Preliminary Economic Outlook for California Residential ZNE

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ABSTRACT

California has set a goal to require zero net energy (ZNE) as the standard for new residential homes by 2020. The requirement for all new homes to meet a ZNE standard will set an example of what is possible for the nation and reflect an unprecedented reduction in energy use. However, California statute requires building codes to be cost-effective for building owners over the life of the building. This paper provides preliminary analysis on the cost-effectiveness challenges the California Energy Commission (CEC) will consider before implementation of residential ZNE and maps out the pros and cons of different ZNE compliance paths.

The CEC uses a Time-Dependent Valuation (TDV) methodology to evaluate cost-effectiveness. Within this framework, the three primary economic challenges are evaluated including (1) the decreasing value of solar generation over time as more rooftop and utility-scale solar is built, (2) offsetting low-cost and efficient natural gas use in buildings, and (3) whether to allow lower-cost off-site renewable electricity and natural gas to offset residential energy use.

The vast majority of California homes are mixed-fuel homes (electricity and natural gas) and the presumed compliance path to meet ZNE is a mixed-fuel home with a solar PV roof. However, the CEC may allow additional compliance pathways including all-electric homes, and given the challenges identified in offsetting natural gas with on-site solar the CEC may consider off-site renewable generation. The presumed path and additional possible pathways are preliminarily assessed for cost-effectiveness.

Introduction

As part of California's ambitious greenhouse gas reduction targets, the California Public Utilities Commission (CPUC), the California Energy Commission (CEC), and the major California utilities have collaboratively endorsed the goal that all new residential construction will be zero net energy (ZNE) by 2020 (CPUC 2011). The CEC is beginning its work on developing the next round of building codes to incorporate these ZNE goals. Since the building code will affect all new construction, and the 2020 ZNE goal implies significant changes in residential construction and design practices, the approach and metrics adopted in the next round of the California building energy code (Title 24) to implement the ZNE policy are among the most significant in California residential energy efficiency in some time.

A ZNE home is generally one that produces as much energy as it consumes. In the 2013 CEC Integrated Energy Policy Report (IEPR) a specific definition of Time Dependent Valuation (TDV) is adopted as the metric to measure energy (CEC 2013). TDV is the same economic standard used to value all building code measures and the TDV values are updated with each code cycle. The dominant source of energy for new ZNE homes is expected to be solar rooftop photovoltaic (PV) systems located on the roof of the new home, though the IEPR does make mention of community-based self-generation as a potential path towards ZNE compliance.

Figure 1 is an illustration of a potential ZNE home that will feed electricity back to the grid periodically during the day, and consume electric, natural gas, and propane energy over time.

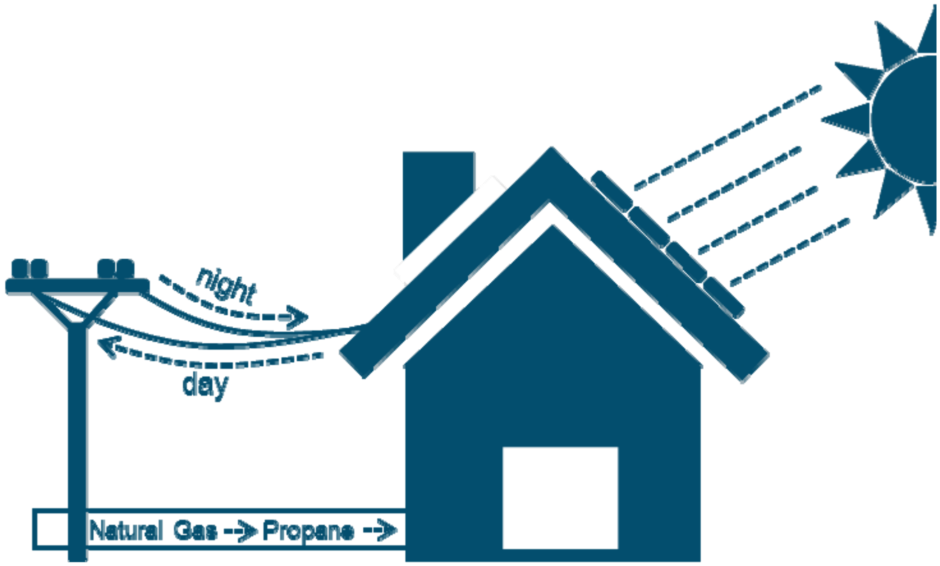

Figure 1. Illustration of a potential ZNE home.

The adoption of new building code measures, including ZNE, requires a cost-effectiveness assessment by statute under the Warren Alquist Act (CEC 1974). Cost-effectiveness is defined using a lifecycle cost analysis over the life of the building or measure to determine whether the benefits to the building in reduced electricity and natural gas expenditures are greater than the incremental costs to the participant. Cost-effectiveness in California is evaluated using TDV.

Within this framework, the three primary cost-effectiveness challenges are evaluated using TDV including:

1. The decreasing value of solar generation over time due to increased rooftop and utility-scale solar generation and changing compensation for rooftop solar systems,
2. Offsetting low-cost and efficient natural gas use in buildings, and
3. Whether to allow lower-cost off-site renewable electricity and natural gas to offset energy use.

The vast majority of California homes are mixed-fuel homes (electricity and natural gas) and the presumed compliance path to meet ZNE is a mixed-fuel home with a solar PV roof. However, the CEC may allow additional compliance pathways including all-electric homes with solar and off-site renewable generation. The presumed path and additional compliance pathways are assessed for cost-effectiveness.

Value of Rooftop Solar

In order for the rooftop solar component of ZNE to be included in a building code requirement it must be cost-effective. The costs are the cost of solar to the home owner, and the benefits are defined by TDV. The TDV metric is an estimate of participant benefits for a building measure based on the statewide average rates and the underlying 'shape' of the marginal costs of producing and delivering energy to a customer.

The marginal costs of electricity are built up as the sum of area- and time-specific components including the cost of energy with embedded CO_2 allowance costs, losses in delivery, generation capacity, transmission and distribution (T&D) capacity, ancillary services, and any avoided costs associated with the renewable portfolio standard (RPS) obligation. These avoided costs are then scaled up with a retail rate adder, to make the TDVs at the average rate level of an average Californian customer's bill. TDV should be thought of as a modified participant cost test (PCT) for those that are accustomed to the California Standard Practice Manual (SPM) for energy efficiency cost-effectiveness. The TDV values are forecast over the assumed lifetime of the building by forecasting each of these respective TDV marginal cost components and the retail rates.

Any changes to the underlying components of TDV will change the value of solar rooftops. However, there are two components in particular that will have significant impact on the value of solar, illustrated further in Figure 2.

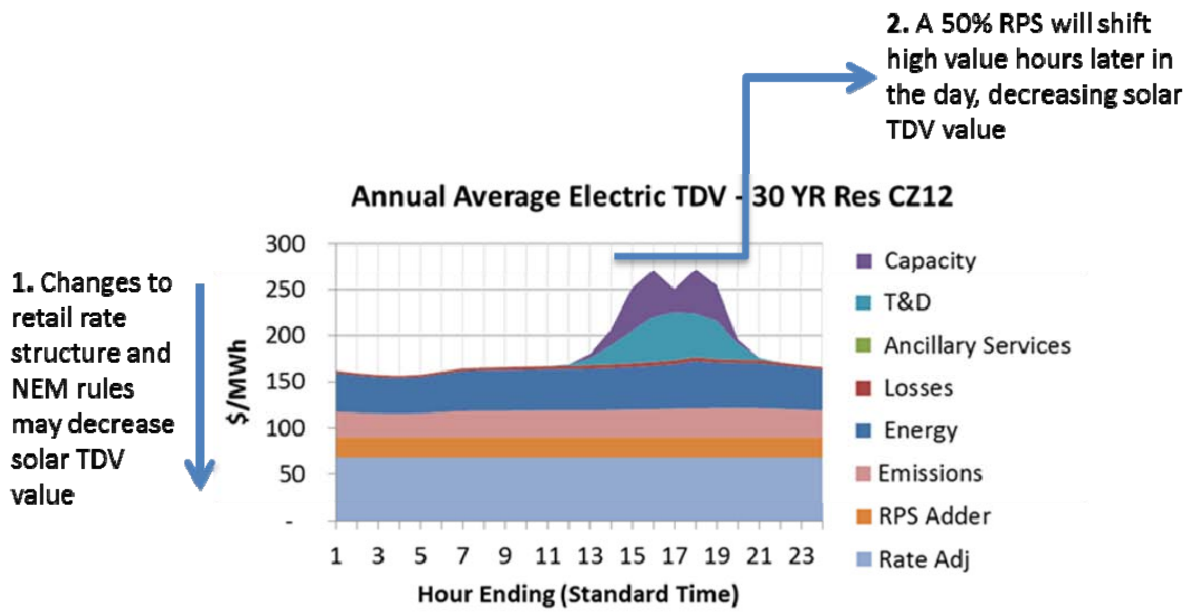

Figure 2. Expected changes in 2016 electric TDV shape based on evolving policy in California.

1. The first component is any change to the compensation mechanism for rooftop solar through either a change to the Net Energy Metering (NEM) rules, or the underlying rate.
2. The second change is to the 'shape' of the electric TDVs which is likely to demonstrate reduced energy prices and capacity value during midday hours due to the utility-scale and distributed solar PV brought online over the life of the building.

Effect of 50% RPS

The most recent adopted TDV values were developed in 2013 as part of the 2016 building code update and reflect the policies and market conditions that existed at the time. A number of developments have occurred since, notably the passage of SB 350 which requires utilities in California to procure 50% of their electricity sales from renewable resources by 2030, an increase from the current requirement of 33% by 2020. This quantity of renewable energy, currently forecasted to be largely solar PV, will have large impacts on the hourly cost and value of electricity during midday hours. Although a rigorous update to reflect the 50% RPS will occur in the next TDV update cycle, we have made an estimate of this impact by modifying the existing TDV values in a manner that reflects a 50% RPS. The following changes were performed:

- Update to hourly energy prices to reflect high solar output during the day.
- Update to system capacity allocation to be later in the evening.
- Update to transmission and distribution (T&D) capacity allocation later in the day.
- Update to avoided renewable energy costs (based on the RPS) to a 50% RPS.
- Increase to electric rate forecast by 20% to reflect current policies and SB 350.

Rooftop Solar Compensation and NEM Reform

The existing TDV framework relies on the assumption that the average TDV throughout the year is equal to the average retail electricity rate. Historically, this was a reasonable assumption for solar PV since the NEM policy allowed all behind-the-meter solar PV generation to be credited at the full retail rate, regardless of whether the energy was being consumed on-site or exported back to the grid. The alignment between the TDVs and the retail rate is accomplished through the retail rate adder component that trues up the TDVs to the average retail rate.

In January 2016 the NEM 2.0 decision scaled back the compensation to NEM generation (CPUC 2016). Beginning in July 2017, new NEM customers will not receive credit for the non-bypassable charge portion of the retail rate for energy that is exported back into the grid (e.g. approximately 2.8 cents[1] per kWh). The next opportunity for significant changes to the compensation of rooftop solar is in 2018 when the CPUC will adopt new rate structures for residential customers including time-of-use pricing.

Over the lifetime of the building, there will be multiple opportunities and decisions that affect compensation for NEM. To span a reasonable range of possibilities and assess the impact on the value of solar, we evaluated four different sets of TDVs to align with the expected compensation that a NEM customer would receive under both the existing NEM policy, the adopted NEM 2.0 policy, and two hypothetical future policies.

- **CPUC Existing NEM Policy**
  - NEM customers receive full retail rate compensation for all electricity generated, including electricity that is consumed behind-the-meter and exported back to the grid.
- **CPUC NEM 2.0 (adopted policy)**
  - NEM customers receive full retail rate compensation for all electricity generated, except for non-bypassable charges of 2.8 cents per kWh which are not paid to generation that is exported back to the grid.

[1] 2.8 cents per kWh is based on the following components: public purpose charges, nuclear decommissioning, competitive transition charge, DWR bond charge, new system generation charge, and PUC reimbursement fee.

- **10% fixed charge (hypothetical policy)**
  - NEM customers receive compensation that is 10% lower than the retail rate since that portion of the electricity bill is collected through a fixed charge component that NEM generation cannot offset. This might be implemented through fixed charges, demand charges, or charges based on gross (not net of behind-the-meter solar generation) electricity consumption.
- **25% fixed charge (hypothetical policy)**
  - NEM customers receive compensation that is 25% lower than the retail rate (see full explanation above). A figure of 25% was chosen as a more aggressive step that the CPUC might take in the next round of NEM reform in an effort to reduce the cost-shift from NEM customers to non-NEM customers.

Value of Solar Results

E3 approximated eight sets of proxy TDVs under both the existing 33% RPS and pending 50% RPS as well as the four different NEM policy scenarios. Using these proxy TDVs and a representative behind-the-meter solar generation profile, E3 calculated the change in benefits for behind-the-meter solar PV as would be used in the current ZNE cost-effectiveness framework. Figure 3 shows how behind-the-meter solar PV becomes less cost-effective as the RPS percentage increase and NEM reforms are implemented. While we show results for Climate Zone (CZ) 6, Los Angeles, we did not find substantial variance in these results across different climate zones[2].

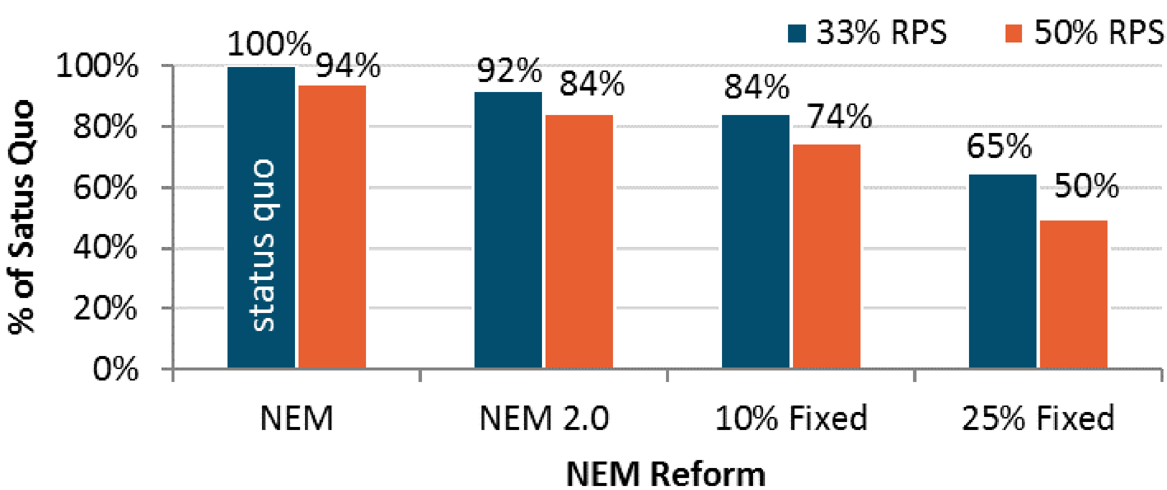

Figure 3. Behind-the-meter proxy TDV value relative to status quo (CZ 6).

As would be expected, NEM reforms decrease the effective compensation to behind-the-meter generation systems. While the adopted CPUC NEM 2.0 decision has a relatively muted effect on benefits, larger fixed charge reforms start to have substantial impact.

The decrease in value due to an increase to 50% RPS is largely due to a shift of electricity value in the middle of the day when behind-the-meter solar PV is generating to later in the

[2] For CZ 14 (China Lake), which is the climate zone with the highest insolation in California, relative reductions to solar PV benefits were within 4% of CZ 6 (Los Angeles) results presented

evening. This is because a 50% RPS is expected to be met using a large percentage of central-scale solar PV, which also produces in the middle of the day. This abundance of energy will decrease both the value of energy and system capacity during this time period and shift the higher value hours to later in the day, once the sun has set but demand still remains relatively high. An example of this shift using the existing 33% RPS TDVs and our estimated 50% RPS TDVs is shown in Figure 4.

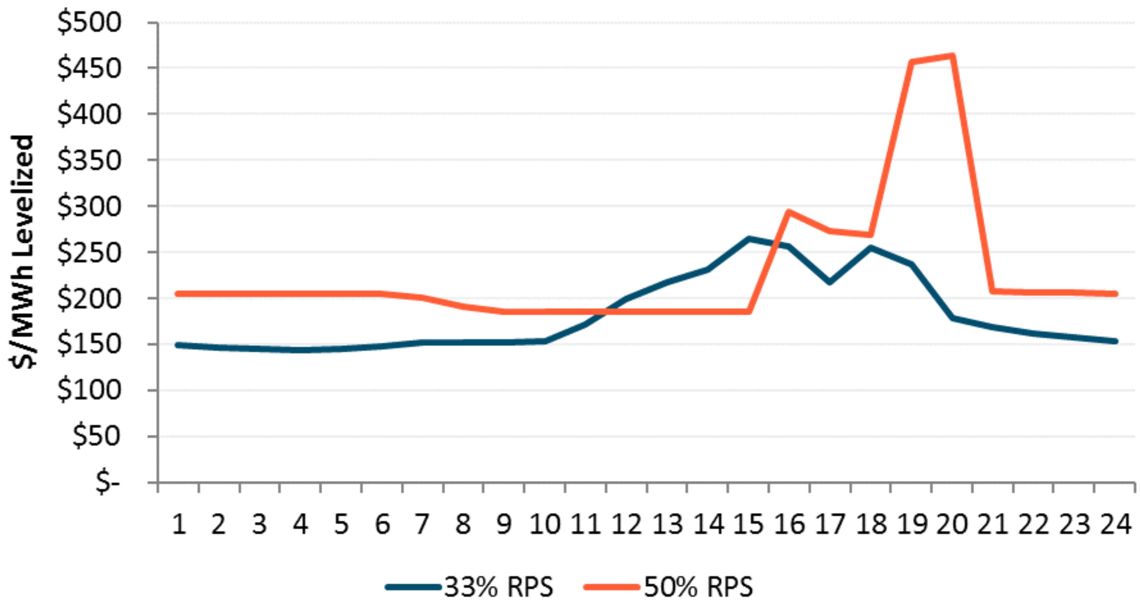

Figure 4. Variation in proxy TDVs during the day by RPS penetration (daily average shape – CZ 6).

These results show that the new 50% RPS policy and potential future rate design or NEM reform decisions will shift the peak later, and depending on the forecasted rate increase may make it more difficult for rooftop solar to be cost effective under the existing TDV framework.

Compliance Pathways for ZNE

We explore four possible pathways for compliance with the proposed ZNE policy. These include:

A. A mixed-fuel building with on-site rooftop solar PV
B. An all-electric building with on-site rooftop solar PV
C. A mixed-fuel building offsetting energy use with off-site renewables
D. An all-electric building using off-site renewables

To better understand these options for ZNE compliance, we used TDV values for a single-family home in California Climate Zone 8 (CZ 8). This data is based on 2016 TDV values, which will change significantly in the 2019 update due to the policy developments in NEM and RPS discussed in the previous section. To reflect the overall reduction in the value of solar due to NEM 2.0 and the progression towards a 50% statewide RPS, we applied an 84% adjustment to the 2016 TDV values. This allowed us to investigate the overall capability of achieving ZNE as well as cost-effectiveness.

Achieving ZNE in a Mixed-Fuel Building

Natural gas is both low cost and relatively lower in greenhouse gas emissions given our current electric generation mix, loss factors in the grid, and standard electric appliances. Current Title 24 code is based on a prescriptive standard that includes natural gas in buildings for which it is available in addition to electricity (i.e. mixed-fuel buildings). Since 2005, this decision has been based explicitly on cost-effectiveness, and before that based on source efficiency.

In this section we use proxy information to investigate how the cost-effectiveness may change as the CEC explores ZNE with updated TDV values for the 2019 building code cycle. Under current NEM and RPS conditions in CZ 8, rooftop PV sized to the home's load offsets its electricity demand, but is not sufficient to reach ZNE due to the inability to offset natural gas use. While technically possible to oversize the solar PV system, the interconnection rule requires that solar generation is expected to produce no more electricity than the building's electricity consumption. In addition, annual surplus generation (if any) is compensated at a low rate, which means that a PV system oversized to offset natural gas consumption may not be cost-effective. Furthermore, as California moves towards its 50% RPS requirement and decreased NEM compensation, the rate of rooftop PV decreases and rooftop PV may not even be able to offset the electricity portion of a home's TDV budget.

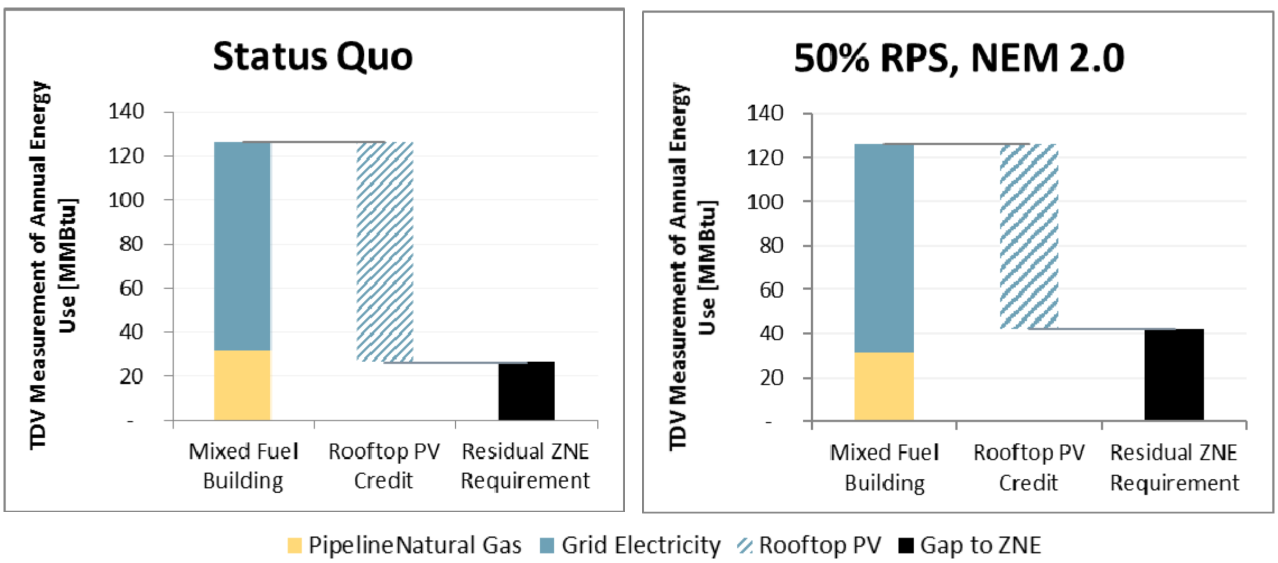

Figure 5. TDV evaluation of a traditional mixed-fuel building in CZ 8 with rooftop PV unable to reach ZNE as defined.[3]

Figure 5 highlights that rooftop solar cannot offset natural gas use in a mixed-fuel home. This is driven largely by the decreasing credit for rooftop solar from updated NEM compensation and the sizing restriction on solar PV.

[3] TDV budgets are measured in Btu and are the measurement for both cost-effectiveness and ZNE compliance. The units are shown in MMBtu's since they are based on time-dependent hourly energy values which do not directly translate to customer rate schedules.

Achieving ZNE in an All-Electric Building

Given the challenge of meeting ZNE with a mixed-fuel home, the CEC could hypothetically require new homes to be all-electric homes to meet the ZNE policy goal. An all-electric building would allow all of the on-site energy needs to be met with a rooftop PV system and therefore reach ZNE. However, natural gas is a relatively low cost fuel and the all-electric home may be more expensive than a mixed fuel home both in terms of operating and capital costs. Figure 6 compares the cost-effectiveness of an all-electric home to a mixed-fuel home, and in fact we find that it is unlikely for an all-electric home to be lower cost when considering both fuel costs and all-electric technology costs for high efficiency heat pump space conditioning and water heating. This means that it is unlikely that the CEC would or could require all new homes to be all-electric. Depending on the relative operating costs as measured by TDV it may be possible for all-electric buildings to pass the energy code as an option if a customer wanted to build an all-electric home. The key drivers of allowing an all-electric compliance *option* will likely be the energy efficiency of heat pumps and the relative increase of electric rates as compared with natural gas rates. The key drivers of allowing an all-electric compliance *mandate* will be the same, but with the additional driver of the incremental costs of all-electric appliances as compared with gas-fired appliances.

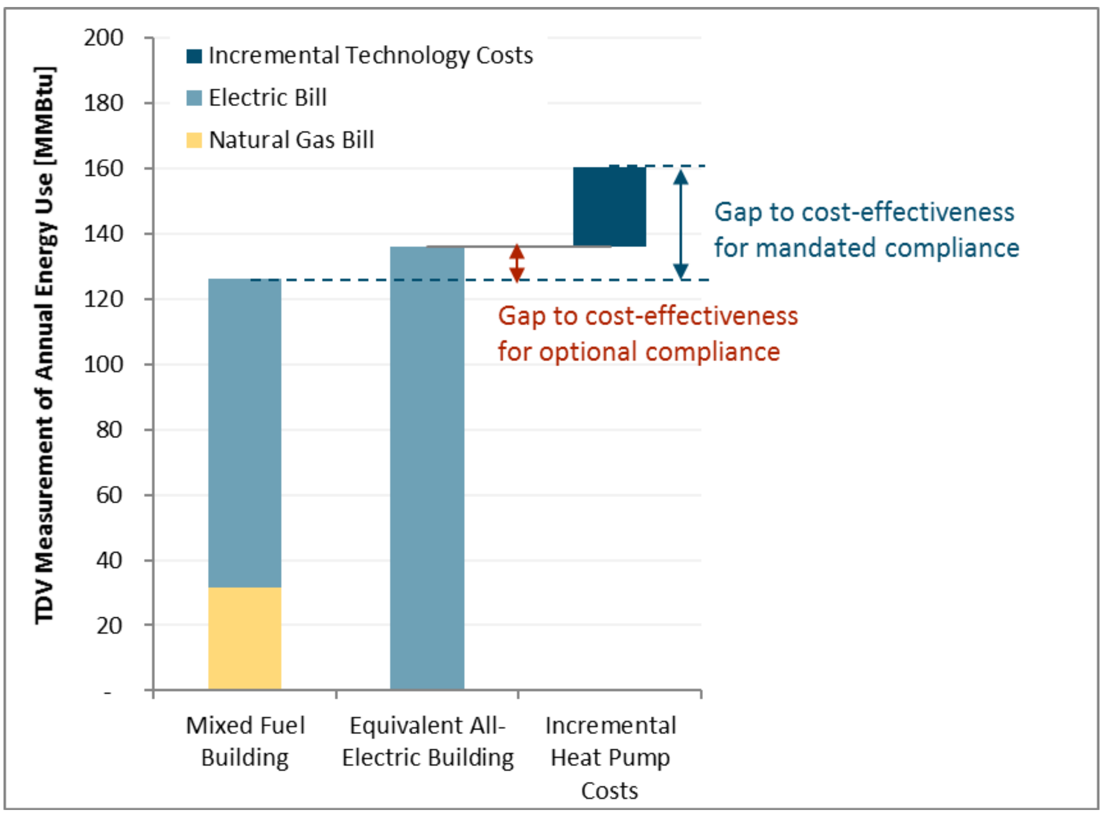

Figure 6. TDV cost effectiveness components for an all-electric home in CZ 8.

Achieving ZNE with Off-Site Renewables

Community solar is the most commonly referenced alternative strategy to meet ZNE and could potentially offset both electricity and natural gas use in buildings without solar rooftop sizing restrictions and interconnection limits. The ZNE Action Plan places significant emphasis on ZNE Community, setting to identify barriers to community solar by late 2015. The state has been working on community solar programs. CA SB43 requires the three major investor-owned utilities (IOUs) to set up programs of up to 600 MW of community solar. Consequently, multiple IOUs have introduced a "green rate," which funds a community solar project through a premium charge on a customer's bill. While these premium green pricing programs are a candidate approach, as demonstrated in Figure 7, this method cannot meet cost effectiveness requirements because the bill is by definition as a premium rate more expensive than the status quo mixed-fuel building.

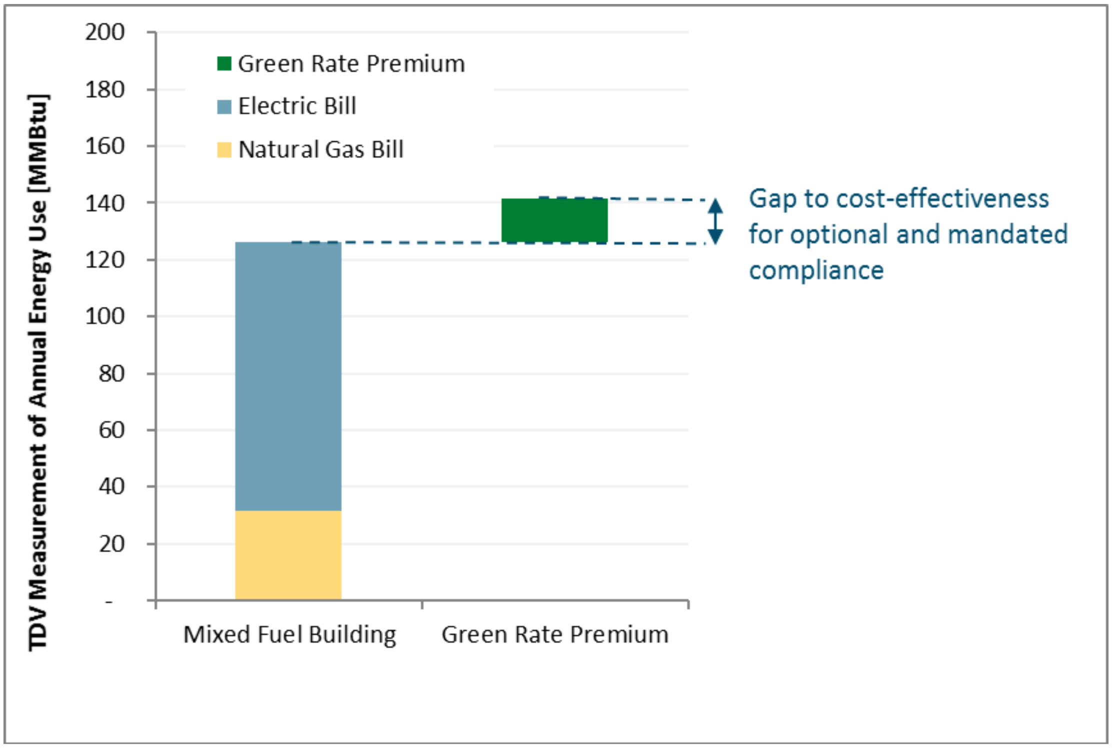

Figure 7. TDV cost effectiveness components for a mixed-fuel home seeking ZNE with a green rate.

In our prior example, we assume a mixed-fuel home with a premium green electricity rate. This arrangement could only meet ZNE if the customer purchased more renewable electricity than they consume to offset the natural gas consumption in the home. Theoretically, a similar program could be introduced for renewable natural gas. A green natural gas tariff would fund the gas utility to blend renewable biogas (e.g. from dairies, wood, or cellulosic biomass) into the pipeline to offset residential consumption. This would likely also be charged as a premium green rate on top of current gas costs and suffer the same cost-effectiveness challenge as a green electric utility program. A green rate for an all-electric home would avoid the issue of offsetting natural gas, but would face the same cost-effectiveness challenge.

Allowing 'community-based' energy systems such as a large solar PV array sized to offset the use in multiple buildings, or utility-scale systems located farther from the building, are lower cost options for generating electricity than rooftop solar. However, from a customer perspective, rooftop solar is a better economic decision. In addition, off-site approaches present practical challenges for compliance testing since they may require projects or purchases that are not associated with the building but need to be verified in the building permitting process.

Conclusions

In this paper we perform an initial analysis of several key issues in the development of the 2019 building standards as the CEC considers a ZNE requirement. These considerations are preliminary but point towards key issues that will be important in considering adoption of ZNE. The broad conclusion is that the cost-effectiveness of adopting ZNE has some significant challenges, and cost-effectiveness is necessary for the CEC to be able to mandate all new residential construction as ZNE. There are multiple paths for voluntary construction of ZNE, but that will fall short of the policy goal of encompassing all new residential construction.

As discussed earlier, the Warren-Alquist Act requires that ZNE be cost-effective using a TDV methodology. The TDV approach compares costs and benefits from a participant perspective, which accounts for certain incentives like net energy metering. Consequently, even though utility-scale and community solar are cheaper than rooftop solar in terms of absolute cost, NEM makes rooftop the least expensive option from a participant's perspective. We find that the TDV value of solar PV rooftops is declining over time as more utility-scale solar is added to the system. However, given the CPUC adoption of a decision on NEM that maintains near retail rate level compensation for solar, it is likely that rooftop PV will be cost-effective as a building code measure unless additional NEM reforms are put in place.

The lack of a practical or cost-effective means to offset natural gas use in buildings makes it difficult to reach the ZNE goal. One or more changes may need to be made to implement the policy. Of course, even with changes, the resulting policy should further the goals and intent of ZNE and be implemented for the greatest possible benefit to California. As currently defined and conceived, there appears to be no practical way to mandate ZNE for Title 24 under the current requirements for cost-effectiveness and deliver on the ZNE policy goal that has been in place for almost 10 years.

This paper explored two primary approaches to offsetting the natural gas use in buildings to achieve ZNE. The first approach was to consider oversizing the rooftop PV system to generate enough TDV credits to offset natural gas. While we did not perform detailed building modeling, this approach seems like it would violate the Rule 21 interconnection limit and NEM rules, which limit PV array size so that it will generate no more energy (kWh) than the building consumes over the year. Even if this rule is relaxed, the relatively low compensation rate for net surplus compensation would significantly degrade the case for cost-effectiveness.

The second approach we considered was switching to all-electric buildings and then using a solar roof to achieve ZNE. Based on our preliminary analysis, we do not think that an all-electric home can be required as a mandate, since the all-electric home would cost more than a mixed-fuel home when considering heat pump water and space heating, operating costs on electricity, and other construction costs. It does seem that given the high efficiency of heat pumps, it would be possible for a residential building to choose to be all electric using the alternative calculation method (ACM) in Title 24 and then use solar PV to offset all of the electricity energy use. Therefore, this may be a viable optional pathway for residential ZNE, but probably could not be adopted as a mandatory requirement.

We also evaluated the approach of community-based solar PV. There are two problems with this approach as currently implemented in SB43. The first is cost-effectiveness. An approach whereby community solar is offered to customers as a 'green rate' at a premium to the standard rate, by definition will cost more and therefore will not be cost-effective. The second is that this would require a system of tracking and crediting the production from the community system. It is paradoxical that although community systems are less expensive than rooftop solar per kWh generated, given the regulatory rules around NEM, rooftop PV is lower cost to the building owners.

Based on this preliminary analysis, a requirement for all new residential construction to be ZNE will not be cost-effective when defined as no higher cost to the home owner. Of course, the definition of ZNE could be changed, for example, offsetting only electricity in mixed-fuel homes might be cost-effective. Adjusting the community renewable tariff so that it is not a premium 'green rate' through virtual net metering or another mechanism may make it cost-effective. However, as an optional measure, there are a range of compliance paths that create choices for developers and home owners, and maintain the spirit and potentially the enthusiasm behind the ZNE provision. A summary of the cost-effectiveness of four ZNE pathways is shown in Figure 8.

	Mixed Fuel: Natural Gas and Electric	**All Electric**
On-Site Solar	(A) Electric-only ZNE will be cost-effective, but it is not clear how to offset natural gas usage.	(B) This appears to be a viable option to customers, but the higher total costs of all-electric homes including heat pumps likely rules out the potential for an all-electric requirement.
Off-Site Renewable Electricity and Natural Gas: Community Scale Solar Utility Scale Solar Biomass Other options	(C) Requires innovative utility and regulatory programmatic support to be cost-effective. Premium green pricing programs are by definition more expensive than standard rates.	(D) Requires innovative utility and regulatory programmatic support to be cost-effective. Premium green pricing programs are by definition more expensive than standard rates.

Figure 8. Matrix of ZNE compliance options.

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