Does Zero Net Energy Mean Zero Net Carbon? Reevaluating California's Time-Dependent Valuation Metric as the State Moves Toward a Net Zero Code

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ABSTRACT

California has set goals of zero net energy new residential and nonresidential construction by 2020 and 2030, respectively. Given the current structure of the energy code, will this push to net zero energy also result in net zero carbon buildings or are changes needed to meet California's goal of 80 percent carbon emissions reduction by 2050?

California's building energy code Title 24 utilizes the Time Dependent Valuation (TDV) metric to measure energy use, which assigns a dollar value per therm and kilowatt-hour for every hour of the year. The vast majority of new construction in California complies with Title 24 through the performance path, which sets a TDV energy budget that a builder must meet. This budget generally uses natural gas as the baseline fuel, as historically natural gas was viewed as the economically and environmentally preferable fuel choice. TDV values for electricity range from three to 100 times greater than those for natural gas, leading to a strong predilection toward the use of natural gas for space and water heating in California.

This paper analyzes the annual emissions from space and water heating of a modeled prototype home in several different envelope and equipment configurations and five California climate zones. It compares these emissions to the outcomes that would be driven by current TDV values and makes recommendations on how the use of TDV should be modified to drive optimal environmental outcomes. It also considers the potential additional benefits of controlled and grid-interactive electric appliances and equipment and considers how to capture these benefits under Title 24's performance path.

Introduction

California has set ambitious goals for both zero net energy (ZNE) buildings and greenhouse gas emissions reductions, but are these goals driving the same environmental outcomes?

As part of the Long-Term Energy Efficiency Strategic Plan first published in 2008 and updated in 2011, California set "Big Bold Energy Efficiency Goals" that all new residential construction be zero net energy by 2020 and all new commercial buildings be zero net energy by 2030. The primary pathway for achieving these goals is Title 24, California's building energy code. The Warren-Alquist Act, which gives the California Energy Commission (CEC) its authority to set energy efficiency standards, directs the CEC to set a building code that increases energy and water efficiency cost-effectively.

California has also set greenhouse gas emissions reductions goals of 80 percent below 1990 levels by 2050. Reducing energy use in buildings to meet zero net energy goals will cut emissions from buildings, but Title 24 and ZNE are defined based on an energy—not emissions—metric.

Title 24 measures energy use reductions and cost-effectiveness using the time dependent valuation (TDV) metric. The purpose of TDV is to take into account the time-value of energy use and to credit energy savings when they occur. For example, reductions in electricity use during peak summer hours are more valuable than in the middle of a winter night. The TDV values are updated each round of the standards, and include a value for emissions associated with energy use, but do not directly measure emissions. TDV values for electricity range from approximately three to 100 times greater than those for natural gas.

Today, the vast majority of residences in California use natural gas for space and water heating: according to the 2009 Residential Appliance Saturation Study (RASS), 93 percent of households in CA have gas space heating, 87 percent have gas water heating (CEC 2010) and these end-uses represent 50 percent of site energy consumption (RECS 2009). While historically, natural gas has been viewed as both the environmentally preferable and economic choice, recent analysis shows that in order to meet deep carbon reduction goals, these end uses must be decarbonized: either through electrification with clean electricity or through decarbonized methane.[1] (E3, 2015)

Most new construction in California complies with Title 24 using the performance path, where modeled TDV energy use is compared to the TDV energy use of a baseline building. Because natural gas was viewed as the economic and environmentally preferred choice historically, it is built into the base case for much of Title 24. That is, electric end-uses are often compared to a natural gas baseline in the code, [2] despite the large differences in TDV values for the two fuel types.

To better understand the scope of this discrepancy, this paper compares the TDV energy use, emissions, and operating costs for space and water heating in a prototype home modeled using 2013 CBECC-RES[3], California's Title 24 compliance software, with a variety of envelope and equipment configurations, in several California climate zones.

Title 24 Background

Time Dependent Valuation

TDV has been used since the 2005 Title 24 Building Energy Standards to evaluate the cost-effectiveness of the building standards and as the measure of energy use under the code. During each standard revision, updated TDV values are determined for each of California's 16 climate zones. These values are then used in the cost-effectiveness analysis used to justify the code update and become the energy use metric under the performance path of the code. TDV values are determined for each fuel type: for electricity the values vary hourly, for natural gas and propane, the values vary monthly. Separate TDV values are determined for residential and nonresidential measures and for 15- and 30-year time periods to reflect the different length of energy efficiency measures.

[1] Decarbonized fuels release no *net* carbon over their lifecycle, including both biogas and synthetic natural gas produced with renewable electricity.
[2] The baseline fuel varies by end-use and circumstance as described in detail in this paper.
[3] After this analysis was conducted, a beta version of the 2016 CBECC-RES software was released which changes the underlying simulation tool for heat pump water heaters. Further analysis using this new software is warranted and underway, but is beyond the scope of this paper.

The electricity TDV values are built up from a variety of components:

- the hourly marginal wholesale value of electricity (determined from the Integrated Energy Policy Report (IEPR) production simulations results and escalated forward using gas price predictions)
- the value of system capacity (based on the fixed cost of a single cycle combustion gas turbine)
- the value of ancillary services
- the cost of carbon dioxide emissions produced by the marginal resource (based on the IEPR)
- an adder to reflect the cost of complying with California's Renewables Portfolio Standard (RPS) (for every kilowatt-hour avoided, a fractional kilowatt-hour from renewables no longer needs to be procured).

These costs are forecast for every hour of the year and into the future 15 and 30 years, based on the sources identified. They are then increased by a flat retail rate adjuster, so that the average TDV values over the course of the year equal the average projected retail rates. The components of the electricity TDV values are shown in Figure 1. (E3 2014, 14)

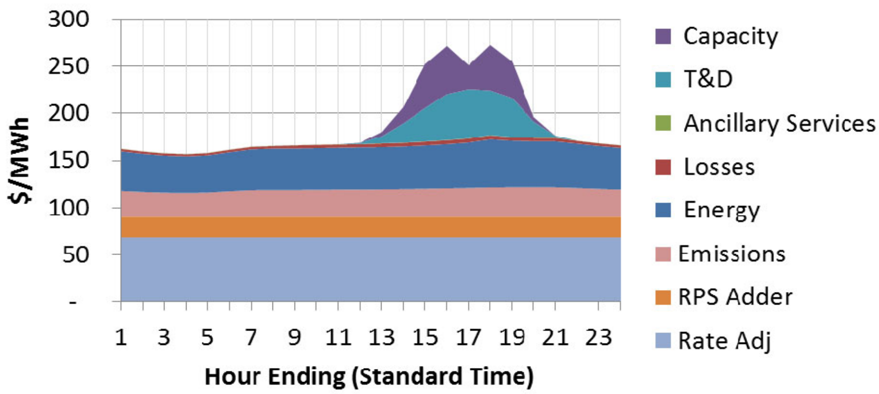

Figure 1: Annual Average Electric 2016 TDV – 30 Year Residential Climate Zone 12 (E3 2014, 15)

The gas TDV values are built up similar to the electric TDV values but with fewer cost components. The components of the gas TDV values are:

- Commodity cost and retail rate adjustment (based on the IEPR)
- Transmission and distribution costs
- Cost of carbon dioxide emissions

The natural gas values vary monthly rather than hourly. The average monthly variation in costs used to generate the gas TDV values is shown in Figure 2.

For both gas and electricity, the costs in dollars per therm and kilowatt-hour are translated using a multiplier to kBTU TDV per therm and kilowatt-hour. The Title 24 performance energy budget relies on this kBTU TDV metric. The purpose of translating TDV from dollars to kBTU TDV is so that the TDV results don't get confused for energy bill costs, as they are not directly reflective of retail rates on an hourly basis.

The TDV values for gas and electricity are dramatically different. Figure 3 shows the variation in gas and electricity 2016 TDV values over a year in Climate Zone 12 as an example, normalized to a common site BTU denominator. During off peak hours, the electricity TDV values are three times that of natural gas. During peak hours, electricity TDV values are 100 times greater than those of natural gas. These differences are largely due to the difference in retail price forecasts for gas and electricity and the large peak costs associated with summer electricity use.

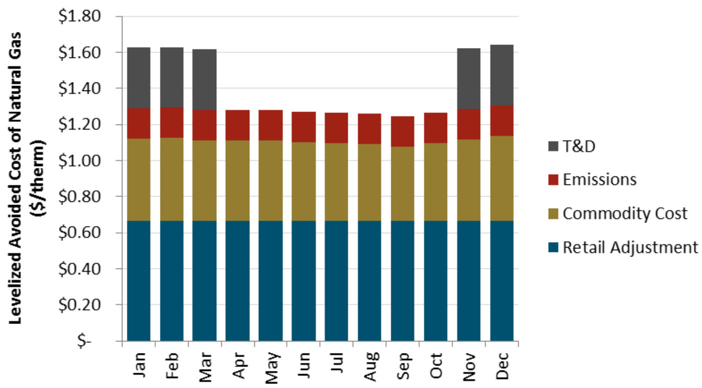

Figure 2: Avoided Cost of Natural Gas for 2016 TDV (E3 2014, 53)

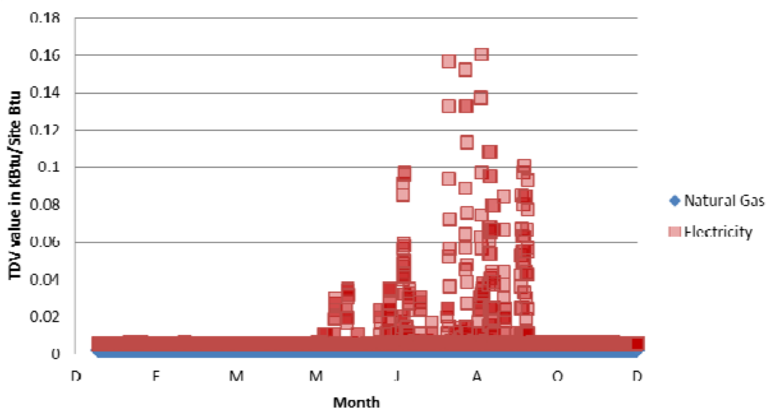

Figure 3: Comparison of gas and electric TDV values on a common site BTU metric.

Determination of the Standard Design in the Performance Path

The vast majority of new construction in California complies with the Title 24 Building Energy Standards using the performance path. (CEC 2015c, 107) The performance path allows builders flexibility to comply with the code through the use of an energy model without having to follow a list of prescriptive measures. Title 24 specifies the requirements for software used to demonstrate code compliance under the performance path and prescribes how the baseline building is generated. Under the performance path, compliance software calculates a TDV budget for the Standard Design Building and a TDV energy use for the Proposed Design Building. The Standard Design Building budget is determined using the same geometry as the Proposed Design building and a prescribed set of features (e.g. insulation, equipment efficiency, etc). To comply, the Proposed Design Building TDV energy use must be lower than the Standard Design TDV budget (the Proposed Design Building must also comply with the mandatory measures of the code).

Title 24 specifies the equipment to be used in the Standard Design Building for space and water heating. The standard design equipment specifications vary for each of these end uses and depending on whether the building is new construction or a renovation of an existing building.

For new construction, the Standard Design Building water heater is generally a natural gas water heater. The 2013 Standards specify that the baseline water heater be a federal minimum efficiency[4] natural gas storage water heater, unless natural gas is not available in which case the baseline is a minimum efficiency electric storage water heater combined with a solar hot water heating system. (CEC 2012, 232) The 2016 Standards specify that the baseline water heater is a single gas or propane instantaneous water heater meeting the minimum federal appliance efficiency standards (an Energy Factor of 0.82), regardless of gas availability. (CEC 2015a, 251)

For new construction space heating in both the 2013 and 2016 Standards, the Standard Design Building uses a NAECA minimum efficiency split system heat pump or furnace, depending on the fuel type used for space heating in the Proposed Design Building. (CEC 2015b, 20)

Table 1. Summary of Space and Water Heater Requirements in the Title 24

Construction Type	**Compliance Pathway**	**Water Heater Requirements**	**Space Heating Requirements**
New Construction	Prescriptive	Natural gas or propane water heater[5] required	Any fuel type (no electric resistance)
	Performance	Performance baseline set by natural gas water heater	Baseline fuel is same as proposed design
Additions and Alterations	Prescriptive	Natural gas, unless existing water heater is electric or natural gas is not available[6]	Natural gas, unless existing equipment is electric
	Performance	Performance baseline set by natural gas or existing water heater (if verified)	Baseline fuel is same as proposed design

For additions and alterations the requirements are the same for both the 2013 and 2016 Standards. For water heaters:

- Under the prescriptive path: replacement or additional water heaters must be natural gas, propane, or a water-heating system determined to use no more energy than a NAECA minimum efficiency natural gas water heater, unless no natural gas is connected to the building. If natural gas is not available, a NAECA minimum efficiency electric water heater may be installed. (CEC 2015a, 260, 264)

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[4] The minimum efficiency prescribed by the National Appliance Energy Conservation Act (NAECA).

[5] The 2013 Standards allow for installation of a solar electric water heater under the prescriptive path if gas is not available, but this allowance was removed in 2016.

[6] In 2015, the CEC published an alternative compliance path that allows for heat pump water heaters meeting specified Energy Factor requirements (by climate zone) to be installed without modeling.

- Under the performance path: the proposed water-heating system may not use more energy than the existing water heater (if verified by a third party) or a natural gas water heater (without verification), regardless of the type of water heater installed.

For additions and alterations of space heating equipment:

- Under the prescriptive path: natural gas or propane equipment, equipment of the same-fuel type as the existing equipment, or equipment that use no more TDV energy than the existing system may be installed. (CEC 2015a, 261)
- Under the performance path: the existing equipment efficiency is the baseline (if verified by a third party) or a NAECA minimum efficiency split system heat pump or furnace, depending on the fuel type used for space heating in the Proposed Design Building (without verification). (CEC 2015a, 266)

Table 1 summarizes these somewhat complex requirements.

Prototype Building Models

In order to compare the TDV energy use and emissions from space and water heating, this project analyzed a prototype home in a variety of configurations and climate zones using CBECC-Res-2013, the California Energy Commission's Title 24 Residential Compliance Software. The base prototype home was the "Example 19" default prototype home: a single family, two-story home, four bedroom, 2700 square foot home, with attached garage, attic, and slab on grade.[7]

Table 2. Envelope Scenarios Analyzed

Scenario	Walls	Attic	Slab	Windows[8]	Air Tightness
Retrofit	2x4 uninsulated (U= 0.361)	R-13 below attic	Unheated	0.32/0.25	10ACH50
2013	2x4, R15+R4 stucco (U=0.065)	R-30 to 38 ceiling[9]	Heated	0.32/0.25	5ACH50
2016	2x4, R19+R6 sheathing+3 coat stucco (U=0.051)[10]	R-30 to 38 ceiling, R-18 below roof deck	Heated	0.32/0.25	5ACH50
Advanced	2x6, R23+R10 sheathing+R4 stucco (U=0.031)	R-49 ceiling, R18 below roof deck	Heated	0.20/0.25	3ACH50

The analysis considers four envelope configurations: "Retrofit envelope" intended to approximate a pre-code home that has had a window replacement but no other energy upgrades; "2013 Envelope" represents the prescriptive levels of the 2013 Title 24 Building Energy

[7] The average square footage in 2014 for newly constructed single family homes in the West Census Region was 2603 square feet and 48 percent of homes in this region had four or more bedrooms. (United States Census Bureau 2016)
[8] U-value/Solar Heat Gain Coefficient
[9] Requirements vary by climate zone.
[10] Except Climate Zone 6, where an R15+4 (U=.065) wall was modeled.

Standards; "2016 Envelope" represents the prescriptive levels of the 2016 Title 24 Building Energy Standards; and "Advanced Envelope" based on the highest envelope constructions evaluated during the 2016 Title 24 development process (Rasin 2015), the maximum ceiling insulation required by the 2015 International Energy Conservation Code, and the Energy Star Most Efficient® windows criteria.

For each of these envelope configurations, 8 equipment scenarios were run, summarized in Table 3.

Table 3. Equipment Scenarios Analyzed

Scenario	**Water Heater**	**Space Heating Equipment**
Standard electric	NAECA min. eff. electric storage water heater (50 gallons, 0.945 EF)	NAECA minimum efficiency heat pump (8.2 HSPF)
Standard electric, large	large NAECA min. eff. electric storage water heater (55 gallons, 2.0 EF)	NAECA minimum efficiency heat pump (8.2 HSPF)
Mid-efficiency electric	Energy Star heat pump water heater (50 gallon, 2.75 EF)	2023 minimum standard heat pump (8.8 HSPF)
High-efficiency electric	Heat pump water heater (3.39 EF)[11]	Energy Star Most Efficient® heat pump (10 HSPF)
Standard gas tankless	NAECA minimum efficiency gas tankless water heater (0.82 EF)	NAECA minimum efficiency gas furnace (80 AFUE)
Standard gas storage	NAECA minimum efficiency gas storage water heater (0.6 EF)	NAECA minimum efficiency gas furnace (80 AFUE)
Mid-efficiency gas	Energy Star gas storage water heater (.67 EF, 50 gallons)	90 AFUE gas furnace
High-efficiency gas	Energy Star gas tankless water heater (0.9 EF)	Energy Star gas furnace (95 AFUE)

The 32 prototype homes described above were modeled in 5 California climate zones: 1 (Arcata), 3 (Oakland), 6 (Torrance), 12 (Sacramento) and 13 (Fresno). The CBECC-Res software produced annual TDV, therm, and kilowatt-hour usage projections for each run. The therm and kilowatt-hour data was converted to emissions and costs using the following methodology.

Emission Rates

Determining the appropriate emissions rate to use when comparing natural gas versus electric equipment over the long-term is a complex question. To the extent this equipment contributes to peak-load, the appropriate rate would be that of the marginal peak-resource. However, when considering increased penetration of electric equipment, the obverse question should be asked: what is the resource that will be built to serve the increased load. It is common, when analyzing the long-term impacts of a change in load, to use the expected variable costs of the resource likely to be built if the energy efficiency were not put in place.[12] In California, the

[11] Based on Energy Star certified product database.
[12] See, for example, National Action Plan for Energy Efficiency, Understanding Cost-Effectiveness of Energy Efficiency Programs, November 2008, Table 4-2.

effect of the renewable portfolio standard (RPS) must also be considered when determining what resource will be built to meet this additional load.

It is unclear how much the electrification of water and space heating will contribute to peak load versus base load. Water heater time of use in particular is highly variable and is specific to each household. Existing data shows that water heating loads tend to peak in the mornings with a secondary peak in the evening, but data is limited. (Hledik 2016) Residential heat pump electricity usage tends to correlate to outdoor air temperature and has a flatter load profile than electric resistance water heaters. (Boait 2011) Both space and water heating also have the potential to be a grid-interactive and/or scheduled load, with water heaters offering particularly promising ability to load shift. (Hledik 2016).

Due to the uncertainty in the emissions rates, this report looks at three electricity emission scenarios. First, the report develops two emissions rates: one for new load added on peak and the other for new load added off peak. The on-peak rate assumes that the marginal resource at peak is a conventional turbine peak natural gas plant, but that for every kilowatt-hour added on peak, renewables must be added off peak to meet the RPS, thereby offsetting the emissions of the base off-peak resource: a combined cycle natural gas plant. An RPS of approximately 40 percent is considered, which is California's average RPS between 2020 and 2030, a conservative estimate for the lifetime of equipment potentially affected by the results of this analysis. The off-peak rate assumes that new off-peak load will be met with combination of a new combined cycle natural gas plant and a 40 percent RPS. [13] All emissions factors assume distribution and transmission system losses of 11 percent.[14] (CEC 2014)

Table 4: On and off-peak emissions rates.

	Description	**Emissions Rate**
On-peak	A blended rate of 60% single-cycle and 40% combined-cycle[15]	0.55 kg CO2/kWh
Off-peak	A blended rate of 60% combined-cycle and 40% RPS	0.26 kg CO2/kWh

These rates were combined into three different scenarios. Scenario 1 represents a worst case scenario: 100 percent of added load is on-peak. It is extremely unlikely that this scenario would occur in the real world, because as discussed above, the usage patterns of space and water heating equipment is variable. Furthermore for heat pump water heaters and space heating equipment, this scenario is likely a physical impossibility as there are not enough peak hours to match the number of hours per day that this equipment runs. Therefore, scenario 1 represents a conservative bookend, primarily relevant for electric resistance equipment. Scenario 2 is characterized as the best estimate and is meant to reflect a load that is naturally distributed

[13] It is reasonable to assume that the plants that will be built to serve this new load are a combination of combined cycle gas plants, which provided 67% of California's natural gas generation in 2013, and whose electricity output grew by 230% between 2004 and 2013 (Thermal Efficiency of Gas Fired Generation in California: 2014 Update, California Energy Commission, CEC-200-2014-005, September, 2014)

[14] See: Comparison of Loss Factors, A Review of Transmission Losses in Planning Studies, August 2011, California Energy Commission, CEC-200-2011-009, p. 24; Derived from in-state and import line loss factors assuming 30% imports.

[15] As described in the text, this blended rate reflects the RPS.

evenly between off- and on-peak use and then is partially controlled to shift an additional 25 percent of load off-peak. Scenario 3 is characterized as the best case: 100 percent of load is off peak.[16]

Table 5: Emissions Scenarios Analyzed

	Description	**Emissions Rate**
Scenario 1 (Worst Case)	Uncontrolled, 100% on-peak	0.55 kg CO2/kWh
Scenario 2 (Best Estimate)	Partially controlled, 25% on-, 75% off-peak	0.33 kg CO2/kWh
Scenario 3 (Best Case)	Controlled, 100% off peak	0.26 kg CO2/kWh
Natural Gas	Direct-use of natural gas	5.31 kg CO2/therm

Costs

The December 2015 year-to-date average residential price to ultimate customers in California of $0.1702/kWh was used for electricity prices.[17] (EIA 2016a) The 2015 average residential natural gas price of $1.11/therm was used for natural gas prices. (EIA 2016b)

Results

The analytical results are presented in Figures 4 through 8. While the water and space heating loads projected by CBECC-RES varied by climate zone, the results were directionally consistent (i.e. if water heater x had lower TDV than water heater y in one climate zone, this was true for all climate zones) and so the results are presented as a simple average across the 5 climate zones analyzed. Figures 4, 6, and 7 show the unweighted average annual emissions and TDV energy use results across the five climate zones analyzed. The water heating loads calculated in CBECC-RES were independent of the envelope configuration and therefore only one envelope scenario is presented (Figure 4). Space heating loads did vary with envelope; the TDV and emissions results for space heating are shown in Figures 6 and 7. For Figures 4, 6, and 7, emissions are shown in blue on the primary y-axis and TDV energy is shown in red on the secondary y-axis. The blue and red dotted horizontal lines show the emissions and TDV baselines set by minimum efficiency natural gas equipment. In both cases, lower is better. Figures 5 and 8 show the annual cost results for water heating and space heating, respectively.

Water Heating

For water heaters, the results showed that:

- Emissions for all three heat pump water heaters analyzed under emissions scenarios 2 and 3 were lower than all of the natural gas water heaters considered, regardless of the EF of the heat pump.

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[16] Notably, a true best case would control some portion of the load to match the availability of zero emissions resources and so would be even better than anticipated here.

[17] In practice, user costs will vary depending on their rate schedule, usage pattern, and electric utility. Tiered rates without baseline adjustments or credits penalize the use of electric appliances. On the other hand, time of use rates, especially those with a large peak/off-peak differential, offer the potential for controlled loads to operate off-peak and benefit from lower than average electricity rates.

- The mid and high efficiency heat pump water heaters analyzed had lower emissions than all of the natural gas water heaters considered in every emissions scenario, even the unrealistic "worst case" scenario 1.
- The standard electric resistance water heater had lower emissions than a natural gas tankless water heater under the best case scenario 3, but higher emissions than all gas water heaters analyzed under the other two emissions scenarios. This indicates both the potential for electric resistance water heaters to achieve emissions reductions if controlled and also the potential emissions implications of uncontrolled electric resistance water heaters under current emission profiles.
- The water heater TDV values are proportionally similar to the Emissions 1 scenario, but not the Emissions 2 and 3 scenarios. Put another way, TDV does not accurately reflect the most likely emissions scenario.
- Only the high-efficiency electric water heater has a lower TDV value than the tankless gas water heater (the baseline water heater in the 2016 Standards).
- The mid and high efficiency heat pumps are cost competitive on an annual operating cost basis with the natural gas water heating options.
- The tankless gas water heater is the lowest cost option on an annual basis, with the high efficiency heat pump water heater as a close second.[18]
- The high efficiency heat pump water heater has the lowest TDV of all options considered.
- The standard (uncontrolled, resistance) electric water heater costs almost twice as much to operate as any other option.

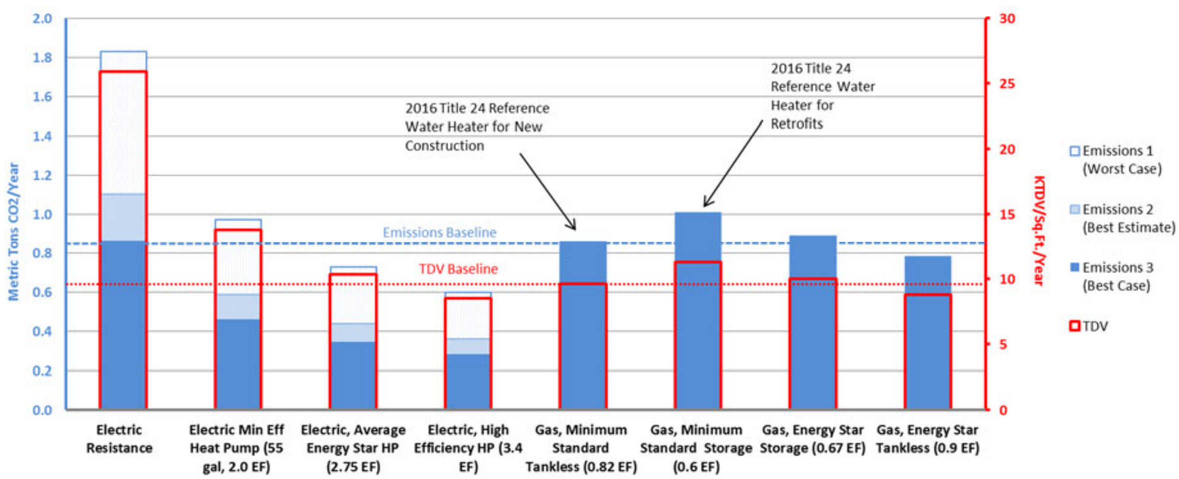

Figure 4: Average Annual TDV and Emissions from Water Heating for Prototype Home with Different Equipment

[18] Noting that electricity costs vary depending on the utility and rate structure.

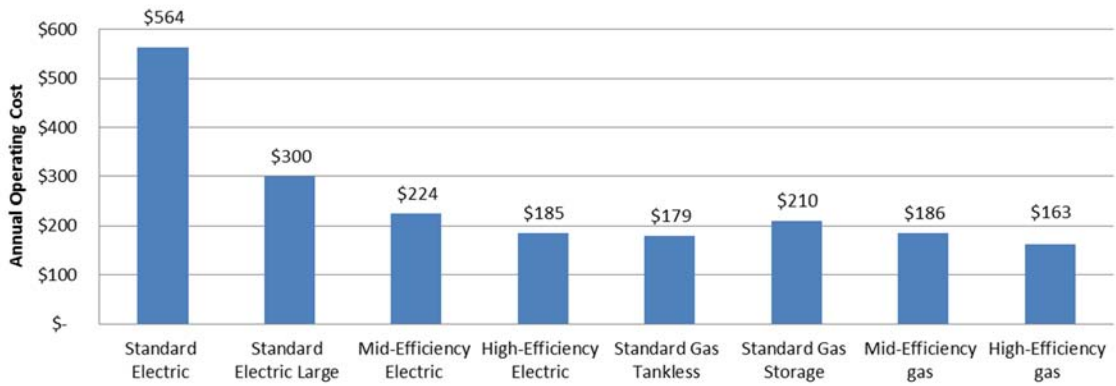

Figure 5: Average Annual Operating Cost of Water Heating for Prototype Home with Different Equipment Options

Space Heating

The space heating results are summarized as follows:

- Under emissions scenario 3, heat pump space heaters have lower emissions than all natural gas options considered, regardless of envelope configuration.
- Under emissions scenario 2, heat pump space heaters have lower emissions than all natural gas options considered, except for the retrofit envelope scenario.
- Heat pump space heaters cost more to operate under all scenarios considered, but the spread in operation costs decreases dramatically as envelope is improved.

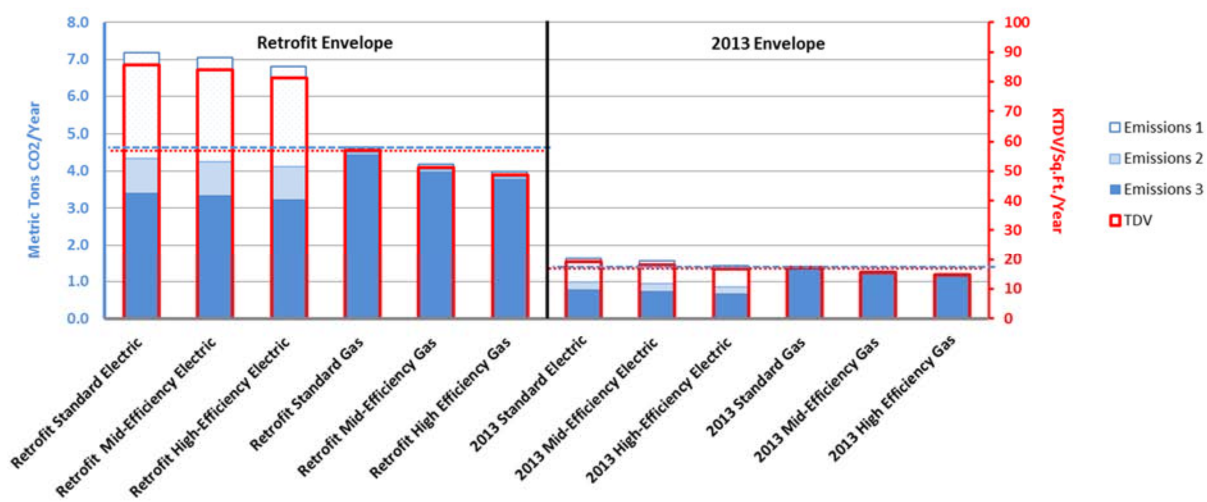

Figure 6: Average Annual Emissions and TDV from Space Heating in the Retrofit and 2013 Envelope Scenarios

- As the envelope improves, TDV values become less reflective of operating costs (i.e. a higher efficiency heat pump under the advanced envelope option reduces TDV more than operating cost).
- In the retrofit and 2013 envelope scenarios, TDV values generally correspond to emissions Scenario 1. For the 2016 and advanced envelope scenarios, TDV values do not

reflect any of the emissions scenarios. This indicates that TDV is poorly correlated with emissions for space heating, in particular under the likely and best case scenarios.

- As the envelope values increase, the percentage emissions reductions from the lowest emissions electric option compared to the lowest emissions gas option increase. That is, electric heat pumps result in a higher percentage emissions reductions the tighter the envelope criteria.
- Electric heat pump heaters perform better on a TDV basis the more efficient the envelope is and beat the natural gas baseline equipment under many scenarios. This is despite the fact that this equipment is more costly to operate.

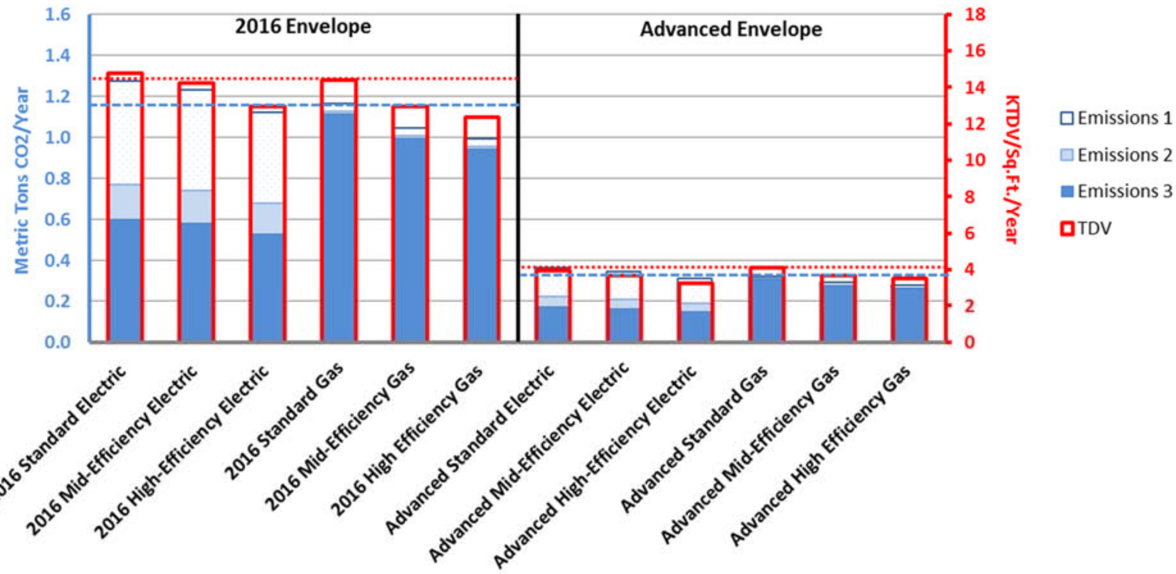

Figure 7: Average Annual Emissions and TDV from Space Heating in the 2016 and Advanced Envelope Scenarios

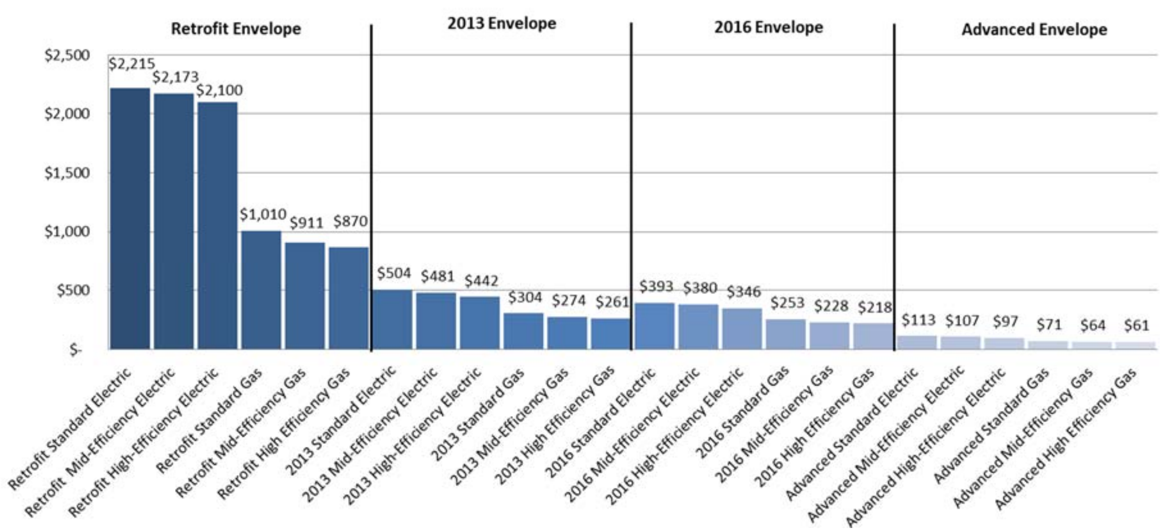

Figure 8: Average Annual Space Heating Costs, All Scenarios

Conclusions

Overall, the results show that the TDV metric does not directly correspond to emissions for residential space and water heating in any scenario and is particularly poorly correlated to the likely and best case emissions scenarios. For water heating, the TDV metric is well correlated to cost, but for space heating the TDV metric becomes less reflective of cost as the envelope gets more stringent, which is the future trend as California moves towards zero net energy.

The results also show that there is significant potential to cut emissions from residential space and water heating through electric end-uses, in particular the use of heat-pump water heaters and high-efficiency heat pump space heaters; This potential increases with space and water heating that is controlled to avoid peak hours and, for space heating, as the envelope becomes more stringent.

These results lead to the conclusion that TDV is not a sufficient metric for determining fuel choice in buildings from an environmental perspective. They also show that TDV currently serves as a barrier to electrification in many circumstances, in particular for water heating, despite the fact that the results show significant potential emissions reductions from electric space and water heating.

While further analysis is warranted, the results are clear that the TDV metric as currently constructed is no longer an adequate tool for helping achieve California's economic and environmental objectives. TDV is fundamentally a consumer-cost metric, directed by the energy and cost-effectiveness requirements specified by the Warren-Alquist Act for Title 24. These energy and cost requirements are not directly aligned with the state's greenhouse gas emission reduction goals. As electricity becomes cleaner with California's policies, the emissions profile of electricity will continue to improve, strengthening the conclusion of this analysis.

Several steps could be taken to address the disparity between the TDV metric and California's emissions goals:

- Modify TDV values to more closely correlate with a reasonable emissions scenario. This option proves challenging as TDV is primarily a consumer cost-based metric and the cost of emissions is already taken into account in the TDV values. A much higher emissions cost would likely need be assumed to make up for the current disconnect between TDV energy and emissions.
- Change the Title 24 energy metric to a greenhouse gas emissions metric. This has the benefit of more closely aligning Title 24 with California's greenhouse gas reduction goals, but the drawback of not including consumer cost. A blended or dual metric that takes into account both cost and emissions could also be considered, but may prove complicated to implement. This change would likely require a revision to the underlying Warren-Alquist Act.
- Maintain the existing TDV metric, but change the reference water heater to use the same fuel as the proposed design. Allowing a same-fuel baseline and setting the baseline electric water heater as a minimum efficiency 55 gallon (heat pump) water heater would have a similar emissions impact to the current gas water heater baseline, but would be a more realistic TDV baseline for electric water heaters to be measured against. For space heating, the prescriptive path for additions and alterations should be modified to allow for heat pump space heating due to the reduced emissions achievable. For other space heating scenarios, the same fuel type is already used as the baseline in the performance path and so no change is needed to remove barriers to electric space heating. While these

changes would not specifically encourage the option with lower greenhouse gas emissions, they would remove the current barriers against it.

All of these options deserve further analysis and consideration, but the final option is likely the simplest to implement and should be considered in the development of the 2019 Title 24 Standards.

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