Guidehouse

2021 Energy Efficiency Potential and Goals Study – Attachment 4: Energy Efficiency-Demand Response Integration

Prepared for:

California Public Utilities Commission

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1. Summary

The EE-DR integration analysis into the Potential and Goals study and into cost-effectiveness analysis is new. The existing programs do not integrate the technology incentives and savings streams together. The study assessed the customer adoption impacts of integrating the co-benefits and costs of DR for DR-enabled EE technologies. The analysis required including and differentiating the cost and benefit streams associated with DR. The Guidehouse team collaborated with the Lawrence Berkeley National Laboratory (Berkeley Lab) DR Potential Study team to select measures and characterize them within the EE potential study framework.[1] Some measures became cost-effective as a result of the DR benefit.

Accounting for DR benefits and costs increases the overall potential results without BROs an average 10.0% increase over the forecast period. Table1-1 shows the achievable potential results for each program type (incentive programs and fuel substitution) with BROs[2]. Table1-1 includes a comparison between the same Scenario 2: TRC Reference with and without DR. To provide a single fuel metric for comparison purposes, fuel substitution includes an alternate calculation where gas savings are converted into electric savings.

Table1-1. 2022 Net First-Year Incremental Savings With and Without DR (Statewide)

Savings Metric	Program Type	Scenario 2: TRC Reference	Scenario 2 (DR): TRC Reference With DR	% Difference
Electric Energy (GWh/Year)	Fuel Substitution	-126.72	-127.00	0.2%
	EE + BROs	707.40	719.96	1.8%
	Total	**580.68**	**592.96**	**2.1%**
Electric Demand (MW)	Fuel Substitution	-12.49	-12.55	0.5%
	EE + BROs	161.82	165.15	2.1%
	Total	**149.33**	**152.60**	**2.2%**
Gas Energy (MMTherms/ Year)	Fuel Substitution	17.13	17.16	0.2%
	EE + BROs	34.68	35.20	1.5%
	Total	**51.81**	**52.35**	**1.0%**
TSB ($ Millions)	Fuel Substitution	$61.46	$63.83	3.9%
	EE + BROs	$465.80	$514.30	10.4%
	Total	**$527.26**	**$578.13**	**9.6%**

Source: Guidehouse

The following are notable takeaways from the savings results:

- Energy savings is minimal when adding EE-DR co-benefits. However, the TSB increases by almost 10% with the EE-DR co-benefits. This is because EE-DR co-benefits act to increase the adoption of EE equipment but not BROs. EE equipment savings dominate the TSB result (as BROs have a very short lifetime) meanwhile BROs dominate first year energy saving results. The disproportional contribution of EE

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

[2] EE-DR co-benefits has no impact on BROs.

equipment impacts to TSB vs first year savings means that including EE-DR co-benefits add significantly more savings to TSB than first year energy savings.

- Residential smart thermostats had the biggest impact from EE-DR co-benefits
- Certain commercial segments became cost-effective sooner due to the EE-DR co-benefit.
- Industrial controls have an increase in savings in the beginning of the forecast period.

2. Introduction

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

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

2.1 Background and Approach

The 2021 Study is a major update to the previous potential and goals study completed in 2019 (2019 Study[3]). During the 2 years since the 2019 Study was completed, several market and policy changes have taken place. These changes are reflected in the 2021 Study. The project kicked off in spring 2020 and was followed by a series of stakeholder workshops held through January 2021. These workshops helped to shape and guide the direction of the work presented in this report.

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

Consistent with previous CPUC potential studies and common industry practice, the 2021 Study final output is an achievable potential analysis. Achievable potential is a calculation of EE savings based on specific incentive levels, program delivery methods, assumptions about existing CPUC policies, market influences, and barriers. This report/memo describes the portion of the PG Study that performed sensitivities which endeavored to assess the impacts of integrating the benefits and costs of DR for DR-enabled EE technologies. Integrating DR benefits and costs allows the model to better simulate the market dynamics of technologies that provide multiple benefit streams.

For the main report of the 2021 Study, please refer to the Final 2021 Energy Efficiency Potential and Goals Study published in August 2021.[4] This 2021 Study forecasts the potential energy savings from various EE programs as well as codes and standards (C&S) advocacy efforts for the following customer sectors: residential, commercial, agriculture, industrial, and mining.

This report documents the data sources for and results of the EE-DR sensitivity scenario for the 2021 Study.

Aside from this report, the following supporting deliverables are available to the public via the CPUC's website:[5]

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

[4] https://pda.energydataweb.com/#!/documents/2531/view

[5] https://www.cpuc.ca.gov/General.aspx?id=6442464362 and 2021 Potential and Goals (ca.gov)

- **2021 PG MICS:** A spreadsheet version of the Measure Input Characterization System documenting all final values for all rebated technologies forecast in the model. This includes EE-DR characteristics used for the analysis.
- **2021 PG Measure Level Results Database (EE-DR Sensitivity):** A spreadsheet of economic and achievable potential for each measure in each sector, end use, and utility is available at https://pda.energydataweb.com. The database also includes measure level and behavior, retro commissioning, and operational (BROs) program results and cost-effectiveness test results for the EE-DR sensitivity.
- **Other 2021 PG Study Files for reference:**
    - Final 2021 PG Study Report August 2021 – Final draft report of the core 2021 PG study and associated measure level results:
        - PG Study Measure Results Database (2021 ACC) – measure level data outputs by scenario using the 2021 avoided cost vintage
        - PG Study Measure Results Database (2020 ACC) – measure level data outputs by scenario using the 2020 avoided cost vintage
    - 2021 PG BROs Input Database - Input data file for the BROs programs
    - Market Adoption Characteristics Study – Market adoption study to understand the value factor characteristics for different measures and customer types including smart thermostats as a representative EE-DR measure.
        - Study Data – raw data from the market adoption study surveys.
    - Industrial/Agricultural Market Saturation Study – Industrial and agricultural measure characterization study that also included references to EE-DR adoption.
    - Low Income Potential Study – Energy efficiency potential study for the low income program.

3. Study Methodology

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

3.1 Modeling Methods

Table 3-1 summarizes the modeling approach for EE-DR.

Table 3-1. Overview of Modeling and Calibration Approach

Savings Source	Summary of Modeling Approach	Summary of Calibration Approach	Methodology Change Relative to 2019 Study
Rebated technologies: EE-DR integration	Sensitivity analysis that includes savings that co-benefit from EE-DR measures.	No specific calibration because this savings source did not exist in historic portfolios. Same calibrated parameters as used for EE are applied to EE-DR	EE-DR co-benefits for economic screening and customer adoption.

Source: Guidehouse

Rebated technologies make up the majority of historical program spending and lifetime savings claims. They are a core part of the forecast. The Guidehouse team's approach of using a bass diffusion model to model rebated technologies has not changed since the 2019 Study. However, additional features were included in the 2021 Study. This study includes a sensitivity that assessed DR-enabled technologies in addition to the rebated EE and fuel substitution technologies. They are a new addition to the study, but they leverage much of the same methodology as used by rebated EE technologies. This section describes additional enhancement made to the methodology to accommodate DR-enabled EE measures.

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

3.1.1 Technology Groups, Efficiency Levels, and Competition

DR-enabled technologies compete with EE measures (and possible fuel substitution measures) within a technology group.[6] Table 3-2 illustrates an example of a DR-enabled technology competing with EE technologies.

[6] The 2021 PG Study report describes technology groups and competition within a technology groups in more detail.

Table 3-2. Example of Technologies within a Technology Group – DR-Enabled

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

Source: Guidehouse

3.1.2 Technical and Economic Potential

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

The Guidehouse team included the DR benefits and associated costs for realizing DR benefits in the economic potential calculations. The team assessed the cost-effectiveness of these technologies from an integrated EE-DR perspective. The DR benefits for these technologies included the avoided capacity (both generation and transmission and distribution (T&D)), avoided energy, and avoided greenhouse gas (GHG) emissions costs based on the CPUC's 2016 DR Cost-Effectiveness Protocols and E3's Avoided Cost Calculator 2020 (ACC).[7] On the costs side, DR-related operations and maintenance (O&M) and program administrative costs were added because the EE-DR technology cost is already considered in the EE economic potential analysis.

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

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

3.1.3 Achievable Potential

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

Approach to Calculating Willingness

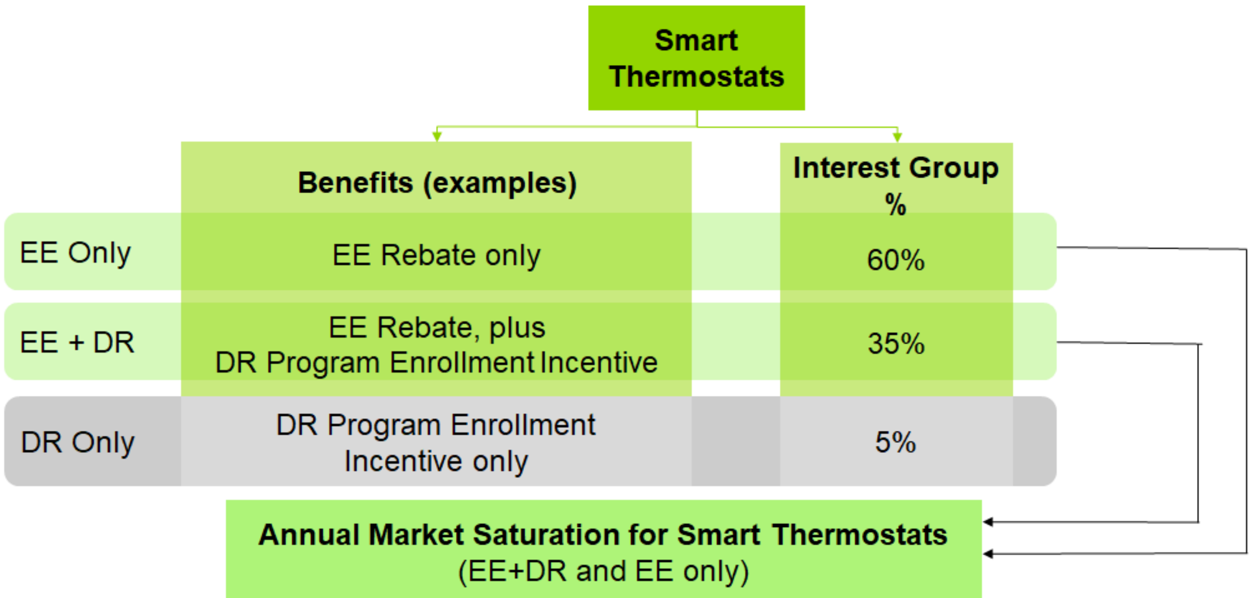
For EE technologies that also have DR capabilities, the model's willingness calculations assess customer adoption from a joint EE-DR perspective for some of the study scenarios. This perspective is illustrated using a smart thermostats example in Figure 3-1 and Table 3-3.

[7] 2016 Demand Response Cost-Effectiveness Protocols available at https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=11573;
The Avoided Cost Calculator (ACC) is available at
ftp://ftp.cpuc.ca.gov/gopher-data/energy_division/EnergyEfficiency/CostEffectiveness/2020%20ACC%20Electric%20Model%20v1c.xlsb

In the smart thermostat adoption example, a customer is faced with three discrete choices[8] to purchase the smart thermostat:

- Decision to purchase a smart thermostat based on EE-only benefits
- Decision to purchase a smart thermostat based on EE and DR benefits
- Decision to purchase a smart thermostat based on DR-only benefits[9]

Figure 3-1. Benefits from EE-DR Technologies in the Adoption Model (Illustrative using Smart Thermostats)[10]



Note: Percentages are for illustrative purpose only.
Source: Guidehouse

This study's integrated EE-DR framework factors in both EE-only benefits and EE-DR joint benefits for smart thermostats or other integrated technologies to model the customer adoption of technologies with co-benefits for EE and DR. The DR-only value stream consideration is outside the scope of this study because it does not include any EE benefits. Accordingly, in Figure 3-1, only customers from the first two benefits streams (EE Only and EE+DR) are incorporated into the adoption modeling for smart thermostats. The Market Adoption Study (described in Section 4.3) informed customer likelihood to adopt EE-DR technologies from EE-only and EE+DR benefits perspectives.[11]

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

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

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

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

Table 3-3 shows how EE and DR benefits and costs map to the value factors that influence customer adoption. It shows the benefit and cost items by value factor for customers that adopt technologies from an EE-only perspective and from a joint EE-DR perspective. These benefits and costs feed into the willingness calculations in the model. The overall technology adoption in the integrated framework is a combination of both groups of customers (those considering EE-only benefits and those considering joint EE and DR benefits from the technology adoption).

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

Table 3-3. Benefits and Costs by Value Factor in an Integrated EE-DR Adoption Framework

Value Factor	Customers Considering EE Benefits only	Customers Considering Both EE and DR Benefits
LMC (numerical value)	**Upfront costs** (+) Technology capital cost (+) Technology installation costs (-) EE incentives **Annual operating costs** (+) O&M costs (-) Bill savings due to kilowatt-hour (kWh) reduction	**Upfront costs** (+) Technology capital cost (+) Technology installation costs (-) EE incentives *(-) DR upfront incentives* **Annual operating costs** (+) O&M costs (-) Bill savings due to kWh reduction *(-) Annual DR incentives* *(-) Additional bill savings from enhanced response to TOU rates*[12]
Upfront costs (numerical value)	**Upfront costs** (+) Technology capital cost (+) Technology installation costs (-) EE incentives	**Upfront costs** (+) Technology capital cost (+) Technology installation costs (-) EE incentives *(-) DR upfront incentives*
Hassle factor (installation cost)	(+) Technology installation costs	(+) Technology installation costs
Eco impacts (energy savings)	• EE kWh savings	• EE kWh savings • *Additional kWh and kilowatt (kW) reduction from DR enrollment*
Eco signaling (*binary scaling of energy savings)	EE kWh savings	• EE kWh savings *Additional kWh and kilowatt (kW) reduction from DR enrollment*
Non-conservation performance (binary)	0 or 1	0 or 1

(+) costs to the consumer
(-) benefits to the consumer
Italics indicate additional items needed for EE-DR items

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

*: First, the technology was qualitatively assessed to be a “1” if it was visible. Then, the “1” or “0” value was multiplied by the eco impacts to increase the weighting of that factor for those who valued eco signaling

Source: Guidehouse

Applying Incentives

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

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

3.2 Scenarios

The 2021 Study considers multiple scenarios to explore market response and how potential might change based on several alternative assumptions. This study considered the co-benefits of DR under one scenario. Table 3-4 describes the scenario. For this report, the TRC Reference and the TRC Reference with DR are compared with each other.

Table 3-4. Summary of Scenario 2 for EE Potential w/ DR

Scenario → Levers ↓	TRC Reference
C-E Test	TRC
C-E Threshold	0.85
Incentive levels*	Capped at 50%
Program engagement†	Reference
Financing	No
Include fuel substitution	Yes

TRC = Total Resource Cost Test; C-E = cost-effectiveness.

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

†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

The **TRC Reference** (Scenario 2) represents business as usual and the continuation of current policies. The cost-effectiveness threshold is set to 0.85, which assumes the balance of cost-effectiveness and other portfolio costs will result in an overall portfolio TRC greater than 1.0. The lower cost-effectiveness screening threshold would allow measures that are less cost-effective into the forecast. A lower threshold reflects current and past EE portfolios that do include measures with low TRC. This scenario includes a separate sensitivity run to test the impact of including EE-DR co-benefits.

The team used the impacts of EE-DR integration to explore the sensitivity in cost-effectiveness and market adoption of the EE potential analysis. The toggling on or off the co-benefits from DR program participation impacts both the possible cost-effectiveness and customer adoption of measures.

4. Data Sources

The 2021 Study relied on vast and varied data sources. Throughout the study, the Guidehouse team sought to rely on CPUC-vetted products as much as possible. In several cases, the team sought alternate data sources where CPUC resources did not provide the necessary information. This section describes the data update process, assumptions, and sources for key topic areas. For the first time in a CPUC potential and goals study, this study characterized DR-enabled technologies — that is, electric technologies that enable customer to participate in DR programs.

4.1 Technology Selection Process

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

Table 4-1 lists all EE-DR technologies included in the study. This list considers energy efficient technologies with integrated controls and communication capabilities that enable DR. It does not consider control technologies (e.g., load control switches) that solely enable DR and do not provide any EE benefits.

Table 4-1. List of Technologies with EE and DR Co-Benefits

Sector	End Use	Technology	Technology Group
Res	AppPlug	Smart Res Clothes Washer (Electric)	Res Clothes Washers (Elec)
Res	AppPlug	Smart Efficient Res Clothes Dryer (Electric)	Clothes Dryers (Elec)
Res	AppPlug	Smart Heat Pump Res Clothes Dryer	Clothes Dryers (Elec)
Res	AppPlug	Smart Refrigerator	Refrigerators
Res	AppPlug	Smart Res Dishwasher	Res Dishwashers
Res	AppPlug	Smart Connected Power Strip	Power Strips
Res	Lighting	Advanced Residential Lighting Controls	Res Indoor Lighting Controls
Res	HVAC	Smart Room AC	Room AC
Res	HVAC	Res Smart Thermostat (Elec SC and Gas SH)	Res Thermostats (Elec/Gas)
Res	HVAC	Res Smart Thermostat (Elec SC and Elec SH)	Res Thermostats (Elec/Elec)
Res	WaterHeat	Smart Water Heating Controls (Elec WH)	Water Heating Controls (Elec)
Res	WaterHeat	Res Smart Electric Storage Water Heater (0.92 UEF - 50 Gal)	Res Elec Water Heaters
Res	WaterHeat	Res Smart Heat Pump Water Heater (Avg 3.09 and 3.31 UEF - 50 Gal)	Res Elec Water Heaters
Com	AppPlug	Com Smart Connected Power Strip	Com Power Strips
Com	AppPlug	PC Power Management	PC Power Management
Com	Lighting	Advanced Commercial Lighting Controls	Com Indoor Lighting Controls

Sector	End Use	Technology	Technology Group
Com	HVAC	HVAC Energy Management System (Elec SC and Gas SH)	EMS (Elec/Gas)
Com	HVAC	HVAC Energy Management System (Elec SC and Elec SH)	EMS (Elec/Elec)
Com	HVAC	PTAC Controls Upgrade	PTAC Controls
Com	HVAC	Com Smart Thermostat (Elec SC and Gas SH)	Com Thermostats (Elec/Gas)
Com	HVAC	Com Smart Thermostat (Elec SC and Elec SH)	Com Thermostats (Elec/Elec)
Com	WaterHeat	Smart Com Water Heating Controls (Elec WH)	Com Water Heating Controls (Elec
Com	WaterHeat	Com Smart Electric Storage Water Heater	Com Elec Water Heaters
Com	WaterHeat	Com Smart Heat Pump Water Heater	Com Elec Water Heaters
Ag	Lighting	Occupancy Sensors/Advanced Daylighting controls	Lighting Controls - Upgrades
Ind	HVAC	Ind | Electronics Chiller Plant Optimization - Efficient	HVAC Equipment Upgrade - Electric
Ind	WholeBlg	Ind | Chem Manf. Advance Automation - Efficient	HVAC Equipment Upgrade - Electric
Ag	MachDr	Ag | Water Pumping- Sensors and Controls Efficient	Ag Pump Control - Irrigation

Source: Guidehouse

4.2 Technology Characterization

The Guidehouse team characterized DR-enabled technologies in coordination with EE technologies that document the same types of inputs as previously listed and described in Table 3-9 of the 2021 Study final report.[13] The technology costs for the energy efficient DR-enabled technologies were characterized as part of the EE measure characterization. The team separately compiled technology cost data on smart equivalents of non-smart, energy efficient technologies.

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

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

The first step to calculate system benefits is to take the unit energy consumption (kWh/unit basis) for the technology and apply the post-EE measure hourly load shape to get the annual

[13] Final 2021 Energy Efficiency Potential and Goals Study

hourly consumption profile of the technology. Next, each hourly value is weighted by the probability of calling a DR event in a particular hour. This probability is represented by the hourly generation capacity allocation factor found in the ACC[14] (higher allocation factor represents higher probability of DR events being called). These weighted hourly loads are summed over 8,760 hours in the year to arrive at the average available capacity for DR from each technology. In cases where the entire capacity is not available for DR, the team applied an appropriate load reduction percentage[15] to the average available capacity to represent the average load reduction from a particular technology during a DR event. The DR benefits are calculated by using the avoided capacity (generation and T&D), energy, and GHG emissions avoided costs described in the DR Cost-effectiveness Protocols.[16] Appendix A describes the method for calculating annual DR benefits for technologies with EE and DR co-benefits.

In addition to the system benefits and O&M costs for the EE-DR measures, the cost-effectiveness analysis of EE-DR measures included incremental DR program administration costs associated with realizing the DR benefits. Net to gross for DR is assumed to be 1.0, so there are no free rider incentives included as TRC costs for DR.[17] The team also characterized DR inputs for adoption calculations, which includes incentives and bill savings to customers (described in Section 3.1.3 and Appendix A).

4.2.1 Non-Incentive Program Costs

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

Guidehouse reviewed the program cost data for SCE's Bring Your Own Thermostat program to determine the split of the incentives to the non-incentive share in the total budget.[18] This review indicated that of the total program costs, approximately 60% were spent on incentives, 5% on DR systems and tech support, and 35% on program administration (which includes all other costs related to the program). Guidehouse used this information to determine the relative magnitude of non-incentive DR program costs vis-à-vis incentives, represented as program administration costs for DR.

4.3 Market Adoption Characteristics

The 2021 Study considers a broader set of customer preferences on economic and non-economic factors when modeling technology adoption than previous PG studies. The 2021 PG Study report discuss in detail the previous methodology and the 2021 methodology for incorporating the recently completed Market Adoption Study results. The Market Adoption Study was conducted to gather data on adoption characteristics and customer attitudes and behaviors

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

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

[16] 2016 Demand Response Cost-Effectiveness Protocols available at https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=11573.

[17] To date, there are no free ridership analysis for DR programs, so by default, the net to gross is assumed to be 1.0.

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

to inform the adoption modeling for four segments: residential single-family, residential multifamily (five or more units) property owners, small commercial, and large commercial.

The customer survey collected data on customers' willingness to adopt select EE and fuel substitution technologies and measures, as well as their willingness to participate in DR programs. The survey assessed factors that may enhance residential and commercial customer willingness, including financial incentives and benefits and nonfinancial motivators. The survey also asked about factors that may negatively influence adoption or program participation across customer segments, including financial barriers, limited technology availability, structural barriers, and low awareness, among others. These barrier and motivator variables fed into characterizing customer sensitivities to several attributes that influence willingness to adopt. These attributes are discussed in more detail in Appendix H of the 2021 PG Study Report.

To help survey respondents imagine real-world decision-making scenarios, specific EE technologies were used as examples in the questions that assessed likelihood of adoption given a set of economic and non-economic factors. Table 4-2 contains the full list of measures included in the survey. Given that customer preferences would likely vary depending on the technology (e.g., thermostat, central AC), measure type (i.e., EE, DR-enabled, or fuel substitution), economic situation, and general attitudes, the Guidehouse team calculated customer preference weightings separately for each combination of technology, measure type, and customer group, where applicable.

Table 4-2. List of All Measures Surveyed

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

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

Source: Attachment A: Market Adoption Study

4.3.1 Processing Survey Responses

The survey provided a table indicating the importance of each of the six value factors (previously introduced in the 2021 Study report) to each respondent's decision on whether to adopt energy efficient technologies. The survey posed questions on a 1-5 Likert scale, with a response of 1 indicating the value factor is not important in the customer's decision-making, and a response of 5 indicating the value factor is very important. While the question responses were on a numeric scale, the responses should be treated as ordinal (ranked) instead of metric data because participants were asked to rank the importance of a value factor. For example, a survey response of 2 means that the category is more important than a response of 1, but not necessarily twice as important. To apply common statistical methods (e.g., averages) over the ordinal responses, the responses need to be transformed into a corresponding metric value.[19] The transformation to a corresponding metric value is done by mapping ordinal survey responses onto a common latent importance scale, which numerically represents the importance respondents place on different factors. An importance of 3 on this latent scale means that a participant values something twice as much as something given a 1.5 on the latent scale. Algorithms incorporating ordered probit model methods can be used to recover a latent normal model from a set of ordinal responses.[20]

4.3.2 Summary of Survey Results

Because the survey was only able to ask about a subset of the 2021 Study measure list, the Guidehouse team conducted an exercise to map the surveyed measures to the entire 2021 Study measure list for residential and commercial measures. The first step in conducting this mapping was categorizing each surveyed technology as high or low for the attributes shown in Table 4-3. Each technology in the 2021 Study was then mapped to the surveyed technologies with which it shares the most attribute categorizations. There are survey responses mapped to each value factor, transformed using the ordinal-to-metric analysis, for DR measures (one for residential and one for commercial).

Table 4-3. 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

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

[20] The ordered probit model was derived from survey data using a Monte Carlo Markov Chain method, which is implemented in the JAGS (Just Another Gibbs Sampler) software through an R interface.[20] The number of responses at each ordinal level was input into the model, and the output was used to generate a mapping from the ordinal value (integers between 1 and 5) to the latent metric value. This mapping was applied onto the raw survey response data before averaging over the responses within each customer group to generate modeling inputs.

Technology Attribute	Description	Examples
Cost	Relative cost of an equipment	Low cost: Thermostat High cost: Refrigerator

Source: Human Behavior and Decarbonization Potential draft paper; Guidehouse

Table 4-4 shows how various combinations of sector and technology attributes (defined in Table 4-3) 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 4-4). Each residential and commercial measure in the 2021 Study is mapped to a combination of urgency, visibility, disruption, cost, and type (DR or fuel substitution, if applicable). Based on the measure assignments, the Guidehouse team applied the appropriate surveyed response dataset for the sampled measures to each 2021 Study measure.

Table 4-4. Attribute Mapping and Linking to Surveyed EE-DR Measures

Sector	Urgency	Visibility	Disruption	Cost	Sample Measure Name
Residential	High	Invisible	High	High	Air Source Heat Pump
Residential	High	Visible	*Both*	Low	Thermostat
Commercial	High	Visible	*Both*	Low	Thermostat

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

Source: Guidehouse

5. 2021 Study Results

Policymakers have used the results of past potential studies as a technical foundation to set savings goals for the next regulatory cycle. The 2021 Study is the basis for the CPUC's 2022 and beyond EE goal setting process.

5.1 EE-DR Integration

This section discusses the impacts of integrating the co-benefits of EE-DR. Integration of EE-DR co-benefits was conducted as a sensitivity analysis on Scenario 2.[21] To include an integrated EE-DR co-benefits analysis in a future core study scenario (not just as a sensitivity), the CPUC would need to investigate, vet, and ultimately adopt or sanction an approach to calculating EE-DR cost-effectiveness via formal proceeding activity.

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

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

Including DR benefits and costs has noticeable impacts at the measure level and overall without BROs (on average 10.0% increase), as shown in Table 5-1.

Table 5-1. Scenario 2 Electric Energy Savings With and Without DR

Year	Scenario 2: TRC Reference	Scenario 2 (DR): TRC Reference With DR	Percent Difference
2022	78.69	90.97	15.6%
2023	81.48	96.81	18.8%
2024	87.99	100.41	14.1%
2025	87.53	96.05	9.7%
2026	72.86	80.55	10.5%
2027	75.23	81.38	8.2%
2028	82.75	90.21	9.0%
2029	72.40	78.11	7.9%
2030	81.96	86.66	5.7%
2031	80.32	85.62	6.6%
2032	87.40	91.14	4.3%

Source: Guidehouse

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

5.1.1 Residential Sector Results

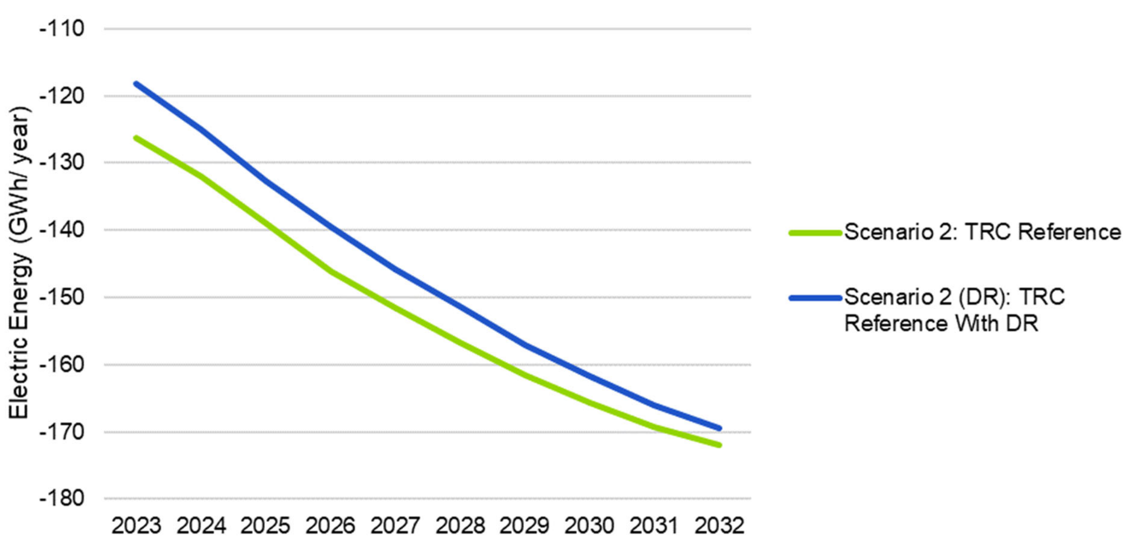
The difference in the residential potential between the two scenarios (Figure 5-1) is primarily accounted for with higher potential in the following measures:

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

DR benefits do not provide a noticeable impact on lighting or app plug end use savings.

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

Figure 5-1. Residential Incremental Annual Achievable Potential Electric Savings With and Without DR



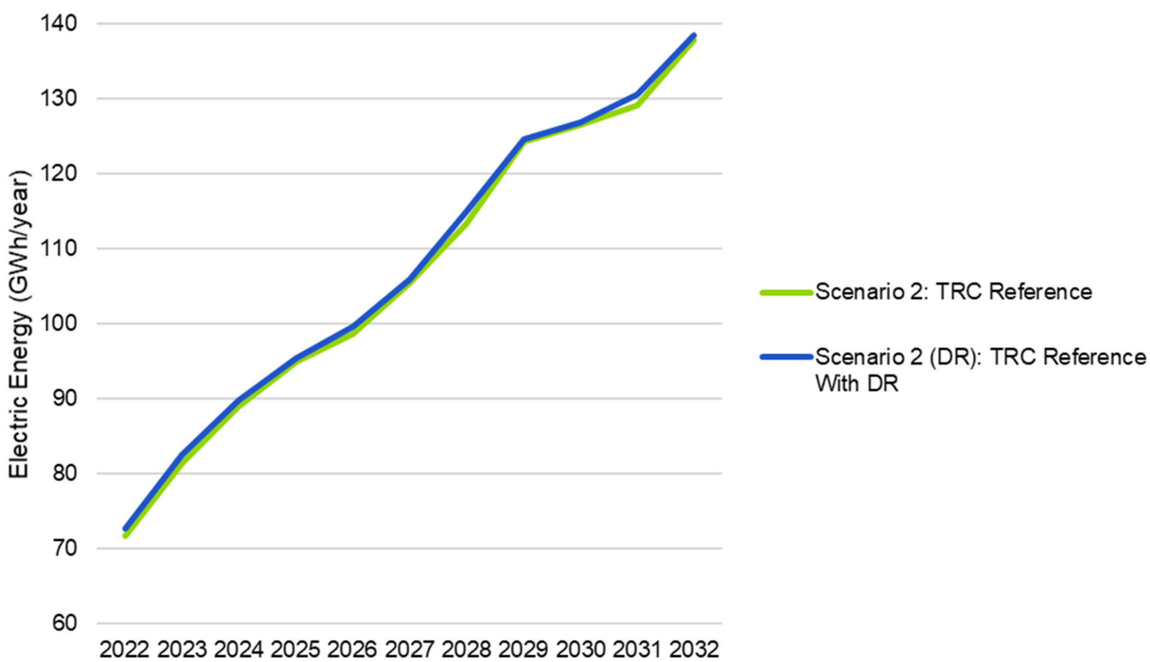
Note: Only includes HVAC, lighting, water heating, and AppPlug end uses. Negative values are a result of fuel substitution.
Source: Guidehouse

5.1.2 Commercial Sector Results

Figure 5-2 shows the incremental annual achievable potential for the commercial sector with and without the DR benefits addition for Scenario 2. Additional details on cost-effectiveness results are in Appendix A.

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

Figure 5-2. Commercial Incremental Annual Achievable Potential Electric Savings With and Without DR



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

5.1.3 Industrial and Agricultural Sector Results

Figure 5-3 shows the annual incremental achievable potential with and without DR for the industrial and agricultural sectors. There is no change in the in number of measures that pass cost-effectiveness screening with the addition of DR benefits and costs. All EE-DR technologies for these two sectors were cost-effective without DR considerations. However, market adoption of some of these technologies is expected to increase in 2022 with DR considerations.

Industrial chiller plant optimization, agriculture water pumping sensors and controls, and industrial chemical manufacturing advanced automation show higher market adoption with the addition of DR in 2022. These technologies have a relatively low share in the overall agricultural and industrial sector potential; therefore, the additional potential from these technologies does not show up as a perceptible difference in Figure 5-3.

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

Figure 5-3. Industrial Incremental Annual Achievable Potential Electric Savings With and Without DR

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

Appendix A. EE-DR Integration Approach and Results

This appendix describes the approach for adding demand response (DR) benefits and costs for technologies with energy efficiency (EE) and DR co-benefits and summarizes the implications of adding DR to technology cost-effectiveness. Appendix A.2 describes the market adoption estimation approach for EE-DR technologies.

A.1 Approach for EE-DR Technologies Cost-Effectiveness Analysis

The cost-effectiveness of technologies that can provide DR benefits is assessed from a joint EE-DR perspective. This is a theoretical construct for this study because there are no cost-effectiveness protocols or policy guidelines for technologies that can provide dual EE-DR benefits. The joint perspective was developed to assess to what extent incorporating DR benefits would influence the cost-effectiveness of EE technologies with DR co-benefits.

Developing a framework for joint EE and DR cost-effectiveness remains a challenge. The issues around integrated demand side cost-effectiveness have been discussed in the Integrated Distributed Energy Resources (IDER) Rulemaking (R.14-10-003) and related proceedings.[22] As noted in an IDSM Cost-Effectiveness Mapping Project Report and Staff Proposal document by the Energy Division,[23] the cost-effectiveness frameworks for EE and DR were developed in different proceedings over the course of many years, and they each have different cost-effectiveness reporting tools. EE uses the Energy Efficiency Cost Effectiveness Tool (CET),[24] while DR uses the DR Reporting Tool[25] for cost-effectiveness. Additionally, the estimation techniques used to determine the cost and benefit inputs for EE and DR differ. These differences are detailed in the costs and benefits matrix available under the IDER proceeding.[26]

Table A-1 summarizes the benefits and costs for EE-DR technologies used in the cost-effectiveness calculations under the total resource cost (TRC) test. Under the program administrator cost (PAC) test, both EE and DR incentives are included. For DR, the incentive costs will include both upfront DR program enrollment incentives and ongoing DR participation incentives.

Table A-1. Benefits and Costs from EE-DR Measures in the Cost-Effectiveness Calculations

Benefits	Costs
• Avoided energy and capacity costs from EE • Avoided capacity, energy, and greenhouse gas (GHG) emissions costs for DR *(further described in the following sections)*	• Full EE-DR measure costs (e.g., cost of a smart thermostat) • EE incentives for free riders[27] • EE administration costs • DR administration costs • EE operations and maintenance (O&M) costs • DR O&M costs

Source: Guidehouse

[22] https://www.cpuc.ca.gov/General.aspx?id=10745
[23] https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=10742
[24] https://www.ethree.com/public_proceedings/energy-efficiency-calculator/
[25] https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=11573;
[26] https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=10741
[27] DR does not have any free riders, so free rider incentives do not apply to DR.

A.1.1 DR System Benefits Calculation Approach for EE-DR Technologies

Lawrence Berkeley National Laboratory (Berkeley Lab) developed DR system benefits for each measure per the following approach. The calculations are primarily guided by California Public Utilities Commission's (CPUC's) 2016 DR Cost-Effectiveness Protocols and Avoided Cost Calculator 2020 (ACC).[28]

System benefits of a DR measure are three-fold: avoided capacity costs, avoided energy costs, and avoided GHG emissions costs. The input data to calculate these values for each of the three investor-owned utilities (IOUs) in California is mostly available in the ACC.

For each measure, Berkeley Lab started by considering the appropriate post-EE-measure hourly load shape, normalized to the measure's characterized annual energy consumption value (kWh/yr). Each hourly value was then weighted by the corresponding hourly generation capacity allocation factor found in the ACC. These allocation factors serve as a proxy for the loss of load probability, and Berkeley Lab assumed that these factors also represent the relative likelihood of a DR event being called in any given hour (i.e., a higher allocation factor means a higher probability of a DR event).

The weighted hourly load values are summed over the 8,760 hours of a year. This sum represents the average DR resource, in kilowatts (kW), expected to arise from a single installed measure during a DR event, assuming the entire associated load can be controlled. For DR measures that can only control a portion of the associated load, according to Berkeley Lab's measure characterization, this average resource is de-rated accordingly. The resulting average resource in kW is used to monetize the three DR system benefits:

1. **Avoided capacity costs:** Avoided capacity costs include the generation and transmission and distribution (T&D) costs avoided by a DR measure. The following are the input values from the ACC used to quantify these costs:
    a. Net Cost of New Entry ($/kW-yr): The proxy for new generation capacity in the ACC is a battery storage resource.
    b. T&D costs ($/kW-yr): DR programs can help defer T&D system upgrades. The study did not include T&D in the avoided capacity costs for DR (indicated in the adjustment factors discussed below).

    The average demand responsive load is then multiplied by the sum of relevant generation costs to determine the total avoided capacity cost value. The avoided capacity cost is adjusted using several factors, which are described below.

2. **Avoided cost of energy:** This is the value of energy saved (kWh) during DR events. The following inputs are used to determine this value:
    a. Cost of Energy ($/MWh): The ACC provides hourly avoided cost of energy values, including fuel cost and power plant operating costs. Each post-measure hourly consumption value weighted by its corresponding allocation factor is then multiplied by this hourly avoided cost of energy value; the result is summed. This result represents the average avoided cost of energy, per hour, during a DR event. Berkeley Lab used an estimate of the number of DR

[28] 2016 Demand Response Cost-Effectiveness Protocols is available at https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=11573;
ACC is available at https://ethreesf-my.sharepoint.com/:f:/g/personal/gabe_mantegna_ethree_com/Eu_rFWIz7r5Kl8r0CLcObtMBnOSVCf1QKlIlxFJl0nM5TA?e=aLqkqe

event hours in a year (discussed below) to obtain the total cost of energy saved.

b. Number of DR event hours: Every measure is mapped to a specific DR program that represents a typical program in which that measure would be enrolled. For example, smart thermostats in SCE's service area is mapped to SCE's Smart Energy Program, which is the smart thermostat based Direct Load Control (DLC) program offered by SCE. The load impact evaluation report of that program provides the information of the number of event hours called in a given year.

The avoided cost of energy is adjusted using some factors described below.

3. **Avoided cost of GHG emissions:** Similar to the avoided cost of energy calculation, the summed product of the average demand responsive load and the avoided GHG emissions from the ACC are combined with the GHG Adder and the expected number of DR events to yield the avoided cost of GHG emissions.

In addition to these avoided cost items, the DR benefits calculations incorporate several DR program-specific adjustment factors used to scale the avoided cost numbers based on guidance in the DR cost-effectiveness protocol. These are described below.[29]

A.1.2 Adjustment Factors for avoided costs

In the DR Cost-Effectiveness Protocols, there are several DR program specific adjustment factors used to scaled the avoided cost numbers. While there are guidelines to compute or select the values of some of these factors, the calculation of some factors is left to the discretion of the LSE.

1. **A Factor** is intended to indicate the availability of a DR program such that, if a program can be called during all hours of capacity constraints, then the A factor would be 100%. The 2016 DR cost-effectiveness protocols did not settle on a final methodology for computing this factor. The approach above of weighting the load shape by the ACC's capacity allocation factors accounts for the relevant issues and is similar to some of the candidate approaches. LBNL assumed the A factor was accounted for by the approach of weighting the load by the ACC capacity allocation factors and thus no further correction factor was applied.
2. **B Factor** is meant to indicate the various notification times such as Day-Ahead, Day-of 30 minutes and Day-of 15 minutes. The DR C-E Protocols document specifies a factor for each category of notification, which **LBNL applied directly**.
3. **C Factor** accounts for the value of flexibility of triggers that each DR program offers. The DR C-E Protocols provides specific values to consider in this factor, which **LBNL applied directly.**
4. **D Factor** is based on "right time", "right place", "right availability" and "right certainty" of DR. This factor has a default value of 0%, which means that the DR program does not avoid or defer any T&D system upgrades. LSEs looking to use other values are required to justify it. **LBNL used a D factor = 0% and thus did not include any T&D costs.**
5. **E Factor** is the energy adjustment factor, that allows utilities to use alternate energy price scenarios to evaluate DR. LBNL's approach of using the hourly energy price weighted by the capacity allocation factors implicitly incorporates an E factor for each

[29] 2016 Demand Response Cost-Effectiveness Protocols available at https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=11573;

measure, representing the average avoided energy price at the time the load would be expected to respond.

6. **F Factor** provides additional value for flexible DR. Qualifying DR programs must satisfy the CAISO rule of FRAC-MOO. According to the DR C-E Protocols, DR programs that are capable of making economic bids and, ramping and sustaining output for 3 consecutive hours can use an F factor of 110%. **LBNL used a factor of 110% for this value.**
7. **G Factor** is used for the DR resources that can be called locally in areas with resource constraints. The DR C-E Protocols documents provides IOU specific values that can directly be used to account for the value of G factor. For SDG&E and PG&E, LBNL plans to use the default G factors of 110% and 100%, respectively. For SCE, the G factor depends on the specifics of the program and whether it can be dispatched locally in capacity constrained areas. LBNL used 110% for SDG&E, 100% for PG&E and 105% for SCE programs.

A.1.3 Implications of Adding DR on Cost-Effectiveness Results of EE-DR Technologies

Table A-2 summarizes the implications of adding DR benefits on technology cost-effectiveness by sector and end use.

Table A-2. Implications of Adding DR Co-Benefits on Cost-Effectiveness and Achievable Potential

Sector	End Use	Implication of Adding DR Co-Benefits on Cost-Effectiveness*
Residential	**HVAC**	**Smart Thermostats** • Benefit-cost ratios increase with addition of DR co-benefits. • Measure passes TRC 1.0 threshold in a few cases by adding DR (not cost-effective on EE basis only). **Smart Room AC** • Benefit-cost ratios increase with addition of DR co-benefits. • Measure does not pass TRC 1.0 threshold with DR addition.
Residential	**Water Heating**	**Smart Electric Storage Water Heater** • Substantial increase in benefit-cost ratios with addition of DR co-benefits. • Measure does not pass TRC 1.0 threshold (except in 2032 for Cold climate). **Smart Heat Pump Water Heater** *Fuel substitution version* • Benefit-cost ratios increase slightly with DR addition. • Measure does not pass TRC 1.0 threshold with DR addition. *Non-fuel substitution version* • Measure passes TRC 1.0 threshold with and without DR. **Smart Water Heater Controls** • Substantial increase in benefit-cost ratios with addition of DR co-benefits. • Measure passes TRC 1.0 threshold in 2022-2026 (does not pass on EE-only basis).

Sector	End Use	Implication of Adding DR Co-Benefits on Cost-Effectiveness*
Residential	**AppPlug**	• None of the smart appliances pass TRC threshold of 1.0 with DR addition.
Residential	**Lighting**	**Advanced Lighting Controls** • Does not pass TRC threshold of 1.0 with DR addition.
Commercial	**HVAC**	**Smart Thermostat** • Benefit-cost ratios increase with addition of DR co-benefits. • Measure passes TRC 1.0 threshold in all cases with DR addition. **Energy Management System** • Substantial increase in benefit-cost ratios with addition of DR. • Measure does not pass TRC 1.0 threshold. **Packaged Terminal Air Conditioner Controls Upgrade** • Slight alterations in benefit-cost ratios with addition of DR. • Cost-effectiveness screening does not change.
Commercial	**Water Heating**	**Smart Electric Storage Water Heater** • Substantial increase in benefit-cost ratios with addition of DR. • Addition of DR benefits leads to measure passing TRC threshold of 1.0. **Smart Heat Pump Water Heater** *Fuel substitution version* • Slight increase in benefit-cost ratios with DR addition. • Measure does not pass TRC threshold of 1.0. *Non-fuel substitution version* • Addition of DR has no impact—measure is highly cost-effective without DR consideration. **Smart Water Heater Controls** • Does not pass TRC threshold of 1.0 with DR addition.
Commercial	**Lighting**	**Advanced Lighting Controls** • Slight increase in benefit-cost ratios with DR addition. • Cost-effectiveness screening is unaltered with DR addition.
Commercial	**AppPlug**	**Smart Power Strip** • Measure benefit-cost ratio increases with DR addition. • Measure passes TRC threshold of 1.0 in specific years with DR addition. **PC Power Management** • Measure benefit-cost ratio increases with DR addition. • Measure passes TRC threshold of 1.0 in all years with DR addition.
Ind/Ag	**HVAC**	**Ind. Chiller Plant Optimization** • Slight alteration in benefit-cost ratio with DR addition. • Measure cost-effective before addition of DR benefits.
Ind/Ag	**Lighting**	**Lighting Controls** • Benefit-cost ratio increases with DR addition. • Measure is not cost-effective with and without DR.

Sector	End Use	Implication of Adding DR Co-Benefits on Cost-Effectiveness*
Ind/Ag	MachDr	**Ag Water Pumping Sensors and Controls** • Slight alteration in benefit-cost ratio with DR addition. • Measure cost-effective before addition of DR benefits.
Ind/Ag	WholeBlg	**Ind. Che Manf. Advanced Automation** • Slight alteration in benefit-cost ratio with DR addition. • Measure cost-effective before addition of DR benefits.

*This is based on comparison of TRC results for Scenarios 2a and 2b.
Source: Guidehouse

A.2 Calculating DR-Related Adoption Inputs[30]

The DR-related inputs feeding the adoption model for calculating market adoption of EE-DR technologies are as follows:

- DR program incentives, which are of the following types:
  - Fixed upfront DR incentives
  - Variable upfront DR incentives
  - Fixed annual DR incentives
  - Variable annual DR incentives
- Bill savings from improved response to time-of-use rates.

DR program incentives were divided into upfront incentives paid for adopting DR-enabling technology and annual incentives paid for ongoing enrollment in the program. Depending on the program and measure, these incentives can be computed as fixed incentives paid per measure (i.e., dollars per customer) or as variable incentives paid per unit of load being enabled to participate in DR (i.e., dollars per kW). The bill savings from time-of-use rates were computed by first associating each measure with a time-of-use rate, estimating the amount of load a customer would be expected to shift based on program evaluations, and computing the resulting savings. The calculations for each component of customer DR benefits are described as follows.

- **Fixed upfront DR incentives.** Certain EE-DR measures (e.g., residential smart thermostats) are eligible for a one-time incentive for enrolling in a DR program. The incentive may be different across sectors and IOU programs. Such one-time incentives are categorized as fixed upfront DR incentives and are applied as a single fixed payment regardless of the underlying load shape.
- **Variable upfront DR incentives.** Most nonresidential measures are eligible to receive upfront incentives through Auto-DR programs (programs that use automated signals to customer-owned devices for curtailment or load reduction). For example, eligible commercial and industrial customers can use Auto-DR incentives to install new DR-enabling technologies such as energy management systems, smart thermostats, HVAC controls, and programmable lighting. The Auto-DR incentives are applied as a certain dollar value per kW of load enabled for DR, up to a fixed fraction of the total project cost for enabling DR. This is calculated as follows:

[30] The DR-related adoption inputs were calculated by the DR Potential Study team at Lawrence Berkeley National Laboratory.

$$Variable\ Upfront\ DR\ incentive = \min(D_{max} * R_{ADR},\ F_{max} * TIC)$$

Where:

D_{max}= the maximum annual demand from the measure's representative load shape
R_{ADR}= the incentive rate for Auto-DR programs, \$200/kW
F_{max} = the maximum fraction of project cost that can be covered by an Auto-DR incentive, 75%
TIC= the measure total installed cost

- **Fixed annual DR incentives.** For certain EE-DR measures (e.g., smart thermostats), a fixed incentive is provided on an annual basis for enrolling in a DR program. The incentive may be different across sectors and IOU programs. Such incentives are categorized as fixed annual DR incentives and applied as a fixed annual payment regardless of the underlying load shape. In some cases, the annual incentive could be prorated over the number of days a device remains activated. In these cases, the fixed annual DR incentive value was determined as the maximum possible incentive value that a device can get on annual basis.
- **Variable annual DR incentives.** For certain EE-DR measures (e.g., load reduction via an energy management system enrolled in a critical peak pricing, or CPP, program), annual enrollment incentives are awarded that vary with the quantity of load enrolled in the program. To determine the incentives, the DR program that could be applied to each measure is identified. As a default, the CPP rate or some form of it is assumed because it is offered to customers across all the sectors. For each measure, sector, and IOU, the difference between the customer's annual electricity bill on a non-CPP time-of-use rate and the bill on a corresponding CPP rate was computed for periods outside of CPP events.[31] This difference is the product of the measure-representative load shape and the difference between the CPP and non-CPP rate (excluding CPP events), which may vary by time period. This savings is taken as a representative annual customer DR incentive. Certain nonresidential CPP rates also include demand charge credits. If demand charge credit information is available, it is applied to the monthly peak values from the representative load shape, and the result is added to the total bill savings.
- **Bill savings from time-of-use response.** For computing time-of-use bill savings, each measure is assigned to a particular time-of-use tariff that is most common for the particular sector and IOU being considered based on a database of customer rate codes provided by the IOUs to Berkeley Lab for the DR Potential Study. For each sector and IOU, Berkeley Lab determined the impact of peak time-of-use rates on customer load, using the most recent load impact reports for residential customers and analyses performed to support the Phase 2 DR Potential Study for nonresidential customers. The impact indicates the fraction of load that can be shifted from peak to off-peak hours. Using the representative load shape for each measure, the savings from shifting the load from peak hours to off-peak hours is calculated as follows:

$$Bill\ Savings = \sum_{peak\ hours} D_h * F_{TOU} * (P_{peak} - P_{off-peak})$$

Where:

D_h= Hourly demand from the representative load shape

[31] During CPP events, Berkeley Lab assumed the customer either sheds load to avoid higher costs or effectively pays a non-performance penalty in the form of a higher electricity rate. Costs and savings that accrue during CPP events are not included as part of the annual program enrollment incentive, which is represented by the bill savings that accrue outside of peak events.

peak hours = Subset of hours that have a peak time-of-use rate
F_{TOU} = Fractional load reduction resulting from peak time-of-use rates for customers in this sector
P_{peak}= Time-of-use peak price
$P_{off-peak}$= Time-of-use off-peak price[32]

[32] Some time-of-use tariffs have more complex structures than simple peak and off-peak prices (e.g., mid-peak and super-off-peak periods). In these cases, Berkeley Lab assumed the off-peak period to be the period immediately adjacent to the peak period, under the assumption that customers will typically only shift load over a short period.