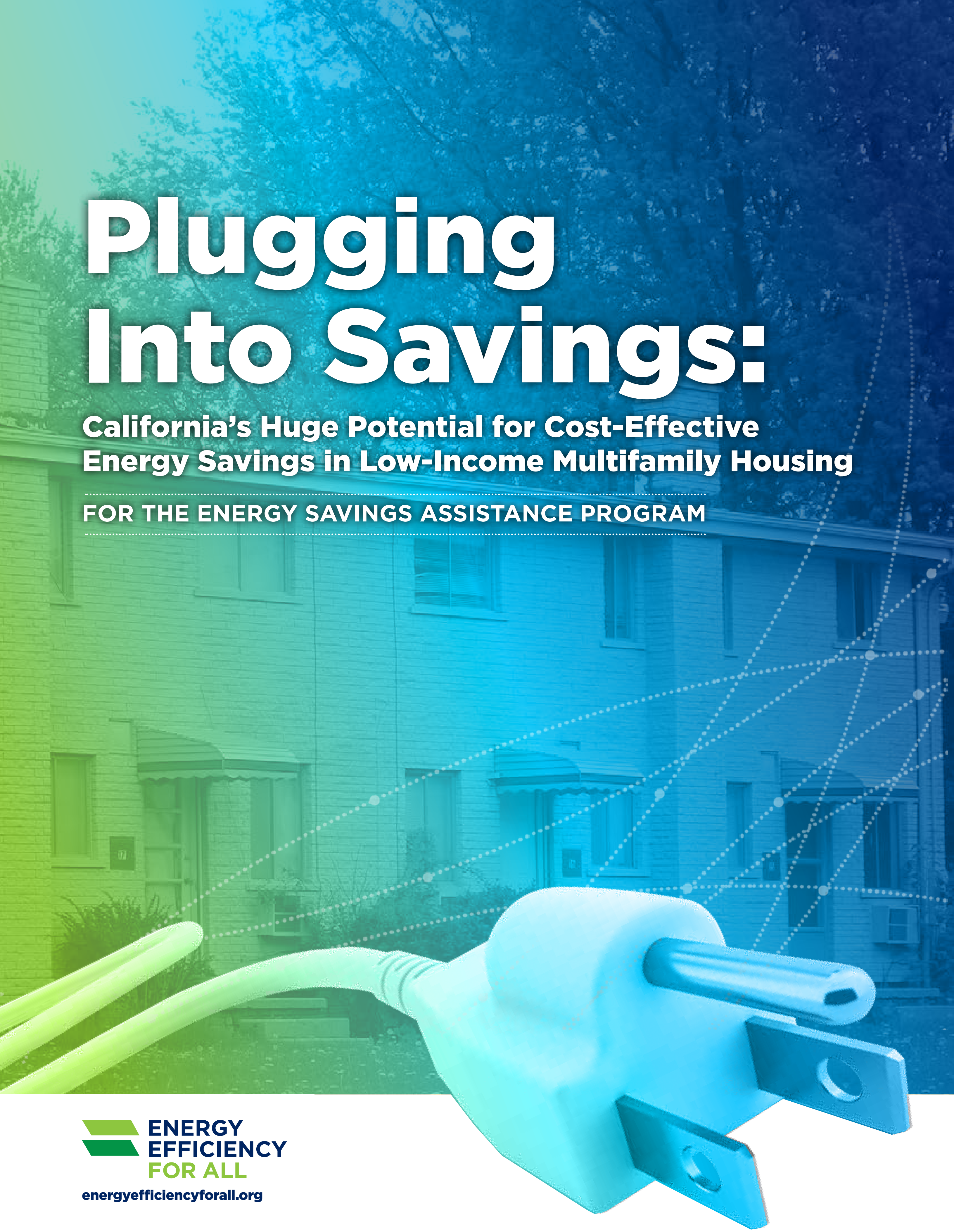

Plugging Into Savings:

California's Huge Potential for Cost-Effective Energy Savings in Low-Income Multifamily Housing

FOR THE ENERGY SAVINGS ASSISTANCE PROGRAM

ENERGY EFFICIENCY FOR ALL
energyefficiencyforall.org

ACKNOWLEDGEMENTS

Energy Efficiency for All (EEFA) is a multistate initiative that works to make multifamily housing healthy and affordable through energy and water efficiency. EEFA provides technical expertise and coordination support to a national network and 12 state-based coalitions to increase efficiency investments in energy and water efficiency. Nationally, EEFA is a project of the Energy Foundation, National Housing Trust, Natural Resources Defense Council, and Elevate Energy.

In California, EEFA works with the Association for Energy Affordability, Build It Green, California Environmental Justice Alliance, California Housing Partnership, The Greenlining Institute, National Housing Law Project, and the National Consumer Law Center, among others, to ensure low-income efficiency programs are designed to capture all cost-effective energy efficiency savings, including non-energy co-benefits, within the multifamily housing sector.[1] We further work together to ensure these energy, health, and safety benefits flow to low-income families and affordable housing owners as well as to the local workforce, and state at large.

The primary authors of this study are Matthew Socks and Philip Mosenthal (Optimal Energy), Maria Stamas, Lindsay Holiday, and Charlene Chi-Johnston (NRDC). We appreciate the extensive internal review provided by Mohit Chhabra, Lara Ettenson, Lindsay Robbins, and Cai Steger of the NRDC team. Also, thank you to Alejandra Mejia Cunningham of Transcendent Energy and Glenn Reed of Energy Futures Group for their critical support and input.

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Executive Summary

POTENTIAL RESULTS AT A GLANCE

From 2018 through 2031, if the California Public Utilities Commission (CPUC) approves investment in all cost-effective efficiency measures in low-income multifamily housing, residents, utilities, building owners, and the state of California can expect to see the following benefits:[2]

$136 MILLION TO $200 MILLION IN UTILITY BILL SAVINGS[3]

934 GWH IN ELECTRICITY SAVINGS

37 MILLION THERMS IN GAS SAVINGS

24% AVERAGE ELECTRICITY USAGE REDUCTION

19% AVERAGE GAS USAGE REDUCTION

520,000 METRIC TONS OF CARBON AVOIDED = AVOIDED POLLUTION FROM ~100,000 PASSENGER VEHICLES

84,000 YEAR-LONG JOBS OR 6,000 LONG-TERM JOBS CREATED

WHAT'S AT STAKE

Through 2031, investing in all cost-effective efficiency measures could lead to **4 times** as much savings compared to current program performance.[4]

Making multifamily residential properties more energy efficient is a key strategy for reducing the disproportionate energy cost burden facing families on limited incomes. Energy cost burden is the percentage of household income spent on energy bills. A recent analysis by the American Council for an Energy-Efficient Economy and Energy Efficiency For All (EEFA) found that "the overwhelming majority of households with incomes below 80% of area median income, minority households, low-income households residing in multifamily properties, and renting households experienced higher energy burdens than the average household in the same city."[5] Low-income families spend an average of twice as much as other families on energy.[6] In rural regions, low-income families spend three times as much as other families on energy.[7]

The state of California created the Energy Savings Assistance (ESA) Program in the 1990s to address this disparity, produce cost-effective energy-efficiency savings, and improve the quality of life for low-income customers. However, the program has largely overlooked the unique needs of renters, who account for 42 percent of eligible households and whose energy expenditures run an average of 37 percent higher per square foot than their single-family counterparts.[8]

There are many reasons that ESA-eligible customers in multifamily properties have been historically underserved. Owners and renters face misaligned incentives with respect to who pays for an efficiency measure versus who benefits from the utility bill savings. Further, more than half of California's low-income population does not use English as their primary language, which makes those customers harder to reach by most efficiency programs.

Programmatic requirements and regulatory limitations, such as the requirement to separately provide upgrades to household units and common areas, strict rules on eligible measures, and a confusing patchwork of eligibility requirements, can make it even more difficult to deliver savings and health, comfort, and safety improvements.

Recognizing these longstanding challenges, the California Public Utilities Commission in November 2016 formally adopted new directives for the ESA program through 2020, including mandating the investor-owned utilities create a new $80 million program for common-area and whole-building measures in affordable housing with rent restrictions in the deed, and setting energy-savings targets by utility for the first time in the program's history.

EEFA commissioned this study as a follow up to a report by The Cadmus Group and the commission's 2016 ruling, to quantify the cost-effective savings available for more than 1.4 million ESA-eligible, low-income, multifamily households. Many of these residents live in market rate housing and are not eligible for the $80 million program authorized in November 2016. This study also pinpoints where these energy-efficiency opportunities are. For example, it quantifies how much can be saved with efficient lighting versus upgraded heating and cooling equipment, and where innovative plug load measures—devices that can help reduce electricity that is consumed when devices are not being used—are needed. The study results can be used to inform future budget setting and savings goals for the ESA program and individual utilities as well as overall program design, including measure selection and program delivery.

Significant Opportunity in Multifamily Properties

Overall, the study finds that from 2018 through 2031, if the California Public Utilities Commission (CPUC) approves investment in all cost-effective efficiency measures in low-income multifamily housing, residents, utilities, building owners, and the state of California can expect to see the following benefits:[9]

- **$136 Million to $200 Million in Utility Bill Savings[10]**
- **934 GWh in Electricity Savings — 37 Million Therms in Gas Savings**
- **24% Average Electricity Usage Reduction —19% Average Gas Usage Reduction**
- **520,000 Metric Tons of Carbon Avoided = Avoided Pollution from ~100,000 Passenger Vehicles**
- **84,000 Year-Long Jobs or 6,000 Long-Term Jobs Created**

Through 2031, investing in all cost-effective efficiency measures could lead to **4 times** as much savings compared to current program performance.

ESA-ELIGIBLE MULTIFAMILY HOUSING

California's Energy Savings Assistance (ESA) Program provides energy-efficiency upgrades at no cost to households earning 200% or less of the federal poverty guidelines. In 2017, a family of four that earned $49,200 or less per year qualified for the program. Created by the state legislature, the program is overseen and regulated by the California Public Utilities Commission and is available to roughly one-third of California's residents or 13 million households. Families must also live in areas served by Pacific Gas and Electric, Southern California Edison, Southern California Gas, or San Diego Gas & Electric to be eligible for the program. This study focuses on a subset of that population: the historically underserved sector of multifamily properties where five or more units are occupied by ESA-eligible households. These properties house roughly one-third of California's total ESA-eligible population.[11]

Details of the Study Methodology

Optimal Energy, which conducted this study of the program's potential, is an energy-efficiency consulting firm with more than 20 years of experience assessing, planning, and designing cost-effective programs in states top-ranked for energy efficiency.[12] Using its proven potential study methodology and drawing on the best available data from California and across the nation, Optimal Energy calculated the maximum energy savings the California utilities can deliver between 2018 and 2031 through their affordable multifamily energy-efficiency programs. The study forecasted the possible gas and electric savings under current program and market constraints as well as the total cost-effective potential, including CPUC-approved non-energy benefit values, for four of the state's four investor-owned utilities (IOUs). These IOUs—San Diego Gas & Electric, Southern California Gas Company, Southern California Edison, and Pacific Gas and Electric—collectively provide energy services for approximately 75 percent of California's residents. The study uses Cadmus's market characterization and segmentation findings to model the energy-savings potential for the ESA-eligible multifamily sector. It further incorporates avoided cost and climate data specific to each investor-owned utility. The study did not include potential savings for publicly-owned utilities because their customers are not eligible for the ESA program. Optimal Energy characterized a comprehensive group of energy-efficiency technologies and practices. The study examined measures that addressed each primary residential end use (e.g., space heating, cooling, and lighting). These measures included, but were not limited to, building envelope improvements, efficient lighting systems and controls, and behavioral programs. Efficiency opportunities in common areas as well as within individual housing units were considered.

BW Research Partnership is an applied research firm that specializes in economic analyses of how industries, jobs, and technologies are changing and the corresponding impact on communities, organizations, and households.[13] Using its survey instrument, BW Research estimated median labor hours for the installation of the major energy-efficiency measures included in the potential analysis. It estimated the total number of jobs that would be created if the full cost-effective energy savings potential were achieved. The majority of this potential would be reached through efficiency measure installation jobs, including replacing or installing hot water heaters, cool roofs, and efficient washing machines. BW Research has conducted similar energy job potential analyses for the U.S. Department of Energy, including conducting the agency's first annual analysis of how changes in America's energy profile are affecting national employment in various energy sectors. The quality of jobs and level of inclusion in hiring practices to realize the job potential available is dependent on associated state, government agency, and business policies and contractual agreements.

Study Results

The projected electric and gas *achievable savings potential* under current regulatory and market constraints through 2031 is estimated to be 619 gigawatt hours (GWh) and 18 million therms (MMtherms); this is roughly equivalent to 16 percent of electric sales and 9 percent of gas sales to this sector.[14]

However, this study finds that ***economic potential* through 2031, the cost-effective potential if program design and regulatory constraints are optimized, is worth 934 GWhs of electricity and 37 MMtherms of natural gas.** This economic potential is equal to roughly 24 percent and 19 percent, respectively, of the affordable multifamily residential sector's current energy use.[15] The economic potential for electricity is 50 percent higher than currently defined as achievable and for gas, it is 100 percent more. Not capturing this full economic potential means the commission and utilities are leaving millions of dollars of bill savings and energy savings on the table.

Realizing these energy savings would avoid the emission of about 520,000 metric tons of carbon dioxide (CO_2) pollution by 2031. **This would be the equivalent of removing the pollution from more than 100,000 passenger vehicles from California's roads for one year and** would represent enough savings to **fully power nearly 120,000 affordable multifamily California homes** for one year.[16]

There would be an approximately two to one payback for accomplishing all of this. That is, **each dollar invested by the California IOUs and their customers in efficiency programs would result in $1.90 in benefits for Californians.**

If programs were designed to capture all cost-effective energy savings, not only would the energy savings and economic benefits be realized, but also numerous jobs could be created. The labor to install efficiency measures such as hot water heaters, cool roofs, and efficient washing machines is significant. BW Research's jobs analysis found that **pursuing**

the potential savings identified here could create more than 84,000 new job-years, or approximately 6,000 permanent installation jobs, a portion of which require highly skilled labor.[17]

These savings estimates only consider the savings potential in ESA-eligible multifamily properties. Potential energy savings in properties with fewer than five ESA-eligible units in IOU territories were not included, but there are more than 660,000 of such low-income households.[18] The estimates also do not include low-income households served by municipally owned utilities, such as those in Sacramento and Los Angeles. These and other conservative assumptions built into the study's methodology indicate that the true economic potential in California affordable multifamily properties is greater than this study estimates.

Savings Opportunities by Measure and Measure Type

The results of this study also indicate which types of efficiency measures hold the most savings potential. **This information can be used to design more effective, targeted programs.**

The five measures with the most impact for electric savings accounted for the majority of the economic potential. These measures, in order of impact, are the following:

1. Lighting: Standard LEDs (in-unit)
2. Plug Load: Advanced Power Strips, which include sensors that reduce energy consumption when no one is in the room
3. Refrigerators: Refrigerators (CEE Tier 3 and ENERGY STAR(®)
4. Efficient Clothes Washers in common areas
5. Plug Load: High Efficiency Set Top Cable Boxes/ DVRs

Fuel-switching measures were not considered in this study. However, it is important to note that electric heat pump water heaters hold a much greater water heating savings and greenhouse gas reduction potential than even the highest efficiency gas water heaters.[19] Apart from this readily available technology, the five measures with the most impact for natural gas savings are the following:

1. High Efficiency Gas Water Heaters
2. Low-Flow Showerheads
3. Low-Flow Faucet Aerators
4. Clothes Washers (common area, not in-unit)
5. Water Heater Tank Wrap

Key Opportunities Being Missed and Recommendations

The large gap between the available economic potential and the achievable potential indicates that significant opportunities remain to capture all cost-effective savings and co-benefits, which include water savings and avoided costs as a result of fewer utility disconnections. Essentially, the current ESA program budgets for multifamily housing are leaving too many savings on the table. Funding needs to be increased or repackaged to facilitate the implementation of measures that produce the most benefits to make energy bills more affordable for lower-income Californians.

Based on the study's results, we make the following recommendations, which, if implemented, are likely to help realize the savings identified in this study.

1. Set Sector-Specific Savings Goals Commensurate With True Potential, Not Forecasted Activity

The total economic potential that was found for the low-income multifamily subsector is as much as two times larger than the savings forecasted by the CPUC's Navigant Potential study for the entire low-income population.[20] This underscores the fact that until now, neither the commission nor any of its consultants have conducted a comprehensive and accurate potential analysis for the ESA population, instead basing projections on forecasts of utilities' currently planned activities.[21]

The results from this potential study should be used to align ESA's goal-setting process with what is expected of all other energy-efficiency programs in the state. The CPUC should use the study's estimated economic savings potential to establish binding energy savings goals for the ESA multifamily sector for each IOU. This will help bring about deeper bill savings to alleviate high energy cost burdens.

2 Update Measure Offerings for ESA-Eligible Multifamily Properties

This study provides a strong rationale for adding new measures to the ESA program, and for targeting the delivery of measures to specific climate or household needs.

For instance, this study identifies several high potential measures that are either not currently offered in the ESA program or are offered on an extremely limited basis, including the following:[22]

- High-efficiency gas water heaters
- Behavioral measures, such as home energy reports
- High-efficiency set top cable boxes

The study also identifies measures in common areas, such as the installation of LEDs, as having significant savings potential. Yet under current program rules, multifamily housing without rent restrictions on the deed of the property is ineligible for this highly impactful measure. We support broadening common area offerings to all low-income multifamily housing so long as protections are in place to prevent rent increases or evictions for tenants due to the property improvements.

Because of commission regulations, other very promising measures, such as providing replacement ENERGY STAR refrigerators, are only available for a limited group of ESA customers—those with refrigerators made before 2001. Adding these high impact measures would cost-effectively bridge the gap between the high energy burdens facing low-income Californians.

3 Increase Funding for Low-Income Multifamily Retrofits

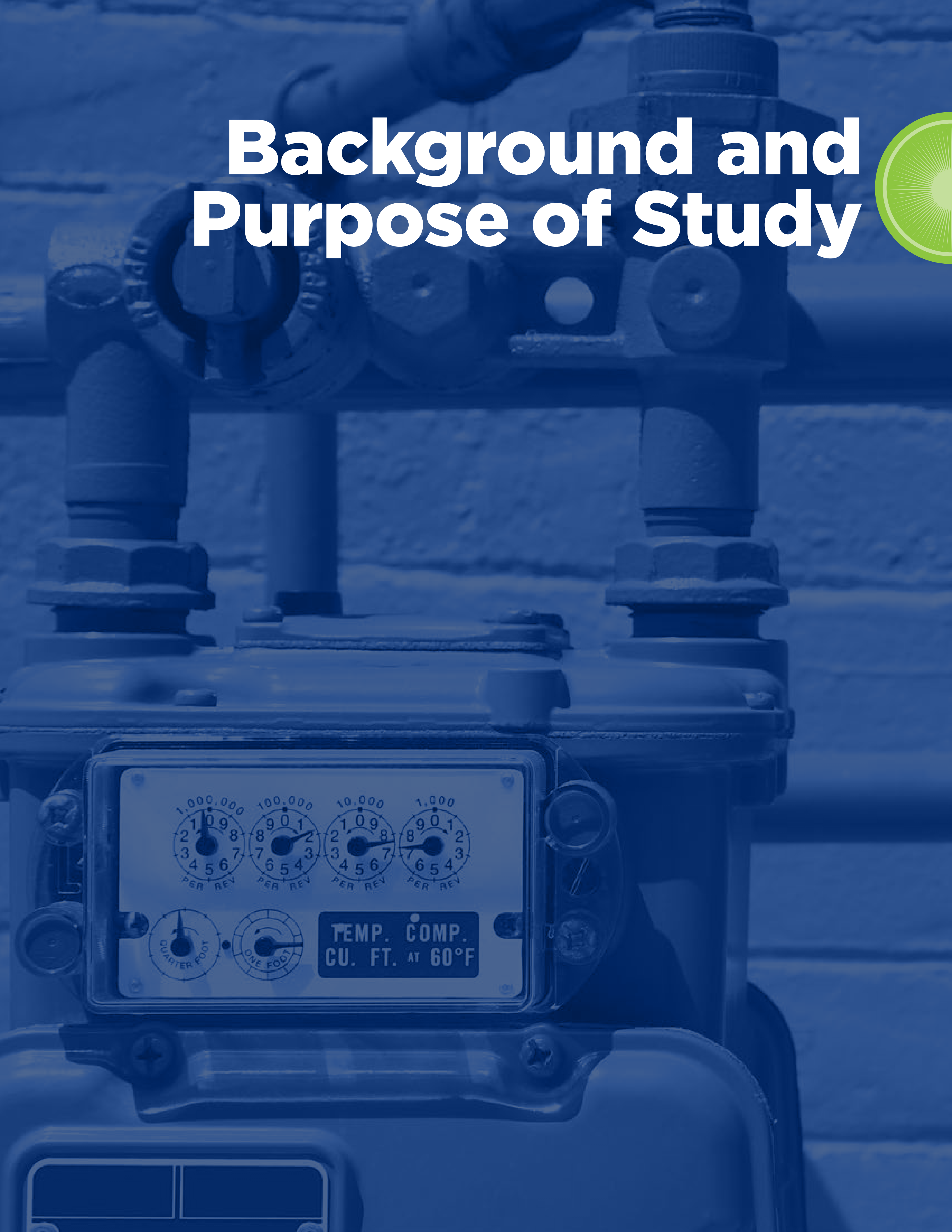
This study found that $2 billion worth of energy-efficiency benefits from both electric and gas measures could be available by 2031. To achieve these benefits, a total investment of $874 million between 2018 and 2031 would be required. Assuming energy-efficiency investments began in 2021, the year that the next ESA program cycle begins, this translates to about $90 million invested annually for 10 years. These total benefits and costs of cost-effective, energy-efficiency investments by 2031 are derived from the IOU-specific benefit and cost data presented in Tables 7 and 8 (for the year 2031). Because current investments in multifamily housing total approximately $20 million a year, this study provides a strong rationale for increasing funding for this sector by $70 million annually through 2030.

4 Take Advantage of Direct-Install Program Elements to Field-Test Innovative Measures

The ESA program has a stronger direct-install (DI) component than the rest of the state's energy-efficiency portfolios. Direct-install delivery channels entail extended contact with customers and offer important data gathering opportunities. This makes the ESA program an ideal avenue for field- testing new measures and intervention strategies. For instance, this study's modeling showed that set top boxes hold significant savings potential. Meanwhile, the IOUs haven't been able to launch a set top box program because of lingering questions about the right baseline assumptions.[23] Offering efficient set top boxes through the ESA DI delivery channel would enable the program to capture those savings while also collecting valuable information about what equipment was previously in place. This approach should be used to incorporate set top boxes and other innovative measures into the ESA program.

Overall, the results of this study can be used to improve on the current offerings for ESA-eligible residents in multifamily properties. By improving its offerings, the commission can ensure that California's energy-efficiency programs deliver on all available potential to reduce bills and improve the health, comfort, and safety of housing for renters.

Background and Purpose of Study



More effective, wider reaching energy-efficiency programs for low-income families reduce energy bills, improve health, comfort, and safety, and deliver deep greenhouse gas emission reductions and cleaner air for all Californians. Families on limited incomes currently bear a disproportionately high share of our nation's energy burden and often stand to benefit the most from energy-efficiency programs.[24] A family's energy burden is the portion of household income that is spent on energy costs. For example, a family that has a smaller income than its neighbor but must pay similar utility bills has a higher energy burden than its neighbor. A recent analysis by The American Council for an Energy-Efficient Economy and EEFA found that "the overwhelming majority of households with incomes below 80% of area median income, minority households, low-income households residing in multifamily properties, and renting households experienced higher energy burdens than the average household in the same city." Low-income families spend an average of twice as much as other families on energy.[25] In rural regions, low-income families spend three times as much as other families on energy.[26]

The state of California created the Energy Savings Assistance (ESA) Program to address this disparity, produce cost-effective energy-efficiency savings, and improve the quality of life for low-income customers.[27] The ESA program provides energy-efficiency upgrades at no cost to households earning 200 percent or less of the federal poverty guidelines. In 2017, a family of four that earned $49,200 or less per year qualified for the program.

While much progress has been made over the past 30 years, significant opportunities remain to reduce bills and provide health, comfort, and safety, especially for residents living in multifamily households. In California, 42 percent of households with incomes below the federal poverty line live in multifamily properties.[28] Furthermore, nationwide, "nearly all (93%) of very low-income households who live in multifamily housing units are renters... and in rented multifamily units, energy expenditures run 37% higher per square foot."[29]

EEFA commissioned this study by Optimal Energy to estimate the potential for cost-effective energy savings in multifamily properties that are eligible for California's ESA program.[30,31,32] The study includes properties with five or more units occupied by households with incomes equal to or less than twice the federal poverty threshold (e.g., an income of just

over $31,000 for a household of two), and that are served by the following major California investor-owned utilities (IOUs): Pacific Gas and Electric Company (PG&E), Southern California Edison (SCE), San Diego Gas & Electric Company (SDG&E), and Southern California Gas Company (SCG).[33]

This study focuses on net savings that could be achieved through energy-efficiency technologies and practices beyond assumed naturally occurring efficiency improvements through 2031.[34] The study provides two types of potential estimates:

Total Economic Potential: Savings that can be realized if all cost-effective efficiency measures are immediately implemented despite market barriers that may exist. This measure only takes into account the costs of efficiency measures themselves, ignoring any programmatic costs, such as marketing, analysis, administration, and evaluation that would be necessary to capture the measures' savings.

Achievable Potential: Savings that can be realized if all cost-effective efficiency measures are implemented assuming an aggressive deployment efforts, but limited by historical implementation and regulatory constraints. This is a subset of the economic potential calculated. It takes into account market barriers to adopting cost-effective, energy-efficiency measures, the non-measure costs of delivering programs (administration, marketing, tracking systems, monitoring, and evaluation), and the capability of programs and administrators to expand program activity over time.[35]

The ESA Program and the Purpose of This Study

The ESA Program, funded through a surcharge on all customers, provides subsidized energy-efficiency services to customers that earn 200 percent or less of the federal poverty guidelines. The program, which costs approximately $375 million annually, serves approximately 300,000 residents each year.[36] The four major California IOUs currently administer the ESA, which is overseen by the California Public Utilities Commission (CPUC), and is available to homeowners and renters, including those in single-family dwellings, multifamily dwellings, and mobile homes, living in the IOUs' service territories.[37] The statutory objective of the ESA program is to meet the need for weatherization as determined by the commission. The program's authorizing legislation also directs the commission to consider both the cost-effectiveness of utility services and the goal of reducing hardships facing low-income households.[38] This analysis focuses on ESA-eligible properties within the four major IOU service territories in California, which represent 75 percent of total electricity sales in the state.

While the ESA program covers low-income customers in all types of housing, in the past, multifamily tenants have not participated at levels representative of their proportion of the population.[39] In response, the CPUC, in recent years, has increasingly directed its attention to this sector. In 2012, the CPUC adopted a robust multifamily segment study of the ESA-eligible population and commissioned The Cadmus Group to characterize the ESA multifamily market to inform strategies that would improve ESA's efficacy in that sector and yield maximum energy savings at reasonable costs.[40] This was followed by a commission ruling adopting the findings of the Cadmus study, and providing guidance to utilities to design their 2015-2017 programs to achieve the overarching goals of ESA, with a focus on reaching the multifamily sector.[41]

In November 2016, the commission formally adopted new directives for the ESA program through 2020, including directing the IOUs to create a new $80 million program for common-area and whole-building measures in subsidized affordable housing, and setting energy savings targets by utility for the first time in the program's history.[42]

EEFA commissioned this study as a follow-up to the Cadmus study and the commission's 2016 ruling, to quantify the cost-effective savings available in all ESA-eligible multifamily households. The study results can be used to inform future budget setting and savings goals for the ESA program and individual utilities as well as overall program design, including measure selection and program delivery. The study uses Cadmus' market characterization and segmentation findings to model the energy savings potential for the ESA-eligible multifamily sector. It further incorporates avoided cost and climate data specific to each investor-owned utility.

Methodology

a. Overview of Methodology

Optimal Energy characterized a comprehensive group of energy-efficiency technologies and practices. The study looked at measures that addressed each primary residential end use (e.g., space heating, cooling, and lighting). Among these measures were building envelope improvements, efficient lighting systems and controls, and behavioral programs. Efficiency opportunities in common areas as well as within individual housing units were analyzed.

Table 1 summarizes the key elements of the study and the methodologies used for each. Appendix A describes all of the study's measure characterization parameters in greater detail.

Measure costs and energy savings were characterized per housing unit and then screened for cost-effectiveness. This study applied a modified Total Resource Cost (TRC) test consistent with the Energy Savings Assistance Cost-Effectiveness Test (ESACET) currently used for low-income programs in California. Like the TRC test, the ESACET includes all the costs (including incentives, participant share

TABLE 1. KEY ELEMENTS AND METHODOLOGIES

Elements	Methodology
Geography	This study covers the service territories of Pacific Gas and Electric (PG&E), San Diego Gas & Electric (SDG&E), Southern California Edison (SCE), and Southern California Gas (SCG), which represent 75 percent of California's utility sales.[43]
Time Frame	The study estimated cumulative savings potential from 2018 to 2031. This document reports cumulative potential for the years 2018 to 2021 and 2031. Cumulative potential for each year between 2021 and 2031 is available by request from NRDC.
Unit Counts	Adopted from the 2013 ESA Program Multifamily Segment Study[44]
Baseline Consumption	U.S. Energy Information Administration's 2009 Residential Energy Consumption Survey[45]
Energy Types	Electricity and natural gas
Non-Energy Benefits Scenarios	IOU-specific non-energy benefits used in ESA Program 2015-2017 application filings[46]
Avoided Costs	IOU-specific avoided costs adopted from the most recent E3 calculator[47]
Real Weighted Average Cost of Capital Discount Rate	IOU-specific real WACC discount rates:[48] • SCE - 7.65 percent • PG&E - 7.66 percent • SDG&E - 7.36 percent • SCG - 7.38 percent
Cost-Effectiveness Threshold	Threshold based on a benefit cost ratio of 0.5 using the ESA Cost Effectiveness Test (ESACET), which is a traditional Total Resource Cost test with non-energy benefits[49]
Measures	182 measures characterized, and 13,000 distinct combinations modeled
Energy Savings	Optimal Energy developed average sector-wide savings estimates for each measure. The study compiles data from more than 30 studies (including potential, market research, and technical reference manuals) listed in the Bibliography to characterize measures for savings potential analysis. The measure parameters characterized included unit energy savings, incremental cost, and effective useful life. NRDC analyzed the measure-level savings potential results, identified the highest energy saving measures for each end-use category, and worked with Optimal Energy to ensure that at least unit energy savings and measure penetration assumptions for these measures were aligned with California expectations.[50]

of measure cost, and program administrative costs) and benefits (e.g., value of all energy and capacity savings and other resource savings, such as reduced water consumption, and operation and maintenance savings) associated with the ESA program. In other words, the ESACET uses the TRC test as a foundation, and adds participant and utility non-energy benefits (NEBs) to account for health, safety, and comfort benefits.

The study assesses measure applicability by determining the portion of housing units in the market for which a given measure is technically feasible. The method for estimating costs and savings is explained in greater detail in the Applicability section in Appendix A.

The following step-by-step methodology was used in the study:

1. Estimated the number of multifamily units housing families with incomes at or below 200 percent of federal poverty guidelines, by utility service territory
2. Estimated baseline energy consumption for the period 2018 to 2031
3. Characterized all cost-effective efficiency measures, even those not currently authorized by the CPUC, with costs, savings, and effective useful life information

   Used the following location-dependent parameters for each IOU service territory:

   - lighting hours of use
   - measure cost adjustment
   - heating degree-days and cooling degree-days as proxy variables for heating and cooling demand (instead of using climate zones)
   - full load hour estimates for heating and cooling equipment
   - avoided energy supply costs
4. Developed a comprehensive measure list representing all pertinent combinations of measures, applications (e.g., natural replacement, natural renovation, and retrofit), and building size
5. Adjusted for measure interactions. (Installing insulation, for example, reduces heating loads, which can lower the savings from high-efficiency heating equipment.)
6. Incorporated utility-specific non-energy benefit adders, based on utility filings for the 2015-2017 ESA program cycle
7. Applied a 0.5 ESACET benefit cost threshold for each measure to determine whether total lifetime benefits exceed half of the lifetime costs. All failing measures were removed from the analysis. (See Appendix E.)
8. Developed penetration profiles for both the total economic and achievable scenarios
9. Established program costs. Incentive costs include direct financial assistance to participants. Non-incentive costs are all other costs to run a program, including those for administration and marketing.

b. Baseline Consumption

Optimal Energy developed annual energy consumption estimates for typical affordable multifamily housing units for each energy type (natural gas and electricity). Consumption estimates were primarily based on data from the U.S. Department of Energy's Renewable Energy Consumption Survey (RECS), a survey of household characteristics and energy use, representative of nationwide patterns.[51] RECS data was analyzed to estimate baseline energy sales by end use for residential properties in California with five or more units. While the baseline consumption estimates used are not specific to the affordable sector, they are consistent with affordable housing energy estimates in Fannie Mae's 2014 study.[52]

Because data for common-area use is not included in RECS, this study supplements that data set with recent studies that quantified common-area characteristics.[53] From this additional analysis, Optimal Energy estimated that an additional 10 percent of space heating, cooling, and water heating end-use energy is consumed in common areas. This methodology is further described in the following section.

The RECS data does not incorporate the impact of changes to federal lighting efficiency standards from the Energy Independence and Security Act of 2007. Therefore, to more accurately reflect the true lighting energy consumption in the base year of analysis, Optimal Energy developed a bottom-up estimate of lighting consumption per housing unit by multiplying the typical type, number, and wattage of lighting fixtures per unit by the assumed hours of use. Hours-of-use assumptions were derived from the NMR Group's Northeast Residential Lighting Hours-of-Use Study, 2014.[54] Lighting fixture types, counts, and wattages were developed from the measure characterization data sources. (See Bibliography and footnote 24.) The per-housing-unit consumption estimates were then multiplied by the number of units to estimate total baseline energy consumption by electric utility service territory.

c. Measure Characterization

Optimal Energy analyzed energy saving measures for each primary multifamily end use in common areas and individual units. For each measure, characterization parameters were primarily drawn from secondary sources, such as technical reference manuals (TRMs) and existing potential studies. For more complex measures not addressed by these sources, engineering calculations were used based on the best available data and the performance impacts of high efficiency equipment or practices. Measure costs were drawn from the sources mentioned above as well as from baseline studies, incremental cost studies, and direct pricing research. Effective useful lives of measures, operation and maintenance impacts (e.g., less frequent lamp replacements for new high efficiency fixtures because of improved operation and maintenance practices), and water impacts were generally developed from TRMs and potential studies. (See the Bibliography for a detailed list of all sources used.) A workbook with measure- and parameter-specific citations and values is available by request from NRDC.

The ESA Program Multifamily Segment Study was used to determine cooling appliance saturation and space heating and water heating fuel shares.[55] Existing equipment efficiency levels were primarily determined from RECS data and reviews of other recent baseline and equipment saturation studies.[56] As discussed above, the results from the ESA study and RECS data were used to develop representative average baseline equipment saturations and efficiencies. By adjusting RECS data, EEFA was able to incorporate common-area loads.

Estimating savings from measures installed in common areas or those measures associated with central building mechanical systems that serve common areas required estimating the common-area load associated with such central systems. Common-area lighting loads were estimated per fixture based on published ratios of in-unit to common-area lighting fixture counts in multifamily housing.[57] Fixture type distributions, estimated average wattage, and annual operating hours estimates were used to derive the common-area lighting loads per unit.[58]

Similarly, common-area, water heating loads were developed by estimating the water requirements from commercial clothes washing equipment installed in common areas.[59] The total water heating load per unit was developed using a variety of sources. The inputs used include typical assumptions for water heating efficiency, estimates of annual clothes washer energy consumption and distribution (portion of energy used to heat water versus operate the machine itself), and the estimated number of clothes washers per unit.[60] There was no location-based normalization for water temperature. Finally, the study assumes that 10 percent of a building's space heating and cooling end-use consumption serves common areas.[61] This

TABLE 2. END USES AND MEASURES INCLUDED IN THE ANALYSIS	
End Use	**Parent Measure Name**
MULTIFAMILY ELECTRIC	
Appliances	Electric Dryer With Moisture Sensor (In-Unit) and Freezer
Cooling	Central AC Tune-Up, Cool Roofs, Efficient In-Unit Central AC, Efficient Windows, Proper Central AC Sizing, Proper Central Heat Pump sizing, and Window Film
Heating and Cooling	Air Sealing, Basement Wall Insulation, Central HP Tune-Up, Duct Sealing and Insulation, Efficient In-Unit Central HP, Wall Insulation, and Wi-Fi Thermostat
Lighting	High Efficiency Common Area Lighting: Linear Fluorescent Lighting; LED Exit Sign; Lighting Controls; Common, Outdoor, and Parking Area Lighting; Specialty Lighting (In-Unit); Standard LED (Common Area); and Standard LED (In-Unit)
Plug Loads, Consumer Electronics, Other	Advanced Power Strip, Dehumidifier, Efficient Furnace Fans, and High-Efficiency Set Top Box
Refrigerators	Refrigerator (CEE Tier 3) and Refrigerator (ENERGY STAR)
Space Heating	Efficient Windows and Wi-Fi Thermostat
Water Heating	Clothes Washer (In-Unit), Commercial Clothes Washer (Common Area), Dishwasher, Heat Pump Water Heater, High Efficiency Electric Water Heater (Electric Resistance, 0.94 Energy Factor), Low-Flow Faucet Aerator, Low-Flow Showerheads, Water Heater Pipe Wrap, and Water Heater Tank Wrap
Whole Building	Behavioral and Retrocommissioning, HVAC Controls[62]
MULTIFAMILY GAS	
Space Heating	Clothes Washer (In-Unit), Commercial Clothes Washer (Common Area), Dishwasher, High Efficiency Gas Water Heater, Low-Flow Faucet Aerator, Low-Flow Showerheads, Water Heater Pipe Wrap, and Water Heater Tank Wrap
Water Heating	Clothes Washer (In-Unit), Commercial Clothes Washer (Common Area), Dishwasher, High Efficiency Gas Water Heater, Low-Flow Faucet Aerator, Low-Flow Showerheads, Water Heater Pipe Wrap, and Water Heater Tank Wrap
Other	Gas Dryer with Moisture Sensor (In-Unit)

10 percent value, an assumption supported by the literature, is the best available estimate of common area as a percentage of total multifamily building area. This estimate was used with the in-unit heating and cooling consumption estimates to develop common-area heating and cooling loads on a per-housing unit basis.

The research provided an estimate of the individual affordable multifamily housing units rather than a discrete estimate of the total number of affordable multifamily properties. Therefore, all common area loads were reported in per-unit terms. For space heating, this involved apportioning the output capacity of the central heating plant equally among all of the units in a given building.

Table 2 presents a list of end uses and measures included in this analysis for electricity and natural gas end uses.

A total of 278 measures were characterized.[63] Individual measure parameters used in this characterization are available upon request from NRDC.

d. Model Framework

Once all parameters were defined at the measure level, iterations of each measure were modeled for each appropriate combination of market, building size, and utility service territory. This process yielded nearly 800 distinct combinations for each year of the analysis.

Beginning with the total housing unit count for each utility, Optimal Energy applied a number of calculations to narrow the unit count down to the population of housing units for which a given measure applies. This total number of measure-applicable housing units is calculated as the product of total units (for a given utility and building size), the fuel share (depending on measure fuel and end use), AC saturation, applicability, and not complete factors (or annual turnover for replacement measures). For example, consider the Efficient In-Unit Furnace replacement measure in PG&E's service territory in 5 to 49 unit properties. The calculation above shows the number of applicable units for this measure.

INPUTS AND ASSUMPTIONS:

Total number of units in 5-49 unit properties in PG&E's territory (Units): **274,882**

Space heating fuel share for gas in 5-49 unit properties (Fuel Share): **49%**

AC Saturation: **N/A**[64]

Applicability: **33%**[65]

Turnover: **5%**

ALGORITHM:

Applicable Units = Units x Fuel Share x AC Saturation x Applicability x Turnover

= 274,882 x 49% x 33% x 5% = 2,222

This means that, annually, a total of 2,222 units in 5 to 49 unit properties in PG&E's territory are eligible for the Efficient In-Unit Furnace replacement measure. Total potential is then estimated by multiplying this value by the per housing unit costs and savings estimates and the appropriate market penetration assumptions. This is discussed in more detail in the Economic and Maximum Achievable Potentials section below.

e. Cost-Effectiveness

The ESACET is the threshold test for measure inclusion for the ESA program; it screens energy-efficient measures for cost-effectiveness. It was used to develop estimated costs and benefits for the measures in this study. Costs and savings for each measure were characterized per housing unit.[66]

The economic potential portion of the study assessed the cost-effectiveness of measures without consideration of the program support necessary to overcome market barriers. In other words, only the incremental costs of the measures themselves, as opposed to program spending, were included in the ESACET calculations. Because incentives represent a cost to the program administrator and a benefit to participants, they are a transfer payment, effectively canceling each other out. This is why they are excluded from the calculations, in accordance with CPUC practice. Estimated non-incentive costs were included only in the cost-effectiveness screening of the maximum achievable potential.

The program administration non-incentive costs were considered at a portfolio level for maximum achievable potential: these program administration costs are a good way to represent the real-world limits of any one program's ability to reach customers. These costs include general administration; technical assistance; marketing; evaluation, measurement, and verification; and performance incentives to add new measures to an IOU's ESA program portfolio. Research on leading programs across the country suggests that non-incentive budgets are approximately 20 percent of incentive spending in the United States.[67] This study applies that 20 percent ratio of non-incentive to incentive costs to estimate the incentives for all measures in this study.

The most important benefits are the energy savings throughout the measures' lifetimes. (Non-energy benefits are described in a later section.) Energy savings estimates include interactive effects. For instance, efficient lighting reduces waste heat, which reduces the cooling load but increases the heating load. All of these impacts are accounted for in estimating a measure's costs and benefits over its lifetime.

Table 3 shows the costs and benefits considered in the ESACET.

i. Avoided Costs

Avoided costs of energy and capacity are taken into account in assessing the relative cost-effectiveness and value of energy savings. These costs, expressed per megawatt hour for electric measures and per therm for gas measures, are multiplied by the energy savings potential to estimate total energy resource benefits.

The Optimal Energy analysis used avoided cost data for each IOU along with the Energy+Environmental Economics' (E3) Energy Efficiency Calculator to compute the cost-effectiveness of energy-efficiency programs.[69] This data presented the electric avoided costs by component (i.e., generation, transmission, and distribution), sector (i.e., residential and nonresidential), measure (e.g., CFL lighting, refrigerators, and heat pumps), and climate zone for each quarter of each year from 2013 to 2037.

For electric measures, Optimal Energy calculated the simple average of the electric avoided costs for each measure across each of the climate zones for both the generation and the transmission and distribution (T&D) components.[70] Optimal Energy then added the quarterly generation to the T&D avoided costs to develop simplified annual avoided costs by end use and measure. Finally, because the analysis uses simplified avoided costs that include the impacts of both generation and T&D, it developed two sets of avoided costs. The first set applies to measures with demand savings that are usually highly coincident with system peak. This set of avoided costs was developed by calculating the straight average of the

TABLE 3. OVERVIEW OF THE ESACET[68]

Evaluated Factors	Cost-Effectiveness
Incremental Measure Costs	Cost
Administrative Non-Incentive Costs	Cost
Avoided Electric and Capacity (Demand, Transmission & Distrib) Costs	Benefit
Operations and Maintenance	Benefit
Deferred Replacement Credit*	Benefit
Non-Energy Benefits	Benefit
Avoided Natural Gas Costs**	Benefit

* The Deferred Replacement Credit is available for early-retirement retrofit measures, measures that obviate or delay the need for the replacement of existing equipment.

** In certain cases, measures can increase the consumption of secondary fuels (e.g., efficient lighting reduces waste heat, thereby increasing space heating loads). This analysis accounts for such increases as negative benefits in the calculation of ESACET benefit-cost ratios.

measures that apply to the space cooling end use in the E3 avoided cost data. The second set applies to measures that reflect average peak coincidence; these were calculated as the straight average of the remaining measures. Which set of avoided costs were used for a given measure was determined by the peak coincidence factor parameter described in Appendix A.

The process was more straightforward for gas avoided costs, which were calculated as the sum of the commodity and T&D cost components in the E3 calculator. The study incorporates the annual avoided gas costs for the commercial sector as a proxy for the multifamily sector.

Tables 7-8 and 11-12 in the Results section present the final avoided costs.

ii. Non-Energy Benefits

Optimal Energy used the non-energy benefits (NEBs) claimed by the IOUs in their 2015-2017 ESA program applications. For each utility, the sum of the total resource benefits and NEBs were divided by the total resource benefits. This produced a utility-specific avoided cost multiplier. For example, SCG reported a planned $59.1 million in gas resource benefits and $88.6 million in non-energy benefits in 2017. Dividing the sum of the resource benefits and NEBs by the resource benefits yields a value of 2.5 (i.e., [59.1+88.6]/59.1 = 2.5).

If an IOU reported both electric and gas savings, the NEBs were apportioned relative to the respective magnitudes of the resource benefits. The electric and gas avoided costs were then multiplied by these factors, represented in Table 4 below, to account for the impact of NEBs on the ESACET. For example, consider a measure installed in SDG&E's service territory. In 2016, the simplified electric avoided costs are $0.126/kWh. The NEBs are approximated by multiplying these avoided costs by 2.08 (from Table 4 below for SDG&E). Therefore, the measure benefits including both energy and NEBs are $0.263/kWh ($0.126/kWh x 2.08 = $0.263/kWh).

TABLE 4. NEB MULTIPLIERS

IOU	Electricity	Gas
SCE	1.21	2.55
PG&E	1.90	1.90
SDG&E	2.08	2.08
SCG	1.21	2.55

f. Economic and Maximum Achievable Potentials

i. Modeling the Total Economic Potential

The total economic potential estimate assesses the cost-effectiveness of measures without considering the program support necessary to overcome market barriers. In other words, only the incremental costs of the measures themselves, as opposed to total program spending, are reflected in the costs to achieve the economic potential.

To estimate the total economic potential, the study assumes all cost-effective measures are implemented at the natural equipment turnover rate for natural replacement measures (which are known as "replace on burnout" in California) and immediately for retrofit measures. Turnover is the percentage of existing equipment that would be ordinarily replaced each year because of failure, remodeling, or renovation. We assume turnover factors are one (1) divided by the baseline equipment measure life. For example, we assume that 5 percent of existing equipment is replaced each year for a measure with a 20-year estimated life. For measures that can be implemented as both natural replacements and retrofits, we assume the retrofit opportunities take precedence. Upon expiration of the retrofit measure life, those opportunities become available as normal replacements. In effect, 100 percent of the cost-effective opportunities are captured over the analysis period.

ii. Modeling the Achievable Potential

The primary focus of this study is the total economic potential in the multifamily sector in order to help focus policy on achieving the full economic potential by addressing market barriers. However, we also recognize the difficulty of reducing these barriers and the merits of providing estimates based on existing program designs. In light of these issues, Optimal Energy also developed an estimate of the achievable potential, a subset of the economic potential that takes into account market barriers. Achievable potential is attained by applying penetration rates that are based on EPRI projections.[71] For market-driven replacements, penetration rates are multiplied by the rate of turnover to estimate the eligible market in each year.[72]

For program budgets, Optimal Energy estimated non-incentive costs (e.g., general administration; technical assistance; marketing; and evaluation, measurement, and verification) using overhead adders, expressed as a percentage of incentive costs and based on the experience of leading programs serving the low-income residential sector.

g. Job Creation Potential

The multifamily energy-efficiency retrofit jobs estimates were derived from the median labor hours for 49 different energy-efficiency measures. BW Research Partnership determined which measures should be included for the analysis based on the measures included in this energy savings potential analysis; the final list included a variety of measures ranging from the installation of commercial clothes washers and dryers to the replacement of standard roofing with cool roofing. The research team then created a comprehensive survey that was distributed, through a web link, to energy-efficiency industry employers in California.

It included questions related to revenue and workforce characteristics, such as employer awareness of specific rebates or incentives and hiring difficulties, employee affiliation with unions, and education and experience requirements. Employers were asked to assign the number of labor hours to complete each measure in a typical energy-efficiency project. The median response was used for each measure and median labor hours were applied to building stock data in California. Depending on the measures, median labor hours were applied to total units, buildings, or square footage. For example, median labor hours for measures that were done on a per-unit basis, such as replacing refrigerators, showerheads, windows, or thermostats, were applied to total unit counts. Similarly, median labor hours for measures performed on a square footage basis, such as air sealing, wall insulation, or duct sealing, were applied to total square footage. And, the median labor hours for building-specific measures such as central A/C or heating, roofing, or centralized lighting, were applied to building counts. The hours-per-job estimate used to convert total job hours to total jobs was 1,875.

Installation accounted for the vast majority of hours. This study did not include an analysis of the quality of jobs and level of inclusion for hiring to realize this full job potential. These factors are dependent on commission, state, and local policy as well as utilities' and other related businesses' contractual terms.

h. Summary of Study Assumptions and Limitations

As in any potential study, it was necessary to make certain assumptions about inputs for this model. Optimal Energy made several conservative assumptions that most likely resulted in an under-estimation of the savings potential. We describe below some of the most important assumptions that were made.

1. Some efficiency opportunities (e.g., customized boiler controls and energy recovery ventilators) were not characterized, primarily because of the lack of available baseline and applicability data.
2. Demand response potential, savings from programs that encourage customers to shift or change their power consumption to better match their demand for power with supply, was not included.

3. In accordance with current ESA program practices, no fuel substitution measures were included. This leaves out some of the most efficient new technologies currently available (such as heat pumps for water and space heating) and significantly reduces savings potential. In light of California's increasingly renewable electricity supply, not including fuel substitution measures also underestimates the potential for greenhouse gas (GHG) reductions.

4. Measures were screened at the measure level rather than at the IOU portfolios' level, and those not found to meet an ESACET threshold of 0.5 were excluded. This approach leads to particularly conservative estimates given that the ESA program is evaluated at the portfolio level and has historically included measures with thresholds as low as 0.25.[73]

5. Efficiency measures were evaluated assuming average baseline conditions across an entire service territory. Savings would have been higher if measures were installed strategically (e.g., by climate zone or targeted to nonworking or inefficient equipment). For example, average climate parameters were assumed for each IOU service territory. This approach omits the explicit characterization of climate extremes; there would most likely be cases in which certain measures would pass the cost-effectiveness screening or yield higher savings, or both, if they were analyzed specifically for warmer or cooler regions.

6. The avoided costs used in this study are conservative because they do not include costs for externalities, such as air quality or reduced greenhouse gas emissions, and do not include the avoided costs of price suppression, or demand reduction induced price effects (DRIPE). Shortly before the release of this study, the CPUC adopted a GHG-adder that incorporates some of the environmental externalities into its standard cost-effectiveness tests.[74,75] However, these values were not available in time to be used for this study.

7. This study is limited to estimated potential savings opportunities in existing properties. New construction, including new additions to the housing stock that might be eligible for subsequent retrofit activities, is not addressed in this study.

Results

The study results highlight the energy-efficiency measures that are the most cost-effective and provide the greatest potential electric and natural gas savings for California.

a. Total Economic Potential

i. Savings

The study found slightly more than 934 GWhs and slightly less than 37 million therms of total economic savings potential. This potential is roughly 24 percent and 19 percent of the affordable multifamily residential sector's current respective electric and gas use and would represent enough savings to fully power nearly 120,000 affordable multifamily California homes for one year.[76] Table 5 and 6 present the cumulative electric and gas savings potential for selected years for the economic potential scenario. For each year, the potential estimates represent the cumulative savings potential for all active measures installed from the first year of analysis through that year.[77] Savings are presented both in units of fuel (i.e., MWh and therms) and as percentages of total electricity or gas sales to ESA-eligible multifamily housing. While the quantity of energy savings varies by IOU, the percentage of average total energy savings in ESA-eligible units is about the same for each IOU.[78]

TABLE 5. TOTAL ECONOMIC POTENTIAL FOR ELECTRIC MEASURES IN ESA-ELIGIBLE MULTIFAMILY (MF) BUILDINGS FROM 2018 THROUGH 2031 FOR CALIFORNIA'S IOUS

		2018	2019	2020	2021	2031
PG&E	MWh	476,822	503,482	530,141	556,800	428,241
	Share of total ESA MF Sales	27.5%	29.0%	30.6%	32.1%	24.7%
SDG&E	MWh	147,935	156,201	164,468	172,734	132,788
	Share of Total ESA MF Sales	27.5%	29.1%	30.6%	32.1%	24.7%
SCE	MWh	416,450	440,172	463,895	487,617	372,982
	Share of Total ESA MF Sales	27.0%	28.5%	30.1%	31.6%	24.2%
Total	**MWh**	**1,041,207**	**1,099,855**	**1,158,504**	**1,217,151**	**934,011**

TABLE 6. TOTAL ECONOMIC POTENTIAL FOR NATURAL GAS MEASURES IN ESA-ELIGIBLE MULTIFAMILY (MF) BUILDINGS FROM 2018 THROUGH 2031 FOR CALIFORNIA IOUS

		2018	2019	2020	2021	2031
PG&E	1000 therms	9,270	9,617	9,964	10,312	12,719
	Share of Total ESA MF Sales	14.1%	14.6%	15.2%	15.7%	19.4%
SDG&E	1000 therms	2,986	3,094	3,201	3,309	4,057
	Share of Total ESA MF Sales	14.7%	15.2%	15.7%	16.3%	19.9%
SCG	1000 therms	14,555	15,102	15,648	16,195	19,979
	Share of Total ESA MF Sales	14.1%	14.6%	15.2%	15.7%	19.4%
Total	**1000 therms**	**26,811**	**27,813**	**28,813**	**29,816**	**36,755**

Increased efficiency in baseline lighting and other technologies from updated appliance standards and building codes is the main reason for the decline in electric savings potential in 2031.[79] As advanced lighting is mandated by building codes and appliance standards, the savings potential formerly held by those technologies becomes part of the baseline conditions. This, combined with the retirement of retrofit measures installed in the first year of the study time frame—and therefore the loss of that savings potential as well—leads to the reduction in cumulative potential seen in 2031.

Using the CPUC's estimate for marginal CO_2 emissions from utility electricity and the California Air Resources Board's value for CO_2 emissions from natural gas burned in the home, this study finds that capturing all of the savings would avoid emitting 520,000 metric tons of carbon into California's air. This is equivalent to removing the pollution from more than 100,000 vehicles from California's roads for a year.[80]

ii. Costs and Benefits

Even though the measure-specific threshold used for this analysis for measure inclusion is 0.5, collectively all of the measures included in the economic potential estimate exceed a 1.0 threshold. Table 7 and 8 show the cumulative life cycle benefit-cost ratios of the modeled economic potential savings. The total benefit-cost ratio for all electric and gas economic potential available up to 2031 is approximately 2.0.

Individual customer savings will vary depending on what measures are installed and what utility rates apply to each customer. However, in aggregate, ESA multifamily customers stand to save between $136 million and $200 million if all the savings identified here are realized.[81]

TABLE 7. TOTAL ECONOMIC POTENTIAL COSTS AND BENEFITS FOR ELECTRICITY MEASURES BY IOU TERRITORY, UTILITY RISK DISCOUNT RATE (PRESENT VALUE MILLION 2017$) FOR MEASURES INSTALLED IN DESIGNATED YEAR (I.E., INCREMENTAL)

	2020				2030			
	Costs	Benefits	Net benefits	BCR	Costs	Benefits	Net benefits	BCR
PG&E	$492	$1,033	$541	2.1	$253	$700	$448	2.8
SDG&E	$143	$347	$201	2.4	$74	$244	$170	3.3
SCE	$401	$583	$182	1.5	$201	$372	$171	1.8

TABLE 8. TOTAL ECONOMIC POTENTIAL COSTS AND BENEFITS FOR GAS MEASURES BY IOU TERRITORY, UTILITY RISK DISCOUNT RATE (PRESENT VALUE MILLION 2017$) FOR MEASURES INSTALLED IN DESIGNATED YEAR (I.E., INCREMENTAL)

	2020				2030			
	Costs	Benefits	Net benefits	BCR	Costs	Benefits	Net benefits	BCR
PG&E	$260	$314	$54	1.2	$260	$149	$448	2.3
SDG&E	$110	$122	$12	1.1	$109	$41	$170	1.6
SCE	$383	$539	$156	1.4	$501	$335	$171	3.0

iii. Savings by Measure Type

The top five most impactful measures for electric savings across all utilities accounted for the majority of the economic potential. These measures, in order of impact, follow:

1. Lighting: Standard LED (in unit)
2. Plug Load: Advanced Power Strips
3. Refrigerators: Refrigerators (CEE Tier 3 and ENERGY STAR)
4. Water Heating: Clothes Washers (Common Area, not in-unit)
5. Plug Load: High Efficiency Set Top Cable Box/ DVR

Per current ESA program practice, fuel switching measures were not considered in this study. However, it is important to note that electric heat pump water heaters offer much greater water heating savings and GHG reduction potential than even the highest efficiency gas water heater.[82] In the absence of this readily available technology, the top five most impactful measures for natural gas savings are the following:

1. Water Heating: High Efficiency Gas Water Heater
2. Water Heating: Low-Flow Showerheads
3. Water Heating: Low-Flow Faucet Aerator
4. Water Heating: Clothes Washers (Common Area, not in-unit)
5. Water Heating: Water Heater Tank Wrap

Figures 1 and 2 show the representative end-use distribution for economic potential savings found for the first year. Electric savings measures were dominated by lighting, plug load, and controls while natural gas saving measures were dominated by water heating. While the majority of characterized measures passed the chosen ESACET cost-effectiveness threshold of 0.5, there were measures that did not meet the threshold. These measures, which were not part of the economic potential estimate, included wall insulation, electric heat, basement wall insulation, efficient windows, gas heat, and boiler economizers.

FIGURE 1. TOTAL ECONOMIC POTENTIAL FOR ELECTRIC SAVINGS BY MEASURE TYPE IN 2018

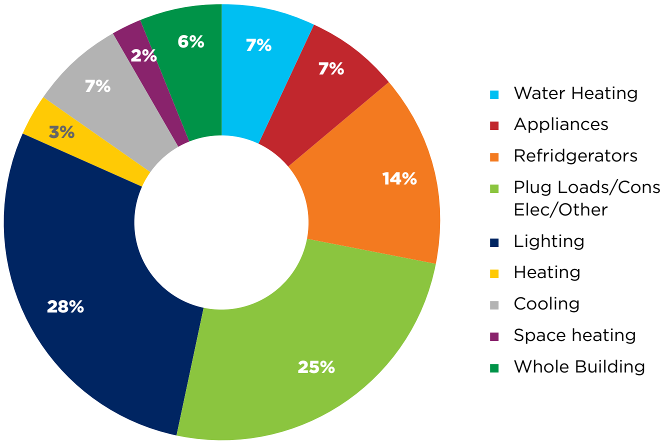
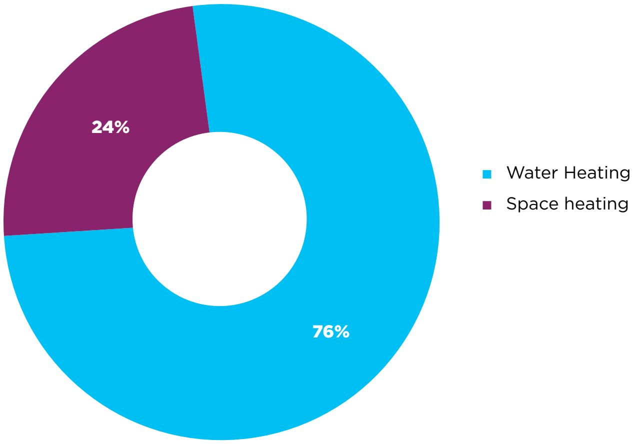


FIGURE 2. TOTAL ECONOMIC POTENTIAL FOR NATURAL GAS SAVINGS BY MEASURE TYPE IN 2018



b. Achievable Potential

i. Savings

The achievable potential is a subset of the economic potential. Achievable potential is calculated by applying the methodology described in Section 2.f. Table 9 and 10 show the cumulative electric and gas savings for selected years for the achievable potential scenario. For each year, the potential estimates represent the cumulative savings potential for all active measures installed from the first year of analysis through that year.[83] These tables show savings that are lower than the economic potential for that year because of market and regulatory barriers. These estimates could be lower or higher depending on the individual IOU's approach for achieving its specific household targets, overall budget, and timelines.

TABLE 9. ACHIEVABLE POTENTIAL FOR ELECTRIC MEASURES IN ESA-ELIGIBLE MULTIFAMILY (MF) BUILDINGS FROM 2018 THROUGH 2031 FOR CALIFORNIA IOUS.

		2018	2019	2020	2021	2031
PG&E	MWh	56,944	90,545	132,772	182,007	282,207
	Share of Total ESA MF Sales	3.3%	5.2%	7.7%	10.5%	16.3%
SDG&E	MWh	17,658	28,079	41,175	56,442	87,506
	Share of Total ESA MF Sales	3.3%	5.2%	7.7%	10.5%	16.3%
SCE	MWh	50,554	80,247	117,559	161,076	249,668
	Share of Total ESA MF Sales	3.3%	5.2%	7.6%	10.4%	16.2%
Total	**MWh**	**125,156**	**198,871**	**291,506**	**399,525**	**619,381**

TABLE 10. ACHIEVABLE POTENTIAL FOR NATURAL GAS MEASURES IN ESA-ELIGIBLE MULTIFAMILY (MF) BUILDINGS FROM 2018 THROUGH 2031 FOR CALIFORNIA IOUS.

		2018	2019	2020	2021	2031
PG&E	1000 therms	198	520	937	1,414	6,205
	Share of Total ESA MF Sales	0.3%	0.8%	1.4%	2.2%	9.4%
SDG&E	1000 therms	63	166	298	450	1,953
	Share of Total ESA MF Sales	0.3%	0.8%	1.5%	2.2%	9.6%
SCG	1000 therms	310	818	1,471	2,220	9,619
	Share of Total ESA MF Sales	0.3%	0.8%	1.4%	2.2%	9.3%
Total	**1000 therms**	**571**	**1,504**	**2,706**	**4,084**	**17,777**

ii. Costs and Benefits

Tables 11 and 12 show the cumulative maximum achievable energy efficiency potential costs and benefits for each IOU, in terms of present value in 2017 dollars, for measures installed up to 2021. In aggregate, the benefit-cost ratio is approximately 2.0 up to 2031 for both gas and electric cumulative energy savings potential.

TABLE 11. ACHIEVABLE POTENTIAL COSTS AND BENEFITS FOR ELECTRICITY MEASURES BY IOU TERRITORY, UTILITY RISK DISCOUNT RATE (PRESENT VALUE2017 $ MILLIONS) FOR MEASURES INSTALLED IN DESIGNATED YEAR (I.E., INCREMENTAL)

	2020				2030			
	Costs	Benefits	Net benefits	BCR	Costs	Benefits	Net benefits	BCR
PG&E	$86	$241	$155	2.8	$167	$399	$232	2.4
SDG&E	$25	$81	$56	3.2	$50	$139	$89	2.8
SCE	$71	$134	$63	1.9	$138	$216	$78	1.6

TABLE 12. ACHIEVABLE POTENTIAL COSTS AND BENEFITS FOR NATURAL GAS MEASURES BY IOU TERRITORY, UTILITY RISK DISCOUNT RATE (PRESENT VALUE MILLION 2017 $ MILLIONS) FOR MEASURES INSTALLED IN DESIGNATED YEAR (I.E., INCREMENTAL)

	2020				2030			
	Costs	Benefits	Net benefits	BCR	Costs	Benefits	Net benefits	BCR
PG&E	$34	$41	$7	1.2	$97	$142	$45	1.5
SDG&E	$14	$15	$1	1.1	$37	$53	$16	1.4
SCE	$51	$71	$20	1.4	$123	$251	$128	2.0

c. Job Creation Potential

BW Research estimated that achieving the total economic potential identified here would create a total of 84,094 full-time job years. A job year is defined here as the equivalent of full-time employment for one person for one year. That means an average of approximately 6,000 full-time jobs would be created per year of the study's time frame of 2018 to 2031. Specific full-time equivalencies per job activity are available from NRDC by request.

Recommendations and Conclusion

EEFA undertook this potential study to better understand the savings opportunities being missed in California's ESA-eligible multifamily properties. The study found significant potential to reduce the energy use and associated financial burden for ESA-eligible families living in multifamily buildings.

The striking difference between total economic potential and the achievable savings forecasted based on current program penetration underscores the importance of updating how California implements energy-efficiency programs aimed at this demographic.

EEFA is committed to working with the CPUC and IOUs to design better programs for all low-income multifamily residents. The following recommendations, if implemented, are likely to help realize the potential savings identified in this study.

1 Set Sector-Specific Savings Goals Commensurate With True Potential, Not Forecasted Activity

Historically, the ESA program has not had to meet CPUC-mandated savings goals. In a significant step forward, the CPUC established the first ESA savings targets in 2016.[84] However, those targets were not based on an accurate or full potential study.[85] Rather, the ESA targets are based on IOU forecasted and planned activity. This sets the program apart from the rest of California's energy-efficiency portfolios, which must deliver an ambitious but achievable percentage of cost-effective savings as determined by regular potential studies. As a result, the total economic potential that was found for the low-income multifamily subsector is as much as two times larger than the savings forecasted by the CPUC's Navigant Potential study for the entire low-income population.[86] This underscores the fact that until now, neither the commission nor any of its consultants have conducted a true potential analysis for the ESA population.[87]

The results from this potential study should be used to align ESA's goal-setting process with what is expected of all other energy-efficiency programs in the state. ***The CPUC should use the study's estimated economic savings potential to establish binding energy savings goals for the ESA multifamily sector for each IOU.*** The achievable potential should not be used, since that value is limited by the program's historically low penetration in this market segment and does not encourage adapting program designs to achieve what is possible.

Measures that are offered exclusively for health, safety, and comfort and do not offer energy savings can be excluded from the savings target. In this way, the program would be designed to achieve the greatest bill reductions possible, while also protecting for health, comfort, and safety improvements.

2 Update Measure Offerings for ESA-Eligible Multifamily Properties

The current CPUC potential model estimates average measure savings for the combined residential and ESA-eligible sectors. These average estimates miss opportunities to target measures toward specific subsectors (i.e., older multifamily properties in specific climate zones) where they may be more cost-effective and able to deliver more savings. Refrigerator recycling, for example, may no longer be cost-effective for the average California resident, but could be a cost-effective measure if it were aimed exclusively at the affordable multifamily sector.

This study used measure savings estimates that are specific to the ESA-eligible multifamily sector, including the appliance recycling measure mentioned above. We recommend these values be incorporated when revising the ESA program. This will help the program deliver more savings for each multifamily household that participates.

To assist with capturing targeted savings opportunities, we further recommend that the results of this study be used to inform updates to the commission's policy and procedures manual and its installation manual, which set criteria and eligibility specifications for measure replacements, based on the age of a previous measure, among other factors.

Other major opportunities that are currently being missed in this sector are savings in the common areas of multifamily properties. Up until recently, ESA was not authorized to make even the most easily achieved and beneficial upgrades in common areas, for example, hallway lighting. Significant other energy use, such as air conditioning, also occurs in common areas. The restriction on common-area savings was recently removed for a subset of deed-restricted multifamily properties. Efforts to take advantage of these newly available common-area opportunities as well as to make the achievable savings opportunities available to the entire multifamily population eligible for the ESA program should be accelerated—so long as protections are in place to prevent rent increases or evictions for tenants that arise due to the energy efficiency improvements.

3 Increase Funding for Low-Income Multifamily Retrofits

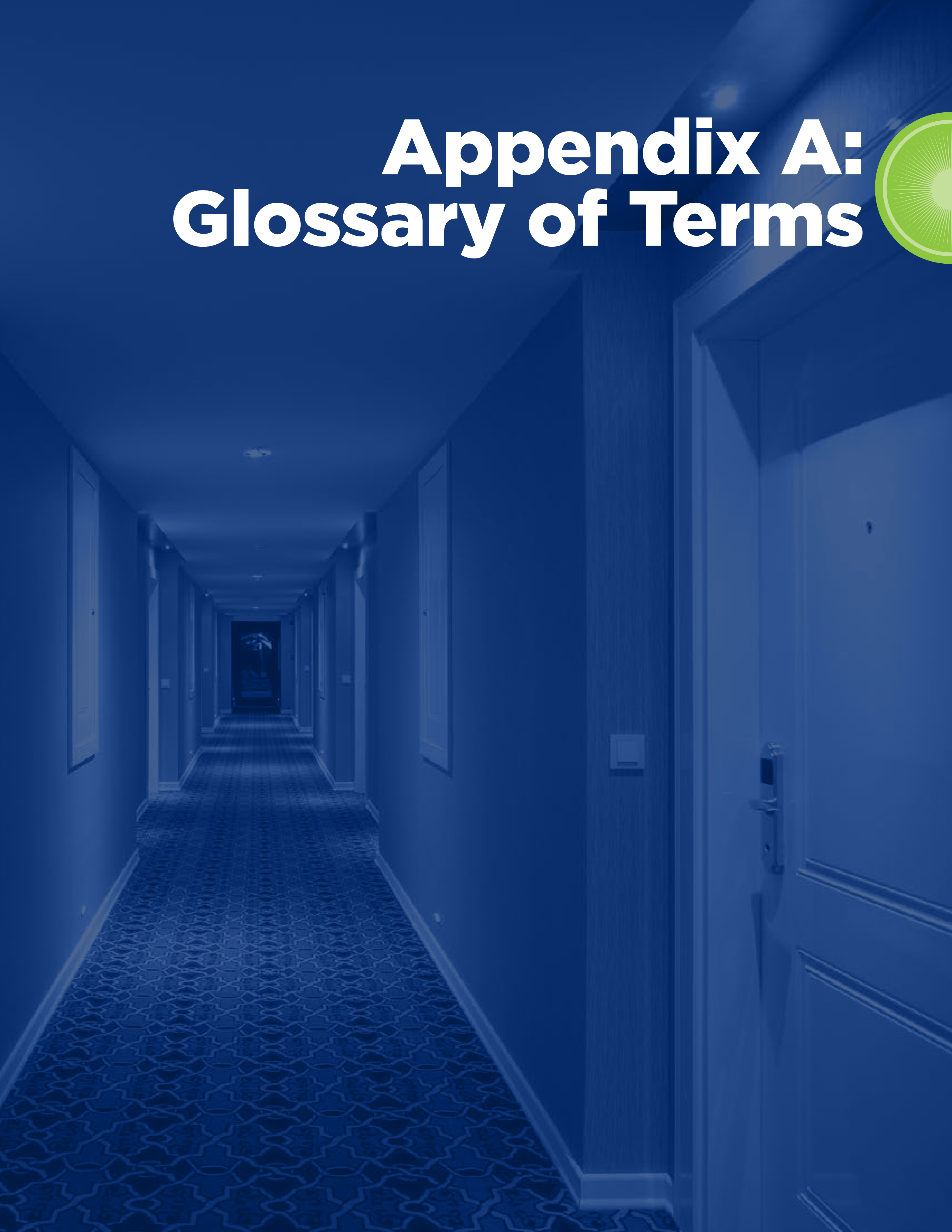
Assuming energy-efficiency investments began in 2021, the year that the next ESA program cycle begins, this translates to about $90 million invested annually for 10 years. These total benefits and costs of cost-effective, energy-efficiency investments by 2031 are derived from the IOU-specific benefit and cost data presented in Tables 7 and 8 (for the year 2031). Because current investments in multifamily housing total approximately $20 million a year, ***this study provides a strong rationale for increasing funding for this sector by $50 million annually through 2031.***

4 Take Advantage of Direct-Install Program Elements to Field Test Innovative Measures

The ESA program has a stronger direct-install (DI) component than the rest of the state's energy-efficiency portfolios. Direct-install delivery channels entail extended contact with customers and offer important data gathering opportunities. This makes the ESA program an ideal avenue for field- testing new measures and intervention strategies. For instance, this study's modeling showed that set top boxes hold significant savings potential. Meanwhile, the IOUs haven't been able to launch a set top box program because of lingering questions about the right baseline assumptions.[88] Offering efficient set top boxes through the ESA DI delivery channel would enable the program to capture those savings while also collecting valuable information about what equipment was previously in place. This approach should be used to incorporate set top boxes and other innovative measures into the ESA program.

These are just some of many recommendations that emerge from this potential analysis. Achieving these savings will greatly reduce the disproportionate energy cost burdens shouldered by lower-income multifamily residents while improving the health, comfort, and safety of their housing.

Appendix A: Glossary of Terms



Report Terminology

CAC
Central air conditioning

Btu
British thermal unit

CARE
California Alternate Rates for Energy program

CCAA
California Clean Air Act

Energy Commission or Commission
California Energy Commission

CO_2
Carbon dioxide

DOE
U.S. Department of Energy

EIA
Energy Information Administration

EPA
U.S. Environmental Protection Agency

ESA
Energy Savings Assistance Program

ESACET
Energy Savings Assistance Cost-Effectiveness Test

FCAA
Federal Clean Air Act

GHG
Greenhouse gas (e.g., CO_2, methane)

GW
gigawatt

GWh
gigawatt-hour

HIM
high impact measure

HP
Heat pump

HVAC
Heating, ventilation, and air conditioning

IOU
Investor-owned utility

LCC
Life cycle cost

MMTherms
Million therms

NEBs
Non-energy benefits

PPHH
Persons per household

PUC
(California) Public Utilities Commission

RECS
Residential Energy Consumption Survey

SB
Senate Bill

SCE
Southern California Edison Company

SDG&E
San Diego Gas & Electric Company

T&D
Transmission and distribution

TOU
Time of use

TRC
Total Resource Cost test

Measure Characterization Terminology

i. Measure Name

The measure name is a unique label that describes an efficient technology by equipment type, efficiency level, and configuration.

ii. Parent Measure Name

The parent measure name aggregates some discrete measures under a common label. This is useful for reporting purposes.

iii. Category

A category sorts measures by technology type, such as appliances, HVAC, lighting, and so on. This identifier is useful for reporting purposes.

iv. Market

Market describes the conditions or scenario in which a given measure is installed. In this study, measures are divided into the natural replacement or renovation and retrofit markets. The market for which a given measure is characterized affects costs and savings assumptions. This concept is more commonly referred to as "measure application" in California (e.g.., replace on burnout and retrofit add on).

- **Retrofit Measure:** A retrofit measure is one involving either the installation of new energy saving equipment (e.g., boiler controls) on an existing system or the replacement of operating but inefficient equipment with entirely new, high efficiency equipment (i.e., early-retirement retrofits). For early-retirement retrofit measures, we model a baseline efficiency shift at the time when the equipment to be retrofitted would have needed to be replaced anyway. Retrofit measures can initially save more when performance is compared with older existing equipment. Incentives are assumed to cover 100 percent of retrofit measure costs (i.e., cost of new equipment and labor to install it as well as disposal of the old equipment).

- **Natural Replacement and Renovation:** For natural replacement (i.e., replacement of equipment at end-of-life) and renovation (i.e., planned renovations affecting multiple building systems), installing new high-efficiency equipment may entail only the incremental cost of a high-efficiency piece of equipment versus a standard efficiency one, as similar labor costs would be incurred in either case. These measure savings reflect only the incremental savings over current standard efficiency purchases, as dictated by applicable federal and California codes and standards or standard industry practices. In the context of the ESA program, one can also interpret natural replacement measures as those measures for which the ESA program covers only the cost differential between more efficient equipment and cheaper, but more inefficient alternatives on the market.

v. Time Period

Some measures are only relevant for certain years in the analysis period. The start- and end-year parameters dictate the installation years for which a measure will be included in the analysis. For example, if an impending efficiency standard change in 2020 is expected to lift the baseline for a given measure and eliminate the opportunity for future improvements, the end year will be set to 2020 to discontinue installations of this measure after that year.

vi. Measure Life

This is the anticipated effective useful life of a given measure. In other words, this is the time period in which a given measure is expected to deliver the estimated savings. The measure life is intended to include the impacts of both savings and measure persistence.

vii. Primary and Secondary Fuel

Each measure is characterized based on the energy consumption of one or more fuel types (i.e., natural gas or electric, or both). Whatever fuel's consumption is most reduced by a given measure is the measure's primary fuel. If a measure requires more than one fuel, the non-primary fuel is defined as the secondary fuel. For example, in a gas-heated building, the installation of efficient lighting measures can reduce the electricity use (primary fuel) and require increased gas use (secondary fuel) because of the reduction in waste heat produced by inefficient light bulbs.

viii. Building Type

When differences could be justified, measures were characterized separately for small (i.e., 5 to 49 unit) and large (i.e., 50 or more unit) buildings. This parameter denotes which building size a given measure characterization uses.

ix. Number per Apartment

Measure costs and savings were estimated on a per-housing-unit basis. However, sources for costs and savings often presented these estimates on a different basis (e.g., per equipment unit or per square foot). When necessary, this parameter expresses the number of equipment units, square feet, or other unit that occurs per housing unit. For example, if the literature presents savings per commercial clothes washer in multifamily properties, and sources show that there are approximately eight housing units per commercial clothes washer, this factor would be calculated as 1/8 = 0.125. This is the preliminary value used to calculate the energy savings, in kWhs, and end-use fuel savings, in millions of Btus, as shown below.

x. Primary and Secondary End Use

Each measure can have an impact on one or more energy end uses, such as space heating and cooling. The end use for which a given measure most reduces consumption is defined as the primary end use. If a measure has an impact on several end uses, the non-primary end use is defined as the secondary end use. For example, insulation measures can reduce consumption in two end uses, space heating (primary) and cooling (secondary).[89]

xi. Energy Savings (MWh)

This represents a measure's annual electric energy savings, in MWhs per housing unit, and is the difference between an efficient case and a baseline one.

xii. Coincident Peak Factor

Some electric measures exhibit greater coincidence with system peak than others, that is, they reduce usage most when demand on the electrical grid is highest. Measures that are highly coincident with system peak can yield higher benefits than other measures because they reduce energy use most when energy costs are highest. This is discussed in more detail in the Avoided Costs section. In this study, measures that produce electric savings are classified as either highly coincident or average coincident. In general, measures that have an impact on space cooling loads are characterized as highly coincident. This factor determines which set of avoided costs are used to calculate monetized benefits.

xiii. Natural Gas Savings (Therms)

This represents a measure's annual natural gas savings, in therms per housing unit. It is the difference between usage in an efficient versus a baseline case scenario.

xiv. Water Savings (gal)

This represents a measure's annual water savings in gallons per housing unit.

xv. Operation and Maintenance Impacts (O&M)

Operation and maintenance impacts represent any monetized savings (or cost increases) resulting from the installation of an efficiency measure. For example, installing efficient lighting can eliminate the need for periodic replacements of baseline technologies, thereby yielding additional equipment and labor savings. For simplicity of analysis, estimates are annualized even though actual maintenance tasks may be spread over a measure's life.

xvi. Incremental Costs

Incremental costs represent the cost differential between installing the efficient case and baseline case. As discussed above, incremental costs vary depending on market type (i.e. retrofit, natural replacement, or renovation). For retrofit measures, the full costs for new equipment, installation labor, and disposal (if applicable) are considered. For natural replacement or renovation, only the increment between the installed cost of the efficient case and the baseline case are considered. Since similar labor costs are often incurred in both cases, this incremental cost usually reflects just the increment in equipment costs.

xvii. Early Retirement Retrofit Measures

Two factors apply only to early retirement retrofit measures: baseline shift for early retirement of existing equipment before the end of its useful life, and avoided replacement costs of the equipment with a new unit. For these measures, we model a baseline shift at the time when existing equipment, to be retrofitted, would have needed to be replaced had it not been retired early. The baseline shift is calculated as the ratio of the measure savings before and after the existing equipment would have needed to be replaced.

The avoided replacement cost is the cost of new baseline equipment that would have been incurred had the existing equipment not been retired early. This is considered a benefit in the analysis model. To simplify the analysis, the model uses an adjusted measure life to account for reduced savings resulting from the baseline shift.

For example, consider the replacement of equipment with a remaining useful life of five years with high efficiency equipment with a measure life of ten years. The new equipment saves 100 kWh annually relative to the existing equipment. However, after five years, had the equipment not been retired early, it would have been replaced with new baseline, efficiency-standard compliant equipment costing $50. Relative to this new baseline, the installed efficient equipment only saves 50 kWh annually. Therefore, the calculated baseline shift is 50 kWh / 100 kWh = 50%. This factor is used to calculate an adjusted measure life as follows:

Adjusted Measure Life = [Existing Equipment Remaining Life + (Measure Life - Existing Equipment Remaining Life) * Early Retirement Baseline Shift]

= 5 + [(10—5) * 50%] = 7.5 years

Using this adjusted measure life simplifies model calculations and yields identical lifetime savings to using an approach in which the savings for the pre- and post-baseline shift periods are independently tracked. Finally, the avoided replacement cost ($50 in the example), is distributed over the pre-baseline shift period by calculating a constant periodic payment. The present value of these payments in the first year of analysis would equal the avoided replacement cost.

xviii. AC Saturation

Air condition (AC) saturation indicates the air conditioning equipment types for which a given measure can be installed. For example, central AC tune-up measures should only be applied to those buildings with central AC. This factor is used in tandem with estimates of the percentages of housing units with certain types of cooling equipment in the estimation of potential. This calculation is described in more detail in the Model Framework section.

xix. Applicability

Applicability determines the fraction of housing units for which a measure represents a realistic option. This factor takes into account both measure applicability (i.e., whether the required baseline conditions for a measure's adoption are met in a housing unit) and technical feasibility (i.e., whether any technical barriers would prevent a measure's implementation in a housing unit). For example, duct sealing measures are only applicable to housing units with ducted HVAC systems. Because applicability based on AC equipment type is captured in the AC Saturation factor described above, this factor does not account for that issue.

xx. Not Complete

Not complete is the percentage of housing units with equipment that already have the high-efficiency option for a given measure. This factor is only relevant for retrofit markets. For example, if 5 percent of sockets already have LED lamps, then the not complete factor for LEDs would be 5 percent, reflecting that only 95 percent of the total potential from LEDs remains.

xxi. Interaction Factor

Interaction factors account for interaction and competition between measures, which result from installation of more than one measure. For example, if one measure provides insulation for a building, then the heating load decreases. If another measure is the installation of a high efficiency furnace, the energy savings from the furnace will be lower because the overall heating needs of the building have been lowered. Because the economic potential assumes all possible measures are adopted, interaction factors assume every building adopts all applicable measures.

Interactions are accounted for by ranking each set of interacting measures by total savings assuming the greatest savings measure is installed first. In some cases, measures with marginal savings may not pass the cost-effectiveness test after all interactions are accounted for. Interaction factors are applied to electric and natural gas savings at the measure level.

xxii. Achievable Penetration Profile

This parameter indicates which penetration profile should be assigned to a given measure for the achievable scenario.

xxiii. Measure Savings Validation

Accurate measure-level savings estimates are critical to ensuring reasonable estimates of energy savings potential. However, developing specific estimates of measure-level savings is challenging since established measure-level savings for California-specific climate zones for the ESA-eligible multifamily sector do not exist. For example, the CPUC ex-ante Database for Energy Efficiency Resources (DEER) does not contain low-income as a specific building type.

As discussed in this appendix, Optimal Energy developed average sector-wide savings estimates for each measure. The study compiles data from more than 30 studies (potential, market research, and technical reference manuals) listed in the Bibliography to characterize measures for savings potential analysis. Measure parameters, such as unit energy savings, incremental cost, and effective useful life, were characterized. NRDC analyzed the measure-level savings potential results, identified the highest energy saving measures for each end-use category, and worked with Optimal Energy to

ensure that at least unit energy savings and measure penetration assumptions for these measures were aligned with California assumptions. A workbook with the complete set of characterized measures, including all parameters and sources used, is available by request from NRDC.

Commonly Asked Stakeholder Questions

Were any sensitivity analyses conducted?

The two types of savings potential that were calculated—economic and achievable—can be read as limits on savings possibilities. The former is the maximum cost-effective savings potential in the ESA-eligible multifamily sector if all market and regulatory barriers are addressed; the latter is the savings potential if most barriers are not addressed. The range between the two boundaries covers all possible scenarios in between.

Were the non-economic benefit adders important considerations in this analysis?

Optimal Energy used the non-energy benefits (NEBs) claimed by the IOUs in their 2015-2017 ESA program applications. The IOU-specific NEB to resource benefit ratios ranged from 1.21 to 2.55. (See p. 28.)

Why are the majority of potential direct install measures claimed for year one? What is the reason for the spike in year one?

The analysis assumes all non-addressed retrofit opportunities are claimed in year one (2018). Incremental savings potential, available upon request to NRDC, would show market-driven opportunities based on the natural rate of equipment turnover from 2018 to 2031.

What does the "% Total Sales" represent?

"Total Sales" is the amount of electricity or natural gas used in ESA multifamily households. "% Total Sales" is the percentage that total sales are reduced as a result of delivering cost-effective efficiency measures.

What is the difference between cumulative and incremental results?

The incremental results show potential savings in one year. Cumulative results include savings that result from a measure throughout its entire useful life.

What are important differences between economic and maximum achievable potential?

Economic potential counts savings from all cost-effective measures for the entire available market. It does not account for the possibility that unaddressed market barriers may hinder fully capturing these savings. These market barriers could include regulatory constraints or inability to reach some customers. Achievable potential takes into account the effects of these market barriers on potential savings.

How do codes and standards affect the analysis?

The study fully incorporates codes and standards. For retrofit measures, the analysis counts first-year savings above existing conditions. For replace-on-burnout measures, the analysis counts first year savings above the codes and standards in that year.

How is this study helpful to IOUs?

The study reveals which measures provide the greatest savings potential in the ESA-eligible multifamily sector. The study results can be used to determine which additional measures merit inclusion in the IOUs' programs and to improve program designs for this historically underserved market segment.

How is this study helpful to the Public Utilities Commission or state government?

The study underscores the need for more ambitious savings goals for the ESA-eligible multifamily sector and creates a better understanding of how to best target those savings opportunities. It also provides a basis for considering what additional measures to include in the program.

What were the key factors for excluding cost-effective measures?

The chief factor for measure exclusion in this study was cost-effectiveness. Using the commission's ESACET, any measures that were found to have a benefit cost ratio below 0.5 were excluded. For example, there are large central system measures that can be replaced early (e.g., new boilers), but whose measure-level ratios are less than 0.5, so these were not included in this study. This is a conservative assumption because as of late 2018, some utilities are offering central system boilers for multifamily buildings with rent-restrictions in their deeds.

What is the difference between retrofit and replacement measures?

A retrofit measure replaces equipment that has not yet reached the end of its effective useful life. In these cases, the full measure cost is considered for cost-effectiveness purposes. These measures are more commonly known as "early retirement measures" in California. Replacement measures are known as "replace on burnout measures" in California. To determine replacement or replace on burnout measure cost-effectiveness, only incremental measure costs were taken into account.

Does affordable multifamily housing include market rate properties with some low-income units? How is low income defined?

The study uses the ESA definition of program-eligible multifamily properties: properties with five or more units occupied by households earning 200 percent or less of the federal poverty guideline.

Doe this analysis include California data or other sources?

Optimal Energy drew on a broad set of data, including information from California as well as other jurisdictions. The study compiles data from more than 30 studies (including potential, market research, and technical reference manuals) listed in the Bibliography to characterize measures for savings potential analysis. The most used data set was the Department of Energy's Residential Energy Consumption Survey (2009) for the Western United States. This source was found to have the most robust sample sizes and data for the ESA-eligible multifamily sector at the time of the analysis.

Is the Database for Energy Efficiency Resources (DEER), which contains information on selected energy-efficient technologies and measures for California, associated with this study? If not, why not?

Optimal Energy developed average sector-wide savings estimates for each measure. NRDC analyzed the measure-level savings potential results, identified the highest energy saving measures for each end-use category, and worked with Optimal Energy to ensure that unit energy savings and measure penetration assumptions for these measures (at a minimum) were aligned with California expectations (DEER values).

Does the analysis establish parameters that are location based?

The study used various IOU territory-specific values, including lighting hours of use, measure cost adjustments, heating degree days, and avoided energy costs. (See p. 19.)

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Endnotes

1 In California, EEFA's work is led by a steering committee of organizations that includes: the Association for Energy Affordability, Build it Green, California Environmental Justice Alliance, California Housing Partnership Corporation, The Greenlining Institute, and Natural Resources Defense Council. EEFA California also collaborates closely with the National Consumer Law Center and the California Housing Partnership's Green Rental home Energy Efficiency Network (GREEN), a nonprofit housing developer network established in 2010 to increase access to energy efficiency, clean energy, and water conservation resources for affordable rental properties in California.

2 Cost-effectiveness is defined here using the California Public Utility Commission's current definition to set program budgets. The commission regulates privately-owned public utilities in the state of California.

3 This range reflects the diversity of utility rates paid by the target demographic. Customer savings are $136 million if all customers are on CARE rates of $0.11/kWh and $0.91/therm (statewide averages). Customer savings are $200 million if all customers are on the standard residential rates of 0$.17/kWh and $1.14/therm. CARE stands for California Alternative Rates for Energy, which are rates available to households on limited incomes.

4 Evergreen Economics, PY2011 Energy Savings Assistance Program Impact Evaluation (2013), the most recent ESA program evaluation, finds the ESA program provided average savings of between 3 and 9 percent per household. This study found natural gas and electric savings worth between 19 and 24 percent through 2031.

5 A family's energy burden is the portion of household income that is spent on energy costs. For example, a family that has a smaller income than its neighbor but must pay similar utility bills has a higher energy burden than its neighbor.

6 Lauren Ross, Ariel Drehobl, and Brian Stickles, *The High Cost of Energy in Rural America: Household Energy Burdens and Opportunities for Energy Efficiency* (Energy Efficiency for All and American Council for an Energy-Efficient Economy: 2018), p. 2, http://energyefficiencyforall.org/sites/default/files/ACEEE%20EEFA%20Rural%20Energy%20burden%20report.pdf.

7 Ibid.

8 The Cadmus Group and ResearchIntoAction, *ESA Program Multifamily Segment Study* (2013), p. iv. Gary Pivo, *Energy Efficiency and its Relationship to Household Income in Multifamily Rental Housing* (2012), p. 1, https://www.fanniemae.com/content/fact_sheet/energy-efficiency-rental-housing.pdf.

9 Cost-effectiveness is defined here using the California Public Utility Commission's current definition to set program budgets. The commission regulates privately-owned public utilities in the state of California.

10 This range reflects the diversity of utility rates paid by the target demographic. Customer savings are $136 million if all customers are on CARE rates of $0.11/kWh and $0.91/therm (statewide averages). Customer savings are $200 million if all customers are on the standard residential rates of 0$.17/kWh and $1.14/therm. CARE stands for California Alternative Rates for Energy, which are rates available to households on limited incomes.

11 The Cadmus Group and ResearchIntoAction, *ESA Program Multifamily Segment Study* (2013).

12 For more information about Optimal Energy, see http://www.optenergy.com/.

13 For more information about BW Research Partnership, see http://www.bwresearch.com/.

14 These achievable savings are based on historical utility spending and program designs for the low-income multifamily sector. However, recent California clean energy and equity laws—in addition to EEFA's advocacy with regulators, stakeholders, and the utilities to improve the efficiency industry's ability to reach low-income families living in multifamily properties—are already leading to program design shifts and are likely to result in an outcome closer to the economic potential.

15 Cost-effectiveness implies that the cost of the measure, including all installation costs, is less than the benefit of reduced energy use and carbon emissions. The CPUC's current cost-effectiveness methods were used to make these determinations.

16 This number is a simple average of the number of electricity and natural gas customers whose energy needs would be met with the combined electricity and natural gas savings.

17 This multifamily-specific ESA estimate is based on the unit and building count and average square-foot per unit data by IOU found in the 2013 Cadmus market characterization study. Specific full-time equivalencies per job activity are available from NRDC by request.

18 This estimate of multifamily households in properties with less than five units comes from The Cadmus Group and ResearchIntoAction, *ESA Program Multifamily Segment Study Vol. 1* (2013) and the U.S. Census estimate of households with incomes 200% or less of the federal poverty level.

19 Steven Nadel, *Comparative Energy Use of Residential Furnaces and Heat Pumps* (Washington, D.C.: The American Council for an Energy-Efficient Economy, 2016), http://aceee.org/comparative-energy-use-residential-furnaces-and.

20 Navigant Consulting, *Energy Efficiency Potential and Goals Study for 2018 and Beyond* (2017), Figures ES-1 and ES-2, http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M194/K614/194614840.PDF. Comparing the potential found in this study with the Navigant results is difficult because one study (Optimal Energy's) reports cumulative potential and the other (Navigant's) only reports incremental potential per year for the low-income sector for the first and last year of the study. The twice-as-large estimate results from a rough comparison of the total economic potential from the Optimal Energy study with the two numbers reported for the low-income sector in the Navigant report.

21 Ibid, pg. 23. The Navigant study states, "The team does not develop its own forecast. The savings potential reported for Low Income are not a true 'Market Potential' but more of a 'forecast of IOU planned activity.'"

22 Heat pump and fuel-switching measures, which are also not currently offered, are likely to provide significant savings as well. However, they were not included in this study.

23 See California Technical Forum discussions on SCE Set Top Box Workpaper: http://www.caltf.org/search?q=set%20top%20boxes.

24 Ariel Drehobl and Lauren Ross, *Lifting the High Energy Burden in America's Largest Cities: How Energy Efficiency Can Improve Low Income and Underserved Communities* (Energy Efficiency For All and The American Council for an Energy-Efficient Economy: 2016), p. 3, http://energyefficiencyforall.org/resources/lifting-high-energy-burden-americas-largest-cities (April 10, 2018).

25 Ibid.

26 Lauren Ross, Ariel Drehobl, and Brian Stickles, *The High Cost of Energy in Rural America: Household Energy Burdens and Opportunities for Energy Efficiency* (Energy Efficiency for All and The American Council for an Energy-Efficient Economy: 2018).

27 For more information about the ESA program, see http://www.cpuc.ca.gov/esap/.

28 The Cadmus Group and ResearchIntoAction, *ESA Program Multifamily Segment Study* (2013), pg. iv.

29 Gary Pivo, *Energy Efficiency and its Relationship to Household Income in Multifamily Rental Housing* (2012), pg. 1, https://www.fanniemae.com/content/fact_sheet/energy-efficiency-rental-housing.pdf.

30 EEFA works to ensure that low-income households benefit from clean, healthy, and affordable housing. In California, EEFA's work is led by a steering committee of organizations that includes: The Association for Energy Affordability, Build it Green, California Environmental Justice Alliance, California Housing Partnership Corporation, The Greenlining Institute, and Natural Resources Defense Council. EEFA California also collaborates closely with the National Consumer Law Center and the California Housing Partnership's Green Rental home Energy Efficiency Network (GREEN), a nonprofit housing developer network established in 2010 to increase access to energy efficiency, clean energy and water conservation resources for affordable rental properties in California.

31 For more information about Optimal Energy, see http://www.optenergy.com/.

32 The unit of analysis in this study is ESA-eligible units. However, we also analyze savings from common areas and central systems in ESA-eligible buildings, as quantified by the Cadmus study. (The Cadmus Group and ResearchIntoAction, *ESA Program Multifamily Segment Study* (2013)) Per commission policy, ESA-eligible buildings are those with 80% or more of tenant households that meet the income eligibility guidelines of the program. The commission's November 2016 decision reduces this threshold to 66% for common area measures in deed-restricted properties.

33 CPUC, *Energy Savings Assistance Program*, http://www.cpuc.ca.gov/esap/, (June 2, 2015).

34 The study used data from the DOE's 2009 Residential Energy Consumption Survey to construct initial energy consumption estimates by end use. This baseline was adjusted upward in some years to account for new building codes and standards over the forecast time frame (2018-2031). The savings potential that was calculated from this baseline was adjusted slightly downward to account for uptake of efficient equipment that would have occurred in the absence of any interventions, also known as naturally occurring efficiency. Usually, naturally occurring efficiency in low-income multifamily housing is very low.

35 GDS Associates, *Michigan Electricity and Natural Gas Energy Efficiency Potential Study* (Marietta, GA.: 2013). Includes definitions for economic and achievable potential, https://www.michigan.gov/documents/deq/DEQ_AQD_EPA_GHG_Rules_Appendix_C_Part_One_475445_7.pdf.

36 California Public Utilities Code Section 382. IOU customers fund the program through the state's public purpose program charge.

37 For more information, see http://consumers.cpuc.ca.gov/esap/.

38 California Public Utility Code Sections 382(e), 386(a)(3), 900, and 2790.

39 Opening *Brief of the Natural Resources Defense Council, National Consumer Law Center, and the California Housing Partnership,* filed July 13, 2015 in A.14-11-007, pg. 41.

40 CPUC Decision 12-08-044; The Cadmus Group and ResearchIntoAction, *ESA Program Multifamily Segment Study* (2013).

41 CPUC Decision 14-11-025.

42 CPUC Decision 16-11-022.

43 California Energy Commission. *Differences Between Publicly and Investor-Owned Utilities*, http://www.energy.ca.gov/pou_reporting/background/difference_pou_iou.html.

44 The Cadmus Group and ResearchIntoAction, ESA Program Multifamily Segment Study (2013).

45 This was the best available data at the time of the analysis.

46 Available upon request.

47 IOU-specific calculators are available at https://ethree.com/public_projects/cpuc4.php.

48 Discount rates equal after-tax weighted average cost of capital (WACC) for each utility.

49 ESACET is a modified Total Resource Cost test that includes all the costs and benefits associated with the ESA program.

50 A workbook with the complete set of characterized measures, including all parameters and sources used, is available from NRDC by request.

51 Given the specific focus of this study (ESA-eligible multifamily), FA determined that RECS offered the most robust applicable data and sample sizes of the data sets available within the project's limited resources. U.S. Energy Information Administration, *2009 Residential Energy Consumption Survey*, https://www.eia.gov/consumption/residential/data/2009/.

52 Fannie Mae, *Transforming Multifamily Housing: Fannie Mae's Green Initiative and Energy Star for Multifamily* (2014), https://www.fanniemae.com/content/fact_sheet/energy-star-for-multifamily.pdf.

53 Referenced studies included: The Cadmus Group et al., *Massachusetts Multifamily Market Characterization and Potential Study* (Watertown, MA: 2012); The Cadmus Group, *Michigan Baseline Study 2011: Residential Baseline Report* (Portland, OR: 2011); , Ecotope, *Residential Building Stock Assessment: Multifamily Characteristics and Energy Use*, (Seattle: 2013); Energy Center of Wisconsin and Franklin Energy, *Minnesota Multifamily Rental Characterization Study* (Madison, WI: 2013); GDS Associates, *2014 Pennsylvania Statewide Act 129 Residential Baseline Study* (2014); and KEMA, *Maryland Energy Baseline Study* (2011).

54 NMR Group, Inc. *Northeast Residential Lighting Hours-of-Use Study* (Somerville, MA: 2014), http://ma-eeac.org/wordpress/wp-content/uploads/Northeast-Residential-Lighting-Hours-of-Use-Study-Final-Report1.pdf. The NMR study did not have hours of use for California IOUs. We used the overall low-income multifamily value for all regions in the study (except downstate New York, which exhibited significantly higher hours of use).

55 The Cadmus Group and ResearchIntoAction, *ESA Program Multifamily Segment Study* (2013).

56 U.S. Energy Information Administration, *2009 Residential Energy Consumption Survey*, https://www.eia.gov/consumption/residential/data/2009/.

57 Referenced studies included: The Cadmus Group et al., *Massachusetts Multifamily Market Characterization and Potential Study* (Watertown, MA: 2012); The Cadmus Group, *Michigan Baseline Study 2011: Residential Baseline Report* (Portland, OR: 2011); Ecotope, *Residential Building Stock Assessment: Multifamily Characteristics and Energy Use*, (Seattle: 2013); Energy Center of Wisconsin and Franklin Energy, *Minnesota Multifamily Rental Characterization Study* (Madison, WI: 2013); GDS Associates, *2014 Pennsylvania Statewide Act 129 Residential Baseline Study* (2014); and KEMA, *Maryland Energy Baseline Study* (2011).

58 *Ibid*.

59 The analysis omitted other common area water uses, such as shared restrooms, janitorial closets, and landscaping.

60 From ENERGY STAR calculators. Energy Center of Wisconsin and Franklin Energy, *Minnesota Multifamily Rental Characterization Study* (2013).

61 In *Residential Building Stock Assessment: Multifamily Characteristics and Energy Use* (2013), Ecotope reported between 5.5% and 12.3% of multifamily building space is common area, depending on building size.

62 The behavioral savings reflect information provided from home energy reports, which are not specific to multifamily because of limited available research.

63 While the ESA program has a limited set of authorized measures as of the writing of this report, this study calculates the potential savings if all cost-effective measures are included based on the ESACET subject to a per-measure ESACET cost-effectiveness threshold of 0.5.

64 Only applies to measures that have either primary or secondary savings against the space cooling end use.

65 In this case, the percentage of total housing units served by an in-unit furnace.

66 The ESACET is a modified Total Resource Cost (TRC) test currently used to screen low-income programs in California. Similar to the TRC test, the ESACET test includes all the costs (e.g., including incentives, participant share of measure cost, and program administrative costs) and benefits (e.g., value of all energy and capacity savings, other resource savings, such as reduced water consumption, and operation and maintenance savings) associated with the ESA program. The ESACET, in contrast to the traditional TRC, adds participant and utility non-energy benefits (NEBs) to account for health, safety, and comfort benefits.

67 State of Rhode Island and Providence Plantations Public Utilities Commission, *Energy Efficiency Program Plan for 2014 Settlement of the Parties* and National Grid (2013); and State of Rhode Island and Providence Plantations Public Utilities Commission, *2013 Energy Efficiency Plan-Year Report* (2014).

68 California Public Utilities Commission, *D.14-08-030*, August 14, 2014, Ordering Paragraph 43.

69 The 2016 version of the calculator was used. Available online, at: https://ethree.com/public_projects/cpuc4.php.

70 In many cases, especially for the generation components, the avoided costs were uniform across all climate zones.

71 EPRI, *Assessment of Achievable Potential from Energy Efficiency and Demand Response Programs in the U.S. (2010–2030)* (2009), http://ma-eeac.org/wordpress/wp-content/uploads/14_-Assess.-of-Achievable-Pot.-from-EE-and-Demand-Response-2010-2013_Siddiqui_Study.pdf.

72 A workbook with measure-specific penetration rates is available by request from NRDC.

73 Although a 0.5 threshold is quite lenient, evaluating costs at the portfolio measure level enables less cost-effective measures to be subsidized by more cost-effective ones. Our study simply excluded a few of the lowest performing measures, those with less than a 0.5 outcome, including non-energy benefits.

74 Energy savings in affordable multifamily housing will reduce carbon emissions and contribute to state efforts to comply with section 111(d) of the Clean Air Act. The potential estimates from this study can be used with appropriate emissions factors to develop preliminary estimates of carbon pollution reduction potential.

75 Energy and Environmental Economics, *Avoided Costs 2017 Interim Update* (2017), http://www.cpuc.ca.gov/General.aspx?id=5267 (April 11, 2018).

76 This number is a simple average of the number of electricity and natural gas customers whose energy needs could be met with the combined electricity and natural gas savings.

77 Active measures are measures that have not yet exceeded their effective useful lives.

78 This study assumed that multifamily sales are constant each year because of upward and downward pressures that cancel each other out. Specifically, residences are

getting more efficient in terms of energy intensity, which is pushing sales down. However, home sizes, plug loads, and prevalence of space conditioning are all driving sales up.

79 The study explicitly modeled the impact of the EISA 2020 lighting efficacy backstop pf 45 lumen per watt for general service lamps. Other appliance standards and building codes also affect savings potential as initial retrofit measures (which are characterized from an existing conditions baseline) retire toward the end of the study and are replaced with natural replacement measures (which are characterized from a codes and standards baseline).

80 The marginal emissions rate for electricity is 0.35 tons CO_2 per MWh; the marginal emissions rate for natural gas is 0.00531 million tons CO_2 per therm. The California Air Resource Board's EFMAC tool for 2017 was used for vehicle conversion.

81 Customer savings are $136 million if all customers are on CARE rates of $0.11/kWh and $0.91/therm (statewide averages). Customer savings are $200 million if all customers are on the standard residential rates of $0.17/kWh and $1.14/therm. CARE rates—California Alternative Rates for Energy—are available to households with limited income.

82 American Council for an Energy-Efficient Economy, *Comparative Energy Use of Residential Furnaces and Heat Pumps*, 2016, http://aceee.org/comparative-energy-use-residential-furnaces-and.

83 Active measures are measures that have not yet exceeded their effective useful lives.

84 California Public Utilities Commission, D.16-11-022.

85 See footnote 54.

86 Navigant Consulting, *Energy Efficiency Potential and Goals Study for 2018 and Beyond* (2017), Figures ES-1 and ES-2, ftp://ftp.cpuc.ca.gov/gopher-data/energy_division/EnergyEfficiency/DAWG/2018_Potential%20and%20Goals%20Study%20Final%20Report_092517.pdf. Comparing the potential found in this study with the Navigant results is difficult because one study (Optimal Energy's) reports cumulative potential and the other (Navigant's) only reports incremental potential per year for the low-income sector for the first and last year of the study. The twice-as-large estimate results from a rough comparison of the total economic potential from the Optimal Energy study with the two numbers reported for the low-income sector in the Navigant report.

87 *Ibid*, pg. 23. According to the Navigant study, "The team does not develop its own forecast. The savings potential reported for Low Income are not a true 'Market Potential' but more of a 'forecast of IOU planned activity.'"

88 See California Technical Forum discussions on SCE Set Top Box Workpaper: http://www.caltf.org/search?q=set%20top%20boxes.

89 The primary and secondary end use and primary and secondary fuel parameters are used in tandem to apply the appropriate percentages of housing units using electricity or natural gas for space heating and water heating (also described as "fuel shares") as a step in the estimation of potential. This aspect of the methodology is described in more detail in the Model Framework section below. For example, a Wi-Fi thermostat measure characterized to estimate gas savings should only be applied to the fraction of housing units using gas as their space heating fuel.

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