Analysis and Implications of California's Long Term Energy Efficiency Strategic Plan for Existing Homes

William Goetzler, Joanna Gubman, and Hirokazu Hiraiwa, Navigant Consulting, Inc.

ABSTRACT

California's Long Term Energy Efficiency Strategic Plan requires that energy purchases in existing homes be reduced by 20% by 2015 and 40% by 2020, with individual homes' reductions ranging from 30% to 70% (CPUC 2008). However, the costs, approaches, and impacts of these goals for existing homes have not yet been analyzed in depth. The California Energy Commission Public Interest Energy Research (PIER) Buildings Program is a key stakeholder in facilitating the successful implementation of this initiative. This paper describes a project sponsored by PIER to assess RD&D priorities to support the achievement of the existing homes goals.

The project consists of two elements. The first element is a modeling-based analysis of the costs, benefits, technical options, and key challenges specific to the Existing Homes Initiative, and of the associated impacts. The second is a compilation of information on existing auditing and retrofitting experiences, tools, future plans, and costs/benefits, both in California and elsewhere, with identification of gaps that PIER can address. Existing homes in California were profiled, and 36 prototype homes were selected to cover common dwelling types, regions, vintages, and orientations. These prototype homes were modeled in BEopt, which developed optimal energy efficiency and renewable energy retrofit packages considering the costs and savings of each available option. The results were then aggregated and analyzed to identify common trends, key technologies, and outliers. A Total Resource Cost (TRC) analysis was conducted to assess cost-effectiveness, and an assessment of the existing homes initiative's potential contribution to greenhouse reduction goals was also performed.

Background

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The last initiative regarding existing homes ("Existing Homes Initiative") will be achieved through a "whole-house approach to energy consumption," with individual homes' reductions ranging from 30-70%[1].

Numerous stakeholders have been involved in developing the Strategic Plan, including utilities, manufacturers, trade associations, advocacy groups, and the building trades. Many issues must be resolved in order to implement the Plan at minimal cost, while achieving maximum benefits. The PIER Buildings program has capabilities, resources, and expertise to support research, development, and demonstration (RD&D) whose results can be used to support the Strategic Plan and ensure that it can be implemented optimally. This study addresses key elements of the Existing Homes Initiative of the CPUC ruling and provides an analysis of RD&D needs to support the Strategic Plan.

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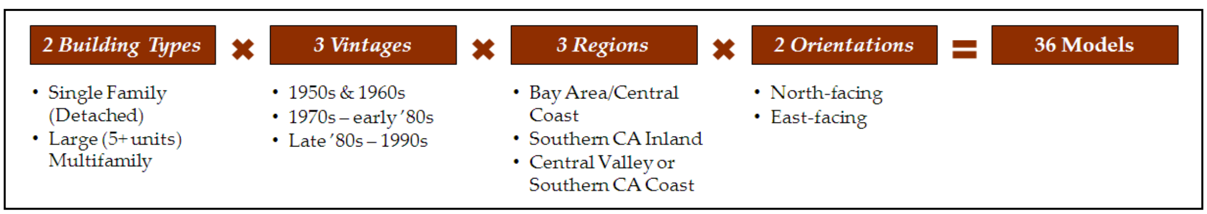
Figure 1: Dwelling Types Selected for BEopt Modeling[2]



Source: Navigant Consulting, Inc.

The 36 prototype homes selected cover common dwelling types, vintages, regions, and orientations.[3] First, we selected two dwelling types, detached single family and large multifamily buildings with five or more units, which together represent 78% of all California dwellings (**Error! Not a valid bookmark self-reference.**). Second, we chose homes built between 1950 and 1999, because 79% of the detached single family homes and 85% of the large multifamily homes in California (as of 2003) were built during that period (**Error! Not a valid bookmark self-reference.**). In modeling, vintages were grouped into three categories: 1950s-1960s; 1970s to early 1980s; and late 1980s through 1990s. These categories were based on common building features such as window type, and prevalence of crawl space versus slab-on-grade construction.

[1] According to the Strategic Plan, 25% of applicable single family homes will reduce their energy consumption by 70% relative to the 2008 baseline, and the remaining 75% will reduce their energy consumption by 30%. All multifamily homes will reduce their energy consumption by 40%.

[2] The Central Valley region was modeled for single family dwellings only. The Southern California Coast region was modeled for multi-family dwellings only.

[3] Profiles based on the Residential Energy Consumption Survey and 2004 Residential Appliance Saturation Survey.

Figure 2: Distribution of California Residential Building Stock, By Dwelling Type[4]

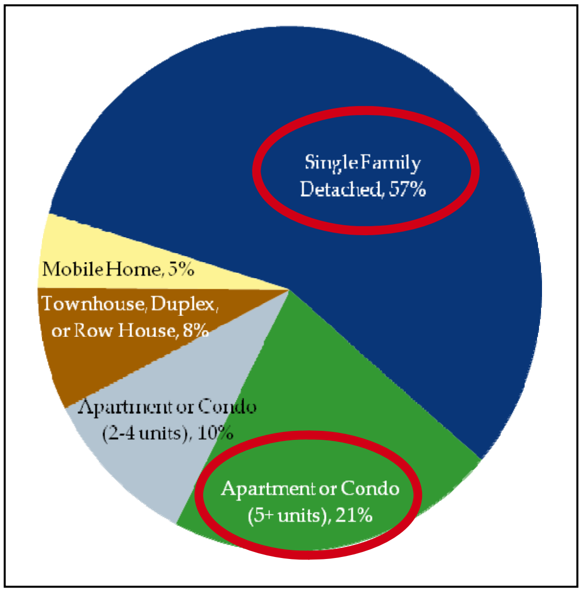


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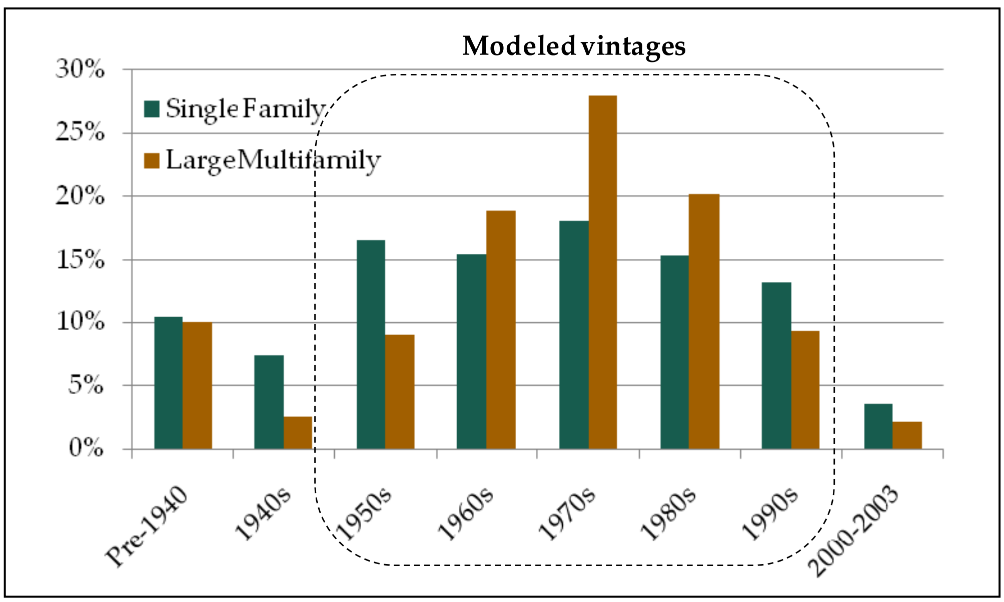
Figure 3: Percentage of Single Family and Large Multifamily Building Stock Built in Each Decade



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[4] Distribution is per-dwelling, not per-structure, so a 20-unit apartment complex counts as 20 dwellings, not as one complex.

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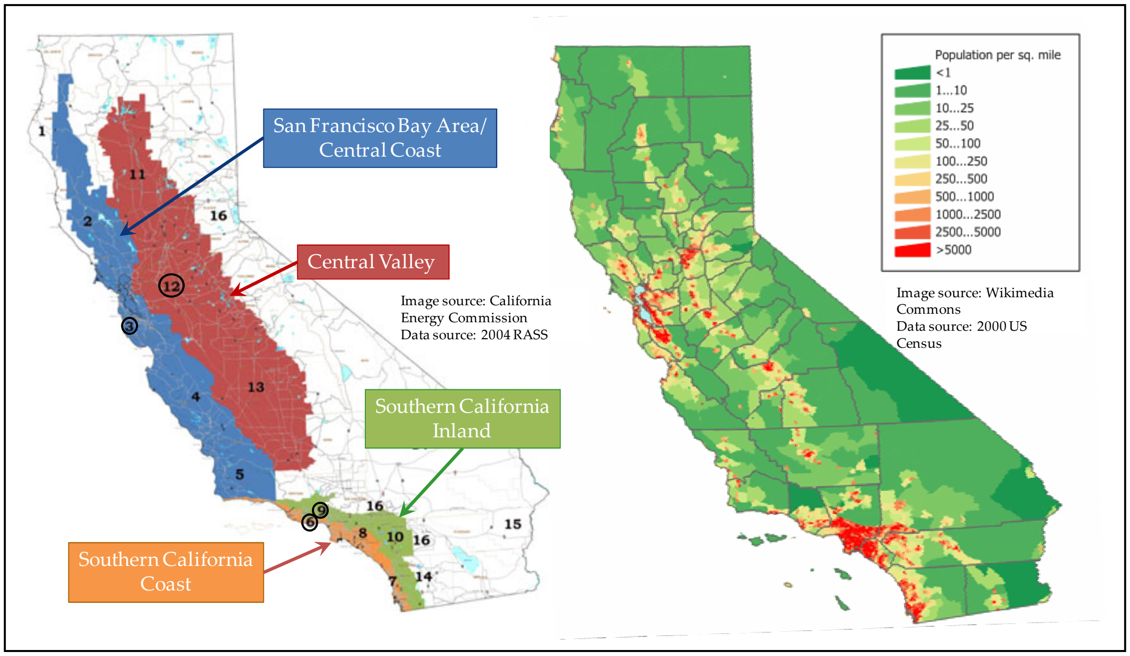

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Costs were also input into BEopt, based primarily on the Database for Energy Efficiency Resources (DEER) but also incorporating BEopt default values and primary research. All costs are for retrofit applications, and were generally chosen to be the full cost in the year 2009, with the exceptions of:

- **Miscellaneous electric loads (MELs) and fluorescent lighting** were optimized based on incremental cost, assuming those miscellaneous appliances responsible for plug load (e.g., TVs and computers) and lighting fixtures that are in use today will likely be retired before 2020 given their expected useful life.
- **Rooftop solar photovoltaics (PV) and LED lighting** were optimized based on projected 2018 cost, assuming that the costs of PV and LED will decrease over the next ten years. These projected costs were developed by Navigant Consulting based on previous studies (CSI 2009, O'Donnell, et. al. 2009, and DOE 2009).

The minimum first cost BEopt result at different savings percentages[5] were aggregated and analyzed to identify common trends, key technologies, and outliers. While BEopt optimizes efficiency packages on net present value basis, first cost was used for this assessment since that will be the most important cost factor to average homeowners. To identify the lowest first cost retrofit package at different savings percentages, we ran BEopt to optimize efficiency packages to 100% savings, and analyzed all iterations simulated by BEopt. Total Resource Cost (TRC) analysis was also conducted to assess cost-effectiveness, as well as an impacts analysis to assess the Existing Homes Initiative's potential contribution to Assembly Bill (AB) 32[6] goals of reducing the state's greenhouse gas emissions to 1990 level by 2020.

The outcomes from the first element was integrated with the findings from the second element of this project, which is a compilation of information on existing auditing and retrofitting experiences, tools, future plans, and costs/benefits, both in California and elsewhere, with identification of gaps that PIER can address.

Analysis Results

Analysis of Illustrative Modeling Results

While 36 different prototypes were modeled, the results for single- and multi-family dwellings each tended to follow similar patterns. **Error! Not a valid bookmark self-reference.** and **Error! Not a valid bookmark self-reference.** summarize the relationship between retrofit first costs and expected energy savings for single family and multifamily dwellings, respectively. The costs to achieve the specific goals set in the Strategic Plan were generally comparable across different regions, with two exceptions. First, the cost to achieve 30% savings in single family homes is slightly lower for the Southern California Inland region. Second, and more significantly, the cost to achieve 40% savings in multifamily dwellings is approximately twice as high for older Bay Area/Central Coast homes.

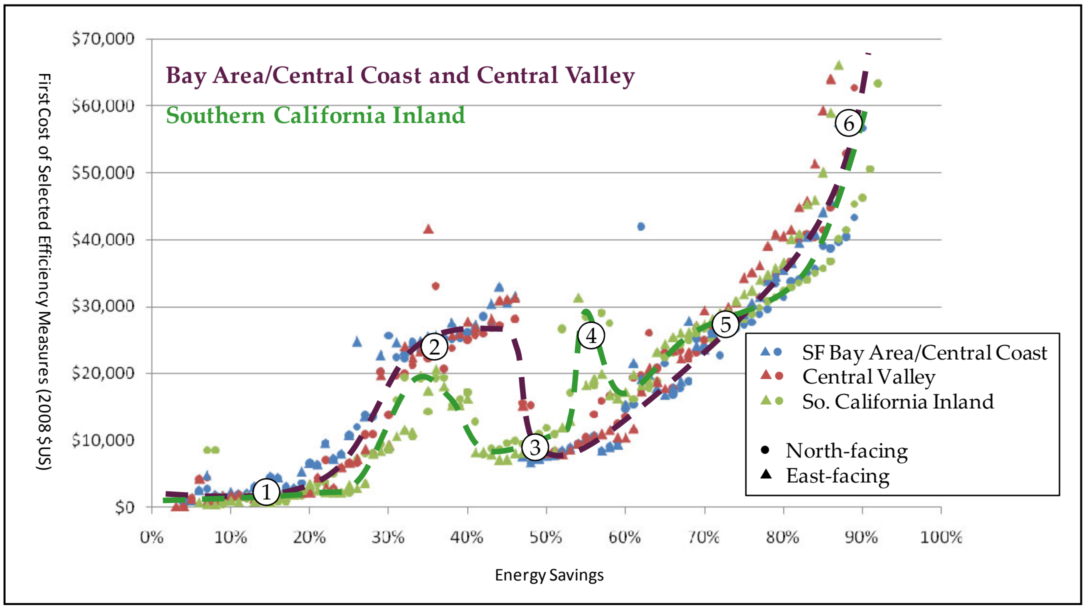
For both single- and multi-family dwellings, orientation was found to be a relatively insignificant factor in the 30-70% savings range. While deeper cuts show a greater cost difference due to the larger quantity of PV required to produce the same savings on an east- or north-facing house, orientation was not found to be a significant cost driver in the savings range specified in the Strategic Plan. Regional differences were more significant, with the Bay Area/Central Coast and Central Valley regions generally having larger costs at mid-level savings

[5] Since the Strategic Plan specifies the savings target at 30%, 40% and 70% for single- and multifamily homes, the analysis focused on what it would take to achieve certain savings percentage, instead of establishing the "loading order" of preferred retrofit measures in the order of cost-effectiveness.

[6] Global Warming Solutions Act of 2006 (Nuñez, Chapter 488, Statutes of 2006)

ranges than the milder Southern California climate regions. Vintage also had some impact; in some cases, implementing the same measures as older homes may result in lower percent savings for newer homes, because newer homes are more efficient than older homes.

Figure 5: Typical Single-Family Results – 1970s to Early 80s Vintage First Costs vs. Savings



Source: Navigant Consulting, Inc.

The same plot for single family homes of other vintages generally followed the pattern shown in Figure 5 above: (1) implementation of low-cost retrofit options up to 20-25% savings; (2) introduction of rooftop PV to achieve 30-40% savings; (3) introduction of a heat pump in place of solar PV to achieve 40-50% savings; (4) temporary switch back to PV instead of a heat pump; and (5) – (6) implementation of higher-cost measures to reach higher savings level. Typical retrofit measures for each of the six sections as follows:

1. Reduction of MELs and lighting fixture upgrades to LED are almost universally selected, along with frequent selection of water heater upgrades. Other common measures include whole-house air leakage reduction, duct sealing, and clothes washer upgrades.
2. MELs and LEDs are selected in all cases. Other frequent selections include whole-house air leakage reduction, duct sealing, rooftop PV, and furnace/water heater upgrades. Clothes washers are occasionally upgraded. Very occasionally, wall insulation upgrades and domestic solar water heating (SWH) are recommended.
3. MELs, LEDs, and water heater upgrades remain frequent selections. The most notable difference that results in the sudden reduction in first cost is the introduction of heat pumps in place of PV installation and furnace upgrades. Also occasionally recommended are whole-house air leakage reduction, clothes washer upgrades, and duct sealing.
4. This section is similar to section 2. Lowest first cost packages identified by BEopt for this range of percentage savings do not include a heat pump, which requires the inclusion of other costly measures including PV and SWH.

5. MELs, LEDs, heat pumps, water heater upgrades, PV, SHW, and duct sealing are almost universally selected. Whole-house air leakage reduction and clothes washers are frequently recommended, and wall insulation is rarely recommended.

6. This section is similar to section 5, with increased frequency of wall insulation. Small appliance upgrades (e.g. refrigerator and dishwashers) and window upgrades are gradually introduced, and duct and roof insulation are introduced at the very highest savings levels.

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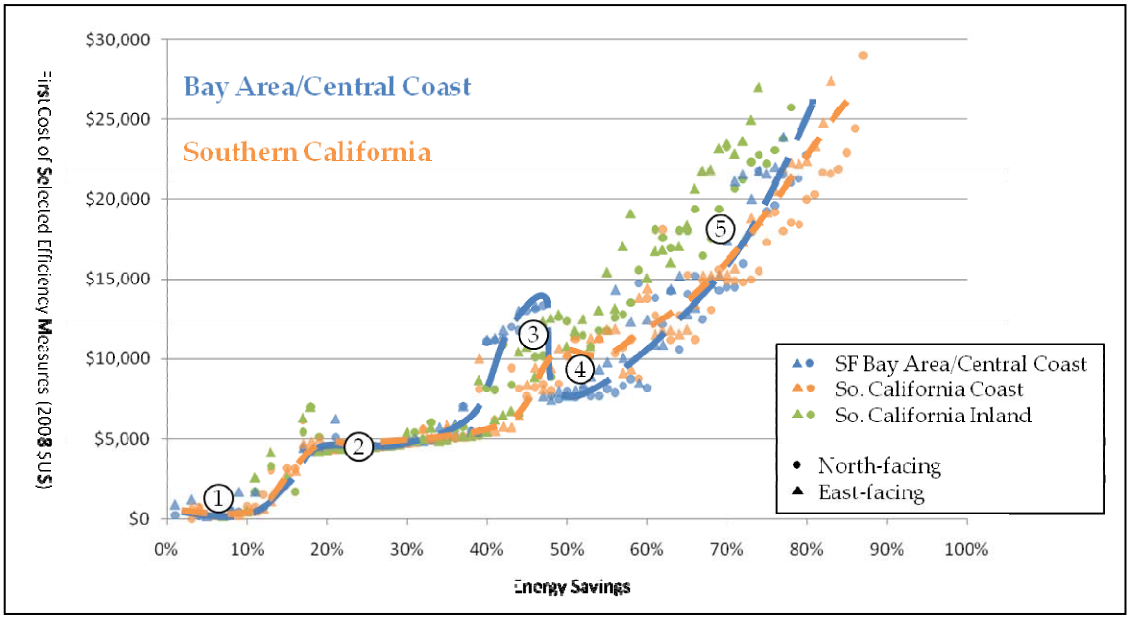

Source: Navigant Consulting, Inc.

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Analysis Results

Analysis of Illustrative Modeling Results

While 36 different prototypes were modeled, the results for single- and multi-family dwellings each tended to follow similar patterns. **Error! Not a valid bookmark self-reference.** and **Error! Not a valid bookmark self-reference.** summarize the relationship between retrofit first costs and expected energy savings for single family and multifamily dwellings, respectively. The costs to achieve the specific goals set in the Strategic Plan were generally comparable across different regions, with two exceptions. First, the cost to achieve 30% savings in single family homes is slightly lower for the Southern California Inland region. Second, and more significantly, the cost to achieve 40% savings in multifamily dwellings is approximately twice as high for older Bay Area/Central Coast homes.

For both single- and multi-family dwellings, orientation was found to be a relatively insignificant factor in the 30-70% savings range. While deeper cuts show a greater cost difference due to the larger quantity of PV required to produce the same savings on an east- or north-facing house, orientation was not found to be a significant cost driver in the savings range specified in the Strategic Plan. Regional differences were more significant, with the Bay Area/Central Coast and Central Valley regions generally having larger costs at mid-level savings ranges than the milder Southern California climate regions. Vintage also had some impact; in some cases, implementing the same measures as older homes may result in lower percent savings for newer homes, because newer homes are more efficient than older homes.

Figure 5: Typical Single-Family Results – 1970s to Early 80s Vintage First Costs vs. Savings
Source: Navigant Consulting, Inc.

The same plot for single family homes of other vintages generally followed the pattern shown in Figure 5 above: (1) implementation of low-cost retrofit options up to 20-25% savings; (2) introduction of rooftop PV to achieve 30-40% savings; (3) introduction of a heat pump in place of solar PV to achieve 40-50% savings; (4) temporary switch back to PV instead of a heat pump; and (5) – (6) implementation of higher-cost measures to reach higher savings level. Typical retrofit measures for each of the six sections as follows:

7. Reduction of MELs and lighting fixture upgrades to LED are almost universally selected, along with frequent selection of water heater upgrades. Other common measures include whole-house air leakage reduction, duct sealing, and clothes washer upgrades.
8. MELs and LEDs are selected in all cases. Other frequent selections include whole-house air leakage reduction, duct sealing, rooftop PV, and furnace/water heater upgrades. Clothes washers are occasionally upgraded. Very occasionally, wall insulation upgrades and domestic solar water heating (SWH) are recommended.
9. MELs, LEDs, and water heater upgrades remain frequent selections. The most notable difference that results in the sudden reduction in first cost is the introduction of heat pumps in place of PV installation and furnace upgrades. Also occasionally recommended are whole-house air leakage reduction, clothes washer upgrades, and duct sealing.
10. This section is similar to section 2. Lowest first cost packages identified by BEopt for this range of percentage savings do not include a heat pump, which requires the inclusion of other costly measures including PV and SWH.
11. MELs, LEDs, heat pumps, water heater upgrades, PV, SHW, and duct sealing are almost universally selected. Whole-house air leakage reduction and clothes washers are frequently recommended, and wall insulation is rarely recommended.

12. This section is similar to section 5, with increased frequency of wall insulation. Small appliance upgrades (e.g. refrigerator and dishwashers) and window upgrades are gradually introduced, and duct and roof insulation are introduced at the very highest savings levels.

Figure 6 above, with typical retrofit scenarios for each of the five sections as follows:

1. MELs and LEDs are almost universally selected, frequently along with water heater and clothes washer upgrades.
2. This section is similar to section 1, with the addition of wall insulation.
3. Whole-house air leakage reduction and PV are applied to the Bay Area/Central Coast prototypes, which results in a dramatic cost increase for this region.
4. Heat pumps and PV are frequently selected for Southern California Inland prototypes. Cost-effective heat pump mitigates the cost spike.
5. SWH, PV, duct sealing, whole-house air leakage reduction, and dishwashers are selected to reach higher energy savings.

Modeling and Impacts Assessment

Our analysis of the model results yielded several key findings. First, we found few significant differences in retrofit recommendations or costs across climates, vintages, and orientations. One exception is multifamily dwellings built in the Bay Area/Central Coast region in late 1980s-1990s, which cost about half as much to retrofit as older homes in the same region.

Second, we found that low-cost LEDs and reductions in MELs are the first steps to reducing energy consumption and are important to achieving all levels of savings. While LED costs continue to drop and energy-efficient electronic appliances are frequently available at no additional cost to consumers, achievement of the modeled costs and savings will nevertheless require continual improvement and collaboration between industry, national labs, and regulators. In multifamily housing, wall insulation was also found to be a frequent retrofit component for savings targets over approximately 20%. Because cost, feasibility, and ease of installation can be highly variable in retrofit applications, these issues could also benefit from further RD&D.

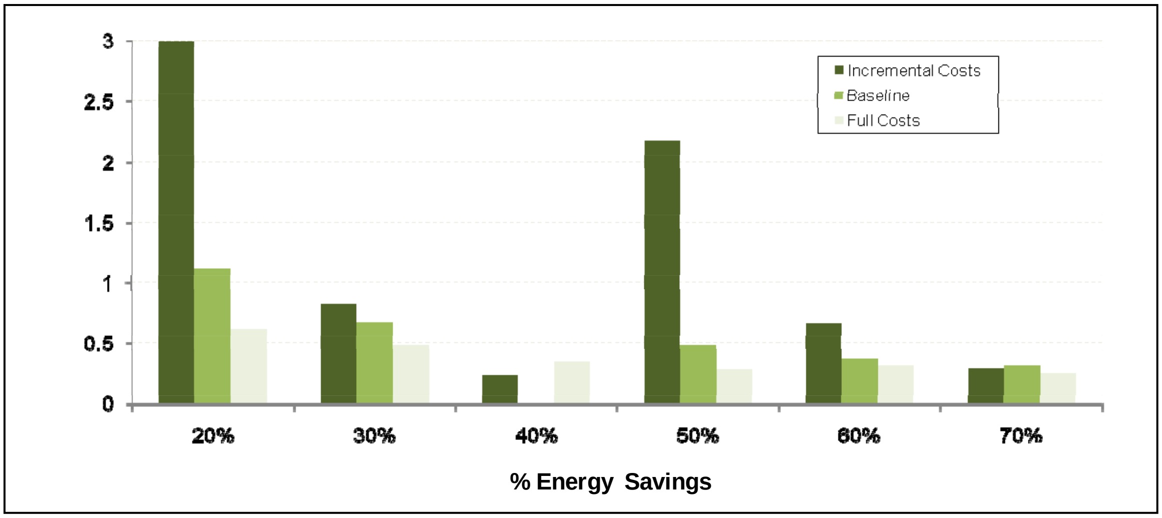
Third, we found that rooftop PV and heat pumps are key technologies driving retrofit costs and savings, particularly in single family homes. Although heat pumps increase electricity consumption and thus operating costs[7], they also enable savings of greater than 30% at a relatively low first cost. Since the use of heat pump would achieve over 30% savings, it is often more expensive to target exactly 30% savings (the “shallow cut” target specified in the Strategic Plan) through a combination of PV and other energy efficiency retrofits. PV is the most significant cost driver and is necessary to achieve 70% savings specified in the Strategic Plan.

Fourth, we found the benefit cost ratio based on existing TRC calculators to be unfavorable. While coordinating retrofits with natural appliance burnout would significantly improve the TRC, this would reduce the whole-house nature of the retrofits and limit the speed and scale of any retrofit program (**Error! Not a valid bookmark self-reference.**). An aggressive carbon tax scheme may help improve the TRC, but it is unlikely to result in dramatic improvement necessary. As indicated in **Error! Not a valid bookmark self-reference.**, even

[7] Operating costs increase because electricity is relatively expensive and gas is relatively inexpensive in California compared to other parts of the country,

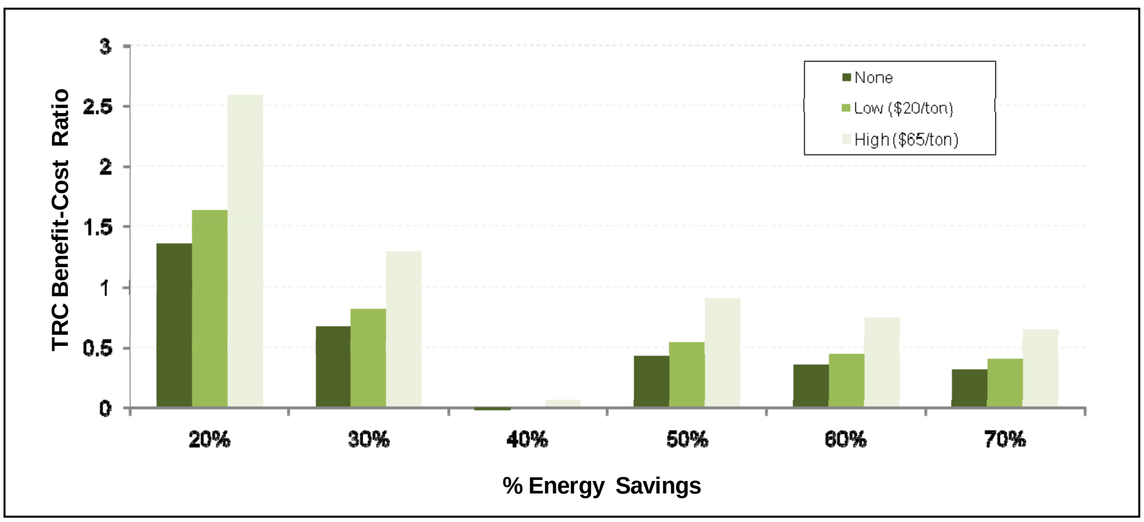
with a $65/ton carbon tax,[8] the TRC is expected to only barely exceed one for the shallow cuts (30% savings), and to remain below one for the deep cuts (70% savings).

Figure 7: Potential Range of TRC Ratio without Carbon Tax, Single-Family 70s/Early 80s Southern California Inland Homes[9]



Source: Navigant Consulting, Inc.

Figure 8: TRC Benefit-Cost Ratios for Different Levels of Carbon Pricing, Single-Family 70s/Early 80s SF Bay Area/Central Coast Homes[9]



Source: Navigant Consulting, Inc.

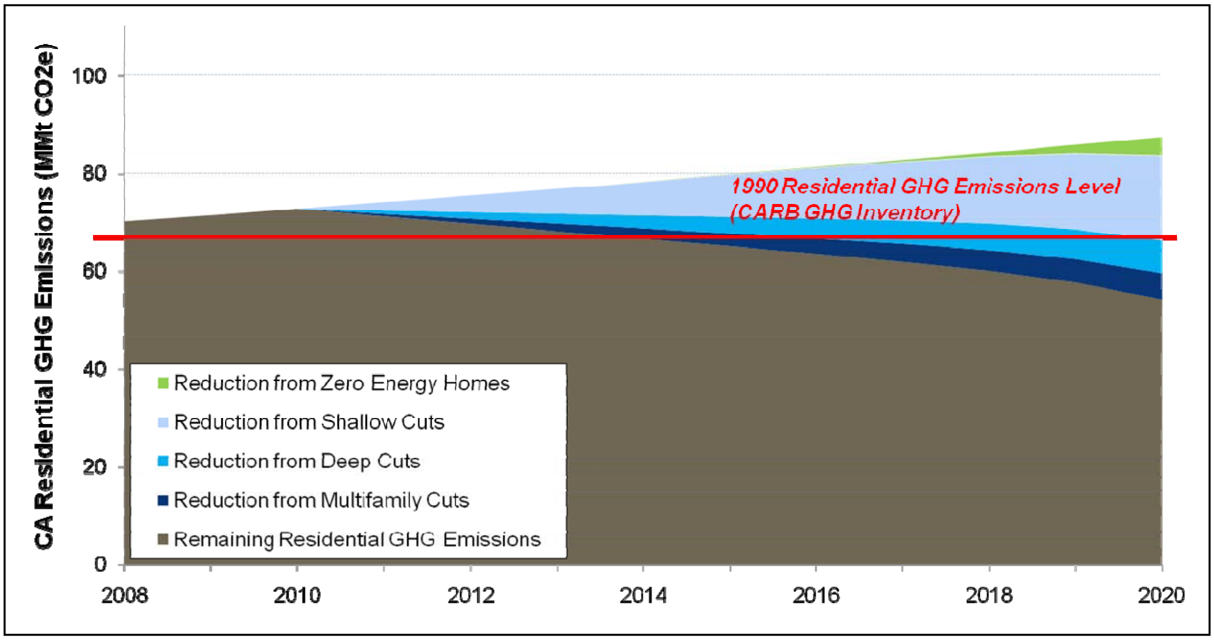
In addition to conducting modeling, we also evaluated the potential contribution of the Existing Homes Initiative to AB 32 goals. We found that full compliance with the Existing Homes Initiative would cause the residential sector to exceed AB 32 goals (Figure 9). The

[8] Carbon must be priced at $65/t$CO_2$e in 2020 for GHG emissions to be reduced to 1990 level by 2020 (Paltsev, et. al. 2007).

[9] Calculation based on Southern California Edison TRC calculator (E3 2009), which includes natural gas savings calculation. Assumes PV is net metered, with feed-in tariff beyond break-even point.

shallow cuts would have the greatest impact on electricity consumption, while the deep cuts would have the greatest impact on natural gas consumption due to replacement of NG furnaces with heat pumps. Alternate scenarios, such as having two-thirds of homes achieve 50% cuts and one-third of homes achieve 20% cuts, could still meet AB 32 targets while having a higher TRC.

Figure 9: Residential Greenhouse Gas Emissions Projection in California, 2008 through 2030[10]



Source: Navigant Consulting, Inc.

Lessons from Existing Retrofit Programs and Practices

There are numerous existing whole-house retrofit programs, from private companies' proprietary processes to utility programs to nationwide initiatives. However, existing processes may not be best suited to support wide-scale implementation of whole-house retrofits. Whole-house building performance contractors are also increasingly common, but their typical process, such as HERS ratings (retrofit packages customized for individual clients), is likely not appropriate for statewide adoption due to the high cost, time, and labor required. Home Performance with Energy Star is probably the most relevant program existing today, with a whole-house approach and strong brand recognition. However, it is nationwide in scope, rather than California-specific.

Major California utilities currently offer online audits rather than in-home assessments. While these audits can help raise homeowner awareness of energy issues, stakeholders expressed concern that such programs are not sufficiently rigorous to achieve the aggressive energy reduction targets set in the Strategic Plan. In part, this is because online audit recommendations are not necessarily optimal. More importantly, however, stakeholders stressed that a

[10] This is based on a bottoms-up estimate based on household number projection based on Census data, building unit energy consumption data based on RASS and percent savings data from Navigant Consulting's BEOpt analysis. The estimate is scaled up so that the 2008 emissions level corresponds to CARB 2009.

comprehensive and interactive process is necessary to ensure that homeowners will take action based on audit results.

RD&D Needs

Technology Needs

Several key technologies that are essential to achievement of the Strategic Plan goals require additional RD&D to enable the widespread adoption necessary. PIER already conducts extensive RD&D in the area of MELs, a rapidly growing end use, and these efforts should be continued or even accelerated to achieve the savings required.

Heat pumps are another important technology, and while they are widely used in other parts of the country such as the Southeast, they are uncommon in California. PIER-supported demonstrations in California, combined with outreach to other agencies and organizations, could help increase awareness and adoption of this important technology.

To reach the 70% savings goal, extensive PV will be required. While there is significant public and private research into PV technologies, PIER could contribute in the areas of retrofit installation optimization and development of technologies or tools to reduce the costs associated with customization.

For all home types, water heater upgrades are frequently required. Water heater types vary, and may include heat pump water heaters, gas tankless water heaters, and solar water heaters. For all of these water heater types, PIER could a comprehensive conduct field studies to validate savings claims and to promote increased adoption.\

Wall insulation appears to be a very promising retrofit option, particularly for multifamily dwellings. However, this retrofit is currently difficult to apply in retrofit situations, can be very costly, and can raise aesthetics issues. As such, further PIER RD&D is warranted to address these issues.

Finally, LEDs, while not essential, are a very common retrofit measure recommended in our modeling. Although costs are already projected to decrease dramatically by 2020 (DOE 2009), it would be helpful for PIER to support the RD&D in this area, and to address color rendering issues with many current generation LEDs.

Knowledge-Building

Beyond technology RD&D, there are other types of knowledge-building efforts in which PIER can play an important role. For example, occupant perceptions and behaviors are essential but poorly understood factors in both adoption of retrofits and in persistence of savings; this study did not address behavioral measures. By addressing issues such as how to influence residents, impact of behaviors, persistence of behaviors, and the "Snackwell Effect" (in which residents use *more* energy after installing efficient devices because they believe it has less impact), PIER can help to ensure that technologies' full savings potentials are realized in the field.

Because of its technology expertise, PIER support is also essential to informing and training various stakeholders in the technologies and strategies needed to achieve the Strategic Plan goals. For example, PIER can assess contractor training needs in the areas of technology awareness, use of available tools, and quality installation, and can develop both training curricula and checklists of retrofit measures that are commonly cost-effective in various climates, vintages, and dwelling types. PIER can also develop informational materials for advocates, program developers, regulators, and industry, to raise awareness and increase understanding of key technologies and strategies that these stakeholders will need to pursue.

Furthermore, better understanding of the costs of various retrofit measures would help generate more effective retrofit package. For instance, this study mainly utilized DEER to develop cost assumptions, but more up-to-date, cost estimates more customizable to specific retrofit applications may lead to different recommendations that have not previously been considered. In addition, establishing the standard deviation of these costs would help identify the areas in which a detailed sensitivity analysis would be especially important.

Implementation

There are numerous aspects of implementation that will need to be addressed in order for the Strategic Plan Existing Homes Initiative to be successful. Most importantly, stakeholders have expressed concern over the definition of compliance – does it include specific measurement of plug loads, cooking, and small appliance energy consumption, which can vary significantly depending on home occupants? If so, how can incentives be aligned for multifamily landlords and tenants to encourage compliance? The verification and enforcement process will also require further development, as Title 24 currently experiences high very rates of non-compliance, particularly for retrofits. PIER could also play a role in researching effective program formats and effective program messaging.

Tools

In order to implement the Strategic Plan's existing homes initiative and verify compliance, user-friendly tools will need to be developed, evaluated, and certified. PIER already supports development of tools such as HEED and BEoptCA. However, additional tool development and evaluation is necessary to ensure ease of use in the mass market. PIER could also support validation of tool savings claims in the field, and development of a tool certification process for compliance verification purposes.

Demonstrations and Case Studies

As mentioned above, demonstrations in various climates and vintages will be necessary to validate the costs and savings predicted here and in other models. Such demonstrations would also be useful in developing case studies to educate stakeholders (e.g., homeowners, contractors, and industry) on the retrofit process and results. In addition to recording energy savings and avoided costs, such case studies could also report on issues such as the time and labor required for retrofits, and on other common concerns such as aesthetics, comfort, occupant health, and customer satisfaction.

Acknowledgement

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