

California Air Resources Board

Final FY 2021-22 Quantification Methodology Woodsmoke Reduction Program

California Climate Investments



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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 CARB’s Woodsmoke Reduction Program, staff developed this Woodsmoke Reduction Quantification Methodology to provide guidance for estimating the GHG emission reductions and selected co-benefits of each proposed project. The Woodsmoke Reduction Program is administered by CARB in partnership with the California Air Pollution Control Officers Association (CAPCOA) as an intermediary, and local air pollution control districts or air quality management districts (Districts) implementing the program at the local level. Participating Districts will help households replace fireplaces and/or uncertified wood stoves or inserts used as the primary source of heat with cleaner burning and more efficient home heating stoves by offering financial incentives for homeowners. Incentive amounts vary depending on location of residence and whether recipients are part of a priority population, with some households qualifying for full replacement cost. For the purposes of the program, a project is defined as the set of change-outs funded by the program within a participating District. This methodology uses calculations to estimate GHG emissions associated with the implementation of Woodsmoke Reduction projects.

The Woodsmoke Reduction Benefits Calculator Tool automates methods described in this document, provides a link to a step-by-step user guide with a project example, and outlines documentation requirements. Projects will report the total project GHG emission reductions and co-benefits estimated using the Woodsmoke Reduction Benefits Calculator Tool as well as the total project GHG emission reductions per dollar of GGRF funds requested. The Woodsmoke Reduction Benefits Calculator Tool is available for download at: <http://www.arb.ca.gov/cci-resources>.

Using many of the same inputs required to estimate GHG emission reductions, the Woodsmoke Reduction Benefits Calculator Tool estimates the following co-benefits and key variables from Woodsmoke Reduction projects: reductions in nitrogen oxides (NO_x) (lbs) and reactive organic gases (ROG) (lbs), and energy and fuel cost savings. Key variables are project characteristics that contribute to a project's GHG emission reductions and signal an additional benefit (e.g., reductions in cord wood burned for the life of the stove, referred to as the quantification period). Additional co-benefits for which CARB assessment methodologies were not incorporated into the Woodsmoke Reduction Benefits Calculator Tool may also be applicable to the project. Applicants should consult the [Woodsmoke Reduction program guidelines](#), solicitation materials, and agreements to ensure they are meeting Woodsmoke Reduction requirements. There may be specific options available for certain home heating stove changeout types detailed in the Woodsmoke Reduction Guidelines depending on the location, region, and jurisdiction of local air district. 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.¹ CARB developed this Woodsmoke Reduction 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 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 Woodsmoke Reduction project types. The methods were developed to provide estimates that are as accurate as possible with data readily available at the project level.

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. As they become available, co-benefit assessment methodologies are posted at: www.arb.ca.gov/cci-cobenefits.

¹ California Air Resources Board. www.arb.ca.gov/cci-fundingguidelines

Tools

The Woodsmoke Reduction Benefits Calculator 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. Applicants must use the Woodsmoke Reduction Benefits Calculator Tool to estimate the GHG emission reductions and co-benefits of the proposed project. The Woodsmoke Reduction Benefits Calculator Tool can be downloaded from: <http://www.arb.ca.gov/cci-resources>.

Updates

CARB staff periodically review each quantification methodology and benefits calculator tool to evaluate their effectiveness and update methodologies to make them more robust, user-friendly, and appropriate to the projects being quantified. CARB updated the Woodsmoke Reduction Quantification Methodology from the previous 2018-2019 version² to enhance the analysis and provide additional clarity. In addition to past changes, the changes for this FINAL 2021-2022 woodsmoke reduction program update includes:

- The addition of certified hybrid woodstoves or inserts.
 - Definition of a Hybrid stove: A U.S. EPA certified use hybrid wood stove or wood insert using both non-catalytic and catalytic technology to meet the performance and emission standards as defined in Title 40 Code of Federal Regulations, Part 60, Subpart AAA, May 15, 2015, or any subsequent revisions. For the purposes of this program, only devices that are certified to U.S. EPA Step 2 New Source Performance Standard (NSPS) are eligible replacement options. For the purposes of this document and tool, due to a lack of certified hybrid stove emissions factor data, certified non-catalytic calculation values are used for certified hybrid wood stoves as a conservative approach to quantification.
- Removal of natural gas home heating stoves as an eligible option for replacement of fireplaces or uncertified wood stoves.
- Removal of propane home heating stoves as an eligible option for replacement of fireplaces or uncertified wood stoves.
- Terminology changes from ductless mini-split heat pump to electric heat pump for replacement of fireplaces or uncertified wood stoves.
- Electric heat pump replacements have an additional change-out category
- Minor updates to electric emission factors for GHG, NO_x, and ROG.
- Fuel cost value adjustments for co-benefit quantification specific to calculator tool.

² [Greenhouse Gas Quantification Methodology for the California Air Resources Board Woodsmoke Reduction Program](#) released September 21, 2020

Section B. Methods

The following section provides details on the methods supporting emission reductions in the Woodsmoke Reduction Benefits Calculator Tool.

Woodsmoke Reduction Project Change-Out Types

The Woodsmoke Reduction Program Guidelines³ identifies eligibility criteria including the types of old to new home heating stoves that can be funded for which there are methods to quantify GHG emission reductions. This quantification methodology matches those eligibility criteria and quantifies benefits based on the quantity of each type of change-out performed by a District. The different change-out types are:

- Replacing fireplaces with certified non-catalytic wood stoves or wood inserts;
- Replacing uncertified wood stoves or wood inserts with certified non-catalytic wood stoves or wood inserts;
- Replacing fireplaces with certified hybrid wood stoves or wood inserts;
- Replacing uncertified wood stoves or wood inserts with certified hybrid wood stoves or wood inserts;
- Replacing fireplaces with certified catalytic wood stoves or wood inserts;
- Replacing uncertified wood stoves or wood inserts with certified catalytic wood stoves or wood inserts;
- Replacing fireplaces with certified pellet stoves or pellet inserts;
- Replacing uncertified wood stoves or wood inserts with certified pellet stoves or pellet inserts;
- Replacing fireplaces with electric heat pump, old fireplace removed;
- Replacing uncertified wood stoves or wood inserts with electric heat pump, old stove removed;
- Replacing fireplaces with electric heat pump, old fireplace retained for emergency heating needs;
- Replacing uncertified wood stoves or wood inserts with electric heat pump, old stove retained for emergency heating needs;
- Replacing fireplaces with electric home heating stoves;
- Replacing uncertified wood stoves or wood inserts with electric home heating stoves;

If the replacement device is an electric heat pump, household may be allowed to retain the old wood burning device to serve as emergency heat in case of a power outage. The approval to retain the old device will be granted on a case-by-case basis by the District. Households would be required to sign an agreement to use their old device only in case of a power outage. View the latest version of Woodsmoke Reduction Program Guidelines³ for more specific information.

³ Residential Woodsmoke Reduction Program. <https://ww2.arb.ca.gov/our-work/programs/residential-woodsmoke-reduction/woodsmoke-reduction-program>

This methodology estimates the benefits of a project based on the quantities of each type of change-out performed. Districts will therefore need to estimate emission reductions both when awarded and implemented.

1. **Awarded Funds:** Upon being awarded funds by CAPCOA, Districts will estimate the expected project outcomes using the methods as described in this section.
2. **Implemented Projects:** When change-outs are performed, Districts will revise earlier estimates, again using the methods as described in this section.

General Approach

Methods used in the Woodsmoke Reduction Benefits Calculator Tool for estimating the GHG emission reductions and air pollutant emission co-benefits by activity type are provided in this section. The Database Documentation explains how emission factors used in CARB benefits calculator tools are developed and updated.

These methods account for the GHG emission reductions resulting from a home heating stove change-out from a fireplace, uncertified wood stove, or wood insert to a cleaner and more efficient home heating stove. In general, the GHG emission reductions are estimated in the Woodsmoke Reduction Benefits Calculator Tool using the approaches in Table 1. The Woodsmoke Reduction Benefits Calculator Tool also estimates air pollutant emission co-benefits and key variables using the same inputs used to estimate GHG emission reductions. This quantification methodology accounts for avoided GHG emissions from uncertified wood stoves, wood inserts, and fireplaces used as primary sources of heat and GHG emissions associated with the use of cleaner, more efficient heating stoves. In general, the GHG emission reductions are calculated using the following approach:

Table 1. General Approach to GHG Quantification

| |
|--|
| GHG Emission Reductions from Change-Out |
| <i>GHG Emission Reductions = GHG Emissions of Uncertified Wood Stove, Wood Insert, or Fireplace – GHG Emissions of New Heating Stove</i> |

The total project GHG, black carbon, and particulate emission reductions per Woodsmoke Reduction Program GGRF dollar requested and per total GGRF dollar requested, as described below.

- **Total Project GHG Emission Reductions** is equal to the total sum of each of the GHG emission reductions by stove type and are automatically summed in the Woodsmoke Reduction GHG Calculator Tool.
- **Total Project GHG Emission Reductions per Dollar of Woodsmoke Reduction Program GGRF Funds Requested** is calculated as shown in Table 2.

Table 2. General Approach to Quantification by Project change-out

| |
|--|
| Total Project GHG Emission Reductions per Dollar of Woodsmoke Reduction Program GGRF Funds Requested |
| $\frac{\text{Total Project GHG Emission Reductions in Metric Tons of CO}_2\text{e}}{\text{Woodsmoke Reduction Program GGRF Funds Requested (\$)}}$ |

Woodsmoke Reduction Program GGRF Funds Requested (\$) for all projects is equal to the amount of GGRF dollars the District is requesting from the Woodsmoke Reduction Program. The Woodsmoke Reduction GHG Calculator Tool will provide the Total Project GHG Emission Reductions per Woodsmoke Reduction Program GGRF Dollar Requested.

Table 3. General Approach to Quantification by Project change-out

| |
|--|
| Total Project GHG Emission Reductions per Dollar of GGRF |
| $\frac{\text{Total Project GHG Emission Reductions in Metric Tons of CO}_2\text{e}}{\text{Total GGRF Funds Requested (\$)}}$ |

The Total GGRF Funds Requested (\$) for all project features is equal to the sum of GGRF dollars the District is requesting for the project from the Woodsmoke Reduction Program, all GGRF dollars from CARB or other agencies that have previously been awarded to the same project, and any GGRF dollars from agencies other than CARB that the District has or plans to apply for. For a list of GGRF funded programs, go to: www.arb.ca.gov/cci-events. If no other GGRF funds are requested, this will be the same amount as the Woodsmoke Reduction Program GGRF Funds Requested. The Woodsmoke Reduction GHG Calculator Tool will provide the Total Project GHG Emission Reductions per GGRF Dollar Requested. Some air districts may transfer implementing dollars between different districts. A district may also implement a program on behalf of neighboring districts as an agreement between districts.

Emission Factors

A. Stove-Specific Cord Wood Consumption and Heating Rates

The Woodsmoke Reduction Program funds the replacement of uncertified, inefficient wood burning stoves with cleaner-burning, more efficient residential heating stoves. For the purposes of estimating emission reductions, this quantification methodology uses data reported by air districts participating in the 2016-17 Pilot Woodsmoke Reduction Program. Benefits accrue because of the difference in the efficiency of existing and replacement stoves and relative improvement in emission rates of GHGs, PM_{2.5}, and black carbon. The 2018-19 Woodsmoke Reduction Program included the addition of co-benefits and key variables NO_x and ROG. These updates remain for this 2021-22 version except for natural gas and propane stoves removed from the list of eligible devices and the inclusion of hybrid wood stoves.

1. Determine the average annual wood use reported by Air Districts participating in the 2016-17 Pilot Woodsmoke Reduction Program. For fireplaces, the average annual baseline is 1.8 cord wood fuel. For uncertified woodstoves, the average annual baseline is 2.8 cord wood fuel.
 - a. As part of the Pilot Program, between January 1, 2018, and December 31, 2019, 445 fireplaces and 964 stoves were replaced throughout California.
 - b. Pilot Program required that participants report on the amount of wood used annually in the existing device intended for replacement.
 - c. Based on these data, the estimated average amount of wood used in fireplaces is 1.8 cords/year and 2.8 cords/year for uncertified woodstoves.
 - d. Fireplaces are generally used as a source of heat in warmer climates like Santa Barbara, San Luis Obispo, Monterey, etc.
2. Determine each stove type efficiency of eligible existing and replacement stoves using:
 - a. Efficiencies from Houk, J. and Tiegs, P. for fireplaces.
 - b. Efficiency from the U.S. Department of Energy Electric Resistance Heating for electric heating stoves.
 - c. Efficiencies from U.S. EPA AP-42 for residential wood stoves.

Efficiencies may vary from those used in Step 2 due to the broader stove categories used compared to the specific existing and replacement stoves eligible under the Program.

3. For existing wood burning fireplaces and uncertified wood stoves, calculate the annual energy use by factoring the average annual wood use as determined by step 1; multiplied by the heating value of wood (dry basis) and converted to tons for emissions calculations.

4. Calculate stove specific energy use using the annual energy use for existing stove type determined in step 3 above, factoring the efficiencies of the existing and replacement device.
5. For resultant emissions calculations, factoring fuel specific emission factors for wood fueled stoves and factoring fuel specific emission factors for non-wood stoves described in sections B and C below.

B. Electricity GHG Emission Factor

For the purposes of quantification methodologies for agencies administering California Climate Investments, CARB developed a California grid average electricity emission factor based on total in-state and imported electricity emissions (in MTCO_{2e}) divided by total consumption (in kWh) as calculated in Equation 1.

Statewide electricity emissions data were obtained from the most recent edition of CARB’s GHG Emission Inventory.⁴ The total in-state electricity generation is combined with the total imported electricity to determine the total emissions for grid electricity. The total electricity consumption data was derived by summing electricity generation and net imports obtained from California Energy Commission’s (CEC) California Energy Almanac.⁵

Equation 1: California Grid Average Electricity Emission Factor

$$EF = \frac{\text{Electricity Emissions}}{\text{Electricity Consumption}}$$

| | | |
|-------------------------|---|--------------------|
| <i>Where,</i> | | <u>Units</u> |
| Electricity Emissions | = Total in-state electricity and imported electricity emissions | MTCO _{2e} |
| Electricity Consumption | = Total California electricity generation and net imports | kWh |

⁴ CARB California Greenhouse Gas Emissions Inventory – 2017 Edition

<https://ww2.arb.ca.gov/ghg-inventory-data>

⁵ CEC California Energy Almanac

http://www.energy.ca.gov/almanac/electricity_data/electricity_generation.html

C. Heating Fuel GHG Emission Factors

Heating fuels for Woodsmoke Reduction projects are wood. The heating fuel emission factors are derived from the United States Environmental Protection Agency's (U.S. EPA) Emission Factors for Greenhouse Gas Inventories, located at:

https://www.epa.gov/sites/production/files/2015-12/documents/emission-factors_nov_2015.pdf.

In the absence of a mechanism to verify that the wood burned in an applicant's primary heating stove is waste material harvested pursuant to an approved timber management plan prepared in accordance with the Z'berg-Nejedly Forest Practice Act of 1973 or other locally or nationally approved plan and harvested for the purpose of forest fire fuel reduction or forest stand improvement, biogenic CO₂ is included in the calculation of GHG benefits for these stoves.

The Emission Factors for Greenhouse Gas Inventories uses the global warming potentials (GWP) from the IPCC Fourth Assessment Report. Gases are converted to MTCO_{2e} by multiplying by their GWP and converting the units appropriately.

| Emission Factors for Greenhouse Gas Inventories | | |
|---|----------|--------------|
| Gas | Units | 100-year GWP |
| CO ₂ | kg/MMBtu | 1 |
| CH ₄ | kg/MMBtu | 25 |
| N ₂ O | kg/MMBtu | 298 |

Equations Supporting the Woodsmoke Reduction Program

Methods used in the Woodsmoke Reduction GHG Calculator Tool for estimating GHG, particulate, and black carbon emission reductions are provided below using the equations below. Additional information is available in the GHG Calculator Tool.

D. GHG Emission Reductions from Change-Outs

The GHG emission reductions from the project are calculated as the difference between the baseline and project scenarios using Equation 2.

Equation 2: GHG Emission Reductions from Change-Outs

$$GHG = Q_{FNC} \times 83 + Q_{UNC} \times 30 + Q_{FC} \times 83 + Q_{UC} \times 30 + Q_{FPS} \times 82 + Q_{UPS} \times 22 + Q_{FHP} \times 65 + Q_{UHP} \times 69 + Q_{FE} \times 57 + Q_{UE} \times 60$$

| Where, | | Units |
|------------------|--|--------------------------------|
| GHG | = GHG benefit from all project change-outs | MTCO _{2e} |
| Q _{FNC} | = Quantity of fireplaces replaced with certified non-catalytic or hybrid* wood stoves or wood inserts | Change-outs |
| Q _{UNC} | = Quantity of uncertified wood stoves or wood inserts replaced with certified non-catalytic or hybrid* wood stoves or wood inserts | Change-outs |
| Q _{FC} | = Quantity of fireplaces replaced with certified catalytic wood stoves or wood inserts | Change-outs |
| Q _{UC} | = Quantity of uncertified wood stoves or wood inserts replaced with certified catalytic wood stoves or wood inserts | Change-outs |
| Q _{FPS} | = Quantity of fireplaces replaced with certified pellet stoves or pellet inserts | Change-outs |
| Q _{UPS} | = Quantity of uncertified wood stoves or wood inserts replaced with certified pellet stoves or pellet inserts | Change-outs |
| Q _{FHP} | = Quantity of fireplaces replaced with electric heat pump | Change-outs |
| Q _{UHP} | = Quantity of uncertified wood stoves or wood inserts replaced with electric heat pump | Change-outs |
| Q _{FE} | = Quantity of fireplaces replaced with electric home heating stoves | Change-outs |
| Q _{UE} | = Quantity of uncertified wood stoves or inserts replaced with electric home heating stoves | Change-outs |
| 83 | = GHG emission reduction from replacing a fireplace with a certified non-catalytic or hybrid* wood stove or wood insert | MTCO _{2e} /change-out |
| 30 | = GHG emission reduction from replacing an uncertified wood stove or wood insert with a certified non-catalytic or hybrid* wood stove or wood insert | MTCO _{2e} /change-out |
| 83 | = GHG emission reduction from replacing a fireplace with a certified catalytic wood stove or wood insert | MTCO _{2e} /change-out |
| 30 | = GHG emission reduction from replacing an uncertified wood stove or wood insert with a certified catalytic wood stove or wood insert | MTCO _{2e} /change-out |
| 82 | = GHG emission reduction from replacing a fireplace with a certified pellet stove or pellet insert | MTCO _{2e} /change-out |
| 22 | = GHG emission reduction from replacing an uncertified wood stove or wood insert with a certified pellet stove or pellet insert | MTCO _{2e} /change-out |
| 65 | = GHG emission reduction from replacing a fireplace with an electric heat pump | MTCO _{2e} /change-out |
| 69 | = GHG emission reduction from replacing an uncertified wood stove or wood insert with an electric heat pump | MTCO _{2e} /change-out |

* Certified non-catalytic calculation values are used for certified hybrid wood stoves as a conservative approach to quantification due to a lack of available data on certified hybrid stove emissions.

**Equation 2: GHG Emission Reductions from Change-Outs
Continued**

| | | | |
|----|---|--|--------------------------------|
| 57 | = | GHG emission reduction from replacing a fireplace with an electric home heating stove | MTCO _{2e} /change-out |
| 60 | = | GHG emission reduction from replacing an uncertified wood stove or wood insert with an electric home heating stove | MTCO _{2e} /change-out |

E. PM_{2.5} Emission Reductions from Change-Outs

The PM_{2.5} emission reductions from the project are calculated as the difference between the baseline and project scenarios using Equation 3.

| Equation 3: PM_{2.5} Emission Reductions from Change-Outs | | |
|--|---|----------------|
| $PM_{2.5} = Q_{FNC} \times 1,239 + Q_{UNC} \times 2,285 + Q_{FC} \times 1,217 + Q_{UC} \times 2,028 + Q_{FPS} \times 1,243 + Q_{UPS} \times 2,339 + Q_{FHP} \times 945 + Q_{UHP} \times 1,906 + Q_{FE} \times 819 + Q_{UE} \times 1,652$ | | |
| Where, | | <u>Units</u> |
| PM _{2.5} | = PM _{2.5} emission reductions from all project change-outs | lbs |
| Q _{FNC} | = Quantity of fireplaces replaced with certified non-catalytic or hybrid* wood stoves or wood inserts | Change-outs |
| Q _{UNC} | = Quantity of uncertified wood stoves or wood inserts replaced with certified non-catalytic or hybrid* wood stoves or wood inserts | Change-outs |
| Q _{FC} | = Quantity of fireplaces replaced with certified catalytic wood stoves or wood inserts | Change-outs |
| Q _{UC} | = Quantity of uncertified wood stoves or wood inserts replaced with certified catalytic wood stoves or wood inserts | Change-outs |
| Q _{FPS} | = Quantity of fireplaces replaced with certified pellet stoves or pellet inserts | Change-outs |
| Q _{UPS} | = Quantity of uncertified wood stoves or wood inserts replaced with certified pellet stoves or pellet inserts | Change-outs |
| Q _{FHP} | = Quantity of fireplaces replaced with electric heat pump | Change-outs |
| Q _{UHP} | = Quantity of uncertified wood stoves or wood inserts replaced with electric heat pump | Change-outs |
| Q _{FE} | = Quantity of fireplaces replaced with electric home heating stoves | Change-outs |
| Q _{UE} | = Quantity of uncertified wood stoves or inserts replaced with electric home heating stoves | Change-outs |
| 1,239 | = PM _{2.5} emission reduction from replacing a fireplace with a certified non-catalytic or hybrid* wood stove or wood insert | lbs/change-out |
| 2,285 | = PM _{2.5} emission reduction from replacing an uncertified wood stove or insert with a certified non-catalytic or hybrid* wood stove or wood insert | lbs/change-out |
| 1,217 | = PM _{2.5} emission reduction from replacing a fireplace with a certified catalytic wood stove or wood insert | lbs/change-out |
| 2,028 | = PM _{2.5} emission reduction from replacing an uncertified wood stove or insert with a certified catalytic wood stove or wood insert | lbs/change-out |
| 1,243 | = PM _{2.5} emission reduction from replacing a fireplace with a certified pellet stove or pellet insert | lbs/change-out |
| 2,339 | = PM _{2.5} emission reduction from replacing an uncertified wood stove or wood insert with a certified pellet stove or pellet insert | lbs/change-out |
| 945 | = PM _{2.5} emission reduction from replacing a fireplace with an electric heat pump | lbs/change-out |
| 1,906 | = PM _{2.5} emission reduction from replacing an uncertified wood stove or wood insert with an electric heat pump | lbs/change-out |
| 819 | = PM _{2.5} emission reduction from replacing a fireplace with an electric home heating stove | lbs/change-out |
| 1,652 | = PM _{2.5} emission reduction from replacing an uncertified wood stove or insert with an electric home heating stove | lbs/change-out |

* Certified non-catalytic calculation values are used for certified hybrid wood stoves as a conservative approach to quantification due to a lack of available data on certified hybrid stove emissions.

F. Black Carbon Emission Reductions from Change-Outs

The black carbon emission reductions from the project are calculated as the difference between the baseline and project scenarios using Equation 4.

Equation 4: Black Carbon Emission Reductions from Change-Outs

$$BC = Q_{FNC} \times 155 + Q_{UNC} \times 286 + Q_{FC} \times 152 + Q_{UC} \times 254 + Q_{FPS} \times 155 + Q_{UPS} \times 292 + Q_{FHP} \times 118 + Q_{UHP} \times 238 + Q_{FE} \times 102 + Q_{UE} \times 206$$

| Where, | | Units |
|-----------|--|----------------|
| BC | = Black carbon emission reductions from all project change-outs | lbs |
| Q_{FNC} | = Quantity of fireplaces replaced with certified non-catalytic or hybrid* wood stoves or wood inserts | Change-outs |
| Q_{UNC} | = Quantity of uncertified wood stoves or wood inserts replaced with certified non-catalytic or hybrid* wood stoves or wood inserts | Change-outs |
| Q_{FC} | = Quantity of fireplaces replaced with certified catalytic wood stoves or wood inserts | Change-outs |
| Q_{UC} | = Quantity of uncertified wood stoves or wood inserts replaced with certified catalytic wood stoves or wood inserts | Change-outs |
| Q_{FPS} | = Quantity of fireplaces replaced with certified pellet stoves or pellet inserts | Change-outs |
| Q_{UPS} | = Quantity of uncertified wood stoves or wood inserts replaced with certified pellet stoves or pellet inserts | Change-outs |
| Q_{FHP} | = Quantity of fireplaces replaced with electric heat pump | Change-outs |
| Q_{UHP} | = Quantity of uncertified wood stoves or wood inserts replaced with electric heat pump | Change-outs |
| Q_{FE} | = Quantity of fireplaces replaced with electric home heating stoves | Change-outs |
| Q_{UE} | = Quantity of uncertified wood stoves or inserts replaced with electric home heating stoves | Change-outs |
| 155 | = Black carbon emission reduction from replacing a fireplace with a certified non-catalytic or hybrid* wood stove or wood insert | lbs/change-out |
| 286 | = Black carbon emission reduction from replacing an uncertified wood stove or insert with a certified non-catalytic or hybrid* wood stove or wood insert | lbs/change-out |
| 152 | = Black carbon emission reduction from replacing a fireplace with a certified catalytic wood stove or wood insert | lbs/change-out |
| 254 | = Black carbon emission reduction from replacing an uncertified wood stove or insert with a certified catalytic wood stove or wood insert | lbs/change-out |
| 155 | = Black carbon emission reduction from replacing a fireplace with a certified pellet stove or pellet insert | lbs/change-out |
| 292 | = Black carbon emission reduction from replacing an uncertified wood stove or wood insert with a certified pellet stove or pellet insert | lbs/change-out |
| 118 | = Black carbon emission reduction from replacing a fireplace with an electric heat pump | lbs/change-out |
| 238 | = Black carbon emission reduction from replacing an uncertified wood stove or wood insert with an electric heat pump | lbs/change-out |
| 102 | = Black carbon emission reduction from replacing a fireplace with an electric home heating stove | lbs/change-out |
| 206 | = Black carbon emission reduction from replacing an uncertified wood stove or insert with an electric home heating stove | lbs/change-out |

* Certified non-catalytic calculation values are used for certified hybrid wood stoves as a conservative approach to quantification due to a lack of available data on certified hybrid stove emissions.

Co-benefit Equations for the Woodsmoke Reduction Program

Methods used in the Woodsmoke Reduction Calculator Tool for estimating the co-benefits and key variables NO_x and ROG for air pollutant emissions based on fuel type. Additional information is available in the Calculator Tool.

G. NO_x Emission Reductions from Change-Outs

The NO_x emission reductions from the project are calculated as the difference between the baseline and project scenarios using Equation 5.

Equation 5: NO_x Emission Reductions from Change-Outs

$$NO_x = Q_{FNC} \times 131 + Q_{UNC} \times 85 + Q_{FC} \times 133 + Q_{UC} \times 105 + Q_{FPS} \times 122 + Q_{UPS} \times -19 + Q_{FHP} \times 107 + Q_{UHP} \times 164 + Q_{FE} \times 92 + Q_{UE} \times 142$$

| Where, | | Units |
|------------------|--|----------------|
| NO _x | = NO _x benefit from all project change-outs | lbs |
| Q _{FNC} | = Quantity of fireplaces replaced with certified non-catalytic or hybrid* wood stoves or wood inserts | Change-outs |
| Q _{UNC} | = Quantity of uncertified wood stoves or wood inserts replaced with certified non-catalytic or hybrid* wood stoves or wood inserts | Change-outs |
| Q _{FC} | = Quantity of fireplaces replaced with certified catalytic wood stoves or wood inserts | Change-outs |
| Q _{UC} | = Quantity of uncertified wood stoves or wood inserts replaced with certified catalytic wood stoves or wood inserts | Change-outs |
| Q _{FPS} | = Quantity of fireplaces replaced with certified pellet stoves or pellet inserts | Change-outs |
| Q _{UPS} | = Quantity of uncertified wood stoves or wood inserts replaced with certified pellet stoves or pellet inserts | Change-outs |
| Q _{FHP} | = Quantity of fireplaces replaced with electric heat pump | Change-outs |
| Q _{UHP} | = Quantity of uncertified wood stoves or wood inserts replaced with electric heat pump | Change-outs |
| Q _{FE} | = Quantity of fireplaces replaced with electric home heating stoves | Change-outs |
| Q _{UE} | = Quantity of uncertified wood stoves or inserts replaced with electric home heating stoves | Change-outs |
| 131 | = NO _x emission reduction from replacing a fireplace with a certified non-catalytic or hybrid* wood stove or wood insert | lbs/change-out |
| 85 | = NO _x emission reduction from replacing an uncertified wood stove or wood insert with a certified non-catalytic or hybrid* wood stove or wood insert | lbs/change-out |
| 133 | = NO _x emission reduction from replacing a fireplace with a certified catalytic wood stove or wood insert | lbs/change-out |
| 105 | = NO _x emission reduction from replacing an uncertified wood stove or wood insert with a certified catalytic wood stove or wood insert | lbs/change-out |
| 122 | = NO _x emission reduction from replacing a fireplace with a certified pellet stove or pellet insert | lbs/change-out |
| -19 | = NO _x emission reduction from replacing an uncertified wood stove or wood insert with a certified pellet stove or pellet insert | lbs/change-out |
| 107 | = NO _x emission reduction from replacing a fireplace with an electric heat pump | lbs/change-out |
| 164 | = NO _x emission reduction from replacing an uncertified wood stove or wood insert with an electric heat pump | lbs/change-out |

* Certified non-catalytic calculation values are used for certified hybrid wood stoves as a conservative approach to quantification due to a lack of available data on certified hybrid stove emissions.

**Equation 5: NO_x Emission Reductions from Change-Outs
Continued**

| | | | |
|-----|---|--|----------------|
| 92 | = | NO _x emission reduction from replacing a fireplace with an electric home heating stove | lbs/change-out |
| 142 | = | NO _x emission reduction from replacing an uncertified wood stove or wood insert with an electric home heating stove | lbs/change-out |

H. ROG Emission Reductions from Change-Outs

The ROG emission reductions from the project are calculated as the difference between the baseline and project scenarios using Equation 6.

| Equation 6: ROG Emission Reductions from Change-Outs | | |
|---|--|----------------|
| $ROG = Q_{FNC} \times 979 + Q_{UNC} \times 3,749 + Q_{FC} \times 962 + Q_{UC} \times 3,543 + Q_{FPS} \times 1,048 + Q_{UPS} \times 4,568 + Q_{FHP} \times 786 + Q_{UHP} \times 3,425 + Q_{FE} \times 681 + Q_{UE} \times 2,968$ | | |
| <i>Where,</i> | | <u>Units</u> |
| ROG | = ROG benefit from all project change-outs | lbs |
| Q_{FNC} | = Quantity of fireplaces replaced with certified non-catalytic or hybrid* wood stoves or wood inserts | Change-outs |
| Q_{UNC} | = Quantity of uncertified wood stoves or wood inserts replaced with certified non-catalytic or hybrid* wood stoves or wood inserts | Change-outs |
| Q_{FC} | = Quantity of fireplaces replaced with certified catalytic wood stoves or wood inserts | Change-outs |
| Q_{UC} | = Quantity of uncertified wood stoves or wood inserts replaced with certified catalytic wood stoves or wood inserts | Change-outs |
| Q_{FPS} | = Quantity of fireplaces replaced with certified pellet stoves or pellet inserts | Change-outs |
| Q_{UPS} | = Quantity of uncertified wood stoves or wood inserts replaced with certified pellet stoves or pellet inserts | Change-outs |
| Q_{FHP} | = Quantity of fireplaces replaced with electric heat pump | Change-outs |
| Q_{UHP} | = Quantity of uncertified wood stoves or wood inserts replaced with electric heat pump | Change-outs |
| Q_{FE} | = Quantity of fireplaces replaced with electric home heating stoves | Change-outs |
| Q_{UE} | = Quantity of uncertified wood stoves or inserts replaced with electric home heating stoves | Change-outs |
| 979 | = ROG emission reduction from replacing a fireplace with a certified non-catalytic or hybrid* wood stove or wood insert | lbs/change-out |
| 3,749 | = ROG emission reduction from replacing an uncertified wood stove or wood insert with a certified non-catalytic or hybrid* wood stove or wood insert | lbs/change-out |
| 962 | = ROG emission reduction from replacing a fireplace with a certified catalytic wood stove or wood insert | lbs/change-out |
| 3,543 | = ROG emission reduction from replacing an uncertified wood stove or wood insert with a certified catalytic wood stove or wood insert | lbs/change-out |
| 1,048 | = ROG emission reduction from replacing a fireplace with a certified pellet stove or pellet insert | lbs/change-out |
| 4,568 | = ROG emission reduction from replacing an uncertified wood stove or wood insert with a certified pellet stove or pellet insert | lbs/change-out |
| 786 | = ROG emission reduction from replacing a fireplace with an electric heat pump | lbs/change-out |
| 3,425 | = ROG emission reduction from replacing an uncertified wood stove or wood insert with an electric heat pump | lbs/change-out |
| 681 | = ROG emission reduction from replacing a fireplace with an electric home heating stove | lbs/change-out |
| 2,968 | = ROG emission reduction from replacing an uncertified wood stove or wood insert with an electric home heating stove | lbs/change-out |

* Certified non-catalytic calculation values are used for certified hybrid wood stoves as a conservative approach to quantification due to a lack of available data on certified hybrid stove emissions.

Section C. References

The following references were used in the development of this Quantification Methodology and the Woodsmoke Reduction Benefits Calculator Tool.

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