Optimizing Energy Efficiency Investments Using the RESOLVE Model

Technical Report

September 2018

Energy+Environmental Economics

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1 Introduction

This technical report documents an exercise to use the RESOLVE capacity expansion model to select energy efficiency resources in the CPUC's Integrated Resource Plan (IRP). While many important aspects of energy efficiency valuation have been included in this exercise, some aspects of the modeling approach should be revisited to provide IRP-quality results. These simplifications and updates are described throughout the text and in the conclusions.

1.1 RESOLVE Overview

RESOLVE is an optimal investment and operational model designed to inform long-term planning questions in electricity systems with high penetration levels of renewable energy. The model is formulated as a linear optimization problem. RESOLVE co-optimizes investment and dispatch for a selected set of days over a multi-year horizon to identify least-cost portfolios for meeting renewable energy targets and other system goals. RESOLVE also incorporates a representation of neighboring regions to characterize transmission flows into and out of a main zone of interest endogenously. RESOLVE can solve for optimal investments in a diverse set of technologies including renewable resources, energy storage technologies, demand response resources, and thermal generators. The optimization results must satisfy an annual constraint on delivered renewable energy that reflects Renewables Portfolio Standard (RPS) requirements, an annual constraint on greenhouse gas emissions, an annual capacity adequacy constraint to maintain reliability, constraints on operations that are based on a linearized version of the unit commitment problem, and constraints on the ability to develop specific renewable resources.

RESOLVE was used to develop resource portfolios for the 2017 IRP. More information about RESOLVE can be found on the **Events and Materials page**[1] of the **CPUC IRP website**[2].

1.2 Energy Efficiency in the 2017 IRP

In the 2017 IRP, energy efficiency was included only as a load-modifier. In this approach RESOLVE was not able to select different levels of energy efficiency, but rather optimized other resources given a fixed level of efficiency. Sensitivities on the aggregate level of energy efficiency indicated the value of different amounts of energy efficiency to the system, but did not optimize investments on a granular, bundle-by-bundle level. The cost of energy efficiency was assumed to be the same across different levels of efficiency on a real $/MWh basis, and was added to the total system cost outside of the optimization.

This technical report builds on 2017 IRP modeling by incorporating data from Navigant on bundle-specific costs, potentials, and hourly demand reduction shapes into the RESOLVE optimization framework. RESOLVE has been modified to allow for energy efficiency bundles to compete directly with supply-side technologies.

[1] http://www.cpuc.ca.gov/General.aspx?id=6442451195
[2] http://www.cpuc.ca.gov/irp/

2 Modeling Energy Efficiency in RESOLVE

2.1 Input Data

2.1.1 ANNUAL DATA FROM NAVIGANT

For each bundle, E3 incorporated annual data from Navigant into RESOLVE:

+ Annual incremental savings limit (GWh). Navigant's annual limits were translated into four-year steps because RESOLVE optimizes investments every four years.
+ Cumulative savings limit (GWh). This limit constrained the total savings from energy efficiency, taking into account bundles that had been deployed in previous years.
+ The levelized cost of each bundle ($/MWh).

2.1.2 MATCHING HOURLY SHAPES TO RESOLVE REPRESENTATIVE DAYS

RESOLVE and Navigant hourly data were based on different calendar years. Navigant provided E3 with hourly energy efficiency load shapes that were based on the historical year 2013. The 2017 IRP RESOLVE model used a set of representative days from 2007-2009. To maintain weather and load correlations between the two datasets, E3 matched each day in the 2007-2009 timeframe with one day from 2013 (Figure 1). Days were required to be within one month (30 calendar days) of each other and to match weekday/weekend status. The matching process selected the day that had the smallest total squared error when comparing the hourly CAISO load profile of the 2007-2009 day and the 2013 day.

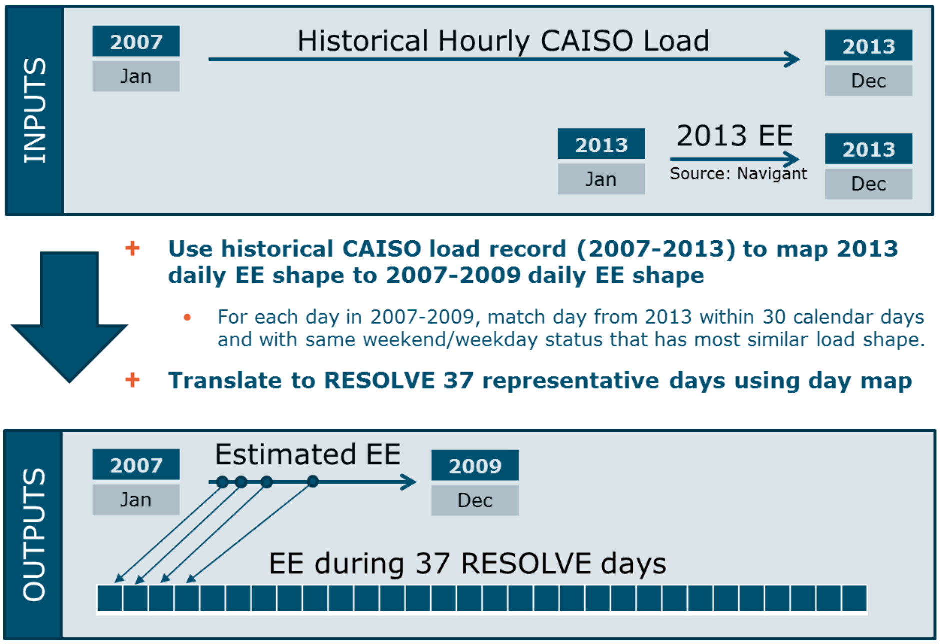

Figure 1. Schematic of day matching methodology

2.1.3 AVOIDED SYSTEM PEAK CAPACITY

Energy efficiency reduces system peak capacity needs, a value stream that is quantified in the avoided cost calculator.[3] Deploying more energy efficiency would result in lower system Resource Adequacy (RA) needs, saving the cost of system RA capacity. The value of avoided system RA capacity depends strongly on the supply-demand balance of capacity, with much higher avoided capacity values occurring when the system must build new resources to satisfy peak needs.

RESOLVE is able capture the value of avoiding system RA capacity when it was necessary to build *new* capacity to satisfy the planning reserve margin. However, input assumptions in 2017 IRP modeling resulted in a capacity surplus over the entire time horizon. Also, RESOLVE was not able to retire resources

[3] http://www.cpuc.ca.gov/General.aspx?id=5267

in the 2017 IRP, thereby not allowing the optimization to save fixed operations and maintenance (fixed O&M) costs when retiring existing resources. The combination of these two factors meant that the 2017 IRP version of RESOLVE did not ascribe value to any resource for avoided system RA capacity.

As an interim methodology to capture the value that energy efficiency would receive from avoiding system RA capacity, E3 multiplied a peak contribution factor (described below) by an assumed system RA cost and subtracted the result from the cost of each energy efficiency bundle. Consistent with input assumptions that result in a capacity surplus, $25/kW-year was used as an indicative value for the cost of RA contracts with existing resources, which is less than the ~$100/kW-year (real) avoided capacity values used in the Avoided Cost Calculator.

The peak capacity contribution factor for each energy efficiency bundle (Figure 2) was calculated as the average savings in the top 100 demand hours from June to September within the 5-9 pm window. The peak contribution factor was normalized to a flat demand profile (one average MW or aMW) - a profile with the same demand reduction in every hour of the year. The peak capacity contribution calculation in this technical report is a simplified version of that used in the Avoided Cost Calculator.

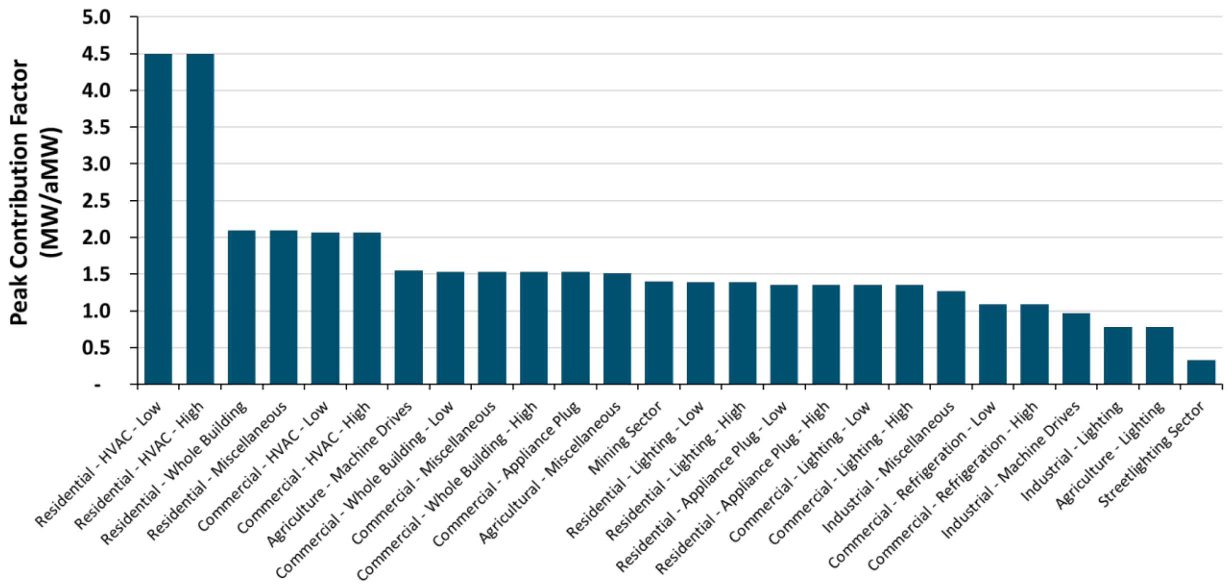

Figure 2. Peak capacity contribution factor for each EE bundle. Higher values indicate better correlation between demand reductions and peak time periods.

2.1.4 AVOIDED T&D CAPACITY VALUE FROM THE AVOIDED COST CALCULATOR

Energy efficiency investments reduce the need for additional transmission and distribution (T&D) capacity. RESOLVE optimizes investments in power system infrastructure at the bulk system level and does not typically include value that a technology can provide at the local level. To represent the T&D deferral value of energy efficiency in RESOLVE, E3 subtracted bundle-specific T&D deferral values from the cost of each bundle. The cost of each energy efficiency measure as input into RESOLVE is *net of avoided T&D deferral value*.

E3 calculated avoided T&D deferral values using data from the 2016 Avoided Cost Interim Update. This dataset start with the values utilities filed in their general rate cases (SCE 2015 GRC, SDG&E 2015 GRC, PG&E 2014 GRC). The values are system averages for SCE and SDG&E and vary by climate zones for PG&E. The values are held constant in real terms to propagate capacity costs past the GRC filing. The T&D capacity costs are further adjusted for losses to reflect the impact of load changes at the customer meter on the T&D investment need. The loss-adjusted T&D capacity costs are allocated to hours of the year in each climate zone when the system is most likely to be constrained and require upgrades – the hours of highest local load. The load is forecasted using a regression model which incorporates the 2015 IEPR Mid-Demand forecast of solar penetration. The inclusion of the solar forecast allows the hourly allocation to reflect the impact of solar on reducing and shifting net peak demand.

In this technical report, bundle-specific avoided T&D capacity costs from climate zone 11 were used as preliminary values. Future analyses could model location-specific bundles that would have different avoided T&D capacity costs.

2.1.5 CUMULATION START YEAR

Navigant provided E3 with energy efficiency potentials that counted savings relative to the year 2018 (the cumulation start year). E3's underlying load data used 2016 as the cumulation start year. E3 advanced the cumulation start year from 2016 to 2018 by reducing CAISO demand in 2018 and subsequent years by 3,445 GWh/yr, the amount of energy efficiency savings assumed to occur between 2016 and 2018.

2.1.6 LOAD MODIFIERS

Appliance standards, building standards, low income programs, and BROs (Behavior, Retrocommissioning, and Operational Efficiency) were not optimized in this analysis and were instead represented as load modifiers. Cumulative net demand savings from 2018 – 2030 for the Mid-Mid scenario were obtained from the **Demand Analysis Working Group website**. The level of load-modifying energy efficiency increased over time, reducing CAISO demand by 12,400 GWh/yr in 2030.

2.1.7 COMPARISON OF ENERGY EFFICIENCY POTENTIAL

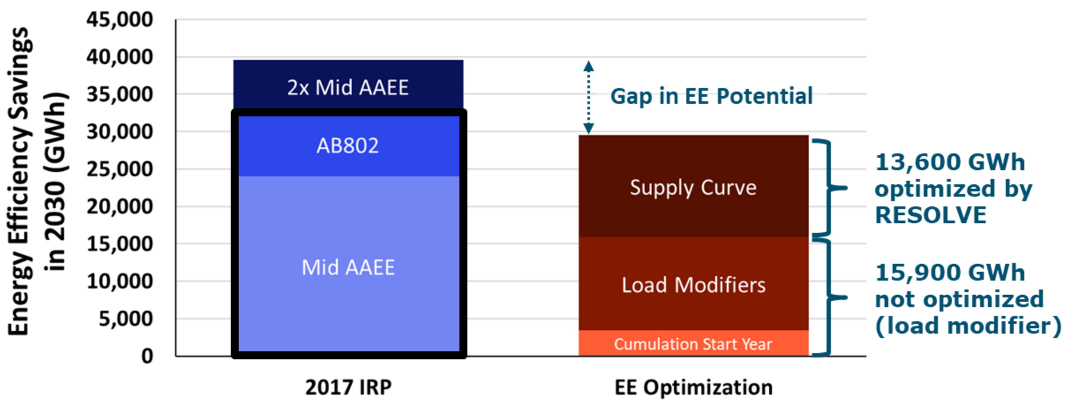

Figure 3. Energy efficiency potential comparison between 2017 IRP modeling and the current energy efficiency optimization exercise.

Adding together load-modifying and optimized energy efficiency potential in this technical report gave a maximum energy efficiency potential of 29,500 GWh in 2030 (Figure 3, right). The 2017 IRP explored a range of energy efficiency levels but used Mid-AAEE + AB802 savings as the default assumption in most model runs, resulting in 32,600 GWh of energy efficiency in 2030 (Figure 3, left). The reduction in maximum energy potential between this technical report and 2017 IRP assumptions results from differences in technologies included, data vintages, as well as differences between the AB802 analysis and the Navigant supply curve methodology.

2.2 Energy Efficiency Investments in RESOLVE

2.2.1 OBJECTIVE FUNCTION

RESOLVE's objective function minimizes the net present value of total costs across a 20+ year time horizon. Energy efficiency costs are included as a function of when an energy efficiency bundle was installed. The model incurs the same annualized cost in each year after the bundle is installed. The stream of annualized costs is discounted back to present using a 5% real discount rate. RESOLVE's cost minimization does not include program administration costs.

2.2.2 CONSTRAINTS AND VALUE STREAMS

The value of any resource in the RESOLVE model is determined by how that resource interacts with the constraints of the optimization. Energy efficiency appears in several RESOLVE constraints, listed below:

Value stream	Interaction with RESOLVE Constraint	Notes
Demand reduction	For each hour of the optimization, EE is subtracted from electricity demand in RESOLVE's load and power balance constraint. EE avoids transmission and distribution losses, which are assumed to be 7.3%.	Value ascribed to reducing GHG emissions will appear here because policies that reduce GHG emissions increase the short run marginal cost of GHG-emitting resources.
Spinning reserve reduction	Spinning reserves are 3% of demand in each hour. For X MWh of energy efficiency in a given hour, the spinning reserve demand will be reduced by X * 3%.	Reductions in load following and regulation requirements are not yet implemented, which would provide additional value for energy efficiency.
RPS compliance obligation	Energy efficiency reduces the RPS compliance obligation. EE is subtracted from retail electricity sales in each optimization period. Retail sales are multiplied by a compliance percentage (e.g. 50% by 2030), so deploying EE will reduce the RPS compliance obligation.	In scenarios with stringent GHG targets (such as the 42MMT and 30MMT scenarios), the RPS constraint is typically not binding and is superseded by the constraint on GHG emissions. These scenarios will not ascribe any value to RPS compliance reduction but will instead add value to energy efficiency bundles based on their ability to reduce GHG emissions.

Value stream	Interaction with RESOLVE Constraint	Notes
Peak capacity reduction	In the capacity reserve margin constraint, EE is subtracted from peak demand. Each EE bundle reduces peak capacity needs by a different factor, described in Section 2.1.3. Because EE reduces peak demand, every MW of peak load reduction from EE will reduce the demand for supply side resources by the planning reserve margin percentage – in this study 15%. EE also avoids transmission and distribution losses during peak demand hours.	Default assumptions for the 2017 IRP modeling result in a surplus of capacity. While EE will reduce peak capacity needs within the model formulation, no value is ascribed to this reduction due to the capacity surplus. As described in Section 2.1.3, $25/kW-year is subtracted from the cost of each bundle as proxy for capacity value.
Avoided T&D Capacity	Not included in any constraint.	As described in Section 2.1.4, the value of avoiding T&D capacity is subtracted from the cost of each bundle.

Two additional constraints limit the deployment of energy efficiency in RESOLVE:

- Energy efficiency deployment is limited by an annual build rate.
- Energy efficiency is limited by a cumulative potential in each investment period, which takes into account bundles that have been deployed in previous years.

2.2.3 OUTPUTS

At the end of an optimization, RESOLVE produces the GWh demand reduction from and cost of each energy efficiency bundle in each investment period (2018, 2022, 2026, and 2030). Peak load and hourly demand reductions are also recorded.

2.2.4 NET PRESENT VALUE POST-PROCESSING CALCULATION

RESOLVE does not directly output the *value* of each energy efficiency bundle. If a bundle is chosen, it is not evident without further analysis if the bundle made small or large reductions in total system cost – i.e. had a relatively low or high value to the system. If a bundle is not chosen, it is not easy to determine whether there is a small or a large discrepancy between the cost and the value of the bundle.

As a preliminary investigation into the *value* of each energy efficiency bundle, E3 used marginal cost outputs from RESOLVE to calculate a levelized value for each energy efficiency bundle. For each of RESOLVE's four investment periods (2018, 2022, 2026, 2030), the hourly energy cost was multiplied by the hourly shape of each energy efficiency bundle, producing the value of avoided energy in each hour. RESOLVE's marginal energy cost included the cost of GHG emissions, so the avoided energy value *included* the value of avoiding GHG emissions. To quantify the value of avoided spinning reserves, the marginal spinning reserve costs were multiplied by 3% (the spinning reserve percentage of demand) of each bundle's hourly shape. A 5% real discount rate was used to calculate the levelized value of each bundle over the study horizon.

The post-processing calculation outlined above was not able to capture all of the dynamics that are modeled in the RESOLVE optimization, and thus the results should be taken as indicative but not precise. One important difference relates to the timing of investment decisions in the post-processing method relative to the RESOLVE optimization. The post-processing method calculated a levelized value for all the years of the study, thereby assuming that the energy efficiency investment was made in the first investment year – in this case 2018. The RESOLVE optimization has more flexibility and may choose to wait to install a bundle until a) the investment cost of the bundle has fallen and/or b) the value of the bundle has risen.

E3 did not develop a methodology for post-processing model runs with a binding RPS target, consequently the Default (50% RPS) case is excluded from this analysis.

3 Results and Discussion

3.1 Core Cases

We explored the same three core cases as the 2017 IRP:

- Default Case: Reflects all existing policies, notably the 50% RPS.
- 42 MMT Case: The low end of the estimated range for electric sector emissions in CARB's Scoping Plan; it reflects a scenario in which the state GHG reduction goal is achieved with 40-85 MMT of reductions from unknown measures.
- 30 MMT Case: The electric sector emissions in CARB's Scoping Plan scenario in which state GHG reduction goal is achieved with known measures.

The only change from 2017 IRP modeling was the way in which energy efficiency is handled:

- The amount load-modifying energy efficiency was reduced from Mid-AAEE + AB802 levels. Only appliance standards, building standards, low income programs, and BROs were treated as load-modifiers in this technical report.
- Part of the energy efficiency potential was modeled as a selectable resource in RESOLVE.

3.2 EE Resources Selected

RESOLVE selected 7,100 to 10,000 GWh/yr of energy efficiency by 2030 ("Selected EE" on Figure 4), out of a maximum potential of 13,700 GWh. Higher levels of energy efficiency investment were observed as more stringent RPS or GHG targets were imposed on the system. Most bundles showed steady investment over time (Table 1), due in part to limits that RESOLVE imposed on annual investments.

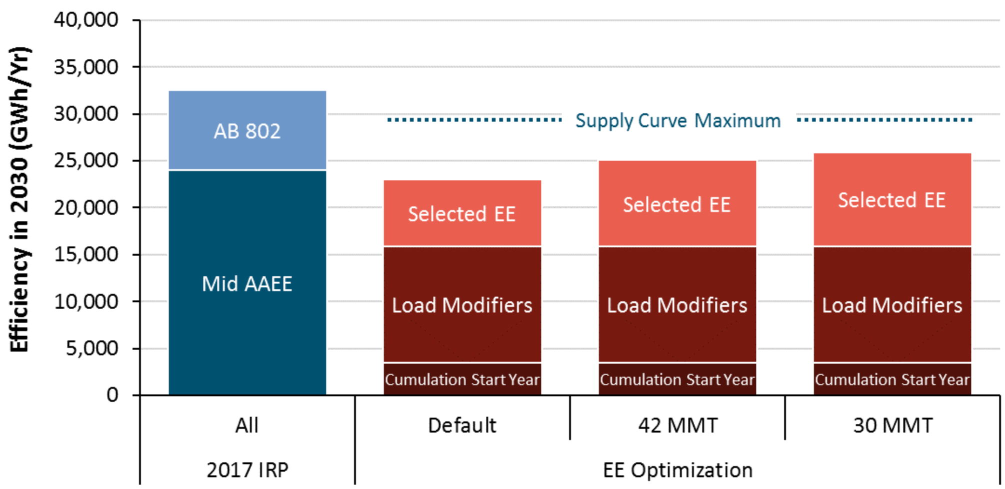

Figure 4. Energy efficiency resources selected by RESOLVE, compared to the default 2017 IRP level of energy efficiency. Values represent cumulative savings – savings from resources selected in previous years are included in the totals.

	Default				42 MMT				30 MMT			
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**

Table 1. Selected EE in RESOLVE (GWh/Yr). Values represent cumulative savings – savings from resources selected in previous years are included in the totals.

3.3 Bundle Levelized Value and Cost

E3 calculated the levelized value of each energy efficiency bundle over the course of the study horizon (Figure 5). The levelized cost and value were similar for many bundles, indicating that these bundles may or may not be cost-effective depending the stringency of renewable or GHG policy, or assumptions about system costs and conditions. Bundles that were consistently picked by RESOLVE – especially low-cost lighting bundles such as Streetlighting, Residential Lighting Low, and Commercial Lighting Low – had levelized values that were much larger than levelized costs. Bundles that were not picked in any of the RESOLVE cases had levelized values that were much less than levelized costs.

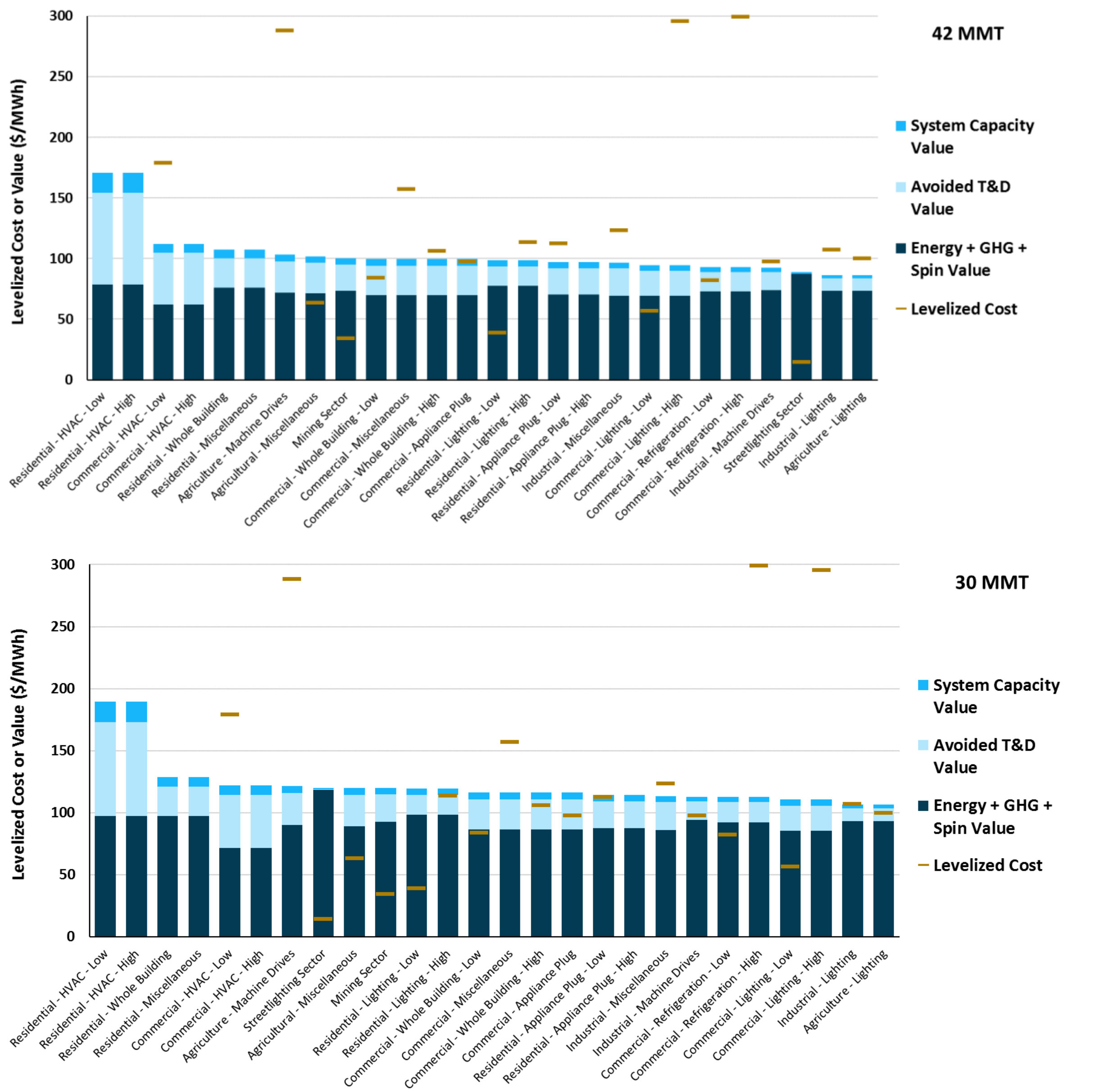

Figure 5. Levelized value and cost for each bundle across the entire study horizon, for the 42 MMT (top) and 30 MMT (bottom) cases. A bundle is likely cost-effective when the levelized cost is within the shaded area. Bundles for which a levelized cost marker is absent had a levelized cost >$300/MWh.

Comparing the 42 MMT case to the 30 MMT case, the hourly 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. Moving from the 42 MMT case to the 30 MMT case, streetlighting efficiency showed the most pronounced difference in value of any bundle because it reduces demand exclusively at night. Also, the difference in levelized value of residential and commercial HVAC bundles became more pronounced because residential HVAC demand is concentrated in the nighttime.

Figure 5 demonstrates that the range of bundle costs was much larger than the range of levelized benefits. For the specific set of 26 energy efficiency bundles explored in this technical report, energy efficiency resources were generally picked in order of cost (see Figure 6 for example), suggesting that the difference in hourly shape (and therefore value) was not large enough to offset differences in cost. More granularity data for resources in the cost range of ~$100-200/MWh may be warranted because bundles in this cost range should show a pronounced dependence on value.

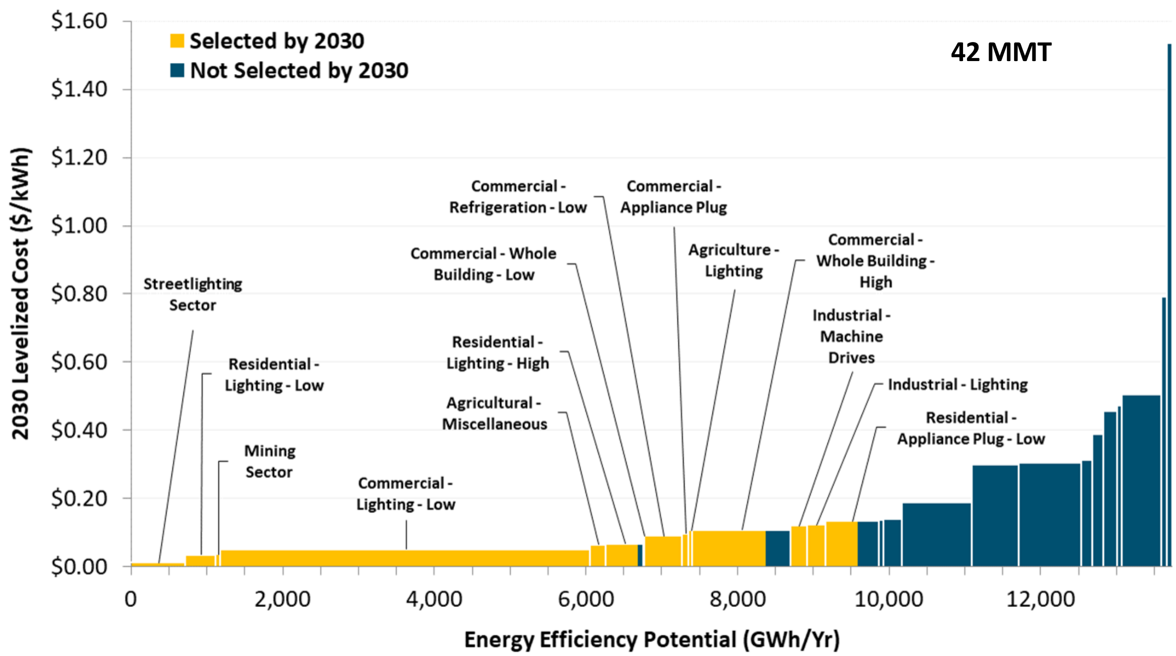

Figure 6. Supply curve of energy efficiency resources selected by 2030 in the 42 MMT case.

3.4 Comparison to 2017 IRP cost and build

The data used by RESOLVE in this technical report resulted in lower energy efficiency potential than the reference 2017 IRP assumptions (Mid-AAEE + AB 802 levels of efficiency - see Section 2.1.7). In the 2017 IRP, all energy efficiency was modeled as a load-modifier with a cost of ~$50/MWh in 2030, a price point on the lower end of the Navigant supply curve.

The combination of lower potential and higher cost in the updated dataset in this technical report resulted in somewhat lower levels of efficiency than Mid-AAEE + AB 802. For the 42 MMT case, the selected supply-side resource portfolio most closely resembled the Mid-AAEE energy efficiency *sensitivity* (p. 185 of the proposed reference system plan[4]), a sensitivity that did not include incremental efficiency savings from the implementation of AB802 (Figure 7). Lower levels of energy efficiency resulted in increased renewable buildout because the optimization is restricted to the same level of GHG emissions in all cases.

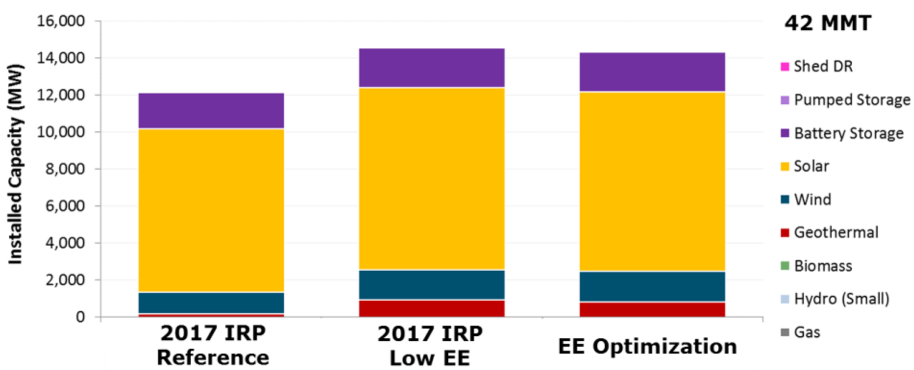

Figure 7. Comparison of supply-side resources selected in the 42 MMT case by 2030. All resources shown in this chart are incremental to baseline resources.

3.5 Potential Data and Model Refinements

3.5.1 DATA

- Potential. Investigate whether more energy efficiency potential is available than was included in this study, perhaps a higher cost. Additional potential would allow RESOLVE to assess the cost-effectiveness of higher levels of energy efficiency.
- High value measures. More granularity on measures with high value. For example, there may be some intermediate cost residential measures not included on the supply curve that merit additional investigation.

[4] http://www.cpuc.ca.gov/uploadedFiles/CPUCWebsite/Content/UtilitiesIndustries/Energy/EnergyPrograms/ElectPowerProcurementGeneration/irp/AttachmentA.CPUC_IRP_Proposed_Ref_System_Plan_2017_09_18.pdf

- Avoided T&D value. This technical report assigned avoided T&D values from one climate zone as a placeholder. Avoided T&D values specific to each utility and/or climate zone would allow RESOLVE to make more granular economic decisions.

3.5.2 MODEL IMPROVEMENTS

- Resource Retirements. In this technical report, the value of system capacity reduction was assumed to be the RA contract cost of $25/kW-year. This assumption was made because system conditions showed a surplus of system capacity. A more robust way to value RA capacity would be to modify the RESOLVE codebase to allow economic retirement resources. In this formulation, the model would incur a yearly fixed O&M cost if it decided to keep a resource online, but would not incur this cost if it decided to retire the resource. Modeling resource retirements endogenously within RESOLVE would allow energy efficiency investments the opportunity to reduce fixed O&M payments for other resources.
- Calculation of peak period. E3 calculated the system peak contribution for each bundle using the top 100 demand hours from June to September within the 5-9 pm window. RESOLVE could be modified to endogenously calculate the time periods of greatest system capacity need, thereby eliminating the need to pick a specific time window before running the optimization.
- Local T&D deferral value for other resources. Other resources that can be located close to demand centers (rooftop PV, local storage, demand response, etc.) may also have significant T&D deferral benefits, RESOLVE does not currently ascribe any value T&D deferral value to other demand side resources. Subtracting T&D deferral benefits from the cost of other resources would allow for a more apples-to-apples valuation of a broad portfolio of supply and demand-side resources.
- Operational Reserves. Energy efficiency as currently represented in RESOLVE does not reduce load following or regulation reserve requirements. RESOLVE could be modified to reduce operational reserve requirements as more energy efficiency is selected.

3.6 Conclusions

This exercise highlights a few key methodological differences between the cost-effectiveness framework used to evaluate energy efficiency resources using the Avoided Cost Calculator and the IRP framework using RESOLVE. The most important of these differences are the following:

- Portfolio vs. Measure Level Cost-effectiveness. The energy efficiency cost-effectiveness criteria is currently based on portfolio cost-effectiveness. The highest cost measures are not necessarily cost-effective on their own. This is an implementation of the directive to capture ‘all cost-effective energy efficiency’ that maximizes energy efficiency savings subject to overall cost-effectiveness. In contrast, the IRP framework and the RESOLVE model only selects energy efficiency that is cost-effective at an individual measure/bundle level to minimize the total cost of the electricity system. The difference in objective function results in fewer high cost measures being selected in RESOLVE. Another consequence of this is that the results are sensitive to measure cost data, particularly for measures on the high end of those selected ($0.10/kWh to $0.15/kWh).
- Capacity Value. Based on the assumptions in the IRP cases evaluated, there is no need for additional system generation capacity over the analysis horizon. Therefore, there is no additional capacity value added to the benefits of energy efficiency when RESOLVE selects the efficiency portfolio. For the purposes of this exercise, a ‘market level’ assumption for the value of resource adequacy of around $25/kW-year is used to value capacity savings of energy efficiency. For energy efficiency cost-effectiveness, by CPUC Decision, the net cost of a new gas generation is used to value capacity in every year, resulting in a significantly higher number for capacity above $100/kW-year.
- Energy and GHG Value. On the other hand, the ‘energy value’ is significantly higher for energy efficiency in the IRP framework than in the avoided cost calculator, particularly at lower (more stringent) GHG emission levels. The reason for this is that as RESOLVE adds resources to reduce GHG emissions, the value of energy includes avoided renewable generation costs, and renewable integration costs including curtailed energy and energy storage for this additional renewable energy. As the GHG level is reduced in these cases from 42MMT to 30MMT, this value increases significantly.