E-12. Install Alternative Type of Water Heater in Place of Gas Storage Tank Heater in Residences

GHG Mitigation Potential

Potentially moderate reduction in GHG emissions from building natural gas

Co-Benefits (icon key on pg. 34)

Climate Resilience

Using alternative types of water heaters that use less fuel can reduce sensitivity to fuel price shocks or scarcity; however, they may decrease resilience if they are the only option available during a power outage. This measure may also power the appliance from the grid rather than from fuel, offering more reliability if the grid has been adapted to climate change or less reliability if the grid has not been adapted.

Health and Equity Considerations

Reduction of natural gas combustion in homes can help reduce indoor pollution.

Measure Description

This measure requires installation of a water heater that is less emissions intensive than a natural gas conventional storage tank water heater in residential developments. Alternatives analyzed in this measure are electric conventional storage tanks, solar water heaters with natural gas backup, and solar water heaters with electric backup. Each alternative reduces GHG emissions in a slightly different way. An electric storage tank heater displaces natural gas consumption with electricity use, replacing more emissions-intensive natural gas with less emissions-intensive electricity. A solar water heater with electric backup reduces GHG emissions by displacing natural gas with zero-emission solar energy when water is heated by the system's solar collectors and grid electricity when the back-up function is utilized. A solar water heater with natural gas backup reduces emissions by displacing natural gas with solar energy when water is heated by the solar collectors.

Subsector

Building Decarbonization

Scale of Application

Project/Site and Plan/Community

Implementation Requirements

Alternative water heaters analyzed in this measure include electric conventional storage tanks, solar water heaters with natural gas backup, and solar water heaters with electric backup.

Cost Considerations

Non-conventional heaters can have high initial and construction costs (e.g., upgrading the electric panel). However, alternatives to natural gas storage tank heaters are more energy efficient and cost less to operate once they are installed. Common alternatives also require less fuel, maintenance, and upkeep than natural gas heaters, leading to additional long-term cost savings.

Expanded Mitigation Options

Pair with Measure E-3-A, *Require Energy Efficiency Residential Boilers,* to reduce energy use from both space heating and water heating, yielding increased GHG reductions. Also, a heat pump is another option for an alternative water heater that is highly efficient, though the associated energy reductions were not quantified as part of this measure (see Measure E-25, *Install Electric Heat Pumps*, in Table 3-2).

GHG Reduction Formula

$$A1 = (-E \times C \times G \times I \times J) + (F_1 \times C \times H \times K \times J)$$

$$A2 = (F_2 - E) \times C \times G \times I \times J$$

GHG Calculation Variables

Based on 2019 survey data, approximately 73 percent of California residences use conventional storage tank heaters fueled by natural gas for primary water heating (CEC 2020). Therefore, for the purposes of this measure, natural gas storage tanks are the type of water heater that the user would be displacing.

ID	Variable	Value	Unit	Source
Output				
A1	Reduction in GHG emissions from building energy for electric storage tank heater or solar water heater with electric backup	[ ]	MT CO_2e per year	calculated
A2	Reduction in GHG emissions from building energy for solar water heater with natural gas backup	[ ]	MT CO_2e per year	calculated
User Inputs				
B	Housing type	[ ]	text	user input
C	Number of dwelling units	[ ]	du	user input
Constants, Assumptions, and Available Defaults				
D	Electricity Demand Forecast Zone	Figure E-1.1 Table E-1.1	integer	CEC 2017
E	Fuel consumption for storage tank heater	Table E-12.1	therm per year per du	CEC 2020
F_1	Electricity use for electric storage tank heater or solar water heater with electric backup	Table E-12.1	kWh per year per du	CEC 2020
F_2	Fuel consumption for solar water heater with natural gas backup	Table E-12.1	therm per year per du	CEC 2020
G	Carbon intensity of residential natural gas	117	lb CO_2e per MMBtu	U.S. EPA 2020
H	Carbon intensity of local electricity provider	Table E-4.3 Table E-4.4	lb CO_2e per MWh	CA Utilities 2021
I	Conversion from therm to 1 million Btu (MMBtu)	0.1	MMBtu per therm	conversion
J	Conversion from lb to metric ton (MT)	0.000454	MT per lb	conversion
K	Conversion from kWh to MWh	0.001	MWh per kWh	conversion

Further explanation of key variables:

- (B) – The housing types are needed to look up the energy use by type of heater (F_1 and F_2) in Table E-12.1.
- (D) – The CEC has specified 28 distinct EDFZs in California. Users should refer to Figure E-1.1 in Appendix C to determine the EDFZ for their project. This measure relies on energy consumption data from the year 2019 tied to the CEC's (2020) 2019 RASS. Because data from all 28 EDFZs are not included in the RASS, representative data from similar EDFZs may need to be used. Users should refer to Table E-1.1 for the proxy EDFZ that corresponds with those listed in Table E-12-1.
- (E, F_1, and F_2) – The CEC administered the statewide RASS in 2019. The study yielded energy consumption estimates for 27 electric and 10 natural gas residential end uses, including hot water heaters. Based on this data for the year 2019, the average natural gas and electricity consumption by heater type for each EDFZ and housing type is provided in Table E-12.1 in Appendix C. If the data is unavailable for a specific EDFZ, users may elect to use the statewide averages. If the user is able to provide a project-specific value, then the user should replace the defaults in the GHG calculation formula. CEC's 2019 Building Energy Standards provide detailed equations for this calculation (CEC 2019).
- (G) – The carbon intensity of residential natural gas was calculated in terms of CO_2e by multiplying the U.S. natural gas combustion emission factors for CO_2, CH_4, and N_2O (U.S. EPA 2020) by the corresponding 100-year GWP values from the IPCC's Fourth Assessment Report (IPCC 2007). See Table E-4.5 in Appendix C for more natural gas emission factors.
- (H) – GHG intensity factors for major California electricity providers are provided in Tables E-4.3 and E-4.4. If the project study area is not serviced by a listed electricity provider, or the user is able to provide a project-specific value (i.e., for a future year not referenced in Tables E-4.3 and E-4.4), the user should use that specific value in the GHG calculation formula. If the electricity provider is not known, users may elect to use the statewide grid average carbon intensity.

GHG Calculation Caps or Maximums

Mutually Exclusive Measures

If the user selects Measure E-15, *Require All-Electric Development*, they may not also take credit for this measure (Measure E-12) or Measure E-13, *Install Electric Ranges in Place of Gas Ranges,* which electrify select appliances. Measure E-15 accounts for the combined GHG reductions achieved by each of these measures, as well as the electrification of other end uses. To combine the GHG reductions from Measure E-15 with Measure E-12 or Measure E-13 would be considered double counting.

Example GHG Reduction Quantification

The user reduces building energy emissions by installing in a proposed residential development an alternative type of water heater in place of a natural gas storage tank heater. In this example, 10 single-family homes (B and C) would be constructed in EDFZ 7 (D) with a solar water heater with electric backup. Therefore, the fuel consumption for each

home's storage tank heater would be 260 therms per year (E), and the electricity consumption for a solar water heater with electric backup would be 483 kilowatt-hours per year (F1), based on Table E-12.1. The homes are in Los Angeles Department of Water and Power's service territory and would be constructed by 2022. It would, therefore, have an electricity carbon intensity of 694 lb CO_2e per MWh (H). The mitigated emissions would be reduced by 12.3 MT CO_2e per year.

$$A1 = \left(\frac{\text{-260 therm}}{\text{yr·du}} \times \textbf{10 du} \times \frac{\text{117 lb } CO_2e}{\text{MMBtu}} \times \frac{\text{0.1 MMBtu}}{\text{therm}} \times \frac{\text{0.000454 MT}}{\text{lb}}\right) + \left(\frac{\text{483 kWh}}{\text{yr·du}} \times \textbf{10 du} \times \frac{\text{694 lb } CO_2e}{\text{MWh}} \times \frac{\text{0.001 MWh}}{\text{kWh}} \times \frac{\text{0.000454 MT}}{\text{lb}}\right) = \text{-12.3} \frac{\text{MT } CO_2e}{\text{yr}}$$

Quantified Co-Benefits

Energy and Fuel Savings

Energy use conversion from major natural gas appliances to their equivalent electric replacements tends not to be straightforward given that most significant gas appliances (e.g., water heaters, space heaters, ovens and cooktops) have varying input-to-output efficiencies and losses from product to product. Equivalent electric appliances also have differing efficiencies, and usage patterns for these equivalent appliances may differ in some way. If installing an electric storage tank heater or solar water heater with electric backup (A_1), the user would decrease the building natural gas consumption (E) and increase the electricity use (F_1). If installing a solar water heater with natural gas backup (B_2), the user would decrease the building natural gas consumption (F_2-E).

Improved Air Quality

The reduction in natural gas fuel consumption from this measure would result in local improvements in air quality because the fuel consumption occurs on site of the project. The reduction in criteria pollutant emissions (L_1 and L_2) achieved by the measure can be calculated as follows.

Criteria Pollutant Emission Reduction Formula

Use (L_1) if installing an electric storage tank heater or solar water heater with electric backup. Use (L_2) if installing a solar water heater with natural gas backup.

$$L1 = \text{-E} \times \textbf{C} \times M \times I \times N$$

$$L2 = (F_2 - E) \times \textbf{C} \times M \times I \times N$$

Criteria Pollutant Emission Reduction Calculation Variables

ID	Variable	Value	Unit	Source
Output				
L1	Reduction in criteria pollutant emissions from building energy for electric storage tank heater or solar water heater with electric backup	[ ]	tons per year	calculated
L2	Reduction in criteria pollutant emissions from building energy for solar water heater with natural gas backup	[ ]	tons per year	calculated
User Inputs				
	None			
Constants, Assumptions, and Available Defaults				
M	Criteria pollutant emission factors of natural gas	Table E-4.5	lb per MMBtu	U.S. EPA 1998
N	Conversion from lb to ton	0.0005	tons per lb	conversion

Further explanation of key variables:

- (M) – Table E-4.5 presents the criteria pollutant emission factors of natural gas for residential and commercial uses (U.S. EPA 1998). For projects in Bay Area Air Quality Management District or South Coast Air Quality Management territory, see the footnote in Table E-4.5 about a regionally specific NO_x emission factor.
- Please refer to the GHG Calculation Variables table above for definitions of variables that have been previously defined.

Sources

- California Energy Commission (CEC). 2017. *California Electricity Demand Forecast Zones*. Available: https://cecgis-caenergy.opendata.arcgis.com/datasets/86fef50f6f344fabbe545e58aec83edd_0/data?geometry=-165.327%2C31.004%2C-72.427%2C43.220. Accessed: June 2021.
- California Energy Commission (CEC). 2019. *Residential Alternative Calculation Method Reference Manual for the 2019 Building Energy Efficiency Standards*. May. Available: https://www.energy.ca.gov/sites/default/files/2020-10/2019%20Residential%20ACM%20Reference%20Manual_ada.pdf. Accessed: January 2021.
- California Energy Commission (CEC). 2020. Excel database with the 2019 Residential Appliance Saturation Study (RASS), provided to ICF. November 13, 2020.
- California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021.
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- U.S. Environmental Protection Agency (U.S. EPA). 2020. Emission Factors for Greenhouse Gas Inventories. March. Available: https://www.epa.gov/sites/production/files/2020-04/documents/ghg-emission-factors-hub.pdf. Accessed: March 2021.
- U.S. Environmental Protection Agency (U.S. EPA). 1998. *AP 42, Fifth Edition, Volume I. Chapter 1: External Combustion Sources*. 1.4, *Natural Gas Combustion*. July. Available: https://www3.epa.gov/ttnchie1/ap42/ch01/final/c01s04.pdf. Accessed: January 2021.