Independent Assessment of Emission Reduction Costs and Benefits for California Homes with Inadequate Electric Panels

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Summary

California's 2022 State Strategy for the State Implementation Plan and 2022 Scoping Plan for Achieving Carbon Neutrality include bans on the sale of natural gas-fired space and water heaters starting in 2035. Those bans will force about 1 million California homeowners to undertake expensive, time-consuming upgrades of their electric panels in order to restore heat or hot water to their home after their gas-fired units fail. They will be forced to find temporary housing during the months-long upgrade process. This assessment indicates that the total homeowner cost of the upgrade is very high on an absolute and per unit avoided emission basis. Statewide, $8 billion of these costs can be eliminated by modifying the ban to exempt homes with inadequate electric service panels and using other programs to encourage or legislate panel upgrades.

Introduction

California's 2022 State Strategy for the State Implementation Plan and 2022 Scoping Plan for Achieving Carbon Neutrality include bans on the sale of natural gas-fired space and water heaters starting in 2035. Those bans will force about 1 million California homeowners to undertake expensive, time-consuming upgrades of their electric panels in order to restore heat or hot water to their home after their gas-fired units fail. They will be forced to find temporary housing during the months-long upgrade process. The cost of that housing was not included in any of the analyses CARB used to justify the bans. This assessment was undertaken to evaluate the effect of that unaccounted cost on homeowner upgrade expense and the cost per unit of avoided emissions.

Background

In September 2022, the California Air Resources Board (CARB) approved the 2022 State Strategy for the State Implementation Plan (SIP) which included a ban on natural gas-fired space and water heaters starting in 2035. CARB is about to approve the 2022 Scoping Plan for Achieving Carbon Neutrality (SP), which includes the same ban. No exception is made for homes without an electric service panel that can support the required electric appliances. Those homes must upgrade their service panels and install zero emission replacement units in order to restore hot water or space heating.

Electric panel upgrade is a time-consuming process. One study referenced by the 2022 Scoping Plan indicates that it can take weeks or months (Ref 1). A key finding of another study referenced in the 2022 Scoping plan indicates that the upgrade process often exceeds six to nine months (Ref 2). Residents of those homes cannot be expected to live without heat or hot water for months. Temporary housing will

be required. Cost of temporary housing was not included in the CARB and California Energy Commission (CEC) studies that informed the SIP or Scoping Plan.

Analysis

A. Cost per Ton of Reduced Emissions

The California Building Decarbonization Assessment-Final Report (Ref 3) states that direct greenhouse gas emissions from natural gas combustion in California homes was 25.7 MMTCO2e as of 2018. The U.S. Energy Information Administration estimates that 72% of California homes use natural gas for space heating and 79% of California homes utilize natural gas water heating (Ref 4). U.S. Census data indicates that there are 8.5 million single family homes in California out of a total of 13.16 million housing units (Ref 5). It is assumed that homes which only use natural gas for water heating use electric space heating. Those homes would not require an electric panel upgrade to switch to electric water heating. Therefore, 0.72 * 8.5million = 6.12million homes might need electric panel upgrades to enable electric space and water heating of the 0.72 * 13.16 million = 9.5 million housing units heated by natural gas combustion.

The California Energy Commission (CEC) (Ref 3) states that a lack of primary data exists that detail the number of buildings that require a panel upgrade in California. They approximated the panel upgrade costs by using the percentage of gas removed due to electrification as an indicator to estimate when a panel upgrade is required. The most aggressive electrification option studied in Reference 3 estimated total panel upgrade costs at $2.25 billion. This option assumed 90% of residential gas space and water heaters would be replaced at burn-out. The CEC assumed panel upgrade cost of $2500 per unit (Ref 6). Therefore, CEC estimates that 2.25 billion/(0.9*2500) = 1 million California homes require a panel upgrade to support electric space and water heating.

Using the data discussed above, homes requiring a panel upgrade emit 1.5*25.7 * 1 million/9.5 million = 4.06 MMTCO2e per year. The 1.5 scaling factor accounts for the fact that a multi-family dwelling unit should require less energy for space heating than a single-family home.

State of California studies consider total emission reductions between present day and 2045. The ban on gas-fired space and water heaters begins in 2035. This assessment assumes that all gas-fired space and water heaters will be replaced with electric units in that span according to a linear profile, such that the emission reduction from these homes increases linearly from zero in 2035 to 4.06 MMTCO2e in 2045, for an average over the span of 2.03 MMTCO2e per year. The total emission reduction opportunity from homes requiring a panel upgrade is, therefore, (2045-2035) * 2.03 MMTCO2e = 20.3 MMTCO2e.

The Scoping Plan and SIP bans on gas-fired space and water heaters make no exception for homes requiring panel retrofits to support electric appliances. Therefore, those homes must upgrade their electric panels prior to replacing burned out gas-fired space and water heaters. Studies referenced by the Scoping Plan indicate lead times of weeks to months, often exceeding six to nine months. Residents in those homes will need to relocate to temporary housing during that long process. CARB and CEC building decarbonization studies do not account for that cost.

The population-scaled average rent for a three-bedroom California home in 2021 was $2659 per month (Ref 7). Assuming an average panel upgrade lead time of three months, a temporary housing cost of $7977 per upgrade must be assumed when performing cost/benefit analyses.

The CEC assumed base cost for panel upgrades is optimistic. A study done for the California Building Industry Association estimates panel upgrade cost as $4671 in 2020 (Ref 8). A study for the California Public Utilities Commission includes an estimate of $3181 in 2016 dollars (Ref 9). This assessment assumes $3500 per panel upgrade. The total panel upgrade cost is $3500+$7977 = $11,477. Costs are in 2020 dollars.

Harvesting single family direct emission benefits also requires replacement of the gas-fired space and water heaters. This assessment assumes that simple resistance water and space heaters will be used and that their costs are the same as gas-fired units. Those costs are attributable to failure of the gas-fired units, so they are not included in the total cost. Also, since resistance heater units are not high efficiency, it is assumed that pre- and post-appliance replacement monthly energy costs are equivalent.

Heat pump water and space heaters offer energy cost savings, but also add to upfront costs. That is a separate trade which is not unique to homes requiring a panel upgrade, so is not addressed in this assessment.

The cost per ton of emission benefit from homes requiring electric panel retrofit is

$11,477 * 1million / (20.3 MMTCO2e) = $565 per MMTCO2e

This is almost 400% higher than the residential electrification cost CEC reported for their moderate electrification scenario which included minimal panel upgrades. It is 1.5 times CEC's low-cost synthetic gas options, which was said to reflect a poor cost/benefit relationship (Ref 3).

It should be noted that the emission benefit is overstated since homes converted to electric space and water heating will use electricity that, at least in part, is provided by gas-fired electric generating stations.

This cost does not include system level costs, such as electric generating stations and utility infrastructure required to support the increased electric demand.

Also note that $7977/$11477 = 70% of the cost can be avoided by preemptive panel upgrades, which eliminates long down times during an emergency space or water heater replacement. This reduces the cost per ton of avoided emissions to $170 per MMTCO2e. The overall statewide cost savings would be $7977 *1 million, about $8 billion.

B. Overall Benefit

AB3232 states that 25% of total statewide greenhouse gas emissions are from the building sector. Of that (25.7 MMTCO2e/98.4 MMTCO2e), 26% is direct emissions from homes (Ref 3). Therefore, (0.26*0.25) = 6.5% of statewide greenhouse gas emissions are the result of natural gas combustion in homes. From previous calculation, homes that require a panel upgrade are responsible for (4.06/25.7) * 6.5% = 1.03% of statewide greenhouse gas emissions. The California homeowner cost to minimize, but not eliminate, those emissions is $11,477 * 1 million = $11.5 billion.

Alternatives

A large portion of the cost to minimize emission from homes with inadequate electric panels can be eliminated by relying on preemptive upgrades for homes with inadequate electric panels, instead of forcing upgrades as part of an emergency replacement. Several options are available and discussed below.

Both alternatives assume that homes with inadequate electric service panels will be exempt from the 2035 natural gas space and water heater ban until their panel is upgraded.

A. Natural Upgrades and Incentive Programs
Homeowners typically upgrade their electric service panel when renovating or remodeling their homes. Installation of electric vehicle chargers also trigger upgrades and will become more common as new car sales transition to 100% electric. This will result in many preemptive upgrades. Incentive programs combined with education of climate benefits will further accelerate panel upgrades. Eventually, natural gas infrastructure retirement will force the remaining homes to upgrade their panels. This approach may not achieve the emission savings assumed for the total gas heater ban, but the residual might be acceptable given that this subset of California home is responsible for only one percent of statewide greenhouse gas emissions. Any emission reduction shortfall could also be offset by bringing the ban forward to 2030 for homes with adequate panel capacity.

B. Legislate Panel Upgrades
The State of California could legislate electric panel upgrades. Instead of a single deadline for all homes, the mandate should be rolled out on a county or city-level schedule to avoid overloading utilities or the contractor base as a deadline approaches. The total time span needs to account for the available contractor base and utility capability. A ten-year span would result in about 8000 statewide upgrades per month, likely beyond the capability of contractor and utility staffing. Programs to increase the contractor base would probably be required regardless of the total time span. Legislation requiring utilities to staff up to meet demand would be needed.

This approach also offers an opportunity to streamline the upgrade process and minimize costs. The majority of affected homes are likely part of housing tracts built between the 1950's and 1970's where standard designs and design practices were used. Panel upgrade designs for those homes would be very similar. Batched permitting at the city level and batched utility approvals would minimize cost and schedule for those process steps. A single contractor could be hired to perform all upgrades within the tract. The utility would make all necessary infrastructure improvements in the tract as a single project instead of piecemeal depending on the order of their wait list. This 'assembly line' approach offers significant cost and schedule savings opportunities. The State could offer grants to municipalities to run the upgrade program within their borders.

Upon Rental Unit Vacancy
In addition to the legislated upgrade process discussed above, or as a stand-alone, the State could legislate panel upgrades for rental homes before a new tenant is allowed to move in. This legislation would be a strong incentive for landlords to preemptively upgrade their

property before a tenant moves out since, otherwise, the property would be vacant for months while the upgrade process drags on.

Conclusions

The cost to homeowners that must upgrade their electric panel to accommodate zero-emission replacement space and water heaters is very high on an absolute and per emission unit basis. Seventy percent of the expense is attributable to temporary housing required during the long panel upgrade process. This $8 billion statewide cost can be eliminated by exempting this subset of homes from the gas-fired heater ban and using other programs or legislation to preemptively upgrade their electric panels before gas-fired unit failure.

References

1. City of Berkeley. 2021."Existing Buildings Electrification Study." Available at: https://drive.google.com/file/d/10OY_USkF2MeoBkLXuzQEewpW8rAm-WTk/view
2. PG&E. 2022. “Service Upgrades for Electrification Retrofits Study Final Report.” CALMAC STUDY ID: PG&E0467.01. Available at: https://pda.energydataweb.com/#!/documents/2635/view
3. Kenney, M., N. Janusch, I. Neumann, and M. Jaske. 2021. "California Building Decarbonization Assessment." California Energy Commission. Publication Number: CEC-400-2021-006-CMF. Available at: https://www.energy.ca.gov/publications/2021/california-building-decarbonization-assessment
4. Kaili Diamond, Matthew Sanders, Carolyn Hronis. July 12, 2022. Over one-quarter of U.S. Households use electricity as the only source of energy. EIA.gov. Available at https://www.eia.gov/todayinenergy/detail.php?id=52999
5. LaFirenza, Mike. 64.7% Of California Homes Are Single-Family, 8th Lowest In U.S. December 19, 2021. Citizens Journal. Available at: https://www.citizensjournal.us/64-7-of-california-homes-are-single-family-8th-lowest-in-u-s/
6. Supplementary materials for AB 3232 report (i.e., workbook for Appendix C). TN237504_20210420T123805_AB 3232 Appendix C. California Energy Commission. Available at: https://efiling.energy.ca.gov/GetDocument.aspx?tn=237504&DocumentContentId=70704
7. California Fair Market Rent for 2021 Accurate Rental Price Data. Rentdata.org. Available at: https://www.rentdata.org/states/california/2021
8. Navigant Consulting, Inc. 2018. "Impacts of Residential Appliance Electrification". California Building Industry Association. Available at: https://drive.google.com/file/d/14cFig3V_G_scSpSJggrI2RcXFhbgx593/view
9. Frontier Energy. 2021. "2019 Cost-Effectiveness Study: Existing Single Family Residential Building Upgrades." Available at: https://frontierenergy.com/wp-content/uploads/2019-Cost-Effectiveness-Study-Existing-Single-Family-Residential-Building-Upgrades-report.pdf