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2023 Energy Efficiency Potential and Goals Study – Public Draft

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Prepared for:

California Public Utilities Commission

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Reference No.: 535313
April 17, 2023

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This study is covered under Contract 21NC0594 between Guidehouse and the California Public Utilities Commission (CPUC).

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Guidehouse was supported by:

Mitchell Analytics, Opinion Dynamics, Tierra, DNV

Special thanks to the staff of the CPUC and the many stakeholders for providing direction, guidance, insight, and data throughout this study.

The project team would like to acknowledge:

- California Energy Commission staff for assistance on project data needs.
- Sound Data for guidance regarding the use of CEDARS data.

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Executive Summary

Guidehouse Inc. (Guidehouse) and its partners, Tierra Resource Consultants, LLC, Jai J. Mitchell Analytics, Opinion Dynamics, and DNV (collectively known as the Guidehouse team), prepared this study (*2023 Energy Efficiency Potential and Goals Study* or 2023 Study) for the California Public Utilities Commission (CPUC).

This study develops estimates of the energy and demand savings and fuel substitution (FS) potential in the service territories of California's major investor-owned utilities (IOUs) during the post-2023 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 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 2023 Study is an update to the previous potential and goals study completed in 2021 (2021 Study).[1] The 2023 Study reflects the market and policy changes that have taken place in the past 2 years since the 2021 Study was completed. The project kicked off in July 2022 and was followed by stakeholder workshops held in the summer for the workplan, fall of 2022 for low income, and December 2022 for scenarios. These workshops helped to shape and guide the direction of the work presented in this report.

Study Objectives

The 2023 Study supports many CPUC objectives:

- Informs the CPUC as it proceeds to adopt updated EE and FS goals for IOUs
- Serves as one of several sources of guidance to the IOUs and other program administrators in portfolio planning
- Informs the budget-setting process for IOU EE portfolios
- Identifies new EE savings and FS 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 doubling EE by 2030

The 2023 Study forecast period spans from 2024 to 2035 and focuses on current and potential drivers of energy savings in IOU service areas.

[1] Guidehouse, *2021 Energy Efficiency Potential and Goals Study*, August 2021.

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

Consistent with previous CPUC potential studies and common industry practice, the 2023 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 existing CPUC policies, market influences, and barriers. Achievable potential has historically been used by the CPUC to inform the goal setting process.

This 2023 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, and industrial. The study does not set IOU goals, nor does it make goal setting recommendations. Rather, it informs the CPUC's goal setting process.

Scenarios

The 2023 Study explores market response and how potential might change based on several alternative scenarios. Table ES-1 summarizes the various scenarios considered for the 2023 Study. These scenarios are built primarily around policies and program decisions that are within the sphere of influence of the CPUC and its stakeholders collectively. The scenario variation focused on assumptions for the Inflation Reduction Act (IRA) Tax Credit[3], FS adoption parameters, and program incentive levels. Each of the four scenarios used the total resource cost (TRC) test as the basis for cost-effectiveness determination:

- Scenario 1: No IRA Reference FS – Comparable to the 2021 Study's Scenario 2 used to inform the IOU goals adopted in 2021.
- Scenario 2: Reference IRA and FS – Consistent with Scenario 1 but incorporates conservative assumptions regarding IRA tax credits for residential and commercial measures.
- Scenario 3: Reference IRA and Aggressive FS – Consistent with Scenario 2 but makes aggressive modeling assumptions for FS technology adoption and higher incentive inputs (both nominal amount and upper bound of measure incremental cost) for both EE and FS.
- Scenario 4: Aggressive IRA and Reference FS – Consistent with the residential sector assumptions in Scenario 2 but with more aggressive assumptions for eligible IRA tax credit amounts in the commercial sector.

[3] The IRA includes provisions for both tax credits and EE program rebates designed to incentivize the adoption of energy-saving measures. Due to uncertainty at the time of this study regarding the design and administration of the program-based IRA rebates, the 2023 PG Study considered only the impact of tax credits mandated by the IRA.

Table ES-1. Summary of Scenarios for Achievable Potential

Levers → Scenario ↓	C-E Test	C-E Threshold	IRA Tax Credits	Incentive Levels Capped*	FS**	Program Engagement***
1: No IRA	TRC	0.85	None	EE 50% FS 75%	Reference	Reference
2: Reference IRA and FS	TRC	0.85	Conservative	EE 50% FS 75%	Reference	Reference
3: Reference IRA and aggressive FS	TRC	0.85	Conservative	EE 75% FS 90%	Aggressive	Reference
4: Aggressive IRA and reference FS	TRC	0.85	Aggressive	EE 50% FS 75%	Reference	Reference

C-E = cost-effectiveness
*Incentives are set based on a $/kWh and $/therm basis consistent with existing IOU programs; incentives are capped at 50%/75% (EE) or 75%/90% (FS) of incremental cost depending on the scenario.
**FS adoption parameters are set based on end use and sector-specific calibration targets
***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.
Source: Guidehouse

Impactful Data Updates and Policy Changes

Table ES-2 highlights key 2023 Study data updates and policy changes and how each change directionally affects overall results. Directional changes reflect impacts on 2023 Scenario 1 relative to the 2021 Goal Setting Scenario unless noted otherwise.

Table ES-2. Key Changes Relative to 2021 Study

Category	Update Relative to Previous Study	Directional Impact on the 2023 PG Study Relative to the 2021 PG Study	
Cost-Effectiveness	A combination of using updated avoided costs, revised measure inputs, and broader FS measures led to a 1%-5% increase in cost-effectiveness.	↑	Updates to 2022 avoided costs combined with revisions to unit energy savings for select high-savings-impact measures served as the primary driver to increase the overall cost-effective energy savings potential for rebated EE measures. Additionally, a greater proportion of first-year savings was attributed to measures with longer effective useful life (EUL) and associated lifetime benefits.
FS	Calibration targets were set using FS-specific historic and budgeted program accomplishments (data not available in the 2021 Study). Panel upgrade costs were incorporated into the model.	↓	Using a combination of historic program data and 2022 budget filings from in-market IOU FS programs, the 2023 Potential & Goals model resulted in an 81%-90% lower potential for Residential and Commercial FS measures in Scenarios 1, 2, and 4. This reflects a lower market maturity for these program types when compared to EE, which was the basis for the 2021 Study Goals setting Scenario as well as 2023 Scenario 3.

Category	Update Relative to Previous Study	Directional Impact on the 2023 PG Study Relative to the 2021 PG Study	
Natural Gas Measures	California Air Resources Board (CARB) State Implementation Plan (SIP) ruling for natural gas appliances	↓	The CARB decision to work towards banning the sale of natural gas appliances for which there is a viable electric alternative was incorporated into the 2023 Study, resulting in the removal of applicable measures from consideration after 2030. This yields a 91-99% year-over year drop in FS achievable potential in 2030[4] as well as a 50% reduction in EE potential for gas EE measures attributed to HVAC and Water Heating end uses.
Inflation Reduction Act (IRA)	Tax credits for eligible residential and commercial EE and FS measures were incorporated into Economic and Achievable potential analyses	↑	The IRA is shown to have an impact on achievable potential for both EE equipment (14%-15% increase) and FS equipment (41%-42% increase) in Scenarios 2 and 4. These increases were primarily the result of additional measures becoming cost-effective due to the effective reduction in measure incremental cost. The largest tax credit impacts were seen for Residential heat pump HVAC and water heating measures.
Behavior, Retrocommissioning, and Operational (BROs) Interventions	Introduced multiple home energy reports (HERs) participant bins representing refined assumptions for energy savings through expanded delivery of this measure	↓	HERs participants are binned into low, medium and high savers. Incrementally new participants in the future are assumed to be in the low saver bin, driving overall BROs savings down 11%-21% for the Residential Sector and represented the largest contributor to reduced BROs potential statewide. More moderate (1%-9%) nominal decreases in BROs were seen in Commercial and Industrial Sectors. Strategic energy management (SEM) measures were removed entirely from the Agricultural Sector to align with what has been seen in the CA market since the prior study cycle.

Source: Guidehouse

Results

The 2023 Study provides a rich dataset of results, the details of which can be found on the CPUC's 2023 Potential and Goals website.[5] The report presents results by program type:

- **EE equipment:** EE traditionally incentivized by IOU programs are modeled in the study. This specifically excludes FS.

[4] Subsequent to the NG appliance ban, FS measures relating to the appliances affected by the ruling are no longer able to be considered as a fuel switching measure, which results in elimination of FS potential for these equipment types.

[5] https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/energy-efficiency/energy-efficiency-potential-and-goals-studies/2023-potential-and-goals-study

- **FS:** FS 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 FS.
- **Behavioral, retrocommissioning, and operational efficiency (BROs):** These programs are based on customer changes that may not rely on any new equipment installations.
- **C&S:** 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 summarizes results for 2024. This section discusses results only for the year 2024 unless otherwise noted. The table shows the achievable potential results for each program type (incentive programs, FS, and BROs) for scenarios 1 through 4 (previously listed in Table ES-1). Table ES-3 also includes the 2021 Study scenario that was used by the CPUC to inform previous goals as a comparison.

Table ES-3. 2024 Net First-Year TSB and Incremental Savings by Scenario (Statewide)

Savings Metric	Program Type	2021 Goals Scenario	1: No IRA	2: Reference IRA and FS	3: Reference IRA and Aggressive FS	4: Aggressive IRA and Reference FS
Total System Benefit (TSB) ($ Millions)	FS	$73	$20	$25	$532	$25
	BROs	$76	$132	$132	$132	$132
	EE Equipment	$166	$357	$377	$377	$379
	Total	**$316**	**$509**	**$534**	**$1,041**	**$536**
Electric Energy (GWh/Year)	FS*	-151	-16	-21	-195	-21
	BROs	578	507	507	507	507
	EE Equipment	119	148	168	167	169
	Total	**546**	**639**	**654**	**480**	**655**
Converted Electric Energy (GWh/Year)**	FS	446	62	88	1,476	89
	BROs	578	507	507	507	507
	EE Equipment	119	148	173	173	174
	Total	**1,143**	**717**	**763**	**2,151**	**765**
Electric Demand (MW)	FS*	-15	-1	-1	-6	-21
	BROs	126	92	92	92	92
	EE Equipment	23	48	53	52	53
	Total	**134**	**140**	**145**	**139**	**145**
Gas Energy	FS	20	3	4	57	4

Savings Metric	Program Type	2021 Goals Scenario	1: No IRA	2: Reference IRA and FS	3: Reference IRA and Aggressive FS	4: Aggressive IRA and Reference FS
(MMtherms/ Year)	BROs	25	21	21	21	21
	EE Equipment	12	19	19	19	19
	Total	**57**	**42**	**44**	**97**	**44**

* FS impacts reflect additional electric energy consumption, resulting in negative savings and peak demand impacts

**Converted Electric Energy represents the net reduction in energy consumption resulting from FS, calculated by converting gas energy units to equivalent electric energy units

Source: Guidehouse

The following are notable takeaways from the TSB results:

- Overall achievable TSB increases relative to the 2021 Study ranging from 61% in Scenario 1 to 229% in Scenario 3.
- 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.
- FS has a comparatively low overall impact on TSB in three of the four scenarios, representing 4%-5% of overall achievable TSB in Scenarios 1, 2, and 4, although the model indicates this has the potential to grow significantly in subsequent years. TSB reflects both gas and electric fuels, and positive gas benefits (and electric benefits, if applicable) are reduced by increased electric supply cost (which negatively affects TSB).

The following are notable takeaways from the energy savings results:

- Overall achievable GWh electric savings for all program types relative to the 2021 Study ranges from a 12% decrease in Scenario 3 to a 20% increase in Scenarios 2 and 4. When FS savings are converted to GWh equivalent, the range is a 37% decrease in Scenario 1 to an 88% increase in Scenario 3. The 2021 goals had large FS savings as opposed to most of the 2023 Study scenario results, which showed significantly lower FS savings resulting in decreases in electric savings.
- Overall achievable gas savings for all program types relative to the 2021 Study range from a 26% decrease in Scenario 1 to a 70% increase in Scenario 3. For reasons similar to those described above, lower FS savings in the 2023 Study relative to the 2021 Study reflect decreases in gas savings.
- In all scenarios, electric savings from EE equipment increase from between 24% and 42% relative to the previous goals. Achievable gas savings from EE equipment increase from 55%-62%. Higher statewide potential for rebated EE measures is driven primarily by the residential and industrial sectors. The commercial sector savings decreased slightly in Scenario 1 but were higher in Scenarios 2-4. BROs savings forecasts are lower due to the additional home energy report (HER) bins included in the 2023 Study.
- The FS impact on electricity and gas consumption is significantly reduced versus the 2021 Study for 2023 Scenarios 1 (90% lower GWh impact, 87% lower MMtherm impact),

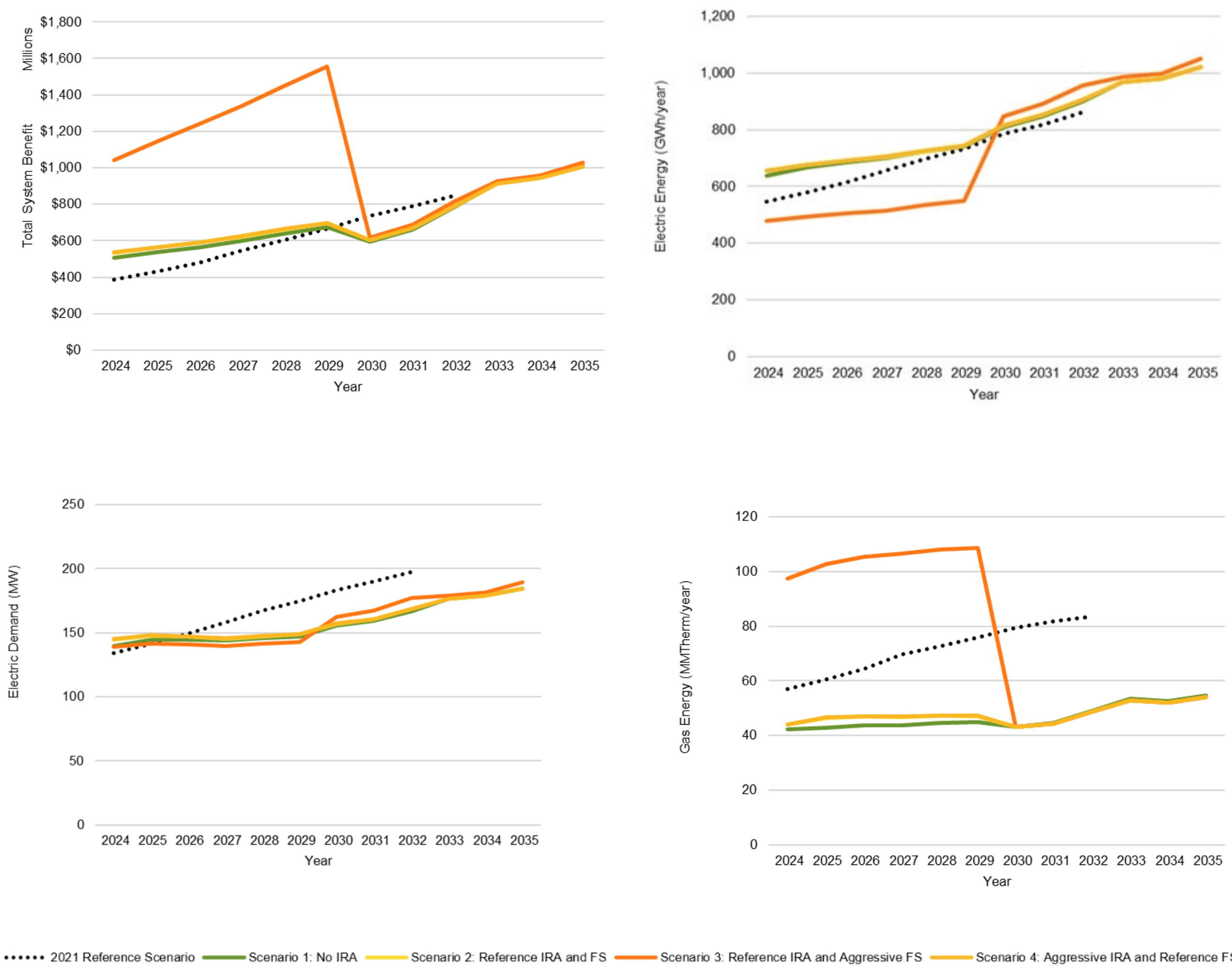
2, and 4 (both 86% lower GWh impact, 82% lower MMtherm impact). In contrast with the 2021 Study where EE-specific adoption parameters were applied to all cost-effective FS measures due to a lack of data for IOU FS programs, in the 2023 Study Guidehouse calibrated the modeled potential outputs using a combination of FS-specific historic program data and 2022 budget data (information that was not available in the 2021 Study).

- Assumptions included in Scenarios 2, 3, and 4 indicate that the IRA will have a measurable impact on both EE and FS adoption. Achievable potential for EE equipment increases by an average of 14% when accounting for the IRA, and FS potential on an electric energy basis increases by 35% in Scenarios 2 and 4. IRA tax credits have the primary impact of making more measures cost-effective, and the provision for additional eligible tax credits for residential heat pumps and heat pump water heaters represent the primary driver of increased potential across sectors for FS between Scenario 1 and the remaining three IRA-inclusive scenarios.

- Scenario 3 applies EE-based adoption parameters to FS measures (as the 2021 Study did), resulting in a dramatically higher calculated achievable potential and relatively lower EE potential versus Scenarios 2 and 4, both of which also included IRA tax credits. This increase is due to a comparatively greater proportion of the population adopting FS measures over EE measures. Although this may indicate a potential future state of the California market where FS programs and measures are much more mature, the Guidehouse team believes it represents a much less realistic scenario for the immediate IOU goal setting period.

Figure ES-1 shows the 11-year forecast for TSB, first-year net electric, peak demand, and gas achievable potential for EE equipment, FS, and BROs combined.

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



Note: Electric savings and TSB values include the impacts of FS where there is an increase in electric supply negatively impacting the savings and system benefit.

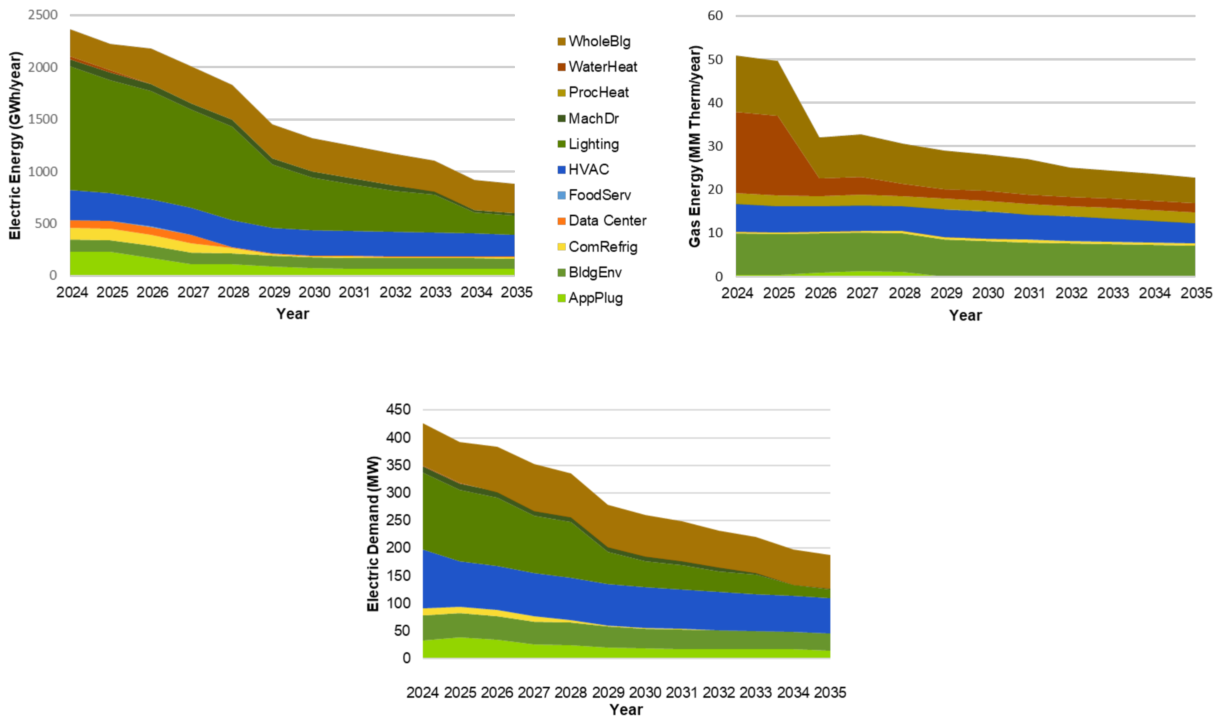
Source: Guidehouse

C&S 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, FS 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 slightly for the early years and decreased slightly after 2029 relative to those estimated in the 2021 Study. Meanwhile, gas savings are largely the same for early years, though they exhibit a steep decline in 2026. Incremental savings attributed to C&S decrease in the outer years of the study as the model assumes the market impacted by a code or standard has typically turned over, i.e., all of the relevant energy consuming equipment has reached the end of its useful life. Beyond this point, there are no longer energy impacts from installation of new equipment attributable to current codes. The steep decline in gas savings in 2026 also coincides with multiple high efficiency water fixture measures that have a complete stock turnover at the same time.

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

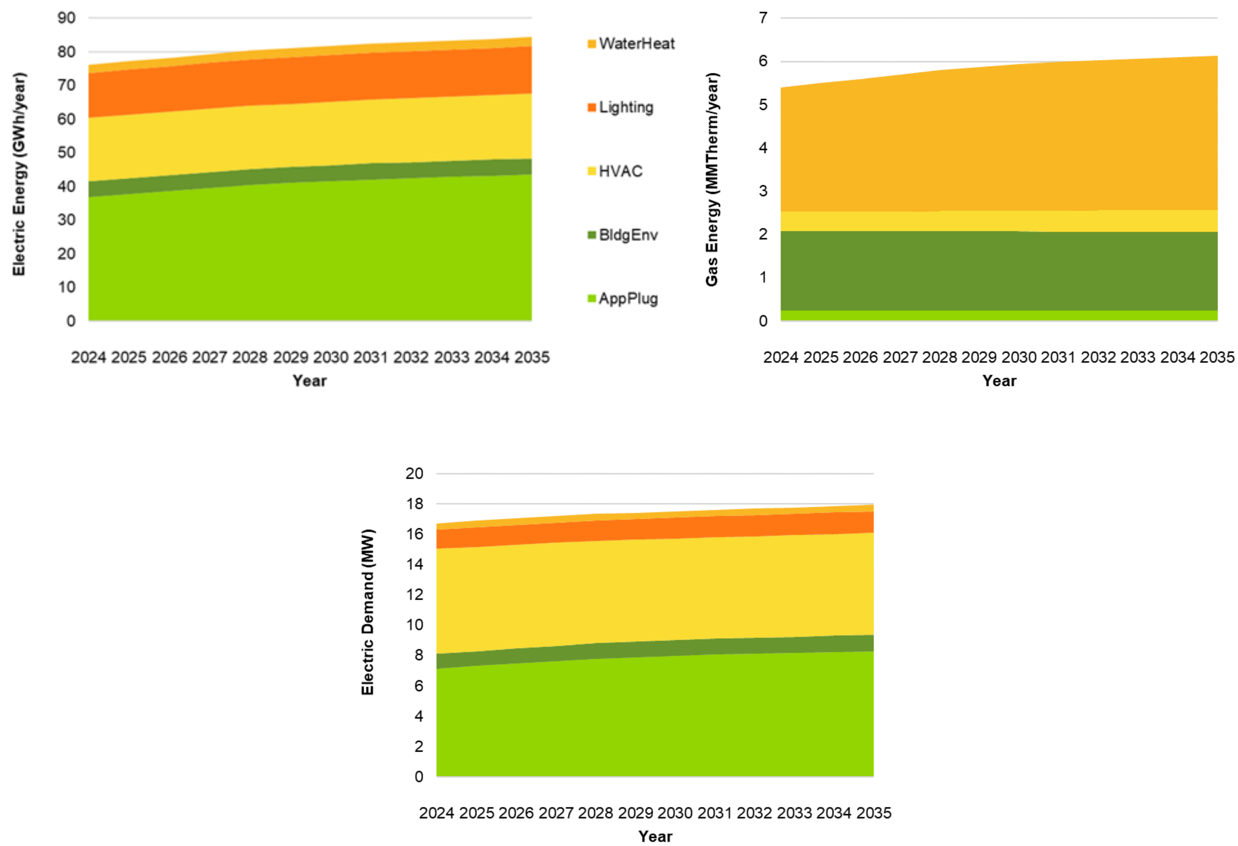


Source: Guidehouse

Low Income Savings

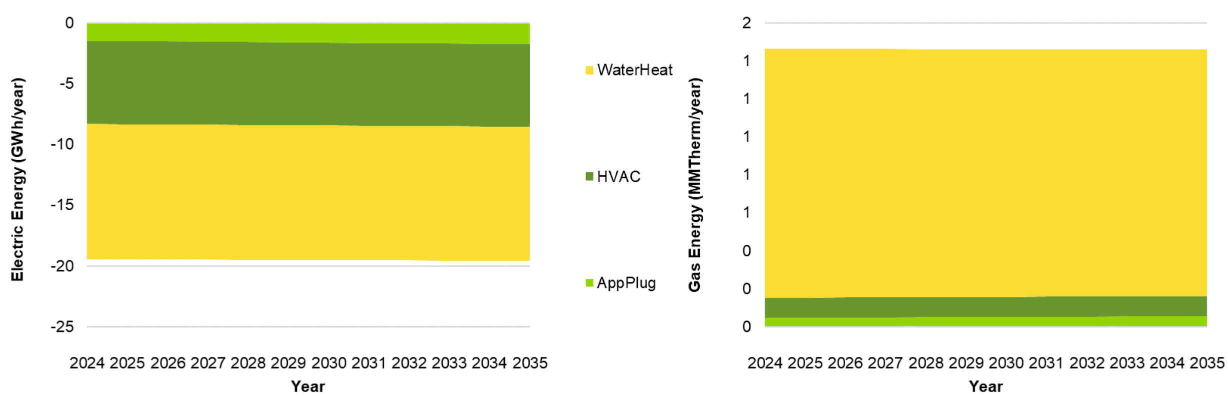
Figure ES-3 provides low income EE electric, gas savings, and electric demand by end use and Figure ES-4 provides low income FS electric, gas savings, and electric demand by applicable end use. This study's low income savings forecast was modeled with a bottom-up approach separate from the applications and goals adopted from D.21-06-015 in A.19-11-003; however, the measures provided by IOUs as part of their ESA programs were key inputs to this study. Additional details can be found in a separate low income savings forecast report.

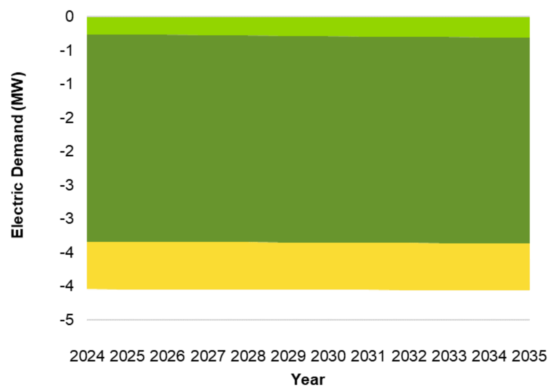
Figure ES-3. Low Income EE Savings by End Use



Source: Guidehouse

Figure ES-4. Low Income FS Savings by End Use





Source: Guidehouse

1. Introduction

1.1 Context of the Potential and Goals Study

Guidehouse and its partners, Tierra Resource Consultants, LLC, Jai J. Mitchell Analytics, Opinion Dynamics, and DNV (collectively known as the Guidehouse team), prepared this study (*2023 Energy Efficiency Potential and Goals Study* or 2023 Study) for the California Public Utilities Commission (CPUC). The purpose of this study is to develop estimates of energy and demand savings potential for energy efficiency and fuel substitution (FS) 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 2023 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 2023 Study is the seventh consecutive potential study conducted by the Guidehouse (formerly Navigant) team on behalf of the CPUC. The previous study published was the 2021 Study, which informed goals for 2022 and beyond.[6]

The 2023 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 (AAEE) and additional achievable fuel substitution (AAFS) potential. Furthermore, the data becomes an input to Senate Bill (SB) 350 scenario analysis, which targets doubling the AAEE by 2030.[7]
- Explores forecasting potential using integrated resource planning (IRP) tools. This study will inform upcoming planned analyses that explore the optimization of EE resources through IRP. Guidehouse plans to deliver EE supply curves to the IRP model in Summer 2023 and will subsequently analyze results for comparison 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 2024 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 provide California's principal energy agencies with the tools and resources

[6] Guidehouse, *2021 Energy Efficiency Potential and Goals Study*, August 2021.

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

necessary to develop outputs in a manner that is most appropriate for their planning and procurement needs.

The 2023 Study continues to apply the enhancements from the 2021 Study (key areas that were updated are discussed further in Section 1.3). The project kicked off in July 2022, and the draft workplan was presented to stakeholders on August 2, 2022. The 2023 Study was further informed by stakeholder sessions to review approaches for the low income sector and 2023 Study scenarios.

The study period spans from 2024 to 2035 based on the direction provided by the CPUC. The study focuses on current and potential drivers of energy savings and total system benefit (TSB) in IOU service areas. Analysis of potential in publicly owned utility service territories is not part of the scope of this effort.

1.2 Types of Potential

Consistent with the 2021 Study and common industry practice, the 2023 Study forecasts 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 or FS 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.[8]
- **Economic potential:** Using the results of the technical potential analysis, the economic potential is calculated as the total potential available when limited to only measures that pass a specific measure-level cost-effectiveness threshold.[9] Economic potential is a subset of technical potential. Economic potential may be a fraction of technical potential as the economic screen is applied separately to new construction versus existing buildings. Economic potential may contain lower efficiency measures compared with those included in the technical potential. This would be the case if the highest efficiency measure representing the technical potential is not cost-effective within a group of competing measures. Economic potential is undefined for C&S, whole building, BROs, and low income programs.[10]
- **Achievable potential:** The final output of the potential study is an achievable potential analysis, which calculates the potential that could be expected in response to specific levels of incentives and assumptions about existing CPUC policies, market influences,

[8] Any statement on technical potential for C&S (a mandatory program) would completely overlap and negate savings potential from voluntary rebate programs. Thus, the team does 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. BRO technical potential is out of scope of this study because it is highly uncertain whether a technical potential for BROs would be additive to a technical potential for rebate programs.

[9] The model can use different metrics of cost-effectiveness as defined by the California Standard Practice Manual.

[10] While technical potential is calculated for low income programs, estimating the cost-effectiveness of these measures using standard cost-effectiveness tests was not in scope for this study.

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' 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. The 2023 Study also includes detailed output for TSB.

Achievable potential is represented in the 2023 Study several ways; each way is based on the same data and assumptions, though each serves separate needs and provides 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 programs will produce.
- **Cumulative savings** represent the total savings from program efforts from measures installed since 2024 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.
- **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 FS of natural gas technologies with electric technologies. TSB is the same as the present value of the TRC benefits for EE measures only; in other words, TSB equals net avoided cost benefits (energy and capacity) for EE measures.

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, and customer willingness to install efficient equipment or operate equipment in ways that are more efficient. The Guidehouse team used the available current market knowledge to calibrate achievable potential for voluntary rebate programs.

1.3 Scope of This Study

This 2023 Study forecasts the above-described types of potential energy savings from the EE and FS programs and C&S across all customer sectors: residential, low income, commercial, agriculture, and industrial. 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 the 2023 Study include the following:

- **Potential forecast emphases:** The core effort to forecast potential includes developing a model and producing scenario results. This forecast accounted for new and enhanced topics such as broader FS results and the Inflation Reduction Act (IRA):
  - **FS:** The CPUC passed a decision on FS instituted by the fuel substitution test (FST) in 2019.[11] Consistent with the past PG study, the 2023 Study incorporated FS measures into the measure list including space heating, water heating, and cooking, and included the modeling methods to allow EE technologies to compete with the FS alternatives. Additionally, secondary research was conducted to assign costs associated with electrical infrastructure upgrades (e.g., electric panel upgrades). See Section 2.1.2 for methodology, Section 3.2.1.1 and Appendix B and C for data sources and characterization, and Section 4.3 for analysis results.
  - **IRA:** The Inflation Reduction Act of 2022 was adopted into law in August of 2022. Among its provisions are the allowance of claimed tax credits to help offset the cost of purchasing and installing energy efficient end use technologies in residential and commercial premises. These tax credits will be available for a 10-year period beginning in 2023. Per direction from the CPUC, the 2023 Study incorporated IRA tax credits into its analysis of achievable potential for applicable EE and FS measures and applied a variable set of assumptions across three of the four executed scenarios.
- **TSB analysis:** The TSB is a metric to show the relative value of each measure compared with each other measure independent of its measure cost, program cost, or fuel type. Although previous studies included calculations of benefits (in avoided costs) from rebate programs in their datasets, this study, like the 2021 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 California electronic Technical Reference Manual (CA eTRM) as the primary data sources for refreshing input assumptions for measures. Old measures no longer in programs were removed while new measures were added. 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.

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

- **Refresh cost-effectiveness inputs and outputs:** This study uses 2022 vintage of avoided costs to assess the cost-effectiveness and benefits generated by IOU programs. Guidehouse employed all avoided costs in alignment with the current eTRM measure details as noted above. Gas avoided costs are overall higher compared with those used in the 2021 Study, while electric avoided costs may increase or decrease depending on the specific sector and IOU. This study also details the types of benefit and cost outputs being provided to stakeholders, including detail on the cost-effectiveness of individual measures and the total benefits, total costs, and TSB 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. A sector-specific cost-effectiveness screen was also applied using the ESA Cost Effectiveness Tool (ESACET). In addition to non-low income cost-effectiveness calculation inputs, ESACET applies a model-based valuation of non-energy benefits to each measure. Measures with an ESACET value below 0.3 were screened out of the 2023 low income analysis unless they had a specific IOU-defined designation of providing health, comfort, or safety benefits.

The top-down forecasting (except for certain measure categories of the industrial and agricultural sectors) is not in the scope of this report, though it may be examined in subsequent analysis at the direction of CPUC staff. Due to prioritization of the above detailed scope items, in particular the addition of IRA analysis within the 2023 Study, a top-down analysis was not included as part of the core PG study during the current cycle.

1.4 Stakeholder Engagement

The Guidehouse team engaged with stakeholders through multiple public workshops. All meeting materials are available on the CPUC 2023 EE Potential and Goals page website.[12] 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 worked directly with CPUC staff to incorporate input provided into the study.

Table 1-1. Stakeholder Meeting Schedule

Date	Topics of Discussion
August 2, 2022	2023 Potential and Goals Study Workplan Webinar
October 27, 2022	Stakeholder input – Low Income Approach*
December 14, 2022	Stakeholder webinar – Scenario Design
May 2023 (planned)	Stakeholder input – Preliminary Results & Scenarios
Summer 2023 (planned)	Stakeholder input – Post Processing Tasks

*Target audience for this webinar was the ESA working group.

[12] California Public Utilities Commission, Potential and Goals Study website, https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/energy-efficiency/energy-efficiency-potential-and-goals-studies/2023-potential-and-goals-study.

Source: Guidehouse

1.5 Contents of This Report

This report documents the data sources for and results of the 2023 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.
- **The appendices** provide additional details on key topic areas. Areas include the IRA, FS methodology, and the BROs methodology and input assumptions.

Aside from this report, the following supporting deliverables are available to the public via the CPUC website:[13]

- **2023 PG Results Viewer:** A tool that allows readers to dynamically explore the results of the study, including all scenarios for each avoided cost vintage.
- **2023 PG Measure Input Workbook:** A spreadsheet version of the Measure Input Characterization System documenting all final values for all rebated technologies forecast in the model.
- **2023 PG BROs Inputs:** A spreadsheet version of all measure-level inputs for BROs measures.
- **2023 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 for each avoided cost vintage.
- **2023 PG Model File(s):** An Analytica-based file that contains the PG Model used to create the results of this study.
- **2023 PG Model Users Guide:** Document that helps advanced users who want to open and run the PG Model file in Analytica.
- **2023 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).

[13] California Public Utilities Commission website, https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/energy-efficiency/energy-efficiency-potential-and-goals-studies/2023-potential-and-goals-study.

2. Study Methodology

The primary purpose of the 2023 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 2023 Study forecasts potential energy savings from a variety of sources within five distinct customer sectors: residential, low income, commercial, agriculture, and industrial. These sectors are also used in the CEC's Integrated Energy Policy Report (IEPR) forecast. The IOU portfolio 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.
- **Residential low income:** The 2023 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 judgement. The study uses adoption calculations different from the residential sector. More details are available in a separate report, and only topline results are provided in this report.

The rest of this section discusses the 2023 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 2021 Study
Rebated technologies: multi-attribute analysis	Bass diffusion forecast puts equipment in competition with each other using multi-attribute analysis for below code, at code, FS (if applicable), and above code technologies	Calibrated to historical program activity and market saturation data, as appropriate	None
Rebated technologies: FS	FS equipment competes with EE equipment using the same fuel as the baseline equipment; FS includes added electric load	Calibrated to 2022 historical program activity, 2023 IOU budget filings data, and market saturation data, as appropriate	No specific calibration was possible for the 2021 Study because this savings source did not exist in historic portfolios; same calibrated parameters as used for EE were applied to FS
Whole building packages	Bass diffusion forecast puts below code, at code, and above code technologies in competition with each other	Calibrated to historical program savings	None
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 is 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

Savings Source	Summary of Modeling Approach	Summary of Calibration Approach	Methodology Change Relative to 2021 Study
Residential low income	Adoption curves based on measure type and historical and planned implementation	Calibrated to historical accomplishments in 2021 for low income programs	Includes FS measures and applied ESACET values for measure screening

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 2021 Study. However, additional features were included in the 2023 Study. This updated methodology is documented in this section.

2.1.1.1 Types of Technologies

The 2023 Study forecasts the adoption of more than 150 representative EE technologies. The Guidehouse team aggregates and reviews the measures in the CA eTRM, California Energy Data and Reporting System (CEDARS), and other industry sources. The team filters the list down to a 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 (weighted average, 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.

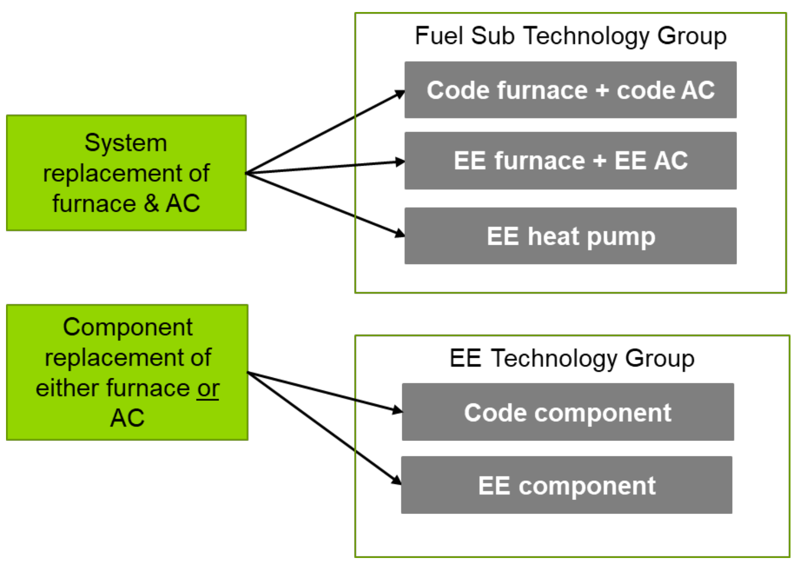
- **Retrofit (RET) – accelerated replacement:** These EE equipment are installed to replace previously existing equipment that has either not failed or is past the end of its EUL but is not compromising use of the building (such as insulation and water fixtures). Many of these installations are subject 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, sometimes called a competition group (CG). Figure 2- 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) FS technologies (discussed further in Section 2.1.2). For technology groups with FS levels, the FS 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 – FS and EE



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 2022. 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.

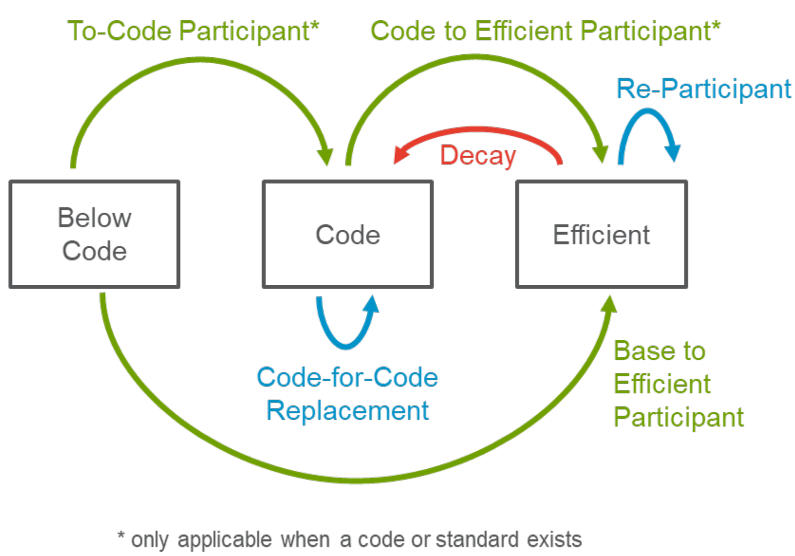
Table 2-2. Example of Technologies within a Technology Group – Non-FS

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

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- illustrates the replacement options a customer faces. 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 are 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 FS) 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 FS) 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 BRO. 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 team's calculation of 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.

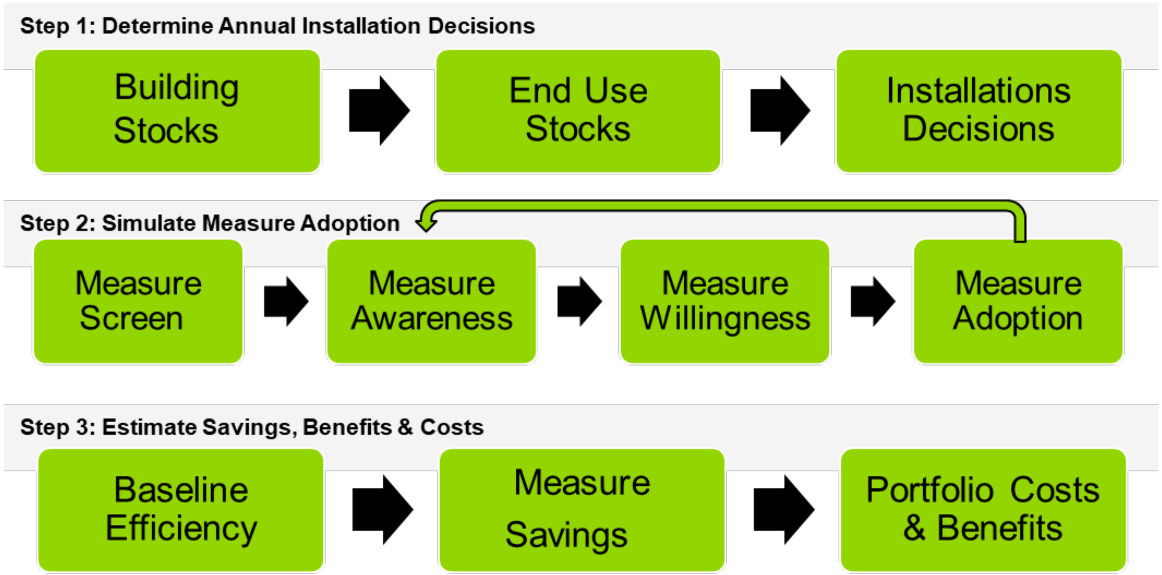
Appendix I describes the cost-effectiveness analysis and the steps the 2023 Study team took to calculate results. The appendix also describes the 2023 Study work to align with the Cost-Effectiveness Tool (CET) methodology and inputs.[14]

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.

[14] https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/energy-efficiency/idsm

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).

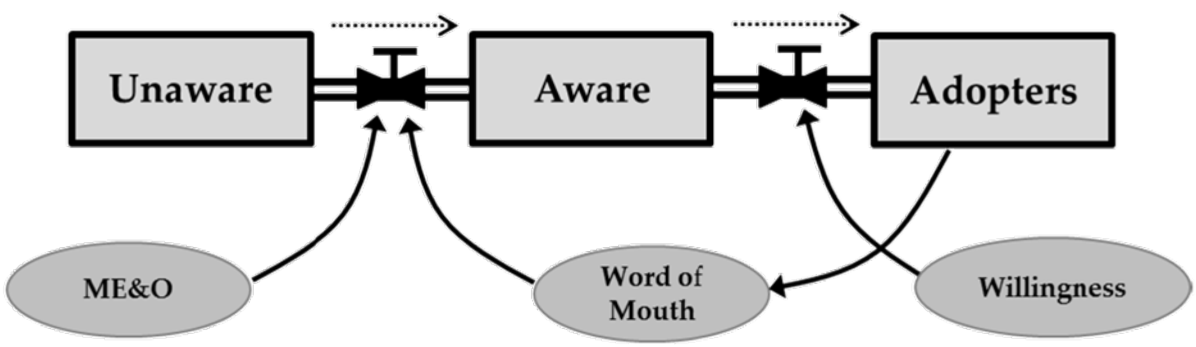
In the second step, the model simulates the adoption of each measure that passes a cost-effectiveness screen in each year. The model estimates awareness level of each measure in the eligible population and the willingness to adopt each measure that passes the cost-effectiveness screen. In this step, the model employs the Bass diffusion approach to simulate adoption (described in more detail later in this section). For the 2023 Study, the Guidehouse team retained the methodology used in the 2021 Study, which incorporated factors beyond financial attractiveness. 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 2023 PG Model uses a multi-attribute decision model to characterize the adoption behaviors of customers and ultimately calculate willingness. The Market Adoption Study conducted in 2021 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[15]



Source: Guidehouse

Approach to Calculating Willingness

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

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. To understand how willingness is calculated in the 2023 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.[16]

A key difference in the 2021 and 2023 PG Models from earlier models is the inclusion of **multiple** value factors that inform a customer's willingness to adopt instead of solely using the LMC.[17] This approach also divides the residential sector into customer groups to reflect that different types of customers behave uniquely and often change what they value when considering different technologies.

The Guidehouse team used the Market Adoption Study conducted in 2021[18] that collected 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 value factor descriptions used in the Market Adoption Study.

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 non-financial and non-energy elements that customers likely consider when deciding to purchase a new appliance or technology

16 Guidehouse (as Navigant), 2019 *Energy Efficiency Potential and Goals Study*, July 2019.

17 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.

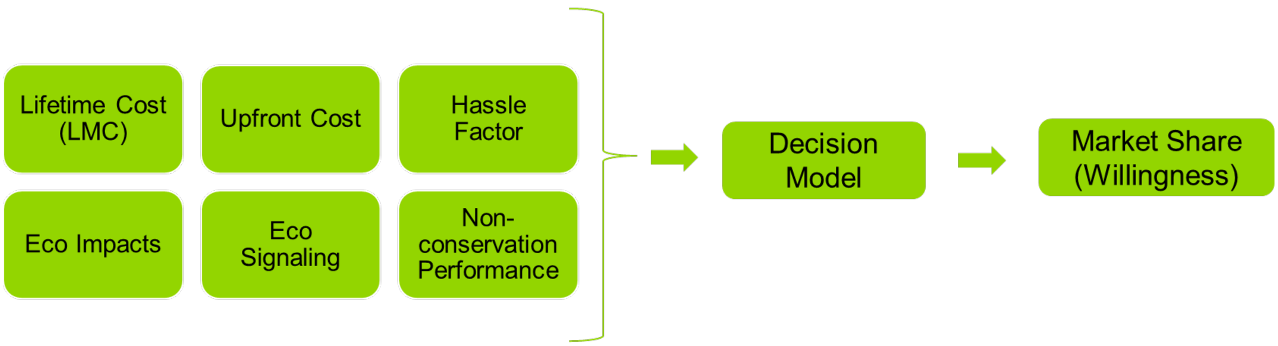
18 Guidehouse and Opinion Dynamics for the CPUC, *Market Adoption Characteristics Study*, 2021.

Value Factor	Customer Value Perspective
Eco Impacts	Environmental impacts from energy consumption
Social Signaling	Being perceived as environmentally or socially responsible by one's peers

Source: Guidehouse

Figure 2- illustrates the 2023 Study's willingness model.

Figure 2-5. 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- 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.[19] 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

[19] 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.

value factors. Combining these two datasets allowed the team to quantify how a customer with a certain preference weighting will assess two competing equipment options with different characteristics. In short, a technology's characteristics that align with a customer's preferences drives their decision to adopt.

The Guidehouse team calculated the equipment characteristics using two different methods depending on whether 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 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.

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

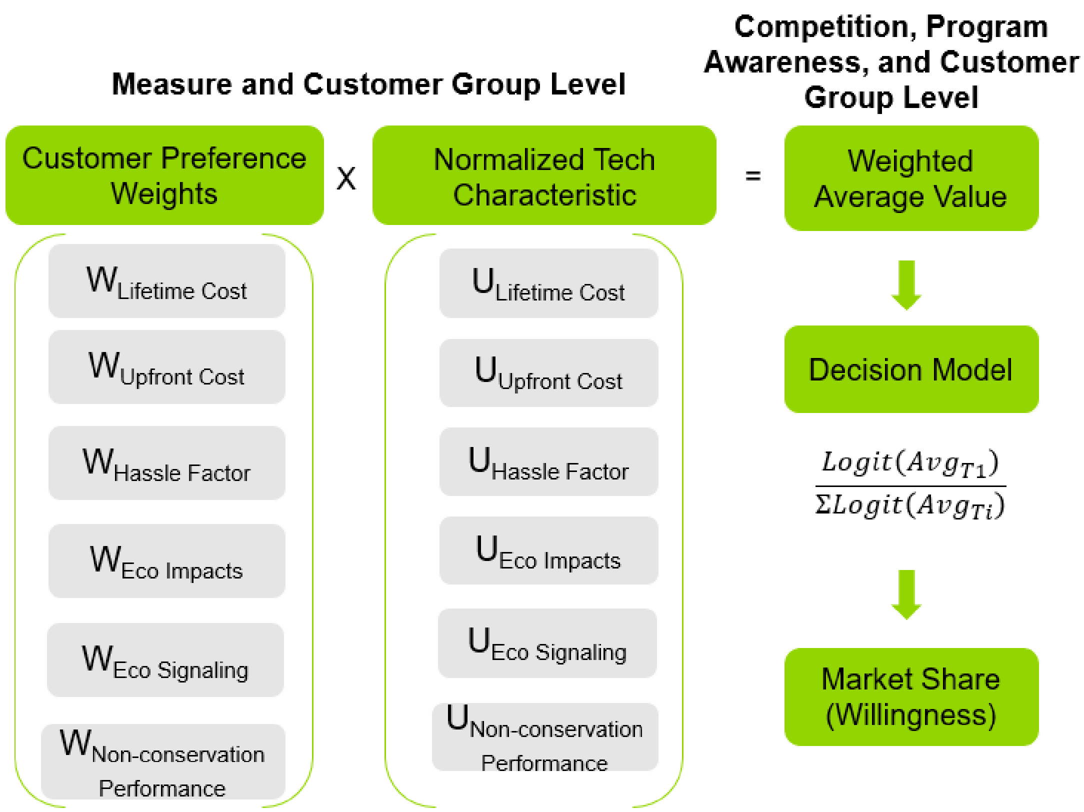
The team then converted the technology characteristics associated with each value factor to a dimensionless, normalized technology characteristic by dividing the value of the technology by the average value of the CG. This value can be interpreted as the relative characteristic value of the technology 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-.

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 CG. Figure 2- shows how customer preference weightings and technology characteristics are combined and fed into the decision model, resulting in the market share calculation for each technology.

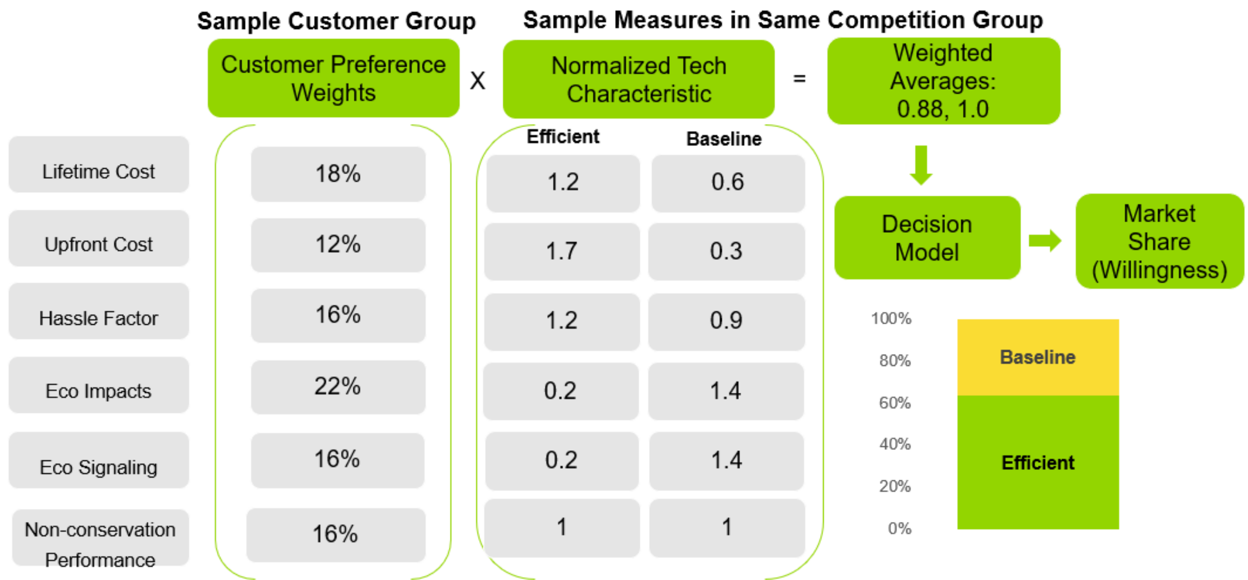
Figure 2-6. Calculating Market Share



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 CG (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 CG.

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. The Guidehouse team used a payback-based approach to calculate willingness.[20] 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 2021 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-).[21] Though the team collected California-specific data in 2021, 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:

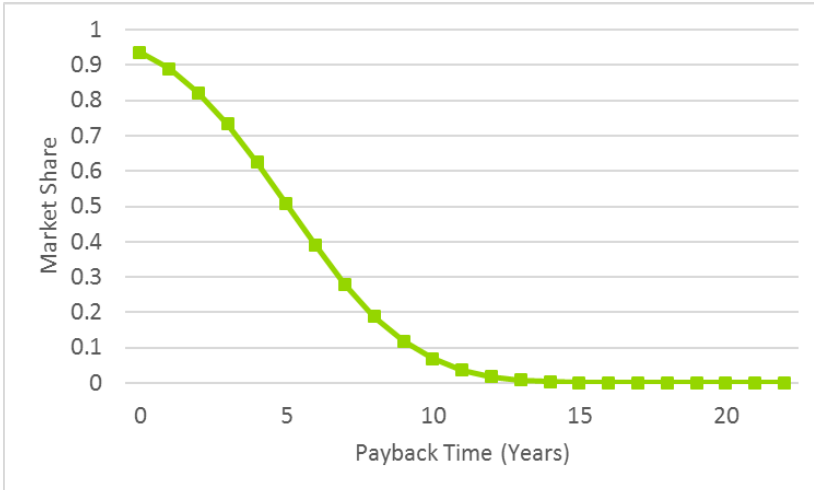
- Limited number of survey responses received regarding sensitivity to payback periods
- Responses received resulted in market share values extremely similar to those of the corresponding payback times in Figure 2-; specifically, when asked about their willingness to adopt an efficient boiler given either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

[20] 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.

[21] 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 FS incentives are calculated on a $/kWh and $/therm basis capped at a maximum value (50% or 75% of incremental cost for EE, 75% or 90% of incremental cost for FS, depending on the scenario).

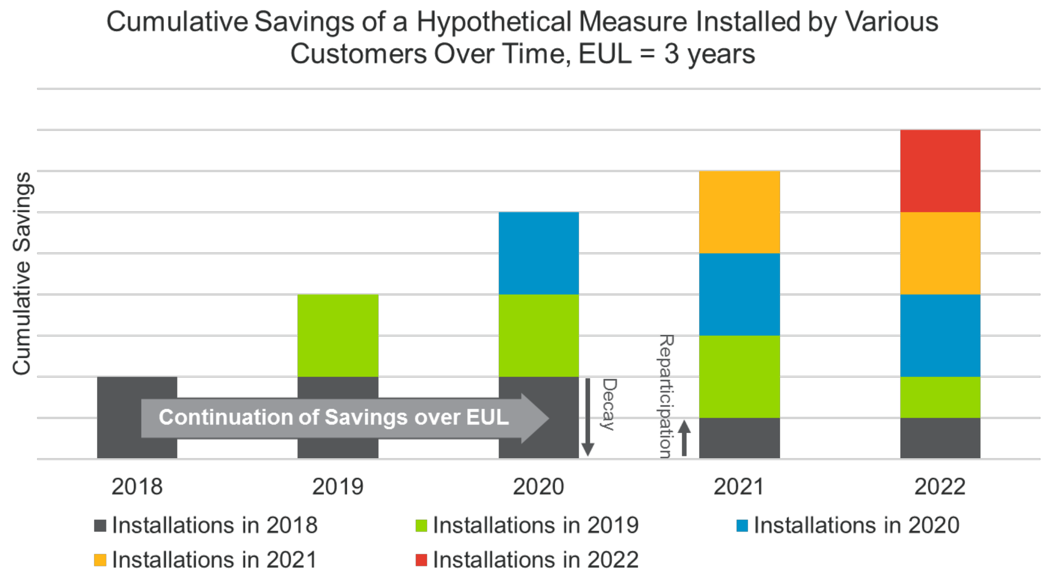
2.1.1.5 Calculating Cumulative Achievable Potential

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 (2024 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 2021 Study. Figure 2- illustrates the calculation of cumulative savings.

Figure 2-9. Cumulative Savings Illustration



Source: Guidehouse

2.1.2 FS

This study includes FS technologies in addition to the historically rebated EE technologies. FS technologies leverage much of the same methodology as used by historically rebated EE technologies previously described in Section 2.1.1. This section describes the methodology to accommodate FS measures. More details on the FS methodology are contained in Appendix B.

FS 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, FS includes replacing a gas baseline technology with an electric efficient technology. The current study includes FS measure packages that were approved and published in the CA eTRM as of late fall 2022. The current scope of FS includes only gas to electric substitution in HVAC, water heating, food service, and appliance end uses.

2.1.2.1 Technology Groups, Efficiency Levels, and Competition

FS 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 FS levels.

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

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

Source: Guidehouse

2.1.2.2 Panel Upgrade and Infrastructure Costs

Substituting gas technologies for electric technologies can increase electric load for a building or house. This can sometimes require upgrades to the infrastructure within the building, for example, increasing the size of the electrical panel to accommodate the added load. Deemed per-unit costs of FS technologies typically do not currently consider such costs, and the previous 2021 Study did not account for these costs. For the 2023 Study, the Guidehouse team conducted a literature review to estimate the cost of a panel upgrade for residential homes, as well as the proportion of homes that would need an upgrade given an installation of FS technology. The 2023 Study did not include other potential FS infrastructure costs beyond panels, such as wiring or outlets.

The team then incorporated these results into the FS measure characterization. For residential FS measures that may require a panel upgrade, the team created two versions of the measure, and applied the FS panel upgrade cost to one of them. The density of the measures (i.e., the number of measure units per household) is split between the measures with and without the upgrade based on the proportion that would require an upgrade. The panel cost is applied to the set of homes that need a panel upgrade and is not applied to the set of homes that do not need a panel upgrade. For example, if the total density of residential gas water heaters is 40%, and 30% of single-family homes would require a panel upgrade when replacing a gas water heater with a heat pump water heater, the measure would be split into two separate measures with the density of the panel upgrade version being 12% (0.4 * 0.3) and the density of the non-panel upgrade version being 28% (0.4 * 0.7).

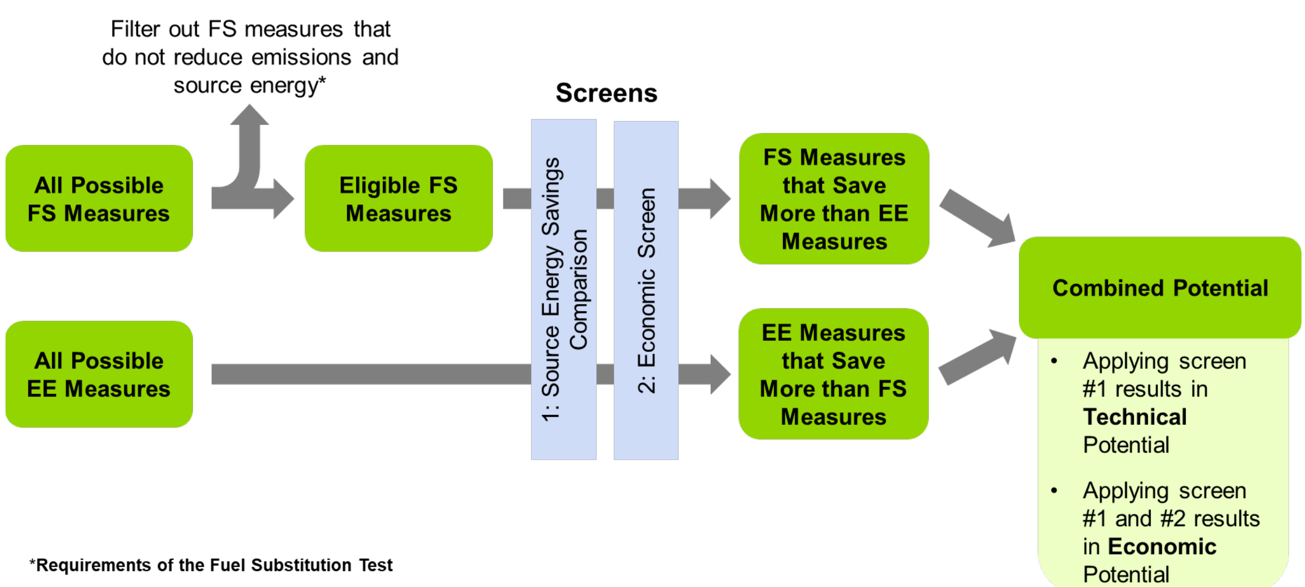
Appendix C contains the results of the literature review and the estimate of panel upgrade infrastructure costs.

2.1.2.3 Technical and Economic Potential

Current FS measures decrease gas load but increase electric load, as per the existing workpapers. FS measures must pass the FST to be included in either the technical or economic potential. Figure 2- illustrates the methods used to screen measures for potential analysis and how the FS measures are handled. The 2023 Study only analyzed eligible FS measures (those determined to pass the FST); the study excluded FS measures that failed the FST. There are some unique differences in assessing FS measures compared to EE measures:

- **Technical Potential** - If the FS measure saves more source energy (in Btus) than its competing EE measures, the FS measure wins the competition and thus represents technical potential.
- **Economic Potential** - FS measures value both the gas savings (a positive benefit) and the increased electricity supply cost (a negative benefit). For FS 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



Source: Guidehouse

Technical and economic potential for FS measures are assigned to the electric IOU that serves the new electric load. This means that reductions in SCG gas energy use due to FS are assigned to SCE. However, if an FS 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 of whether it wins technical or economic competition is carried through to the achievable potential calculations as well.

2.1.2.4 Achievable Potential

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

Approach to Calculating Willingness

The approach to calculating willingness to adopt FS 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 FS technologies as compared to same fuel technologies. Factors most important to customers for adopting an energy efficient or FS technology include energy savings, lifespan, and comfort benefits. The most important barriers include uncertainty about energy savings, upfront costs, and the potential disruption to install the technology. FS has an additional important barrier in that the unfamiliarity with the technology does not get identified for EE. 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. FS incentives (like those for EE) are calculated on a $/kWh and $/therm basis capped at a maximum value (75% or 90% of incremental cost depending on the scenario). Furthermore, for the 2023 Study, additional incentives available from outside the IOU programs under Technology and Equipment for Clean Heating (TECH) and Self-Generation Incentive Program (SGIP) Heat Pump Water Heater (HPWH) are included. These were not included in the constrained (capped) incentive amounts for applicable FS measures, and Guidehouse did not assign weighting or unique attribution values to these incentives based on direction from CPUC staff.

2.1.3 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 in whole building packages because these results are duplicative with the technical and economic potential of individual rebated technologies. Highly efficient new buildings or retrofitted buildings will have no additional opportunity for individual EE technologies to be installed. When accounting for other measures that could technically be installed in the highly efficient building, double counting of savings would occur (to prevent double counting, either the whole building package would have to be removed or all other technologies potentials would be underestimated).

2.1.4 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 2-6. 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 (BRO or the strategic energy management [SEM]-like program for the industrial and agriculture sector are also discussed in Section 2.1.5). Definitions and data sources are provided in more detail in Section 3.5.

Table 2-6. Industrial and Agriculture Technology Categories and Modeling Methodology

Category	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 BRO 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 technology measures is applied at the subsector level (e.g., chemicals, plastics, dairy) and uses
 to calculate incremental achievable potential. The top-down approach for generic custom is applied at the market segment level (i.e., agriculture and industrial) and is presented in Equation 2-3. Guidehouse defined unit energy savings in terms of savings as a percentage of the sector-level consumption. Additional variable details and definitions follow
 and Equation 2-3.

Equation 2-2. Incremental Achievable Potential for Emerging Technologies

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

Equation 2-3. Incremental Achievable Potential for Generic Custom

$$\begin{aligned} &Incremental\ Market\ Potential \\ &\quad = Savings\ Rate\ Multiplier \times Annual\ Sector\ Consumpion \times Penetration\ Rate \end{aligned}$$

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.
- **Savings Rate Multiplier** represent the percentage of savings expected from customers adopting technologies at the total sector consumption level.
- **Annual Sector Consumption** represents the total energy consumption by total sector for the industrial and agriculture sectors

- **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 2023 Study did not update the emerging technology list, inputs, or analysis. Emerging technologies were screened for consideration in past study years 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 G. 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 2-4. Section 3.6 discusses the data inputs for this equation.

Equation 2-4. 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, T_e.
- California market data defines the sector end use percentage of total energy consumption, $E_{i,j}$.
- The market trajectory for each sector, MT_j, 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).[22]
- The segment energy consumption trend weight, TW_j, 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 3.6 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.

2.1.5 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).

2.1.5.1 Energy and Demand Savings

Equation 2-5 is the general equation for the BROs potential model. Each of the components are described below.

Equation 2-5. Incremental Achievable Potential for BROs

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

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.

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

- **Unit energy savings** represent the savings expected from participants and can be represented in two ways: kWh and therms or percentage of consumption. Savings may vary by segment and amount within a program. For example, the home energy report (HER) participants are binned into low, medium, and high savers.
- **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, and 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., Demand Response) but includes demand savings from the characterized BROs programs using Equation 2-6.

Equation 2-6. BROs Demand Savings

$$Incremental\ Market\ Potential\ (kW) = Incremental\ Market\ Potential\ (kWh)\ \times\ Peak\ to\ Energy\ Ratio$$

2.1.5.2 BROs Costs

Similar to demand savings, utility program costs are calculated from the energy savings in Equation 2-5. The cost factor in Equation 2-7 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 2-7. BROs Program Costs

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

Although cost and cost-effectiveness of BROs measures are calculated by this study, the methodology does not include any screening for cost-effectiveness; there is no calculation of an economic potential for BRO. There are reasons for this:

- Costs for new BROs are inherently uncertain and are sometimes based on pilot programs or programs from other jurisdictions.
- Cost-effectiveness for HERs can vary by treatment wave. In the real world, there is an inherent supply curve for cost-effective HERs enrollment that factors into enrollment levels. All previous enrollments could be cost-effective but reaching the next incremental wave might not be. However, the simpler approach for the PG Model outlined earlier does not model waves. Applying an economic screen is binary, either a measure is

included or excluded. For a program as large as HERs to be as uncertain as it would in the PG Model would be too far removed from the real world and would lead to vast swings in potential that are unrealistic.

2.1.6 C&S

C&S impact EE potential in two ways:

- C&S impacts the code baseline for IOU-rebated measures. The Guidehouse team have modeled 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 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 greenhouse gas (GHG) targets. The net C&S savings inform 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.

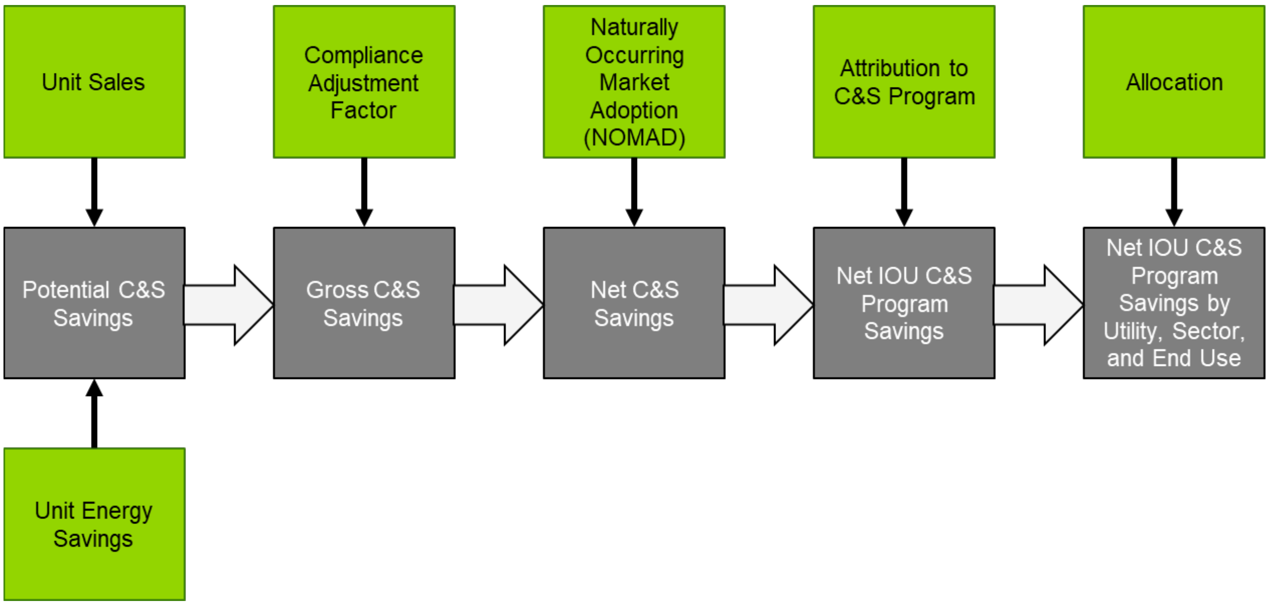
The modeling methodology of C&S savings was based on the ISSM[23] developed by Cadmus and DNV GL and used by CPUC in C&S program evaluation. The Guidehouse team replicated the ISSM methodology in the PG Model for use in this study. Figure 2- illustrates the process to calculate net C&S savings and net IOU C&S program savings. Key components of the calculation listed in Figure 2- 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:** 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 C&S

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

- **Attribution:** The portion of gross C&S savings in California that can be claimed by IOU code support programs
- **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 2-11. C&S Savings Calculation Methodology



Source: Guidehouse

2.1.7 IRA

IRA was passed into US federal law in August 2022. It includes provisions for tax credits to help reduce the cost of purchasing energy efficient end use equipment in both residential and nonresidential premises. The IRA also provides rebates through programs. The modeling of these programs is not included in this current study. The Guidehouse team incorporated measure-level tax credit impacts into the Guidehouse team's PG Model. IRA tax credits impact the model in two ways:

1. **Changing Cost-Effectiveness:** Tax credits feed into the TRC test and act to increase cost-effectiveness of measures. This increased economic potential overall as a result measures that were near the threshold of cost-effectiveness becoming so due to the tax credit. The PG Model followed the California Standard Practice Manual and supplemental guidance from CPUC staff on how to properly incorporate tax credits into the TRC test.
2. **Increasing Willingness to Adopt:** Tax credits reduce the lifetime ownership cost of energy efficient equipment. Lifetime cost is an input to the PG Model's calculation of willingness to adopt; reducing cost increases willingness and thus increases achievable potential. No significant algorithm changes were necessary to model this aspect.

The DSMSim model has an input for tax credit that can be defined at the measure level, which impacts the model output as defined above. The methodology for developing measure-specific tax credit values differs between residential and commercial sectors:

Residential Sector Characterization: For applicable residential EE and FS measures, the following steps are taken to derive a per-unit tax credit amount for IRA-eligible measures characterized and included in the model:

- Identify pre-adjustment tax credit amount ($/measure) using the IRA provisions
- Adjust tax credit to account for the requirements that the measures are installed in owner-occupied single-family homes
- Account for the functional requirement that the homeowner has sufficient tax burden to receive the value of the tax credit

Commercial Sector Characterization: The IRA tax credit for commercial buildings applies to HVAC, Lighting, and Water measures. The tax credit within the legislation is specified as $/sq ft and is a range depending on the total reduction in baseline energy usage. Using secondary research, Guidehouse applied California-specific building vintage and stock data, market-level efficiency potential and measure density to estimate a measure-level tax credit value ($/unit) that was input into the PG Model and reflected in the outputs of Scenarios 2, 3, and 4.

Further detail regarding the methodology and assumptions employed to incorporate IRA tax credits into the PG Model can be found in Appendix K.

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:

- Reflect actual market conditions for the bottom-up approach model to calculate potential of historical adoption. This enables a process for ensuring the model can calculate previous market conditions.
- Establish 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 2018-2021 EE program data (gross savings, program spending data) and performs a backcast to fit model parameters such that historical achievements are generally matched.

FS calibration methodology differs from the 2021 Study approach. For the 2021 Study, no specific calibration was possible because this savings source did not exist in historic portfolios. For the 2023 Study, historical data for 2022 was available, which was used to calibrate FS adoption to historical program activity and market saturation data, as appropriate. The study also applied FS program-specific budget filings for 2022 to ensure a robust basis of sector and end use calibration data.

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 with actual program gross savings spending. Modeling parameters are adjusted to reasonably align the backcast to historical data.

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 explore variables beyond the 2021 Study variables. One reference scenario (Scenario 1: No IRA) stems directly from the calibration process and is similar to the adopted scenario from the 2021 Study. Alternate scenarios are informed by stakeholder and policy input.

Guidehouse will conduct additional scenario analysis as part of the additional achievable energy efficiency (AAEE)/additional achievable fuel substitution (AAFS) analysis after the 2023 Study is finalized. AA scenarios feed into the CEC's IEPR and are built around the adopted IOU goals and are informed by potential and goals scenarios. AA 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. External variables are those the CPUC and IOUs collectively have no control over. Table 2-7 provides examples of internally and externally influenced variables.

Table 2-7. Variables Affecting EE Potential

Internally Influenced	Externally Influenced
• Cost-effectiveness test • Cost-effectiveness measure screening threshold • Incentive levels • Marketing & outreach level of effort (ME&O) • BROs customer enrollment over time • IOU financing programs	• Federal tax credits • 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 the following externally influenced variables to a single setting across all scenarios:

- CEC mid-case forecast for retail rates, population, and building stock
- CA eTRM values used as is (measure-level inputs)
- One set of assumptions about future C&S

Table 2-8 lists additional details on each of the variables used for scenario setting. Guidehouse has always used only internally influenced variables for scenario levers. The 2023 Study includes the federal tax credits, an externally influenced variable, within the scenario levers to provide boundaries on probable impacts from the IRA. Furthermore, Guidehouse did not include all internally influenced variables including cost-effectiveness, cost-effectiveness threshold, ME&O aggressiveness, and BROs program enrollment.

All scenarios use the following internally influenced variables with no variations across the scenarios:

- **Cost-effectiveness test and threshold.** The cost-effectiveness threshold is set to a TRC of 0.85, which assumes the balance of cost-effectiveness and other portfolio costs will result in an overall portfolio TRC greater than 1.0. A lower-than-unity cost-effectiveness screening threshold for measures allows those that are less cost-effective into the forecast and reflects current and past EE portfolios that do include measures with TRC values below 1.0. 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.

- **ME&O level of effort.** Varying marketing and outreach levels impact the rate at which technologies are adopted by customers. The ranges have been the default calibrated value for the reference and increased marketing strength for the aggressive scenarios. All scenarios use the default calibrated value.

- **BROs program assumptions.** Enrollment in BROs programs is an input vector. Guidehouse assumes a reference or aggressive rollout of BROs programs. Reference is the continued offering of existing BROs interventions and planned new interventions based on policy directions. Aggressive penetration grows program participation faster, as well as BROs programs that are not currently in the California utility plans. For the 2023 Study, only the reference BROs program enrollments are used.

Table 2-8. Variables Considered for Scenario Setting

Lever	Description	Potential Impact Applicability	
		Economic	Achievable
Federal Tax Credits (IRA)	Including tax credit impact levels specified by the IRA within the P&G Model for applicable measures	✔	✔
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	✔	✔
FS	Varying adoption parameters (Awareness, Willingness, Sensitivity, Stock Turnover)		✔

Source: Guidehouse

Each variable used for the scenarios has a range of options, as Table 2-9 describes.

Table 2-9. Range of Values for Scenario Variables

Lever	Range/Bounds	
	Lower	Upper
IRA Credits	Conservative: Estimated Residential Sector and Low EE Potential Commercial Sector	Aggressive: Estimated Residential Sector and High EE Potential Commercial Sector
Incentive levels	Capped at 50% of incremental cost or existing program levels for EE Capped at 75% of incremental cost or existing program levels for FS	Capped at 75% of incremental cost for EE, 90% for FS
FS	Reference: Default calibrated value	Aggressive: Increased parametric adoption lever values

Source: Guidehouse

The Guidehouse team presented this scenario framework to stakeholders on December 14, 2022 and invited stakeholders to provide feedback. Building on stakeholder feedback, the Guidehouse team worked with CPUC staff to develop scenarios to consider in the goal setting process. Each of the selected variables in Table 2-9 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 2-10. Every scenario includes FS.

Table 2-10. Summary of Final Scenarios for EE Potential

Levers → Scenario ↓	C-E Test	C-E Threshold	IRA Tax Credits	Incentive Levels Capped*	FS**
1: No IRA	TRC	0.85	None	EE 50% FS 75%	Reference
2: Reference IRA and FS			Conservative	EE 50% FS 75%	Reference
3: Reference IRA and aggressive FS			Conservative	EE 75% FS 90%	Aggressive
4: Aggressive IRA and reference FS			Aggressive	EE 50% FS 75%	Reference

C-E = cost-effectiveness
*Incentives are set based on a $/kWh and $/therm basis consistent with existing IOU programs; incentives are capped at 50%/75% (EE) or 75%/90% (FS) of incremental cost depending on the scenario.
**FS adoption parameters are set based on end use and sector-specific calibration targets.

Source: Guidehouse

The scenarios can be interpreted as follows:

- **Scenario 1: No IRA** represents business as usual with no impact (adoption) from the IRA tax credit and the continuation of current policies.
- **Scenario 2: Reference IRA and FS** represents the same parameters as Scenario 1 with the addition of tax credits for residential and commercial EE and FS measures specified within the IRA provisions. Assumptions applied to specify per-measure tax credit values represent the best available information regarding provisions of the law, and a conservative set of assumptions related to the proportion of commercial sector buildings able to achieve the minimum IRA-specified reduction in baseline energy consumption required to qualify for tax credits.
- **Scenario 3: Reference IRA and Aggressive FS** builds on Scenario 2 with increased adoption parameter values assigned to FS measures designed to align these technologies with EE in terms of how the overall market responds to programmatic interventions. In addition, Scenario 3 includes a 75% incentive cap on incremental cost for EE measures and 90% incentive cap for FS measures. These were determined through discussions between Guidehouse and the CPUC and assigned to be reflective of state regulators' relative high prioritization of FS measures but still accounting for some of the measure incremental cost burden to be assigned to technology adopters.
- **Scenario 4: Aggressive IRA and Reference FS** is consistent with Scenario 2 except the IRA tax credit values applied to the commercial sector EE and FS measures represent a more aggressive set of assumptions regarding the percentage of buildings

across the market that can achieve the minimum IRA-qualifying reduction in baseline energy consumption through eligible measures.[24]

[24] Guidehouse assigned the base threshold value of 25% for the proportion of commercial buildings that can achieve the minimum tax credit qualifying reduction in overall energy consumption conservative IRA scenario. This value was increased by a factor of 1.5 for the aggressive IRA scenario. More detail on these assumptions can be found in Appendix K.

3. Data Sources

The 2023 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 apply to market segments or sectors. The Guidehouse team reviewed the data source for each of these inputs to determine the most recent data to be used for the 2023 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)*	Electric rate: CEC, 2022 IEPR (preliminary; communication with the CEC) Gas rate: CEC, *2021 Integrated Energy Policy Report (IEPR).*[25] Adopted Feb. 2022
Consumption forecasts *(GWh, MW, and MMtherm)*	CEC, *2021 Integrated Energy Policy Report (IEPR).* Adopted Feb. 2022
Building stocks *(Households, floor space, consumption)*	CEC, *2021 Integrated Energy Policy Report (IEPR).* Adopted Feb. 2022
Avoided costs *(Avoided energy and capacity costs)*	2022 Avoided costs: *E3 Avoided Cost Calculator*. Files received from DNV Oct. 2022.
Historical program accomplishments *(Used for calibration)*	CPUC, California Energy Data and Reporting System (CEDARS) program cycle 2018-2021 data. CPUC, California Energy Data and Reporting System (CEDARS) 2021 fillings and 2023 Plan (FS).
Non-incentive program costs	CPUC, California Energy Data and Reporting System (CEDARS) program cycle 2023 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 2023 Study. The Guidehouse team used the preliminary

[25] As of October 2022, the CEC indicated that they did not anticipate changing the gas retail rate forecast from the 2021 to the 2022 IEPR.

2022 IEPR for electric rates and the 2021 IEPR for gas rates with the understanding that the CEC was not anticipating updating the gas rate forecast in 2022. The team used the 2021 IEPR consumption forecasts because the 2022 IEPR forecasts were not available at the time of the PG study analysis.

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 or other non-IOU electricity providers, so an adjustment is needed. Using data from the CEC's Energy Consumption Database (ECDMS)[26] on service territory and planning area sales for 2021, the most recent year for which data was available, 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 are referred to as service territory to planning area adjustment ratios and are detailed in Table 3-2.

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

IOU	Residential	Commercial	Industrial	Agriculture
PG&E	80.6%	74.3%	70.4%	84.1%
SCE	81.7%	83.2%	71.4%	57.1%
SDG&E	73.7%	87.5%	89.3%	92.8%

Source: ECDMS, 2021

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 2021 data from the CEC's Energy Consumption Database (ECDMS), shown in Table 3-3.[27] 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. Gas Service Territory to Planning Area Adjustment Ratios

IOU	Residential	Commercial	Industrial	Agriculture
PG&E	99.5%	98.4%	99.9%	100.0%
SCG	97.9%	96.7%	97.5%	97.9%
SDG&E	100%	100%	100%	100%

Source: ECDMS, 2021

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

[26] California Energy Consumption Database. Accessed October 2022: http://ecdms.energy.ca.gov/

[27] Ibid.

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. The 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 2013-2035

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

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

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 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 2023 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 2018-2021 gross ex post savings at the utility and sector levels for EE programs, 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 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. 2018-2021 IOU-Reported Portfolio Gross Program Savings – EE

IOU	Sector	Gross GWh	Gross MMtherms	Expenditures ($ Millions)
PG&E	Residential	209.60	0.72	$161.98
	Commercial	438.57	15.01	$256.85
	Industrial	67.94	42.16	$73.36
	Agriculture	68.13	1.93	$43.06
SCE	Residential	171.48	0.84	$125.81
	Commercial	198.84	0.62	$142.76
	Industrial	36.24	-	$9.25
	Agriculture	11.59	-	$6.30
SCG	Residential	37.83	24.82	$153.79
	Commercial	0.24	23.00	$75.38
	Industrial	0.01	9.51	$19.32
	Agriculture	1.31	4.54	$5.89
SDG&E	Residential	36.82	2.39	$59.96
	Commercial	85.05	1.54	$60.37
	Industrial	12.22	0.38	$4.78
	Agriculture	0.74	0.05	$1.42

Source: CPUC, CEDARS (2018-2021) Claims Data

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

Program Category	Reason for Exclusion	Modeling Location
BROs-type programs	Behavioral programs are modeled through the BROs methodology.	BROs

Program Category	Reason for Exclusion	Modeling Location
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
ESA	The Guidehouse team modeled low income potential separately.	Low income
Financing programs	Most historical financing programs only report a cost and no savings.[28]	N/A
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

FS calibration data from 2021 was limited because that was the first year that utilities were directed to have FS programs. Prior to that year, FS programs were either non-existent (2018-2019) or pilot-only (2019-2020). To include more robust FS-specific program data to form a basis for calibration, 2022 Q1-Q2 IOU budget data for was also included in the analysis.

Table 3-7 provides the 2022 gross savings at the utility and sector levels for FS programs, which informed calibration. GWh savings are negative because FS results in increased energy consumption.

Table 3-7. 2022 IOU-Filed Portfolio Gross Program Savings-FS

IOU	Sector	Gross GWh	Gross MMtherms	Expenditures ($ Millions)
PG&E	Residential	-0.59	0.17	$2.15
	Commercial	-0.42	0.06	$0.49
	Industrial	0.00	0.00	$0.00
	Agriculture	0.00	0.00	$0.00
SCE	Residential	-1.46	0.38	$3.21
	Commercial	-6.45	1.88	$12.00
	Industrial	-0.63	0.17	$1.12
	Agriculture	0.00	0.00	$0.00

[28] 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.

IOU	Sector	Gross GWh	Gross MMtherms	Expenditures ($ Millions)
SDG&E	Residential	-0.15	0.05	$0.63
	Commercial	-0.03	0.00	$0.01
	Industrial	0.00	0.00	$0.00
	Agriculture	0.00	0.00	$0.00

Source: CEDARS 2022 Budget Data

Appendix A includes additional discussion on the calibration process.

3.1.4 Non-Incentive Program Costs

Non-incentive program costs come from the IOU 2023 filings data (as of December 2022), 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, 2023 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 3-8 provides an overview of the non-incentive program costs based on gross reported savings.

Table 3-8. Non-Incentive Program Costs Summary

IOU	Electric Savings ($/Gross kWh)				Gas Savings ($/Gross therms)			
	Res	Com	Ag	Ind	Res	Com	Ag	Ind
PG&E	$0.33	$0.11	$0.33	$0.01	$9.76	$3.31	$9.81	$0.29
SCE	$0.19	$0.43	$0.25	$0.15	N/A	N/A	N/A	N/A
SCG	N/A	N/A	N/A	N/A	$1.70	$1.65	$0.26	$1.65
SDG&E	$0.03	$0.17	$0.19	$0.11	$0.83	$5.11	$5.58	$3.35

Source: CPUC, CEDARS – 2023 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. One set of avoided costs are used for this analysis, the 2022 vintage of the avoided cost calculators (ACC).

To source the 2022 vintage of avoided costs, Guidehouse worked with CPUC contractors E3 and DNV to obtain avoided cost inputs. Gas avoided costs were provided for each utility and sector, and electric avoided costs were provided by sector, utility, and end use. For the electric avoided costs, Guidehouse mapped each measure to an end use by matching to the Electric Loadshape Identifier in the eTRM.

The 2023 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 2023 Study analysis.

3.2 Residential and Commercial 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 2021 Study, the 2023 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 (CG). For example, floor insulation retrofit measures with different efficiency levels (below code R0, code level R19, efficient level R30, etc.) are considered a single technology group termed floor insulation retrofits.

3.2.1 Technology Selection Process

The technology selection process for the 2023 Study used the 2021 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 draft residential and commercial measure list for the 2023 Study was released to stakeholders and posted to the CPUC website on August 12, 2022, for review and feedback. Major changes from the previous study include the following:

- Added new gas to electricity FS measures based on available eTRM measure packages. Some new FS measure levels like Heat Pump Clothes Dryers were added to existing gas-only technology groups such that they compete with existing efficient gas levels. Other measures like Ductless Mini-Split Heat Pump Fuel Substitution, Heat Pump Pool Heaters, and Large Com and Multifamily Heat Pump Water Heaters were added with new technology groups.
- Reorganized commercial air conditioning and heat pump measures into Small Unitary and Large Unitary technology groups to align with eTRM measure packages. Previous

versions of the Study organized these measures using a split system versus packaged rooftop distinction.

- Added HVAC efficiency level granularity (e.g., SEER 15, SEER 16, SEER 17) to air conditioning and heat pump technology groups. The characterized efficiency levels now align with the measure offerings in eTRM measure packages. The 2021 Study included only SEER 18 and SEER 22 levels relative to a SEER 14 baseline.
- Added residential FS technology groups to represent the portion of homes that may require an electrical panel upgrade to substitute from gas to electricity. For example, where the 2021 Study only had a single technology group for Res Central HVAC System FS, the 2023 Study has two technology groups, with and without a panel upgrade.
- Removed smart appliance technology levels (e.g., smart refrigerators, smart water heaters) which were used in the 2021 Study to estimate DR co-benefits but otherwise did not differ from non-smart efficient technology levels EE savings.

Table 3-9 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.[29]

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

Table 3-9. 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	12	28
	Building Envelope	Wall Insulation, Floor Insulation, Duct Insulation	5	13
	HVAC	Air Conditioners (ACs), Heat Pumps, Furnaces	21	77
	Lighting	Indoor Screw-In Lamps, Specialty Lamps, Lighting Controls	7	20
	Water Heating	Electric Water Heaters, Faucet Aerators, Showerheads	15	36
	Total		**60**	**174**
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	4	8
	Food Service	Ovens, Steamers, Fryers	16	39
	HVAC	Unitary ACs, Mini-Split Heat Pumps, Chillers, Energy Management Systems (EMSs)	22	61
	Lighting	High and Low Bay Fixtures, Indoor Reflector Lamps, Lighting Controls	7	20
	Water Heating	Storage Water Heaters, Faucet Aerators, Pre-Rinse Spray Valves	10	23
	Total		**73**	**182**

*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 measure input characterization system spreadsheet for a complete list of the technologies included in the study.

Source: Guidehouse

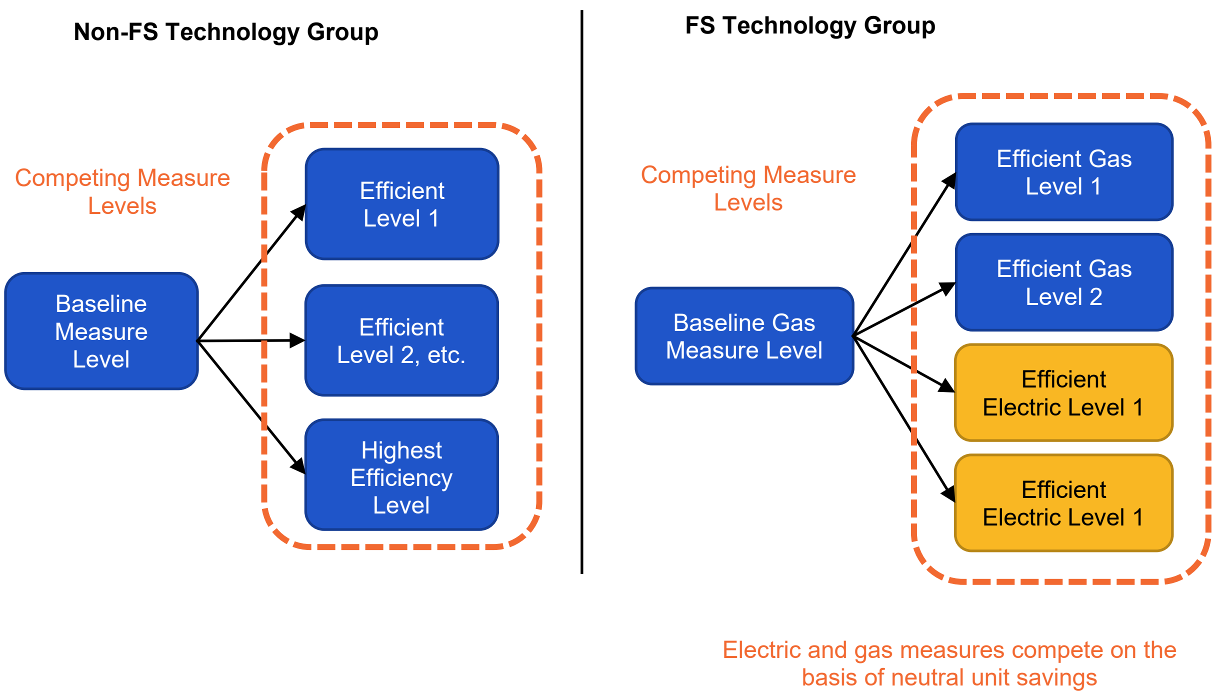
3.2.1.1 FS Considerations

The team followed a similar approach to the non-FS (EE technologies) technology selection process. The team excluded any measures that did not pass the FST, alternatively, the team included only approved measure packages in the eTRM. As implemented by CPUC Decision 19-08-009, the FST specifies that to be 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).[30]

The Guidehouse team analyzed FS technologies in the same technology group as the gas technology being replaced. In other words, a FS 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 based on neutral unit savings; unit energy consumption for the technologies are converted to the same unit by converting gas energy units to equivalent electric energy units.

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

Figure 3-1. Example FS Technology Group



Source: Guidehouse

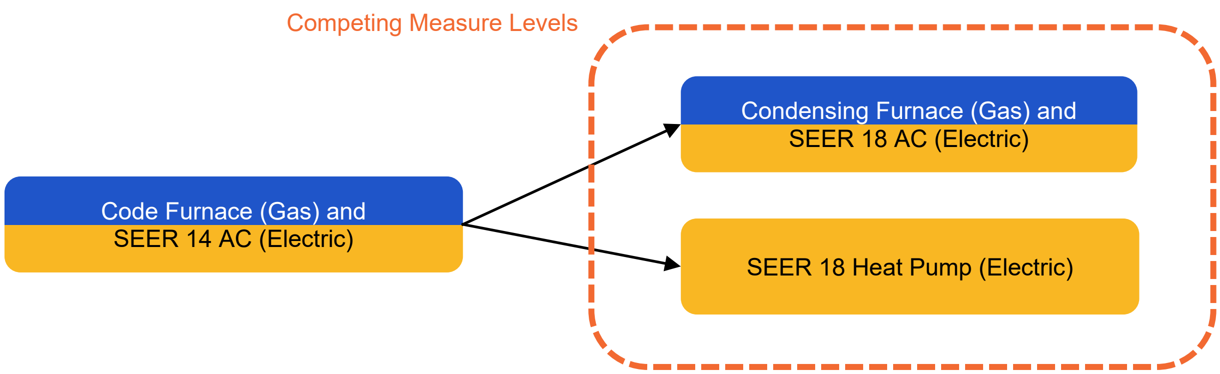
30 https://www.cpuc.ca.gov/General.aspx?id=6442463306

For most FS technology groups, an electric appliance directly replaces a gas appliance. For residential HVAC FS measures, however, the electric FS level—a heat pump—provides heating and cooling, while the gas appliance being replaced only provides heating. The 2023 Study considers three possible situations:

- Homes with a central gas furnace providing heating and an electric central air conditioner providing cooling
- Homes with a ductless wall furnace providing heating and an electric ductless room air conditioner providing cooling
- Homes with a central gas furnace and no cooling

For homes with both a gas furnace and an electric air conditioner, FS would involve replacing both the furnace and the air conditioner with a heat pump (central heat pump or ductless mini-split heat pump), which provides heating and cooling. The technology group(s) consist of a heat pump competing with an efficient furnace and air conditioner combination, as Figure 3-2 shows for the Central HVAC System situation.

Figure 3-2. Residential HVAC FS Technology Group

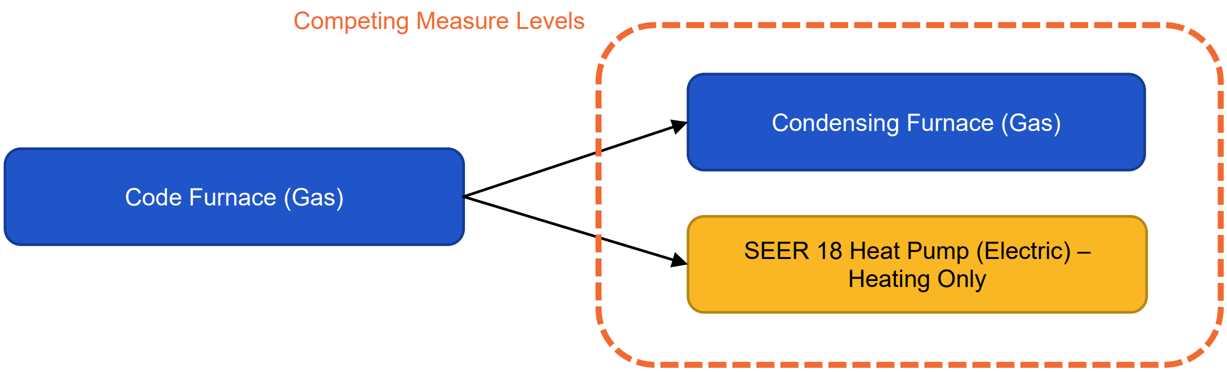


Source: Guidehouse

For homes with a gas furnace only, the FS level competed with the efficient gas appliance only. Like the 2021 Study, 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 in the characterization to the full cost of the baseline furnace.[31] Figure 3-3 shows the efficiency levels in this technology group.

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

Figure 3-3. Residential Furnace FS Technology Group



Source: Guidehouse

3.2.2 Technology Characterization

Characterizing selected technologies involves developing various inputs for each technology necessary to calculate potential. Table 3-10 summarizes the key items the Guidehouse team used to characterize the technologies and provides brief descriptions.

Table 3-10. Key Fields for Measure Characterization

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 • Panel upgrade costs (for applicable FS technology groups)
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

Source: Guidehouse

For the 2023 Study, Guidehouse used a prioritization approach to determine which existing measures that were previously characterized in the 2021 Study were most important to update.

The prioritization was based on potential results from the 2021 Study. Any measure within a technology group that had a 1% or greater contribution to total electric or gas economic potential within any scenario was marked as high priority for update. In addition, all FS measures were considered high priority to update, regardless of 2021 Study potential results. Measures that were not designated as high priority were still included in the 2023 Study, but the technology characterization inputs and sources for these measures were largely unchanged from what was used in the 2021 Study.

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 requires that the energy use associated with each technology level be specified relative to the baseline level of the technology group in which the technology competes. If the measure is an early retirement measure (i.e. efficient equipment replacing old equipment before the end of its life) or a retrofit component being added on to existing equipment, the baseline is typically considered to be at the average efficiency of that equipment type currently existing in homes or buildings (termed "average existing"). If the measure is replacing burned-out equipment or being installed in new construction, the baseline is considered to be the minimally code-compliant efficiency level, because that is the least efficient equipment that could be purchased.

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 Database for Energy Efficient Resources (DEER) changed per DEER Resolution E-4952, published October 11, 2018.[32] 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 demand data from non-eTRM 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, ACs 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

[32] https://docs.cpuc.ca.gov/publisheddocs/published/g000/m232/k459/232459122.pdf

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 achievable because low cost-effectiveness in one region could outweigh high cost-effectiveness in another region, making the entire measure appear nonviable.

As in the 2021 Study, the Guidehouse team characterized climate-dependent 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 most of the state's population.[33]

Most California energy data sources provide energy values for climate-dependent measures for each of the 16 climate zones. Table 3-11 shows the mapping the team used to select the appropriate energy value from data sources that calculated energy consumption by climate zone. In the 2023 Study, Guidehouse updated the designated climate zone for SCE Hot-Dry and SCE All from CZ08 to CZ09 because CZ09 was a more representative zone in terms of climate characteristics across all of SCE service territory.

Table 3-11. 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	CZ09	CZ09	CZ07
Cold	CZ16	CZ16	CZ16	N/A
Non-Climate-Dependent*	CZ03	CZ09	CZ09	CZ07

CZ = climate zone

*The Non-Climate-Dependent row shows the mapping used for measures not treated as climate-dependent in the 2023 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 16) – Marine). The model does not aggregate the costs and savings across the 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. Like energy

[33] 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.

savings data, most cost data for characterized technologies came from eTRM measure packages. Many of the other California-specific technology cost data sources reference underlying research conducted through the California Measure Cost Study.[34]

The Guidehouse team assumed constant technology cost through the study period (adjusted for inflation) for most measures.[35] 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.

Labor costs for FS technologies generally account for the cost of capping the original gas line and wiring needed to accommodate the new electric appliance. Infrastructure costs associated with residential FS panel upgrade requirements were added to the 2023 Study, as described in Appendix C.

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.

As an example, Table 3-12. shows the densities and saturations for the floor insulation retrofit technology group in single-family homes in PG&E's service territory.

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

[35] Inflation rate assumption of around 2% comes from the 2022 avoided cost calculator documentation. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/demand-side-management/acc-models-latest-version/2022-acc-documentation-v1a.pdf

Table 3-12. 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 prerequisites 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.

As noted in 3.2.1, for the 2023 Study Guidehouse added residential FS technology groups to represent the portion of homes that may require an electrical panel upgrade to substitute from gas to electricity. Based on the findings of the panel upgrade research described in Appendix C, Guidehouse split the total density for a FS technology among the panel upgrade and non-panel upgrade. For example, if the total density of residential gas stove is 0.75 per household and the estimated proportion of homes that would require a panel upgrade for induction cooking FS is one-third, then the total density would be split up to 0.25 stovetops per household in the panel upgrade technology group and 0.5 stovetops per household in the non-panel upgrade technology group.[36]

3.2.2.4 Effect of 2030 Natural Gas Appliance Ban

In September 2022, the California Air Resources Board (CARB) published a state implementation plan (SIP) memo to propose a "zero-emission standard for space and water heaters," which would ban the sale of natural gas-burning HVAC and water heating appliances

[36] These numbers are for illustrative purposes only.

starting in 2030.[37] The team accounted for this proposed ban by removing any natural gas EE or FS savings for space heating and water heating appliances beginning in 2030. (However, the Guidehouse team did include natural gas savings from technologies that indirectly save gas, such as home insulation, because these would not involve the replacement of the gas-burning appliance.) For FS technologies, this means that starting in 2030, the minimum efficient appliance replacing a burned-out natural gas space or water heating appliance would be a minimum efficiency electric appliance. More efficient electric appliances within this technology group would therefore save electricity, resulting in apparent electric savings for FS measures from 2030 onward. See Appendix B for more details on how this is implemented for FS.

3.2.3 Data Sources

Data to characterize new technologies and update high-priority existing technologies were primarily sourced from the CA eTRM measure packages. The data source for lower-priority measures is the same as the 2021 Study, which is primarily a mix of eTRM, DEER and IOU workpapers. Table 3-133 lists the data sources for cost and energy use (in hierarchical order) and provides brief descriptions of each source.

Table 3-13. Hierarchy of Data Sources for Cost and Energy Use Information

Priority	Energy Consumption Source Name	Description	Author	Publication Year
1	California Electronic Technical Reference Manual (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	2020-2022 (continuously updated)
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 CEDARS database for the California IOUs in cases where energy use information was not available from the above-listed sources.	CPUC, IOUs	2021

[37] California Air Resources Board, "2022 State Strategy for the State Implementation Plan," Adopted September 22, 2022. https://ww2.arb.ca.gov/sites/default/files/2022-08/2022_State_SIP_Strategy.pdf

Priority	Energy Consumption Source Name	Description	Author	Publication Year
4	Non-California source examples	In cases where California-specific sources were not available for energy use information	Various	Various
	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
	Guidehouse potential study database	Guidehouse's archive of characterized measure savings from previous potential studies and projects with other utilities.	Guidehouse	Various

Source: Guidehouse

Table 3-144 lists the resources used to calculate density and saturation for the residential and commercial sectors in the 2023 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 3-14. Sources for Density and Saturation Characterization

Priority	Sources	Description	Author	Year
1	Residential Appliance Saturation Study (RASS)	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
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.	U.S. Department of Energy (DOE)	2018, 2021

Priority	Sources	Description	Author	Year
	• ENERGY STAR Shipment Database	Unit shipment data of ENERGY STAR-certified products collected to evaluate market penetration and performance.	US Environmental Protection Agency (EPA)	2003-2020

Source: Guidehouse

3.2.4 Measure Characterization Workbook

The measure characterization 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 characterized measures with all the separate fields used for modeling. The workbook is publicly available and can be downloaded through the CPUC website.[38]

3.3 Market Adoption Characteristics

As discussed in Section 2.1.1.4, the 2021 Study updated the drivers of customer willingness to adopt EE technologies. The 2021 Study used a broader set of customer preferences on economic and non-economic factors when modeling technology adoption. The 2023 Study retained the 2021 Study's new approach to adoption modeling. The market adoption characteristics collected via surveys in the 2021 Market Adoption Survey

resulted in 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.

Table 3-15 summarizes the survey responses mapped to each value factor, transformed using an ordinal-to-metric analysis[39] (described in more detail in the 2021 Study report), and averaged over all example EE technologies. There are analogous tables for each EE measure, FS measure, and DR measure used in the surveys.

Table 3-15. 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

[38] 2023 CPUC Potential and Goals Study website.

[39] Ordinal is a non-metric scale and cannot be used for analysis. The survey responses are transformed to a numerical value, ordinal -to-metric.

Value Factor	Average Americans	Eager Adopters	Economically Strained Environmentalists	Likely Laggards	Multifamily	Commercial
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 which align with the 2023 measures. The first step in conducting this mapping was categorizing each surveyed technology as high or low for the attributes shown in Table 3-16. Each technology in the 2021 Study was then mapped to the surveyed technologies with which it shares the most attribute categorizations.

Table 3-16. 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
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 3-17 shows how various combinations of sector and technology attributes (defined in Table 3-16) 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 3-17). For example, Clothes Dryer is listed as both for disruption and costs. For low urgency, visible technology, the team did not survey different technologies that are low and high disruption and low and high cost. Each residential and commercial measure in the Study is mapped to a combination of urgency, visibility, disruption, cost, and type (DR or FS, 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. Based on the example, if a characterized measure is low urgency and visible, it will be mapped to the survey results for Clothes Dryer.

Table 3-17. Attribute Mapping and Linking to Surveyed Measures

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

* Blank cells indicate that the survey did not address FS for the specific measure.

Source: Guidehouse

3.3.1 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-, 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 CG 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- for instantaneous gas water heaters, the value factors address both benefits and barriers to the adoption of this measure. If the model only considered LMC, there would be adoption of instantaneous gas water heaters because LMC is preferable to the baseline. With the addition of all the value factors and application of the customer preference weightings, there is lower adoption of efficient instantaneous water heaters. The reason is that the barriers from upfront costs and hassle factor lead to efficient measures being less attractive compared with 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 3-18 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. No residential technology group is included in the table since including non-LMC value factors did not have significant impacts on high savings residential technology groups.

Table 3-18. 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	FS 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.

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

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

Source: Guidehouse

3.4 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 2023 Study models whole building initiatives via the technology levels indicated in Table 3-19.. These levels are unchanged from the 2021 Study. 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 3-19. 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	Zero Net Energy
Retrofit	Existing Building – No Retrofit	-
	Energy Upgrade CA – Basic	-
	Energy Upgrade CA – Advanced	-

Source: Guidehouse

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

3.4.1 New Construction

The teams used the new construction whole building technology group to analyze the potential for new construction programs increasing adoption of building above code. The Guidehouse team analyzed the following 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 is 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 published outputs of the California Building Energy Code Compliance (CBECC) software to demonstrate compliance with California energy codes.[40] The team used results from 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 with the 2016 level for commercial buildings and 7% of the home energy

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

use compared with the 2016 level for residential buildings.[41] Similar assumptions as the previous study were used to forecast EE savings to the ZNE level, including an adjustment to the lighting baseline.

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 3-20. provides the sources used to characterize new construction whole building initiatives. These sources represent the best usable datasets 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 3-20. 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[42]
	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*: https://newbuildings.org/wp-content/uploads/2015/11/GettingtoZeroReport_01.pdf 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

3.4.2 Retrofit

The 2023 Study includes only residential whole building retrofits, which are characterized using the same inputs as the 2021 Study. 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

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

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

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,[43] supplemented by data from the All Things Reported database for PY 2017 whole building retrofits analyzed in the Guidehouse Group A EUL Study. The impact evaluation provided percentage 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 the team 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.)

3.5 Agriculture and Industrial Technology Characterization

The 2023 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:**[44] 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.

This section and the material in Appendix E represent the team's use of the best available data for the technology characterization of the industrial and agricultural sectors. 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[45] 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[46] to various levels.

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

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

[45] One example is the Energy Efficiency Alberta study: https://open.alberta.ca/dataset/f63b924c-3134-4a81-a42c-2fb0a416eb72/resource/955757bd-de5b-43a3-ac52-4cb19f9630e3/download/aep-eea-2019-2038-energy-efficiency-small-scale-renewables-potential-study.pdf.

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

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).

3.5.1 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 each subsequent 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[47] and now the CEDARS database). The team identified over 1,300 measure-level data points for the industrial and agriculture sectors in the 2021 CEDARS program data.
2. Categorize measures into technology groupings:
    a. **Characterized custom** measures are 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 3.6 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 3.6 describes the methodology used to characterize these generic custom measures.

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

d. **BROs or 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.

3. Append 2023 savings totals to previously collected savings data for 2015 to 2021 associated with the agriculture and industrial sectors. This dataset retains measure-level data for each technology grouping and forms the basis for the Guidehouse team analysis (more details are provided in Appendix G5.2Appendix E).

3.5.1.1 Characterized Custom for Agriculture and Industrial

For the 2023 Study, the Guidehouse team characterized 29 technology groups for the agriculture sector and 24 for the industrial sector, representing the characterized custom measures for the market adoption model using Bass diffusion.[48] 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.

3.5.1.2 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, DEER, and data provided by the IOUs. The team completed measure savings updates, measure costs, and net-to-gross (NTG) updates per the 2021 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 estimates, the team used the IAC.[49] The team completed measure updates including measure costs and NTG updates per the 2021 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.[50]

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

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

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

[50] 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 (https://www.michigan.gov/mpsc/regulatory/ewr/michigan-energy-measures-database); and the Wisconsin TRM (http://dsmexplorer.esource.com/documents/Wisconsin%20-%2010.22.2015%20-%202016%20TRM.pdf). See the Agriculture measure characterization workbook for more detail on which measures these sources informed.

technologies. The IAC network consists of over 30 universities that have completed over 20,000 assessments at industrial facilities across the nation. Each assessment completed by the IAC includes detailed recommendations for improving energy consumption at a given site,[51] 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.[52] 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: 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 in 2021, which are detailed in 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)

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.[53] The team aligned the costs to the more recent dataset 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 2021 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

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

[52] 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.

[53] The costs 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.

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).[54] 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 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.

3.6 Industrial and Agriculture Custom Technologies Data Sources

Generic custom (GC) measures in the industrial and agriculture sector are projects that implement EE on a wide diversity of production processes and operating environments. These projects are diverse and often unique, and typically have generic, non-descript names such as Other, Process, or System in program tracking data such as CEDARS.[55] Generic custom measures present several challenges within a potential forecast:

- GC projects have unique attributes that make them difficult to forecast within the diffusion-based PG Model. For example, there are no formal estimates of GC measure saturation, such as Commercial End Use Survey or RASS, and EE potential forecasts are more dependent on an analysis of long-term trends of reported savings.
- Common engineering resources such as IOU workpapers, DEER or the California eTRM are well designed for building system applications but do not apply to the unique production-oriented projects being implemented in the industrial and agriculture segments.

As discussed further in Section 3.5.1.1, the definition of generic custom measures for the 2023 Study accounts for the following:

- Measures reported in CEDARS that are named as Other, Process, or System.
- 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.

[54] 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).

[55] Generic custom also includes a large number of discrete measures that each contribute a small amount of savings and collectively account for a small percentage of sector savings.

Similar to the 2021 PG Model, the 2023 model treats generic custom measures as a specific measure class. Table 3-21. 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 G provides additional details on the generic custom analysis and forecast methodology.

Table 3-21. Generic Custom Measures – Key Assumptions

Sector	Type	EUL Years	Savings		Cost		kW/kWh Savings Ratio
			kWh	therms	kWh	therms	
Industrial	Generic Custom	15	0.0651%	0.0496%	$0.48	$2.81	0.000195
Agriculture			0.0570%	0.5540%			

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 2023 Study on an analysis of data previously extracted through the California EEStats portal[56] and more recent data from CEDARS for programs operating from 2016 through 2021. 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 3-22. summarizes the generic custom savings contribution to the overall sector over six-year periods between 2016 through 2021. These averages exclude RCx from generic custom and include the addition of the large number of smaller measures now considered part of the generic custom measure class.

Table 3-22. Generic Custom Contribution as a Percentage of Sector Savings, Average of 2016 through 2021

Sector	Electricity	Gas
Industrial	22%	21%
Agriculture	21%	32%

Source: Guidehouse

Based on this analysis and sector-level consumption forecasts provided by the CEC IEPR team, the Guidehouse team determined that generic custom measures would save roughly 0.065% 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 0.057% of annual electricity consumption and roughly 0.554% of annual gas usage. These percentages are used in both the reference or aggressive cases and remain constant throughout the forecast horizon.

56 http://eestats.cpuc.ca.gov/Default.aspx

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 2023 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 2021 Study. The 2023 Study uses a compound annual decline rate of -4.2% for the reference case and this produced a declining forecast where generic custom savings potential in 2035 would be 52.5% of savings potential in 2020, the base year for the generic custom forecast. The decline rate is based on analyzing the trends of generic custom savings achievement in the EE portfolio, see Appendix G.1.

3.6.1 Industrial and Agriculture Emerging Technologies

New emerging technologies to reduce energy use and energy demand are continually being introduced in the California marketplace. The 2023 Study used the same approaches and inputs (some updates in 2019) built on analysis conducted for the 2017 Study. For the 2017 Study, the Guidehouse team identified approximately 1,100 potential emerging technologies. 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[57] 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 G 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 3-23 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 3-23. 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

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

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

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 may 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 G includes additional information on the methodology used to derives UES values and costs for emerging technologies measures.

The Guidehouse team assessed segment-specific technology applicability during the screening process since emerging technologies apply to different industrial and agriculture sectors in varying degrees. 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 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 2035. The 2035 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 2032 to 2035, the penetration rate remains at the 1.84% level.

3.7 C&S

C&S modeled in the 2023 Study uses data from multiple sources.

- For evaluated C&S, the study uses ISSM[58] as its data source.
- For unevaluated C&S, the study uses data provided by California IOUs via a formal data request.[59]

[58] Market Logics and Opinion Dynamics, *Integrated Standards Savings Model (ISSM),* 2020.
[59] PG&E, SCE, SDG&E, and SCG all responded to the data request on October 14, 2022.

- For future T-24 C&S, the study uses additional data and information collected as part of the 2021 Study from the CEC along with additional assumptions made by the Guidehouse team.

Table 3-24 lists the number and type of C&S and their data source. Appendix F contains a full list of the modeled C&S, their compliance rates, effective dates, and policy status (on-the-books, possible, or expected).[60]

Table 3-24. C&S Data Source Summary

IOU C&S Group	Number and Type of C&S	Data Source
Evaluated Title 20 and Federal	99 appliance standards	ISSM
Evaluated Title 24 2005-2016	119 building codes	ISSM
Unevaluated Title 20 and Federal	29 appliance standards	IOU data request
Unevaluated Title 24 2019	40 building codes	IOU data request
2022-2028 Title 24	85 building codes	IOU data request, Guidehouse assumptions for 2024 and beyond

Sources: Market Logics and Opinion Dynamics. ISSM. 2022.; IOU data request filed September 29, 2022; 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.[61] 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 2023 Study uses bounded values from the ISSM.

The 2023 Study carries forward assumptions made during the 2021 Study on energy savings estimates for future Title 24 code cycles in 2025 and 2028 for the commercial sector. Personal communication with staff at CEC during the 2019 Study provided insight on the path between 2019 Title 24 and 2028 Title 24, as Table 3-25 illustrates. The Guidehouse team continued to

[60] **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 2023 Study but are made available for the CEC's AAEE forecasting process.

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

use these assumptions for the 2023 Study. However, Guidehouse updated the allocation factors using the most recent impact evaluation published in May 2021.[62]

Table 3-25. Progression of Commercial Title 24

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%

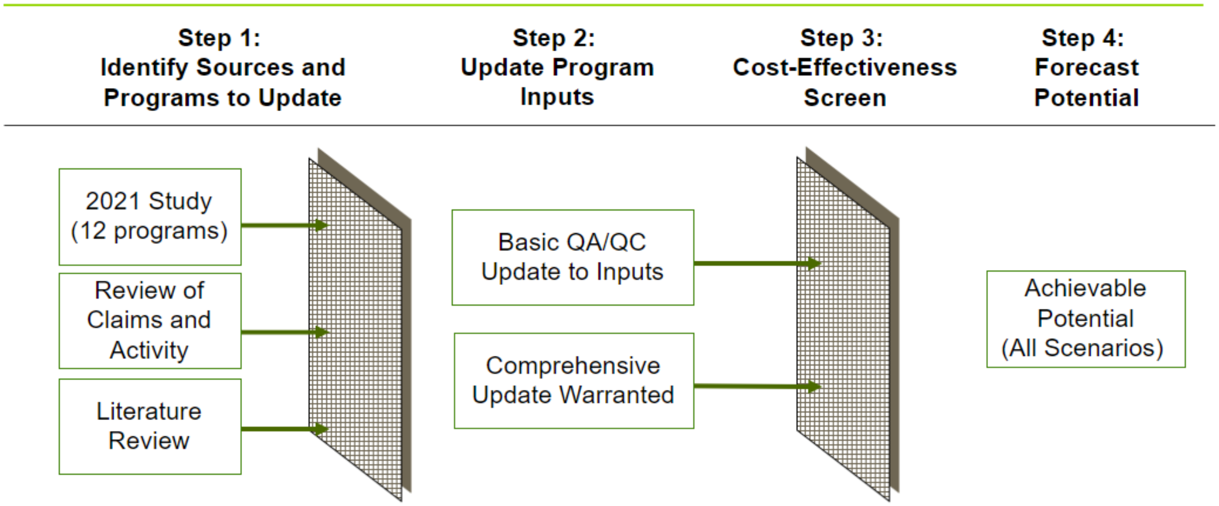
Source: Guidehouse 2019 based on communications with CEC Staff

The team scaled 2019 Title 24 claimed savings based on the Incremental Savings toward 2028 Target column in Table 3-25 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.

3.8 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- illustrates the process used to update BROs measures in the 2023 Study.

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



Source: Guidehouse

[62] Opinion Dynamics, *Final Report: Appliance Standards Vol. 1 CPUC Energy Efficiency Program Evaluation of Group B Sectors,* May 21, 2021, Table 13.

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 2021 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 such as 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 2021 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 2035 and, for programs with little evidence of implementation through 2022, updating the starting year in which non-zero penetration rate begins to 2023.

Based on the review in Step 1, the Guidehouse team identified only the HERs program for more thorough updates in the 2023 Study.

As with the 2021 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 SEM programs were assigned an EUL of 4.3 years, while commercial SEM-like programs were assigned an EUL of 5 years.

Appendix D details specific modeling inputs for each intervention type.

Step 3. 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 scenario.

Many intervention types were characterized to forecast potential. A more detailed description of each of the final intervention types follows in Table 3-26.; Appendix D includes additional details.

Table 3-26. Behavioral Intervention Summary

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 with 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 with other individuals or groups as they try to reach goals by reducing energy consumption	1
Residential	Universal Audit Tool (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 midsize 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 with 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	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)
Commercial	Building energy and information management system (BEIMS)	Enables building operations staff to achieve significant energy savings by monitoring, analyzing, and controlling building system performance and energy use; BEIMSs 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 EE 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 RCx 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 might further preclude IOUs from claiming savings, the team included benchmarking only in the aggressive BROs scenario.

Source: Guidehouse

3.8.1 Data Rigor

The Guidehouse team conducted an extensive industry scan for data on BROs initiatives for the 2019 and 2021 Studies and only for HERs in 2023. The team found that many of these programs are still relatively new and learning about their effectiveness is ongoing. The published data has studies with different levels of statistical rigor on the data around energy savings resulting from these interventions. Table 3-27. provides a snapshot of the quality of data collected for these studies. Across the board, demand savings data is often limited, and cost data is hard to obtain. No new primary research on BROs was conducted for the 2023 Study.

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. Examples of interventions that literature claims to show promise, though limited verified data exists, include prepay programs, commercial SEM, building benchmarking, competitions, web-based feedback, and in-home real-time feedback.

Table 3-27. Qualitative Assessment of Data Quality

Sector	Program	Savings			Cost	Applicability	Participation Rate	Penetration Forecast	Major 2023 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 2021 Potential and Goals Study

Source: Guidehouse

4. 2023 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 2023 Study is the basis for the CPUC's 2024 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. 2023 Study Key Findings and Implications

Key Finding	Implication
1. The savings potential from C&S measures represents a significant portion (46-78%) of the potential highlighted in this study.	C&S savings show approximately 2,340 GWh and 56 MMtherms in 2024, a 3% reduction and 43% increase respectively versus the 2021 Study. C&S 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.
2. FS implementation remains in a relatively early stage, however application of actual historic and near-term planned program activity indicate a lower potential than past study results have shown.	The 2023 Study's analysis used existing program data for the first time to quantify the adoption parameters applied FS measure & end use-specific adoption parameters. The result was a significantly lower (81-90%) overall achievable potential compared to the 2021 Study. Scenarios accounting for IRA tax credits do show a significant increase in the FS potential for Residential measures in particular.
3. The savings potential from BROs programs represents a significant portion of the first-year savings potential.	BROs programs has higher first-year savings than rebate program measures. However, when reviewing TSB results, the scale of BROs impact is much smaller. Additionally, this study does not screen cost-effectiveness resulting in some of BROs programs as not cost-effective.
4. Industrial and agriculture sector shows an increasing sector savings potential trend.	CEDARS data overall showed lower costs associated with unit energy savings, leading to a moderate increase in Industrial and Agricultural sector achievable potential overall. SEM savings were removed from the Agricultural sector potential, as recent program activity has been absent in this program category.
5. The tax credits specified by the IRA are expected to have a measurable but overall moderate impact on Residential and Commercial Sector potential.	Precise impacts of the IRA are difficult to predict, however the assumptions employed in the 2023 Study do indicate they will impact the cost-effectiveness and eventual market adoption of applicable EE and FS measures. The largest impacts are likely to occur due to the larger credits eligible to be claimed for heat pump (HVAC and water heating) measures, in Residential markets.

Source: Guidehouse

4.1 Summary

The 2023 Study provides a rich dataset of results, the details of which can be found on the CPUC's 2023 Potential and Goals website.[63] The report presents results by program type:

[63] https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/energy-efficiency/energy-efficiency-potential-and-goals-studies/2023-potential-and-goals-study

- **EE equipment:** EE traditionally incentivized by IOU programs are modeled in the study. This specifically excludes FS.
- **FS:** FS 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 FS.
- **Behavior, retrocommissioning, and operational efficiency (BROs):** These programs are based on customer changes that may not rely on any new equipment installations. BROs programs are a key driver of the total first-year savings. However, the impact that BROs have on TSB is limited due to the shorter measure life.

C&S savings are provided separately. The evaluated IOU advocacy for the development of new C&S and level of adoption in the marketplace are the source for the C&S savings.

Total Achievable Potential

Table 4-2 shows results in the year 2024. It shows the achievable potential results for each program type (EE equipment, FS, and BROs) for the scenarios listed in Table 2-10. Table 4-2 also includes the 2021 Study scenario that was used by the CPUC to inform previous goals as a comparison.

Table 4-2. 2022 Net First-Year Incremental Savings by Scenario (Statewide)

Savings Metric	Program Type	2021 Goals Scenario	1: No IRA	2: Reference IRA and FS	3: Reference IRA and Aggressive FS	4: Aggressive IRA and Reference FS
Total System Benefit (TSB) ($ Millions)	FS	$73	$20	$25	$532	$25
	BROs	$76	$132	$132	$132	$132
	EE Equipment	$166	$357	$377	$377	$379
	Total	**$316**	**$509**	**$534**	**$1,041**	**$536**
Electric Energy (GWh/Year)	FS*	-151	-16	-21	-195	-21
	BROs	578	507	507	507	507
	EE Equipment	119	148	168	167	169
	Total	**546**	**639**	**654**	**480**	**655**
Converted Electric Energy (GWh/Year)**	FS	446	62	88	1,476	89
	BROs	578	507	507	507	507
	EE Equipment	119	148	173	173	174
	Total	**1,143**	**717**	**763**	**2,151**	**765**
Electric Demand (MW)	FS*	-15	-1	-1	-6	-21
	BROs	126	92	92	92	92
	EE Equipment	23	48	53	52	53
	Total	**134**	**140**	**145**	**139**	**145**
Gas Energy (MMtherms/Year)	FS	20	3	4	57	4
	BROs	25	21	21	21	21
	EE Equipment	12	19	19	19	19
	Total	**57**	**42**	**44**	**97**	**44**

Source: Guidehouse

* FS impacts reflect additional electric energy consumption, resulting in negative savings and peak demand impacts
**Converted Electric Energy represents the net reduction in energy consumption resulting from FS, calculated by converting gas energy units to equivalent electric energy units

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 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. The lower proportion of overall Achievable savings represented by BROs in 2023 versus the prior study cycle results in a substantially larger increase in TSB.
- FS has a comparatively low overall impact on TSB in three of the four Scenarios, although the model does indicate this has the potential to grow significantly in subsequent years. TSB reflects both gas and electric fuels, and positive gas benefits (and electric benefits, if applicable) are reduced by increased electric supply cost (which negatively impacts TSB).

The following are notable takeaways from the savings results:

- Electric and gas savings from EE equipment overall increase relative to the previous goals. Higher statewide potential for rebated EE measures is driven primary by Residential and Industrial Sectors. Commercial sector savings decreased slightly in the Scenario 1 but is higher in Scenarios 2-4. BROs savings forecasts are lower due to the additional HER bins included in the 2023 Study.

- FS's impact on electricity and gas consumption is significantly lower than the 2021 Goals Scenario for 2023 Scenarios 1, 2, and 4. This result of the modeled potential outputs being calibrated using FS-specific historic and 2022 budget data, is in contrast to the 2021 Study where EE-specific adoption parameters were applied to all cost-effective FS measures due to a lack of data for IOU FS programs.

- Assumptions included in Scenarios 2, 3, and 4 indicate that the IRA will have a measurable impact on both EE and FS adoption. IRA tax credits have the primary impact of making more measures cost-effective, and the provision for additional eligible tax credits for Residential Heat Pumps and Heat Pump Water Heaters represent the primary driver of increased potential across sectors for FS between Scenario 1 and the remaining three IRA-inclusive Scenarios.

- Scenario 3 applies EE-based adoption parameters to FS measures, resulting in a dramatically higher calculated achievable potential and relatively lower EE potential versus Scenarios 2 and 4, both of which also included IRA tax credits, due to a comparatively greater proportion of the population adopting FS measures over EE measures. While this may indicate a potential future state of the California market where FS programs and measures are much more mature, the Guidehouse team believes it represents a much less realistic scenario for the immediate IOU goal setting period.

4.2 Incentive and BROs Program Savings

This section summarizes statewide achievable potential results for each scenario. 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 4.5 for details). All results are presented as net savings. All results are inclusive of interactive effects[64] and include FS 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 2023 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 TSB electric savings, peak demand impact, and gas savings. Full results for all scenarios and all utilities are available in the Results Viewer (discussed further in Section 4.5).

This section describes primarily the high level scenario results "top line" (the sum of EE equipment, BROs, and FS for all sectors and IOUs). The findings primarily show the impact of differences across levers for the four scenarios:

- Scenario 1 serves as the reference or "business as usual" case, and most directly compares to the 2021 Scenario used to set the EE goals.
- IRA tax credits for residential and commercial EE and FS measures identified within the law as eligible:
    - Scenarios 2 and 3 represent the assumptions detailed in Section 2.1.7 for the Residential sector and a conservative set of assumptions for the commercial sector.
    - Scenarios 4 represent the above noted assumptions for the residential sector and more aggressive set of assumptions for the commercial sector.
- Capped incentives
    - Scenarios 1, 2, and 4 include Incentives capped at 50% and 75% of measure incremental cost for EE and FS, respectively,
    - Scenario 3 increases the incentive cap to 75% for EE and 90% for FS measures.
- FS
    - Scenario 3 applies the calibrated EE market-specified adoption parameters to all measures including FS representing a more aggressive scenario overall for this measure type.

Details of the findings at the measure, end use, sector, and utility level are available in the data files and viewers.

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

- Equipment rebate program savings, which include savings from discrete equipment including FS, whole building, and shell measures, are different for each scenario based on parameters discussed in Section 2.3.
- BROs savings do not vary by scenario. Section 4.2.4 provides additional detail regarding BROs savings by year. BROs residential savings includes low income and

[64] 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.

non-low income customers since these programs are applicable to all customers independent of income. Furthermore, there are no low income specific BROs programs.

- C&S savings do not vary by scenario and are not presented in these three figures. C&S savings are in Section 4.4.

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

4.2.1 TSB by Scenario

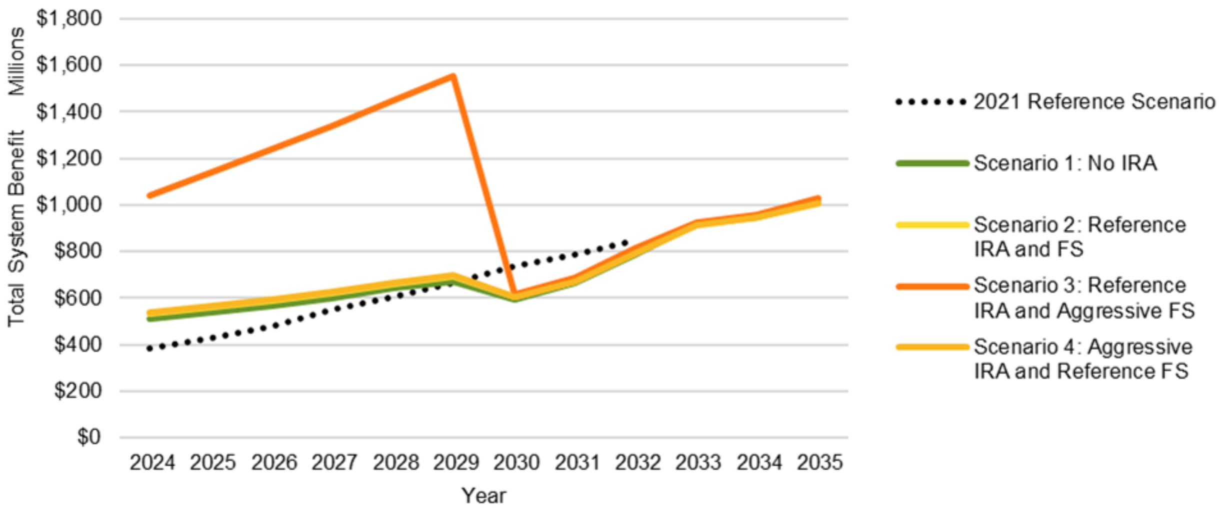
Achievable TSB across all sectors follow the same trend directionally as electric energy impacts, however increases are proportionally larger due to the relative mix of rebated measures versus BROs. Figure 4-1 shows the TSB by scenario including rebate (FS and EE equipment) and BROs programs. TSB output from Scenario 3 is not comparable to the other scenarios due to the dramatic increase in calculated FS potential.

TSB generally increases over time, and the trends and shape (except for Scenario 3) do not vary significantly across scenarios. The modeled achievable TSB in 2024 in Scenarios 1,2, and 4 is 32%-39% higher in this study compared to the 2021 Study, although the comparative increase declines in subsequent years. A notable departure from the year-over-year trend occurs in 2030 when Gas EE and FS potential decreases significantly due to the CARB SIP decision to propose banning many natural gas appliances. 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.

The following are notable takeaways from the TSB results:

- As opposed to first-year electric and gas savings, BROs amount to a much smaller proportion of TSB. This is due to 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.
- FS has a small overall impact on TSB except for Scenario 3. FS savings in all scenarios provide lower TSB impacts relative to their nominal gas savings impacts. This is because TSB reflects both gas and electric fuels, and positive gas benefits (and electric benefits, if applicable) are reduced by increased electric supply cost (which negatively impacts TSB).

Figure 4-1. TSB ($) by Scenario



Source: Guidehouse

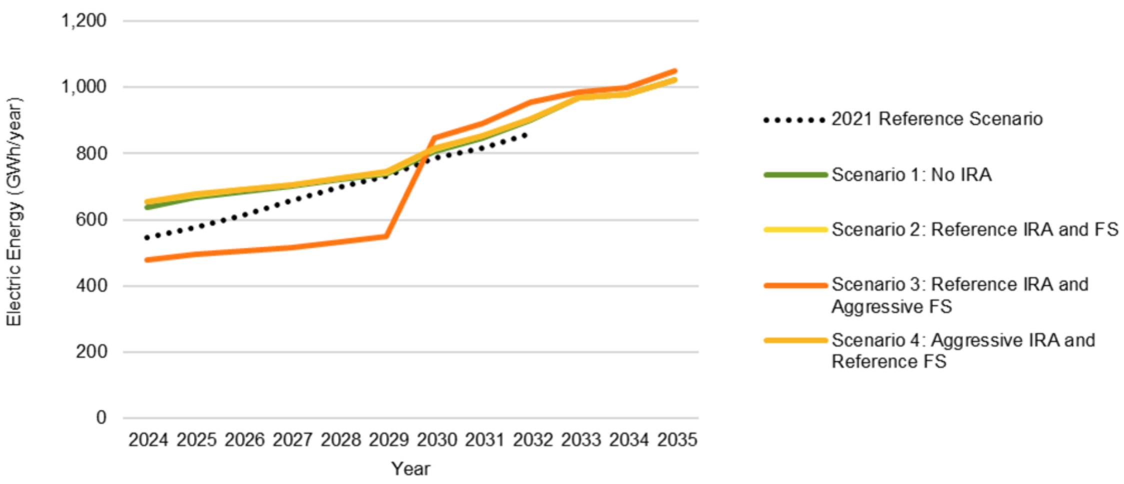
4.2.2 Total Savings by Scenario

Figure 4-2 to Figure 4-4 provide the top line savings (electric energy, peak demand, and natural gas) by scenario for the 2024-2035 forecast period. After the first few years, savings potential from all scenarios for electric savings tend to be lower, except for the aggressiveness in Scenario 3, from the previous goals. Gas savings are higher than the previous goals due to the impacts of FS. The larger increase in Scenario 3 is due to aggressive assumptions about BROs programs. Key findings include:

- In all scenarios, electric energy and peak demand impacts from EE equipment increase relative to the previous goals. BROs savings forecasts decreases are driven by modified assumptions regarding the treatment of HER delivery expansion to new residential IOU customer groups. While impacts from EE alone are lower, aggregate increases in electric energy and demand impacts for all measure types are mostly tied to the reduced potential for FS versus the 2021 Study. Consistently, gas impacts reflecting EE and FS combined are smaller due to lower achievable FS.
- The incorporation of IRA tax credits was shown to impact overall statewide achievable electric energy impacts by approximately 0.5%-1% in most years, and gas impacts by 7% on average. Gas impacts tied to the IRA are primarily driven by increased Residential FS potential. Applying a more aggressive set of assumptions for Commercial IRA tax credits did not impact overall potential to a significant degree, indicating the nonresidential sector is relatively less responsive to measure cost changes of this magnitude.
- FS impact on electricity use is lower in Scenarios 1, 2, and 4. Scenario 3's more aggressive application of FS market adoption characteristics yields a higher overall potential than the 2021 Reference Scenario, however this is not likely to be a realistic outcome of planned market interventions within the near-term planning period. FS potential in all scenarios drops significantly in 2030 as a result of the CARB SIP decision to propose a rule banning the sale of new natural gas space and water heating measures in the residential and commercial sectors for which there is a

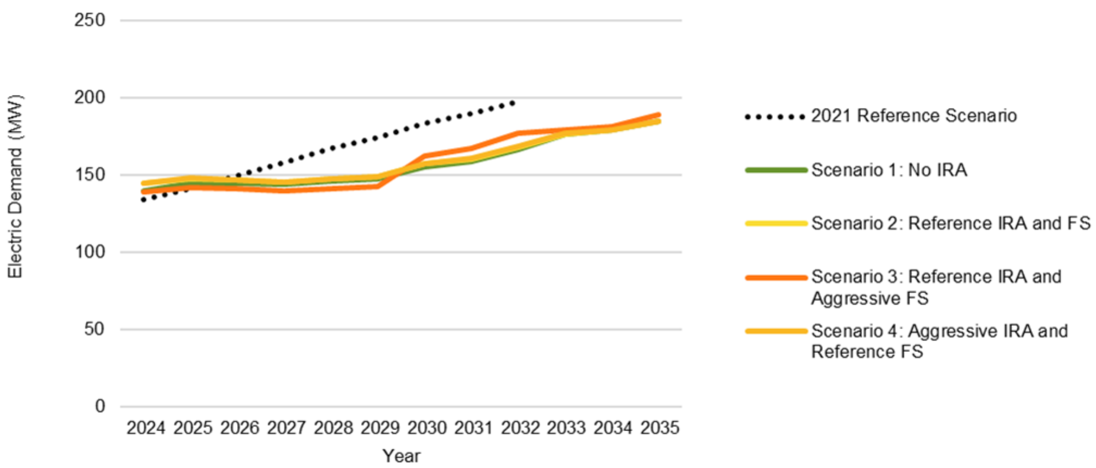
viable electric alternative. This has the effect of eliminating most options for gas appliances that define adoption of an electric technology over a competing gas technology.

Figure 4-2. Statewide Net First-Year Incremental Electric Savings by Scenario



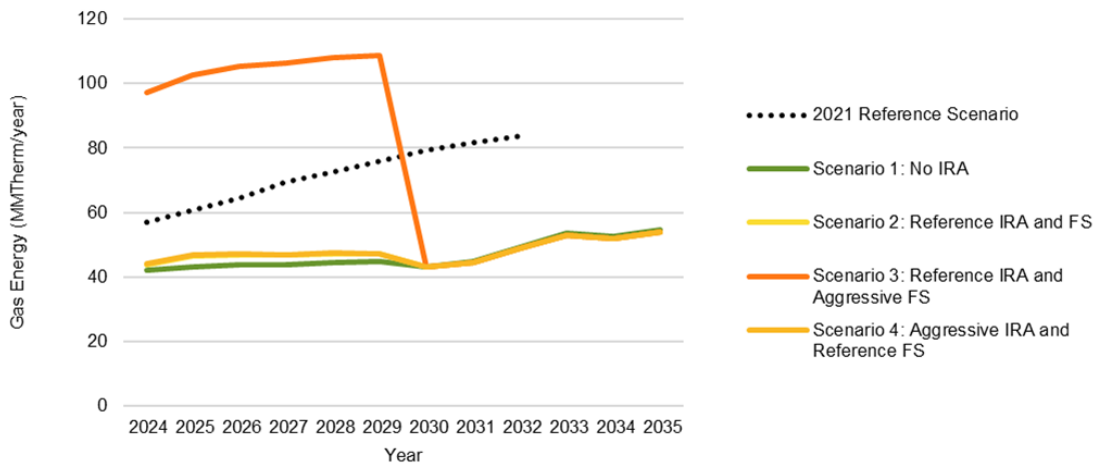
Source: Guidehouse

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



Source: Guidehouse

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

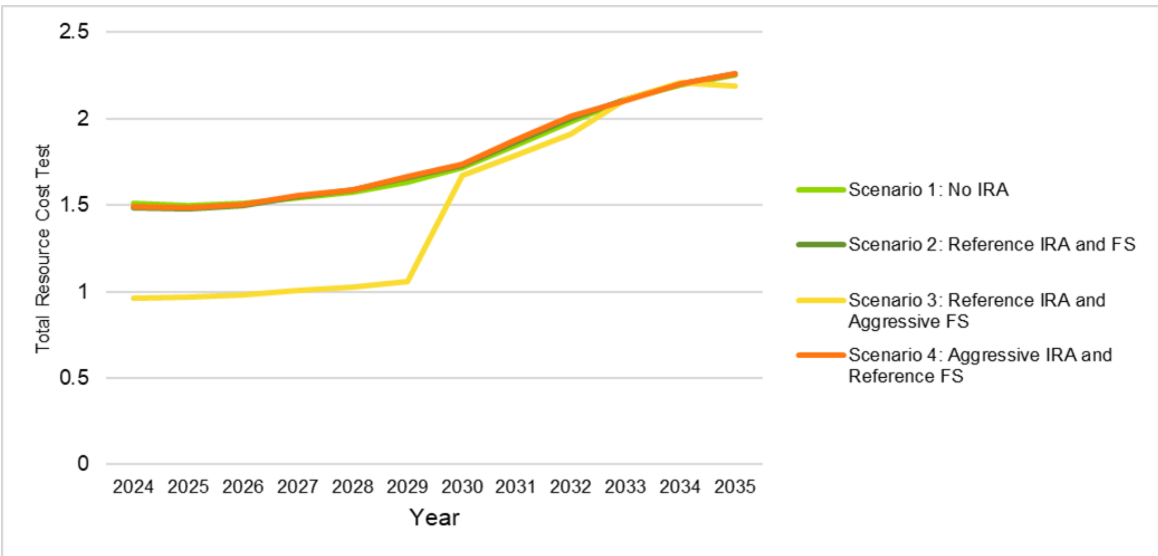


Source: Guidehouse

4.2.3 Cost-Effectiveness by Scenario

Figure 4-5 provides the statewide TRC ratio for each scenarios in each year of the study. 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 4-5. TRC Test Benefit to Cost Ratio by Scenario



Source: Guidehouse

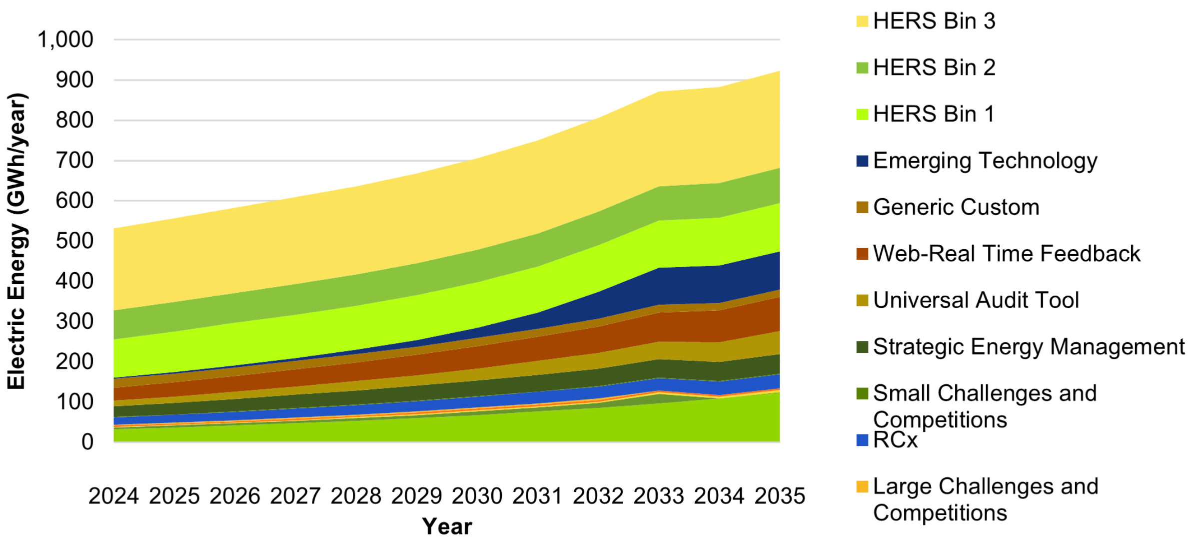
The aggregate TRC ratio for Scenarios 1, 2, and 4 all start at or near 1.5 and remain relatively consistent through 2027. The Aggressive FS assumptions in Scenario 3 lead to much larger assumed program costs, driving cost-effectiveness down prior to the 2030 natural gas appliance ban, subsequent to which the reduction in FS potential brings the cost-effectiveness in close alignment with the other Reference FS Scenarios. All scenarios show statewide TRC growing significantly in the 2030-2035 period, in alignment with concurrent growth in forecasted avoided costs. The separate IOU-specific TRC ratio varies from as low as 0.82 in 2024 for SCE for Scenario 3 to as high as 2.9 for SCG for Scenario 2-4.

4.2.4 BROs Program Results

The next set of figures are the BROs program savings. These savings are independent of the avoided costs since they are not screened by cost-effectiveness. The program adoption rates are based on the program rollout and participation assumptions outlined in Appendix D.

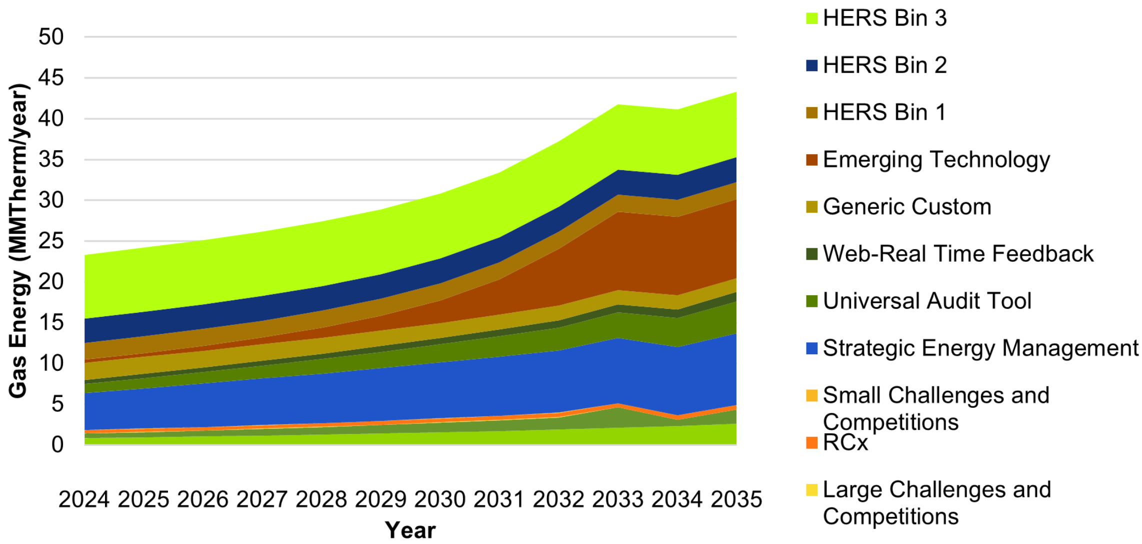
Figure 4-6 and Figure 4-7 provide BROs impacts for electric and gas fuel types across all sectors, detailed by BROs intervention. BROs savings grow over time as program participation rates increase. The residential HERs program dominates the BROs savings for electric and gas energy and peak demand savings. Web-based real-time feedback for residential and BIEMS for commercial show significant electric energy and peak demand savings. Industrial SEM shows significant gas savings.

Figure 4-6. BROs Program First-Year Electric Energy Savings by Program Type



Source: Guidehouse

Figure 4-7. BROs Program First-Year Gas Energy Savings by Program Type



Source: Guidehouse

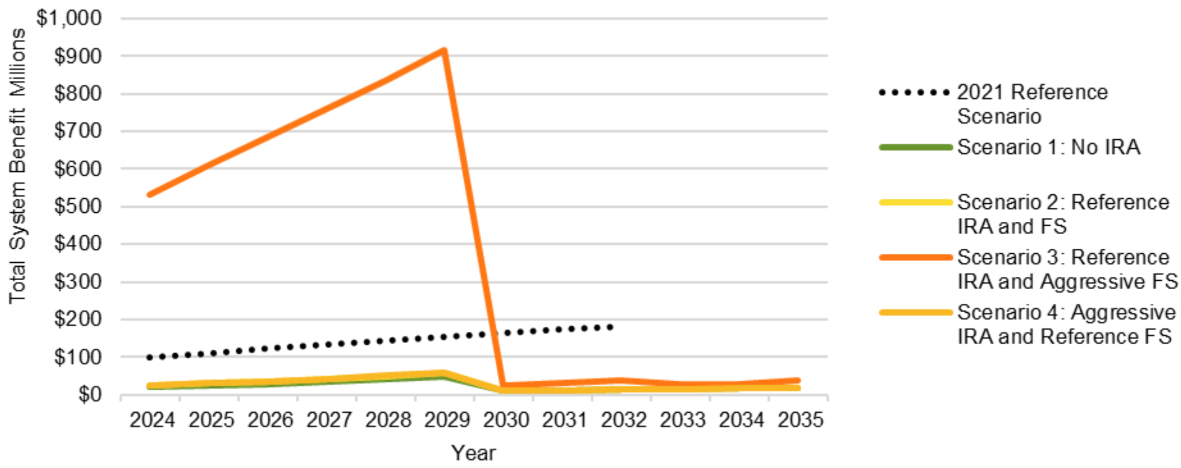
4.3 FS

This section provides FS-specific results. Overall, the 2023 Study indicates lower statewide achievable FS potential than was presented in the 2021 analysis. The primary driver of this reduction is the incorporation of FS program data during the calibration process for the potential model. This represents an update to the prior study, which applied EE data-derived adoption parameters due to a lack of available FS program data. This impact is further illustrated through the 2023 Scenario 3 results, which applies market adoption parameters at the sector and end use level that were generated through historic EE program filings.

4.3.1 Results

For all scenarios that Figure 4-8 shows, the FS potential benefit growth rate is steady through 2030 over time but with notable drop in 2030 reflecting the impact of the CARB SIP appliance decision that removes much of the FS potential for Water Heating and HVAC end uses. All achievable FS potential subsequent to 2030 is generated by commercial Food Service end use measures.

Figure 4-8. FS TSB ($) by Scenario

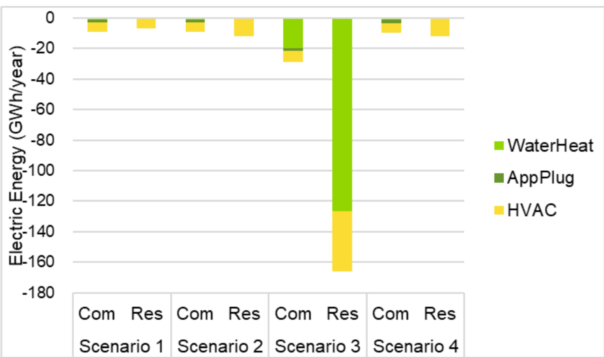


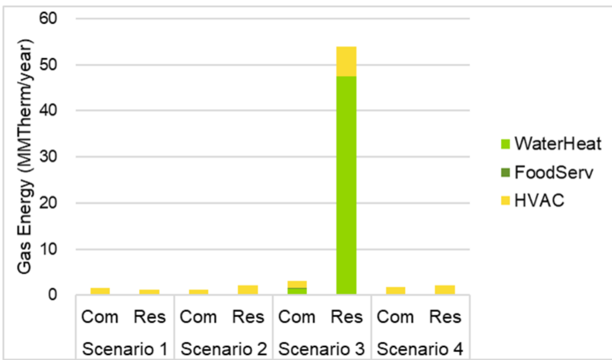
Source: Guidehouse

Figure 4-9 shows electric consumption increase and natural gas consumption decrease (savings) resulting from achievable FS impacts in 2024 for the four scenarios. All FS measures in the analysis pass the FST[65] independent of cost-effectiveness or customer adoption metrics.

In scenarios 1, 2, and 4, HVAC measures are the primary driver of overall FS potential prior to 2030 ranging from 79 to 83%. The aggressive Scenario parameters in Scenario 3 drive Water Heating measures to a significantly larger degree in both Residential and Commercial sectors. At the sector level, Commercial FS potential on an energy and TSB basis is higher than Residential in the No IRA reference scenario. Incorporating the impact of tax credits has a proportionally larger impact on Residential measures and yields larger overall potential in Scenarios 2-4, indicating this sector has a greater sensitivity to measure cost at the levels specified by the IRA. Food Service end use also generated impacts within the commercial sector, however it represents a lower proportion of overall achievable potential prior to 2030.

Figure 4-9. FS Electric and Gas Energy Impacts in 2024





[65] California Public Utilities Commission, *Decision Modifying The Energy Efficiency Three-Prong Test Related to Fuel Substitution*, 2019. CPUC Decision 19-08-009 specifies that to be 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).

Note: Negative electric savings indicated an increase in electricity use due to FS.

Source: Guidehouse

4.4 C&S Savings

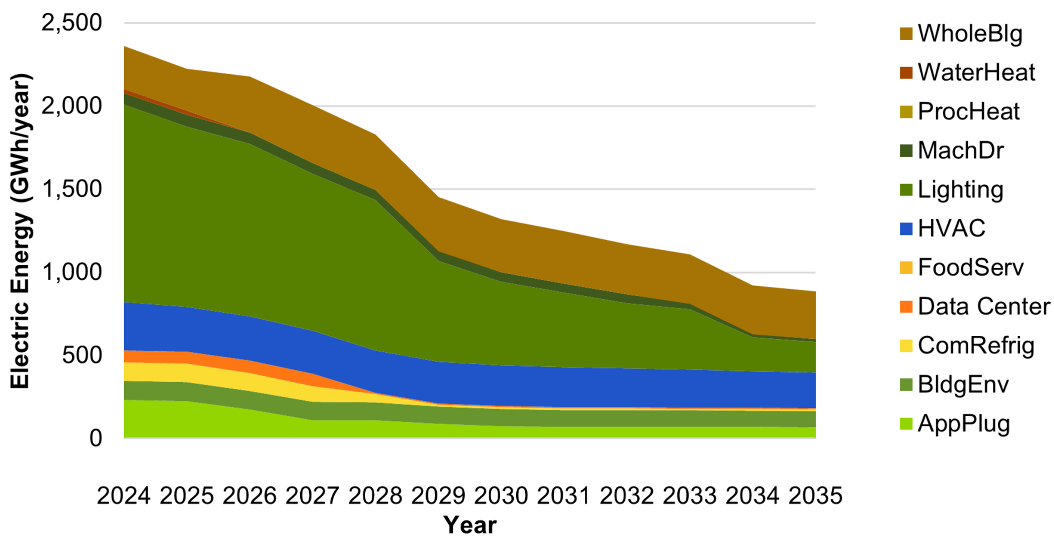
Incremental annual savings from on-the-books and expected C&S are illustrated in Figure 4-10 and Figure 4-11. Unlike results displayed earlier in this section, C&S savings do not vary by scenarios because there are no modeled policy or program design decisions under the purview of the IOUs or CPUC that influence C&S savings.

Electric savings from on-the-books C&S have increased by 14%-25% relative to those estimated in the 2021 Study, with larger increases shown in the earlier years of the 2023 Study. 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:

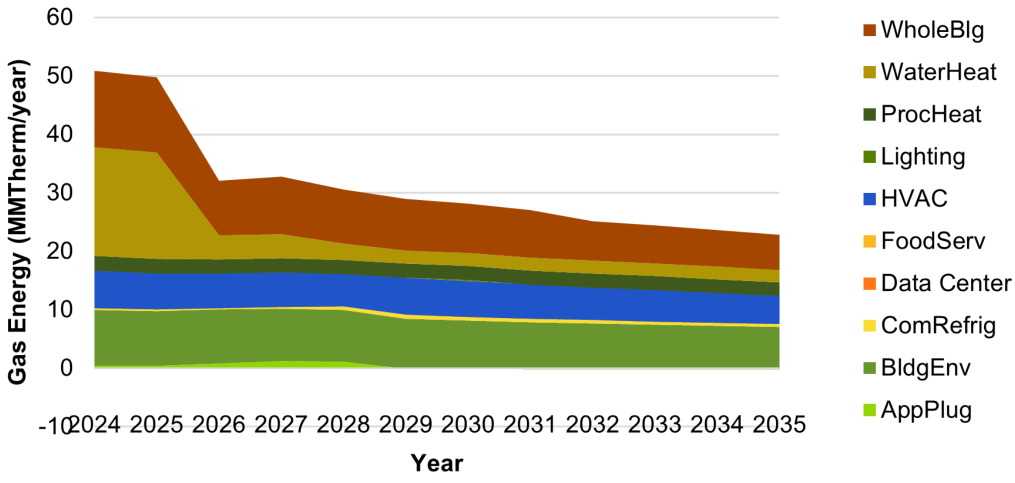
- The evaluation shows a decrease in savings from lighting-related standards relative to those estimated in the 2021 Study.
- The evaluation database shows a truncated stop in the claimable new installations of multiple high efficiency water fixtures that leads to the drop in gas savings in 2026. These standards went into effect in 2015 and have a 10-year measure life.
- This evaluation quantified the impact of the 2016 vintage of Title 24 building codes.

Figure 4-10. C&S Electric Savings (Including Interactive Effects)



Source: Guidehouse

Figure 4-11. C&S Gas Savings (Including Interactive Effects)



Source: Guidehouse

Additional versions of Figure 4-10 and Figure 4-11 for each IOU and including peak demand savings can be found in the Results Viewer, under the Codes & Standards tab.

4.5 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 2023 PG Results Viewer and a measure-level database. The Results Viewer allows stakeholders to manipulate and visualize model outputs. A separate spreadsheet database of measure-level results for rebate (EE, FS, and BROs) 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, and agriculture
- **End Use category:** Includes appliances and plug loads, lighting, HVAC, data centers, building envelope, commercial refrigeration, process heat and refrigeration, water heating, and food service. Whole building and BROs are also identified as end use categories
- **Measure type:** EE, FS, or both

4.5.1 Results Viewer Tabs

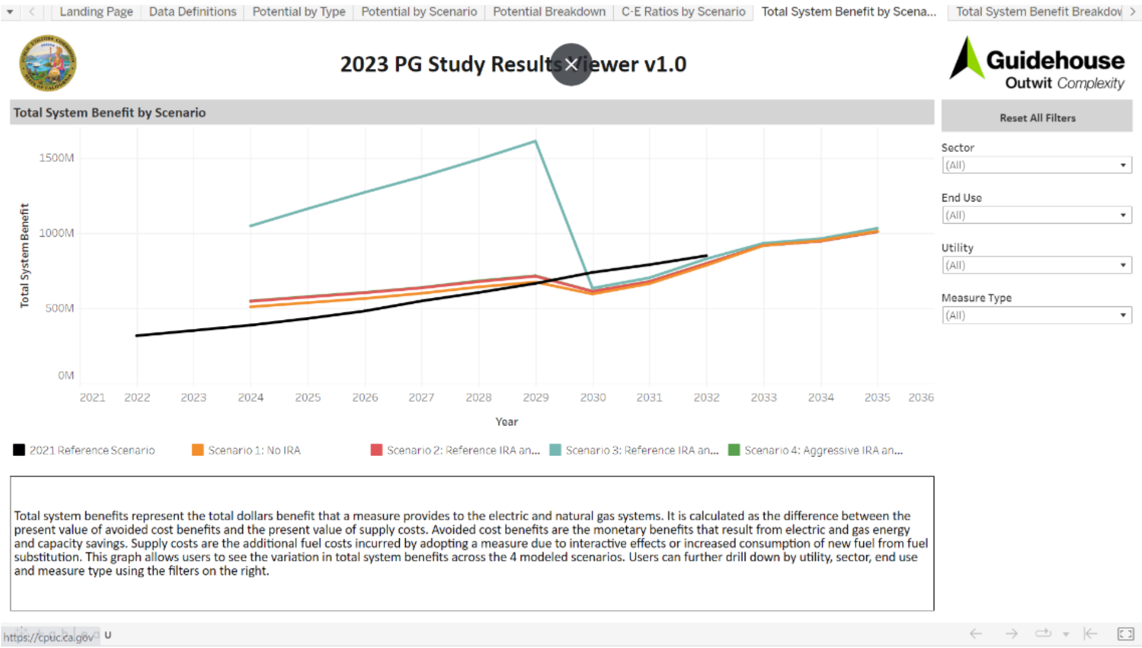
The full Results Viewer can be found at: https://bit.ly/2023PGViewerV1v The Results Viewer consists of 11 tabs. The Landing Page and Data Definitions tabs give a short overview of the project and provide key definitions used throughout the results tabs. The remaining nine tabs allow users to view and 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 only show IOU claimable savings from behavior and C&S advocacy programs. for the cumulative achievable potential result, because the technical and economic potential for these sources are undefined. 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, PAC, participant cost (PCT), and ratepayer impact measure (RIM) tests.
- **TSB 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.
- **TSB 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.

- **C&S 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.

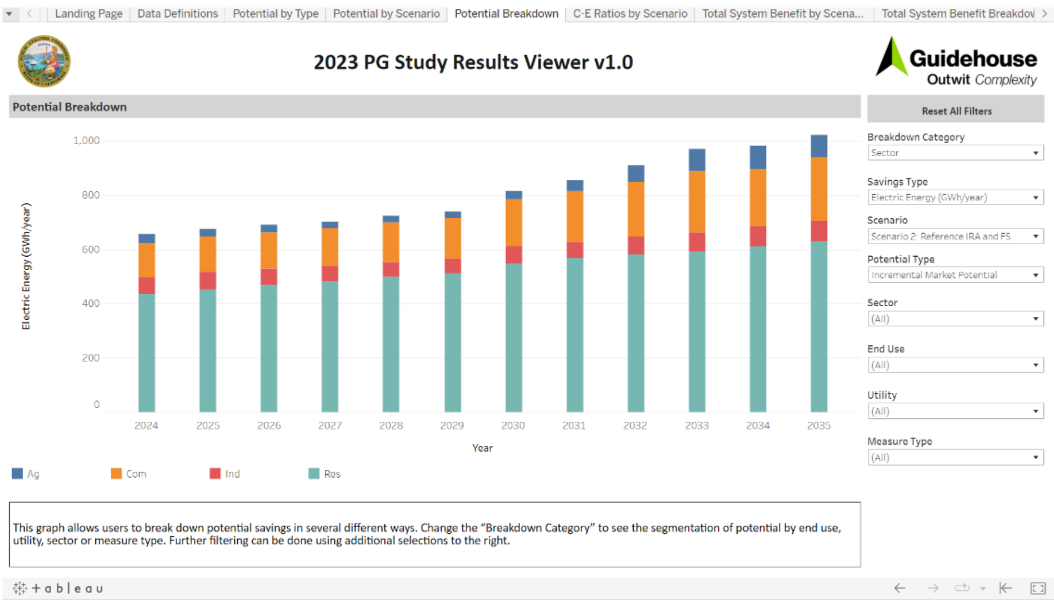
Each results tab includes a description of the viewable data, a dynamic chart, and drop-down filters for available chart configuration dimensions. The viewer is illustrated in Figure 4-12 and Figure 4-13.

Figure 4-12. Results Viewer TSB by Scenario (Illustrative)



Source: Guidehouse

Figure 4-13. Results Viewer Potential Breakdown by Sector (Illustrative)



Source: Guidehouse

5. Impacts of Future Policy on Potential

The 2023 PG Study results detailed in Section 4 reflect the impact of several statewide and Federal policies designed to address broad decarbonization goals. Notably, the planned 2030 CARB decision prohibiting the sale of new natural gas appliances in California and IRA tax credits both were identified as having a significant expected impact on achievable EE and FS potential. Two additional future policies were considered during this Study cycle but ultimately were not included in the 2023 PG Model and results described in the above sections – the proposed partial EE Natural Gas Incentive Phase Out and the EE rebate programs introduced through the IRA. Further detail on each, as well as discussion regarding their consideration in the context of the 2023 PG Study analysis, are in the following sections.

5.1 Partial EE Natural Gas Incentive Phase Out

In July 2022, the CPUC released a proposal outlining "an orderly and gradual transition away from using IOU ratepayer funds to incentivize natural gas EE measures."[66] The proposal was developed in response to a motion filed by Sierra Club in early 2022, as well as a recognition of the general trends in statewide and national EE C&S. The proposal sought to phase out many IOU-administered incentives for natural gas efficiency measures for which there is a viable electric alternative. At the April 6th, 2023 voting meeting the Commission unanimously approved a decision that included a pared down version of the policy in the staff proposal. The April 6th decision defines the elimination of rebates for non-exempt, non-cost-effective measures installed within newly constructed homes and facilities serving Residential and Commercial sectors. Exempted measures are defined as those for which natural gas is not directly consumed, for example building envelope, weatherization, and thermostat measures. The decision also directed Commission staff to create a Viable Electric Alternative (VEA) Technical Guidance Document (TGD) that would allow the new construction policy to be expanded to other gas measures by defining VEA.

As of the drafting of this PG Study the decision had not been approved, however Guidehouse worked with CPUC to assess the potential for this policy to impact the achievable potential detailed within the results.

To assess the degree to which this expected initial track will impact the goals set by the 2023 PG Study Guidehouse examined both the savings claimed during the study's calibration period (2018 – 2022) and the first four years of the 2023 Study (2024-2027) for Southern California Gas (SCG) and identified the total proportion of these past and forecasted savings that would be impacted as non-exempt, non-cost-effective, and impacting only new construction. For all historic measure-level SCG EE claims data available from CEDARS for the period identified above, the Guidehouse team found a total of 1.8% of savings on a first-year net MMtherm basis would meet the criteria identified above.

Examining the 2023 PG Study's Scenario 1, the Guidehouse team found negligible non-cost-effective gas savings potential for SCG in 2024-2027 outside of the Residential whole building new construction (ZNE measure). This ZNE measure, accounting for a total of just under 2% of achievable potential, is defined as technology agnostic, meaning conceptually it could account for any building equipment or system, including non-exempt measures. Given the low overall calculated proportion of both historic and forecasted savings that would be impacted by the expected initial phase of the decision, Guidehouse did not adjust the total

[66] https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/energy-efficiency/rolling-portfolio-program-guidance/ng-staff-prop-81622.pdf

achievable potential for any of the 2023 PG Study Scenarios based on this policy. However, the April 6th decision directs the Commission staff to include the new construction policy, as well as the VEA TGD, in the 2025 Potential and Goals Study.

5.2 IRA EE Rebate Programs

The Inflation Reduction Act of 2022 defined specific tax credits which are available to individuals and businesses who adopt defined EE and FS measures between 2023 and 2032, and these are accounted for within the 2023 PG Study as discussed in previous sections and Appendix J. In addition to tax credits, the IRA includes:

- $4.3 billion to award grants to state energy offices (SEOs) to develop and implement Home Energy Performance-Based Whole House Rebates, also known as a **HOMES (Home Owner Managing Energy Savings) rebate program**, and
- $4.5 billion available to SEOs and Indian tribes to implement **High-Efficiency Electric Home Rebate (HEEHR)** programs. A further $200 million is appropriated for SEOs to provide training and education to contractors involved in these rebate programs.[67]

While these programs are anticipated to significantly influence the adoption of EE and efficient electrification measures, the programs themselves have not been defined as of the completion of this study in terms of allocation of the specified funding to California, specific eligible measures, eligible customers, incentive amounts, or time frame. Due to these uncertainties, incentives from future IRA-funded rebate programs were not included in the 2023 PG Study. Guidehouse will work with the CPUC and CEC as well as other California stakeholders to develop a comprehensive understanding of how the HOMES and HEEHR programs ultimately influence statewide EE goals and accomplishments. The Guidehouse team recommends considering further the inclusion of these IRA measure rebates in future PG Study cycles.

[67] https://crsreports.congress.gov/product/pdf/IF/IF12258/2?itid=lk_inline_enhanced-template#:~:text=High%2DEfficiency%20Electric%20Home%20Rebates&text=The%20IRA%20also%20funds%20rebates,%2C%20air%20sealing%2C%20and%20ventilation.

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 the fact 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.
- Establish 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 based on historical program and market data from 2018 through 2021 for EE measures, and Q1 – Q2 2022 data for fuel substitution (FS) measures. Program accomplishments prior to 2018 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. Due to the recency of rebated FS parameters, no reliable data on FS adoption prior to 2022 was available. For the calibration, any new measures or programmatic aspects not applicable in the historical years were removed from the analysis to optimize the PG Model compatibility to the historical period.

A.2 Necessity of Calibration

SB 350 directs the following: “In assessing the feasibility and cost-effectiveness of EE savings … the Public Utilities Commission shall consider the results of EE potential studies that are not restricted by previous levels of utility EE 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 into the model are provided at the sector and end use level, yet calibration allows the Guidehouse 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. Straight averaging of customer willingness and awareness may not lead to the correct total savings and costs calculations due to unevenness of adoption of technologies.
- 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 reflect more accurately 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 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 2018-2021 program data (gross savings, program spending data) and performs a backcast to fit model parameters such that historical achievements are generally matched. Q1 – Q2 2022 program data was used to calibrate FS measures, as it was the only year for which historical achievement data was available.

The Guidehouse team calibrated by reviewing the EE portfolio data from 2018 through 2021 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 2018-2021 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 2018 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, the 2019 Residential Appliance Saturation Study (RASS) 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 2018-2021. Guidehouse made individual adjustments to four 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 CG. • 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 agriculture, industrial, and mining [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.
Adoption	• Adjusting adoption of FS measures enables better alignment of the model’s backcast with limited historic program data.

Source: Guidehouse

The 2023 PG Model is informed by the 2021 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 2023 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. FS Methodology Details

The potential and goals study characterized FS 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 FS technologies and formulate technology groups.

- The Guidehouse team considered FS measures in the residential and commercial space heating, water heating, appliance, and cooking end uses.
- The team excluded technologies that did not pass the CPUC fuel substitution test (FST)[68] or that did not have a technically suitable, commercially available electric equivalent to the gas technology being replaced.
- The team analyzed FS technologies in the same technology group as the gas technology being replaced. In other words, a FS 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 FS 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 FS 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 FS 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 FS 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.

3. Account for 2030 phaseout of gas technologies.

[68] As implemented by CPUC Decision 19-08-009, the FST specifies that to be 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). https://www.cpuc.ca.gov/about-cpuc/divisions/energy-division/building-decarbonization/fuel-substitution-in-energy-efficiency

- In September 2022, the California Air Resources Board published a memo to propose a "zero-emission standard for space and water heaters." [69] The Guidehouse team anticipates that this will effectively eliminate natural gas savings from FS measures from 2030 onward, because customers would not be able to install a new gas appliance in a new building or as a replacement for an existing gas appliance at the end of its life.

- The Guidehouse team accounted for this by removing the natural gas baseline and any competing natural gas efficiency levels from FS technology groups from 2030 onwards. From 2030 onwards, the "baseline" for that technology group is a low-efficiency electric appliance—in other words, the minimum cost and minimum efficiency product that the customer would be able to install at that point in time. This is a similar effect as other measures when a code or standard takes effect and removes non-code-compliant baseline products from the market.

- In August 2022, the CPUC released a staff proposal detailing a proposed policy to phase out many natural gas EE incentives.[70] In March 2023, a proposed decision based on the staff proposal was released that would eliminate EE incentives for non-cost-effective natural gas new construction measures.[71] Because this proposed policy had not been adopted by the CPUC when the 2023 Study's model was being created and run, the Guidehouse team did not include this it in the results. Further discussion regarding this proposed ruling and its consideration within the 2023 PG Study can be found in Section 5.2.

4. Calculate infrastructure costs.

- Substituting gas technologies for electric technologies can increase electric load for a building or house. This can sometimes require upgrades to the infrastructure within the building, for example, increasing the size of the electrical panel to accommodate the added load.

- The Guidehouse team, led by Opinion Dynamics, conducted a literature review to estimate the cost of a panel upgrade, as well as the likelihood that a given installation of FS technology would necessitate a panel upgrade.

- The team then incorporated these costs into the measure characterization by determining the proportion of installations of each technology that would be likely to require a panel upgrade, and including the cost of the panel upgrade for that proportion of installations.

- Appendix C contains the full literature review, including tables of costs and proportion of installations requiring a panel upgrade.

The following sections discuss the technology selection process and the technology characterization method in further detail.

[69] California Air Resources Board, "2022 State Strategy for the State Implementation Plan," Adopted September 22, 2022. https://ww2.arb.ca.gov/sites/default/files/2022-08/2022_State_SIP_Strategy.pdf.

[70] https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M496/K397/496397066.PDF

[71] https://docs.cpuc.ca.gov/SearchRes.aspx?docformat=ALL&docid=502981822

B.1 Technology Selection Process

The Guidehouse team followed a similar approach to the technology selection process as the other, non-FS measures, excluding 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 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).[72] The team assumed that measures with active workpapers had already been determined by the CPUC to pass the FST.

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 FS 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 FS 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. FS Technologies Characterized

Sector	End Use	FS Technology	Technology Group
Residential	AppPlug	Heat Pump Clothes Dryer	Clothes Dryers (Gas)
Residential	AppPlug	Heat Pump Pool Heater	Res Pool Heaters
Residential	AppPlug	Induction Cooking	Res Cooking Appliances
Residential	HVAC	Ductless Mini-Split Heat Pump (SEER* 15)	Res Ductless HVAC System – Fuel Sub
Residential	HVAC	Ductless Mini-Split Heat Pump (SEER 16)	Res Ductless HVAC System – Fuel Sub
Residential	HVAC	Ductless Mini-Split Heat Pump (SEER 17)	Res Ductless HVAC System – Fuel Sub
Residential	HVAC	Ductless Mini-Split Heat Pump (SEER 18)	Res Ductless HVAC System – Fuel Sub

[72] https://www.cpuc.ca.gov/about-cpuc/divisions/energy-division/building-decarbonization/fuel-substitution-in-energy-efficiency

Sector	End Use	FS Technology	Technology Group
Residential	HVAC	Packaged/Split Heat Pump (SEER 15)	Res Central HVAC System – Fuel Sub
Residential	HVAC	Packaged/Split Heat Pump (SEER 16)	Res Central HVAC System – Fuel Sub
Residential	HVAC	Packaged/Split Heat Pump (SEER 17)	Res Central HVAC System – Fuel Sub
Residential	HVAC	Packaged/Split Heat Pump (SEER 18)	Res Central HVAC System – Fuel Sub
Residential	HVAC	Res Furnace Heat Pump Heating Only (SEER 15)	Res Central Furnace Only – Fuel Sub
Residential	HVAC	Res Furnace Heat Pump Heating Only (SEER 16)	Res Central Furnace Only – Fuel Sub
Residential	HVAC	Res Furnace Heat Pump Heating Only (SEER 17)	Res Central Furnace Only – Fuel Sub
Residential	HVAC	Res Furnace Heat Pump Heating Only (SEER 18)	Res Central Furnace Only – Fuel Sub
Residential	Water Heat	Res Heat Pump Water Heater (3.30 UEF - 50 Gal)	Res Gas Water Heaters
Residential	Water Heat	Res Central Heat Pump Water Heater (3.00 COP, 150+ kBtuh)	Res Multifamily Central 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
Commercial	HVAC	Small Packaged Heat Pump (SEER 15)	Com Central HVAC (Small) – Fuel Sub
Commercial	HVAC	Small Packaged Heat Pump (SEER 16)	Com Central HVAC (Small) – Fuel Sub
Commercial	HVAC	Small Packaged Heat Pump (SEER 17)	Com Central HVAC (Small) – Fuel Sub
Commercial	HVAC	Small Packaged Heat Pump (SEER 18)	Com Central HVAC (Small) – Fuel Sub
Commercial	HVAC	Large Packaged Heat Pump (IEER 14.0)	Com Central HVAC (Large) - Fuel Sub
Commercial	Water Heat	Com Heat Pump Water Heater (3.30 UEF - 50 Gal)	Com Small Gas Water Heaters
Commercial	Water Heat	Com Heat Pump Water Heater (4.3 COP - 100+ Gal, 200+ kBtuh)	Com Large Gas Water Heaters

*SEER = seasonal energy efficiency ratio; UEF = unit energy factor

Source: Guidehouse

B.2 Technology Characterization

The Guidehouse team characterized FS 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 3-10 for a full list of technology characterization inputs). As with non-FS technologies, the absolute energy use associated with the technology level is specified. Because the FS technology is specifically substituting gas use with electricity use, the energy use for the FS 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.[73]

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 FS 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 2023 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 FS measure to compete with the efficient gas measure.

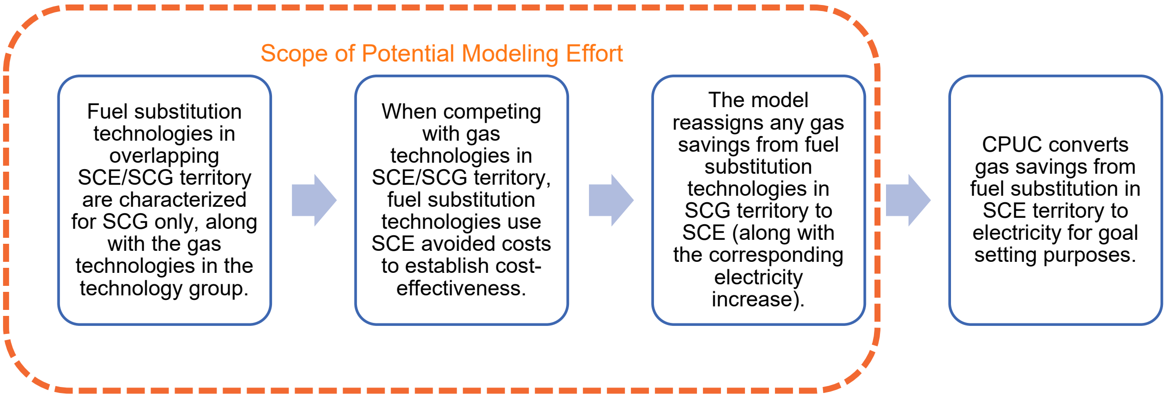
- **Step 1. Characterization:** The team characterized FS technology groups as though they were in SCG territory only (not in SCE territory). This was done so the FS measures could compete with the gas measures.
- **Step 2. Cost-effectiveness analysis:** The team used SCE avoided costs for fuel sub measures competing with gas measures for the cost-effectiveness analysis.
- **Step 3. Potential modeling:** The model logic reassigns any gas savings from FS 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 FS savings to the new fuel units.

Figure B-1. illustrates this step-by-step process for characterizing FS measures in overlapping SCE/SCG territory.[73]

[73]Neutral Unit Conversion (Btu) = Electric Energy (kWh/year) * 3,412.14 + Gas Energy (Therms/year) * 99,976.1

[73] This study does not incorporate incentive and savings alignment to the different incentive offerings that exist. Some FS programs incur incentive layering. The assessment of allocating savings and incentives to the various FS programs is outside the scope of this study.

Figure B-1. Steps in FS Characterization in SCE/SCG Territory



Source: Guidehouse

For most FS 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. 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.

The following subsections detail these technology-specific modifications.

B.2.1 Residential Heat Pump Replacing Residential Furnace and AC Combination

The electric FS 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, FS 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. For homes with a gas furnace only, FS would involve replacing the furnace with a heat pump that provides heating and cooling. This technology group consists of a heat pump competing with an efficient furnace only. The two technology groups are shown in Table B-2..

Table B-2. Residential Heat Pump FS Technology Groups

Technology Group	Technology Name	Base Year Efficiency Level
Res Central HVAC System – Fuel Sub	Code Furnace and SEER 14 AC	Code
	Condensing Furnace and SEER 15 AC	Efficient
	Packaged/Split Heat Pump (SEER 15)	Efficient
	Packaged/Split Heat Pump (SEER 16)	Efficient
	Packaged/Split Heat Pump (SEER 17)	Efficient
	Packaged/Split Heat Pump (SEER 18)	Efficient
Res Central Furnace Only – Fuel Sub	Res Furnace FS (AFUE and HIR at Code Level)	Code
	Res Efficient Condensing Furnace FS (AFUE = 97)	Efficient
	Res Furnace Heat Pump Heating Only (SEER 15)	Efficient
	Res Furnace Heat Pump Heating Only (SEER 16)	Efficient
	Res Furnace Heat Pump Heating Only (SEER 17)	Efficient
	Res Furnace Heat Pump Heating Only (SEER 18)	Efficient

Source: Guidehouse

The Guidehouse team used the 2019 RASS to determine the proportion of households with both a furnace and an AC 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., the gas appliance and electric appliance—at the same time. The team researched information to estimate what proportion of households would be likely to 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.

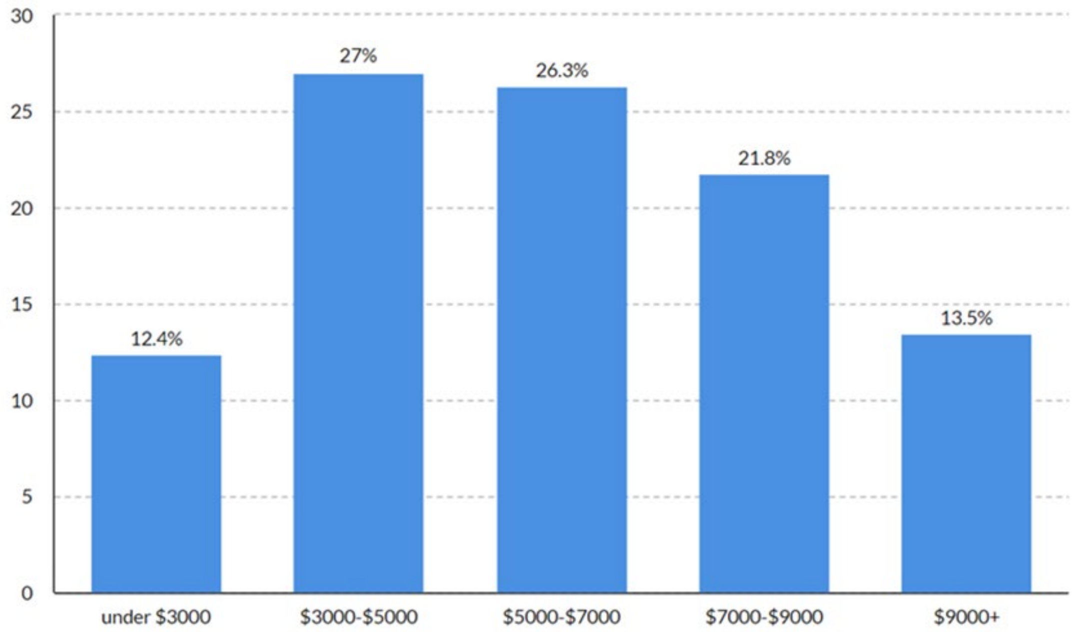
The team completed a literature review to assess what percentage of HVAC projects involve component replacements versus whole system replacements.

1. A 2020 survey by PickHVAC[74] 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.

[74] 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/.

- $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.

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*[75] reviewed 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. Figure B-4. illustrates the differences in AC and gas furnace EULs by the study climate regions defined in Table B-4..

Table B-4. EULs by Climate Region and Equipment Type

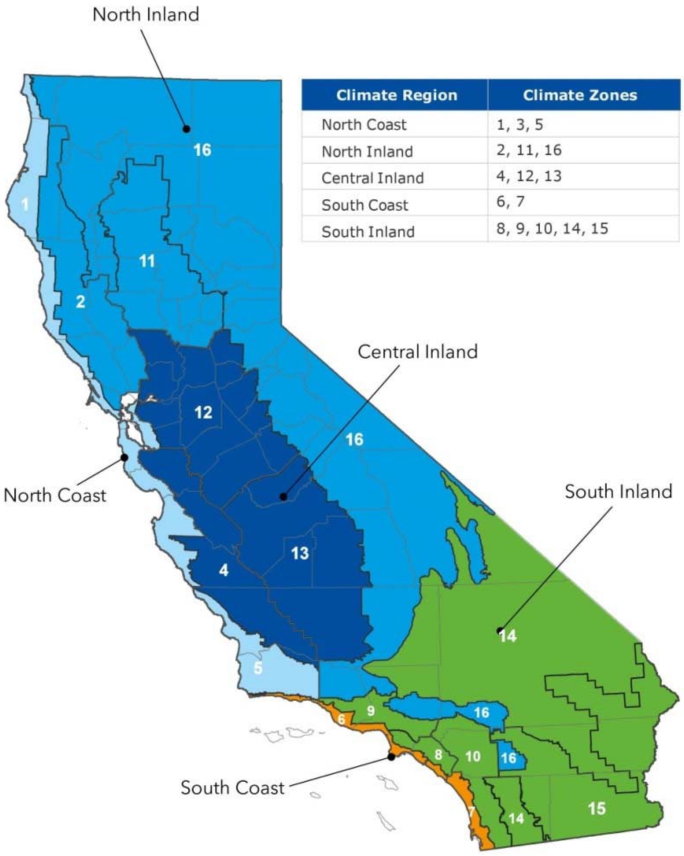
Region	Central AC EUL	Central Natural Gas Furnace EUL	Ratio (Furnace EUL/ AC EUL)
North Coast: CZ 1, 3, 5	30	17	0.57
North Inland: CZ 2, 11, 16	16	17	1.06
Central Inland: CZ 4, 12, 13	14	23	1.64
South Coast: CZ 6, 7	21	19	0.90
South Inland: CZ 8, 9, 10, 14, 15	11	27	2.45

CZ = climate zone

Source: DNV GL, 2017

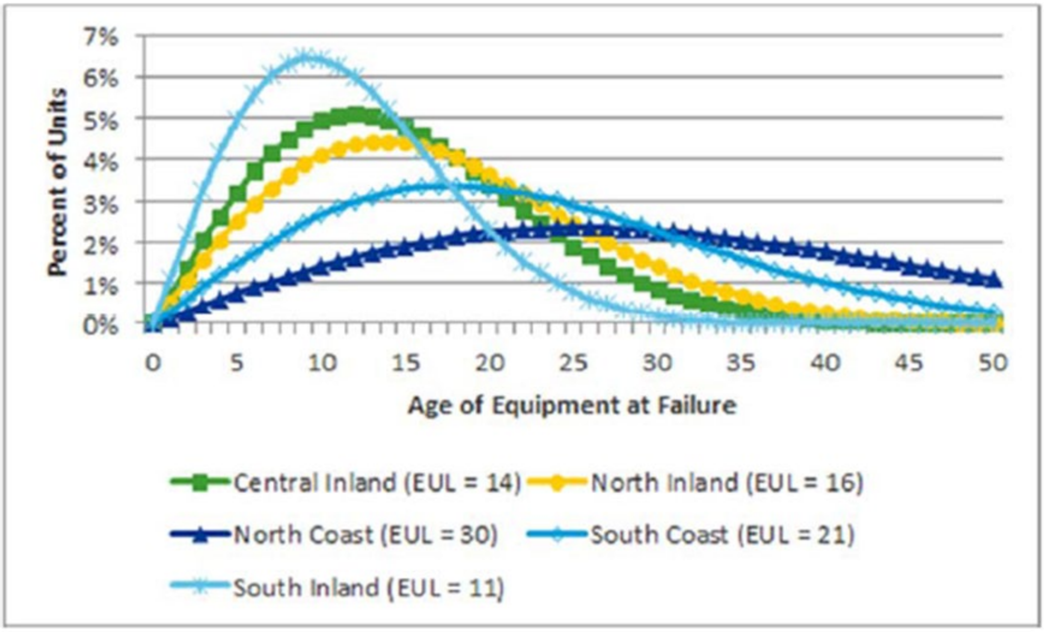
[75] Final Report: 2014-16 HVAC Permit and Code Compliance Market Assessment (Work Order 6) Volume I – Report.
California Public Utilities Commission. DNV-GL, September 22, 2017. CALMAC Study ID: CPU0172.01. Contract #12PS5119 (HVAC WO6).

Figure B-3. HVAC Permit and Code Compliance Market Assessment Climate Regions



Source: DNV GL, 2017

Figure B-4. Probability Distribution of Lifetimes for Central ACs



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[76] 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.

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.

[76] 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-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.

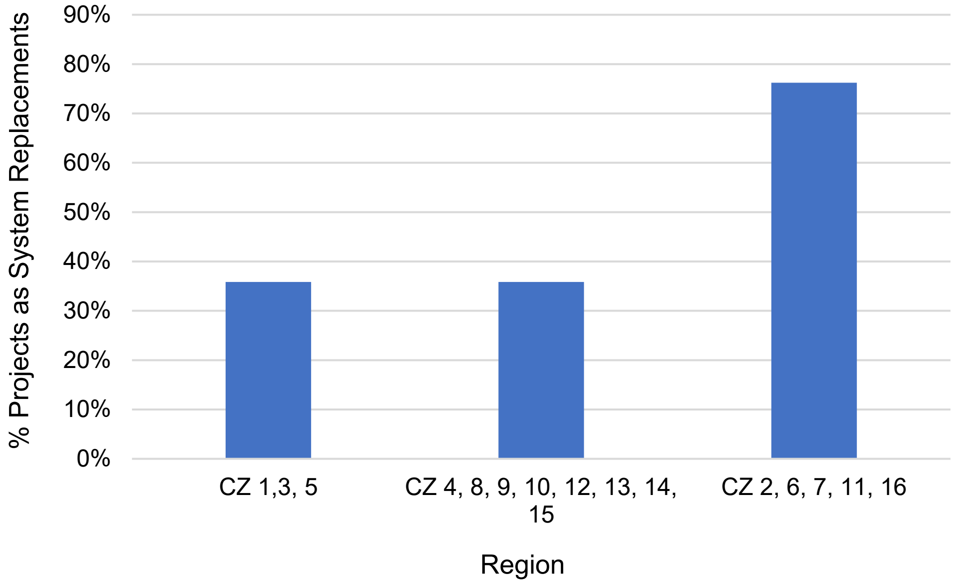
Table B-7. Probable Project Type by Region

Region	System	Component
North Coast: CZ 1, 3, 5	36%	64%
North Inland: CZ 2, 11, 16	76%	24%
South Coast: CZ 6, 7		
Central Inland: CZ 4, 12, 13	36%	64%
South Inland: CZ 8, 9, 10, 14, 15		

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 FS 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%

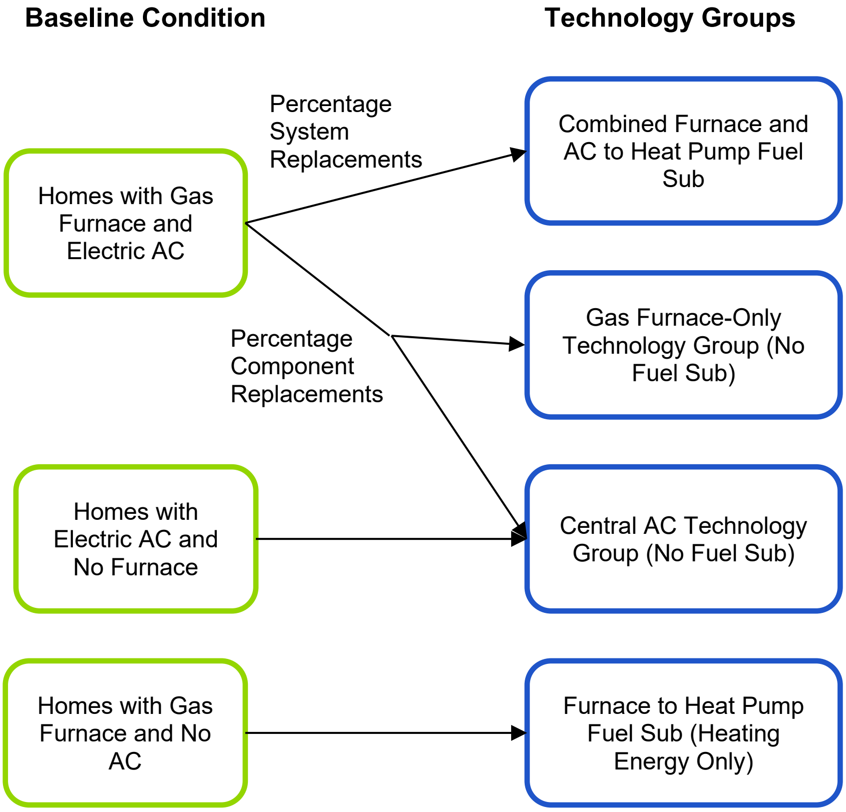
Source: Guidehouse

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.[77]

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

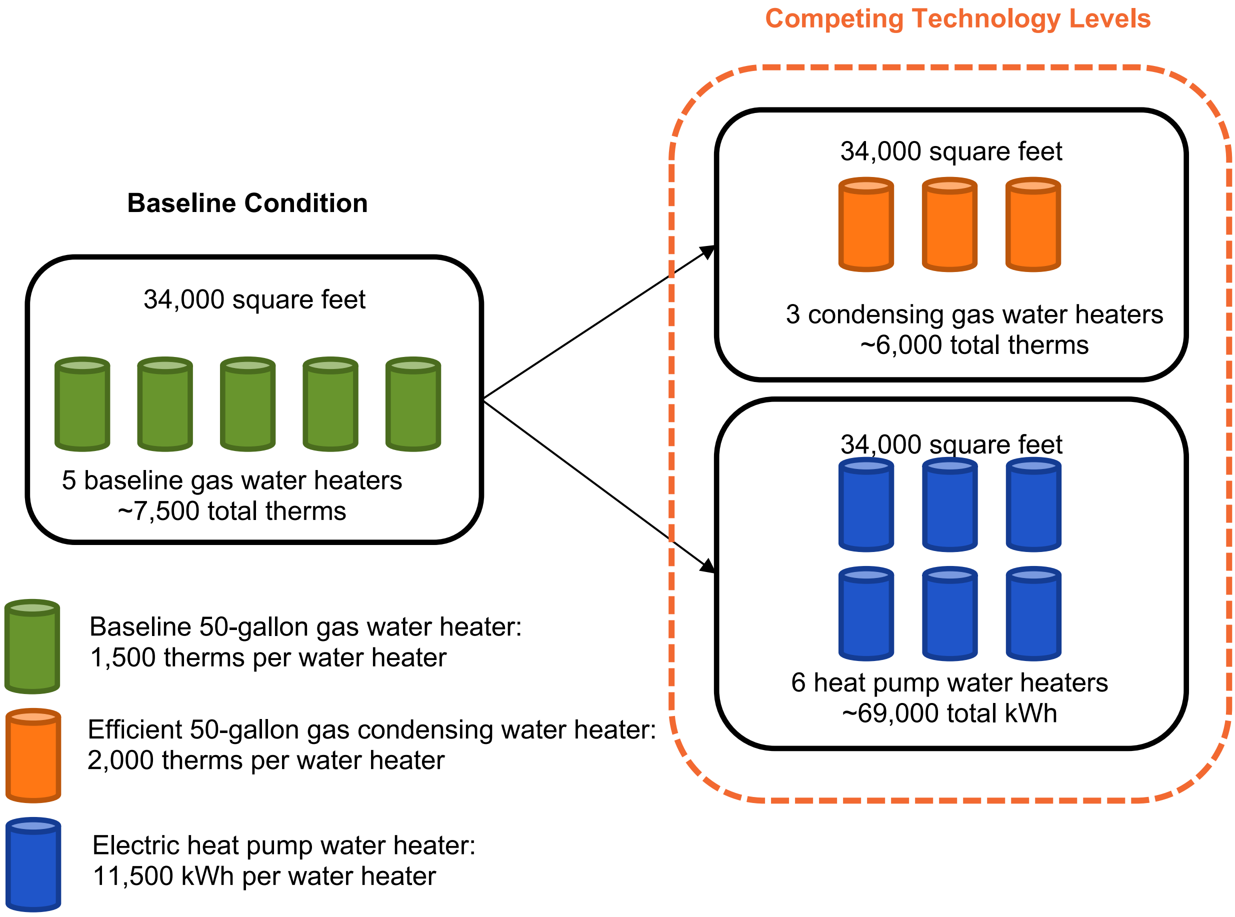
B.2.2 Commercial Water Heating

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.[78] 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 FS for 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

[77] Conversation with CPUC on October 21, 2020.
[78] Available at http://www.deeresources.com/index.php/23-deer-versions.

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

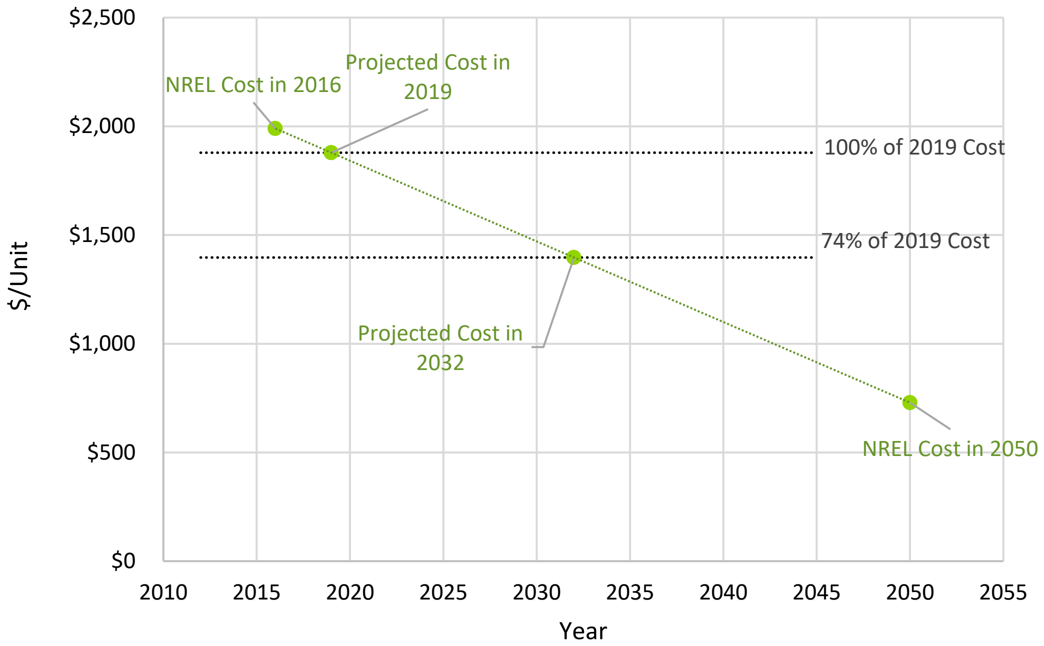
Source: Guidehouse

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.[79] 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.

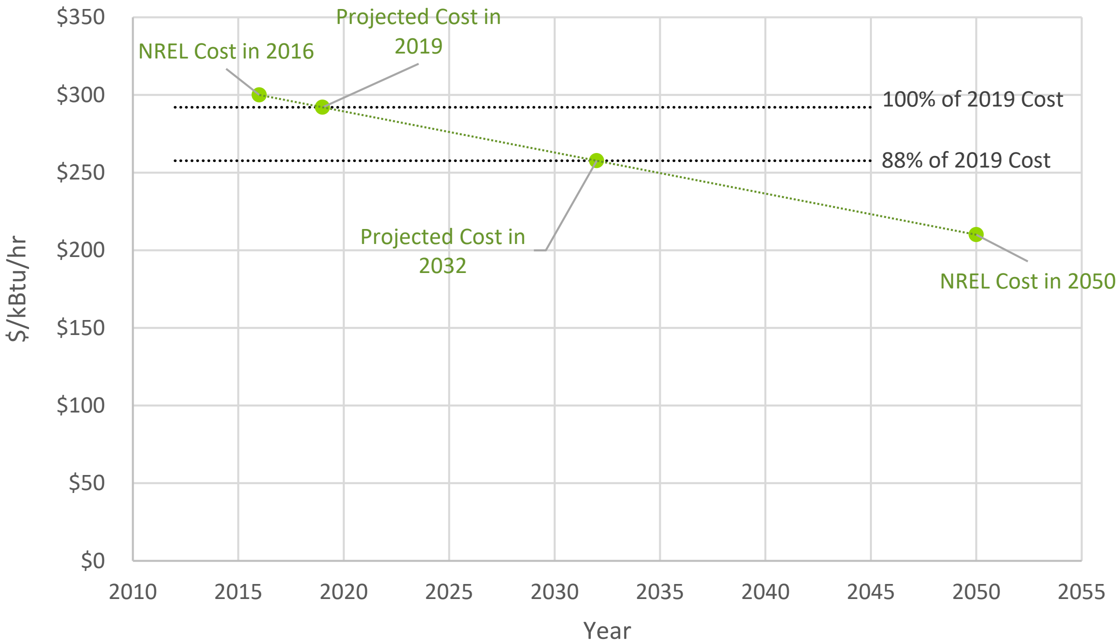
Figure B-8. Calculation of Cost Trajectory for Residential Heat Pump Water Heaters



Source: Guidehouse analysis of NREL study

[79] 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 FS Cost-Effectiveness Analysis

The FS analysis follows the cost-effectiveness calculations that require addressing the increase in supply costs. FS measures value both the gas savings (a positive benefit) and the increased electricity supply cost (a negative benefit). FS measures are assigned to the

IOU that serves the new load. FS for dual fuel utilities (PG&E and SDG&E) is straightforward in the 2023 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), PG&E, and even San Diego Gas & Electric (SDG&E). The Guidehouse team developed a simplifying assumption as part of the 2021 PG Study that for each SCG FS replacement 64% of that occurs in the territory overlapping with SCE and is subsequently tracked in the model. Consistent with the prior Study, 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).

B.4 Accounting for 2030 Natural Gas Appliance Ban

In September 2022, the California Air Resources Board published a memo to propose a "zero-emission standard for space and water heaters," which would ban the sale of natural gas-burning HVAC and water heating appliances starting in 2030.[80] The Guidehouse team anticipates that this will effectively eliminate natural gas savings from FS measures from 2030 onward, because customers would not be able to install a new gas appliance in a new building or as a replacement for an existing gas appliance at the end of its life. This is a similar effect as other measures when a code or standard takes effect and increases the efficiency of the baseline product. In this case, the study considers the "baseline" for this product group to be a low-efficiency electric appliance—in other words, the minimum cost and minimum efficiency product that the customer would be able to install at that point in time.

This is implemented in the measure characterization as a "future baseline" level that becomes the baseline starting in 2030. The natural gas baseline and any competing natural gas efficiency levels are removed from the analysis from 2030 onwards. In effect, this means that technologies categorized as FS technologies will appear to have electric EE savings beginning in 2030.

Figure B-10 below illustrates the change in technology levels for an example technology group.

[80] California Air Resources Board, "2022 State Strategy for the State Implementation Plan," Adopted September 22, 2022. https://ww2.arb.ca.gov/sites/default/files/2022-08/2022_State_SIP_Strategy.pdf

Figure B-10. Example Technology Group Change After Natural Gas Appliance Ban

Pre-2030			2030 Onward	
Technology	**Description**		**Technology**	**Description**
Small Gas Storage Water Heater	Code Efficiency Level	→	Electric Resistance Water Heater	Baseline Electric 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
Heat Pump Water Heater	High Efficiency Electric Level			

Source: Guidehouse

Appendix C. Panel Upgrade Literature Review

Research and Summary of Panel Upgrade Costs to Support FS Measure Potential Study

Substituting gas technologies for electric technologies can increase electric load for a building or house. This can sometimes require upgrades to the infrastructure within the building, for example, increasing the size of the electrical panel to accommodate the added load. Deemed per-unit costs of FS technologies typically do not consider such costs, and the previous 2021 Study did not account for these costs. For the 2023 Study, the Guidehouse team, led by Opinion Dynamics, conducted a literature review to estimate the cost of a panel upgrade, as well as the likelihood that a given installation of FS technology would necessitate a panel upgrade. The scope of this research was to review existing literature and publicly available data sources to provide an overview of the costs associated with panel upgrades (and other electrical upgrades not included in the measure cost) in existing residential building stock in California as part of FS infrastructure. The team then incorporated these costs into the measure characterization. The following subsections detail the findings of the literature review and describe how the results were used in the 2023 Study.

C.1 Method

For the 2023 Study, the Guidehouse team reviewed 16 reports published between 2016 and 2022 that included cost data on electrical panel upgrades for residential buildings in California. The review also included a panel upgrade quote for a California homeowner who works at Opinion Dynamics to serve as a recent real-world panel upgrade example. The team also became aware of the CARB's equitable electrification of existing buildings study. This is a collaboration between CARB and the University of California, Los Angeles. This project will look at challenges associated with electrical service panel upgrades and the results for the tasks related to panel upgrades are scheduled for approximately June/July 2023. A summary of the key data sources the team identified is provided in Table C-1. Throughout this section, the Study Numbers relevant to a discussion will be referenced in brackets [ ].

Table C-1. Key Data Sources Included in this Review

Study No.	Title	Prepared By / Authors	Publisher	Publication Date
1	What is the final bill for a heat pump residential retrofit installation? A Delphi approach to uncovering the costs of electrification's favorite technology	Ellen Steiner	International Energy Program Evaluation Conference	2022
2	Service Upgrades for Electrification Retrofits Study Final Report	NV5 INC and REDWOOD ENERGY	NV5.COM	2022
3	Palo Alto Electrification Final Report	TRC	City of Palo Alto	2016
4	Home Energy Upgrades as a Pathway to Home Decarbonization in the US: A Literature Review	Brennan D. Less, Núria Casquero-Modrego, and Iain S. Walker	Energies	2022

Study No.	Title	Prepared By / Authors	Publisher	Publication Date
5	Costs and Benefits of a 2022 Zero Emissions Cooking Technology Code Requirement for New Food Service Kitchens in California	Evergreen Energy and Synergy Energy	PG&E	2022
6	Costs and Benefits of a 2022 Zero Emissions Cooking Technology Code Requirement for New Housing in California	Evergreen Energy and Synergy Energy	PG&E	2022
7	Cost of Conversion Case Study of Electric Home Energy Retrofits in Sacramento	Integrated Communications Strategies, LLC	N/A	2022
8	Accelerating Electrification of California's Multifamily Buildings Policy Considerations and Technical Guidelines	The report was written by Jack Aitchison, Nick Dirr and Aubrey Dority (Association for Energy Affordability) and Ben Cooper (StopWaste). Heather Larson provided policy context.	Stopwaste	2021
9	How Much Does It Cost to Replace or Upgrade an Electrical Panel?	Fixr.com	Fixr.com	2022
10	A Pocket Guide to All-Electric Retrofits of Single-Family Homes	Redwood Energy, Menlo Spark	Redwood Energy	2021
11	Example Quote for a California homeowner	Old Town Electrical	N/A	2021
12	PG&E Furnace Replacement Initiative Case Study	TRC	PG&E	2022
13	Residential Building Electrification in California Consumer Economics, Greenhouse Gases and Grid Impacts	E3 (Energy +Environmental Economics)	ethree.com	2019
14	Dig here: Insights from Direct Burial Cable Study and Implications for Electrification	Gomathi Sadhasivan, DNV Lullit Getachew, DNV Amber Watkins, DNV	N/A	2022
15	Bay Area Regional Energy Network (BayREN) Home Energy Score: Electrification Checklist Pilot Report	StopWaste Frontier Energy, Inc.	BayREN	2022
16	Addressing an Electrification Roadblock: Residential Electric Panel Capacity: Analysis and Policy Recommendations on Electric Panel Sizing	Pecan Street	Pecan Street	2021

Source: Guidehouse analysis

C.2 Findings

C.2.1 Panel Upgrade Costs

The electric panel upgrade costs for single-family homes vary considerably, ranging from $1,900 to $8,188, with a rough average cost of about $4,600. For multifamily buildings, the cost ranges from $11,500–$122,000 depending on the number of units and the complexity of the upgrade. Table C-2 provides a detailed summary as presented in the reports, including the cost breakdown for both multifamily and single-family homes.

These costs represent a variety of scenarios and also show significant variation in the type of costs reported. The majority of studies report only total average cost ranges, do not provide the underlying data on which the study is based, and do not include the individual cost elements. Others provide details including labor, permits, new subpanels, new branch circuits and outlets, upsizing, service connection fees, and other miscellaneous services. Without the site-level source data used to develop the costs for these studies, it is difficult to develop costs consistently.

Table C-2. Summary of Upgrade Costs

Building Type	Cost		Source [81]	Comments (Reliability of the Source)
Single Family	**Total:**	**$1,900–$4,000**	1	Based on interview with seven water heater and 15 HVAC contractors for a specific home
Single Family	**Total:**	**$2,000–$4,500**	2	It appears that the cost does not include overhead
	Total (With Overhead to underground conversions or panel relocations):	**$3,000-$10,000**		
	Average:	$2,780		
Single Family	**Total:**	**$4,671**	3	The report was published in 2016. The cost estimates are based on RSMeans data and it does not include overhead
	HPWH Branch Circuit (15A to 30A):	*$640*		
	Panel:	*$3,181*		
	Service Connection (utility Fee):	*$850*		
Single Family	**Total Cost:**	**$8,188**	11	This is based on a recent upgrade in California (2021). The high labor cost is a result of panel relocation.
	Labor:	*$4,740*		
	Material – New Panel:	*$1,400*		
	Material – New Subpanel:	*$500*		
	Rough in and Outlet for EV:	*$600*		
	Breakers:	*$480*		
	City Permit:	*$600*		
	Overhead (15%):	*$1,068*		
Single Family	**Total:**	**$4,256**	13	Used available cost data from [3]
All Building Types	**Total cost (the national average):**	**$1,500–$4,000**	9	Cost data from a great variety of sources and does not reflect specific region or building type
	Average:	*$2,500*		
	Lowest (to upgrade to 100Amps):	*$800*		
	Highest (to upgrade to 400 Amps):	*$10,000*		

[81] Source Numbers from above table

Building Type	Cost		Source [81]	Comments (Reliability of the Source)
Residential Buildings	**Total:**	**$4,750-$10,000**	14	Used HomeAdvisor estimates for the period of study (Q4 2019) in California but assumptions are not clear.
	Electrical wiring (depending on length of run and whether trenching is under landscaping or hardscaping):	*$4,000-$8,000*		
	Electrical panel upgrade:	*$750 to $2,000*		
Multifamily	**Total (Low rise-appears to be per-unit costs):**	**$2,744**	13	Used available cost data from [3]
Low Rise Multifamily	**Total (Eight dwelling units):**	**$35,192**	3	Report published in 2016; cost estimates are based on RSMeans data and does not include overhead
	Total (per unit):	**$4,399**		
	HPWH Branch Circuit (15A to 30A):	*$5,120*		
	Panel:	*$20,792*		
	Service connection (utility Fee):	*$1,160*		
Multifamily[82]	**Total:**	***$13,500–$122,000***	8	Estimated costs provide a wide range and cannot be used for a MF building with a specific number of units. .
	Add circuits for a new electric appliance:	*$500–$2,000*		
	Upgrade subpanels:	*$1,000–$7,000*		
	Replace disconnects at meter bank:	*$1,000–$3,000*		
	Upsize feeder cable:	*$1,000–$10,000*		
	Convert from single to three phase (depends on building size):	*$10,000–$100,000*		
Multifamily	**Total:**	***$11,500–$14,000***	12	Interviewed five HVAC contractors experienced with gas furnace-to-HP retrofits in SF homes in CA; Could not recruit contractors with experience in MF residences
	Electrical wiring:	*$1,500–$2,000*		
	Electrical panel upgrade:	*$10,000–$12,000*		

Source: Guidehouse analysis

C.2.2 Assessing the Basis and Need for Panel Upgrades

Not every FS installation will require an upgrade to the home electrical panel. Factors that may affect panel upgrade requirements include:

- **Size of the existing panel.** A study by Pecan Street cited the National Fire Protection Association's (NFPA) National Electric Code (NEC), which requires electric panels to be of sufficient size to serve a home's electrical loads. The study built a model to assess whether adding an electrical load through electrification would exceed the current panel's capacity, thus requiring a panel upgrade [16]. This study observed that most homes with 100 amp panels would need to upgrade their panel to fully electrify, but most homes with 200 amp panels would not.

[82] The lower cost limit represents a typical multifamily building (20 or fewer units) that doesn't have major upgrade hurdles. The upper limits of the cost ranges represent more complicated upgrades typically associated with commercial or large multifamily properties.

Several sources contained data on the distribution of homes by panel size. The Pecan Street study reported the following distribution among a sample of approximately 250 single-family homes [16]:

- <= 125 amps: 47%
- >125 amps and <200 amps: 12%
- >= 200 amps: 41%

Analysis by BayREN based on visual inspections of 4,605 California Bay Area single-family homes suggested that most panels were classified as having a capacity between 100 and 200 amps and approximately 35% of the local housing stock had 200 amp (200 A) panels [4].

Table C-3. Electrical Panel Capacity by County

County	Total number of homes	<100 A	100-200 A	200-300 A	>300 A
Alameda	1,653	39	1,039	526	49
Contra Costa	1,158	75	726	339	18
Marin	220	1	86	125	8
Napa	27	0	20	7	0
San Francisco	22	2	15	5	0
San Mateo	233	2	120	106	5
Santa Clara	565	4	287	272	2
Solano	169	1	119	49	0
Sonoma	335	4	173	153	5
Total	**4,382**	**128 (3%)**	**2,585 (59%)**	**1,582 (36%)**	**87 (2%)**

Source: Guidehouse analysis

Detailed information on panel size and upgrades is also available from the CPUC's residential Technology and Equipment for Clean Heating (TECH) decarbonization program tracking data. Analysis of the TECH data publicly available at the time of this research is provided in Table C-4, which presents the percentage of TECH projects that needed an electric panel upgrade when electrifying the HVAC or water heating system.

Table C-4. TECH Program Tracking Data - downloaded 09/23/2022

Building Type	Panel Amp Range Pre-Installed	Total Projects	% of Total Projects in Building Type	Panel Upgrade				Comment
				No	Yes	% of Projects Upgraded		
Single Family	<100	93	1%	87	6	6.5%	4.7%	Low upgrade % even when

Building Type	Panel Amp Range Pre-Installed	Total Projects	% of Total Projects in Building Type	Panel Upgrade				Comment
Single Family	>=100 and <200	3,971	47%	3,811	160	4.0%		panel range is less than 100 A: Could be "modernization" from fuse box to breakers
Single Family	>=200	4,330	52%	4,101	229	5.3%		
Multifamily	<100	8	6%	7	1	12.5%	6.9%	Slightly higher than SF but much smaller sample size
Multifamily	>=100 and <200	80	62%	74	6	7.5%		
Multifamily	>=200	42	32%	40	2	4.8%		

Source: Guidehouse analysis

Very few projects in the TECH program required a panel upgrade, even for homes with panels smaller than 100 amps. This could be due to program participants self-selecting to participate only if they would not require a panel upgrade. Another study reported some cases of homes with existing 100 amp panels switching to all-electric homes that received incentives for panel optimization as part of the demand response (DR) programs to avoid upgrading to 200 amp panels but did not specify the exact number [2].

- **Home Vintage (year built)** was used by multiple studies to predict existing panel size and use that as a proxy to gauge the necessity for a panel upgrade. For example, one study reported the following breakdown for estimating electrical panel size in multifamily buildings: Pre-1950: 30–40 amp, 1950–1974: 30–60 amp, 1974–2010: 60–90 amp, 2010–present: 100–150 amp [8]. In addition, 2022 Title 24 Code requires all new residential single- and multifamily homes to be "electric cooking ready," meaning the necessary panel and wiring upgrade have been completed [6]. In another electrification study [13] the panel upgrade costs were assumed to be applied to pre-1978 vintage single-family homes, but the study did not cite any data or evidence to support this assumption. Based on this criteria, up to 58% of single-family homes would require an electric upgrade. However, a study in Texas found no significant correlation between home vintage and panel size [16]. Another study suggested that based on the home vintage approximately 71% of homes have at least 100 amp (100 A) panels [2].

Table C-5. Statewide Building Vintage – RASS[83] estimated population data (1000s)

Building Type	Totals	Built Prior to 1978			Built 1979-2012		Built After 2012
Single-Family Detached	6,825	3,933	58%	2,405	35%	169	2%

[83] 2019 Residential Appliance Saturation Survey (RASS) (dnv.com).

Townhouse, Duplex, Or Row House	977	415	43%	473	48%	25	3%
Apartment Or Condo (2-4 Units)	1,007	429	43%	373	37%	29	3%
Apartment Or Condo (5+ Units)	2,244	901	40%	889	40%	91	4%
Mobile Home	243	127	52%	95	39%	2	1%
Other	204	119	58%	56	27%	1	0%
No Response	707	259	37%	172	24%	5	1%
Total	**12,206**	**6,183**	**51%**	**4,462**	**37%**	**321**	**3%**

Source: Guidehouse analysis

- **Building Type (single family vs. multifamily)** is also an indicator of existing panel size and potential upgrade requirements. In the Palo Alto Electrification study [3], electrical panels for all existing single-family buildings with gas-fired water heaters converting to a heat pump water heater are upgraded from 100 A to 200 A; existing multifamily dwelling panels are upgraded from 60 A to 125A [3]. As Table C-5 shows, slightly more of the TECH program participants in multifamily homes upgraded their panel versus single-family homes. This difference was more pronounced among homes that initially had smaller panels.

- **Building Size** is another indicator of the required panel size to accommodate electrification. One study indicates that a 100 amp panel has enough power for complete electrification of a 3,000 square foot single-family home in the relatively mild climate of Northern California (e.g., Sacramento, Bay Area) [10]. They used the "Watt Diet" Calculator[84] for calculating the electric load requirement based on code. Another study referred to the Watt Diet Calculator and stated that in most of California, a panel less than or equal to 100 amps would be insufficient only for electrification of single-family homes over approximately 2,000 square feet [2]. According to the RASS data, 35% of existing single-family detached homes in California are over 2000 square feet, and any of those homes with a 100 amp panel would need to upgrade to a 200 amp panel.

Table C-6. Statewide RASS Estimated Population by Building Size (1,000s)

Building Type	<= 2,000 SQFT		>2,000 and <=3,000 SQFT		>3,000 SQFT	
Single-Family Detached	4,220	65%	1,683	26%	617	9%

[84] Redwood Energy Website. "Watt Diet Calculator". https://redwoodenergy.net/watt-diet-calculator/

Building Type	<= 2,000 SQFT		>2,000 and <=3,000 SQFT		>3,000 SQFT	
Townhouse, Duplex, or Row House	806	88%	98	11%	12	1%
Apartment or Condo (2-4 Units)	767	93%	45	5%	15	2%
Apartment or Condo (5+ Units)	1950	98%	30	2%	12	1%
Subtotal: All Multifamily	**3,523**	**94%**	**173**	**5%**	**39**	**1%**
Mobile Home	189	94%	11	5%	0	0%
Other	160	87%	19	11%	3	2%
No Response	298	71%	80	19%	40	10%
Total	**8,391**	**76%**	**1967**	**18%**	**700**	**6%**

Source: Guidehouse analysis

- **Type and Number of Electrification Equipment** (e.g., space heating, water heating, cooking equipment, EV) is also a driver for potential panel upgrades and panel size, particularly when multiple systems are included.
- **Existing Air Conditioning System Present** is also an indicator of existing panel size and 220 V–240 V capacity. Homes with existing AC have at least a 100 A panel and the existing circuits can be reused for a new electric heat pump [2]. Climate zones can also be an indicator of the need for panel upgrades driven by a lack of an existing AC system. AC is more predominant in Southern California and desert areas, and accordingly, panels there tend to be larger (200 A). For many Northern California regions where AC is atypical, panels may be sized at 100 A or less. The recent RASS study shows that 30% of California residential buildings still do not have AC. However, the Technology and Equipment for Clean Heating (TECH) Initiative tracking data shows that the pre-retrofit presence or absence of AC does not have any impact on the need for a panel upgrade. For example, for central HVAC HPs in single-family homes, projects where no AC was originally present had a 3% panel upgrade rate but projects where AC was already present had a 4% panel upgrade rate. This 1% difference is the opposite of the expected trend, but more likely illustrates the uncertainty in how the data was collected. Both rates are below the 9% estimated from the 2019 RASS data.

The following table summarizes the estimated percent of homes that would need a panel upgrade for each technology in the PG study.

Table C-7. Summary of Panel Upgrade Necessity by Technology

Building Type	Technology	% Needing Upgrade	Comments
Single Family and Multifamily	Clothes Dryer	0%	Per the Pecan Street study, almost all homes' panels are sized to accommodate an electric dryer.
Single Family and Multifamily	Heat Pump Pool Heater	50%	None of the sources specifically addressed pool heating equipment. Pool heat pumps can require up to 50 amps.[85] Many inground pools have a subpanel installed, but not all have enough capacity, thus requiring an upgrade to the subpanel and/or the home's main panel.[86]
Single Family	Induction Cooktop	55%	Given the relatively high amp draw of a cooktop (at least 40 amps per the Watt Diet calculator), the Guidehouse team assumes any homes with a panel <100 amps would need to upgrade. Available data suggests that between 45% and 65% of single-family homes have a 100 amp or smaller panel.
Multifamily	Induction Cooktop	65%	Limited data suggests that approximately 65% of multifamily homes have a 100 amp or smaller panel.
Single Family and Multifamily	Heat Pump replacing Central HVAC System	0%	One study suggested that homes with existing air conditioning would be able to reuse the existing circuits for an electric heat pump [2].
Single Family	Heat Pump replacing Furnace Only	35%	Heat pump amp draw scales with the size of the heat pump, which scales with the size of the home. Most homes without AC have a 100 amp or smaller panel. A study using the Watt Diet calculator estimated that a 100 amp panel would be insufficient to electrify homes larger than 2000 square feet [2], accounting for 35% of single-family homes according to the RASS data.
Multifamily	Heat Pump replacing Furnace Only	6%	Heat pump amp draw scales with the size of the heat pump, which scales with the size of the home. Most homes without AC have a 100 amp or smaller panel. A study using the Watt Diet calculator estimated that a 100 amp panel would be insufficient to electrify homes larger than 2000 square feet [2], accounting for 6% of multifamily homes according to the RASS data.

85 https://www.riverpoolsandspas.com/blog/will-i-need-an-electrical-service-panel-upgrade-for-my-swimming-pool
86 https://blog.intheswim.com/installing-a-swimming-pool-heat-pump

Building Type	Technology	% Needing Upgrade	Comments
Single Family	Ductless Mini-Split Heat Pump	55%	Amp draw of a mini-split heat pump ranges from 15-45 amps per unit.[87],[88] In the eTRM, single-family homes are assumed to install 2 units.[89] This would exceed the capacity of a 100 amp panel in many cases.
Multifamily	Ductless Mini-Split Heat Pump	5%	According to the eTRM, multifamily homes are assumed to install 1 unit. This would require at least a 100 amp panel but may not require a 200 amp panel. Limited data suggests that approximately 5% of multifamily homes have panels smaller than 100 amps.
Single Family	Heat Pump Water Heater	30%	Heat pump water heater power draw is relatively small, ranging from approximately 10-20 amps according to the Watt Diet calculator, leading the Redwood Energy study to suggest that a panel upgrade can be avoided by choosing a lower amperage model [10]. On the other hand, the Palo Alto Electrification study assumed that all single-family buildings with a 100 amp panel would require an upgrade to install a heat pump water heater [3]. This figure assumes that approximately half of single-family buildings with a 100 amp or smaller panel would require an upgrade.
Multifamily	Heat Pump Water Heater	35%	This figure assumes that approximately half of multifamily homes with a 100 amp or smaller panel would require an upgrade.

Source: Guidehouse analysis

C.3 Gap Analysis

This section discusses the reliability and validity of data sources and the key gaps in the data that should be addressed through further research and primary data acquisition.

- Panel upgrade drivers and cost elements are not gathered consistently. The estimated costs for electrical infrastructure upgrades are building-specific, equipment-specific, and vary greatly by region. As the findings of this review suggest, there is a wide range of costs and costing approaches depending on the scope of the upgrade and configuration of the existing home. For example, in [3] the labor cost is high since the relocation of the panel was required. The average costs presented here may not be representative of actual costs for specific buildings.

[87] https://powersaveac.com/blog/post/how-many-amps-are-required-for-a-ductless-mini-split

[88] https://www.daycosystems.com/blog/air-conditioning-service/how-many-amps-are-required-for-a-ductless-mini-split-system/

[89] https://www.caetrm.com/measure/SWHC044/02/

- A standardized panel upgrade cost data structure and terminology framework is needed. Creating a standardized structure for capturing the scenarios and elemental costs of panel upgrades is an essential step for developing better panel upgrade cost estimates. This structure also needs to include taxonomy and terminology definitions to address the various scenarios that occur such as service upgrades, panel replacement, panel modernizations (e.g., conversion from fuse box to breakers), panel optimization, etc. This research can be used to develop a framework, which can be tested and refined to gather data for EE program FS measures and the TECH program.

- Undocumented assumptions make cost comparisons difficult. There are many assumptions built into the cost estimates in these studies and not all of the details are documented nor completely grounded in real data. For example, minor variations in contractor overhead or the labor hourly rates may lead to significant differences. According to [13], labor rates vary from $65/hour to $95/hour and the mark-up for overhead varies between 15% to 20% depending on the region of the state. In addition, some of the resources are referring to a 2016 study [3] and the cost data might not reflect the current inflation and supply chain challenges. In one study [2], it was noted that the price estimates are far different since the COVID-19 pandemic has impacted the economy. Material cost has increased due to supply chain disruptions and manufacturing and shipping delays from the pandemic, making it the dominant cost in service upgrades [2].

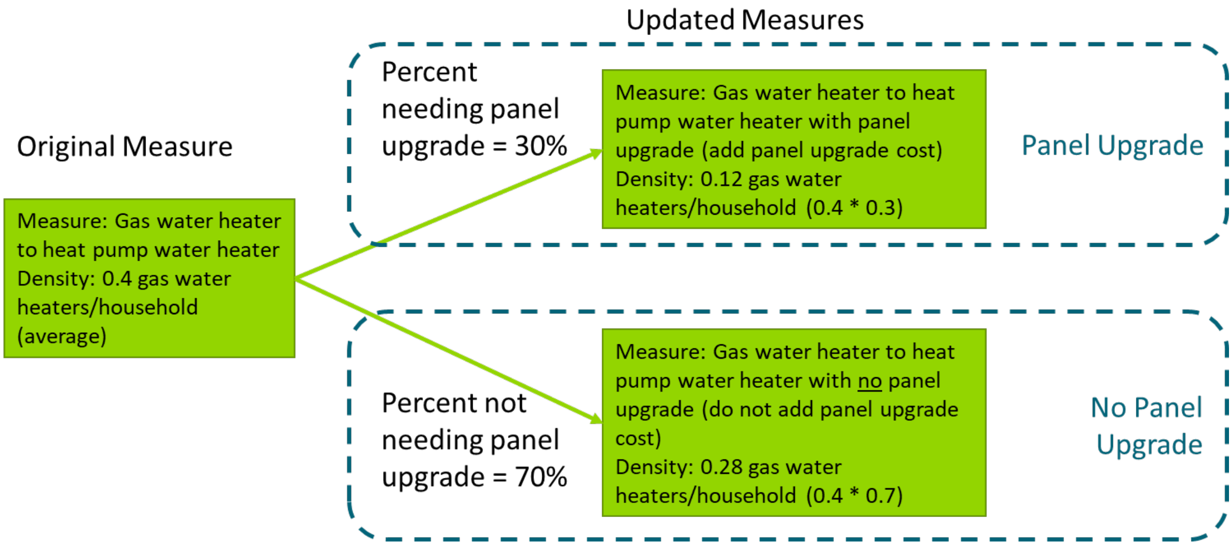
- Differences in terminology make cost comparisons difficult. There is a lack of granular cost data with a clear breakdown and consistent terminology. A better structure for data collection in the TECH Initiative would address this gap. There is also some inconsistency as to the purpose of a panel upgrade—whether it is to address code compliance associated with outdated equipment or a problematic location, or an upgrade to increase service.

- Lack of data on panel size in existing building stock. There is a lack of data on statewide characterization of residential electrical panel sizes, so it is difficult to estimate the precise number of homes in California for which FS requires a panel upgrade. As a result of this research, the Guidehouse team learned that the California Energy Commission (CEC) may be gathering data from the utilities for this purpose related to their Senate Bill (SB) 67 work. There is also some data available from the TECH Initiative tracking data that is available from the public website (provided in the Excel workbook that accompanies this memo). The Guidehouse team's preliminary analysis of the data showed that very few panel upgrades are needed but panel upgrades may have been done prior to TECH Initiative participation.

C.4 Incorporating Panel Upgrade Data into the Measure Characterization

The Guidehouse team accounted for the percent of homes needing a panel upgrade for each technology substitution in the above table by disaggregating the density of each technology into a panel upgrade percentage and a non-panel upgrade percentage. For example, if the total density of residential gas water heaters is 40%, and 30% of single-family homes would require a panel upgrade when replacing a gas water heater with a heat pump water heater, the measure would be split into two separate measures with the density of the panel upgrade version being 12% (0.4 * 0.3) and the density of the non-panel upgrade version being 28% (0.4 * 0.7). Figure C-1 illustrates this split (percentages are for illustrative purposes only).

Figure C-1. Illustration of Disaggregating Measures to with Panel Upgrade and No Panel Upgrade



Source: Guidehouse analysis

Appendix D. 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.

D.1 Residential – Home Energy Reports

D.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 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 and gas savings ranges differ based on savings bin. Costs are less variable are set at $0.05-$0.14 per kWh and $0.49-$1.88 per therm. Table D-1 provides details.

Table D-1. HERs – Key Assumptions

Sector	Type	EUL Years	Savings		Cost		kW/kWh Savings Ratio
			kWh	therms	kWh	therms	
Residential	HERs Bin 1	1	0.52-0.56%	0.00%-0.42%	$0.05-$0.14	$0.49-$1.88	0.000166 – 0.000243
	HERs Bin 2	1	0.92-1.03%	0.52%-1.12%	$0.05-$0.13	$0.49-$1.88	0.000088 – 0.000232
	HERs Bin 3	1	1.33-1.62%	0.80%-1.66%	$0.05-$0.14	$0.49-$1.88	0.000220 – 0.000226

Source: Guidehouse

D.1.2 Assumptions and Methodology

Bin-based Measures

For the 2023 PG Study, Guidehouse introduced a new method to forecast future HERs savings by establishing three bins based on grouping historical waves (batches of new participants) of customers into low, moderate, and high energy savers. The purpose of this change was to better describe the expected trend of new customers entering the program who are more likely to have lower energy savings than the historical participants that resulted in higher energy savings.

Bin assignments were based on the reported kWh savings. For those gas-only waves without kWh savings, a bin was assigned based on the reported therm savings. Low energy savers (Bin 1) include waves with reported energy savings less than 0.75%. Moderate energy savers (Bin 2) include waves with a minimum reported energy savings of 0.75% and a maximum reported energy savings of 1.249%. High energy savers (Bin 3) include waves with a minimum reported energy savings of 1.25%. Table D-2 provides an over of these ranges.

Table D-2. HERs Bins

Bin Name	Energy Savings Range
1	<0.75%
2	0.75%- 1.249%
3	<1.25%

Source: Guidehouse

Eligibility and Participation

Although all targeted residential households may receive HERs as participants in an opt out program, 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 American Council for an Energy-Efficient Economy (ACEEE) study that found an average of 10% master-metered multifamily buildings across 50 metropolitan areas across the country.[90] 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.

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. Additionally, the use of the new Bin methodology means that the eligible population is spread across three groups with separate penetration rates depending on the population of previous waves and their reported energy savings.

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 an average of wave sizes to forecast the future cohort waves in each HERs measure. The 2021 Study included results from formal impact evaluations through program year (PY)

[90] 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

2018.[91, 92, 93] For the 2023 Study, the Guidehouse team added data from PY2019 and PY2020 for PG&E.[94]

The forecast uses a cap of 60% on the penetration of all three HERs measures based on the following considerations:

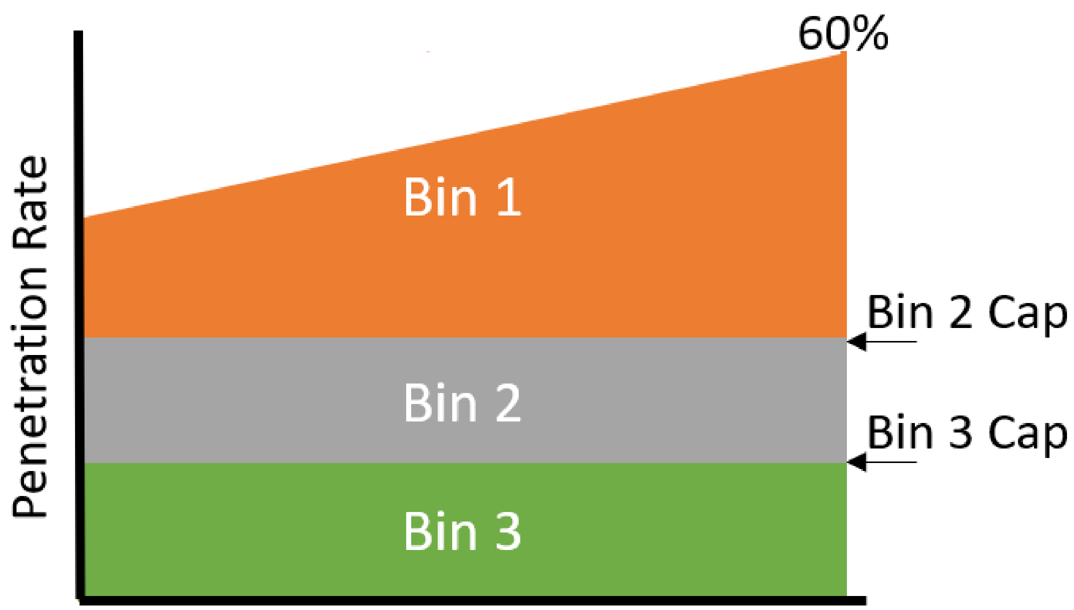
- Feedback from previous potential and goals studies noted that the bottom quartile of energy consumers will not be targeted for cost-effectiveness reasons.
- Not all of the remaining 75% of customers can be targeted because some need to be reserved as a control group for evaluation purposes. The PY2018 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.

In following the expected trend of new customers entering the program with lower energy savings, penetration for moderate and high energy savings measures (Bins 2 and 3), are held to the latest reported year, either PY2018 or PY2020 based on the data available. The low energy savings measure (Bin 1) has a penetration cap using Equation D-1. Figure D-1 provides an illustrative view of the calculation.

Equation D-1. HERs Bin 1 Penetration Cap

$$Penetration\ Cap = 60\% - (Bin\ 2\ Penetration\ Cap + Bin\ 3\ Penetration\ Cap)$$

Figure D-1. Illustrative Application of Penetration Cap by Bin



Source: Guidehouse

[91] DNV GL. May 1, 2019. Impact Evaluation Report: Home Energy Reports – Residential Program Year 2016. California Public Utilities Commission. CALMAC Study ID: CPU0190.01.

[92] DNV GL. May 1, 2019. Impact Evaluation Report: Home Energy Reports – Residential Program Year 2017. California Public Utilities Commission. CALMAC Study ID: CPU0194.01.

[93] 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.

[94] Nexant. January 3, 2021. PG&E HER 2020 Energy and Demand Savings Early EM&V. Pacific Gas & Electric. CALMAC Study ID: PGE0466.01.

The PG Model applies these projected penetration rates to the number of forecast IOU households, which increases over time from 2024 to 2035, 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 model uses an 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 an average of adjusted kW and kWh savings as reported in the impact evaluation findings for PG&E, SCE, and SDG&E through 2018. This ratio was then updated based on California hourly load profiles to align with the current DEER peak period definition.[95]

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 a result of a calibration effort to align with reported program costs for 2018 (the most recent year with evaluated savings).[96] 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 UAT costs.

D.2 Residential – Universal Audit Tool

D.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 large 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

[95] 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

[96] 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).

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.[97] 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."[98]

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 D-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

Source: Guidehouse

D.2.2 Assumptions and Methodology

No major updates were made to UAT potential analysis in the 2023 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 2021 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,[99] 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 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.

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97 Stakeholder comments from 2019 Study May 9, 2019 stakeholder meeting.

98 DNV GL. March 31, 2017. Universal Audit Tool Impact Evaluation-Residential: California Public Utilities Commission, March 31, 2017. CALMAC ID: CPU0160.01.

99 DNV GL. March 31, 2017. Universal Audit Tool Impact Evaluation-Residential: California Public Utilities Commission, March 31, 2017. CALMAC ID: CPU0160.01.

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.

Per the SWWB002-01 workpaper for the UAT,[100] there is uncertainty on claiming peak demand savings. As a result, Guidehouse does not include peak demand savings potential for UAT.

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.[101] These costs were distributed to the kWh and therm savings (weighted by savings) as reported in the CEDARS database.

D.3 Residential – Real-Time Feedback: In-Home Displays and Online Portals

D.3.1 Summary

Unlike HERs that arrive in the mail or email 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 reviewed 38 programs, including 20 providing IHDs and 18 offering online portals. Several

[100] https://www.caetrm.com/measure/SWWB002/01/

[101] Energy Advisor programs savings and costs, CEDARS, 2017.

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 D-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

D.3.2 Assumptions and Methodology

No major updates were made to real-time feedback input data for the 2023 Study. The Guidehouse team determined that real-time feedback is 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 2021 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.[102]

As in the 2021 Study, IHDs are not included in the BROs analysis.[103] Previously, SCE indicated it would not deploy these programs until 2019, and they would only be pilots at that time.[104] 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 assumes an 8% increase in penetration per year. PG&E provided penetration rate data for IHDs and used for all IOUs.[105]

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%

[102] 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

[103] IHDs were excluded from the reference case because they did not pass the cost-effectiveness screen in the 2019 Study.

[104] Informal comments on the 2019 Study April 20, 2017 webinar.

[105] 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.[106,107,108,109,110,111]

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.[112]

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.[113] 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).

D.4 Residential – Competitions: Large and Small

D.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

[106] Kira Ashby, *2016 Behavior Program Summary*, 2016, Consortium for Energy Efficiency, https://library.cee1.org/content/2016-behavior-program-summary-public

[107] 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.

[108] 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

[109] Ben Foster and Susan Mazur-Stommen. 2012. “Results from Real-Time Feedback Studies.” American Council for an Energy Efficient Economy. Report Number B122

[110] Reuven Sussman and Maxine Chikumbo. 2016. “Behavior Change Programs: Status and Impact.” American Council for an Energy Efficient Economy. Report Number B1601

[111] 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.

[112] 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

[113] Alberta Energy Efficiency Alliance, *Energy Savings through Consumer Feedback Programs*, February 2014, City of Calgary.

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 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 D-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

D.4.2 Assumptions and Methodology

No major updates were made to the inputs for residential competitions in the 2023 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 2021 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.[114] CoolCalifornia Challenge[115] provided a participation rate of 0.1% for large competitions. This information was supplemented with findings from program reviews

[114] Grossberg, Frederick; Wolfson, Mariel; Mazur-Stommen, Susan; Farley, Kate; and Steven Nadel. 2015. (February) "Gamified Energy Efficiency Programs." ACEEE Report B1501.

[115] 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

conducted by the Consortium for Energy Efficiency,[116] American Council for an Energy Efficient Economy,[117] and Illume Advising.[118]

Penetration rates assume that small competitions are conducted by each utility with a consistent target population of 10,000 households per year each year 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. 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 analysis assumes for large competitions 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.

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.[119] 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%.[120]

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[121] 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:

[116] Kira Ashby, *2016 Behavior Program Summary*, 2016, Consortium for Energy Efficiency, https://library.cee1.org/content/2016-behavior-program-summary-public.
[117] 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
[118] 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.
[119] 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
[120] Grossberg, Frederick; Wolfson, Mariel; Mazur-Stommen, Susan; Farley, Kate; and Steven Nadel. 2015. (February) "Gamified Energy Efficiency Programs." ACEEE Report B1501.
[121] Consortium for Energy Efficiency Program Library, https://library.cee1.org/

- 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 Cooperative's Beat The Peak program.[122] 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.

D.5 Commercial – Strategic Energy Management-Like Programs

D.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

[122] Grossberg, Frederick; Wolfson, Mariel; Mazur-Stommen, Susan; Farley, Kate; and Steven Nadel. 2015. (February) "Gamified Energy Efficiency Programs." ACEEE Report B1501.

- 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 D-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.

Table D-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

D.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 2023 Study. The methodology described here is unchanged from the 2021 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[123]) 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 2023 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,[124] resulting in reduced applicability of any commercial SEM program. After accounting for the estimate of customers that have already

[123] Group D – D01.02. Workplan for 2018 Industrial Strategic Energy Management (SEM) Evaluation. SBW, Revised July 2, 2019.

[124] 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.

implemented SEM outside of any program intervention, the 2023 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.[125] The analysis case used a 2% CAGR which expects to achieve segment penetrations of approximately 1.3% by 2035.

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 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[126] and market studies such as the Northwest Energy Efficiency Alliance (NEEA) Market Progress Evaluation Report,[127] 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.[128] 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.[129]

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.

D.6 Commercial – Building Operator Certification

D.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

[125] Informal comments in response to the 2019 Study webinar held on April 20, 2017.

[126] Joint Strategic Energy Management Plan for Listowel Wingham Hospitals Alliance, 2014

[127] *Hospitals and Healthcare Initiative Market Progress Evaluation Report 7*, Northwest Energy Efficiency Alliance. March 26, 2015. REPORT #E15-310

[128] Personal communication with Kay Hardy, CPUC. May 9, 2017.

[129] CPUC. Resolution E-4952, October 11, 2018. https://docs.cpuc.ca.gov/publisheddocs/published/g000/m232/k459/232459122.pdf

savings since the 2011 Study, and research conducted for previous studies indicates that O&M practices mostly fell into the following categories:[130]

- 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

The model inputs for electric and natural gas shown in Table D-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).[131] 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 D-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

D.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 2023 Study. The methodology described here is unchanged from the 2021 Study. The team expects to revise inputs in future studies based on the forthcoming update to the CEUS (scheduled for completion in April 2023).[132]

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 of 12.5% through the model forecast horizon. While these growth rates appear ambitious, low initial sector

[130] Literature search results provided in Appendix C, *Analysis to Update Potential Goals and Targets for 2013 and Beyond*, Navigant Consulting Inc., March 19, 2012

[131] 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/

[132] At https://www.energy.ca.gov/data-reports/surveys/california-commercial-end-use-survey, accessed October 2022. Data collection for the 2021 Study ended in Q3 2020.

engagement in BOC results in forecast market penetrations of 8.25% in 2032. 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 2023 Study uses the same approach and values as the 2017, 2019, and 2021 studies. For context, the 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.[133] 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 2021 Study, the 2023 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.[134]

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.

D.7 Commercial – Building Energy and Information Management Systems

D.7.1 Summary

The potential for building energy and information management systems (BEIMSs) was first modeled by Guidehouse (formerly Navigant) as part of the Assembly Bill (AB) 802 Technical

[133] 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.

[134] CPUC. Resolution E-4952, October 11, 2018. https://docs.cpuc.ca.gov/publisheddocs/published/g000/m232/k459/232459122.pdf

Analysis.[135] The Technical Analysis, issued in March 2016, was not used at that time to set goals, but 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

In the 2023 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 D-8 shows the unit energy savings (UES) value used for these segments for the 2019 and 2021 studies.

135 Navigant Consulting, Inc., *AB 802 Technical Analysis, Potential Savings Analysis*. Reference No.: 174655. March 31, 2016

Table D-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 2021 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[136] update and any additional revisions to the saturation of building energy management or energy information systems that enable BEIMS savings.

Table D-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

D.7.2 Assumptions and Methodology

Eligibility and Participation

The technologies that enable BEIMS are primarily associated with energy management systems (EMSs) that are broadly applicable across all market sectors; the existing market saturation of these technologies ranges across market segments from 1% to 80%.[137] 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 SCG does not claim savings until 2018, and a CAGR was used to forecast growth in BEIMS technology penetration over time. The analysis used a 12% CAGR. Based on estimates of market saturations as of 2017, these

[136] At https://www.energy.ca.gov/data-reports/surveys/california-commercial-end-use-survey, accessed October 2022.
[137] Navigant Consulting, Inc. *AB 802 Technical Analysis, Potential Savings Analysis*. Reference No.: 174655, March 31, 2016

growth rates result in BEIMS forecast penetration of 7.1% by the end of the forecast horizon in 2035.

The FASP focuses on small- to medium-sized commercial buildings. While SCE and SDG&E plan to discontinue their current programs, [138,139] 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 D-2.

Equation D-2. 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 D-3, defined through work on the AB 802 Technical Analysis, is used in the potential model to calculate annual segment-level savings for each fuel type and IOU using Equation D-3.

Equation D-3. BEIMS Segment Savings

Segment Savings, BIEMS = Segment UES x Penetration Rate x Total Annual Segment Consumption x Segment Applicability Factor

Consistent with the 2021 Study, 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.[140] This ratio was then updated based on California hourly load profiles to align with the current DEER peak period definition.[141]

[138] Program - SCE-13-TP-025 details for the 2021 filing - CEDARS (sound-data.com)
[139] Program - SDGE4061 details for the 2021 filing - CEDARS (sound-data.com)
[140] Program - SDGE4061 details for the 2021 filing - CEDARS (sound-data.com)
[141] CPUC. Resolution E-4952, October 11, 2018. https://docs.cpuc.ca.gov/publisheddocs/published/g000/m232/k459/232459122.pdf

Cost

Costs for electricity and natural gas savings are estimated based on research referenced in the AB 802 Technical Analysis.[142] Guidehouse calculated costs per unit of fuel savings for each utility and fuel type as shown in Table D-10.

Table D-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

D.8 Commercial – Business Energy Reports

D.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.
- 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.[143] In the Commonwealth Edison pilot, the utility engaged 6,009 medium-sized (100 kW-1,000 kW) commercial

[142] CPUC. Resolution E-4952.

[143] Jim Stewart, Energy Savings from Business Energy Feedback [for Xcel Energy], Cadmus, October 21, 2015, Behavior, Energy, and Climate Change Conference 2015

customers in Illinois.[144] While the Commonwealth Edison customers represented numerous sectors, only those businesses in the lodging and other categories showed significant savings.

Table D-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

D.8.2 Assumptions and Methodology

No major updates to inputs were made to BERs in the 2023 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 2021 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 that approximately 63% of retail space is shown to be under 100,000 square feet.[145] 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

[144] 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.

[145] U.S. EIA, CBECS, http://www.eia.gov/consumption/commercial/data/2012/index.php?view=consumption#c13-c22

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 analysis assumes a starting penetration of 1% in 2021, increasing 1% per year and reaching 12% by 2032.

Savings

The model uses electricity savings of 0.32%, no gas savings,[146] 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.

D.9 Commercial – Benchmarking

D.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 as 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.[147]

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.

[146] 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.

Table D-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

D.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.[148] Table D-13 compares the applicability factors for benchmarking in the 2023 PG Model, which ranges from 16% to 31% to address the mandate change, to the 2021 Study in which applicability ranged from 35% to 100%. No changes were made to the applicability factors in the 2023 Study.

Table D-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 mandated 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 analysis.

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

[148] U.S. EIA. "Table B7. Building size, floorspace, 2012." CBECS (May 2016).

estimates are based on actual savings levels from city benchmarking reports.[149,150,151,152,153] 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.[154] 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.

D.10 Commercial – Competitions

D.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 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.

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[149] SF Environment and ULI Greenprint Center for Building Performance. "San Francisco Existing Commercial Buildings Performance Report: 2010-2014." (2015)

[150] Katherine Tweed. "Benchmarking Drives 7 Percent Cut in Building Energy." Greentech Media. October 2012.

[151] City of Chicago. "City of Chicago Energy Benchmarking Report 2016."

[152] 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.

[153] 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.

[154] CPUC, *Statewide Benchmarking Process Evaluation*, Volume 1, CPU0055.01, Submitted by NMR Group and Optimal Energy, April 2012.

In addition to overall summary data available through the ACEEE[155] and CEE,[156] 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.[157,158] 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.[159]

Table D-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

D.10.2 Assumptions and Methodology

No major updates were made to the inputs for commercial competitions in the 2023 Study. Guidehouse determined that commercial competitions were 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 2021 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.[160,161] 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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[155] Kira Ashby, 2016 Behavior Program Summary, 2016, Consortium for Energy Efficiency, https://library.cee1.org/content/2016-behavior-program-summary-public

[156] 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

[157] 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

[158] 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*.

[159] TecMarket Works, *Impact Evaluation of the Smart Energy Now Program (NC) (Pilot) for Duke Energy*, February 21, 2014.

[160] 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.

[161] 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.[162]

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.

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.[163]

D.11 Commercial – Retrocommissioning

D.11.1 Summary

The potential for retrocommissioning (RCx) has been modeled as a component of behavioral savings in previous studies since 2013. The 2023 update retains the underlying assumptions and inputs used in the 2021 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:[164]

- Correct actuator/damper operations
- Correct economizer operations
- Adjust condenser water reset

[162] 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.
[163] TecMarket Works, *Impact Evaluation of the Smart Energy Now Program (NC) (Pilot) for Duke Energy*, February 21, 2014.
[164] 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 2021 Study based on a review of the claimed first-year gross kWh and therm savings from the SCE Enhanced Retrocommissioning[165] and SDG&E HOPPs – Building Retrocommissioning programs.[166] The model inputs for electric and natural gas for RCx (shown in Table D-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 D-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

D.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 2023 Study. The methodology described here is unchanged from the 2021 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

[165] Program ID: SCE-13-TP-021
[166] 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. A 3.1% CAGR was used to forecast growth in RCx. 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% over the forecast horizon.

Savings

Consistent with past studies, energy savings associated with RCx are calculated using Equation D-4.

Equation D-4. RCx Energy Savings

$$\textit{Energy Savings, RCx} = \textit{Penetration of RCx by Building Type x Total Annual Consumption x \% End Use Consumption for HVAC x \% End Use Savings by Building Type}$$

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.[167,168,169] Savings for offices, colleges, and schools were capped at 5% to reflect feedback from SCE on its experience.[170] 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.

D.12 Industrial/Agriculture – SEM

D.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

[167] 2014 Retro-Commissioning (RCx) Program Extreme Makeover, CenterPoint Energy at http://www.centerpointenergy.com/en-us/Documents/2014%20RCx%20Kickoff%20Slides.pdf

[168] US Environmental Protection Agency: http://www.epa.gov/statelocalclimate/documents/pdf/table_rules_of_thumb.pdf

[169] DEER ExAnte2013 - RTU-Retro, Rooftop Unit retrocommissioning COM IOU workpaper

[170] Informal comment received in response to a webinar held on April 20, 2017.

SEM Design Guide,[171] 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 energy management system (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 D-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;[172] these values are also applied consistently by building and fuel type across utilities.

Table D-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

D.12.2 Assumptions and Methodology

Eligibility and Participation

Eligibility and participation estimates in the 2023 Study are consistent with the 2021 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.[173] 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

[171] Version 1.0, February 8, 2017. Prepared by Sergio Dias Consulting LLC.

[172] Analysis of reported costs from using the 2019 Claims CEDARS data.

[173] 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.

agriculture market sectors; this factor ranged between 39% and 93% for electricity and 48% to 99% for natural gas for the industrial sector, as Table D-17 shows, and between 40% and 65% for both electricity and natural gas for the agriculture sector, as Table D-18 shows.

Table D-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 D-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 2023 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 2021 and is forecast to be 21% year-over-year.[174] This change in methodology resulted in SEM penetration forecasts of 6.1% in 2035.

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 D-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 D-20 provides the UES multipliers used to forecast natural gas savings.

Table D-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 Refrigeration			
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%

[174] 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			
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%
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 D-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 2023 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 D-21 shows.

Table D-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 analysis uses the SEM UES multiplier to forecast segment-level potential net savings using Equation D-5.

Equation D-5. SEM Segment-Level Savings

$$\text{SEM Segment-Level EE Net Savings Potential} = \\ \text{SEM UES Multiplier x Annual Segment Consumption}^{175}$$

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 2021 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.

[175] Electric (GWh) and natural gas (therms) consumption from the 2019 IEPR forecast.

Appendix E. Industrial and Agriculture Sectors – Characterized Measures

This appendix provides additional detail and data for the industrial and agriculture sectors. Industrial and agriculture building types are classified by grouping buildings in NAICS codes. Table E-1 references the building types used in this study with their associated NAICS codes.

Table E-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

E.1 Industrial

Table E-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 E-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 EE rating).

Measure Name	End Use Category	Description
EE Lighting	Lighting	Lighting controls and early retirement potential to LED fixtures.
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	VFD controls on process motors to take advantage of partial load conditions.
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.

Measure Name	End Use Category	Description
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.
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 Retrocommissioning[176]	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[177]	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.

[176] 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.
[177] 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.

Source: Guidehouse team

E.2 Agriculture

Table E-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.

Table E-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[178]	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.).

[178] All lighting considers the LED baseline and efficient changes reflected in the commercial sector.

Measure Name	End Use Category	Description
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).
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.

Measure Name	End Use Category	Description
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.
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 ideally 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

Appendix F. Codes and Standards

Table F-1 describes the list of codes and standards (C&S) accounted for in the model.

Table F-1. C&S in the Model

Regulation	Code or Standard Name	Compliance Rate[179]	Effective Date	Policy View
2005 T-20	2005 T-20: Commercial Dishwasher Pre-Rinse Spray Valves	100%	1/1/2006	On-the-books
2005 T-20	2005 T-20: Commercial Refrigeration Equipment, Solid Door	70%	1/1/2008	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%	1/1/2007	On-the-books
2005 T-20	2005 T-20: General Service Incandescent Lamps, Tier 1	69%	1/1/2007	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%	1/1/2007	On-the-books
2005 T-20	2005 T-20: Refrigerated Beverage Vending Machines	37%	7/1/2008	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%	10/1/2006	On-the-books
2005 T-20	2005 T-20: Water Dispensers	70%	1/1/2010	On-the-books
2005 T-20	2005 T-20: Large Packaged Commercial Air-Conditioners, Tier 1	70%	1/1/2006	On-the-books
2005 T-20	2005 T-20: Commercial Refrigeration Equipment, Transparent Door	70%	1/1/2006	On-the-books
2005 T-20	2005 T-20: Consumer Electronics - Audio Players	100%	1/1/2006	On-the-books
2005 T-20	2005 T-20: External Power Supplies, Tier 1	100%	1/1/2006	On-the-books
2005 T-20	2005 T-20: Commercial Ice Maker Equipment	70%	1/1/2006	On-the-books

[179] Compliance rates are specific to 2022 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.

Regulation	Code or Standard Name	Compliance Rate[179]	Effective Date	Policy View
2005 T-20	2005 T-20: Modular Furniture Task Lighting Fixtures	70%	1/1/2006	On-the-books
2005 T-20	2005 T-20: Pulse Start Metal Halide HID Luminaires, Tier 2(All other MH	100%	1/1/2006	On-the-books
2005 T-24	2005 T-24: Bi-level lighting control credits	79%	1/1/2008	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%	1/1/2008	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%	1/1/2006	On-the-books
2006 T-20	2006 T-20: General Service Incandescent Lamps, Tier 2 #2	87%	1/1/2006	On-the-books
2006 T-20	2006 T-20: General Service Incandescent Lamps, Tier 2 #3	89%	1/8/2008	On-the-books
2006 T-20	2006 T-20: Residential Pool Pumps, 2-speed Motors, Tier 2	86%	1/8/2008	On-the-books
2006 T-20	2006 T-20: BR, ER and R20 Incandescent Reflector Lamps: Commercial	82%	1/1/2008	On-the-books

Regulation	Code or Standard Name	Compliance Rate[179]	Effective Date	Policy View
2006 T-20	2006 T-20: BR, ER and R20 Incandescent Reflector Lamps: Residential	82%	1/1/2008	On-the-books
2006 T-20	2005 T-20: External Power Supplies, Tier 2	99%	1/1/2008	On-the-books
2006 T-20	2005 T-20: Large Packaged Commercial Air-Conditioners, Tier 2	70%	1/1/2008	On-the-books
2006 T-20	2008 T-20: Metal Halide Fixtures	95%	1/1/2011	On-the-books
2006 T-20	2008 T-20: Portable Lighting Fixtures	93%	1/1/2013	On-the-books
2008 T-20	2008 T-20: General Purpose Lighting -- 100 watt	88%	10/1/2010	On-the-books
2008 T-20	2008 T-20: General Purpose Lighting -- 75 watt	40%	1/1/2013	On-the-books
2008 T-20	2008 T-20: General Purpose Lighting -- 60 and 40 watt	85%	7/1/2014	On-the-books
2008 T-24	2008 T-24: Residential Fenestration	83%	1/1/2012	On-the-books
2008 T-24	2008 T-24: Residential Swimming pool	83%	1/1/2010	On-the-books
2008 T-24	2008 T-24: CfR HVAC Efficiency	397%	1/1/2010	On-the-books
2008 T-24	2008 T-24: CfR IL Area Category Method	569%	9/1/2010	On-the-books
2008 T-24	2008 T-24: CfR IL Complete Building Method	571%	9/1/2010	On-the-books
2008 T-24	2008 T-24: CfR IL Egress Control	397%	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	0%	9/1/2010	On-the-books
2008 T-24	2008 T-24: Cool Roof Expansion	253%	10/1/2010	On-the-books
2008 T-24	2008 T-24: DDC to Zone	397%	10/1/2010	On-the-books
2008 T-24	2008 T-24: DR Indoor Lighting	397%	10/1/2010	On-the-books
2008 T-24	2008 T-24: Envelope insulation	123%	10/1/2010	On-the-books
2008 T-24	2008 T-24: Outdoor Lighting	83%	9/1/2010	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	397%	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	397%	10/1/2010	On-the-books
2008 T-24	2008 T-24: Site Built Fenestration	83%	7/1/2010	On-the-books
2008 T-24	2008 T-24: Skylighting	397%	7/1/2010	On-the-books
2008 T-24	2008 T-24: Tailored Indoor lighting	573%	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%	10/1/2010	On-the-books
2009 T-20	2009 T-20: Televisions - Tier 2	99%	7/1/2014	On-the-books

Regulation	Code or Standard Name	Compliance Rate[179]	Effective Date	Policy View
2011 T-20	2011 T-20: Small Battery Chargers – Tier 1 (consumer with no USB charger or USB charger <20 watt-hours)	90%	7/1/2014	On-the-books
2011 T-20	2011 T-20: Large Battery Chargers (≥2kW rated input)	78%	4/1/2015	On-the-books
2011 T-20	2011 T-20: Small Battery Chargers – Tier 2 (consumer with USB charger ≥20 watt-hours)	88%	4/1/2015	On-the-books
2011 T-20	2011 T-20: Small Battery Chargers – Tier 3 (non-consumer)	85%	10/01/20	On-the-books
2013 T-24	2013 T-24: NRA-Envelope-Cool Roofs	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRA-HVAC-Equipment Efficiency	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRA-Lighting-Alterations-Existing Measures	91%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRA-Lighting-Alterations-New Measures	91%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRA-Lighting-Egress Lighting Control	91%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRA-Lighting-Hotel Corridors	91%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRA-Lighting-MF Building Corridors	91%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRA-Lighting-Warehouses and Libraries	91%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRA-Process-Air Compressors	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: RA-MF Whole Building	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: RA-SF Whole Building	67%	4/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-DHW - High Efficiency Water Heater Ready	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-DHW - Solar for Electrically Heated Homes	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-DHW-SF DHW	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-Envelope-Advanced Envelope	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-Envelope-Fenestration	47%	4/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-Envelope-Roof Envelope	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-Envelope-Wall Insulation	76%	4/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-HVAC - Refrigerant Charge	83%	4/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-HVAC-Duct	68%	4/1/2015	On-the-books

Regulation	Code or Standard Name	Compliance Rate[179]	Effective Date	Policy View
2013 T-24	2013 T-24: RNC-HVAC-Whole House Fans	59%	4/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-HVAC-Zoned AC	42%	4/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-Lighting	0%	4/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-SF Whole Building	67%	4/1/2015	On-the-books
2013 T-24	2013 T-24: RNC-Solar - Solar Ready & Oriented Homes	83%	4/1/2015	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
2013 T-24	2013 T-24: NRNC-Envelope-Cool Roofs	93%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-Envelope-Fenestration	93%	7/1/2014	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Acceptance Requirements	83%	7/1/2014	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Chiller Min Efficiency	93%	1/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Commercial Boilers	93%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Cooling Towers Water	83%	1/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Evap Cooling Credit	83%	1/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Fan Control & Economizers	93%	1/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Garage Exhaust	83%	1/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Guest Room OC Controls	93%	1/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-HVAC Controls and Economizers	93%	1/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Kitchen Ventilation	93%	1/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Laboratory Exhaust	83%	1/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Low-Temp Radiant Cooling	83%	1/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Occupant Controlled Smart Thermostats	83%	1/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Outside Air	83%	1/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Reduced Reheat	93%	4/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-HVAC-Small ECM Motor	83%	1/1/2015	On-the-books

Regulation	Code or Standard Name	Compliance Rate[179]	Effective Date	Policy View
2013 T-24	2013 T-24: NRNC-HVAC-Water & Space Heating ACM	83%	1/1/2015	On-the-books
2013 T-24	2013 T-24: NRNC-Lighting-Controllable Lighting	83%	01/01/19	On-the-books
2013 T-24	2013 T-24: NRNC-Lighting-Daylighting	93%	07/01/21	On-the-books
2013 T-24	2013 T-24: NRNC-Lighting-DR Lighting Controls	83%	01/01/19	On-the-books
2013 T-24	2013 T-24: NRNC-Lighting-Egress Lighting Control	83%	07/01/19	On-the-books
2013 T-24	2013 T-24: NRNC-Lighting-Hotel Corridors	83%	07/01/19	On-the-books
2013 T-24	2013 T-24: NRNC-Lighting-Indoor Lighting Controls	93%	1/1/2017	On-the-books
2013 T-24	2013 T-24: NRNC-Lighting-MF Building Corridors	83%	1/1/2017	On-the-books
2013 T-24	2013 T-24: NRNC-Lighting-Office Plug Load Control	83%	1/1/2017	On-the-books
2013 T-24	2013 T-24: NRNC-Lighting-Outdoor Lighting & Controls	83%	1/1/2017	On-the-books
2013 T-24	2013 T-24: NRNC-Lighting-Parking Garage	83%	1/1/2017	On-the-books
2013 T-24	2013 T-24: NRNC-Lighting-Retail	93%	1/1/2017	On-the-books
2013 T-24	2013 T-24: NRNC-Lighting-Warehouses and Libraries	83%	1/1/2017	On-the-books
2013 T-24	2013 T-24: NRNC-Process-Air Compressors	83%	1/1/2017	On-the-books
2013 T-24	2013 T-24: NRNC-Process-Data Centers	83%	1/1/2017	On-the-books
2013 T-24	2013 T-24: NRNC-Process-Process Boilers	83%	1/1/2017	On-the-books
2013 T-24	2013 T-24: NRNC-Refrigeration-Supermarket	83%	1/1/2017	On-the-books
2013 T-24	2013 T-24: NRNC-Refrigeration-Warehouse	83%	01/01/23	On-the-books
2013 T-24	2013 T-24: NRNC-Solar-Solar Ready	83%	02/01/20	On-the-books
2013 T-24	2013 T-24: NRNC-Whole Building	93%	06/01/19	On-the-books
2013 T-24	2013 T-24: RNC-DHW - MF DHW Control and Solar	83%	06/01/19	On-the-books
2013 T-24	2013 T-24: RNC-MF Whole Building	83%	01/01/22	On-the-books
2015 T-20	T-20: Residential Faucets & Aerators - Lavatory w/ Electric Water Heating - Tier 1	89%	02/01/20	On-the-books
2015 T-20	T-20: Residential Faucets & Aerators - Lavatory w/ Natural Gas Water Heating - Tier 1	89%	02/01/20	On-the-books

Regulation	Code or Standard Name	Compliance Rate[179]	Effective Date	Policy View
2016 T-20	T-20: Commercial Toilets	85%	02/01/20	On-the-books
2016 T-20	T-20: Public Lavatory Faucets	0%	02/01/20	On-the-books
2016 T-20	T-20: Residential Faucets & Aerators - Kitchen w/ Electric Water Heating	85%	02/01/20	On-the-books
2016 T-20	T-20: Residential Faucets & Aerators - Kitchen w/ Natural Gas Water Heating	85%	02/01/20	On-the-books
2016 T-20	T-20: Residential Toilets	85%	02/01/20	On-the-books
2016 T-20	T-20: Urinals	76%	10/01/20	On-the-books
2016 T-20	T-20: Dimming Ballasts	83%	10/01/20	On-the-books
2016 T-20	T-20: Residential Faucets & Aerators - Lavatory w/ Electric Water Heating - Tier 2	100%	10/01/20	On-the-books
2016 T-20	T-20: Residential Faucets & Aerators - Lavatory w/ Natural Gas Water Heating - Tier 2	100%	10/01/20	On-the-books
2016 T-20	T-20: Showerheads - w/ Electric Water Heaters - Tier 1	85%	10/01/20	On-the-books
2016 T-20	T-20: Showerheads - w/ Natural Gas Water Heaters - Tier 1	85%	10/01/20	On-the-books
2016 T-20	2016 T-20: LED Quality - Tier 2	85%	01/15/21	On-the-books
2016 T-20	2016 T-20: Computers - Notebooks	85%	01/15/21	On-the-books
2016 T-20	2016 T-20: Computers - Desktops - Tier 1	85%	09/23/19	On-the-books
2016 T-20	2016 T-20: Computers - Desktops - Tier 2	85%	10/28/19	On-the-books
2016 T-20	2016 T-20: Displays - Monitors	85%	02/01/23	On-the-books
2016 T-24	2016 T-24: Nonresidential Lighting-Alterations (Units = sq ft)	97%	07/01/20	On-the-books
2016 T-24	2016 T-24: Non-Residential New Construction-Whole Building (Units = sq ft)	96%	07/01/20	On-the-books
2016 T-24	2016 T-24: NRA-HVAC-ASHRAE Equipment Efficiency	95%	07/01/20	On-the-books
2016 T-24	2016 T-24: NRA-HVAC-ASHRAE Measure-DDC	95%	01/21/20	On-the-books
2016 T-24	2016 T-24: NRA-Lighting-ASHRAE Elevator Lighting & Ventilation	95%	01/21/20	On-the-books
2016 T-24	2016 T-24: NRA-Lighting-Outdoor Lighting Controls (unit = control)	95%	01/27/20	On-the-books
2016 T-24	2016 T-24: NRA-Process-ASHRAE Measure-Escalator Speed Control	95%	07/19/21	On-the-books
2016 T-24	2016 T-24: Residential Alterations-Multifamily Whole Building (Units = # of dwellings)	95%	06/13/19	On-the-books

Regulation	Code or Standard Name	Compliance Rate[179]	Effective Date	Policy View
2016 T-24	2016 T-24: Residential Alterations-Single Family Whole Building (Units = # of homes)	95%	07/03/19	On-the-books
2016 T-24	2016 T-24: Residential New Construction-Multifamily Whole Building (Units = # of dwellings)	95%	01/28/19	On-the-books
2016 T-24	2016 T-24: Residential New Construction-Whole Building (units=# of homes)	100%	01/08/19	On-the-books
2018 T-20	T-20: Computers - Small Scale Servers	85%	04/01/20	On-the-books
2018 T-20	T-20: Computers - Workstations	85%	04/01/20	On-the-books
2018 T-20	T-20: GSLs - Original Scope - Tier 2	100%	04/01/20	On-the-books
2018 T-20	T-20: LED Lamps - Tier 1	99%	09/01/20	On-the-books
2018 T-20	T-20: Small Diameter Directional Lamps	67%	09/01/20	On-the-books
2018 T-20	T-20: Showerheads - w/ Electric Water Heaters - Tier 2	70%	07/01/20	On-the-books
2018 T-20	T-20: Showerheads - w/ Natural Gas Water Heaters - Tier 2	70%	07/01/20	On-the-books
2018 T-20	2018 T-20: Portable Electric Spas - Inflatable	85%	02/01/23	On-the-books
2018 T-20	2018 T-20: Portable Electric Spas - Rigid	85%	02/01/23	On-the-books
2018 T-20	2018 T-20: Portable ACs	85%	02/01/23	On-the-books
2019 T-20	2019 T-20: General Service Lamps - Expanded Scope	85%	02/01/23	On-the-books
2019 T-20	2019 T-20: Replacement Dedicated-Purpose Pool Pump Motors	85%	02/01/23	On-the-books
2019 T-20	2019 T-20: Compressors	85%	09/01/23	On-the-books
2019 T-24	2019 T-24: NRA-Indoor Lighting-Alterations (Control)	85%	02/01/23	On-the-books
2019 T-24	2019 T-24: NRA-Indoor Lighting-Alterations (LPD)	85%	02/01/23	On-the-books
2019 T-24	2019 T-24: NRA-Indoor Lighting-New LPD	85%	02/01/23	On-the-books
2019 T-24	2019 T-24: NRA-Indoor Lighting-New Controls	85%	02/01/23	On-the-books
2019 T-24	2019 T-24: NRA-Outdoor Lighting-LPA (General Hardscape)	85%	02/01/23	On-the-books
2019 T-24	2019 T-24: NRA-Outdoor Lighting-LPA (Specific Applications)	85%	02/01/23	On-the-books
2019 T-24	2019 T-24: NRA-Outdoor Lighting-Controls	85%	02/01/23	On-the-books
2019 T-24	2019 T-24: NRA-MECH-ASHRAE 90.1	85%	02/01/23	On-the-books

Regulation	Code or Standard Name	Compliance Rate[179]	Effective Date	Policy View
2019 T-24	2019 T-24: NRA-MECH-Cooling Towers	85%	02/01/23	On-the-books
2019 T-24	2019 T-24: NRA-MECH-HE Fume Hoods in Lab Spaces	85%	02/01/23	On-the-books
2019 T-24	2019 T-24: NRA-MECH-Variable Exhaust Flow Control	85%	02/01/23	On-the-books
2019 T-24	2019 T-24: NRNC-Indoor Lighting-LPD	85%	02/01/23	On-the-books
2019 T-24	2019 T-24: NRNC-Indoor Lighting-Controls	85%	02/01/23	On-the-books
2019 T-24	2019 T-24: NRNC- Outdoor Lighting-LPA (General Hardscape)	85%	02/01/23	On-the-books
2019 T-24	2019 T-24: NRNC- Outdoor Lighting-LPA (Specific Applications)	85%	02/01/23	On-the-books
2019 T-24	2019 T-24: NRNC-Outdoor Lighting-Controls	85%	02/01/23	On-the-books
2019 T-24	2019 T-24: NRNC-Envelope-Dock Seals	85%	02/01/23	On-the-books
2019 T-24	2019 T-24: NRNC-MECH-Adiabatic Condensers for Refrigeration	85%	10/01/23	On-the-books
2019 T-24	2019 T-24: NRNC-MECH-ASHRAE 90.1	85%	10/01/23	On-the-books
2019 T-24	2019 T-24: NRNC-MECH-Cooling Towers	85%	10/01/23	On-the-books
2019 T-24	2019 T-24: NRNC-MECH-Economizer FDD	85%	10/01/23	On-the-books
2019 T-24	2019 T-24: NRNC-MECH-HE Fume Hoods in Lab Spaces	85%	10/01/23	On-the-books
2019 T-24	2019 T-24: NRNC-MECH-Variable Exhaust Flow Control	85%	10/01/23	On-the-books
2019 T-24	2019 T-24: NRNC-MECH-Ventilation & IAQ	85%	10/01/23	On-the-books
2019 T-24	2019 T-24: RNC(SF)-Envelope-High Performance Attics	85%	10/01/23	On-the-books
2019 T-24	2019 T-24: RNC(SF)-Envelope-High Performance Walls	85%	10/01/23	On-the-books
2019 T-24	2019 T-24: RNC(SF)-Envelope-QII	85%	10/01/23	On-the-books
2019 T-24	2019 T-24: RNC(SF)-Envelope-Windows and Doors	85%	10/01/23	On-the-books
2019 T-24	2019 T-24: RNC(SF)-MECH-Quality HVAC	85%	10/01/23	On-the-books
2019 T-24	2019 T-24: RNC(MF)-Envelope-High Performance Attics	85%	10/01/23	On-the-books
2019 T-24	2019 T-24: RNC(MF)-Envelope-QII	85%	10/01/23	On-the-books
2019 T-24	2019 T-24: RNC(MF)-Envelope-Windows and Doors	85%	10/01/23	On-the-books

Regulation	Code or Standard Name	Compliance Rate[179]	Effective Date	Policy View
2019 T-24	2019 T-24: RNC(MF)-MECH-Quality HVAC	85%	10/01/23	On-the-books
2019 T-24	2019 T-24: RA(SF)-Envelope-High Performance Walls	85%	10/01/23	On-the-books
2019 T-24	2019 T-24: RA(SF)-Envelope-QII	85%	10/01/23	On-the-books
2019 T-24	2019 T-24: RA(SF)-Envelope-Windows and Doors	85%	10/01/23	On-the-books
2019 T-24	2019 T-24: RA(SF)-MECH-Quality HVAC	85%	10/01/23	On-the-books
2019 T-24	2019 T-24: RA(MF)-Envelope-QII	85%	10/01/23	On-the-books
2019 T-24	2019 T-24: RA(MF)-Envelope-Windows and Doors	85%	10/01/23	On-the-books
2019 T-24	2019 T-24: RA(MF)-MECH-Quality HVAC	85%	10/01/23	On-the-books
2022 T-24	2022 T-24: NRA - Air Distribution - Duct Leakage Testing	85%	10/01/23	On-the-books
2022 T-24	2022 T-24: NRA - Air Distribution - Fan Energy Index	85%	10/01/23	On-the-books
2022 T-24	2022 T-24: NRA - Air Distribution - Fan Power Budget	85%	10/01/23	On-the-books
2022 T-24	2022 T-24: NRA - Boilers and Service Water Heating - Oxygen Concentration	85%	10/01/23	On-the-books
2022 T-24	2022 T-24: NRA - Compressed Air Systems - Monitoring	85%	10/01/23	On-the-books
2022 T-24	2022 T-24: NRA - Computer Room Efficiency - Uninterruptible Power Supply Efficiency	85%	10/01/23	On-the-books
2022 T-24	2022 T-24: NRA - Controlled Environment Horticulture - Efficient Dehumidification	85%	10/01/23	On-the-books
2022 T-24	2022 T-24: NRA - Controlled Environment Horticulture - Lighting Efficacy	85%	10/01/23	On-the-books
2022 T-24	2022 T-24: NRA - Daylighting - Automatic Daylight Dimming to 10%	85%	02/01/23	On-the-books
2022 T-24	2022 T-24: NRA - Envelope - Cool Roofs: Steep-Sloped	85%	02/01/23	On-the-books
2022 T-24	2022 T-24: NRA - Envelope - Roof Recovers	85%	02/01/23	On-the-books
2022 T-24	2022 T-24: NRA - Envelope - Roof Replacements	85%	02/01/23	On-the-books
2022 T-24	2022 T-24: NRA - Grid Integration - Demand Responsive Lighting Systems	85%	02/01/23	On-the-books
2022 T-24	2022 T-24: NRA - HVAC Controls - Dedicated Outdoor Air Systems	85%	02/01/23	On-the-books

Regulation	Code or Standard Name	Compliance Rate[179]	Effective Date	Policy View
2022 T-24	2022 T-24: NRA - HVAC Controls - Exhaust Air Heat Recovery	85%	02/01/23	On-the-books
2022 T-24	2022 T-24: NRA - HVAC Controls - Expand Economizer Requirements	85%	02/01/23	On-the-books
2022 T-24	2022 T-24: NRA - HVAC Controls - VAV Deadband Airflow	85%	01/10/25	On-the-books
2022 T-24	2022 T-24: NRA - Indoor Lighting - Lighting Power Densities	85%	01/10/23	On-the-books
2022 T-24	2022 T-24: NRA - Indoor Lighting - Multi-zone Occupancy Sensing in Large Offices	85%	03/10/25	On-the-books
2022 T-24	2022 T-24: NRA - Outdoor Lighting - Lighting Power Allowances for General Hardscapes	85%	01/01/23	On-the-books
2022 T-24	2022 T-24: NRA - Outdoor Lighting - Lighting Zone Reclassification	85%	01/10/22	On-the-books
2022 T-24	2022 T-24: NRA - Reduce Infiltration - Require air barrier where not currently required	85%	3/2/2012	On-the-books
2022 T-24	2022 T-24: NRA - Refrigeration System - Automatic Door Closers for Refrigerated Spaces	85%	1/1/2017	On-the-books
2022 T-24	2022 T-24: NRNC - Air Distribution - Duct Leakage Testing	85%	1/1/2018	On-the-books
2022 T-24	2022 T-24: NRNC - Air Distribution - Fan Energy Index	85%	1/1/2018	On-the-books
2022 T-24	2022 T-24: NRNC - Air Distribution - Fan Power Budget	85%	1/8/2013	On-the-books
2022 T-24	2022 T-24: NRNC - Boilers and Service Water Heating - Gas Boiler Systems	85%	1/28/2018	On-the-books
2022 T-24	2022 T-24: NRNC - Boilers and Service Water Heating - Gas Service Water Heating	85%	1/1/2012	On-the-books
2022 T-24	2022 T-24: NRNC - Boilers and Service Water Heating - Process Boiler Oxygen Concentration	85%	3/27/2017	On-the-books
2022 T-24	2022 T-24: NRNC - Compressed Air Systems - Leak Testing	85%	10/29/2013	On-the-books
2022 T-24	2022 T-24: NRNC - Compressed Air Systems - Monitoring	85%	1/1/2016	On-the-books
2022 T-24	2022 T-24: NRNC - Compressed Air Systems - Pipe Sizing	85%	6/1/2016	On-the-books
2022 T-24	2022 T-24: NRNC - Computer Room Efficiency - Increased Temperature Thresholds for Economizers	85%	12/1/2010	On-the-books

Regulation	Code or Standard Name	Compliance Rate[179]	Effective Date	Policy View
2022 T-24	2022 T-24: NRNC - Computer Room Efficiency - Uninterruptible Power Supply Efficiency	85%	2/10/2016	On-the-books
2022 T-24	2022 T-24: NRNC - Controlled Environment Horticulture - Efficient Dehumidification	85%	11/14/2014	On-the-books
2022 T-24	2022 T-24: NRNC - Controlled Environment Horticulture - Lighting Efficacy	85%	7/14/2012	On-the-books
2022 T-24	2022 T-24: NRNC - Daylighting - Automatic Daylight Dimming to 10%	85%	1/26/2018	On-the-books
2022 T-24	2022 T-24: NRNC - Envelope - Cool Roofs: Steep-Sloped	85%	7/14/2012	On-the-books
2022 T-24	2022 T-24: NRNC - Envelope - High Performance Windows	85%	6/1/2014	On-the-books
2022 T-24	2022 T-24: NRNC - Envelope - Opaque Envelope	85%	2/10/2017	On-the-books
2022 T-24	2022 T-24: NRNC - Grid Integration - Demand Responsive Lighting Systems	85%	6/17/2016	On-the-books
2022 T-24	2022 T-24: NRNC - HVAC Controls - Dedicated Outdoor Air Systems	85%	8/31/2011	On-the-books
2022 T-24	2022 T-24: NRNC - HVAC Controls - Exhaust Air Heat Recovery	85%	1/1/2015	On-the-books
2022 T-24	2022 T-24: NRNC - HVAC Controls - Expand Economizer Requirements	85%	1/15/2015	On-the-books
2022 T-24	2022 T-24: NRNC - HVAC Controls - VAV Deadband Airflow	85%	1/1/2018	On-the-books
2022 T-24	2022 T-24: NRNC - Indoor Lighting - Lighting Power Densities	85%	3/7/2015	On-the-books
2022 T-24	2022 T-24: NRNC - Indoor Lighting - Multi-zone Occupancy Sensing in Large Offices	85%	3/7/2015	On-the-books
2022 T-24	2022 T-24: NRNC - Outdoor Lighting - Nonresidential Lighting Power Allowances for General Hardscapes	85%	4/16/2013	On-the-books
2022 T-24	2022 T-24: NRNC - Outdoor Lighting - Nonresidential Lighting Zone Reclassification	85%	5/30/2013	On-the-books
2022 T-24	2022 T-24: NRNC - Reduce Infiltration - Require air barrier where not currently required	85%	4/9/2012	On-the-books
2022 T-24	2022 T-24: NRNC - Refrigeration System - Automatic Door Closers for Refrigerated Spaces	85%	4/16/2015	On-the-books
2022 T-24	2022 T-24: NRNC - Refrigeration System - Design and Control Requirements for Transcritical CO2 Systems - Adiabatic Condenser	85%	4/16/2015	On-the-books

Regulation	Code or Standard Name	Compliance Rate[179]	Effective Date	Policy View
2022 T-24	2022 T-24: NRNC - Steam Trap - FDD	85%	4/16/2015	On-the-books
2022 T-24	2022 T-24: NRNC - Steam Trap - Strainers	85%	4/16/2015	On-the-books
2022 T-24	2022 T-24: SFAA - Cool roof for low-sloped roof	85%	4/16/2013	On-the-books
2022 T-24	2022 T-24: SFAA - Cool roof for steep-sloped roofs	85%	9/15/2014	On-the-books
2022 T-24	2022 T-24: SFAA - Electric resistance space heating	85%	6/1/2014	On-the-books
2022 T-24	2022 T-24: SFAA - Prescriptive attic insulation for additions	85%	10/9/2015	On-the-books
2022 T-24	2022 T-24: SFAA - Prescriptive attic insulation for alterations	85%	6/1/2013	On-the-books
2022 T-24	2022 T-24: SFAA - Prescriptive duct insulation	85%	3/9/2015	On-the-books
2022 T-24	2022 T-24: SFAA - Prescriptive duct sealing	85%	6/5/2017	On-the-books
2022 T-24	2022 T-24: SFAA - Roof deck insulation for low-sloped roofs	85%	1/1/2016	On-the-books
2022 T-24	2022 T-24: MFA - Outdoor Lighting - Power Allowances	85%	1/1/2018	On-the-books
2022 T-24	2022 T-24: MFA - Restructuring - Airflow and Fan Watt Draw	85%	1/1/2018	On-the-books
2022 T-24	2022 T-24: MFA - Restructuring - Duct Sealing and Testing	85%	7/1/2016	On-the-books
2022 T-24	2022 T-24: MFA - Restructuring - Fenestration Properties	85%	1/1/2018	On-the-books
2022 T-24	2022 T-24: MFA - Restructuring - Refrigerant Charge Verification	85%	1/1/2018	On-the-books
2022 T-24	2022 T-24: MFA - Restructuring - Roof Assemblies	85%	1/1/2016	On-the-books
2022 T-24	2022 T-24: MFNC - All Electric Package - Prescriptive Alternative for Central HPWH	85%	1/1/2016	On-the-books
2022 T-24	2022 T-24: MFNC - All Electric Package - Single Zone Heat Pump Electric Space Heating for Mid-rise and High-rise MF	85%	1/1/2016	On-the-books
2022 T-24	2022 T-24: MFNC - Boilers and Service Water Heating - Gas Service Water Heating	85%	9/1/2015	On-the-books
2022 T-24	2022 T-24: MFNC - Domestic Hot Water - Increased Insulation for Hot Water Distribution	85%	7/1/2016	On-the-books
2022 T-24	2022 T-24: MFNC - Indoor Air Quality - Central Ventilation Duct Sealing	85%	9/1/2015	On-the-books

Regulation	Code or Standard Name	Compliance Rate[179]	Effective Date	Policy View
2022 T-24	2022 T-24: MFNC - Indoor Air Quality - Heat or Energy Recovery Ventilator	85%	7/1/2016	On-the-books
2022 T-24	2022 T-24: MFNC - Outdoor Lighting - Power Allowances	85%	1/1/2016	On-the-books
2022 T-24	2022 T-24: MFNC - Restructuring - Airflow and Fan Watt Draw	85%	7/1/2016	On-the-books
2022 T-24	2022 T-24: MFNC - Restructuring - Duct Sealing and Testing	85%	7/1/2018	On-the-books
2022 T-24	2022 T-24: MFNC - Restructuring - Fenestration Properties	85%	7/1/2016	On-the-books
2022 T-24	2022 T-24: MFNC - Restructuring - Refrigerant Charge Verification	85%	7/1/2018	On-the-books
2022 T-24	2022 T-24: MFNC - Restructuring - Roof Assemblies	85%	1/1/2018	On-the-books
2022 T-24	2022 T-24: MFNC - Restructuring - Wall U-Factor	85%	1/1/2016	On-the-books
Federal	Fed Appliance: Electric Motors 1-200HP	91%	10/1/2010	On-the-books
Federal	Fed Appliance: Refrigerated Beverage Vending Machines	37%	1/1/2011	On-the-books
Federal	Fed Appliance: Commercial Refrigeration	70%	1/1/2014	On-the-books
Federal	Fed Appliance: ASHRAE Products (Commercial boilers)	95%	2/1/2013	On-the-books
Federal	Fed Appliance: Residential Electric & Gas Ranges	100%	1/1/2014	On-the-books
Federal	Fed Appliance: General Service Fluorescent Lamps #1	95%	1/1/2017	On-the-books
Federal	Fed Appliance: Incandescent Reflector Lamps	65%	7/1/2014	On-the-books
Federal	Fed Appliance: Commercial Clothes Washers #1	94%	7/1/2014	On-the-books
Federal	Fed Appliance: Residential Direct Heating Equipment	95%	7/1/2014	On-the-books
Federal	Fed Appliance: Residential Pool Heaters	95%	7/1/2014	On-the-books
Federal	Fed Appliance: Residential Dishwashers	99%	7/1/2014	On-the-books
Federal	Fed Appliance: Small Commercial Package Air-Conditioners ≥65 and <135 kBtu/h	100%	7/1/2014	On-the-books
Federal	Fed Appliance: Computer Room ACs >=65,000 Btu/h and < 760,000 Btu/h	100%	4/1/2015	On-the-books
Federal	Fed Appliance: Large and Very Large Commercial Package Air-Conditioners ≥135 kBtu/h	100%	4/1/2015	On-the-books
Federal	Fed Appliance: Residential Room AC	91%	4/1/2015	On-the-books

Regulation	Code or Standard Name	Compliance Rate[179]	Effective Date	Policy View
Federal	Fed Appliance: Residential Refrigerators & Freezers	95%	4/1/2015	On-the-books
Federal	Fed Appliance: Fluorescent Ballasts	80%	4/1/2015	On-the-books
Federal	Fed Appliance: Residential Central AC, Heat Pumps and Furnaces	99%	4/1/2015	On-the-books
Federal	Fed Appliance: Residential Clothes Dryers	99%	4/1/2015	On-the-books
Federal	Fed Appliance: Residential Clothes Washers (Front Loading)	100%	4/1/2015	On-the-books
Federal	Fed Appliance: Residential Clothes Washers (Top-Loading) Tier I	100%	4/1/2015	On-the-books
Federal	Fed Appliance: Small Electric Motors	35%	4/1/2015	On-the-books
Federal	Fed Appliance: Residential Electric storage water heater	88%	01/01/20	On-the-books
Federal	Fed Appliance: Residential Gas-fired instantaneous water heater	87%	07/19/21	On-the-books
Federal	Fed Appliance: Residential Gas-fired water heater	98%	02/01/20	On-the-books
Federal	Fed Appliance: Residential Oil-fired storage water heater	85%	02/01/20	On-the-books
Federal	Fed Appliance: Single package vertical AC and HP - >65,000 Btu/hr and <240,000 Btu/hr	90%	02/01/20	On-the-books
Federal	Fed Appliance: Distribution transformers	100%	02/01/20	On-the-books
Federal	Fed Appliance: External Power Supplies	70%	10/01/20	On-the-books
Federal	Fed Appliance: Electric Motors	97%	10/01/20	On-the-books
Federal	Fed Appliance: Microwave ovens	91%	10/01/20	On-the-books
Federal	Fed Appliance: Commercial CAC and HP - <65,000 Btu/hr	100%	10/01/20	On-the-books
Federal	Fed Appliance: Metal Halide Lamp Fixtures	86%	10/01/20	On-the-books
Federal	Fed Appliance: Commercial Refrigeration Equipment	100%	10/01/20	On-the-books
Federal	Fed Appliance: Walk-in coolers and freezers	79%	04/01/20	On-the-books
Federal	Fed Appliance: Commercial CAC and HP - 65,000 Btu/hr to 760,000 Btu/hr - Tier 1	99%	04/01/20	On-the-books
Federal	Fed Appliance: Commercial Clothes Washers	80%	04/01/20	On-the-books
Federal	Fed Appliance: Residential Clothes Washers - Top-Loading	100%	04/01/20	On-the-books
Federal	Fed Appliance: GSFLs	80%	09/01/20	On-the-books

Regulation	Code or Standard Name	Compliance Rate[179]	Effective Date	Policy View
Federal	Fed Appliance: Commercial Ice Makers	100%	09/01/20	On-the-books
Federal	2016-18 Fed App: Commercial CAC and HP (65,000 Btu/hr to 760,000 Btu/hr) - Tier 2	95%	09/01/23	On-the-books
Federal	2019-21 Fed App: Refrigerated beverage vending machines	95%	09/01/23	On-the-books
Federal	2019-21 Fed App: Pre-rinse Spray Valves	95%	09/01/23	On-the-books
Federal	2019-21 Fed App: Dehumidifiers	95%	09/01/23	On-the-books
Federal	2019-21 Fed App: Furnace fans	95%	09/01/23	On-the-books
Federal	2019-21 Fed App: Single package vertical AC and HP - <65,000 Btu/hr	95%	09/01/23	On-the-books
Federal	2019-21 Fed App: Wine chillers	95%	09/01/23	On-the-books
Federal	2019-21 Fed App: Residential Boilers - Gas-fired Hot Water and Electric Hot Water	95%	09/01/23	On-the-books
Federal	2019-21 Fed App: Residential Boilers - Gas-fired Steam and Electric Steam	95%	09/01/23	On-the-books
Federal	2019-21 Fed App: Ceiling Fans	95%	09/01/23	On-the-books
Federal	2019-21 Fed App: Ceiling Fan Light Kits	95%	09/01/23	On-the-books
Federal	2019-21 Fed App: Commercial and Industrial Pumps	95%	09/01/23	On-the-books
Federal	2019-21 Fed App: Dedicated-Purpose Pool Pumps	95%	02/01/23	On-the-books
Federal	2022-24 Fed App: Uninterruptible Power Supplies	90%	02/01/23	On-the-books
Federal	2022-24 Fed App: Commercial Boilers	95%	02/01/23	On-the-books
Federal	2022-24 Fed App: Residential Central AC & HP	95%	02/01/23	On-the-books
Federal	2022-24 Fed App: Air Compressors	90%	02/01/23	On-the-books
Federal	2022-24 Fed App: Portable ACs	90%	02/01/23	On-the-books
Future T-24	2025 T-24: NRA	80%	1/30/2026	Expected
Future T-24	2025 T-24: NRNC-Whole Building	80%	10/30/2026	Expected
Future T-24	2028 T-24: NRA	80%	1/29/2029	Possible
Future T-24	2028 T-24: NRNC-Whole Building	80%	10/29/2029	Possible

Source: Guidehouse

Table F-2 specifies all standards that are assumed to be superseded by other standards.

Table F-2. 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
2006 T-20: Residential Pool Pumps, 2-speed Motors, Tier 2	Fed Appliance: Pool Pumps	Guidehouse assumption

Source: Guidehouse

Appendix G. Industrial and Agriculture Generic Custom and Emerging Technologies

G.1 Industrial and Agriculture Generic Custom Measures

G.1.1 Summary

Generic custom (GC) measures in the industrial and agriculture sector are projects that implement EE on a wide diversity of production processes and operating environments. These projects are diverse and often unique and typically have generic names such as Other, Process, or System in program tracking data such as CEDARS. The generic naming and unique nature of these projects present several complications when forecasting EE potential:

1. Common engineering resources such as IOU workpapers, DEER or the California eTRM are well designed for building system applications but do not apply well to unique production processes.
2. There are no formal EE saturation estimates of, such as CEUS or RASS, for industrial processes.

To address these complications, forecasting the EE potential for GC measures requires a different approach that involves several steps.

1. Program records (i.e., CEDARS) are reviewed to determine what annual ex ante gross natural gas and electricity savings have historically been reported for GC measures (i.e., Other, Process, or System).
2. A Savings Rate Multiplier is calculated by dividing the annual ex ante gross natural gas and electricity savings by total sector consumption for each year being analyzed. The final Savings Rate Multiplier used in the 2023 forecast is based on the average annual reported ex ante savings for six program years, from 2016 through 2021.
3. CEDARS data is also analyzed to determine the trend in GC savings over time. This trend is referred to as the GC Penetration Rate and is used to increase or decrease savings over the forecast horizon. For the GC forecast, the penetration rate is stated as a compound annual growth or decline rate.
4. An annual EE savings forecast (GWh and MMtherms) is produced by 1) multiplying annual sector consumption forecasts by the Savings Rate Multiplier, and 2) multiplying the annual forecast by the Penetration Rate % to account for saturation over time.

The Savings Rate Multiplier, and other inputs for the 2023 Study forecast of GC potential are provided in Table G-1. The following discussions provide additional details on the assumptions and methodology used to derive these inputs.

Table G-1. Industrial and Agriculture GC – Key Assumptions

<table>
<tr><th rowspan="2">Sector</th><th rowspan="2">Type</th><th rowspan="2">EUL Years</th><th colspan="2">Savings Rate Multiplier</th><th colspan="2">Cost</th><th rowspan="2">kW/kWh Savings Ratio</th></tr>
<tr><th>kWh</th><th>therm</th><th>kWh</th><th>therm</th></tr>
<tr><td>Industrial</td><td rowspan="2">Generic Custom</td><td rowspan="2">15</td><td>0.0651%</td><td>0.0496%</td><td rowspan="2">$0.48</td><td rowspan="2">$2.81</td><td rowspan="2">0.000195</td></tr>
<tr><td>Agriculture</td><td>0.0570%</td><td>0.5540%</td></tr>
</table>

Source: Guidehouse

G.1.2 Savings Rate Multiplier

Savings rate multipliers are defined as the percent of total sector energy consumed in a year that can be reduced through EE. The forecast energy savings values (kWh and Therms) are then derived by multiplying total forecast sector consumption by the savings rate multiplier. For the 2023 Study, the team analyzed CEDARS data for program years 2016 through 2021 to define savings associated with generic customer measures and Table G-2 provides a summary of GC ex ante savings by program year, and the sector electricity and natural gas consumption provided by the IEPR mid-forecast for the same years. The average savings and consumption data was used to develop the savings rate multipliers presented in Table G-1.

Table G-2. CEDARS Reported Industrial and Agriculture Ex Ante GC Measure Savings

Year	2016	2017	2018	2019	2020	2021	Average
Industrial							
GC GWh Savings	23.8	19.9	21.1	15	11.4	6.6	16.3
Industrial GWh Consumption	25,159	25,240	25,148	24,986	24,807	24,963	25,050
%	0.095%	0.079%	0.084%	0.060%	0.046%	0.026%	0.065%
GC MMtherms Savings	2.3	3	1.3	1.5	1.9	0.3	1.7
Industrial MMtherms Consumption	3,530	3,457	3,511	3,503	3,485	3,485	3,495
%	0.065%	0.087%	0.037%	0.043%	0.055%	0.009%	0.049%
Agriculture							
GC GWh Savings	17.98	5.5	12.2	6.47	5.11	5.21	8.7
Agriculture GWh Consumption	14,795	15,279	13,644	14,087	14,203	14,313	14,387
%	0.122%	0.036%	0.089%	0.046%	0.036%	0.036%	0.060%
GC MMtherms Savings	1.71	0.31	0.27	0.11	1.43	0.01	0.6
Agriculture MMtherms Consumption	116	109	119	118	117	117	116
%	1.474%	0.284%	0.227%	0.093%	1.222%	0.009%	0.517%

Source: Guidehouse

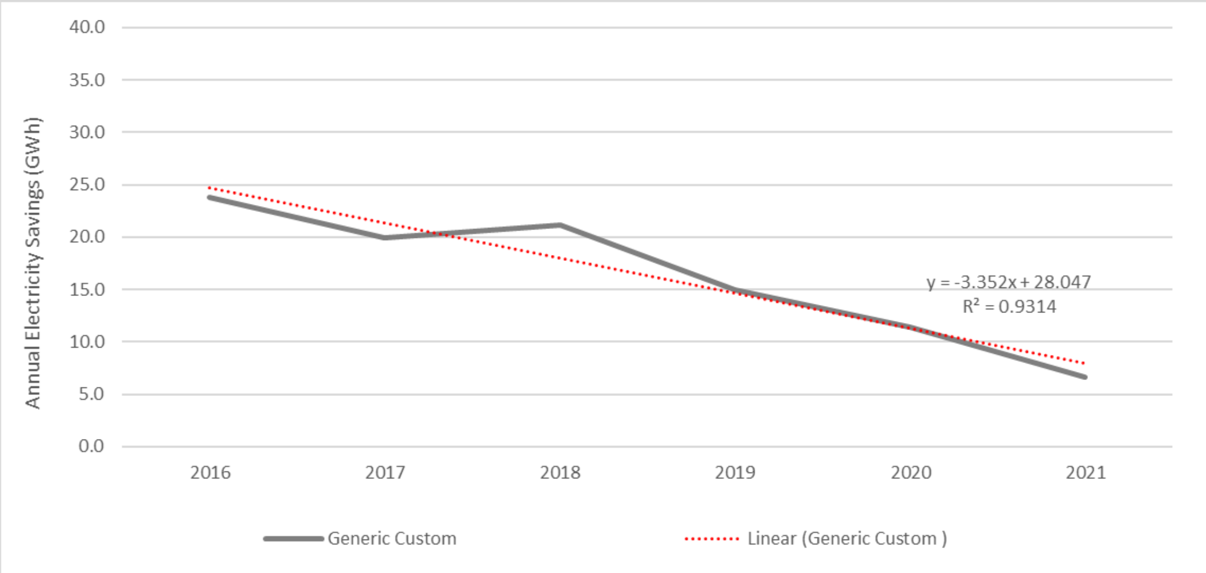
The savings rate multiplier has been decreasing over time and Table G-3 shows the changes between the 2021 and 2023 PG studies. Figure G-1 through Figure G-4 show the annual electricity and natural gas savings for program years 2016 through 2021.

Table G-3. Change In GC Savings Rate Multipliers

Sector	GWh	Therms
Industrial		
2023 Factor	0.0651%	0.0496%
2021 Factor	0.0673%	0.0535%
2023 % of 2021	96.7%	92.8%
Agriculture		
2023 Factor	0.0570%	0.5540%
2021 Factor	0.0602%	0.6227%
2023 % of 2021	94.7%	89.0%

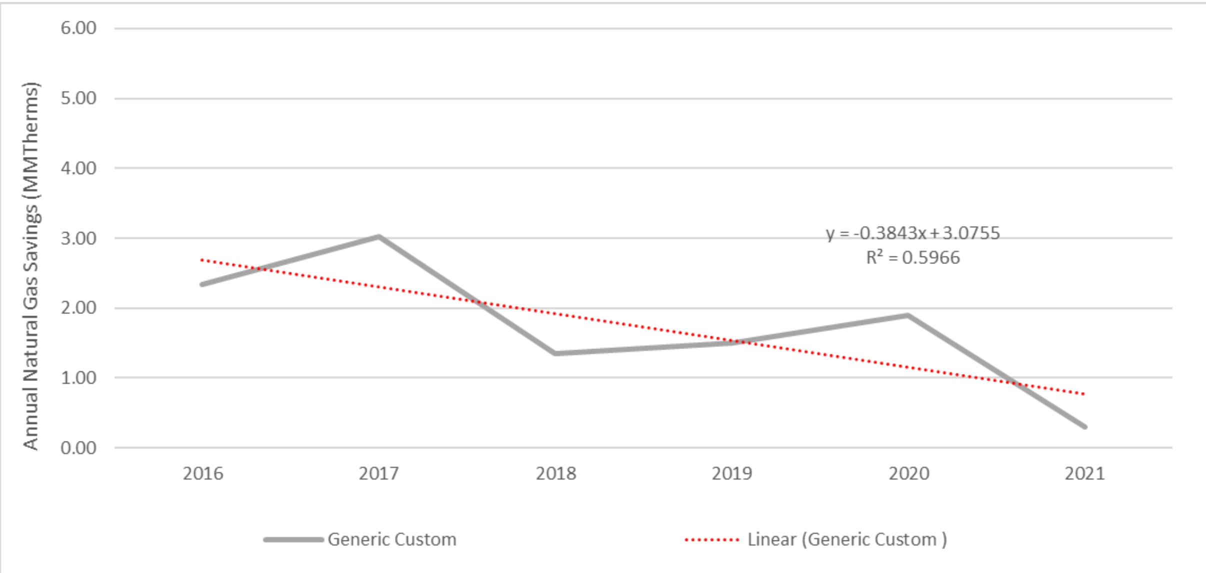
Source: Guidehouse

Figure G-1. Industrial Sector GC Electricity Savings Trends



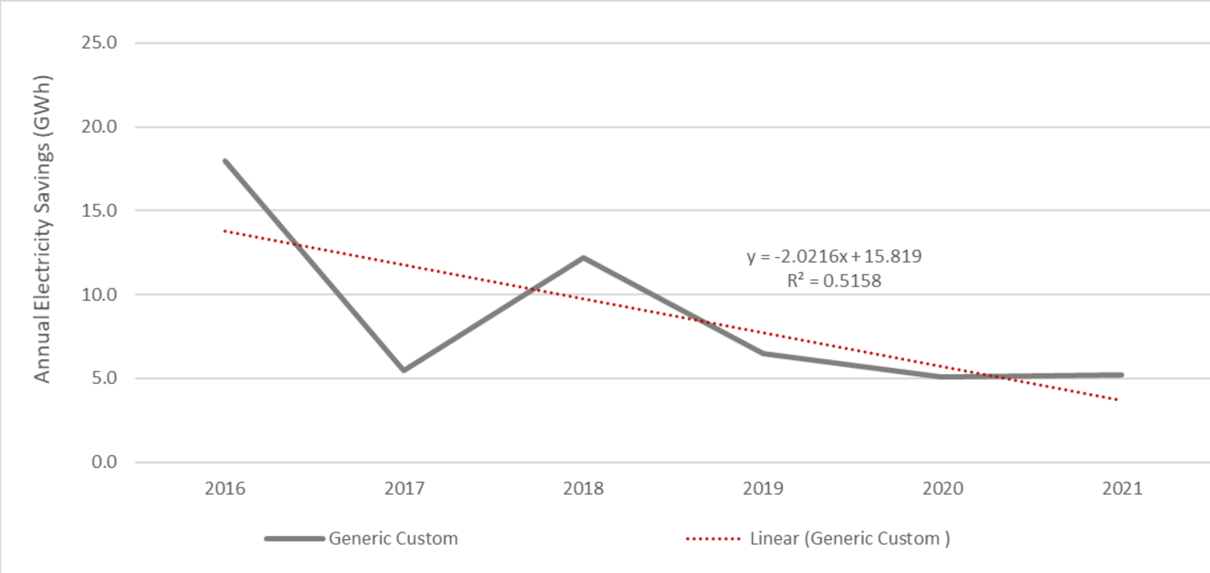
Source: Guidehouse

Figure G-2. Industrial Sector GC Natural Gas Savings Trends



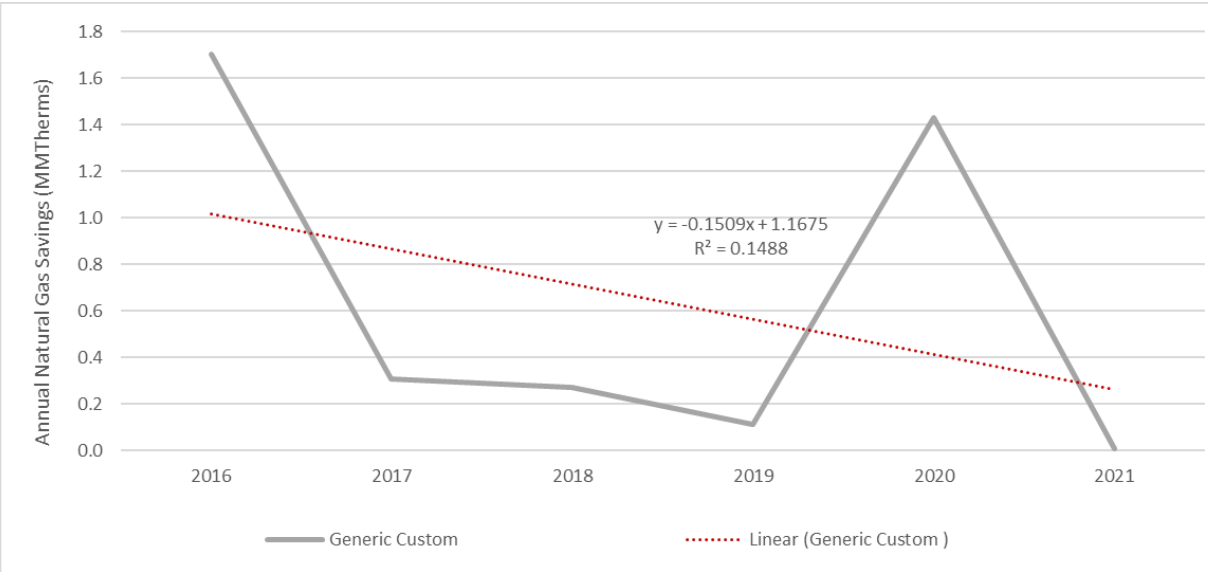
Source: Guidehouse

Figure G-3. Agriculture Sector GC Electricity Savings Trends



Source: Guidehouse

Figure G-4. Agriculture Sector GC Natural Gas Savings Trends



Source: Guidehouse

G.1.3 Applicability and Penetration Rate

Applicability of GC measures in the industrial and agriculture sectors is 100% because these measures are considered ubiquitous to all types of production processes in all industrial and agriculture market segments. These measures saturate over time and to account for this the forecast uses an annual penetration rate to decrease the overall size of the market for GC measures. The penetration rate in the 2023 Study uses a compound annual decline rate of 4.2% for the reference case and this produced a declining forecast where GC savings potential in 2035 would be 52.5% of savings potential in 2020, the base year for the GC forecast.

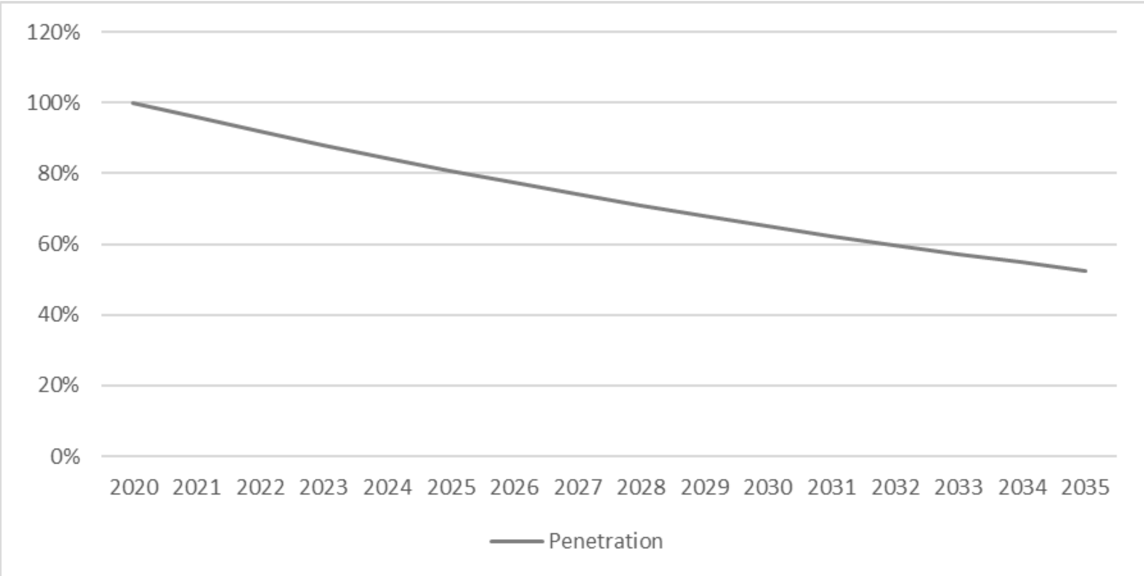
The calculation for industrial and agriculture segment-level EE annual GC savings potential is provided in Equation G-1. The savings rate multiplier is applied to the annual consumption forecast at the market segment level (e.g., chemicals, plastics, industrial machinery, paper, etc.) and is held constant throughout the forecast horizon.

Equation G-1. GC Segment Savings Potential

$$\text{GC Segment-Level EE Annual Savings Potential} =$$

$$\text{GC Savings Rate Multiplier x Annual Segment Consumption x Penetration Rate}^{180}$$

Figure G-5. Reference Case Penetration



Source: Guidehouse

G.1.4 Other Input Assumptions and Observations

As stated in the 2021 report, GC measures tend to be larger capital investments that operate for long periods of time and the Guidehouse team used an EUL of 15 years in the forecasts.[181] The team applied a ratio of kW to kWh of 0.000195.

The team has retained the GC electric incremental measure cost used in the 2021 forecast of $0.478/kWh for both the industrial and agriculture sectors. Natural gas incremental measure costs are also unchanged from the 2021 forecast and remain $2.81/therm. The same measure costs are applied consistently across sectors, segments and utilities

G.2 Industrial and Agriculture Emerging Technology Measures

G.2.1 Summary

In the context of this study, emerging technologies (ETs) are new technologies that have demonstrated energy benefits to the industrial and agriculture sectors but are not yet widely

[180] Electric (GWh) and natural gas (therms) consumption from the 2019 IEPR forecast.

[181] The team selected 15 years as representative of emerging technology measures that are more technology based versus controls or retrofit add-on technologies.

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 yielded 173 ET processes[182] 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 since the 2019 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 G-4). Segment-specific electric and gas savings are consistently applied across all utilities. Cost, EUL, and the kW/kWh savings ratio are also universally applied.

Table G-4. 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

G.2.2 Eligibility and Participation

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[183]
- CEC Publications Database[184]
- U.S. Department of Energy (DOE) Research and Development Projects[185]

[182] The ETs represent a process to reduce energy consumption, not necessarily a specific technology.
[183] http://www.etcc-ca.com/reports
[184] http://www.energy.ca.gov/publications/searchReports.php?pier1=Buildings%20End-Use%20Energy%20Efficiency
[185] https://energy.gov/eere/amo/research-development-projects

- DOE Energy Efficiency & Renewable Energy Emerging Technologies Database[186]
- 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 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 G-5 shows.

- **Classification information:**
  - Fuel savings (electricity/gas)
  - End use
  - 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 G-5 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 G-5. ET Evaluation Criteria

Technology Characteristics	Weight	1	2	3	4	5
Energy Technical Potential	3	Low	Low	Medium	High	High

186 https://energy.gov/eere/buildings/emerging-technologies

Technology Characteristics	Weight	1	2	3	4	5
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
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 G-2 to calculate the multiplier for each ET that was then applied to a specific market segment and end use energy consumption.

Equation G-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.[187]
- 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.[188] 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 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 G-6) to forecast segment-level potential net savings using Equation G-3:

Equation G-3. ET Segment Net Savings Potential

$$\textit{ET Segment-Level EE Net Savings Potential} = \textit{ET UES Multiplier x Annual Segment Consumption}^{189}$$

Table G-6. 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%

[187] Energy use trend analysis provided by CEC.
[188] Sirkin, H. et al. *U.S. Manufacturing Nears the Tipping Point*, The Boston Consulting Group, March 2012.
[189] Electric (GWh) and natural gas (therms) consumption from the 2019 IEPR forecast.

Segment	UES Multiplier (kWh)	UES Multiplier (therms)
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 2023 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 6.37% by 2033. The 2030 target saturation of the portfolio of relevant ETs 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 production equipment associated with many industrial processes. From 2033 to 2035, the penetration rate remains at 6.31%. The aggressive case assumes a CAGR of 4.25% until 2032, where the penetration is held at 11.97% through 2035.

G.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 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 past 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[190] was selected from widely accepted research in behavioral science; this model uses a single sensitivity parameter to define choice based on 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.[191] 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 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.[192, 193] 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.[194]

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.[195] Until the 2021 Study, 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 potential studies before 2021 modeled, customer preferences are not based solely on the financial attributes of the product. Instead, customers make decisions based on

[190] McFadden, D. and K. Train, "Mixed MNL Models for Discrete Response," *Journal of Applied Econometrics* 15, no. 5: 447-470, 2000.

[191] Gillingham, Newell, Palmer, "Energy Efficiency Economics and Policy," 2009.

[192] 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.

[193] Gillingham, Newell, Palmer, "Energy Efficiency Economics and Policy," 2009.

[194] Jaffe, Newell, and Stavins, "Economics of Energy Efficiency," *Encyclopedia of Energy* Vol. 2: 79-89, 2004.

[195] Corfee et.al., "Riding the Financing Wave: Integrating Financing with Traditional DSM Programming," International Energy Program Evaluation Conference, 2013.

multiple product attributes. Switching to a multi-attribute model in a potential study offers two key advantages:

- 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 product type and the consumer type. 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 (implemented since 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 lightweight). 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. However, when decisions consider all attributes and values, the outcome may be completely rational.

H.3 Implementing the Multi-Attribute Model

This 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 FS)
- 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 conducted in 2019, 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

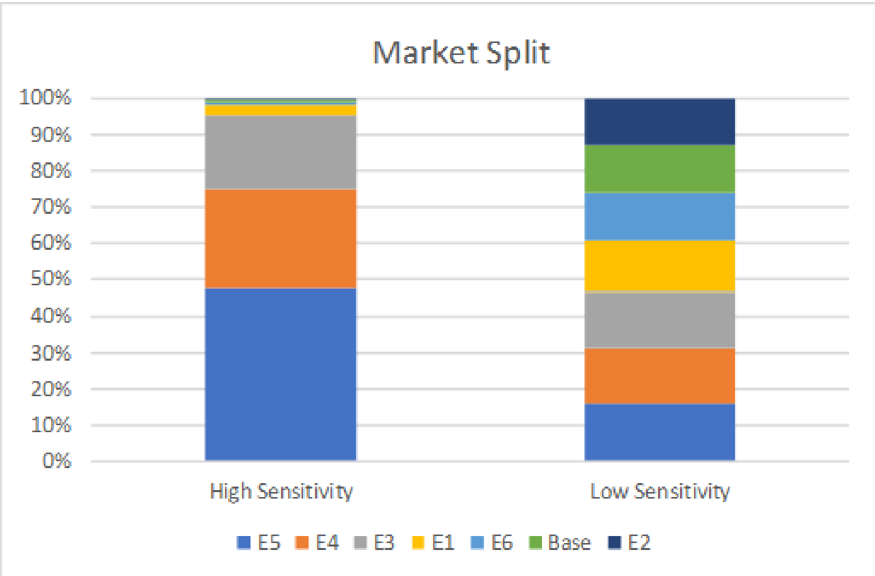
Preference Weighting =

$$\frac{Average\ Transformed\ Response\ (for\ Tech\ Attribute)}{Sum\ of\ Average\ Response\ (of\ all\ Tech\ Attributes)}$$

Although 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 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 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 with the other CG measures.

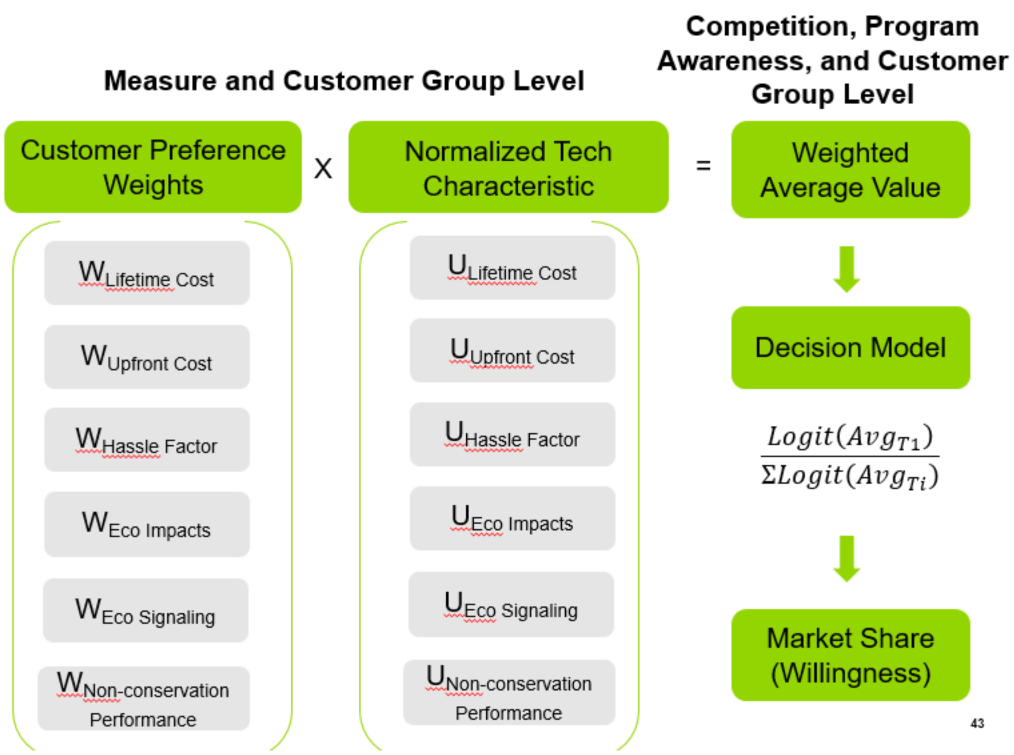
Equation H-2. Normalized Technology Characteristic

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

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

$$MarketShare(t) = \frac{e_t^{-\beta A_t}}{\sum_i^n e_i^{-\beta A_i}}$$

Where:

$n =$ Number of technologies in competition group
$n =$ Number of technologies in competition group
$t =$ Technology of interest

β = Customer group sensitivity to differences in technology characteristics (or customer preference weighting)
A = Weighted average, dimensionless technology characteristic

Appendix I. Cost-Effectiveness Analysis Methodology

Assessing cost-effectiveness for each measure is a core element to the 2023 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) 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 FS 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 IOUs to inform program plans and filed savings claims to evaluate program cost-effectiveness. The 2023 Study mirrors 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 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 I-1 highlights similarities and differences between the CET and the PG Model.

Table I-1. CET and PG Model Comparison

Category	Difference?	CET	PG Model
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 (published in 2022)	
Avoided Cost Components	No	Inputs primarily two types of avoided cost: Generation (which embeds emissions) and T&D. Applies these as appropriate to UES to calculate total avoided cost benefits. Refrigerant avoided costs (RACs) are also applied specific to individual measures (and not embedded within Generation or T&D)	
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 as shown in Table 3-11.

Category	Difference?	CET	PG Model
Electric Load Shape Input	Yes	Allows users to select a specific load shape and assign it to each measure. Load shapes vary by utility (PA), end use (EU), sector (TS), and climate zone (CZ). There are over 1,000 possible load shapes to choose from in CET.	The PG Model using the mapping provided by eTRM which assigns each measure an EU. For each EU and PA, Guidehouse selected a representative climate zone (see Table 3-11) to apply to each measure within each PA.
Load Shape Processing	Yes	Load shapes are input with quarterly (every 3 months) 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 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

Although these differences are a necessary simplification, they are sufficient and common practice for this type of higher level forecasting in a potential study.

I.1 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 and T&D from the CET.

- Generation in the CET is expressed in $/annual kWh. The CET embeds the cost of carbon in its valuation of generation avoided cost.
- 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. When the PG study team mapped avoided costs to eTRM, only those EUs that have kWh DSTypes were needed, thus only the Guidehouse team only needed and processed T&D costs on a per kWh basis.
- The avoided cost of refrigerant leakage is not applied per kWh saved and therefore must be calculated differently. RACs are quantified at the measure level and are expressed in units of dollars. They are a net present value of the avoided cost over the lifetime of the technology. In the case of FS measures, RAC often is a negative value implying it appears as a cost component in the C-E calculations.

Gas avoided costs are the sum of the avoided costs of generation and T&D as reported by the CET. There is no DSType for gas T&D avoided costs. Gas avoided costs include the valuation of methane leakage.

I.2 Cost-Effectiveness Definitions

The cost-effectiveness analysis in the 2023 Study includes calculating the TRC. 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 test.

I.2.1 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 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 I-1.

Equation I-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
- **Incremental Cost** is the measure cost as defined by replacement type. This is sourced from the electronic Technical Reference Manual (eTRM), measure packages, and other sources as appropriate and are decremented by any applicable tax credits. Incremental cost specifically excludes panel upgrade costs for FS measures
- **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 and refrigerant leakage for FS 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 and adding the refrigerant avoided cost.

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.

I.2.2 TSB

TSB represents the sum of the 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 I-2.

Equation I-2. 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 several forms:
  - Interactive effects such as increased heating load due to decreased heat gain from more efficient lighting
  - Increased fuel consumption (i.e., electricity) due to FS
  - Refrigerant avoided costs that result in negative benefits (i.e., a furnace being replaced by a heat pump thus introducing refrigerants where there previously were none)

Appendix J. Detailed Scenario Results by IOU

J.1 TSB by Utility

This section presents the TSB by utility and Scenario.

Table J-1. TSB by Utility by Scenario ($ Millions)

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
PG&E												
Scenario 1: No IRA	$205	$205	$207	$211	$223	$234	$220	$249	$306	$367	$376	$399
Scenario 2: Reference IRA and FS	$212	$212	$212	$217	$228	$238	$223	$251	$307	$368	$376	$399
Scenario 3: Reference IRA and aggressive FS	$246	$256	$266	$282	$304	$328	$231	$260	$318	$379	$389	$413
Scenario 4: Aggressive IRA and reference FS	$213	$212	$213	$217	$228	$239	$223	$251	$308	$368	$377	$399
SCE												
Scenario 1: No IRA	$98	$107	$117	$133	$146	$156	$120	$131	$143	$155	$157	$163
Scenario 2: Reference IRA and FS	$112	$117	$128	$142	$154	$165	$123	$134	$146	$155	$157	$163
Scenario 3: Reference IRA and aggressive FS	$397	$450	$510	$572	$633	$697	$129	$142	$156	$155	$158	$163
Scenario 4: Aggressive IRA and reference FS	$113	$118	$129	$142	$157	$167	$123	$134	$146	$155	$157	$163
SCG												
Scenario 1: No IRA	$162	$180	$195	$207	$219	$230	$208	$235	$282	$332	$352	$382
Scenario 2: Reference IRA and FS	$164	$189	$204	$215	$227	$237	$209	$234	$281	$329	$349	$378
Scenario 3: Reference IRA and aggressive FS	$165	$189	$204	$216	$228	$238	$209	$234	$281	$329	$349	$378
Scenario 4: Aggressive IRA and reference FS	$166	$189	$204	$216	$228	$238	$209	$234	$281	$329	$348	$378
SDG&E												
Scenario 1: No IRA	$44	$45	$45	$47	$53	$53	$46	$50	$55	$63	$63	$68
Scenario 2: Reference IRA and FS	$45	$45	$46	$48	$54	$55	$47	$51	$56	$63	$63	$68
Scenario 3: Reference IRA and aggressive FS	$233	$247	$258	$269	$283	$292	$50	$54	$60	$64	$64	$74
Scenario 4: Aggressive IRA and reference FS	$45	$46	$47	$49	$54	$55	$48	$51	$56	$64	$64	$68

Source: Guidehouse

J.2 Detailed Achievable Energy Impacts by IOU

This section presents impacts by fuel type using the 2022 vintage of avoided cost. The tables reflect FS as positive gas savings (decreased gas consumption) with negative electric savings (increased electric consumption). In this section, SCE shows gas savings due to FS measures funded by SCE ratepayers.

J.2.1 PG&E

Table J-2. PG&E Electric Energy Savings (GWh/year)

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Scenario 1: No IRA												
EE	81.8	76.7	68.0	59.9	58.5	55.0	62.5	65.5	82.2	98.5	99.0	99.6
FS	-5.1	-5.2	-6.3	-6.4	-6.8	-7.8	0.5	0.5	0.6	0.7	0.8	0.8
BROs	231.3	240.6	250.6	261.0	271.7	283.1	295.8	308.7	322.0	339.0	344.0	360.8
Scenario 2: Reference IRA and FS												
EE	86.8	80.8	70.6	61.7	59.8	56.4	64.4	66.8	83.2	98.8	99.0	99.5
FS	-8.7	-8.7	-8.7	-8.8	-8.8	-8.9	0.5	0.6	0.7	0.7	0.8	0.8
BROs	231.3	240.6	250.6	261.0	271.7	283.1	295.8	308.7	322.0	339.0	344.0	360.8
Scenario 3: Reference IRA and aggressive FS												
EE	86.8	80.6	70.3	61.3	59.5	56.1	64.2	66.6	83.2	98.8	99.1	99.7
FS	-48.0	-49.8	-51.3	-52.7	-54.0	-55.3	12.9	15.7	17.8	17.0	18.5	19.3
BROs	231.3	240.6	250.6	261.0	271.7	283.1	295.8	308.7	322.0	339.0	344.0	360.8
Scenario 4: Aggressive IRA and reference FS												
EE	87.2	81.0	70.8	61.8	60.1	56.6	64.6	67.0	83.4	98.9	99.0	99.5
FS	-8.7	-8.7	-8.7	-8.8	-8.8	-8.9	0.5	0.6	0.7	0.7	0.8	0.8
BROs	231.3	240.6	250.6	261.0	271.7	283.1	295.8	308.7	322.0	339.0	344.0	360.8
C&S (All Scenarios)												
w/ Interactive Effects	1,071.2	1,008.4	987.2	909.8	830.0	659.5	599.0	565.9	530.2	502.5	417.5	401.6
w/o Interactive Effects	1,062.2	999.4	978.6	903.3	826.2	661.3	602.3	569.2	533.4	505.7	420.6	404.6

Source: Guidehouse

Table J-3. PG&E Demand Savings (MW)

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Scenario 1: No IRA												
EE	29.0	27.0	23.0	18.6	17.0	14.9	16.7	15.3	18.1	20.9	20.9	20.9
FS	-0.1	-0.2	-0.2	-0.2	-0.2	-0.2	0.1	0.1	0.1	0.1	0.1	0.1
BROs	35.1	36.5	38.0	39.5	41.0	42.6	44.4	46.2	48.1	50.0	51.1	53.3
Scenario 2: Reference IRA and FS												
EE	31.3	28.4	23.7	18.9	17.2	15.4	17.5	15.8	18.6	21.0	20.9	20.9
FS	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	0.1	0.1	0.1	0.1	0.1	0.1
BROs	35.1	36.5	38.0	39.5	41.0	42.6	44.4	46.2	48.1	50.0	51.1	53.3
Scenario 3: Reference IRA and aggressive FS												
EE	31.1	28.2	23.5	18.6	17.0	15.2	17.4	15.6	18.5	21.0	20.9	20.9
FS	-1.2	-1.3	-1.4	-1.4	-1.5	-1.5	1.8	2.2	2.5	2.4	2.6	2.7
BROs	35.1	36.5	38.0	39.5	41.0	42.6	44.4	46.2	48.1	50.0	51.1	53.3

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Scenario 4: Aggressive IRA and reference FS												
EE	31.1	28.3	23.7	18.8	17.2	15.4	17.5	15.8	18.6	21.0	20.9	20.9
FS	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	0.1	0.1	0.1	0.1	0.1	0.1
BROs	35.1	36.5	38.0	39.5	41.0	42.6	44.4	46.2	48.1	50.0	51.1	53.3
C&S (All Scenarios)												
w/ Interactive Effects	201.9	184.7	180.7	165.9	157.8	132.0	123.2	118.3	110.0	104.3	94.0	89.5
w/o Interactive Effects	195.4	178.4	174.5	161.3	153.3	130.6	122.5	117.7	109.5	103.8	93.4	88.9

Source: Guidehouse

Table J-4. PG&E Gas Energy Savings (MMtherm/year)

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Scenario 1: No IRA												
EE	6.7	6.0	5.2	4.6	4.2	4.0	4.1	4.3	5.6	7.0	7.0	7.0
FS	0.7	0.7	0.9	0.9	0.9	1.1	0.0	0.0	0.0	0.0	0.0	0.0
BROs	11.3	11.7	12.1	12.5	13.0	13.4	14.0	14.5	15.1	16.3	15.4	16.1
Scenario 2: Reference IRA and FS												
EE	7.0	6.2	5.4	4.7	4.3	4.0	4.1	4.3	5.7	7.0	7.0	7.0
FS	1.2	1.2	1.2	1.3	1.3	1.3	0.0	0.0	0.0	0.0	0.0	0.0
BROs	11.3	11.7	12.1	12.5	13.0	13.4	14.0	14.5	15.1	16.3	15.4	16.1
Scenario 3: Reference IRA and aggressive FS												
EE	7.0	6.3	5.4	4.7	4.3	4.0	4.2	4.4	5.7	7.0	7.0	7.0
FS	6.8	7.3	7.6	8.0	8.3	8.6	0.0	0.0	0.0	0.0	0.0	0.0
BROs	11.3	11.7	12.1	12.5	13.0	13.4	14.0	14.5	15.1	16.3	15.4	16.1
Scenario 4: Aggressive IRA and reference FS												
EE	7.0	6.2	5.4	4.7	4.3	4.0	4.2	4.4	5.7	7.0	7.0	7.0
FS	1.2	1.2	1.2	1.3	1.3	1.3	0.0	0.0	0.0	0.0	0.0	0.0
BROs	11.3	11.7	12.1	12.5	13.0	13.4	14.0	14.5	15.1	16.3	15.4	16.1
C&S (All Scenarios)												
w/ Interactive Effects	23.0	22.5	14.5	14.8	13.8	13.1	12.7	12.2	11.4	11.0	10.7	10.3
w/o Interactive Effects	25.1	24.5	16.3	16.2	15.0	13.7	13.2	12.6	11.8	11.4	11.1	10.7

Source: Guidehouse

J.2.2 SCE

Table J-5. SCE Electric Energy Savings (GWh/year)

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Scenario 1: No IRA												
EE	46.4	52.1	54.1	56.0	56.7	55.0	56.6	59.8	65.6	72.3	72.2	72.5
FS	-10.4	-11.8	-12.4	-13.5	-14.3	-15.0	-3.3	-3.6	-3.8	-4.0	-4.2	-4.5
BROs	218.1	230.6	243.1	254.0	264.8	276.3	289.0	302.0	315.5	333.5	337.7	355.3
Scenario 2: Reference IRA and FS												
EE	61.1	59.5	60.9	60.7	60.7	58.5	60.0	63.2	68.9	72.6	72.2	72.5
FS	-12.2	-13.6	-14.3	-15.0	-15.7	-15.7	-3.2	-3.4	-3.6	-4.0	-4.2	-4.5

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
BROs	218.1	230.6	243.1	254.0	264.8	276.3	289.0	302.0	315.5	333.5	337.7	355.3
Scenario 3: Reference IRA and aggressive FS												
EE	60.1	58.9	60.7	60.7	60.8	58.6	60.1	63.4	69.1	72.8	72.4	72.6
FS	-107.7	-114.1	-118.0	-121.8	-124.7	-126.9	11.9	16.0	21.8	-4.1	-4.3	-4.5
BROs	218.1	230.6	243.1	254.0	264.8	276.3	289.0	302.0	315.5	333.5	337.7	355.3
Scenario 4: Aggressive IRA and reference FS												
EE	61.4	61.7	62.3	61.5	61.3	59.0	60.5	63.4	69.0	72.7	72.2	72.4
FS	-12.3	-13.7	-14.4	-15.0	-14.9	-15.3	-3.2	-3.4	-3.6	-4.0	-4.2	-4.5
BROs	218.1	230.6	243.1	254.0	264.8	276.3	289.0	302.0	315.5	333.5	337.7	355.3
C&S (All Scenarios)												
w/ Interactive Effects	1,071.2	1,008.4	987.2	909.8	830.0	659.5	599.0	565.9	530.2	502.5	417.5	401.6
w/o Interactive Effects	1,062.2	999.4	978.6	903.3	826.2	661.3	602.3	569.2	533.4	505.7	420.6	404.6

Source: Guidehouse

Table J-6. SCE Demand Savings (MW)

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Scenario 1: No IRA												
EE	13.6	14.4	14.3	14.5	14.5	14.1	14.5	14.9	15.8	17.0	16.8	16.7
FS	-0.5	-0.6	-0.7	-0.7	-0.8	-0.8	-0.3	-0.3	-0.3	-0.3	-0.3	-0.4
BROs	45.4	47.7	50.0	51.8	53.4	55.2	57.1	59.0	60.8	62.9	63.9	66.2
Scenario 2: Reference IRA and FS												
EE	16.1	15.9	15.8	15.6	15.5	15.0	15.3	15.7	16.6	17.1	16.8	16.7
FS	-0.5	-0.6	-0.6	-0.7	-0.7	-0.8	-0.2	-0.3	-0.3	-0.3	-0.3	-0.4
BROs	45.4	47.7	50.0	51.8	53.4	55.2	57.1	59.0	60.8	62.9	63.9	66.2
Scenario 3: Reference IRA and aggressive FS												
EE	15.5	15.6	15.7	15.6	15.5	15.0	15.3	15.7	16.6	17.1	16.8	16.7
FS	-3.7	-3.8	-3.9	-4.0	-4.0	-4.1	2.7	3.5	4.7	-0.3	-0.3	-0.4
BROs	45.4	47.7	50.0	51.8	53.4	55.2	57.1	59.0	60.8	62.9	63.9	66.2
Scenario 4: Aggressive IRA and reference FS												
EE	16.2	16.3	16.0	15.7	15.5	15.0	15.4	15.7	16.6	17.1	16.8	16.7
FS	-0.5	-0.6	-0.6	-0.7	-0.7	-0.8	-0.2	-0.3	-0.3	-0.3	-0.3	-0.4
BROs	45.4	47.7	50.0	51.8	53.4	55.2	57.1	59.0	60.8	62.9	63.9	66.2
C&S (All Scenarios)												
w/ Interactive Effects	186.5	172.4	168.9	154.7	147.1	121.9	113.3	108.7	101.0	95.8	85.9	81.6
w/o Interactive Effects	180.2	166.2	162.8	150.2	142.7	120.5	112.7	108.2	100.4	95.2	85.3	81.0

Source: Guidehouse

Table J-7. SCE Gas Savings (MMtherms) – FS Only

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Scenario 1: No IRA												
EE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
FS	1.9	2.1	2.2	2.5	2.7	2.8	0.4	0.4	0.4	0.4	0.5	0.5
BROs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scenario 2: Reference IRA and FS												
EE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FS	2.4	2.7	2.8	3.0	3.1	3.2	0.4	0.4	0.4	0.4	0.5	0.5
BROs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scenario 3: Reference IRA and aggressive FS												
EE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FS	32.8	35.5	37.5	39.2	40.4	41.6	0.4	0.4	0.4	0.4	0.5	0.5
BROs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scenario 4: Aggressive IRA and reference FS												
EE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FS	2.5	2.7	2.8	3.0	3.2	3.2	0.4	0.4	0.4	0.4	0.5	0.5
BROs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0
w/o Interactive Effects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source: Guidehouse

J.2.3 SCG

Table J-8. SCG Gas Savings (MMtherm/year)

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Scenario 1: No IRA												
EE	10.4	11.0	11.3	10.8	10.4	9.7	10.8	11.1	13.1	14.1	13.7	13.5
FS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BROs	7.9	8.2	8.6	8.9	9.3	9.7	10.1	10.6	11.1	11.6	12.1	13.5
Scenario 2: Reference IRA and FS												
EE	20.3	19.0	18.1	17.4	17.0	16.2	16.5	16.8	17.7	17.2	16.8	16.7
FS	-0.5	-0.6	-0.6	-0.7	-0.7	-0.8	-0.2	-0.3	-0.3	-0.3	-0.3	-0.4
BROs	45.4	47.7	50.0	51.8	53.4	55.2	57.1	59.0	60.8	62.9	63.9	66.2
Scenario 3: Reference IRA and aggressive FS												
EE	10.8	13.1	13.4	12.7	12.1	11.1	10.8	10.7	12.6	13.4	13.0	12.8
FS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BROs	7.9	8.2	8.6	8.9	9.3	9.7	10.1	10.6	11.1	11.6	12.1	13.5
Scenario 4: Aggressive IRA and reference FS												
EE	10.9	13.2	13.4	12.7	12.1	11.1	10.8	10.7	12.5	13.4	13.0	12.8
FS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BROs	7.9	8.2	8.6	8.9	9.3	9.7	10.1	10.6	11.1	11.6	12.1	13.5
C&S (All Scenarios)												
w/ Interactive Effects	25.6	25.0	16.1	16.5	15.4	14.6	14.2	13.6	12.6	12.3	11.9	11.5
w/o Interactive Effects	28.0	27.3	18.1	18.0	16.7	15.2	14.7	14.0	13.1	12.7	12.3	11.9

Source: Guidehouse

J.2.4 SDG&E

Table J-9. SDG&E Electric Energy Savings (GWh/year)

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Scenario 1: No IRA												
EE	15.2	14.0	12.4	11.5	11.0	9.4	9.3	9.5	10.4	11.7	11.8	12.1
FS	-0.2	-0.4	-0.9	-1.5	-2.6	-3.5	4.7	5.7	6.8	7.7	8.4	9.2
BROs	57.5	59.9	62.5	65.3	68.2	71.3	74.8	78.6	82.5	87.7	88.9	93.8
Scenario 2: Reference IRA and FS												
EE	15.8	14.7	13.0	12.1	11.6	10.2	9.9	10.0	10.8	11.7	11.9	12.2
FS	-0.3	-0.7	-1.2	-1.9	-3.1	-4.1	5.2	6.1	7.1	7.9	8.6	9.3
BROs	57.5	59.9	62.5	65.3	68.2	71.3	74.8	78.6	82.5	87.7	88.9	93.8
Scenario 3: Reference IRA and aggressive FS												
EE	15.9	14.8	13.1	12.2	11.7	10.3	9.9	10.1	10.9	11.8	11.9	12.2
FS	-38.9	-39.2	-39.5	-39.6	-40.0	-40.2	9.8	11.9	14.6	7.9	8.6	19.8
BROs	57.5	59.9	62.5	65.3	68.2	71.3	74.8	78.6	82.5	87.7	88.9	93.8
Scenario 4: Aggressive IRA and reference FS												
EE	16.1	15.0	13.4	12.6	12.0	10.5	10.0	10.2	11.0	11.8	11.9	12.2
FS	-0.4	-0.8	-1.3	-2.0	-3.2	-4.1	5.2	6.2	7.2	8.0	8.7	9.4
BROs	57.5	59.9	62.5	65.3	68.2	71.3	74.8	78.6	82.5	87.7	88.9	93.8
C&S (All Scenarios)												
w/ Interactive Effects	219.4	206.5	202.2	186.3	170.0	135.1	122.7	115.9	108.6	102.9	85.5	82.2
w/o Interactive Effects	217.5	204.7	200.4	185.0	169.2	135.4	123.3	116.6	109.2	103.6	86.1	82.9

Source: Guidehouse

Table J-10. SDG&E Demand Savings (MW)

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Scenario 1: No IRA												
EE	3.7	3.5	3.2	2.9	2.7	2.4	2.2	2.2	2.4	2.6	2.6	2.6
FS	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	0.7	0.9	1.0	1.2	1.3	1.4
BROs	11.9	12.3	12.7	13.2	13.6	14.1	14.6	15.1	15.6	16.2	16.5	17.1
Scenario 2: Reference IRA and FS												
EE	3.9	3.6	3.3	3.0	2.8	2.5	2.3	2.3	2.4	2.6	2.6	2.6
FS	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	0.8	0.9	1.1	1.2	1.3	1.4
BROs	11.9	12.3	12.7	13.2	13.6	14.1	14.6	15.1	15.6	16.2	16.5	17.1
Scenario 3: Reference IRA and aggressive FS												
EE	3.9	3.6	3.3	3.0	2.8	2.5	2.3	2.3	2.4	2.6	2.6	2.6
FS	-1.0	-1.0	-1.0	-1.1	-1.1	-1.2	1.7	2.1	2.6	1.2	1.3	3.5
BROs	11.9	12.3	12.7	13.2	13.6	14.1	14.6	15.1	15.6	16.2	16.5	17.1
Scenario 4: Aggressive IRA and reference FS												
EE	4.0	3.8	3.4	3.2	2.9	2.5	2.3	2.3	2.4	2.6	2.6	2.6
FS	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	0.8	0.9	1.1	1.2	1.3	1.4
BROs	11.9	12.3	12.7	13.2	13.6	14.1	14.6	15.1	15.6	16.2	16.5	17.1
C&S (All Scenarios)												

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
w/ Interactive Effects	38.2	35.6	34.9	31.9	30.3	25.0	23.3	22.3	20.7	19.6	17.5	16.6
w/o Interactive Effects	36.9	34.3	33.6	31.0	29.4	24.8	23.2	22.2	20.5	19.5	17.4	16.5

Source: Guidehouse

Table J-11. SDG&E Gas Energy Savings (MMtherm/year)

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Scenario 1: No IRA												
EE	1.0	1.0	1.0	1.0	1.2	1.2	0.8	0.8	0.8	0.8	0.8	0.8
FS	0.0	0.1	0.1	0.2	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0
BROs	1.8	1.8	1.8	1.9	2.0	2.0	2.1	2.2	2.3	2.6	2.2	2.3
Scenario 2: Reference IRA and FS												
EE	1.0	1.0	1.0	1.0	1.3	1.2	0.9	0.8	0.8	0.8	0.8	0.8
FS	0.1	0.1	0.2	0.3	0.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0
BROs	1.8	1.8	1.8	1.9	2.0	2.0	2.1	2.2	2.3	2.6	2.2	2.3
Scenario 3: Reference IRA and aggressive FS												
EE	1.0	1.0	1.0	1.0	1.3	1.2	0.9	0.8	0.8	0.8	0.8	0.8
FS	17.4	17.6	17.4	17.1	16.6	16.2	0.0	0.0	0.0	0.0	0.0	0.0
BROs	1.8	1.8	1.8	1.9	2.0	2.0	2.1	2.2	2.3	2.6	2.2	2.3
Scenario 4: Aggressive IRA and reference FS												
EE	1.0	1.0	1.0	1.0	1.3	1.2	0.9	0.8	0.8	0.8	0.8	0.8
FS	0.1	0.1	0.2	0.3	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0
BROs	1.8	1.8	1.8	1.9	2.0	2.0	2.1	2.2	2.3	2.6	2.2	2.3
C&S (All Scenarios)												
w/ Interactive Effects	2.3	2.3	1.5	1.5	1.4	1.3	1.3	1.2	1.1	1.1	1.1	1.0
w/o Interactive Effects	2.5	2.5	1.6	1.6	1.5	1.4	1.3	1.3	1.2	1.2	1.1	1.1

Source: Guidehouse

J.3 Impacts Converted to Energy Savings Credits – 2022 Avoided Costs

This section presents impacts in terms of energy savings credits using the 2022 vintage of avoided costs. The tables reflect FS with their net electric energy savings credit (decreased gas consumption converted into kWh savings credit minus increased electric consumption). In this section, FS savings are only expressed in kWh units—no gas units are used to express FS savings.

J.3.1 PG&E

Table J-12. PG&E Electric Energy Savings (GWh/year)

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Scenario 1: No IRA												
EE	81.8	76.7	68.0	59.9	58.5	55.0	62.5	65.5	82.2	98.5	99.0	99.6
FS	15.4	15.7	19.0	19.3	21.1	24.5	0.6	0.6	0.7	0.9	0.9	1.0

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
BROs	231.3	240.6	250.6	261.0	271.7	283.1	295.8	308.7	322.0	339.0	344.0	360.8
Scenario 2: Reference IRA and FS												
EE	86.8	80.8	70.6	61.7	59.8	56.4	64.4	66.8	83.2	98.8	99.0	99.5
FS	27.6	27.8	27.9	28.1	28.4	28.9	0.6	0.7	0.8	0.9	1.0	1.0
BROs	231.3	240.6	250.6	261.0	271.7	283.1	295.8	308.7	322.0	339.0	344.0	360.8
Scenario 3: Reference IRA and aggressive FS												
EE	86.8	80.6	70.3	61.3	59.5	56.1	64.2	66.6	83.2	98.8	99.1	99.7
FS	151.8	163.2	172.8	181.5	189.2	197.0	13.7	16.6	18.7	18.1	19.7	20.6
BROs	231.3	240.6	250.6	261.0	271.7	283.1	295.8	308.7	322.0	339.0	344.0	360.8
Scenario 4: Aggressive IRA and reference FS												
EE	87.2	81.0	70.8	61.8	60.1	56.6	64.6	67.0	83.4	98.9	99.0	99.5
FS	27.7	27.8	27.9	28.2	28.4	28.9	0.6	0.8	0.9	0.9	1.0	1.0
BROs	231.3	240.6	250.6	261.0	271.7	283.1	295.8	308.7	322.0	339.0	344.0	360.8
C&S (All Scenarios)												
w/ Interactive Effects	1,071.2	1,008.4	987.2	909.8	830.0	659.5	599.0	565.9	530.2	502.5	417.5	401.6
w/o Interactive Effects	1,062.2	999.4	978.6	903.3	826.2	661.3	602.3	569.2	533.4	505.7	420.6	404.6

Source: Guidehouse

Table J-13. PG&E Demand Savings (MW)

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Scenario 1: No IRA												
EE	29.0	27.0	23.0	18.6	17.0	14.9	16.7	15.3	18.1	20.9	20.9	20.9
FS	20.4	20.8	25.2	25.5	27.7	32.2	0.2	0.2	0.2	0.3	0.3	0.3
BROs	35.1	36.5	38.0	39.5	41.0	42.6	44.4	46.2	48.1	50.0	51.1	53.3
Scenario 2: Reference IRA and FS												
EE	31.3	28.4	23.7	18.9	17.2	15.4	17.5	15.8	18.6	21.0	20.9	20.9
FS	36.1	36.3	36.4	36.8	37.1	37.7	0.2	0.2	0.2	0.3	0.3	0.3
BROs	35.1	36.5	38.0	39.5	41.0	42.6	44.4	46.2	48.1	50.0	51.1	53.3
Scenario 3: Reference IRA and aggressive FS												
EE	31.1	28.2	23.5	18.6	17.0	15.2	17.4	15.6	18.5	21.0	20.9	20.9
FS	198.6	211.7	222.7	232.8	241.8	250.7	2.6	3.1	3.5	3.5	3.8	4.0
BROs	35.1	36.5	38.0	39.5	41.0	42.6	44.4	46.2	48.1	50.0	51.1	53.3
Scenario 4: Aggressive IRA and reference FS												
EE	31.1	28.3	23.7	18.8	17.2	15.4	17.5	15.8	18.6	21.0	20.9	20.9
FS	36.2	36.3	36.5	36.8	37.1	37.7	0.2	0.2	0.2	0.3	0.3	0.3
BROs	35.1	36.5	38.0	39.5	41.0	42.6	44.4	46.2	48.1	50.0	51.1	53.3
C&S (All Scenarios)												
w/ Interactive Effects	201.9	184.7	180.7	165.9	157.8	132.0	123.2	118.3	110.0	104.3	94.0	89.5
w/o Interactive Effects	195.4	178.4	174.5	161.3	153.3	130.6	122.5	117.7	109.5	103.8	93.4	88.9

Source: Guidehouse

Table J-14. PG&E Gas Energy Savings (MMtherm/year)

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Scenario 1: No IRA												
EE	6.7	6.0	5.2	4.6	4.2	4.0	4.1	4.3	5.6	7.0	7.0	7.0
FS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BROs	11.3	11.7	12.1	12.5	13.0	13.4	14.0	14.5	15.1	16.3	15.4	16.1
Scenario 2: Reference IRA and FS												
EE	7.0	6.2	5.4	4.7	4.3	4.0	4.1	4.3	5.7	7.0	7.0	7.0
FS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BROs	11.3	11.7	12.1	12.5	13.0	13.4	14.0	14.5	15.1	16.3	15.4	16.1
Scenario 3: Reference IRA and aggressive FS												
EE	7.0	6.3	5.4	4.7	4.3	4.0	4.2	4.4	5.7	7.0	7.0	7.0
FS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BROs	11.3	11.7	12.1	12.5	13.0	13.4	14.0	14.5	15.1	16.3	15.4	16.1
Scenario 4: Aggressive IRA and reference FS												
EE	7.0	6.2	5.4	4.7	4.3	4.0	4.2	4.4	5.7	7.0	7.0	7.0
FS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BROs	11.3	11.7	12.1	12.5	13.0	13.4	14.0	14.5	15.1	16.3	15.4	16.1
C&S (All Scenarios)												
w/ Interactive Effects	23.0	22.5	14.5	14.8	13.8	13.1	12.7	12.2	11.4	11.0	10.7	10.3
w/o Interactive Effects	25.1	24.5	16.3	16.2	15.0	13.7	13.2	12.6	11.8	11.4	11.1	10.7

Source: Guidehouse

J.3.2 SCE

Table J-15. SCE Electric Energy Savings (GWh/year)

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Scenario 1: No IRA												
EE	46.4	52.1	54.1	56.0	56.7	55.0	56.6	59.8	65.6	72.3	72.2	72.5
FS	45.7	50.4	53.3	60.3	63.6	66.1	7.6	8.1	8.5	9.0	9.4	9.8
BROs	218.1	230.6	243.1	254.0	264.8	276.3	289.0	302.0	315.5	333.5	337.7	355.3
Scenario 2: Reference IRA and FS												
EE	61.1	59.5	60.9	60.7	60.7	58.5	60.0	63.2	68.9	72.6	72.2	72.5
FS	59.3	64.8	68.2	71.6	74.1	77.5	7.7	8.2	8.7	9.0	9.4	9.8
BROs	218.1	230.6	243.1	254.0	264.8	276.3	289.0	302.0	315.5	333.5	337.7	355.3
Scenario 3: Reference IRA and aggressive FS												
EE	60.1	58.9	60.7	60.7	60.8	58.6	60.1	63.4	69.1	72.8	72.4	72.6
FS	852.8	924.6	981.3	1,025.5	1,059.4	1,091.8	22.9	27.7	34.2	9.1	9.5	9.9
BROs	218.1	230.6	243.1	254.0	264.8	276.3	289.0	302.0	315.5	333.5	337.7	355.3
Scenario 4: Aggressive IRA and reference FS												
EE	61.4	61.7	62.3	61.5	61.3	59.0	60.5	63.4	69.0	72.7	72.2	72.4
FS	60.0	65.4	68.8	71.8	77.6	79.4	7.7	8.2	8.7	9.0	9.4	9.8
BROs	218.1	230.6	243.1	254.0	264.8	276.3	289.0	302.0	315.5	333.5	337.7	355.3
C&S (All Scenarios)												

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
w/ Interactive Effects	1,071.2	1,008.4	987.2	909.8	830.0	659.5	599.0	565.9	530.2	502.5	417.5	401.6
w/o Interactive Effects	1,062.2	999.4	978.6	903.3	826.2	661.3	602.3	569.2	533.4	505.7	420.6	404.6

Source: Guidehouse

Table J-16. SCE Demand Savings (MW)

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Scenario 1: No IRA												
EE	13.6	14.4	14.3	14.5	14.5	14.1	14.5	14.9	15.8	17.0	16.8	16.7
FS	55.5	61.6	65.0	73.1	77.1	80.3	10.6	11.3	12.0	12.7	13.3	13.9
BROs	45.4	47.7	50.0	51.8	53.4	55.2	57.1	59.0	60.8	62.9	63.9	66.2
Scenario 2: Reference IRA and FS												
EE	16.1	15.9	15.8	15.6	15.5	15.0	15.3	15.7	16.6	17.1	16.8	16.7
FS	71.0	77.8	81.8	85.9	89.1	92.5	10.6	11.4	12.1	12.7	13.3	13.9
BROs	45.4	47.7	50.0	51.8	53.4	55.2	57.1	59.0	60.8	62.9	63.9	66.2
Scenario 3: Reference IRA and aggressive FS												
EE	15.5	15.6	15.7	15.6	15.5	15.0	15.3	15.7	16.6	17.1	16.8	16.7
FS	956.8	1,034.9	1,095.5	1,143.4	1,180.1	1,214.6	13.7	15.3	17.1	12.8	13.4	14.1
BROs	45.4	47.7	50.0	51.8	53.4	55.2	57.1	59.0	60.8	62.9	63.9	66.2
Scenario 4: Aggressive IRA and reference FS												
EE	16.2	16.3	16.0	15.7	15.5	15.0	15.4	15.7	16.6	17.1	16.8	16.7
FS	71.8	78.5	82.5	86.1	91.7	93.9	10.6	11.4	12.1	12.7	13.3	13.9
BROs	45.4	47.7	50.0	51.8	53.4	55.2	57.1	59.0	60.8	62.9	63.9	66.2
C&S (All Scenarios)												
w/ Interactive Effects	186.5	172.4	168.9	154.7	147.1	121.9	113.3	108.7	101.0	95.8	85.9	81.6
w/o Interactive Effects	180.2	166.2	162.8	150.2	142.7	120.5	112.7	108.2	100.4	95.2	85.3	81.0

Source: Guidehouse

J.3.3 SCG

Table J-17. SCG Gas Savings

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Scenario 1: No IRA												
EE	10.4	11.0	11.3	10.8	10.4	9.7	10.8	11.1	13.1	14.1	13.7	13.5
FS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BROs	7.9	8.2	8.6	8.9	9.3	9.7	10.1	10.6	11.1	11.6	12.1	13.5
Scenario 2: Reference IRA and FS												
EE	10.8	13.1	13.3	12.7	12.1	11.1	10.8	10.7	12.6	13.4	13.0	12.8
FS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BROs	7.9	8.2	8.6	8.9	9.3	9.7	10.1	10.6	11.1	11.6	12.1	13.5
Scenario 3: Reference IRA and aggressive FS												
EE	10.8	13.1	13.4	12.7	12.1	11.1	10.8	10.7	12.6	13.4	13.0	12.8

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
FS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BROs	7.9	8.2	8.6	8.9	9.3	9.7	10.1	10.6	11.1	11.6	12.1	13.5
Scenario 4: Aggressive IRA and reference FS												
EE	10.9	13.2	13.4	12.7	12.1	11.1	10.8	10.7	12.5	13.4	13.0	12.8
FS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BROs	7.9	8.2	8.6	8.9	9.3	9.7	10.1	10.6	11.1	11.6	12.1	13.5
C&S (All Scenarios)												
w/ Interactive Effects	25.6	25.0	16.1	16.5	15.4	14.6	14.2	13.6	12.6	12.3	11.9	11.5
w/o Interactive Effects	28.0	27.3	18.1	18.0	16.7	15.2	14.7	14.0	13.1	12.7	12.3	11.9

Source: Guidehouse

J.3.4 SDG&E

Table J-18. SDG&E Electric Energy Savings (GWh/year)

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Scenario 1: No IRA												
EE	15.2	14.0	12.4	11.5	11.0	9.4	9.3	9.5	10.4	11.7	11.8	12.1
FS	0.8	1.3	2.9	3.8	4.8	5.7	4.8	5.8	6.9	7.8	8.6	9.4
BROs	57.5	59.9	62.5	65.3	68.2	71.3	74.8	78.6	82.5	87.7	88.9	93.8
Scenario 2: Reference IRA and FS												
EE	15.8	14.7	13.0	12.1	11.6	10.2	9.9	10.0	10.8	11.7	11.9	12.2
FS	1.3	2.7	4.5	5.8	6.8	8.1	5.3	6.2	7.2	8.1	8.8	9.5
BROs	57.5	59.9	62.5	65.3	68.2	71.3	74.8	78.6	82.5	87.7	88.9	93.8
Scenario 3: Reference IRA and aggressive FS												
EE	15.9	14.8	13.1	12.2	11.7	10.3	9.9	10.1	10.9	11.8	11.9	12.2
FS	471.9	475.1	470.5	460.1	447.5	434.9	9.9	12.0	14.8	8.1	8.8	20.0
BROs	57.5	59.9	62.5	65.3	68.2	71.3	74.8	78.6	82.5	87.7	88.9	93.8
Scenario 4: Aggressive IRA and reference FS												
EE	16.1	15.0	13.4	12.6	12.0	10.5	10.0	10.2	11.0	11.8	11.9	12.2
FS	1.6	3.0	4.9	6.2	7.3	8.2	5.3	6.3	7.3	8.2	8.8	9.6
BROs	57.5	59.9	62.5	65.3	68.2	71.3	74.8	78.6	82.5	87.7	88.9	93.8
C&S (All Scenarios)												
w/ Interactive Effects	219.4	206.5	202.2	186.3	170.0	135.1	122.7	115.9	108.6	102.9	85.5	82.2
w/o Interactive Effects	217.5	204.7	200.4	185.0	169.2	135.4	123.3	116.6	109.2	103.6	86.1	82.9

Source: Guidehouse

Table J-19. SDG&E Demand Savings (MW)

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Scenario 1: No IRA												
EE	3.7	3.5	3.2	2.9	2.7	2.4	2.2	2.2	2.4	2.6	2.6	2.6
FS	1.0	1.7	3.8	5.2	7.2	9.0	0.8	1.0	1.2	1.3	1.4	1.6
BROs	11.9	12.3	12.7	13.2	13.6	14.1	14.6	15.1	15.6	16.2	16.5	17.1
Scenario 2: Reference IRA and FS												

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
EE	3.9	3.6	3.3	3.0	2.8	2.5	2.3	2.3	2.4	2.6	2.6	2.6
FS	1.6	3.4	5.7	7.6	9.7	12.0	0.9	1.0	1.2	1.4	1.5	1.6
BROs	11.9	12.3	12.7	13.2	13.6	14.1	14.6	15.1	15.6	16.2	16.5	17.1
Scenario 3: Reference IRA and aggressive FS												
EE	3.9	3.6	3.3	3.0	2.8	2.5	2.3	2.3	2.4	2.6	2.6	2.6
FS	509.8	513.4	509.0	498.7	486.4	473.9	1.8	2.2	2.7	1.4	1.5	3.7
BROs	11.9	12.3	12.7	13.2	13.6	14.1	14.6	15.1	15.6	16.2	16.5	17.1
Scenario 4: Aggressive IRA and reference FS												
EE	4.0	3.8	3.4	3.2	2.9	2.5	2.3	2.3	2.4	2.6	2.6	2.6
FS	1.9	3.8	6.2	8.1	10.3	12.1	0.9	1.1	1.2	1.4	1.5	1.6
BROs	11.9	12.3	12.7	13.2	13.6	14.1	14.6	15.1	15.6	16.2	16.5	17.1
C&S (All Scenarios)												
w/ Interactive Effects	38.2	35.6	34.9	31.9	30.3	25.0	23.3	22.3	20.7	19.6	17.5	16.6
w/o Interactive Effects	36.9	34.3	33.6	31.0	29.4	24.8	23.2	22.2	20.5	19.5	17.4	16.5

Source: Guidehouse

Table J-20. SDG&E Gas Energy Savings (MMtherm/year)

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Scenario 1: No IRA												
EE	1.0	1.0	1.0	1.0	1.2	1.2	0.8	0.8	0.8	0.8	0.8	0.8
FS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BROs	1.8	1.8	1.8	1.9	2.0	2.0	2.1	2.2	2.3	2.6	2.2	2.3
Scenario 2: Reference IRA and FS												
EE	1.0	1.0	1.0	1.0	1.3	1.2	0.9	0.8	0.8	0.8	0.8	0.8
FS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BROs	1.8	1.8	1.8	1.9	2.0	2.0	2.1	2.2	2.3	2.6	2.2	2.3
Scenario 3: Reference IRA and aggressive FS												
EE	1.0	1.0	1.0	1.0	1.3	1.2	0.9	0.8	0.8	0.8	0.8	0.8
FS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BROs	1.8	1.8	1.8	1.9	2.0	2.0	2.1	2.2	2.3	2.6	2.2	2.3
Scenario 4: Aggressive IRA and reference FS												
EE	1.0	1.0	1.0	1.0	1.3	1.2	0.9	0.8	0.8	0.8	0.8	0.8
FS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BROs	1.8	1.8	1.8	1.9	2.0	2.0	2.1	2.2	2.3	2.6	2.2	2.3
C&S (All Scenarios)												
w/ Interactive Effects	2.3	2.3	1.5	1.5	1.4	1.3	1.3	1.2	1.1	1.1	1.1	1.0
w/o Interactive Effects	2.5	2.5	1.6	1.6	1.5	1.4	1.3	1.3	1.2	1.2	1.1	1.1

Source: Guidehouse

Appendix K. Inflation Reduction Act Tax Credits

The Guidehouse team accounted for Inflation Reduction Act (IRA) tax credits within three scenarios in the 2023 Study. While the IRA also specifies EE rebate programs designed to promote the adoption of efficient and electrified end use technologies, these programs will be left to individual states to design and administer. At the time of this study, specific details were not finalized regarding qualifying measures and incentive levels. As a result, the 2023 Study accounted only for the IRA tax credits in its modeled potential. Additional detail regarding these programs and their consideration within the 2023 Study can be found in Section 5.2.

The model includes two effects potentially caused by the tax credits:

- **Changing Cost-Effectiveness:** Tax credits are a benefit in the TRC test and could act to increase cost-effectiveness of measures. Economic Potential could increase if measures cross the threshold of cost-effectiveness due to the tax credit. The PG Model followed the California Standard Practice Manual and supplemental guidance from CPUC staff to properly incorporate tax credits into the TRC test.

- **Increasing Willingness to Adopt:** Tax credits reduce the lifetime ownership cost of energy efficient equipment. Lifetime cost is an input to the PG Model's calculation of willingness to adopt; reducing cost increases willingness and thus increases Achievable Potential. We do not expect significant algorithm changes to be necessary to model this aspect.

The critical step to modeling the IRA in the PG Model is to characterize the tax credits for each applicable measure. Within the PG Model measure input workbooks, there is a field for both residential and commercial measures input workbooks for tax credits in a $/unit value.

The IRA has specific provisions for developing and quantifying the appropriate tax credit for measures in the residential and commercial sectors, which are detailed below. Once the values are characterized, they can be imported to the PG Model and run to calculate the resulting savings.

The IRA also provides rebates through programs. The modeling of these programs is not included in this current study as they are still undergoing design as of Q4 2022.

K.1 Residential Sector Characterization

For applicable Residential EE and FS measures, Guidehouse defined a "base" tax credit amount for the value that will be added to the Tax Credit field for each measure. To quantify the tax credit amount, Guidehouse quantified scaling factors for the population to account for the requirements that the measures are installed in owner-occupied single-family homes, and the functional requirement that the homeowner has sufficient tax burden to receive the value of the tax credit.

- Step 1 – Assign **base tax credit (**$/unit) for applicable residential measures *(Source – IRA provisions)*
  - The smaller of $1,200 or 30% of the installed measure cost for non-heat pump HVAC, insulation and envelope measures (excluding windows and exterior doors)

  - The smaller of $2000 or 30% of the installed the measure cost for heat pump HVAC or HPWH
  - The smaller of $600 or 30% of the installed measure cost for windows
  - The smaller of $500 or 30% of the installed measure cost for doors
- Step 2 – Calculate **adjusted tax credit** ($/unit)
  - 2a - Multiply by the % of homes that are SF *(Source – RASS)*
  - 2b - Multiply by the % of above that are owner-occupied *(Source – RASS)*
  - 2c - Multiply by the % of homes that meet a conservative estimate of income threshold that would indicate they have a big enough tax burden to take advantage of the IRA credit.
    - For homes that meet the conditions specified in Steps 2a and 2b, estimate the % of households with income sufficient to exceed the tax burden equal or greater to the Base Tax Credit value to qualify receiving the credit. *(Source – RASS)*
    - The above considered the jointly filed household Standard Deduction ($27,700) and the 2023 federal tax rates *(Source - 2023 Federal Tax Code)*
- Step 3 - Add adjusted tax credit from Step 2 to applicable residential measures.
  - Applicable measures include HVAC equipment, air sealing, insulation, improvements to or replacements of panelboards, sub-panelboards, branch circuits, or feeders used with qualifying property. These may not all be in the PG study measure list.
  - The tax credits provided specifically through the IRA are effective as of Jan 1, 2023. There are lower tax credits from prior passed laws that are eligible for measures installed in 2022. For the purposes of the 2023 Study, only the IRA tax credit is used for the 2023-2035 period.
  - The Home Audit tax credit is not applied to any PG study residential measure.

K.2 Commercial Sector Characterization

The IRA tax credit for commercial buildings applies to HVAC, Lighting, and Water measures achieving at least 25% reduction from baseline energy consumption. The tax credit is $/sq ft and dependent on the total reduction in baseline energy usage:

> *The deduction would be set at $0.50 per square foot and increased by $0.02 for each percentage point by which the certified efficiency improvements reduce energy and power costs, with a maximum amount of $1.00 per square foot. For projects that meet prevailing wage and registered apprenticeship requirements the base amount is $2.50, which would be increased by $0.10 for each percentage point increase in energy efficiency, with a maximum amount of $5.00 per square foot.*
>
> *(Source - https://crsreports.congress.gov/product/pdf/R/R47202)*

Similar to the Residential Sector, the PG study measure characterization quantifies the tax credit as a $/unit input. The following steps were taken to derive this $/unit value:

- Step 1 – Estimate the **total portion of Commercial buildings**, by building type, that have the potential to achieve at least 25% reduction in baseline energy consumption.

- While there is not a market-specific data source that has established to quantify the total portion of Commercial buildings, Guidehouse conducted a review of publicly available secondary data sources combined with Guidehouse expertise. The Guidehouse team research found that "on average, 30% of the energy used in commercial buildings is wasted[196]" and the Commercial Buildings Integration program has set a target of a 30% reduction in commercial building energy use intensity from 2010 levels by 2030.
- To refine this assumption, Guidehouse analyzed the overall commercial building stock by building type by vintage. Only the proportion of overall premises constructed prior to 1992 was assumed to be realistically able to meet the baseline energy usage reduction threshold. Of these buildings, it was assumed that on average 30% can reduce energy usage by 25% or greater through analyzed EE measures.
- To differentiate relative EE savings potential between building types, the 2021 Study results were applied to the Commercial sector building stock to compare the relative achievable potential by overall building area (sq ft) for each of the Commercial sector building types. These building type-specific values (see Table K-1 were indexed and assigned varying penetration levels: high (45% of buildings can achieve the IRA savings threshold), medium (30%), or low (15%) potential representing the assumed proportion of buildings built prior to 1992 in each category that could achieve required overall energy reduction.

Table K-1. Assumed Penetration Levels of Buildings Achieving > 25% Energy Reduction to Qualify for IRA Tax Credits

Building Stock	Percent of Buildings Achieving >25% Energy Reduction
Com - College	15%
Com - Grocery	45%
Com - Health	30%
Com - Lodging	30%
Com - Office (Large)	15%
Com - Office (Small)	15%
Com - Other	30%
Com - Refrig. Warehouse	30%
Com - Restaurant	45%
Com - Retail	40%
Com - School	15%
Com - Warehouse	30%

Source: Guidehouse

196 https://www.energy.gov/eere/buildings/about-commercial-buildings-integration-program

- Step 2 – Generate an estimate for the **median savings potential** (value between 25% and 50% of baseline energy consumption) of the building stock identified in Step 1 achievable through rebated efficiency measures analyzed in the 2023 Study.
    - Based on the results of past potential and goals study cycles and the reduction of lighting end use potential, Guidehouse assigned the base threshold value of 25% for the conservative IRA Scenarios.
    - This value was increased by a factor of 1.5 for the Aggressive IRA Scenario.
- Step 3 – Calculate the **effective median savings potential** by adjusting the base tax credit value to account for prevailing wage and apprenticeship requirements
    - The value assigned for compliance with prevailing wage and apprenticeship requirements was estimated to be 85%. With significant confidence, Guidehouse assumed the value less than 100%. Given that compliance permits a 500% increase in the realized tax credit, there is also a case that it should be relatively close to unity, particularly over time. It was also noted that California law requires all large public projects to meet prevailing wage requirements where a majority of workers employed on any job earn the designated prevailing wage.
- Step 4 – Using the adjusted % savings estimate from Step 2 and the IRA guidelines, Table K-2 provides the **base unadjusted $/sq ft tax credit** for IRA-eligible buildings.

Table K-2. IRA Tax Credit Value by Building Type

Building Type	Conservative IRA tax credit value ($/sq ft)	Aggressive IRA tax credit value ($/sq ft)
Com - College	$0.28	$0.42
Com - Grocery	$0.80	$1.20
Com - Health	$0.45	$0.68
Com - Lodging	$0.54	$.80
Com - Office (Large)	$0.26	$0.40
Com - Office (Small)	$0.26	$0.40
Com - Other	$0.54	$0.80
Com - Refrig. Warehouse	$0.45	$0.68
Com - Restaurant	$0.72	$1.08
Com - Retail	$0.81	$1.22
Com - School	$0.28	$0.42
Com - Warehouse	$0.45	$0.68

Source: Guidehouse

- Step 4 –calculate **Expected tax credit ($/unit)** for each IOU and Building Type
    - The above $/sq ft tax credit values were divided by the overall savings per unit building area for each building type (kWh/sq ft or Therms/sq ft) resulting in an average IRA tax credit $/unit energy savings. This product was multiplied by the unit energy savings (kWh/Unit or Therms/Unit for each applicable measure, deriving the IRA tax credit $/unit.
- Step 5 - Expected tax credit/unit values from Step 4 were then added to applicable Commercial measure workbooks