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IRP Technical Analysis: Considerations for Integrating Energy Efficiency into California's Integrated Resource Plan – Final DRAFT

Prepared for:

California Public Utilities Commission

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TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

Figures

Tables

DISCLAIMER

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1. INTRODUCTION

1.1 Policy Background

An integrated resource plan (IRP)[1] is a roadmap for utilities to meet forecasted annual peak and energy demand, with consideration of an established reserve margin, through a combination of supply-side and demand-side resources over a specified future period. IRP has historically been the domain of single, vertically integrated utilities. In California, this process is uniquely challenging because electricity is served by multiple Load Serving Entities (LSEs) including utilities, community choice aggregators (CCAs) and competitive retail service providers, with varying load profiles, resource mixes, and planning and procurement practices. Additionally, the IRP process in California must strike a balance between ensuring program and policy requirements are met by LSEs, while allowing for enough flexibility to utilize low-cost solutions.

Senate Bill (SB 350), also known as the Clean Energy and Pollution Reduction Act of 2015, mandates that the California Public Utilities Commission (CPUC) examine the future of California's energy procurement practices through an IRP process. Traditionally, the CPUC has relied on a long-term procurement planning (LTPP) proceeding to determine the type and quantity of resources California utilities should seek to produce. SB350 changed the CPUC's resource planning approach in two noteworthy ways. The bill required the CPUC to:

- Identify a portfolio of resources that meets multiple objectives including maintaining reliability, minimizing costs, and reducing greenhouse gas emissions (Pub. Uti. Code 454.41).
- Adopt a process for each load-serving entity to file an integrated resource plan (Pub. Util. Code 454.52).

With these requirements in mind, under the proposed IRP process, the CPUC is using a capacity expansion model called RESOLVE from Energy + Environmental Economics (E3) to produce portfolios of resources that are least-cost under a variety of different possible future conditions[2]. The results from RESOLVE will inform the development of a "Reference System Plan"[3]. To date, the CPUC's IRP modeling efforts have considered energy efficiency (EE) as a "baseline resource"; i.e., a resource that is included the model as an assumption with a set magnitude rather than being selected by the model as part of an optimal solution. In consideration of future updates to the IRP, the CPUC is developing a staff proposal with multiple stages for integrating EE into the IRP process. CPUC also commissioned a technical analysis to explore the technical feasibility of full optimization of energy efficiency as supply side resource.

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

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

[3] This plan forms the basis for future analytical work by LSEs to develop their respective LSE Plans, which will subsequently be reviewed by the CPUC and aggregated into a "Preferred System Plan". See IRP Staff Proposal for further details on implementing IRP at the CPUC (http://www.cpuc.ca.gov/irp_proposal/)

1.2 Scope of Technical Analysis

As part of its role in the Energy Efficiency Potential and Goals Study for 2018 and Beyond (2018 PG Study)[4], Navigant developed methodologies, data sources, and conducted a preliminary analysis for optimization of EE into CPUC's IRP. The overarching objective of this report is to develop a proof of concept and serve as an input to a staff proposal for how EE can be integrated into future IRP modeling efforts in California. This analysis continues to leverage the CPUC 2018 Potential Study model framework developed by Navigant; the model was modified to accommodate this analysis. This study reflects the first technical analysis of methodologies for optimizing EE into IRP modeling efforts in California. As a result, the CPUC and Navigant set the scope of the study with the following objectives:

- Develop staged methodologies for full optimization EE into IRP.
- For relevant methodologies, conduct preliminary analysis to develop EE data for testing in RESOLVE[5].
- Collaborate with E3 and the CPUC IRP team to test relevant methodologies in RESOLVE.
- Summarize observations and conclusions based on test results.
- Identify methodological and data considerations for future IRP modeling efforts.

This analysis focused on optimizing EE savings from equipment rebate measures for testing purposes. Savings from Behavior, Retrocommissioning and Operational (BROs), Code and Standards (C&S), and Low Income (LI) programs to remained as baseline (load-modifying) resources in this technical analysis for the following reasons:

- C&S development, while influenced by LSEs are largely outside the control of LSEs. They are not procured the same way other demand side resources are.
- LI programs are subject to a different set of regulations than all other demand side resources. They are required to be offered to IOU customers and are not subject to a cost effectiveness test.
- The full universe of BROs programs in the 2018 PG study lack reliable cost and savings data to be able to model them as supply side resources as this time.

Content of this Report

This report, which relies upon data and results of the 2018 PG Study, is organized as follows:

- **Section 2** provides an overview of the study's methodology for each of the stages considered.
- **Section 3** provides preliminary results for Stage 2, which was the methodology tested in this analysis.
- **Section 4** describes caveats associated with this technical analysis as well as considerations for integrating EE into future IRP efforts.

[4] Navigant. *Energy Efficiency Potential and Goals Study for 2018 and Beyond.* September 2017

[5] As such, this analysis only focused on testing integration of electric EE measures into IRP. Gas measures were not examined or tested.

2. STUDY METHODOLOGY

This analysis largely uses the same model framework and results as the 2018 PG Study. This section discusses the modifications made to the study and model methodology to accommodate the IRP technical analysis scope.

- Section **Error! Reference source not found.** provides an overview of stages for integrating EE into the CPUC IRP.
- Section 2.2 discusses the approach to calculating levelized costs for IRP.
- Section 0 discusses the rationale for and approach to assigning measures to bundles.
- Section 2.4 discusses the load shape research and development conducted by Navigant.
- Section 2.5 discusses the process of data aggregation and extraction from the Potential Study model.
- Section 2.6 discusses the iteration with IRP modeling team to carry out the technical analysis.

2.1 Integrating EE into IRP

The CPUC staff proposal is considering two stages for integrating EE into the IRP. This section provides an overview of these stages with considerations for if/when they are implemented. This technical analysis primarily focused on Stage 2 (as it is a previously untested concept) and provides observations on enabling Stage 1 (which is very similar to the status quo).

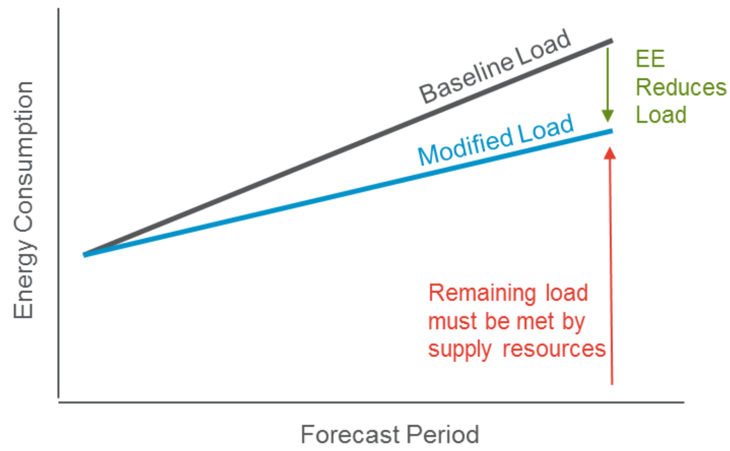
Table 1: Integration Stages

EE IRP Integration Stage	Description
Stage 1	EE is considered as a "baseline", load modifying resource. PG Study develops a set of pre-determined EE scenario-based portfolios for IRP sensitivity analysis
Stage 2	EE bundled supply curves fed into IRP model, and model picks optimal bundles of measures.

2.1.1 Stage 1: Scenario-based Portfolio Approach

In the context of integrating EE into the CPUC IRP, Stage 1 partially reflects the status quo wherein EE is treated as a baseline (also referred to as "load modifying") resource. Baseline resources are input to an IRP model as a set value. In the IRP model framework, baseline resources are intended to capture projected achievement of demand-side programs under current policy assumptions for resource planning. As illustrated in Figure 1, baseline resources act to reduce the baseline load such that the IRP model then optimizes supply resources to meet the remaining (i.e. modified) load; hence the term "load modifying" resource.

Figure 1: Illustration of EE as a Load Modifying Resource.



Currently, the IRP model incorporates savings derived from the PG Study, which reflect IOU program goals, as a load modifying resource. This methodology and associated result files are documented on the CPUC website.[6] The IRP model to date sourced data from the CEC 2016 IEPR Mid AAEE (which is based on the CPUC adopted goals for 2016 and beyond), additional savings from the AB802 Technical Analysis[7], and 2015 compliance filing data from the IOUs[8] (for cost data).

The PG Study determines the EE market potential that is cost-effective per CPUC guidelines over the same time horizon as the IRP model. In addition to producing a savings portfolio that was eventually adopted as IOU program goals, the 2018 PG Study produced four other savings portfolios under its scenarios framework.

Building on these scenarios, CPUC staff is proposing going beyond simply incorporating the adopted IOU program goals into the IRP model. But rather enhancing the process by performing a sensitivity analysis in the IRP model using multiple scenario-based portfolios produced by the PG Study. According to CPUC staff, operationally integrating these scenario-based portfolios into the current IRP model would entail manually running each of the pre-determined scenarios as a load modifying resources and then allowing the IRP model to optimize remaining supply-side resources to meet the modified load. The IRP model results for total system cost could be compared against each other to select an optimal combination of supply side resources and load modifier options.

The pre-determined scenarios would be set as part of the PG Study. For example, as part of the 2018 PG Study a set of five scenarios were developed based on considerations of cost-effectiveness tests, avoided costs and program engagement. Scenarios in the 2018 PG Study were primarily built around policies and program decisions that are under control of the CPUC and IOUs collectively, these are referred to as “internally influenced” variables. Variation in “externally influenced” variables (such as economic and demographic conditions) were not considered in the goals study but are considered in the CEC’s Additional Achievable Energy Efficiency scenarios. A list of internally and externally influenced variables can be found in Table 2 below. Additional details on each of the internally influenced variables

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[6] Proposed Reference System Plan http://cpuc.ca.gov/irp/proposedrsp/

can be found in the study team's presentation to the Demand Analysis Working Group (DAWG) on December 12, 2016.[9]

Table 2: Variables Affecting Energy Efficiency Potential

Internally Influenced	Externally Influenced
• Cost-effectiveness (C-E) test • C-E measure screening threshold • Incentive levels • Marketing & Outreach • Behavior, Retro commissioning & Operational (BROs) customer enrollment over time • IOU financing programs	• Building stock forecast • Retail energy price forecast • Measure-level input uncertainties (unit energy savings, unit costs, densities) • Non-IOU financing programs

The 2018 PG Study's five scenarios are listed in Table 3. CPUC staff's intent was to keep the number of scenarios manageable but still provide a range of alternatives to bound market potential. The cost effectiveness (C-E) screen was the primary variation across scenarios to allow CPUC staff to observe the impacts of changing C-E policies. Program engagement captured remaining internally influenced variables other than C-E related items. Externally influenced variables were held constants across all scenarios.

Table 3: Final Scenarios for Energy Efficiency Potential – Summary

Scenario	Cost Effectiveness Screen	Program Engagement
1: TRC | Reference	TRC test using 2016 Avoided Costs	Reference
2: mTRC (GHG Adder #1) | Reference	TRC test using 2016 Avoided Costs + IOU proposed GHG Adder	Reference
3: mTRC (GHG Adder #2) | Reference	TRC test using 2016 Avoided Costs + Commission staff proposed GHG Adder	Reference
4: PAC | Reference	PAC test using 2016 Avoided Costs	Reference
5: PAC | Aggressive	PAC test using 2016 Avoided Costs	Aggressive

Future updates to the PG Study define the scenario framework that can be applied to the IRP given policies and methods available. While externally influenced variable settings in future PG studies should match those used by the IRP model, internally influenced variables should be reviewed. For example, should the cost effectiveness screen continue to be the primary differentiator between the selected scenarios (should additional C-E tests be considered)? Considering alternative cost effectiveness tests could allow a broader range of definition for cost effectiveness that the IRP model could select from. Or should other variables around program design a more central role? Variable such as:

- BROs interventions
- Emerging technology programs
- Equipment rebate levels

[9] Slides available at: http://demandanalysisworkinggroup.org/event/energy-savings-pup-cpuc-2018-beyond-ee-potential-goals-study-model-calibration-and-forecasting-scenarios/?instance_id=445

- Program marketing and outreach
- Market transformation mechanisms
- Financing mechanisms/programs
- Alternative portfolio constructs

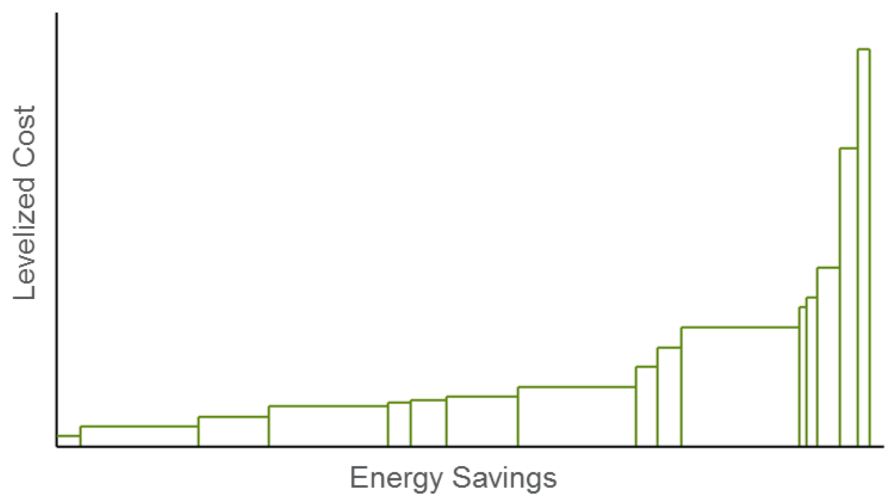
For the purposes of this technical analysis, no testing was conducted for the scenario-based portfolio approach. This is because the approach is already partially reflective of the status quo and the sensitivity analysis is straightforward relative to a true optimization of demand-side EE against supply side resources in the IRP model (e.g. Stage 2), as discussed in the following section.

2.1.2 Stage 2: Bundled Supply Curve Approach

While a scenario-based portfolio approach is feasible enough to implement under the current paradigm, the CPUC is considering a future in which the IRP model attempts to put energy efficiency on equal footing, as much as possible, with supply resources. Energy efficiency supply curves from the PG Study are fed into the CPUC IRP model and the IRP model selects the optimal amount of EE in relation to other resources. A supply curve is used since different EE technologies have different costs. Some are low cost and are competitive with current conventional supply resources while others are higher cost that may not be competitive until later years.

Supply curves offer a useful way to illustrate the amount of energy savings per dollar spent. A supply curve typically consists of two axes – one that shows the cost per unit of savings (e.g., levelized cost per kWh saved) and one that captures the energy savings at each cost level. The supply curve sorts EE on a least-cost basis[10], and savings that are calculated on an incremental basis relative to the EE resources that precede them. Figure 2 illustrates a supply curve; each "bar" in the graph represents a measure with a levelized cost (bar height) and savings potential (bar width).

Figure 2: Illustration of an EE Supply Curve



[10] Levelized costs were used as the basis for sorting the supply curves

Supply curves can contain different levels of granularity but are often constructed using "bundled" efficiency measures. Bundling in this context refers to the grouping of measure-level results into higher levels of aggregation (for e.g., sector or end-use). Bundle measures simplifies the inputs required to be fed into the IRP model. Through initial discussions with E3, Navigant was advised to aggregate EE measures into no more than 30 bundles to allow the IRP model to run efficiently during testing. Each supply curve bundle has an associated weighted average levelized cost, market potential and hourly load profile all of which are inputs into the IRP model.

To support the development of the supply curves, the PG Study would provide estimates of market potential (without any cost-effectiveness screen) along with levelized cost information in the form of bundled supply curves. The IRP model would then include EE as a DER in the optimization alongside other DERs as well as supply-side resources. The output of the analysis could be used to inform EE planning.

This technical analysis focuses almost entirely on the production of the supply curve largely because it was the untested approach. To this end, the supply curve in this technical analysis was conceived of as a "proof of concept" with the goal of testing the methodological and modeling feasibility. In that spirit, the supply curve was developed with certain simplifying assumptions and is not meant to set any precedent for how future supply curves must be carried out; rather, it provides an opportunity to better understand capabilities and limitations of such an approach. The remaining discussion in Section 2 below specifically focus on topics related to the development of supply curves that can be optimized by the RESOLVE model.

2.2 Calculating Levelized Costs for IRP

Calculating the levelized cost of conserved energy is an important step and allows the cost of conservation to be compared with other distributed energy and supply-side resources in the IRP. In this technical analysis, the bundled supply curves that were developed include both estimates of savings and costs. Levelized costs were used as the cost basis for sorting the supply curves. The levelized cost of energy (LCOE) is the discounted present value net cost of each measure over a 20-year planning horizon divided by the discounted present value of energy savings over the same period. Consistent with the potential study, net energy savings were using in this analysis.

Equation 1: Formula for Computing LCOE

$$Levelized\ Cost\ of\ Energy = \frac{PV\ of\ Costs}{PV\ of\ Net\ Energy\ Savings}$$

The costs include all cash flows considered in the Total Resource Cost screening test. These include incremental equipment costs, less any O&M Savings, plus any variable program costs The equipment costs include technology, installation and repair costs for "accelerated replacement" technologies. The equipment costs account for inflation on equipment and labor cost, projected cost reductions over time, and changes in incremental cost due to code baseline changes. The program costs include incentives awarded to free riders, administrative costs, marketing costs, implementation (customer service) costs, overhead, and EM&V costs. Information on sources for these costs can be found in the 2018 PG Study Report in section 3.1.4.[11]

[11] Navigant. *Energy Efficiency Potential and Goals Study for 2018 and Beyond.* September 2017

The present value in the levelized cost calculation is computed over a 20-year planning horizon[12]. For measures with lifetimes less than 20 years, a combination of a true cash flow approach and an annuitization approach was used to calculate the present values. For example, a measure with a 5-year lifetime can be installed exactly four times over a 20-year horizon, and the resulting cash and energy flows repeat exactly four times during the horizon. A measure with an 8-year lifetime can be installed twice during the horizon and receive credit for its full lifetime savings potential each time. To account for the remaining 4 years in the horizon, the costs and benefits over the full measure life are annuitized and assigned to each of the last 4 years. This ensures that the 8-year measure is not penalized with the full incremental costs when installed in year 17 while only being credited with the final 4 years of benefits.

The above calculation as implemented in the Potential Study model results in a levelized cost for each measure by service territory (e.g. PG&E), customer segment (e.g. Commercial-Office), and replacement type (e.g. Replace-on-Burnout). To create statewide supply curves for the IRP Navigant calculated an average levelized cost for each measure weighted by the number of installations that are projected to occur for each service territory, customer segment and replacement type. These measure-level costs were then aggregated further to create levelized costs for each of the supply curve bundles, as described in the next section.

2.3 Assigning Measures to Bundles

As described in Section 2.1.2, integrating EE into IRP via the supply curve approach requires that the measures identified as technically viable in the PG Study are aggregated into "bundles" and subsequently input into the IRP Model. The notion of creating EE supply curve bundles for IRP is to allow for measure-level results to be aggregated for resource planning purposes at an appropriate level of granularity that strikes a balance between capturing bottom-up result detail (e.g. savings and cost trends) and limiting the size of the bundles to keep IRP model run times manageable.

For the purpose of this analysis, bundles are defined as a group of EE measures with an associated levelized cost (weighted based on individual measure potential savings), potential savings, and a representative load profile (8760 format)[13]. This bundling approach was primarily selected to reduce the granularity of the data fed into the IRP model, and is not meant to set any precedent for future work that integrates EE into an IRP.[14] It is conceivable that a future IRP model may not need to bundle EE if it can handle more granular data for individual measures.

In aggregating measures into bundles for this technical analysis, Navigant focused on two considerations:

1) The relative affinity of measures in the same bundle to one another. For example, affinity of measures in a bundle might be determined by the sector/end use/cost level associated with a measure, the overall load impacts of the individual measures by bundle (i.e. 8760 load profile), and/or the likelihood that bundled measures might be included in the same utility program.

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[12] Consistent with the CPUC IRP model, Navigant used the after-tax weighted average cost of capital as the discount rate in this study.

[13] Further methodological discussion on load profiles can be found in Section 2.4.

[14] Based on feedback from E3, Navigant was advised to aggregate EE measures into no more than 30 bundles to allow the IRP model to run efficiently during testing. As such, the assigning of measures to bundles was carried out primarily to enable proof-of-concept testing.

2) How closely the supply curve generated from bundled measures aligns to a supply curve generated from the complete disaggregated population of measures defined by the Potential Study.

Navigant assured measure affinity within bundles by grouping by a measure's associated sector, end use, and/or cost. Other metrics of measure affinity, such as overall load impact and potential to be in the same utility program, are likely to be predicated on the measure's sector and end use and are thus captured by bundling measures this way. Four bundling approaches were considered based on this methodology and are summarized in **Error! Reference source not found.**.

Table 4: Stage 2 Bundling Approaches

Bundling Approach	Bundle Description[a]	Number of Bundles
Sector Level	Measures grouped into bundles according to associated sector	6
End Use Level	Measures grouped into bundles according to associated end-use	13
Sector | End Use Level	Measures grouped hierarchically based first upon sector and second upon end use	26
Sector | End Use | Cost Level	Measures grouped hierarchically based first upon sector, second upon end use, and third upon levelized cost	26[b]

a. Each bundle has an associated weighted cost, market potential, and an 8760 load profile
b. Some professional judgment is employed to limit bundle count

The sector/end use/cost level approach in Table 4 groups measures hierarchically based first upon sector, second upon end use, and third upon levelized cost. For bundling purposes, measures were defined as having a ***high*** levelized cost if the individual levelized cost of the measure was higher than the average cost of measures associated with that sector and end use. Conversely, measures were defined as having a ***low*** levelized cost if the measure had a lower than average levelized cost. After the measures were bundled by this method, some bundles that contributed relatively low potential energy savings were combined to limit the total number of bundles. Further detail on the recombination of bundles based on potential savings is provided in Table 5. Data is provided for the residential sector only in Table 5 to illustrate the method by which bundles were recombined for all sectors.

Table 5: Recombination Process for Sector/End Use/Cost Bundling Approach – Residential Sector

Sector | End Use | Levelized Cost Bundles	Market Potential Savings Share
Residential | HVAC | High	2.28%
Residential | HVAC | Low	11.20%
Residential | Lighting | High	2.33%
Residential | Lighting | Low	3.79%
Residential | Appliance Plug | High	0.54%
Residential | Appliance Plug | Low	6.63%
Residential | Whole Building | High	0.37%
Residential | Whole Building | Low	2.33%
Residential | Water Heat | High	0.05%
Residential | Water Heat | Low	0.37%
Residential | Building Envelope | High	0.26%
Residential | Building Envelope | Low	0.71%
Total Savings Share	30.9%

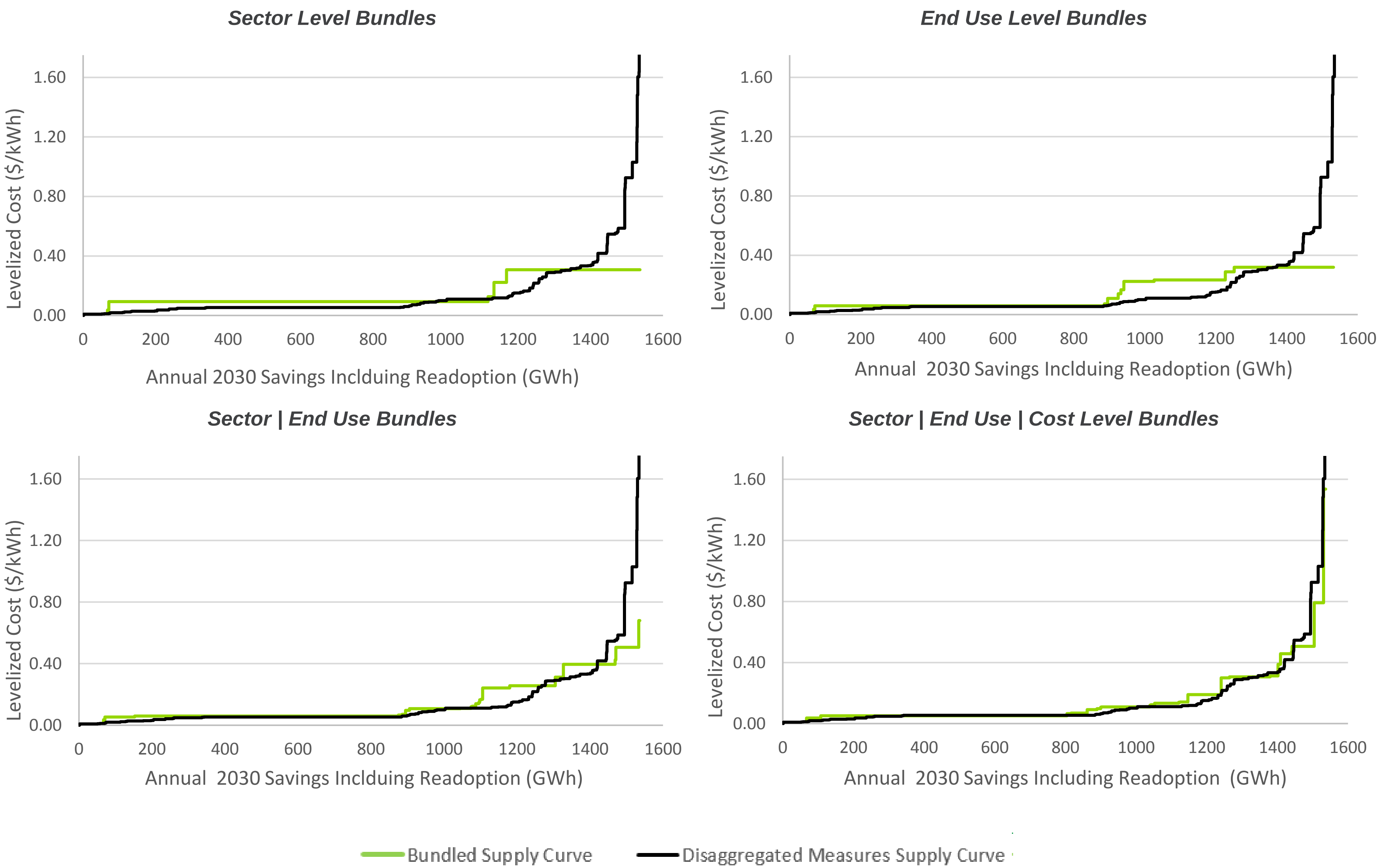
Sector | End Use | Levelized Cost Recombined Bundles	Market Potential Savings Share
Residential | HVAC | High	2.3%
Residential | HVAC | Low	11.2%
Residential | Lighting | High	2.3%
Residential | Lighting | Low	3.8%
Residential | Appliance Plug | High	0.5%
Residential | Appliance Plug | Low	6.6%
Residential | Whole Building	2.7%
Residential | Miscellaneous	1.4%
Total Savings Share	30.9%

To assess how well each bundling approach modeled complete disaggregation of measures, Navigant compared the supply curves generated from the different bundling approaches to a supply curve generated from the complete disaggregated population of measures defined by the Potential Study. This visual comparison is displayed via the four graphs in Figure 3. The following can be seen in the graphs:

- Sector Level Bundles (of which there are only 6 bundles) perform crudely in mimicking the disaggregated supply curve particularly in the tail end, high-cost part of the curve (above 1,100 GWh)
- End Use Level Bundles (of which there are 13 bundles) perform slightly better than sector level bundles in mimicking the disaggregated curve. It provides a better match on the low-cost side of the curve but still deviates considerably on the high-cost end.
- The Sector/End Use/Cost Bundles best follows the disaggregated supply curve. This bundling approach has 26 bundles total. The Sector/ End Use Bundles also contain 26 bundles but are grouped in a way that do not mimic the disaggregated curve as well.

The sector/end use/cost bundling approach most closely modeled disaggregation of measures while still maintaining affinity for measures bundled together relative to one another. For these reasons, Navigant used this bundling approach for integrating EE into IRP in this technical analysis.

Figure 3: Supply Curve of Bundling Approaches



2.4 Load Profile Development

The IRP model's ability to compare resources for energy capacity planning and needs is in part predicated upon understanding how each resource will affect overall system peak. To properly value system peak in a future where the peak time is expected to shift, Navigant provided a representative 8760 hourly load profile for each EE bundle as part of this technical analysis

For the purposes of this test load profiles were sourced from existing public information. The 2015 Additional Achievable Energy Efficiency (AAEE)[15] load profiles previously developed by Navigant were leveraged to provide representative load profiles for each EE bundle in in this technical analysis. The individual 2015 AAEE IOU load profiles were combined by end use and then mapped to each defined EE bundle. The mapping described is tabulated in Table 6.

Table 6: Load Profile Mapping

Stage 2 Bundles	2015 AAEE Mapped Load Profile [b]
Residential | HVAC | High	Residential HVAC
Residential | HVAC | Low	Residential HVAC
Residential | Lighting | High	Residential Lighting
Residential | Lighting | Low	Residential Lighting
Residential | Appliance Plug | High	Residential AppPlug
Residential | Appliance Plug | Low	Residential AppPlug
Residential | Whole Building	Residential WholeBlg
Residential | Miscellaneous	Residential WholeBlg
Commercial | HVAC | High	Commercial HVAC
Commercial | HVAC | Low	Commercial HVAC
Commercial | Lighting | High	Commercial Lighting
Commercial | Lighting | Low	Commercial Lighting
Commercial | Commercial Refrigeration | High	California Commercial End Use Survey [a]
Commercial | Commercial Refrigeration | Low	California Commercial End Use Survey [a]
Commercial | Whole Building | High	Commercial WholeBlg
Commercial | Whole Building | Low	Commercial WholeBlg
Commercial | Appliance Plug	Commercial WholeBlg
Commercial | Miscellaneous	Commercial WholeBlg
Agricultural | Machine Drives	Agricultural MachDr
Agricultural | Lighting	Industrial Lighting
Agricultural | Low Market Potential Savings	Average of Agricultural Profiles

[15] Wikler, G., Sathe, A., Oztreves, S., and Menon, C. Memo to Jaske, M., Kavalec C., California Energy Commission. *Energy Efficiency Potential and Goals Study: Additional Achievable Energy Efficiency Load Shape Analysis.* 29 January 2016

Stage 2 Bundles	2015 AAEE Mapped Load Profile [b]
Industrial | Lighting	Industrial Lighting
Industrial | Machine Drives	Industrial MachDr
Industrial | Miscellaneous	Average of Industrial Profiles
Mining	Mining OilGasExtract
Street Lighting	Street Lighting Stl

a. No relevant profile for Commercial Refrigeration is available in the 2015 AAEE Load Profile Study. As such, this profile is sourced from the CEC's California Commercial End Use Survey [16].
b. The load profiles given by IOU in the 2015 AAEE Load Profiles are averaged together (weighted by IOU territory consumption) to obtain the listed representative load profiles.

2.5 Data Aggregation and Extraction from Potential Study Model

To create the sector/end-use/cost bundles for testing purposes, Navigant first leveraged the PG Model to export measure-level savings and levelized cost information to a spreadsheet. The measure-level results were then aggregated as a post-processing step into the bundles per the approach summarized in section 2.3 above. The savings and cost information along with 8760 hourly load profiles were then input into an IRP spreadsheet template provided by the E3, as summarized in Table 7 below[17].

Table 7: Summary of Input Data Provided to IRP Model

Data Type	Units	Description	Time Horizon
Cumulative Savings	GWh	Year-over-year sustained savings based on installations in prior years starting in 2018, accounting for dual baseline savings, decay, and re-installations	2018-2030
Annual Savings Limit	GWh	Annual first-year savings from installations of equipment based on stock turnover. Unlike the potential study, where annual savings are only reported for first-time upgrades to set goals, the annual savings used in this analysis include savings from re-installations. This is because the IRP model uses annual savings to limit the amount of cumulative EE deployment, which includes re-installations, over time.	2018-2030
Levelized Cost	$/kWh	Discounted present value net cost of each bundle over a 20-year planning horizon divided by the discounted present value of energy savings over the same period	2018-2030
8760 Load Profiles	Fraction	Normalized 2013 calendar year hourly load profiles for each bundle	2013

[16] Pigeon-Bergmann, Peg A. California Commercial End-Use Survey.

[17] For Stage 2, Navigant provided both cumulative and annual savings values for each of the 26 sector/end-use/cost bundles to the CPUC IRP team. This is to ensure that cumulative savings in the IRP model can be used to set a target value (in 2030) while using the annual savings values as a year-over-year limit of how much EE can be procured.

2.6 Iteration with IRP Model

As part of the technical analysis, the Navigant team iterated with the CPUC IRP team in the vetting of the methodology and results documented in this report. At the beginning of the analysis, feedback was solicited from the broader CPUC IRP team, including the IRP modeling team, on the appropriate size and composition of the supply curve bundles. After Navigant constructed the bundled EE supply curves for this technical analysis, they were handed off to the CPUC IRP modeling team for testing purposes. Based on the results of the IRP model runs, Navigant collaborated with the CPUC IRP team in the vetting and interpretation of the preliminary IRP model results, which are discussed in Section 3 below.

3. PRELIMINARY RESULTS

This chapter presents preliminary test results of integrating EE into the RESOLVE model. Per the scope of the analysis described in Section 1.2, this study focused on the bundled supply curve approach (Stage 2) as it is an untested method in California.

The RESOLVE model was run for three scenarios as described in the E3 Report.[18] The model runs and produces results every four years from 2018 through 2030. The outputs are in the format of cumulative energy savings in each four-year time step for each scenario. Table 8 indicates the cumulative savings from each bundle in each scenario as copied from the E3 Report. In this section, references to "optimal" imply the REVOLVE model deemed a bundle to be the optimal supply resource when compared to other possible resources at that point in the forecast. Navigant notes several observations from Table 8:

- Bundles that are deemed optimal in all years produce the same results regardless of scenario. For example: see the *Streetlighting Sector*.
- Bundles that are initially optimal but become non-optimal in later years cap and hold their cumulative savings for the remainder of the forecast based on the last cost-effective year. For example: *Commercial - Refrigeration – Low* in the Default scenario is not selected by the model in 2026 and 2030, thus maintaining its 2022 cumulative savings level. The RESOLVE model assumed no decay of EE savings in this case.
- Bundles that are initially not optimal but become optimal in later years do not begin cumulating savings until the year they become optimal. For example: *Residential - Lighting - High* in the Default scenario is not selected in 2026 or prior while in the other two scenarios it is selected in 2026. As a result, the Default scenario shows lower cumulative savings for this bundle in 2030 when compared to the other two scenarios. When calculating cumulative savings for these bundles, the RESOLVE model simply sums annual savings over the years for which the bundle is selected assuming no decay of EE savings.

[18] E3. *Optimizing Energy Efficiency Investments Using the RESOLVE Model*, September 2018

Table 8: Preliminary Cumulative Savings Results by IRP Scenario

	Default (50% RPS, 51 MMT)				42 MMT				30 MMT			
Bundle Name	2018	2022	2026	2030	2018	2022	2026	2030	2018	2022	2026	2030
Streetlighting Sector	43	238	469	728	43	238	469	728	43	238	469	728
Residential - Lighting - Low	14	98	246	401	14	98	246	401	14	98	246	401
Mining Sector	7	27	45	59	7	27	45	59	7	27	45	59
Commercial - Lighting - Low	114	884	2,407	4,876	114	884	2,407	4,876	114	884	2,407	4,876
Agricultural - Miscellaneous	19	105	174	214	19	105	174	214	19	105	174	214
Residential - Lighting - High	-	-	-	196	-	-	213	409	-	-	213	409
Commercial - Whole Building - Low	7	7	7	16	7	7	7	16	7	7	16	16
Commercial - Refrigeration - Low	64	309	309	309	64	309	421	501	64	309	421	501
Commercial - Appliance Plug	-	-	-	-	-	-	38	90	-	-	38	90
Agriculture - Lighting	-	-	-	-	-	46	46	46	-	46	46	46
Commercial - Whole Building - High	-	-	-	-	-	-	438	960	56	335	773	1,295
Industrial - Machine Drives	73	219	219	219	73	219	219	219	73	219	219	219
Industrial - Lighting	-	-	-	-	-	243	243	243	-	243	243	243
Residential - Appliance Plug - Low	113	113	113	113	113	421	421	421	113	421	568	698
Industrial - Miscellaneous	-	-	-	-	-	-	-	-	-	20	60	60
Commercial - Miscellaneous	-	-	-	-	-	-	-	-	-	-	-	93
Commercial - HVAC - Low	-	-	-	-	-	-	-	-	-	-	-	-
Commercial - Lighting - High	-	-	-	-	-	-	-	-	-	-	-	-
Residential - HVAC - Low	-	-	-	-	-	-	-	-	-	-	-	-
Agriculture - Machine Drives	-	-	-	-	-	-	-	-	-	-	-	-
Residential - Miscellaneous	-	-	-	-	-	-	-	-	-	-	-	-
Commercial - HVAC - High	-	-	-	-	-	-	-	-	-	-	-	-
Commercial - Refrigeration - High	-	-	-	-	-	-	-	-	-	61	61	61
Residential - Whole Building	-	-	-	-	-	-	-	-	-	-	-	-
Residential - HVAC - High	-	-	-	-	-	-	-	-	-	-	-	-
Residential - Appliance Plug - High	-	-	-	-	-	-	-	-	-	-	-	-
Total	**454**	**2,002**	**3,990**	**7,131**	**454**	**2,599**	**5,388**	**9,183**	**509**	**3,014**	**5,997**	**10,008**

Source: E3. Optimizing Energy Efficiency Investments Using the RESOLVE Model, September 2018

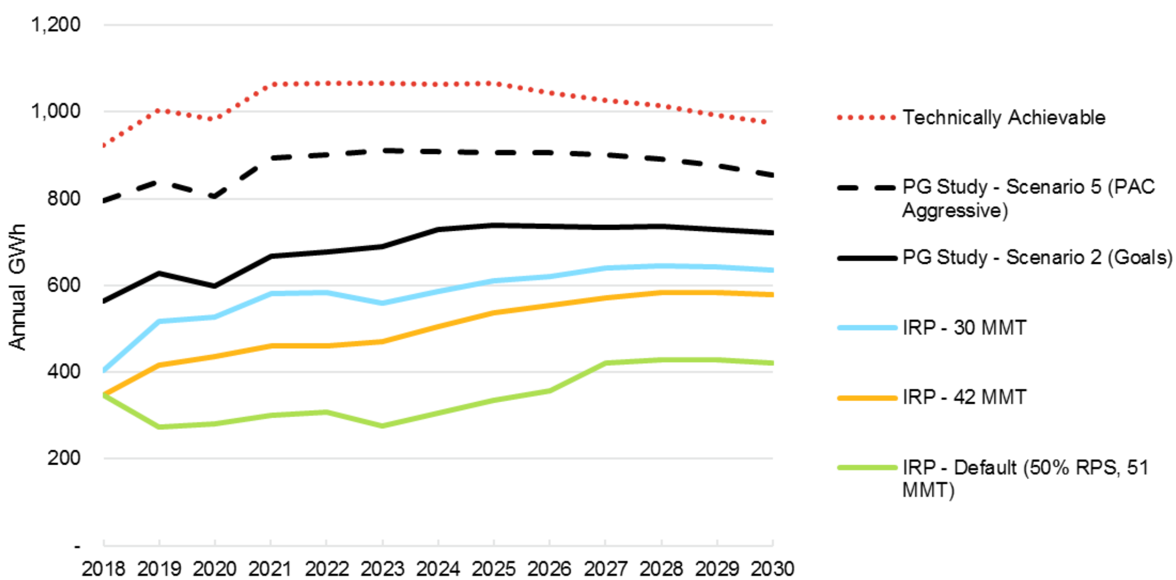
Historically, the PG Study has produced incremental potential results on an annual time step to inform the CPUC's goal setting process. Navigant translated the cumulative results from the IRP model to annual potential value to be able to compare the RESOLVE model results to the 2018 PG Study. This was accomplished by referencing the appropriate annual potential values for each bundle selected. Two issues needed to be addressed in this translation

1. **Format of Annual Savings.** As described in Table 7 the RESOLVE model required annual savings that included first time adoptions plus re-adoptions. However, goals are based just on first time adoptions. Thus, Navigant needed to remove re-adopters from annual savings for the purposes of translating results to a similar format that is used in the goal setting process.
2. **Bundles being selected (or "de-selected") mid-forecast.** When RESOLVE picks a bundle as optimal for a portion of the forecast but not the entire forecast period, Navigant needed to determine what year the bundle is assumed to become optimal. An analysis of RESOLVE results indicates the following cases:
    - If a bundle is selected in 2018 but not in 2022 or any later years, the bundle only provides annual savings in 2018 and no additional savings in years beyond.

- If a bundle is selected in as optimal in a time step (t) but not the previous time step (t - 4), the bundle begins to provide savings in the year (t - 3). This is to say, if a bundle is not optimal in 2022 but is optimal in 2026, annual savings begin accruing in 2023.

Conducting this translation allowed Navigant to compare the results of the three RESOLVE scenarios to the 2018 PG Study, illustrated below in Figure 4. Note that in Figure 4, results from the PG Study exclude BROs, C&S, Low Income, and Industrial and Agriculture Custom and Emerging Technologies. The results of all three RESOLVE scenarios shows less savings than the 2018 PG Study Scenario 2 (which was used to inform goals). The technically achievable potential (savings from all bundles combined in the supply curve) show there is still more savings that could be tapped beyond the most aggressive scenario from the 2018 PG Study (Scenario 5) if the marginal cost of energy in the IRP is high enough.

Figure 4: 2018 – 2030 Annual Savings Comparison



When comparing savings at the sector and end use level, we observe the RESOLVE model picks a “diversity” of savings across all sectors. Figure 5 illustrates annual savings by sector in 2018 while Figure 7 illustrates cumulative savings by sector in 2030. Both figures compare the PG Study results (Scenario 2 which was used to inform goals) to the three RESOLVE scenarios. These figures show all sectors are represented in all scenario results. In 2018, RESOLVE picks slightly more Residential savings that was in goals and significantly less commercial savings. Looking at cumulative savings in 2030, Commercial savings dominated the PG study result and this trend is reflected in the RESOLVE outputs as well.

Figure 5: 2018 Annual Savings Comparison by Sector

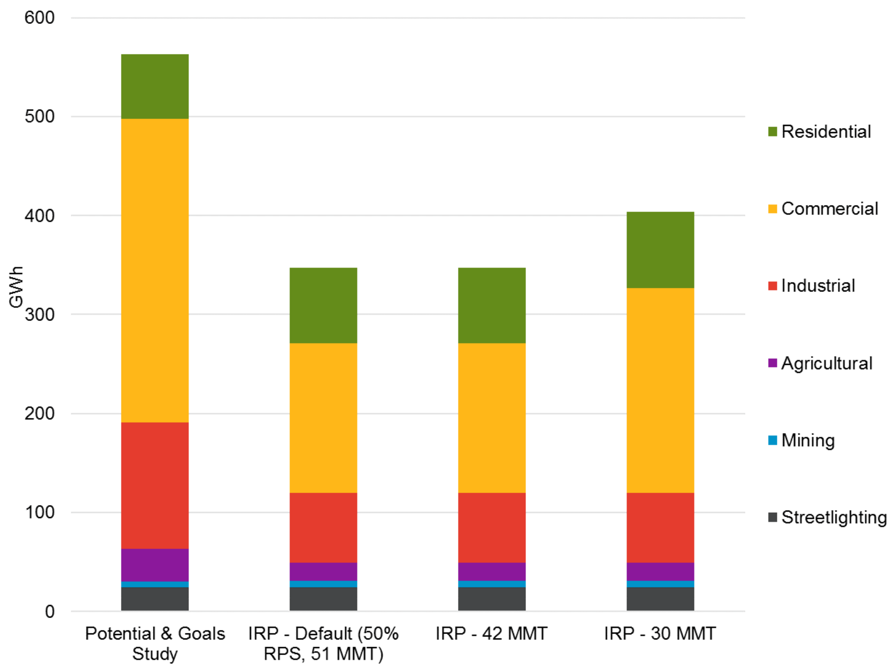


Figure 6: 2030 Annual Savings Comparison by Sector

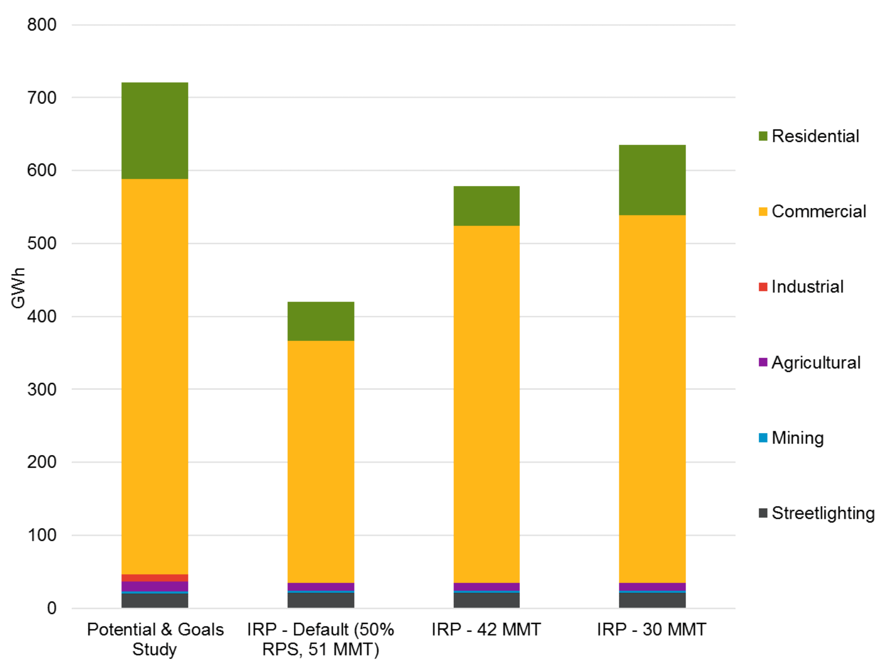
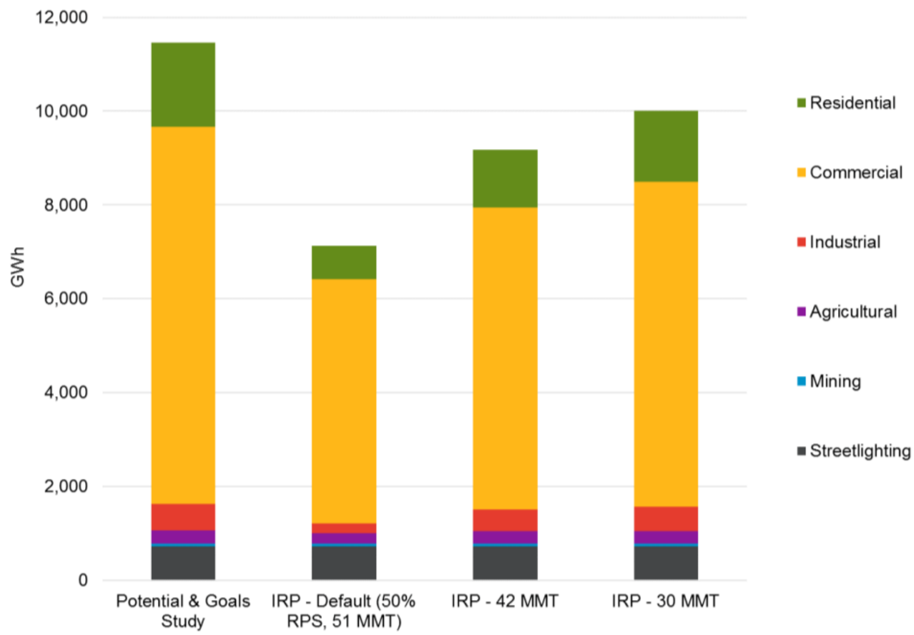


Figure 7: 2030 Cumulative Savings Comparison by Sector



When diving deeper into end uses within each sector, we start to observe differences between the PG Study and the RESOLVE scenario results. Figure 8 illustrates annual savings by sector in 2018 while Figure 10 illustrates cumulative savings by sector in 2030. Both figures compare the PG Study results (Scenario 2 which was used to inform goals) to the three RESOLVE scenarios. The following sectors and end uses are present in the 2018 PG study at non-trivial amounts of savings but are not represented in all the RESOLVE scenarios: Commercial HVAC, Commercial Appliance/Plug Loads, Industrial Lighting, Residential Whole Building, and Agricultural Lighting.

Figure 8: 2018 Annual Savings Comparison by Sector and End Use

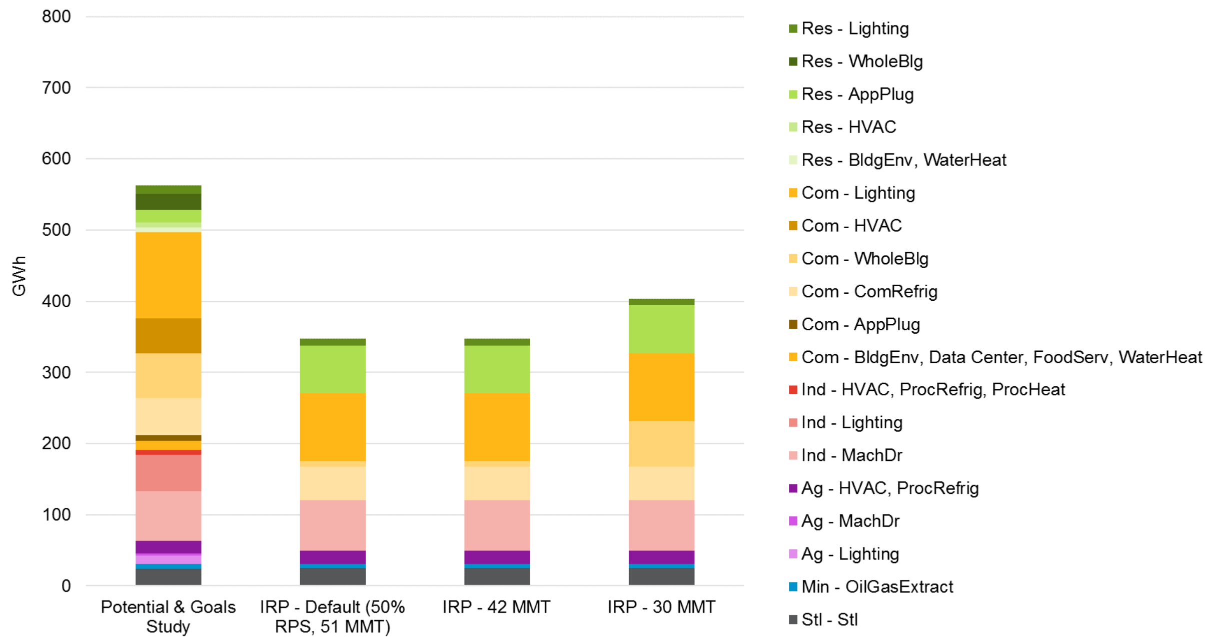


Figure 9: 2030 Annual Savings Comparison by Sector and End Use

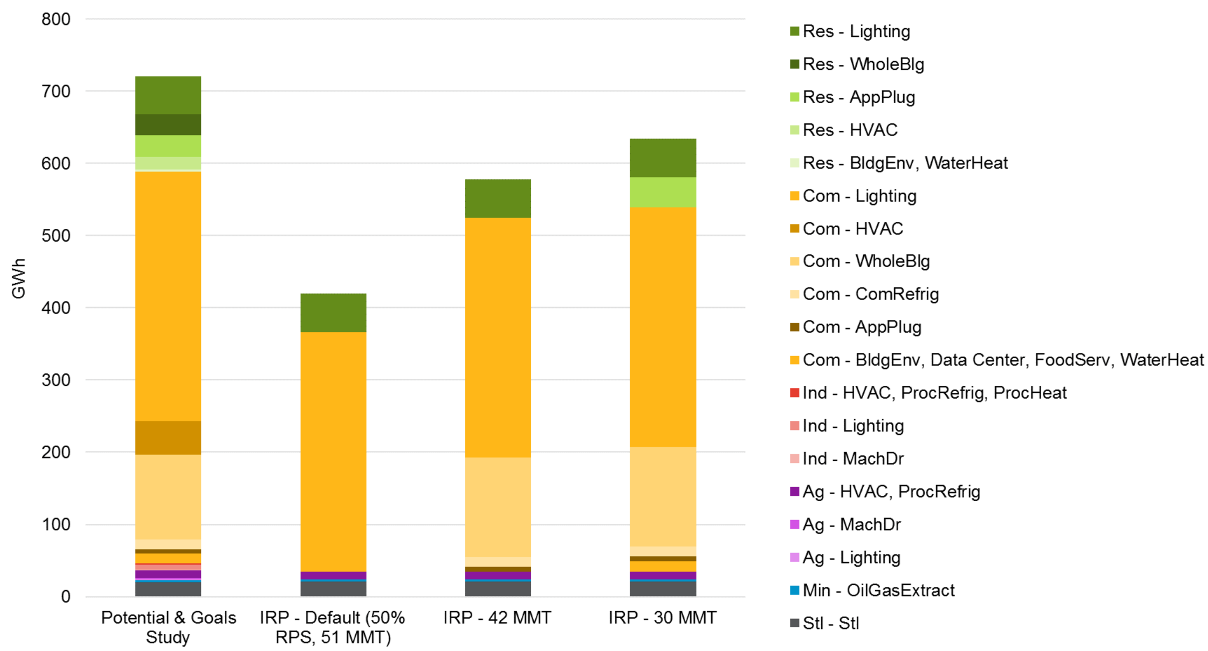
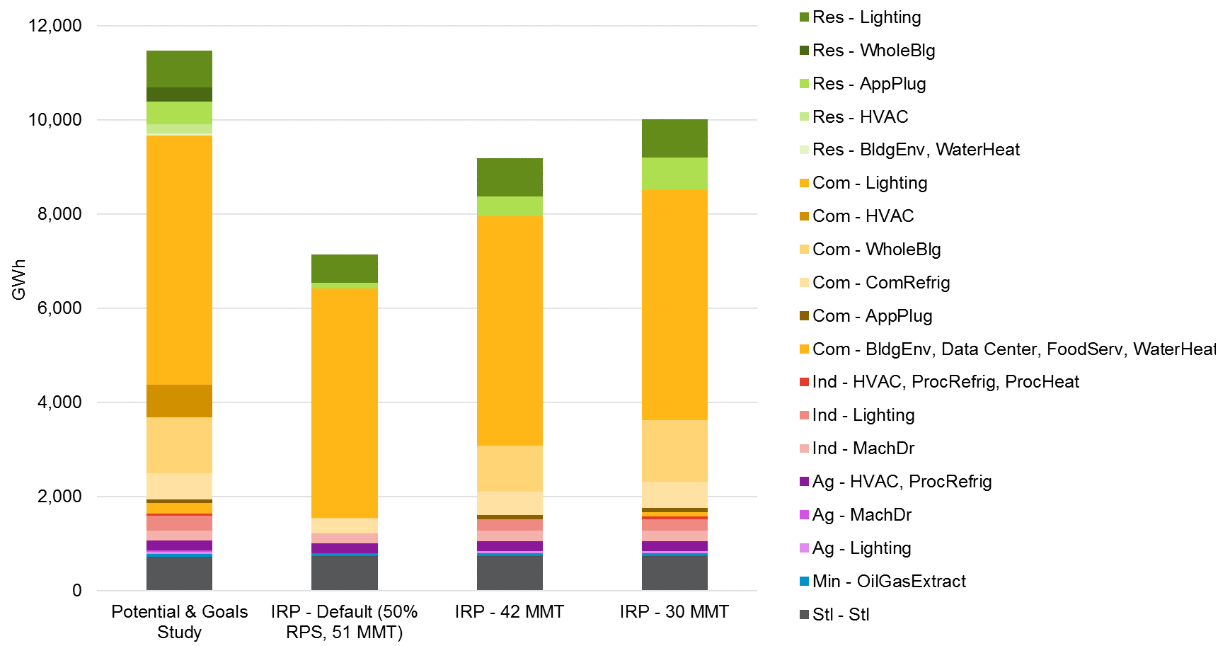
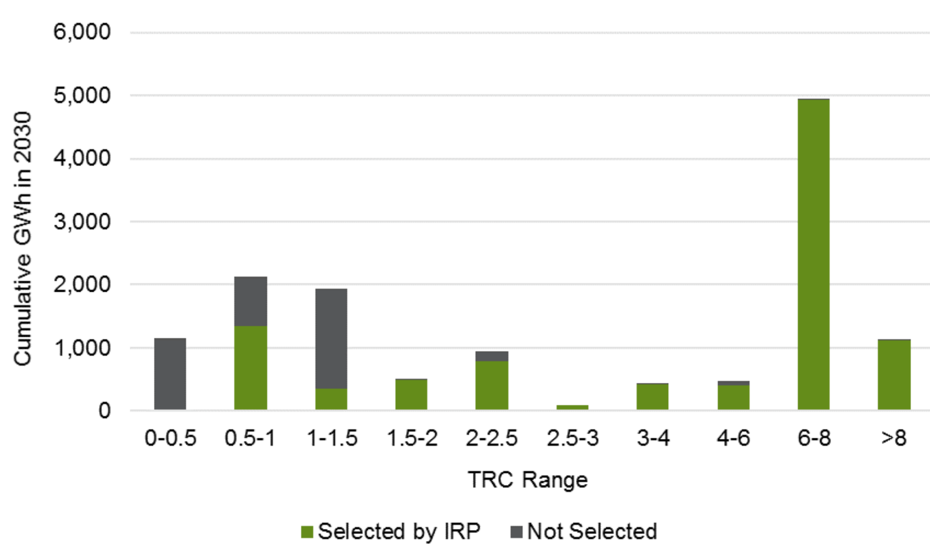


Figure 10: 2030 Cumulative Savings Comparison by Sector and End Use



To further explore how the REVOLVE model results and the PG study results differ, Navigant examined the relationship of each bundle's TRC and its selection status by the RESOLVE model. Figure 11 below illustrates plots the Technically Achievable potential from all bundles. The figure places savings from each bundle into a TRC range and further indicates the portion of savings within the TRC range that was select the RESOLVE model under the 30 MMT Scenario. Almost all of the Technically Achievable at high TRC is selected by the RESOLVE Model (above TRC 2.5 all bundles are selected except a small portion of savings in the TRC 4-6 range). Technically Achievable potential below a TRC of 0.5 are not selected.

Figure 11: Portion of Technically Achievable Savings Selected by the 30 MMT Scenario



This implies that the IRP optimization process values the benefits of EE slightly different than the TRC equation does. Indeed, highly cost-effective measures are generally selected, and highly non-cost-effective measures are not selected. However, in the middle ground (0.5 < TRC < 1.5) it's evident that the avoided costs used in the TRC test place a different value on EE than the RESOLVE model does. Bundles that have TRC < 1 that were selected include: Commercial - Refrigeration – High and Commercial - Whole Building – Low. Meanwhile Bundles that have TRC > 1 and were not selected include: Commercial - HVAC – Low, Residential – Miscellaneous, and Residential - Whole Building.

4. OBSERVATIONS AND CONCLUSIONS

4.1 Observations and Conclusions

During the conduct of this technical analysis, Navigant developed the following observations and conclusions for consideration in future analysis.

Ideal Characteristics of an IRP Model to Enable EE integration.
The current IRP model was not built with the original intent to incorporate EE as a supply side option. An ideal future IRP model would be able to report results for individual load serving entities. It would also report results on an annual time step to be able to inform the EE goal setting process (which set goals on an annual basis). An IRP model should also be able to accurately model decay of EE resources. The current IRP model does not allow for supply side resource to retire, once they come online they are fixed in place. However, EE as a resource can decay over time as measures reach the end of their useful lives and are not reinstalled. If decay is not properly accounted for in an IRP model, it can lead to an overstatement of EE savings and under-procurement of other resources.

Revisit Tradeoffs in Measure Bundling.
In this technical analysis, measures were bundled to streamline the input data provided to the IRP model. A future IRP model may or may not be constrained by these inputs. Regardless, Navigant observes that bundling measures may have merit. Bundling measures together inherently allows some highly cost-effective measures to subsidize those with low cost effectiveness (a dynamic that currently happens in IOU programs). However, excessive bundling (with low granularity or very large bundles) may reduce resolution too much that the real "tipping point" of what amount of EE is optimal is lost. On the other hand, modeling measures individually in the IRP ensures only those optimal measures are selected, but lost is the ability to subsidize the early years of market transformation programs/technologies with higher cost-effective programs/technologies. This technical analysis bundled measures based primarily on sector and end-use affinities. Other IRPs (like that used by the Northwest Power and Conservation Council) bundle measures purely based on cost, an alternative to consider in the future.[19]

Accounting for Natural Gas EE Technologies.
The current IRP model only examines electricity. Thus, only electric efficiency resources are optimized. IOU goals include both electric and gas savings and have historically been modeled in one platform. Modeling electric and gas savings in the same platform offers two advantages over using separate models: 1) the ability to account for interactive effects and dual-fuel saving measures (such as insulation) and 2) the ability to model fuel substitution (i.e. switching between electric and gas appliances) by tracking the stock dynamics of both electric and gas appliances together.

If two separate models are used, building shell measures that save both gas and electric would have to solely reside within one or the other model so that adoption forecasts are conducted consistently and not double counted. Furthermore, the model would need to be capable of valuing the benefits and customer economics of both fuel savings. Savings from one model would then need to be added to the other model. Optimizing the EE procurement for one fuel (for example electric) would necessarily impact the EE procurement of the other fuel. Interdependencies between the two models would not be impossible to track, but would be tedious and more error-prone than using a single platform.

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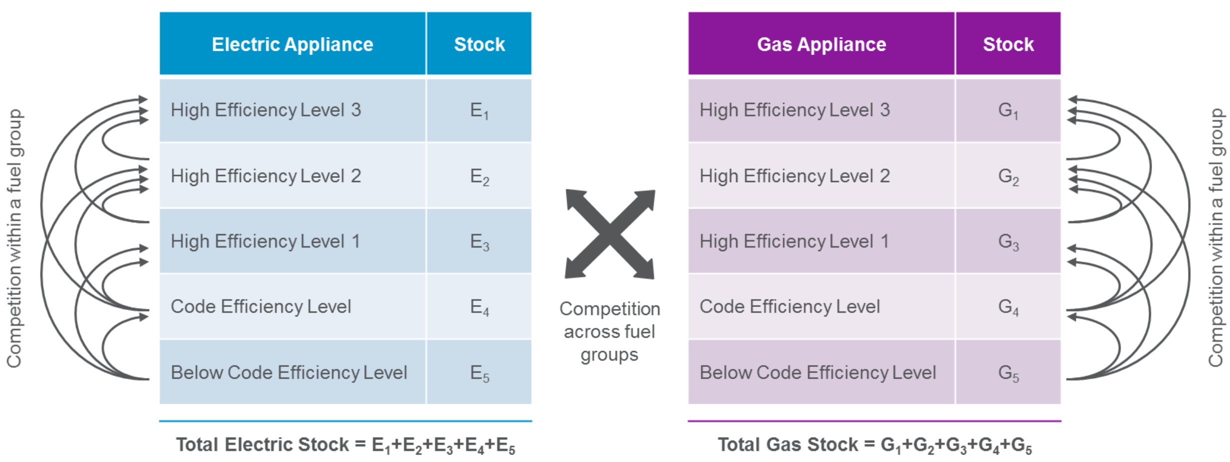
[19] NPCC. *Seventh Northwest Conservation and Electric Power Plan – Chapter 12*. February 2016. https://www.nwcouncil.org/media/7149926/7thplanfinal_chap12_conservationres.pdf

Splitting the electric and gas models causes much larger complications when trying to examine fuel substitution measures. The 2018 PG Model does not include fuel substitution. However, it does contain technologies that are both gas and electric powered that meet the same end use need (for example: residential gas and electric water heaters). When modeling such measures, the 2018 PG Study completes technologies within each fuel type against each other and tracks the stock of appliances at each efficiency level. This is illustrated in Figure 12 by the labels “Competition within a fuel group”. Although the distribution of stock across each efficiency level can vary over time, the total stock stays the same (aside from expected growth in population). The introduction of fuel substitution in the model would allow cross competition between the groups competing all fuels and efficiency levels against each other (i.e. all 10 appliances in Figure 12 compete against each other). In this situation, the total stock for one fuel type may grow faster than the rate of population growth at the expense of the total stock of the other fuel type. This dynamic between stock of each fuel type must be modeled within a single platform for accounting purposes. Furthermore, a joint gas/electric model is more streamlined to simulate the consumer decision process of fuel substitution.

Figure 12: Technology Competition and Fuel Substitution



As policymakers grapple with achieving carbon reduction goals, a combined gas/electric potential model feeding into an IRP model would be a useful tool to assess various fuel switching scenarios.

Integrating Updated Load Shapes

Testing in the current IRP model reveled load shape “had a more pronounced impact on the value of a bundle as the GHG emissions target became more stringent. Bundles that reduced demand at night became more valuable because solar resources cannot serve load during nighttime hours without storage.”[20] This value is compared to levelized cost in the optimization process. Having accurate load shapes matter especially in an expected future where net system peak is expected to move to later hours in the day. The next IRP model and EE potential study should leverage current efforts by the CEC to develop new California-specific electricity load shapes. The project is contracted to be completed by March 2018, no public information exists on if this timeline is still accurate.[21] This study would represent the latest comprehensive assessment of load shapes in California, and would presumably be consistent

[20] E3. *Optimizing Energy Efficiency Investments Using the RESOLVE Model*. September 2018.

[21] Additional information available at: http://innovation.energy.ca.gov/SearchResultProject.aspx?p=31147&tks=636523229983436968

with what CEC uses for demand forecasting. Current load shapes used the PG Study and IRP are sourced from DEER (load shape data vintage is over 5 years old) or estimated from other sources.

Align Treatment of Resource Costs
The next IRP and EE studies should consider a deeper dive on cost inputs. Specifically, analysis should ensure that the costs of EE resources are be accounted for appropriately compared to other DERs and supply side resources in the IRP. In this technical analysis, not enough time and resources were available to fully explore and document this. When developing levelized cost for EE supply curves, Navigant included all cost components used in the TRC test. Non-incentive costs included the costs of EE non-resource programs. Non-resource programs in this situation act to "burden" the levelized cost of EE resource programs. Navigant was unable to ascertain if the levelized costs for other DERs and supply side resources included similar categories of costs as the EE programs uses. A mismatch or discrepancy in treatment of costs across DERs will harm the ability of future IRP models to equally treat DERs and supply side resources in the optimization process.

4.2 Caveats

We note the following caveats of this Technical Analysis

- This analysis produces preliminary results. This does not constitute a restatement of market potential or goals published in the 2018 PG study and CPUC Decision D-17-09-025
- BROs savings were not included due to lack of reliable cost data for the universe of BROs interventions. However, Navigant believes BROs should be included in IRP optimization pending better data. BROs savings can and should be treated as an optimizable supply side resource.
- Custom programs were not included in the optimization as they lacked proper data in the PG study for translation into the IRP data needs. We believe sufficient data exists on Custom programs to include them in the optimization if future PG and IRP studies re-process raw data from Custom Programs.
- While preliminary scenarios presented for Stage 1 primarily focus on cost effectiveness tests from the 2018 PG study, this proof of concept analysis primarily to explore if a scenario/portfolio approach can work for IRP. The same cost effectiveness tests used in the 2018 PG study may not the same that are considered in the future.

APPENDIX A. GLOSSARY

- BROs – Behavior, Retrocommissioning and Operational Efficiency
- DER – Distributed Energy Resource
- EE – Energy Efficiency
- EUL – Effective Useful Life
- IRP – Integrated Resource Plan
- TRC – Total Resource Cost Test
- Baseline energy consumption – the forecasted business as usual energy consumption for California as developed by the California Energy Commission
- Bundle – the grouping of measures into higher levels of aggregation based on common attributes
- Decay – the reduction in cumulative market potential that occurs when an energy efficient measures reaches the end of its useful life and is assumed to revert to the code baseline
- Levelized Cost - the discounted present value net cost of a measure over the IRP planning horizon divided by the discounted present value of energy savings over the same period
- Load Modifying Resource – a resource that acts to reduce baseline energy consumption and is not part of the IRP optimization process
- Load Shape – a technologies hourly profile over an entire year of its energy consumption; load profiles in this study are expressed as a normalized profile over 8760 hours of the year
- Planning Horizon – the period over which financial obligations for an energy resource are calculated
- Rebated Equipment – energy efficiency technologies that can be incentivized by IOUs. These do not include codes and standards, BROs, or low-income programs
- Reparticipation – the installation of high efficiency equipment which replaces an equally high efficiency piece of equipment at the end of its useful life
- Supply Curve - a graph of energy savings technically achievable for a set of bundles and their respective levelized costs

APPENDIX B. BUNDLE DETAILS

Table B.1: Final Sector | End Use | Levelized Cost Bundle Data

Sector | End Use | Levelized Cost	2030 Cumulative Savings (GWh) [a]	2030 Levelized Cost ($/kWh) [b]	2030 mTRC GH Adder #1 [c]
Agricultural | Lighting	45.9	$ 0.11	1.3
Agricultural | Machine Drives	149.6	$ 0.31	0.7
Agricultural | Miscellaneous	213.9	$ 0.07	3.2
Commercial | Appliance Plug	90.2	$ 0.10	2.6
Commercial | HVAC | High	183.2	$ 0.46	0.3
Commercial | HVAC | Low	926.3	$ 0.19	1.2
Commercial | Lighting | High	624.7	$ 0.30	0.8
Commercial | Lighting | Low	4876.2	$ 0.05	7.3
Commercial | Miscellaneous	244.6	$ 0.14	2.0
Commercial | Refrigeration | High	60.6	$ 0.47	0.5
Commercial | Refrigeration | Low	500.7	$ 0.09	1.8
Commercial | Whole Building | High	1295.0	$ 0.11	1.0
Commercial | Whole Building | Low	15.6	-	-
Industrial | Lighting	243.2	$ 0.12	1.0
Industrial | Machine Drives	219.2	$ 0.12	3.5
Industrial | Miscellaneous	59.6	$ 0.14	1.1
Mining Sector	58.9	$ 0.04	7.0
Residential | Appliance Plug | High	68.2	$ 1.54	0.1
Residential | Appliance Plug | Low	698.1	$ 0.13	2.1
Residential | HVAC | High	74.2	$ 0.79	0.1
Residential | HVAC | Low	822.2	$ 0.31	0.5
Residential | Lighting | High	484.9	$ 0.07	5.4
Residential | Lighting | Low	401.0	$ 0.04	8.2
Residential | Miscellaneous	138.8	$ 0.39	1.0
Residential | Whole Building	517.7	$ 0.51	1.4
Streetlighting Sector	727.7	$ 0.01	13.5

a. Savings are aggregated to a bundle level as a sum total of constituent measure savings.
b. Levelized Costs are aggregated to a bundle level using a weighted average based on constituent measure savings.
c. The modified *2018 Potential and Goals Study* Total Resource Cost (mTRC) test ratios are aggregated to a bundle level using a weighted average based on the constituent measure level mTRC test ratios.

Table B.2: Constituent Measures by Bundle

Sector | End Use | Levelized Cost Bundle	Measure
Agriculture | Lighting	Ag | Exterior Lighting - Upgrades Ag | Lighting Controls - Upgrades Ag | Interior Lighting Upgrades - LED Ag | Interior Lighting Upgrades - Non-LED Ag | LED Interior Hort. Grow Lights
Agriculture | Machine Drives	Ag | VFD addition to Ag Pumps (Non-Irrigation or Dairy) Ag | Efficient Ag Irrigation Pumps Ag | VFD addition to standard Ag Irrigation Pumps Ag | Efficient Ag Pumps (non-Irrigation) Ag | VFD addition to Ag Dairy Pumps Ag | Low Pressure Irrigation
Agriculture | Miscellaneous	Ag | Dairy Process Refrigeration Efficient Retrofits Ag | HVAC Ventilation (Fan Ventilation Improvement) - Post-Harvesting Process Ag | HVAC Ventilation (Fan Ventilation Improvement) - Other Ag Ag | HVAC Ventilation (Fan Ventilation Improvement) - Dairies
Commercial | Appliance Plug	Com | ENERGY STAR Television Com | ENERGY STAR Refrigerator (Residential Size) Com | PC Power Management Com | Vending Machine Controls Com | Advanced Power Strip Com | ENERGY STAR Freezer Com | Zero & Thin Client - PC Virtualization Com | Variable Speed Pool Pump Com | Electric Clothes Dryer - High Efficiency Com | Efficient Clothes Washer - Tier 1 - 2.2 IMEF Com | Efficient Clothes Washer - Tier 2 - 2.4 IMEF Com | Efficient Clothes Washer - Tier 3 - 2.92 IMEF

Sector | End Use | Levelized Cost Bundle	Measure
Commercial | HVAC | High	Com | HVAC Motor - PSC
	Com | HVAC Motor - ECM
	Com | Variable Air Volume (VAV) Air Dist. System (Elec SC and Gas SH)
	Com | Dedicated Outdoor Air System (DOAS)
	Com | HVAC Pump Variable Frequency Drive (VFD)
	Com | Code Compliant Chiller
	Com | Split System HP - Air Source (SEER 13)
	Com | Packaged RTU HP - Air Source (EER 10.3)
	Com | Packaged RTU AC (IEER 11.8)
	Com | Split System AC (SEER 13)
	Com | Variable Refrigerant Flow (VRF) Heat Pump
	Com | Water Source Heat Pump (EER 15)
	Com | Demand Controlled Ventilation (HVAC)

Sector | End Use | Levelized Cost Bundle	Measure
Commercial | HVAC | Low	Com | HVAC Quality Maintenance (Elec SH)
	Com | Programmable Thermostat (Elec SC and Gas SH)
	Com | Smart Thermostat (Elec SC and Gas SH)
	Com | Duct Insulation (R6 - Elec SC and Gas SH)
	Com | Duct Insulation (R8 - Elec SC and Gas SH)
	Com | Efficient Chiller
	Com | Split System HP - Air Source (SEER 14)
	Com | Split System HP - Air Source (SEER 16)
	Com | Split System HP - Air Source (SEER 18)
	Com | Split System HP - Air Source (SEER 22)
	Com | Packaged RTU HP - Air Source (IEER 11.4)
	Com | Packaged RTU HP - Air Source (IEER 13.3)
	Com | Packaged RTU HP - Air Source (IEER 15)
	Com | Packaged RTU HP - Air Source (IEER 16.5)
	Com | Packaged RTU AC (IEER 12.2)
	Com | Packaged RTU AC (IEER 14.0)
	Com | Packaged RTU AC (IEER 15.5)
	Com | Packaged RTU AC (IEER 17.0)
	Com | Split System AC (SEER 14)
	Com | Split System AC (SEER 16)
	Com | Split System AC (SEER 18)
	Com | Split System AC (SEER 22)
	Com | Ductless Mini Split Heat Pump (SEER 13)
	Com | Ductless Mini Split Heat Pump (SEER 14)
	Com | Ductless Mini Split Heat Pump (SEER 16)
	Com | Ductless Mini Split Heat Pump (SEER 18)
	Com | Ductless Mini Split Heat Pump (SEER 21)
	Com | Geothermal Heat Pump
	Com | Economizer
	Com | Packaged Terminal Air Conditioner (PTAC- EER 10.4)
	Com | Packaged Terminal Air Conditioner (PTAC- EER 11.5)
	Com | PTAC Controls Upgrade
Commercial | Lighting | High	Com | CFL Fixture w/ Integrated Occupancy Controls (Indoor - 36Wlamp)
	Com | Low Bay, Standard T8 Fixture (2 Lamp - 59W - Fixture)
	Com | Low Bay, Premium T8 Fixture (2 Lamp - 51W - Fixture)
	Com | Low Bay, Std. Output T5 Fixture (2 Lamp - 54W - Fixture)
	Com | Bi-Level Stairway Lighting

Sector | End Use | Levelized Cost Bundle	Measure
Commercial | Lighting | Low	Com | LED Fixture (Indoor - 24W)
	Com | LED Lamp (Basic Low - 11W - Indoor)
	Com | LED Lamp (Basic High - 24W - Indoor)
	Com | LED Lamp (Reflector - 12W - Indoor)
	Com | LED Lamp (Specialty Low - 8W - Indoor)
	Com | LED Lamp (Specialty High - 18W - Indoor)
	Com | LED Fixture (Outdoor - 20W)
	Com | Low Bay, LED Troffer
	Com | High Bay, PSMH 320w(Indoor - 365W - Fixture)
	Com | High Bay, T8 Fixture (Indoor - 302W - Fixture)
	Com | High Bay, T5 Fixture (Indoor - 234W - Fixture)
	Com | High Bay, LED Fixture (Indoor - 220W - Fixture)
	Com | LED Metal Halide Replacement Fixture (Outdoor - 220W - Fixture)
	Com | Advanced Lighting Controls
Commercial | Miscellaneous	Com | Small Electric Storage Water Heater (0.88 EF - 50 Gal)
	Com | High Eff. Small Electric Storage Water Heater (0.93 EF - 50 Gal)
	Com | Heat Pump Water Heater (>= 2.0 EF - 50 Gal)
	Com | High Efficiency Servers
	Com | Air Flow Management
	Com | Efficient CRAC
	Com | Efficient UPS
	Com | Data Center Server Virtualization
	Com | ENERGY STAR Hot Food Holding Cabinet
	Com | Demand Controlled Ventilation (DCV) Exhaust Hood
	Com | ENERGY STAR Convection Oven - Elec
	Com | ENERGY STAR Steamer - Elec
	Com | Ceiling/Roof Insulation (R19 - Elec SC and Gas SH)
	Com | Ceiling/Roof Insulation (>=R30 - Elec SC and Gas SH)
	Com | Dual Pane Windows (Elec SC and Gas SH)
	Com | High Performance Windows (Elec SC and Gas SH)
	Com | Wall Insulation (R13 - Elec SC and Gas SH)
	Com | Wall Insulation (R14 - Elec SC and Gas SH)
	Com | Window Film (Elec SC and Gas SH)

Sector | End Use | Levelized Cost Bundle	Measure
Commercial | Refrigeration | High	Com | Efficient Refrigeration Compressor Com | Strip Curtains Com | Add Doors to Open Display Cases
Commercial | Refrigeration | Low	Com | LED Display Case Lighting Com | Floating Head Pressure Controls Com | Permanent Split Capacitor Motor on Walk-Ins Com | EC Motors on Walk-Ins Com | Anti Sweat Heat Controls Com | Automatic Door Closers Com | 2017 Code Compliant Display Case Com | Efficient Display Case Replacement
Commercial | Whole Building | High	Com | ZNE Com | Whole Building Retrofit
Commercial | Whole Building | Low	Com | Title 24 2019 Code
Industrial | Lighting	Ind | Lighting Controls - Efficient Ind | Lighting Upgrades - Other - Efficient Ind | Lighting Upgrades - LED - Efficient
Industrial | Machine Drives	Ind | Premium Motors - Efficient Ind | Pump Sizing and Optimization - Efficient Ind | Air Compressor VFD - Efficient Ind | Fan VFD - Efficient Ind | Pump VFD - Efficient Ind | Air Compressor Control and Optimization - Efficient Ind | HVAC VFD Upgrade - Efficient Ind | Injection Molding - Efficient Ind | Wastewater Aerators - Efficient
Industrial | Miscellaneous	Ind | Process Optimization Controls - Efficient Ind | Refrigeration System Optimization - Efficient Ind | HVAC Chiller Upgrade - Efficient Ind | HVAC System Controls - Efficient Ind | HVAC Equipment Upgrade - Electric - Efficient
Mining Sector	Min | Stripper Pump Motor Replacement Min | Stripper Pump Motor Controls Min | Stripper Pump Motor Replacement and Controls Min | Regular Pump Motor Replacement Min | Regular Pump Motor Controls Min | Regular Pump Motor Replacement and Controls Min | Injecting Pump Efficient Motor Min | Injecting Pump VFD Min | Injecting Pump Efficient Motor and VFD

Sector | End Use | Levelized Cost Bundle	Measure
Residential | Appliance Plug | High	Res | ENERGY STAR Audio Equipment Res | ENERGY STAR Television Res | Induction Cooking Stove
Residential | Appliance Plug | Low	Res | Efficient Clothes Dryer- 3.93 CEF Res | Most Eff. Heat Pump Clothes Dryer Res | Advanced Power Strip Res | Two Speed Pool Pump Res | Variable Speed Pool Pump Res | ENERGY STAR Freezer Res | Efficient Clothes Washer - Tier 1 - 2.2 IMEF Res | Efficient Clothes Washer - Tier 2 - 2.4 IMEF Res | Efficient Clothes Washer - Tier 3 - 2.92 IMEF Res | ENERGY STAR Refrigerator Res | Recycle Secondary Freezer Res | Recycle Secondary Refrigerator
Residential | HVAC | High	Res | Whole House Fan Res | HVAC Quality Maintenance (Elec SH) Res | Quality HVAC Installation (Elec SH) Res | DC Ceiling Fan (Energy Star) Res | Room AC (EER 11.0) Res | Packaged/Split Heat Pump (SEER 13) Res | Packaged/Split Heat Pump (SEER 16)

Sector | End Use | Levelized Cost Bundle	Measure
Residential | HVAC | Low	Res | Packaged/Split System AC (SEER 13)
	Res | Packaged/Split System AC (SEER 14)
	Res | Packaged/Split System AC (SEER 16)
	Res | Packaged/Split System AC (SEER 18)
	Res | Packaged/Split System AC (SEER 21)
	Res | HVAC Controls Upgrade (Elec SH)
	Res | Refrigeration Charge to Factory Levels
	Res | Variable Capacity Space Conditioning System
	Res | Duct Sealing (Elec SC and Gas SH)
	Res | ECM HVAC Motor
	Res | Packaged/Split Heat Pump (SEER 14)
	Res | Packaged/Split Heat Pump (SEER 18)
	Res | Packaged/Split Heat Pump (SEER 21)
	Res | Ductless Mini Split Heat Pump (SEER 21)
	Res | Ground Source Heat Pump
	Res | Programmable Thermostat (Elec SC and Gas SH)
	Res | Smart Thermostat (Elec SC and Gas SH)
Residential | Lighting | High	Res | LED Fixture (Indoor - 10W)
	Res | LED Lamp (Basic High - 16.5W - Indoor)
	Res | LED Lamp (Reflector - 12W - Indoor)
	Res | LED Lamp (Specialty High - 18W - Indoor)
	Res | LED Fixture (Outdoor - 20W)
	Res | LED Lamp (Reflector - 14W - Outdoor)
	Res | Occupancy Sensor
Residential | Lighting | Low	Res | CFL Fixture (Indoor - 17.5W)
	Res | LED Lamp (Basic Low - 8W - Indoor)
	Res | LED Lamp (Specialty Low - 8W - Indoor)
	Res | CFL Fixture (Outdoor - 28W)
	Res | LED Lamp (Basic Low - 9W - Outdoor)
	Res | LED Lamp (Basic High - 16.5W - Outdoor)
	Res | LED Lamp (Specialty - 11W - Outdoor)
	Res | Low Bay, LED LF Fixture

Sector | End Use | Levelized Cost Bundle	Measure
Residential | Miscellaneous	Res | Attic/Ceiling Duct Insulation (R6 - Elec SC and Gas SH)
	Res | Cool Roof (Elec SC and Gas SH)
	Res | Crawlspace Duct Insulation (R6 - Elec SC and Gas SH)
	Res | Windows with Low E Film (Elec SC and Gas SH)
	Res | Ceiling/Roof Insulation (R19 - Elec SC and Gas SH)
	Res | Ceiling/Roof Insulation (>=R30 - Elec SC and Gas SH)
	Res | Wall Insulation (R13 - Elec SC and Gas SH)
	Res | Wall Insulation (R14 or greater - Elec SC and Gas SH)
	Res | Attic/Ceiling Duct Insulation (R8 - Elec SC and Gas SH)
	Res | Crawlspace Duct Insulation (R8 - Elec SC and Gas SH)
	Res | Dual Pane Windows (Elec SC and Gas SH)
	Res | High Performance Windows (Elec SC and Gas SH)
	Res | Small Electric Storage Water Heater (0.90 EF - 50 Gal)
	Res | High Eff. Small Electric Storage Water Heater (0.93 EF - 50 Gal)
	Res | Heat Pump Water Heater (>= 2.0 EF - 50 Gal)
	Res | Faucet Aerators (Electric WH)
	Res | Low Flow Showerheads (Electric WH)
	Res | Drain Water Heat Recovery (Electric WH)
Residential | Whole Building	Res | Energy Upgrade CA Basic
	Res | Energy Upgrade CA Advanced
	Res | Title 24 2019 Code
	Res | ZNE
Streetlighting Sector	Stl | Baseline Streetlights with Advanced Controls
	Stl | Induction Streetlights with Advanced Controls
	Stl | LED Streetlights
	Stl | LED Streetlights with Advanced Controls
	Stl | Induction Streetlights
	Stl | LED Street Sign Lights
	Stl | Induction Street Sign Lights