California Air Resources Board

Quantification Methodology

California Energy Commission
California Schools Healthy Air, Plumbing, and Efficiency Program

California Climate Investments

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List of Acronyms and Abbreviations

Acronym	Term
AFUE	annual fuel utilization efficiency
CalSHAPE	California Schools Healthy Air, Plumbing, And Efficiency Program
CARB	California Air Resources Board
CEC	California Energy Commission
COP	coefficient of performance
EER	energy efficiency ratio
GGRF	Greenhouse Gas Reduction Fund
GHG	greenhouse gas
GWP	global warming potential
HSPF	heating seasonal performance factor
HVAC	heating, ventilation, and air conditioning
IPLV	integrated part load value
kWh	kilowatt hours
lbs	pounds
$MTCO_2e$	metric tons of carbon dioxide equivalent
NO_x	oxides of nitrogen
$PM_{2.5}$	particulate matter with a diameter less than 2.5 micrometers
ROG	reactive organic gas
SEER	seasonal energy efficiency ratio
Wh	watt hours

List of Definitions

Term	Definition
Co-benefit	A social, economic, and/or environmental benefit as a result of the proposed project in addition to the GHG emission reduction benefit.
Energy and fuel cost savings	Changes in energy and fuel costs to the operator because of changing the quantity of energy or fuel used, changing to an alternative energy or fuel source, and renewable energy or fuel generation.
CalSHAPE GGRF funds requested	Funds that are requested to be contributed to the project by CalSHAPE.
Key variable	Project characteristics that contribute to a project's GHG emission reductions and signal an additional benefit (e.g., renewable energy generated).
Non-GGRF leveraged funds	Match funding contributed from all other sources that are not funded by the Greenhouse Gas Reduction Fund.

Term	Definition
Other GGRF leveraged funds	Match funding contributed from other California Climate Investment programs, aside from CalSHAPE, which source funding from the Greenhouse Gas Reduction Fund.
Quantification period	Number of years that the project activity will provide GHG emission reductions. Also referred to as "Project Life", "Useful Life", or "System Lifetime". For CalSHAPE projects, the quantification period is the average lifetime of the cooling/heating system.

Section A. Introduction

California Climate Investments is a statewide initiative that puts billions of Cap-and-Trade dollars to work facilitating greenhouse gas (GHG) emission reductions; strengthening the economy; improving public health and the environment; and providing benefits to residents of disadvantaged communities, low-income communities, and low-income households, collectively referred to as "priority populations." Where applicable and to the extent feasible, California Climate Investments must maximize economic, environmental, and public health co-benefits to the State.

The California Air Resources Board (CARB) is responsible for providing guidance on estimating the GHG emission reductions and co-benefits from projects receiving monies from the Greenhouse Gas Reduction Fund (GGRF). This guidance includes quantification methodologies, co-benefit assessment methodologies, and benefits calculator tools. CARB develops these methodologies and tools based on the project types eligible for funding by each administering agency, as reflected in the program expenditure records available at: www.arb.ca.gov/cci-expenditurerecords.

For the California Energy Commission (CEC) California Schools Healthy Air, Plumbing, and Efficiency Program (CalSHAPE), CARB staff developed this CalSHAPE Quantification Methodology to provide guidance for estimating the GHG emission reductions and selected co-benefits of each proposed project type, as defined in the CalSHAPE guidelines.[1] Although the CalSHAPE program provides funding for ventilation and plumbing systems, only ventilation systems are expected to receive GGRF funding. Thus, no methodology is provided for plumbing systems. This methodology outlines the calculations used to estimate GHG emission reductions from installing or replacing older cooling and heating systems with systems that are more functional and energy efficient.

The CalSHAPE Tool automates methods described in this document. Projects will report the total project GHG emission reductions and co-benefits estimated using the CalSHAPE Tool as well as the total dollars of GGRF funds requested per project GHG emission reductions ($/MTCO_2e$).

Applicants must use the CalSHAPE Tool to estimate GHG emission reductions and co-benefits of the proposed project. The CalSHAPE Tool is available for download at: http://www.arb.ca.gov/cci-resources and https://calshape.energy.ca.gov/.

Using many of the same inputs required to estimate GHG emission reductions, the CalSHAPE Tool estimates the following co-benefits and key variables from CalSHAPE

[1] California Air Resources Board. 2023. CalSHAPE Program Guidelines. https://calshape.energy.ca.gov/

projects: energy and fuel cost savings ($) and fossil fuel-based energy use reductions (kWh). Key variables are project characteristics that contribute to a project's GHG emission reductions and signal an additional benefit. Additional co-benefits for which CARB assessment methodologies were not incorporated into the CalSHAPE Tool may also be applicable to the project. Applicants should consult the CalSHAPE program guidelines, solicitation materials, and agreements to ensure they are meeting CalSHAPE requirements. All CARB co-benefit assessment methodologies are available at: www.arb.ca.gov/cci-cobenefits.

Methodology Development

CARB developed this Quantification Methodology consistent with the guiding principles of California Climate Investments, including ensuring transparency and accountability.[2] CARB developed the CalSHAPE Quantification Methodology to be used to estimate the outcomes of proposed projects, inform project selection, and track results of funded projects. The implementing principles ensure that the methodology would:

- Apply at the project-level;
- Provide uniform methods to be applied statewide, and be accessible by all applicants;
- Use existing and proven tools and methods;
- Use project-level data, where available and appropriate; and
- Result in GHG emission reduction estimates that are conservative and supported by empirical literature.

CARB assessed peer-reviewed literature and tools and consulted with experts, as needed, to determine methods appropriate for the CalSHAPE project types. The methods were developed to provide estimates that are as accurate as possible with data readily available at the project level. CARB released the Draft CalSHAPE Quantification Methodology and Draft CalSHAPE Benefits Calculator Tool for public comment in April 2023. This Final CalSHAPE Quantification Methodology and accompanying CalSHAPE Benefits Calculator Tool have been updated to address public comments, where appropriate, and for consistency with updates to the CalSHAPE Guidelines.

In addition, the University of California, Berkeley, in collaboration with CARB, developed assessment methodologies for a variety of co-benefits such as providing cost savings, lessening the impacts and effects of climate change, and strengthening community engagement. Co-benefit assessment methodologies are posted at: www.arb.ca.gov/cci-cobenefits.

[2] California Air Resources Board. California Climate Investments Funding Guidelines. www.arb.ca.gov/cci-fundingguidelines

Tools

The CalSHAPE Tool relies on CARB-developed emission factors. CARB has established a single repository for emission factors used in CARB benefits calculator tools, referred to as the California Climate Investments Quantification Methodology Emission Factor Database (Database), available at: http://www.arb.ca.gov/cci-resources. The Database Documentation explains how emission factors used in CARB benefits calculator tools are developed and updated.

Program Assistance

Applicants should use the following resources for additional questions and comments:

- Questions on this document should be sent to: GGRFProgram@arb.ca.gov.
- For more information on CARB's efforts to support implementation of California Climate Investments, see: www.arb.ca.gov/auctionproceeds.
- Questions pertaining to the CalSHAPE should be sent to: CalSHAPE@energy.ca.gov.

Section B. Calculating GHG Emission Reductions using the CalSHAPE Tool

GHG Quantification Methodology for CalSHAPE Projects

Methods used in the CalSHAPE Tool for estimating GHG emission reductions and air pollutant emission co-benefits from heating, ventilation, and air conditioning (HVAC) system replacements are provided in this section. For more information about how emission factors are used in CARB benefits calculator tools and are developed and updated, refer to the Database Documentation available at: https://ww2.arb.ca.gov/cci-resources.

The CalSHAPE Quantification Methodology accounts for GHG emission reductions from HVAC system replacement. In general, the GHG emission reductions are estimated in the CalSHAPE Tool using the approach outlined in Table 1. The CalSHAPE Tool also estimates air pollutant emission co-benefits and key variables using the same inputs used to estimate GHG emission reductions.

Table 1. General Approach to Quantification

HVAC System Replacement
GHG Emission Reductions = Baseline system energy consumption emissions – Replacement system energy consumption emissions

Applicants are not required to manually calculate GHG emissions for their proposed project using this methodology; it is outlined for informational purposes only and is already built into the CalSHAPE Tool. Applicants need only enter their project-specific information into the tool following the instructions in the accompanying User Guide and the tool will automatically calculate GHG emission reductions and co-benefits associated with their proposed project.

For more detail, the following sections provide specific equations about how HVAC system energy consumption emissions are quantified in the tool.

GHG Emission Reductions from CalSHAPE Projects

GHG emission reductions are quantified for the replacement of existing HVAC equipment with more energy-efficient HVAC equipment, and/or conversion from natural gas HVAC equipment to electric HVAC equipment. The calculation is based on the amount of electricity and/or natural gas saved by the project, as shown in Equation 1.

Equation 1: GHG Emission Reductions from HVAC System Replacement

$$ER_{GHG} = (S_{Elec} \times EF_{GHG,Elec}) + (S_{NG} \times EF_{GHG,NG})$$

Where,

			Units
ER_{GHG}	=	Total GHG emission reductions from HVAC replacement	$MTCO_2e$
S_{Elec}	=	Total electricity savings from HVAC replacement	kWh
$EF_{GHG,Elec}$	=	GHG emission factor for grid electricity	$MTCO_2e$/kWh
S_{NG}	=	Total natural gas savings from HVAC replacement	kWh
$EF_{GHG,NG}$	=	GHG emission factor for natural gas	$MTCO_2e$/therm

Equation 1. Total GHG emission reductions from HVAC replacement are estimated as the product of the electricity energy savings and the GHG emission factor for grid electricity, plus the product of the natural gas energy savings and the GHG emission factor for natural gas.

Electricity and/or natural gas savings are determined by the difference in electricity and/or natural gas energy consumption between the baseline HVAC system and the replacement HVAC system, as shown in Equation 2.

Equation 2: Electricity and Natural Gas Savings from HVAC System Replacement

$$S_i = S_{i,heat} + S_{i,cool} = (C_{i,heat,base} - C_{i,heat,repl}) + (C_{i,cool,base} - C_{i,cool,repl})$$

Where,

			Units
S_i	=	Total energy savings from HVAC replacement	kWh or therm
$S_{i,\ heat}$	=	Total energy savings from heating system replacement	kWh or therm
$S_{i,\ cool}$	=	Total energy savings from cooling system replacement	kWh or therm
$C_{i,\ heat,\ base}$	=	Energy consumption of the existing baseline heating system	kWh or therm
$C_{i,\ heat,\ repl}$	=	Energy consumption of the replacement heating system	kWh or therm
$C_{i,\ cool,\ base}$	=	Energy consumption of the existing baseline cooling system	kWh or therm
$C_{i,\ cool,\ repl}$	=	Energy consumption of the replacement cooling system	kWh or therm
i	=	Electricity or natural gas	

Equation 2. Total energy savings from HVAC system replacement is calculated as the difference between the baseline and replacement systems' energy consumption.

The amount and type of energy consumption of an HVAC system is dependent on the particular technology. For HVAC systems that provide cooling such as air conditioners, chillers, and heat pumps, the electricity consumption is calculated using Equation 3, Equation 4, and Equation 5, respectively.

For air conditioners, the amount of energy consumed is determined by the equipment's Energy Efficiency Ratio (EER) or Seasonal Energy Efficiency Ratio (SEER) rating. Either the EER or SEER rating is used, depending on the cooling capacity of the air conditioning unit. The EER rating is the ratio of the cooling capacity (in Btu per hour) to the power input (in watts). Similarly, the SEER rating is the ratio of cooling output over an average cooling season divided by the total energy used.

Equation 3: Electricity Consumption of Air Conditioners

For units with cooling capacities < 65,000 Btu/hr

$$C_{Elec} = \left(\frac{Cap_C}{1{,}000}\right) \times \left(\frac{1}{SEER}\right) \times EFLH_C \times UL \times N$$

For units with cooling capacities ≥ 65,000 Btu/hr

$$C_{Elec} = \left(\frac{Cap_C}{1{,}000}\right) \times \left(\frac{1}{EER}\right) \times EFLH_C \times UL \times N$$

Where,

			Units
C_{Elec}	=	Electricity consumption	kWh
Cap_C	=	Full load cooling output capacity	Btu/hr
$SEER$	=	Seasonal energy efficiency ratio	Btu/Wh
EER	=	Energy efficiency ratio	Btu/Wh
$EFLH_C$	=	Equivalent full load cooling hours	hours/year
UL	=	Useful life of the air conditioner	years
N	=	Number of air conditioning units	[unitless]

Equation 3. Electricity consumption from air conditioners is calculated as the full load cooling output capacity divided by the seasonal energy efficiency ratio (or energy efficiency ratio if the output capacity is greater than 65,000 Btu per hour), multiplied by the equivalent full load cooling hours, the useful life of the equipment, and the number of air conditioners.

For chillers, the amount of energy consumed is determined by the equipment's Integrated Part Load Value (IPLV), analogous to SEER for air conditioners. IPLV is a measure of the chiller's part-load efficiency based on the average weighted operation at various partial load capacities for the chiller.

Equation 4: Electricity Consumption of Chillers

$$C_{Elec} = \left(\frac{Cap_C}{12{,}000}\right) \times IPLV \times EFLH_C \times UL \times N$$

Where,			Units
C_{Elec}	=	Electricity consumption	kWh
Cap_C	=	Full load cooling output capacity	Btu/hr
IPLV	=	Integrated Part Load Value	kW/ton
$EFLH_C$	=	Equivalent full load cooling hours	hours/year
UL	=	Useful life of the chiller	years
N	=	Number of chiller units	[unitless]
12,000	=	Conversion from tons of cooling to Btu/hr	Btu/hr/ton

Equation 4. Electricity consumption from chillers is calculated as the full load cooling output capacity multiplied by the integrated part load value, the equivalent full load cooling hours, the useful life of the equipment, and the number of chillers.

For heat pumps, the energy efficiency is also measured in terms of EER and SEER ratings.

Equation 5: Cooling Electricity Consumption of Heat Pumps

For units with cooling capacities < 65,000 Btu/hr

$$C_{Elec} = \left(\frac{Cap_C}{1{,}000}\right) \times \left(\frac{1}{SEER}\right) \times EFLH_C \times UL \times N$$

For units with cooling capacities ≥ 65,000 Btu/hr

$$C_{Elec} = \left(\frac{Cap_C}{1{,}000}\right) \times \left(\frac{1}{EER}\right) \times EFLH_C \times UL \times N$$

Where,			Units
C_{Elec}	=	Electricity consumption	kWh
Cap_C	=	Full load cooling output capacity	Btu/hr
$SEER$	=	Seasonal energy efficiency ratio	Btu/Wh
EER	=	Energy efficiency ratio	Btu/Wh
$EFLH_C$	=	Equivalent full load cooling hours	hours/year
UL	=	Useful life of the heat pump	years
N	=	Number of heat pumps	[unitless]

Equation 5. The cooling electricity consumption for heat pumps is estimated as the full load cooling output capacity divided by the energy efficiency ratio (seasonal ratio if the output capacity is less than 65,000 Btu per hour), multiplied by the equivalent full load cooling hours, the useful life of the equipment, and the number of heat pumps.

HVAC systems that provide heating can either use electricity of natural gas depending on the technology. Whereas boilers use natural gas and heat pumps use electricity, furnaces can either run on natural gas or electricity. Hybrid heating systems are also available, which use a combination of electric heat pumps and gas furnaces depending on the outdoor temperature. For this methodology, hybrid systems are assumed to use the gas furnace when the outside temperature is below 40 °F and use the electric heat pump when the outside temperature is 40 °F and above.

For gas furnaces and boilers, the amount of energy consumed is determined by the equipment's Annual Fuel Utilization Efficiency (AFUE). AFUE is a measurement of how efficiently a furnace converts energy from the fuel it uses into warm air. The AFUE rating is calculated as the total annual heating output from the furnace divided by the amount of fuel input over the same time period.

Equation 6: Natural Gas Consumption of Gas Furnaces and Boilers

$$C_{NG} = \left(\frac{Cap_H}{100{,}000}\right) \times \left(\frac{1}{AFUE}\right) \times EFLH_H \times UL \times N$$

Where,			Units
C_{NG}	=	Natural gas consumption	therm
Cap_H	=	Full load heating output capacity	Btu/hr
AFUE	=	Annual Fuel Utilization Efficiency rating	%
$EFLH_H$	=	Equivalent full load heating hours	hours/year
UL	=	Useful life of the gas furnace or boiler	Years
N	=	Number of gas furnaces or boilers	[unitless]
100,000	=	Conversion from therm to Btu	Btu/therm

Equation 6. Electricity consumption from gas furnaces and boilers is calculated as the full load heating output capacity multiplied by inverse of the annual fuel utilization efficiency, the equivalent full load heating hours, the useful life of the equipment, and the number of gas furnaces or boilers.

For electric furnaces, all of the electricity used is converted into heat. Thus, the AFUE rating for electric furnaces is considered to be 100% and is therefore not required for calculating electricity consumption, as shown in Equation 7.

Equation 7: Electricity Consumption of Electric Furnaces

$$C_{Elec} = \left(\frac{Cap_H}{3{,}412}\right) \times EFLH_H \times UL \times N$$

Where,			Units
C_{Elec}	=	Electricity consumption	kWh
Cap_H	=	Full load heating output capacity	Btu/hr
$EFLH_H$	=	Equivalent full load heating hours	hours/year
UL	=	Useful life of the electric furnace	Years
N	=	Number of electric furnaces	[unitless]
3,412	=	Conversion from kWh to Btu	Btu/kWh

Equation 7. Electricity consumption from electric furnaces is calculated as the full load heating output capacity multiplied by the equivalent full load cooling hours, the useful life of the equipment, and the number of electric furnaces.

For heat pumps, the amount of energy consumed is determined by the equipment's Heating Seasonal Performance Factor (HSPF) or Coefficient of Performance (COP) rating. Either the HSPF or COP rating is used, depending on the heating capacity of the heat pump. HSPF the ratio of heat output (in Btu) over the heating season to electricity used (in watt-hours), while COP is the ratio of heat energy delivered (in kW) to electrical energy supplied to the compressor (in kW).

Equation 8: Heating Electricity Consumption of Heat Pumps

For units with heating capacities < 65,000 Btu/hr

$$C_{Elec} = \left(\frac{Cap_H}{1{,}000}\right) \times \left(\frac{1}{HSPF}\right) \times EFLH_H \times UL \times N$$

For units with heating capacities ≥ 65,000 Btu/hr

$$C_{Elec} = \left(\frac{Cap_H}{1{,}000}\right) \times \left(\frac{1}{3.412 \times COP}\right) \times EFLH_H \times UL \times N$$

Where,			Units
C_{Elec}	=	Electricity consumption	kWh
Cap_H	=	Full load heating output capacity	Btu/hr
HSPF	=	Heating seasonal performance factor	Btu/Wh
COP	=	Coefficient of performance	unitless
$EFLH_H$	=	Equivalent full load heating hours	hours/year
UL	=	Useful life of the heat pump	years
N	=	Number of heat pumps	[unitless]
3.412	=	Conversion from Wh to Btu	Btu/Wh

Equation 8. The heating electricity consumption for heat pumps is estimated as the full load heating output capacity divided by the heating seasonal performance factor (or coefficient of performance if the output capacity is greater than 65,000 Btu per hour), multiplied by the equivalent full load cooling hours, the useful life of the equipment, and the number of heat pumps.

To ultimately calculate the energy consumption from any HVAC equipment, the amount of necessary cooling and/or heating must be determined. Equivalent full load hours (EFLH) are the number of hours that an HVAC system would need to operate at full load to equal the amount of cooling or heating delivered by the system at a constant temperature (e.g., thermostat setting) over a year. Although the simplest and most direct method to calculate EFLH is using energy consumption data, this data is not always available, especially when considering prospective projects. When metering data unavailable, it may be estimated using historical weather data as shown in Equation 9 and Equation 11. EFLH is approximately estimated as the cumulative amount of cooling or heating temperature differences over the difference the between the equipment's test design temperature and an operating setpoint temperature.

Equation 9: Equivalent Full Load Cooling Hours

$$EFLH_C = \frac{CDH}{T_{DesignC} - T_{SetpointC}}$$

Where,			Units
$EFLH_C$	=	Equivalent full load cooling hours	hours/year
CDH	=	Cooling degree hours	°F- hours/year
$T_{DesignC}$	=	HVAC system total capacity cooling design temperature	°F
$T_{SetpointC}$	=	Thermostat setpoint temperature for cooling	°F

Equation 9. The equivalent full load cooling hours is calculated as the total annual cooling degree hours divided by the difference between the HVAC system's total capacity cooling design temperature and the operating setpoint cooling temperature.

Cooling degree hours is a measure of how much (in degrees), and for how long (in hours), the outside air temperature is higher than a specific base or setpoint temperature. The more extreme the outside temperature, the higher the number of degree hours. A high number of degree hours generally results in higher levels of energy use for cooling or heating. Degree hours are geographic-specific and, for the purposes of the CalSHAPE tool, vary by county or climate zone[3]. Average hourly temperature data was sourced from the National Oceanic and Atmospheric Administration's data on 30-year climate normals[4]. For counties or climates zones where hourly data was unavailable, an hourly dataset was derived by interpolating maximum and minimum daily temperatures.

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[3] California Energy Commission. Climate Zone tool, maps, and information supporting the California Energy Code. https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/climate-zone-tool-maps-and

[4] National Oceanic and Atmospheric Administration. U.S. Climate Normals. https://www.ncei.noaa.gov/products/land-based-station/us-climate-normals

Equation 10: Cooling Degree Hours

$$CDH = \sum_{D1}^{DF} \sum_{H1}^{HF} \left(T_{Out,H,D} - T_{SetpointC}\right)^{+}$$

Where,			Units
CDH	=	Cooling degree hours	°F- hours/year
D1	=	First day of HVAC annual operation	unitless
DF	=	Final day of HVAC annual operation	unitless
H1	=	Typical weekly HVAC thermostat start time	unitless
HF	=	Typical weekly HVAC thermostat end time	unitless
$T_{Out,\ H,\ D}$	=	Average hourly outdoor temperature for a particular hour and day, in a specific county or climate zone	°F
$T_{SetpointC}$	=	Setpoint temperature for cooling	°F

Equation 10. Cooling degree hours are calculated as the positive difference between the average hourly outdoor temperature and the thermostat cooling setpoint temperature, summed for all the hours and days when the equipment is operational. When the average hourly outdoor temperature is below the thermostat cooling setpoint temperature, it is not included in the summation.

For heating applications, equivalent full load heating hours and heating degree hours are calculated, analogous to their cooling counterpart. Heating degree hours is a measure of how much (in degrees), and for how long (in hours), the outside air temperature is lower than a specific base or setpoint temperature.

Equation 11: Equivalent Full Load Heating Hours

$$EFLH_H = \frac{HDH}{T_{DesignC} - T_{SetpointH}}$$

Where,			Units
$EFLH_H$	=	Equivalent full load heating hours	hours/year
HDH	=	Heating degree hours	°F- hours/year
$T_{SetpointH}$	=	Thermostat setpoint temperature for heating	°F
$T_{DesignH}$	=	HVAC system total capacity heating design temperature	°F

Equation 11. The equivalent full load heating hours is calculated as the total annual heating degree hours divided by the difference between the operating setpoint

heating temperature and the HVAC system's total capacity heating design temperature.

Equation 12: Heating Degree Hours

$$HDH = \sum_{D1}^{DF} \sum_{H1}^{HF} \left(T_{SetpointH} - T_{Out,H,D}\right)^{+}$$

Where,			Units
HDH	=	Heating degree hours	°F- hours/year
D1	=	First day of HVAC annual operation	unitless
DF	=	Final day of HVAC annual operation	unitless
H1	=	Typical weekly HVAC thermostat start time	unitless
HF	=	Typical weekly HVAC thermostat end time	unitless
$T_{SetpointH}$	=	Setpoint temperature for heating	°F
$T_{Out, H, D}$	=	Average hourly outdoor temperature for a particular hour and day, in a specific county	°F

Equation 12. Heating degree hours are calculated as the positive difference between the thermostat heating setpoint temperature and the average hourly outdoor temperature and the, summed for all the hours and days when the equipment is operational. When the average hourly outdoor temperature is above the thermostat heating setpoint temperature, it is not included in the summation.

Air Pollutant Emission Reductions from CalSHAPE Projects

Air pollutant emission reductions are calculated as the sum of reductions in remote air pollutant emissions and local air pollutant emissions. Remote air pollutant emissions are emissions that occur away from the project site (e.g., grid electricity emissions resulting from an offsite power plant). Conversely, local air pollutant emissions are emissions that occur at the project site and directly impact the surrounding community (e.g., onsite natural gas combustion).

Equation 13: Air Pollutant Emission Reductions from HVAC System Replacement

$$ER_{AP} = ER_{AP,Loc} + ER_{AP,Rem}$$

Where,			Units
ER_{AP}	=	Total air pollutant emission reductions from HVAC replacement	lbs
$ER_{AP, Loc}$	=	Local air pollutant emission reductions from HVAC replacement	lbs
$ER_{AP, Rem}$	=	Remote air pollutant emission reductions from HVAC replacement	lbs

Equation 13. Total air pollutant emission reductions are calculated as the sum of reduced local and remote air pollutant emissions from HVAC system replacement.

Local air pollutant emission reductions are calculated based on the amount of natural gas use avoided by the project. For HVAC systems, only heating equipment may use natural gas.

Equation 14: Local Air Pollutant Emission Reductions from HVAC System Replacement

$$ER_{AP,Loc} = C_{NG,heat,base} \times EF_{AP,NG,heat,base} - C_{NG,heat,repl} \times EF_{AP,NG,heat,repl}$$

Where,

			Units
$ER_{AP, Loc}$	=	Local air pollutant emission reductions from HVAC replacement	lbs
$C_{NG, heat, base}$	=	Natural gas consumption of the existing baseline heating system	therm
$EF_{AP, NG, heat, base}$	=	Air pollutant emission factor for natural gas, dependent on baseline technology	lbs/therm
$C_{NG, heat, repl}$	=	Natural gas consumption of the replacement heating system	therm
$EF_{AP, NG, heat, repl}$	=	Air pollutant emission factor for natural gas, dependent on replacement technology	lbs/therm

Equation 14. Local air pollutant emission reductions are estimated by the sum of total avoided air pollutant emissions from reduced onsite use of natural gas. This is quantified as the sum of the difference between the total baseline and replacement scenario natural gas consumption multiplied by the respective air pollutant emission factor for natural gas relative to the type of heating equipment.

Remote air pollutant emission reductions are calculated based on the amount of electricity use avoided by the project. For HVAC systems, either the cooling or heating equipment may use electricity.

Equation 15: Remote Air Pollutant Emission Reductions from HVAC System Replacement

$$ER_{AP,Rem} = \left(\left(C_{Elec,cool,base} - C_{Elec,cool,repl}\right) + \left(C_{Elec,heat,base} - C_{Elec,heat,repl}\right)\right) \times EF_{AP,Elec}$$

Where,

			Units
$ER_{AP,\ Rem}$	=	Remote air pollutant emission reductions from HVAC replacement	lbs
$C_{Elec,\ cool,\ base}$	=	Electricity consumption of the existing baseline cooling system	kWh
$C_{Elec,\ cool,\ base}$	=	Electricity consumption of the replacement cooling system	kWh
$C_{Elec,\ heat,\ base}$	=	Electricity consumption of the existing baseline heating system	kWh
$C_{Elec,\ heat,\ base}$	=	Electricity consumption of the replacement heating system	kWh
$EF_{AP,\ Elec}$	=	Air pollutant emission factor for electricity	lbs/kWh

Equation 15. Remote air pollutant emission reductions are estimated by the sum of total avoided air pollutant emissions from reduced onsite use of grid electricity. This is quantified as the sum of the difference between the total baseline and replacement electricity consumption for all HVAC systems (cooling and/or heating), multiplied by the air pollutant emission factor for grid electricity.

Section C. References

The following references were used in the development of this Quantification Methodology and the CalSHAPE Tool.

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