3. Three-Step Approach to Calculating Achievable Potential for Rebated Measures



Source: Guidehouse

In the first step, the model calculates the number of installation decisions expected to occur for each measure in each year. The types of installation decisions vary by technology type.

- For normal replacement technologies (e.g., residential lighting), the customer decision to adopt occurs at the end of the base measure's life.
- For retrofit add-on or retrofit accelerated replacement technologies, the customer decision to adopt is not governed by equipment failure and can occur before or after the EUL.

The model simulates technology stocks for base and efficient technologies separately to account for EUL differences. The number of adoption decisions that occur in each year is considered the eligible population, which is a function of the building stocks, technology saturation, technology type, and technology burnout rates (i.e., based on EUL).

[28] https://www.cpuc.ca.gov/general.aspx?id=5267

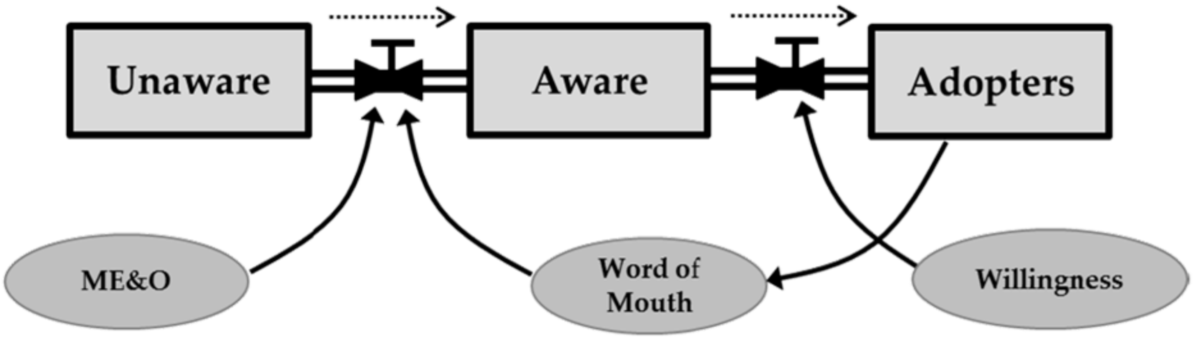
In the second step, the model simulates the adoption of each measure that passes a cost-effectiveness screen in each year. The model estimates awareness level of each measure in the eligible population and the willingness to adopt each measure that passes the cost-effectiveness screen. In this step, the model employs the Bass diffusion approach to simulate adoption (described in more detail later in this section). For the 2021 Study, the Guidehouse team updated the willingness-to-adopt methodology to consider factors beyond just financial attractiveness, which was used in the 2019 Study. These factors were typically based on the customers' lifetime cost or payback period.

In the final step, the model calculates energy savings and corresponding costs and benefits resulting from measure adoption decisions in the second step. Savings are calculated relative to the appropriate baseline efficiency level depending on the type of replacement.

The model employs a bottom-up, dynamic Bass diffusion approach to simulate market adoption of efficient measures. Figure 2-4 illustrates the Bass diffusion model, which contains three parameters:

- **Marketing, education, and outreach (ME&O)** moves customers from the unaware group to the aware group at a consistent rate annually. Unaware customers have no knowledge of the energy efficient technology option. Aware customers have knowledge of the product and understand its attributes. ME&O is often referred to as the advertising effect in Bass diffusion modeling.
- **Word of mouth** represents the influence of adopters (or other aware consumers) on the unaware population by informing them of efficient technologies and their attributes. This influence increases the rate at which customers move from the unaware group to the aware group. Word of mouth influence occurs in addition to ongoing ME&O. When a product is new to the market with few installations, ME&O is often the main source driving unaware customers to the aware group. As more customers become aware and adopt, however, word of mouth can have a greater influence on awareness than ME&O and lead to exponential growth. Exponential growth is ultimately damped by market saturation, leading to a bass diffusion model adoption curve, which has been observed frequently for efficient technologies.
- **Willingness** is the key factor affecting the move from an aware customer to an adopter. Once customers are aware of the measure, they consider adopting the technology based on the attractiveness of the measure. The 2021 PG Model uses a multi-attribute decision model to characterize the adoption behaviors of customers and ultimately calculate willingness. The Market Adoption Study collected survey data from customers to provide quantitative inputs to the new multi-attribute decision model. Additional discussion of willingness and how the Market Adoption Study was used follows Figure 2-4.

Figure 2-4. The Bass Diffusion Framework:
A Dynamic Approach to Calculating Measure Adoption[29]



Source: Guidehouse

Approach to Calculating Willingness

Customer willingness to adopt is a key determinant of long-run market share—that is, what percentage of individuals choose to purchase a technology provided those individuals are aware of the technology and its relative merits (e.g., the energy- and cost-saving features of the technology). The PG Model applies two approaches to calculating willingness depending on the sector: the logit approach or the payback-based approach. The residential and commercial sector equipment rebate programs use a logit-based approach. The industrial and agriculture equipment incentive programs (referred to as characterized custom technologies) use a payback-based approach.

Logit approach: For the residential and commercial sectors with information on baseline and efficient costs, the Guidehouse team applied a logit approach. This approach more appropriately captures the impacts of EE financing on market adoption. To understand how willingness is calculated in the 2021 Study, it helps to understand the logic used in the 2019 Study.

The 2019 PG Model calculated willingness using a single attribute decision model focusing on financial attractiveness, where the levelized measure cost (LMC) was the main value factor input. Value factors are the factors that customers consider valuable when deciding to adopt energy efficient equipment. Refer to Section 2 of the 2019 Study for more information on the willingness model.[30]

A key difference in the 2021 PG Model from earlier models is the inclusion of **multiple** value factors that inform a customer's willingness to adopt instead of solely using the LMC.[31] The 2021 PG Model also divides the residential sector into customer groups to reflect that different

[29] Adapted from John Sterman. *Business Dynamics: Systems Thinking and Modeling for a Complex World*. McGraw-Hill. 2000.

[30] Guidehouse (as Navigant). 2019 *Energy Efficiency Potential and Goals Study*. July 2019.

[31] The 2019 Study only used the LMC but did attempt to value non-cost factors that drive decisions through an assumed implied discount rate. The additional value factors included in the 2021 Study replace the use of an implied discount rate and provide actual data to inform the adoption drivers.

types of customers behave uniquely and often change what they value when considering different technologies.

The Guidehouse team designed the Market Adoption Study (detailed in Attachment 1) to collect information from customers to understand the relative importance of these six value factors and how each factor would affect a customer's multifaceted consumer decision-making process and ultimately their willingness to adopt a technology. Table 2-3 provides the values factor descriptions.

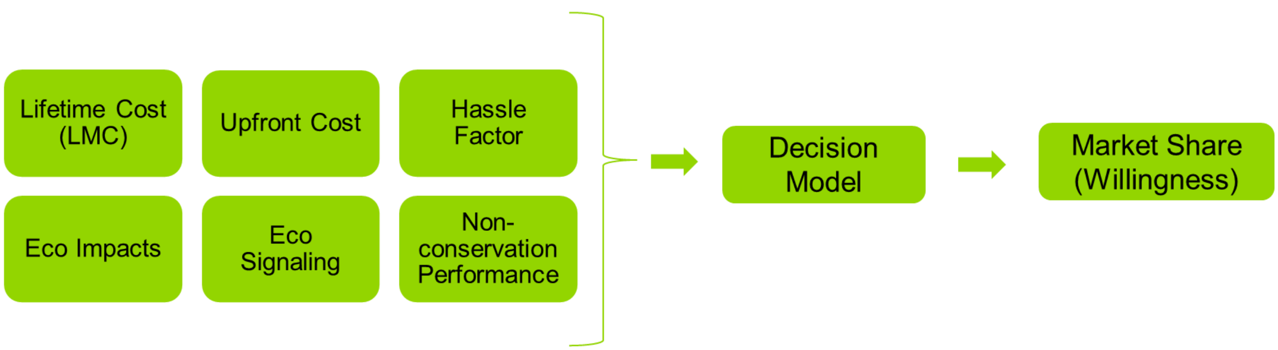
Table 2-3. Value Factor Descriptions

Value Factor	Customer Value Perspective
Lifetime Costs	Long-term energy costs and savings of the technology
Upfront Costs	Initial out-of-pocket price of the technology
Hassle Factor	Ease in installing and using a technology, which is also related to convenience of the purchase and installation
Non-consumption Performance	Other nonfinancial and non-energy elements that customers likely consider when deciding to purchase a new appliance or technology
Eco Impacts	Environmental impacts from energy consumption
Social Signaling	Being perceived as environmentally or socially responsible by one's peers

Source: Guidehouse

Figure 2-5 shows the 2021 Study's updated willingness model, and Appendix H provides more detail regarding the research and theory used to develop this approach.

Figure 2-5. 2021 Model Willingness Calculation



Source: Guidehouse

Through surveys, the Market Adoption Study determined the levels to which a customer values one or more factors than the others. The Guidehouse team refers to this set of information as customer preference weights. Customer preference weights indicate how much of a customer's total decision to adopt is attributed to a given value factor. For example, 18% of a customer's decision to adopt may be driven by the lifetime cost, 16% by the hassle associated, and so on, with all factors summing to 100% (Figure 2-7 provides an example). These weights vary by technology type and for each individual customer. Although there are variations across individual customers, customer preference weighting tends to cluster into distinct groups in the population.

Using a clustering analysis of these preference weights, the Market Adoption Study created customer groups in the residential single-family customer segment. The survey analysis resulted in four distinct residential customer groups: Average Californians, Eager Adopters, Likely Laggards, and Economically Strained Environmentalists. Each customer group had its own set of customer preference weights defining how these customers approach making purchase decisions. After forming these groups, the Market Adoption Study calculated a set of preference weights for each customer group. For the multifamily segment and commercial sector, the team did not develop any further analysis to formulate customer segment groups.[32] The Market Adoption Study did calculate the average preference weights for multifamily and commercial.

Building on the customer preference weights associated with the six value factors, the Guidehouse team developed corresponding characteristics for equipment across the same six value factors. Combining these two datasets allowed the team to quantify how a customer with a certain preference weighting will assess two competing equipment with different characteristics. In short, a technology's characteristics that best align with a customer's preferences drives their decision to adopt.

The Guidehouse team calculated the equipment characteristics using two different methods depending on if the value factor represented a quantitative or qualitative value. For the quantitative value factors (lifetime cost, upfront cost, hassle factor, eco impact), technology characterization data was used and resulted in a numerical value for each technology. For the qualitative value factors (eco signaling and non-conservation performance), qualitative assessments of each technology were performed, which resulted in a binary value for each technology. This binary value represented whether or not the technology exhibited this characteristic (e.g., a non-conservation performance value of 1 indicates the technology exhibits this characteristic). Table 2-4 shows how each value factor is assigned a numeric value for the characteristic value determination.

[32] The customer grouping analysis conducted for the single-family segment was not replicated for the multifamily and commercial segments because they did not have sufficient sample sizes for additional sub-segmentation.

Table 2-4. Value Factors

Value Factor	Technology Characteristic	Characteristic Value Determination
Lifetime cost	LMC	Present value of lifetime energy costs and upfront technology costs.*
Upfront cost	Measure cost	Upfront cost of purchasing the technology.*
Hassle factor	Labor cost	Hassle assumed to scale with the level of effort required to install the technology. Because labor costs scale with effort and complexity, these costs were used as a proxy for hassle.*
Eco impact	Energy consumption	Total annual energy consumption, converted to neutral units of Btu and summed over gas and electric impacts.*
Eco signaling	Energy consumption and 1 = Value eco-signaling 0 = Not value eco-signaling	First, the technology was qualitatively assessed to be a 1 if it was visible. Then, the 1 or 0 value was multiplied by the eco impacts to increase the weighting of that factor for those who valued eco signaling.*
Non-conservation performance	1 = High touch 0 = Low touch	Qualitatively assessed to be a 1 if the technology was both visible in the space AND customers interacted with it relatively frequently (e.g., refrigerator).

**Indicates technology characterization data was used to calculate the associated value.*

Source: Guidehouse

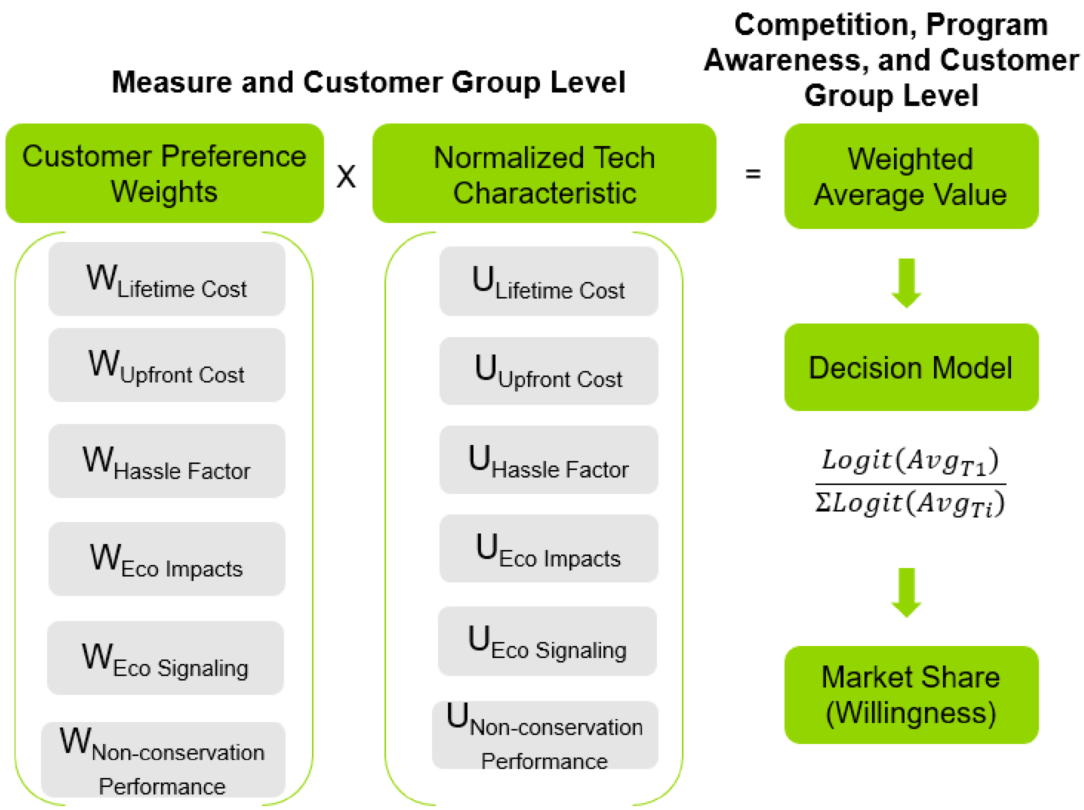
The team then converted the technology characteristics associated with each value factor to a dimensionless, normalized technology characteristic by dividing the value of the technology by the average value of the competition group (CG). This value can be interpreted as the relative characteristic value of the technology compared to the other CG measures, as Equation 2-1 shows. Further description of the CG analysis in calculating market share is shown in Figure 2-6.

Equation 2-1. Normalized Technology Characteristic Calculation

$$Normalized\ Technology\ Characteristic = \frac{Characteristic\ Value\ (for\ measure)}{Average\ Characteristic\ Value\ (across\ CG)}$$

For each technology and customer group, the Guidehouse team generated weighted average characteristics by taking the sum-product of the customer preference weightings for that customer group and the normalized technology characteristics for that technology. This weighted average is the combined value that indicates the relative attractiveness of a technology compared to the other measures in its competition group. Figure 2-6 shows how customer preference weightings and technology characteristics are combined and fed into the decision model, which then follows the same logic model as the 2019 Study, resulting in the market share calculation for each technology.

Figure 2-6. Calculating Market Share



Source: Guidehouse

Figure 2-7 shows an example with values provided for customer preference weights and normalized technology characteristics for two technologies within the same competition group (the baseline and efficient technologies). The weighted averages for the efficient and baseline case are calculated by multiplying the customer preference weights by the normalized technology characteristics. After running the resulting weighted averages through the logit decision model, the efficient technology in this example garners 60% of the market share within its competition group.

Figure 2-7. Multi-Attribute Market Share Example

Source: Guidehouse

Payback-based approach: In the agriculture, industrial, and mining (AIM) sectors, the technology characterization did not incorporate baseline technology costs, a driver in the multi-attribute analysis. These sectors also did not explore the effects of EE financing; the Guidehouse team used a payback-based approach to calculate willingness.[33] Payback time reflects the length of time (years) required for an EE investment to recover the initial upfront cost in terms of energy savings. Consistent with the 2019 Study, to estimate market share for the AIM measures, the team relied on payback acceptance curves based on Guidehouse-led primary research in the US Midwest in 2012 (shown in Figure 2-8).[34] Though the team collected California-specific data, qualitative information helped adjust the model willingness curves accordingly. Actual data from the Industrial and Agriculture Market Study was not used to recalculate the payback curves due to a combination of factors:

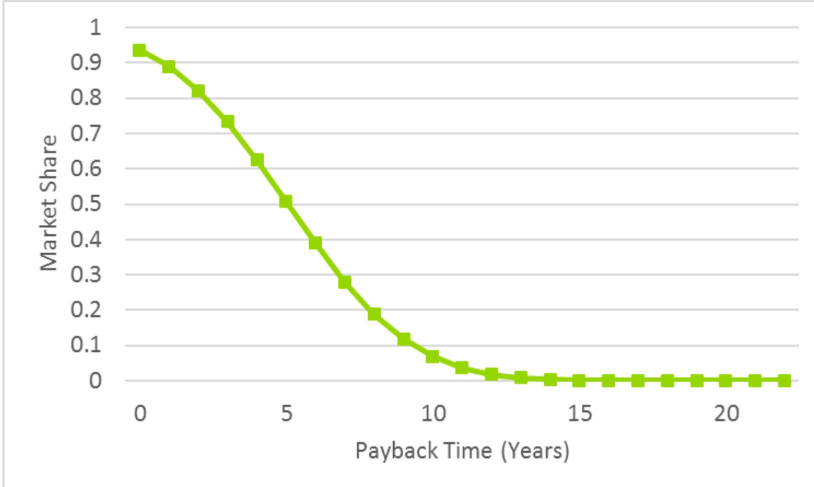
- Limited number of survey responses received regarding sensitivity to payback periods.
- Responses received resulted in market share values extremely similar to those of the corresponding payback times in Figure 2-8. Specifically, when asked about their willingness to adopt an efficient boiler given either a 2.3- or 4.7-year payback period, the average difference from the corresponding values in Figure 2-8 was approximately 3%.

Based on the nature of the customer decision-making process, the Guidehouse team believes the data developed using North American customers represents the best industry-wide data available at the time of this study.

[33] The primary objective of the Industrial and Agriculture Market Study was to inform the measure characterization. The secondary objective was to include data to inform the model's market adoption algorithms.

[34] A detailed discussion of the methodology and findings of this research are contained in the *Demand Side Resource Potential Study*, prepared for Kansas City Power and Light, August 2013.

Figure 2-8. Payback Acceptance Curve for AIM Sectors



Source: Guidehouse (formerly Navigant) analysis of data contained in the Demand Side Resource Potential Study prepared for Kansas City Power and Light, August 2013.

Applying Incentives

The two value factors for informing customer adoption are upfront cost and lifetime cost. These are the net out-of-pocket costs a customer pays to purchase and install a technology. Rebates and incentives provided to the customer act to decrease the cost.

The PG Model is agnostic as to the funding source for the utility incentive; instead it models the customer's response to the total incentive amount they are offered. EE and fuel substitution incentives are calculated on a $/kWh and $/therm basis capped at a maximum value (50% or 75% of incremental cost depending on the scenario).

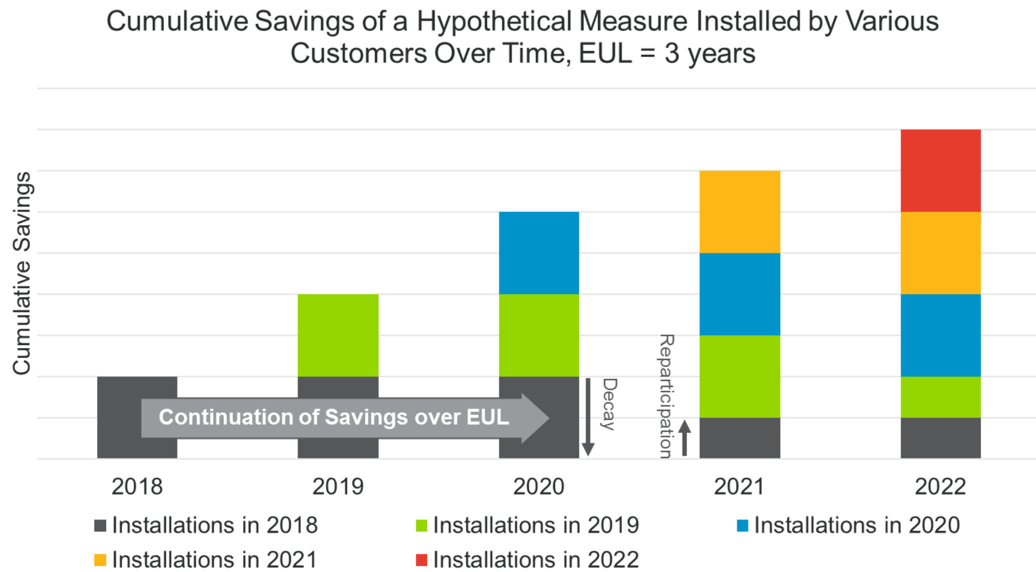
2.1.1.5 Calculating Cumulative Achievable Potential

Potential and goals studies report incremental and cumulative savings. Recently, IOU goals have been based on incremental savings only, while cumulative savings were used to inform the CEC demand forecast. Cumulative savings represent the total EE program savings from measures installed since a start year (2022 for this study) and that are still active in the current year. Active savings are calculated by accounting for the following:

- Decay of savings as measures reach the end of their useful lives
- C&S that come into effect over time

Unlike annual savings, cumulative savings include savings from re-participants. Incremental savings only consider first-time adopters. Sustained savings from re-adoptions need to be counted in cumulative savings for the demand forecast. The PG Model assumes re-participants re-adopt measures at the same rate as new participants, consistent with the 2019 Study. Figure 2-9 illustrates the calculation of cumulative savings.

Figure 2-9. Cumulative Savings Illustration



Source: Guidehouse

2.1.2 Fuel Substitution

This study includes fuel substitution technologies in addition to the historically rebated EE technologies. Fuel substitution technologies are a new addition to the forecast; however, they leverage much of the same methodology as used by historically rebated EE technologies previously described in Section 2.1.1. This section describes additional enhancement made to the methodology to accommodate fuel substitution measures.

Fuel substitution involves replacing equipment utilizing one regulated fuel with equipment utilizing another regulated fuel, for example, substituting gas equipment for electric equipment. In this current study, fuel substitution includes replacing a gas baseline technology with an electric efficient technology. The current study only includes fuel substitution measures if there is a pending or approved workpaper as of the summer of 2020 resulting only gas to electric substitution in the scope. Additionally, only fuel substitution measures that passed the FST are included in the measures analyzed in the 2021 Study.

2.1.2.1 Technology Groups, Efficiency Levels, and Competition

Fuel substitution measures compete with EE measures within a technology group. The electric technology competes with high efficiency gas technologies. Table 2-5 illustrates a technology group with fuel substitution levels. It is also possible that a DR-enabled technology resides within the same technology group (discussed further in Section 2.1.3).

Table 2-5. Example of Technologies within a Technology Group – Fuel Substitution

Technology Group	Technology	Description
Small Gas Water Heaters (normal replacement and New)	Small Gas Storage Water Heater	Code Efficiency Level
	Condensing Gas Storage Water Heater	High Efficiency Gas Level
	Instantaneous Gas Water Heater	High Efficiency Gas Level
	Heat Pump Water Heater	High Efficiency Electric Level
	DR-enabled Smart Heat Pump Water Heater	High Efficiency Electric Level

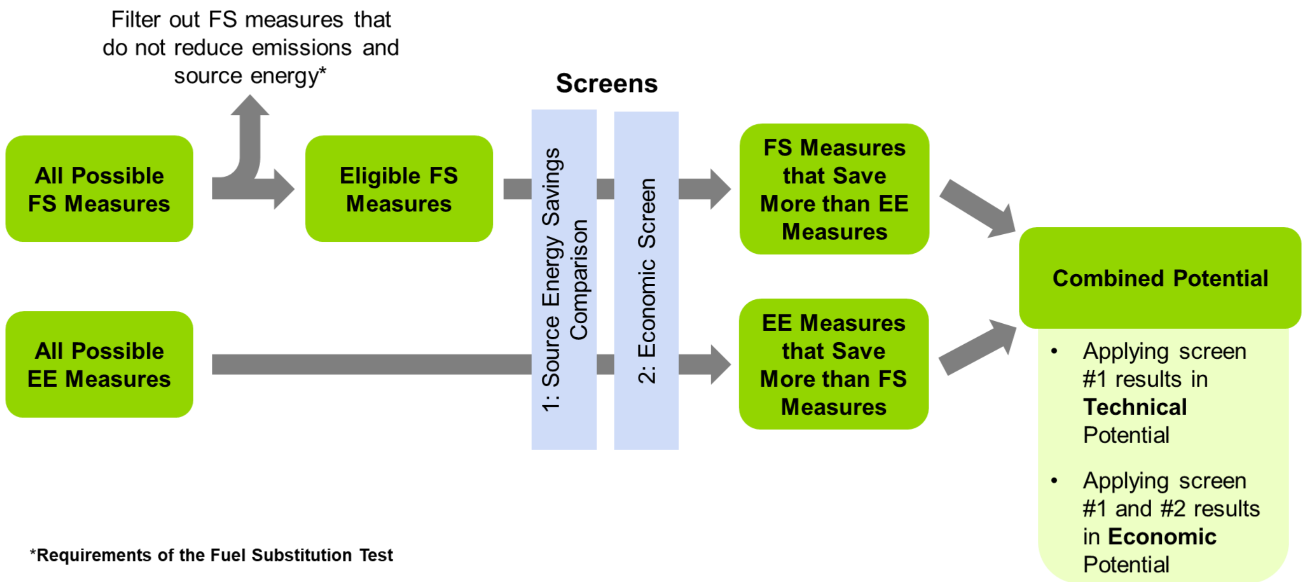
Source: Guidehouse

2.1.2.2 Technical and Economic Potential

Current fuel substitution measures decrease gas load but increase electric load, as per the existing workpapers. Fuel substitution measures must pass the FST to be included in either the technical or economic potential. Figure 2-10 illustrates the methods used to screen measures for potential analysis and how the fuel substitution measures are handled. The 2021 Study only analyzed eligible fuel substitution measures (those determined to pass the FST); the study excluded fuel substitution measures that failed the FST. There are some unique differences in assessing fuel substitution measures compared to EE measures:

- **Technical Potential** - If the fuel substitution measure saves more source energy (in Btus) than its competing EE measures, the fuel substitution measure wins the competition and thus represents technical potential.
- **Economic Potential** - Fuel substitution measures value both the gas savings (a positive benefit) and the increased electricity supply cost (a negative benefit). For fuel substitution measures that fall in the overlapping SCG and SCE territory, the model applies SCG avoided gas costs to value the gas savings benefits and SCE avoided electric costs to value the increased supply cost. This contrasts with EE measures in the SCG and SCE territories where only one fuel is valued for each utility (even in the case of interactive effects or dual fuel saving measures).

Figure 2-10. Screening for Technical and Economic Potential



FS= fuel substitution
Source: Guidehouse

Technical and economic potential for fuel substitution measures are assigned to the electric IOU that serves the new electric load. This means that reductions in SCG gas energy use due to fuel substitution are assigned to SCE. However, if a fuel substitution measure does not win the technical or economic potential competition, the gas efficiency savings resulting from the competing efficient gas technology remain with SCG. Equipment that passes the cost-effectiveness screening criteria regardless if it wins technical or economic competition is carried through to the achievable potential calculations as well. There are exceptions for EE or fuel substitution equipment that do not pass the cost-effectiveness screening where they are pushed through to achievable potential analysis.

2.1.2.3 Achievable Potential

Because fuel substitution technologies compete with EE measures, their market adoption is modeled the same way. This section describes the additional considerations made for fuel substitution technologies.

Approach to Calculating Willingness

The approach to calculating willingness to adopt fuel substitution measures is nearly identical to the methods discussed in Section 2.1.1.4, except for one difference. The customer preference weights defining how much of a customer's total decision to adopt is attributed to a given factor varies by technology type. The results of the market study revealed that customers indeed have different customer preference weights for fuel substitution technologies as compared to same fuel technologies. Thus, although the approach to calculating market share is the same as it is for same fuel technologies, the customer preference weights used in the calculation are different.

Applying Incentives

The two value factors for informing customer adoption are upfront cost and lifetime cost. These are the net out-of-pocket costs a customer pays to purchase and install a technology. Rebates and incentives provided to the customer act to decrease the cost.

The PG Model is agnostic as to the funding source for the utility incentive; instead it models the customer's response to the total incentive amount they are offered. Fuel substitution incentives (like those for EE) are calculated on a $/kWh and $/therm basis capped at a maximum value (50% or 75% of incremental cost depending on the scenario). Furthermore, the model is agnostic to the issue of incentive layering for fuel substitution measures. Explicit modeling of the additional incentives available from outside the EE program are not examined.

2.1.3 DR-Enabled Technologies

This study includes a sensitivity that assessed DR-enabled technologies in addition to the rebated EE and fuel substitution technologies. They are a new addition to the study, but they leverage much of the same methodology as used by rebated EE technologies previously described in Section 2.1.1. This section describes additional enhancement made to the methodology to accommodate DR-enabled EE measures.

This sensitivity is not meant to forecast the potential for DR. Rather is its meant to capture the added costs and benefits of DR-enabled technologies that also reside within the EE programs. These added costs and benefits give a more complete picture of the cost-effectiveness and customer adoption dynamics for these measures that offer multiple benefit streams.

2.1.3.1 Technology Groups, Efficiency Levels, and Competition

DR-enabled technologies compete with EE measures (and possible fuel substitution measures) within a technology group. Table 2-6 illustrates an example of a DR-enabled technology competing with EE technologies.

Table 2-6. Example of Technologies within a Technology Group – DR-Enabled

Technology Group	Technology	Description
Res Clothes Washer	Code Level Res Clothes Washer	Average Existing and Code
	Efficient Res Clothes Washer	Efficient
	Smart Res Clothes Washer (DR-Enabled)	Efficient

Source: Guidehouse

2.1.3.2 Technical and Economic Potential

Technical potential for DR-enabled technologies is calculated the same way as EE technologies. The uniqueness of DR-enabled measures does impact economic potential calculations.

The Guidehouse team included the DR benefits and associated costs for realizing DR benefits in the economic potential calculations. The team assessed the cost-effectiveness of these technologies from an integrated EE-DR perspective. The DR benefits for these technologies included the avoided capacity (both generation and T&D), avoided energy, and avoided greenhouse gas (GHG) emissions costs based on the CPUC's 2016 DR Cost-Effectiveness Protocols and E3's Avoided Cost Calculator 2020 (ACC).[35] On the costs side, DR-related operations and maintenance (O&M) and program administrative costs were added because the EE-DR technology cost is already considered in the EE economic potential analysis.

In some cases, the addition of DR benefits can make an EE measure more cost-effective such that it crosses the cost-effectiveness screening threshold to be included in the economic potential. It is also possible that these DR benefits are outweighed by DR costs potentially reducing the cost-effectiveness of some measures.

Appendix I describes the study's approach for calculating DR co-benefits for measures with EE and DR co-benefits.

2.1.3.3 Achievable Potential

Because DR-enabled technologies compete with EE measures, their market adoption is modeled the same way. This section describes the additional considerations made for DR-enabled technologies.

Approach to Calculating Willingness

For EE technologies that also have DR capabilities, the model's willingness calculations assess customer adoption from a joint EE-DR perspective for some of the study scenarios. This perspective is illustrated using a smart thermostats example in Figure 2-11 and Table 2-7.

In the smart thermostat adoption example, a customer is faced with three discrete choices[36] to purchase the smart thermostat:

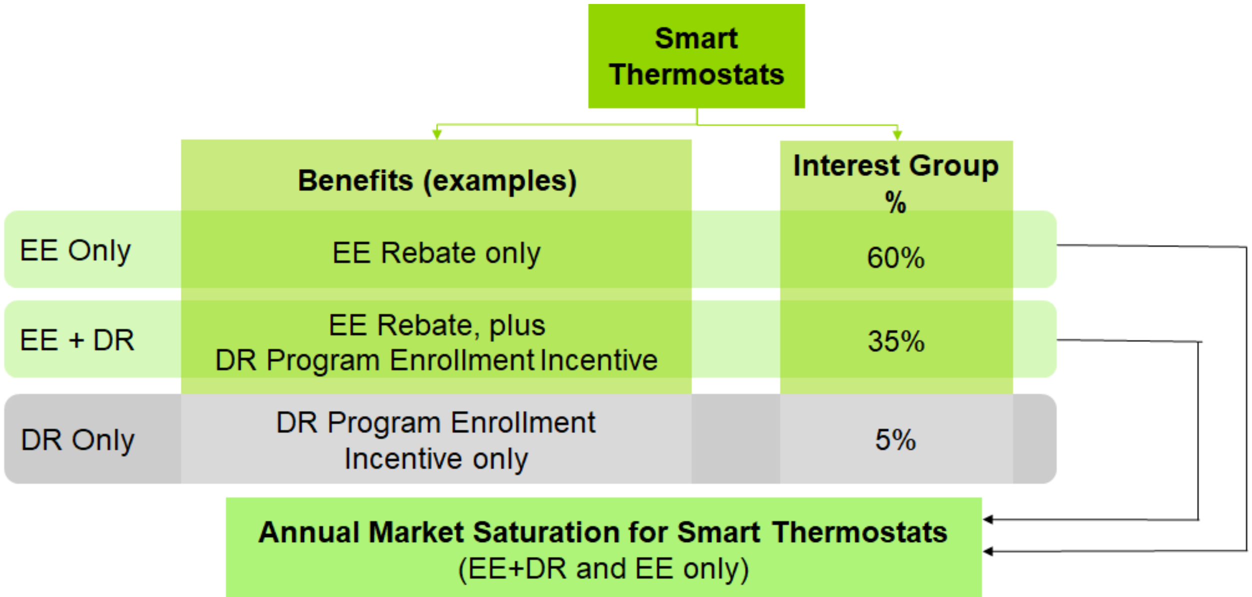
- Decision to purchase a smart thermostat based on EE-only benefits
- Decision to purchase a smart thermostat based on EE and DR benefits
- Decision to purchase a smart thermostat based on DR-only benefits[37]

[35] 2016 Demand Response Cost-Effectiveness Protocols available at https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=11573;
The Avoided Cost Calculator (ACC) is available at
ftp://ftp.cpuc.ca.gov/gopher-data/energy_division/EnergyEfficiency/CostEffectiveness/2020%20ACC%20Electric%20Model%20v1c.xlsb

[36] These are mutually exclusive and collectively exhaustive choices for customer adoption of a technology with joint EE and DR benefits.

[37] In this case, the customer does not receive any EE incentives for purchasing the thermostat.

Figure 2-11. Benefits from EE-DR Technologies in the Adoption Model (Illustrative using Smart Thermostats)[38]



Source: Guidehouse

This study's integrated EE-DR framework factors in both EE-only benefits and EE-DR joint benefits for smart thermostats or other integrated technologies to model the customer adoption of technologies with co-benefits for EE and DR. The DR-only value stream consideration is outside the scope of this study because it does not include any EE benefits. Accordingly, in Figure 2-11, only customers from the first two benefits streams (EE Only and EE+DR) are incorporated into the adoption modeling for smart thermostats. The market Adoption Study (described in Section 3.5) informed customer likelihood to adopt EE-DR technologies from EE-only and EE+DR benefits perspectives. [39]

Table 2-7 shows how EE and DR benefits and costs map to the value factors that influence customer adoption. It shows the benefit and cost items by value factor for customers that adopt technologies from an EE-only perspective and from a joint EE-DR perspective. These benefits and costs feed into the willingness calculations in the model. The overall technology adoption in the integrated framework is a combination of both groups of customers (those considering EE-only benefits and those considering joint EE and DR benefits from the technology adoption).

Appendix I.2 describes the DR-related inputs used for adoption calculations.

[38] In the smart thermostat illustration, the "DR Program Enrollment Incentive" represents the one-time bill credit that customers could get from enrolling in a DR program. This is in addition to EE rebates on smart thermostats. For example, in SCE's Smart Energy Program, customers receive a one-time $75 bill credit for signing up in the DR program in addition to getting rebates on the smart thermostat purchase. So the DR Program Enrollment Incentive refers to the one-time $75 bill credit.

[39] The adoption percentage for customers who are likely to adopt thermostats or other EE-DR technologies from a DR-only perspective would need to be from separate market research efforts and was not within the scope of the Market Adoption Study research.

Table 2-7. Benefits and Costs by Value Factor in an Integrated EE-DR Adoption Framework

Value Factor	Customers Considering EE Benefits only	Customers Considering Both EE and DR Benefits
LMC (numerical value)	**Upfront costs** (+) Technology capital cost (+) Technology installation costs (-) EE incentives **Annual operating costs** (+) O&M costs (-) Bill savings due to kilowatt-hour (kWh) reduction	**Upfront costs** (+) Technology capital cost (+) Technology installation costs (-) EE incentives *(-) DR upfront incentives* **Annual operating costs** (+) O&M costs (-) Bill savings due to kWh reduction *(-) Annual DR incentives* *(-) Additional bill savings from enhanced response to TOU rates*[40]
Upfront costs (numerical value)	**Upfront costs** (+) Technology capital cost (+) Technology installation costs (-) EE incentives	**Upfront costs** (+) Technology capital cost (+) Technology installation costs (-) EE incentives *(-) DR upfront incentives*
Hassle factor (installation cost)	(+) Technology installation costs	(+) Technology installation costs
Eco impacts (energy savings)	• EE kWh savings	• EE kWh savings • *Additional kWh and kilowatt (kW) reduction from DR enrollment*
Eco signaling (*binary scaling of energy savings)	EE kWh savings	• EE kWh savings *Additional kWh and kilowatt (kW) reduction from DR enrollment*
Non-conservation performance (binary)	0 or 1	0 or 1

(+) costs to the consumer
(-) benefits to the consumer
Italics indicate additional items needed for EE-DR items
*: First, the technology was qualitatively assessed to be a “1” if it was visible. Then, the “1” or “0” value was multiplied by the eco impacts to increase the weighting of that factor for those who valued eco signaling
Source: Guidehouse

Applying Incentives

The two value factors for informing customer adoption are upfront cost and lifetime cost. These are the net out-of-pocket costs a customer pays to purchase and install a technology. Rebates and incentives provided to the customer act to decrease the cost.

[40] This represents the additional bill savings from TOU rates through enhanced response to these rates by utilizing the flexibility provided by EE-DR enabling technologies.

The PG Model is agnostic as to the funding source for the utility incentive; instead it models the customer's response to the total incentive amount they are offered. Any DR incentive offered is additive to EE and fuel substitution incentives allowing the model to exceed the scenario-defined incentive cap.

2.1.4 Whole Building Packages

Whole building packages are modeled the same way as rebated technologies with one exception. Technical and economic potential results are not presented because they are duplicative with the technical and economic potential of rebated technologies. Whole building packages are excluded from the technical potential because including them would be duplicative with the technical potential for individual measures. Highly efficient new building or retrofitted building will have no additional opportunity for individual EE technologies to be installed. When accounting for other measures that could technically be installed in the same building, double counting of savings would occur (or if wishing to prevent double counting, either the whole building package would have to be removed or all other technologies potentials would be underestimated).

2.1.5 Industrial and Agriculture Custom Measures and Emerging Technologies

The potential and goals study categorizes the industrial and agriculture sector EE opportunities into different technology groups defined in Table 2-8. The rebated EE technologies via incentive programs, follow the same analysis methodology for residential and commercial technologies. These rebated EE technologies are called characterized custom. This section addresses the technology categories using a top-down approach (BROs or the SEM-like program for the industrial and agriculture sector are also discussed in Section 2.1.6). Definitions and data sources are provided in more detail in Section 3.7.

Table 2-8. Industrial and Agriculture Technology Categories

Categories	Definition	Model Approach
Emerging Technologies	Nascent or emerging technology	Top-down approach
BROs*	RCx, SEM, or optimization	Top-down approach
Characterized Custom†	Readily defined measures	Bottom-up Bass diffusion approach
Generic Custom	Unique and/or process improvement measures	Top-down approach

*SEM is modeled as an Industrial and Agriculture BROs measure by allocating the historical RCx as a proxy for SEM savings.

†Mining only has characterized custom measures.

Source: Guidehouse

The top-down approach for emerging technologies and generic custom measures uses Equation 2-2 to calculate incremental achievable potential. Guidehouse defined unit energy savings in terms of savings as a percentage of the sector level consumption. Additional variable details and definitions follow Equation 2-2.

Equation 2-2. Incremental Achievable Potential for Generic Custom and Emerging Technologies

$$Incremental\ Market\ Potential = Population \times Applicability\ Factor \times Unit\ Energy\ Savings \times Penetration\ Rate$$

Where:

- **Population** is a global input represented as the total energy consumption by subsector within the industrial and agriculture sectors.
- **Applicability Factor** represents eligibility and other program-specific variables applied at the subsector level.
- **Unit Energy Savings** represent the percentage of savings expected from customers adopting technologies at the subsector level.
- **Penetration Rate** represents annual new participation and varies over time; it can also vary by scenario for emerging technologies. Penetration rate is applied at the market sector level.

The 2021 Study did not update the emerging technology list, inputs, or analysis. Emerging technologies were screened for consideration based on an eight-level screening process considering the following factors:

- Relevance to the industrial and agriculture sectors
- Relevance by North American Industry Classification System (NAICS) segment
- End-use application
- Type of fuel savings
- Potential energy savings percentage
- Impact potential (including technical and achievable potential, risks, and non-energy benefits)
- Segment energy consumption trends
- Segment market trajectory

Emerging technologies that passed the screening criteria were used to derive emerging technology unit energy savings (UES) values grouped by market segment (e.g., petroleum, food processing) using the methodology defined in Appendix F. Emerging technology UES is represented as a percentage of savings relative to the total building energy consumption. It is meant to reflect the combination of available emerging technologies that pass the screening process for each sector and segment rather than individual technologies. UES is estimated based on multiple factors listed below Equation 2-3.

Equation 2-3. UES for Emerging Technologies

$$UES_{e,i,j} = T_e \times E_{i,j} \times MT_j \times TW_j$$

Where:

e	= subscript indicating the specific emerging technology
i	= subscript indicating the specific end use and fuel type
j	= subscript indicating the market subsector and NAICS segment
T_e	= technology energy savings percentage for emerging technology *e* by end-use application
$E_{i,j}$	= percentage of total energy consumption by subsector *j* energy attributable to end-use *i*
MT_j	= market trajectory for sector *j*
TW_j	= segment energy consumption trend weight for sector *j*

The following factors make up the UES:

- Each emerging technology has a unique technology energy savings percentage, Te.
- California market data defines the sector end-use percentage of total energy consumption, Ei,j.
- The market trajectory for each sector, MTj, is a value between 0 and 1, indicating if the sector is likely to move offshore (0.33), close to tipping point of moving offshore (0.67), or likely to remain in the US (1).[41]
- The segment energy consumption trend weight, TWj, is a value between 0 and 1, indicating the trend of energy consumption of each sector over time based on an analysis provided by the CEC showing the electricity consumption trend for various industries.

Section 3.8 discusses the data inputs for this equation.

Industry standard practices (ISPs) are not forecast to impact the potential from custom measures and emerging technologies. ISPs are technology- and segment-specific, while custom programs and emerging technologies as forecast in this study do not contain technology-specific information to allow ISPs to be applied.

2.1.6 Behavior, RCx, and Operational Efficiency (BROs)

For this study, the Guidehouse team defines behavior-based initiatives as those providing information about energy use and conservation actions to drive customer actions rather than financial incentives, equipment, or services to support customer investment. The savings potential modeled for these initiatives is designed to be additive to the savings from rebated technologies (which do not account for any behavior based savings).

[41] Sirkin, H. et al. *U.S. Manufacturing Nears the Tipping Point*, The Boston Consulting Group, March 2012.

2.1.6.1 Energy and Demand Savings

Equation 2-4 is the general equation for the BROs potential model. Each of the components are described below.

Equation 2-4. Incremental Achievable Potential for BROs

$$\begin{aligned} &\mathit{Incremental\ Market\ Potential} \\ &\qquad = \mathit{Population} \times \mathit{Applicability\ Factor} \times \mathit{Unit\ Energy\ Savings} \\ &\qquad \times \mathit{Penetration\ Rate} \end{aligned}$$

Where:

- **Population** is a global input that can be represented in two ways: number of homes and square feet of floor space or sector energy consumption.
- **Applicability Factor** represents eligibility and other program-specific variables, including existing saturation that precludes customers from participating in future IOU interventions.
- **Unit Energy Savings** represent the savings expected from participants and can also be represented in two ways: kWh and therms or percentage of consumption.
- **Penetration Rate** represents participation and varies over time and by scenario (reference or aggressive). The penetration rate reflects both utility-driven rollout and customer uptake of the program, depending on the nature of the program.

The initial penetration rates are based on existing levels of participation, either for the California IOUs for existing programs or the program from which data was drawn and applied to California IOU territories. The forecast inputs are the result of previous study stakeholder review, existing program operations, historical participation rates, and on whether participation is utility-driven (opt out) or customer-driven (opt in).

The potential for double counting among BROs programs was addressed in the characterization of programs in the same sector. The Guidehouse team adjusted penetration and applicability to avoid the double counting of savings.

This effort does not examine programs that focus on demand reduction (e.g., DR) but does include demand savings from the characterized BROs programs using Equation 2-5.

Equation 2-5. BROs Demand Savings

$$\begin{aligned} &\mathit{Incremental\ Market\ Potential}\ (kW) \\ &\qquad = \mathit{Incremental\ Market\ Potential}\ (kWh) \times \mathit{Peak\ to\ Energy\ Ratio} \end{aligned}$$

2.1.6.2 BROs Costs

Similar to demand savings, utility program costs are calculated from the energy savings in Equation 2-4. The cost factor in Equation 2-6 is a unit energy cost expressed in either dollars per kWh or dollars per therm. For programs that save both electricity and gas, it was sometimes possible to divide the costs by fuel type; however, in instances where this was not possible, all costs were assigned to one fuel type to avoid double counting.

Equation 2-6. BROs Program Costs

$$Program\ Cost = Incremental\ Market\ Potential\ \times\ Cost\ Factor$$

2.1.7 Codes and Standards

C&S impact EE potential in two different ways:

- C&S impacts the code baseline for IOU-rebated measures. The Guidehouse team model that as C&S become more stringent in the future, above code savings claimable by IOU programs decrease. The impacts of code baseline changes on existing measures in the incentive programs are addressed in the EE technology rebates methodology and discussed further in Section 2.1.1.2.
- C&S results in holistic changes in the market penetration of efficient technologies. Per the CPUC policies, IOUs can claim a portion of savings from C&S that come into effect through the IOU C&S advocacy programs. This section describes the calculation of IOU-claimable savings from C&S.

This study calculates the estimated savings of C&S in multiple formats, each for a different use:

- **Net C&S savings** are the total energy savings estimated to be achieved from the updates to C&S since 2006. Net savings calculations account for naturally occurring market adoption (NOMAD) of code-compliant equipment and are used to inform demand forecasting, procurement planning, and tracking against GHG targets. The net C&S savings informs the CEC forecast of AAEE and SB 350 target setting.
- **Net IOU C&S program savings** identifies the portion of the net C&S savings that can be attributed to the advocacy work of the IOU's C&S program. This result is used to inform the IOU's program goals.

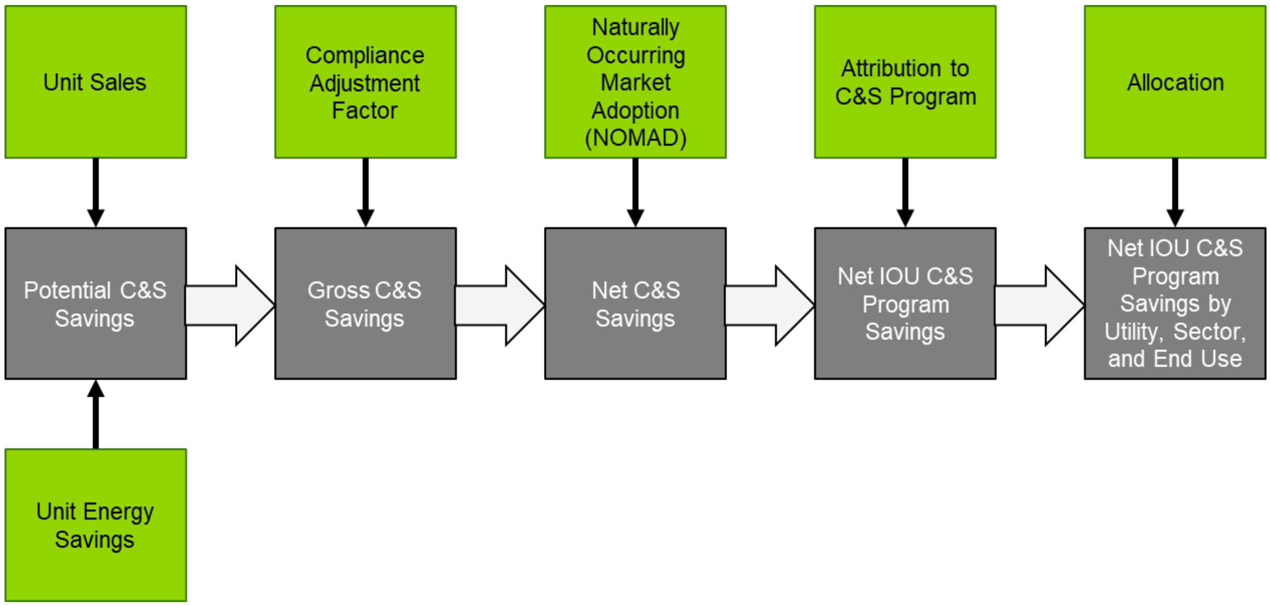
The modeling methodology of C&S savings was based on the ISSM[42] developed by Cadmus and DNV GL and used by the CPUC in C&S program evaluation. The Guidehouse team replicated the ISSM methodology in the PG Model for use in this study. Figure 2-12 illustrates the process to calculate net C&S savings and net IOU C&S program savings. Key components of the calculation listed in Figure 2-12 include the following:

- **Unit sales:** The assumed baseline units sold each year for each measure. They represent the expected population of code-compliant or standard-compliant equipment adopted.
- **UES:** The energy savings (in kWh, kW, or therms) relative to the previous code or standard for the new compliant equipment.
- **Compliance adjustment factor (CAF):** The baseline assumption for the rate at which the population complies with codes or standards.
- **NOMAD:** The fraction of the population that would naturally adopt the code-compliant or standard-compliant measure in the absence of any code or standard.
- **Attribution:** The portion of gross C&S savings in California that can be claimed by IOU code support programs.

[42] Cadmus and DNV GL. *Integrated Standards Savings Model (ISSM).* 2017.

- **Allocation factors:** The fraction of the statewide C&S savings that occur in each IOU territory. Additional allocation factors assumed by the Guidehouse team break down the savings into sectors and end uses.

Figure 2-12. C&S Savings Calculation Methodology



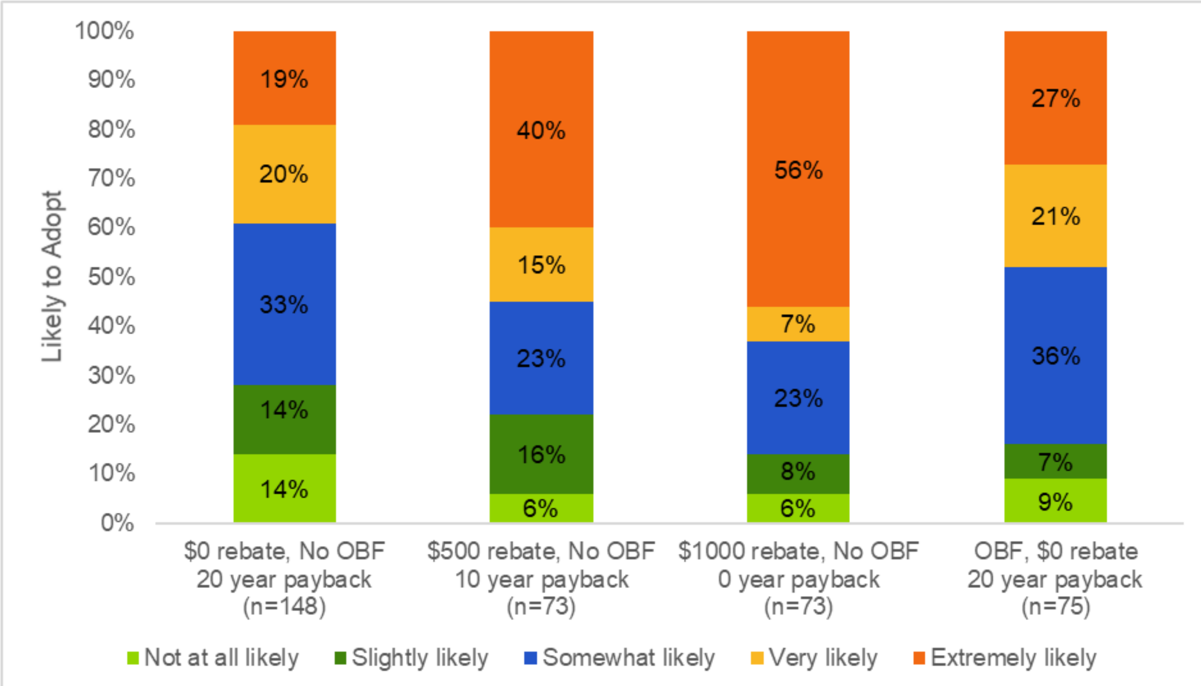
Source: Guidehouse

2.1.8 Financing

Financing has the potential to break through several market barriers that have limited the widespread market adoption of cost-effective EE measures. The PG Model is able to estimate the added effects of introducing EE financing to qualified residential and commercial customers on EE achievable potential and how shifting assumptions about financing affect potential energy savings. Guidehouse continued to use the methodology and data inputs related to financing in the 2019 Study (no updates were made for the 2021 Study). Additional details on the methodology and data inputs can be found in Appendix G.

While the Market Adoption Study asked questions about a customer's likelihood to adopt technologies with and without EE financing (example results shown in Figure 2-13), this study did not have the time to explore integrating this dataset nor corroborating financing program evaluation results to reliably inform calibration. This effort could be explored in future studies alongside results from future financing program impact evaluations.

Figure 2-13.Single-Family Residential[43] Customers' Reported Willingness to Adopt an EE Central Air Conditioner (CAC) Under Different Payback and On-Bill Financing (OBF) Scenarios*



*Surveyed customers were asked to consider needing to replace their CAC and their willingness to adopt the EE model (versus a standard efficiency model) under different payback scenarios. All respondents were asked the first baseline scenario without a rebate or OBF; about half were then asked the two follow-up rebate scenarios and about half were asked the follow-up OBF scenario. Respondents who reported they were extremely likely to adopt in one scenario were not asked but were included as extremely likely in the follow-up scenarios. Respondents also could not report a lower willingness to adopt in a follow-up scenario than what they reported in a previous scenario. Costs and payback periods are from market and engineering estimates for average-sized CACs in California. A payback period is the amount of time for the average energy savings from the EE technology to equal the difference in cost between the EE and standard efficiency models.

Source: Opinion Dynamics analysis

2.1.9 IRP Integration

Section 5 addresses the details of the IRP integration methodology. The IRP integration analysis focused on optimizing EE savings from equipment rebate measures and BROs programs through the CPUC's IRP model. Savings from C&S and low income programs remained as baseline (load-modifying) resources in this technical analysis for the following reasons:

- C&S development, while influenced by load service entities (LSEs), are largely outside the control of LSEs. They are not procured the same way as other demand side resources.
- Low income programs are subject to a different set of regulations than all other demand side resources. They must be offered to IOU customers and are not subject to a cost-effectiveness test.

[43] No residential OBF is currently offered by the California IOUs.

Hourly savings forecasts for C&S and low income were obtained from CEC staff. These were used as inputs to the IRP model to represent these load modifying resources.

Guidehouse used the PG Model to develop a set of EE supply curves that can feed into the CPUC's IRP model (RESOLVE), which was developed by its contractor E3. While building on this history, Guidehouse:

- Prepared the PG Model to calculate the IRP scenario (maximum technical achievable) and extracted required data streams for the E3 model.
- Developed a scenario to compare to the reference scenario.
- Prepared a load shape library to map potential and goals study measures.
- Prepared measure bundles with IRP model data requirements (bundle load shapes, EUL, levelized costs).
- Submitted to the E3 model data streams for the IRP scenario.
- Received E3 data (measure bundles adopted and in what year) and disaggregated it to the utility and measure levels.
- Calculated portfolio cost-effectiveness for the IRP scenario.

2.2 Calibrating Rebated Technologies and Whole Building Approaches

Like any model that forecasts the future, the PG Model faces challenges with validating results because there is no future basis against which one can compare simulated versus actual results. Calibration, however, provides both the developer and recipient of the model results with a level of comfort that simulated results are reasonable. Calibration is intended to achieve the following:

- Anchor the model in actual market conditions and ensure the bottom-up approach to calculating potential can replicate previous market conditions.
- Ensure a realistic starting point from which future projections are made.
- Account for varying levels of market barriers and influences across different types of technologies observed by historical trends. The model applies general market and consumer parameters to forecast technology adoption. There are often reasons why markets for certain end uses or technologies behave differently than the norm—both higher and lower. Calibration offers a mechanism for using historical observations to account for these differences.

The calibration process is not a regression of savings or spending (not drawing a future trend line of savings based on past program accomplishments). Rather, calibration develops parameters that align the customer decision-making process and the velocity of the market based on recent history. Once these parameters are set, the model uses them as a starting point for the forecast period.

The process to develop these parameters requires historical market data. The PG Model uses 2016-2019 program data (gross savings, program spending data) and performs a backcast to fit model parameters such that historical achievements are generally matched.

The primary method of calibration was reviewing EE portfolio achievements to assess how the market has reacted to program offerings in the past. The gross savings and spending during this backcast period are compared to actual program gross savings spending. Modeling parameters are adjusted to reasonably align the backcast to historical data.

When this primary method of calibration was not possible (in cases the market has significantly changed since 2016), a secondary method was used. The secondary method focused on tuning saturation and penetration rates to observed market conditions rather than relying on historical program savings and spending.

Calibration excludes fuel substitution measures and DR benefits and costs since there are no applicable historical performance period available. These are only added and layered into the model during the forecast period. For more details on calibration, see Appendix A.

2.3 Scenarios

This study forecasts multiple achievable potential scenarios to inform the CPUC's goal setting process. Scenario development in this study follows the same framework as the 2019 Study. One reference scenario stems directly from the calibration process. Alternate scenarios are informed by stakeholder and policy input.

Guidehouse will conduct additional scenario analysis as part of the AAEE analysis after the 2021 Study is finalized. AAEE scenarios feed into the CEC's IEPR and are built around the adopted IOU goals and are informed by potential and goals scenarios. AAEE scenarios consider additional variables, policy context, and, most importantly, do not impact IOU goals.

This study considers scenarios primarily built around policies and program decisions under the control of the CPUC and IOUs collectively; these are referred to as internally influenced variables. Externally influenced variables were not considered in scenarios that inform the goals. External variables are those the CPUC and IOUs collectively have no control over. Table 2-9 provides examples of internally and externally influenced variables.

Table 2-9. Variables Affecting EE Potential

Internally Influenced	Externally Influenced
• Cost-effectiveness test • Cost-effectiveness measure screening threshold • Incentive levels • ME&O • BROs customer enrollment over time • IOU financing programs	• Building stock forecast • Retail energy price forecast • Measure-level input uncertainties (UES, unit costs, densities) • Non-IOU financing programs • Enacting future C&S

Source: Guidehouse

Potential and goals scenarios fix externally influenced variables to a single setting across all scenarios:

- CEC mid-case forecast for retail rates, population, and building stock
- DEER and workpaper values used as-is

- One set of assumptions about future C&S

Table 2-10 lists additional details on each of the internally influenced variables.

Table 2-10. Internally Influenced Variables Considered for Scenario Setting

Lever	Description	Potential Impact Applicability	
		Economic	Market
Cost-effectiveness test	Different cost-effectiveness screening tests or thresholds yield different amounts of economic potential and cause the achievable potential model to incentivize different sets of measures. The cost-effectiveness screening test threshold only applies to rebate programs.	✔	✔
Cost-effectiveness measure screening threshold		✔	✔
Incentive levels	Varying incentive levels (at a percentage of incremental measure cost) will change the cost-effectiveness of measures and their value proposition to customers.	✔	✔
ME&O	Varying marketing and outreach levels impact the rate at which technologies are adopted by customers.		✔
BROs program assumptions	Enrollment in BROs programs is an input vector. Guidehouse can assume a reference or aggressive rollout of BROs programs.		✔
Financing programs	IOU financing programs help reduce the cost burden associated with efficient measure adoption.		✔

Source: Guidehouse

The Guidehouse team presented this scenario framework to stakeholders on November 5, 2020, and invited stakeholders to provide feedback.

Each available internally influenced variable has a range of options, as described in Table 2-11.

Table 2-11. Range of Values for Internally Influenced Variables

Lever	Range/Bounds	
	Lower	Upper
Cost-effectiveness test	Total resource cost (TRC) test, program administrator cost (PAC) test	
Cost-effectiveness measure screening threshold	0.85 for all measures	1.25 for all measures
Incentive levels	Capped at 50% of incremental cost or existing program levels	Capped at 75% of incremental cost
ME&O	**Reference:** Default calibrated value	**Aggressive:** Increased marketing strength
BROs program assumptions	**Reference:** Continued offering of existing BROs interventions and planned new interventions based on policy directions	**Aggressive:** Intervention penetration grows faster than the Reference case, and additional BROs not currently in California utility plans are included
Financing programs	No savings claimed from financing programs*	IOU financing programs broadly available to residential and commercial customers

*Consistent with 2019 Study

Source: Guidehouse

Building on stakeholder feedback, the Guidehouse team worked with CPUC staff to develop scenarios to consider in the goal setting process. Each of the internally influenced variables in Table 2-11 is expected to impact the forecast of EE potential. The combined impact of these variables represents a scenario. The final selected scenarios are listed in Table 2-12 Every scenario includes fuel substitution.

Table 2-12. Summary of Final Scenarios for EE Potential[44]

Levers → Scenario ↓	C-E Test	C-E Threshold	Incentive Levels Capped*	Program Engagement†	Include Financing	Include EE-DR
1: TRC Low	TRC	1	50%	Reference	No	No
2: TRC Reference‡	TRC	0.85	50%	Reference.	No	No
3: TRC High	TRC	0.85	75%	Aggressive	Yes	No

C-E = cost-effectiveness

*Incentives are set based on a $/kWh and $/therm basis consistent with existing IOU programs; incentives are capped at 50% or 75% of incremental cost depending on the scenario.

[44] Scenarios 1, 2, and 3 also have COVID sensitivity analysis presented in Appendix K.

†Program engagement refers to the level of marketing awareness and effectiveness, as well as, the level of aggressiveness of BROs program participation.
‡ An additional scenario (not listed in this table) is a sensitivity of the TRC Reference with demand response costs and benefits included.
Source: Guidehouse

The scenarios can be interpreted as follows (not necessarily described in numerical order):

- **TRC Low** (Scenario 1) is has a cost-effectiveness screening threshold of 1.0 TRC. This scenario would ensure the overall portfolio of resource programs has a TRC greater than 1.0 and most likely above 1.25. This scenario is to simulate programs complying with CPUC Decision 18-05-041, which requires portfolios to have an ex ante TRC of at least 1.25 starting in 2023.
- **TRC Reference** (Scenario 2) represents business as usual and the continuation of current policies. The cost-effectiveness threshold is set to 0.85, which assumes the balance of cost-effectiveness and other portfolio costs will result in an overall portfolio TRC greater than 1.0. The lower cost-effectiveness screening threshold would allow measures that are less cost-effective into the forecast. A lower threshold reflects current and past EE portfolios that do include measures with low TRC. Scenario 2 includes a separate sensitivity run to test the impact of including EE-DR co-benefits.
- **TRC High** (Scenario 3) builds on Scenario 2 with the more aggressive program design from program administrators. BROs programs are assumed to be aggressive, and program administrators are assumed to increase their marketing and outreach effort to better drive customers to programs. This scenario also includes financing and a 75% incentive cap on incremental cost.

The Guidehouse team also incorporated an IRP scenario, which is provided in Table 2-13. The difference for the IRP scenario is that the achievable potential analysis only relies on the technical potential to calculate the maximum technical achievable potential with no economic screening threshold.

Table 2-13. IRP Scenarios

Scenario → Levers ↓	IRP
Levelized cost basis	TRC
Incentive levels	Capped at 50%
Program engagement	Reference
Financing	No
Include fuel substitution	No
Include EE-DR	No

Source: Guidehouse

2.3.1 EE-DR Integration

The Guidehouse team used the impacts of EE-DR integration to explore the sensitivity in cost-effectiveness and market adoption of the EE potential analysis. The toggling on or off the co-benefits from DR program participation impacts both the possible cost-effectiveness and customer adoption of measures. See Section 2.1.3 for methodology and Section 3.4 and Appendix I for data and analysis for a description of the EE-DR integration.

2.3.2 Impacts of COVID-19 Pandemic

The impacts of the COVID-19 pandemic on the California economy are far-reaching and not something this potential study can ignore. The default scenario runs described in this section are rooted in data developed pre-pandemic. Thus, the default forecasts inherently assume the pandemic did not affect the economy. A separate set of COVID-19 sensitivity scenarios were also run for Scenarios 1, 2, and 3 to estimate the effects of the pandemic on the future EE potential. The Guidehouse team presented the planned COVID-19 adjustments in the January 2021 stakeholder webinar and received feedback on this approach. The impacts of COVID-19 manifest themselves in two ways in the model:

3. Adjustments to commercial and residential building stocks due to business closures and more households becoming eligible for Low Income programs due to lowered household income.
4. Adjustments to the consumer decision value factors that represent altered importance of barriers in their purchasing decision processes.

These impacts are not modeled as permanent shifts but rather as temporary deviations. It is impossible to tell when the pandemic will end and when the economy will recover. The Guidehouse team makes no claim that it can project this. However, for the purposes of modeling, the team assumes that consumer confidence and business closures start to recover in 2022 and takes 4 years to recover to pre-pandemic levels.

2.3.2.1 Building Stock Adjustments

Adjustments are made to select building types in the model: restaurant, retail, low income residential, and non-low income residential. The Guidehouse team assumes 20% of restaurants have permanently closed, decreasing restaurant building stock by 20%. This assumption is based on a variety of data sources from which the team infers an average:

- A California Restaurant Association survey in August 2020 showed 30% of respondents were concerned they would be closing permanently soon.[45]
- A National Restaurant Association survey from November 2020 shows 17% of restaurants are closed (permanently or temporarily).[46]
- The U.S. Bureau of Labor Statistics shows restaurant sector employment is about 15% below pre-pandemic during Q4 2020.[47]
- Data from Yelp in Q2 2020 indicated of all the restaurant closures, 60% are noted as permanent; the other 40% are noted as temporary.[48]

[45] https://www.calrest.org/news/thousands-california-restaurants-close-permanently
[46] https://restaurant.org/downloads/pdfs/advocacy/covid-19-restaurant-impact-survey-v-state-results.pdf
[47] https://data.bls.gov/timeseries/CES7072200001?amp%253bdata_tool=XGtable&output_view=data&include_graphs=true
[48] https://www.yelpeconomicaverage.com/yea-q2-2020.html

The team assumes 1.5% of retail space has permanently closed, decreasing retail building stock by 1.5%. This assumption is based on two data sources:

- The U.S. Bureau of Labor Statistics shows retail sector employment dropped 15% below normal in April 2020 but recovered and is just 3.5% below pre-pandemic levels during Q4 2020.[49]
- Data from Yelp in Q2 2020 says of all the stores and retail closures, 48% are noted as permanent; the other 52% are noted as temporary.[50]

The Guidehouse team assumes the eligible population of households for the ESA program that serves low income residential customers has increased on the order of 10%-20%. This assumption is based on the change in the number of enrollees in the California Alternate Rates for Energy program (CARES), as Table 2-14 shows.

Table 2-14. Change in CARES Enrollees

IOU	Sept,-Nov, 2019 Average Enrollees	Sept. - Nov. 2020 Average Enrollees	Percent Change
PG&E	1,382,144	1,566,949	13.4%
SCE	1,183,212	1,425,847	20.5%
SCG	1,603,584	1,744,436	8.8%
SDG&E	301,507	334,250	10.9%

Source: CPUC Low Income Oversight Board, ESA/CARE Monthly and Annual Reports (CARES Table 2).

The team assumes low income populations increase by the percent change values shown in Table 2-14. The team also assumes a corresponding decrease in the residential non-low income households that the PG Model targets for rebated equipment.

2.3.2.2 Consumer Decision Factor Adjustments

Similar to the building stock adjustments made to account for COVID-19 impacts, the Guidehouse team adjusted the parameters that influence a consumer's willingness to adopt. Specifically, the team adjusted a customer's overall sensitivity to decision-making factors (described in Section 2.1.1.4) to reflect the changed viewpoint and priorities of residential and commercial customers due to the pandemic.

The Market Adoption Study was fielded in summer 2020 and asked customers a set of questions that revealed their preference weightings at that time (during the pandemic). The study asked survey respondents to describe the overall impact of the COVID-19 pandemic on their finances. The team observed that the pandemic had a slightly negative impact on customer finances, with groups like restaurants, retailers, and schools experiencing the strongest negative impacts. Accordingly, the sensitivity of customers to the different characteristics of rebated measures was adjusted upward, reflecting that customers were generally more concerned about decision factors like upfront cost and installation hassle (technicians installing onsite) during the pandemic than they were before.

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[49] https://data.bls.gov/timeseries/CES4200000001?amp%253bdata_tool=XGtable&output_view=data&include_graphs=true

[50] https://www.yelpeconomicaverage.com/yea-q2-2020.html

Pre-pandemic values for customer preference weightings are used in all default scenarios in this study. COVID-19 sensitivity scenarios divert from this default and use the customer preference weightings as derived from survey responses conducted during the pandemic. Like the building stock adjustments, the Guidehouse team does not assume this is a permeant shift. Rather, customer sensitivity factors revert to their pre-pandemic levels on a linear ramp from 2021 to 2025.

3. Data Sources

The 2021 Study relied on vast and varied data sources. Throughout the study, the Guidehouse team sought to rely on CPUC-vetted products as much as possible. In several cases, the team sought alternate data sources where CPUC resources did not provide the necessary information. This section describes the data update process, assumptions, and sources for key topic areas.

3.1 Global Inputs

Global inputs are macro-level model inputs not specific to any measure that applies to market segments or sectors. The Guidehouse team reviewed the data source for each of these inputs to ensure the most recent data is used for the 2021 Study. Table 3-1 provides an overview of all global inputs within the PG Model and their data source. Each item is discussed in the subsections that follow.

Table 3-1. Overview of Global Inputs Updates and Sources

Global Input ***(Description)***	**Data Source for Update**
Retail rates *($/kWh, $/therm)*	CEC, *2019 Integrated Energy Policy Report (IEPR) Update and Demand Forecast Forms*. Adopted Feb. 2020.
Consumption forecasts *(GWh, MW, and MMtherms)*	
Building stocks *(Households, floor space, consumption)*	CEC, *California Energy Demand 2019*[51]
Avoided costs *(Avoided energy and capacity costs)*	CPUC, *Cost Effectiveness Tool*. Accessed Sep. 2020.
Historical program accomplishments *(Used for calibration)*	CPUC, California Energy Data and Reporting System (CEDARS) program cycle 2016-2019 data.
Non-incentive program costs	CPUC, California Energy Data and Reporting System (CEDARS) program cycle 2021 filings.

Source: Guidehouse

3.1.1 Retail Rates and Consumption Forecasts

The CEC's IEPR, which includes a forecast that is updated annually, is the source for retail rates and consumption forecasts in the 2021 Study. The Guidehouse team used the 2019 IEPR for electric and gas rates and the consumption forecasts.

The consumption forecasts from the IEPR were disaggregated by the CEC's eight planning areas, which differ slightly from the IOU service territory areas. Some CEC planning areas include the territories of small publicly owned utilities in California, so an adjustment is needed.

[51] Provided by CEC staff via email.

Using data on service territory and planning area sales for 2019, the team calculated ratios to adjust the planning area consumption (found within the IEPR) down to each IOU's actual service territory consumption for all electric utilities. These ratios, with the service territory consumption based on the 2019 quarterly fuel energy reports (QFERs), are referred to as service territory to planning area adjustment ratios and are detailed in Table 3.

Table 3-2. 2019 IEPR Electric Service Territory to Planning Area Adjustment Ratios

IOU	Residential	Commercial	Industrial	Mining	Agriculture
PG&E	86.0%	80.7%	65.9%	34.9%	79.8%
SCE	85.9%	84.8 %	73.5%	62.9%	70.7%
SDG&E	83.0%	91.3%	90.7%	99.9%	94.5%

Source: CEC, 2020

Most publicly owned utilities in California do not offer gas service (only the City of Palo Alto and Island Energy offer natural gas service). The CEC estimates that California IOUs sell approximately 99% of the state's natural gas. To obtain service territory consumption values, the Guidehouse team used 2018 data from the CEC's Energy Consumption Database (ECDMS), shown in Table 3-3.[52] The CEC planning area for San Diego directly maps to the SDG&E service territory, so the team did not need to calculate an adjustment ratio for SDG&E.

Table 3-3. 2018 IEPR Gas Service Territory to Planning Area Adjustment Ratios

IOU	Residential	Commercial	Industrial	Mining	Agriculture	Street Lighting
PG&E	99.4%	98.4%	99.9%	99.8%	99.8%	N/A
SCG	97.9%	97.3%	97.7%	10.5%	99.8%	N/A

Source: CEC, 2020

While most of the adjustment ratios are close to or at 100%, SCG mining is 10.5% based on service territory sales found in the ECDMS. Many of the largest oil and gas extraction companies in SCG's planning area purchase gas directly from the pipeline companies. The service territory to planning area adjustment calculation must remove the gas sales attributed to those large oil and gas companies.

The Guidehouse team applied these ratios to the sales forecast and the building stocks for electric and gas impacts.

3.1.2 Building Stocks

Building stocks are the total population metrics of a given sector, though represented by different metrics for most sectors. Residential building stocks are based on the number of households in an IOU's service territory. Commercial building stocks are represented by total floor space for each commercial building type. Industrial and agriculture building stocks are represented by energy consumption. Mining building stocks are the number of pumps. The

[52] California Energy Consumption Database. Accessed August 2020: http://ecdms.energy.ca.gov/

residential, commercial, industrial, and agriculture building stock metrics are derived from the CEC's IEPR. The model requires building stocks by sector, scenario, and utility for 2013-2032.

The IEPR organizes building stock data into the eight electric planning areas. Each planning area aligns to a utility and includes one or more CEC forecasting zones, as listed in Table 3-4.

Table 3-4. Mapping CEC Electric and Gas Planning Areas to IOU Service Territories

CEC Forecasting Climate Zone	Electric Planning Area Number	Electric Planning Area Utilities	Natural Gas Planning Area Utilities
Climate Zone 1	1 - PG&E	PG&E	PG&E
Climate Zone 2			
Climate Zone 3			
Climate Zone 4			
Climate Zone 5			
Climate Zone 6			
Climate Zone 7	2- SCE	SCE	SCG
Climate Zone 8			
Climate Zone 9			
Climate Zone 10			
Climate Zone 11			
Climate Zone 12	3 - SDG&E	SDG&E	SDG&E
Climate Zone 13	4 - NCNC	SMUD	PG&E
Climate Zone 14		Turlock Irrigation District	
Climate Zone 15		Other (Modesto, Redding, Roseville, Trinity, and Shasta Lake)	
Climate Zone 16	5 - LADWP	Los Angeles Department of Water and Power (LADWP)	SCG
Climate Zone 17			
Climate Zone 18	6 - Burbank/Glendale	Burbank/Glendale	
Climate Zone 19	7 - IID	Imperial Irrigation District	
Climate Zone 20	8 - Valley Electric	Valley Electric	

Source: CEC

3.1.3 Historical Rebate Program Activity

The historical rebate program achievements for each of the IOUs are important inputs to calibrate the forecast of rebate programs. The CPUC maintains the California Energy Data and Reporting System (CEDARS), an online resource that collects program achievement data, for public use. These datasets include program savings, expenditures, cost-effectiveness, and emissions for EE programs statewide. For the 2021 Study, the team used this dataset to quantify historical portfolio net and gross savings for each utility, sector, and end use.

Table 3-5 provides the 2016-2019 gross ex post savings at the utility and sector levels, which informed calibration. Actual calibration was conducted at the end use level. Some program savings were not modeled as a rebate program; those savings are excluded from this analysis. For example, residential home energy reports (HERs) and RCx fall under the definition of BROs and were removed to prevent double counting savings. Table 3-6 shows the excluded programs and their reasons for exclusion.

Table 3-5. 2016-2019 IOU-Reported Portfolio Gross Program Savings

IOU	Sector	Gross GWh	Gross MMtherms	Expenditures ($ Millions)
PG&E	Residential	387.98	-0.722	$266.91
	Commercial	752.46	12.768	$456.83
	Industrial	125.56	15.271	$95.04
	Agriculture	99.28	1.684	$54.44
	Mining	10.29	0.010	$4.95
SCE	Residential	612.15	-	$273.40
	Commercial	534.10	-	$294.02
	Industrial	158.09	-	$38.62
	Agriculture	9.27	-	$4.90
	Mining	5.34	-	$0.76
SCG	Residential	-	21.741	$128.75
	Commercial	-	16.410	$70.93
	Industrial	-	6.499	$18.45
	Agriculture	-	4.033	$5.86
	Mining	-	-	-
SDG&E	Residential	108.03	-0.350	$110.19
	Commercial	176.68	3.472	$116.57
	Industrial	7.38	0.317	$7.29
	Agriculture	0.98	0.220	$2.16
	Mining	-	-	-

Source: CPUC, CEDARS (2016-2019) Claims Data

Table 3-6. Programs Excluded from Portfolio Gross Program Savings

Program Category	Reason for Exclusion	Modeling Location
BROs-type programs	Behavioral programs are modeled through the BROs methodology.	BROs
Agriculture and industrial calculated incentives	These are custom measures or programs that are modeled separately.	Industrial and agriculture generic custom technologies
C&S	The Guidehouse team modeled C&S separately from the rebate programs	C&S

Program Category	Reason for Exclusion	Modeling Location
Financing programs	Most historical financing programs only report a cost and no savings.[53]	Embedded as a factor into residential and commercial decision adoption modeling
Non-resource or non-savings programs	These programs have no associated savings and do not contribute to the goals.	N/A
Whole building retrofit	These programs have not been cost-effective historically and are rarely cost-effective in the PG Model. The team removed them so its calibration for whole building new construction would not be artificially inflated,	N/A

Source: Guidehouse

Appendix A includes additional discussion on the calibration process.

3.1.4 Non-Incentive Program Costs

Non-incentive program costs come from the IOU 2021 filings data (as of December 2020), commonly referred to as the Annual Budget Advice Letters, in CEDARS. In past PG studies Guidehouse would source non-incentive program costs from historic evaluated program participation data. However, upon conferring with IOU staff and with CPUC staff, 2021 IOU filing data was determined to be a far more representative view of program costs going forward than historic evaluated data could offer.

For the PG Model, the Guidehouse team determined program costs per unit of first-year kWh or therm by sector. In CEDARS, program costs for each program and measure line are already listed, and program costs combine administrative costs, marketing costs, implementation (customer service) costs, overhead, and evaluation, measurement, and verification (EM&V) costs. Interactive effects and non-resource programs are not included in in calculating the program costs. Similarly, BROs program and C&S program costs were not included in the rebate program costs because these categories are modeled elsewhere and their costs are accounted for in that analysis.

Table 3-7 provides an overview of the non-incentive program costs based on gross reported savings. The displayed AIM program cost is an average of the individual agriculture, industrial, mining, and street lighting costs calculated.

[53] There are two types of on bill financing (OBF) programs administered by the CA IOUs. For several years, the IOUs have offered the OBF plus rebate pathway as this program requires participants to receive a rebate through another IOU program to qualify for OBF. The program savings are claimed through the incentive programs. The other OBF program is known as AP or Alternative Pathway. PG&E started this as a pilot program in 2018. No claims have been made for both costs and savings, yet.

Table 3-7. Non-Incentive Program Costs Summary

IOU	Electric Savings ($/Gross kWh)					Gas Savings ($/Gross therms)				
	Res	Com	Ag	Ind	Min	Res	Com	Ag	Ind	Min
PG&E	$0.35	$0.15	$0.21	$0.09	$0.15	$10.12	$4.39	$6.07	$2.62	$4.35
SCE	$0.15	$0.14	$0.28	$0.15	$0.21	N/A	N/A	N/A	N/A	N/A
SCG	N/A	N/A	N/A	N/A	N/A	$1.22	$2.11	$1.64	$0.60	$1.12
SDG&E	$0.11	$0.10	$0.19	$0.02	$0.11	$3.17	$2.79	$5.58	$0.63	$3.10

Source: CPUC, CEDARS – 2021 Program Filings Data

3.1.5 Avoided Costs

Avoided costs place an economic value on the amount of energy and GHG emissions saved by implementing an energy-saving measure. Avoided costs are a key input to calculating cost-effectiveness.

To determine avoided costs, the Guidehouse team used the 2021 version of the CET, a calculator commissioned by the CPUC, and[54] the 2021 vintage of the avoided cost data. Post-processing of the CET calculator data conducted by the team resulted in a dataset that displays total annual avoided costs for 2020-2050 by IOU, sector, end-use category, and sub-end-use category.

This post-processing of avoided costs, which includes carbon cost, from the CET prior to incorporating them into the 2021 PG Model is a necessary simplification for this study. The 2021 PG Model is not meant to exactly replicate the CET in all its functions and granularity. Rather, the model applies avoided costs to the algorithms specified in the California Standard Practice Manual for cost-effectiveness calculations. Appendix I describes the avoided cost development for the 2021 Study analysis.

3.2 Residential and Commercial EE Technology Characterization

The technology characterization step develops the essential inputs used in the PG Model to calculate potential. This section provides an overview of the technology selection process for the residential and commercial sectors, describes the fields along which technologies are characterized, lists the data sources and describes how these sources are used for characterization, and directs the reader to the complete database of characterized technologies.

Like the 2019 Study, the 2021 Study uses a technology-based characterization, which characterizes individual technology levels within a technology group. A **technology group** includes multiple technologies with different efficiency levels that compete for stock replacement under an end use. A technology group is also commonly referred to as a competition group. For example, floor insulation retrofit measures with different efficiency levels (below code R0, code

[54] CPUC. "CET Desktop The Cost Effectiveness Tool." Accessed September 2020. https://file.ac/W1JDsjbKXOU/..

level R19, efficient level R30, etc.) are considered a single technology group termed floor insulation retrofits.[55]

3.2.1 Technology Selection Process

The technology selection process for the 2021 Study used the 2019 Study's technology list as a starting point. The Guidehouse team retained many technologies from the previous study but refreshed the list by adding and removing some technology groups and levels within groups. The team presented the changes to CPUC staff and stakeholders in a webinar on June 2, 2020, for review and feedback. Major changes from the previous study include the following:

- Established LED lighting as the baseline for all lighting technology groups and removed all lighting efficiency levels below LED. The efficient level in these technology groups is now an efficient LED lamp or fixture.[56]
- Added fuel substitution measures that replace gas with electricity (e.g., a heat pump water heater replacing a gas storage water heater). These measures were added to the technology groups for the corresponding gas appliances and compete with the efficient gas levels. (see Section 3.3 for additional details)
- Added technology levels that enable DR (e.g., a smart, Wi-Fi-connected power strip) and estimated DR co-benefits for these measures. (see Section 3.4 for additional details)
- Removed any technology levels that were below code level in 2019 in normal replacement and new construction technology groups because savings are assessed against a code baseline for normal replacement or new construction measure applications. (Retrofit or early retirement measures are assessed against an existing conditions baseline for part of the life of the equipment.)
- Removed appliance recycling measures per direction from CPUC staff (based on stakeholder feedback from the 2019 Study).
- Removed technology groups that represented less than 0.5% of achievable potential and less than 1% of technical potential in the 2019 Study and that represented less than 0.5% of program portfolio claims. This does not mean there is no future potential from these technologies; rather the team aimed to reduce the complexity and length of the measure list to fit within the available budget for this study.

Table 3-8 shows the number of technology groups and individual technologies characterized in the study by end use for the residential and commercial sectors, including technologies under the electric and gas fuel types.[57]

[55] This is different from the 2015 and earlier versions of the study, which classified measures defined by a base technology upgrading to an efficient technology (e.g., SEER 13 to SEER 16 ACs and SEER 13 to SEER 21 ACs were considered two different measures).

[56] See DEER Resolution E-4952, which revised the code and standard practice baseline for most interior and exterior lighting to LEDs, including lighting retrofits. https://docs.cpuc.ca.gov/publisheddocs/published/g000/m232/k459/232459122.pdf

[57] Please refer to the Measure Input Characterization System (MICS) database for additional detail.

Table 3-8. Final List of Technology Groups

Sector	End Use	Technology Group Examples*	Number of Technology Groups	Number of Individual Technologies†
Residential	Appliances/ Plug Loads	Refrigerators, Dishwashers, Clothes Dryers	9	24
	Building Envelope	Wall Insulation, Floor Insulation, Duct Insulation	5	13
	HVAC	Air Conditioners (ACs), Heat Pumps, Furnaces	17	42
	Lighting	Indoor Screw-In Lamps, Specialty Lamps, Lighting Controls	7	20
	Water Heating	Electric Water Heaters, Faucet Aerators, Showerheads	12	30
	Total		**50**	**129**
Commercial	Appliances/ Plug Loads	Power Strips, Servers, Pool Covers	5	11
	Building Envelope	Wall Insulation	1	3
	Com. Refrigeration	Display Case Motors, Refrigeration Compressors, Anti-Sweat Heat Controls	8	17
	Data Center	Server Virtualization, High Efficiency Universal Power Supply, Computer Room AC Upgrades	16	8
	Food Service	Ovens, Steamers, Fryers	20	37
	HVAC	Chillers, Split AC, Mini-Split Heat Pumps	6	48
	Lighting	High and Low Bay Fixtures, Indoor Reflector Lamps, Lighting Controls	9	18
	Water Heating	Electric Storage Water Heaters, Faucet Aerators, Pre-Rinse Spray Valves	1	24
	Total		**66**	**166**

*The complete list of technology groups is presented in the measure-level input workbook.

†The technology list does not include whole building packages and BROs interventions. The approach used to select and characterize these measures is discussed in separate sections of this report. Please refer to the MICS (measure input characterization system) spreadsheet for a complete list of the technologies included in the study.

Source: Guidehouse

3.2.2 Technology Characterization

Characterizing selected technologies involves developing various inputs for each technology necessary to calculate potential. Table 3-9 summarizes the key items the Guidehouse team used to characterize the technologies and provides brief descriptions.

Table 3-9. Key Fields for Measure Characterization with Brief Descriptions

Items	Brief Description
Technology description	• Sector • End use • Fuel type • Climate zone • Segment or building type • Replacement type
Energy use	• Energy use (electric and gas) • Coincident peak demand • Interactive effects
Technology costs	• Equipment cost • Installation cost
Market information	• Applicability by segment or building type • Density associated with the technology group • Saturation for individual technologies
Other items	• Technology lifetime (EUL and RUL) • Net-to-gross (NTG) ratio • DR co-benefits for DR-enabled measures (expressed as an avoided cost)

Source: Guidehouse

The following subsections detail how the Guidehouse team developed energy use, costs, market information, and other relevant fields and provide the associated hierarchical list of data sources for this information.

3.2.2.1 Energy Use

Energy use is a key input for technology characterization. The technology-based approach followed in this study implies that the absolute energy use associated with each technology level in a technology group needs to be specified.

Unit energy use is specified in kWh for electric technologies and in therms for gas-fueled technologies. For dual fuel technologies that can achieve both electric and gas savings such as insulation, both metrics are calculated. Some technologies have interactive effects. An example is energy efficient lighting, which produces less waste heat than inefficient lighting and has additional HVAC energy consumption associated with it. These interactive effects are included in the savings for the technology characterization.

Electric technologies also require the characterization of coincident peak demand. Effective January 1, 2020, the peak period used to calculate demand impacts in DEER changed per DEER Resolution E-4952, published October 11, 2018.[58] The Guidehouse team assumed the demand impacts in sources for deemed savings (e.g., approved workpapers and the California eTRM) published in 2019 and beyond already incorporated this new peak demand period. For

58 https://docs.cpuc.ca.gov/publisheddocs/published/g000/m232/k459/232459122.pdf

demand data from sources that do not incorporate the peak demand period update (those that have not been updated since 2018), the team updated the peak demand impacts to be consistent with the new DEER definitions, leveraging available load shape data and prioritizing the use of DEER load shapes when available.

Some measures' energy use varies depending on the climate where they are located. For example, air conditioners are operated more frequently in hotter climates and have higher annual energy use in these climates. Previous studies characterized climate-dependent measures for each of the 16 climate zones that existed in each utility's service territory. The model then aggregated the costs and savings across the climate zones in a pre-processing step before determining overall cost-effectiveness for an IOU territory and assigning achievable potential. This approach could result in some measures appearing to have lower savings than were actually achievable because low cost-effectiveness in one region could outweigh high cost-effectiveness in another region, making the entire measure appear nonviable.

In this study, the Guidehouse team updated the treatment of climate-dependent measures by characterizing the measures in up to three climate regions for each utility: Marine, Hot-Dry, and Cold. The team chose these designations to approximately align with the International Energy Conservation Code regions 3C, 3B, and 4B, respectively, which cover the majority of the state's population.[59]

Most California energy data sources provide energy values for climate-dependent measures for each of the 16 climate zones. Table 3-10 shows the mapping the team used to select the appropriate energy value from data sources that calculated energy consumption by climate zone.

Table 3-10. Map of Climate Region to Designated Climate Zones 1-16 for Each IOU

Climate Region	PG&E	SCE	SCG	SDG&E
Marine	CZ03	CZ06	CZ06	CZ06
Hot-Dry	CZ12	CZ08	CZ09	CZ07
Cold	CZ16	CZ16	CZ16	N/A
Non-Climate Dependent*	CZ03	CZ08	CZ09	CZ07

CZ = climate zone

*The Non-Climate Dependent row shows the mapping used for measures not treated as climate-dependent in the 2021 Study. Measures were treated this way if their savings did not vary significantly across climate regions, but the data source had climate zone-specific savings. An example is lighting measures with interactive effects varying slightly across climate zones. For simplification purposes, the Guidehouse team did not characterize this measure separately for individual climate regions and chose the deemed savings value corresponding to the climate zone in the Non-Climate Dependent row.

Source: Guidehouse

The team characterized climate-dependent measures separately for each climate region and appended the climate region name to the measure name. The climate-specific measures were considered as entirely separate measures throughout the analysis (e.g., Packaged/Split System AC (SEER 18) – Marine). The model does not aggregate the costs and savings across the

[59] See https://www.energy.gov/sites/prod/files/2015/10/f27/ba_climate_region_guide_7.3.pdf for a map of the International Energy Conservation Code climate zones.

climate zones, which allows it to consider a measure's cost-effectiveness independently for each climate region.

3.2.2.2 Equipment Costs

The measure characterization database requires specification of equipment costs, which include material costs, labor costs for installation, and repair costs where applicable. Many California-specific technology cost data sources reference underlying research conducted through the California Measure Cost Study.[60] Some of the other cost data sources are the same as those used for energy use, such as the IOU workpapers.

The Guidehouse team assumed constant technology cost through the study period (adjusted for inflation) for most measures. For one measure—heat pump water heaters—the team developed cost reduction vectors for residential and commercial products. Heat pump water heaters are an emerging technology with few products currently on the market, but they have the potential to undergo market transformation as they are more widely adopted. See Appendix IC for heat pump water heater cost adjustments.

3.2.2.3 Market Information: Density and Saturation Values

Density and saturation are two essential technology characterization calculations.

- **Density** is a measure of the number of units per building. The PG Model uses density information to determine the number of applicable technology units on the appropriate scaling basis (per household for residential and per square foot for commercial) to scale up the technology stock by segment or building type. Density is specified by technology group. Technologies within a technology group share the same density under the assumption that lower efficiency technologies are replaced on an equivalent unit basis with higher efficiency technologies. Density can be expressed as the following: units/home, bulbs/home, lighting fixtures/1,000 square feet, tons of cooling/1,000 square feet, etc.
- **Saturation** is the share of a specific technology within a technology group, so that the sum of the saturations across a technology group always sums to 100%. Saturation can also be calculated by dividing the individual technology density by the total technology group maximum density.

[60] http://www.calmac.org/publications/2010-2012_WO017_Ex_Ante_Measure_Cost_Study_-_Final_Report.pdf

As an example, Table 3-11 shows the densities and saturations for the floor insulation retrofit technology group in single-family homes in PG&E's service territory.

Table 3-11. Example of Density and Saturation Calculation: Floor Insulation Retrofit Technology Group in Single-Family Homes, PG&E Service Territory

Technology Name	Base Year Efficiency Level	Unit Basis	Technology Density (Units per Household)	Technology Saturation
Floor Insulation (R0)	Below Code	sq.ft.insulation	1,840	90%
Floor Insulation (R19)	Code	sq.ft.insulation	1,840	8%
Floor Insulation (R30)	Efficient	sq.ft.insulation	1,840	2%
Total			**1,840**	**100%**

Source: Guidehouse

The table shows that an average single-family home in PG&E's territory has 1,840 square feet of floor insulation per home, which is the density for floor insulation in single-family homes. The saturations of below code, code-compliant, and efficient floor insulation for single-family homes is 90%, 8%, and 2%, respectively. This means that 90% of existing floor insulation is at a below code level, 8% is at code, and 2% is above code. The saturation changes over time with population growth and stock turnover as more below code stock gets replaced with at code and higher efficiency stock.

Measure characterization also requires specifying the technical suitability factor. Technical suitability refers to the percentage of customers with the physical or infrastructural pre-requisites to install a technology. Technical suitability is less than 100% for technologies that cannot physically be installed in some cases. For example, the technical suitability for geothermal heat pumps is less than 100% because not all homes have access to space below the ground where a heat exchanger loop can be installed. The technical suitability factor assumptions are based on data sources, wherever available, and the team's industry and subject matter expertise in the area.

3.2.3 Data Sources

Table 3-12 lists the data sources for cost and energy use (in hierarchical order) and provides brief descriptions of each source.

Table 3-12. Hierarchy of Data Sources for Cost and Energy Use Information

Priority	Energy Consumption Source Name	Description	Author	Publication Year
1	DEER (as extracted from California eTRM)	According to the website, "the eTRM is a statewide repository of California's deemed measures, including supporting values and documentation." It includes DEER and non-DEER measures and aligns with the latest approved workpapers.	California Technical Forum	2020 (continuously updated)

Priority	Energy Consumption Source Name	Description	Author	Publication Year
2	IOU workpapers (with CPUC disposition)	The team referred to approved workpapers for additional measure information not contained in the eTRM or for measures that had not yet been added to the eTRM. In some cases, the team referred to expired workpapers for underlying data when those workpapers had not been superseded and no other information was available.	California IOUs	Various
3	IOU program data	The team referred to the program year (PY) 2019 CEDARS database for the California IOUs in cases where energy use information was not available from the above-listed sources.	CPUC, IOUs	2019
4	Non-California source examples:	In cases where California-specific sources were not available for energy use information, the team referred to the following sources:		
	Regional Technical Forum database	Measure-level savings data from evaluated programs in the Pacific Northwest region, available through the Regional Technical Forum.	Northwest Power and Conservation Council	2015
	Navigant/ Guidehouse potential study database	Guidehouse’s archive of characterized measure savings from potential studies and projects with other utilities.	Guidehouse	2017-2018

Source: Guidehouse

Table 3-13 lists the resources used to calculate density and saturation for the residential and commercial sectors in the 2021 Study (in order of priority). The Guidehouse team primarily used California-specific sources for this data and referred to non-California sources only in cases the California-specific sources did not have the required data.

Table 3-13. Sources for Density and Saturation Characterization

Priority	Sources	Description	Author	Year
1	Residential Appliance Saturation Study (RASS)[61]	Residential end-use saturations for 39,000 households in California.	DNV GL	2019
2	California Lighting and Appliance Saturation Survey	Residential baseline study of 1,987 homes across California.	DNV GL	2012

[61] The team received an advance copy of the 2019 RASS data from DNV GL. The RASS study was not published at the time of the analysis.

Priority	Sources	Description	Author	Year
3	Commercial Saturation Survey	Baseline study of 1,439 commercial buildings across California.	Itron	2012
4	Non-California source examples: • Residential Building Stock Assessment • Commercial Building Stock Assessment	Survey of residential and commercial building stock across the Northwest states (Idaho, Montana, Oregon, Washington).	Northwest Energy Efficiency Alliance (NEEA)	2014
	• Residential Energy Consumption Survey (RECS) • Commercial Building Energy Consumption Survey (CBECS)	RECS and CBECS are surveys of residential and commercial building stock in the US by region. Used West regional data only.	US Department of Energy (DOE)	2009
	• ENERGY STAR Shipment Database	Unit shipment data of ENERGY STAR-certified products collected to evaluate market penetration and performance.	US Environmental Protection Agency (EPA)	2003-2016

Source: Guidehouse

3.2.4 MICS Workbook

The MICS workbook consolidates information from the measure characterization effort in an Excel spreadsheet that serves as an input to the PG Model. The workbook presents the various dimensions along which measures are characterized as separate fields. The workbook is publicly available and can be downloaded through the CPUC website.[62]

3.3 Fuel Substitution Technology Characterization

For the first time in a CPUC potential and goals study, this study characterized fuel substitution measures. The Guidehouse team considered fuel substitution measures for the space heating, water heating, and cooking end uses. The fuel substitution measures are only characterized for the residential and commercial sectors.

Fuel substitution technologies are characterized similar to EE technologies (described in Section 3.2). This section provides an overview of the unique considerations made for fuel substitution technologies.

3.3.1 Technology Selection Process

The team followed a similar approach as to the non-fuel substitution (EE technologies) for the technology selection process but added a screening step to omit any measures that did not pass the FST. As implemented by CPUC Decision 19-08-009, the FST specifies that to be

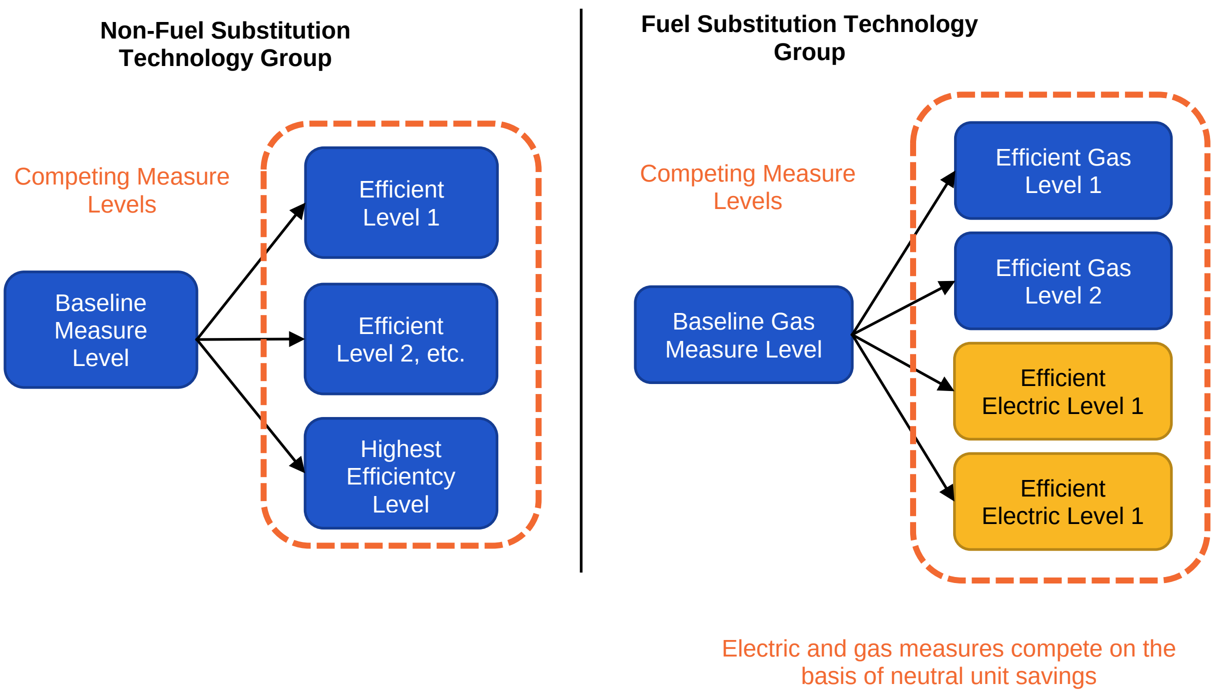
[62] https://www.cpuc.ca.gov/General.aspx?id=6442464362

included in an EE portfolio, a measure must not increase source energy, and it must not harm the environment (where environmental harm is measured by net CO_2 emissions).[63]

The Guidehouse team analyzed fuel substitution technologies in the same technology group as the gas technology being replaced. In other words, a fuel substitution measure replacing a baseline gas technology would compete with the efficient gas technology that would replace the gas technology. The electric and gas measures compete on the basis of neutral unit savings.

Figure 3-1 illustrates how measures compete within a technology group, comparing a technology group without fuel substitution (left side) to a technology group incorporating fuel substitution (right side). In the fuel substitution technology group, two efficient gas technology levels compete with two efficient fuel substitution levels.

Figure 3-1. Example Fuel Substitution Technology Group



Source: Guidehouse

For most fuel substitution technology groups, an electric appliance directly replaces a gas appliance. For residential HVAC fuel substitution measures, however, the electric fuel substitution level—a heat pump—provides heating and cooling, while the gas appliance being replaced only provides heating. The team considered two types of situations:

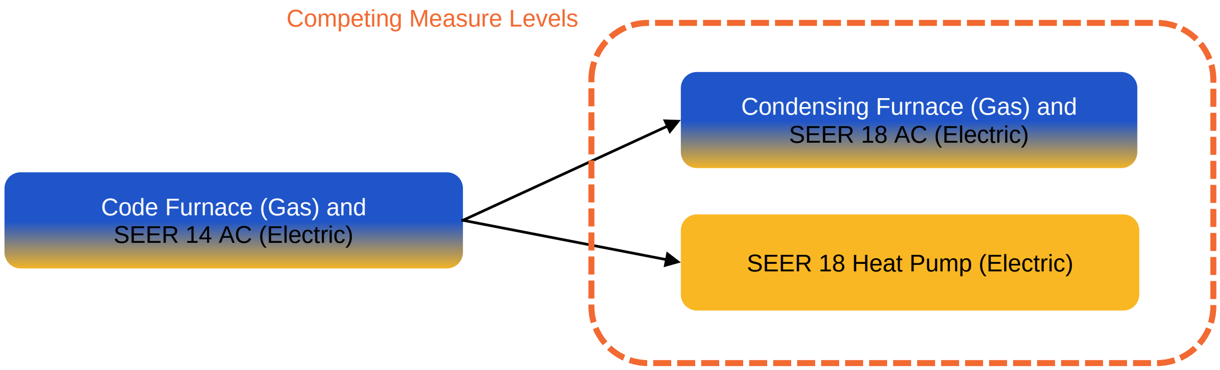
- Homes with a gas furnace providing heating and an electric air conditioner providing cooling
- Homes with a gas furnace and no cooling

For homes with both a gas furnace and an electric air conditioner, fuel substitution would involve replacing both the furnace and the air conditioner with a heat pump, which provides heating and

[63] https://www.cpuc.ca.gov/General.aspx?id=6442463306

cooling. The technology group consists of a heat pump competing with an efficient furnace and air conditioner combination, as Figure 3-2 shows.

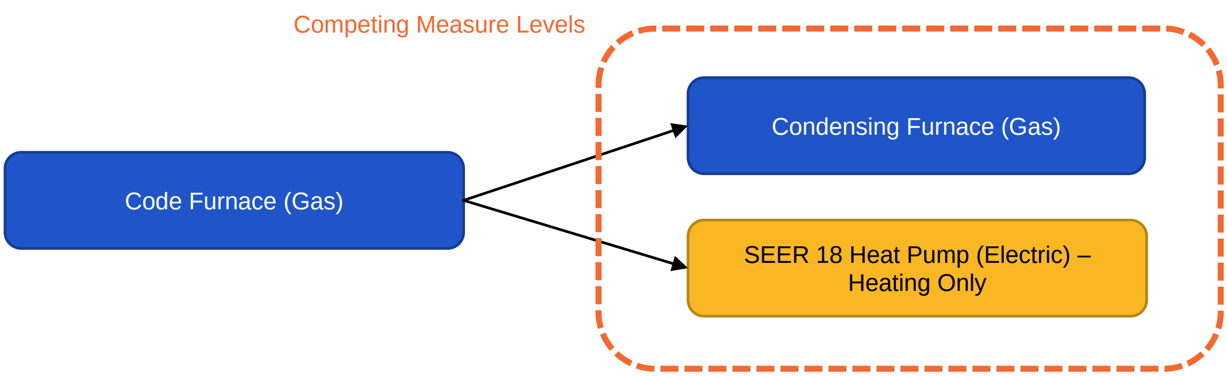
Figure 3-2. Residential HVAC Fuel Substitution Technology Group



Source: Guidehouse

For homes with a gas furnace only, the fuel substitution level competed with the efficient gas appliance only. Per guidance from the CPUC, the Guidehouse team only considered the heating energy from the heat pump when comparing energy use across the technology group. However, Guidehouse compared the full cost of the heat pump i characterization to the full cost of the baseline furnace.[64] Figure 3-3 shows the efficiency levels in this technology group.

Figure 3-3. Residential Furnace Fuel Substitution Technology Group



Source: Guidehouse

3.3.2 Technology Characterization

The Guidehouse team characterized fuel substitution technologies in coordination with EE technologies, documenting the same types of inputs as previously listed and described in Table 3-9. Several noted differences are discussed as follows.

Data to characterize fuel substitution technologies were primarily sourced from the eTRM and IOU workpapers. Labor costs for electric fuel substitution technologies generally account for the cost of capping the original gas line and wiring needed to accommodate the new electric

[64] Conversation with CPUC on October 21, 2020.

appliance, but neither the labor nor material costs incorporate the cost of any necessary electric panel upgrades.[65]

HVAC systems required additional consideration in our analysis. The Guidehouse team first used the 2019 Residential Appliance Saturation Study (RASS) to determine the proportion of households with both a furnace and an air conditioner that would be eligible to replace the equipment with a heat pump. The team also assumed that not all households would be willing to replace the whole system—i.e., both the gas and electric appliance—at the same time. Whole system replacements are most likely to be the consumer's choice when both units are at or near the end of their useful life. These projects are generally initiated when either the heating or air conditioner unit fails, and it is most practical to simply replace the furnace, indoor AC coil, and outdoor AC condenser at the same time. Appendix B provides the assumptions developed to characterize the potential options for furnace and AC unit retrofits and replacements.

3.3.3 Non-Incentive Program Costs

When calculating non-incentive program costs for fuel substitution technologies based on data presented earlier in Table 3-7 the model takes a sum of the positive costs associated with the gas savings and the negative costs associated with the increase in electric consumption. In addition, the total costs was constrained to be less than or equal to the incentives applied to the technology to maintain an incentive to non-incentive program cost ratio that more accurately reflects existing data found in reviewing the 2021 Annual Budget Advice Letters (ABALs).

3.4 DR-Enabled Technology Characterization

For the first time in a CPUC potential and goals study, this study characterized DR-enabled technologies — that is, electric technologies that enable customer to participate in DR programs.

3.4.1 Technology Selection Process

The Guidehouse team coordinated with Berkeley Lab and CPUC staff to develop a list of DR-enabled technologies to include in this study. The team considered DR-enabled technologies across the residential, commercial, industrial, and agriculture sectors for lighting, HVAC, water heating, and appliance/plug load end uses.

Table 3-14 lists all EE-DR technologies included in the study. This list considers energy efficient technologies with integrated controls and communication capabilities that enable DR. It does not consider control technologies (e.g., load control switches) that solely enable DR and do not provide any EE benefits.

[65] For example, documentation in workpaper SWHC045-01 for heat pump fuel substitution states, "The measure case labor costs include the cost of: installing the heat pump system; capping the existing gas line; [and] demolition of existing AC and gas furnace." The accompanying fuel substitution calculation workbook for this workpaper includes two hours of electrician costs in the labor cost, implying that this is part of the heat pump system installation. Panel upgrade cost is also calculated, but not included in the labor cost. Likewise, the material cost does not include the cost of upgrading the panel.

Table 3-14. List of Technologies with EE and DR Co-Benefits

Sector	End Use	Technology	Technology Group
Res	AppPlug	Smart Res Clothes Washer (Electric)	Res Clothes Washers (Elec)
Res	AppPlug	Smart Efficient Res Clothes Dryer (Electric)	Clothes Dryers (Elec)
Res	AppPlug	Smart Heat Pump Res Clothes Dryer	Clothes Dryers (Elec)
Res	AppPlug	Smart Refrigerator	Refrigerators
Res	AppPlug	Smart Res Dishwasher	Res Dishwashers
Res	AppPlug	Smart Connected Power Strip	Power Strips
Res	Lighting	Advanced Residential Lighting Controls	Res Indoor Lighting Controls
Res	HVAC	Smart Room AC	Room AC
Res	HVAC	Res Smart Thermostat (Elec SC and Gas SH)	Res Thermostats (Elec/Gas)
Res	HVAC	Res Smart Thermostat (Elec SC and Elec SH)	Res Thermostats (Elec/Elec)
Res	WaterHeat	Smart Water Heating Controls (Elec WH)	Water Heating Controls (Elec)
Res	WaterHeat	Res Smart Electric Storage Water Heater (0.92 UEF - 50 Gal)	Res Elec Water Heaters
Res	WaterHeat	Res Smart Heat Pump Water Heater (Avg 3.09 and 3.31 UEF - 50 Gal)	Res Elec Water Heaters
Com	AppPlug	Com Smart Connected Power Strip	Com Power Strips
Com	AppPlug	PC Power Management	PC Power Management
Com	Lighting	Advanced Commercial Lighting Controls	Com Indoor Lighting Controls
Com	HVAC	HVAC Energy Management System (Elec SC and Gas SH)	EMS (Elec/Gas)
Com	HVAC	HVAC Energy Management System (Elec SC and Elec SH)	EMS (Elec/Elec)
Com	HVAC	PTAC Controls Upgrade	PTAC Controls
Com	HVAC	Com Smart Thermostat (Elec SC and Gas SH)	Com Thermostats (Elec/Gas)
Com	HVAC	Com Smart Thermostat (Elec SC and Elec SH)	Com Thermostats (Elec/Elec)
Com	WaterHeat	Smart Com Water Heating Controls (Elec WH)	Com Water Heating Controls (Elec
Com	WaterHeat	Com Smart Electric Storage Water Heater	Com Elec Water Heaters
Com	WaterHeat	Com Smart Heat Pump Water Heater	Com Elec Water Heaters
Ag	Lighting	Occupancy Sensors/Advanced Daylighting controls	Lighting Controls - Upgrades
Ind	HVAC	Ind | Electronics Chiller Plant Optimization - Efficient	HVAC Equipment Upgrade - Electric
Ind	WholeBlg	Ind | Chem Manf. Advance Automation - Efficient	HVAC Equipment Upgrade - Electric
Ag	MachDr	Ag | Water Pumping- Sensors and Controls Efficient	Ag Pump Control - Irrigation

Source: Guidehouse

3.4.2 Technology Characterization

The Guidehouse team characterized DR-enabled technologies in coordination with EE technologies that document the same types of inputs as previously listed and described in Table 3-9. The technology costs for the energy efficient DR-enabled technologies were characterized as part of the EE measure characterization. The team separately compiled technology cost data on smart equivalents of non-smart, energy efficient technologies.

The measure characterization database includes additional fields that represent an attempt to understand possible annual system benefits from EE-DR technologies. These possible system benefits are added to the EE benefits in the cost-effectiveness calculations used to screen these measures, in the DR sensitivity (but not in the Study's core scenarios). In addition to the system benefits, the EE-DR technology characterization included O&M costs for EE-DR technologies.

In order to assess DR benefits in the Study's core scenarios, the CPUC would need to conduct a formal process to investigate, vet and adopt possible EE-DR cost-effectiveness approach(es) for EE-DR cost-effectiveness. The Study's approach used to calculate annual DR system benefits from EE-DR technologies is briefly described below and further detailed in Appendix I.

The first step to calculate system benefits is to take the unit energy consumption (kWh/unit basis) for the technology and apply the post-EE measure hourly load shape to get the annual hourly consumption profile of the technology. Next, each hourly value is weighted by the probability of calling a DR event in a particular hour. This probability is represented by the hourly generation capacity allocation factor found in the ACC[66] (higher allocation factor represents higher probability of DR events being called). These weighted hourly loads are summed over 8,760 hours in the year to arrive at the average available capacity for DR from each technology. In cases where the entire capacity is not available for DR, the team applied an appropriate load reduction percentage[67] to the average available capacity to represent the average load reduction from a particular technology during a DR event. The DR benefits are calculated by using the avoided capacity (generation and T&D), energy, and GHG emissions costs based on the DR cost-effectiveness protocol.[68] Appendix I describes the method for calculating annual DR benefits for technologies with EE and DR co-benefits.

In addition to the system benefits and O&M costs for the EE-DR measures, the cost-effectiveness analysis of EE-DR measures included incremental DR program administration costs associated with realizing the DR benefits. Net to gross for DR is assumed to be 1.0, so there are no free rider incentives included as TRC costs for DR. The team also characterized DR inputs for adoption calculations, which includes incentives and bill savings to customers (described in Section 2.1.3 and Appendix I).

[66] The Avoided Cost Calculator (ACC) is available at ftp://ftp.cpuc.ca.gov/gopher-data/energy_division/EnergyEfficiency/CostEffectiveness/2020%20ACC%20Electric%20Model%20v1c.xlsb

[67] The unit impacts or the load reduction percentage are informed by Berkeley Lab's DR potential studies technology characterization.

[68] 2016 Demand Response Cost-Effectiveness Protocols available at https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=11573.

3.4.3 Non-Incentive Program Costs

Given the difficulty of separating out the DR portion of the non-incentive program costs from the total, the Guidehouse team made simplifying assumptions using available data.

Guidehouse reviewed the program cost data for SCE's Bring Your Own Thermostat program to determine the split of the incentives to the non-incentive share in the total budget.[69] This review indicated that of the total program costs, approximately 60% were spent on incentives, 5% on DR systems and tech support, and 35% on program administration (which includes all other costs related to the program). Guidehouse used this information to determine the relative magnitude of non-incentive DR program costs vis-à-vis incentives, represented as program administration costs for DR.

3.5 Market Adoption Characteristics

As discussed in Section 2.1.1.4, the 2019 Study considered LMC as the primary driver of customer willingness to adopt EE technologies. The 2021 Study considers a broader set of customer preferences on economic and non-economic factors when modeling technology adoption.

3.5.1 Market Adoption Study

The Market Adoption Study was conducted to gather data on adoption characteristics and customer attitudes and behaviors to inform the adoption modeling for four segments: residential single-family, residential multifamily (five or more units) property owners, small commercial, and large commercial.

The customer survey collected data on customers' willingness to adopt select EE and fuel substitution technologies and measures, as well as their willingness to participate in DR programs. The survey assessed factors that may enhance residential and commercial customer willingness, including financial incentives and benefits and nonfinancial motivators. The survey also asked about factors that may negatively influence adoption or program participation across customer segments, including financial barriers, limited technology availability, structural barriers, and low awareness, among others. These barrier and motivator variables fed into characterizing customer sensitivities to several attributes that influence willingness to adopt. These attributes are discussed in more detail in Section H.3 of Appendix H.

To help survey respondents imagine real-world decision-making scenarios, specific EE technologies were used as examples in the questions that assessed likelihood of adoption given a set of economic and non-economic factors. Table 3-16 contains the full list of measures included in the survey. Given that customer preferences would likely vary depending on the technology (e.g., thermostat, central AC), measure type (i.e., EE, DR-enabled, or fuel substitution), economic situation, and general attitudes, the Guidehouse team calculated customer preference weightings separately for each combination of technology, measure type, and customer group (as introduced earlier in Section 2.1.1.4), where applicable. To account for potential impacts of the COVID-19 pandemic, the survey included questions asking respondents

[69] DVICE 4182-E (U 338-E) PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA ENERGY DIVISION; SUBJECT: Southern California Edison Company's Demand Response; 2018-2022 Mid-Cycle Status Report Advice Letter Pursuant to Decision 16-09-056; April 1, 2020

how they felt about certain questions prior to the pandemic in addition to current barriers and motivators.

Table 3-15. List of All Measures Surveyed

Sector	Measure Name	Fuel Substitution or DR Measure?*
Residential	Central AC	
	Furnace	
	Heat Pump Water Heater	FS
	Air Source Heat Pump	FS
	Water Heater	
	Refrigerator	
	Thermostat	DR
	Insulation	
	Clothes Dryer	
Commercial	Water Heater	
	EMS	DR
	Refrigeration case/unit	
	Thermostat	DR
	Insulation	
	PC Power Management System	
	Power Strip	
	Lighting Control	

*FS = fuel substitution; blank cells indicate that the survey did not address fuel substitution or DR for the specific measure.

Source: Attachment A: Market Adoption Study

3.5.2 Processing Survey Responses

The survey provided a table indicating the importance of each of the six value factors (previously introduced in Section 2.1.1.4) to each respondent's decision on whether to adopt energy efficient technologies. The survey posed questions on a 1-5 likert scale, with a response of 1 indicating the value factor is not important in the customer's decision-making, and a response of 5 indicating the value factor is very important. While the question responses were on a numeric scale, the responses should be treated as ordinal (ranked) instead of metric data because participants were asked to rank the importance of a value factor. For example, a survey response of 2 means that the category is more important than a response of 1, but not necessarily twice as important. To apply common statistical methods (e.g., averages) over the ordinal responses, the responses need to be transformed into a corresponding metric value.[70] The transformation to a corresponding metric value is done by mapping ordinal survey responses onto a common latent importance scale, which numerically represents the importance respondents place on different factors. An importance of 3 on this latent scale means that a participant values something twice as much as something given a 1.5 on the latent

[70] Kruschke, John; Liddell, Torrin. Ordinal Data Analysis. https://osf.io/53ce9/

scale. Algorithms incorporating ordered probit model methods can be used to recover a latent normal model from a set of ordinal responses.[71]

3.5.3 Summary of Survey Results

Table 3-16 summarizes the survey responses mapped to each value factor, transformed using the ordinal-to-metric analysis, and averaged over all example EE technologies. There are analogous tables for each EE measure, fuel substitution measure, and DR measure. For EE measures, there are seven such tables for single-family, four for multifamily, and eight for commercial. For fuel substitution measures, there is an additional table for each sector; for DR measures, there are one to two additional tables per sector.

Table 3-16. Average Importance of Value Factors by Customer Clusters Across All EE Measures

Value Factor	Average Americans	Eager Adopters	Economically Strained Environmentalists	Likely Laggards	Multifamily	Commercial
Eco Impacts	4.00	5.10	4.50	3.20	4.10	4.03
Hassle Factor	3.09	3.11	3.39	3.06	3.33	3.13
Lifetime Costs	3.23	3.27	3.60	2.87	3.03	3.28
Non-Consumption Performance	2.97	3.09	3.41	2.80	2.73	2.91
Social Signaling	2.80	3.40	3.80	2.50	3.50	3.63
Upfront Costs	2.27	1.80	2.73	2.14	2.63	2.53

Source: CEC Market Adoption Characteristics Study; Guidehouse

Because the survey was only able to ask about a subset of the 2021 Study measure list, the Guidehouse team conducted an exercise to map the surveyed measures to the entire 2021 Study measure list for residential and commercial measures. The first step in conducting this mapping was categorizing each surveyed technology as high or low for the attributes shown in Table 3-17. Each technology in the 2021 Study was then mapped to the surveyed technologies with which it shares the most attribute categorizations.

Table 3-17. Technology Attributes and Examples

Technology Attribute	Description	Examples
Urgency	How urgently a piece of equipment needs to be replaced when it fails	Low urgency: LED bulb High urgency: Water heater

[71] The ordered probit model was derived from survey data using a Monte Carlo Markov Chain method, which is implemented in the JAGS (Just Another Gibbs Sampler) software through an R interface.[71] The number of responses at each ordinal level was input into the model, and the output was used to generate a mapping from the ordinal value (integers between 1 and 5) to the latent metric value. This mapping was applied onto the raw survey response data before averaging over the responses within each customer group to generate modeling inputs.

Technology Attribute	Description	Examples
Visibility	Whether or not the equipment is visible on the customer premise on a day-to-day basis	Visible: Clothes dryer Invisible: Insulation
Disruption	Level of disruption experienced by the customer when adopting a new or replacement version of the equipment	Low disruption: Power strip High disruption: Insulation
Cost	Relative cost of an equipment	Low cost: Thermostat High cost: Refrigerator

Source: Human Behavior and Decarbonization Potential draft paper; Guidehouse

Table 3-18 shows how various combinations of sector and technology attributes (defined in Table 3-17) are linked to sample measures. Due to the limited number of sampled measures, one measure may appear to represent the full range of one of the attributes (indicated by both under each attribute in Table 3-18). Each residential and commercial measure in the 2021 Study is mapped to a combination of urgency, visibility, disruption, cost, and type (DR or fuel substitution, if applicable). Based on the measure assignments, the Guidehouse team applied the appropriate surveyed response dataset for the sampled measures to each 2021 Study measure.

Table 3-18. Attribute Mapping and Linking to Surveyed Measures

Sector	Urgency	Visibility	Disruption	Cost	DR or FS?*	Sample Measure Name
Residential	High	Invisible	High	High	DR	Air Source Heat Pump
Residential	High	Invisible	High	High		Central AC
Residential	Low	Visible	*Both*	*Both*		Clothes Dryer
Residential	High	Invisible	*Both*	*Both*		Furnace
Residential	High	Invisible	High	High	FS	Heat Pump Water Heater
Residential	Low	Invisible	*Both*	*Both*		Insulation
Residential	High	Visible	*Both*	High		Refrigerator
Residential	High	Visible	*Both*	Low	DR	Thermostat
Residential	High	Invisible	High	Low		Water Heater
Commercial	High	Invisible	Low	*Both*		EMS
Commercial	Low	Invisible	High	*Both*		Insulation
Commercial	Low	Visible	Low	*Both*		Lighting Control
Commercial	Low	Invisible	Low	*Both*		PC Power Management System
Commercial	Low	Visible	High	*Both*		Power Strip
Commercial	High	Visible	*Both*	High		Refrigeration Case/Unit
Commercial	High	Visible	*Both*	Low	DR	Thermostat

Sector	Urgency	Visibility	Disruption	Cost	DR or FS?*	Sample Measure Name
Commercial	High	Invisible	High	*Both*		Water Heater

* Blank cells indicate that the survey did not address FS or DR for the specific measure.
Source: Guidehouse

3.5.4 Impacts of the Multi-Attribute Analysis

The market study results have the greatest effect on measure groups where the relative magnitude of the levelized measure cost (LMC) value factor alone is different than the weighted average of the non-LMC value factors.

The examples in this section show the value factors associated with the efficient measure and indicates whether their associated technology characteristics serve as a benefit or barrier to adoption relative to the rest of the competition group.

In the illustrative instance in Figure 3-4, all of the value factors add benefits (+) to the efficient measure. However, a multi-attribute analysis does not necessarily calculate an increase in efficient measure adoption compared to the single-attribute analysis. This is because the adoption depends on the relative magnitude of the technology characteristics between measures in a technology competition group when all value factors are included compared to when only LMC is included. For a single attribute analysis only considering LMC, if the LMC of the efficient measure is only slightly better than the baseline measure, then, correspondingly, there would be slightly more adoption of the efficient measure compared to the baseline measure. In a multi-attribute analysis, the following are cases where this figure can hold true.

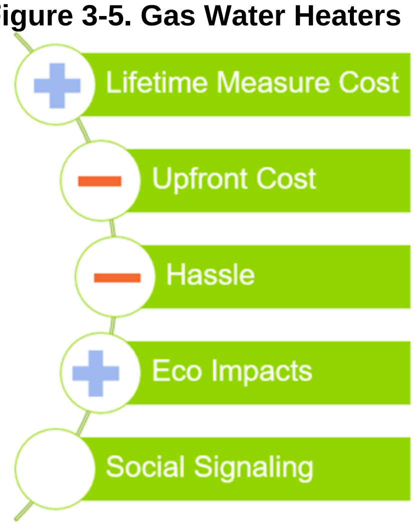
- The technology characteristics for all the other (non-LMC) value factors for the efficient measure are only slightly better than the baseline measure. In this case, the adoption of the efficient measure would be nearly identical to the adoption in the LMC-only case since the LMC value factor is also only slightly more attractive for the efficient measure.
- The technology characteristics for all the other (non-LMC) value factors are significantly more attractive for the efficient measure compared to the baseline measure, then the adoption of the efficient measure would be higher when considering all value factors than in the LMC-only case since the LMC value factor is only slightly more attractive for the efficient measure.

Figure 3-4. Illustrative Example of Efficient Measure

Source: Guidehouse

In the applied example in Figure 3-5 for instantaneous gas water heaters, the value factors address both benefits and barriers to adoption this measure. If the model only considered LMC, there would be adoption of instantaneous gas water heaters since the LMC is preferable to the baseline. After adding in all the value factors and applying the customer preference weightings, there is lower adoption of efficient instantaneous water heaters because the barriers from upfront costs and hassle factor lead to efficient measures being less attractive compared to if only LMC was considered. While there are benefits in the eco-impacts value factor, those are outweighed by the barriers from upfront cost and hassle factor.

Figure 3-5. Gas Water Heaters



Note: Social signaling for this measure is blank because it is not a visible measure; thus, this value factor does not have any impact on adoption.

Source: Guidehouse

Table 3-19 summarizes the impacts of including multiple value factors into the adoption logic for several case study measure groups. The examples above and the case studies below show that the impacts of the market study logic are dependent on both the individual measure characteristics and the customer preference weightings. The market study impacts column describes the relative change in adoption compared to an LMC-only attribute analysis. Only one residential technology group is included in the table since including non-LMC value factors did not have significant impacts on other, high savings residential technology groups.

Table 3-19. Technology Group Case Studies

Sector	Technology Group	Market Study Impacts	Description
Commercial	Split System AC - Hot-Dry*	Higher adoption	Benefits from eco impacts outweigh the barriers posed by upfront costs, which makes the efficient measures more attractive compared to a pure LMC analysis.
Commercial	LED High and Low Bay	Minimal impact to adoption	Relative benefits of other value factors are similar to the benefits of LMC.
Commercial	Small Gas Water Heaters	Lower adoption	Barriers from upfront costs and hassle factor lead to efficient measures being less attractive than the baseline measure compared to the LMC-only case.
Commercial	Fuel Substitution Convection Oven†	Lower adoption	Upfront costs, which are a barrier to adoption, feature more prominently in the decision-making consideration as a barrier to adoption.
Residential	Smart Water Heating Controls (Elec)	Higher adoption	DR incentives reduce upfront costs, which improves the attractiveness of the DR-enabled, efficient measure when considering all value factors.

* In this instance, only LMC, upfront costs, and eco impacts serve to differentiate measures within a competition group.

†Not all value factors are applicable and social signaling is not considered for fuel substitution technologies.

Source: Guidehouse

3.6 Whole Building Initiatives

Whole building initiatives aim to deliver savings to residential and commercial customers as a package of multiple efficiency measures all installed at the same time. The 2021 Study models whole building initiatives via the technology levels indicated in Table 3-20. As Section 2.1.1.2

describes, the technology levels within the technology group include existing baseline, code baseline, and the efficient result of a whole building initiative.

Table 3-20. Whole Building Technology Levels

Technology Group	Residential Technology Level	Commercial Technology Level
New Construction	Title 24 2016 Code	Title 24 2016 Code
	Title 24 2019 Code	Title 24 2019 Code
	Zero Net Energy (ZNE)	ZNE
Retrofit	Existing Building – No Retrofit	-
	Energy Upgrade CA – Basic	-
	Energy Upgrade CA – Advanced	-

Source: Guidehouse

The following sections discuss the technology levels used in the 2021 Study. The final values for savings, cost, measure life, and other key model inputs can be found in the MICS spreadsheet.

3.6.1 New Construction

The new construction whole building technology group is to analyze the potential for new construction programs increasing adoption of building above code. The Guidehouse team analyzed three efficiency levels for new construction:

- Consistent with the Title 24-2016 code, which became effective in 2017 and was the code baseline level in 2019, the base year of the study.
- Consistent with the Title 24-2019 code, which became effective in 2020. This level was considered the code baseline level for all forecast years after 2020.
- Consistent with zero net energy (ZNE) performance where EE is maximized prior to sizing onsite generation systems.

To calculate energy use, the team used the most recent California Building Energy Code Compliance (CBECC) software to demonstrate compliance with California energy codes.[72] In an update from the previous study, the team used the 2019 version of the software and analyzed building characteristics for a 2019 code-compliant building to establish the energy consumption of the Title 24-2019 code level. The energy consumption of a 2016 code-compliant building was calculated using an assumption from the CEC that the 2019 code level saves 2% of the building energy use compared to the 2016 level for commercial buildings and 7% of the home energy use compared to the 2016 level for residential buildings.[73] Similar assumptions of ZNE energy use as the previous study were used to forecast EE savings to the ZNE level.

The Guidehouse team calculated incremental cost assumptions in a manner similar to the previous study and based them on cost impact analyses and communications from the CEC and a New Building Institute study. Table 3-21 provides the sources used to characterize new construction whole building initiatives. These sources represent the best and usable datasets

[72] http://bees.archenergy.com/index.html

[73] https://www.energy.ca.gov/sites/default/files/2020-03/Title_24_2019_Building_Standards_FAQ_ada.pdf

available to the team at the time of characterization. The data from the 2019 CBECC software was particularly valuable because it provided variability by climate zone.

Table 3-21. New Construction Whole Building Data Sources

Data Category	Data Items	Data Sources
Cost	Cost of 2016 Title 24	California Energy Commission, 2016 Notice of Proposed Action[74]
	Incremental cost of 2019 Title 24	Extrapolation based on 2016 Title 24
	Incremental cost of ZNE	Residential: CEC Draft Title 24 Code Update Analysis provided to the team Commercial: New Building Institute, *Getting to Zero 2012 Status Update: A First Look at the Costs and Features of Zero Energy Commercial Buildings*: http://newbuildings.org/getting-zero-2012-status-update-first-look-costs-and-features-zero-energy-commercial-buildings Comm. RE Specialists, Cost Per Square Foot For New Commercial Construction, 2013 Reed Construction Data Inc., RS Means Square Foot Estimator, 2013: http://www.rsmeansonline.com
Energy consumption and savings	2016 Title 24 energy consumption	Communications with the CEC, January 2019
	2019 Title 24 energy consumption	Communications with the CEC, January 2019 CEC, CBECC-Res and CBECC-Com 2019 Standard Design Results, September 2020
	ZNE energy consumption	ARUP, *The Technical Feasibility of Zero Net Energy Buildings in California*, December 2012

Source: Guidehouse

3.6.2 Retrofit

The 2021 Study only includes residential whole building retrofits. The Guidehouse team did not analyze commercial retrofits based on a review of CEDARS data, which suggested there are few commercial retrofit projects and the large majority are undertaken as non-standard custom projects with savings that vary widely. Furthermore, the upgrade types undertaken in a whole building retrofit are sufficiently covered by other measures in the study, such as HVAC and lighting upgrades.

The team characterized energy savings from residential whole building retrofits using data from the DNV GL PY2017 impact evaluation of the Home Upgrade Program,[75] supplemented by data from the All Things Reported database for PY 2017 whole building retrofits analyzed in the

[74] http://www.energy.ca.gov/title24/2016standards/rulemaking/documents/NOPA_title24_parts_01_06.pdf, Last accessed September 2018.

[75] DNV GL. *Impact Evaluation Report: Home Upgrade Program – Residential Program Year 2017*. April 29, 2019. (CALMAC ID: CPU0191.01)

Guidehouse Group A EUL Study. The impact evaluation provided percent energy savings, while the All Things Reported database provided per-home kWh, kW, and therm savings.

The Guidehouse team characterized cost savings by reviewing costs of home upgrade projects included in the evaluation. The team found that for projects below $15,000 savings appeared to correlate with cost and used this data to establish a cost per unit savings for the characterization. (For the relatively small number of projects greater than $15,000, there appeared to be no strong correlation of cost to energy savings, so the team excluded these outliers from the cost analysis.)

3.7 Agriculture, Industrial, and Mining Technology Characterization

The 2021 Study update for the AIM sectors focused on agriculture and industrial and did not include an update for mining. The Guidehouse team's approach to each sector's data sources varied. The primary effort for agriculture and industrial was to leverage two key data sources:

- **Recently completed Industrial and Agriculture Market Study:**[76] This study identified new measures and collected California-specific data to inform measure characterization.
- **Historical IOU program data:** This data allowed the team to directly characterize measures developed for the PG Model to IOU program activities.

Consistent with the scope, the mining sector data remains the same as 2019 Study, with no update for the 2021 Study.

The following sections discuss the technology characterization data for the three AIM sectors. Appendix D provides additional detail on the industrial and agriculture sectors and measures.

This section and the material in Appendix D represent the team's use of the best available data. The existing datasets for AIM sectors still have data gaps and are not all necessarily California-specific. Guidehouse has conducted similar industrial potential analysis in other jurisdictions[77] and, in all cases, stakeholder reviewers believed the savings estimates to be higher than calculated for the studies. There are several reasons that results and observations of what occurs in the market do not align:

- No good baseline or saturation data exists for the industrial sector.
- Assumptions are made regarding costs.
- Many studies leverage the Industrial Assessment Center (IAC) database[78] to various levels.

0E also addresses the new Industrial and Agriculture market study which provides California-specific data. The Industrial and Agriculture market study describes the specific data collected. The report limited the scope to six segments and the three top potential measures per segment. Future studies would need to expand the scope to other segments and end uses to expand savings potential (beyond those identified as top savers by experts).

[76] The report is Attachment 2 to this report.

[77] One example is the Energy Efficiency Alberta study: https://www.efficiencyalberta.ca/potentialstudy.

[78] https://iac.university/#database

Since the 2019 Study, the CPUC has been addressing concerns related to program participation and if policies prohibit further program participation. It is important to review if projects are stalled or reduced in scope when denied rebates. The outcomes of this work in increasing program participation and savings are yet unknown.

3.7.1 Agriculture and Industrial Sectors

The Guidehouse team characterized the agriculture and industrial sectors following the overall approach that stakeholders agreed to in the 2017 Study and duplicated in the 2019 Study. No new studies or datasets are available for the team to change this approach. The approach leveraged historical program data and included the following steps:

1. Extract measure-level data from the reported program data (prior to 2017, California EEStats portal[79] and now the CEDARS database). The team identified over 1,300 measure-level data points for the industrial and agriculture sectors in the 2019 CEDARS program data.
2. Categorize measures into technology groupings:
    a. **Characterized custom** measures are measures identified by the team's review of the records list, focusing on the high impact measures (i.e., those contributing significant amounts of energy savings) and excluding records with negligible savings contributions or those representing niche activities. The characterized custom category includes readily defined measures. They make up the forecast using the Bass diffusion model and savings estimates sourced from the Industrial and Agriculture Market Study (as the primary source) and are supplemented with the IAC database for measures and segments not included in the data collection study. Some measures in this category may fall under the custom review process established by the CPUC.

    b. **Generic custom** measures are those measures included in projects unique to various subsectors that cannot be readily defined at the measure level or forecast using a Bass diffusion model. Section 3.8 describes the methodology used to characterize these generic custom measures. CEDARS measures that were marked as process improvement or other process were considered as generic custom. Additionally, if there were measures with small portfolio savings contribution within the sector that could be considered as characterized custom, then the team aggregated them under the generic custom group. The aggregated savings of these small savers contribute no more than 10% of the sector savings of the characterized custom list. Most of the savings established within generic custom fall under the custom review process.

    c. **Emerging technologies** measures are considered nascent or emerging and cannot be readily defined at the measure level or forecast using a Bass diffusion model. Section 3.8 describes the methodology used to characterize these generic custom measures.

    d. **BROs or strategic energy management (SEM)-like** measures that include RCx and some optimization. This group is modeled alongside other BROs measures and cannot be readily forecast using a diffusion model, as Section 2.1.1 describes.

[79] http://eestats.cpuc.ca.gov/Default.aspx

3. Append 2019 savings totals to previously collected savings data for 2013 to 2017 associated with the agriculture and industrial sectors. This dataset retains measure level data for each technology grouping and forms the basis for our analysis (more details are provided in 5.8Appendix D).

Table 3-22 summarizes the final technology list, which is broken into four categories.

Table 3-22. AIM Modeling Methodology

Categories	Model Approach	Applicability
Emerging Technologies	Top-down approach	Agriculture and Industrial
BROs*	Top-down approach	Agriculture and Industrial
Characterized Custom†	Bottom-up Bass diffusion approach	Agriculture, Industrial, and Mining
Generic Custom	Top-down approach	Agriculture and Industrial

*SEM is modeled as an Industrial and Agriculture BROs measure by allocating the historical RCx as a proxy for SEM savings.
†Mining only has characterized custom measures.
Source: Guidehouse

3.7.1.1 Characterized Custom for Agriculture and Industrial

For the 2021 Study, the Guidehouse team characterized 29 technology groups for the agriculture sector (nine additional measures relative to the previous study) and 24 for the industrial sector (nine additional), representing the characterized custom measures for the market adoption model using bass diffusion.[80] The technology groups are sourced from past potential and goals studies and the Industrial and Agriculture Market Study. This approach provided consistency with the methods used in the residential and commercial sectors and allowed the Guidehouse team to calibrate the PG Model using prior program achievements and establish greater confidence in the results.

3.7.1.2 Technology Characterization

The PG Model required characterizing technology-level inputs including UES, unit costs, and the saturation or density of efficient versions of each technology existing in the marketplace. The team mined data sources to complete a thorough characterization of the agriculture and industrial technologies.

- **Agriculture** data sources for measure characterization included CEDARS, CPUC workpapers, and data provided by the IOUs. The Guidehouse team also relied on DEER for information on energy savings estimates by technology. The team completed measure savings updates for the nine new measures from the Industrial and Agriculture Market Study, lighting (to be consistent with the commercial sector), measure costs, and net-to-gross (NTG) updates per the 2019 CEDARS program data.
- **Industrial** data sources were similar to those mined for the agriculture sector, including CEDARS and data provided by IOUs, the CPUC, and the CEC. For energy savings

[80] Appendix E provides details for the technology group.

estimates, the team used the IAC.[81] The team completed measure savings updates for the nine new measures from the Industrial and Agriculture Market Study, measure costs, and NTG updates per the 2019 CEDARS program data.

For most measures, the Guidehouse team leveraged California-specific resources; when these resources were not applicable or available to certain measure types, the team used other peer group jurisdictions and substituted in California-specific variables where possible.[82]

Energy savings. The team used data from the national IAC database to supplement CEDARS data and inform the energy savings estimates for the industrial characterized custom technologies. The IAC network consists of 24 universities that have completed over 16,000 assessments at industrial facilities across the nation. Each assessment completed by the IAC includes detailed recommendations for improving energy consumption at a given site,[83] the specific energy savings the site can expect by implementing such improvements, and the total energy each site currently uses. PG Model efforts have relied on IAC data since 2011.

The Guidehouse team mapped all the unique IAC recommendations to the list of characterized custom industrial technologies created from the EEStats and CEDARS databases. The team then used NAICS coding to sum the energy savings estimates for each technology to the entire industrial sector by building type and divided it by the total energy consumption for all buildings of that type. Using the measure level data from IAC provided the percentage each technology saves by building type across the entire industrial sector.[84] The team followed this process for electric (kWh)- and gas (therm)-consuming industrial measures.

The IAC database included robust, informative data for all but one industrial technology also identified in EEStats: wastewater aerators. Wastewater aerators are listed as energy efficient aerators in the technology list and use an SCE workpaper for data.

Other measures not using the IAC database are the new measures established from the Industrial and Agriculture Market Study, which are detailed in the Appendix E. The data from the study includes (and provided in the separate report):

- Percent savings, as a percentage of end use related to the measure
- Percent end use, as a percentage of total site usage
- Percentage of sites with equipment (technical applicability and suitability for the technology)

[81] https://energy.gov/eere/amo/industrial-assessment-centers-iacs

[82] Other sources include the Pennsylvania Technical Reference Manual (TRM) (http://www.puc.pa.gov/filing_resources/issues_laws_regulations/act_129_information/technical_reference_manual.aspx); the Illinois TRM (http://www.ilsag.info/technical-reference-manual.html); the Michigan Energy Measures Database (http://www.michigan.gov/mpsc/0,4639,7-159-52495_55129---,00.html); and the Wisconsin TRM (http://dsmexplorer.esource.com/documents/Wisconsin%20-%2010.22.2015%20-%202016%20TRM.pdf). See the Agriculture MICS for more detail on which measures these sources informed.

[83] The IAC recommendations cover upgrades to inefficient equipment, the addition of energy-reducing technologies to existing equipment, and improvements to industrial processes through controls.

[84] The final percentages of savings by building type are a nationwide value. The IAC data does not contain enough assessment data points to calculate these values on a state or region level with any degree of statistical confidence. Further, the Guidehouse team's vetting of IAC data during previous potential and goals study efforts determined that national-level IAC data is representative of California industrial sector activities.

Costs. The Guidehouse team primarily used the CEDARS database to calculate the incremental cost per UES for technologies included in the industrial and agriculture analysis.[85] The team compared the 2019 Study to ensure the costs aligned because measure costs can be variable year-over-year and from project to project. The team multiplied the incremental cost per unit by the technology energy savings to estimate technology costs.

EUL and NTG. The Guidehouse team used the CEDARS database to calculate the EUL (some measures relied on the DEER EUL estimates) and NTG ratios for all technologies included in the industrial technology list. The team compared this calculation across industrial and agriculture findings and the 2019 Study. Adjustments were made as necessary.

Saturations and Densities. Technology characterization requires data on the saturation of efficient technologies existing in the marketplace. The saturation data provides a clearer picture of how much potential energy savings still exist by upgrading remaining baseline technologies within that marketplace. For industrial technologies analyzed using the IAC database, the team assumed that every recommendation made at an industrial facility meant that this facility still had the inefficient baseline technology installed. For example, if a facility received a recommendation to upgrade its lighting system, the team assumed this facility still used inefficient or baseline lighting technologies. This assumption allowed the team to identify the percentage of sites with baseline equipment (i.e., those receiving a recommendation for a technology).[86] This baseline percentage was used as one of the variables to calculate the total sector savings available for each measure defined in the Energy Savings section above.

For measures not covered in the IAC database, the team used professional judgement based on data sources such as commercial sector saturation data and feedback from stakeholders to estimate a density of efficient versus inefficient technology.

The new measures established from the Industrial and Agriculture Market Study and detailed in the Appendix E use the study's input from the interviews of technology vendors and end users. The data includes percent suitability, percentage of site with equipment, and percent of equipment at energy efficient level. The data is provided in the Industrial and Agriculture Market Study report.

3.7.2 Mining Sector

The 2021 Study approach and data inputs are unchanged from the 2019 Study. The Guidehouse team defined the mining sector inputs using a bottom-up approach consistent with the other AIM sectors. The team sourced data from several sources including region-specific information on oil and gas extraction activities from the California Department of Conservation.[87] This data provided the number of active and idle wells, the amount of oil and water produced

[85] The costs in EEStats include labor to represent the full incremental cost of implementation. The lighting end use relied on cost per kWh consumed rather than cost per kWh saved because the team relied on commercial data for the industrial lighting end use measures.

[86] The IAC recommendations do not provide a density of efficient equipment in the marketplace because the inverse of the assumption regarding recommendations is not true (i.e., just because an industrial facility did not receive a recommendation does not mean it already had the efficient version of the recommendation installed).

[87] http://www.conservation.ca.gov/dog

from wells, the amount of steam and hot water generated for mining operations, and the number new wells created.[88]

The Guidehouse team also used consumption data from the CPUC and other secondary sources, including IOU program data and industry-specific reports and studies. These sources inform estimates for energy savings, costs, EUL, and NTG. The team also updated select model inputs such as sector consumption.

3.8 Industrial and Agriculture Custom Technologies Data Sources

Generic custom measures in the industrial and agriculture market sectors are projects that tend to be specific to an industry segment or production method. Generic custom measures are often listed by non-descript names such as Process-Other in publicly reported IOU tracking data,[89] and they present several challenges within a potential forecast:

- Have unique attributes that make them difficult to forecast within the diffusion-based PG Model.
- Unlikely to saturate over time due to continual process changes in the industrial and agriculture sectors.
- Often consist of emerging technologies that are in the early adoption phase, with little to no engineering details, market parameters, or workpapers.

As discussed further in Section 3.7.1.1, the definition of generic custom measures for the 2021 Study accounts for the following:

- Any one measure that contributes only a small percentage of portfolio savings (e.g., faucet aerator or HVAC controls) is now included in the generic custom measure class.
- RCx savings separated out from generic custom savings and considered to be part of SEM savings.

The 2021 PG Model treats generic custom measures as a specific measure class. Table 3-23 provides the inputs for electricity and natural gas for these measures; additional discussion follows the table. The Guidehouse team provides separate UES estimates for the industrial and agriculture market sectors. The team calculated the EUL for these measures at 15 years because most savings come from larger capital investments with long operating lives. Appendix F provides additional details on the generic custom analysis and forecast methodology.

Table 3-23. Generic Custom Measures – Key Assumptions

Sector	Type	EUL Years	Savings		Cost		kW/kWh Savings Ratio
			kWh	therms	kWh	therms	
Industrial	Generic Custom	15	0.0673%	0.0535%	$0.48	$2.81	0.000195
Agriculture	Generic Custom	15	0.060%	0.624%	$0.48	$2.81	0.000195

[88] http://www.conservation.ca.gov/dog/pubs_stats/annual_reports/Pages/annual_reports.aspx

[89] Generic custom also includes a large number of discrete measures that each contribute a small amount of savings and collectively account for less than ~5% of sector savings.

Source: Guidehouse

The Guidehouse team estimated savings based on building type consumption (kWh or therms/year); however, because these technologies are forecast as a single class of measure, savings do not vary by market segment or IOU. The team based generic custom savings in the 2021 Study on an analysis of data previously extracted through the California EEStats portal[90] and more recent data from CEDARS for programs operating from 2016, 2017, and2019.[91] Data for these program years provided the level of detail necessary to separate generic custom measures from RCx and other custom measures that could be defined and modeled using a Bass diffusion approach. Table 3-24 summarizes the generic custom savings contribution to the overall sector when accounting for the removal of RCx from generic custom and the addition of the large number of smaller measures now considered part of the generic custom measure class.

Table 3-24. Generic Custom Contribution as a Percentage of Sector Savings, Average of 2016, 2017, and 2019

Sector	Electricity	Gas
Industrial	19%	28%*
Agriculture	17%	37%

In 2019, a lot of industrial pipe insulation savings contributed to a higher percentage of characterized custom gas savings than in previous years.

Source: Guidehouse

Based on this analysis and sector-level consumption forecasts provided by the CEC, the Guidehouse team determined that generic custom measures would save roughly 0.07% and 0.05% of annual industrial sector electricity and natural gas usage, respectively. Using a similar methodology, the team forecast savings from generic custom measures in the agriculture sector at 0.06% of annual electricity consumption and roughly 0.6% of annual gas usage. These percentages are used in the reference or aggressive cases and remain constant throughout the forecast horizon.

The costs for electricity and natural gas savings were based on an analysis of industrial and agriculture programs operating in California in 2019. These costs are estimated at $0.48/kWh and $2.81/therm and are applied consistently across sectors and utilities throughout the 2021 Study forecast horizon.

Applicability and penetration rate are key inputs to the savings forecast. Applicability of generic custom measures in the industrial and agriculture sectors is 100% because these measures are considered ubiquitous to all activities in all market segments. The approach to forecasting the penetration rate for generic custom measures remained the same from the 2019 Study.

3.8.1 Industrial and Agriculture Emerging Technologies

New emerging technologies to reduce energy use and energy demand are continually being introduced in the California marketplace. The 2021 Study used the same approaches and inputs and the 2019 Study, which was built on analysis conducted for the 2017 Study. For the 2017 Study, the Guidehouse team identified approximately 1,100 potential emerging technologies.

[90] http://eestats.cpuc.ca.gov/Default.aspx

[91] The team did not analyze 2018 data to the technology group level because the overall savings for that program year for the industrial and agriculture sectors was low.

These emerging technologies were run through a screening process to rate energy technical potential, energy achievable potential, market risk, technical risk, and utility ability to impact market adoption. This process yielded 169 emerging technology processes[92] for final consideration within the model. For the 2019 Study, the team reviewed the data sources used in the 2017 Study to include measures that might have been added since the initial review and updated measures for which there might be more recent data. Appendix F includes a summary of the emerging technology literature reviewed and details on the screening process and how it was used to define subsector potential.

Table 3-25 summarizes the resulting savings and cost factors; additional discussion follows the table. The Guidehouse team applied segment-specific electric and gas savings, as well as costs, EUL, and kW/kWh savings ratio consistently across all utilities.

Table 3-25. Emerging Technologies – Key Assumptions

Sector	Type	EUL Years	Savings Range		Cost		kW/kWh Savings Ratio
			kWh	therms	kWh	therms	
Industrial Agriculture	Emerging Technology	10	0.93% - 9.62%	0.0% - 14.21%	$0.42	$2.83	0.000195

Source: Guidehouse Team

The model uses a universal EUL of 10 years to accommodate the broad range of emerging technology adoption curves. Similarly, a universal 0.000195 ratio of kW to kWh was applied to the three electric utilities. This is the same value used for SEM, and it is based on an analysis of several third-party SEM programs operating in California during the 2014-2015 portfolio cycle. Actual emerging technology-specific EULs and kW/kWh are presently unknown and can be refined during future emerging technologies market studies as additional information becomes available.

The Guidehouse team estimated costs for electricity and natural gas emerging technologies savings based on an analysis of industrial and agriculture programs operating throughout 2016. Costs for electricity and natural gas savings are estimated at $0.42/kWh and $2.83/therm and are applied consistently for all utilities and across all industrial and agriculture sectors. Appendix F includes additional information on the methodology used to derives UES values and costs for emerging technologies measures.

In determining applicability, emerging technologies apply to different industrial and agriculture sectors in varying degrees, and the Guidehouse team assessed segment-specific technology applicability during the screening process. For emerging technologies determined to be feasible at the segment level, a UES estimate that includes adjustment for applicability was completed for each emerging technology. The team assigned each sector 100% applicability in the forecast model with the understanding that applicability was considered during the screening process and is embedded in the UES value for each emerging technology.

Adoption of future emerging technologies will vary by technology. Some emerging technologies will gain widespread customer acceptance and capture broad market share based on price, energy savings, and other customer-driven factors, while other emerging technologies will see more limited adoption. Although the team assigned unique risk factors to each new technology

[92] The emerging technologies represent a process for reducing energy consumption and not necessarily a specific technology.

during the screening process, it is impossible to definitively predetermine which technology will be successful. Therefore, the model considers all emerging technologies in aggregate and applies a consistent participation rate to all emerging technologies.

Penetration forecasts for the industrial and agriculture sectors begin with a saturation level of 0.1% for the reference case and follow a compound annual growth rate (CAGR) of 3.25%, yielding a target saturation of 1.84% by 2030. The 2030 target saturation of the portfolio of AIM-relevant emerging technologies is an estimate that acknowledges the timeline over which new technologies move through the adoption cycle to reach 80% saturation (typically ranging from 10 to 30 years) and the relatively slow turnover of the diverse set of production equipment associated with many industrial processes. From 2030 to 2032, the penetration rate remains at the 1.84% level.

3.9 Codes and Standards

C&S modeled in the 2021 Study uses data from multiple sources.

- For evaluated C&S, the study uses ISSM[93] as its data source.
- For unevaluated C&S, the study uses data provided by California IOUs via a formal data request.[94]
- For all other future C&S, the study uses additional data and information collected as part of the 2019 Study from the CEC along with additional assumptions made by the Guidehouse team.

Table 3-26 lists the number and type of C&S and their data source. Appendix E contains a full list of the modeled C&S, their compliance rates, effective dates, and policy status (on the books, possible, or expected).[95]

[93] Market Logics and Opinion Dynamics*. Integrated Standards Savings Model (ISSM).* 2020.

[94] PG&E, SCE, SDG&E, and SCG all responded to the data request on November 3, 2020.

[95] **On the books:** A code or standard that has been passed into law.
Expected: A code or standard that is in development.
Possible: A code or standard that is not actively being developed, but other policy guidance suggests these should be the next logical C&S to be developed. Possible C&S are not included in the forecasted results of the 2021 Study but are made available for the CEC's AAEE forecasting process.

Table 3-26. C&S Data Source Summary

IOU C&S Group	Number and Type of C&S	Data Source
Evaluated Title 20 and Federal	116 appliance standards	ISSM
Evaluated Title 24 2005-2013	108 building codes	ISSM
Unevaluated Title 20 and Federal	8 appliance standards	IOU data request
Unevaluated Title 24 2016-2019	14 building codes	IOU data request
Future Title 20	9 appliance standards	IOU data request, Guidehouse assumptions for 2024 and beyond
Future Federal	17 appliance standards	IOU data request, Guidehouse assumptions for 2024 and beyond
2022-2029 Title 24	7 building codes	IOU data request, Guidehouse assumptions for 2024 and beyond

Sources: Market Logics and Opinion Dynamics. ISSM. 2020.; IOU data request filed November 3, 2020; CEC

For 2013 Title 24, the ISSM provides the option to use either bounded or unbounded energy savings adjustment factors, which are analogous to compliance factors for appliance standards.[96] Unbounded refers to the case where a building, project, or measure can consume less energy than the level established by the current Title 24 code, resulting in an energy savings adjustment factor greater than 100%. Bounded refers to limiting the energy savings adjustment factor values to a maximum of 100%. The 2021 Study uses bounded values from the ISSM.

The 2021 Study carries forward assumptions made during the 2019 Study on energy savings estimates for future Title 24 code cycles in 2025 and 2028 for the commercial sector. Personal communication with staff at the CEC during the 2019 Study provided insight on the path between 2019 Title 24 and 2028 Title 24, as Table 3-27 illustrates. The Guidehouse team continued to use these assumptions for the 2021 Study.

[96] Cadmus and DNV GL. *California Statewide Codes and Standards Program Impact Evaluation Phase Two, Volume Two: 2013 Title 24*. August 2017.

Table 3-27. Progression of Commercial T24

Title 24 Code Cycle	Cumulative Percentage of 2028 Savings Target	Incremental Savings toward 2028 Target
2016	0%	-
2019	33%	33%
2022	50%	17%
2025	67%	17%
2028	100%	33%

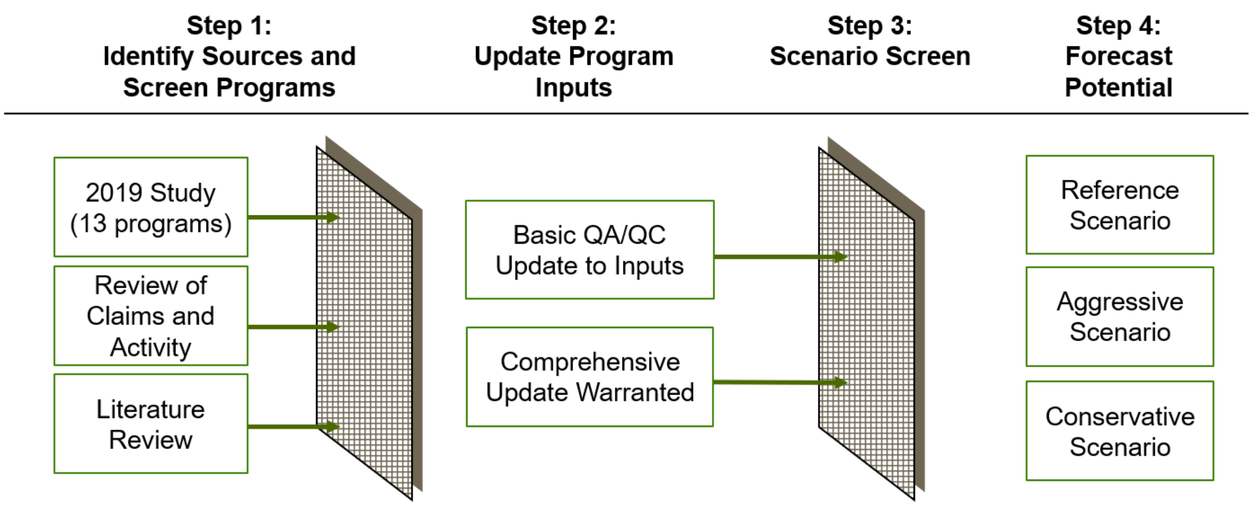
Source: Guidehouse 2019 based on communications with CEC Staff

The team scaled 2019 Title 24 claimed savings based on the last column in Table 3-27 to develop estimates of savings for the 2025-2028 Title 24. NOMAD factors for 2025-2028 Title 24 were adapted from 2019 Title 24 and time-shifted to an appropriate start date.

3.10 BROs EE

To forecast customer BROs energy savings, the Guidehouse team considered a wide range of behavioral intervention types for residential and commercial customers. Figure 3-6 illustrates the process used to update BROs measures in the 2021 Study.

Figure 3-6. Selection Process for Residential and Commercial BROs EE Programs



Source: Guidehouse

Step 1: Identify new sources and screen programs. The first step in the BROs update process was to determine which previously characterized behavioral programs had new and relevant available data. The team kept the same broad list of 13 BROs measures from the 2019 Study and worked to identify any recently published data sources for each program. This review targeted claims or other evidence of implementation activity and sources from the broader literature. The review focused on California-specific data sources like formal evaluations, CEDARS claims, and Annual Budget Advice Letter filings but also drew on broader sources such as the Consortium for Energy Efficiency Database, American Council for an Energy-Efficient Economy proceedings, and Behavior, Energy & Climate Change Conference materials.

For most programs, there was little new data or evidence of implementation to warrant significant updates to the program inputs.

Step 2: Update program inputs. For most of the BROs programs, the review in Step 1 indicated that thorough or significant updates were not needed. For these programs, the inputs used were largely the same as those in the 2019 Study. Prior to passing through the data and inputs from the previous study, the team performed a basic quality assurance/quality control (QA/QC) review of the inputs and made any minor updates as needed. The QA/QC process included extending the forecast period out to 2032 and, for programs with little evidence of implementation through 2020, updating the starting year in which non-zero penetration rate begins to 2021.

Based on the review in Step 1, the Guidehouse team identified a few programs to target for more thorough updates in the 2021 Study. These programs were HERs, Building Benchmarking, and Building Energy Information Management Systems (BEIMS).

- **HERs:** All inputs were updated using data from the PY2016, PY2017, and PY2018 impact evaluations and CEDARS data from 2016 to 2020.
- **Building Benchmarking:** Major updates were made to applicability inputs to reflect updated statewide benchmarking requirements.
- **BEIMS:** Updates to UES were made to incorporate the existing Facility Assessment Service Program into BEIMS.

As with the 2019 Study, the team calculated savings rates and penetration rates using relevant EM&V-reported program participation rates for current California IOU program offerings and reported participation in programs in other states. The team modeled an EUL of 1 year for residential programs. Commercial programs used a 2- or 3-year EUL per CPUC Decision 16-08-019 unless evidence supported a longer duration. Industrial and agriculture SEM programs were assigned an EUL of 4.3 years, while commercial SEM-like programs were assigned an EUL of 5 years.

Appendix B details specific modeling inputs for each intervention type.

Step 3. Scenario screen. The team sorted each BROs program to determine whether it would be included in each of the two BROs scenarios.

- **Reference scenario:** Includes BROs programs found to be cost-effective in the 2019 Study, which screened programs using the TRC test and the latest CPUC-approved avoided costs for each utility.
- **Aggressive scenario:** Includes all BROs programs considered in this study regardless of cost-effectiveness . The penetration forecasts for each program are also more aggressive compared to the reference case. Penetration assumptions are provided in the BROs input assumption spreadsheet released along with this study.

Step 4. Forecast potential. The forecasts are the result of professional judgement based on program operations, historical participation, and whether participation is utility-driven (opt out) or customer-driven (opt in). The Guidehouse team adjusted the forecast penetration rates to represent the reference and aggressive scenarios.

Many intervention types were characterized to forecast potential. A more detailed description of each of the final intervention types follows in Table 3-28; Appendix B includes additional details.

Table 3-28. Behavioral Intervention Summary Table

Sector	Type of Behavioral Intervention	Brief Description	EUL (Years)
Residential	HERs	Reports periodically mailed to residential customers that provide feedback about their home's energy use, including normative comparisons to similar neighbors, tips for improving EE, and occasionally messaging about rewards or incentives.	1
Residential	Web-based real-time feedback	Real-time information and feedback about household energy use provided via websites or mobile apps.	1
Residential	In-home display real-time feedback	Real-time information and feedback about household energy use provided via energy monitoring and feedback devices installed in customer homes.	1
Residential	Small residential competitions	Organized competitions with fewer than 10,000 participants per year in which participants compete in events, contests, or challenges to achieve a specific objective or the highest rank compared to other individuals or groups as they try to reach goals by reducing energy consumption.	1
Residential	Large residential competitions	Organized competitions with more than 10,000 participants per year in which participants compete in events, contests, or challenges to achieve a specific objective or the highest rank compared to other individuals or groups as they try to reach goals by reducing energy consumption.	1
Residential	UAT	An opt-in online tool that asks residential customers questions about their homes, their use of household appliances, and occupancy patterns; it then offers EE advice regarding ways they can save money and energy.	1
Commercial	Commercial competitions	Organized competitions between cities, businesses, or tenants in multi-unit buildings in which participants compete in events, contests, or challenges to achieve a specific objective or the highest rank compared with other groups as they try to reach goals by reducing energy consumption.	2
Commercial	Business energy reports (BERs)	Reports periodically mailed to small and medium size businesses to provide feedback about their energy use, including normative comparisons to similar businesses, tips for improving EE, and occasionally messaging about rewards or incentives.	2
Commercial	Building benchmarking	Scores a business customer's facility or plant and compares it to other peer facilities based on energy consumption. It also often includes goal setting and rewards in the form of recognition.*	2

Sector	Type of Behavioral Intervention	Brief Description	EUL (Years)
Commercial /Industrial/ Agriculture	SEM-like and SEM programs	Long-term continuous improvement process that educates and trains business energy users to develop and execute long-term energy goal setting and strategic planning and to integrate energy management into business practices throughout the organization—from the corporate board office to the boiler room and the work floor. It can include consulting services, customized training, benchmarking and measurement, feedback, data analysis, and performance review. A SEM-like program is assumed for the commercial sector. Industrial RCx falls under this category.	5 (COM) 4.3 (IND/AG)
Commercial	BEIMS	Enables building operations staff to achieve significant energy savings by monitoring, analyzing, and controlling building system performance and energy use. BEIMS can include benchmarking and utility bill tracking software, energy information systems, building automation systems, fault detection and diagnostic tools, automated system optimization software, and value-added services and contracts.	3
Commercial	Building operator certification	Trains and educates commercial building operators about how to save energy by encouraging them to adopt energy efficient behaviors and make building changes that reduce energy use.	3
Commercial	RCx	Whole building systems approach to improving an existing building's performance by identifying and implementing operational improvements to save energy and increase comfort. RCx refers to commissioning a building that has not previously been commissioned. This program also includes recommissioning or commissioning a building that has been commissioned at least 5 years prior.	3

*Pursuant to Assembly Bill (AB) 802, building benchmarking is mandated for all commercial buildings greater than 50,000 sq. ft. under the CEC's Building Energy Benchmarking Program. In the 2021 Study, the Guidehouse team limited the applicability of the benchmarking measure to buildings less than 50,000 sq. ft. but greater than 10,000 sq. ft. to reflect additionality from IOU interventions. Due to uncertainty surrounding additional benchmarking requirements from local ordinances that may further preclude IOUs from claiming savings, the team included benchmarking only in the aggressive BROs scenario.

Source: Guidehouse

3.10.1 Data Rigor

The Guidehouse team conducted an extensive industry scan for data on BROs initiatives for the 2019 and 2021 Studies. The team found that many of these programs are still relatively new and learning about their effectiveness is ongoing. The published data has studies different with levels of statistical rigor on the data around energy savings that resulting from these interventions. Table 3-29 provides a snapshot of the quality of data collected for this study. Across the board, demand savings data is often limited and cost data is hard to obtain. Penetration forecasts are the most uncertain because of limited historical penetration rates on which to base a forecast.

The team recommends the industry consider pilot studies and measurement and verification to provide better data to future potential and goals studies. Interventions that literature claims to show large promise though limited verified data exists include prepay programs, commercial SEM, building benchmarking, competitions, web-based feedback, and in-home real-time feedback.

Table 3-29. Qualitative Assessment of Data Quality

Sector	Program	Savings			Cost	Applicability	Participation Rate	Penetration Forecast	Major 2021 Updates
		kWh	therms	kW					
Residential	Home Energy Reports	Green	Green	Green	Green	Green	Green	Green	✓
	In-Home Display Real-Time Feedback	Yellow	Yellow	Orange	Yellow	Green	Orange	Orange	
	Web-Based Real-Time Feedback	Yellow	Yellow	Orange	Green	Green	Green	Green	
	Small Res Competitions	Yellow	Yellow	Orange	Yellow	Green	Yellow	Orange	
	Large Res Competitions	Green	Green	Orange	Yellow	Green	Green	Orange	
	Universal Audit Tool	Green	Green	Green	Green	Green	Green	Green	
Commercial	Commercial Competitions	Green	Green	Orange	Yellow	Orange	Green	Orange	
	Business Energy Reports	Green	Green	Orange	Orange	Green	Orange	Orange	
	Building Operator Certification	Green	Green	Orange	Orange	Green	Orange	Orange	
	BEIMS	Green	Green	Green	Green	Green	Green	Orange	✓
	Building Benchmarking	Yellow	Yellow	Orange	Green	Green	Orange	Orange	✓
	Strategic Energy Management-type	Yellow	Orange	Orange	Orange	Green	Orange	Orange	
	Retrocommissioning	Green	Green	Green	Green	Green	Green	Orange	

Legend	
Green	California-specific program data or derivatives
Yellow	Aggregated reports or non-verified savings reported by utilities outside of California
Orange	Assumed equivalence to similar programs or other forms of professional judgement
✓	Indicates that this program had major changes to inputs since the 2019 Potential and Goals Study

Source: Guidehouse

4. 2021 Study Results

Policymakers have used the results of past potential studies as a technical foundation to set savings goals for the next regulatory cycle. The 2021 Study is the basis for the CPUC's 2022 and beyond EE goal setting process. Table 4-1 summarizes key findings from this study and the potential implications of each finding.

Table 4-1. 2021 Study Key Findings and Implications

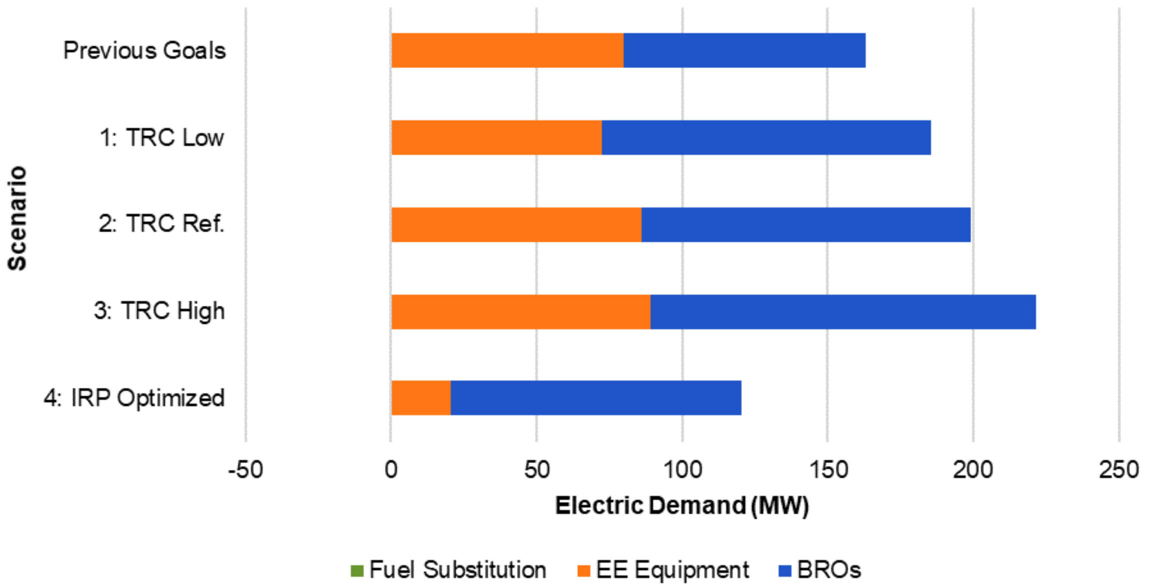
Key Finding	Implication
1. Lighting measures have remaining potential.	As lighting technology evolves, new opportunities for savings potential become available. The emergence of efficient LED fixtures provide new potential for commercial LED fixtures whereas, in the previous study, limited lighting potential existed due to the LED baseline policy.
2. The savings potential from C&S measures represents a significant portion (60-70%) of the potential highlighted in this study.	C&S savings show approximately 2,200 GWh and 35 MMTherms in 2022 and accounts for well over half of EE that eventually feed into the CEC's IEPR forecast. The primary challenge with C&S forecasting is obtaining reliable data; the industry should seek continuous improvement of C&S savings estimates and evaluation practices.
3. The savings potential from BROs programs represents a significant portion of the potential.	This study heavily focuses on rebate programs over the other program types. Despite this focus, BROs has higher first-year savings than all other program types. However, when reviewing TSB results, the scale of BROs impact is much smaller.
4. Adjustments to nonfinancial factors such as consumer awareness and education appear to lead to larger savings potential.	IOUs and program administrators should consider revamping their marketing and outreach efforts to promote the non-economic benefits of energy efficiency in addition to the economic benefits. The Market Adoption Study highlighted that factors such as perceived eco-friendliness impact adoption, in some cases more strongly than economic factors. Findings from the Market Adoption Study are reflected in the modeling analysis for the 2021 Study.
5. Industrial and agriculture sector shows a decreasing sector savings potential trend.	The new Industrial and Agriculture Market Study did uncover additional opportunities for savings by using actual California-based data on high savings potential measures. However, overall sector first-year incremental savings are still forecast to decrease over time due to the market saturation of characterized EE measures.
6. Normalized meter energy consumption policy changes are yet unknown.	The 2021 Study did not model potential based on new program interventions (such as pay-for-performance models). Future potential and goals studies will need to consider any changes to program impacts based on CEDARS and evaluation data.
7. CPUC should develop a single source load shape library to be used consistently across DEER, CET, IRP, potential and goals studies, and CEC IEPR).	Many different tools and studies use consumption and energy efficiency load shapes as a foundation to forecasting and reporting impacts of demand side resources. This study found it challenging to navigate the various existing sources of load shapes and (when multiple options existed) select the appropriate load shape. This is a source of uncertainty in the study's results. A central library of load shapes will provide more certainty in potential and goals study results, as well as cost efficiencies and consistency across multiple CPUC efforts.
8. Fuel substitution policy and implementation is in its nascent stage and requires testing to model its potential more accurately.	The 2021 Study's fuel substitution analysis identified more questions and data needs to appropriately model its potential. These needs include developing fuel substitution-specific load shapes, assessing if long-term natural gas avoided costs are representative of a decarbonized future, and saturation data.

Key Finding	Implication
9. **Based on limited available data and PG Model methodology, the impact of the COVID-19 pandemic on total portfolio savings is expected to be limited.**	Unless further data comes to light, the CPUC goal setting process is not expected to be significantly impacted.

Source: Guidehouse

4.1 Summary

The following set of figures, **Error! Reference source not found.** to Figure 4-3. 2022 Net First-Year Incremental Statewide Demand Savings by Scenario



Note: Fuel substitution is not visible on this graph and does not count toward demand savings claims or goals per the *Fuel Substitution Technical Guidance for Energy Efficiency v1.1* (CPUC, October 2019).
Source: Guidehouse

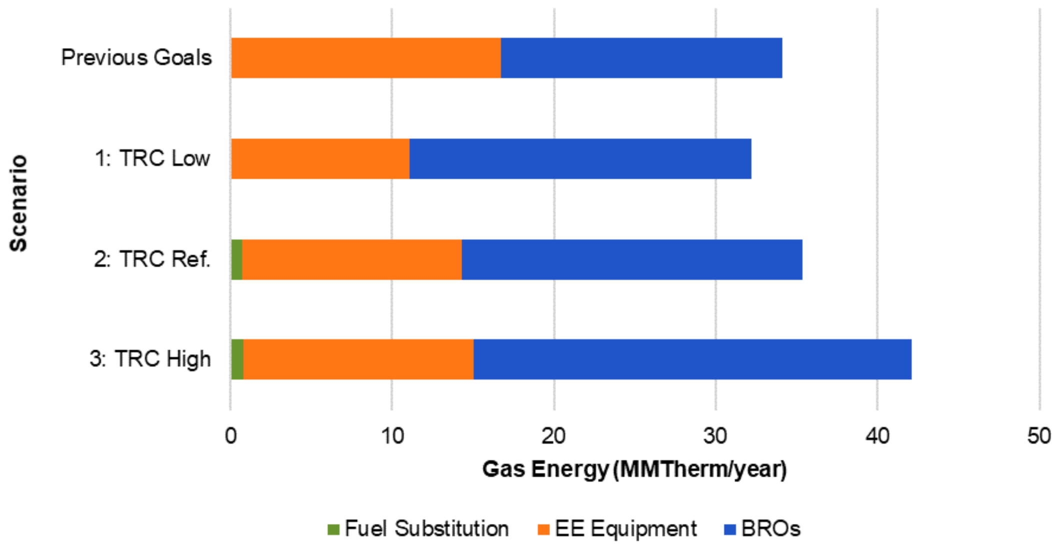
The following are notable takeaways from the demand results:

- Unlike electricity savings, total demand savings in the non-IRP scenarios are larger than previous goals, which is primarily driven by an increase in demand savings from BROs (35%-60% larger than previous goals). BROs savings forecasts are based on recent impact evaluation studies that show increased demand savings than the data available in the 2019 Study.
- While all non-IRP scenarios showed a decrease in EE equipment electricity savings, some scenarios show an increase in EE equipment demand savings. EE equipment demand savings range from a 10% decrease to a 10% increase relative to previous goals. The peak demand savings differential is a result of revised input data for EE equipment showing higher demand savings per unit and the mix of measures adopted in the 2021 Study versus the 2019 Study.
- The IRP (Scenario 4) selected far less EE demand savings than the other scenarios. BROs savings are approximately 10% lower and EE equipment savings are approximately 75% lower than Scenario 2.

- Per CPUC guidance, fuel substitution does not count for or against peak demand savings goals and are, therefore, zero in this study.

Figure 4-4 shows the total 2022 (first-year) gas achievable potential excluding C&S. The figure illustrates the magnitude of achievable potential for each program type (incentive programs, fuel substitution, and BROs) for each of the scenarios listed as well as the 2019 Study scenario that was used by the CPUC to inform previous goals.

Figure 4-4. 2022 Net First-Year Incremental Statewide Gas Savings by Scenario



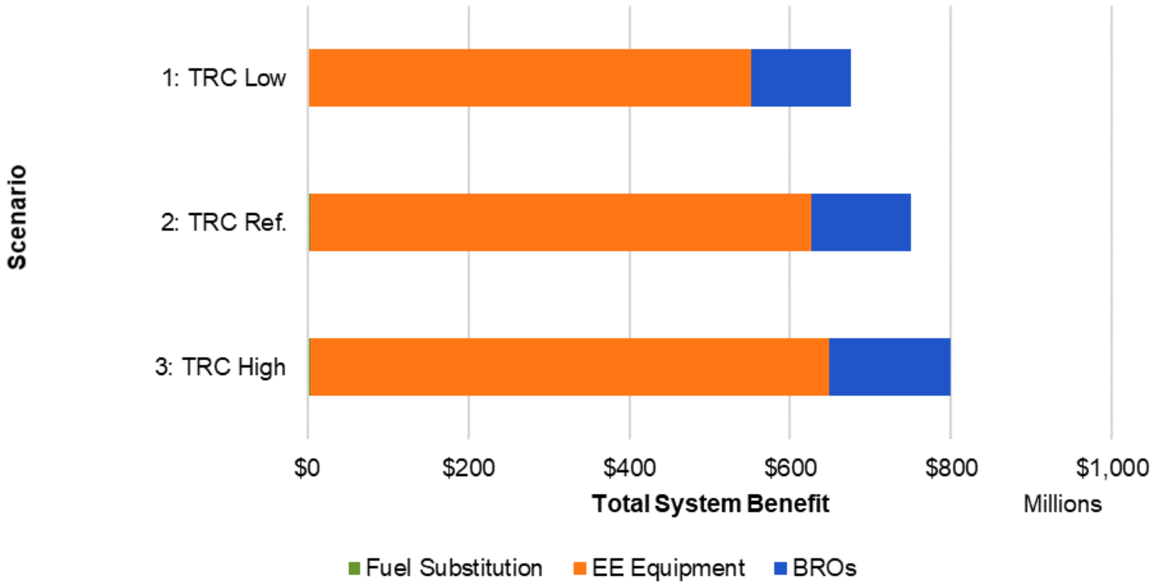
Note: Scenario 4 is not shown in this chart because natural gas savings and usage are not included in the CPUC's IRP model.
Source: Guidehouse

The following are notable takeaways from the gas results:

- The IRP does not model gas resources; therefore, no gas savings are reported for Scenario 4. If electric goals are to be set based on the IRP (Scenario 4), gas goals would need to be informed by a different scenario.
- In all scenarios, first-year savings from incentive programs decrease relative to the previous goals.
- The reduction in savings from EE equipment is counterbalanced by increases in BROs savings. In all scenarios, BROs savings are larger than the previous goals, primarily driven by updates to HERs in the residential sector.
- Fuel substitution savings are minimal in all scenarios. Fuel substitution impacts are reflected as positive gas savings (reduced gas load); these savings are counterbalanced to some extent by the minor amounts of increased electric supply resulting from fuel substitution, shown as negative savings in Figure 4-1. If the CPUC sets goals that allow electric energy savings credits from fuel substitution, the gas fuel substitution savings should be removed from consideration for gas goals.

Figure 4-5 provides the 2022 statewide TSB values by scenario (excluding C&S). The figure illustrates the magnitude of TSB for each program type (EE, fuel substitution, and BROs) for each of the non-IRP scenarios. TSB was not an output of the 2019 Study, so no comparison is shown. The TSB output from Scenario 4 is not comparable to the other scenarios (see additional discussion in Section 5.8).

Figure 4-5. 2022 Statewide Total System Benefit by Scenario

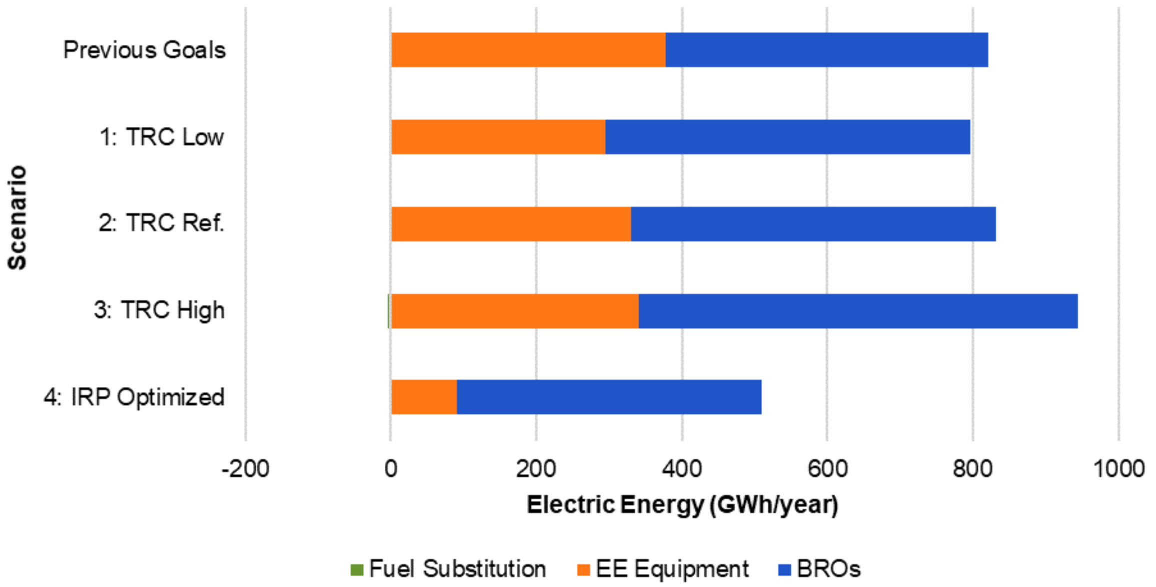


Note: Fuel substitution TSB may not be visible on this graph, but it amounts to approximately 0.5% of the total TSB in Scenarios 2 and 3.

, provide the high level savings for fuel substitution, EE equipment, and BROs programs in 2022. Figure 4-1 to Figure 4-5 also include the IRP Optimized scenario 4 (which does not include any fuel substitution). BROs programs are a key driver of the total savings. The figures show how the BROs programs only change in impacts based on the program engagement level and not by economic screening threshold or incentive levels. However, the impact that BROs have on TSB is limited due to the shorter measure life.

Figure 4-1 shows the total 2022 (first-year) net electric energy achievable potential excluding C&S (C&S is discussed in Section 4.5). The figure illustrates the magnitude of achievable potential for each program type (incentive programs, fuel substitution, and BROs) for each of the four scenarios listed as well as the 2019 Study scenario that was used by the CPUC to inform previous goals.

Figure 4-1. 2022 Net First-Year Incremental Statewide Electric Savings by Scenario



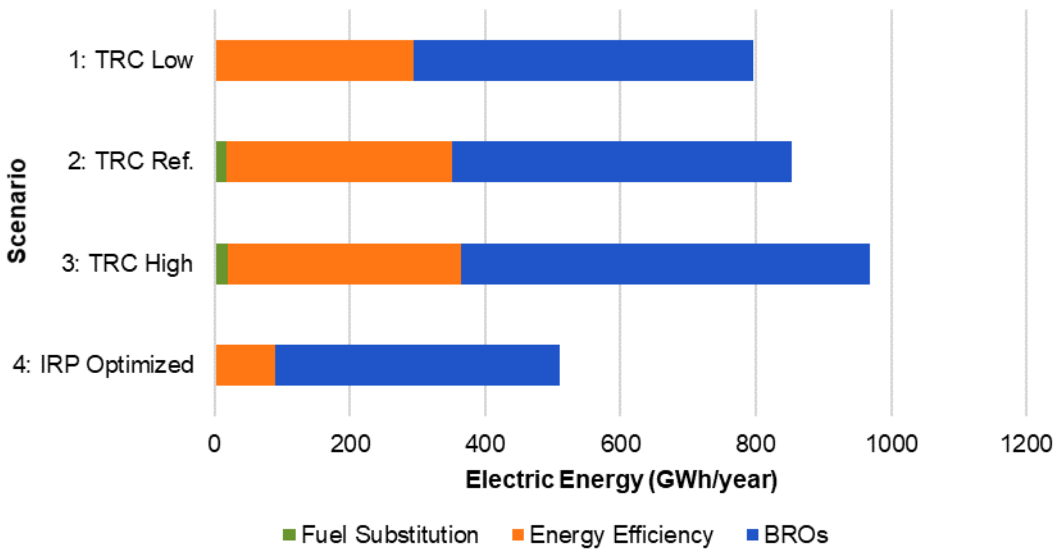
Note: Fuel substitution may not be visible on this graph, but it amounts to approximately an increase of 3.5 GWh of electric consumption in Scenarios 2 and 3.
Source: Guidehouse

The following are notable takeaways from the electric results:

- In all scenarios, savings from EE equipment decrease relative to the previous goals.
- In non-IRP scenarios, the reduction in first-year savings from EE equipment is counterbalanced by increases in BROs savings. In these scenarios, BROs savings are similar to or larger than previous goals, mostly due to updated HERs evaluation reports from the residential sector published by the CPUC; these reports showed higher customer participation rates *than* what was assumed in the 2019 Study.
- The IRP (Scenario 4) has far less EE savings than the other scenarios in 2022 based on the IRP model's selection of optimal bundles. BROs savings are approximately 15% lower, and EE equipment savings are more than 70% lower than Scenario 2. This scenario does not include any gas or fuel substitution savings. If goals were to be set based on this scenario, fuel substitution results would need to be appended using results from other scenarios.
- Fuel substitution's impact on electricity use is minimal in all scenarios. Figure 4-1 shows fuel substitution impacts as negative savings (an increase in electric load); the increased load is balanced (and exceeded) by gas savings from measures shown in Figure 4-4. In Figure 4-1, fuel substitution is barely visible. Figure 4-2 shows an alternate statement of potential where gas savings from fuel substitution are converted into electric energy savings credit in units of kWh.[97] When making this conversion, fuel substitution does visibly register in the results, though it is still small in magnitude. Fuel substitution was not considered in the IRP (Scenario 4).

[97] Uses calculations found in the *Fuel Substitution Technical Guidance Document v.1.1*, https://www.cpuc.ca.gov/General.aspx?id=6442463306.

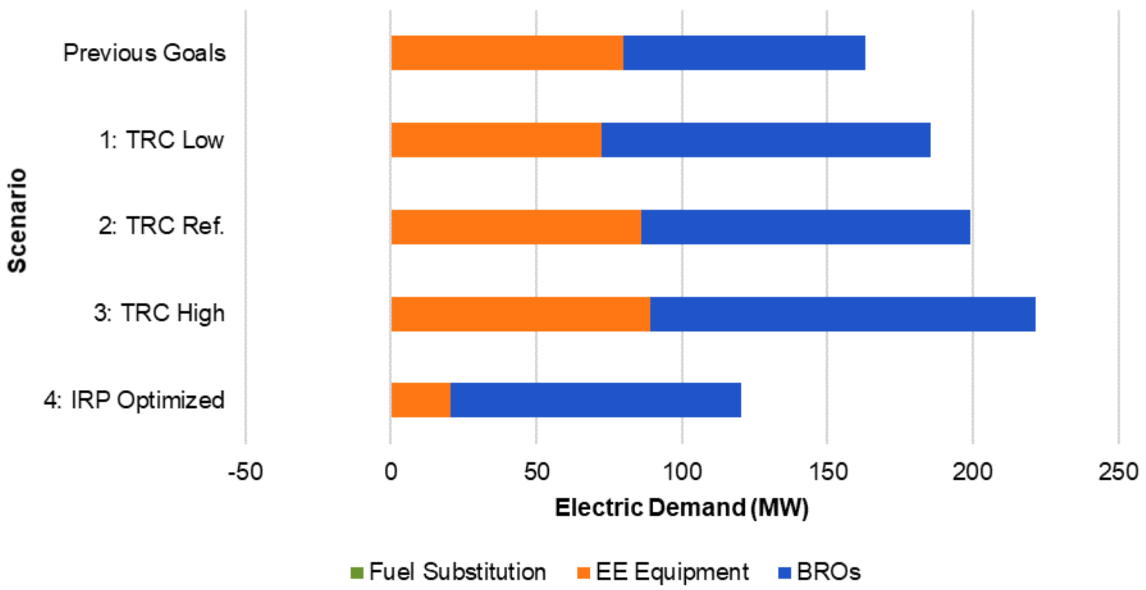
Figure 4-2. 2022 Net First-Year Incremental Statewide Electric Savings by Scenario (Fuel Substitution Converted)



Source: Guidehouse

Figure 4-3 shows the total 2022 (first-year) net demand achievable potential excluding C&S. The figure illustrates the magnitude of achievable potential for each program type (incentive programs, fuel substitution, and BROs) for each of the scenarios as well as the 2019 Study scenario that was used by the CPUC to inform previous goals.

Figure 4-3. 2022 Net First-Year Incremental Statewide Demand Savings by Scenario



Note: Fuel substitution is not visible on this graph and does not count toward demand savings claims or goals per the *Fuel Substitution Technical Guidance for Energy Efficiency v1.1* (CPUC, October 2019).
Source: Guidehouse

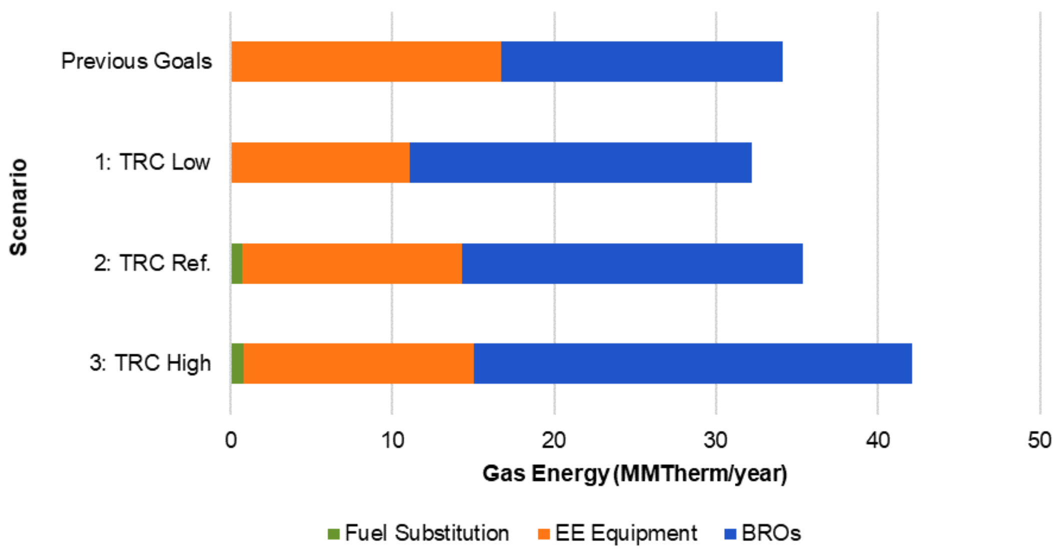
The following are notable takeaways from the demand results:

- Unlike electricity savings, total demand savings in the non-IRP scenarios are larger than previous goals, which is primarily driven by an increase in demand savings from BROs (35%-60% larger than previous goals). BROs savings forecasts are based on recent impact evaluation studies that show increased demand savings than the data available in the 2019 Study.

- While all non-IRP scenarios showed a decrease in EE equipment electricity savings, some scenarios show an increase in EE equipment demand savings. EE equipment demand savings range from a 10% decrease to a 10% increase relative to previous goals. The peak demand savings differential is a result of revised input data for EE equipment showing higher demand savings per unit and the mix of measures adopted in the 2021 Study versus the 2019 Study.
- The IRP (Scenario 4) selected far less EE demand savings than the other scenarios. BROs savings are approximately 10% lower and EE equipment savings are approximately 75% lower than Scenario 2.
- Per CPUC guidance, fuel substitution does not count for or against peak demand savings goals and are, therefore, zero in this study.[98]

Figure 4-4 shows the total 2022 (first-year) gas achievable potential excluding C&S. The figure illustrates the magnitude of achievable potential for each program type (incentive programs, fuel substitution, and BROs) for each of the scenarios listed as well as the 2019 Study scenario that was used by the CPUC to inform previous goals.

Figure 4-4. 2022 Net First-Year Incremental Statewide Gas Savings by Scenario



Note: Scenario 4 is not shown in this chart because natural gas savings and usage are not included in the CPUC's IRP model.
Source: Guidehouse

The following are notable takeaways from the gas results:

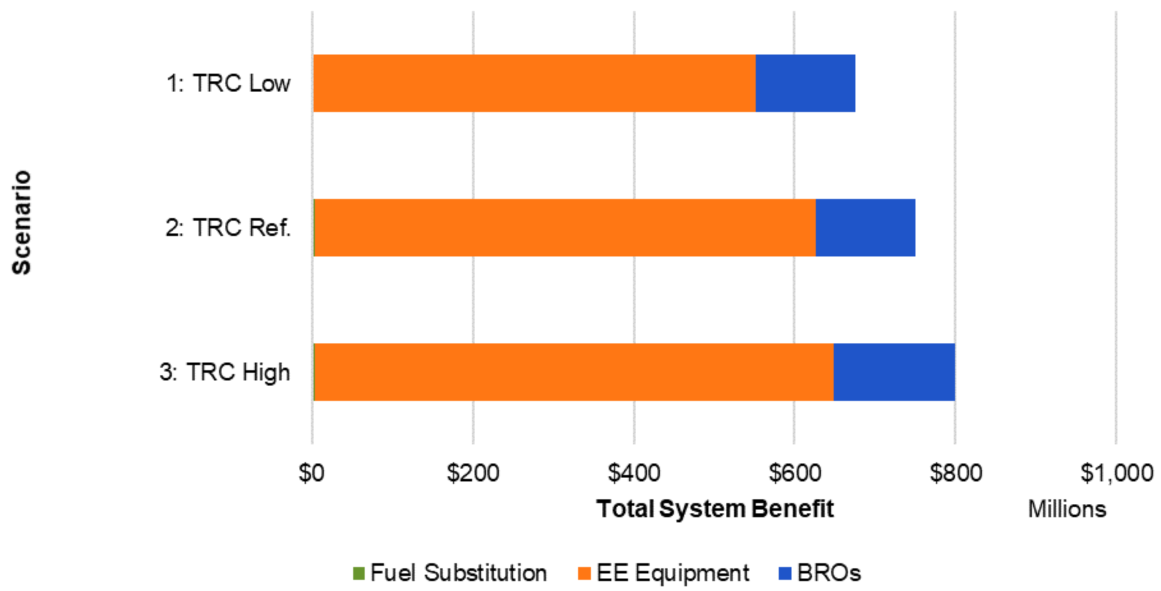
- The IRP does not model gas resources; therefore, no gas savings are reported for Scenario 4. If electric goals are to be set based on the IRP (Scenario 4), gas goals would need to be informed by a different scenario.
- In all scenarios, first-year savings from incentive programs decrease relative to the previous goals.

[98] California Public Utilities Commission (CPUC), Energy Division. 2019. *Fuel Substitution Technical Guidance, Version 1.1*. October 31. 2019

- The reduction in savings from EE equipment is counterbalanced by increases in BROs savings. In all scenarios, BROs savings are larger than the previous goals, primarily driven by updates to HERs in the residential sector.
- Fuel substitution savings are minimal in all scenarios. Fuel substitution impacts are reflected as positive gas savings (reduced gas load); these savings are counterbalanced to some extent by the minor amounts of increased electric supply resulting from fuel substitution, shown as negative savings in Figure 4-1. If the CPUC sets goals that allow electric energy savings credits from fuel substitution, the gas fuel substitution savings should be removed from consideration for gas goals.

Figure 4-5 provides the 2022 statewide TSB values by scenario (excluding C&S). The figure illustrates the magnitude of TSB for each program type (EE, fuel substitution, and BROs) for each of the non-IRP scenarios. TSB was not an output of the 2019 Study, so no comparison is shown. The TSB output from Scenario 4 is not comparable to the other scenarios (see additional discussion in Section 5.8).

Figure 4-5. 2022 Statewide Total System Benefit by Scenario



Note: Fuel substitution TSB may not be visible on this graph, but it amounts to approximately 0.5% of the total TSB in Scenarios 2 and 3.

Source: Guidehouse

The following are notable takeaways from the gas results:

- As opposed to Figure 4-1 and Figure 4-4, BROs amount to a much smaller proportion of TSB due to the short EUL of BROs savings relative to EE equipment. TSB represents the benefits that accrue over the life of the intervention; because EE equipment tends to have a long useful life, it is the key driver for TSB.
- Fuel substitution seems to have a negligible impact on TSB. Although fuel substitution has seemingly small savings in Scenarios 2 and 3, its contribution to TSB is even smaller as a proportion of the whole because positive benefits due to reduced gas consumption are largely offset by increased electric supply cost (which negatively impacts TSB).

4.2 Incentive and BROs Program Savings

The following subsections summarize statewide achievable potential results. These results are for all IOUs combined. The IOU breakdown for these savings can be found in the results viewer that accompanies this report (see Section 4.7 for details). All results are presented as net savings. All results are inclusive of interactive effects[99] and include fuel substitution in the form of positive gas savings and negative electric savings. The purpose of this report is to present the findings of the Guidehouse team's 2021 Study and not to establish goals—goal setting is under the purview of the CPUC. As such, the scenario comparisons presented in the following subsections are meant to illustrate a range of potential that can be achieved based on the team's study.

Figures in this section focus on electric, peak demand, and gas savings. Full results for all scenarios and all utilities are available in the results viewer (discussed further in Section 4.7).

The Guidehouse team also analyzed impacts of the COVID-19 pandemic on the California economy, as described in Section 2.3.2. Appendix K provides outputs of the three core scenarios (TRC Low, TRC Reference, and TRC High) with COVID sensitivities. The data provides the change in overall program savings potential (EE, fuel substitution, and BROs). The impact is, at most, about a 2% decrease in potential in 2022 depending on the metric.

4.2.1 Total Savings and Spending by Scenario

This section describes the total incremental achievable potential and costs from all savings sources by scenario. A few important notes about these results:

- Equipment rebate program savings, which include savings from discrete equipment, whole building, and shell measures, are different for each scenario based on parameters discussed in Section 2.3. Section 4.2 provides additional discussion of the variation in rebate program savings by scenario.
- BROs savings vary only in terms of reference versus aggressive. BROs savings only have these two possible forecasts across the scenarios. Section 4.2 provides additional discussion of the variation in BROs savings by scenario. BROs residential savings includes the low income sector.
- C&S savings do not vary by scenario and are not presented in these three figures.

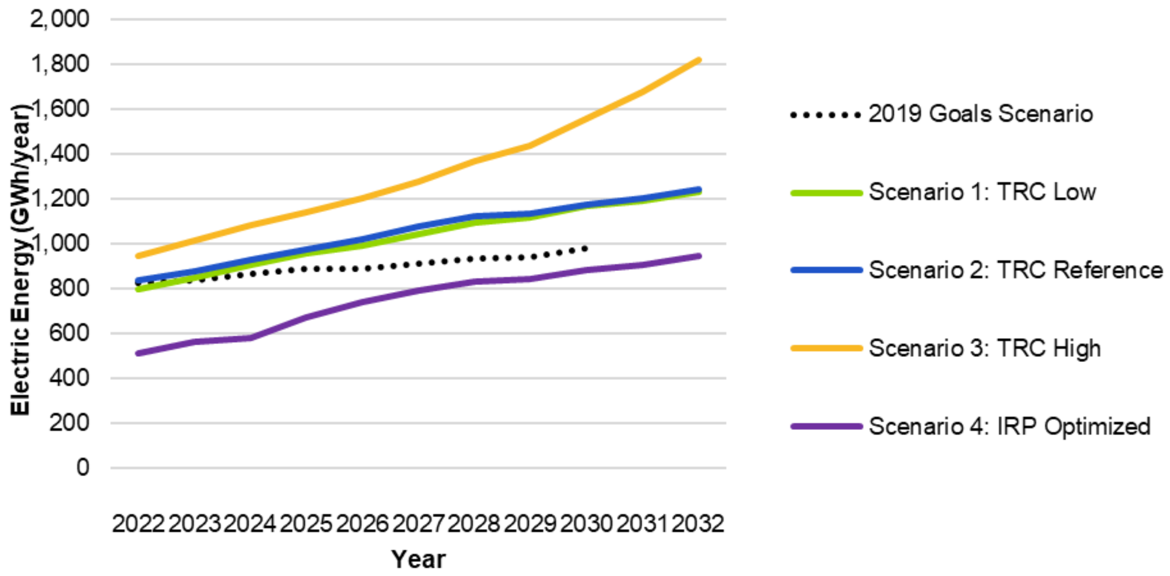
True variability in savings originates from equipment rebate programs and BROs.

Appendix K contains versions of the results in tabular format for each IOU.

The following set of figures, Figure 4-6 to Figure 4-8, provide the top line savings by scenario for the 2022-2032 forecast period. Figure 4-6 shows the 11-year forecast for first-year net electric achievable potential for EE equipment, fuel substitution, and BROs combined. After the first few years, all non-IRP scenarios tend to separate from the previous goals and increase over time. The larger increase in Scenario 3 is due to aggressive assumptions about BROs programs.

[99] Interactive effects are the unintended consequence of increasing a fuel's consumption due to a reduction in energy use. For example, efficient lighting results in reduced internal heat gain, resulting in a higher need for space heating.

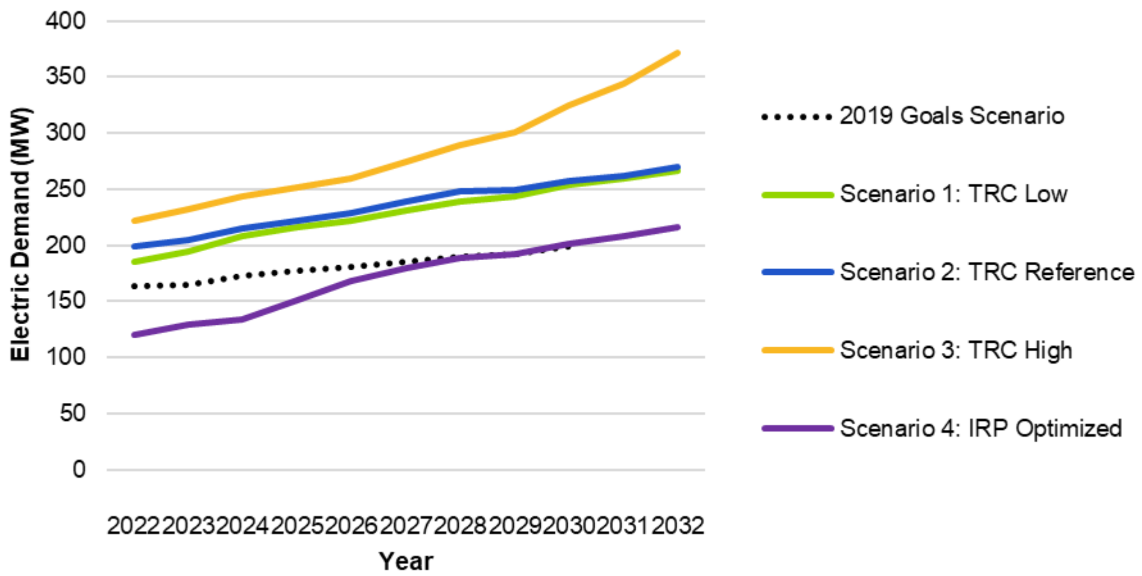
Figure 4-6. Statewide Net First-Year Incremental Electric Savings by Scenario



Source: Guidehouse

Figure 4-7 shows the 11-year forecast for first-year net demand achievable potential for EE equipment, fuel substitution, and BROs combined. The larger increase in Scenario 3 is due to aggressive assumptions for the BROs programs. EE equipment first-year demand savings are generally higher for the 2021 Study scenarios relative to previous goals. The IRP scenario near the end of forecast period increases to exceed the 2019 Study goal. This increase possible as a result of revised input data for EE equipment showing higher demand savings per unit and the mix of measures adopted in the 2021 Study versus the 2019 Study.

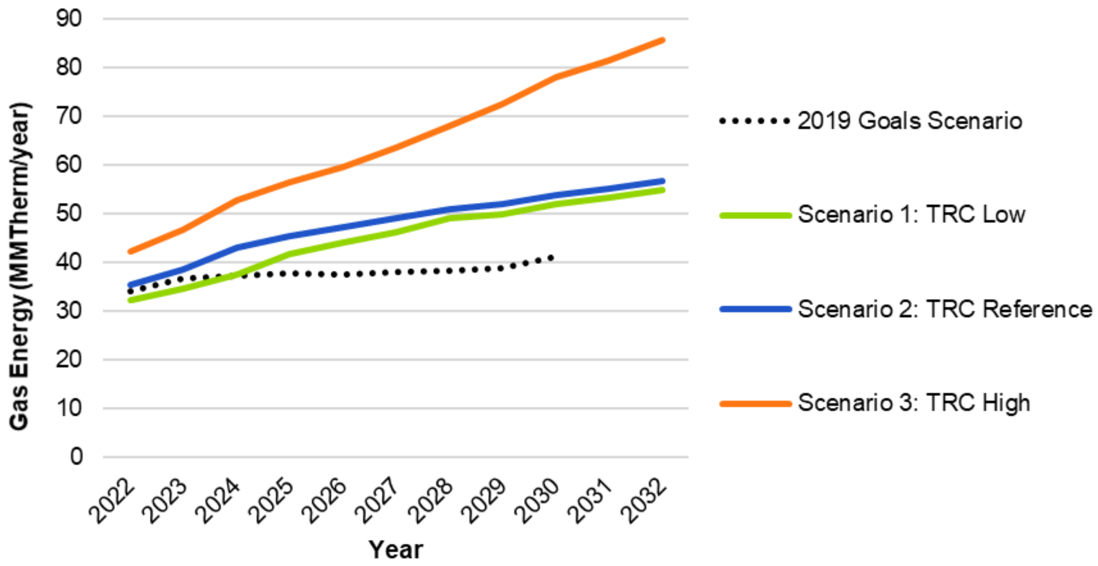
Figure 4-7. Statewide Net First-Year Incremental Demand Savings by Scenario



Source: Guidehouse

Figure 4-8 shows the 11-year forecast for first-year net gas achievable potential for EE equipment, fuel substitution, and BROs combined. Scenario 4 is not displayed because the IRP only considers electric savings. After the first few years all scenarios tend to separate from the previous goals and increase over time. The larger increase in Scenario 3 is due to aggressive assumptions about BROs programs.

Figure 4-8. Statewide Net First-Year Incremental Gas Savings by Scenario



Source: Guidehouse

Differences across the scenarios for all savings types are driven by the TRC and the aggressiveness of program engagement.

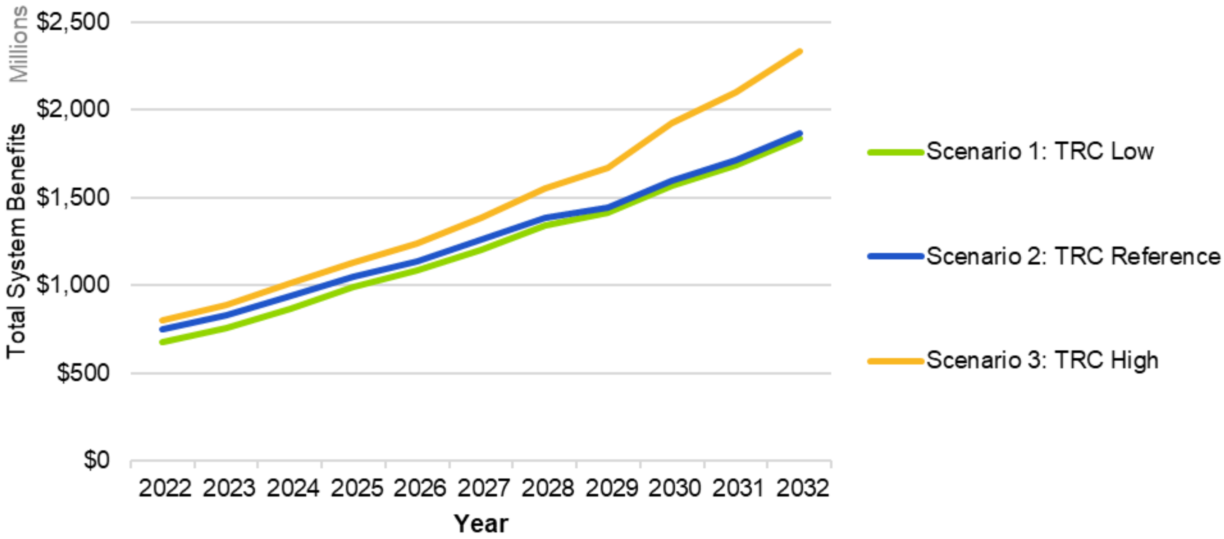
- Scenario 1 with a TRC of 1.0 and Scenario 2 with a TRC of 0.85 have little difference in their savings potential. These two scenarios are at the reference level of program intervention.
- The trends to increase savings are driven in Scenario 3 by changing to aggressive program engagement (increased marketing and program interventions modeled by increasing incentives and higher levels of BROs program rollout).

The differences in program engagement are two-fold:

- **Program marketing and delivery.** The model parameters are adjusted to increase marketing awareness and marketing effectiveness. Increased program spending comes with program aggressiveness. The increase is reflected by an increase in incentives, which also change certain characteristics in the multi-attribute adoption algorithm by changing the equipment financial attractiveness. Figure 4-11 provides data on program spending by scenario.
- **BROs program rollout.** BROs rollout has two levels:
    - **Reference:** Includes BROs programs found to be cost-effective in the 2019 Study, which screened programs using the TRC test and the latest CPUC-approved avoided costs for each utility. The reference level is used in Scenario 1 and Scenario 2.
    - **Aggressive:** Includes all BROs programs considered in this study regardless of cost-effectiveness. The penetration forecasts for each program are also more aggressive compared to the reference case. The aggressive level is used in Scenario 3.

Figure 4-9 shows the 2022 TSB excluding C&S. The figure illustrates the magnitude of TSB for each program type (EE, fuel substitution, and BROs) for each of the scenarios. TSB was not an output of the 2019 Study, so no comparison is shown. The TSB tracks with the savings. This metric captures the total system benefit of the avoided costs saved by the utilities. TSB output from Scenario 4 is not comparable to the other scenarios (see additional discussion in Section 5.8).

Figure 4-9. Statewide Total System Benefit ($ Millions) by Scenario



Note: Graph does not include Scenario 4: Optimized IRP because this scenario does not include gas or fuel substitution, resulting in lower TSB levels when limited to electric and demand savings.

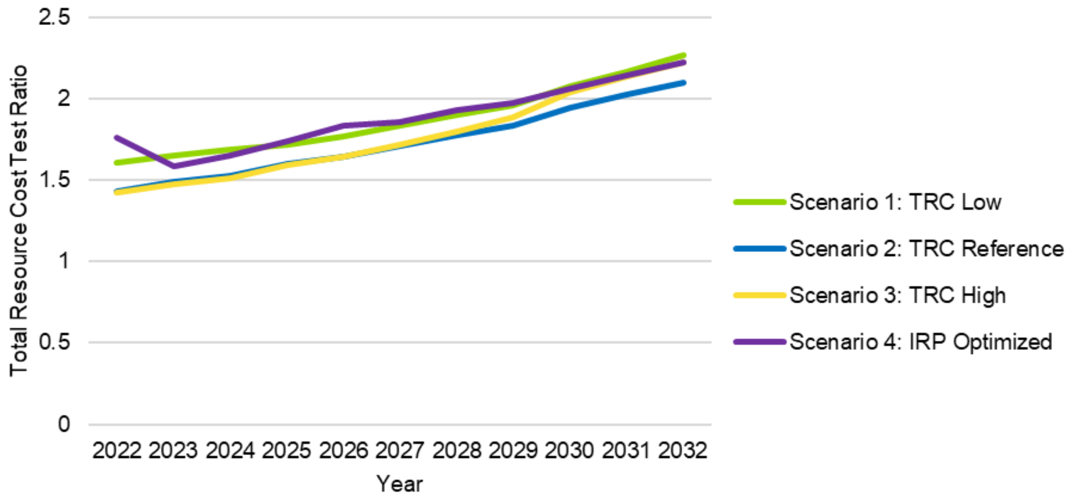
Source: Guidehouse

The TSB forecast appears smoother than the first-year savings forecasts because TSB is a lifecycle benefit calculation across all savings. Longer life measures have high lifecycle benefits resulting in high TSB. Most of the increases in TSB over time is related to the trend of the avoided cost increases over time.

Figure 4-10 provides the TRC ratio for all scenarios.

- These results account for benefits and costs from rebated measures that contribute to equipment savings but exclude low income and C&S savings.
- Results exclude non-resource program costs, which are typically accounted for in a portfolio-level cost-effectiveness assessment.

Figure 4-10. TRC Test Benefit to Cost Ratio by Scenario

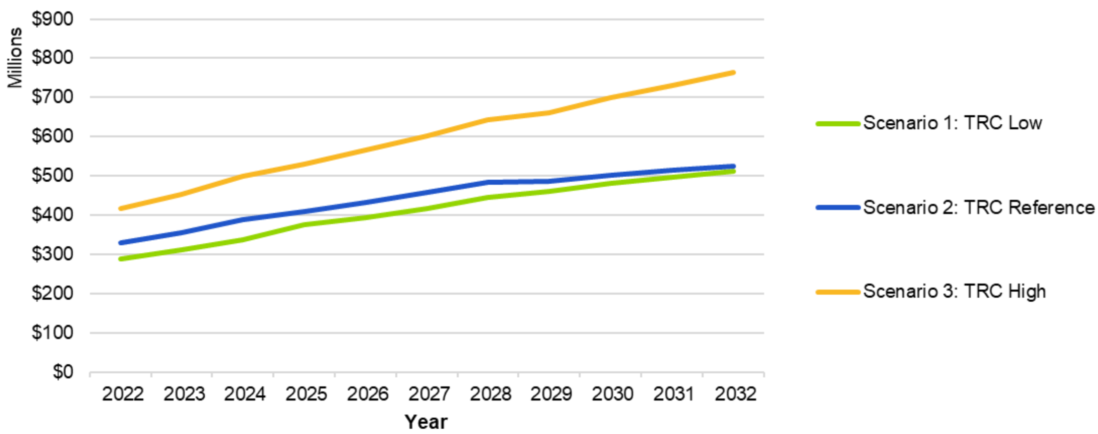


Source: Guidehouse

The TRC ratio for all scenarios (except for Scenarios 1 and 4) starts below 1.5 even for the two 0.85 scenarios. This result tracks the 2019 Study results trends. Scenario 3 is higher than Scenario 2 in the later years, mostly due to the growth in BROs program penetration over the study period. BROs programs tend to have a higher TRC than the EE equipment. The TRC is highest for the IRP Optimized scenario because the IRP model selects the lowest cost measure bundles on the supply curve and BROs programs.

Figure 4-11 shows projected statewide spending for rebate programs and BROs programs by scenario. Spending includes incentive and non-incentive resource program costs. Scenario 3 produces the most expensive portfolio for equipment savings due to the increase in incentives (as a percentage of measure costs) and Scenario 1, the least. Scenario 2 requires slightly more budget than the least expensive portfolio but produces proportionally more savings because Scenario 2 allows a lower TRC, which implies higher measure costs than Scenario 1. Spending output from Scenario 4 is not comparable to the other scenarios (see additional discussion in Section 5.8).

Figure 4-11. Statewide Spending by Scenario for IOU Incentive and BROs Programs ($ Millions)



Note: Graph does not include Scenario 4: Optimized IRP because this scenario does not include gas or fuel substitution, resulting in lower spending levels when limited to electric and demand savings.
Source: Guidehouse

4.2.2 Total Savings and Spending by Sector and Program Type

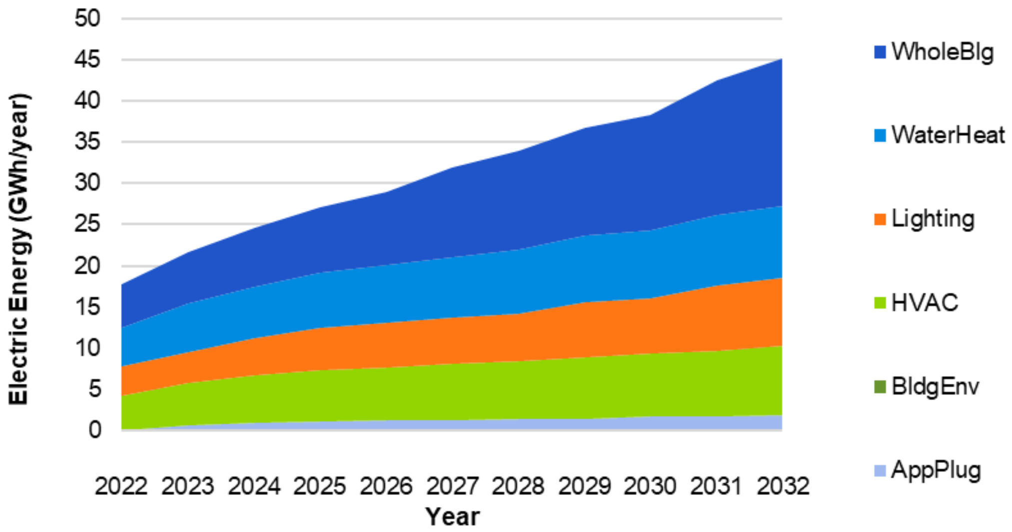
This section shows a set of figures for the three non-IRP scenarios, focusing on the savings across sectors and end uses. The figures primarily show the impact of differences across levers for the three scenarios:

- Changes in TRC threshold:
  - Scenario 1 at 1.0
  - Scenario 2 at 0.85
- Capped incentives, program engagement level, and financing:
  - Scenario 2
    - Incentives capped 50% of measure cost
    - Reference levels of program engagement
    - No utility EE program financing
  - Scenario 3
    - Incentives capped 75% of measure cost
    - Aggressive levels of program engagement
    - Includes utility EE financing programs

Figure 4-12 to Figure 4-37 provide the stacked area end-use graphs by sector and fuel and only include EE equipment and fuel substitution equipment (BROs are excluded). There are negative gas savings due to interactive effects from lighting measures, which reduces the overall net gas potential in the residential and commercial sectors across all scenarios. There is also negative electric savings due to fuel substitution and some building envelope measures (for example, floor insulation). The subsequent measure in the stack with savings overlaps with the negative savings.

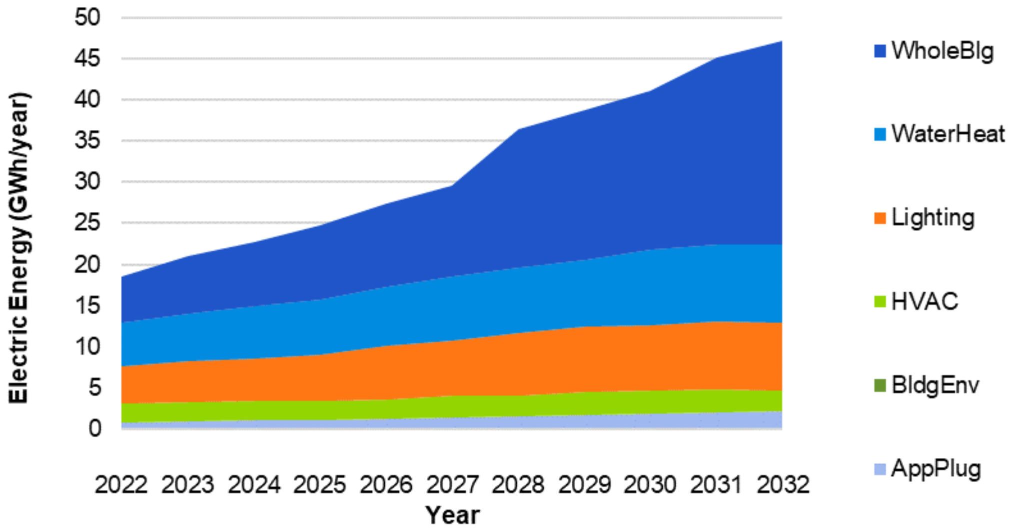
Figure 4-12 through Figure 4-14 show the residential rebate program electric savings. Whole building is the key driver for residential sector savings across all the three scenarios. The whole building savings for residential are mostly from exceeding building code in new construction homes. Because fuel substitution is adopted at 0.85 TRC (reference and high scenarios) and not 1.0 TRC (low scenario), a decrease is visible in the HVAC savings from Scenario 1 at 1.0 TRC threshold as compared to the other two scenarios. Additionally, the change in the TRC threshold allows for an increase in water heating and appliance/plug load measures to be included in the achievable potential in Scenario 2 and Scenario 3 as compared to Scenario 1.

Figure 4-12. Residential Rebate Program First-Year Electric Energy Savings by End Use (Scenario 1:TRC Low)



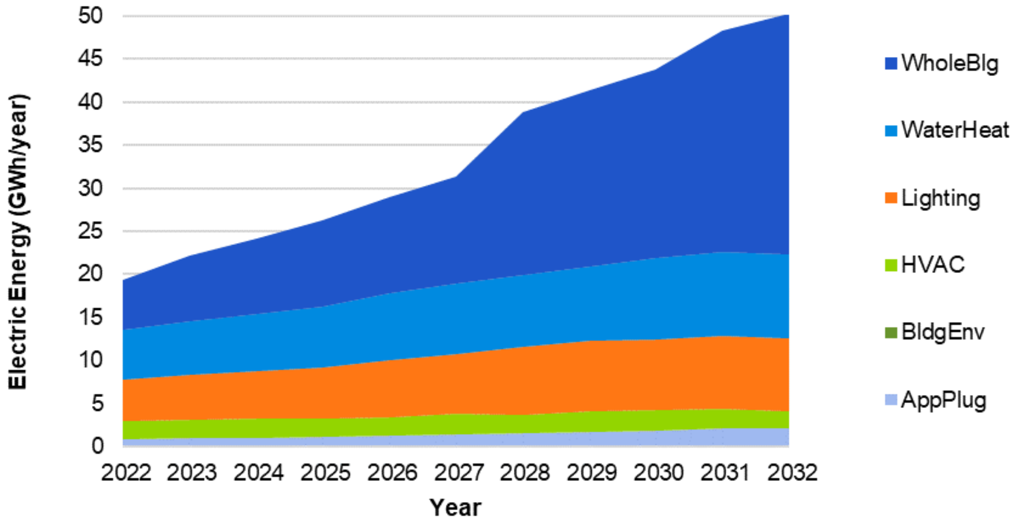
Source: Guidehouse

Figure 4-13. Residential Rebate Program First-Year Electric Energy Savings by End Use (Scenario 2: TRC Reference)



Source: Guidehouse

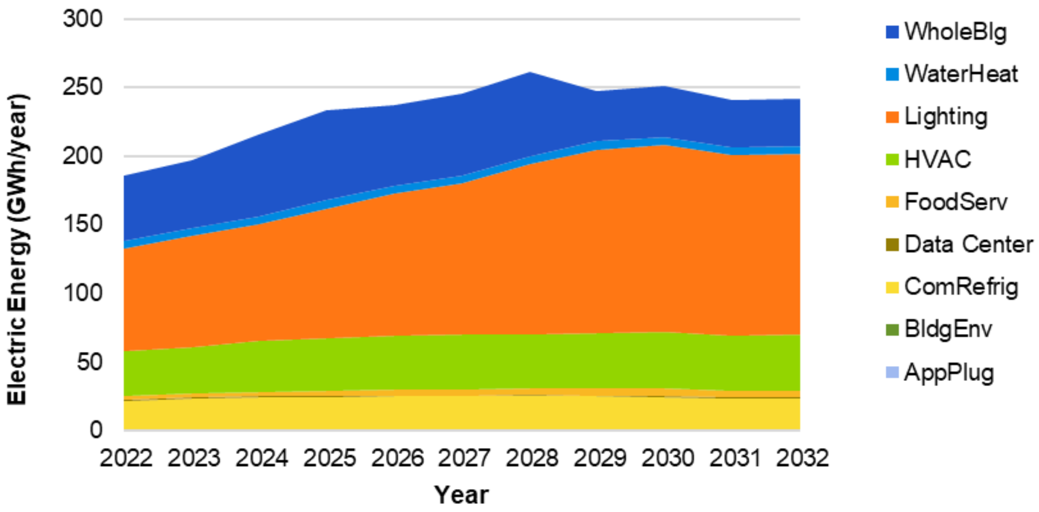
Figure 4-14. Residential Rebate Program First-Year Electric Energy Savings by End Use (Scenario 3: TRC High)



Source: Guidehouse

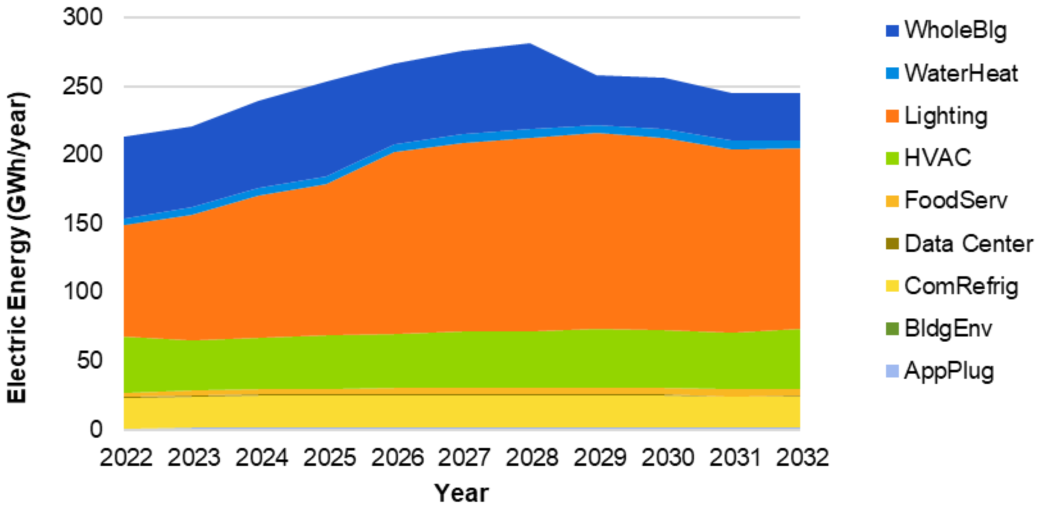
Figure 4-15 through Figure 4-17 show the commercial rebate program electric savings. The change in TRC threshold between Scenario 1 and Scenario 2 and Scenario 3 affects most end uses. The change in TRC threshold increased savings for the commercial sector 10% from Scenario 1 to Scenario 2. Changing the incentive cap and program engagement changed savings for most end uses and about 5% from Scenario 2 to Scenario 3. Commercial lighting and whole building are large contributors for the commercial sector across all scenarios. The whole building savings decreases seen in years 2023, 2026, and 2029 are adjustments made to a shifting baseline due to Title 24 code updates (see Table 3-27).

Figure 4-15. Commercial Rebate Program First-Year Electric Energy Savings by End Use (Scenario 1: TRC Low)



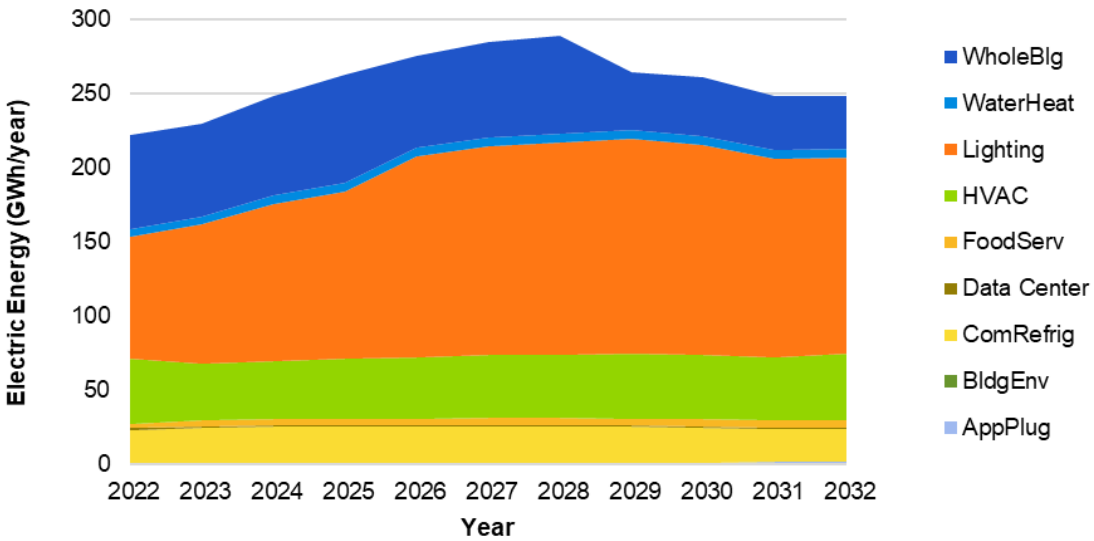
Source: Guidehouse

Figure 4-16. Commercial Rebate Program First-Year Electric Energy Savings by End Use (Scenario 2: TRC Reference)



Source: Guidehouse

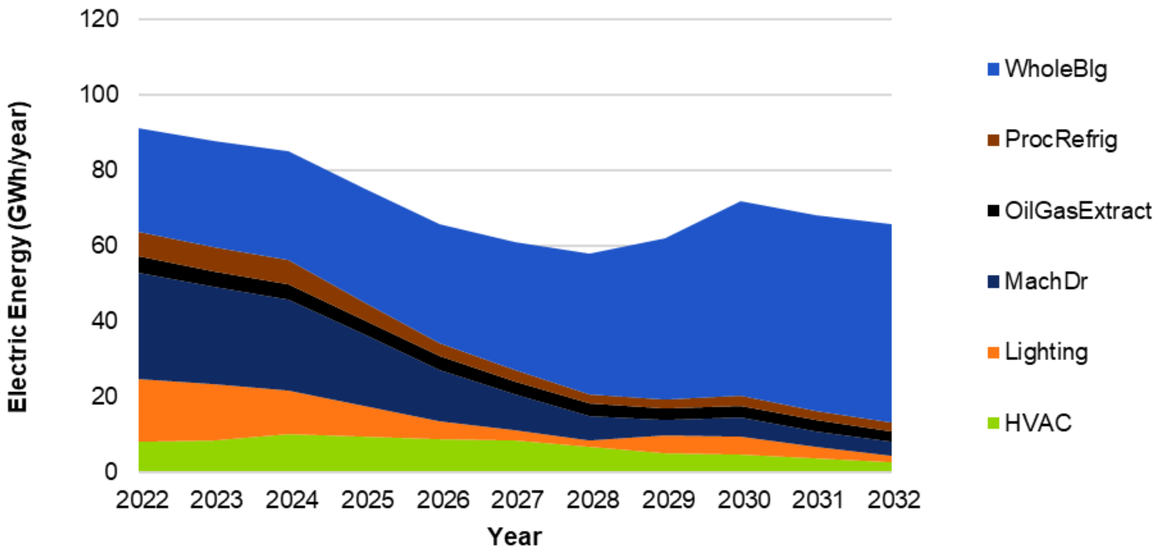
Figure 4-17. Commercial Rebate Program First-Year Electric Energy Savings by End Use (Scenario 3: TRC High)



Source: Guidehouse

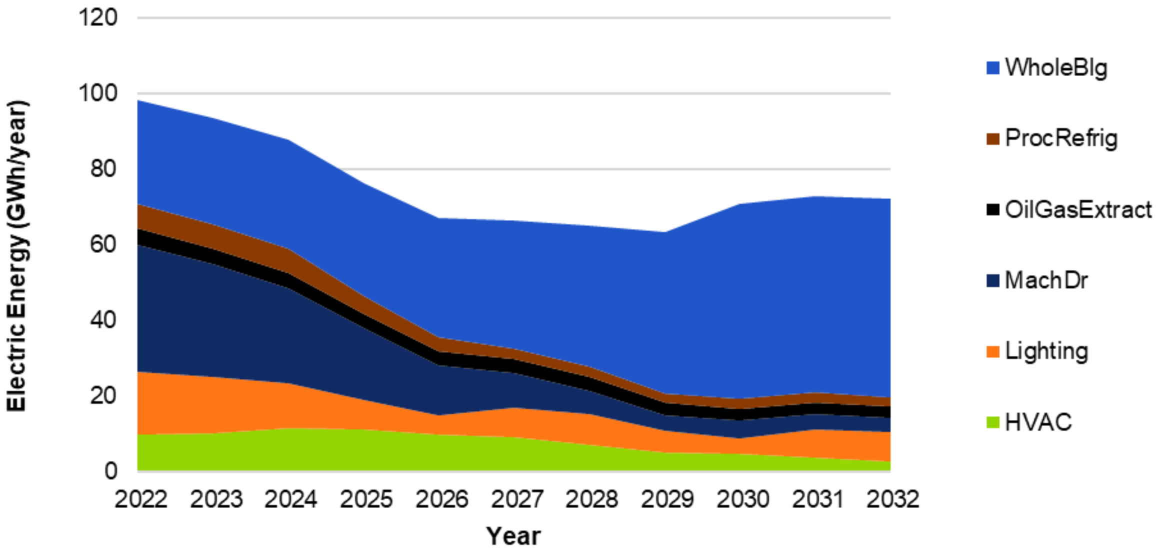
Figure 4-18 through Figure 4-20 show electric savings for the AIM sectors. Whole building is the largest contributor, and these savings are from generic custom and emerging technologies (see Section 3.8.1). There is a ramp up in whole building savings, especially for aggressive program-level engagement in Scenario 3, due to the increase in emerging technology penetration over time that levels off in 2031 and 2032. Savings decrease over time in other end uses due to the market saturation of characterized EE measures. Of these other end uses, HVAC and machine drive have higher savings attributed to a lower economic screening exhibited in the differences between Scenario 1 and Scenario 2.

Figure 4-18. AIM Rebate Program First-Year Electric Energy Savings by End Use (Scenario 1: TRC Low)



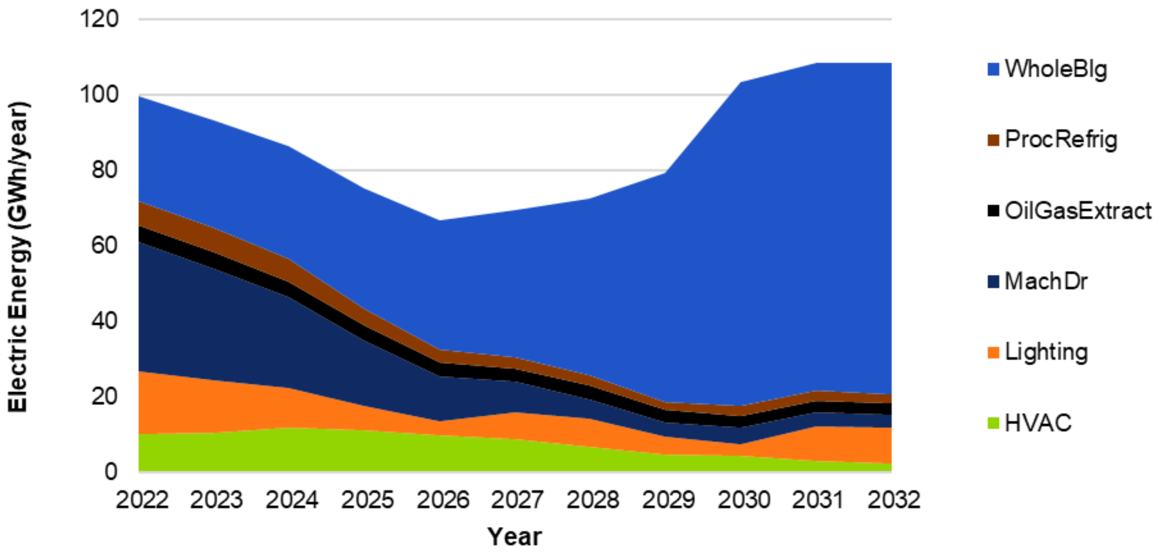
Source: Guidehouse

Figure 4-19. AIM Rebate Program First-Year Electric Energy Savings by End Use (Scenario 2: TRC Reference)



Source: Guidehouse

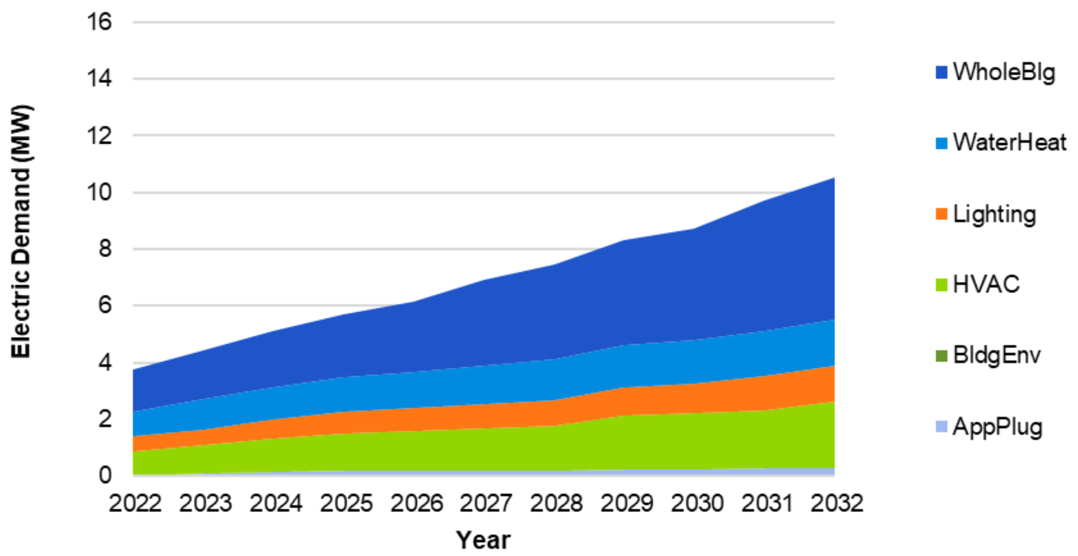
Figure 4-20. AIM Rebate Program First-Year Electric Energy Savings by End Use (Scenario 3: TRC High)



Source: Guidehouse

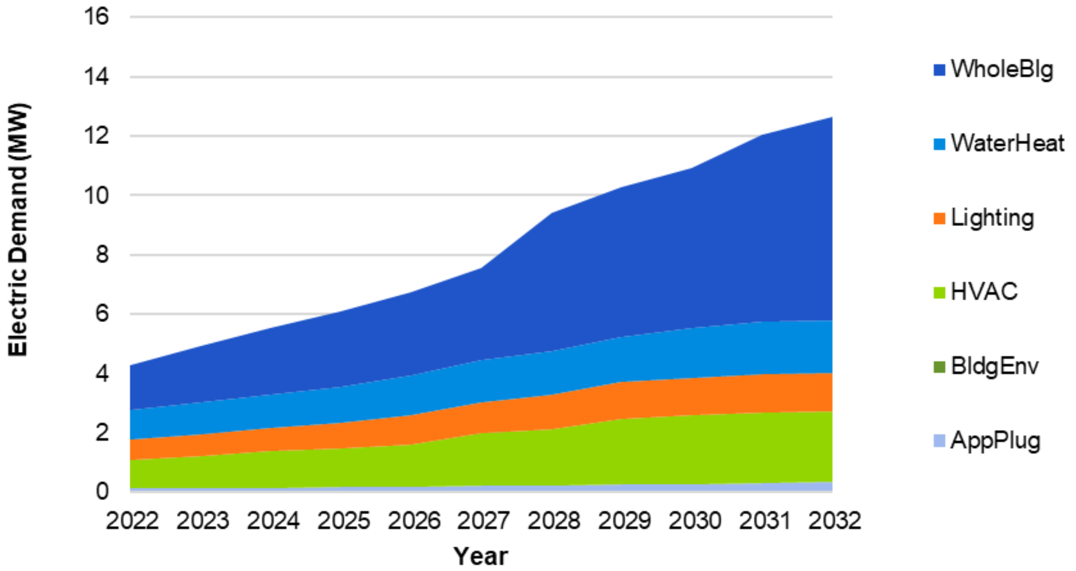
Similar trends for electric savings are observed for peak demand savings, as Figure 4-21 to Figure 4-29 show.

Figure 4-21. Residential Rebate Program First-Year Peak Demand Savings by End Use (Scenario 1: TRC Low)



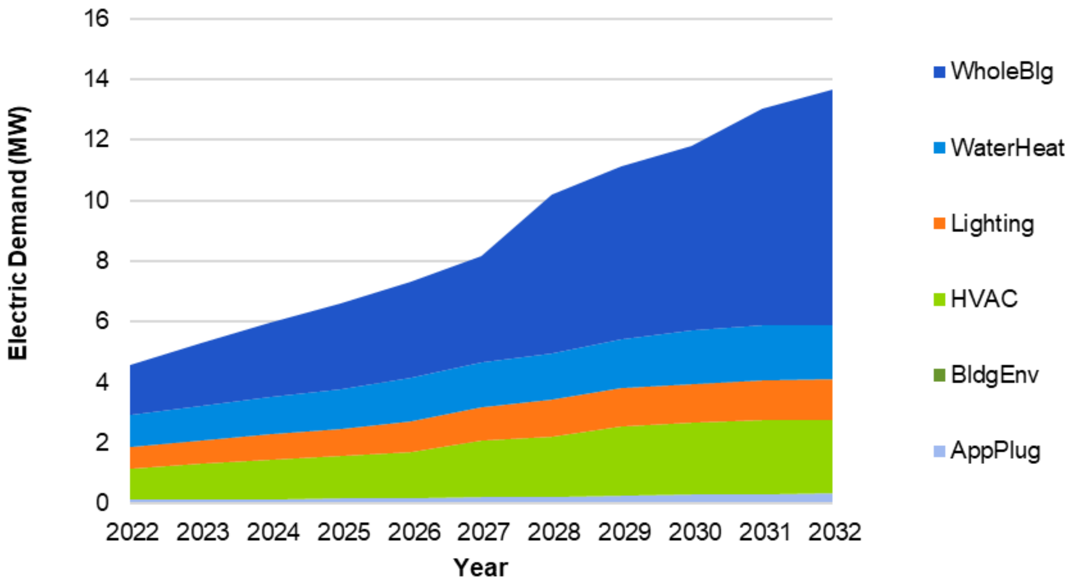
Source: Guidehouse

Figure 4-22. Residential Rebate Program First-Year Peak Demand Savings by End Use (Scenario 2: TRC Reference)



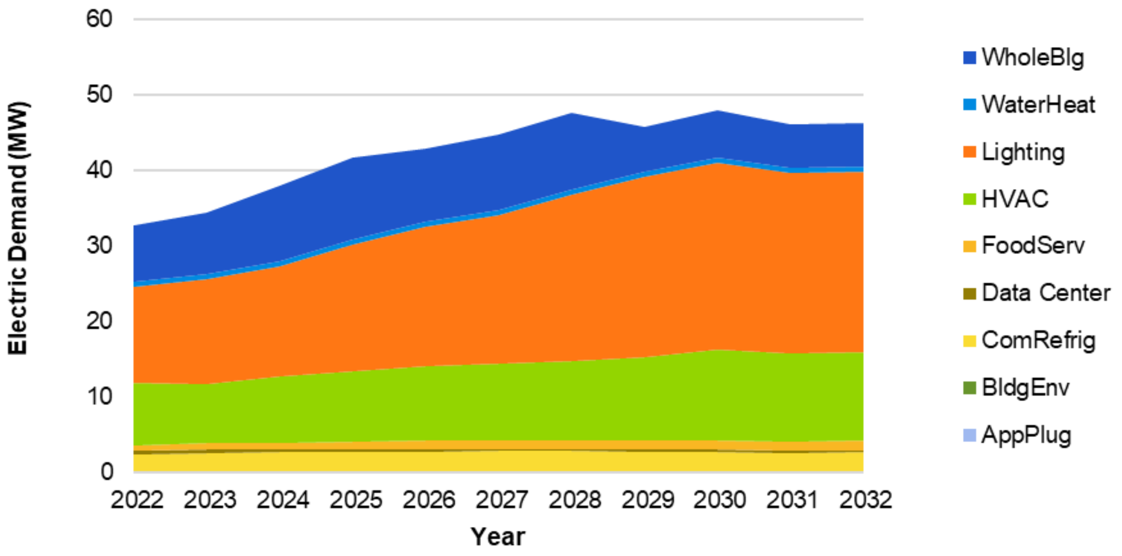
Source: Guidehouse

Figure 4-23. Residential Rebate Program First-Year Peak Demand Savings by End Use (Scenario 3: TRC High)



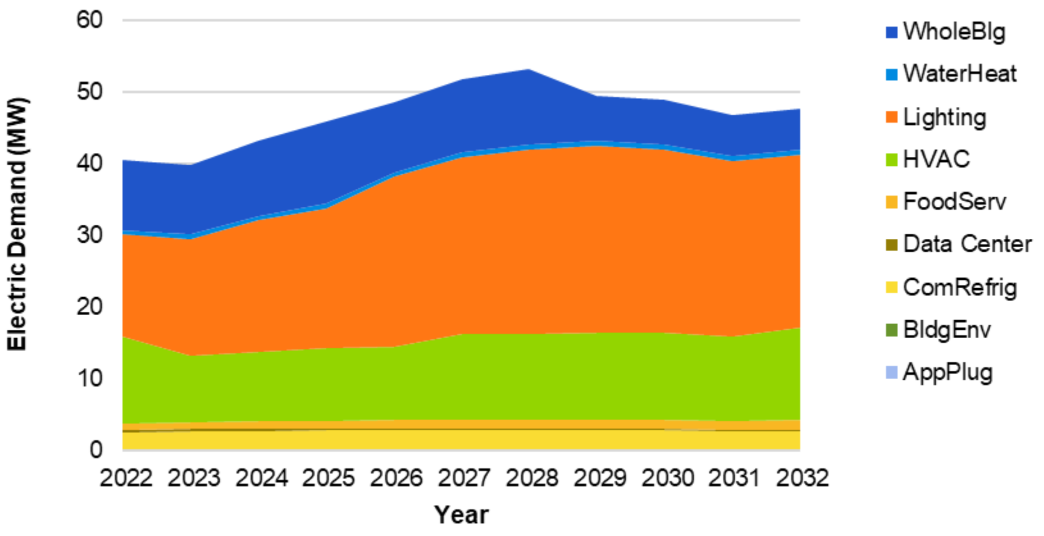
Source: Guidehouse

Figure 4-24. Commercial Rebate Program First-Year Peak Demand Savings by End Use (Scenario 1: TRC Low)



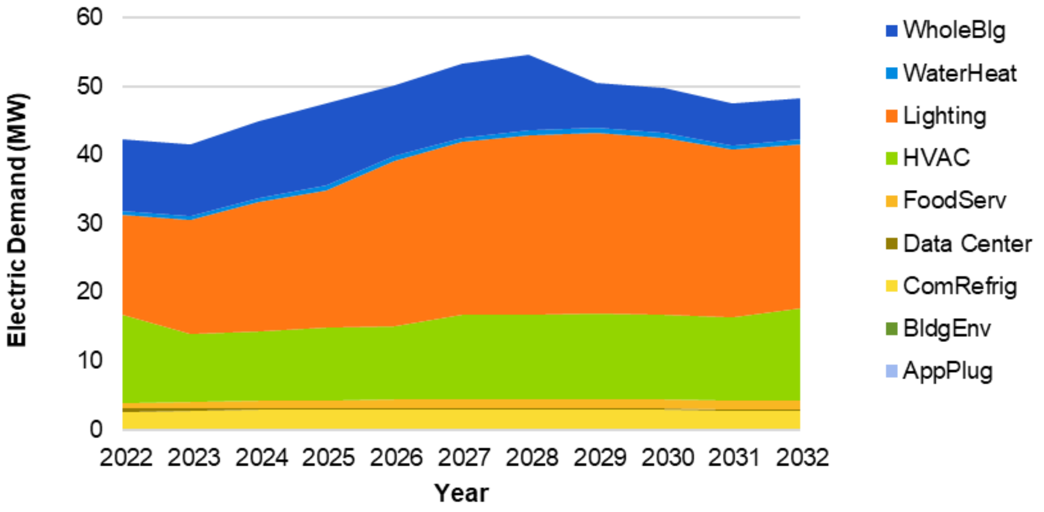
Source: Guidehouse

Figure 4-25. Commercial Rebate Program First-Year Peak Demand Savings by End Use (Scenario 2: TRC Reference)



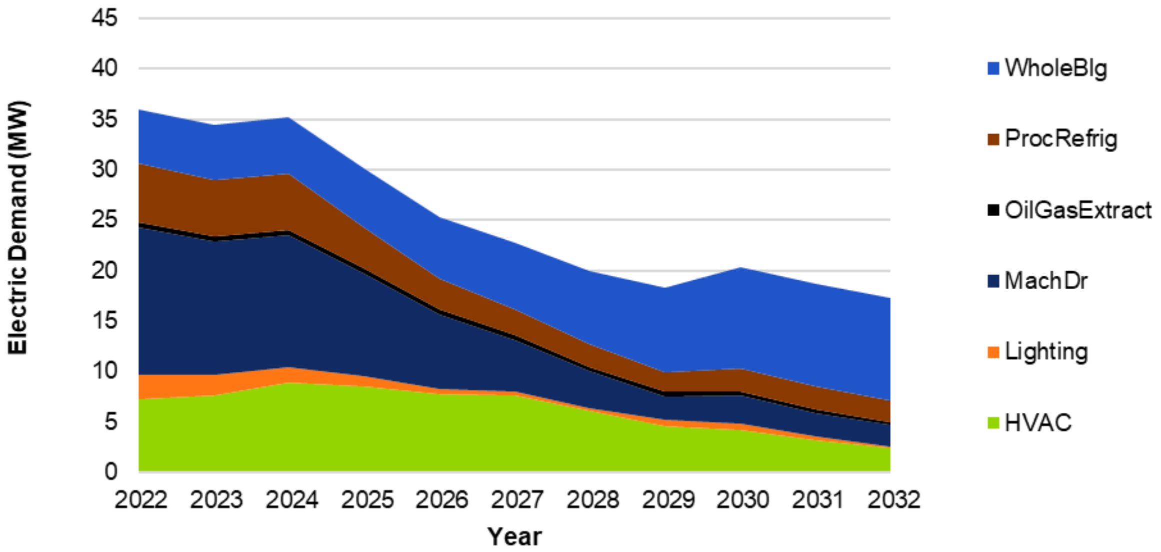
Source: Guidehouse

Figure 4-26. Commercial Rebate Program First-Year Peak Demand Savings by End Use (Scenario 3: TRC High)



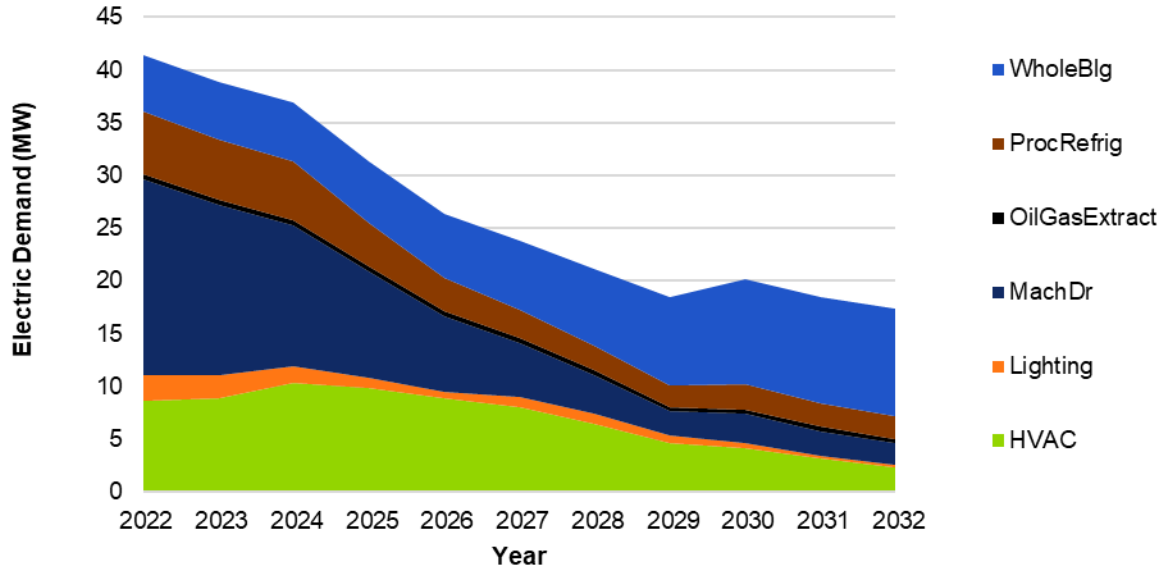
Source: Guidehouse

Figure 4-27. AIM Rebate Program First-Year Peak Demand Savings by End Use (Scenario 1: TRC Low)



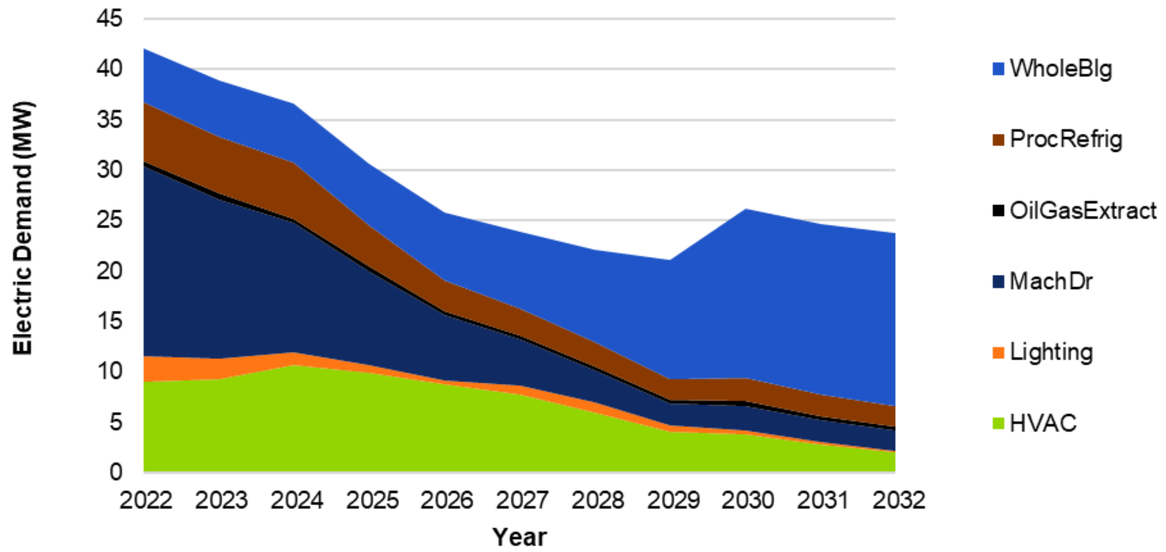
Source: Guidehouse

Figure 4-28. AIM Rebate Program First-Year Peak Demand Savings by End Use (Scenario 2: TRC Reference)



Source: Guidehouse

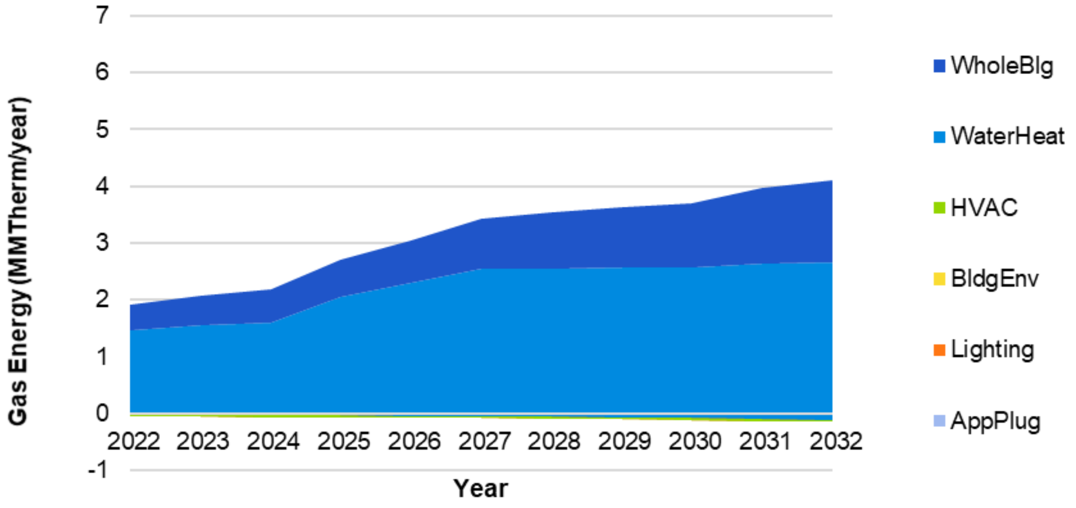
Figure 4-29. AIM Rebate Program First-Year Peak Demand Savings by End Use (Scenario 3: TRC High)



Source: Guidehouse

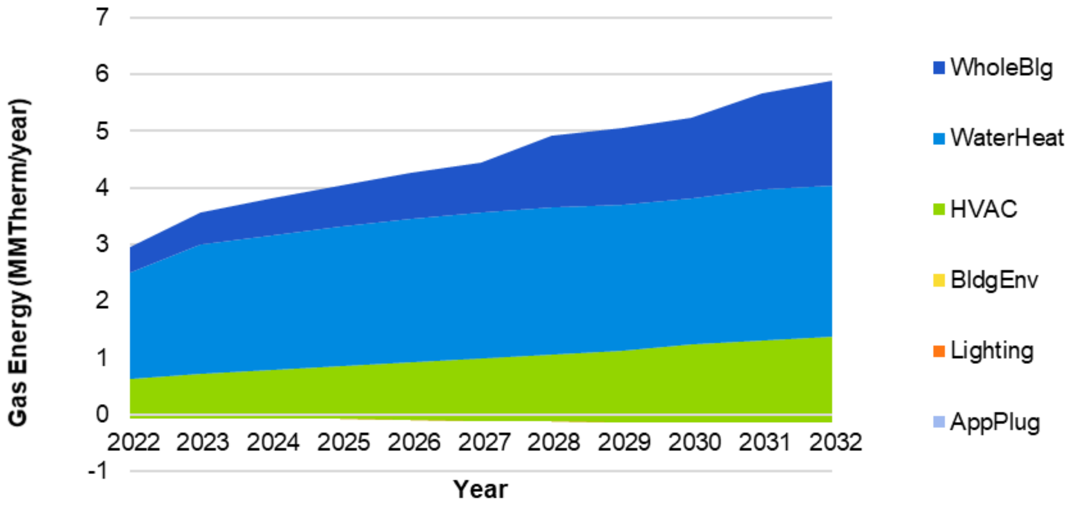
Figure 4-30 through Figure 4-32 show gas savings for the residential sector. Most of the savings come from water heating (dominated by instantaneous water heaters) and whole building. HVAC savings only become significant when fuel substitution (combined furnace and air conditioning replaced by a heat pump) becomes a cost-effective measure in Scenario 2 and Scenario 3. There are small negative savings due to interactive effects from appliances/plug loads and lighting. Savings from Scenario 1 to Scenario 2 increase by about 50% in 2022. The higher incentives and aggressive program engagement increases savings by less than 10% between Scenario 2 and 3 in 2022. This increase continues through the forecast period.

Figure 4-30. Residential Rebate Program First-Year Gas Energy Savings by End Use (Scenario 1: TRC Low)



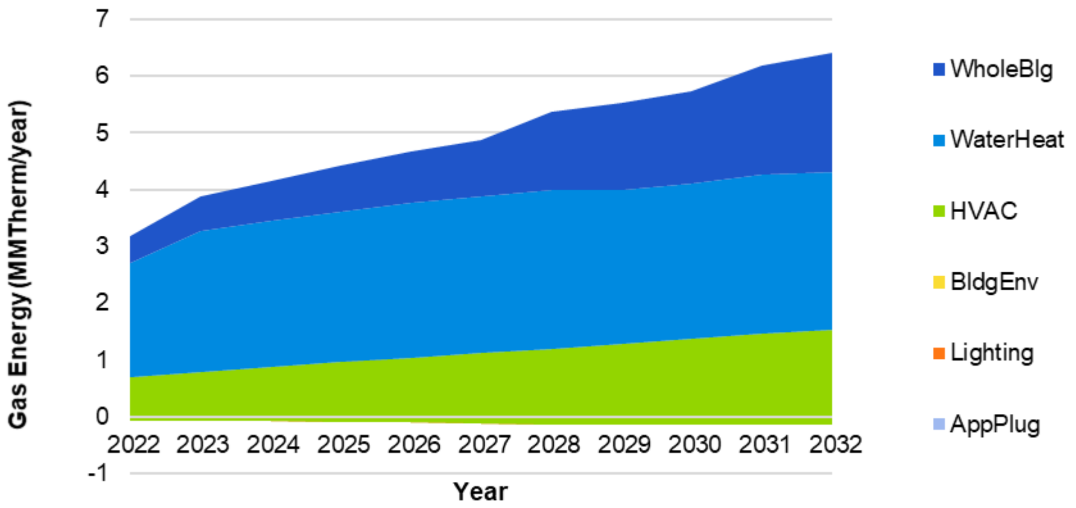
Source: Guidehouse

Figure 4-31. Residential Rebate Program First-Year Gas Energy Savings by End Use (Scenario 2: TRC Reference)



Source: Guidehouse

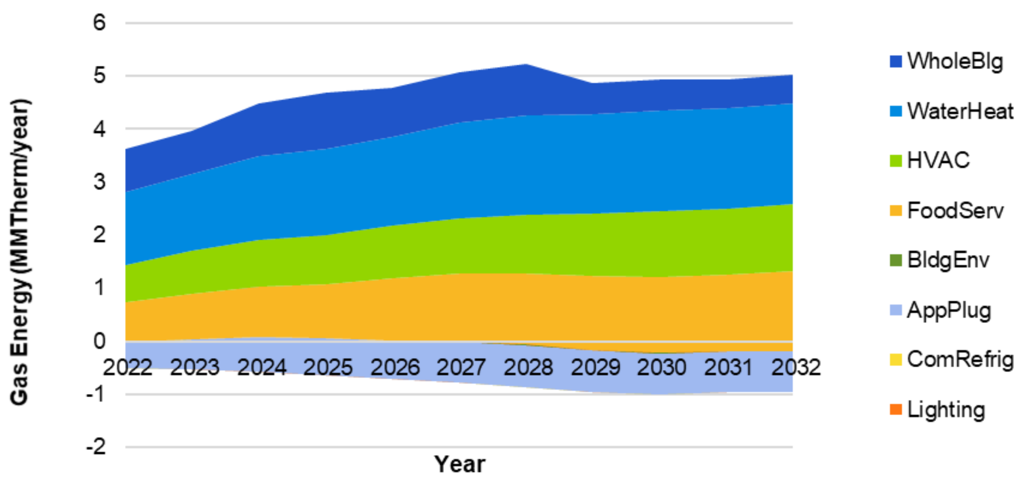
Figure 4-32. Residential Rebate Program First-Year Gas Energy Savings by End Use (Scenario 3: TRC High)



Source: Guidehouse

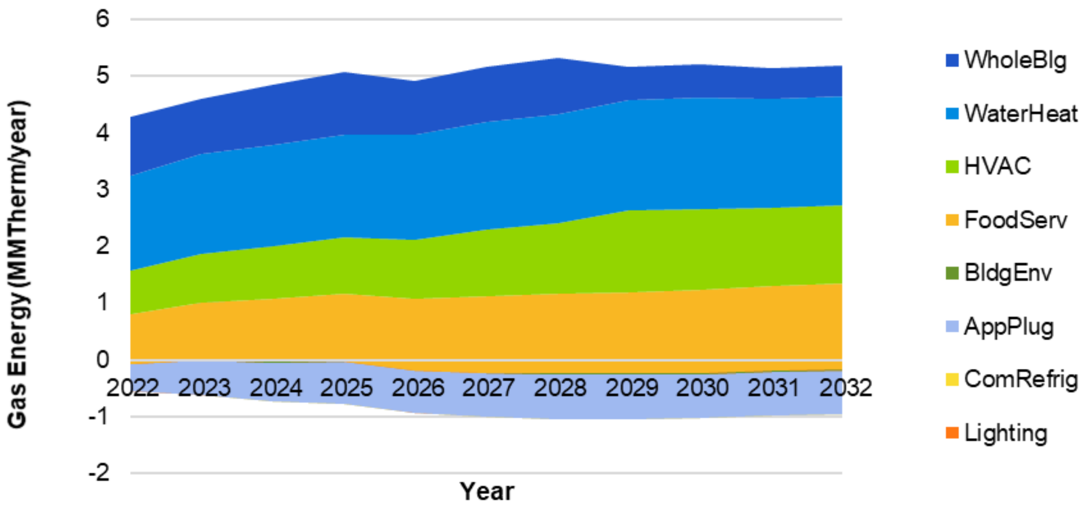
Figure 4-33 through Figure 4-35 show gas savings for the commercial sector. Negative gas savings are due to the lighting interactive effects. The AppPlug end use has positive savings that overlaps on the figure with the negative lighting savings; most AppPlug savings come from ozone laundry system retrofit. The FoodServ end use also shows positive savings overlapping with lighting's negative savings in the later years. Commercial water heating from instantaneous gas water heaters is a large contributor to the savings. Scenario 2 has a nearly 20% increase in savings compared to Scenario 1. Reducing the TRC threshold from 1.0 to 0.85 allowed technologies to pass the economic screening, such as convection ovens in food service and increased adoption of ZNE commercial buildings (two additional building segments become cost-effective above a 0.85 TRC).

Figure 4-33. Commercial Rebate Program First-Year Gas Energy Savings by End Use (Scenario 1: TRC Low)



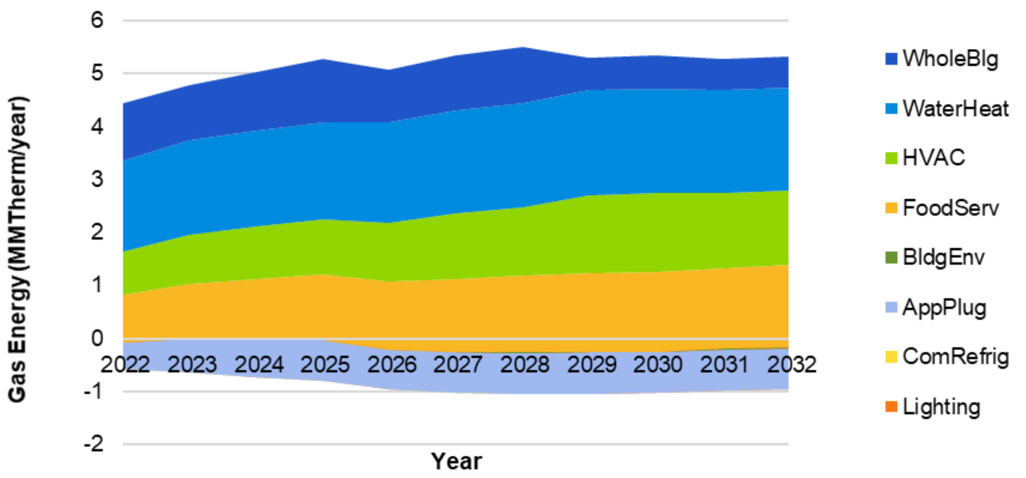
Source: Guidehouse

Figure 4-34. Commercial Rebate Program First-Year Gas Energy Savings by End Use (Scenario 2: TRC Reference)



Source: Guidehouse

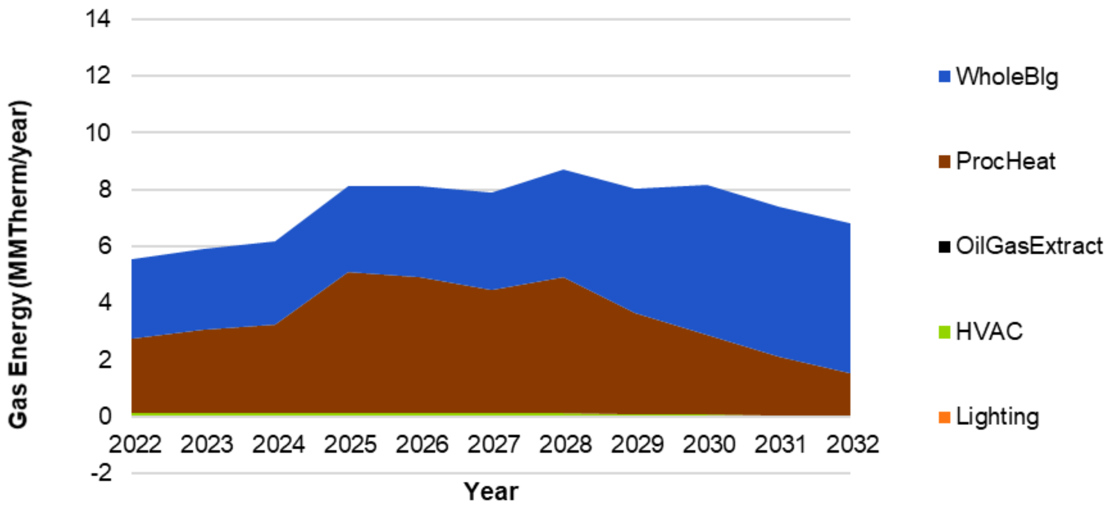
Figure 4-35. Commercial Rebate Program First-Year Gas Energy Savings by End Use (Scenario 3: TRC High)



Source: Guidehouse

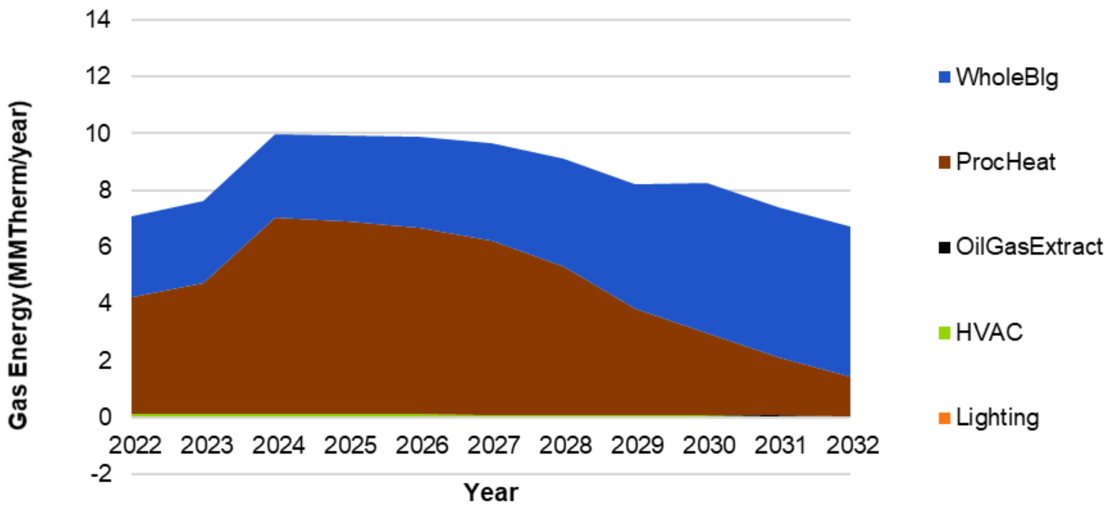
Figure 4-36 through Figure 4-38 show the AIM sector savings. These savings are primarily driven by process heating and generic custom (which fall under the whole building end use). In 2022, Scenario 2 is 27% more savings than Scenario 1 due to process heat, with the largest increase in insulation savings potential. In 2022, Scenario 3 is 5% larger than Scenario 2, driven by process heat. In future years, the increase in emerging technology (part of the whole building end use) drives the Scenario 3 increases in savings.

Figure 4-36. AIM Rebate Program First-Year Gas Energy Savings by End Use (Scenario 1: TRC Low)



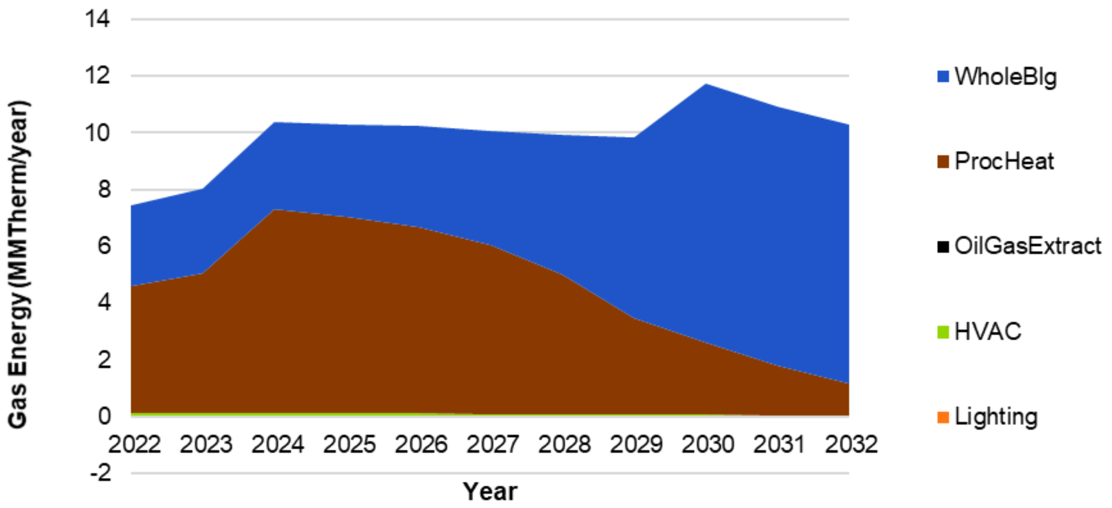
Source: Guidehouse

Figure 4-37. AIM Rebate Program First-Year Gas Energy Savings by End Use (Scenario 2: TRC Reference)



Source: Guidehouse

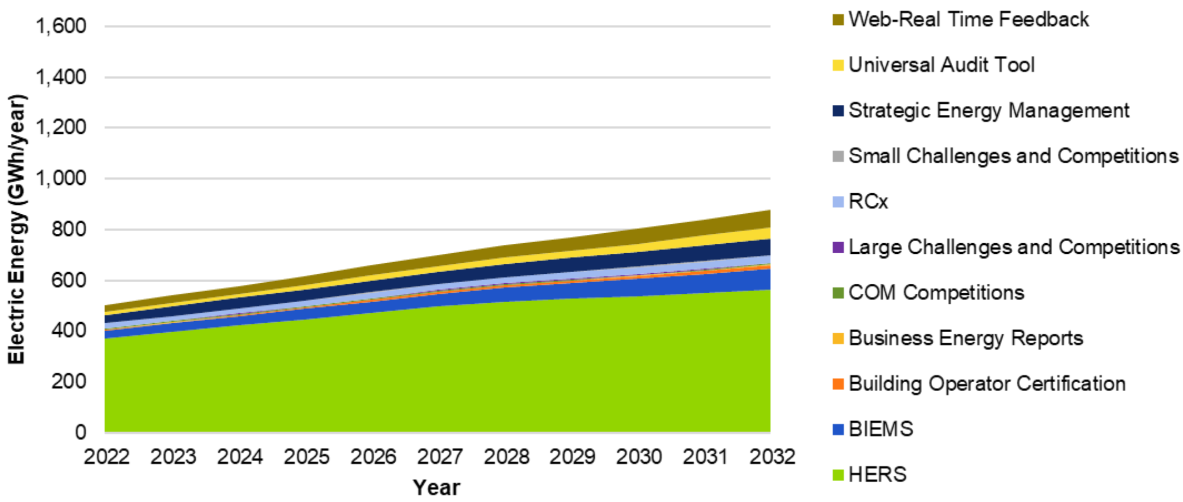
Figure 4-38. AIM Rebate Program First-Year Gas Energy Savings by End Use (Scenario 3: TRC High)



Source: Guidehouse

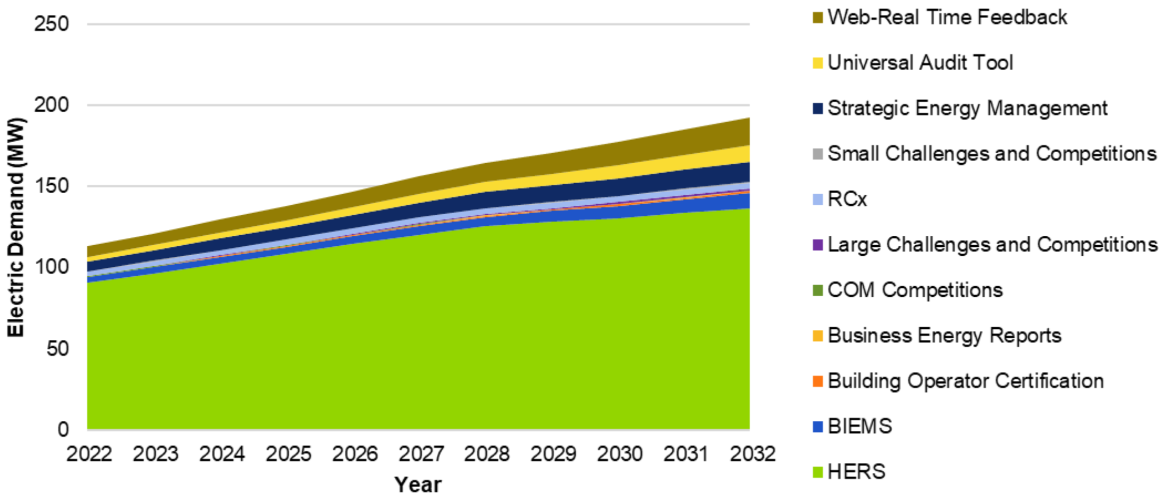
Figure 4-39 to Figure 4-41 provide BROs program savings, which are detailed by BROs intervention for the reference level of program engagement (Scenario 1 and Scenario 2). BROs savings grow over time as program participation rates increase. The residential HERs program dominates the BROs savings for electric and gas energy and peak demand savings. Web-based real-time feedback for residential and BIEMs for commercial show significant electric energy and peak demand savings. Industrial and agriculture SEM show significant gas savings.

Figure 4-39. BROs Program First-Year Electric Energy Savings by Program Type (Scenario 1 and Scenario 2)



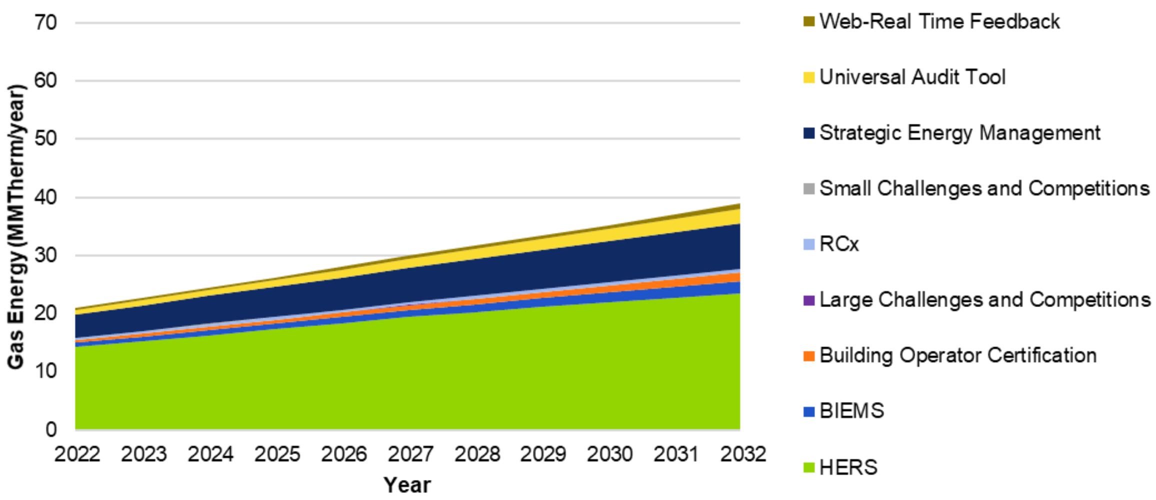
Source: Guidehouse

Figure 4-40. BROs Program First-Year Peak Demand Savings by Program Type (Scenario 1 and Scenario 2)



Source: Guidehouse

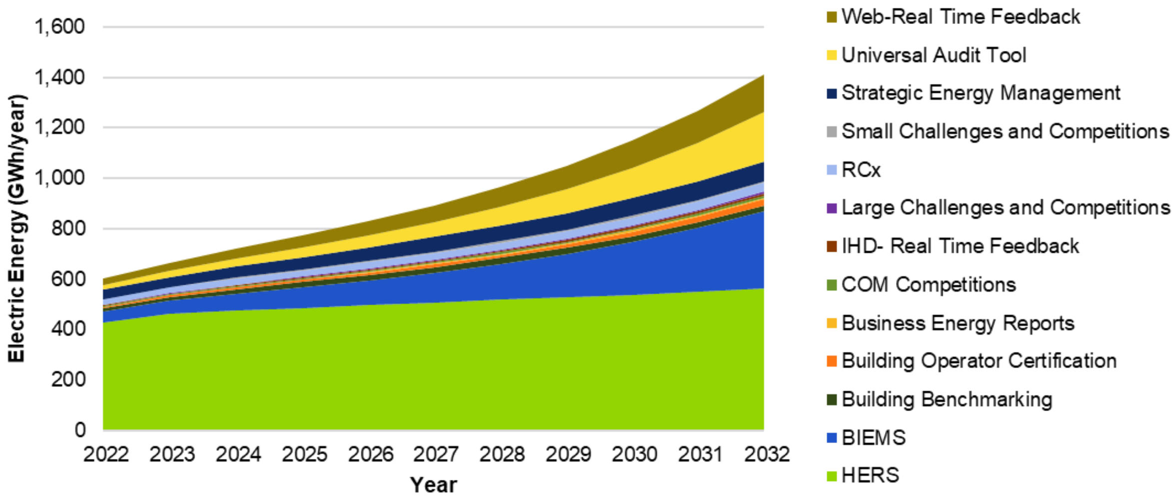
Figure 4-41. BROs Program First-Year Gas Energy Savings by Program Type (Scenario 1 and Scenario 2)



Source: Guidehouse

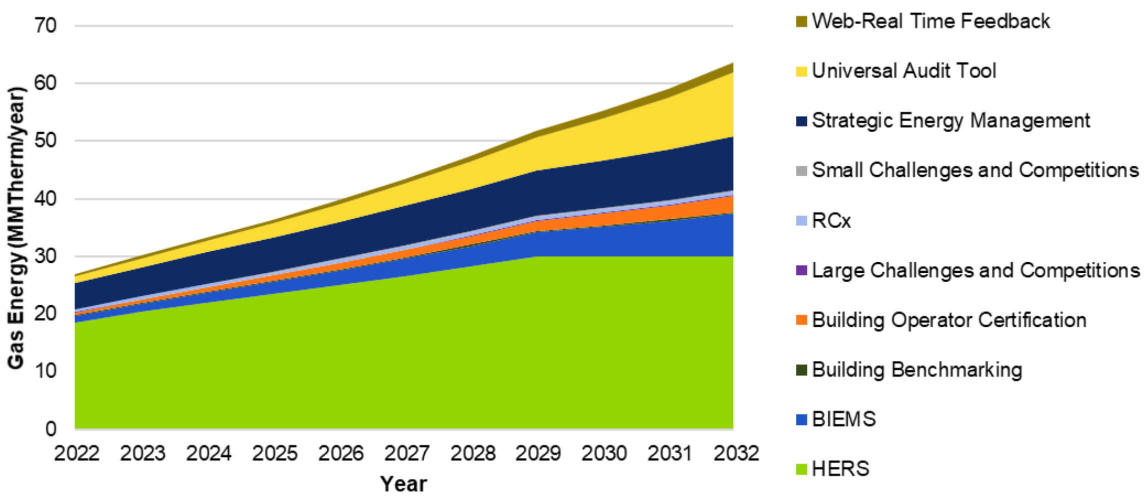
BROs program savings for Scenario 3 are much larger than Scenarios 1 and 2 because it reflects the aggressive level of engagement. Electric savings (shown in Figure 4-42) are 18% larger in 2022 than the reference case and 61% larger in 2032. Demand savings (not shown) follow a similar trend. Gas savings (shown in Figure 4-43) are 28% larger in 2022 than the reference case and 63% larger in 2032.

Figure 4-42. Aggressive BROs Program First-Year Electric Energy Savings by Program Type (Scenario 3)



Source: Guidehouse

Figure 4-43. Aggressive BROs Program First-Year Gas Energy Savings by Program Type (Scenario 3)



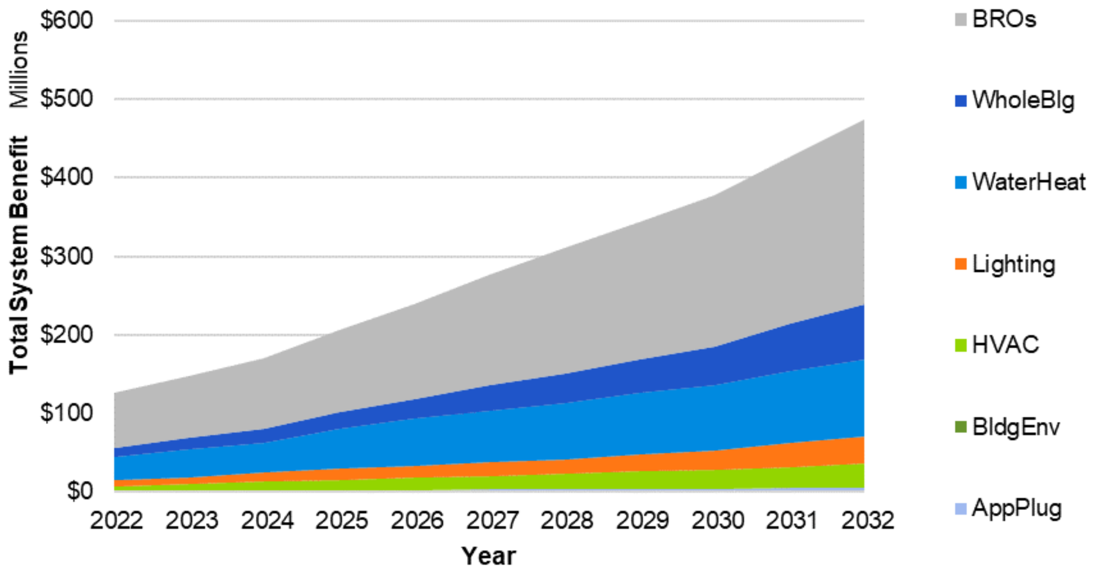
Source: Guidehouse

4.2.3 Total System Benefit for Rebate and BROs Programs

Figure 4-44 to Figure 4-52 show the TSB by end use including rebate (fuel substitution and EE equipment) and BROs programs. TSB increases over time, and the trends and shape do not vary significantly across scenarios; magnitude does vary, however.

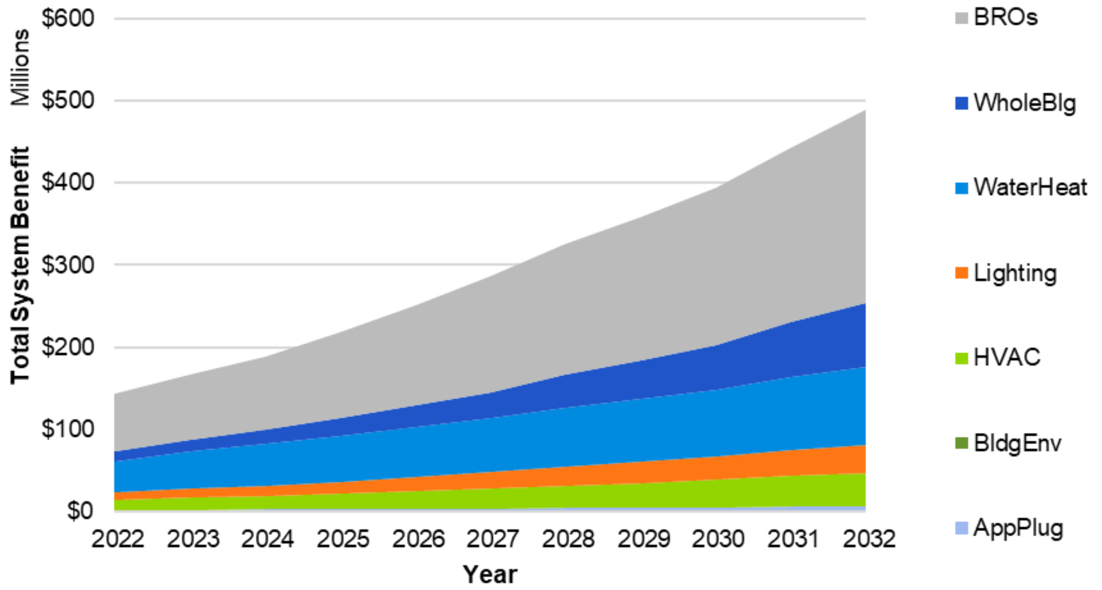
Although the residential sector first-year savings are largely driven by BROs (over 60% of the total), the BROs contribution to TSB is reduced due to the overall low EUL for BROs (HERs has an EUL of 1 year) to about 50% of the residential sector TSB value. For Scenario 3, BROs is a higher percentage, mostly as a result of the aggressive program engagement lever.

Figure 4-44. Residential TSB by End Use (Scenario 1: TRC Low)



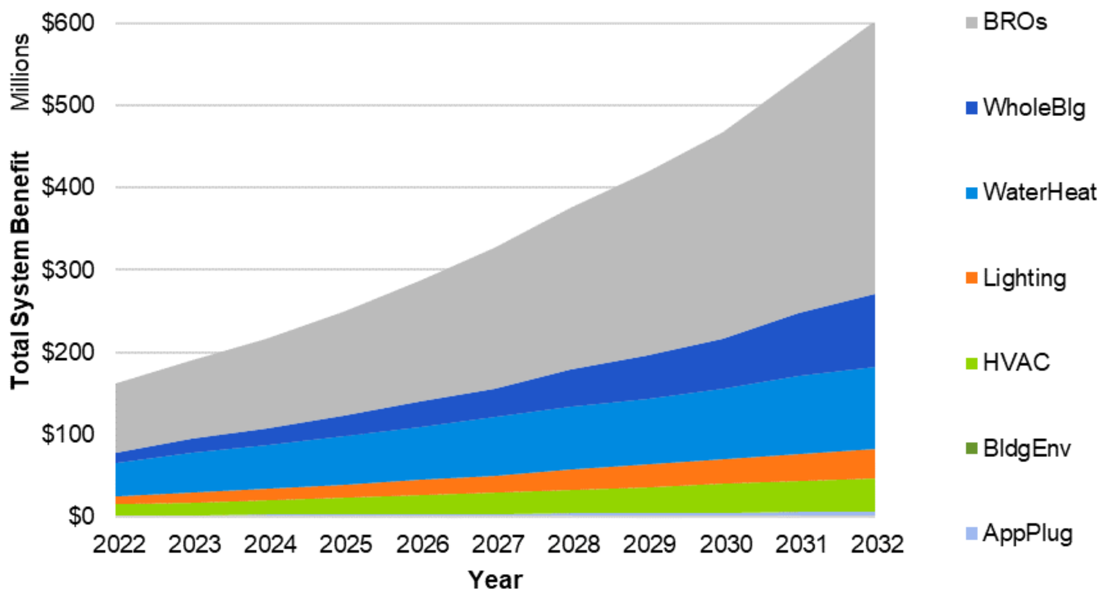
Source: Guidehouse

Figure 4-45. Residential TSB by End Use (Scenario 2: TRC Reference)



Source: Guidehouse

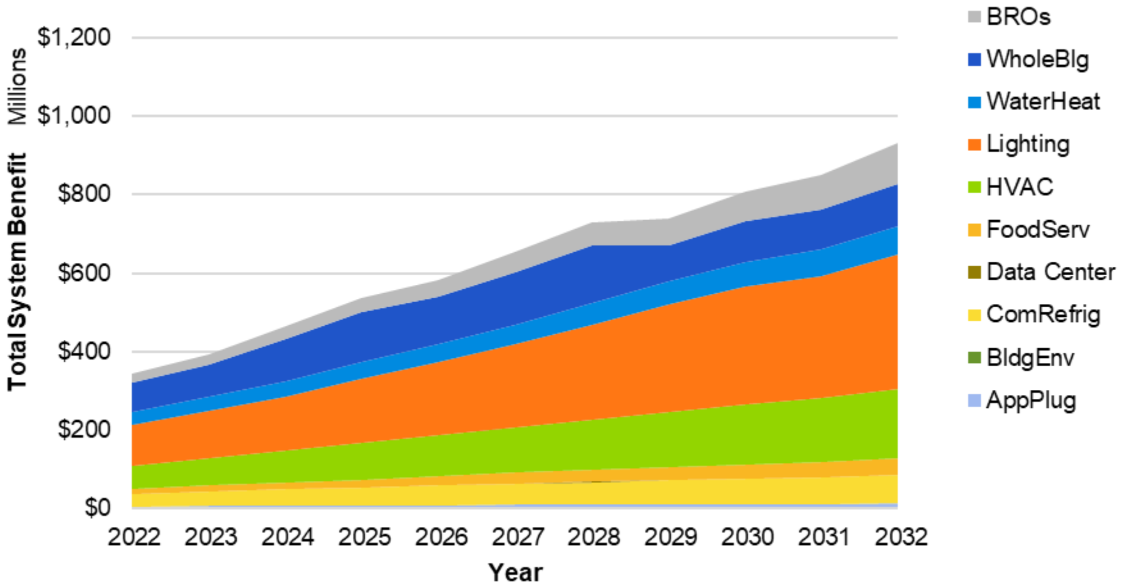
Figure 4-46. Residential TSB by End Use (Scenario 3: TRC High)



Source: Guidehouse

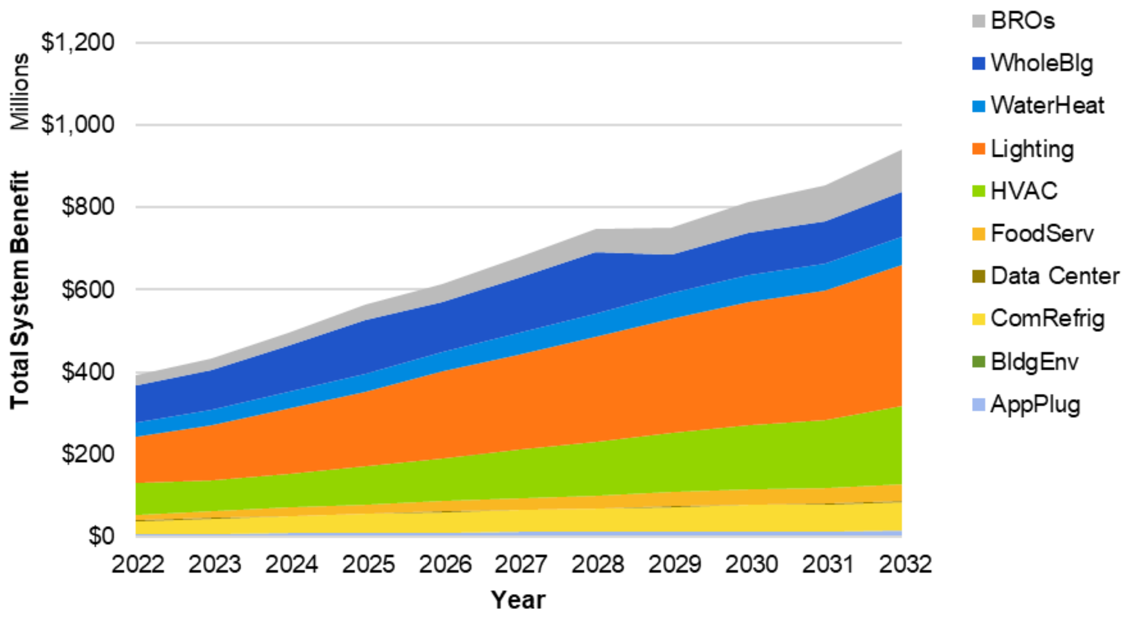
Figure 4-47 through Figure 4-49 show TSB for the commercial sector. Scenario 1 and Scenario 2 have about a 15% difference in the early years and decrease to about 1% by 2032. The trend is mostly driven by Scenario 2 having higher HVAC and whole building benefits in the early years and then saturation matching to Scenario 1 savings from the two commercial end uses. The differences between Scenario 2 and Scenario 3 are driven by the BROs level of engagement, where Scenario 2 is at the reference level and Scenario 3 at the aggressive level.

Figure 4-47. Commercial TSB by End Use (Scenario 1: TRC Low)



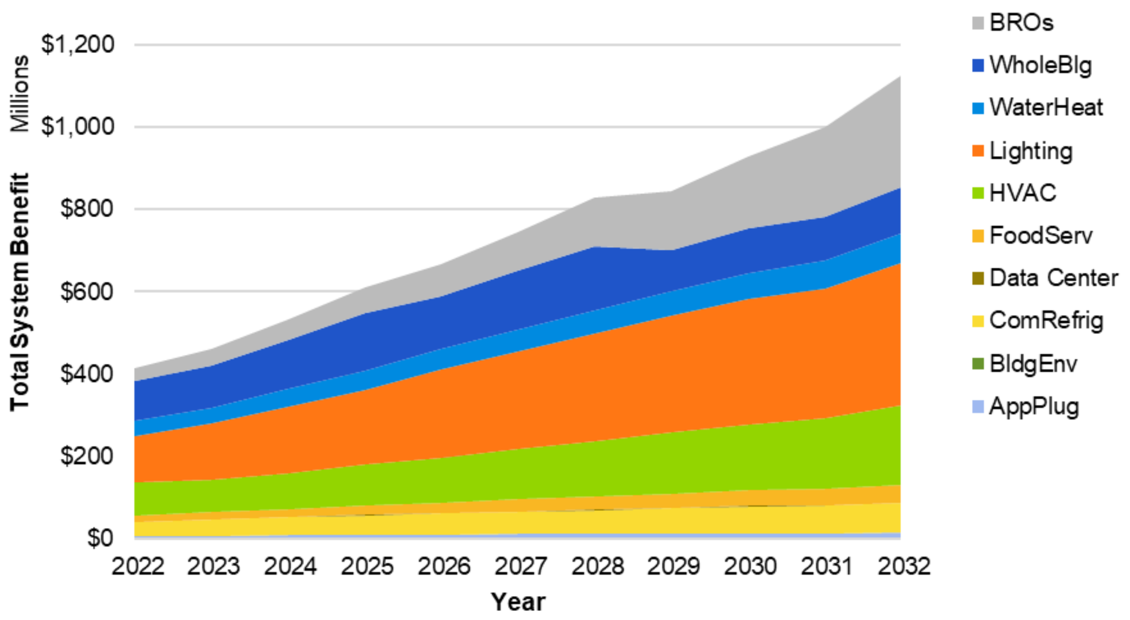
Source: Guidehouse

Figure 4-48. Commercial TSB by End Use (Scenario 2: TRC Reference)



Source: Guidehouse

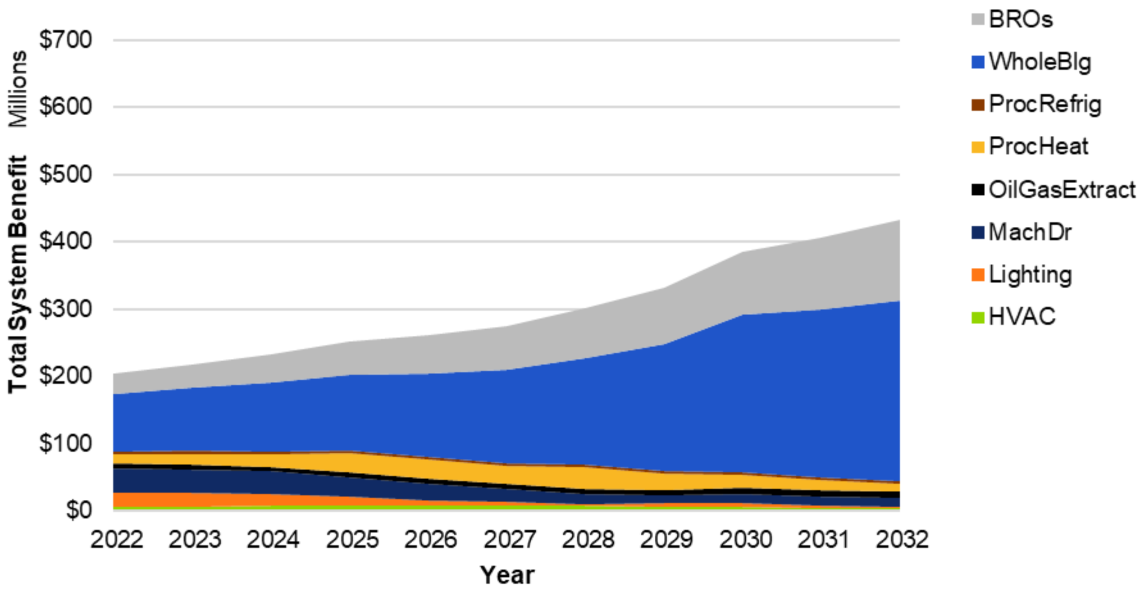
Figure 4-49. Commercial TSB by End Use (Scenario 3: TRC High)



Source: Guidehouse

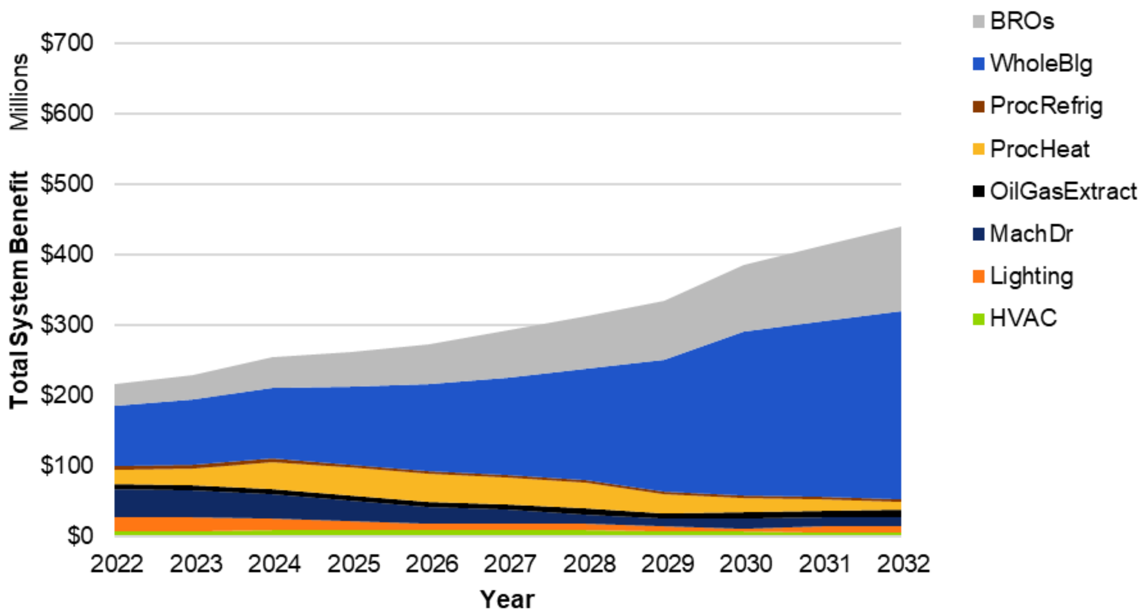
Figure 4-50 through Figure 4-52 show the AIM sector TSB results. AIM TSB increases over time despite the decrease in energy savings due to the increasing avoided costs. Additionally, for Scenario 3, the impacts to the growth of the SEM program and emerging technology (part of the whole building end use) are significant and result in about a 3% increase in TSB compared to Scenario 2 in 2022 to nearly a 40% difference in 2032.

Figure 4-50. AIM TSB by End Use ($) (Scenario 1: TRC Low)



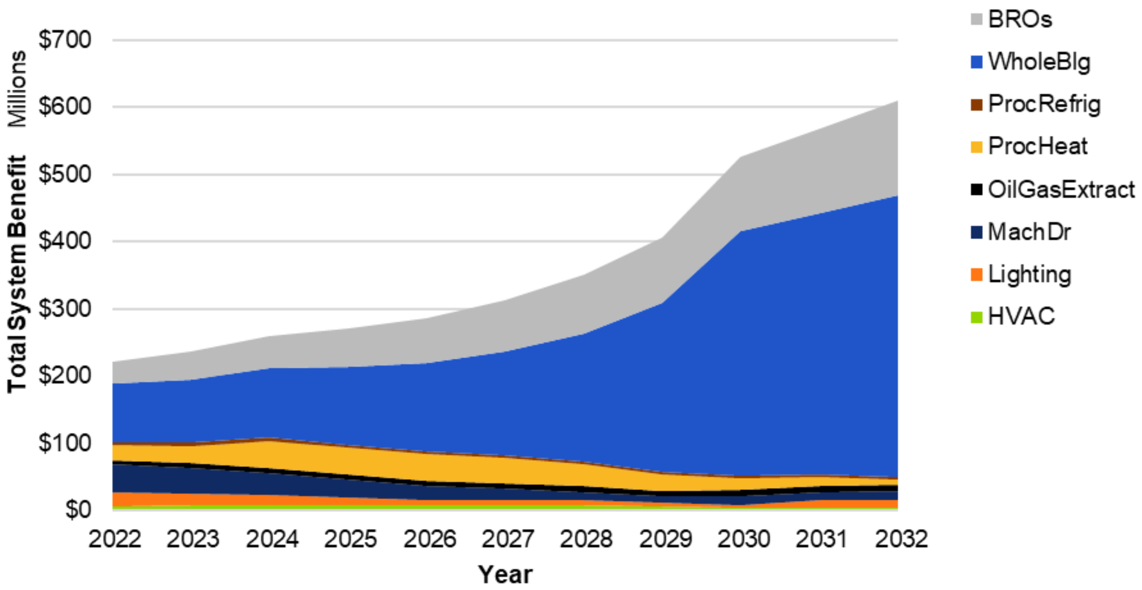
Source: Guidehouse

Figure 4-51. AIM TSB by End Use ($) (Scenario 2: TRC Reference)



Source: Guidehouse

Figure 4-52. AIM TSB by End Use ($) (Scenario 3: TRC High)



Source: Guidehouse

4.3 Fuel Substitution

This section provides fuel substitution-specific results and a discussion of the Guidehouse team's key observations and findings.

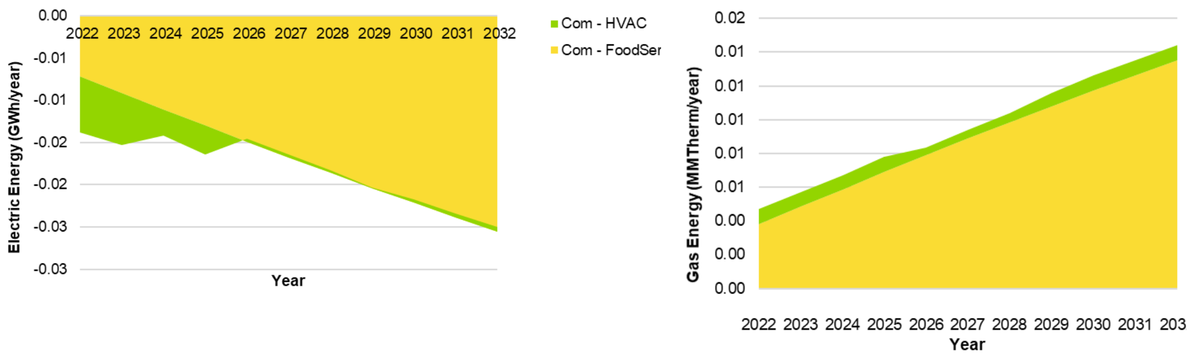
4.3.1 Results

Figure 4-53 to Figure 4-55 show electric consumption increase and natural gas consumption decrease (savings) for the three scenarios. All fuel substitution measures in the analysis pass the fuel substitution test independent of cost-effectiveness or customer adoption metrics. For Scenario 1, commercial steamers (food service) and packaged heat pumps are the only fuel substitution measures that are cost-effective; in this scenario cost effectiveness means a TRC of 1.0 or greater. As the TRC threshold is reduced in Scenarios 2 and 3 to 0.85 other measures become cost-effective, notably commercial heat pump water heaters and, for SCE only, heat pumps in the hot-dry weather zone. The 2021 Study forced the residential hot-dry climate heat pumps replacing both heating and air conditioning in SCE territory to be included in Scenario 2 and 3 achievable potential for all years of the forecast period. The measure does pass the 0.85 TRC threshold for the initial years of the forecast but then drop below 0.85 in later years.[100] For residential heat pumps, the PG Study team accommodated more appropriate matching to load shapes and this helped the SCE hot/dry combined replacement heat pumps exceed the 0.85 TRC threshold. The Study modeled SEER 18 heat pumps; lower efficiency models like SEER 15 and 16 (with lower measure cost) could achieve higher TRC levels in the near-term (though likely not in the long-term). See additional discussion in Section 4.3.2 on additional analysis that may be needed to improve estimates cost effectiveness.

[100] The measures forced through were only for the SCE heat pump SEER 18 replacing furnaces in the hot-dry weather zone. For most of the early years (2022-2027 for single-family and 2022-2029 for multifamily), the SCE heat pump SEER 18 replacing combined cooling and heating in the hot-dry weather zone has a TRC greater than 0.85, the threshold for Scenario 2 and Scenario 3.

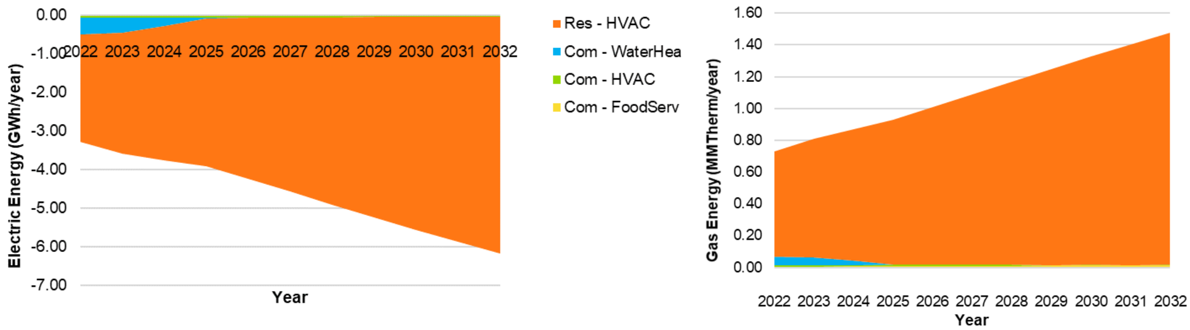
The adoption of commercial measures is low as compared to the residential heat pumps when Scenarios 2 and 3 include these measures.

Figure 4-53. Fuel Substitution Electric Increase and Gas Energy Decrease by End Use (Scenario 1: TRC Low)



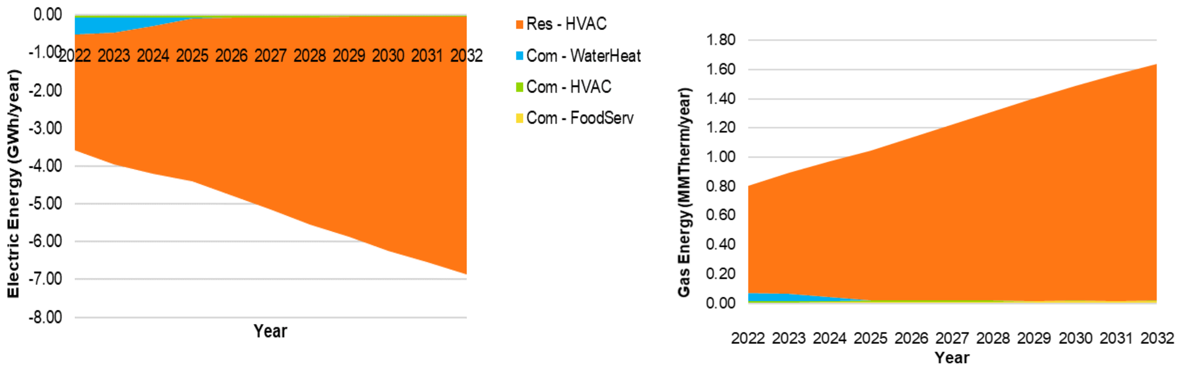
Source: Guidehouse

Figure 4-54. Fuel Substitution Electric and Gas Energy Increase by End Use (Scenario 2: TRC Reference)



Source: Guidehouse

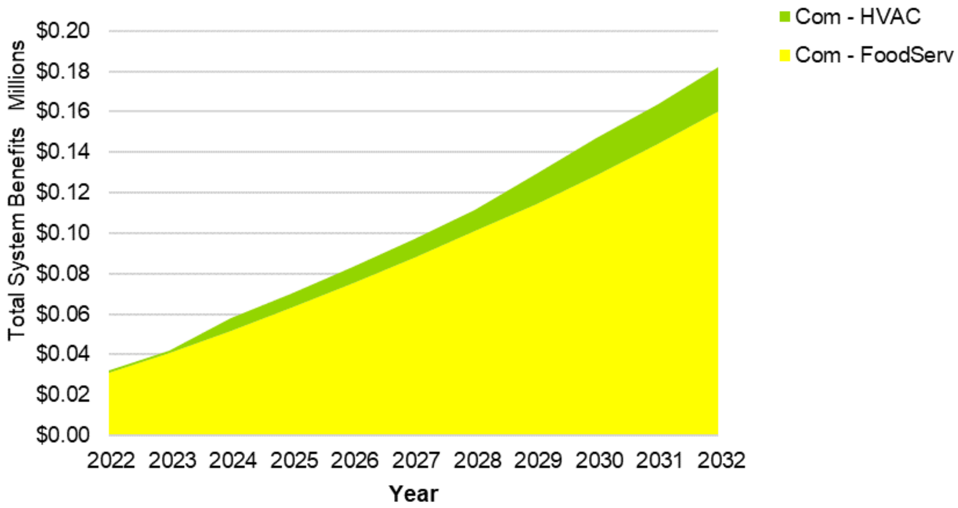
Figure 4-55. Fuel Substitution Electric and Gas Energy Increase by End Use (Scenario 3: TRC High)



Source: Guidehouse

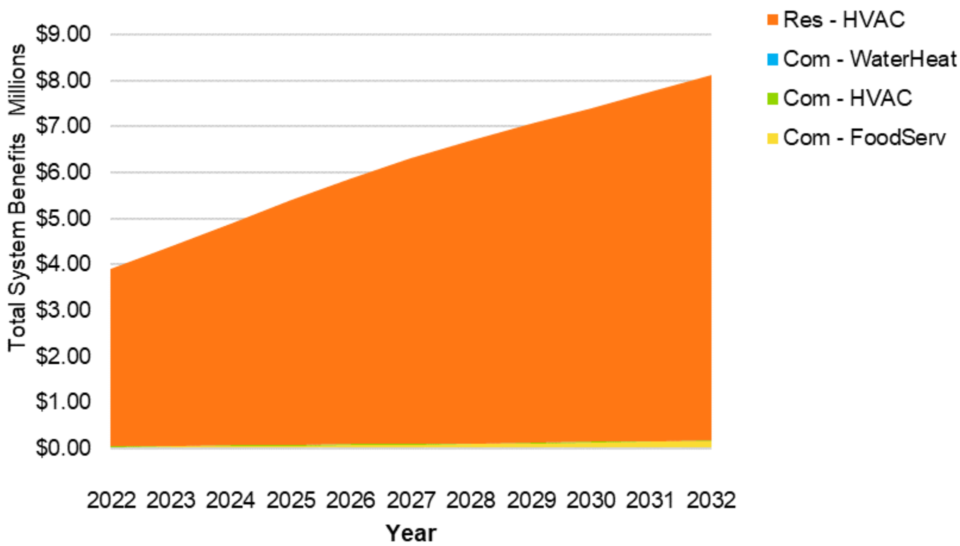
Figure 4-56 to Figure 4-58 provide the fuel substitution TSB results. Measures with a TRC greater than 1.0 should always have a positive TSB. When a measure TRC is less than 1.0, the TSB may be negative (TRC includes the increased supply cost from fuel substitution in the denominator where as it is subtracted from the avoided cost benefit in the TSB). Scenarios 2 and 3 used a TRC cost-effectiveness threshold of 0.85. As a result, one fuel substitution measure (commercial heat pump water heaters) does result in negative TSB (when summing across all building types and utilities) for 2023 and 2024 only (in 2027-2032, they are no longer passing the TRC threshold). The negative TSB occurred when the avoided cost benefit for natural gas does not exceed the increased supply cost for some years even though the technology passed the fuel substitution test and exceeded the 0.85 TRC threshold. For all scenarios, the fuel substitution potential benefit growth rate decreases over time. The Guidehouse team mostly attributes this to the greater increases in electric avoided costs than the gas avoided costs.

Figure 4-56. Fuel Substitution TSB ($) (Scenario 1: TRC Low)



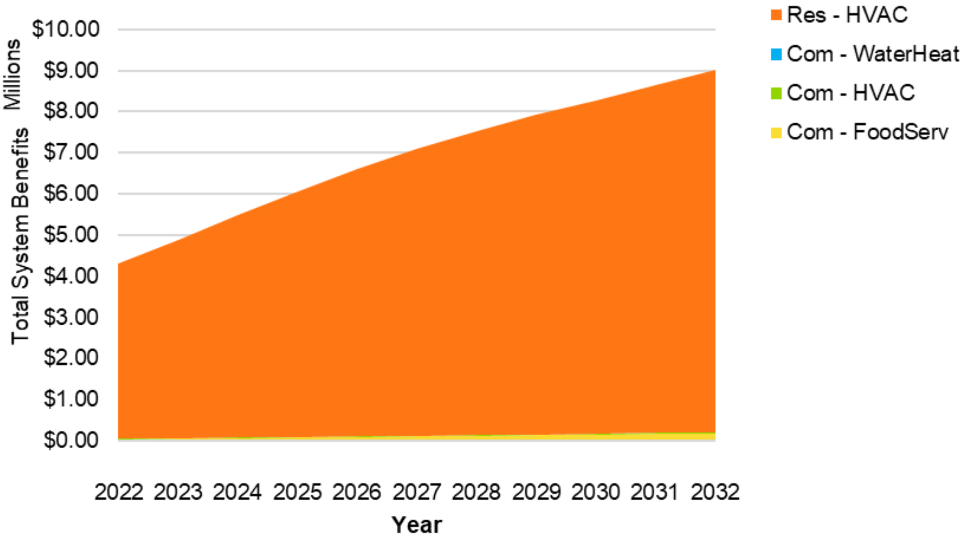
Source: Guidehouse

Figure 4-57. Fuel Substitution TSB ($) (Scenario 2: TRC Reference)



Source: Guidehouse

Figure 4-58. Fuel Substitution TSB ($) (Scenario 3: TRC High)



Source: Guidehouse

4.3.2 Key Observations and Findings

Relatively few fuel substitution measures have been included in 2021 ABALs filed by the IOUs. The Guidehouse team and CPUC staff reviewed SCE filings and found several measures to have a TRC greater than 1.0 when specifically modeled in climate zone 9:

- Commercial steamers (food service) and commercial packaged heat pumps (both of which were found to be cost-effective in the analysis)
- SEER 15 residential heat pumps (the 2021 Study does not have this exact measure but instead models SEER 18)
- Residential ductless mini-split heat pumps

While the 2021 Study analysis generally corroborates with SCE's filing, the Guidehouse team further investigated to observe why few fuel substitution measures seem to pass TRC cost-effectiveness and why cost-effectiveness decreases over time. The rest of this section contains the observations and findings regarding the inputs to fuel substitution cost-effectiveness.

The TRC test for fuel substitution measures counts gas savings as a benefit and counts the added marginal cost of supplying electric service that result from fuel substitution, as estimated by the Avoided Cost Calculator (ACC), as a cost. The Guidehouse team has observed that electric avoided costs in the current CPUC CET increase significantly over the coming decades while gas avoided costs increase at a lower rate. Electric avoided cost for some measures increases approximately 100% from 2022 to 2030 and more than 400% by 2047.[101] Gas avoided cost for some measures increases approximately 50% from 2022 to 2030 and less than 180% by 2047.[102] This shifts the balance of benefits and costs over time. While a fuel substitution installation in 2022 may be cost-effective, that same installation made in the year 2030 may not be cost-effective due to much higher costs with limited

[101] Based on a sample of avoided cost data observed by Guidehouse. Sample is based on the annual sum of quarterly electric avoided cost data found in CET for SCE residential heat pumps.

[102] Based on a sample of avoided cost data observed by Guidehouse. Sample is based on the annual sum of quarterly gas avoided cost data found in CET for SCG residential applications.

increases in benefits. The findings of the fuel substitution analysis results in the following topic areas that the team poses to CPUC staff and stakeholders for further investigation.

As the forecast of fuel substitution measures is highly dependent on avoided costs and supply cost valuation methods, it is important to ensure that inputs and tools reflect best available information and current policies throughout the forecasted period. For example, CPUC should ensure both electric and gas avoided costs are based on consistent assumptions and input data.

Further investigation and documentation may be needed around load shapes. The CPUC ACC generates hourly avoided costs as its output. These hourly avoided costs are applied to prototypical load shapes for use in the CET to calculate cost-effectiveness. Currently, only a limited number of fuel substitution-specific load shapes are in use. This library of fuel substitution-specific load shapes could be expanded.

Measure cost is another key component of the TRC test. In the review of measure cost and discussions with CPUC staff, the Guidehouse team observed differing data sources for baseline and replacement technologies, possibly outdated data sources, and a lack of clarity in unit basis for published cost data. CPUC last funded a comprehensive measure cost study in 2012. CPUC may need to consider a revised measure cost study specifically for fuel substitution measures.

Program (non-incentive) cost is also a cost component of the TRC test. In the team's review, there was limited information for the basis of quantifying fuel substitution program costs. Initial utility programs around fuel substitution may be more expensive than their EE counterparts, as many new efforts may be needed to tune the effectiveness of fuel substitution programs. However, in the long run, program costs may be lower. Obtaining better program cost data will improve the calculation of TRC.

4.4 EE-DR Integration

This section discusses the impacts of integrating the co-benefits of EE-DR. Integration of EE-DR co-benefits was conducted as a sensitivity analysis on Scenario 2.[103] To include an integrated EE-DR co-benefits analysis in a future core study scenario (not just as a sensitivity), the CPUC would need to investigate, vet, and ultimately adopt or sanction an approach to calculating EE-DR cost-effectiveness via formal proceeding activity.

Appendix I.2 summarizes the possible implications of adding DR on the cost-effectiveness of EE-DR technologies. There are two impacts of adding DR co-benefits:

1. Change the terms of technology cost-effectiveness with adding DR benefits and costs.
2. Change customer financial attractiveness with the additional benefit of DR program participation even if the technology comes at a higher cost for the smart features.

While including DR benefits and costs has noticeable impacts at the measure level, it has a minimal impact (on average 1.8% increase) overall without BROs, as shown in Table 4-2.

[103] As this was a first of its kind analysis, CPUC staff directed the Guidehouse team to conduct a single sensitivity analysis on the reference case only. This is primarily to observe the magnitude of impact that could be expected from EE-DR integration. The model is capable of assessing this impact on other scenarios.

Table 4-2. Scenario 2 Electric Energy Savings With and Without DR

Year	Scenario 2: TRC Reference	Scenario 2 (DR): TRC Reference With DR	Percent Difference
2022	330.41	340.85	3.2%
2023	335.49	344.79	2.8%
2024	349.66	358.84	2.6%
2025	354.45	362.98	2.4%
2026	360.77	368.09	2.0%
2027	372.06	378.71	1.8%
2028	382.64	388.28	1.5%
2029	360.87	365.33	1.2%
2030	368.22	371.44	0.9%
2031	362.88	365.67	0.8%
2032	364.46	366.98	0.7%

Source: Guidehouse

4.4.1 Residential Sector Results

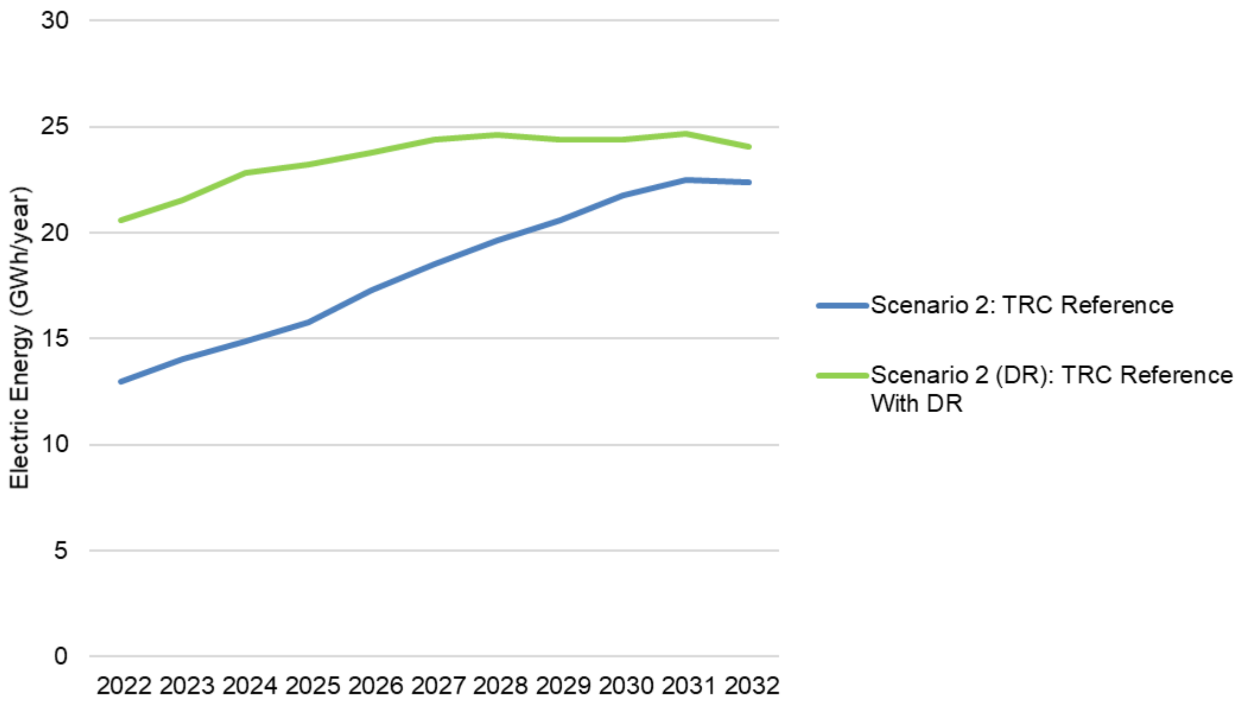
The difference in the residential potential between the two scenarios (Figure 4-59) is primarily accounted for with higher potential in the following measures:

- **Smart thermostats.** Smart thermostat cost-effectiveness may significantly increase with the addition of DR benefits. Addition of DR benefits leads to the technology being cost-effective in a few cases (and not cost-effective on an EE-only basis). The smart thermostat annual incremental potential with the addition of DR is almost double the potential without DR in the early years, with the difference narrowing over time.
- **Smart water heating controls.** The impact of this measure on achievable potential is relatively small when compared to the impact from smart thermostats. The adoption of smart water heater controls is about 4 times the amount of adoption in the scenario without DR.

DR benefits do not provide a noticeable impact on increasing lighting savings.

As described in Appendix I, the TRC results for the other EE-DR technologies alter with the inclusion of DR benefits and costs. However, they do not change enough to cross over the threshold of becoming cost effective. Therefore, these EE-DR technologies do not yield changes in the achievable potential estimates. Appendix I provides examples using a TRC threshold of 1.0.

Figure 4-59. Residential Incremental Annual Achievable Potential Electric Savings With and Without DR



Note: Only includes HVAC, lighting, water heating, and AppPlug end uses.
Source: Guidehouse

4.4.2 Commercial Sector Results

Figure 4-60 shows the incremental annual achievable potential for the commercial sector with and without the DR benefits addition for Scenario 2. Additional details on cost-effectiveness results are in Appendix I.

- Commercial smart thermostat cost-effectiveness significantly improves with the addition of DR. On average across all utilities, cost-effectiveness exceeds the 0.85 TRC threshold for all weather zones for most of the forecast period. However, the technology has a relatively small share of the total commercial sector potential and, therefore, the figure does not show any perceptible difference.
- The other commercial EE-DR technologies that pass the TRC threshold of 0.85 earlier in the forecast period with the addition of DR benefits (while not being cost-effective on an EE-only basis) are smart electric storage water heaters (non-heat pump), smart power strips, and PC power management. These measures have a relatively small contribution to the overall commercial sector potential; therefore, there is no perceptible change in commercial sector potential with the addition of DR.
- The cost-effectiveness of energy management system improves with addition of DR, but the technology does not pass 0.85 TRC threshold with inclusion of DR. Similarly, the cost-effectiveness screening of advanced lighting controls is not impacted with the addition of DR benefits. Therefore, the adoption of these measures is not impacted with inclusion of DR.

Figure 4-60. Commercial Incremental Annual Achievable Potential Electric Savings With and Without DR

Note: Only includes HVAC, lighting, water heating, AppPlug, and ComRef end uses.
Source: Guidehouse

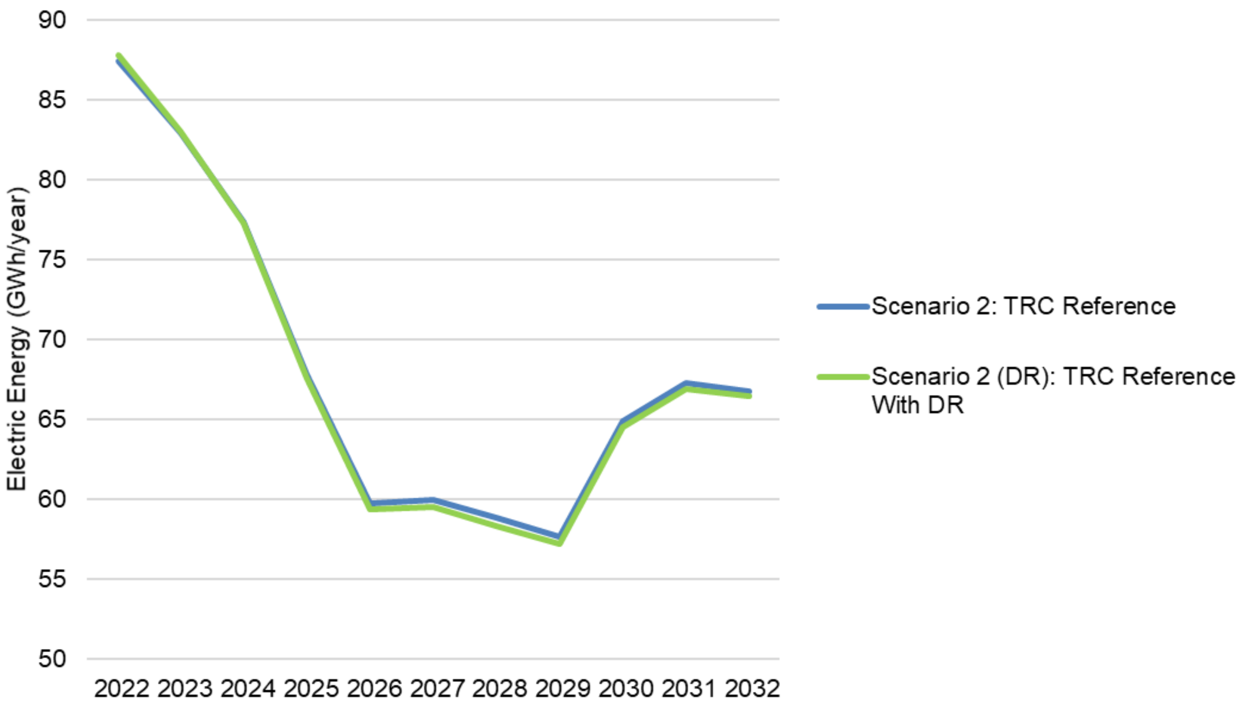
4.4.3 Industrial and Agricultural Sector Results

Figure 4-61 shows the annual incremental achievable potential with and without DR for the industrial and agricultural sectors. There is no change in the in number of measures that pass cost-effectiveness screening with the addition of DR benefits and costs. All EE-DR technologies for these two sectors were cost-effective without DR considerations. However, market adoption of some of these technologies is expected to increase in 2022 with DR considerations.

Industrial chiller plant optimization, agriculture water pumping sensors and controls, and industrial chemical manufacturing advanced automation show higher market adoption with the addition of DR in 2022. These technologies have a relatively low share in the overall agricultural and industrial sector potential; therefore, the additional potential from these technologies does not show up as a perceptible difference in Figure 4-61.

In years 2024 and beyond, achievable potential is expected to slightly decrease with the addition of DR benefits and cost. This may be due to the market for EE equipment beginning to saturate earlier. Overall DR has a limited impact (positive or negative) on the adoption of EE equipment in the industrial and agriculture sectors.

Figure 4-61. Industrial Incremental Annual Achievable Potential Electric Savings With and Without DR



Note: Only includes HVAC, lighting, machine drives, and whole building end uses.
Source: Guidehouse

4.5 C&S Savings

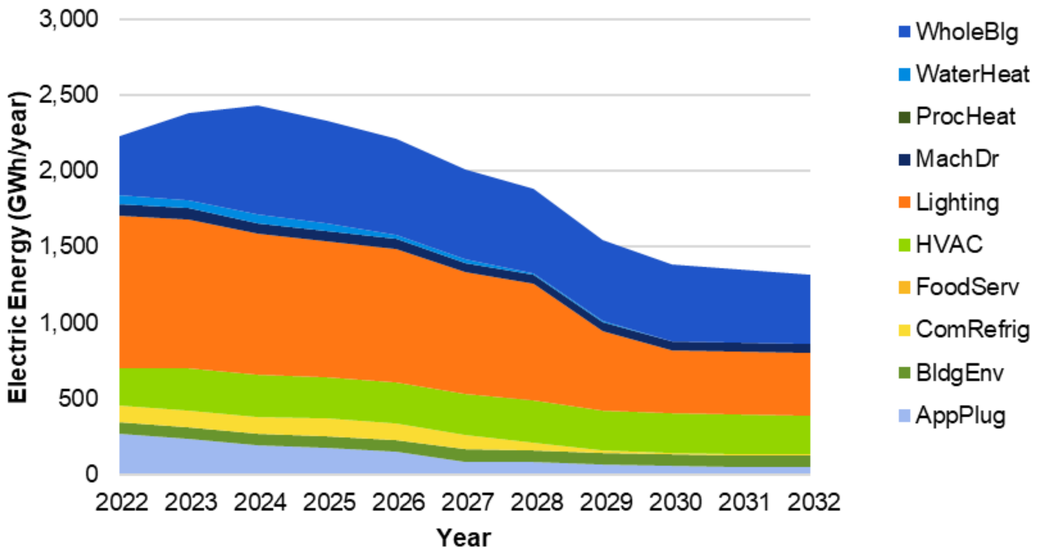
Incremental annual savings from on the books and expected C&S are illustrated in Figure 4-62 and Figure 4-63. Unlike results displayed earlier in this section, C&S savings do not vary by scenarios because there are no modeled policy or program design decisions under the purview of the IOUs or CPUC that influence C&S savings.

Electric savings from C&S have increased relative to those estimated in the 2019 Study, while gas savings are largely the same for the early years, though they exhibit a steep decline in 2026. Incremental savings seem to decrease in the later years as the market affected by a code or standard has completely turned over and savings from the retrofit market are no longer counted.

This study uses draft results from the latest CPUC impact evaluation of appliance standards. Several key notes regarding the evaluation that influence the team's results include the following:

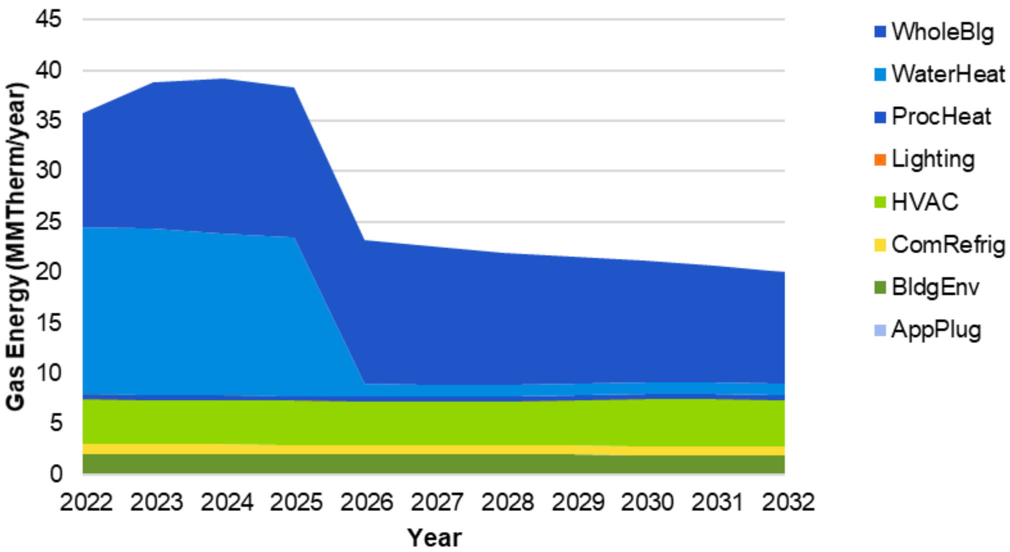
- The evaluation shows a considerable increase in savings from lighting-related standards relative to those estimated in the 2019 Study (which were not evaluated at the time).
- The evaluation database shows a truncated stop in the claimable new installations of multiple high efficiency water fixtures that leads to the drop in gas savings in 2026. These standards went into effect in 2015 and have a 10-year measure life.
- The evaluation has not yet quantified the impact of the 2016 vintage of Title 24 building codes. Thus, inputs and assumptions for these codes are carried over from the 2019 Study.

Figure 4-62. C&S Electric Savings (Including Interactive Effects)



Source: Guidehouse

Figure 4-63. C&S Gas Savings (Including Interactive Effects)



Source: Guidehouse

Additional versions of Figure 4-62 and Figure 4-63 for each IOU and including peak demand savings can be found in the results viewer, under the Codes & Standards tab.

4.6 COVID-19 Sensitivity Analysis

The impacts of the COVID-19 pandemic on the California economy are far-reaching and not something the 2021 Study can ignore. The default scenario runs described in this section are rooted in data developed pre-pandemic. Thus, the default forecasts inherently assume the pandemic did not affect the economy. A separate set of COVID-19 sensitivity scenarios were run to estimate the effects of the pandemic on the future EE potential.

Table 4-3 provides the electric savings results for three scenarios before and after applying COVID-19 sensitivities. The data provides the change in overall program savings potential (EE, fuel substitution, and BROs). The impact is, at most, about a 2% decrease in potential in 2022 depending on the metric.

Table 4-3. Scenario-Level Comparison After Adjusting for COVID-19 Impacts (Electric Energy Savings)

Unit	Sensitivity	2022	2023	2024	2025
GWh	No COVID-19	832.4	874.6	927.3	971.4
	COVID-19	825.8	869.7	924.4	971.1
	% Difference	0.8%	0.6%	0.3%	0.0%
MW	No COVID-19	199.1	204.7	215.2	221.4
	COVID-19	197.8	203.7	214.6	221.3
	% Difference	0.6%	0.5%	0.3%	0.0%
MMTherms	No COVID-19	35.4	38.6	43.1	45.3
	COVID-19	35.0	38.3	43.0	45.3
	% Difference	1.0%	0.7%	0.3%	0.0%
TSB ($ Millions)	No COVID-19	$750.25	$828.09	$938.75	$1,045.61
	COVID-19	$737.38	$817.84	$931.99	$1,043.32
	% Difference	1.7%	1.2%	0.7%	0.2%

Source: Guidehouse

Details of the COVID-19 sensitivity results are provided in Appendix K.

4.7 Detailed Study Results

Along with the model file and the summary results shown in the previous sections, the Guidehouse team developed an online Tableau dashboard, the 2021 PG Results Viewer. The Results Viewer allows stakeholders to manipulate and visualize model outputs. A separate spreadsheet database of measure-level results for rebate programs is also made available with this release.

Users can look at energy savings, including yearly incremental and cumulative savings over time, as well as their equivalent TSB values. They can also explore the cost-effectiveness of program subcategories and the spending from the utility rebate and BROs programs. The results can be viewed by the following:

- **Savings type:** Electrical energy, peak power demand, and natural gas
- **Utility:** PG&E, SDG&E, SCE, and SCG
- **Scenario:** Multiple scenarios as discussed earlier in this report
- **Sector:** Covers residential, commercial, industrial, agriculture, and mining
- **End Use category:** Includes appliances and plug loads, lighting, HVAC, data centers, building envelope, commercial refrigeration, process heat and refrigeration, oil and gas extraction, water heating, and food service. Whole building and BROs are identified as end-use categories, too.
- **Measure type:** Energy efficiency, fuel substitution, or both

The full results viewer can be found at https://bit.ly/2021PGViewer.

4.7.1 Results Viewer Tabs

The Results Viewer consists of 12 tabs. The Landing Page and Data Definitions tabs give a short overview of the project and provide key definitions used throughout the results tabs. The remaining 10 tabs allow users to view and slice data in a variety of ways, from high level statewide to granular utility and end-use-specific results. Results tabs include the following:

- **Potential by Type:** Detailed data on technical, economic, and cumulative achievable potential from IOU equipment rebate programs. These graphs do not show IOU claimable savings from behavior or C&S advocacy programs because the technical and economic potential for these sources are undefined. BROs is included in the cumulative achievable potential result. Technical potential in this view is based on instantaneous potential, which is defined as the amount of energy savings that would be possible if the highest level of efficiency for all technically applicable opportunities to improve EE were taken. It does not account for equipment stock turnover. Economic potential is the subset of technical potential that is cost-effective under the relevant screening test in each scenario.
- **Potential by Scenario:** Detailed data on incremental and cumulative achievable potential across each of the modeled scenarios. Dimensions include end use, building type, sector, utility, and measure type. Achievable potential includes rebate programs and BROs. This tab does not include C&S savings.
- **Potential Breakdown:** Detailed data showing how different subcategories make up the total potential results. All potential types for all scenarios can be broken down to show their components by end use, sector, utility, or measure type. These results can be further filtered down to provide more specific insights.
- **Cost-Effectiveness:** The cost-effectiveness ratio compares total program benefits to total program costs for the portfolio of forecast measures under the equipment rebate and BROs programs for each scenario. Tests define costs and benefits differently, and all are defined by the California Standard Practice Manual. The four cost tests shown are the TRC, program administrator cost (PAC), participant cost (PCT), and rate impact measure (RIM) tests.
- **Total System Benefit by Scenario:** Detailed data on TSB from the equipment rebate and BROs programs under each scenario. The TSB is the present value of avoided cost less additional supply costs due to measure adoption.
- **Total System Benefit Breakdown:** Detailed data showing the subcategories of the TSB. The TSB can be broken down to show its components by end use, sector, utility, or measure type.
- **Program Costs by Scenario:** Detailed data on utility program costs across the scenarios. Utility program costs includes incentives and non-incentive costs paid for equipment rebate programs and BROs interventions. This data does not include costs associated with non-resource programs or C&S advocacy.
- **Program Costs Breakdown:** Detailed data showing the subcategories of program costs. Utility program costs includes incentives and non-incentive (admin) costs paid for equipment rebate programs and BROs interventions. This data does not include costs associated with non-resource programs or C&S advocacy. Program spending can be broken down to show its components by end use, sector, utility, or incentive type.
- **Codes and Standards Breakdown:** Data showing savings as a result of C&S implemented under three different policy scenarios (on the books, expected, and possible). These savings can be broken down by end use, sector, or utility.

- **Potential Sensitivity:** Data showing how incremental achievable savings varies across two sensitivity tests: COVID-19 impacts and DR impacts. These savings can be broken down by utility and measure type.

Each results tab includes a description of the viewable data, a dynamic chart, and drop-down filters for available chart configuration dimensions. The viewer is illustrated in Figure 4-64 and Figure 4-65.

Figure 4-64. Results Viewer Total System Benefit by Scenario (Illustrative)

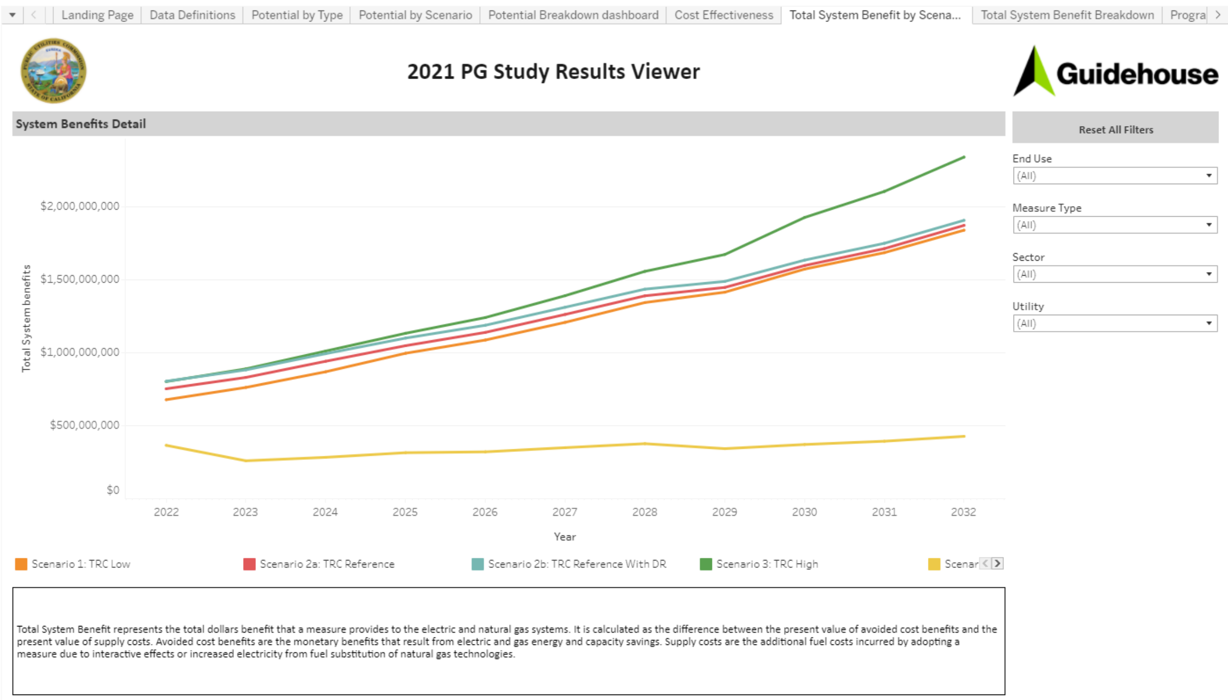
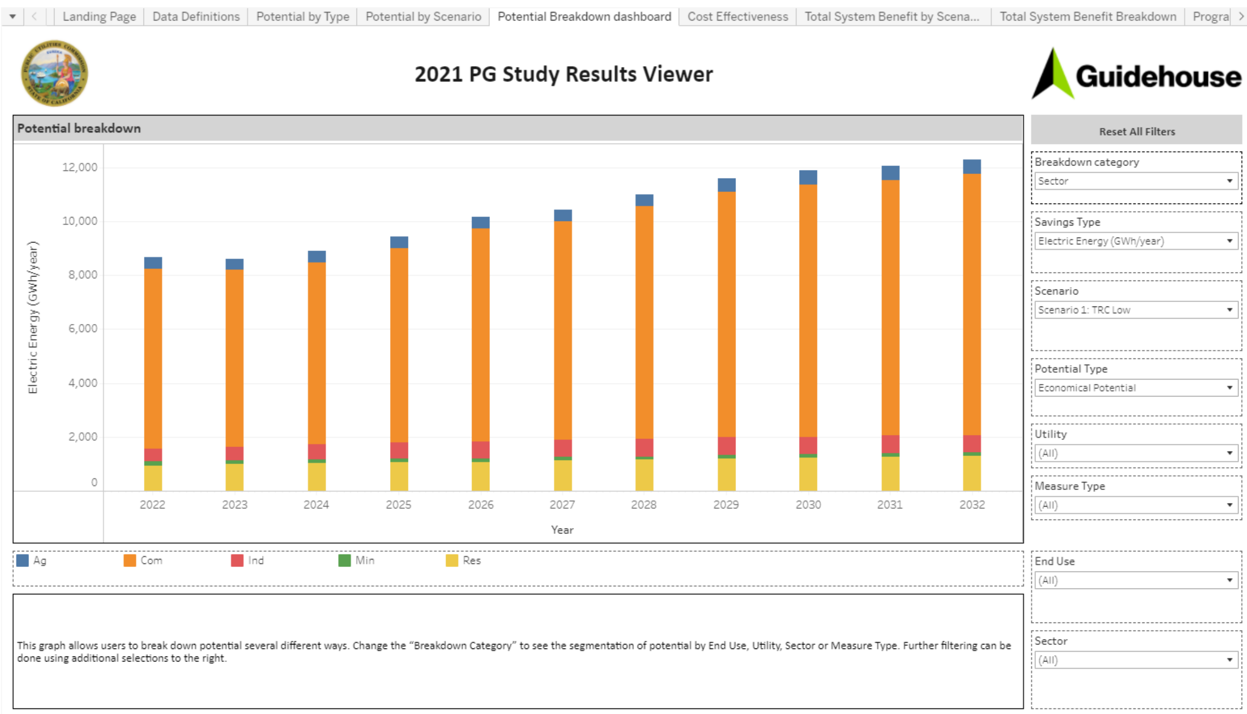


Figure 4-65. Results Viewer Potential Breakdown by Sector (Illustrative)



5. Integrated Resource Planning (IRP) – Energy Efficiency

An IRP[104] is a roadmap for utilities to meet forecast annual peak and energy demand, considering an established reserve margin and other constraints, through a combination of supply side and demand side resources over a specified future period. IRP has historically been the domain of single, vertically integrated utilities. In California, this process is uniquely challenging because electricity is served by multiple LSEs including investor-owned-utilities, community choice aggregators, and competitive retail service providers (referred to as Electric Service Providers), with varying load profiles, resource mixes, and planning and procurement practices. Additionally, the IRP process in California must strike a balance between ensuring program and policy requirements are met by LSEs, while allowing for enough flexibility to use low cost solutions.

In 2018, CPUC staff released a staff proposal including a proof-of-concept technical analysis to explore policy, process and technical challenges and opportunities of optimizing EE as a supply side resource in the IRP.[105] The proposal made several recommendations necessary to support integration. This study is continuing the work of exploring technical alignment between the current EE forecasting approach and IRP competition-based planning.

SB 350, also known as the Clean Energy and Pollution Reduction Act of 2015, mandates the CPUC examine the future of California's energy procurement practices through an IRP process. Traditionally, the CPUC has relied on a long-term procurement planning proceeding to determine the type and quantity of resources California utilities should seek to produce.[106] SB 350 changed the CPUC's resource planning approach in two noteworthy ways. The bill required the CPUC to:

- Identify a portfolio of resources that meets multiple objectives including maintaining reliability, minimizing costs, and reducing GHG emissions (Public Utility Code 454.41).
- Adopt a process for each LSE to file an IRP (Public Utility Code 454.52).

With these requirements in mind, under the proposed IRP process, the CPUC is using a capacity expansion model called RESOLVE from E3 to produce portfolios of resources that are least-cost under a variety of different possible future conditions.[107] The results from RESOLVE inform the development of a Reference System Plan.[108] To date, the CPUC's IRP Reference System Plans have considered EE as a baseline resource (i.e., a resource included in the model as an assumption with a set magnitude rather than being selected by the model as part of an optimal solution). In 2018, the Guidehouse team provided the RESOLVE model EE bundles for optimization analysis. The lessons from that analysis[109]

[104] In this report, the acronym IRP is used to denote either an integrated resource plan or the process of integrated resource planning, depending on the context.

[105] CPUC staff. *Staff Proposal for Incorporating Energy Efficiency into the SB 350 Integrated Resource Planning Process.* September 2018.

[106] https://www.cpuc.ca.gov/irp/

[107] https://www.ethree.com/tools/resolve-renewable-energy-solutions-model/

[108] This plan forms the basis for future analytical work by LSEs to develop their respective LSE plans, which will be reviewed by the CPUC and aggregated into a Preferred System Plan. https://www.cpuc.ca.gov/General.aspx?id=6442463190. See the IRP Staff Proposal for further details on implementing IRP at the CPUC (http://www.cpuc.ca.gov/irp_proposal/)

[109] Navigant, "IRP Technical Analysis: Considerations for integrating Energy Efficiency into California's Integrated Resource Plan – Final Draft," prepared for CPUC, 2018. https://www.google.com/url?client=internal-element-cse&cx=001779225245372747843:e2wnztai65q&q=https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx%3Fid%3D6442464366&sa=U&ved=2ahUKEwjtnrqfzaHvAhVKMVkFHfXjBacQFjAAegQIARAC&usg=AOvVaw2R_HyBGyfE1YoC_MiDDbgz

and the subsequent CPUC staff proposal[110] led to this current effort for a full optimization analysis of EE as a selectable resource in RESOLVE.

There are several key differences between a RESOLVE-based framework used in the IRP analysis, and the TRC framework that is based on the CPUC ACC. The differences yield lower adoption of EE in the current IRP approach relative to what is deemed cost-effective with the integrated distributed energy resource (IDER) ACC approach. If the CPUC moves EE target setting to a RESOLVE-based framework, these differences should be considered, and the approach should be re-tuned to more accurately evaluate EE benefits. Key differences include:

- RESOLVE is a least-cost capacity expansion model. It will only pick candidate distributed energy resources (DER) that are cost-effective on their own. DER programs (including energy efficiency programs), on the other hand, design overall portfolios that are cost-effective, including some measures that are not cost-effective and some measures that are extremely cost-effective.

- RESOLVE is designed with an objective function to meet emissions targets on annual basis. RESOLVE tends to have a low GHG shadow price in earlier years due a tighter Planning Reserve Margin requirement that drives renewables and storage growth, before GHG targets become binding in later years. The IDER ACC uses the 2030 GHG value from RESOLVE and discounts the price forward to 2020 at the utility WACC. This provides higher GHG value in the IDER ACC than the GHG shadow price in RESOLVE.

- The IDER ACC calculates a generation capacity value based on the Net Cost of New Entry of a new storage resource (based on costs and results provided by RESOLVE modeling in the IRP). The IDER ACC further assumes new capacity is needed immediately in part to reflect the state's loading order that prioritizes energy efficiency and treats EE as a preferred resource.

- The IDER ACC uses hourly energy prices produced with Strategic Energy & Risk Valuation Model (SERVM) production simulation (using a No New DER portfolio generated by RESOLVE). In the 2020 IDER ACC model, SERVM produced higher energy prices than the energy values generated by RESOLVE.

- The two models (RESOLVE and SERVM) are fundamentally different and should not be expected to produce similar energy prices.

RESOLVE allows resources to be built with a gradual year-over-year ramp up in production level, but it is not currently tuned to reflect actual industry needs. In practice, resources like EE require consistent investment and continuity over time to be successful. EE resources that are found to be cost-effective in RESOLVE in 2030 or 2045 should be supported by action in the near-term.

5.1 Scope of Technical Analysis

The Guidehouse team leveraged previously developed methodologies and data sources from the 2021 Study to conduct an analysis on optimizing EE for the CPUC's IRP. The overarching objective of this report is to provide a parallel analysis to the standard potential and goals study to allow CPUC staff to assess the option for using the IRP process for EE

[110] CPUC, "IRP Staff Proposal 2017-05-15_FINAL.pdf", 2017. https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442453456

goal setting. This analysis leveraged the 2018 IRP Technical Analysis study's model framework; the Guidehouse team modified the model to accommodate this analysis and uses the 2021 updates. The IRP analysis for the 2021 Study did not include any gas, fuel substitution or EE-DR integration. Fuel substitution is added electric load and the RESOLVE model is not currently configured for this type of analysis. For DR co-benefits, the RESOLVE model uses different inputs to fully characterize the DR valuation.

The IRP integration analysis focused on optimizing EE electric savings from equipment rebate measures and BROs programs through the CPUC's IRP model. Savings from C&S and low income programs remained as baseline (load-modifying) resources in this technical analysis for the following reasons:

- C&S development, while influenced by LSEs, are largely outside the control of LSEs. They are not procured the same way as other demand side resources.
- Low income programs are subject to a different set of regulations than all other demand side resources. They must be offered to IOU customers and are not subject to a cost-effectiveness test.

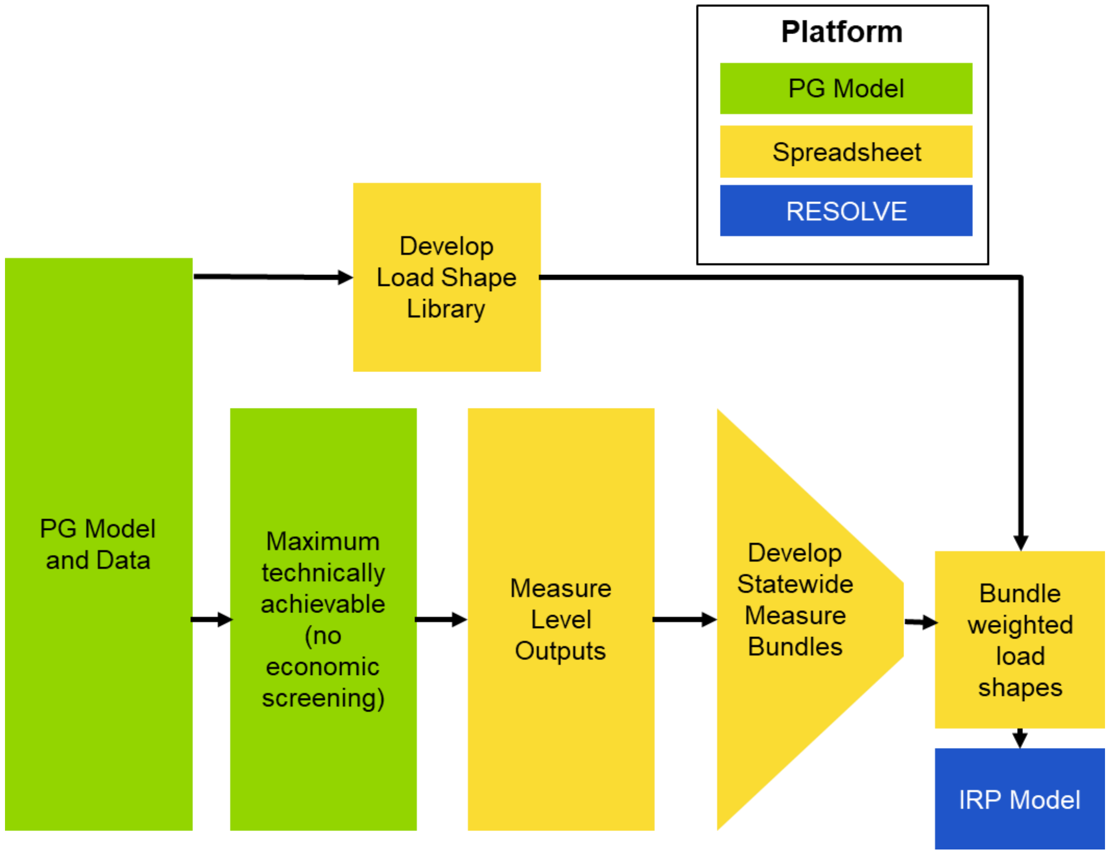
Guidehouse used the PG Model to develop a set of EE supply curves that can feed into the CPUC's IRP model and accept results of the IRP model analysis. The PG Model data output required various data processing steps before passing supply curves to RESOLVE (for pre-processing steps, see). E3 conducted additional pre-processing steps to enable compatibility with RESOLVE. Upon receiving results from RESOLVE, Guidehouse conducted several post-processing steps (see Figure 5-2):

- Guidehouse pre-processing steps:
    - Prepared the PG Model to calculate the maximum technical achievable[111] and extracted required data streams for RESOLVE.
    - Prepared a load shape library to map individual measures to a normalized 8,760 load shape.
    - Prepared measure bundles and associated data required for RESOLVE (savings, levelized cost, bundle load shapes) and additional data required for post-processing (program costs and components of cost-effectiveness tests).
    - Extrapolated 2021 Study forecast from 2032 to 2045.
    - Submitted data to the E3 team.
- E3 pre-processing steps:
    - Required unit conversions for RESOLVE:
        - Savings converted from GWh to average MW (aMW)
        - Levelized cost converted from $/kWh to $/aMW-yr.
        - Hourly load shapes converted from MW to aMW
    - Converted costs from nominal to 2016 $ using a 2% inflation rate.
    - Assumed that the cumulative potential stays flat after reaching its peak value to accommodate the inability to retire resources in the version of RESOLVE used for this study. This step is necessary for a limited number of bundles that show a decline in cumulative potential in earlier years,
    - Mapped annual hourly load shapes onto RESOLVEs 37 model days

[111] The maximum technical achievable is the achievable potential with no economic screening to filter the technical potential.

  - Calculated peak capacity contribution from the hourly load shapes by averaging the load for each measure during summer peak hours[112]
  - Calculated transmission and distribution (T&D) deferral value using hourly data from 2020 avoided cost calculator for climate zone 11 multiplied against each bundle's hourly load shape, converted to $/aMW-yr, and subtracted from the bundle levelized costs.
  - Assumed T&D losses of 7.2%, taken from the avoided cost calculator.
- Guidehouse post-processing steps:
  - Received E3 data (measure bundles adopted and in what year).
  - Disaggregated savings of the selected bundles to each utility and measure.
  - Calculated portfolio cost-effectiveness for the IRP scenario.

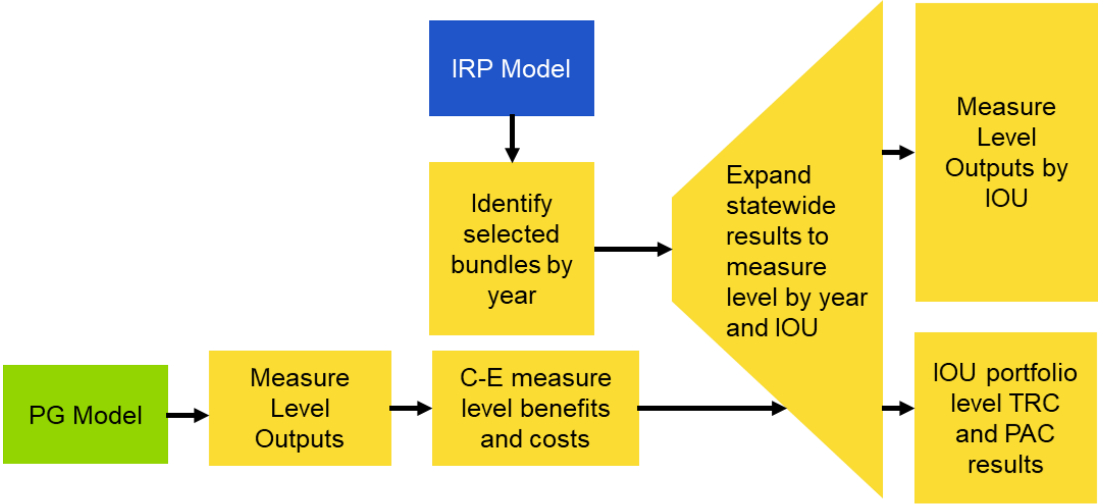
Figure 5-1. Guidehouse Analysis Steps to Pre-Process Data for RESOLVE



Source: Guidehouse

[112] In this study RESOLVE uses the peak capacity contribution to calculate avoided capacity value endogenously, unlike the previous study in which capacity value was calculated exogenously using the avoided cost calculator and subtracted from the capital cost.

Figure 5-2. Guidehouse Analysis Steps to Post-Process Data from RESOLVE



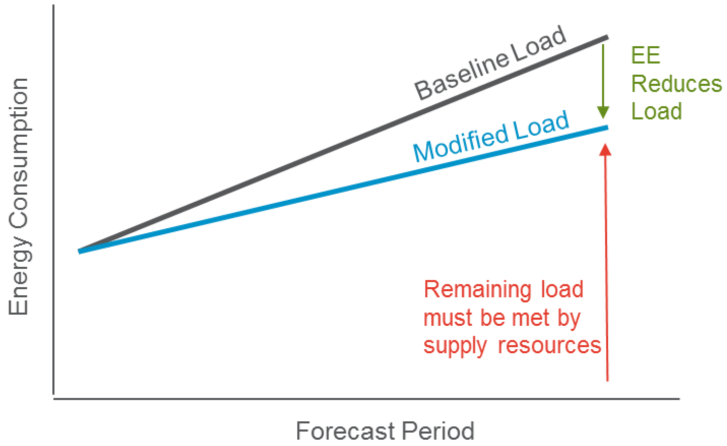
Source: Guidehouse

5.2 Study Methodology – Bundled Supply Curves

This analysis largely uses the same model framework and results as the 2021 Study with modifications made to the study and model methodology to accommodate the IRP technical analysis scope.

The status quo for the Reference System Plan is for EE to be included as a baseline (also referred to as load-modifying) resource. Baseline resources are input to an IRP model as a set value. In the IRP model framework, baseline resources are intended to capture projected achievement of demand side programs under current policy assumptions for resource planning. As Figure 5-3 illustrates, baseline resources act to reduce the baseline load such that the IRP model then optimizes supply resources to meet the remaining (i.e., modified) load. This methodology and associated result files are documented on the CPUC website.[113]

Figure 5-3. Illustration of EE as a Load Modifying Resource.



Source: Guidehouse

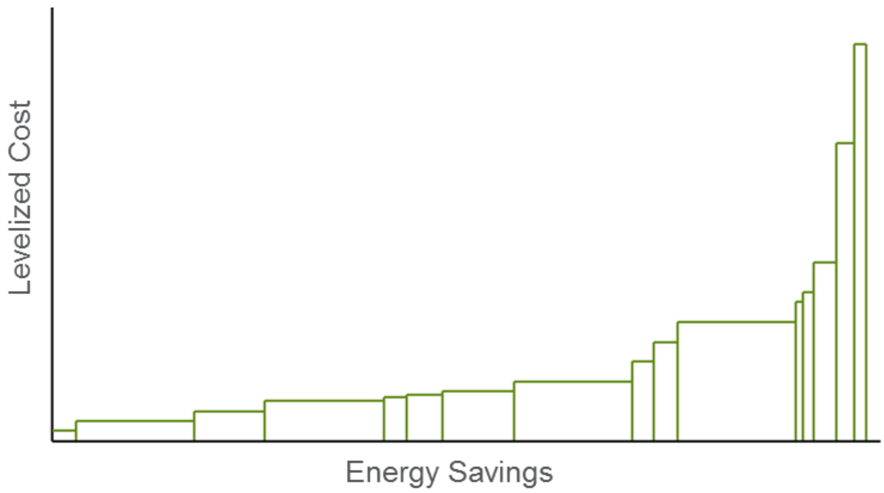
The CPUC is considering a future in which the IRP model attempts to put EE (and potentially other demand-side resources) on equal footing, as much as possible, with supply resources. EE supply curves from the potential and goals study are fed into the CPUC IRP model, and

[113] Proposed Reference System Plan: http://cpuc.ca.gov/irp/proposedrsp/.

the IRP model selects the optimal amount of EE in relation to other resources. The RESOLVE IRP model values each resource using 1) hourly energy, 2) peak reduction and resource adequacy, and 3) avoided T&D. A supply curve is used because different EE technologies have different costs, but the 2021 Study recognizes that the IRP model considers other valuation for the RESOLVE analysis. Some are low cost and are competitive with current conventional supply resources while others are higher cost and may not be competitive until later years.

Supply curves offer a useful way to illustrate the amount of energy savings per dollar spent. A supply curve typically consists of two axes: one that shows the cost per unit of savings (e.g., levelized cost per kWh saved) and one that captures the energy savings at each cost level. The supply curve sorts EE technologies on a least-cost basis[114] and the savings calculated on an incremental basis relative to the EE resources that precede them. Figure 5-4 illustrates a supply curve; each bar in the graph represents a measure with a levelized cost (bar height) and savings potential (bar width).

Figure 5-4. Illustration of an EE Supply Curve



Source: Guidehouse

Supply curves can contain different levels of granularity but are often constructed using bundled efficiency measures. Bundling in this context refers to the grouping of measure-level results into higher levels of aggregation (for example, sector or end use). Bundling measures simplifies the inputs that are required to be fed into the IRP model. Through initial discussions with E3, the Guidehouse team was advised to aggregate EE measures into no more than 30 bundles to allow the RESOLVE model to run efficiently during testing. Each supply curve bundle has an associated weighted average levelized cost, incremental annual and cumulative achievable potential, and hourly load profile, all of which are inputs into the RESOLVE model. It is noted that while RESOLVE selects resources loosely in cost order of supply curve, it also considers load shape, peak impacts and avoided T&D.

To support supply curve development, the 2021 Study provides estimates of maximum achievable potential (achievable potential without any cost-effectiveness screen) along with levelized cost information in the form of bundled supply curves. The RESOLVE model then includes EE as a distributed energy resource in the optimization alongside other distributed energy resources and supply side resources.

[114] Levelized costs were used as the basis for sorting the supply curves.

5.3 Calculating Levelized Costs for IRP

Calculating the levelized cost of conserved energy is an important step and allows the cost of conservation to be compared with other distributed energy and supply side resources in the IRP. In this technical analysis, the bundled supply curves that were developed include estimates of savings and costs. Levelized costs were used as the cost basis for sorting the supply curves. The levelized cost of energy is the discounted present value net cost of each measure over a 20-year planning horizon divided by the discounted present value of energy savings over the same period and shown in Equation 5-1. Consistent with the potential and goals study, net energy savings were used in this analysis.

Equation 5-1. Formula for Computing Levelized Cost of Energy

$$Levelized\ Cost\ of\ Energy = \frac{PV\ of\ Costs}{PV\ of\ Net\ Energy\ Savings}$$

The costs include all cash flows considered in the TRC screening test. These include incremental equipment costs, less any O&M savings,[115] plus any variable program costs. The equipment costs include technology and installation costs. The equipment costs account for inflation on equipment and labor cost, projected cost reductions over time, and changes in incremental cost due to code baseline changes. The program costs include incentives awarded to free riders, administrative costs, marketing costs, implementation (customer service) costs, overhead, and EM&V costs. Information on sources for these costs can be found in Section 3.1.4.

The present value in the levelized cost calculation is computed over a 20-year planning horizon.[116] For measures with lifetimes less than 20 years, the Guidehouse team used a combination of a true cash flow approach and an annuitization approach to calculate the present values. For example, a measure with a 5-year lifetime can be installed exactly four times over a 20-year horizon, and the resulting cash and energy flows repeat exactly four times during the horizon. A measure with an 8-year lifetime can be installed twice during the horizon and receive credit for its full lifetime savings potential each time. To account for the remaining 4 years in the horizon, the costs and benefits over the full measure life are annuitized and assigned to each of the last 4 years. The annuitization step ensures the 8-year measure is not penalized with the full incremental costs when installed in year 17 while only being credited with the final 4 years of benefits.

The above calculation in Equation 5-1 as implemented in the PG Model results in a levelized cost for each measure by service territory (e.g., PG&E), customer segment (e.g., Commercial-Office), and replacement type (e.g., normal replacement). To create statewide supply curves for the IRP, the team calculated an average levelized cost for each measure weighted by the savings projected to occur for each service territory, customer segment, and replacement type. These measure-level costs were then aggregated further to create levelized costs for each of the supply curve bundles, as described in Section 5.4.

A final adjustment to the levelized cost of BROs based bundles was necessary. This adjustment reduced levelized cost to recognize that BROs measures across all sectors save both electric and gas. To fully burden the cost of a measure onto the levelized cost of electricity ends up penalizing the measure in the IRP. It burdens the bundle with an unfairly high levelized cost as it doesn't recognize the gas savings benefits that are produced. For these bundles the calculated levelized cost was reduced by an amount equal to the share of

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[115] No O&M costs were quantified to 2021 Study measures.

[116] Consistent with the CPUC IRP model, the Guidehouse team used the after-tax weighted average cost of capital as the discount rate in this study.

energy savings (in btus) generated by gas vs. electric. Levelized costs were reduced 50-80% depending on the sector.

5.4 Assigning Measures to Bundles

Integrating EE into IRP via the supply curve approach requires that the measures identified as technically viable in the 2021 Study are aggregated into bundles and subsequently input into the IRP Model. Creating EE supply curve bundles for IRP allows for measure-level results to be aggregated for resource planning purposes at an appropriate level of granularity that strikes a balance between capturing bottom-up result detail (e.g., savings and cost trends) and limiting the size of the bundles to keep RESOLVE model run times manageable.

For this analysis, bundles are defined as a group of EE measures with an associated levelized cost (weighted based on individual measure potential savings), incremental annual and cumulative potential savings, and a representative load profile (8,760 format).[117] This bundling approach was selected to reduce the granularity of the data fed into the RESOLVE model.[118]

In aggregating measures into bundles for this analysis, the Guidehouse team focused on the relative affinity of measures in the same bundle to one another. For example, affinity of measures in a bundle might be determined by the sector, end-use, or cost level associated with a measure, the overall load impacts of the individual measures by bundle (i.e., 8,760 load profile), or the likelihood that bundled measures might be included in the same utility program.

The team assured measure affinity within bundles by grouping by a measure's associated sector, end use, or levelized cost. Other metrics of measure affinity, such as overall load impact and potential to be in the same utility program, are likely to be predicated on the measure's sector and end use and are captured by bundling measures this way. Four bundling approaches were considered based on this methodology and are summarized in Table 5-1.

Table 5-1. Bundling Approaches Considered

Bundling Approach	Bundle Description*	Number of Bundles
Sector Level	Measures grouped into bundles according to associated sector.	5†
End-Use Level	Measures grouped into bundles according to associated end use.	12
Sector | End-Use Level	Measures grouped hierarchically based first on sector and second on end use.	22
Sector | End-Use | Cost Level	Measures grouped hierarchically based first on sector, second on end use, and third on levelized cost.	30‡

*Each bundle has an associated weighted cost, achievable potential, and 8,760 load profile.
†Industrial and agriculture are aggregated together for whole facility, BROs, and lighting bundles. All other industrial and agriculture bundles are by sector.
‡Some assumptions and simplifications are employed to limit bundle count.
Source: Guidehouse

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[117] Further methodological discussion on load profiles can be found in Section 5.5.

[118] Based on feedback from E3, Guidehouse was advised to aggregate EE measures into no more than 30 bundles to allow the IRP model to run efficiently.

The sector, end-use, cost level approach in Table 5-1 groups measures hierarchically based first on sector, second on end use, and third on levelized cost. For bundling purposes, measures were defined as having a **high** levelized cost if the individual levelized cost of the measure was higher than the average cost of measures associated with that sector and end use. Conversely, measures were defined as having a **low** levelized cost if the measure had a lower-than-average levelized cost. In some cases, the high/low determination varied based on the level of savings in each bundle and if there was a clear discontinuity in levelized costs between the highest low levelized cost value and the lowest high levelized cost value. After the team bundled measures using this method, some bundles that contributed relatively low potential energy savings were combined to limit the total number of bundles.

5.5 Load Profile Development

The IRP model's ability to compare resources for energy capacity planning and needs is in part predicated on understanding how each resource affects overall system peak. To properly value system peak in a future where the peak time is expected to shift, the Guidehouse team provided a representative 8,760 hourly load profile for each EE bundle as part of this technical analysis.

The team sourced the load profiles from existing public information and prioritized load profiles developed by the CPUC for a load shape library for the IRP analysis. The team acquired the load profiles from a variety of existing data sources:

- 2017 AAEE[119] work
- 2016 EnergyPlus load shapes
- 2010 RASS
- 2011 DEER
- 2020 DEER
- Load shapes provided by California IOUs from a recently completed ADM study for the CEC[120]

The Guidehouse team relied largely on the 2017 AAEE work, which gathered a robust set of load profiles. After identifying a set of usable load shapes, the team:

- Used load profiles that matched each measure in the 2021 Study, where available.
- Substituted a qualitatively close fit profile when a load profile was not available for a specific measure.
- Combined individual load profiles from the appropriate sources (using averages across building types and climate zones) and mapped them to each measure.
- Combined the measure-level load profiles using savings-weighted averages by the defined and mapped EE bundle.

Table 5-2 tabulates the load profile mapping to the EE bundle described. All load profiles are adjusted for the 2018 calendar year.

[119] Wikler, G., Sathe, A., Oztreves, S., and Menon, C. Memo to Jaske, M., Kavalec C., California Energy Commission. *Energy Efficiency Potential and Goals Study: Additional Achievable Energy Efficiency Load Shape Analysis.* 29 January 2016. The load profiles given by IOU in the 2017 AAEE Load Profiles are averaged together (weighted by IOU territory consumption) to obtain the listed representative load profiles.

[120] Baroiant, Sasha, John Barnes, Daniel Chapman, Steven Keates and Jeffrey Phung (ADM Associates, Inc.). *California Investor Owned Utility Load Shapes.* 2019. California Energy Commission.

Table 5-2. EE Bundle and Load Profile Mapping

EE Bundles	Source(s)	Data Year(s)*
Agricultural | Machine Drive	DEER 2011, EnergyPlus 2016	2016
Agricultural & Industrial | Miscellaneous	DEER 2011	2016
Agricultural & Industrial | Behavior	DEER 2013	2016
Agricultural & Industrial | Lighting	DEER 2013, EnergyPlus 2016	2016
High | Commercial | Behavior	EnergyPlus 2016, ADM – CA IOU	2016, 2018
Low | Commercial | Behavior	DEER 2011	2016, 2018
High | Residential | Appliance Plugs	RASS 2010, DEER 2011	2016, 2018
High | Residential | HVAC	DEER 2011	2016
High | Residential | Lighting	DEER 2011, RASS 2010	2016, 2018
Industrial | HVAC	DEER 2011	2018
Industrial | Machine Drive	ADM – CA IOU, DEER 2011, DEER 2020	2016, 2018
Industrial | Process Refrigeration	DEER 2011	2016
Low | Agricultural & Industrial | Lighting	DEER 2011	2016
Low | Residential | Appliance Plugs	DEER 2011, RASS 2010	2016, 2018
Low | Residential | HVAC	DEER 2011, ADM – CA IOU	2016, 2018
Low | Residential | Lighting	DEER 2011	2016
Mining | Oil & Gas Extract	DEER 2011	2016
Residential | Behavior	DEER 2011	2016
Residential | Water Heating	DEER 2020	2017
Residential | Whole Building	DEER 2011	2016
Commercial | Appliance Plugs	EnergyPlus	2016
Commercial | Food Service	ADM – CA IOU	2018
Commercial | Water Heating	DEER 2020	2017
Commercial | Whole Building	DEER 2011	2016
High | Commercial | Refrigeration	DEER 2013	2016
High | Commercial | HVAC	DEER 2011	2016
High | Commercial | Lighting	DEER 2011	2016
Low | Commercial | Refrigeration	DEER 2013	2016
Low | Commercial | HVAC	DEER 2011	2016
Low | Commercial | Lighting	DEER 2011	2016

*Refers to the calendar year of the original data before it was adjusted to match the 2018 RESOLVE calendar year.

Source: Guidehouse

5.6 Data Aggregation and Extraction from PG Model

To create the bundles, the Guidehouse team leveraged the PG Model to export measure-level savings and levelized cost information to a spreadsheet. The measure-level results were then aggregated into the bundles per the approach summarized in Section 5.4. The savings and cost information, along with 8,760 hourly load profiles, were then input to a RESOLVE input template provided by E3, as Table 5-3 summarizes.[121]

Table 5-3. Summary of Input Data Provided to IRP Model

Data Type	Units	Description	Time Horizon
Cumulative Savings	GWh	Year-over-year sustained savings based on installations in prior years starting in 2020, accounting for dual baseline savings, decay, and reinstallations.	2020-2045
Annual Savings Limit	GWh	Annual first-year savings from installations of equipment based on stock turnover. Unlike the 2021 Study, where annual savings are only reported for first-time upgrades to set goals, the annual savings used in this analysis include savings from reinstallations. This is because the IRP model uses annual savings to limit the amount of cumulative EE deployment, which includes reinstallations, over time.	2020-2045
Levelized Cost	$/kWh	Discounted present value net cost of each bundle over a 20-year planning horizon divided by the discounted present value of energy savings over the same period.	2020-2045
8,760 Load Profiles	Fraction	Normalized 2018 calendar year hourly load profiles for each bundle. Drawn from a variety of sources across different original data years (2016-2018), with 2016 and 2017 profiles adjusted such that the dates and weekdays match the 2018 calendar year. For leap years (2016), February 29 is listed as March 1, and December 31 has been removed.	2018

Source: Guidehouse

The PG Model produces results from 2020 to 2032. The Guidehouse team extrapolated the savings and costs out to 2045 using the following assumptions:

- Savings and costs cannot become negative.
- All bundles, except for the list of exception bundles below, extrapolate the savings and cost trends from the previous 3 years.
- Exceptions include:
    - Low EUL measures and residential BROs have no change in incremental and cumulative savings and equal the 2032 savings.
    - The annual savings limit for the following bundles stay at their 2032 savings because the trends for an increase or decrease are uncertain:
        - Agriculture and industrial miscellaneous (includes generic custom and emerging technologies)
        - Agriculture and industrial BROs
        - Commercial BROs

[121] The team provided both cumulative and annual savings values for each of the 30 sector, end-use, cost bundles to the CPUC IRP team to ensure that cumulative savings in the IRP model can be used to set a target value (in 2032) while using the annual savings values as a year-over-year limit of how much EE can be procured.

5.7 RESOLVE Model Output Analysis Methodology

The RESOLVE model calculated outputs for specific forecast years by scenario. The six scenarios in RESOLVE were:

- Reference Storage Cost
    - 46 million metric tons (MMT)
    - 38 MMT
    - 30 MMT
- High Storage Cost
    - 46 MMT
    - 38 MMT
    - 30 MMT

The Guidehouse team provided the RESOLVE model total adoptions (new adoptions and re-adoptions).[122] However, to compare the IRP-produced EE potential estimates to the 2021 Study potential estimates, the team calculated maximum technical achievable potential for the new adoptions only, which reflects the allowable IOU EE program claims. As a parallel step to E3 running the RESOLVE model, the team developed the exact same dataset of supply curves but only using new adoptions. This new adoptions data was then used as the basis for post-processing steps.

In the RESOLVE outputs for the 38 MMT/reference storage cost scenario, the RESOLVE model selected 11 of the Guidehouse team's 30 bundles for adoption. Bundle adoption is not a binary result, as many scenarios adopted fractional bundles. RESOLVE returned energy savings by measure bundle for 8 years (2020-2024, 2026, 2030, and 2045), meaning the team had to interpolate to estimate energy savings in the interim years. After identifying the selected bundles and interpolating the data, the Guidehouse team had a fractional outlay to measure the level of new adoption results. These fractions were then applied to total system benefits, present value costs, present value benefits, and achievable potential. The level of granularity of this data is comparable to that of the 2021 Study, as the annual results were by measure, utility, and climate zone, where applicable.

5.8 Results

E3 modeled EE optimization under the six IRP scenarios mentioned earlier (see Figure 5-5). The RESOLVE model selects which measure bundles should optimally be adopted in each scenario in each year of the optimization. The Guidehouse team translated this information into annual savings forecasts based on the selected bundles and calculated TSB.

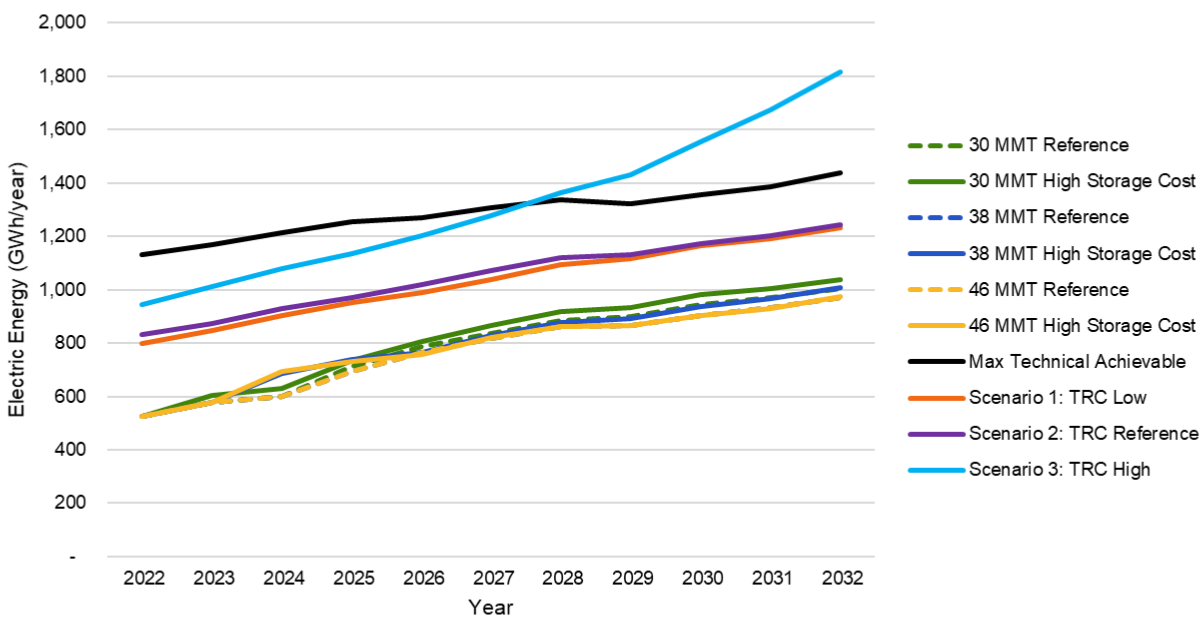
Figure 5-5 shows the annual first-year net electric savings for maximum technical achievable potential (calculated by the PG Model and provided to RESOLVE) alongside the six IRP scenario results and the non-IRP scenarios. The maximum technical achievable potential represents the savings that could be expected if the IRP model selected all 30 bundles as optimal to include. As can be observed, all six scenarios show considerably less savings as

[122] Re-adoptions: Installation of high efficiency equipment that replaces an equally high efficiency piece of equipment at the end of its useful life.

far fewer bundles (ranging from 17 to 18 out of the 30, with low cost residential HVAC being adopted only for the high storage cost scenarios) are selected as optimal. Several additional observations are listed below.

- With the bundle design strategy used in this study, relatively few bundles reside near the margin. This results in far less sensitively than one might expect in the amount of EE selected across different IRP scenarios. In the future, bundles may be more purposefully designed such that more reside near the margin, possibly resulting in greater sensitivity.
- With more aggressive targets for reduced carbon emissions (46 MMT vs. 38 MMT vs. 30 MMT) more clean energy resources are needed. As a result, the IRP model shows increased reliance on EE resources as the carbon emissions targets ratchet down independent of storage costs.
- The IRP assumption of high energy storage costs increases the cost of the resources that compete with EE resources. As other resources become more expensive while EE resource costs remain, there is a shift in the IRP model toward optimally selecting more EE resources. One example can be found in 2024 where the 46 MMT Reference scenario has lower savings than the 46 MMT High Storage Cost scenario. If the bundles had a wider spread between the low and high cost bundles, high storage costs scenarios may have resulted in increased efficiency adoption. With the bundles as designed, the team observes relatively little sensitivity to energy storage cost overall. This may change if bundles were to be redesigned as mentioned above.
- Scenario 3 (a non-IRP scenario) exceeds the maximum technical potential in the later years. This is expected as the IRP analysis used reference program design assumptions, while Scenario 3 uses aggressive assumptions.

Figure 5-5. IRP Scenario Electric Savings (Including Maximum Technical Achievable)



Source: Guidehouse

From these six IRP scenarios, CPUC staff directed Guidehouse to use the 38 MMT reference IRP scenario as the 2021 Study's Scenario 4: IRP Optimized. The biggest differences between Scenarios 1-3 and the Scenario 4: IRP Optimized scenario are that for the IRP analysis:

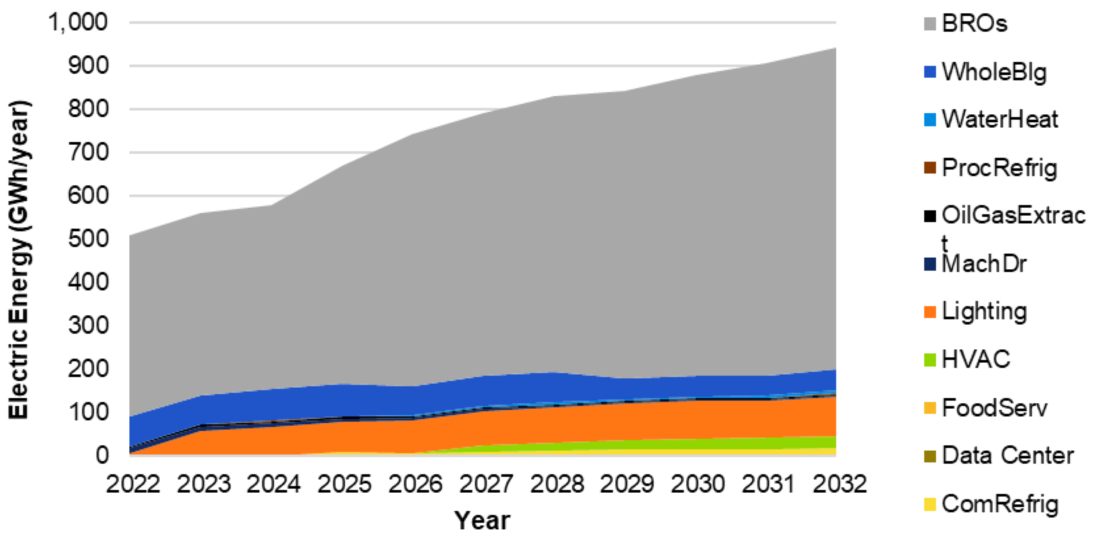
- RESOLVE values each bundle differently based on the profile of savings over the year. The levelized cost is the main driver of selection for the bundles studied as compared to other available resources.
- There is added emphasis on hourly savings because the RESOLVE model optimizes based on cost and by meeting electric resource needs at specific hours of the day and year.

The IRP only analyzes electric resources; therefore, TSB and all other cost and benefit metrics only reflect electric costs and benefits and excludes gas costs and benefits. Scenario 4 is comparable to Scenarios 1-3 when examining electric savings results only (GWh and MW savings). However, when examining costs and benefits, Scenario 4 is not directly comparable to Scenarios 1- to 3. For cost and benefits metrics, the results for Scenario 4 appear far lower because gas resource benefits and costs are not included. Beyond this difference, costs and benefits in Scenario 4 are further reduced compared to Scenario 1-3 due to the lower amount of electric potential selected by the IRP model compared to the other scenarios. For example, in 2022, the TSB for Scenario 4 is $230 million compared to the Scenario 2: TRC Reference at $750 million. Similarly, in 2022, the program cost for Scenario 4 is $99 million compared to the Scenario 2: TRC Reference at $329 million.

One consequence of the methodology for IRP integration is that bundle aggregation may result in a large spread of levelized costs as measures were grouped. The Guidehouse team calculated the weighted average levelized cost of each bundle. The simplification of measure bundles may result in grouping some lower cost measures that may have been adopted when not combined with higher cost measures. For example, the low commercial lighting bundle has measures the range in levelized cost from 0.04 to 0.12 $/kWh while the high commercial lighting bundle ranges from 0.13 to 0.27 $/kWh.

Figure 5-6 shows the Scenario 4: IRP Optimized (38 MMT) scenario electric savings by end use. The adopted end-use mix does not vary significantly across IRP scenarios, as shown earlier in Figure 5-5. Initially, in 2022, the RESOLVE model only selects seven bundles with two more bundles selected in 2025 (commercial water heating and low cost commercial refrigeration). In 2032, RESOLVE selects 17 bundles.[123]

Figure 5-6. 38 MMT IRP Scenario Electric Energy Savings by End Use



[123] It is unknown exactly when the additional savings are adopted because the RESOLVE model provides data for 2031 and 2045. The Guidehouse team conducted a linear interpolation to identify savings in the years between, resulting in savings in 2032 if there are savings in 2045.

Source: Guidehouse

Notable findings on the adopted bundles in the 38 MMT IRP scenario (Scenario 4) relative to Scenarios 1-3 are listed below.

- The IRP selected a higher proportion of BROs compared to EE equipment. This is partly because BROs, on average, have a lower levelized cost. All sectors have BROs savings selected by the IRP scenario.
- In the residential sector, in addition to BROs, the IRP selects whole building programs as optimal. Residential lighting, HVAC, and appliances/plug loads are not selected at all (Scenarios 1-3 do have savings in these areas).
- In the commercial sector, food service and appliance/plug loads are not selected as optimal (Scenarios 1-3 do have savings in these areas). HVAC is selected in 2027 and beyond, and lighting (a large saver in Scenarios 1-3) is selected in 2023 and beyond.

Appendix A. Calibration

A.1 Overview

Forecasting is the inherently uncertain process of estimating future outcomes by applying a model to historical and current observations. As with all forecasts, the Potential and Goals Model (PG Model) results cannot be empirically validated a priori because there is no future basis against which one can compare simulated versus actual results. Despite that all future estimates are untestable at the time they are developed forecasts can still warrant confidence when historical observations can be shown to reliably correspond with generally accepted theory and models.

Calibration refers to the standard process of adjusting model parameters such that model results align with observed data. Calibration provides the forecaster and stakeholders with a degree of confidence that simulated results are reasonable and reliable. Calibration is intended to achieve three main purposes:

- Anchor the model in actual market conditions and ensure the bottom-up approach to calculating potential can replicate previous market conditions.
- Ensure a realistic starting point from which future projections are made.
- Account for varying levels of market barriers and influences across different types of technologies.

The PG Model applies general market and consumer parameters to forecast technology adoption. There are often reasons why markets for certain end uses or technologies behave differently than the norm—both higher and lower. Calibration offers a mechanism for using historical observations to account for these differences.

The calibration process is not a regression of savings or spending (not drawing a future trend line of savings based on past program accomplishments). Rather, calibration develops parameters that describe the customer decision-making process and the velocity of the market based on recent history. Once these parameters are set, the model uses them as a starting point for the forecast period.

The Guidehouse team calibrated the PG Model was based on historical program and market data from 2016 through 2019. Program accomplishments prior to 2016 were judged by the Guidehouse team as too different in terms of the measures offered by programs and the baselines set by code or policy. For the calibration, any new measures or programmatic aspects not present in the historical years were removed from the analysis to maximize the PG Model analysis compatibility to the historical period. For the 2021 Study, this excluded fuel substitution or energy efficiency (EE)-demand response (DR) benefits in the calibrated analysis.

A.2 Necessity of Calibration

SB 350 directs the following: “In assessing the feasibility and cost-effectiveness of energy efficiency savings … the Public Utilities Commission shall consider the results of energy efficiency potential studies that are not restricted by previous levels of utility energy efficiency savings.” This does not imply that a potential study should not be calibrated.

In evaluative statistical models, calibration is called regression, and goodness of fit is typically the main focus because the models are usually simple. In situations of complex dynamics and non-linearity (as in this study), model sophistication and adequacy can become the main focus. However, grounding the model in observation remains equally necessary. The ability of a forecast to reasonably simulate observed data affords credibility and confidence to forecast estimates.

Although data supports all underlying parameters in the PG Model, much of the data is at an aggregate level that can be inadequate to forecast differences across the various classes of technologies and end uses. The incentive costs are a good example of this effect. The model uses incentives to forecast customer purchase tendencies (thus their adoption of technologies) based on the upfront and lifetime cost factors for which customers have self-reported their importance. The incentive inputs read in to the model are provided at the sector and end use level, yet calibration allows our team to scale up and down these inputs by utility to better match historical market activity.

Calibration is not an optional exercise in modeling. One might suggest that the average customer data should be sufficient to make a reliable aggregated forecast. Nevertheless, two important non-linearities compel a more granular parameterization:

- Program portfolios are not evenly composed across end uses, which leads to an uneven weighting issue whereby average customer willingness and awareness may not lead to the correct total savings and costs calculations.
- The dynamics in the model regarding the timing of adoption can become incompatible with the remaining potential indicated by program achievements. For example, if the forecast results were not calibrated for LED lighting in the residential sector, the saturation may remain inaccurately low in early years and indicate a larger remaining potential in future years. Calibrating upward may increase potential in the early years but decrease potential in later years. Without the calibration, the model adoption would imply that in the absence of IOU program intervention, residential LED lighting would have historically had much lower adoption. Calibration allows us to capture these program influences to more accurately reflect remaining potential.

The team treats the calibrated results as the most basic set of interpretable results from which to develop alternate scenarios.

A.3 Interpreting Calibration

Calibration can constrain achievable potential for certain end uses when aligning model results with past IOU EE portfolio accomplishments. Although calibration provides a reasonable historical basis for estimating future achievable potential, past program achievements may not capture the potential because of structural changes in future programs or changes in consumer values. Calibration can be viewed as holding constant certain factors that might otherwise change future program potential, such as:

- Consumer values and attitudes toward energy efficient measures (the Market Adoption Study created the value factors to address this item in the forecast)
- Market barriers associated with different end uses (the Market Adoption Study created the value factors to address this item in the forecast)
- Program efficacy in delivering measures
- Program spending constraints and priorities

Changing values and shifting program characteristics would likely cause deviations from achievable potential estimates calibrated to past program achievements.

Does calibrating to historical data constrain the future forecast? In a strictly numeric sense, yes. If a certain end use is calibrated downward or upward, then future adoption and its timing are affected. Nevertheless, this should not be interpreted as “calibration constrains the level of adoption thought possible.” Rather, calibration provides a more accurate estimate of the rate of technology turnover in the market, current state of customer willingness, market barriers, program characteristics, and remaining adoption potential

One interpretation is that the calibration process creates a floor for the remaining potential. Market barriers, customer attitudes, and program efficacy generally move in the direction of improvement.

A.4 Implementing Calibration

The potential and goals study calibration process primarily seeks to develop a set of consumer decision and market parameters that best represent recent history. Once developed, these parameters are used as the starting point for the PG Model’s stock turnover algorithms and consumer decision algorithms.

Developing these parameters requires historical market data. The PG Model uses 2016-2019 program data (gross savings, program spending data) and performs a backcast to fit model parameters such that historical achievements are generally matched.

The Guidehouse team’s calibrated by reviewing the EE portfolio data from 2016 through 2019 to assess how the market has reacted to program offerings in the past. This method calibrated gross program savings in the PG Model to gross program savings in the 2016-2019 period. After reviewing the gross savings calibration, the Guidehouse team additionally calibrated on the resulting program cost to further tune the incentive levels offered to each end use. In some cases, the first calibration step of gross savings matched the historical gross savings, but the resulting program costs may have been significantly different. This result implies the model overpredicts or underpredicts the sensitivity of customers to rebates. The Guidehouse team further tuned the incentive levels (within their specified scenario caps). Changing incentives would result in a change in gross savings, so an iterative process of adjusting factors to calibrate gross savings and program budget was needed in some cases.

For some sectors and end uses this primary calibration method was not possible because program offerings and the market have significantly changed since 2016 and the PG Model no longer tracked below code technologies (e.g., lighting programs and the baseline change from CFLs to LEDs). When the primary calibration method was not possible, a secondary method was used that focused on tuning saturation and penetration rates of the end use as a whole to market data. For example, RASS 2019 provides data on the saturation of residential LEDs in 2019. This saturation is a more reliable calibration target because it seeds the model with an accurate starting point to assess the potential for future high efficiency LED savings.

To execute calibration, the Guidehouse team adjusted model parameters and compared the backcast of the model against historical program data for 2016-2019. Guidehouse made individual adjustments to three key levers (listed in Table A-1) primarily at the IOU, sector, and end-use levels until achieving a reasonable match with historical data. In some cases where a specific technology witnessed adoption at unexpectedly high or low levels, the team adjusted these levers at the technology level; adjusting at the end-use level in these cases would cause the entire end use to undershoot or overshoot the historical program targets.

Table A-1. Calibration Levers

Lever	Drivers and Impact on Model Results
Awareness	• Increasing initial awareness shortens the time required for a measure to reach 100% consumer awareness and accelerates adoption. • Increasing marketing strength increases the adoption rate of technologies in the nascent stage (i.e., having low initial consumer awareness). • Increasing word of mouth strength increases the adoption rate of technologies in the mid to later stages of adoption (i.e., having medium to high consumer awareness).
Willingness	• Increasing incentive levels increases adoption, budget, and savings. • Overriding a technology’s cost-effectiveness allows it to be considered for adoption (otherwise, non-cost-effective measures are not considered in achievable potential). • Adjusting the weighted utility adjusts the attractiveness of a technology relative to the others in its competition group. • Adjusting the consumer-implied discount rate can account for non-cost-related market barriers that may be higher or lower than normal (only applicable for AIM sectors).
Stock Turnover	• Adjusting turnover rates allows the model to better reflect real-world market dynamics. The model assumes technologies turn over based on effective useful life (EUL). However, the real velocity of the market and turnover dynamics are not this perfect or exact.

Source: Guidehouse

The 2021 PG Model is informed by the Market Adoption Study, which provided data to better model the dynamics of customer willingness. Use of the Market Adoption Study data alone does not itself address calibration. The Market Adoption Study data provided a more accurate starting point for the 2021 PG Model calibration. However, the true value of the Market Adoption Study is in governing the dynamics of customer choice that influence which measures they prefer when presented with multiple competing measures, each with different characteristics. Calibration happens at the IOU, sector, and end-use levels, whereas the Market Adoption Study data influences adoption at a much more granular (measure) level.

Appendix B. Fuel Substitution Data Sources Details

For the first time, the California Public Utilities Commission (CPUC) potential and goals study characterized fuel substitution measures—that is, replacing equipment utilizing one regulated fuel with equipment utilizing another regulated fuel, for example, substituting gas equipment for electric equipment. The characterization process involved the following steps:

1. Select fuel substitution technologies and formulate technology groups.

- The Guidehouse team considered fuel substitution measures in the residential and commercial space heating, water heating, and cooking end uses.
- The team excluded technologies that did not pass the CPUC fuel substitution test (FST) or that did not have a technically suitable, commercially available electric equivalent to the gas technology being replaced.
- The team analyzed fuel substitution technologies in the same technology group as the gas technology being replaced. In other words, a fuel substitution measure replacing a baseline gas technology would compete with the efficient gas technology(ies) that would be a candidate to replace the baseline gas technology.

2. Characterize fuel substitution technologies.

- In most cases, the Guidehouse team characterized the electric technology that would directly replace the gas technology in a one-for-one replacement. Inputs for each technology included energy use, costs, market information, and other relevant fields.
- For fuel substitution measures competing with gas measures in Southern California Edison (SCE)/Southern California Gas (SCG) territory, the team characterized the entire technology group in SCG territory and then assigned gas savings from the fuel sub-measure to SCE.
- For residential HVAC situations where the fuel substitution measure (a heat pump) would replace both a gas appliance (furnace) and an electric appliance (air conditioner, or AC), the team conducted a literature review to estimate what proportion of households would likely replace both appliances with the fuel substitution measure and adjusted the technology group density accordingly.
- For commercial water heaters, the Guidehouse team found no one-to-one replacement of gas to electric equipment covering the same building area, so the team normalized the cost and energy savings on a per-1,000 square foot basis to obtain an equivalent comparison.
- Heat pump water heaters are beginning to increase in prevalence and could undergo market transformation as they are more widely adopted. The team used data from a National Renewable Energy Laboratory (NREL) study to develop cost reduction factors to adjust the cost of heat pump water heaters over the study period, assuming their cost decreases as they become more commercialized.

The following sections discuss the technology selection process and the technology characterization method in further detail.

B.1 Technology Selection Process

The Guidehouse team followed a similar approach to the technology selection process as the other, non-fuel substitution measures but added a screening step to omit any measures that did not pass the FST. As implemented by CPUC Decision 19-08-009, the FST specifies that to be included in an energy efficiency (EE) portfolio, a measure must not increase source energy, and it must not harm the environment (where environmental harm is measured by net CO_2 emissions).[124] The team assumed that measures with active workpapers had already been determined by the CPUC to pass the FST. For measures without active workpapers, the team used the fuel substitution calculator on the CPUC's website to determine whether the measure passed the FST.[125]

Technology groups that did not have a technically suitable, commercially available electric equivalent that could directly replace the gas technology were excluded from consideration. An example is commercial gas boilers. Each electric option for commercial space heating that could replace an existing gas boiler has physical or operational considerations that would discourage a direct replacement:

- Commercial **electric resistance boilers** carry large electrical demands in addition to likely higher operating costs.
- **Hydronic heat pumps, including air-to-water systems and heat recovery chillers,** have supply temperature limitations (140°F-160°F max) that are lower than the design temperatures for many existing steam or hot water boiler heating systems. For fuel substitution of steam or hot water boilers would require a system redesign, which would likely be prohibitive in a normal replacement or accelerated replacement scenario.
- **Central air-to-air heat pumps, variable refrigerant flow systems, water source heat pumps, and ground source heat pumps** would also require an alternative design configuration than the hot water/chilled water distribution systems.

Table B-1 shows the list of fuel substitution technologies characterized in this study, along with the technology group to which each belongs. The technology group often includes the gas designation because the baseline technology is a gas technology. The designation distinguishes these technology groups from those where electric technologies replace baseline electric technologies.

Table B-1. Fuel Substitution Technologies Characterized

Sector	End Use	Fuel Substitution Technology	Technology Group
Residential	AppPlug	Induction Cooking	Res Cooking Appliances
Residential	HVAC	SEER* 18 Heat Pump	Res Central HVAC System Fuel Sub
Residential	HVAC	SEER 18 Heat Pump (Heating Only)	Res Furnace Only Fuel Sub
Residential	Water Heat	Heat Pump Water Heater (Avg 3.09 and 3.31 UEF* - 50 Gal)	Res Gas Water Heaters
Residential	Water Heat	Smart Heat Pump Water Heater (Avg 3.09 and 3.31 UEF - 50 Gal)	Res Gas Water Heaters
Commercial	Food Service	ENERGY STAR Combination Oven	Gas Combination Ovens
Commercial	Food Service	ENERGY STAR Convection Oven	Gas Convection Ovens
Commercial	Food Service	ENERGY STAR Fryer	Gas Fryers
Commercial	Food Service	ENERGY STAR Griddle	Gas Griddles
Commercial	Food Service	ENERGY STAR Steamer	Gas Steamers

124 https://www.cpuc.ca.gov/General.aspx?id=6442463306

125 https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442467181

Sector	End Use	Fuel Substitution Technology	Technology Group
Commercial	HVAC	Com Fuel Sub Packaged Heat Pump	Com Central HVAC System Fuel Sub
Commercial	Water Heat	Heat Pump Water Heater (Avg 3.09 and 3.31 UEF - 50 Gal)	Com Small Gas Water Heaters
Commercial	Water Heat	Smart Heat Pump Water Heater (Avg 3.09 and 3.31 UEF - 50 Gal)	Com Small Gas Water Heaters

**SEER = seasonal energy efficiency ratio; UEF = unit energy factor*

Source: Guidehouse

B.2 Technology Characterization

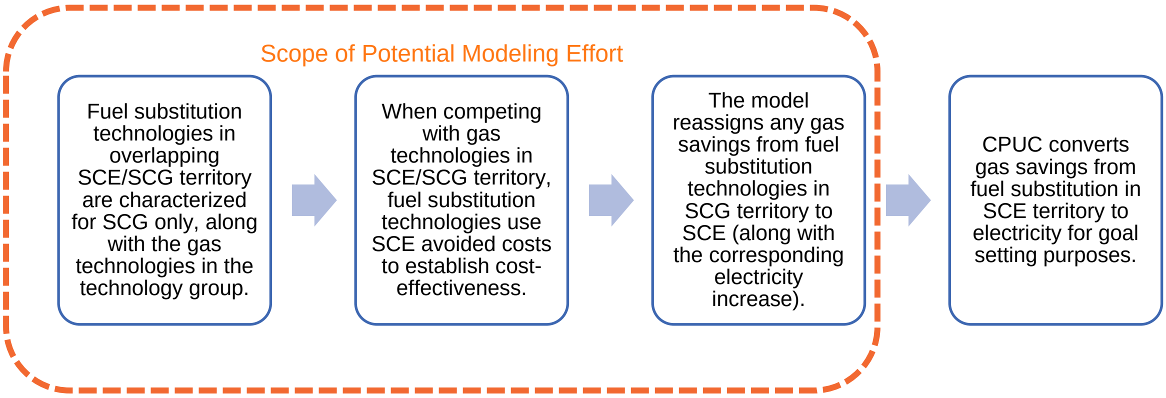
The Guidehouse team characterized fuel substitution technologies and competing technologies within a technology group in the same way. The team developed inputs for each technology; these inputs include energy use, costs, market information, and other relevant fields (see Table 3-9 for a full list of technology characterization inputs). As with non-fuel substitution technologies, the absolute energy use associated with the technology level is specified. Because the fuel substitution technology is specifically substituting gas use with electricity use, the energy use for the fuel substitution level is specified in kilowatt-hours (kWh), while the energy use for the baseline and competing gas efficient technology levels are specified in therms. The model converts all of these energy use values into a common energy metric—Btu—so the technologies can compete on a neutral unit basis.

For customers whose electricity and gas are provided by different utilities (i.e., where SCG is the gas utility and SCE is the electric utility), the Guidehouse team modified the usual approach to allow the gas and electric technologies to compete in the same technology group. Under California policy, when SCE implements fuel substitution programs in areas where the gas service is provided by SCG, SCE is assigned savings by converting the gas savings to electricity savings using a predetermined conversion factor. Within the 2021 study, however, the model needs to account for the competing gas efficient technology, whose gas savings would normally be assigned to SCG. The team implemented the following analysis steps to allow the electric fuel substitution measure to compete with the efficient gas measure.

- **Step 1. Characterization:** The team characterized fuel substitution technology groups as though they were in SCG territory only (not in SCE territory). This was done so the fuel substitution measures could compete with the gas measures.
- **Step 2. Cost-effectiveness analysis:** The team used SCE avoided costs for fuel sub-measures competing with gas measures for the cost-effectiveness analysis.
- **Step 3. Potential modeling:** The model logic reassigns any gas savings from fuel substitution technologies from SCG to SCE with a de-rating factor to account for the proportion of SCG customers whose electricity is provided by utilities other than SCE (primarily Los Angeles Department of Water and Power, or LADWP). The energy savings potential for the study would include a certain amount of gas savings being assigned to SCE.
- **Step 4. Goal setting:** Guidehouse calculated a converted fuel substitution savings to the new fuel units.

Figure B-1. illustrates this step-by-step process for characterizing fuel substitution measures in overlapping SCE/SCG territory.[126]

Figure B-1. Steps in Fuel Substitution Characterization in SCE/SCG Territory



Source: Guidehouse

For most fuel substitution measures, electric technologies replace gas technologies on a one-to-one basis. For example, a commercial gas fryer is replaced by an electric fryer. Two technologies need an alternative approach:

- **Residential furnace replacements:** The heat pump would also be replacing the AC.
- **Commercial water heaters:** In many cases, buildings are served by multiple water heating units. Because of differences in capacity between gas and electric water heaters, there is not necessarily a unit-for-unit replacement, so the team characterized this measure by normalizing the water heater energy to building square footage.

The following subsections detail these technology-specific modifications.

B.2.1 Residential Heat Pump Replacing Residential Furnace and AC Combination

The electric fuel substitution level for residential HVAC—a heat pump—provides heating and cooling, while the gas appliance being replaced provides heating only. For homes with a gas furnace and an electric AC, fuel substitution would involve replacing both the furnace and the AC with a heat pump that provides heating and cooling. This technology group consists of a heat pump competing with an efficient furnace and AC combination, as Table B-2 shows.

Table B-2. Residential Heat Pump Fuel Substitution Technology Group

Technology Name	Fuel Type	Base Year Efficiency Level
Code Furnace and SEER 14 AC	Gas and Electric	Code
Condensing Furnace and SEER 18 AC	Gas and Electric	Efficient
SEER 18 Heat Pump	Electric	Efficient

Source: Guidehouse

The Guidehouse team used the 2019 Residential Appliance Saturation Study (RASS) to determine the proportion of households with both a furnace and an AC that would be eligible

[126] This study does not incorporate incentive and savings alignment to the different incentive offerings that exist. Some fuel substitution programs incur incentive layering. The assessment of allocating savings and incentives to the various fuel substitution programs is outside the scope of this study.

to replace the equipment with a heat pump. The team also assumed that not all households would be willing to replace the whole system—i.e., the gas appliance and electric appliance—at the same time. The team researched information to estimate what proportion of households would be likely replace the whole space conditioning system with a heat pump.

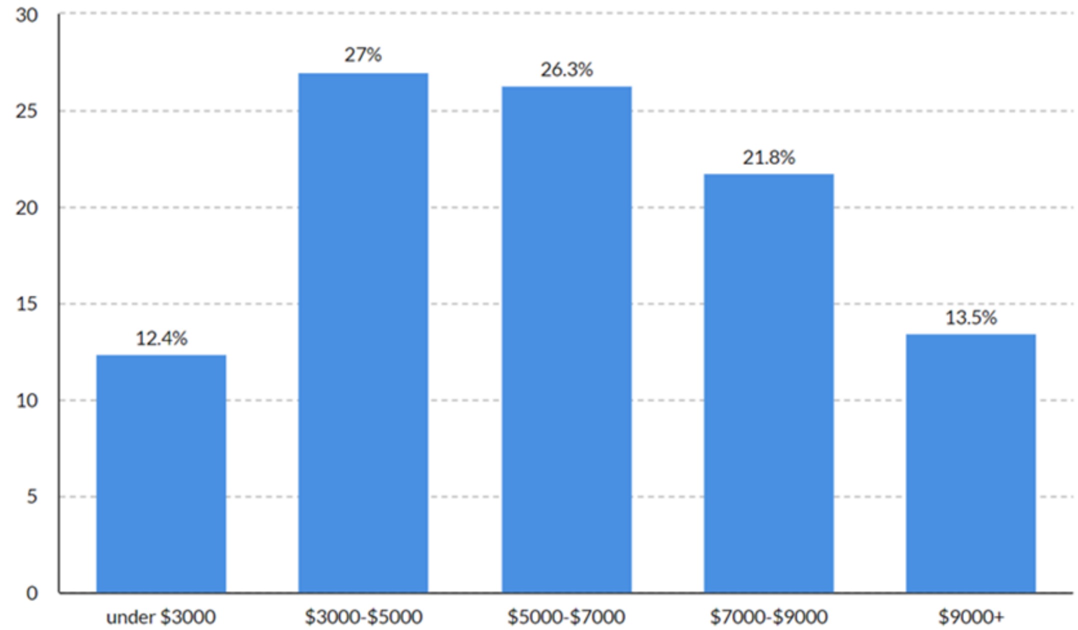
Whole system replacements are the most likely consumer choice when the furnace and AC are at or near the end of their useful life. These projects are generally initiated when either the heating or AC unit fail and it is most practical to replace a component, such as the furnace, indoor coil, and outdoor condenser. Rarely will both the heating and AC units fail at the same time; however, in climate zones where heating and AC systems are each used for long periods every year, they will often fail within a few years of one another. In those cases a whole system replacement makes sense.

The team completed a literature review to assess what percentage of HVAC projects involve component replacements versus whole system replacements.

1. A 2020 survey by PickHVAC[127] surveyed the typical project cost and included a breakdown of what project types are being completed, component versus whole systems, within various project cost categories:
    - Under $3,000: One component was installed or replaced.
    - $3,000-$5,000: One midrange component, perhaps with a thermostat or other accessory, or two entry-level components were installed or replaced.
    - $5,000-$7,000: The homeowner bought one midrange or top tier component and thermostat, two entry-level or small midrange components, or a complete system with a thermostat.
    - $7,000-$9,000: One top tier component, perhaps with an accessory such as a thermostat or media filter, two midrange components, or a complete system was installed or replaced.
    - $9,000+: These sales were either one large, efficient, top tier component or, in more cases, a complete midrange HVAC system.

[127] PickHVAC is a for-profit HVAC advisory service and is a participant in the Amazon Services LLC Associates Program, an affiliate advertising program designed to provide a means for sites to earn advertising fees by advertising and linking to amazon.com. Survey accessed in August 2020 at https://www.pickhvac.com/.

Figure B-2. Distribution of HVAC Projects by Total Project Cost



Source: PickHVAC, 2020

Table B-3 shows two items: (1) the percentage of HVAC projects across the cost bins provided in Figure B-2; and (2) what percentage of each cost bin and the total sales are for whole systems. The estimates for whole systems replacement percentage are based on professional judgement and an estimate of whole system projects as a percentage of all sales.

Table B-3. Whole Systems as a Percentage of All Sales

Cost Bin	% of All Sales	Whole Systems as % of Cost Bin	Whole Systems as % of All Sales
Under $3,000	12.4%	0.0%	0.0%
$3,000-$5,000	27.0%	10.0%	2.7%
$5,000-$7,000	26.3%	33.0%	8.6%
$7,000-$9,000	21.8%	66.0%	14.5%
$9,000+	13.5%	90.0%	11.7%
Total	**100%**	**37.5%**	**37.5%**

Source: Tierra Resource Consultants

2. The *2014-16 HVAC Permit and Code Compliance Market Assessment*[128] reviewed effective useful life (EUL) values by climate region and equipment type, as Table B-4 summarizes; Figure B-3. shows the geographic regions defined in the study. Table B-4 indicates that the EUL of AC systems and furnaces is roughly the same in the South Coast region, while furnaces in the North Coast have EULs that are 57% of the AC EULs, likely the result of longer annual run hours due to the colder climate. In contrast, all inland regions have furnace EULs that exceed the AC EUL, but the extent varies by location. The average inland EUL is 14 years for AC systems and 22 years for furnaces.

[128] Final Report: 2014-16 HVAC Permit and Code Compliance Market Assessment (Work Order 6) Volume I – Report

California Public Utilities Commission. DNV-GL, September 22, 2017. CALMAC Study ID: CPU0172.01. Contract #12PS5119 (HVAC WO6)

Figure B-4. illustrates the differences in AC and heat pump EULs by the study climate regions defined in Table B-4.

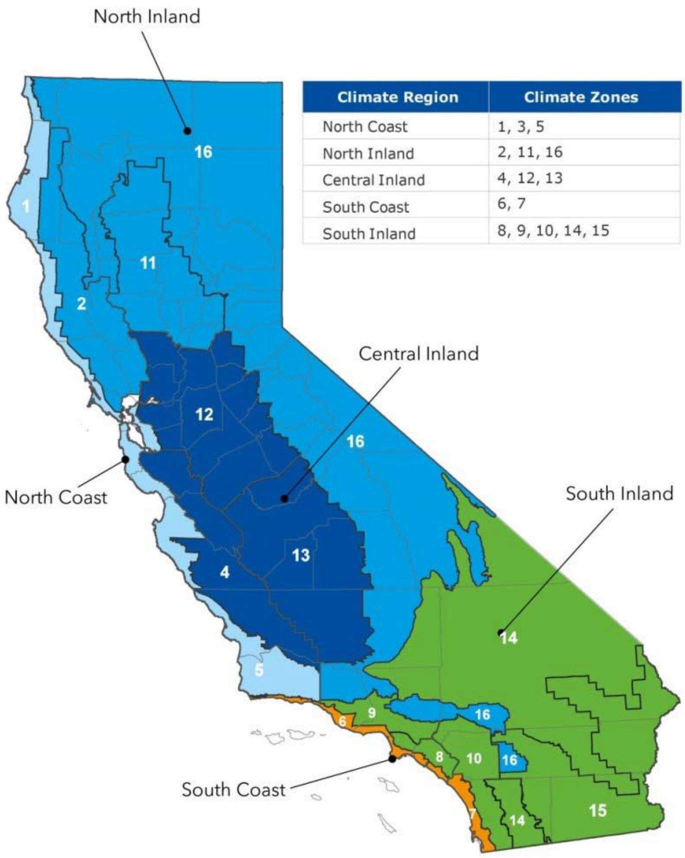
Table B-4. EULs by Climate Region and Equipment Type

Region	Central AC EUL	Central Natural Gas Furnace EUL	Ratio (Furnace EUL/ AC EUL)
North Coast: CZ 1, 3, 5	30	17	0.57
North Inland: CZ 2, 11, 16	16	17	1.06
Central Inland: CZ 4, 12, 13	14	23	1.64
South Coast: CZ 6, 7	21	19	0.90
South Inland: CZ 8, 9, 10, 14, 15	11	27	2.45

CZ = climate zone

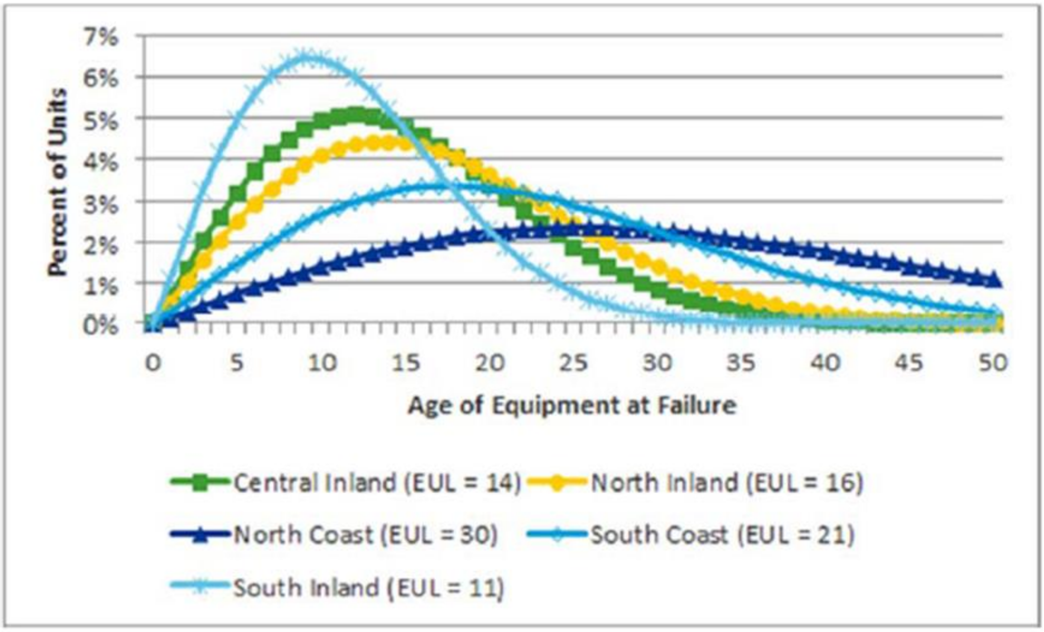
Source: DNV GL, 2017

Figure B-3. HVAC Permit and Code Compliance Market Assessment Climate Regions



Source: DNV GL, 2017

Figure B-4. Probability Distribution of Lifetimes for Central ACs and Heat Pumps



Source: DNV GL, 2017

The 2014-16 HVAC Permit and Code Compliance Market Assessment study also reviewed the permitting records on 196 HVAC changeout projects for the 2008 and 2013 code cycles. The study completed onsite inspections for two climate regions: a coastal region comprising climate zones 1, 3, 5, 6, and 7, and an inland region comprising climate zones 2, 4, and 8-16. The final sample of 196 inspections contained 143 installations in the inland region and 53 in the coastal region. Because this was a random sample of actual permitted projects, this analysis is considered representative of broader market characteristics for HVAC replacements. Table B-5 contains analysis of data provided in the *2014-16 HVAC Permit and Code Compliance Market Assessment* on the distribution of HVAC system type by climate region[129] and compares the sample HVAC system distribution by the coastal and inland climate regions. Overall, 65% of replacements projects included heating and AC components. This result varies by area, with 36% of coastal projects being full system replacements versus 76% of inland projects.

[129] Final Report: 2014-16 HVAC Permit and Code Compliance Market Assessment (Work Order 6) Volume I – Report
California Public Utilities Commission. Table 14. Distribution of HVAC system type by climate region.

Table B-5. Distribution of HVAC Replacements by System Component and Climate Region

System Type	Coastal	Inland	Total
Both heating and cooling components	19	109	128
Cooling component only	3	8	11
Heating component only	31	26	57
Total Onsite	**53**	**143**	**196**
% Both heating and cooling components	36%	76%	65%
% Cooling component only	6%	6%	6%
% Heating component only	58%	18%	29%
Total %	**100%**	**100%**	**100%**

Source: Tierra Resource Consultants

Based on component EUL discussed in Table B-4, Table B-6 illustrates the relationship between system EUL and the probability that heating or AC component replacement align by study region and corresponding climate zone. Where a heating or AC EUL do not align, there is a low probability that a full system replacement will occur. Conversely, when the component EULs align, there is a high probability that a full system replacement will occur, offering the best opportunity to convert a gas furnace to a heat pump.

Table B-6. Component EUL Comparison and Probability of System Replacement Alignment

Region	Ratio (Furnace EUL/ AC EUL)	Observation	EUL Alignment	Likely Project Type
North Coast: CZ 1, 3, 5	0.57	Furnace has a shorter EUL than the AC and is replaced more frequently	Low probability of alignment between furnace and AC EULs	Higher probability of a furnace-only project
North Inland: CZ 2, 11, 16	1.06	Furnace has approximately the same EUL as the AC and is replaced with the same frequency	High probability of alignment between furnace and AC EULs	Higher probability of whole system project
South Coast: CZ 6, 7	0.90			
Central Inland: CZ 4, 12, 13	1.64	Furnace has a longer EUL than the AC and is replaced less frequently	Low probability of alignment between furnace and AC EULs	Higher probability of an AC-only project
South Inland: CZ 8, 9, 10, 14, 15	2.45			

CZ = climate zone

Source: Tierra Resource Consultants

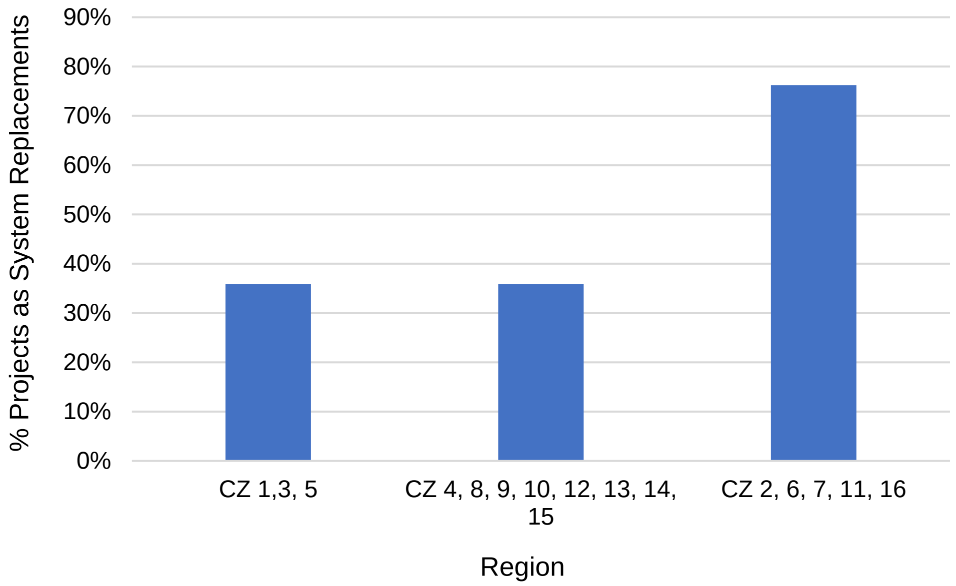
Using the component EUL comparison and probability of system replacement alignment discussed in Table B-6 and the distribution of HVAC replacements by system component and climate region discussed in Table B-5, Table B-7 provides the Guidehouse team's recommended distribution of projects types by region. Figure B-5 graphically represents the percentage of projects that are system replacements as listed in Table B-7.

Table B-7. Probable Project Type by Region

Region	System	Component
North Coast: CZ 1, 3, 5	36%	64%
North Inland: CZ 2, 11, 16 South Coast: CZ 6, 7	76%	24%
Central Inland: CZ 4, 12, 13 South Inland: CZ 8, 9, 10, 14, 15	36%	64%

CZ = climate zone
Source: Tierra Resource Consultants

Figure B-5. Percentage of Projects as Whole System Replacements by Region



CZ = climate zone
Source: Tierra Resource Consultants

Table B-8 maps the percentage of system versus component replacements discussed in the previous tables and figures to the climate regions analyzed in the 2021 Study.

Table B-8. System vs. Component Replacements for Residential HVAC Fuel Substitution by Climate Region

Climate Region	System Replacements	Component Replacements
SCE-Marine SCG-Marine SDG&E-Marine SDG&E-Hot-Dry	76%	24%
All others	36%	64%

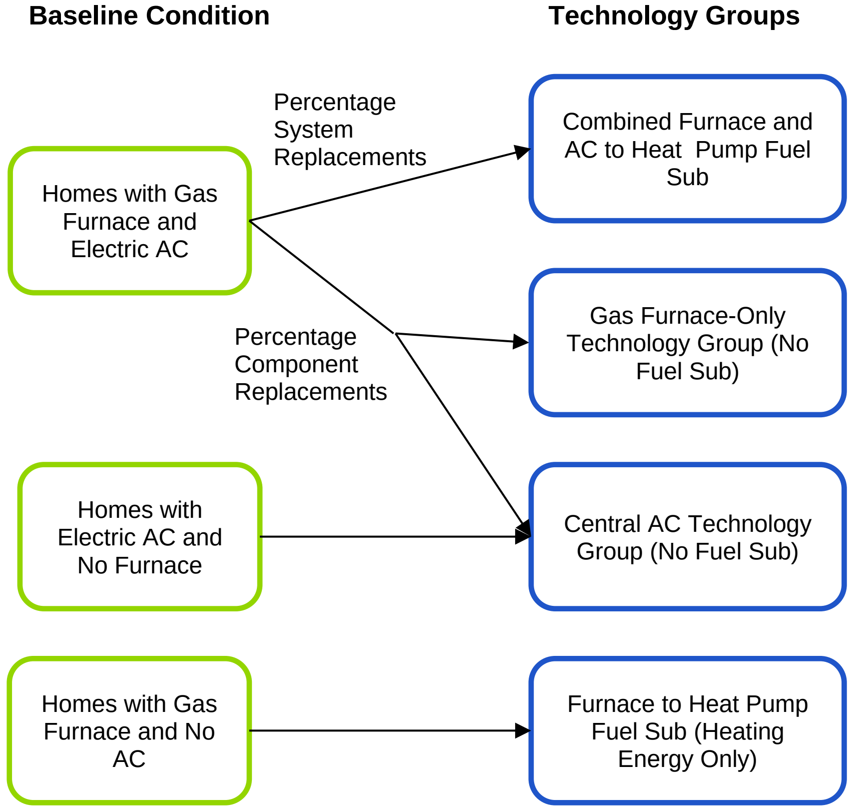
Source: Guidehouse

These percentages influenced the density of the residential HVAC technology groups. The technology group that consists of a heat pump replacing the furnace and AC combination (shown in Table B-2) would apply to all households with both a furnace and an AC multiplied by the percentage of households undergoing whole system replacements (shown in Table B-8—e.g., 76% in the SDG&E-Marine climate region). The remaining percentage of households would undergo component replacements; the components are characterized separately in furnace-only or AC-only technology groups.

In this approach, the furnace-only technology group is separate from the furnace-only fuel sub-technology group. The latter applies in cases where homes have a gas furnace but no AC. For homes with a gas furnace only, the electric heat pump competes with the efficient gas appliance. Although a heat pump provides heating and cooling, introducing an additional cooling load where there was none before, per guidance from the CPUC, the team only considered the heating energy from the heat pump when comparing energy use across the technology group. However, the full cost of the heat pump compared to the full cost of the baseline technology is included in the characterization.[130]

Figure B-6. illustrates how the various scenarios are distributed among the relevant residential HVAC technology groups.

Figure B-6. Distribution of Residential HVAC Scenarios among Technology Groups



Source: Guidehouse

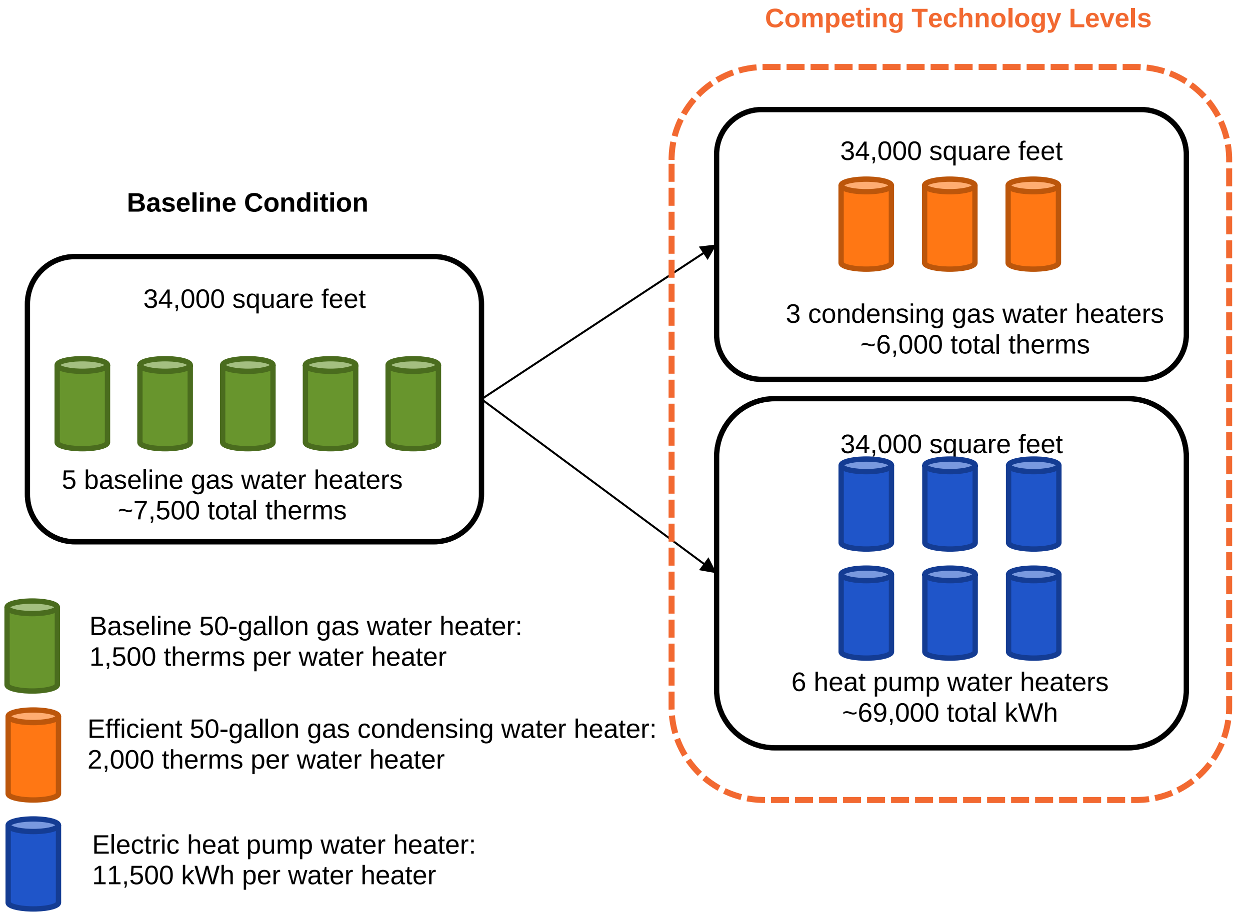
B.2.2 Commercial Water Heating

Electric appliances typically replace gas appliances on a one-for-one basis. Commercial water heaters, however, do not necessarily follow a unit-for-unit replacement, so the team characterized this measure by normalizing the water heater energy to building square footage. The team characterized commercial water heaters using the 2020 Database for Energy Efficient Resources (DEER) Water Heater Calculator.[131] The water heater calculator determines the water heating energy used in the DEER building types for various types of water heaters, including gas water heaters and electric heat pump water heaters. The calculator first calculates the required water heating load for an example building and then determines the number of water heaters necessary to serve the load. This number varies depending on the type of water heater being installed, meaning that fuel substitution for

[130] Conversation with CPUC on October 21, 2020.
[131] Available at http://www.deeresources.com/index.php/23-deer-versions

water heaters is not a simple one-for-one unit replacement. Figure B-7. illustrates the water heater replacement for an example building. In this example, six heat pump water heaters compete against the three condensing gas water heaters needed to provide hot water for the same 34,000-square foot building.

Figure B-7. Commercial Water Heater Technology Levels – Illustrative Example



Source: Guidehouse

To fairly compare the competing technologies, the team normalized the water heating consumption to the building area on a per-1,000 square foot basis. Table B-9 illustrates this process for the example outlined in Figure B-7.

Table B-9. Normalization of Energy Consumption for Commercial Water Heaters – Illustrative Example

Efficiency Level	Total kWh/ Building	Total therms/ Building	Sq. Ft. of Building	kWh/ 1,000 Sq. Ft.	Therms/ 1,000 Sq. Ft.
Baseline gas	0	7,500	34,000	0	220
Efficient gas	0	6,000	34,000	0	176
Electric heat pump water heater	69,000	0	34,000	2,029	0

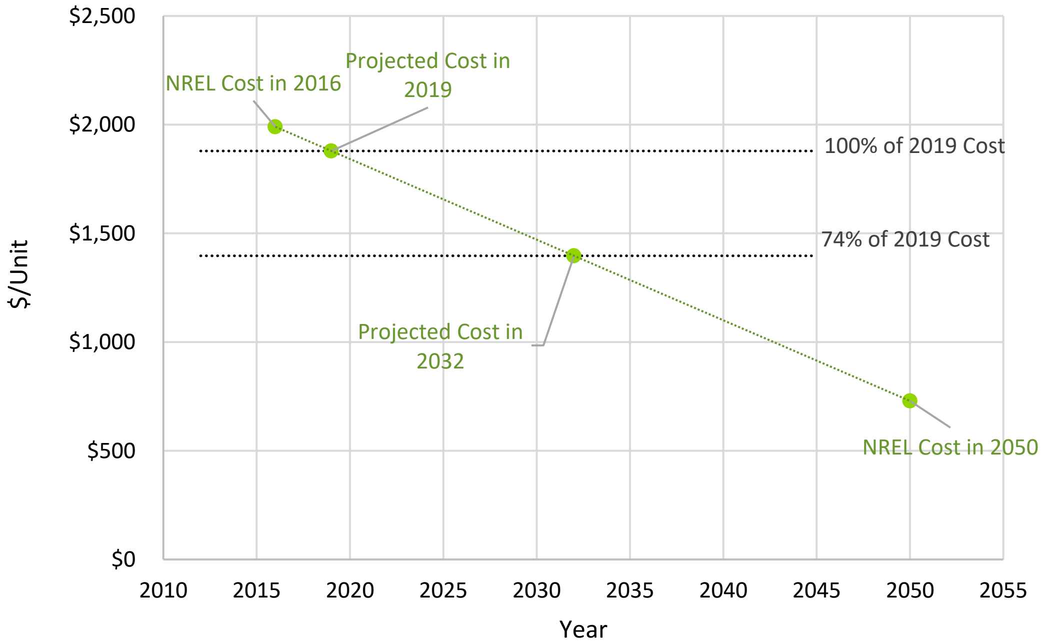
Source: Guidehouse

B.2.3 Heat Pump Water Heater Costs

The Guidehouse team assumed a constant technology cost through the study period (adjusted for inflation) for most measures. For heat pump water heaters, the team developed cost reduction vectors for residential and commercial products because this is an emerging technology with few products currently on the market. However, the technology has the potential to undergo market transformation as it is more widely adopted.

The team adapted cost reduction factors from a 2019 NREL Study.[132] NREL estimated residential and commercial heat pump water heater costs in 2016 and 2050 for three scenarios: slow advancement, moderate advancement, and rapid advancement. For this analysis, the team used the moderate advancement scenario and linearly interpolated the costs to find the NREL-estimated cost in 2019-2032 (the 2021 Study's analysis period). By calculating the ratio of the NREL equipment costs from 2020 to 2032 versus the 2019 cost, the team produced cost multiplier ratios. These ratios produced a set of percentages from 2019 to 2032, which the PG Model then applied to the 2019 measure cost in the technology characterization to obtain the equipment cost in a particular year. The team used the ratio methodology rather than the costs directly from the NREL paper because of differences in source data (the measure cost in 2019 was based on workpapers and was more recent than the NREL numbers). Figure B-8. , Figure B-9., and Table B-10 illustrate how the team calculated the cost multiplier ratios from interpolating between the NREL costs in 2016 and 2050.

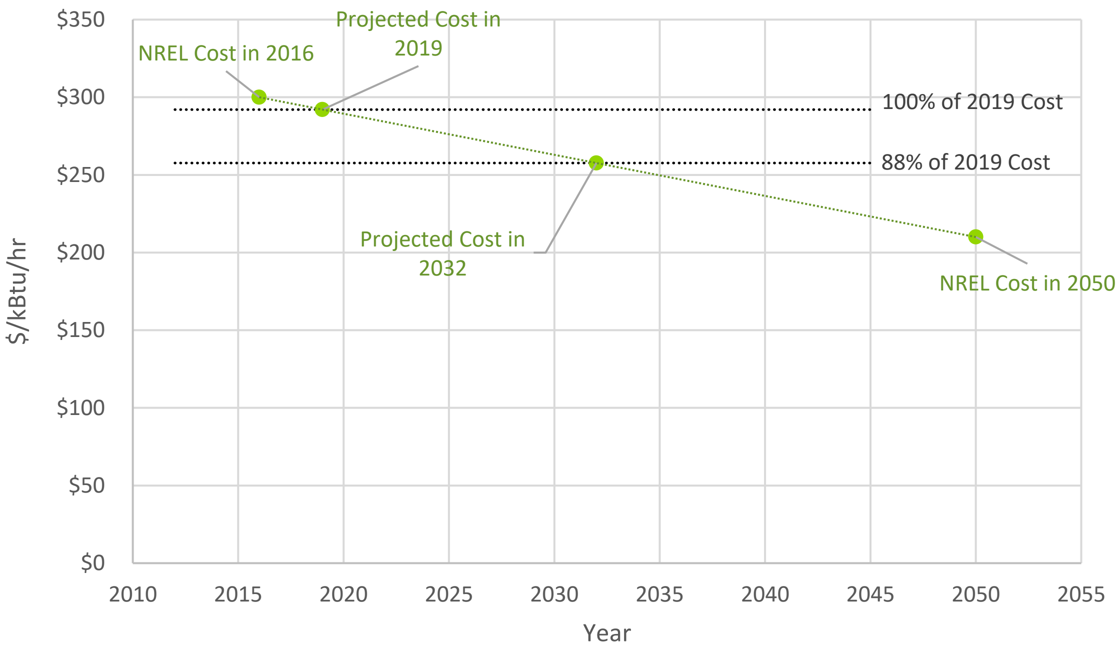
Figure B-8. Calculation of Cost Trajectory for Residential Heat Pump Water Heaters



Source: Guidehouse analysis of NREL study

[132] NREL Electrification Futures Study: End-Use Electric Technology Cost and Performance Projections through 2050. https://www.nrel.gov/docs/fy18osti/70485.pdf

Figure B-9. Calculation of Cost Trajectory for Commercial Heat Pump Water Heaters



Source: Guidehouse analysis of NREL study

Table B-10. Cost Multipliers for Heat Pump Water Heaters

Year	Residential Heat Pump Water Heater	Commercial Heat Pump Water Heater
2019	1.00	1.00
2020	0.98	0.99
2021	0.96	0.98
2022	0.94	0.97
2023	0.92	0.96
2024	0.90	0.95
2025	0.88	0.95
2026	0.86	0.94
2027	0.84	0.93
2028	0.82	0.92
2029	0.80	0.91
2030	0.78	0.90
2031	0.76	0.89
2032	0.74	0.88

Source: Guidehouse analysis of NREL study

B.3 Approach for Fuel Substitution Cost-Effectiveness Analysis

The fuel substitution analysis follows the cost-effectiveness calculations that require addressing the increase in supply costs. Fuel substitution measures value both the gas savings (a positive benefit) and the increased electricity supply cost (a negative benefit). Fuel substitution measures are assigned to the IOU that serves the new load. Fuel substitution for dual fuel utilities (PG&E and SDG&E) is straightforward in the 2021 Study because the model assumes the customer is not shifting revenue from one utility to another when making the switch.

This matter is far more complicated when dealing with gas technologies in SCG territory being replaced by electric technologies. SCG territory overlaps mostly with SCE territory. However, there is overlap with publicly owned utilities (e.g., LADWP), Pacific Gas and Electric (PG&E), and even San Diego Gas & Electric (SDG&E). The Guidehouse team made a simplifying assumption that for each SCG fuel substitution replacement 64% of that occurs in the territory overlapping with SCE and is subsequently tracked in the model. The remaining 36% is not tracked further. The reason the team only tracks SCG to SCE substitution is because valuing cost-effectiveness and increased supply cost is far simpler when dealing with just two utilities and two sets of avoided costs (one gas and one electric).

Appendix C. BROs

This appendix discusses the BROs interventions included in the PG Model. It describes each intervention and discusses data sources and assumptions. A separate spreadsheet is also made available for stakeholders to review the final detailed inputs for each intervention specific to each utility and building type.

C.1 Residential – Home Energy Reports

C.1.1 Summary

Home energy reports (HERs) are among the most prevalent and widely studied behavioral interventions and are the largest source of behavior-based savings in California. Residential customers are periodically mailed HERs that provide feedback about their home's energy use, including normative comparisons to similar neighbors, tips for improving energy efficiency (EE), and occasionally messaging about rewards or incentives. HER programs are generally provided to customers on an opt-out basis, although utilities in other states have conducted opt-in programs.

Estimated electric savings range from 1.0% to 1.5%, while gas savings are 0.7%-1.7%. Costs are set at $0.06-$0.10 per kWh and $1.22-$1.77 per therm.[133,134]

Table C-1. HERs – Key Assumptions

Sector	Type	EUL Years	Savings		Cost		kW/kWh Savings Ratio
			kWh	therms	kWh	therms	
Residential	HERs	1	1.0-1.5%	0.7%-1.7%	$0.06-$0.10	$1.22-$1.77	0.000221 – 0.000263

Source: Guidehouse

C.1.2 Assumptions and Methodology

Eligibility and Participation

Although all targeted residential households may receive HERs as participants in an opt-out program, Pacific Gas and Electric (PG&E) found that 0.5% of customers elect to opt out. For this reason, the Guidehouse team reduced applicability to 99.5% for single-family homes. The team applied this assumption to all IOUs as similar utility-specific data was not available. The team reduced the applicability for multifamily homes by 10% to 89.5% based on an ACEEE study that found an average of 10% master-metered multifamily buildings across 50 metropolitan areas across the country.[135] SCE provided data indicating that only 0.17% of its multifamily customers are master metered, so the applicability in its territory remains higher at 99.33%. The applicability factor adjustment applies to the targeted treatment population; the PG Model assumes a separate control population is still required for evaluation purposes.

[133] PG&E and San Diego Gas & Electric (SDG&E) costs are split across electric and gas fuel types.

[134] Savings and cost ranges are based on 2013-2018 impact evaluations and CEDARS data (2016-2020).

[135] Kate Johnson and Eric Mackres, *Scaling up Multifamily Energy Efficiency Programs: A Metropolitan Area Assessment*, Report Number E135, March 2013, American Council for an Energy Efficient Economy, from http://www.prezcat.org/sites/default/files/Scaling%20up%20MF%20Energy%20Efficiency%20Programs_0.pdf

While participation rates in HER programs fluctuate over time due to program opt outs and attrition, customer moves, and changes in program implementation such as adding new waves, specific forecasts require details beyond those publicly available via investor-owned utility (IOU)-filed rolling Business Plans. For this reason, the Guidehouse team reviewed all formal California IOU evaluations of HER programs to ascertain historical participation rates and wave sizes. The team then applied a weighted average of wave sizes to forecast the future cohort waves according to the number of households within a given service territory. The 2019 Study included results from formal impact evaluations through program year (PY) 2015. For the 2021 Study, the Guidehouse team added data from the PY2016, PY2017, and PY2018 impact evaluations.[136, 137, 138]

The forecast uses a cap of 60% on the penetration of HERs based on the following considerations:

- Feedback from previous potential and goals studies noted that the bottom quartile of energy consumers will not be targeted for cost-effectiveness reasons.
- Not all of the remaining 75% of customers can be targeted because some need to be reserved as a control group for evaluation purposes. The PY2018 evaluation shows that the ratio of treatment customers to control group customers ranges from approximately 3:1 to over 6:1. The Guidehouse team assumed a 4:1 ratio.[139]

The PG Model applies these projected penetration rates to the number of forecast IOU households, which increases over time from 2018 to 2032, resulting in an increase in the absolute number of actual HER participants over time. Penetration is modeled using a linear growth rate rather than an exponential compound annual growth rate (CAGR) to better reflect the observed rollout of the program over the evaluated years.

Savings

The Guidehouse team reviewed the impact evaluations of all IOU HER programs to compile per-household adjusted savings rates for each wave of each year of each HER program, spanning from 2011 to 2018, depending on each utility's first year of operation. The team then calculated weighted averages using each individual wave treatment participation numbers and per-household savings percentages to derive singular values for kilowatt-hour (kWh) and therm savings that can be applied across the full treatment populations for each utility. Informal comments from stakeholders suggest that future HER customers will save less energy on average than current waves because the customers with the highest potential for savings participated in early program years.[140] This effect is captured in the weighted HER savings rates to the extent that impact evaluations have shown declining savings values over time.

[136] DNV GL. May 1, 2019. Impact Evaluation Report: Home Energy Reports – Residential Program Year 2016. California Public Utilities Commission. CALMAC Study ID: CPU0190.01.

[137] DNV GL. May 1, 2019. Impact Evaluation Report: Home Energy Reports – Residential Program Year 2017. California Public Utilities Commission. CALMAC Study ID: CPU0194.01.

[138] DNV GL. April 16, 2020. Impact Evaluation of Home Energy Reports: Residential Sector – Program Year 2018. California Public Utilities Commission. CALMAC Study ID: CPU0206.01.

[139] The 2019 Study assumed a 1:1 treatment to control group ratio, which led to a penetration cap of 37.5%. Wave size data from the PY2016, PY2017, and PY2018 data no longer supports this 1:1 ratio assumption.

[140] Stakeholder comments from 2019 Study May 9, 2019 stakeholder meeting.

The team further calibrated the model inputs to align with the PY2018 HERs impact evaluation issued by the CPUC. Table C-2 summarizes the impact evaluation reported savings for PY2018.[141]

Table C-2. Summary of Evaluated Impacts for 2018 HER Programs

Utility	Adjusted Electric Savings (GWh)	Adjusted Gas Savings (MMTherms)
PG&E	125.6	4.8
SCE	127.9	-
SCG	-	4.7
SDG&E	49.7	1.1
Total	**303.3**	**10.6**

Source: Guidehouse

The model uses an effective useful life (EUL) of 1 year for HER program participants. That is, while customers may participate in a utility HER program for more than 1 year, their average adjusted savings are assumed to be the same as for all other participants in that year. While some recent evaluations of HER programs have found savings persistence of more than 1 year, reported savings percentages vary—some sources citing higher later year savings and others showing a degradation of savings over time. For this model, an EUL of 1 year is assumed, as is standard with traditional persistence calculations for HER programs.

The team developed the ratio of kilowatt (kW) to kWh savings using a weighted average of adjusted kW and kWh savings as reported in the impact evaluation findings for PG&E, Southern California Edison (SCE), and SDG&E through 2018. This ratio was then updated based on California hourly load profiles to align with the current Database for Energy Efficient Resources (DEER) peak period definition.[142]

Cost

The Guidehouse team sourced the costs per unit of kWh and therm savings from EEStats data for PY2013 through PY2015 and California Energy Data and Reporting System (CEDARS) data for PY2016 through PY2020. The specific program years used to calculate costs for each utility varied depending on data availability and as a result of a calibration effort to align with reported program costs for 2018 (the most recent year with evaluated savings).[143] The team divided the costs reported in CEDARS by the evaluated kWh and therms savings values from impact evaluations (through 2018) or by the claimed savings in CEDARS for 2019 and 2020. The team then weighted and apportioned the costs for PG&E and SDG&E to electric and gas using a common energy conversion to Btus. The Energy Advisor costs sourced from the CEDARS database for PG&E and SCE are an aggregate of HER and universal audit tool costs.

[141] DNV GL. May 1, 2019. Impact Evaluation Report: Home Energy Reports – Residential Program Year 2017. California Public Utilities Commission. CALMAC Study ID: CPU0194.01.

[142] California Public Utilities Commission (CPUC). Resolution E-4952, October 11, 2018, effective 2020. https://docs.cpuc.ca.gov/publisheddocs/published/g000/m232/k459/232459122.pdf

[143] PG&E: “Residential Energy Advisor” program savings and costs, 2015-2020 (Program ID: PGE21001).
SCE: “Residential Energy Advisor” program savings and costs, 2013-2020 (Program ID: SCE-13-SW-001A).
SCG: “RES-Behavioral Program” savings and costs, 2018-2019 (Program ID: SCG3824).
SDG&E: “Local-IDSM-ME&O-Behavioral” savings and costs, 2016-2020 (Program ID: SCGE3261).

C.2 Residential – Universal Audit Tool

C.2.1 Summary

The Universal Audit Tool (UAT) is an opt-in online tool that asks residential customers questions about their homes, household appliance use, and occupancy patterns and then offers EE advice on how they can save money and energy. The UAT is provided by all four of California's IOUs. While each utility has its own branding and some utilities require customers to log in and others do not, their features and functionality are similar. All four tools enable customers to develop plans to save energy based on estimates of the annual savings they are likely to see if the enact the recommended energy-saving advice.

There is some danger of double-counting UAT savings with other program savings such as HERs.[144] The DNV GL study used to characterize savings specifically addresses this potential and "find[s] no evidence of joint savings between the UAT and HER programs."[145]

Estimated electric savings range from 1.2% to 1.8%, while gas savings are 1.5%-2.6%. Costs are set at $0.01-$0.02 per kWh and $0.18-$0.38 per therm.

Table C-3. UAT – Key Assumptions

Sector	Type	EUL Years	Savings		Cost		kW/kWh Savings Ratio
			kWh	therms	kWh	therms	
Residential	UAT	1	1.2% - 1.8%	1.5%- 2.6%	$0.01- $0.02	$0.18- $0.38	0.000221 – 0.000263

Source: Guidehouse

C.2.2 Assumptions and Methodology

No major updates were made to UAT potential analysis in the 2021 Study. The Guidehouse team determined that UAT to be a low priority measure for updates based on a review of implementation activity and recently published California-specific data sources. The methodology described here is unchanged from the 2019 Study.

Eligibility and Participation

All residential customers of the four IOUs are eligible to use the UAT. Customers can access the tool after signing up for online services through their utility's My Energy or Energy Advisor web portals. As with the HERs forecast, the Guidehouse team reduced the applicability for multifamily homes by 10% to account for multifamily homes that do not have individual meters.

According to a 2017 evaluation of the UAT by DNV GL,[146] the UAT tools have seen active growth in customer use. Customer engagement and online survey completion vary by IOU, as does the associated level of marketing effort to drive customers to participate or re-participate for deeper savings. To forecast participation levels for the 2021 PG Model, the Guidehouse team relied on the participation numbers from the 2017 DNV GL evaluation to

[144] Stakeholder comments from 2019 Study May 9, 2019 stakeholder meeting.

[145] DNV GL. March 31, 2017. Universal Audit Tool Impact Evaluation-Residential: California Public Utilities Commission, March 31, 2017. CALMAC ID: CPU0160.01.

[146] DNV GL. March 31, 2017. Universal Audit Tool Impact Evaluation-Residential: California Public Utilities Commission, March 31, 2017. CALMAC ID: CPU0160.01.

establish cumulative treatment sizes; the team then determined saturation levels based on the number of households per utility. Because evaluated participation rates were not available for SCE in reviewed sources, the team calculated this value using an average saturation percentage from the other California electric utilities. Starting saturation rates for early model years range from 0.5% to 0.8% and grow at a compound annual growth rate of 12% per year, topping out at between 3.2% and 5.0% participation by 2032.

Savings

The Guidehouse team relied on the above-mentioned 2017 DNV GL evaluation of the UAT to set per-household adjusted kWh and therm savings values for participating customers at each utility. Evaluated kWh savings were not available for SCE, so a rate of 1.2% kWh savings was applied because it equaled the evaluated savings for PG&E, which was more conservative than the higher percentage of evaluated savings for SDG&E.

The PG Model uses an EUL of 1 year for UAT participants. While customers may participate in a utility UAT for more than 1 year, their average adjusted savings are assumed to be the same as for all other participants in that year. This assumed value is standard with traditional persistence calculations for residential behavior programs.

Because evaluated demand savings data was unavailable for UAT participants, the team applied the same kW/kWh ratio used for HERs for all three electric utilities.

Cost

The team based the costs per unit of kWh and therm savings on CEDARS data for Residential Energy Advisor, which is an aggregate of HER and online audit tool costs.[147] These costs were distributed to the kWh and therm savings (weighted by savings) as reported in the CEDARS database.

C.3 Residential – Real-Time Feedback: In-Home Displays and Online Portals

C.3.1 Summary

Unlike HERs that arrive in the mail on a periodic basis, real-time feedback programs change customer behaviors by delivering advanced metering data on household consumption to utility customers via an in-home display (IHD) or remotely via an online portal, such as a website or a smartphone application. While some feedback programs only provide information, others provide energy-saving tips, rewards, social comparisons, and alerts.

Although utility behavior programs using IHDs and online portals both provide feedback opportunities, the Guidehouse team separated its modeling inputs for the two categories to better capture differences in adoption, energy savings, and costs between the two types of programs. Of note is the higher cost typically associated with offering IHDs due to the need to install specialized hardware, whereas online portals typically provide cloud-based information directly to the customer’s smartphone, tablet, or computer.

Real-time feedback programs may also be associated with different customer rates, including time-of-use plans and more traditional usage-based billing. Although real-time feedback is a popular behavioral intervention for demand response (DR) programs, the team’s analysis focused on programs designed to drive EE. In all, the Guidehouse team

[147] Energy Advisor programs savings and costs, CEDARS, 2017.

reviewed 38 programs, including 20 providing IHDs and 18 offering online portals. Several programs offered both types of feedback. In those cases, the team categorized them in the IHD category because they had associated costs for the hardware.

Table C-4. Real-Time Feedback – Key Assumptions

Sector	Type	EUL Years	Savings		Cost		kW/kWh Savings Ratio
			kWh	therms	kWh	therms	
Residential	Real-Time Feedback – IHD	1	2.3%	–	$0.19	–	0.000224
Residential	Real-Time Feedback – Online Portal	1	2.2%	1.3%	$0.07	–	0.000224

Source: Guidehouse

C.3.2 Assumptions and Methodology

No major updates were made to real-time feedback input data for the 2021 Study. The Guidehouse team determined that real-rime feedback be a low-priority measure for updates based on a review of implementation activity and recently published California-specific data sources. The methodology described here is unchanged from the 2019 Study.

Eligibility and Participation

Web-based and IHD real-time feedback programs are offered on an opt-in basis to customers with smart meter-equipped homes. Although most residential feedback programs are focused on providing information about electricity consumption, some natural gas savings result from these programs; these savings are likely the result of tips and recommendations concerning thermostat settings. For modeling purposes, the Guidehouse team assumes 100% applicability for electric savings among individually metered homes and 59% applicability for gas. This latter figure is conservative given that 59% of California households use natural gas as their main source of space heating and 84.4% of California homes use natural gas for water heating.[148]

As in the 2019 Study, IHDs are not included in the BROs reference case scenario.[149] Previously, SCE indicated it would not deploy these programs until 2019, and they would only be pilots at that time.[150] The team assumes penetration rates for programs that use online portals to display customer information will be higher than those that rely on IHDs. For online portals, the team's reference case assumes an 8% increase in penetration per year, while the aggressive case assumes a 15% annual increase based on professional judgement. PG&E provided penetration rate data for IHDs and used for all IOUs.[151]

Savings

Savings forecasts differ for online portals and IHDs. For online portals, the Guidehouse team estimates 1.3% savings for both kWh and therms. For IHDs, the team estimates 2.3%

[148] U.S. Energy Information Administration (EIA) Residential Energy Consumption Survey (RECS). "Table CE2.5 – Household Site Fuel Consumption in the West Region, Totals and Averages." (2009). Available at: http://www.eia.gov/consumption/residential/data/2009/index.php?view=consumption#fuel-consumption

[149] IHDs were excluded from the reference case because they did not pass the cost-effectiveness screen in the 2019 Study.

[150] Informal comments on the 2019 Study April 20, 2017 webinar.

[151] Informal comments on the 2019 Study April 20, 2017 webinar.

savings for kWh and no gas (therms) savings. The team developed these estimates based on numerous data points for kWh savings.[152,153,154,155,156,157]

The PG Model uses an EUL of 1 year, the same as the team applies for HER program participants. Because insufficient demand savings data was available for real-time feedback for non-DR programs, the ratio of kW to kWh for HERs is used for the three electric utilities.

Cost

Hardware acquisition and installation constitute the primary cost associated with IHD programs and are accrued during the first year of customer participation. Sometimes these costs are paid by the utility, and other times they are paid by the customer. For modeling purposes, the Guidehouse team assumed utilities will provide the hardware and that IHDs cost $100, annualized over 5 years, which is similar to the life of other consumer electronics.[158]

To calculate the cost, the team began with a 2014 report by the Alberta Energy Efficiency Alliance for the City of Calgary that estimates the cost for a real-time direct feedback program to be about $0.07 per kWh saved not including the hardware.[159] For IHDs, the team added in the annualized $100 hardware acquisition and installation cost, resulting in $0.19 per kWh of savings (assuming 7,000 kWh per household).

C.4 Residential – Competitions: Large and Small

C.4.1 Summary

Residential competitions are a behavioral intervention approach in which participants compete in energy-related challenges, events, or contests. The goal of such challenges is to reduce energy consumption either directly or by raising awareness, increasing knowledge, or encouraging one or more types of action. Competitions can run for different lengths of time, ranging from a single month to multiple years. They can also include a mix of behavioral strategies, including goal setting, commitments, games, social norms, and feedback. This analysis does not include competitions and challenges that focus on the use of equipment upgrades as a means to generate energy savings.

The way in which competitions are designed can vary depending on the size of the targeted participant group. Small-scale competitions are typically designed to engage participants

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[152] Kira Ashby, *2016 Behavior Program Summary*, 2016, Consortium for Energy Efficiency, https://library.cee1.org/content/2016-behavior-program-summary-public

[153] Susan Mazur-Stommen and Kate Farley, “ACEEE Field Guide to Utility-Run Behavior Programs,” 2013, American Council for an Energy-Efficient Economy (ACEEE), http://aceee.org/research-report/b132.

[154] Illume Advising, *Energy Efficiency Behavioral Programs: Literature Review, Benchmarking Analysis, and Evaluation Guidelines, Conservation Applied Research & Development (CARD) FINAL REPORT*, Prepared for: Minnesota Department of Commerce, Division of Energy Resources, May 4, 2015

[155] Ben Foster and Susan Mazur-Stommen. 2012. “Results from Real-Time Feedback Studies.” American Council for an Energy Efficient Economy. Report Number B122

[156] Reuven Sussman and Maxine Chikumbo. 2016. “Behavior Change Programs: Status and Impact.” American Council for an Energy Efficient Economy. Report Number B1601

[157] Opinion Dynamics. “PY2013-2014 California Energy Efficiency and Demand Response Residential Behavior Market Characterization Study Report: Volume 1.” Prepared for the California Public Utilities Commission Energy Division. July 2015.

[158] PG&E provided this reference in response to the webinar on April 20, 2109: https://www.amazon.com/Rainforest-Energy-Monitor-ZigBee-Gateway/dp/B00AII248U

[159] Alberta Energy Efficiency Alliance, *Energy Savings through Consumer Feedback Programs*, February 2014, City of Calgary.

more deeply, with a higher number of touches and a broad spectrum of targeted behaviors that generate higher savings and serve as a model to get the larger population engaged. Large-scale competitions engage greater numbers of people in a more superficial way and encourage a limited number of behaviors. For this reason, the team separates its modeling calculations to estimate the savings for the two competition types separately.

The Guidehouse team defines small competitions as having less than 10,000 participants per year and large competitions as having more than 10,000 participants per year. The team reviewed 18 small competitions and five large competitions. Data availability varied across programs.

Table C-5. Residential Competitions – Key Assumptions

Sector	Type	EUL Years	Savings		Cost		kW/kWh Savings Ratio
			kWh	therms	kWh	therms	
Residential	Small Competitions (<10,000 people)	1	8.1%	5.2%	$0.050	$1.344	0.000224
Residential	Large Competitions (>10,000 people)	1	14%	5.2%	$0.002	$0.101	0.000224

Source: Guidehouse

C.4.2 Assumptions and Methodology

No major updates were made to the inputs for residential competitions in the 2021 Study. The Guidehouse team determined that residential competitions be a low priority measure for updates based on a review of implementation activity and recently published California-specific data sources. The methodology described here is unchanged from the 2019 Study.

Eligibility and Participation

All residential customers are considered eligible to participate in competitions. The team determined the estimated participation rate of 6.5% for small competitions by averaging available reported participation rates from SDG&E's Biggest Energy Saver program, SMECO's Energy Savings Challenge, and Minnesota Valley Electric Cooperative's Beat The Peak program.[160] CoolChallenge California[161] provided a participation rate of 0.1% for large competitions. This information was supplemented with findings from program reviews conducted by the Consortium for Energy Efficiency,[162] American Council for an Energy-Efficient Economy,[163] and Illume Advising.[164]

Penetration rates for the reference case assume that small competitions are conducted by each utility with a consistent target population of 10,000 households per year each year

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160 Grossberg, Frederick; Wolfson, Mariel; Mazur-Stommen, Susan; Farley, Kate; and Steven Nadel. 2015. (February) "Gamified Energy Efficiency Programs." ACEEE Report B1501.

161 PG&E provided the following reference: Jones, Christopher M. and Kammen, Daniel M. 2014. "The CoolCalifornia Challenge: A Pilot Inter-City Household Carbon Footprint Reduction Competition." Contract Number: 10-325, California Air Resources Board. https://www.arb.ca.gov/research/apr/past/10-325.pdf

162 Kira Ashby, *2016 Behavior Program Summary*, 2016, Consortium for Energy Efficiency, https://library.cee1.org/content/2016-behavior-program-summary-public.

163 Susan Mazur-Stommen and Kate Farley, ACEEE Field Guide to Utility-Run Behavior Programs, 2013, American Council for an Energy-Efficient Economy, http://aceee.org/research-report/b132

164 Illume Advising, Energy Efficiency Behavioral Programs: Literature Review, Benchmarking Analysis, and Evaluation Guidelines Conservation Applied Research & Development (CARD) FINAL REPORT, Prepared for: Minnesota Department of Commerce, Division of Energy Resources, May 4, 2015.

between 2021 and 2032. The starting saturation is determined by dividing 10,000 by the number of residential households per utility and multiplying that value by the 6.5% participation rate. The aggressive case also starts in 2021 and assumes that 2021-2023 are limited to two target groups of 10,000, but that this increase to five target groups of 10,000 each in subsequent years. These treatment groups could be small towns, neighborhoods within larger cities, or a similar population group.

Penetration rates for large competitions are based on the participation rate and a targeted percentage of utility households. The reference case for large competitions assumes that each utility targets 10% of its residential customers between 2021 and 2023, rising to 15% of customers from 2024 to 2026 before increasing to 20% in 2027 and 25% in 2030. The aggressive case uses the same time intervals, but it starts at 20% of customers and rises in increments of 10% rather than the 5% increased used in the reference scenario.

Savings

The team averaged the percentage of kWh savings for small competitions, arriving at a value of 8.1%; the CoolCalifornia Challenge reported 14% savings for large competitions.[165] Gas savings of 5.3% are used for small and large competitions and are based on an average of an ACEEE review of three programs that report gas savings between 0.4% and 10%.[166]

Because competitions can be run for different lengths of time, lasting from a few months to multiple years, the Guidehouse team standardized the model on an EUL of 1 year (the same EUL applied for other residential interventions). Because insufficient demand savings data was available for residential competitions, the team applied the ratio used for HERs for the three electric utilities.

Cost

Costs associated with competitions are largely associated with program administration and game-related prizes. The Guidehouse team used data gathered from the 2015 ACEEE's report on EE and gamification and information from the Consortium for Energy Efficiency database of behavioral programs[167] to create cost estimates for small and large behavior-based competitions. The team approached the calculations for small and large competitions in the same way: by estimating total program costs and total program savings and then dividing total program costs by total program savings to get the average cost per kWh. The team estimated total program savings using the following two steps:

- Multiplying the average number of participants per competition by the cost per participant
- Multiplying annual average household electricity consumption by the average number of participants and the average savings rate per participant.

The Guidehouse team assumes that prizes account for 50% of program costs. The estimated cost per kWh of $0.050 for small competitions was based on the prizes and participation reported for SMECO's Energy Savings Challenge and Minnesota Valley Electric

165 PG&E provided the following reference: Jones, Christopher M. and Kammen, Daniel M. 2014 "The CoolCalifornia Challenge: A Pilot Inter-City Household Carbon Footprint Reduction Competition." Contract Number: 10-325, California Air Resources Board. https://www.arb.ca.gov/research/apr/past/10-325.pdf

166 Grossberg, Frederick; Wolfson, Mariel; Mazur-Stommen, Susan; Farley, Kate; and Steven Nadel. 2015. (February) "Gamified Energy Efficiency Programs." ACEEE Report B1501.

167 Consortium for Energy Efficiency Program Library, https://library.cee1.org/

Cooperative's Beat The Peak program.[168] The estimated cost per kWh of $0.007 for large competitions was based on the prizes and participation reported for SDG&E's San Diego Energy Challenge and Puget Sound Energy's Rock the Bulb program.

C.5 Commercial – Strategic Energy Management-Like Programs

C.5.1 Summary

Strategic energy management (SEM) is a continuous improvement approach that focuses on changing business practices to enable companies to save money by reducing energy consumption and waste. In California, pilot SEM programs are being administered in the industrial sector. The Guidehouse team uses the term "SEM-like programs" to refer to similar offerings for the commercial sector. Customers that benefit the most from SEM-like programs typically fall under one of the following categories:

- Campuses with multiple buildings and building types
- Customers with a large portfolio of buildings and a range of building types
- Buildings with complex energy systems

SEM provides the processes and systems needed to incorporate energy considerations and energy management into daily operations. While SEM applications vary depending on customer-specific needs, program participants generally implement the following policies and activities:

- Measure and track energy use to help inform strategic business decisions
- Drive managerial and corporate behavioral changes around energy
- Develop the mechanisms to track and evaluate energy optimization efforts
- Implement ongoing operations and maintenance (O&M) practices
- Reduce total annual energy costs between 5% and 10%
- Identify and prioritize capital improvements or process changes that lead to more savings
- Justify additional resources to energy management as a result of demonstrated success
- Overcome barriers to efficiency
- Boost employee engagement to contribute to sustainability goals
- Embed SEM principles into a company's operations

The model inputs for electric and natural gas shown in Table C-6 represent savings associated with operational and behavioral changes. The savings are estimated at 3% of customer segment consumption (kWh or therms per year) and are applied consistently by building and fuel type across utilities. Costs for electricity and natural gas are $0.27 per kWh and $3.65 per therm; these values are also applied consistently by building type across utilities.

[168] Grossberg, Frederick; Wolfson, Mariel; Mazur-Stommen, Susan; Farley, Kate; and Steven Nadel. 2015. (February) "Gamified Energy Efficiency Programs." ACEEE Report B1501.

Table C-6. Commercial SEM-Like Programs – Key Assumptions

Sector	Type	EUL Years	Savings		Cost		kW/kWh Savings Ratio
			kWh	therms	kWh	therms	
Commercial	SEM-Like Programs	5	3.0%	3.0%	$0.27	$3.65	0.000102

Source: Guidehouse

C.5.2 Assumptions and Methodology

After reviewing implementation activity and recently published California-specific data sources, no major updates were made to commercial SEM-like programs in the 2021 Study. The methodology described here is unchanged from the 2019 Study. The Guidehouse team will continue to monitor industry literature, ex ante and ex post savings records, and relevant evaluations occurring in California (such as the SEM evaluation occurring under the evaluation contract Group D[169]) for indications if input parameters should be revised in the future.

Eligibility and Participation

Segments of the commercial market are considered suitable for SEM-like program approaches. Customers that benefit the most from SEM typically operate portfolios or campuses with multiple buildings, building types, and a variety of complex energy systems, each with its own unique set of energy management requirements. The market defined for the 2021 Study includes the following commercial segments:

- Schools
- Colleges
- Healthcare
- Large office buildings

Depending on the segment, the model assumes that between 10% and 55% of buildings have already implemented SEM-like solutions,[170] resulting in reduced applicability of any commercial SEM program. After accounting for the estimate of customers that have already implemented SEM outside of any program intervention, the 2021 Study applies an applicability factor of between 45% and 90%. The team used a CAGR to forecast growth in participation over time, starting in 2021.[171] The reference case used a 2% CAGR, while the aggressive case used a 4% CAGR. These CAGRs are expected to achieve segment penetrations of approximately 1.3% for the reference case and 1.6% for the aggressive case by 2032.

Savings

The Guidehouse team's literature review indicates that electric savings for all activities associated with SEM-like interventions range from 5% to 10% of customer consumption for electricity and gas (kWh or therms) per year. These savings estimates include a mix of

[169] Group D – D01.02. Workplan for 2018 Industrial Strategic Energy Management (SEM) Evaluation. SBW, Revised July 2, 2019.

[170] Healthcare participation estimates are based on the *Hospitals and Healthcare Initiative Market Progress Evaluation Report 7*, Northwest Energy Efficiency Alliance. March 26, 2015. REPORT #E15-310. Participation estimates for other market segments are based on professional judgement.

[171] Informal comments in response to the 2019 Study webinar held on April 20, 2017.

operational savings and savings associated with capital investments (i.e., equipment retrofit and replacement projects). Because savings from capital investments are addressed in other components of the potential model, the SEM savings associated with BROs activities are constrained to estimates of operational savings such as improved maintenance or optimizing equipment operating setpoints. Based on the literature review of 16 institutional SEM plans such as the LW Hospitals Alliance 2014 plan[172] and market studies such as the Northwest Energy Efficiency Alliance (NEEA) Market Progress Evaluation Report,[173] O&M savings are estimated to be 3% and are applied consistently by building and fuel type across all utilities for the market segments considered.

The model uses an EUL of 5 years.[174] A ratio of 0.000102 kW to kWh was applied to the three electric utilities based on an analysis of several third-party programs operating in California during the 2014-2015 portfolio cycle that included some components of SEM initiatives. This ratio was then updated based on California hourly load profiles to align with the current DEER peak period definition.[175]

Cost

Consistent with previous studies, costs for electricity and natural gas savings are estimated at $0.27 per kWh and $3.65 per therm and are applied consistently by building and fuel type across utilities. These values are based on an analysis of several third-party programs operating in California during the 2014-2015 portfolio cycle that included some components of SEM initiatives, including the Commercial Energy Advisor, Monitoring-Based Persistence Commissioning, and Energy Fitness programs.

C.6 Commercial – Building Operator Certification

C.6.1 Summary

Building operator certification (BOC) offers EE training and certification courses to building operators in the commercial sector. BOC has been modeled as a component of behavioral savings since the 2011 Study, and research conducted for previous studies indicates that O&M practices mostly fell into the following categories:[176]

- Improved air compressor O&M
- Improved HVAC O&M
- Improved lighting O&M
- Improved motors/drives O&M
- Water conservation resulting in energy savings
- Adjusted controls of HVAC systems
- Adjusted controls of energy management systems

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[172] Joint Strategic Energy Management Plan for Listowel Wingham Hospitals Alliance, 2014

[173] *Hospitals and Healthcare Initiative Market Progress Evaluation Report 7*, Northwest Energy Efficiency Alliance. March 26, 2015. REPORT #E15-310

[174] Personal communication with Kay Hardy, CPUC. May 9, 2017.

[175] CPUC. Resolution E-4952, October 11, 2018. https://docs.cpuc.ca.gov/publisheddocs/published/g000/m232/k459/232459122.pdf

[176] Literature search results provided in Appendix C, *Analysis to Update Potential Goals and Targets for 2013 and Beyond*, Navigant Consulting Inc., March 19, 2012

The model inputs for electric and natural gas shown in Table C-7 represent savings associated with changes in operation and behavior estimated per 1,000 square feet of floor space. Savings vary depending on the energy intensity of facilities in each market segment and IOU and as defined in the 2009 Commercial End Use Survey (CEUS).[177] The EUL is set to 3 years per CPUC Decision 16-08-019, and costs for electricity and natural gas savings are sourced from EEStats data from 2013 through 2017. The model applies cost and EUL values consistently by building and fuel type across all utilities.

Table C-7. Commercial Building Operator Certification – Key Assumptions

Sector	Type	EUL Years	Savings		Cost		kW/kWh Savings Ratio
			kWh	therms	kWh	therms	
Commercial	BOC	3	14-153	0.3-35.7	$0.29	$3.65	0.000092

Source: Guidehouse

C.6.2 Assumptions and Methodology

After reviewing implementation activity and recently published California-specific data sources, no major updates were made to BOC in the 2021 Study. The methodology described here is unchanged from the 2019 Study. The team expects to revise inputs in future studies based on the forthcoming update to the CEUS (scheduled for completion in March 2021).[178]

Eligibility and Participation

Consistent with prior studies, BOC savings apply to all commercial market segments, though the applicability factor of BOC ranges from 5% to 100% depending on the market segment. The PG Model assumes that BOC program interventions in the commercial market have been ongoing, and a CAGR was used to forecast growth in participation through the model forecast horizon. In the reference case, a 12.5% CAGR was used to forecast growth, while the aggressive case used a 18.0% CAGR. While these growth rates appear ambitious, low initial sector engagement in BOC results in forecast market penetrations of 8.25% and 16.87% for the reference and aggressive cases in 2032, respectively. While there is the potential for overlap in savings between BOC and SEM interventions, the current saturation of these measures and relatively low penetration rate forecast indicate that the risk of double counting savings is minimal and ,therefore, was not considered in this model.

Going forward, the team expects the role of BOC to expand with the development and increasingly widespread use of energy management and information systems to help building operators identify and address building performance issues. Future revisions of the study should consider data on the relationship between BOC and energy management and information systems as it becomes available, including revised saturation estimates for equipment associated with energy management and information systems from the forthcoming CEUS update.

Savings

The method to calculate unit energy savings (UES) has changed over time, and the 2021 Study uses the same approach and values as the 2017 and 2019 studies. For context, the

[177] As defined in the California Energy Commission (CEC), California Commercial End-Use Survey, CEC-400-2006-005, prepared by Itron, Inc., March 2006. Final report available at: http://www.energy.ca.gov/ceus/index.html. Data available at: http://capabilities.itron.com/ceusweb/

[178] At https://www.energy.ca.gov/data-reports/surveys/california-commercial-end-use-survey, accessed October 2020. Data collection for the 2021 Study ended in Q3 2020.

2015 Study used the average electric and natural gas savings of 58 kWh and 5.6 therms per 1,000 square feet of participating building space for all market segments.[179] The 2017 Study refined this approach and applied a market segment-specific UES value that accounted for differences in building energy density. For example, a grocery store with much higher energy densities than a warehouse would experience a proportionally greater savings rate per unit of conditioned space. In this example, a grocery store in PG&E territory is expected to save 151.3 kWh and 5.2 therms per 1,000 square feet compared to an unrefrigerated warehouse that would be expected to save 18.2 kWh and 0.8 therms per 1,000 square feet after accounting for differences in energy density.

Consistent with the 2019 Study, the 2021 PG Model uses an EUL of 3 years per CPUC Decision 16-08-019, and a ratio of 0.000092 kW to kWh was applied to the three electric utilities. The peak kW to kWh value is based on an analysis of several third-party programs operating in California during the 2014-2015 portfolio cycle. This ratio was then updated based on California hourly load profiles to align with the current DEER peak period definition.[180]

Cost

Costs for electricity and natural gas savings are estimated at $0.29 per kWh and $3.65 per therm; these values are applied consistently by building type across utilities.

C.7 Commercial – Building Energy and Information Management Systems

C.7.1 Summary

The potential for building energy and information management systems (BEIMS) was first modeled by Guidehouse (then Navigant) as part of the Assembly Bill (AB) 802 Technical Analysis.[181] The Technical Analysis, issued in March 2016, was not used at that time to set goals. The technical analysis work was incorporated into the PG Model in 2019.

BEIMS includes IT-based monitoring and control systems that provide information on the performance of various components of a building's infrastructure, including systems related to the envelope, heating and ventilation, lighting, plug load, water use, occupancy, and other critical resources. BEIMS infrastructure primarily consists of software, hardware (such as dedicated controllers, sensors, and submeters), and value-added services (including outsourced software management, building maintenance contracts, and others). The PG Model focuses on the potential for BIEMS to change the energy consumption associated with operating building HVAC systems by applying the following BEIMS technologies:

- Energy visualization
- Energy analytics
- Operational control and facility management
- Continuous commissioning and self-healing buildings

[179] Navigant Consulting, Inc. "Section 3.7.1 Non-Residential Behavior Model Updates," *Energy Efficiency Potential and Goals Study for 2015 and Beyond Stage 1*. Final Report., September 25, 2015.

[180] CPUC. Resolution E-4952, October 11, 2018. https://docs.cpuc.ca.gov/publisheddocs/published/g000/m232/k459/232459122.pdf

[181] Navigant Consulting, Inc., *AB 802 Technical Analysis, Potential Savings Analysis*. Reference No.: 174655. March 31, 2016

In the 2021 Study, the Guidehouse team adjusted inputs for select market segments that include a higher concentration of small- and medium-sized facilities based on a review of the Facilities Assessment Service Program (FASP). The FASP is intended to support AB 793 and the associated Commission Resolution E-4820, which mandate all IOUs develop and implement incentive programs targeting small-to-medium business customers that acquire energy management technologies. FASP offerings include a mechanism to incentivize small-to-medium business customers to acquire energy management technologies to meet EE savings goals under a pay-for-performance model. Based on a review of FASP, the team adjusted electric and gas UES values for the following building types:

- Grocery
- Lodging
- Office (Small)
- Restaurant
- Retail

Table C-8 shows the UES value used for these segments for the 2019 and 2021 studies.

Table C-8. Changes in UES Values for BEIMS Based on FASP

Utility	Study	Average UES	
		Electric	Gas
PG&E	2019	2.12%	5.10%
	2021	5.00%	5.26%
SCE	2019	2.86%	-
	2021	5.00%	-
SCG	2019	-	1.88%
	2021	-	2.87%
SDG&E	2019	2.68%	3.10%
	2021	5.00%	3.29%

Source: Guidehouse

Inputs for other building types are the same as the 2019 Study and are based on customer segment consumption (kWh or therms per year). Electricity savings range from 1.1% to 4.2%, and natural gas savings range from 0.2% to 9.3%. Variations are due to differences in segments' energy densities and differences in climate across utilities. Costs for electricity and natural gas savings also varied by utility and are between $0.20 and $0.46 per kWh and $0.18 and $0.49 per therm. The Guidehouse team expects to revise these inputs based on the forthcoming CEUS[182] update and any additional revisions to the saturation of building energy management or energy information systems that enable BEIMS savings.

[182] At https://www.energy.ca.gov/data-reports/surveys/california-commercial-end-use-survey, accessed October 2020.

Table C-9. BEIMS – Key Assumptions

Sector	Type	EUL Years	Savings		Cost		kW/kWh Savings Ratio
			kWh	therms	kWh	therms	
Commercial	BEIMS	3	1.1%-4.2%	0.2%-9.3%	$0.20-$0.44	$0.18-$0.49	0.000112

Source: Guidehouse

C.7.2 Assumptions and Methodology

Eligibility and Participation

The technologies that enable BEIMS are primarily associated with energy management systems (EMS) that are broadly applicable across all market sectors; the existing market saturation of these technologies ranges across market segments from 1% to 80%.[183] In general, segments that operate larger facilities (e.g., large offices) or facilities that are energy-intensive (e.g., grocery stores) will have a higher existing saturation of BEIMS-enabling technologies. Penetration reflects that Southern California Gas (SCG) does not claim savings until 2018, and a CAGR was used to forecast growth in BEIMS technology penetration over time. The reference case used a 12% CAGR, while the aggressive case used a 24% CAGR. Based on estimates of market saturations as of 2017, these growth rates result in BEIMS forecast penetrations of 5.3% and 19.7% for the reference and aggressive cases, respectively, by the end of the forecast horizon in 2032.

The FASP focuses on small- to medium-sized commercial buildings. While SCE and SDG&E plan to discontinue their current programs, [184,185] because FASP was designed in response to legislation intended to target this sector (AB 793), the team anticipates that market intervention will be ongoing throughout the forecast horizon—either through a continuation of existing programs or new program designs that will be implemented over time.

Savings

As discussed in the AB 802 Technical Analysis, UES associated with BEIMS are calculated using Equation C-1.

Equation C-1. BEIMS Unit Energy Savings

Unit Energy Savings, BEIMS = Starting Saturation of EMS by Building Type x Total Annual Consumption x % End-Use Consumption for HVAC x % End Use Savings by Building Type

This equation resulted in a range of UES values associated with BEIMS. While there is the potential for overlap in savings between BEIMS, BOC, and SEM interventions, the current saturation of these measures and relatively low penetration rates forecast indicate the risk of double counting savings is minimal and, therefore, was not considered in this model. Additionally, BEIMS often requires capital investment while BOC and SEM typically do not, providing some differentiation in the market penetration models and potential to mitigate the risk of double counting savings. The UES from Equation C-1, defined through work on the

[183] Navigant Consulting, Inc. *AB 802 Technical Analysis, Potential Savings Analysis*. Reference No.: 174655, March 31, 2016

[184] Program - SCE-13-TP-025 details for the 2021 filing - CEDARS (sound-data.com)

[185] Program - SDGE4061 details for the 2021 filing - CEDARS (sound-data.com)

AB 802 Technical Analysis, is used in the potential model to calculate annual segment-level savings for each fuel type and IOU using Equation C-2.

Equation C-2. BEIMS Segment Savings

Segment Savings, BIEMS = Segment UES x Penetration Rate x Total Annual Segment Consumption x Segment Applicability Factor

Consistent with the 2017 and 2019 studies, the PG Model uses an EUL of 3 years per CPUC Decision 16-08-019, and a ratio of kW to kWh of 0.000112 was applied to the three electric utilities as defined in the AB 802 Technical Analysis.[186] This ratio was then updated based on California hourly load profiles to align with the current DEER peak period definition.[187]

Cost

Costs for electricity and natural gas savings are estimated based on research referenced in the AB 802 Technical Analysis.[188] Guidehouse calculated costs per unit of fuel savings for each utility and fuel type as shown in Table C-10.

Table C-10. BEIMS Cost per UES

Utility	Fuel	Cost
PG&E	kWh	$0.435
SCE	kWh	$0.204
SDG&E	kWh	$0.323
PG&E	therms	$0.340
SCG	therms	$0.180
SDG&E	therms	$0.489

Source: Guidehouse

C.8 Commercial – Business Energy Reports

C.8.1 Summary

Business energy reports (BERs) are the commercial sector equivalent to the HERs sent to residential customers. BERs (and other similar programs) shares reports via mail or electronic format) with small- and medium-sized businesses at specific intervals (often monthly). The objective is to provide feedback about the business' energy use, including normative comparisons to similar businesses, tips for improving EE, and occasionally messaging about rewards or incentives. BERs and other similar programs typically send reports to customers on opt-out basis. BER-type programs are a relatively new addition in the emerging field of behavior change programs and are in pilot testing at PG&E and other non-California utilities.

The Guidehouse team's modeling estimates are primarily based on three sources:

- PG&E's response to the 2019 Study webinar on April 20, 2017.

[186] Program - SDGE4061 details for the 2021 filing - CEDARS (sound-data.com)
[187] CPUC. Resolution E-4952, October 11, 2018. https://docs.cpuc.ca.gov/publisheddocs/published/g000/m232/k459/232459122.pdf
[188] CPUC. Resolution E-4952.

- Cadmus review of a BER pilot with Xcel Energy business customers (smaller than 250 kW service) in Colorado (10,000 participants) and Minnesota (20,000 participants) conducted between June 2014 and June 2015.
- Commercial customer behavior change pilot conducted by Commonwealth Edison and Agentis Energy in Illinois beginning in 2012.

Xcel Energy provided BERs to a sample of businesses operating in the following sectors: small office, small retail trade, small retail service, and restaurants.[189] In the Commonwealth Edison pilot ,the utility engaged 6,009 medium-sized (100 kW-1,000 kW) commercial customers in Illinois.[190] While the Commonwealth Edison customers represented numerous sectors, only those businesses in the lodging and other categories showed significant savings.

Table C-11. BERs – Key Assumptions

Sector	Type	EUL Years	Savings		Cost		kW/kWh Savings Ratio
			kWh	therms	kWh	therms	
Commercial	BERs	2	0.32%	–	$0.20	$6.12	0.000102

Source: Guidehouse

C.8.2 Assumptions and Methodology

No major updates to inputs were made to BERs in the 2021 Study. Guidehouse determined that BERs be a low priority measure for updates based on a review of implementation activity and recently published California-specific data sources. The methodology described here is unchanged from the 2019 Study.

Eligibility and Participation

BERs typically target small- or medium-sized businesses. Utilities may use BERs to target businesses across all sectors or only a select set. As the number of BER pilots continues to grow, a greater amount of information about the effectiveness of BER programs in different business sectors will become available. The team assumes utilities will be more likely to limit the use of BERs to those sectors for which significant savings have been documented. The PG Model constrains its savings estimates to those business sectors that have already achieved significant energy savings by means of business energy feedback programs such as BERs.

The model includes businesses in the following sectors: retail, restaurants, lodging, and other. Within each of these business sectors, the applicability of savings is further constrained by the estimated proportion of business customers in each of the relevant sectors that may be classified as either a small- or medium-sized enterprise. Based on data from the Commercial Building Energy Consumption Survey (CBECS), the team estimated that roughly 63% of retail customers can be considered small or medium businesses given

[189] Jim Stewart, Energy Savings from Business Energy Feedback [for Xcel Energy], Cadmus, October 21, 2015, Behavior, Energy, and Climate Change Conference 2015

[190] Gajus Miknaitis, John Lux and Deb Dynako, Mark Hamann and William Burns, “Tapping Energy Savings from an Overlooked Source: Results from Behavioral Change Pilot Program Targeting Mid-Sized Commercial Customers,” 2014 ACEEE Summer Study on Energy Efficiency in Buildings, Commonwealth Edison and Agentis Energy, http://aceee.org/files/proceedings/2014/data/papers/7-153.pdf.

that approximately 63% of retail space is shown to be under 100,000 square feet.[191] Given the small size of restaurants, the team assumes 100% applicability for this sector.

The Commonwealth Edison study specifically targeted medium-sized businesses in the lodging and other sectors. Therefore, the model's savings estimates are only calculated for medium-sized customers in the lodging and other categories based on relevant data from the CBECS. For example, the model assumes that 50% of lodging establishments can be considered medium-sized establishments based on CBECS data, which indicates 50% of lodging establishments have an average annual energy consumption of 500,000 kWh or more per year. For businesses in the other category, the Guidehouse team used CBECS data to estimate the proportion of establishments that fall in the medium-sized category (<1 million kWh per year). The team estimates that 25% of buildings in the other category are using an average of 400,000 kWh per year.

The projected penetration rates assume a delayed start for BERs, with formal utility programs launching in 2021. The reference scenario assumes a starting penetration of 1% in 2021, increasing 1% per year and reaching 12% by 2032. Under the aggressive scenario, penetration begins at 2% in 2021 and increases 2% per year, reaching 24% by 2032.

Savings

The model uses electricity savings of 0.32%, no gas savings,[192] and an EUL of 2 years per CPUC Decision 16-08-019. Because no demand savings data was available for BERs, the team averaged the ratio of kW to kWh savings calculated for BEIMS, BOC, and SEM. This yielded a result of 0.000102, which is the figure used for all four utilities.

Cost

Because BER programs are new and in pilot phases, data regarding utility costs is scant. Furthermore, the limited availability of statistically significant adjusted savings percentages reported to-date indicates that BER-related savings are lower among businesses than the household savings produced by HERs. For these reasons, the Guidehouse team modeled BER costs that are double those of HERs. The team projects $0.20 per kWh (2 x $0.10) for electric savings for PG&E, SCE, and SDG&E.

C.9 Commercial – Benchmarking

C.9.1 Summary

Building benchmarking scores a business customer's facility or plant and compares it to peer facilities based on energy consumption. It also often includes goal setting and rewards in the form of recognition. In previous potential and goals studies, benchmarking was generally modeled an opt-in activity, although some municipalities (e.g., San Francisco) had passed ordinances requiring it for buildings of certain types and sizes. For the 2021 Study, the team updated the measure to reflect that benchmarking is mandated statewide for commercial buildings greater than 50,000 square feet under the CEC's Building Energy Benchmarking Program.[193]

[191] U.S. EIA, CBECS, http://www.eia.gov/consumption/commercial/data/2012/index.php?view=consumption#c13-c22
[192] Informal comments on the 2019 Study webinar presented on April 20, 2017 from PG&E cite results of a trial that ran January-October 2014.

Estimated electric savings range from 0.4% to 1.6%, while gas savings are 0.3%-1.0%. These values are applied consistently across utilities but vary by building type. Costs are estimated to be $0.08 per kWh and $0.37 per therm and are not utility-specific.

Table C-12. Benchmarking – Key Assumptions

Sector	Type	EUL Years	Savings		Cost		kW/kWh Savings Ratio
			kWh	therms	kWh	therms	
Commercial	Building Benchmarking	2	0.4%-1.6%	0.3%-1.0%	$0.08	$0.37	0.000102

Source: Guidehouse

C.9.2 Assumptions and Methodology

Eligibility and Participation

Pursuant to AB 802, building benchmarking is mandated for all commercial buildings greater than 50,000 square feet under the CEC's Building Energy Benchmarking Program. Therefore, the Guidehouse team limited the applicability of the benchmarking measure to buildings less than 50,000 square feet but greater than 10,000 square feet to reflect additionality from IOU intervention. While any building and business type may be subject to benchmarking, reliable savings data exists for the following segments: colleges, healthcare, lodging, large offices, retail, and schools. For these sectors, the team applied CBECS data to determine the proportion of commercial stock in buildings between 10,000 and 50,000 square feet.[194] Table C-13 compares the applicability factors for benchmarking in the 2021 PG Model, which ranges from 16% to 31% to address the mandate change, to the 2019 Study in which applicability ranged from 35% to 100%.

Table C-13. Adjustments to Building Benchmarking Applicability Factors

Building Type	Applicability Factor	
	2019 Study	2021 Study
Com – College	100%	21%
Com – Health	69-83%	16%
Com – Lodging	100%	25%
Com – Office (Large)	100%	27%
Com – Retail	35%	31%
Com – School	90%	22%

Source: Guidehouse

There is uncertainty as to what extent the utilities will be able to claim savings from benchmarking if it is manded to a greater degree by another level of government. For example, San Francisco has a benchmarking ordinance for any building greater than 10,000 square feet. To account for this uncertainty, building benchmarking is excluded from the reference scenario but is included in the aggressive scenario. In the aggressive scenario, PG&E begins with 7.6% penetration, climbing to 15.1% in 2020 and 22.7% in 2025. The aggressive scenario penetrations for the other three utilities begin with 7.6% in 2019 and step up to 15.1% starting in 2024.

[194] U.S. EIA. "Table B7. Building size, floorspace, 2012." CBECS (May 2016).

Savings

Estimated electric savings range from 1.1% to 2.2%, while gas savings range from 0.7% to 1.3%; these values are applied consistently by building and fuel type across utilities. Savings estimates are based on actual savings levels from city benchmarking reports.[195,196,197,198,199] Reported savings were divided in half because the team assumes that half of the savings come from technologies and half from operation-related behaviors. Furthermore, the team applied a consistent split of 60% electric savings and 40% gas savings. This split likely varies by building type, but because this data was not available, the team did not make this calculation based on specific building type consumption information.

The model uses an EUL of 2 years per CPUC Decision 16-08-019.

Because no demand savings data was available for benchmarking, the team averaged the ratio of kW to kWh savings calculated for BEIMS, BOC, and SEM. This yielded a result of 0.000102, which is the figure used for the three electric utilities.

Cost

Available data suggests that benchmarking programs often include a utility in concert with a municipality. The model's estimates use PG&E's estimated 3-year program budget of $2.3 million.[200] Attributing all costs to either electricity or gas, this utility program cost was divided by estimated savings to calculate a per-unit savings cost. Costs amounted to $0.0396 per kWh and $0.2352 per therm and are not utility-specific.

C.10 Commercial – Competitions

C.10.1 Summary

Commercial competitions are a behavioral intervention approach in which participants compete in events, contests, or challenges to achieve a specific objective (i.e., reducing energy consumption) or the highest rank compared with other individuals or groups. Competitions can run for varying time periods ranging from a single month to multiple years. They can include a mix of behavioral strategies, including goal setting, commitments, games, social norms, and feedback. Those competitions designed to produce energy savings via equipment upgrades were not included in the Guidehouse team's analysis.

Competitions may be designed differently depending on the size and nature of the targeted participant group. Small-scale competitions are typically designed to engage participants more deeply, with a higher number of touches and a broad spectrum of targeted behaviors that generate higher savings and serve as a model to get the larger population engaged. Large scale competitions engage greater numbers of people in a more superficial way and

[195] SF Environment and ULI Greenprint Center for Building Performance. "San Francisco Existing Commercial Buildings Performance Report: 2010-2014." (2015)
[196] Katherine Tweed. "Benchmarking Drives 7 Percent Cut in Building Energy." Greentech Media. October 2012.
[197] City of Chicago. "City of Chicago Energy Benchmarking Report 2016."
[198] Jewel, Amy; Kimmel, Jamie; Palmer, Doug; Pigg, Scott; Ponce, Jamie; Vigliotta, David; and Weigert, Karen. "Using Nudges and Energy Benchmarking to Drive Behavior Change in Commercial, Institutional, and Multifamily Residential Buildings." 2016. Proceedings of the ACEEE Summer Study on Energy Efficiency in Buildings.
[199] Navigant Consulting, Inc., Steven Winter Associates, Inc., and Newport Partners, LLC. *New York City Benchmarking and Transparency Policy and Impact Evaluation Report*. Prepared for the U.S. Department of Energy. May 2015.
[200] CPUC, *Statewide Benchmarking Process Evaluation*, Volume 1, CPU0055.01, Submitted by NMR Group and Optimal Energy, April 2012.

encourage a limited number of behaviors. Because the team had limited data for this type of behavioral intervention all commercial competitions are considered as a single category.

In addition to overall summary data available through the ACEEE[201] and CEE,[202] the team considered 10 different challenges, including the US Environmental Protection Agency's ENERGY STAR Building Competition, NEEA's Kilowatt Crackdown, Chicago's Green Office Challenge, and PG&E's Step Up and Power Down campaign.[203,204] The completeness of data available for each program varied; some of the most robust data came from Duke Energy's Smart Energy Now effort in Charlotte, North Carolina.[205]

Table C-14. Commercial Competitions – Key Assumptions

Sector	Type	EUL Years	Savings		Cost		kW/kWh Savings Ratio
			kWh	therms	kWh	therms	
Commercial	Competitions	2	1.9%	–	$ 0.04	–	0.000102

Source: Guidehouse

C.10.2 Assumptions and Methodology

No major updates were made to the inputs for commercial competitions in the 2021 Study. Guidehouse determined that commercial competitions be a low priority measure for updates based on a review of implementation activity and recently published California-specific data sources. The methodology described here is unchanged from the 2019 Study.

Eligibility and Participation

Eligibility for commercial competitions is defined by the program administrator. Competitions can focus on occupants within an individual building or across a single company. More often they embrace wider audiences at the municipal level, in which groups of tenants within large buildings or across campuses or neighborhoods compete with one another. Certain business sectors and business types constitute more receptive customer types than others.

For this model, the team focused on savings in those building types targeted by PG&E's Step Up and Power Down campaign that is being carried out in San Francisco and San Jose. These building types include: large offices, small offices, retail, restaurants, and lodging.[206,207] The applicability factor was defined in terms of potential program reach because it applies to larger and smaller types of buildings. The team assumes an

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201 Kira Ashby, 2016 Behavior Program Summary, 2016, Consortium for Energy Efficiency, https://library.cee1.org/content/2016-behavior-program-summary-public

202 Susan Mazur-Stommen and Kate Farley, *ACEEE Field Guide to Utility-Run Behavior Programs*, 2013, American Council for an Energy-Efficient Economy, from http://aceee.org/research-report/b132

203 Edward Vine and Christopher Jones, *A Review of Energy Reduction Competitions. What Have We Learned?,* 2015 (May), California Institute for Energy and Environment. Report sponsored by the CPUC. Available at: http://escholarship.org/uc/item/30x859hv

204 Edward L. Vine and Christopher M. Jones. "Competition, carbon, and conservation: Assessing the energy savings potential of energy efficiency competitions." 2016. Vol 19: 158-176. *Energy Research and Social Science*.

205 TecMarket Works, *Impact Evaluation of the Smart Energy Now Program (NC) (Pilot) for Duke Energy*, February 21, 2014.

206 Linda Dethman, Brian Arthur Smith, Jillian Rich, and James Russell. "Engaging Small and Medium Businesses in Behavior Change through a Multifaceted Marketing Campaign." 2016. Proceedings of the ACEEE Summer Study on Energy Efficiency in Buildings.

207 Kat A. Donnelly. "Workplace Engagement: Finding and Filling the Gaps for Fruitful Energy Savings." 2016 (October). Presentation at the 2016 Behavior, Energy and Climate Change Conference. Baltimore, MD.

applicability of 8% for large offices and lodging and a 4% applicability factor for small offices, restaurants, and retail.[208]

At the time the model was prepared, PG&E was the only California IOU running a commercial competition, but there were no claimed savings. Because of this, the penetration forecast for PG&E shows 0% until 2021, at which point the rate reflects savings claimed for one city. SCE and SDG&E also do not begin with non-zero penetration until 2021. The Guidehouse team does not anticipate that SCG will run commercial competitions given that the team currently does not have sufficient data with which to model gas savings. For the aggressive scenario, PG&E, SCE, and SDG&E all begin to claim savings in 2021, and in 2026, they add a second city-sized competition.

The penetration rates for each utility assume they will target the largest cities within their service territories (e.g., San Francisco, San Jose, Anaheim, and San Diego) or that groups of smaller communities (the size of Walnut Creek, Santa Barbara, or Oceanside) may be pooled together within a service territory to reach a similar number of businesses.

Savings

The team based savings estimates on PG&E's study of the Step Up and Power Down campaign (1.9% kWh). No gas savings are modeled.

The model uses an EUL of 2 years to maintain consistency with CPUC Decision 16-08-019.

Because no demand savings data was available, the team averaged the ratio of kW to kWh savings calculated for BEIMS, BOC, and SEM. This yielded a result of 0.000102, which is the figure used for the three electric utilities.

Cost

The cost of $0.04 per kWh is drawn from Smart Energy Now.[209]

C.11 Commercial – Retrocommissioning

C.11.1 Summary

The potential for retrocommissioning (RCx) has been modeled as a component of behavioral savings in previous studies since 2013. The 2021 update retains the underlying assumptions and inputs used in the 2019 Study. RCx is defined as commissioning performed on buildings that have not been previously commissioned. The PG Model also includes the allowed recommissioning of buildings that have undergone commissioning after 5 years have passed. The model focuses on RCx activities that impact HVAC system operations and includes measures such as the following:[210]

- Correct actuator/damper operations
- Correct economizer operations
- Adjust condenser water reset

[208] Informal comments received in response to the 2019 Study webinar on April 20, 2017 from PG&E indicate a limited willingness to participate in commercial competitions.
[209] TecMarket Works, *Impact Evaluation of the Smart Energy Now Program (NC) (Pilot) for Duke Energy*, February 21, 2014.
[210] 2016 Statewide Retrocommissioning Policy & Procedures Manual, Version 1.0. Effective Date: July 19, 2016

- Adjust supply air temperature reset
- Adjust zone temperature deadbands
- Adjust equipment scheduling
- Adjust duct static pressure reset
- Adjust hot or cold deck reset
- Optimize variable frequency drives on fans or pumps
- Recode Controls HVAC airflow rebalance/adjust
- Reduce simultaneous heating and cooling
- Adjust boiler lockout schedule

The team retained the inputs used in the 2019 Study based on a review of the claimed first-year gross kWh and therm savings from the SCE Enhanced Retrocommissioning[211] and SDG&E HOPPs – Building Retro-Commissioning programs.[212] The model inputs for electric and natural gas for RCx (shown in Table C-15) are based on customer segment consumption (kWh or therms per year). Electricity and natural gas savings range from 2.3% to 5.2% and are applied consistently for all utilities. Costs for electricity and natural gas savings are also constant across utilities at $0.21 per kWh and $0.38 per therm. Industry literature indicates that demand savings associated with RCx are minimal, and the study does not forecast demand savings for RCx.

Table C-15. Commercial RCx – Key Assumptions

Sector	Type	EUL Years	Savings		Cost		kW/kWh Savings Ratio
			kWh	therms	kWh	therms	
Commercial	RCx	5	2.3%-5.2%	2.3%-5.2%	$0.21	$0.38	0.000112

Source: Guidehouse

C.11.2 Assumptions and Methodology

After reviewing implementation activity and recently published California-specific data sources, no major updates were made to RCx in the 2021 Study. The methodology described here is unchanged from the 2019 Study.

Eligibility and Participation

Consistent with previous studies, RCx savings are applied to select commercial market segments, and the applicability factor ranges from 18% to 91%. Consistent with the 2019 Study, the 2021 Study adjusted the eligibility and participation estimates for RCx to exclude BEIMS achievable potential and buildings built after 2011 when commissioning became a requirement under CalGreen. Guidehouse estimated that approximately 92% of commercial building stock was constructed before 2011. Excluding market savings from BEIMS is intended to reduce the risk of double counting savings because the EMS technologies

[211] Program ID: SCE-13-TP-021
[212] Program ID: SDGE3317

inherent in the BEIMS measure allow for continuous commissioning that would exclude commissioning activities defined in the RCx measure.

The model assumes that RCx program interventions in the commercial market have been ongoing since the 2015 Study (though SCG does not claim savings until 2018), and the team used a CAGR to forecast growth in participation over the forecast horizon through 2032. In the reference case, a 3.1% CAGR was used to forecast growth in RCx, while the aggressive case used a 4.5% CAGR. Recommissioning is anticipated in 25% of RCx participants after 5 years, and re-participation is discounted by 25% to avoid double counting of savings influenced by other programs such as BOC and SEM. Low initial penetration of RCx results in forecast penetrations of 2.5% and 3.0% for the reference and aggressive cases, respectively, over the forecast horizon.

Savings

Consistent with past studies, energy savings associated with RCx are calculated using Equation C-3.

Equation C-3. RCx Energy Savings

Energy Savings, RCx = Penetration of RCx by Building Type x Total Annual Consumption x % End-Use Consumption for HVAC x % End Use Savings by Building Type

The percentage of end-use consumption for HVAC systems affected by RCx is based on the 2009 CEUS, while the end-use savings by building type is based on literature reviewed for the 2015 and 2018 studies.[213,214,215] Savings for offices, colleges, and schools were capped at 5% to reflect feedback from SCE on its experience.[216] The model uses an EUL of 3 years per CPUC Decision 16-08-019. A ratio of kW to kWh of 0.000112 was applied to the three electric utilities based on an analysis of several statewide and third-party programs operating in California during the 2014-2015 portfolio cycle that included RCx-related initiatives.

Cost

Costs for electricity and natural gas savings are estimated based on an analysis of the same programs reviewed and referenced in previous studies.

C.12 Industrial/Agriculture – SEM

C.12.1 Summary

SEM in the industrial and agriculture sectors is a holistic approach to managing energy use that continuously improves energy performance based on various initiatives. SEM, per CPUC and California IOU design, is a continuous improvement approach that focuses on changing business practices to enable companies to save money by reducing energy consumption and waste. The industrial sector SEM pilot program being administered by California IOUs served as the basis for this forecast. As defined in the California Industrial

213 2014 Retro-Commissioning (RCx) Program Extreme Makeover, CenterPoint Energy at http://www.centerpointenergy.com/en-us/Documents/2014%20RCx%20Kickoff%20Slides.pdf
214 US Environmental Protection Agency: http://www.epa.gov/statelocalclimate/documents/pdf/table_rules_of_thumb.pdf
215 DEER ExAnte2013 - RTU-Retro, Rooftop Unit retrocommissioning COM IOU workpaper
216 Informal comment received in response to a webinar held on April 20, 2017.

SEM Design Guide,[217] leading SEM programs are designed to support industrial companies by focusing on several high level objectives:

- Implementing EE projects and saving energy, primarily from savings in O&M.
- Establishing the EMS or business practices that help a facility to manage and continuously improve energy performance.
- Normalizing, quantifying, and reporting facility-wide energy performance.
- Getting peers to talk to one another.

The model inputs for electric and natural gas shown in Table C-16 represent savings associated with SEM operational and behavioral changes. Savings are estimated based on building type consumption (kWh or therms per year) for each market segment and are applied consistently across utilities. Incremental measure costs for electricity and natural gas are $0.033/kWh and $0.27/therm;[218] these values are also applied consistently by building and fuel type across utilities.

Table C-16. Industrial/Agriculture SEM – Key Assumptions

Sector	Type	EUL Years	Savings		Cost		kW/kWh Savings Ratio
			kWh	therms	kWh	therms	
Industrial	SEM	4.3	1.9%-4.4%	1.9%-3.9%	$0.033	$0.27	0.000195
Agriculture	SEM	4.3	3.1%-3.9%	3.0	$0.20	$1.35	0.000195

Source: Guidehouse

C.12.2 Assumptions and Methodology

Eligibility and Participation

Eligibility and participation estimates in the 2021 Study are consistent with the 2019 Study, which defined eligibility and participation based on guidance provided by the CPUC regarding the IOUs and as part of the 2017 SEM pilot program development effort and program-reported savings.[219] The analysis also considers historical RCx participation as a proxy for SEM to establish costs and trends. Per the design of the CPUC SEM pilot and the market considerations expressed in the IOU business plans, savings in the industrial sector begin in 2019 for high use market segments, including the petroleum, food, electronics, and chemicals segments, while more widespread implementation for all other industrial segments begins in 2021. Although SEM applies to all customer sizes in theory, in practice, the applicability of SEM is constrained to large customers. In general, this guidance does not mean that any industrial or agriculture market segment will be excluded from participating in SEM, but it does restrict the applicability of SEM to larger participants in each market segment. Consequently, an applicability factor for SEM was defined for all industrial and agriculture market sectors; this factor ranged between 39% and 93% for electricity and 48%

[217] Version 1.0, February 8, 2017. Prepared by Sergio Dias Consulting LLC

[218] Analysis of reported costs from using the 2019 Claims CEDARS data.

[219] Strategic Energy Management – Comments and Responses on Design and EMV Guides, http://www.energydataweb.com/cpuc/search.aspx; program-reported savings are from the CEDARS 2019 claims. Evaluation, measurement, and verification reports of recent SEM participation have not yet been reported at the time of this analysis.

to 99% for natural gas for the industrial sector, as Table C-17 shows, and between 40% and 65% for both electricity and natural gas for the agriculture sector, as Table C-18 shows.

Table C-17. Industrial SEM Applicability

Segment	Fuel	Applicability
Ind – Petroleum	kWh	93%
Ind – Food	kWh	77%
Ind – Electronics	kWh	45%
Ind – Stone-Glass-Clay	kWh	85%
Ind – Chemicals	kWh	74%
Ind – Plastics	kWh	75%
Ind – Fabricated Metals	kWh	72%
Ind – Primary Metals	kWh	59%
Ind – Industrial Machinery	kWh	48%
Ind – Transportation Equipment	kWh	56%
Ind – Paper	kWh	82%
Ind – Printing & Publishing	kWh	61%
Ind – Textiles	kWh	39%
Ind – Lumber & Furniture	kWh	48%
Ind – All Other Industrial	kWh	48%
Ind – Petroleum	therms	99%
Ind – Food	therms	95%
Ind – Electronics	therms	64%
Ind – Stone-Glass-Clay	therms	97%
Ind – Chemicals	therms	98%
Ind – Plastics	therms	81%
Ind – Fabricated Metals	therms	85%
Ind – Primary Metals	therms	94%
Ind – Industrial Machinery	therms	48%
Ind – Transportation Equipment	therms	66%
Ind – Paper	therms	97%
Ind – Printing & Publishing	therms	82%
Ind – Textiles	therms	50%
Ind – Lumber & Furniture	therms	52%
Ind – All Other Industrial	therms	48%

Source: 2019 Potential and Goals Study

Table C-18. Agriculture SEM Applicability

Segment	Applicability
Ag – Irrigated Agriculture, Vineyards, Forestry, and Greenhouses	65%
Ag – Dairies, Fishing, and Hunting	65%
Ag – Water Pumping	40%

Source: 2019 Potential and Goals Study

The starting saturation for all segments is estimated at 1.5% in 2017 because savings have been occurring with RCx prior to SEM program rollout. For the 2021 analysis, the team revised the industrial and agriculture SEM penetration forecast methodology to use a linear forecast versus the CAGR approach used in previous studies. The slope of the linear forecast is based on an analysis of SEM savings trends recorded in CEDARS for 2013 through 2019 and is forecast to be 21% year-over-year for the reference case and 25% for the aggressive case.[220] This change in methodology resulted in SEM penetration forecasts of 6.1% and 7.2% for the reference and aggressive case, respectively, in 2032.

Savings

The savings forecast for SEM is an estimate of O&M savings based on a literature review from previous potential and goals study iterations; this review indicated that an average UES for O&M savings of 3.0% of annual sector-level consumption is appropriate for the industrial and agriculture sectors. Savings at the segment level will vary because SEM in the industrial and agriculture sectors applies primarily to usage associated with machine drive, process heating, and process refrigeration. As such, the team calculated segment-specific UES values based on how much energy is consumed for these three uses.

Table C-19 shows how usage varies by sector for the industrial segment; for example, 93% of petroleum segment consumption is accounted for by the end uses impacted by SEM, while only 39% of energy is consumed by these same end-use categories in the textile segment. On average, these end uses account for 64% of total industrial sector usage. The Guidehouse team calculated a SEM segment savings adjustment factor by dividing the SEM-applicable segment consumption by the market average consumption. For the petroleum sector, for example, the SEM-applicable segment consumption of 93% was divided by the industrial sector average consumption of 64% to yield an SEM segment UES adjustment factor of 1.5 for the petroleum segment. The Guidehouse team then calculated a SEM UES multiplier by multiplying the average SEM industrial sector savings of 3.0% by the SEM segment savings adjustment factor. In this example, the average SEM industrial sector savings of 3.0% was multiplied by the UES adjustment factor of 1.5 for the petroleum segment, yielding a multiplier of 4.4%. Table C-20 provides the UES multipliers used to forecast natural gas savings.

Table C-19. Industrial SEM Electricity UES Multipliers

Segment	SEM Target End Uses			SEM Applicable Segment Consumption	SEM Segment Savings Adjustment Factor	SEM UES Multiplier
	Machine Drives	Process Heat	Process Refriger ation			
Petroleum	88%	0%	6%	93%	1.5	4.4%
Stone-Glass-Clay	61%	24%	1%	85%	1.3	4.0%
Paper	77%	4%	2%	82%	1.3	3.9%
Food	42%	7%	29%	77%	1.2	3.7%
Plastics	51%	15%	9%	75%	1.2	3.6%
Chemicals	61%	5%	9%	74%	1.2	3.5%
Fabricated Metals	49%	20%	3%	72%	1.1	3.4%
Printing & Publishing	52%	2%	7%	61%	1.0	2.9%
Primary Metals	29%	29%	1%	59%	0.9	2.8%

[220] The differences between reference and aggressive are the years used to calculate the average growth rate. In 2014, there was a 73% increase in SEM (and RCx) savings. In 2016, there was a 33% decrease. The range from year to year is large. The resulting values is a best guess estimate.

Segment	SEM Target End Uses			SEM Applicable Segment Consumption	SEM Segment Savings Adjustment Factor	SEM UES Multiplier
	Machine Drives	Process Heat	Process Refrigeration			
Transportation Equipment	37%	13%	6%	56%	0.9	2.7%
All Other Industrial	33%	9%	6%	48%	0.8	2.3%
Industrial Machinery	33%	9%	6%	48%	0.8	2.3%
Lumber & Furniture	36%	8%	4%	48%	0.7	2.3%
Electronics	21%	12%	12%	45%	0.7	2.2%
Textiles	31%	5%	3%	39%	0.6	1.9%

Source: Guidehouse team

Table C-20. Industrial SEM Natural Gas UES Multipliers

Segment	SEM Target End Uses			SEM Segment Savings Adjustment Factor	SEM UES Multiplier
	Machine Drives	Process Heat	Process Refrigeration		
Petroleum	14%	59%	26%	1.3	3.861%
Stone-Glass-Clay	1%	90%	6%	1.3	3.765%
Paper	25%	26%	46%	1.3	3.783%
Food	59%	28%	9%	1.2	3.713%
Plastics	46%	24%	11%	1.1	3.162%
Chemicals	28%	28%	43%	1.3	3.834%
Fabricated Metals	15%	65%	6%	1.1	3.330%
Printing & Publishing	13%	64%	5%	1.1	3.199%
Primary Metals	5%	78%	10%	1.2	3.645%
Transportation Equipment	15%	30%	21%	0.9	2.569%
All Other Industrial	16%	20%	12%	0.6	1.873%
Industrial Machinery	16%	20%	12%	0.6	1.873%
Lumber & Furniture	12%	28%	12%	0.7	2.023%
Electronics	42%	10%	12%	0.8	2.496%
Textiles	18%	19%	13%	0.6	1.947%

Source: Guidehouse team

The 2021 Study uses this same process to develop savings multipliers for the agriculture sector; however, because North American Industry Classification System (NAICS) codes associated with the agriculture sector were changed to align with the Integrated Energy Policy Report (IEPR) definition of the agriculture sector, the same level of data used in the industrial sector forecast was not available. As such, the Guidehouse team used the average UES for O&M savings of 3.0% of annual sector-level consumption for most agriculture market segments and adjusted it for segments that are primarily large motor loads, such as municipal and irrigation water pumping, as Table C-21 shows.

Table C-21. Agriculture SEM Electricity and Natural Gas UES Multipliers

Segment	Fuel	SEM UES Multiplier
Ag – Irrigated Agriculture, Vineyards, Forestry, and Greenhouses	kWh	3.1%
Ag – Dairies, Fishing, and Hunting	kWh	3.1%
Ag – Water Pumping	kWh	3.9%
Ag – Irrigated Agriculture, Vineyards, Forestry, and Greenhouses	therms	3.0%
Ag – Dairies, Fishing, and Hunting	therms	3.0%

Source: Guidehouse analysis

The 2021 Study uses the SEM UES multiplier to forecast segment-level potential net savings using Equation C-4.

Equation C-4. SEM Segment Level Savings

SEM Segment-Level EE Net Savings Potential =
SEM UES Multiplier x Annual Segment Consumption[221]

The model holds the industrial and agriculture segment UES multiplier constant throughout the forecast horizon.

Cost

Costs for electricity and natural gas savings are estimated at $0.023/kWh and $0.27/therm and are applied consistently by building and fuel type across utilities. Costs are based on an analysis of the 2019 CEDARS Claims data. These costs are lower than those for emerging technology and generic custom type measures, reflecting that SEM savings are O&M based and do not include rebate measures for large capital investments.

[221] Electric (GWh) and natural gas (therms) consumption from the 2019 IEPR forecast.

Appendix D. Industrial and Agriculture Sectors

This appendix provides additional detail and data for the industrial and agriculture sectors. Industrial and agriculture building types are classified by grouping buildings in North American Industry Classification System (NAICS) codes. Table D-1 references the building types used in this study with their associated NAICS codes.

Table D-1. Industrial and Agriculture Subsector NAICS Mapping

Sector	Subsector (Building Type)	NAICS
Industrial	Chemicals	325
	Electronics	334x, 335
	Fabricated Metals	332
	Food	311x, 312
	Industrial Machinery	333
	Lumber & Furniture	337, 321, 1133
	Paper	322x
	Petroleum	324
	Plastics	326
	Primary Metals	331
	Printing & Publishing	323, 511, 516
	Stone-Glass-Clay	327x
	Textiles	313, 314, 315, 316
	Transportation Equipment	336
	All Other Industrial	339
Agriculture	Dairies, Fishing, and Hunting	112, 114
	Irrigated Agriculture, Vineyards, Forestry, and Greenhouses	111, 113
	Water Pumping	221

Source: Guidehouse team

D.1 Industrial

Table D-2 displays the industrial measure list used in the PG Model using the diffusion model. Generic measures apply to all subsectors. Specific measures for a particular subsector are noted within the measure name.

Table D-2. Industrial Sector Characterized Custom Measures

Measure Name	End-Use Category	Description
HVAC Equipment Upgrade (Electric and Gas)	HVAC	Upgrades to electric and gas HVAC equipment (using better than code energy- efficiency [EE] rating), and heat recovery.
EE Lighting	Lighting	Lighting controls and early retirement potential to LED fixtures.

Measure Name	End-Use Category	Description
Compressed Air	Machine Drive	Air compressor adjustments such as pressure reduction, staging, system controls, and leak identification and repair. Variable frequency drive (VFD) controls on air compressors to allow for loading/unloading of the compressed air system and to replace any inefficient throttling devices.
Fan VFD	Machine Drive	VFD controls on fans (not including HVAC fans) to take advantage of partial load conditions.
Pump Upgrades	Machine Drive	Proper sizing and operation of pumps to increase pump efficiency.
Energy Efficient Aerator	Machine Drive	Replacing existing inefficient aerators on wastewater systems with higher efficiency aerator technologies.
Motor VFD	Machine Drive	Installation of higher efficiency or premium motors across all industry processes.
Pump VFD	Machine Drive	VFD controls on pumps to take advantage of partial load conditions.
Boiler Controls and Optimization	Process Heating	Pressure reduction, leak reduction, steam trap maintenance, and advanced controls on boilers.
Process Heat	Process Heating	Upgrades and add-ons to gas furnaces and ovens, including infrared, furnace configuration, and advanced controls.
Heat Recovery	Process Heating	Capturing waste heat produced primarily from gas boilers and using it in other phases of the industrial process.
Insulation	Process Heating	Insulation or improved insulation on boiler equipment, storage tanks, and other process piping.
Chiller	Process Refrigeration	Chiller upgrades including advanced controls, higher efficiency equipment, and overall system efficiency improvements.
Refrigeration	Process Refrigeration	Advanced controls on refrigeration systems including floating head controls, evaporator fan controls, and condenser controls.
Food Processing Heat Recovery	Process Heating	Includes low cost boiler EE improvements such as measuring boiler system performance based on condensate return, improving insulation of the boiler system and loops, boiler controls, and boiler system tune-ups. The measure also includes opportunities for heat recovery via heat exchangers from process heat (e.g., used in canning tomatoes), compressors, boilers, and hot water systems.
Food Processing Refrigeration Optimization	Process Refrigeration	Includes a variety of smaller measures to improve the EE of refrigeration systems, mostly through controls. These include head pressure adjustments, suction pressure adjustments, sequencing of refrigeration compressors, temperature adjustments, improving insulation, adding VFDs to compressors, and the installation of new more EE compressors.

Measure Name	End-Use Category	Description
Food Processing VFDs	Machine Drive	The installation of VFDs on pumps and motors produces energy savings because many motors in this subsector operate well below the design load. This is especially true for facilities that have large seasonal swings in production. VFD savings can also be further enhanced by moving to smart controls. However, expertise in complex controls systems is needed.
Electronics Retro-commissioning[222]	Whole Facility	Retrocommissioning (RCx) involves making low and no-cost energy performance improvements to a system or process, resulting in short payback periods. Typical activities include reviewing trend data within the building automation systems, performing functional testing, and identifying control enhancements.
Electronics Chiller Plant Optimization	HVAC	Chilled water plant optimization consists of adding or updating hardware and control sequences to an existing chilled water system to reduce the energy consumption associated with the chiller plant as a whole, which can consist of chillers, pumps, and cooling tower fans.
Electronics Low Pressure Drop Filters	HVAC	The cleanrooms in electronics manufacturing facilities use many filters to purify the air. If these filters get too clogged, they can cause the fans that drive the airflow in the cleanrooms to work harder. Lower pressure drop filters have greater dirt holding capacity than standard filters because of their greater media surface area with deeper-pleated filters and closer pleat spacing. This greater dirt holding capacity reduces filter pressure drop and results in less fan energy use for the same airflow rate.
Chem Manf Heat Recovery	Process Heating	Includes the installation of heat exchangers, also known as economizers.
Chem Manf Advance Automation[223]	Whole Facility	Includes diverse set of measures such as: plant-wide monitoring and automated control systems; fuel to air controls for combustion systems; and variable flow primary loop systems for cooling.
Chem Manf VFDs	Machine Drive	Includes replacing constant speed drives and single stage systems with multi-stage systems.

Source: Guidehouse team

D.2 Agriculture

Table D-3 displays the agriculture measure list used in the PG Model using a diffusion model. Generic measures apply to all subsectors. Specific measures for a particular subsector are noted within the measure name.

[222] There may be overlap with the SEM-like industrial measure with RCx; however, the Industrial and Agriculture Market Study provided specific characterization to quantify the measure under characterized custom.

[223] There may be overlap with the SEM-like industrial measure with RCx; however, the Industrial and Agriculture Market Study provided specific characterization to quantify the measure under characterized custom.

Table D-3. Agriculture Sector Characterized Custom Measures

Measure Name	End-Use Category	Description
HVAC Ventilation (Fan Ventilation Improvement)	HVAC	Upgrade to more efficient fans, temperature and humidity controls, VFDs (includes post-harvest process fan aeration improvements).
HVAC Chiller Water Cooled	HVAC	Chiller upgrades including advanced controls, higher efficiency equipment, and overall system efficiency improvements.
Ag Irrigation Pump	Machine Drive	Irrigation-specific pump improvement, maintenance, and replacement designed to increase pump efficiency.
Ag Pump VFD	Machine Drive	VFD for irrigation-specific pumps (well, irrigation, booster, etc.).
Low Pressure Irrigation	Machine Drive	Conversion from high to low pressure irrigation (sprinkler to drip, low pressure nozzles, etc.).
Ag Pump Retrofit – Non-Irrigation	Machine Drive	Pump retrofits geared to all other pumps besides irrigation-specific pumps.
Ag Pump VFD – Dairy	Machine Drive	VFD for dairy-specific pumps (vacuum, transfer, etc.)
Process Wastewater Aerator	Machine Drive	Replacing existing inefficient aerators on wastewater systems with higher efficiency aerator technologies.
Exterior Lighting Upgrades	Lighting[224]	Includes typical commercial and industrial exterior LED lighting measures and exterior security lights.
Horticulture Interior LED Grow Lighting	Lighting	Indoor LED lamps and fixtures used for growing a variety of plants.
Interior Lighting Upgrades – LED	Lighting	Includes typical commercial and industrial LED lighting measures and applications as well as agriculture-rated LEDs for animal health and animal-specific purposes.
Interior Lighting Upgrades – Non-LED	Lighting	Includes typical commercial and industrial non-LED lighting measures and applications.
Lighting Controls	Lighting	Occupancy sensors, photocells/timers, etc.
Greenhouse Process Heating Optimization	Process Heating	Heating optimization and equipment improvements for greenhouses (unit to bench heating conversion, boiler improvement measures, dynamic temperature controls, etc.).
Greenhouse Shell Improvements	Process Heating	Heating optimization improvements for greenhouses centered around shell improvements (thermal and shade curtains, insulation upgrades, film, etc.).
Post-Harvest Process Improvements	Process Heating	Gas improvements to post-harvesting such as more efficient heated grain drying, heat recovery, process controls.
Pipe Insulation Hot Application	Process Heating	Insulation or improved insulation on boiler equipment, storage tanks, and other process piping.
Process Refrigeration Retrofit – Dairy	Process Refrigeration	Refrigeration improvements to process milk cooling on dairies (plate coolers, scroll compressors).

[224] All lighting considers the LED baseline and efficient changes reflected in the commercial sector.

Measure Name	End-Use Category	Description
Refrigeration Retrofit (Refrigeration System Optimization)	Process Refrigeration	Includes typical commercial and industrial refrigeration improvements to cold storage areas (floating head pressure controls, evaporator fan controls, evaporator fans, etc.).
Dairies Refrigeration System Heat Recovery	Process Heating	Dairy refrigeration systems keep raw milk cool and the heat removed by these refrigeration systems is typically rejected to the environment. Installation of a heat recovery system (a heat exchanger on the condensing unit) allows waste heat to be recovered for pre-heating water for cleaning processes, which is another large energy use on a dairy farm.
Dairies VFDs on Pumps	Machine Drives	The milking and collection system pumps milk through the milking system from cow to cooling tank. Current practice is a constant speed pump with a manually adjusted orifice to maximize the vacuum level in the system. As a result, systems typically run well below capacity, wasting most of the pump motor's power. A VFD allows the system to adjust vacuum levels on the fly, reducing pump power when not under full load conditions.
Dairies EE Fans and Ventilation	Machine Drives	High efficiency fan blades are made from lighter materials and reduce overall power consumption. A variety of fan sizes are now available, and the experts said this was a newer market that was expanding quickly.
Water Pumping Efficient Pumps and Motors	Machine Drives	Premium efficiency motors offered savings upward of 4% when compared to standard efficiency motors. When comparing premium efficiency motors to the motors that are installed, a large quantity of savings could be realized from the installation of premium efficient motors.
Water Pumping Sensors and Controls	Machine Drives	Irrigation often is done manually and based on rule of thumb, as farmers know, on average, how many acre feet of water a certain crop needs and adjust their pumping schedule to fit that demand. In these cases, crops are often over- or under-irrigated, which can have a negative impact on the crop's yield and the pump's energy consumption. Use of sensors to monitor soil moisture content would help avoid over or underwatering. It would also minimize energy costs associated with pumping because a control system would optimize operation and reduce water and energy consumption.

Measure Name	End-Use Category	Description
Water Pumping Comprehensive Program	Machine Drives	The irrigation system is made up of three parts: pump/well hydraulics, electric to hydraulics conversion, and the discharge or water distribution system. Studies show that improving pumping efficiency can reduce energy consumption by 19%-34%, on average. However, when such a measure is implemented on its own within such a closely knitted system, it may just shift inefficiencies to the next part of the system. For example, an EE motor or pump will not work as intended if that piece of equipment is still expected to meet a high discharge pressure on a system that overirrigates because no moisture sensors have been deployed or the water is being distributed through an old, inefficient, and leaking aluminum pipe system instead of a more efficient yellow mine system.
LED Grow Lights	Lighting	Lighting loads in a greenhouse vary with location and type of crop being cultivated. Greenhouses growing vegetables or other high value crops do not have significant lighting loads. Cannabis greenhouses have a considerably large lighting load. Market saturation and adoption depend on multiple factors such as crop being cultivated, geography, and greenhouse size.
EE HVAC	HVAC	Conventional greenhouse HVAC systems are not best suited for greenhouse applications, especially in the cannabis subsector because they are designed for a different purpose—comfort cooling for people loads rather than plant loads. Additionally, psychrometric requirements of the cannabis plant typically require the HVAC system to operate at different conditions than what they normally operate at because plants need different internal climate conditions compared to comfort cooling for humans.
Energy Curtains	Process Heating	Energy curtain would be more effective in realizing energy savings by reducing heat loss to the external environment compared to installing a higher efficiency heating system like a condensing boiler. The energy curtain would have a lower initial cost and a shorter payback period than the boiler.

Source: Guidehouse team

The 2021 Study included new data for measure characterization. Instead of relying only on historical program participation and accounting for the characterized custom, the 2021 Study referenced the Industrial and Agriculture Market Study. The measures characterized in the study were either new or they replaced the specific subsector characterization under an existing measure. Table D-4 describes if the new measure replaces an existing measure or is new.

Table D-4. Industrial and Agriculture Characterized Custom Measure Updates

2019 Measure Status Changes	Industrial New Measure
Food sector removed from heat recovery	Food Processing Heat Recovery
Food sector removed from refrigeration	Food Processing Refrigeration Optimization
Food sector removed from Motor/Pump VFD	Food Processing VFDs
New measure, nothing removed	Electronics Retro-commissioning
Electronics sector removed from HVAC equipment upgrade	Electronics Chiller Plant Optimization
New measure, nothing removed	Electronics Low Pressure Drop HEPA/ULPA Filters
Chem Manf sector removed from heat recovery	Chem Manf Heat Recovery
New measure, nothing removed	Chem Manf Advance Automation
Chem Manf sector removed from Motor/Pump VFD	Chem Manf VFDs
Dairy sector removed from HVAC Ventilation	Dairy – EE Fans and Vent-Motor
Dairy sector removed from VFD, added to Ag Dairy Pumps	Dairy – VFD-Motor
New measure, nothing removed	Dairy – Refrigeration system heat recovery
Water pumping sector removed from Efficient Ag Irrigation Pumps	Water Pumping – Sensors and Controls
Water pumping sector removed from VFD, added to standard Ag Irrigation Pumps	Water Pumping – EE Pump Motors
Water pumping sector removed from Low Pressure Irrigation	Water Pumping – Comprehensive Program
Greenhouse sector of Process Heating Optimization	Greenhouse – High EE HVAC
Greenhouse sector of Shell Improvements	Greenhouse – Energy Curtain
Greenhouse sector removed from LED Interior Hort. Grow Lights	Greenhouse – LED Grow Lights

Source: Guidehouse

Appendix E. Codes and Standards

Table E-1 describes the list of codes and standards (C&S) accounted for in the model.

Table E-1. C&S in the Model

Regulation	Code or Standard Name	Compliance Rate[225]	Effective Date	Policy View
2005 T-20	2005 T-20: Dishwasher Pre-Rinse Spray Valves	100%	1/1/2006	On-the-books
2005 T-20	2005 T-20: Commercial Refrigeration Equipment, Solid Door	70%	1/1/2006	On-the-books
2005 T-20	2005 T-20: Consumer Electronics - DVDs	31%	1/1/2006	On-the-books
2005 T-20	2005 T-20: Consumer Electronics - TVs	96%	1/1/2006	On-the-books
2005 T-20	2005 T-20: General Service Incandescent Lamps, Tier 1	69%	1/1/2006	On-the-books
2005 T-20	2005 T-20: Hot Food Holding Cabinets	70%	1/1/2006	On-the-books
2005 T-20	2005 T-20: Portable Electric Spas	70%	1/1/2006	On-the-books
2005 T-20	2005 T-20: Pulse Start Metal Halide HID Luminaires, Tier 1(Vertical Lamps)	100%	1/1/2006	On-the-books
2005 T-20	2005 T-20: Refrigerated Beverage Vending Machines	37%	1/1/2006	On-the-books
2005 T-20	2005 T-20: Residential Pool Pumps, High Eff Motor, Tier 1	100%	1/1/2006	On-the-books
2005 T-20	2005 T-20: Unit Heaters and Duct Furnaces	100%	1/1/2006	On-the-books
2005 T-20	2005 T-20: Walk-In Refrigerators / Freezers	91%	1/1/2006	On-the-books
2005 T-20	2005 T-20: Water Dispensers	70%	1/1/2006	On-the-books
2005 T-20	2005 T-20: Large Packaged Commercial Air-Conditioners, Tier 1	70%	10/1/2006	On-the-books
2005 T-20	2005 T-20: Commercial Refrigeration Equipment, Transparent Door	70%	1/1/2007	On-the-books
2005 T-20	2005 T-20: Consumer Electronics - Audio Players	100%	1/1/2007	On-the-books
2005 T-20	2005 T-20: External Power Supplies, Tier 1	100%	1/1/2007	On-the-books
2005 T-20	2005 T-20: Commercial Ice Maker Equipment	70%	1/1/2008	On-the-books
2005 T-20	2005 T-20: Modular Furniture Task Lighting Fixtures	70%	1/1/2008	On-the-books

[225] Compliance rates are specific to 2016 for electric energy savings. Full details are available in the model. Standards included in Integrated Standards Savings Model (ISSM) data had varying compliance values for each year in the analysis. For this table, the Guidehouse team averaged the compliance rates for the period 2022-2032.

Regulation	Code or Standard Name	Compliance Rate[225]	Effective Date	Policy View
2005 T-20	2005 T-20: Pulse Start Metal Halide HID Luminaires, Tier 2(All other MH	100%	1/1/2008	On-the-books
2005 T-20	2005 T-20: External Power Supplies, Tier 2	99%	7/1/2008	On-the-books
2005 T-20	2005 T-20: Large Packaged Commercial Air-Conditioners, Tier 2	70%	1/1/2010	On-the-books
2005 T-24	2005 T-24: Bi-level lighting control credits	79%	1/1/2006	On-the-books
2005 T-24	2005 T-24: Composite for Remainder - Non-Res	85%	1/1/2006	On-the-books
2005 T-24	2005 T-24: Composite for Remainder - Res	120%	1/1/2006	On-the-books
2005 T-24	2005 T-24: Cool roofs	75%	1/1/2006	On-the-books
2005 T-24	2005 T-24: Cooling tower applications	88%	1/1/2006	On-the-books
2005 T-24	2005 T-24: Duct improvement	59%	1/1/2006	On-the-books
2005 T-24	2005 T-24: Duct testing/sealing in new commercial buildings	82%	1/1/2006	On-the-books
2005 T-24	2005 T-24: Ducts in existing commercial buildings	75%	1/1/2006	On-the-books
2005 T-24	2005 T-24: Lighting controls under skylights	8%	1/1/2006	On-the-books
2005 T-24	2005 T-24: Multifamily Water Heating	78%	1/1/2006	On-the-books
2005 T-24	2005 T-24: Relocatable classrooms	100%	1/1/2006	On-the-books
2005 T-24	2005 T-24: Res. Hardwired lighting	113%	1/1/2006	On-the-books
2005 T-24	2005 T-24: Time dependent valuation, Nonresidential	0%	1/1/2006	On-the-books
2005 T-24	2005 T-24: Time dependent valuation, Residential	0%	1/1/2006	On-the-books
2005 T-24	2005 T-24: Whole Building - Non-Res New Construction (Electric)	0%	1/1/2006	On-the-books
2005 T-24	2005 T-24: Whole Building - Non-Res New Construction (Gas)	0%	1/1/2006	On-the-books
2005 T-24	2005 T-24: Whole Building - Res New Construction (Electric)	120%	1/1/2006	On-the-books
2005 T-24	2005 T-24: Whole Building - Res New Construction (Gas)	235%	1/1/2006	On-the-books
2005 T-24	2005 T-24: Window replacement	80%	1/1/2006	On-the-books
2006 T-20	2006 T-20: General Service Incandescent Lamps, Tier 2 #1	87%	1/1/2008	On-the-books
2006 T-20	2006 T-20: General Service Incandescent Lamps, Tier 2 #2	87%	1/1/2008	On-the-books
2006 T-20	2006 T-20: General Service Incandescent Lamps, Tier 2 #3	89%	1/1/2008	On-the-books
2006 T-20	2006 T-20: Residential Pool Pumps, 2-speed Motors, Tier 2	86%	1/1/2008	On-the-books
2006 T-20	2006 T-20: BR, ER and R20 Incandescent Reflector Lamps: Commercial	82%	1/8/2008	On-the-books

Regulation	Code or Standard Name	Compliance Rate[225]	Effective Date	Policy View
2006 T-20	2006 T-20: BR, ER and R20 Incandescent Reflector Lamps: Residential	82%	1/8/2008	On-the-books
2008 T-20	2008 T-20: Metal Halide Fixtures	95%	1/1/2010	On-the-books
2008 T-20	2008 T-20: Portable Lighting Fixtures	93%	1/1/2010	On-the-books
2008 T-20	2008 T-20: General Purpose Lighting -- 100 watt	88%	1/1/2011	On-the-books
2008 T-20	2008 T-20: General Purpose Lighting -- 75 watt	40%	1/1/2012	On-the-books
2008 T-20	2008 T-20: General Purpose Lighting -- 60 and 40 watt	85%	1/1/2013	On-the-books
2008 T-24	2008 T-24: Residential Fenestration	83%	7/1/2010	On-the-books
2008 T-24	2008 T-24: Residential Swimming pool	54%	7/1/2010	On-the-books
2008 T-24	2008 T-24: CfR HVAC Efficiency	287%	9/1/2010	On-the-books
2008 T-24	2008 T-24: CfR IL Area Category Method	529%	9/1/2010	On-the-books
2008 T-24	2008 T-24: CfR IL Complete Building Method	531%	9/1/2010	On-the-books
2008 T-24	2008 T-24: CfR IL Egress Control	287%	9/1/2010	On-the-books
2008 T-24	2008 T-24: CfR Res Central Fan WL	83%	9/1/2010	On-the-books
2008 T-24	2008 T-24: CfR Res Cool Roofs	83%	9/1/2010	On-the-books
2008 T-24	2008 T-24: MF Water heating control	49%	9/1/2010	On-the-books
2008 T-24	2008 T-24: Cool Roof Expansion	234%	10/1/2010	On-the-books
2008 T-24	2008 T-24: DDC to Zone	287%	10/1/2010	On-the-books
2008 T-24	2008 T-24: DR Indoor Lighting	239%	10/1/2010	On-the-books
2008 T-24	2008 T-24: Envelope insulation	173%	10/1/2010	On-the-books
2008 T-24	2008 T-24: Outdoor Lighting	54%	10/1/2010	On-the-books
2008 T-24	2008 T-24: Outdoor Signs	83%	10/1/2010	On-the-books
2008 T-24	2008 T-24: Overall Envelope Tradeoff	287%	10/1/2010	On-the-books
2008 T-24	2008 T-24: Refrigerated warehouses	83%	10/1/2010	On-the-books
2008 T-24	2008 T-24: Sidelighting	287%	10/1/2010	On-the-books
2008 T-24	2008 T-24: Site Built Fenestration	83%	10/1/2010	On-the-books
2008 T-24	2008 T-24: Skylighting	287%	10/1/2010	On-the-books
2008 T-24	2008 T-24: Tailored Indoor lighting	534%	10/1/2010	On-the-books
2008 T-24	2008 T-24: TDV Lighting Controls	0%	10/1/2010	On-the-books
2009 T-20	2009 T-20: Televisions - Tier 1	98%	1/1/2011	On-the-books
2009 T-20	2009 T-20: Televisions - Tier 2	85%	1/1/2013	On-the-books
2011 T-20	2011 T-20: Small Battery Chargers – Tier 1 (consumer with no USB charger or USB charger <20 watt-hours)	85%	2/1/2013	On-the-books
2011 T-20	2011 T-20: Large Battery Chargers (≥2kW rated input)	85%	1/1/2014	On-the-books
2011 T-20	2011 T-20: Small Battery Chargers – Tier 2 (consumer with USB charger ≥20 watt-hours)	85%	1/1/2014	On-the-books

Regulation	Code or Standard Name	Compliance Rate[225]	Effective Date	Policy View
2011 T-20	2011 T-20: Small Battery Chargers – Tier 3 (non-consumer)	0%	1/1/2017	On-the-books
2013 T-24	2013 T-24: NRA-Envelope-Cool Roofs	83%	7/1/2014	On-the-books
2013 T-24	2013 T-24: NRA-HVAC-Equipment Efficiency	83%	7/1/2014	On-the-books
2013 T-24	2013 T-24: NRA-Lighting-Alterations-Existing Measures	83%	7/1/2014	On-the-books
2013 T-24	2013 T-24: NRA-Lighting-Alterations-New Measures	83%	7/1/2014	On-the-books
2013 T-24	2013 T-24: NRA-Lighting-Egress Lighting Control	83%	7/1/2014	On-the-books
2013 T-24	2013 T-24: NRA-Lighting-Hotel Corridors	83%	7/1/2014	On-the-books
2013 T-24	2013 T-24: NRA-Lighting-MF Building Corridors	83%	7/1/2014	On-the-books
2013 T-24	2013 T-24: NRA-Lighting-Warehouses and Libraries	83%	7/1/2014	On-the-books
2013 T-24	2013 T-24: NRA-Process-Air Compressors	83%	7/1/2014	On-the-books
2013 T-24	2013 T-24: RA-MF Whole Building	83%	7/1/2014	On-the-books
2013 T-24	2013 T-24: RA-SF Whole Building	83%	7/1/2014	On-the-books
2013 T-24	2013 T-24: RNC-DHW - High Efficiency Water Heater Ready	83%	1/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-DHW - Solar for Electrically Heated Homes	83%	1/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-DHW-SF DHW	83%	1/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-Envelope-Advanced Envelope	83%	1/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-Envelope-Fenestration	83%	1/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-Envelope-Roof Envelope	83%	1/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-Envelope-Wall Insulation	83%	1/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-HVAC - Refrigerant Charge	83%	1/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-HVAC-Duct	83%	1/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-HVAC-Whole House Fans	83%	1/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-HVAC-Zoned AC	83%	1/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-Lighting	83%	1/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-SF Whole Building	83%	1/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-Solar - Solar Ready & Oriented Homes	83%	1/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-DHW - Hotel DHW Control and Solar	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-DHW-Solar Water Heating	83%	4/1/2015	On-the-books

Regulation	Code or Standard Name	Compliance Rate[225]	Effective Date	Policy View
2013 T-24	2013 T-24: NRNC-Envelope-Cool Roofs	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-Envelope-Fenestration	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Acceptance Requirements	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Chiller Min Efficiency	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Commercial Boilers	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Cooling Towers Water	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Evap Cooling Credit	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Fan Control & Economizers	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Garage Exhaust	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Guest Room OC Controls	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-HVAC Controls and Economizers	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Kitchen Ventilation	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Laboratory Exhaust	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Low-Temp Radiant Cooling	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Occupant Controlled Smart Thermostats	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Outside Air	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Reduced Reheat	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Small ECM Motor	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Water & Space Heating ACM	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-Lighting-Controllable Lighting	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-Lighting-Daylighting	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-Lighting-DR Lighting Controls	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-Lighting-Egress Lighting Control	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-Lighting-Hotel Corridors	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-Lighting-Indoor Lighting Controls	83%	4/1/2015	On-the-books

Regulation	Code or Standard Name	Compliance Rate[225]	Effective Date	Policy View
2013 T-24	2013 T-24: NRNC-Lighting-MF Building Corridors	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-Lighting-Office Plug Load Control	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-Lighting-Outdoor Lighting & Controls	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-Lighting-Parking Garage	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-Lighting-Retail	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-Lighting-Warehouses and Libraries	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-Process-Air Compressors	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-Process-Data Centers	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-Process-Process Boilers	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-Refrigeration-Supermarket	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-Refrigeration-Warehouse	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-Solar-Solar Ready	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-Whole Building	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-DHW - MF DHW Control and Solar	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-MF Whole Building	83%	4/1/2015	On-the-books
2015 T-20	T-20: Residential Faucets & Aerators - Lavatory w/ Electric Water Heating - Tier 1	0%	9/1/2015	On-the-books
2015 T-20	T-20: Residential Faucets & Aerators - Lavatory w/ Natural Gas Water Heating - Tier 1	0%	9/1/2015	On-the-books
2016 T-20	T-20: Commercial Toilets	59%	1/1/2016	On-the-books
2016 T-20	T-20: Public Lavatory Faucets	0%	1/1/2016	On-the-books
2016 T-20	T-20: Residential Faucets & Aerators - Kitchen w/ Electric Water Heating	39%	1/1/2016	On-the-books
2016 T-20	T-20: Residential Faucets & Aerators - Kitchen w/ Natural Gas Water Heating	39%	1/1/2016	On-the-books
2016 T-20	T-20: Residential Toilets	85%	1/1/2016	On-the-books
2016 T-20	T-20: Urinals	53%	1/1/2016	On-the-books
2016 T-20	T-20: Dimming Ballasts	67%	7/1/2016	On-the-books
2016 T-20	T-20: Residential Faucets & Aerators - Lavatory w/ Electric Water Heating - Tier 2	46%	7/1/2016	On-the-books
2016 T-20	T-20: Residential Faucets & Aerators - Lavatory w/ Natural Gas Water Heating - Tier 2	46%	7/1/2016	On-the-books

Regulation	Code or Standard Name	Compliance Rate[225]	Effective Date	Policy View
2016 T-20	T-20: Showerheads - w/ Electric Water Heaters - Tier 1	39%	7/1/2016	On-the-books
2016 T-20	T-20: Showerheads - w/ Natural Gas Water Heaters - Tier 1	39%	7/1/2016	On-the-books
2016 T-24	2016 T-24: NRA-HVAC-ASHARE Measure-DDC	56%	2/1/2017	On-the-books
2016 T-24	2016 T-24: NRA-HVAC-ASHRAE Equipment Efficiency	56%	2/1/2017	On-the-books
2016 T-24	2016 T-24: NRA-Lighting-Alterations	56%	2/1/2017	On-the-books
2016 T-24	2016 T-24: NRA-Lighting-ASHARE Measure-Elevator Lighting & Ventilation	56%	2/1/2017	On-the-books
2016 T-24	2016 T-24: NRA-Lighting-Outdoor Lighting Controls	56%	2/1/2017	On-the-books
2016 T-24	2016 T-24: NRA-Process-ASHARE Measure-Escalator Speed Control	56%	2/1/2017	On-the-books
2016 T-24	2016 T-24: RA-Multifamily Whole Building	56%	4/1/2017	On-the-books
2016 T-24	2016 T-24: RA-Single Family Whole Building	56%	4/1/2017	On-the-books
2016 T-24	2016 T-24: RNC-Multifamily Whole Building	56%	7/1/2017	On-the-books
2016 T-24	2016 T-24: RNC-Single Family Whole Building	56%	7/1/2017	On-the-books
2016 T-24	2016 T-24: NRNC-Whole Building	56%	11/1/2017	On-the-books
2018 T-20	T-20: Computers - Small Scale Servers	10%	1/1/2018	On-the-books
2018 T-20	T-20: Computers - Workstations	10%	1/1/2018	On-the-books
2018 T-20	T-20: GSLs - Original Scope - Tier 2	100%	1/1/2018	On-the-books
2018 T-20	T-20: LED Lamps - Tier 1	99%	1/1/2018	On-the-books
2018 T-20	T-20: Small Diameter Directional Lamps	39%	1/1/2018	On-the-books
2018 T-20	T-20: Showerheads - w/ Electric Water Heaters - Tier 2	32%	7/1/2018	On-the-books
2018 T-20	T-20: Showerheads - w/ Natural Gas Water Heaters - Tier 2	32%	7/1/2018	On-the-books
2019 T-24	2019 T-24: RA	0%	1/1/2020	On-the-books
2019 T-24	2019 T-24: RNC	0%	7/1/2020	On-the-books
2019 T-24	2019 T-24: NRNC	0%	11/1/2020	On-the-books
Federal	Fed Appliance: Electric Motors 1-200HP	91%	12/1/2010	On-the-books
Federal	Fed Appliance: Refrigerated Beverage Vending Machines	37%	8/31/2011	On-the-books
Federal	Fed Appliance: Commercial Refrigeration	70%	1/1/2012	On-the-books
Federal	Fed Appliance: ASHRAE Products (Commercial boilers)	95%	3/2/2012	On-the-books
Federal	Fed Appliance: Residential Electric & Gas Ranges	100%	4/9/2012	On-the-books

Regulation	Code or Standard Name	Compliance Rate[225]	Effective Date	Policy View
Federal	Fed Appliance: General Service Fluorescent Lamps #1	95%	7/14/2012	On-the-books
Federal	Fed Appliance: Incandescent Reflector Lamps	7%	7/14/2012	On-the-books
Federal	Fed Appliance: Commercial Clothes Washers #1	89%	1/8/2013	On-the-books
Federal	Fed Appliance: Residential Direct Heating Equipment	89%	4/16/2013	On-the-books
Federal	Fed Appliance: Residential Pool Heaters	89%	4/16/2013	On-the-books
Federal	Fed Appliance: Residential Dishwashers	89%	5/30/2013	On-the-books
Federal	Fed Appliance: Small Commercial Package Air-Conditioners ≥65 and <135 kBtu/h	89%	6/1/2013	On-the-books
Federal	Fed Appliance: Computer Room ACs >=65,000 Btu/h and < 760,000 Btu/h	89%	10/29/2013	On-the-books
Federal	Fed Appliance: Large and Very Large Commercial Package Air-Conditioners ≥135 kBtu/h	89%	6/1/2014	On-the-books
Federal	Fed Appliance: Residential Room AC	89%	6/1/2014	On-the-books
Federal	Fed Appliance: Residential Refrigerators & Freezers	89%	9/15/2014	On-the-books
Federal	Fed Appliance: Fluorescent Ballasts	89%	11/14/2014	On-the-books
Federal	Fed Appliance: Residential Central AC, Heat Pumps and Furnaces	85%	1/1/2015	On-the-books
Federal	Fed Appliance: Residential Clothes Dryers	85%	1/15/2015	On-the-books
Federal	Fed Appliance: Residential Clothes Washers (Front Loading)	85%	3/7/2015	On-the-books
Federal	Fed Appliance: Residential Clothes Washers (Top Loading) Tier I	85%	3/7/2015	On-the-books
Federal	Fed Appliance: Small Electric Motors	85%	3/9/2015	On-the-books
Federal	Fed Appliance: Residential Electric storage water heater	85%	4/16/2015	On-the-books
Federal	Fed Appliance: Residential Gas-fired instantaneous water heater	85%	4/16/2015	On-the-books
Federal	Fed Appliance: Residential Gas-fired water heater	85%	4/16/2015	On-the-books
Federal	Fed Appliance: Residential Oil-fired storage water heater	85%	4/16/2015	On-the-books
Federal	Fed Appliance: Single package vertical AC and HP - >65,000 Btu/hr and <240,000 Btu/hr	100%	10/9/2015	On-the-books
Federal	Fed Appliance: Distribution transformers	100%	1/1/2016	On-the-books
Federal	Fed Appliance: External Power Supplies	0%	2/10/2016	On-the-books
Federal	Fed Appliance: Electric Motors	97%	6/1/2016	On-the-books

Regulation	Code or Standard Name	Compliance Rate[225]	Effective Date	Policy View
Federal	Fed Appliance: Microwave ovens	53%	6/17/2016	On-the-books

Source: Guidehouse

Table E-2 specifies all standards that are assumed to be superseded by other standards.

Table E-2. C&S Superseded C&S

Superseded Code or Standard	Superseding Code or Standard	Source
2005 T-20: Walk-in Refrigerators/Freezers	Fed Appliance: Walk-in coolers and freezers	Guidehouse assumption
2005 T-20: Commercial Dishwasher Pre-Rinse Spray Valves	Fed Appliance: Pre-Rinse Spray Valves	Guidehouse assumption
2005 T-20: Consumer Electronics - TVs	2009 T-20: Televisions - Tier 1	ISSM
2005 T-20: Commercial Refrigeration Equipment, Solid Door	Fed Appliance: Commercial Refrigeration	ISSM
2005 T-20: Commercial Refrigeration Equipment, Transparent Door	Fed Appliance: Commercial Refrigeration	ISSM
2005 T-20: Commercial Ice Maker Equipment	Fed Appliance: Commercial Refrigeration	ISSM
2005 T-20: Refrigerated Beverage Vending Machines	Fed Appliance: Refrigerated Beverage Vending Machines	ISSM
2006 T-20: Residential Pool Pumps, 2-speed Motors, Tier 2	Fed Appliance: Pool Pumps	Guidehouse assumption
2006 T-20: BR, ER and R20 Incandescent Reflector Lamps: Residential	Fed Appliance: Incandescent Reflector Lamps	ISSM
2006 T-20: BR, ER and R20 Incandescent Reflector Lamps: Commercial	Fed Appliance: Incandescent Reflector Lamps	ISSM
2006 T-20: General Service Incandescent Lamps, Tier 2 #1	2008 T-20: General Purpose Lighting -- 100 watt	ISSM
2006 T-20: General Service Incandescent Lamps, Tier 2 #2	2008 T-20: General Purpose Lighting -- 75 watt	ISSM
2006 T-20: General Service Incandescent Lamps, Tier 2 #3	2008 T-20: General Purpose Lighting -- 60 and 40 watt	ISSM
2006 T-20: General Service Incandescent Lamps, Tier 2 #1	Energy Independence and Security Act (EISA)	ISSM
2006 T-20: General Service Incandescent Lamps, Tier 2 #2	EISA	ISSM
2006 T-20: General Service Incandescent Lamps, Tier 2 #3	EISA	ISSM
2008 T-20: General Purpose Lighting – 100 watt	EISA	ISSM

Superseded Code or Standard	Superseding Code or Standard	Source
2008 T-20: General Purpose Lighting – 75 watt	EISA	ISSM
2008 T-20: General Purpose Lighting – 60 and 40 watt	EISA	ISSM
Unevaluated T-20: General Service Lamps – Original Scope – Tier 2	Future Fed Appliance: GSLs - Expanded Scope	Guidehouse assumption

Source: Guidehouse

Appendix F. Industrial and Agriculture Generic Custom and Emerging Technologies

F.1 Industrial and Agriculture Generic Custom Measures

F.1.1 Summary

Generic custom (GC) measures in the industrial and agriculture sector are projects that tend to be specific to an industry segment or production method. Table F-1 provides the inputs for the GC measures in the 2021 Study and the rest of this section details the assumptions and methodology used to derive these inputs.

Table F-1. Industrial and Agriculture GC – Key Assumptions

Sector	Type	EUL Years	Savings		Cost		kW/kWh Savings Ratio
			kWh	therm	kWh	therm	
Industrial	Generic Custom	15	0.0673%	0.0535%	$0.48	$2.81	0.000195
Agriculture	Generic Custom	15	0.060%	0.624%	$0.48	$2.81	0.000195

Source: Guidehouse

F.1.2 Applicability and Penetration

Applicability of GC measures in the industrial and agriculture sectors is 100% because these measures are considered ubiquitous to all activities in all market segments. The approach to forecasting the penetration rate for GC measures changed for the 2019 model and changed again for 2021. In the 2017 Study (and prior years), penetration rates were held constant over the forecast horizon under the assumption that industrial facilities continually upgrade equipment and processes and that GC measures would be installed at the same rate as past program activity. Based on an analysis of EEStats data from 2013 through 2017 and CEDARS for 2019,[226] the Guidehouse team determined that GC savings are decreasing over time after separating out the contribution from retrocommissioning (RCx).

For the 2021 analysis, the team revised the industrial and agriculture GC penetration forecast methodology to use a linear forecast versus the compound annual growth rate (CAGR) approach used in the 2019 Study. The slope of the linear forecast is based on changes in GC measure savings recorded in CEDARS for 2013 through 2019. This change in methodology resulted in a GC savings forecast that remains nearly constant for both the industrial and agriculture sectors throughout the forecast horizon. The penetration rate for GC measures was revised to show an annual decrease of approximately 0.017% and 0.021% for industrial and agriculture, respectively, using data from 2013 through 2019, which is applied to electricity and gas savings.

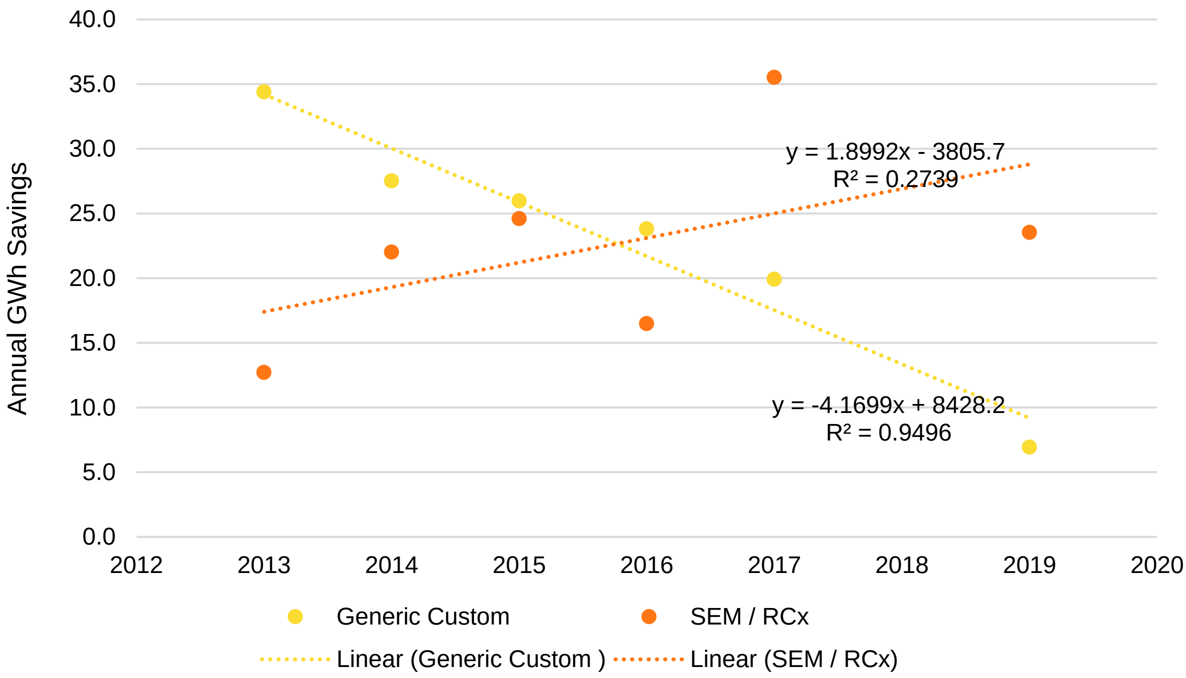
The team only leveraged the CPUC EEStats and CEDARS data for net program savings for the 2013-2019 program cycles. For the 2019 and 2021 PG Models, the definition of GC measures was revised to account for the following:

[226] The Guidehouse team did not disaggregate the 2018 Industrial and Agriculture program savings to characterized custom, GC, and SEM. The 2018 program year had a holistic reduction in savings compared to 2017, which continued through 2019.

- A large number of measures are defined but some measures contribute only a small percentage of portfolio savings (e.g., faucet aerator). These measures were aggregated, and the total impact was included within the generic measure category. A review of the 2019 CEDARS portfolio shows these smaller measures accounted for less than 10% of industrial sector and 5% of agriculture sector electricity savings.
- RCx savings separated out from GC savings and considered to be part of SEM savings instead because RCx is an integral part of effective SEM program designs.

Considering the definition of the GC measure class, an analysis of data indicates GC savings have declined over time, while RCx savings have shown a positive trend, as Figure F-1. shows.

Figure F-1. Industrial Sector Comparison of GC and RCx (SEM-Like) Savings Trends



Source: Guidehouse

After separating out the RCx savings and considering small measures to be part of GC, the Guidehouse team assessed the contribution of GC measures to the total savings in the industrial and agriculture sectors. For the industrial sector, the team analyzed data available through the California EEStats portal for 2016-17[227] for and CEDARS for 2019 and determined that GC measures contributed 19% of net electricity savings and 28% of natural gas savings. Based on this analysis, the team determined that GC measures saved an average of 16.9 GWh annually in the industrial sector and 1.9 MMtherms over the 3-year period. A GC unit energy savings (UES) multiplier was then developed by dividing these annual average energy savings by average sector consumption forecast for 2019 through 2032. This methodology defined GC UES multipliers of 0.0673% for annual industrial sector electricity usage and 0.0535% for annual natural gas usage. The UES factors in the 2021 model are smaller than those used in the 2019 Study because they include savings values from 2019, which are considerably lower than savings realized in earlier program years.

227 http://eestats.cpuc.ca.gov/Default.aspx

For the agriculture sector, the Guidehouse team analyzed data available through the California EEStats portal for 2016-17[228] and CEDARS 2019 and determined that GC measures contributed 17% of net electricity savings and 37% of net natural gas savings. Based on this analysis, the team determined that GC measures save an average of 9.2 GWh and 0.7 MMtherms annually. A GC UES multiplier was then developed by dividing annual average energy savings by average sector consumption forecast for 2019 through 2032. This defined GC UES multipliers of 0.0602% for annual agriculture sector electricity usage and 0.6227% for annual natural gas usage. As with the industrial sector, the agriculture sector UES factors in the 2021 model are smaller than those used in the 2019 Study because they include 2019 savings, which are considerably lower than savings realized in previous program years.

The GC UES multipliers for the industrial and agriculture sectors are held constant throughout the forecast horizon and are applied to the consumption forecast for each market segment level throughout the forecast horizon using Equation F-1.

Equation F-1. GC Segment Net Savings Potential

$$\textit{GC Segment-Level Energy Efficiency (EE) Net Savings Potential} = \textit{GC UES Multiplier x Annual Segment Consumption}$$[229]

F.1.3 Other Input Assumptions

Because GC measures tend to be larger capital investments that operate for long periods of time, the Guidehouse team used an EUL of 15 years in the forecasts.[230] The team applied a ratio of kW to kWh of 0.000195.

For the 2021 analysis, the team revised GC electric incremental measure cost from $0.330/kWh (used in the 2019 forecast) to $0.478/kWh based on a review of 21 large custom projects evaluated as part of the 2019 commercial, industrial, agriculture custom evaluation. Natural gas savings are based on an analysis of industrial and agriculture programs operating throughout 2019 from CEDARS. These savings are estimated at $2.81/therm and are applied consistently across sectors and utilities.

F.2 Industrial and Agriculture Emerging Technology Measures

F.2.1 Summary

In the context of the 2021 Study, emerging technologies (ETs) are new technologies that have demonstrated energy benefits to the industrial and agriculture sectors but are not yet widely adopted in the market. The team evaluated ETs at varying stages along the path to market readiness—some were demonstrated in a laboratory or research setting, while others had been proven effective through pilot tests and are in early commercial adoption.

The 2019 Study updated the approach used for the 2017 Study. For the 2017 Study, the Guidehouse team identified approximately 1,100 potential ETs. The study analysis included screening these ETs to rate energy technical potential, energy achievable potential, market risk, technical risk, and utility ability to impact market adoption. This process ultimately

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[228] http://eestats.cpuc.ca.gov/Default.aspx

[229] Electric (GWh) and natural gas (therms) consumption from the 2019 Integrated Energy Policy Report (IEPR) forecast.

[230] The team selected 15 years as representative of emerging technology measures that are more technology based versus controls or retrofit add-on technologies.

yielded 173 ET processes[231] for final consideration within the model. For the 2019 Study, the team reviewed the data source used in the 2017 Study to include measures that might have been added since the initial review and to update measures originally identified that might have more recent data. No updates to this analysis occurred for the 2021 Study.

The remainder of this section describes the methodology used to evaluate the ET market and the process used to develop the model inputs for energy savings (also summarized in Table F-2). Segment-specific electric and gas savings are consistently applied across all utilities. Cost, effective useful life (EUL), and the kW/kWh savings ratio are also universally applied.

Table F-2. Industrial and Agriculture ET – Key Assumptions

Sector	Type	EUL Years	Savings		Cost		kW/kWh Savings Ratio
			kWh	therms	kWh	therms	
Industrial & Agriculture	ETs	10	0.93%-9.62%	0.0%-14.21%	$0.42	$2.83	0.000195

Source: Guidehouse

F.2.2 Eligibility and Participation

The 2021 assessment of eligibility and participation began with quality assurance and quality control (QA/QC) efforts to review the 2017 and 2019 Study inputs to assess data entry, technology assessment, classification and scoring, and Excel formula references. For reference, the 2017 and 2019 approach is also included in this report.

The Guidehouse team first identified the portfolio of ETs applicable to the industrial and agriculture sectors using the following steps:

1. Collect data to assemble a broad portfolio of ETs.
2. Characterize ETs based on various savings potential and risk criteria.

To collect data, the team reviewed the following web sources:

- Emerging Technologies Coordinating Council[232]
- California Energy Commission (CEC) Publications Database[233]
- US Department of Energy (DOE) Research and Development Projects[234]
- DOE Energy Efficiency & Renewable Energy Emerging Technologies Database[235]
- Broad web search that included independent research of topics and keywords that seemed relevant to the team based on the initial web scrape results of the other sources.

This process yielded an Excel-based database with approximately 1,100 different ETs; the database includes the name of the ET, a description of the technology, and key dates in the research process. Web scraping is an effective method to gather a broad wealth of

[231] The ETs represent a process to reduce energy consumption, not necessarily a specific technology.

[232] http://www.etcc-ca.com/reports

[233] http://www.energy.ca.gov/publications/searchReports.php?pier1=Buildings%20End-Use%20Energy%20Efficiency

[234] https://energy.gov/eere/amo/research-development-projects

[235] https://energy.gov/eere/buildings/emerging-technologies

information. However, it does not filter out irrelevant information. The team refined the database by deleting certain entries or by enhancing information on select ETs with additional research data from identified sources.

Each ET was then characterized to determine its relevance to the industrial or agriculture sectors and to define how each ET might impact each market segment within those sectors. The team gave each relevant technology a unique ID and characterized it with the following criteria. Criteria were also weighted to prioritize their relevance, as Table F-3 shows.

- **Classification information:**
  - Fuel savings (electricity/gas)
  - End use
  - North American Industry Classification System (NAICS) sector (3 or 4 digit)
  - Energy savings as a percentage of sector consumption
- **Evaluation criteria (used to calculate overall impact evaluation score):**
  - Energy technical potential
  - Energy achievable potential
  - Market risk
  - Technical risk
  - Utility ability to impact outcome
  - Non-energy benefits (NEBs)

The team gave each ET a score of 1-5 for each evaluation criterion, which were then weighted and summed to calculate the overall impact evaluation score. ETs that earn a higher score are expected to have a greater impact (i.e., greater energy savings) on the agriculture or industrial sectors. Table F-3 provides the scoring and weighting information for the evaluation criteria. The process yielded 173 ET processes that were used to forecast the savings potential for ETs.

Table F-3. ET Evaluation Criteria

Technology Characteristics	Weight	1	2	3	4	5
Energy Technical Potential	3	Low	Low	Medium	High	High
Energy Achievable Potential	3	Low	Low	Medium	High	High
Market Risk	2	High risk	High risk	Medium risk	Low risk	Low risk
Technical Risk	2	High risk	High risk	Medium risk	Low risk	Low risk
Utility Ability to Impact Market	1	Private sector will succeed without utility involvement	Utility is unlikely to be critical to adoption	Utility is likely to accelerate adoption	Utility is important to accelerate adoption	Utility is essential for catalyzing market

Technology Characteristics	Weight	1	2	3	4	5
NEBs	1	Zero or few NEBs	Some modest NEBs likely	Significant benefits but difficult to quantify/not understood	1 or 2 quantified, well-documented NEBs	Extensive, quantified, well-understood NEBs

Source: Guidehouse analysis

The characterization process worked to distinguish between energy technical potential and energy achievable potential. The energy technical potential evaluates the energy savings of the specific technology relative to the energy consumption of the baseline equivalent technology. The energy achievable potential takes a broader view and is a measure of the energy savings potential of that ET relative to the entire market's energy consumption. ETs that have a high energy technical potential but low energy achievable potential include technologies that drastically improve efficiency of a certain technology but have limited market application.

To estimate savings, the team calculated multipliers for each ET. These multipliers represent information on the total energy savings potential of the ET and other influential market data. The team used Equation F-2 to calculate the multiplier for each ET that was then applied to a specific market segment and end-use energy consumption.

Equation F-2. ET Multiplier

$$M_{e,i,j} = T_e \times E_{i,j} \times MT_j \times TW_j$$

Where:

$M_{e,i,j}$	=	multiplier for each ET, *e*, applied to end use, *i*, and segment, *j*
e	=	subscript indicating the ET
i	=	subscript indicating the end use
j	=	subscript indicating the market segment
T_e	=	technology energy savings percentage for ET, *e*
$E_{i,j}$	=	percentage of segment, *j*, energy attributable to end use, *i*
MT_j	=	market trajectory for segment, *j*
TW_j	=	segment energy consumption trend weight for segment, *j*

- The technology energy savings percentage, T_e, was identified during the ET characterization process.
- The segment end-use percentage, $E_{i,j}$, is derived from California market data.[236]
- The market trajectory for each sector, MT_j , is a value between 0 and 1 and is intended to define if a market segment is likely to stay active in California long enough for the ET to move up the adoption curve to a point where it makes an impact on segment energy use. No specific timeline was defined; however, the team assigned a weight to segments.[237] For the 2019 model and likewise for the 2021 model, all measures have a market trajectory of 1 as a result of discussions with CEC that determined the IEPR segment forecasts include considerations for

[236] Energy use trend analysis provided by CEC.
[237] Sirkin, H. et al. *U.S. Manufacturing Nears the Tipping Point*, The Boston Consulting Group, March 2012.

reductions in electricity and natural gas that result from industries relocating outside of California, including offshoring.

- 0.33: Indicates a segment is likely to move or remain offshore. It is not expected to benefit from the ET adoption cycle.
- 0.67: Indicates a segment is close to the tipping point of moving out of California or the US. It is at risk of not benefitting from the ET adoption cycle.
- 1.0: Indicates a segment is likely to remain in the California. It is expected to benefit from the ET adoption cycle.

The team summed the values of all applicable ET multipliers for each market segment to define an ET UES multiplier (provided in Table F-4) to forecast segment-level potential net savings using Equation F-3:

Equation F-3. ET Segment Net Savings Potential

ET Segment-Level EE Net Savings Potential = ET UES Multiplier x Annual Segment Consumption[238]

Table F-4. ET UES Multipliers by Segment and Fuel

Segment	UES Multiplier (kWh)	UES Multiplier (therms)
Ind – Petroleum	0.17%	1.22%
Ind – Food	1.58%	9.18%
Ind – Electronics	2.45%	4.10%
Ind – Stone-Glass-Clay	0.97%	0.99%
Ind – Chemicals	0.93%	9.19%
Ind – Plastics	1.40%	5.37%
Ind – Fabricated Metals	1.45%	14.21%
Ind – Primary Metals	0.26%	8.61%
Ind – Industrial Machinery	2.90%	5.62%
Ind – Transportation Equipment	1.18%	1.94%
Ind – Paper	0.71%	1.87%
Ind – Printing & Publishing	0.99%	1.02%
Ind – Textiles	1.42%	2.85%
Ind – Lumber & Furniture	1.28%	2.74%
Ind – All Other Industrial	4.52%	4.58%
Ag – Irrigated Agriculture, Vineyards, Forestry, and Greenhouses	9.62%	0.00%
Ag – Dairies, Fishing, and Hunting	0.96%	0.44%
Ag – Water Pumping	3.40%	0.00%

Source: Guidehouse team

The ET UES multipliers were held constant throughout the 2021 Study forecast horizon. The Guidehouse team developed reference and aggressive case forecasts based on a CAGR by which the portfolio of ETs is expected to be adopted by the market (i.e., penetration). The reference case assumes a CAGR of 3.25%, yielding a target saturation of 1.84% by 2030. The 2030 target saturation of the portfolio of relevant ETs is an estimate that acknowledges

[238] Electric (GWh) and natural gas (therms) consumption from the 2019 IEPR forecast.

the timeline over which new technologies move through the adoption cycle to reach 80% saturation (typically ranging from 10 to 30 years) and the relatively slow turnover of the production equipment associated with many industrial processes. From 2030 to 2032, the penetration rate remains at 1.84%. The aggressive case assumes a CAGR of 4.25% until 2030, where the growth shifts to 4.4% through 2032.

F.2.3 Other Input Assumptions

The model uses a universal EUL of 10 years to accommodate the broad range of ET adoption curves. The team applied a ratio of kW to kWh of 0.000195.

Costs for electricity and natural gas savings are estimated at $0.42/kWh and $2.83/therm and are applied consistently for all utilities and across all industrial and agriculture sectors. Costs are based on an analysis of industrial and agriculture programs operating throughout 2016 and reflect costs that are higher than average for the portfolio; these higher costs are based on the expectation that ETs will be more expensive than more established technologies and will require higher incentives and evaluation, measurement, and verification costs to verify performance. No adjustments were made to costs as of the 2017 Study.

Appendix G. Financing Methodology and Inputs

Financing has the potential to break through several market barriers that have limited the widespread market adoption of cost-effective energy efficiency (EE) measures. The PG Model estimates the added effects of introducing EE financing on EE achievable potential and how shifting assumptions about financing affect the potential energy savings.

The Guidehouse team did not update the methodology or inputs related to financing in the 2021 Study relative to the 2019 or 2017 studies. This appendix replicates the explanation of methods and inputs from the 2017 Study final report.

The following are examples of market barriers that can slow EE adoption:[239]

- **Information search cost:** Even when information of new technologies is publicly available, it is costly for consumers to learn about the innovation.
- **Lack of capital access and liquidity constraint:** Lack of upfront capital or credit for EE investments.
- **Un-internalized externalities:** Energy is heavily subsidized; consumers are not aware of the true cost of energy.
- **Split incentives:** Party making the efficiency investment decision is not the party benefitting from the decision.
- **Hassle factor:** This includes efforts invested in completing transactions such as the application process.
- **Behavioral failures:** Consumers are not perfectly rational, resulting in consumer behavior inconsistent with utility maximization or energy cost minimization.

G.1 Financing Programs Background

California financing programs address some of these market barriers, such as lack of capital access and liquidity. Per the California Public Utility Commission's (CPUC's) *PY2014 Finance Residential Market Baseline Study Report*,[240] more than half of homeowners (54%) believe the higher upfront costs present a barrier to EE projects, and one-third of respondents stated that financing could help reduce that barrier.

Furthermore, research suggests that financing programs encourage deeper energy savings per project because consumers can take on larger projects with higher associated savings, beyond what they could have otherwise afforded in the absence of financing.[241] Among homeowners who made an energy upgrade and used financing, nearly three-quarters using financing indicated the financing allowed them to do a larger project or purchase higher quality equipment than what they would have done on their own.[242] For the nonresidential

[239] Jaffe, Newell, and Stavins. "Economics of Energy Efficiency." *Encyclopedia of Energy* Vol. 2: 79-89. 2004.

[240] Opinion Dynamics Corporation and Dunsky Energy Consulting. *PY2014 Finance Residential Market Baseline Study Report.* March 2016

[241] Southwest Energy Efficiency Project. *Energy Efficiency Finance Options and Roles for Utilities*. October 2011.

[242] Opinion Dynamics Corporation and Dunsky Energy Consulting. *PY2014 Finance Residential Market Baseline Study Report.* March 2016

sector, 83% of on-bill financing (OBF) loans were for projects exceeding 10% energy savings.[243]

Financing may also reduce the hassle factor barrier that may affect a consumer's willingness to take on an EE project. In a California study of homeowners who chose to use financing, a clear majority (88%) felt that financing was the most convenient option for them.[244]

For nonresidential customers, qualified customers can access 0% OBF through a statewide program administered by the investor-owned utilities (IOUs). The OBF programs use alternative underwriting criteria that considers utility bill repayment history as a measure of creditworthiness.[245] Participating in OBF and repaying the financed cost through a utility bill may be easier to understand and more convenient than applying for and repaying a conventional financing option.

Because a significant proportion of customers (46%) indicated a preference for 0% financing over rebates (34%),[246] Pacific Gas and Electric (PG&E) is testing an OBF alternative pathway that will be paired with metered energy data instead of an incentive.[247,248] The program is currently under evaluation. Because the incentive applications are where most problems occur in the application process, the alternate pathway program may further reduce the complexity and hassle barrier that some customers may associate with participating in utility EE programs.[249]

G.2 Impact of Financing on Consumer Economics

Financing allows consumers to use private capital to fund EE projects; borrowers avoid the upfront cost and repay the project cost over time. Evaluators can assess the attractiveness of a financing option by looking at the annual cash flows for an efficient measure compared to an efficient measure that is financed and by comparing the net present value (NPV) of the options.

The NPV is calculated by assigning costs and benefits, discounting future costs and benefits (future value, or FV) by an appropriate discount rate (i) and subtracting the present value total costs from the present value total benefits.[250]

To discount future payments, the annual consumer discount rate (i) is applied per Equation G-1, where n is the number of years:

Equation G-1. Present Value Equation

$$Present\ Value\ = Future\ Value\ \times (1+i)^{-n}$$

[243] Disposition approving Advice Letter 3697-G /4812-E, 3697-G-A/4812-E-A, PG&E's On Bill Financing Alternative Pathway Program, as a High Opportunity Program. July 12, 2016.

[244] Opinion Dynamics Corporation and Dunsky Energy Consulting. *PY2014 Finance Residential Market Baseline Study Report.* March 2016

[245] State and Local Energy Efficiency Action Network (SEE Action). Financing Energy Improvements on Utility Bills. Technical Appendix Case Studies. May 2014.

[246] California 2010-2012 On-Bill Financing Process Evaluation and Market Assessment (CALMAC ID CPU0056.01),

[247] Commercial customers can receive up to a $100,000 loan for 5 years, and the government can receive up to a $250,000 loan for 10 years. The alternative path leverages existing infrastructure and the existing OBF program's revolving loan fund.

[248] Final report on the net-to-gross and process evaluation was published in summer 2020. https://pda.energydataweb.com/#!/documents/2422/view

[249] 2010-2012 CA IOU On-bill Financing Process Evaluation and Market Assessment. May 2012.

[250] OMB Circular A-94. Available at: https://www.wbdg.org/FFC/FED/OMB/OMB-Circular-A94.pdf

The present value of an EE measure over the useful life of the equipment can be evaluated by comparing the NPV of the hypothetical costs of the equipment and energy. For example, Table G-1 shows three calculations. The first calculation for the base technology shows the present value cost of a base efficiency technology ($1,000) purchased in year 0, followed by energy costs for that unit of $200 annually for 10 years. The total cash outflows are discounted by the assumed consumer discount rate, which for this example is 7%. The net present cost of the base technology is $2,405.

The next calculation for the efficiency technology shows the net present cost of the efficient technology. In this case, the technology costs $1,250 to the consumer upfront after a 50% rebate on the incremental cost of the efficient technology whose original cost was $1,500 (i.e., $1,500 – [($1,500-$1,000) x 50%] = $1,250). The annual energy cost of the efficient technology is $125 per year. The total cash outflows are discounted by the same consumer discount rate (7%), yielding a net present cost for the efficient technology is $2,128. This total cost is less than the base technology.

Finally, the third calculation for the efficient technology with financing shows the net present cost of the efficient technology after financing. The efficient technology costs $1,250 with the utility incentive. Assuming a consumer uses an EE loan at 4% for 10 years, the equipment and financing costs are spread over 10 years at $148 per year. The annual energy cost of the efficient technology financed is still $125 per year. The total cash outflows are discounted by the same consumer discount rate (7%), yielding a net present cost for the efficient technology with financing of $1,992. This total cost is less than the base model and less than the efficient technology without financing.

Table G-1. Example Present Value Comparisons for Base and Efficient Technologies and Financing

Base Technology											
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Base Equipment Cost	$1,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Energy Cost	$0	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200
Total Cash Out	$1,000	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200
Present Value	$1,000	$187	$175	$163	$153	$143	$133	$125	$116	$109	$102
NPV Cost	**$2,405**										

Efficient Technology											
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Efficient Equipment Cost	$1,250	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Energy Cost	$0	$125	$125	$125	$125	$125	$125	$125	$125	$125	$125
Total Cash Out	$1,250	$125	$125	$125	$125	$125	$125	$125	$125	$125	$125
Present Value	$1,250	$117	$109	$102	$95	$89	$83	$78	$73	$68	$64
NPV Cost	**$2,128**										

Efficient Technology with Financing											
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Equipment Cost Financed	$148	$148	$148	$148	$148	$148	$148	$148	$148	$148	$0
Energy Cost	$0	$125	$125	$125	$125	$125	$125	$125	$125	$125	$125
Total Cash Out	$148	$273	$273	$273	$273	$273	$273	$273	$273	$273	$125
Present Value	$148	$255	$239	$223	$208	$195	$182	$170	$159	$149	$64
NPV Cost	**$1,992**										

Source: Guidehouse

The modified cash flows feed into the calculation of consumer willingness (described in Section 2.1.1.4) by representing the effective present value of financing to the customer as a fraction of the upfront cost. Increasing willingness results in higher adoption of EE measures and more savings. The model does not estimate the technical or economic potential of financing, only achievable potential.

The CPUC has recognized financing as an EE resource program.[251] However, as of March 2017 (when research for the 2019 Study was finalized), no impact evaluations had been published to provide verified savings estimates. In the absence of impact studies, the input data to model financing was developed by the Guidehouse team using available market studies. The 2021 Study did not conduct a refresh of financing inputs as budget and focus was placed on many other new additions to the study.

[251] CPUC Decision 12-05-2015, May 8, 2012 and Decision Approving 2013-14 Energy Efficiency Programs and Budgets, October 9, 2012.

G.3 Residential Inputs

To develop the residential financing cash flow PG Model inputs, the Guidehouse team considered the achievements to date of the existing Regional Finance Programs and the key financing terms for the Residential Energy Efficiency Loan (REEL) Program lenders.[252]

Table G-2. 2013-2015 Achievements by Regional Financing Program

Program	Start Date	Utility	Min. FICO	Avg. Rate	Avg. Term (yrs.)	Avg. Amount ($)	Loans to Date
Golden State Financing Authority Energy Retrofit Program	Sep-2012	PG&E	640	6.50%	15	25,612	201
EmPower Central Coast	Nov-2011	SCE, SCG, PG&E	590	5.85%	14.5	20,809	52
SoCalREN Home Energy Loans	Dec-2013	SCE, SCG	660	5.87%	9.5	18,087	100

Source: Regional Finance Program Attribution and Cost-effectiveness Study: Evaluation Plan

G.3.1 Interest Rate

The interest rate is the percentage of the principal that a lender charges to a borrower for taking out a loan. The Guidehouse team considered the average discount rates of the Regional Financing Programs and the range of interest rates available to borrowers of the REEL Program. Based on this information, the team assumed an interest rate of 6% for REELs in the cash flow model.

G.3.2 Loan Term

The loan term is the length of time of the loan agreement. REEL Program loans offer terms up to 15 years.[253] The average term of the Regional Finance Program loans ranges from 9.5 to 15 years. Based on this information, the team assumed a loan term of 12 years in the cash flow model.

G.3.3 Consumer Discount Rate

The discount rate is the rate by which future cash flows are discounted to determine the present value of the payment stream. Using a consumer discount rate allows multiple payment streams to be compared in the same timeframe. A low discount rate indicates the value of future cash flows is low compared to the value now. The Guidehouse team uses the real discount rate instead of the nominal discount rate to eliminate the effect of inflation.

Estimating the discount rate for residential customers is not straightforward and may vary by demographic factors such as credit score, income, race, and household size. The Office of Management and Budget (OMB) has prescribed a discount rate of 7% for benefit-cost analysis, and the US Department of Energy (DOE) uses 3% and 7% in the analyses for residential appliance standards.[254] Other government organizations use discount rates in this

[252] REEL Lenders Chart. Available at: http://www.thecheef.com/lender-chart
[253] REEL Lenders Chart.
[254] For example, see: http://www.gao.gov/assets/690/682586.pdf

range—for example, the Northwest Power and Conservation Council used 3% in the Seventh Power and Conservation Plan and a lighting study by the DOE calculated a consumer discount rate of 5.6%.

The estimated discount rate for residential customers may be much higher than the range of 3%-7% used in regulatory analysis. For example, one study looked at the observed discount rates for individuals and their preferences for EE and found that "a simple fact emerges that in making decisions which involve discounting over time, individuals behave in a manner which implies a much higher discount rate than can be explained in terms of the opportunity costs of funds available in credit markets."[255] Based on these considerations, the team used a consumer discount rate of 7% for the financing model.

G.3.4 Eligible Population

The Guidehouse team updated the residential population eligibility in the 2015 Study using Experian Consumer Credit data, accessed in November 2014. The 2015 Study identified the residential population eligibility at 98%. Like the 2015 Study, the team assumes that residential customers with FICO credit scores above 580 are eligible for financing and that 98% of single-family customers are eligible for financing. The credit requirement aligns with the REEL Program, which requires a minimum FICO score of 580 with income verification and 640 without income verification.

Following the approach to eligibility assumptions for the multifamily sector in the 2013 and 2015 studies, the Guidehouse team estimated multifamily sector eligibility to be 5% based on the proportion of the segment that is affordable housing.[256]

The team used the inputs shown in Table G-3 for the residential cash flow model.

Table G-3. Key Inputs to Residential Financing Cash Flow Model

Model Input	Assumption	Source
Interest Rate	6%	Guidehouse analysis of California IOU financing programs data
Loan Term	12 years	Guidehouse analysis of California IOU financing programs data
Discount Rate	7%	OMB Circular No. A-94
Eligible Population	98% of single-family customers 5% of multifamily customers	2015 California Potential and Goals Study

Source: Guidehouse analysis of the Regional Finance Program Attribution and Cost-effectiveness Study: Evaluation Plan

G.4 Commercial Inputs

G.4.1 Interest Rate

Nonresidential customers can access 0% financing through the statewide OBF program. The projects eligible for OBF are designed to be bill-neutral, such that the monthly payment is

[255] Hausman, Jerry. "Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables." *The Bell Journal of Economics*, Vol. 10, No. 1. Spring 1979.
[256] The affordable housing market segment is the focus of the proposed EE financing programs. Due to legal and regulatory issues, on-bill repayment is not a viable option except master-metered properties.

less than the projected energy savings.[257] Based on these guidelines, the Guidehouse team assumed an interest rate of 0% in the cash flow model for OBF loans for the commercial and industrial sector.

G.4.2 Loan Term

The OBF program offers 0% financing for loans up to 5 years for the small and large commercial sector and up to 10 years for the government segment. Given the model does not distinguish between the commercial and government sector, the team applies a single assumption for the commercial sector.

G.4.3 Consumer Discount Rate

For nonresidential customers, the discount rate is the weighted average cost of capital for companies that use both debt and equity to fund their investments.

The Guidehouse team used the inputs shown in Table G-4 for the commercial and industrial cash flow model.

Table G-4. Key Inputs to Commercial and Industrial Financing Cash Flow Model

Model Input	Assumption	Source
Interest Rate	0%	California OBF program terms
Loan Term	5 years	California OBF program terms
Discount Rate	5.8%	2016 Lawrence Berkeley National Laboratory Commercial Discount Rate Estimation for Efficiency Standards

Source: Guidehouse

[257] Appendix A of SEE Action OBF report:https://www4.eere.energy.gov/seeaction/system/files/documents/publications/chapters/onbill_financing_appendix.pdf

Appendix H. Adoption Logic Theory and Application of a Multi-Attribute Model

H.1 Background

The method to estimate customer willingness to purchase energy efficient equipment in potential studies has evolved over the last decade. Early approaches used adoption curves that directly related willingness to a simple payback period based on survey questions. This approach was not desirable because it lacked a formal model of customer decision making and lacked parameters with values that might vary across measures and customers and that might change over time. Eventually a formal choice model[258] was selected from widely accepted research in behavioral science; this model has a single sensitivity parameter that operates over choice expected value factor. This model could closely fit the earlier payback curves when simple payback was used as the metric for the decision-making value factor.

Around the same time, another measure of utility was introduced, the levelized measure cost (LMC), that better described the investment characteristics of competing measures in terms of standard cash flow analysis. Rather than using a simple time value of money for the discount rate in the LMC calculation, an implied discount rate was used to better describe economic inefficiencies in customer choices.[259] The implied discount rate is the effective discount rate that would describe consumer adoption behavior if adoption was based solely on the financial characteristics of an energy efficiency (EE) measure. High observed implied discount rates for EE purchases indicated a range of market barriers and risk factors influence adoption beyond just the consumer time value of money such as lack of access to capital, liquidity constraints, split incentives, hassle, information search costs, and behavioral failures.[260, 261] The difference between the consumer's implied discount rate and their risk-adjusted time value of money is often referred to as the efficiency gap. Research has explained the discrepancy between the implied discount rate and the risk-adjusted time value of money as due to market barriers facing the EE industry.[262]

This gap in consumer choices contributes substantially to the inability of achievable potential forecasts to reach economic potential forecasts in EE potential studies. Model scenarios have since been run using assumptions about improvements in implied discount rate as a basis of finding the future limits of achievable potential. Studies have also attempted to estimate improvements in implied discount rates due to specific program interventions like financing and on-bill repayment.[263] Until now, the measure of utility used in the logit choice model is a purely economic measure (LMC) adjusted in aggregate by the degree to which this measure is insufficient (implied discount rate).

Unlike what past potential studies modeled, customer preferences are not based solely on the financial attributes of the product. Instead, customers make decisions based on multiple product attributes. Switching to a multi-attribute model in a potential study offers two key advantages:

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[258] McFadden, D. and K. Train. "Mixed MNL Models for Discrete Response." *Journal of Applied Econometrics* 15, no. 5: 447-470. 2000

[259] Gillingham, Newell, Palmer. "Energy Efficiency Economics and Policy." 2009

[260] J A Dubin "Market barriers to conservation: are implicit discount rates too high?" Proceedings of the POWER Conference on Energy Conservation, p. 21-33. 1992

[261] Gillingham, Newell, Palmer. "Energy Efficiency Economics and Policy." 2009

[262] Jaffe, Newell, and Stavins. "Economics of Energy Efficiency." *Encyclopedia of Energy* Vol. 2: 79-89. 2004.

[263] Corfee et.al. "Riding the Financing Wave: Integrating Financing with Traditional DSM Programming." International Energy Program Evaluation Conference, 2013

- Accounts for customers' different price sensitivities to different types of products (for example, dishwasher price, capacity, and noise level versus water heater may just be price and capacity).
- Accounts for the different customer responses for the same product based on each customer's unique set of preferences and attitudes (for example, customer attitudes toward sustainability, waste, environment, and climate).

H.2 Multi-Attribute Theory

Competition between products is based on multiple attributes, and the importance of each attribute to the decision-making process is likely to vary depending on the type of product and the type of consumer. Consumer preferences determine the relative importance of a product's attributes, and those preferences can affect a consumer's sensitivity to price and potential future energy savings. Even when all other attributes are equal, a consumer may be less sensitive to prices and financial characteristics for certain classes of products. As an example, this section compares dishwasher and water heater purchasing decisions. When purchasing a dishwasher, consumers are likely to consider the price, capacity, internal design features, noise levels, and EE. When purchasing a water heater, a consumer is likely to have a much shorter and somewhat different set of attributes in mind such as capacity, efficiency, and price. Given these differences, a 5% (for example) rebate for purchasing an energy efficient dishwasher is unlikely to be as influential as it would be for the purchase of a water heater because price is of higher relative importance for a water heater.

The expansion of the willingness to adopt factor in the 2021 Study to include multiple features allows the model to account for the relative importance of price and future cost savings in the context of how important they are relative to other product features (such as style, size, etc.). This expansion also allows the model to incorporate variation between segments of customers that have different preferences for product attributes and, importantly, different attitudes toward the sustainability attributes of the products.

A multi-attribute model requires additional data beyond what is normally collected in the EE industry. This new data is collected through surveys designed for conjoint analysis—a sample-efficient survey design technique that helps determine customer preferences for different features and feature combinations. Product design processes often use conjoint analysis to prioritize tradeoffs between feature areas (for example, strong versus light weight). Conjoint analysis can also be combined with other survey data to help establish customer segments that behave differently toward electrification decisions.

Consumer values and attitudes toward sustainability, waste, environment, and climate can be accounted for in this new multi-attribute model. Product attributes that align with the decision maker's values are likely to be the primary driver of consumer preferences. Strong values can overwhelm purchase decisions and lead consumers to make seeming irrational decisions from a purely financial perspective but decisions that are completely rational when considering all attributes and values.

H.3 Implementing the Multi-Attribute Model

The 2021 Study uses the following attributes to characterize a product:

- LMC at a consumer discount rate rather than the implied discount rate
- Upfront cost for increased sensitivity to budget and decreased sensitivity to future economic benefits

- Hassle (with install costs as a proxy) to assess inconvenience especially for retrofit measures or switching to new kinds of technology that require different infrastructure (such as insulation, instantaneous water heaters, or fuel substitution)
- Eco friendliness, which is based on energy or greenhouse gas (GHG) savings
- Eco signaling, which is based on energy or GHG savings and is only applied to public-facing end uses
- Non-consumption performance to account for other important attributes of certain product types (like aesthetic appeal) that are not typically correlated with efficiency levels but that may reduce sensitivity to the other attributes

The Guidehouse team conducted primary data collection through surveys to obtain data on the customer preferences for these attributes across each residential and commercial building type. The team used preference clusters to determine the proper number and sizes of customer segments and their preferences.

H.3.1 Customer Preference Weighting

Through the Market Adoption Study surveys, customers answered questions on a 1-5 scale indicating how important each value factor is to their decision-making process.

After applying an ordinal-to-metric transformation to the raw responses, the Guidehouse team converted transformed responses for each value factor to relative weightings (0%-100%) that indicate the importance of each value factor in determining adoption. Values can be interpreted as a percentage of decision driven by each technology characteristic. Table H-1 provides information on converting survey response to preference weightings with the calculation in Equation H-1.

Table H-1. Converting Survey Responses to Preference Weightings

Value Factor	Average Transformed Response	Preference Weighting
	Sample Customer Group	Sample Customer Group
Lifetime Cost (LMC)	3.5	18%
Upfront Cost	2.3	12%
Hassle Factor	3.1	16%
Eco Impacts	4.1	22%
Eco Signaling	3.0	16%
Non-Consumption Performance	3.0	16%
Total		**100%**

Source: Guidehouse

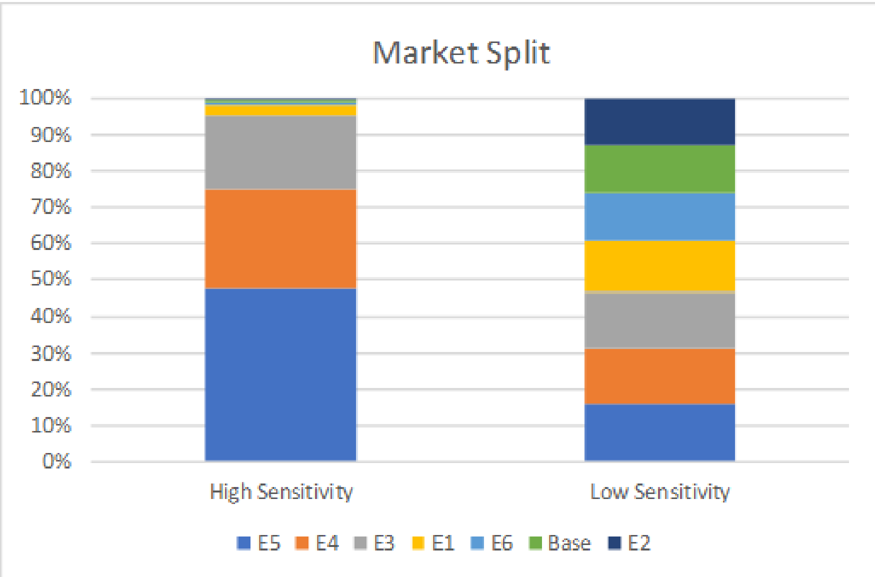
Equation H-1. Customer Preference Weighting

$$\text{Preference Weighting} = \frac{\textit{Average Transformed Response (for Tech Attribute)}}{\textit{Sum of Average Response (of all Tech Attributes)}}$$

While converting the responses into percentages accounts for variation across value factors, the model also accounts for variation in magnitude of responses across customer groups. Imagine a scenario where one customer group answered all 1s to the questions, and another group answered all 5s, with 1 indicating that the value factors do not influence decision-making and a 5 indicating that the value factors have a high influence on decision-making. Simply using the percentage approach would lead to the same customer preference weightings across the board for both customer groups even though the raw data shows that one group feels far more strongly than the other about each value.

To account for this difference in magnitude, the 2021 Study applied a parameter that indicates the level of sensitivity to differences in technology characteristics. This parameter is correlated to the average response across all value factors and influences how evenly the market splits. Lower sensitivities indicate the customer is not significantly more likely to adopt one technology over another due to the technology characteristics, so the market share is split evenly across all technologies. High sensitivities mean that customers are highly attuned to the technology characteristics that distinguish one technology from another and thus they tend to adopt the ones that align the closest with their preferences. Figure H-1 illustrates an example of how the market split could differ for two customer groups with different sensitivities.

Figure H-1. Effect of Sensitivity on Market Split



Source: Guidehouse

H.3.2 Normalized Technology Characteristic

The team used measure characterization data and subject matter knowledge to develop a numerical or binary value for each characteristic for each measure, which was converted to a dimensionless, normalized technology characteristic (shown in Equation H-2) by dividing by the average over the competition group (CG). This value can be interpreted as the relative characteristic value of the measure compared to the other CG measures.

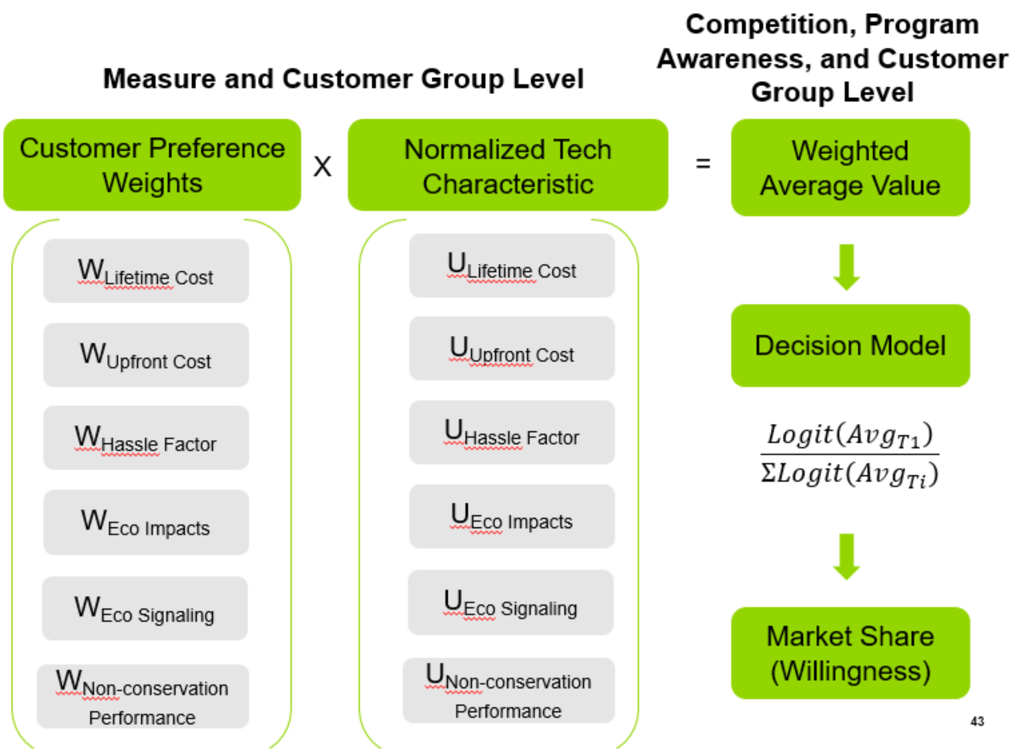
Equation H-2. Normalized Technology Characteristic

$$Normalized\ Technology\ Characteristic_{ValueFactor}(measure) = \frac{Characteristic\ Value\ (for\ measure)}{Average\ Characteristic\ Value\ (across\ CG)}$$

H.4 Calculating Market Share

For each measure and customer group, the Guidehouse team generated weighted average characteristics by taking the sum-product of the preference weightings for that customer group and the normalized technology characteristics for that measure. Figure H-2 shows how customer preference weightings and technology characteristics are combined and fed into the decision model.

Figure H-2. Calculating Market Share



Source: Guidehouse

The full equation for the decision model is shown in Equation H-3.

Equation H-3. Decision Model Market Share Calculation

$$MarketShare(t) = \frac{e_t^{-\beta A_t}}{\sum_i^n e_i^{-\beta A_i}}$$

$n = Number\ of\ technologies\ in\ competition\ group$
$n = Number\ of\ technologies\ in\ competition\ group$
$t = Technology\ of\ interest$
$\beta = Customer\ group\ sensitivity\ to\ differences\ in\ technology\ characteristics\ (or\ customer\ preference\ weighting)$
$A = Weighted\ average,\ dimensionless\ technology\ characteristic$

Appendix I. EE-DR Integration Approach and Results

This appendix describes the approach for adding demand response (DR) benefits and costs for technologies with energy efficiency (EE) and DR co-benefits and summarizes the implications of adding DR to technology cost-effectiveness. Appendix I.2 describes the market adoption estimation approach for EE-DR technologies.

I.1 Approach for EE-DR Technologies Cost-Effectiveness Analysis

The cost-effectiveness of technologies that can provide DR benefits is assessed from a joint EE-DR perspective. This is a theoretical construct for this study because there are no integrated demand side management (IDSM) cost-effectiveness protocols or policy guidelines for technologies that can provide dual EE-DR benefits. The joint perspective was developed to assess to what extent incorporating DR benefits would influence the cost-effectiveness of EE technologies with DR co-benefits.

Developing an IDSM framework for joint EE and DR cost-effectiveness remains a challenge. The issues around integrated demand side cost-effectiveness have been discussed in the Integrated Distributed Energy Resources (IDER) Rulemaking (R.14-10-003) and related proceedings.[264] As noted in an IDSM Cost-Effectiveness Mapping Project Report and Staff Proposal document by the Energy Division,[265] the cost-effectiveness frameworks for EE and DR were developed in different proceedings over the course of many years, and they each have different cost-effectiveness reporting tools. EE uses the Energy and Environmental Economics (E3) EE cost-effectiveness calculator,[266] while DR uses the DR Reporting Template[267] for cost-effectiveness. Additionally, the estimation techniques used to determine the cost and benefit inputs for EE and DR differ. These differences are detailed in the costs and benefits matrix available under the IDER proceeding.[268]

Table I-1 summarizes the benefits and costs for EE-DR technologies used in the cost-effectiveness calculations under the total resource cost (TRC) test. Under the program administrator cost (PAC) test, both EE and DR incentives need to be included under costs. For DR, the incentive costs will include upfront DR program enrollment incentives and ongoing DR participation incentives.

Table I-1. Benefits and Costs from EE-DR Measures in the Cost-Effectiveness Calculations

Benefits	Costs
• Avoided energy and demand costs from EE • Avoided capacity, energy, and greenhouse gas (GHG) emissions costs for DR *(further described in the following sections)*	• Full EE-DR measure costs (e.g., cost of a smart thermostat) • EE incentives for free riders[269] • EE administration costs • DR administration costs • EE operations and maintenance (O&M) costs • DR O&M costs

Source: Guidehouse

[264] https://www.cpuc.ca.gov/General.aspx?id=10745
[265] https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=10742
[266] https://www.ethree.com/public_proceedings/energy-efficiency-calculator/
[267] https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=11573;
[268] https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=10741
[269] DR does not have any free riders, so free rider incentives do not apply to DR.

I.1.1 DR System Benefits Calculation Approach for EE-DR Technologies

Lawrence Berkeley National Laboratory (Berkeley Lab) developed DR system benefits for each measure per the following approach. The calculations are primarily guided by California Public Utilities Commission's (CPUC's) 2016 DR Cost-Effectiveness Protocols and E3's Avoided Cost Calculator 2020 (ACC).[270]

System benefits of a DR measure are three-fold: avoided capacity costs, avoided energy costs, and avoided GHG emissions costs. The input data to calculate these values for each of the three investor-owned utilities (IOUs) in California is mostly available in the ACC.

For each measure, Berkeley Lab started by considering the appropriate post-EE-measure hourly load shape, normalized to the measure's characterized annual energy consumption value (kWh/yr). Each hourly value was then weighted by the corresponding hourly generation capacity allocation factor found in the ACC. These allocation factors serve as a proxy for the loss of load probability, and Berkeley Lab assumed that these factors also represent the relative likelihood of a DR event being called in any given hour (i.e., a higher allocation factor means a higher probability of a DR event).

The weighted hourly load values are summed over the 8,760 hours of a year. This sum represents the average DR resource, in kilowatts (kW), expected to arise from a single installed measure during a DR event, assuming the entire associated load can be controlled. For DR measures that can only control a portion of the associated load, according to Berkeley Lab's measure characterization, this average resource is de-rated accordingly. The resulting average resource in kW is used to monetize the three DR system benefits:

1. **Avoided capacity costs:** Avoided capacity costs include the generation and transmission and distribution (T&D) costs avoided by a DR measure. The following are the input values from the ACC used to quantify these costs:
    a. Net Cost of New Entry ($/kW-yr): The proxy for new generation capacity in the ACC is a battery storage resource.
    b. T&D costs ($/kW-yr): DR programs can help defer T&D system upgrades. The study did not include T&D in the avoided capacity costs for DR (indicated in the adjustment factors discussed below).

    The average demand responsive load is then multiplied by the sum of relevant generation costs to determine the total avoided capacity cost value. The avoided capacity cost is adjusted using several factors, which are described below.

2. **Avoided cost of energy:** This is the value of energy saved (kWh) during DR events. The following inputs are used to determine this value:
    a. Cost of Energy ($/MWh): The ACC provides hourly avoided cost of energy values, including fuel cost and power plant operating costs. Each post-measure hourly consumption value weighted by its corresponding allocation factor is then multiplied by this hourly avoided cost of energy value; the result is summed. This result represents the average avoided cost of energy, per hour, during a DR event. Berkeley Lab used an estimate of the number of DR

[270] 2016 Demand Response Cost-Effectiveness Protocols is available at https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=11573;
E3's ACC is available at https://ethreesf-my.sharepoint.com/:f:/g/personal/gabe_mantegna_ethree_com/Eu_rFWIz7r5Kl8r0CLcObtMBnOSVCf1QKlIlxFJl0nM5TA?e=aLgkge

event hours in a year (discussed below) to obtain the total cost of energy saved.

   b. Number of DR event hours: Every measure is mapped to a specific DR program that represents a typical program in which that measure would be enrolled. For example, smart thermostats in SCE's service area is mapped to SCE's Smart Energy Program, which is the smart thermostat based Direct Load Control (DLC) program offered by SCE. The load impact evaluation report of that program provides the information of the number of event hours called in a given year.

The avoided cost of energy is adjusted using some factors described below.

3. **Avoided cost of GHG emissions:** Similar to the avoided cost of energy calculation, the summed product of the average demand responsive load and the avoided GHG emissions from the ACC are combined with the social cost of emissions (GHG Adder) and the expected number of DR events to yield the avoided cost of GHG emissions.

In addition to these avoided cost items, the DR benefits calculations incorporate several DR program-specific adjustment factors used to scale the avoided cost numbers based on guidance in the DR cost-effectiveness protocol. These are described below.[271]

I.1.2 Adjustment Factors for avoided costs

In the DR Cost-Effectiveness Protocols, there are several DR program specific adjustment factors used to scaled the avoided cost numbers. While there are guidelines to compute or select the values of some of these factors, the calculation of some factors is left to the discretion of the LSE.

1. **A Factor** is intended to indicate the availability of a DR program such that, if a program can be called during all hours of capacity constraints, then the A factor would be 100%. The 2016 DR cost-effectiveness protocols did not settle on a final methodology for computing this factor. The approach above of weighting the load shape by the ACC's capacity allocation factors accounts for the relevant issues and is similar to some of the candidate approaches. LBNL assumed the A factor was accounted for by the approach of weighting the load by the ACC capacity allocation factors and thus no further correction factor was applied.
2. **B Factor** is meant to indicate the various notification times such as Day-Ahead, Day-of 30 minutes and Day-of 15 minutes. The DR C-E Protocols document specifies a factor for each category of notification, which **LBNL applied directly**.
3. **C Factor** accounts for the value of flexibility of triggers that each DR program offers. The DR C-E Protocols provides specific values to consider in this factor, which **LBNL applied directly.**
4. **D Factor** is based on "right time", "right place", "right availability" and "right certainty" of DR. This factor has a default value of 0%, which means that the DR program does not avoid or defer any T&D system upgrades. LSEs looking to use other values are required to justify it. **LBNL used a D factor = 0% and thus did not include any T&D costs.**
5. **E Factor** is the energy adjustment factor, that allows utilities to use alternate energy price scenarios to evaluate DR. LBNL's approach of using the hourly energy price weighted by the capacity allocation factors implicitly incorporates an E factor for each

[271] 2016 Demand Response Cost-Effectiveness Protocols available at https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=11573;

measure, representing the average avoided energy price at the time the load would be expected to respond.

6. **F Factor** provides additional value for flexible DR. Qualifying DR programs must satisfy the CAISO rule of FRAC-MOO. According to the DR C-E Protocols, DR programs that are capable of making economic bids and, ramping and sustaining output for 3 consecutive hours can use an F factor of 110%. **LBNL used a factor of 110% for this value.**
7. **G Factor** is used for the DR resources that can be called locally in areas with resource constraints. The DR C-E Protocols documents provides IOU specific values that can directly be used to account for the value of G factor. For SDG&E and PG&E, LBNL plans to use the default G factors of 110% and 100%, respectively. For SCE, the G factor depends on the specifics of the program and whether it can be dispatched locally in capacity constrained areas. LBNL used 110% for SDG&E, 100% for PG&E and 105% for SCE programs.

I.1.3 Implications of Adding DR on Cost-Effectiveness Results of EE-DR Technologies

Table I-2 summarizes the implications of adding DR benefits on technology cost-effectiveness by sector and end use.

Table I-2. Implications of Adding DR Co-Benefits on Cost-Effectiveness and Achievable Potential

Sector	End Use	Implication of Adding DR Co-Benefits on Cost-Effectiveness*
Residential	**HVAC**	**Smart Thermostats** • Benefit-cost ratios increase with addition of DR co-benefits. • Measure passes TRC 1.0 threshold in a few cases by adding DR (not cost-effective on EE basis only). **Smart Room AC** • Benefit-cost ratios increase with addition of DR co-benefits. • Measure does not pass TRC 1.0 threshold with DR addition.
Residential	**Water Heating**	**Smart Electric Storage Water Heater** • Substantial increase in benefit-cost ratios with addition of DR co-benefits. • Measure does not pass TRC 1.0 threshold (except in 2032 for Cold climate). **Smart Heat Pump Water Heater** *Fuel substitution version* • Benefit-cost ratios increase slightly with DR addition. • Measure does not pass TRC 1.0 threshold with DR addition. *Non-fuel substitution version* • Measure passes TRC 1.0 threshold with and without DR. **Smart Water Heater Controls** • Substantial increase in benefit-cost ratios with addition of DR co-benefits. • Measure passes TRC 1.0 threshold in 2022-2026 (does not pass on EE-only basis).

Sector	End Use	Implication of Adding DR Co-Benefits on Cost-Effectiveness*
Residential	**AppPlug**	• None of the smart appliances pass TRC threshold of 1.0 with DR addition.
Residential	**Lighting**	**Advanced Lighting Controls** • Does not pass TRC threshold of 1.0 with DR addition.
Commercial	**HVAC**	**Smart Thermostat** • Benefit-cost ratios increase with addition of DR co-benefits. • Measure passes TRC 1.0 threshold in all cases with DR addition. **Energy Management System** • Substantial increase in benefit-cost ratios with addition of DR. • Measure does not pass TRC 1.0 threshold. **Packaged Terminal Air Conditioner Controls Upgrade** • Slight alterations in benefit-cost ratios with addition of DR. • Cost-effectiveness screening does not change.
Commercial	**Water Heating**	**Smart Electric Storage Water Heater** • Substantial increase in benefit-cost ratios with addition of DR. • Addition of DR benefits leads to measure passing TRC threshold of 1.0. **Smart Heat Pump Water Heater** *Fuel substitution version* • Slight increase in benefit-cost ratios with DR addition. • Measure does not pass TRC threshold of 1.0. *Non-fuel substitution version* • Addition of DR has no impact—measure is highly cost-effective without DR consideration. **Smart Water Heater Controls** • Does not pass TRC threshold of 1.0 with DR addition.
Commercial	**Lighting**	**Advanced Lighting Controls** • Slight increase in benefit-cost ratios with DR addition. • Cost-effectiveness screening is unaltered with DR addition.
Commercial	**AppPlug**	**Smart Power Strip** • Measure benefit-cost ratio increases with DR addition. • Measure passes TRC threshold of 1.0 in specific years with DR addition. **PC Power Management** • Measure benefit-cost ratio increases with DR addition. • Measure passes TRC threshold of 1.0 in all years with DR addition.
Ind/Ag	**HVAC**	**Ind. Chiller Plant Optimization** • Slight alteration in benefit-cost ratio with DR addition. • Measure cost-effective before addition of DR benefits.
Ind/Ag	**Lighting**	**Lighting Controls** • Benefit-cost ratio increases with DR addition. • Measure is not cost-effective with and without DR.

Sector	End Use	Implication of Adding DR Co-Benefits on Cost-Effectiveness*
Ind/Ag	**MachDr**	**Ag Water Pumping Sensors and Controls** • Slight alteration in benefit-cost ratio with DR addition. • Measure cost-effective before addition of DR benefits.
Ind/Ag	**WholeBlg**	**Ind. Che Manf. Advanced Automation** • Slight alteration in benefit-cost ratio with DR addition. • Measure cost-effective before addition of DR benefits.

*This is based on comparison of TRC results for Scenarios 2a and 2b.
Source: Guidehouse

I.2 Calculating DR-Related Adoption Inputs[272]

The DR-related inputs feeding the adoption model for calculating market adoption of EE-DR technologies are as follows:

- DR program incentives, which are of the following types:
  - Fixed upfront DR incentives
  - Variable upfront DR incentives
  - Fixed annual DR incentives
  - Variable annual DR incentives
- Bill savings from improved response to time-of-use rates.

DR program incentives were divided into upfront incentives paid for adopting DR-enabling technology and annual incentives paid for ongoing enrollment in the program. Depending on the program and measure, these incentives can be computed as fixed incentives paid per measure (i.e., dollars per customer) or as variable incentives paid per unit of load being enabled to participate in DR (i.e., dollars per kW). The bill savings from time-of-use rates were computed by first associating each measure with a time-of-use rate, estimating the amount of load a customer would be expected to shift based on program evaluations, and computing the resulting savings. The calculations for each component of customer DR benefits are described as follows.

- **Fixed upfront DR incentives.** Certain EE-DR measures (e.g., residential smart thermostats) are eligible for a one-time incentive for enrolling in a DR program. The incentive may be different across sectors and IOU programs. Such one-time incentives are categorized as fixed upfront DR incentives and are applied as a single fixed payment regardless of the underlying load shape.
- **Variable upfront DR incentives.** Most nonresidential measures are eligible to receive upfront incentives through Auto-DR programs (programs that use automated signals to customer-owned devices for curtailment or load reduction). For example, eligible commercial and industrial customers can use Auto-DR incentives to install new DR-enabling technologies such as energy management systems, smart thermostats, HVAC controls, and programmable lighting. The Auto-DR incentives are applied as a certain dollar value per kW of load enabled for DR, up to a fixed fraction of the total project cost for enabling DR. This is calculated as follows:

$$Variable\ Upfront\ DR\ incentive = \min\left(D_{max} * R_{ADR},\ F_{max} * TIC\right)$$

[272] The DR-related adoption inputs were calculated by the DR Potential Study team at Lawrence Berkeley National Laboratory.

Where:

D_{max}= the maximum annual demand from the measure's representative load shape
R_{ADR}= the incentive rate for Auto-DR programs, $200/kW
F_{max} = the maximum fraction of project cost that can be covered by an Auto-DR incentive, 75%
TIC= the measure total installed cost

- **Fixed annual DR incentives.** For certain EE-DR measures (e.g., smart thermostats), a fixed incentive is provided on an annual basis for enrolling in a DR program. The incentive may be different across sectors and IOU programs. Such incentives are categorized as fixed annual DR incentives and applied as a fixed annual payment regardless of the underlying load shape. In some cases, the annual incentive could be prorated over the number of days a device remains activated. In these cases, the fixed annual DR incentive value was determined as the maximum possible incentive value that a device can get on annual basis.
- **Variable annual DR incentives.** For certain EE-DR measures (e.g., load reduction via an energy management system enrolled in a critical peak pricing, or CPP, program), annual enrollment incentives are awarded that vary with the quantity of load enrolled in the program. To determine the incentives, the DR program that could be applied to each measure is identified. As a default, the CPP rate or some form of it is assumed because it is offered to customers across all the sectors. For each measure, sector, and IOU, the difference between the customer's annual electricity bill on a non-CPP time-of-use rate and the bill on a corresponding CPP rate was computed for periods outside of CPP events.[273] This difference is the product of the measure-representative load shape and the difference between the CPP and non-CPP rate (excluding CPP events), which may vary by time period. This savings is taken as a representative annual customer DR incentive. Certain nonresidential CPP rates also include demand charge credits. If demand charge credit information is available, it is applied to the monthly peak values from the representative load shape, and the result is added to the total bill savings.
- **Bill savings from time-of-use response.** For computing time-of-use bill savings, each measure is assigned to a particular time-of-use tariff that is most common for the particular sector and IOU being considered based on a database of customer rate codes provided by the IOUs to Berkeley Lab for the DR Potential Study. For each sector and IOU, Berkeley Lab determined the impact of peak time-of-use rates on customer load, using the most recent load impact reports for residential customers and analyses performed to support the Phase 2 DR Potential Study for nonresidential customers. The impact indicates the fraction of load that can be shifted from peak to off-peak hours. Using the representative load shape for each measure, the savings from shifting the load from peak hours to off-peak hours is calculated as follows:

$$Bill\ Savings = \sum_{peak\ hours} D_h * F_{TOU} * (P_{peak} - P_{off-peak})$$

Where:

D_h= Hourly demand from the representative load shape
peak hours = Subset of hours that have a peak time-of-use rate

[273] During CPP events, Berkeley Lab assumed the customer either sheds load to avoid higher costs or effectively pays a non-performance penalty in the form of a higher electricity rate. Costs and savings that accrue during CPP events are not included as part of the annual program enrollment incentive, which is represented by the bill savings that accrue outside of peak events.

F_{TOU} = Fractional load reduction resulting from peak time-of-use rates for customers in this sector
P_{peak}= Time-of-use peak price
$P_{off-peak}$= Time-of-use off-peak price[274]

[274] Some time-of-use tariffs have more complex structures than simple peak and off-peak prices (e.g., mid-peak and super-off-peak periods). In these cases, Berkeley Lab assumed the off-peak period to be the period immediately adjacent to the peak period, under the assumption that customers will typically only shift load over a short period.

Appendix J. Cost-Effectiveness Analysis Methodology

Assessing cost-effectiveness for each measure is a core element to the 2021 Study. Cost-effectiveness at the measure level drives multiple critical outputs of the study:

- Cost-effectiveness of each measure determines what measures are included or excluded for each scenario—based on total resource cost (TRC), program administrator cost (PAC), and cost-effectiveness thresholds—driving the amount of savings each scenario produces.
- Aggregation of measure-level cost-effectiveness data informs the study's output for portfolio cost-effectiveness.
- Avoided cost benefits for each measure and increased supply cost for fuel substitution measures are the key inputs to calculating the total system benefit (TSB).

The California Public Utilities Commission (CPUC) maintains the Cost-Effectiveness Tool (CET) used by the investor-owned utilities (IOUs) to inform program plans and filed savings claims to evaluate program cost-effectiveness. The 2021 Study mirrors as best it can the CET's calculation methodologies. However, the study cannot capture the full granularity that the CET does. This is a purposeful design to keep the 2021 PG Model to a reasonable size to allow it to run efficiently, both for the Guidehouse team and for stakeholders who choose to run the model.

Table J-1 highlights similarities and differences between the CET and the 2021 PG Model. The rest of this appendix discuss the key categories in greater detail.

Table J-1. CET and 2021 PG Model Comparison

Category	Difference?	CET	2021 Study
Cost-Effectiveness Definitions	No	Cost-effectiveness definitions for TRC, PAC and ratepayer impact measure (RIM) come from the California Standard Practice Manual and additional guidance from CPUC staff.	
Vintage of Avoided Cost	No	Uses the latest CPUC approved avoided costs.	
Avoided Cost Components	No	Inputs three types of avoided cost: Generation, T&D, and emissions. Applies these as appropriate to unit energy savings (UES) to calculate total avoided cost benefits.	
Unit Energy Savings Input	Yes	Allows users to input UES for any measure specific to any utility, any building type, and any climate zone within the IOU territory.	Measure list is constrained to those representative measures characterized in the study. Not every level of efficiency is captured. Climate zones are grouped in three representative regions for each IOU.

Category	Difference?	CET	2021 Study
Load Shape Input	Yes	Allows users to select a specific load shape and assign it to each measure. Load shapes vary by utility, sector, end use, building type, and climate zone. There are over 5,000 possible load shapes to choose from in CET.	The 2021 PG Model cannot accommodate 5,000+ load shapes. Instead of assigning specific load shapes to each measure combination, the Guidehouse team calculated average load shapes across each IOU, sector, and end use (removing building type, climate zone, and measure-level granularity).
Load Shape Processing	Yes	Load shapes are input with quarterly time steps. CET splits annual UES into quarterly savings and applies each quarter's savings to the quarterly avoided costs. Discounting to present data is possible on a quarterly time step.	The 2021 Study operates on an annual basis, not a quarterly basis. Quarterly avoided costs are summed into an annual value before they are fed into the model.

Source: Guidehouse

While these differences are a necessary simplification, they are sufficient and common practice for this type of higher level forecasting in a potential study. To delve deeper and uniquely assign a load shape to each measure, utility, building type, and sector combination introduces complexities in the model that can significantly affect computation time and introduces a false level of precision in cases where new measures are being analyzed that do not have a precedent for using a specific load shape. Further mitigating conditions are present to ensure the study's approach does not result in large-scale inaccuracies of top-line results:

- In the process of calibrating the model, the Guidehouse team reviewed the high impact measure categories from recent programs for each sector and end use. In cases where the PG Model found a measure was not cost-effective even though the measure has historically been included in the portfolio, the measure was forced to be included in the calibration process. Examples include attic/ceiling insulation, zero net energy (ZNE) measures, chillers, and smart thermostats.
- The averaging of load shapes can result in some measures decreasing in cost-effectiveness relative to their true value while others may increase in cost-effectiveness if their assigned load shapes in CET deviate significantly from the average for the sector and end use. For example, if a measure is typically assigned a load shape with a high avoided cost value and its load shape is instead averaged with other (lower avoided cost) load shapes, its cost-effectiveness result could decrease. Measures typically assigned a load shape with a low avoided cost could see the opposite effect when using an average load shape. At a top-line level, this averaging should not result in a major shift in aggregate results.

J.1 Cost-Effectiveness Definitions

The cost-effectiveness analysis in the 2021 Study includes calculating the TRC and PAC. The model also calculated TSB. TSB is not a cost-effectiveness test itself, but it is calculated from key components that also feed into the TRC and PAC tests.

J.1.1 TRC

The TRC ratio for each measure is calculated each year and compared against the measure-level TRC ratio screening threshold. A measure with a TRC ratio greater than or equal to 1.0 is a measure that provides monetary benefits greater than or equal to its total resource costs. If a measure's TRC meets or exceeds a given scenario's threshold, it is included in the economic potential for that scenario.

The TRC test is a benefit-cost metric that measures the net benefits of energy efficiency (EE) measures from the combined stakeholder viewpoint of the utility (or program administrator) and the customers. The TRC benefit-cost ratio is calculated in the model using Equation J-1.

Equation J-1. Benefit-Cost Ratio for the TRC Test

$$TRC = \frac{PV(Avoided\ Cost\ Benefits)}{PV(Incremental\ Cost + Admin\ Costs) - \mathrm{PV}(Supply\ Costs)}$$

Where:

- PV is the present value calculation that discounts cost streams over time. Discount rates are sourced from the CET and vary by utility.
- Avoided Cost Benefits are the monetary benefits that result from electric and gas energy and capacity savings—e.g., avoided or deferred costs of infrastructure investments and avoided long-run marginal cost (commodity costs) due to electric energy conserved by efficient measures. These avoided costs decrease due to the increased consumption of any interactive effects. The avoided cost benefits is calculated by applying annual measure savings to avoided costs over the lifetime of the measure. More details on the source and processing of avoided costs is provided later in this section.
- Incremental Cost is the measure cost as defined by replacement type. This is sourced from the electronic Technical Reference Manual (eTRM), workpapers, Database for Energy Efficient Resources (DEER), and other sources as appropriate.
- Admin Costs are the non-incentive costs incurred by the utility or program administrator (not including incentives). These are described in Section 3.1.4.
- Supply Costs are the increased electric or gas consumption for fuel substitution measures. Increased supply cost is valued by applying the annual increase in the new fuel use to the avoided electricity or gas cost over the life of the measure.

The Guidehouse team calculated TRC ratios for each measure based on the present value of benefits and costs (as defined in the numerator and denominator, respectively) over each measure's life.

J.1.2 PAC

The PAC ratio for each measure is calculated each year and compared against the measure-level PAC ratio screening threshold. A measure with a PAC ratio greater than or equal to 1.0 is a measure that provides monetary benefits greater than or equal to its program administrator costs.

The PAC test is a benefit-cost metric that measures the net benefits of EE measures from the viewpoint of the utility (or program administrator). The PAC benefit-cost ratio is calculated in the model using Equation J-2.

Equation J-2. Benefit-Cost Ratio for the PAC Test

$$TRC = \frac{PV(Avoided\ Cost\ Benefits)}{PV(Incentives + Admin\ Costs) - \mathrm{PV}(Supply\ Costs)}$$

Where:

- PV is the present value calculation that discounts cost streams over time.
- Avoided Costs are the monetary benefits that result from electric and gas energy and capacity savings—e.g., avoided or deferred costs of infrastructure investments and avoided long-run marginal cost (commodity costs) due to electric energy conserved by efficient measures. These avoided costs decrease due to the increased consumption of any interactive effects for dual fuel utilities—i.e., Pacific Gas and Electric (PG&E) and San Diego Gas & Electric (SDG&E).
- Incentives is the rebate or incentives paid to buydown the measure cost directly to a customer or to a vendor passing on the benefit to the customer.
- Admin Costs are the non-incentive costs incurred by the utility or program administrator (not including incentives).
- Supply Costs are the increased new fuel consumption for fuel substitution measures.

The team calculated PAC ratios for each measure based on the present value of benefits and costs (as defined in the numerator and denominator, respectively) over each measure's life.

J.1.3 TSB

TSB represents the total net benefit that a measure provides to the electric and natural gas systems. TSB is a metric to show the relative value of each measure compared to each other independent of its measure cost, program cost, or fuel type. TSB is calculated in the model using Equation J-3.

Equation J-3. Total System Benefit

$$TSB = PV(Avoided\ Cost\ Benefits) - PV(Supply\ Costs)$$

Where:

- PV is the present value calculation that discounts cost streams over time.
- Avoided Cost Benefits are the monetary benefits that result from electric and gas energy and capacity savings—e.g., avoided or deferred costs of infrastructure investments and avoided long-run marginal cost (commodity costs) due to electric energy conserved by efficient measures. The avoided costs are only included for fuels offered by the utility.
- Supply Costs come in two forms: one is for interactive effects such as increased heating load due to decreased heat gain from more efficient lighting, and the other is for fuel consumption due to fuel substitution.

J.2 Avoided Cost Components

The PG Model applies avoided costs to the algorithms outlined for TRC, PAC, and TSB taking guidance from the California Standard Practice Manual. Electric avoided costs for the PG Model are the aggregate of the avoided costs of generation, transmission and distribution (T&D), and carbon from the CET.

- Generation in the CET is expressed in $/annual kWh.

- Carbon in the CET is expressed in tons/kWh, so this value is multiplied by the cost of carbon.
- T&D costs are expressed in two different ways (denoted by DSType within CET): kWh and kW. Those with kW DSTypes have this component of avoided cost valuing peak demand reductions and those with kWh DSTypes have value reductions in annual electric consumption.

Gas-avoided costs are the sum of the avoided costs of generation and T&D as reported by the CET. The CET embeds the cost of carbon in its valuation of gas generation avoided cost.

Cost of carbon is valued using data provided by Energy and Environmental Economics (E3) and provided to the CPUC in its “2020 ACC Electric Model.”[275] The carbon cost is the sum of the cap and trade allowance price and a GHG adder, as Table J-2 shows.[276]

[275] CPUC. “Cost-effectiveness Air Quality Adder Data.” 2018. http://www.cpuc.ca.gov/General.aspx?id=5267

[276] Horii, Brian, Eric Cutter, Zach Ming. *Avoided Costs 2018 Update*. 2018. p. 39. http://www.cpuc.ca.gov/General.aspx?id=5267

Table J-2. Costs of Carbon, 2019-2050

Year	Carbon Cost (nominal $/ton)
2019	$89.54
2020	$96.42
2021	$103.82
2022	$111.79
2023	$120.38
2024	$129.62
2025	$139.58
2026	$150.30
2027	$161.84
2028	$174.27
2029	$187.66
2030	$202.07
2031	$217.59
2032	$234.30
2033	$252.29
2034	$271.67
2035	$292.53
2036	$315.00
2037	$339.19
2038	$365.24
2039	$393.29
2040	$423.50
2041	$456.02
2042	$491.04
2043	$528.75
2044	$569.36
2045	$613.09
2046	$660.18
2047	$710.88
2048	$765.47
2049	$824.26
2050	$887.56

Source: CPUC at http://www.cpuc.ca.gov/General.aspx?id=5267

The 2021 Study did not consider the avoided cost of refrigerant emissions.

J.3 Load Shape Input and Processing

This section discusses the process the Guidehouse team used to calculate average load shapes across each IOU, sector, and end use. The 2021 Study cannot capture the full granularity that the CET does. This is a purposeful design to keep the 2021 PG Model to a reasonable size to allow it to run efficiently, both for the Guidehouse team and for stakeholders who choose to run the model. This reduction in granularity is processed in two places:

- The CET contains quarterly avoided cost data. The 2021 Study does not track quarterly savings, so the team summed the data across the quarters to produce annual avoided costs data.
- The CET contains more than 5,000 load shapes to apply to measures. Load shapes vary by utility, sector, end use, building type, and climate zone. The Guidehouse team calculated average load shapes across each IOU, sector, and end use (removing building type, climate zone and measure level granularity). The rest of this section discusses this process.

The CET contains load shapes that vary by climate zone and contains an aggregate “SYSTEM” value. The 2021 Study does not operate on a climate zone level for all measures, so the team used the “SYSTEM” values across all IOUs as representative of their service territory.

Each measure in the 2021 Study is tied to a sector, end use, and load shape. The nomenclature used by the Guidehouse team for sector, end use, and load shape does not necessarily align with the CET’s nomenclature. The CET itself is not internally consistent in its nomenclature of sectors and end uses. The CET reports Target Sectors (TS) for each utility; for some utilities, commonly used sectors such as Agriculture and Commercial are used, while for others it is vague (Res vs. Non-Res) or more specific (Res_New_Construction or Large Office). The CET also reports end uses and measures somewhat interchangeably (e.g., “Refrigeration” and “65K-135K_Air_AC-NC” are vastly different levels of granularity).

The relationship of the CET’s listed TS and end uses can have a one-to-one, one-to-many, or many-to-many relationship with the 2021 Study sectors and end uses. The Guidehouse team undertook a process to map CET end uses and sectors to the sectors and load shapes in the 2021 Study, which is shown in Table J-3. For 2021 Study load shapes that map to multiple CET TS and end uses, the CET end use load shapes were averaged into one load shape to be used by the PG Model. The following are examples of how to interpret this table:

- PG&E has two agricultural load shapes in the CET: 14 = Agricultural and 19= Agricultural EMS. These two load shapes were averaged together, and they map to every PG&E agriculture load shape in the 2021 Study (Ag, HVAC, Lighting, ProcHeat, ProcRefrig, SHW, WholeBlg). In this case, the PG Model allows for more granularity than what the CET can provide.
- PG&E residential load shapes for KitchenApp and Electronics in the 2021 Study are sourced from 11 different CET TS and end use combinations. In this case, the PG Model has less granularity than the CET offers. CET has three different residential TS for PG&E (Res, Residential, and Res_New_Construction) and 11 load shapes:
    - DEER:RefgFrzr_HighEff
    - DEER:RefgFrzr_Recyc-Conditioned
    - DEER:RefgFrzr_Recycling
    - DEER:RefgFrzr_Recyc-UnConditioned
    - DEER:Res_ClothesDishWasher
    - 24 = Res. Refrigeration (two different values for Residential and Res_New_Construction)
    - 31 = Res. Cooking (two different values for Residential and Res_New_Construction)

- 43 = Res. Dir. Assist. Refrigeration (two different values for Residential and Res_New_Construction)

- Southern California Edison's (SCE's) commercial load shape for Controls (lighting) in the 2021 Study is sourced from four different CET end uses available for 21 different building types under the end use combinations. More than 80 load shapes were averaged into one for use in the 2021 Study. The four CET EUs are as follows:
  - Occupancy Sensor
  - Perimeter Lt Control
  - DayLt & Controls
  - DayLt_Cntrl-NC

Table J-3. 2021 Study End Uses Mapping to CET End Uses

Utility	2021 Study Sector	2021 Study Load Shape(s)	CET TS	CET End Use
PG&E	Ag	Ag, HVAC, Lighting, ProcHeat, ProcRefrig, SHW, WholeBlg	AGRICULTURAL	14 = Agricultural
PG&E	Ag	Ag, HVAC, Lighting, ProcHeat, ProcRefrig, SHW, WholeBlg	AGRICULTURAL	19= Agricultural EMS
PG&E	Com	Cooking	COMMERCIAL	5 = Commercial Food Service
PG&E	Com	HeatCool, Diagnostic, EnvCtrl, Fenestration, HeatPump, Opaque, RetroComm. VentAirDist	Non_Res	DEER:HVAC_Duct_Sealing
PG&E	Com	HeatCool, Diagnostic, EnvCtrl, Fenestration, HeatPump, Opaque, RetroComm. VentAirDist	Non_Res	DEER:HVAC_Refrig_Charge
PG&E	Com	HeatCool, Diagnostic, EnvCtrl, Fenestration, HeatPump, Opaque, RetroComm. VentAirDist	Non_Res	DEER:HVAC_Split-Package_AC
PG&E	Com	HeatCool, Diagnostic, EnvCtrl, Fenestration, HeatPump, Opaque, RetroComm. VentAirDist	Non_Res	DEER:HVAC_Split-Package_HP
PG&E	Com	InGen, Controls, Electronics, Heating, Indoor, InExit, Vending	Non_Res	DEER:Indoor_CFL_Ltg
PG&E	Com	InGen, Controls, Electronics, Heating, Indoor, InExit, Vending	Non_Res	DEER:Indoor_Non-CFL_Ltg
PG&E	Com	Opaque	COMMERCIAL	4 = Commercial Refrigeration
PG&E	Com	OutGen	COMMERCIAL	2 = Commercial Outdoor Lighting
PG&E	Com	SpaceCool	Non_Res	DEER:HVAC_Chillers
PG&E	Com	SteamDist	COMMERCIAL	6 = Commercial Motors
PG&E	Com	SteamDist	COMMERCIAL	7 = Commercial Process
PG&E	Ind	HVAC	INDUSTRIAL	10 = Industrial HVAC
PG&E	Ind	HVAC	INDUSTRIAL	18 = Industrial EMS
PG&E	Ind	InGen	INDUSTRIAL	8 = Industrial Indoor Lighting

Utility	2021 Study Sector	2021 Study Load Shape(s)	CET TS	CET End Use
PG&E	Ind	Motors, MachDr, WoleBlg	INDUSTRIAL	12 = Industrial Motors
PG&E	Ind	ProcHeat, SHW	INDUSTRIAL	11 = Industrial Process
PG&E	Ind	ProcRefrig	INDUSTRIAL	13 = Industrial Refrigeration
PG&E	Res	HeatPump (all climate zones)	Res	DEER:HVAC_Eff_HP
PG&E	Res	HeatCool, VentAirDist	Res	DEER:HVAC_Duct_Sealing
PG&E	Res	HeatCool, VentAirDist	Res	DEER:HVAC_Eff_AC
PG&E	Res	HeatCool, VentAirDist	Res	DEER:HVAC_Refrig_Charge
PG&E	Res	HeatCool, VentAirDist	Res	DEER:Refg_Chrg_Duct_Seal
PG&E	Res	HeatCool, VentAirDist	Res_New_Construction	22 = Res. Ht. Pump Cooling
PG&E	Res	HeatCool, VentAirDist	Res_New_Construction	23 = Res. Ele. & Ht. Pump Heating
PG&E	Res	HeatCool, VentAirDist	Residential	22 = Res. Ht. Pump Cooling
PG&E	Res	HeatCool, VentAirDist	Residential	23 = Res. Ele. & Ht. Pump Heating
PG&E	Res	Heating	Res_New_Construction	21 = Res. Wtr. Heating
PG&E	Res	Heating	Residential	21 = Res. Wtr. Heating
PG&E	Res	InGen, Indoor, Outdoor, Outgen, Seasonal	Res	DEER:Indoor_CFL_Ltg
PG&E	Res	InGen, Indoor, Outdoor, Outgen, Seasonal	Res_New_Construction	25 = Res. Lighting
PG&E	Res	InGen, Indoor, Outdoor, Outgen, Seasonal	Res_New_Construction	28 = Res. New Const. Lighting
PG&E	Res	InGen, Indoor, Outdoor, Outgen, Seasonal	Res_New_Construction	44 = Res. Dir. Assist. Lighting
PG&E	Res	InGen, Indoor, Outdoor, Outgen, Seasonal	Residential	25 = Res. Lighting
PG&E	Res	InGen, Indoor, Outdoor, Outgen, Seasonal	Residential	28 = Res. New Const. Lighting
PG&E	Res	InGen, Indoor, Outdoor, Outgen, Seasonal	Residential	44 = Res. Dir. Assist. Lighting
PG&E	Res	KitchenApp, Electronics	Res	DEER:RefgFrzr_HighEff
PG&E	Res	KitchenApp, Electronics	Res	DEER:RefgFrzr_Recyc-Conditioned
PG&E	Res	KitchenApp, Electronics	Res	DEER:RefgFrzr_Recycling
PG&E	Res	KitchenApp, Electronics	Res	DEER:RefgFrzr_Recyc-UnConditioned
PG&E	Res	KitchenApp, Electronics	Res	DEER:Res_ClothesDishWasher
PG&E	Res	KitchenApp, Electronics	Res_New_Construction	24 = Res. Refrigeration
PG&E	Res	KitchenApp, Electronics	Res_New_Construction	31 = Res. Cooking
PG&E	Res	KitchenApp, Electronics	Res_New_Construction	43 = Res. Dir. Assist. Refrigeration
PG&E	Res	KitchenApp, Electronics	Residential	24 = Res. Refrigeration
PG&E	Res	KitchenApp, Electronics	Residential	31 = Res. Cooking
PG&E	Res	KitchenApp, Electronics	Residential	43 = Res. Dir. Assist. Refrigeration

Utility	2021 Study Sector	2021 Study Load Shape(s)	CET TS	CET End Use
PG&E	Res	Laundry	Res_New_Construction	32 = Res. Clothes Dry
PG&E	Res	Laundry	Residential	32 = Res. Clothes Dry
PG&E	Res	Opaque, Fenestration	Res	DEER:Res_BldgShell_Ins
PG&E	Res	Opaque, Fenestration	Res_New_Construction	33 = Res. Insul. Cen. A/C
PG&E	Res	Opaque, Fenestration	Res_New_Construction	34 = Res. Insul. Elect. Heat
PG&E	Res	Opaque, Fenestration	Res_New_Construction	35 = Res. Ceil. Insul. HP Cooling
PG&E	Res	Opaque, Fenestration	Res_New_Construction	36 = Res. Ceil. Insul. HP Heating
PG&E	Res	Opaque, Fenestration	Res_New_Construction	37 = Res. Wall Insul. HP Cooling
PG&E	Res	Opaque, Fenestration	Res_New_Construction	38 = Res. Wall Insul. HP Heating
PG&E	Res	Opaque, Fenestration	Res_New_Construction	39 = Res. Flr. Insul. HP Cooling
PG&E	Res	Opaque, Fenestration	Res_New_Construction	40 = Res. Flr. Insul. HP Heating
PG&E	Res	Opaque, Fenestration	Res_New_Construction	42 = Res. Dir. Assist. Weatherization
PG&E	Res	Opaque, Fenestration	Residential	33 = Res. Insul. Cen. A/C
PG&E	Res	Opaque, Fenestration	Residential	34 = Res. Insul. Elect. Heat
PG&E	Res	Opaque, Fenestration	Residential	35 = Res. Ceil. Insul. HP Cooling
PG&E	Res	Opaque, Fenestration	Residential	36 = Res. Ceil. Insul. HP Heating
PG&E	Res	Opaque, Fenestration	Residential	37 = Res. Wall Insul. HP Cooling
PG&E	Res	Opaque, Fenestration	Residential	38 = Res. Wall Insul. HP Heating
PG&E	Res	Opaque, Fenestration	Residential	39 = Res. Flr. Insul. HP Cooling
PG&E	Res	Opaque, Fenestration	Residential	40 = Res. Flr. Insul. HP Heating
PG&E	Res	Opaque, Fenestration	Residential	42 = Res. Dir. Assist. Weatherization
PG&E	Res	SpaceCool	Res_New_Construction	26 = Res. Central Air Conditioning
PG&E	Res	SpaceCool	Res_New_Construction	29 = Res. New Const. Cooling
PG&E	Res	SpaceCool	Res_New_Construction	45 = Res. Dir. Assist. Evap. Cooler
PG&E	Res	SpaceCool	Residential	26 = Res. Central Air Conditioning
PG&E	Res	SpaceCool	Residential	29 = Res. New Const. Cooling
PG&E	Res	SpaceCool	Residential	45 = Res. Dir. Assist. Evap. Cooler
PG&E	Res	WholeBlg	Res_New_Construction	41 = Res. EMS
PG&E	Res	WholeBlg	Residential	41 = Res. EMS
SCE	Ag	HVAC	Agricultural	Replace_Chiller-Ret

Utility	2021 Study Sector	2021 Study Load Shape(s)	CET TS	CET End Use
SCE	Ag	HVAC	Agricultural	Roof_insul-Ret
SCE	Ag	HVAC	Agricultural	Wall_insul-Ret
SCE	Ag	HVAC	Agricultural	Reduce_Cooling_Load-Ret
SCE	Ag	HVAC	Agricultural	New_HtPmp-Ret
SCE	Ag	HVAC	Agricultural	New_AC-Ret
SCE	Ag	Lighting	Agricultural	Perimter Lt Control
SCE	Ag	Lighting	Agricultural	Outdoor Lt
SCE	Ag	Lighting	Agricultural	Occupancy Sensor
SCE	Ag	Lighting	Agricultural	IndoorLt
SCE	Ag	Lighting	Agricultural	DayLt & Controls
SCE	Ag	MachDr, WholeBlg	Agricultural	Ag & Water Pumping
SCE	Ag	ProcHeat, SHW	Agricultural	Pool HtPmp
SCE	Ag	ProcHeat, SHW	Agricultural	DHW HtPmp
SCE	Ag	ProcRefrig	Agricultural	Refrigeration
SCE	Com	Controls	[All Available Commercial Building Types]	Occupancy Sensor
SCE	Com	Controls	[All Available Commercial Building Types]	Perimter Lt Control
SCE	Com	Controls	[All Available Commercial Building Types]	DayLt & Controls
SCE	Com	Controls	[All Available Commercial Building Types]	DayLt_Cntrl-NC
SCE	Com	Electronics, Vending	[All Available Commercial Building Types]	Pool HtPmp
SCE	Com	HeatCool, Diagnostics, EnvCtrl, HeatPump, RetroComm, VentAirDist	[All Available Commercial Building Types]	>135K_Air_AC-NC
SCE	Com	HeatCool, Diagnostics, EnvCtrl, HeatPump, RetroComm, VentAirDist	[All Available Commercial Building Types]	>135K_Wtr_AC-NC
SCE	Com	HeatCool, Diagnostics, EnvCtrl, HeatPump, RetroComm, VentAirDist	[All Available Commercial Building Types]	Var_Spd_AC_Mtr-NC
SCE	Com	HeatCool, Diagnostics, EnvCtrl, HeatPump, RetroComm, VentAirDist	[All Available Commercial Building Types]	65K-135_Wtr_AC-NC
SCE	Com	HeatCool, Diagnostics, EnvCtrl, HeatPump, RetroComm, VentAirDist	[All Available Commercial Building Types]	65K-135K_Air_AC-NC
SCE	Com	HeatCool, Diagnostics, EnvCtrl, HeatPump, RetroComm, VentAirDist	[All Available Commercial Building Types]	Economy_cycle-Ret
SCE	Com	HeatCool, Diagnostics, EnvCtrl, HeatPump, RetroComm, VentAirDist	[All Available Commercial Building Types]	New_HtPmp-Ret

Utility	2021 Study Sector	2021 Study Load Shape(s)	CET TS	CET End Use
SCE	Com	HeatCool, Diagnostics, EnvCtrl, HeatPump, RetroComm, VentAirDist	[All Available Commercial Building Types]	<65K_AC_Pckg-NC
SCE	Com	HeatCool, Diagnostics, EnvCtrl, HeatPump, RetroComm, VentAirDist	[All Available Commercial Building Types]	<65K_AC_Split-NC
SCE	Com	HeatCool, Diagnostics, EnvCtrl, HeatPump, RetroComm, VentAirDist	[All Available Commercial Building Types]	Package_AC-NC
SCE	Com	HeatCool, Diagnostics, EnvCtrl, HeatPump, RetroComm, VentAirDist	[All Available Commercial Building Types]	Lower_Cond_temp-Ret
SCE	Com	Heating, SteamDist	[All Available Commercial Building Types]	DHW HtPmp
SCE	Com	InGen, Cooking, Indoor, InExit	Non_Res	DEER:Indoor_Non-CFL_Ltg
SCE	Com	InGen, Cooking, Indoor, InExit	Non_Res	DEER:Indoor_CFL_Ltg
SCE	Com	Opaque, Fenestration	[All Available Commercial Building Types]	Hi_Perf_Glass-NC
SCE	Com	Opaque, Fenestration	[All Available Commercial Building Types]	Lo_Gain_Wndw-NC
SCE	Com	Opaque, Fenestration	[All Available Commercial Building Types]	Roof_insul-Ret
SCE	Com	Opaque, Fenestration	[All Available Commercial Building Types]	Wall_insul-Ret
SCE	Com	Opaque, Fenestration	[All Available Commercial Building Types]	Window_Tint-Ret
SCE	Com	OutGen	[All Available Commercial Building Types]	Outdoor Lt
SCE	Com	SpaceCool	[All Available Commercial Building Types]	Hi_Eff_AC_Mtr-NC
SCE	Com	SpaceCool	[All Available Commercial Building Types]	Wtr_Cool_Chiller-NC
SCE	Com	SpaceCool	[All Available Commercial Building Types]	Evap_Cooling-Ret
SCE	Com	SpaceCool	[All Available Commercial Building Types]	New_AC-Ret
SCE	Com	SpaceCool	[All Available Commercial Building Types]	Reduce_Cooling_Load-Ret
SCE	Com	SpaceCool	[All Available Commercial Building Types]	<65K_EvapCool-NC

Utility	2021 Study Sector	2021 Study Load Shape(s)	CET TS	CET End Use
SCE	Com	SpaceCool	[All Available Commercial Building Types]	Replace_Chiller-Ret
SCE	Com	Storage	[All Available Commercial Building Types]	Refrigeration
SCE	Com	Storage	Misc._Commercial	Frig Barrier
SCE	Ind	HVAC	Industrial	New_HtPmp-Ret
SCE	Ind	HVAC	Industrial	New_AC-Ret
SCE	Ind	HVAC	Industrial	Reduce_Cooling_Load-Ret
SCE	Ind	HVAC	Industrial	Replace_Chiller-Ret
SCE	Ind	Lighting	Industrial	Occupancy Sensor
SCE	Ind	Lighting	Industrial	Outdoor Lt
SCE	Ind	Lighting	Industrial	Perimter Lt Control
SCE	Ind	Lighting	Industrial	DayLt & Controls
SCE	Ind	Lighting	Industrial	IndoorLt
SCE	Ind	MachDr, WholeBlg	Industrial	Industrial
SCE	Ind	ProcHeat, SHW	Industrial	Pool HtPmp
SCE	Ind	ProcRefrig	Industrial	Refrigeration
SCE	Res	HeatPump - Cold	Res	Heat_Pump-NC (CZ 16)
SCE	Res	HeatPump - Hot-Dry	Res	Heat_Pump-NC (CZ 8)_
SCE	Res	HeatPump - Marine	Res	Heat_Pump-NC (CZ 6)
SCE	Res	HeatCool, VentAirDist	Res	DEER:HVAC_Duct_Sealing
SCE	Res	HeatCool, VentAirDist	Res	DEER:HVAC_Eff_AC
SCE	Res	HeatCool, VentAirDist	Res	DEER:HVAC_Refrig_Charge
SCE	Res	Heating	Residential	HeatPump_WtrHt-RC
SCE	Res	InGen, Indoor, Lighting, Outdoor, Outgen, Seasonal	Res	DEER:Indoor_CFL_Ltg
SCE	Res	KitchenApp, Electronics	Res	DEER:RefgFrzr_Recyc-Conditioned
SCE	Res	KitchenApp, Electronics	Res	DEER:RefgFrzr_HighEff
SCE	Res	KitchenApp, Electronics	Res	DEER:RefgFrzr_Recyc-UnConditioned
SCE	Res	KitchenApp, Electronics	Res	DEER:RefgFrzr_Recycling
SCE	Res	Laundry	Res	DEER:Res_ClothesDishWasher
SCE	Res	Opaque, Fenestration	Res	DEER:Res_BldgShell_Ins
SCE	Res	SpaceCool	Residential	AC-NC
SCE	Res	SpaceCool	Residential	AC_Cooling-RC
SCE	Res	SpaceHeat	Residential	HeatPump_Heating_Only-RC
SDG&E	Com	Electronics, Vending	[All Available Commercial Building Types]	POOL_PMP
SDG&E	Com	Electronics, Vending	[All Available Commercial Building Types]	DSH_WASH

Utility	2021 Study Sector	2021 Study Load Shape(s)	CET TS	CET End Use
SDG&E	Com	Electronics, Vending	[All Available Commercial Building Types]	CL_DRY
SDG&E	Com	Electronics, Vending	[All Available Commercial Building Types]	CL_WASH
SDG&E	Com	Electronics, Vending	[All Available Commercial Building Types]	OffEquip
SDG&E	Com	Electronics, Vending	[All Available Commercial Building Types]	OFF_EQ
SDG&E	Com	HeatCool, Fenestration, Opaque, EnvCtrl, VentAirDist, HeatPump, Diagnostic, RetroComm	Non_Res	DEER:HVAC_Duct_Sealing
SDG&E	Com	Heating, SteamDist	SMO	WAT_HEAT
SDG&E	Com	InGen, Cooking, Controls, Indoor, InExit	[All Available Commercial Building Types]	LIGHT
SDG&E	Com	InGen, Cooking, Controls, Indoor, InExit	[All Available Commercial Building Types]	IntLight
SDG&E	Com	InGen, Cooking, Controls, Indoor, InExit	[All Available Commercial Building Types]	DEER:Indoor_Non-CFL_Ltg
SDG&E	Com	InGen, Cooking, Controls, Indoor, InExit	[All Available Commercial Building Types]	LIT_INT
SDG&E	Com	InGen, Cooking, Controls, Indoor, InExit	[All Available Commercial Building Types]	DEER:Indoor_CFL_Ltg
SDG&E	Com	OutGen	[All Available Commercial Building Types]	ExtLight
SDG&E	Com	OutGen	[All Available Commercial Building Types]	LIT_EXT
SDG&E	Com	SpaceCool	[All Available Commercial Building Types]	Cooling
SDG&E	Com	SpaceCool	[All Available Commercial Building Types]	SP_COOL
SDG&E	Com	SpaceCool	[All Available Commercial Building Types]	DEER:HVAC_Split-Package_AC
SDG&E	Com	SpaceCool	[All Available Commercial Building Types]	DEER:HVAC_Refrig_Charge
SDG&E	Com	SpaceCool	[All Available Commercial Building Types]	COOL
SDG&E	Com	SpaceCool	[All Available Commercial Building Types]	DEER:HVAC_Split-Package_HP

Utility	2021 Study Sector	2021 Study Load Shape(s)	CET TS	CET End Use
SDG&E	Com	SpaceCool	[All Available Commercial Building Types]	DEER:HVAC_Chillers
SDG&E	Com	SpaceCool	[All Available Commercial Building Types]	DEER:HVAC_Eff_HP
SDG&E	Com	SpaceCool	[All Available Commercial Building Types]	DEER:HVAC_Eff_AC
SDG&E	Com	Storage	[All Available Commercial Building Types]	REFG
SDG&E	Com	Storage	[All Available Commercial Building Types]	FREEZ
SDG&E	Com	Storage	[All Available Commercial Building Types]	Refrig
SDG&E	Ind	HVAC	S33	COOL
SDG&E	Ind	HVAC	S29	COOL
SDG&E	Ind	HVAC	S28	COOL
SDG&E	Ind	HVAC	MBT	COOL
SDG&E	Ind	HVAC	S26	COOL
SDG&E	Ind	HVAC	S20	COOL
SDG&E	Ind	HVAC	BCR	COOL
SDG&E	Ind	HVAC	ALC	Cooling
SDG&E	Ind	HVAC	BCR	VENT
SDG&E	Ind	HVAC	OTI	COOL
SDG&E	Ind	HVAC	ALC	Vent/Fan
SDG&E	Ind	HVAC	MLI	COOL
SDG&E	Ind	Lighting, SHW	S33	LIGHT
SDG&E	Ind	Lighting, SHW	S29	LIGHT
SDG&E	Ind	Lighting, SHW	S28	LIGHT
SDG&E	Ind	Lighting, SHW	S26	LIGHT
SDG&E	Ind	Lighting, SHW	S20	LIGHT
SDG&E	Ind	Lighting, SHW	MLI	LIGHT
SDG&E	Ind	Lighting, SHW	MBT	LIGHT
SDG&E	Ind	Lighting, SHW	BCR	LIT_INT
SDG&E	Ind	Lighting, SHW	BCR	LIT_EXT
SDG&E	Ind	Lighting, SHW	ALC	ExtLight
SDG&E	Ind	Lighting, SHW	ALC	IntLight
SDG&E	Ind	Lighting, SHW	OTI	LIGHT
SDG&E	Ind	MachDr, WholeBlg	[All available Industrial Building Types]	AG_PUMP
SDG&E	Ind	MachDr, WholeBlg	[All available Industrial Building Types]	COMP_AIR

Utility	2021 Study Sector	2021 Study Load Shape(s)	CET TS	CET End Use
SDG&E	Ind	MachDr, WholeBlg	[All available Industrial Building Types]	MOTOR
SDG&E	Ind	ProcHeat	[All available Industrial Building Types]	PROC_OTH
SDG&E	Ind	ProcRefrig	BCR	REFG
SDG&E	Ind	ProcRefrig	ALC	Refrig
SDG&E	Res	HeatPump	Res	DEER:HVAC_Eff_HP
SDG&E	Res	HeatCool, VentAirDist,	Res	DEER:Refg_Chrg_Duct_Seal
SDG&E	Res	HeatCool, VentAirDist,	Res	DEER:HVAC_Duct_Sealing
SDG&E	Res	Heating	SFM	WAT_HEAT
SDG&E	Res	Heating	MFM	WAT_HEAT
SDG&E	Res	Heating	RES	WAT_HEAT
SDG&E	Res	Heating	DMO	WAT_HEAT
SDG&E	Res	InGen, Indoor, Outdoor, Outgen, Seasonal	MFM	LIGHT
SDG&E	Res	InGen, Indoor, Outdoor, Outgen, Seasonal	Res	DEER:Indoor_CFL_Ltg
SDG&E	Res	InGen, Indoor, Outdoor, Outgen, Seasonal	RES	LIGHT
SDG&E	Res	InGen, Indoor, Outdoor, Outgen, Seasonal	DMO	LIGHT
SDG&E	Res	InGen, Indoor, Outdoor, Outgen, Seasonal	SFM	LIGHT
SDG&E	Res	KitchenApp, Electronics	SFM	REFG
SDG&E	Res	KitchenApp, Electronics	SFM	FREEZ
SDG&E	Res	KitchenApp, Electronics	SFM	DSH_WASH
SDG&E	Res	KitchenApp, Electronics	MFM	REFG
SDG&E	Res	KitchenApp, Electronics	MFM	DSH_WASH
SDG&E	Res	KitchenApp, Electronics	Res	DEER:Res_ClothesDishWasher
SDG&E	Res	KitchenApp, Electronics	Res	DEER:RefgFrzr_Recycling
SDG&E	Res	KitchenApp, Electronics	Res	DEER:RefgFrzr_Recyc-UnConditioned
SDG&E	Res	KitchenApp, Electronics	Res	DEER:RefgFrzr_HighEff
SDG&E	Res	KitchenApp, Electronics	Res	DEER:RefgFrzr_Recyc-Conditioned
SDG&E	Res	KitchenApp, Electronics	DMO	REFG
SDG&E	Res	KitchenApp, Electronics	DMO	DSH_WASH
SDG&E	Res	KitchenApp, Electronics	RES	REFG
SDG&E	Res	KitchenApp, Electronics	RES	DSH_WASH
SDG&E	Res	KitchenApp, Electronics	RES	FREEZ
SDG&E	Res	KitchenApp, Electronics	MFM	FREEZ
SDG&E	Res	KitchenApp, Electronics	DMO	FREEZ
SDG&E	Res	Laundry	SFM, MFM, RES, DMO	CL_DRY
SDG&E	Res	Laundry	SFM, MFM, RES, DMO	CL_WASH

Utility	2021 Study Sector	2021 Study Load Shape(s)	CET TS	CET End Use
SDG&E	Res	Opaque, Fenestration	Res	DEER:Res_BldgShell_Ins
SDG&E	Res	SpaceHeat	SFM	SP_HEAT
SDG&E	Res	SpaceHeat	DMO	SP_HEAT
SDG&E	Res	SpaceHeat	RES	SP_HEAT
SDG&E	Res	SpaceHeat	MFM	SP_HEAT

Source: Guidehouse analysis of CET avoided cost load shape data

Appendix K. Detailed Scenario Results by IOU and COVID-19 Sensitivities

K.1 Impacts by Fuel Type

This section presents impacts by fuel type. The tables reflect fuel substitution as positive gas savings (decreased gas consumption) with negative electric savings (increased electric consumption). In this section, SCE shows gas savings due to fuel substitution measures funded by SCE ratepayers.

K.1.1 PG&E

Table K-1. PG&E Electric Energy Savings (GWh/year)

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Scenario 1: TRC Low											
Energy Efficiency	144.4	144.9	151.0	146.0	138.4	140.7	150.9	156.0	164.2	157.9	157.0
Fuel Substitution	-0.01	-0.01	-0.01	-0.01	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
BROs	222.2	240.0	258.8	277.8	298.0	318.4	333.7	345.7	359.1	374.4	390.8
Scenario 2a: TRC Reference											
Energy Efficiency	160.4	155.6	160.5	155.8	167.2	175.0	175.9	167.6	170.0	167.3	163.8
Fuel Substitution	-0.49	-0.45	-0.27	-0.07	-0.06	-0.04	-0.04	-0.02	-0.02	-0.01	-0.01
BROs	222.2	240.0	258.8	277.8	298.0	318.4	333.7	345.7	359.1	374.4	390.8
Scenario 3: TRC High											
Energy Efficiency	163.5	157.8	162.4	157.6	170.2	179.9	182.9	179.5	191.9	191.5	187.9
Fuel Substitution	-0.50	-0.45	-0.27	-0.08	-0.06	-0.05	-0.05	-0.03	-0.03	-0.01	-0.01
BROs	275.1	302.3	322.0	346.2	370.2	395.8	424.8	457.6	497.2	544.7	600.9
Scenario 4: IRP Optimized											
Energy Efficiency	48.6	66.7	72.9	74.4	70.7	78.1	80.8	74.7	77.3	77.0	82.0
Fuel Substitution	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BROs	187.7	190.5	193.3	229.6	266.4	280.7	291.9	303.1	314.8	326.1	335.4
C&S (All Scenarios)											
w/ Interactive Effects	1,039.7	1,096.6	1,118.3	1,071.6	1,013.0	920.9	862.4	699.6	626.7	609.8	595.5
w/o Interactive Effects	1,014.1	1,082.2	1,105.8	1,060.3	1,003.0	913.9	856.8	699.6	628.2	611.8	597.9

Source: Guidehouse

Table K-2. PG&E Demand Savings (MW)

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Scenario 1: TRC Low											
Energy Efficiency	40.7	40.1	40.1	36.6	32.9	32.4	32.7	32.3	35.5	33.9	33.2
Fuel Substitution	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
BROs	46.4	50.1	54.0	58.0	62.1	66.3	69.4	71.7	74.2	77.2	80.3
Scenario 2: TRC Reference											
Energy Efficiency	44.8	42.4	43.3	39.7	39.3	40.0	39.1	35.8	36.7	34.6	33.3
Fuel Substitution	-0.04	-0.04	-0.02	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
BROs	46.4	50.1	54.0	58.0	62.1	66.3	69.4	71.7	74.2	77.2	80.3
Scenario 3: TRC High											
Energy Efficiency	45.6	42.7	43.5	39.6	39.3	40.5	40.1	37.9	40.7	38.8	37.6
Fuel Substitution	-0.04	-0.04	-0.02	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
BROs	56.3	61.8	65.5	69.7	74.0	78.6	83.8	89.6	96.6	105.1	115.1
Scenario 4: IRP Optimized											
Energy Efficiency	13.3	16.1	18.0	15.9	14.7	16.0	16.3	15.3	15.7	15.9	17.0
Fuel Substitution	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BROs	41.1	41.7	42.2	50.3	58.4	61.6	64.0	66.5	69.1	71.6	72.8
C&S (All Scenarios)											
w/ Interactive Effects	232.0	256.3	256.4	247.3	235.8	216.8	207.2	177.4	162.5	154.6	147.6
w/o Interactive Effects	216.6	245.9	247.6	239.1	228.3	211.7	202.6	175.8	161.3	153.8	146.9

Source: Guidehouse

Table K-3. PG&E Gas Energy Savings (MMtherm/year)

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Scenario 1: TRC Low											
Energy Efficiency	2.70	2.78	3.09	3.81	4.01	4.16	5.04	4.68	5.00	5.01	5.12
Fuel Substitution	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BROs	9.15	9.72	10.31	10.90	11.51	12.15	12.65	13.13	13.59	14.06	14.56
Scenario 2: TRC Reference											
Energy Efficiency	3.77	3.94	5.56	5.35	5.17	5.43	5.52	5.19	5.40	5.32	5.27
Fuel Substitution	0.06	0.06	0.04	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
BROs	9.15	9.72	10.31	10.90	11.51	12.15	12.65	13.13	13.59	14.06	14.56
Scenario 3: TRC High											
Energy Efficiency	3.88	4.07	5.71	5.52	5.40	5.77	6.13	6.25	7.36	7.30	7.28
Fuel Substitution	0.07	0.06	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
BROs	11.09	12.03	12.71	13.47	14.30	15.27	16.37	17.73	19.26	21.02	23.10
Scenario 4: IRP Optimized											
Energy Efficiency	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fuel Substitution	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BROs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C&S (All Scenarios)											
w/ Interactive Effects	13.24	14.86	15.54	15.18	8.58	8.67	8.49	8.83	8.82	8.65	8.40
w/o Interactive Effects	16.19	17.59	17.77	17.34	10.50	10.23	9.95	9.76	9.59	9.36	9.10

Source: Guidehouse

K.1.2 SCE

Table K-4. SCE Electric Energy Savings (GWh/year)

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Scenario 1: TRC Low											
Energy Efficiency	121.3	128.0	138.1	149.9	150.9	153.1	156.8	146.7	154.2	151.5	153.9
Fuel Substitution	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02	-0.02	-0.02	-0.02
BROs	205.4	221.6	238.1	255.0	272.6	291.0	310.3	325.3	340.3	356.8	374.4
Scenario 2: TRC Reference											
Energy Efficiency	139.0	143.6	148.7	156.4	152.1	155.1	160.0	149.8	154.7	152.5	157.4
Fuel Substitution	-2.80	-3.14	-3.49	-3.84	-4.19	-4.53	-4.88	-5.21	-5.54	-5.87	-6.18
BROs	205.4	221.6	238.1	255.0	272.6	291.0	310.3	325.3	340.3	356.8	374.4
Scenario 3: TRC High											
Energy Efficiency	145.0	149.2	154.4	162.6	158.0	162.0	168.6	159.8	170.3	168.2	173.5
Fuel Substitution	-3.09	-3.50	-3.91	-4.32	-4.72	-5.11	-5.49	-5.85	-6.20	-6.54	-6.87
BROs	248.3	277.7	304.5	326.4	351.7	380.6	413.7	452.6	499.2	554.8	620.8
Scenario 4: IRP Optimized											
Energy Efficiency	31.5	53.8	61.6	72.1	70.4	81.7	87.5	79.8	84.4	85.2	92.1
Fuel Substitution	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BROs	170.3	172.5	174.4	206.2	237.8	250.1	264.8	278.2	290.8	302.7	314.5
C&S (All Scenarios)											
w/ Interactive Effects	1,039.7	1,096.6	1,118.3	1,071.6	1,013.0	920.9	862.4	699.6	626.7	609.8	595.5
w/o Interactive Effects	1,014.1	1,082.2	1,105.8	1,060.3	1,003.0	913.9	856.8	699.6	628.2	611.8	597.9

Source: Guidehouse

Table K-5. SCE Demand Savings (MW)

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Scenario 1: TRC Low											
Energy Efficiency	25.6	26.3	30.7	32.8	32.7	32.8	33.1	31.4	33.0	32.3	32.8
Fuel Substitution	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.01	-0.01	-0.01	-0.01	-0.01
BROs	48.5	52.3	56.1	60.0	64.0	68.1	72.5	75.7	78.8	82.2	85.9
Scenario 2: TRC Reference											
Energy Efficiency	34.2	33.1	33.3	34.1	33.0	33.6	33.9	32.1	33.3	32.7	34.0
Fuel Substitution	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.01	-0.01	-0.01	-0.01	-0.01
BROs	48.5	52.3	56.1	60.0	64.0	68.1	72.5	75.7	78.8	82.2	85.9
Scenario 3: TRC High											
Energy Efficiency	35.8	34.4	34.5	35.4	34.2	35.0	35.6	34.1	36.4	35.8	37.2
Fuel Substitution	-0.00	-0.00	-0.00	-0.00	-0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
BROs	57.6	64.1	69.2	73.5	78.4	84.0	90.3	97.7	106.7	117.4	130.0
Scenario 4: IRP Optimized											
Energy Efficiency	5.4	9.3	11.7	12.5	12.4	15.0	16.3	15.3	16.3	16.8	19.8
Fuel Substitution	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BROs	42.9	43.3	43.7	51.8	59.9	63.0	66.7	70.0	73.1	76.1	77.7
C&S (All Scenarios)											
w/ Interactive Effects	220.6	240.8	240.9	232.5	221.4	203.1	193.9	164.4	149.7	142.9	136.9
w/o Interactive Effects	205.4	230.7	232.4	224.4	214.2	198.1	189.4	162.8	148.6	142.1	136.3

Source: Guidehouse

Table K-6. SCE Gas Savings (MMTherms) – Fuel Substitution Only

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Scenario 1: TRC Low											
Energy Efficiency	0	0	0	0	0	0	0	0	0	0	0
Fuel Substitution	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
BROs	0	0	0	0	0	0	0	0	0	0	0
Scenario 2: TRC Reference											
Energy Efficiency	0	0	0	0	0	0	0	0	0	0	0
Fuel Substitution	0.67	0.75	0.83	0.92	1.00	1.08	1.16	1.24	1.32	1.40	1.47
BROs	0	0	0	0	0	0	0	0	0	0	0
Scenario 3: TRC High											
Energy Efficiency	0	0	0	0	0	0	0	0	0	0	0
Fuel Substitution	0.74	0.84	0.93	1.03	1.12	1.22	1.31	1.40	1.48	1.56	1.64
BROs	0	0	0	0	0	0	0	0	0	0	0
Scenario 4: IRP Optimized											
Energy Efficiency	0	0	0	0	0	0	0	0	0	0	0
Fuel Substitution	0	0	0	0	0	0	0	0	0	0	0
BROs	0	0	0	0	0	0	0	0	0	0	0
C&S (All Scenarios)											
w/ Interactive Effects	0	0	0	0	0	0	0	0	0	0	0
w/o Interactive Effects	0	0	0	0	0	0	0	0	0	0	0

Source: Guidehouse

K.1.3 SCG

Table K-7. SCG Gas Savings (MMtherm/year)

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Scenario 1: TRC Low											
Energy Efficiency	7.41	8.08	8.55	10.41	10.61	10.82	10.96	10.53	10.49	9.90	9.39
Fuel Substitution	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BROs	10.23	11.31	12.44	13.54	14.67	15.84	17.02	18.25	19.50	20.75	22.02
Scenario 2: TRC Reference											
Energy Efficiency	8.74	9.85	10.89	11.37	11.52	11.33	11.17	10.67	10.64	10.09	9.61
Fuel Substitution	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BROs	10.23	11.31	12.44	13.54	14.67	15.84	17.02	18.25	19.50	20.75	22.02
Scenario 3: TRC High											
Energy Efficiency	9.23	10.40	11.45	11.88	11.96	11.74	11.72	11.60	12.48	11.94	11.49
Fuel Substitution	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BROs	14.10	16.19	18.47	20.69	23.02	25.50	28.12	30.94	32.42	34.05	35.99
Scenario 4: IRP Optimized											
Energy Efficiency	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fuel Substitution	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BROs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C&S (All Scenarios)											
w/ Interactive Effects	14.61	16.41	17.15	16.76	9.47	9.57	9.37	9.75	9.73	9.55	9.27
w/o Interactive Effects	17.87	19.42	19.62	19.14	11.59	11.30	10.98	10.77	10.59	10.34	10.04

Source: Guidehouse

K.1.4 SDG&E

Table K-8. SDG&E Electric Energy Savings (GWh/year)

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Scenario 1: TRC Low											
Energy Efficiency	29.3	33.5	36.4	40.0	42.3	43.6	44.8	41.8	41.8	40.4	40.3
Fuel Substitution	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
BROs	74.4	77.5	80.8	84.1	87.5	91.0	94.7	98.7	103.0	107.9	113.1
Scenario 2: TRC Reference											
Energy Efficiency	34.1	39.1	43.3	45.2	44.6	45.3	45.7	42.2	42.1	40.9	40.6
Fuel Substitution	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
BROs	74.4	77.5	80.8	84.1	87.5	91.0	94.7	98.7	103.0	107.9	113.1
Scenario 3: TRC High											
Energy Efficiency	35.8	41.1	45.4	47.3	46.6	47.3	47.6	44.0	44.3	43.0	42.5
Fuel Substitution	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
BROs	80.3	85.4	93.4	99.8	107.2	115.8	125.6	137.1	151.0	167.7	187.7
Scenario 4: IRP Optimized											
Energy Efficiency	10.1	16.8	18.3	20.5	19.7	22.7	24.1	22.3	23.3	23.3	24.8
Fuel Substitution	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BROs	61.4	59.7	58.1	67.2	75.8	77.5	80.0	83.6	87.5	91.0	94.3
C&S (All Scenarios)											
w/ Interactive Effects	212.9	224.6	229.0	219.5	207.5	188.6	176.6	143.3	128.3	124.9	122.0
w/o Interactive Effects	207.7	221.6	226.5	217.1	205.4	187.2	175.5	143.3	128.7	125.3	122.4

Source: Guidehouse

Table K-9. SDG&E Demand Savings (MW)

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Scenario 1: TRC Low											
Energy Efficiency	6.2	7.0	7.4	8.1	8.7	8.9	9.0	8.4	8.3	7.9	7.8
Fuel Substitution	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
BROs	18.0	18.7	19.4	20.2	20.9	21.7	22.5	23.4	24.3	25.4	26.5
Scenario 2: TRC Reference											
Energy Efficiency	7.2	8.0	8.9	9.2	9.1	9.2	9.2	8.5	8.3	8.0	7.9
Fuel Substitution	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
BROs	18.0	18.7	19.4	20.2	20.9	21.7	22.5	23.4	24.3	25.4	26.5
Scenario 3: TRC High											
Energy Efficiency	7.6	8.4	9.4	9.7	9.5	9.6	9.6	8.8	8.7	8.4	8.2
Fuel Substitution	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
BROs	19.0	20.0	21.6	22.9	24.4	26.2	28.2	30.5	33.3	36.7	40.8
Scenario 4: IRP Optimized											
Energy Efficiency	1.8	3.0	3.3	3.6	3.5	4.0	4.3	4.0	4.3	4.3	4.7
Fuel Substitution	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BROs	15.9	15.4	15.0	17.4	19.6	20.0	20.6	21.6	22.6	23.5	23.9
C&S (All Scenarios)											
w/ Interactive Effects	46.3	50.7	50.9	49.1	46.7	42.8	40.8	34.7	31.5	30.1	28.9
w/o Interactive Effects	43.1	48.4	49.0	47.3	45.1	41.7	39.8	34.3	31.2	29.9	28.7

Source: Guidehouse

Table K-10. SDG&E Gas Energy Savings (MMtherm/year)

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Scenario 1: TRC Low											
Energy Efficiency	0.55	0.60	0.64	0.68	0.68	0.71	0.73	0.71	0.74	0.76	0.79
Fuel Substitution	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BROs	1.68	1.71	1.76	1.80	1.86	1.92	1.99	2.06	2.15	2.23	2.33
Scenario 2: TRC Reference											
Energy Efficiency	0.62	0.67	0.68	0.69	0.69	0.72	0.74	0.72	0.74	0.76	0.78
Fuel Substitution	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BROs	1.68	1.71	1.76	1.80	1.86	1.92	1.99	2.06	2.15	2.23	2.33
Scenario 3: TRC High											
Energy Efficiency	0.65	0.71	0.72	0.73	0.74	0.77	0.80	0.78	0.82	0.84	0.86
Fuel Substitution	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BROs	1.83	1.92	2.08	2.21	2.38	2.59	2.84	3.14	3.51	3.95	4.49
Scenario 4: IRP Optimized											
Energy Efficiency	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fuel Substitution	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BROs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C&S (All Scenarios)											
w/ Interactive Effects	1.36	1.52	1.59	1.56	0.88	0.89	0.87	0.91	0.90	0.89	0.86
w/o Interactive Effects	1.66	1.80	1.82	1.78	1.08	1.05	1.02	1.00	0.98	0.96	0.93

Source: Guidehouse

K.1.5 COVID-19 Sensitivities

All COVID-19 sensitivities for the three scenarios are in the online results viewer. This section provides specific details for the Scenario 2: TRC Reference and to compare it with and without the COVID-19 sensitivity.

Table K-11 provides the savings results for the Scenario 2: TRC Reference scenarios before and after applying the COVID-19 sensitivities. The data shows the change in overall program savings potential (EE, fuel substitution, and BROs). The impact is, at most, about a 2% decrease in potential in 2022 depending on the metric.

Table K-11. Scenario 2: TRC Reference-Level Comparison After Adjusting for COVID-19 Impacts (Electric Energy Savings)

Unit	Sensitivity	2022	2023	2024	2025
GWh	No COVID-19	832.4	874.6	927.3	971.4
	COVID-19	825.8	869.7	924.4	971.1
	% Difference	0.8%	0.6%	0.3%	0.0%
MW	No COVID-19	199.1	204.7	215.2	221.4
	COVID-19	197.8	203.7	214.6	221.3
	% Difference	0.6%	0.5%	0.3%	0.0%
MMTherms	No COVID-19	35.4	38.6	43.1	45.3
	COVID-19	35.0	38.3	43.0	45.3
	% Difference	1.0%	0.7%	0.3%	0.0%
TSB ($ Millions)	No COVID-19	$750.25	$828.09	$938.75	$1,045.61
	COVID-19	$737.38	$817.84	$931.99	$1,043.32
	% Difference	1.7%	1.2%	0.7%	0.2%

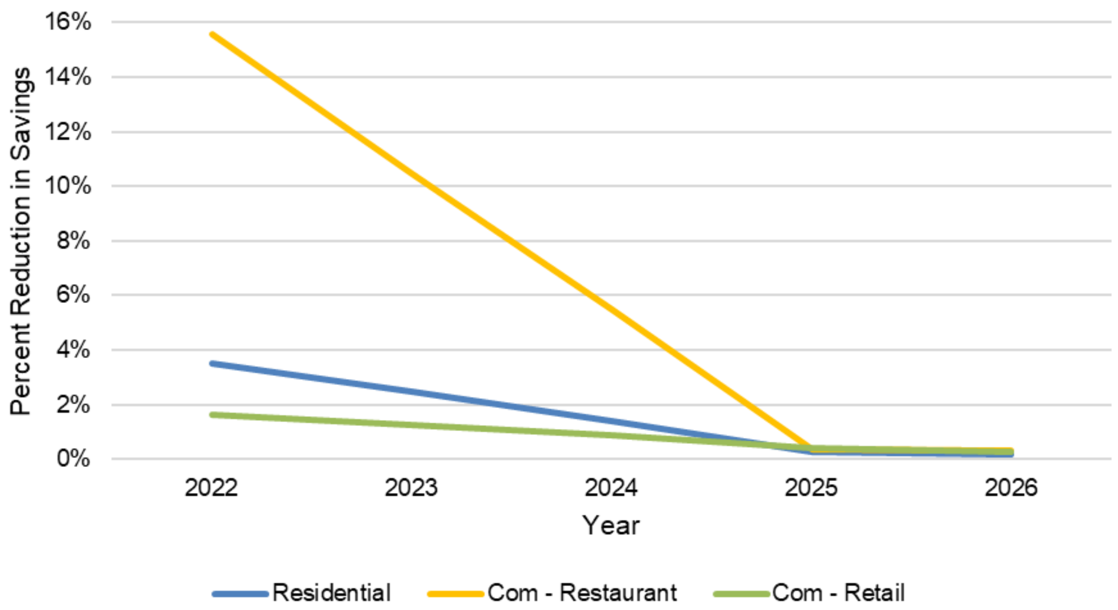
Source: Guidehouse

The residential sector impacts occur by reducing the household stock for the residential sector and reassigning the stock to the low income sector. There are no changes to the overall BROs program savings because both the low income and residential sectors are included in the analysis; therefore, the Guidehouse team removed BROs in the comparison analysis. For the commercial sectors, the stock for retail and restaurants changed.

Other impacts to adoption are included in the analysis based on the Market Adoption Study. These impacts are included in the savings analysis along with the stock changes.

Figure K-1 shows the impacts on savings by affected customer group: residential, restaurants, and retail. The analysis assumed that there is a reduction in stock as of 2020, with a gradual return to pre-COVID levels by 2025.

Figure K-1. Percent Reduction in Savings by Affected Customer Group



Source: Guidehouse

K.2 Impacts Converted to Energy Savings Credits

This section presents impacts in terms of energy savings credits. The tables reflect fuel substitution with their net electric energy savings credit (decreased gas consumption converted into kWh savings credit minus increased electric consumption). In this section, fuel substitution savings are only expressed in kWh units—no gas units are used to express fuel substitution savings.

K.2.1 PG&E

Table K-12. PG&E Electric Energy Savings (GWh/year)

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Scenario 1: TRC Low											
Energy Efficiency	144.4	144.9	151.0	146.0	138.4	140.7	150.9	156.0	164.2	157.9	157.0
Fuel Substitution	0.03	0.04	0.04	0.04	0.03	0.04	0.04	0.05	0.05	0.06	0.06
BROs	222.2	240.0	258.8	277.8	298.0	318.4	333.7	345.7	359.1	374.4	390.8
Scenario 2: TRC Reference											
Energy Efficiency	160.4	155.6	160.5	155.8	167.2	175.0	175.9	167.6	170.0	167.3	163.8
Fuel Substitution	1.39	1.27	0.80	0.26	0.20	0.16	0.17	0.11	0.12	0.07	0.08
BROs	222.2	240.0	258.8	277.8	298.0	318.4	333.7	345.7	359.1	374.4	390.8
Scenario 3: TRC High											
Energy Efficiency	163.5	157.8	162.4	157.6	170.2	179.9	182.9	179.5	191.9	191.5	187.9
Fuel Substitution	1.41	1.29	0.83	0.29	0.23	0.18	0.19	0.13	0.13	0.08	0.09
BROs	275.1	302.3	322.0	346.2	370.2	395.8	424.8	457.6	497.2	544.7	600.9
Scenario 4: IRP Optimized											
Energy Efficiency	48.6	66.7	72.9	74.4	70.7	78.1	80.8	74.7	77.3	77.0	82.0
Fuel Substitution	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BROs	187.7	190.5	193.3	229.6	266.4	280.7	291.9	303.1	314.8	326.1	335.4
C&S (All Scenarios)											
w/ Interactive Effects	1,039.7	1,096.6	1,118.3	1,071.6	1,013.0	920.9	862.4	699.6	626.7	609.8	595.5
w/o Interactive Effects	1,014.1	1,082.2	1,105.8	1,060.3	1,003.0	913.9	856.8	699.6	628.2	611.8	597.9

Source: Guidehouse

Table K-13. PG&E Demand Savings (MW)

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Scenario 1: TRC Low											
Energy Efficiency	40.7	40.1	40.1	36.6	32.9	32.4	32.7	32.3	35.5	33.9	33.2
Fuel Substitution	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
BROs	46.4	50.1	54.0	58.0	62.1	66.3	69.4	71.7	74.2	77.2	80.3
Scenario 2: TRC Reference											
Energy Efficiency	44.8	42.4	43.3	39.7	39.3	40.0	39.1	35.8	36.7	34.6	33.3
Fuel Substitution	-0.04	-0.04	-0.02	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
BROs	46.4	50.1	54.0	58.0	62.1	66.3	69.4	71.7	74.2	77.2	80.3
Scenario 3: TRC High											
Energy Efficiency	45.6	42.7	43.5	39.6	39.3	40.5	40.1	37.9	40.7	38.8	37.6
Fuel Substitution	-0.04	-0.04	-0.02	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
BROs	56.3	61.8	65.5	69.7	74.0	78.6	83.8	89.6	96.6	105.1	115.1
Scenario 4: IRP Optimized											
Energy Efficiency	13.3	16.1	18.0	15.9	14.7	16.0	16.3	15.3	15.7	15.9	17.0
Fuel Substitution	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BROs	41.1	41.7	42.2	50.3	58.4	61.6	64.0	66.5	69.1	71.6	72.8
C&S (All Scenarios)											
w/ Interactive Effects	232.0	256.3	256.4	247.3	235.8	216.8	207.2	177.4	162.5	154.6	147.6
w/o Interactive Effects	216.6	245.9	247.6	239.1	228.3	211.7	202.6	175.8	161.3	153.8	146.9

Source: Guidehouse

Table K-14. PG&E Gas Energy Savings (MMtherm/year)

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Scenario 1: TRC Low											
Energy Efficiency	2.70	2.78	3.09	3.81	4.01	4.16	5.04	4.68	5.00	5.01	5.12
Fuel Substitution	0	0	0	0	0	0	0	0	0	0	0
BROs	9.15	9.72	10.31	10.90	11.51	12.15	12.65	13.13	13.59	14.06	14.56
Scenario 2: TRC Reference											
Energy Efficiency	3.77	3.94	5.56	5.35	5.17	5.43	5.52	5.19	5.40	5.32	5.27
Fuel Substitution	0	0	0	0	0	0	0	0	0	0	0
BROs	9.15	9.72	10.31	10.90	11.51	12.15	12.65	13.13	13.59	14.06	14.56
Scenario 3: TRC High											
Energy Efficiency	3.88	4.07	5.71	5.52	5.40	5.77	6.13	6.25	7.36	7.30	7.28
Fuel Substitution	0	0	0	0	0	0	0	0	0	0	0
BROs	11.09	12.03	12.71	13.47	14.30	15.27	16.37	17.73	19.26	21.02	23.10
Scenario 4: IRP Optimized											
Energy Efficiency	0	0	0	0	0	0	0	0	0	0	0
Fuel Substitution	0	0	0	0	0	0	0	0	0	0	0
BROs	0	0	0	0	0	0	0	0	0	0	0
C&S (All Scenarios)											
w/ Interactive Effects	13.24	14.86	15.54	15.18	8.58	8.67	8.49	8.83	8.82	8.65	8.40
w/o Interactive Effects	16.19	17.59	17.77	17.34	10.50	10.23	9.95	9.76	9.59	9.36	9.10

Source: Guidehouse

K.2.2 SCE

Table K-15. SCE Electric Energy Savings (GWh/year)

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Scenario 1: TRC Low											
Energy Efficiency	121.3	128.0	138.1	149.9	150.9	153.1	156.8	146.7	154.2	151.5	153.9
Fuel Substitution	0.09	0.11	0.14	0.17	0.19	0.21	0.23	0.26	0.28	0.30	0.32
BROs	205.4	221.6	238.1	255.0	272.6	291.0	310.3	325.3	340.3	356.8	374.4
Scenario 2: TRC Reference											
Energy Efficiency	139.0	143.6	148.7	156.4	152.1	155.1	160.0	149.8	154.7	152.5	157.4
Fuel Substitution	16.74	18.81	20.89	22.98	25.06	27.14	29.20	31.22	33.19	35.13	37.02
BROs	205.4	221.6	238.1	255.0	272.6	291.0	310.3	325.3	340.3	356.8	374.4
Scenario 3: TRC High											
Energy Efficiency	145.0	149.2	154.4	162.6	158.0	162.0	168.6	159.8	170.3	168.2	173.5
Fuel Substitution	18.49	20.97	23.43	25.85	28.23	30.56	32.84	35.03	37.13	39.17	41.10
BROs	248.3	277.7	304.5	326.4	351.7	380.6	413.7	452.6	499.2	554.8	620.8
Scenario 4: IRP Optimized											
Energy Efficiency	31.5	53.8	61.6	72.1	70.4	81.7	87.5	79.8	84.4	85.2	92.1
Fuel Substitution	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BROs	170.3	172.5	174.4	206.2	237.8	250.1	264.8	278.2	290.8	302.7	314.5
C&S (All Scenarios)											
w/ Interactive Effects	1,039.7	1,096.6	1,118.3	1,071.6	1,013.0	920.9	862.4	699.6	626.7	609.8	595.5
w/o Interactive Effects	1,014.1	1,082.2	1,105.8	1,060.3	1,003.0	913.9	856.8	699.6	628.2	611.8	597.9

Source: Guidehouse

Table K-16. SCE Demand Savings (MW)

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Scenario 1: TRC Low											
Energy Efficiency	25.6	26.3	30.7	32.8	32.7	32.8	33.1	31.4	33.0	32.3	32.8
Fuel Substitution	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.01	-0.01	-0.01	-0.01	-0.01
BROs	48.5	52.3	56.1	60.0	64.0	68.1	72.5	75.7	78.8	82.2	85.9
Scenario 2: TRC Reference											
Energy Efficiency	34.2	33.1	33.3	34.1	33.0	33.6	33.9	32.1	33.3	32.7	34.0
Fuel Substitution	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.01	-0.01	-0.01	-0.01	-0.01
BROs	48.5	52.3	56.1	60.0	64.0	68.1	72.5	75.7	78.8	82.2	85.9
Scenario 3: TRC High											
Energy Efficiency	35.8	34.4	34.5	35.4	34.2	35.0	35.6	34.1	36.4	35.8	37.2
Fuel Substitution	-0.00	-0.00	-0.00	-0.00	-0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
BROs	57.6	64.1	69.2	73.5	78.4	84.0	90.3	97.7	106.7	117.4	130.0
Scenario 4: IRP Optimized											
Energy Efficiency	5.4	9.3	11.7	12.5	12.4	15.0	16.3	15.3	16.3	16.8	19.8
Fuel Substitution	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BROs	42.9	43.3	43.7	51.8	59.9	63.0	66.7	70.0	73.1	76.1	77.7
C&S (All Scenarios)											
w/ Interactive Effects	220.6	240.8	240.9	232.5	221.4	203.1	193.9	164.4	149.7	142.9	136.9
w/o Interactive Effects	205.4	230.7	232.4	224.4	214.2	198.1	189.4	162.8	148.6	142.1	136.3

Source: Guidehouse

K.2.3 SCG

Table K-17. SCG Gas Savings (MMtherm/year)

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Scenario 1: TRC Low											
Energy Efficiency	7.41	8.08	8.55	10.41	10.61	10.82	10.96	10.53	10.49	9.90	9.39
Fuel Substitution	0	0	0	0	0	0	0	0	0	0	0
BROs	10.23	11.31	12.44	13.54	14.67	15.84	17.02	18.25	19.50	20.75	22.02
Scenario 2: TRC Reference											
Energy Efficiency	8.74	9.85	10.89	11.37	11.52	11.33	11.17	10.67	10.64	10.09	9.61
Fuel Substitution	0	0	0	0	0	0	0	0	0	0	0
BROs	10.23	11.31	12.44	13.54	14.67	15.84	17.02	18.25	19.50	20.75	22.02
Scenario 3: TRC High											
Energy Efficiency	9.23	10.40	11.45	11.88	11.96	11.74	11.72	11.60	12.48	11.94	11.49
Fuel Substitution	0	0	0	0	0	0	0	0	0	0	0
BROs	14.10	16.19	18.47	20.69	23.02	25.50	28.12	30.94	32.42	34.05	35.99
Scenario 4: IRP Optimized											
Energy Efficiency	0	0	0	0	0	0	0	0	0	0	0
Fuel Substitution	0	0	0	0	0	0	0	0	0	0	0
BROs	0	0	0	0	0	0	0	0	0	0	0
C&S (All Scenarios)											
w/ Interactive Effects	14.61	16.41	17.15	16.76	9.47	9.57	9.37	9.75	9.73	9.55	9.27
w/o Interactive Effects	17.87	19.42	19.62	19.14	11.59	11.30	10.98	10.77	10.59	10.34	10.04

Source: Guidehouse

K.2.4 SDG&E

Table K-18. SDG&E Electric Energy Savings (GWh/year)

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Scenario 1: TRC Low											
Energy Efficiency	29.3	33.5	36.4	40.0	42.3	43.6	44.8	41.8	41.8	40.4	40.3
Fuel Substitution	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
BROs	74.4	77.5	80.8	84.1	87.5	91.0	94.7	98.7	103.0	107.9	113.1
Scenario 2: TRC Reference											
Energy Efficiency	34.1	39.1	43.3	45.2	44.6	45.3	45.7	42.2	42.1	40.9	40.6
Fuel Substitution	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.02
BROs	74.4	77.5	80.8	84.1	87.5	91.0	94.7	98.7	103.0	107.9	113.1
Scenario 3: TRC High											
Energy Efficiency	35.8	41.1	45.4	47.3	46.6	47.3	47.6	44.0	44.3	43.0	42.5
Fuel Substitution	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
BROs	80.3	85.4	93.4	99.8	107.2	115.8	125.6	137.1	151.0	167.7	187.7
Scenario 4: IRP Optimized											
Energy Efficiency	10.1	16.8	18.3	20.5	19.7	22.7	24.1	22.3	23.3	23.3	24.8
Fuel Substitution	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BROs	61.4	59.7	58.1	67.2	75.8	77.5	80.0	83.6	87.5	91.0	94.3
C&S (All Scenarios)											
w/ Interactive Effects	212.9	224.6	229.0	219.5	207.5	188.6	176.6	143.3	128.3	124.9	122.0
w/o Interactive Effects	207.7	221.6	226.5	217.1	205.4	187.2	175.5	143.3	128.7	125.3	122.4

Source: Guidehouse

Table K-19. SDG&E Demand Savings (MW)

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Scenario 1: TRC Low											
Energy Efficiency	6.2	7.0	7.4	8.1	8.7	8.9	9.0	8.4	8.3	7.9	7.8
Fuel Substitution	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
BROs	18.0	18.7	19.4	20.2	20.9	21.7	22.5	23.4	24.3	25.4	26.5
Scenario 2: TRC Reference											
Energy Efficiency	7.2	8.0	8.9	9.2	9.1	9.2	9.2	8.5	8.3	8.0	7.9
Fuel Substitution	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
BROs	18.0	18.7	19.4	20.2	20.9	21.7	22.5	23.4	24.3	25.4	26.5
Scenario 3: TRC High											
Energy Efficiency	7.6	8.4	9.4	9.7	9.5	9.6	9.6	8.8	8.7	8.4	8.2
Fuel Substitution	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
BROs	19.0	20.0	21.6	22.9	24.4	26.2	28.2	30.5	33.3	36.7	40.8
Scenario 4: IRP Optimized											
Energy Efficiency	1.8	3.0	3.3	3.6	3.5	4.0	4.3	4.0	4.3	4.3	4.7
Fuel Substitution	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BROs	15.9	15.4	15.0	17.4	19.6	20.0	20.6	21.6	22.6	23.5	23.9
C&S (All Scenarios)											
w/ Interactive Effects	46.3	50.7	50.9	49.1	46.7	42.8	40.8	34.7	31.5	30.1	28.9
w/o Interactive Effects	43.1	48.4	49.0	47.3	45.1	41.7	39.8	34.3	31.2	29.9	28.7

Source: Guidehouse

Table K-20. SDG&E Gas Energy Savings (MMtherm/year)

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Scenario 1: TRC Low											
Energy Efficiency	0.55	0.60	0.64	0.68	0.68	0.71	0.73	0.71	0.74	0.76	0.79
Fuel Substitution	0	0	0	0	0	0	0	0	0	0	0
BROs	1.68	1.71	1.76	1.80	1.86	1.92	1.99	2.06	2.15	2.23	2.33
Scenario 2: TRC Reference											
Energy Efficiency	0.62	0.67	0.68	0.69	0.69	0.72	0.74	0.72	0.74	0.76	0.78
Fuel Substitution	0	0	0	0	0	0	0	0	0	0	0
BROs	1.68	1.71	1.76	1.80	1.86	1.92	1.99	2.06	2.15	2.23	2.33
Scenario 3: TRC High											
Energy Efficiency	0.65	0.71	0.72	0.73	0.74	0.77	0.80	0.78	0.82	0.84	0.86
Fuel Substitution	0	0	0	0	0	0	0	0	0	0	0
BROs	1.83	1.92	2.08	2.21	2.38	2.59	2.84	3.14	3.51	3.95	4.49
Scenario 4: IRP Optimized											
Energy Efficiency	0	0	0	0	0	0	0	0	0	0	0
Fuel Substitution	0	0	0	0	0	0	0	0	0	0	0
BROs	0	0	0	0	0	0	0	0	0	0	0
C&S (All Scenarios)											
w/ Interactive Effects	1.36	1.52	1.59	1.56	0.88	0.89	0.87	0.91	0.90	0.89	0.86
w/o Interactive Effects	1.66	1.80	1.82	1.78	1.08	1.05	1.02	1.00	0.98	0.96	0.93

Source: Guidehouse

guidehouse.com