What If Efficiency Goals Were Carbon Goals?

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ABSTRACT

California has set a goal of reducing the state's greenhouse gas emissions to 40% below 1990 levels by 2030, and 80% below by 2050. Energy efficiency is acknowledged as a critical strategy in meeting the state's climate targets, and in reducing greenhouse gas emissions globally. California's recent landmark climate legislation, SB 350, sets the goal of doubling energy savings in statewide retail electricity and natural gas end uses by 2030. The approach to energy efficiency in SB 350 is in alignment with the established energy efficiency paradigm in California and other jurisdictions – energy efficiency goals are defined in terms of energy savings. However, with an increasingly decarbonized electricity grid like California's, energy use is no longer synonymous with carbon emissions. Given the state's long-term goals to reduce carbon emissions, is energy still the right metric for setting efficiency goals and tracking savings? What if carbon reductions were explicitly recognized as the driver of energy efficiency policy? This paper is a thought piece which discusses how California currently sets energy goals and measure efficiency, evaluates different options for addressing carbon in energy efficiency policies, and suggests concrete changes to the current cost-effectiveness approach that would more explicitly factor carbon savings into energy efficiency goals and decisions.

Introduction

In California, and indeed across the globe, policy attention has been focusing on reducing carbon dioxide and other greenhouse gases in order to address the risk of catastrophic climate change. Buildings in California today consume about 70% of the state's electricity and 60% of the state's natural gas usage (excluding gas used for electricity generation). This means that buildings in California are currently responsible for approximately 20% to 25% of the state's total greenhouse gas emissions (Figure 1), or about 100 million metric tons of carbon dioxide per year, given today's energy usage and electricity generation mix. (E3 2015).

The scientific community estimates that to mitigate the worst risks of climate change, global temperature rise must be limited to less than 2 degrees Celsius, which will require reducing global greenhouse emissions by 80% or more by 2050 compared to 1990 levels, and even more deeply beyond 2050 (IPCC 2014). With this information in mind, California's climate goals include reducing statewide greenhouse gas emissions by 40% by 2030, and by 80% by 2050, relative to 1990 levels (Brown 2015). To meet these ambitious goals, the contribution of the state's building stock to greenhouse gas emissions should fall by at least this much, if not more, since it may not be feasible to achieve these deep levels of greenhouse gas (GHG) reductions in all sectors of the economy.

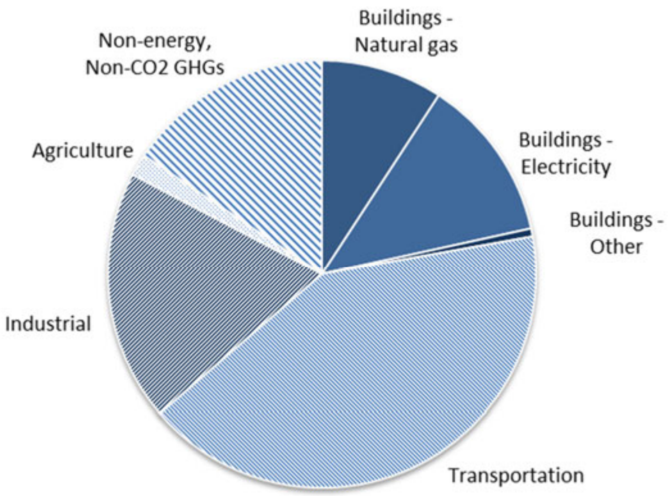

Figure 1. California greenhouse gas emissions by sector, 2015 estimate.
Source: Author's calculations based on E3's California PATHWAYS model v.2.3.2.

This paper assesses the question of what the best policy mechanisms are to support climate goals for the state's building sector. Are energy efficiency goals still relevant when defined as energy targets rather than carbon targets? Should policy makers instead focus on the GHG emissions from individual buildings, or the building sector as a whole?

This paper explores these questions by:

1. providing some context about the role of buildings in statewide greenhouse gas emissions and a brief history of building energy efficiency policies in California,
2. discussing the pros and cons of different policy mechanisms for building efficiency, including energy budgets versus carbon budgets, and finally
3. developing a set of conclusions and recommendations for California policy makers.

Role of Buildings in Carbon Emissions

Greenhouse gas emissions from buildings are defined here as the GHG emissions that result from energy consumption in buildings.[1] There are three primary ways to reduce the greenhouse gas emissions from buildings:

- **Energy efficiency and conservation:** The first and often most cost-effective way to achieve greenhouse gas reductions in buildings is through conservation and the improvement of a building's shell and end uses to reduce energy consumption.
- **Low-GHG electricity:** Buildings must also be increasingly powered by low-GHG sources of electricity. Low-GHG electricity can come from renewable power, hydropower, nuclear power, and fossil fuel generation with carbon capture and

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[1] We purposefully exclude from this definition the GHG emissions associated with the non-energy consumption activities in buildings such as GHGs associated with construction of the building, transportation to and from the building, or the embedded emissions in the building materials, for example. This is a broader topic for another paper.

sequestration. In California, renewable electricity is the most readily available option. Whether the renewable electricity is best generated at the building site, or off-site, depends on the relative cost and benefits of each.

- **Low-GHG fuels:** Fossil fuel use in buildings (primarily natural gas in California, but also propane or, in other regions, fuel oil) must be either eliminated by switching to electric end-uses, or replaced with lower-carbon fuel sources such as biogas and potentially hydrogen (produced with low-carbon electricity).

In California, each of these three elements has been addressed through separate policies and initiatives, without a comprehensive or systematic view towards how these policies influence or impact the carbon emissions of buildings.

- **Energy efficiency and conservation** have been encouraged primarily through building codes, appliance standards, and voluntary, incentive-based efficiency programs such as those administered by the electric and gas utilities and other program administrators.
- **Low-GHG electricity** has been encouraged through supply-side policies such as the state's Renewable Portfolio Standard. Building energy codes have sought to encourage the use of on-site renewable power, by treating these resources as another form of energy efficiency, as a "load reduction measure", rather than explicitly as a source of low carbon energy. Net energy metering rules and other state incentives have also encouraged the development of behind-the-meter renewables, primarily rooftop solar.
- **Low-GHG fuel** use in buildings has received relatively little policy attention to date. California has introduced some standards and policies to support blending renewable biogas into the natural gas pipeline, but these efforts remain relatively limited. Legislative proposals have been introduced to create a 10% renewable natural gas standard but none have yet succeeded.

California's cap and trade program is one policy which does serve to provide a cross-cutting price signal to reduce carbon emissions from buildings overall. It established a carbon price on the GHG emissions from power plants, imported electricity and large industrial facilities in 2012, and to the wholesale distribution of fossil fuels, including gasoline, diesel and natural gas in 2015. We will come back to a discussion of how carbon prices can influence building design and operation choices later in the paper.

In general, and apart from the relatively recent cap and trade program, there has been a stark separation between "demand-side" and "supply-side" policies. As a result, building designers in particular have not received any clear incentive or guidance on how to reduce the greenhouse gas emissions of their buildings. Policies have generally assumed that reductions in energy use serve as an acceptable proxy for reduction in carbon emissions, neglecting the impact or potential of the other two strategies described above. Likewise, there is no policy mechanism today for a building designer to consider the GHG implications of different energy efficiency investment decisions, or the GHG emissions associated with on-site natural gas vs. electricity consumption in buildings.

Brief History of Building Energy Efficiency in California

Because California's efforts to improve energy efficiency in buildings have been underway for more than 35 years, the state's approach evolved in a world before the reduction of carbon emissions was a central policy priority. It is useful then to briefly review the history of the state's energy efficiency efforts. Here we highlight the evolution in thinking about how best to change the way buildings are designed, built and operated, and how the goals for building energy performance have also evolved.

Early California Energy Codes: Source vs. Site Energy

The foundation for energy efficiency in buildings was laid in 1974, when California adopted the Warren-Alquist Act. This created the California Energy Commission (CEC) in 1975, and authorized it to promulgate cost-effective energy efficiency codes for new residential buildings. The objective was to reduce the overall energy use of buildings at the societal level, taking into account "any costs and benefits to the environment, including air quality" (Warren-Alquist Act, 1974). A major consequence of this was the goal of reducing source energy, rather than the more traditional focus on site energy.

The distinction is that site energy is measured based on energy consumed at the building site, whereas source energy accounts for the extra energy needed to generate and transport energy from its source to the building site. In practical terms, this distinction applied primarily to electricity; it historically required about three units of energy at the source (power plant) to generate and transmit one unit of energy to the site (the building).

This 3-to-1 rule of thumb for source vs. site energy assumed that the marginal source of electricity, e.g. the power generation that was avoided by energy efficiency, was generated in a natural gas or coal-fired power plant and was then transmitted over electrical wires. The efficiency of a thermal power plant is generally between 30% and 40%. Transmission and distribution losses vary by region and temperature, but generally are 8 – 9% in California. For electrical systems that rely on increasing amounts of renewable electricity, which are not concerned with thermal efficiency, the rules of thumb and calculations around source energy are outdated.

The CEC's original energy requirements for the building energy code were developed based on savings in source energy. Applying a 3x source energy multiplier to electric site energy savings meant that the California energy codes strongly encouraged on-site use of natural gas over electricity for heating and hot water. Because the energy code established an overall energy budget for a given building, it also allowed users to make trade-offs between measures. This meant that measures that saved electricity were favored over measures that saved natural gas.

Current California Energy Codes: Time Dependent Valuation

Beginning with the 2005 code cycle, California's energy codes have added a refinement to the source energy paradigm based on the avoided cost of electricity and natural gas called Time Dependent Valuation (TDV). TDV reflects the hourly differences in the cost of producing and delivering electricity. In essence, the purpose of the TDV factors is to reflect the greater value of energy efficiency savings during on-peak hours versus off-peak hours. Specifically, the TDV factors reflect the hourly variations in the marginal cost of generating electricity, including the impact of carbon prices on electricity generation, as well as other electricity cost factors. In this way, the hourly TDV factors provide designers who use the alternative compliance performance trade-off method with a clear signal to install measures that reduce on-peak electricity use (HMG 2000).

Under the current TDV methodology, a carbon price forecast is included in the calculation of the hourly marginal electricity prices and natural gas prices, which affects the hourly *shape* of the TDVs. The carbon price also increases electricity and natural gas retail rates. By increasing electricity and natural gas retail rates, the carbon price also affects the overall *level* of the TDVs. Both the shape and the level of the TDVs affects what kinds of measures are considered cost-effective to be required in the building code. Figure 2 illustrates the various components of the TDV values. The "Retail Adjustment" increases the overall *level* of the TDVs to reflect a forecasted average statewide retail rate for residential or non-residential customers. The other components shown in the figure affect the *shape* of the TDVs.

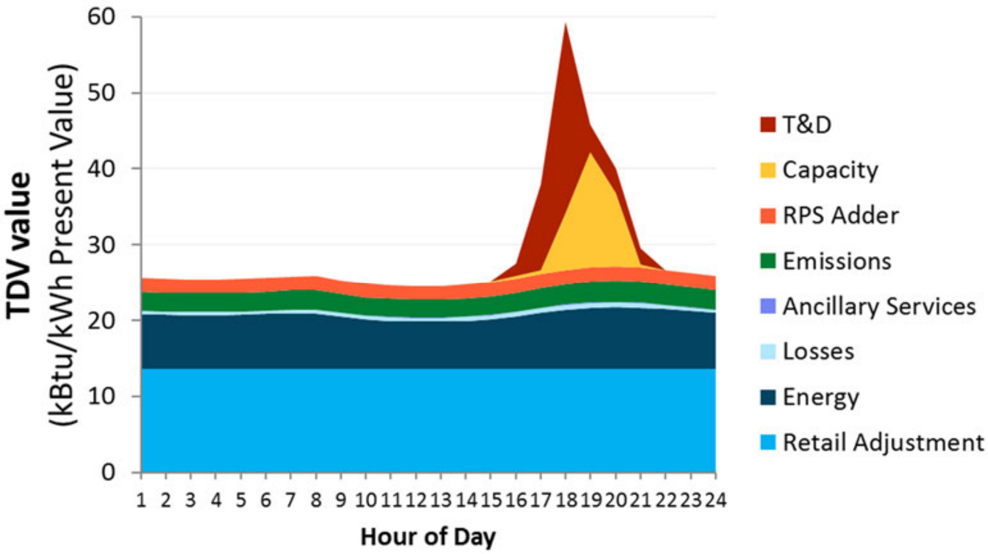

Figure 2. Components of the 2019 electric TDVs for an illustrative 24-hour period (non-residential Climate Zone 12). Source*:* E3, 2016.

The end result is that current TDV factors still generally favor on-site use of natural gas rather than electric end-uses in buildings. This is because, in general, on-site combustion of natural gas is still the cheaper energy source compared to electricity using current projections for energy and carbon prices.

Zero Net Energy Goals

As requirements for energy efficiency in buildings have developed, and the use of renewables has also grown, California state energy agencies have set more ambitious goals for new construction buildings to achieve zero net energy (ZNE). Although there are varying definitions of ZNE, and some rather knotty issues in achieving ZNE performance in a given building, the general strategy is to first maximize the energy efficiency of the building and its systems, and then to provide the remaining energy needs from renewable sources (HMG 2012).

This is often easiest when dealing with electricity consumption and with renewable electricity sources, and becomes somewhat more complex when dealing with on-site fossil fuel consumption and renewable fuels. The CEC is currently working on ZNE building codes based on a "net-zero TDV" definition of a ZNE building. As discussed above, the TDV factors are an hourly avoided cost metric defined by retail prices for electricity and natural gas. Because it is more cost-effective to use natural gas end uses over electricity, this definition of a ZNE home will again tend to favor on-site natural gas consumption over electric end uses (Torcellini et al. 2006). As discussed in the next section, a more explicit treatment of carbon reductions in energy efficiency decision-making is both desirable and possible.

Calculating and Comparing Carbon Emissions in Buildings

If one of the primary goals of encouraging energy efficiency in buildings is to reduce the GHG emissions associated with buildings, then it is important to incorporate the carbon content of the electricity and natural gas that buildings use into decision making; both at the time that the building is designed, and when the building is in operation. When the energy codes were established in California it was assumed that energy savings were reducing marginal electricity generation defined by combined cycle gas turbines, which use three times as much energy to produce and deliver to the building site compared on on-site natural gas use.

An Example: Carbon Emissions from Electric versus Natural Gas Water Heaters

The example below illustrates the implications of the changing mix of the electric grid, and its implications for energy efficiency decisions. Figure 3 shows a simplified example of the greenhouse gas emissions associated with operating four different types of water heaters, both electric and natural gas, across a range of potential electricity mixes, from 100% natural gas generation to 100% renewable generation. The energy factor (EF), a measure of water heater overall efficiency, for each technology is indicated in the chart. The emissions associated with the electric water heaters change based on the emissions intensity of the electricity that powers them.

On the left-side of the graph, we show the emissions of each technology, assuming that the avoided electricity generation resource is 0% renewable (100% natural gas). This side of the graph represents today's current approach to valuing water heater efficiency, which assumes that 100% natural gas generation is the marginal resource displaced by electric efficiency on the grid. On the right side of the graph, we show the emissions associated with each technology assuming that the avoided electricity generation resource is 100% renewable. In the 100% renewable case, the electric end uses would have zero emissions associated with their operation. For the purposes of this example, we assume that the emissions intensity of natural gas is based on fossil natural gas, (rather than a potential future mixture of biogas and fossil natural gas).

Figure 3 shows that the GHG emissions associated with an electric resistance water heater are higher than a conventional gas water heater, when the electricity that powers the electric water heater comes from 100% natural gas (0% renewable electricity). Emissions are also higher for heat pump water heaters, although marginally so. These facts drive the current California energy code's implicit preference for on-site natural gas end uses over electric end uses.

However, as we have described in Mahone (2009), it is appropriate to consider today's RPS policy in our definition of the avoided cost for energy efficiency electric grid. Given today's 20% RPS, (and ignoring the future increase in the RPS to 50% for the time being), then a high efficiency, electric heat pump water heater is actually lower in carbon than a natural gas water heater today. At a 50% renewable mix, a high efficiency electric resistance water heater is likely to be lower carbon than a conventional gas water heater.

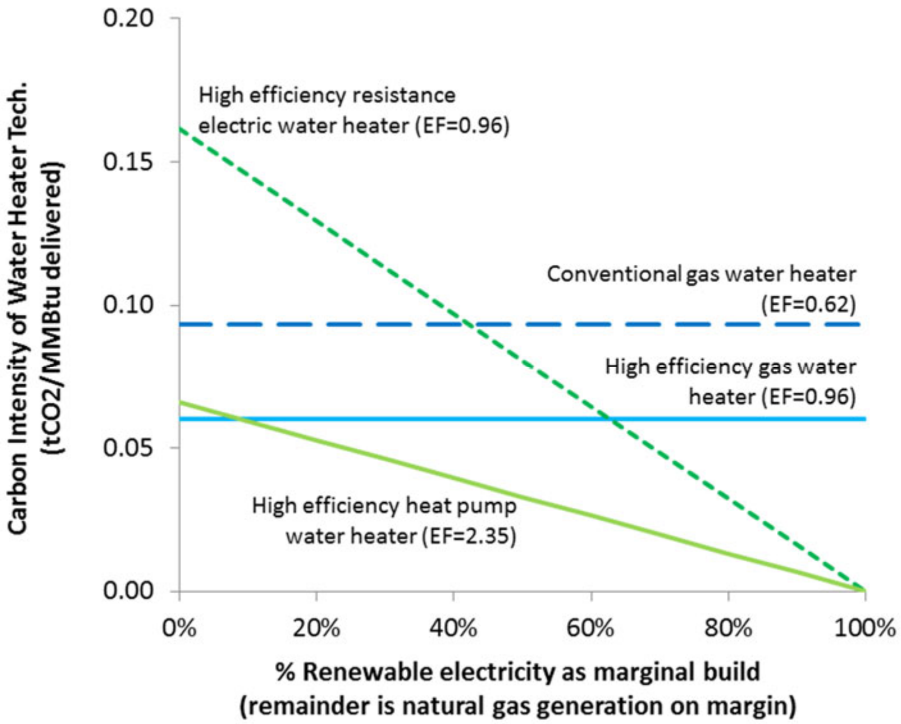

Figure 3. Carbon intensity of water heater technologies, as a function of renewable electricity percentage. Source: Author's calculations

It is important to note that the calculations above do not reflect the lifecycle greenhouse gas emissions associated with the operation of each appliance over its expected lifetime, nor does it reflect the hourly operation of the water heater. Rather the figure represents the greenhouse gas emissions using a long-run, annual treatment of marginal renewable generation. This simple example is designed to illustrate the following point: given that the renewable mix on California's electric grid is getting cleaner over time, from a carbon perspective, energy efficiency decisions should increasingly favor electric end uses – unless the carbon intensity of natural gas also declines over time.[2]

Options for Incorporating Climate Goals into Building Efficiency Policies

Through this brief review of California's evolution of energy efficiency standards in buildings, we have demonstrated that carbon reductions in buildings have not been the primary focus of energy efficiency policies. Rather, the focus has been on cost-effective energy reductions, which does result in carbon savings, but does not necessarily send building designers or operators the right signals to maximize or optimize carbon savings. This fact is illustrated above by the water heater example. Using a standard source-energy evaluation, or today's avoided cost metrics, high efficiency natural gas water heaters are preferable to electric heat pump water heaters. However, using a carbon-based evaluation, the electric heat pumps are

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[2] This analysis has not included the possibility of low-carbon gas as an option because there are currently no major policies in California to encourage this. However, it would be possible to reduce the GHG emissions from natural gas by blending in biogas from sources such as landfills, wastewater treatment facilities, manure and other sources of sustainable biomass.

shown to actually result in lower total carbon emissions, and even electric resistance water heaters eventually outperform their natural gas counterparts on a carbon basis at a sufficiently high renewable penetration.

So, what changes would be needed to the state's building code to ensure that carbon reduction in buildings is at least one of the factors contributing to building design decisions? We consider the two main options here, and subsequently discuss the key implications. The first option is to replace the current building code energy budget with a carbon budget for buildings. The second option is to modify the current approach to calculating the energy budget to reflect a greater emphasis on greenhouse gas reduction goals.

Option 1: Carbon Budget

Rather than setting building energy budgets for new construction and remodeled buildings, as the California building code has done since 1978, the budgets could instead be set in terms of carbon emissions. A carbon budget would reflect the expected "lifecycle" carbon content of grid electricity, on-site fuel combustion, and on-site electricity generation. While this approach would create a direct linkage between the GHG emissions associated with a building and the building design choices that guide its development, practical implementation challenges make this approach less desirable.

There are a number of ways that a carbon budget could be determined for a building, or for the building sector as a whole. One approach would be to first calculate the greenhouse gas emissions associated with a building using the current code. Future energy codes would require reductions in buildings' greenhouse gas emissions relative to current code, consistent with the state's climate goals.

To calculate a building's GHG emissions, a designer would first calculate the expected hourly energy consumption of the building using a building simulation tool, as is currently done in building code alternative compliance calculations. Second, an estimate of the carbon intensity of the fuels used in that building (both electricity and natural gas) would be applied to calculate the total expected carbon emissions.

There is, of course, uncertainty in the future carbon intensity of fuels used by buildings. While the emissions intensity of electricity is more-or-less defined through 2030 by current RPS law, this law could change or other factors could result in a change to the future carbon intensity of electricity. Likewise, while the emissions intensity of fossil natural gas is not going to change, if more biogas or other low-carbon fuels are blended into the gas distribution pipeline in the future, the emissions intensity of on-site gas use would change as well. However, even the most basic and well-established energy efficiency cost-effectiveness metrics rely on the prediction of uncertain variables, including the future performance and energy cost savings of an energy efficiency measure.

Another challenge with the carbon budget approach is that it would represent a fundamentally disruptive change to the way building standards have been set in California for at least the last 30 years, not to mention the difficulties of communicating and administering the new approach. Building designers today are not equipped to calculate and interpret carbon metrics. Even though a new carbon budget approach may not be technically very different from today's TDV calculations, it would still represent a conceptually different approach to thinking about building design. Changing the fundamental framework of the state's building code to focus on carbon would require a massive education and outreach effort, and could not be undertaken lightly. Such an approach could potentially be phased in over a number of years, beginning with voluntary approaches and voluntary carbon metric reports.

However, perhaps the biggest challenge with the carbon budget approach is the fact that the Energy Commission has a mandate under the Warren-Alquist Act to encourage energy efficiency, not necessarily carbon reductions. Furthermore, the Warren-Alquist Act requires that energy efficiency measures be cost-effective. It would require an additional analysis step to justify a building's carbon budget in cost-effectiveness terms.

Option 2: Modify the Current TDV and Cost-Effectiveness Frameworks

Rather than changing the building code to be entirely based on carbon savings, the current code could be simply modified to more directly encourage carbon reductions and carbon-based trade-offs using the current cost effectiveness framework.

If energy efficiency programs are to shift towards placing a greater emphasis on carbon reductions, then a more substantial carbon cost should be identified and implemented in the TDVs. Of course, a higher carbon price would not replace energy costs, which would continue to be included as one of the components of cost-effectiveness.

Current California carbon market prices are about \$12/ton of CO_2. The CEC's 2015 "mid" carbon price forecast shows these prices could be expected to increase to \$44/ton by 2030. The CEC includes a low and high range from \$29 to \$88/ton in 2030 (in 2013 dollars) (CEC 2015). However, with current natural gas and electricity prices, and even assuming an emissions intensity of electricity based on a 50% renewable/50% gas mix, the price of carbon would need to be over \$100/ton before the cost of operating an electric heat pump water heater would break even with the cost of operating a high efficiency natural gas water heater (assuming an Energy Factor of 2.35 for heat pumps and 0.95 for high efficiency gas water heaters).

A long-term, societal value for carbon reductions would likely be substantially higher than the current market clearing costs for carbon credits. The U.S. Interagency Working Group on the Social Cost of Carbon estimates ranges from \$11 to \$123/ton today, and up to \$16 to \$152/ton by 2030 (in 2007\$) (Interagency Working Group on Social Cost of Carbon 2015).

Using a societal cost of carbon in the cost-effectiveness calculations for energy efficiency could be a seriously contentious issue, but basing energy code requirements on societal cost considerations is not new. The California energy codes, for example, have long applied a societal discount factor in assessing life-cycle cost effectiveness of code requirements (HMG 2000). This has the effect of encouraging energy efficiency measures that have much longer paybacks than many owners would find acceptable. The use of a societal discount rate is based on the observation that buildings often last a lot longer than original owners own them. Consequently, efficiency measures will continue to provide economic benefits to building owners, and to society, long after the original owner has left the scene.

A similar argument could be made for carbon reductions: the enormous consequences of human-induced climate change should be factored into cost-effectiveness considerations for measures that building owners could implement to help mitigate carbon emissions.

An alternative approach to applying a societal carbon price in energy efficiency cost-effectiveness calculations would be to estimate the average, or marginal, implied cost per ton of CO_2 associated with meeting the state's 2030 or 2050 climate goals. This implied cost per ton metric could become the basis for making energy efficiency trade-offs and cost-effectiveness evaluations. Like the societal cost of carbon, this value would be difficult and controversial to calculate. However, if done well, it could provide a better price signal to guide long-term energy efficiency investment decisions than the current approach.

Changing Signals to Building Designers

The current, energy-based codes signal building designers to favor reductions in on-peak energy use. This tends to favor energy efficiency measures in air conditioning, over outside lighting efficiency, for example. A low-carbon energy code, that provides greater encouragement to both save energy and select low-carbon energy sources, could lead to very different building design signals. For example, it could encourage, rather than discourage, energy use on springtime afternoons when there is ample renewable energy on the grid, and it could discourage electricity use in the hours after sunset when the renewable sources fall away. Perhaps more dramatically, it could encourage greater reliance on electric rather than natural gas end uses in buildings, such as electric space heating, water heating and cooking.

This change in signals would impact how buildings are designed, how their energy systems are operated, and perhaps whether they incorporate on-site energy storage. It could also encourage the use of on-site renewables, if it was a cheaper, lower-carbon source of electricity than the grid. Likewise, if building designers could get code credit for the use of off-site renewable energy, this policy could lead to more investments in low-carbon electricity and gas options.

Implications for Voluntary Energy Efficiency Programs and Incentives

Current voluntary energy efficiency programs, such as those run by utilities and other program administrators, are focused on encouraging customers to implement cost-effective measures whose efficiencies exceed those required by codes and standards. These measures must pass their own cost-effectiveness criteria, established by the CPUC and differing from the criteria used by the CEC in setting energy code requirements. Just like the building code standards, we suggest that the CPUC consider implementing a higher carbon price in its cost-effectiveness criteria in order to place greater emphasis on measures that reduce carbon. A full exploration of the implications of including a higher carbon price in voluntary CPUC energy efficiency programs is beyond the scope of this paper, but is a topic worthy of further consideration.

Conclusions and Recommendations

Reducing greenhouse gas emissions is of central importance to society, and reducing greenhouse gas emissions in buildings is a critical component of achieving our long-term carbon goals. Buildings in California account for approximately 70% of electricity use, and 60% of non-electric generation natural gas use. This means that the energy used in California buildings constitutes between 20% and 25% of the state’s total greenhouse gas emissions.

Energy efficiency in buildings is generally the least-cost option for reducing carbon in buildings, but it is not sufficient. Low-carbon fuel use in buildings, either low-carbon grid electricity or on-site use of low-carbon electricity and fuels is also necessary. California has mandated renewable electricity goals through the Renewable Portfolio Standard, which is reducing the carbon content of the electricity grid and fundamentally shifting the definition of the avoided cost of electricity in California. Likewise, the avoided greenhouse gas emissions associated with energy efficiency in buildings is shifting over time.

Current energy efficiency policies and goals were not developed with a carbon reduction framework in mind, and so some modifications to the current framework are necessary. Namely, the marginal or avoided generation resource is no longer just natural gas generation. Zero-carbon, renewable electricity represents a growing share of the electricity mix, reducing the carbon emissions associated with electricity and changing the economics of electricity generation. This has implications for the GHG savings associated with electricity and natural gas efficiency in buildings, as well as the cost-effectiveness of electricity and natural gas efficiency. As one example, this paper has demonstrated that a high efficiency electric heat pump water heater is likely to be lower-carbon than a natural gas water heater today. However, the economics of operating an electric water heater are unlikely to be cost-effective compared to a gas water heater, given current projections for natural gas and carbon costs.

A full-scale re-design of energy efficiency goals to carbon-based goals is not necessary, and likely would not be feasible without new enabling legislation. However, some important changes are needed, and achievable within today's energy efficiency frameworks, to ensure that carbon reductions are not overlooked when making building design or operation choices. The simplest approach to ensure that carbon reductions are properly valued in energy efficiency valuation is to apply a higher carbon price to the cost-effectiveness calculations. This carbon price could reflect the societal cost of carbon emissions, or the long-run cost of compliance with the state's climate goals. Further, zero-net energy goals should be redefined to reflect zero-net carbon goals – whereby the carbon emissions associated with a buildings' energy use should net to zero over the course of a year.

The building sector is notoriously slow and difficult to change. The current success of California's energy codes is the result of over thirty years of concerted effort to implement some substantial changes in practices, methods and materials. A fundamental shift in those codes would also require years, if not decades, to achieve substantial market penetration in the buildings sector, but could contribute substantially to a low carbon future. One way to speed this transition today would be through the adoption of voluntary carbon metrics for buildings, to raise awareness about the need to better align our carbon goals with our energy efficiency goals, and to better understand the GHG tradeoffs between the choice of gas versus electric end uses in buildings.

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