Local Government Policy Calculator for Existing Single-Family Buildings – User Guide

A customizable tool to help guide local governments in the development of energy efficiency and decarbonization policies for the existing single-family residential sector

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- Establish metrics to evaluate compliance with existing energy codes.
- Identify and deliver targeted trainings for those involved in energy code enforcement.
- Accelerate energy code compliance throughout the region.

The C&S Program is a locally driven effort of local governments to reduce energy use in buildings through improved design and construction. The program is administered jointly by each of the nine Bay Area counties and the Association of Bay Area Governments (ABAG). Funding for the program is provided through the California Public Utilities Commission (CPUC)

Table of Contents

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Introduction

This document is meant to act as a "User Manual" to explain how to use the accompanying Local Government Policy Calculator for Existing Single-Family Buildings. The Policy Calculator aims to help local governments estimate and visualize the potential energy and greenhouse gas (GHG) impacts from a suite of policy options for upgrading the existing single-family housing stock. The tool analyzes five policy options, as discussed in the BayREN white paper *Local Government Levers for Energy Policy in the Existing Single-Family Residential Sector* (Alvarez and Mast, December 2020).

Acknowledging the ambitious climate goals established in California, and the crucial role that energy efficiency and decarbonization of buildings plays in meeting those goals, the white paper examined energy-related policies currently being leveraged by cities in the existing building sector, and how additional requirements could be layered on that would address mandatory energy efficiency/and or electrification upgrades. It then attempts to quantify how these actions can contribute to energy efficiency and GHG emission reduction targets and consider how such policies impact equity, indoor air quality, and resilience.

The white paper and this Policy Calculator look specifically at existing single-family residential buildings due to complexity in upgrading this entire sector. There are approximately 2.9 million housing units in the nine-county Bay Area region. Of those, approximately 2.1 million are single family units (defined as having four or fewer units).[1] For all housing unit types, approximately 66 percent were constructed before 1979 (residential energy efficiency codes went into place in 1978) and only 12 percent were constructed since 2000.[2] While increasingly rigorous energy standards are implemented on a three-year cycle through the California Building Code (CBC) updates, these primarily affect new construction and not existing buildings, and many cities throughout the State have passed or are considering new construction "reach codes" that require all-electric new construction or higher efficiency standards for mixed-fuel buildings. In contrast, most existing buildings are upgraded through voluntary efforts and incentivized through rebate programs, such as those overseen by the California Public Utilities Commission (including BayREN). Nationwide, very few cities have any sort of existing building requirements regarding energy, and most that exist mandate disclosure and not performance or improvements. In order to adequately address residential emissions, governments cannot rely solely on new construction policies and will have to develop policies for existing buildings.

The white paper was general in its nature, aiming to introduce the available policy levers and broadly estimating their potential impacts. Calculations for GHG reductions, cost, and energy included in the paper were based on several broad assumptions to simplify the analysis and present a more focused set of options. In reality, the impact of such policies would differ drastically based on an individual city's number of single-family homes, the proportion that is owner- versus renter-occupied, utility costs, permit compliance rates, and more. The Local Government Policy Calculator for Existing Single-Family Buildings

[1] State of California, Department of Finance, *E-5 Population and Housing Estimates for Cities, Counties and the State — January 1, 2011-2020*. Sacramento, California, May 2020.

[2] U.S. Census Bureau (2018). *Selected Housing Characteristics, 2014-2018 American Community Survey 5-year estimates*. Retrieved from https://data.census.gov/cedsci/table?t=Housing%3AHousing%20Units&g=0500000US06001,06013,06041,06055,06075,06081,06085,06095,06097&y=2018&tid=ACSDP5Y2018.DP04&hidePreview=true

builds upon the findings of the 2020 white paper by turning those generic calculations into a customizable tool that should more accurately model policy scenarios in a specific jurisdiction.

The policy options modeled in the calculator are:

1. **Code Compliance:** Local governments are primarily responsible for permit enforcement, including building energy standards under the California Code of Regulations (CCR) Title 24, Parts 6 and 11. Permits are required for many energy efficiency improvements, including hot water heaters; insulation; heating, ventilation, and air conditioning (HVAC) systems; duct replacement; and more. However, permit evasion remains an issue in many jurisdictions, with permitted HVAC systems only accounting for 8-29% of total installations according to a 2017 DNV-GL report on behalf of the PUC. Several cities, such as Davis, CA and Minneapolis, MN have passed Code Compliance policies that inspect permit and renovation history and charge fees for non-compliance. These have shown to increase permitted work significantly.
2. **Energy Assessment & Disclosure:** Residential energy rating and disclosure, often at time of sale, is a promising low-cost policy option that can help increase consumer transparency about the costs associated with operating a home, promoting more sound purchasing and renovation decisions. Such policies exist in Berkeley, CA and Portland, OR. Literature suggests that such policies can prompt voluntary improvements. Also, by cataloging the existing building conditions and energy use, these policies can inform future policy and program efforts to reduce building energy consumption and track progress toward achieving community-wide climate and/or energy targets.
3. **Upgrade at Time of Equipment Replacement:** A time of replacement policy requires that a natural gas-fueled appliance be replaced with a high-efficiency electric option (such as heat pumps) either at burnout or an early replacement. This policy prevents natural gas emissions from being locked into a home for 10-20+ years (average useful life of equipment). While this policy option has the ability to be very effective, there are concerns with the cost and availability of heat pumps in comparison to status-quo natural gas options. Because electrical appliances are currently more expensive than gas, a policy like this could also have a disproportionately negative impact on low-income households with less disposable income. Additionally, switching from gas to electric may require panel or electrical wiring upgrades, which can delay installation, add costs, and deter homeowners who may be replacing their appliances in a burnout scenario. This policy does not include stoves and dryers, since while the capping of the gas line and new electrical requires a permit, the appliances change-out itself does not.
4. **Upgrade at Time of Major Renovation:** A jurisdiction may consider requiring a prescriptive menu of energy efficiency or electrification measures or mandate specific measures around the time of a major renovation of existing buildings. A major renovation may be defined by the cost or scope of the project. Depending on how many homes in a jurisdiction undergo major renovations within a year, this could have a greater impact than a time of sale metric. However, it may not lead to deep energy retrofits if the low-hanging fruit options are consistently chosen. The cities of Piedmont and Carlsbad, CA have adopted such policies and include a performance path where a home may opt out of the mandate if a minimum Home Energy Score is achieved. This acknowledges the energy efficiency upgrades of homes that have already been improved.
5. **Building Performance Standards:** A jurisdiction may require that all homes be upgraded to a minimum energy efficiency by a date certain. An example of this can be seen in Boulder, CO where all rental properties had 8 years to improve their efficiency.

In addition, the tool models two related policy options that have a direct impact on the appliance stock and energy performance of existing homes:

- **New Home Reach Code or All-Electric Ordinance:** Today's new home is tomorrow's existing home. The adoption of aggressive performance standards for new construction is an effective method for minimizing the need to retrofit those homes in the future.
- **End of Flow:** To meet California's climate action goals and limit global climate damage, communities will eventually need to limit or stop delivering piped fossil fuels to retail customers. This option models this outcome for the existing single-family sector.

It is hoped that jurisdictions in the Bay Area can use this tool to craft and compare policies to increase energy efficiency and decarbonization in existing single-family residential buildings. The Policy Impact Dashboard shows how each policy option contributes to the jurisdiction's GHG emissions goals and allows for a quick comparison between options, both visually and numerically. This can be useful when examining what type of policy is the best fit. While designed for city staff, including sustainability staff, building departments, and planners, it could also be used at sustainability committees or excerpts included in staff reports.

While the Policy Calculator does estimate energy consumption and GHG reductions, it also looks more holistically at other factors that a jurisdiction may consider when developing policy. A policy such as a disclosure ordinance at time of sale may be politically easier to pass than mandating appliances be electrified on burn out, but it may also take decades longer to touch the entire housing stock. Replace on burnout may seem like the most impactful policy for reducing GHG emissions, but given the low permit compliance for heating, cooling, and ventilation (HVAC) systems and hot water heaters, it is unlikely to show the expected reductions without greater permit enforcement.

In examining best practices for jurisdictions with both new construction and existing building reach codes, several elements emerged regarding creating a successful policy, outside of calculating GHG emissions reduction or energy consumption. These include establishing when the policy or mandate is triggered (e.g., time of major renovation) and what is required (e.g., replacing gas water heater with a heat pump water heater), and how a policy will be both implemented and enforced (e.g., permit disclosures at time of sale). Users also have the option to select the year that a policy goes into effect and how delaying implementation affects GHG reductions.

The next sections of this report go into greater detail on what is included in the Local Government Policy Calculator for Existing Single-Family Buildings, how to use the tool, and data sources. The tool is in its beta testing phase, and jurisdictions and other stakeholders are encouraged to use it and contact Emily Alvarez from BayREN with feedback.

How to Use the Policy Calculator

The Local Government Policy Calculator for Existing Single-Family Buildings is meant to compare policy options available to local governments to reduce energy use and GHG emissions from the existing single family residential building stock. At a minimum, users enter their county and city (or select entire county or unincorporate county) and the policies they wish to model, and the tool will produce an estimate of the impacts, including GHG emissions reductions and years to complete saturation. Users can then go through each sheet in the tool to further customize and compare policy options. This section explains how to use the calculator and explains options for customization.

User Inputs

The cells in the Policy Calculator are color-coded to distinguish between cells that require user-inputs and ones where assumptions or calculations are pre-loaded. Some pre-loaded cells can be overwritten but others are locked for editing.

User input cells are shown in green. These cells will require a user to confirm or change the input in order for the calculator to work. Some green cells are auto filled with best practices or examples from case studies. Examples include trigger points for policies, inspection costs, and estimated energy savings. Others will start blank and provide more options for customization that a user may wish to explore, such as layering electrification upgrade requirements on to a policy. If a green cell is overwritten, a user would have to refer to the unedited tool to see the original value.

Optional inputs are shown in yellow. Default values are calculated via formulas from source data within the spreadsheet. A user may override these defaults if they have more accurate or jurisdiction-specific data by inputting their desired value in the corresponding yellow cell. An example includes housing stock data, where the default is pulled from CA DOF data but a jurisdiction may have more accurate information or only wish to use a subset of the housing data for the calculations. A user can revert back to the default by clearing the modified yellow cell.

Cells are shown in blue include calculations or references to other data and are locked for editing. In some cases, a user may override these inputs by editing an adjacent yellow cell.

Policy Impact Dashboard

On the Policy Impact Dashboard outputs are shown in two forms:

1. A stacked area graph showing community-level unabated emissions from the single-family existing housing stock by year, plus the impact of six abatement strategies.
2. A tabular Forecast of Annual Policy Outcomes showing an array of outcomes for each policy option, as follows:
    - Number of Inspections per Year
    - Annual City Revenue from Inspections
    - Annual Electricity Savings (MWh)
    - Annual Gas Savings (Mtherms)
    - Annual GHG Reductions (Mt CO2e)
    - Number of Affected Properties / Year
    - % of 1-4 Unit Housing Stock

- Number of Years to 100% Market Penetration

To customize the outputs for a particular jurisdiction and specific policy options, follow the steps below.

Step 1. Specify the County (cell B4) **and then select the city** from the list associated with that county (Cell B5). The user can also select the entire county or the unincorporated county only.

Step 2. Check the boxes to **specify which policy options to include in the analysis** (cells B8-B14).

Step 3. For the selected policy options, **specify the year the policies should take effect** (cells C8-C14).

Step 4. For the selected policy options, **specify the starting and final compliance rate** (cells D8-E14)**.** The starting rate can be understood as the percentage of eligible customers who voluntarily comply with the policy provisions without being required to do so. The final compliance rate is the compliance rate at full adoption. More specifically, the starting compliance rate for each of the following would be:

- **New Home Reach Code or All-Electric Ordinance:** Percentage of new homes that are all-electric without a reach code or ordinance requirements.
- **Code Compliance:** Percentage of installations that already receive permits (studies indicate this is usually 8% - 29%; we have suggested a default of 30% based on the City of Davis' permit compliance ordinance).
- **Energy Assessment and Disclosure:** Percentage of resale homes already receiving assessments.
- **Upgrade at Time of Equipment Replacement:** Percentage of equipment replacements that are being upgraded at time of replacement without any requirements.
- **Upgrade at Time of Major Renovation:** Percentage of renovations that include equipment upgrades without additional requirements.
- **Building Performance Standards:** Percentage of homes that already comply with the performance standard.
- **End of Flow:** Percentage of homes that do not have natural gas infrastructure.

If the starting compliance for any of the policies is unknown, users may default to 0%.

Note: the final compliance rate for "Upgrade at Time of Equipment Replacement" and "Building Performance Standards" is a function of Code Compliance.

Step 5. Specify which fuels to analyze, electricity, gas, or both (cells B17 and B18).

Step 6 (optional). Specify the deadlines for acquiring zero emissions electricity (cell B19) and the goal year for achieving zero emissions from existing homes (cell B20).

Step 7 (optional). Set policy parameters for selected policy options. Click on the policy titles in cells A9 to A13 to navigate to separate tabs for each policy in which parameters are specified and impacts are calculated. The dashboard will calculate policy impacts using default values if you do not customize the policy sheets. However, customization will lead to more accurate and jurisdiction-specific modeling results. Further explanations and instructions are provided in each policy sheet. *See "Customizing Policy Options" section below for more information.*

Step 8 (optional). Set input parameters for Housing Stock (cell D4) and Appliance Stock (Cell D5) as discussed below. *See "Housing Stock Profile" and "Appliance Stock Profile" sections below for more information.*

Customizing Policy Options

1 - Code Compliance

- **Inspection trigger.** Drop down menu to choose the market event that triggers code compliance inspection. Options are:
    - Home resale
    - Rental
    - Resale and Rental
    - Major renovation
- **Inspect rentals every (years).** Numeric entry to specify how frequently rental units get inspected.
- **Inspection fee.** Dollar value

2- Energy Assessment & Disclosure

- **Assessment trigger.** Drop down menu to choose the market event that triggers the assessment and disclosure requirement. Options are:
    - Home resale
    - Rental
    - Resale and Rental
    - Major renovation
- **Assessment fee:** Dollar value
- **City inspector or Third Party?** Drop down menu to assign assessment responsibility.
- **Disclosure point.** Drop down menu to specify when assessment results must be disclosed. Choices depend on the assessment trigger as follows:
    - Home resale
        - Listing
        - Closing
    - Rental
        - Listing
        - Lease
    - Resale and Rental
        - Listing
        - Closing or Lease
    - Major renovation
        - Permit Application
- **Conversion rate:** Percentage of homes that receive an assessment and then go on to get an energy upgrade.
- **Upgrade Scope**
    - Specify the percentage improvement in whole house energy efficiency.
    - Specify the fraction of upgraded homes that also convert the gas furnace to a heat pump.
    - Specify the fraction of upgraded homes that also convert the gas water heater to a heat pump water heater.
    - Specify the fraction of upgraded homes that convert all gas end uses to electric.

3- Upgrade @ Time of Equipment Replacement

- **Replacement requirement applies to:** Specify the scope of the requirement. Check the boxes to include a replacement event within scope.
    - Furnace replacement
    - DHW replacement
    - Space cooling replacement or addition
- **Permit fee:** Dollar value

4- Upgrade @ Time of Major Renovation

- **Number of affected renovation projects:** Default or user input
- **Inspection fee:** Dollar value
- **Required Renovation Scope**
    - Improve whole house EE by (%)
    - Furnace replacement (check box)
    - DHW replacement (check box)
    - All gas end uses (check box)
- **Fraction of Upgrades that include voluntary electrification measures**
- Only applicable if electrification measures are not required at renovation
    - Fraction of upgraded homes that also convert the gas furnace to a heat pump (%)
    - Fraction of upgraded homes that also convert the gas water heater to a heat pump water heater (%)
    - Fraction of upgraded homes that convert all gas end uses to electric (%)

5- Building Performance Standards

- **Compliance trigger.** Drop down menu to select the applicable market trigger for the performance standard. Options are:
    - Date Certain-Rentals Only
    - Date Certain-All Homes
- **Inspection fee:** Dollar value
- **Number of years to full compliance.** Set the number of years from the implementation of the policy (i.e., the Start Year on the Policy Impact Dashboard) to the date-certain compliance requirement.
- **Required Renovation Scope**
    - Improve whole house EE by (%)
    - Furnace replacement (check box)
    - DHW replacement (check box)
    - All gas end uses (check box)

Housing Stock Profile

This tab summarizes the housing stock and utility emissions factors for the County and City specified on the Policy Impact Dashboard. Default values are populated via formulas. User may overwrite default values by inputting values in the optional input cells highlighted in yellow. Housing data comes from the U.S. Census American Housing Survey and the California Department of Finance. Emissions factors come from the most recent utility power content labels (as of July 2021). User may overwrite default values by inputting values in the optional input cells highlighted in yellow.

Appliance Stock Profile

This tab summarizes average energy usage and equipment efficiencies for the County and City specified on the Policy Impact Dashboard. Default values are populated via formulas. User may overwrite default values by inputting values in the optional input cells highlighted in yellow. Inputs include market saturation for the jurisdiction being modeled, Unit Energy Consumption by climate zone, expected useful life, and equipment efficiency. Unit Energy Consumption values are derived from analysis from the Statewide Codes and Standards program. Useful lives are taken from DEER. Equipment saturation data derives from the American Housing Survey.

Methodology & Calculations

This section explains the methodology, calculations, data sources, and assumptions made in developing and programming the Policy Calculator. The discussion is divided into the following sections:

- Business as Usual
- New Construction Reach Code Impacts
- Policy Tabs
    - Code Compliance
    - Energy Assessments
    - Time of Replacement
    - Time of Renovation
    - Performance Standards
- End of Flow
- Data Sources
    - Housing Stock Profile
    - Appliance Stock Profile
- Key Assumptions

Business As Usual

The Business as Usual (BAU) scenario models the carbon emission from the existing housing stock, plus newly constructed homes, over time with no policy interventions. Emissions change due to three factors: (1) the addition of newly constructed housing units with the same mix of gas versus electric appliances as the existing housing stock (with the exception of air conditioning, which is assumed to be installed in all new homes going forward); (2) the replacement of existing appliances at baseline efficiencies with new appliances at performance efficiencies (e.g., due to higher appliance standards); and (3) declining carbon intensity of grid electricity.

- **New Construction Forecast:** Applies a fixed number of new construction units to the cumulative number of Occupied Units (from the Housing Stock Profile, discussed below starting on p. 22).
- **Number of Occupied Mixed Fuel Homes:** Cumulative number of Occupied Units, including homes built in prior years. Assumes all occupied units are mixed fuel.
- **# Rental Units:** Applies a fixed Rental Saturation to the number of occupied mixed fuel homes.
- **Initial New Equipment Stock.** Assumes that all new homes are built with the same mix of gas versus electric appliances as shown in the Appliance Stock Profile under Market Saturation.
    - **New # Gas Furnace Units:** Applies a fixed Furnace Saturation to the number of new mixed fuel homes built since 2020.
    - **New # Gas DHW Units:** Applies a fixed Gas DHW Saturation to the number of new mixed fuel homes built since 2020.
    - **New # Misc. Gas End Uses:** Same as number of new mixed fuel homes built since 2020.
    - **New # Central AC Units:** Assumes all new homes get AC. Thus, same as number of new mixed fuel homes built since 2020.
    - **New # Heat Pump Space Heating:** Assumes that all homes that lack a gas furnace have a heat pump instead. Calculated as the difference between number of new mixed fuel homes built since 2020 and # Gas Furnace Units.

    - **New # HPWHs:** Assumes that all homes that lack a gas water heater have a heat pump water heater (HPWH) instead. Calculated as the difference between number of new mixed fuel homes built since 2020 and # Gas DHW Units.
    - **New # Misc. Elec. End Uses:** Same as number of new mixed fuel homes built since 2020.
- **Initial Existing Equipment Stock (2020 only)**
    - **Existing # Gas Furnace Units:** Applies a fixed Furnace Saturation to the number of occupied mixed fuel homes as of 2020.
    - **Existing # Gas DHW Units:** Applies a fixed Gas DHW Saturation to the number of occupied mixed fuel homes as of 2020.
    - **Existing # Misc. Gas End Uses:** Same as number of occupied mixed fuel homes as of 2020.
    - **Existing # Central AC Units:** Number of existing AC units from the Appliance Stock Profile.
    - **Existing # Heat Pump Space Heating:** Assumes that all homes that lack a gas furnace have a heat pump instead. Calculated as the difference between Number of Occupied Mixed Fuel Homes as of 2020 and # Gas Furnace Units.
    - **Existing # HPWHs:** Assumes that all homes that lack a gas water heater have a heat pump water heater instead. Calculated as the difference between Number of Occupied Mixed Fuel Homes as of 2020 and # Gas DHW Units.
    - **Existing # Misc. Elec. End Uses:** Same as number of occupied mixed fuel homes as of 2020.
- **Existing Equipment Replacement Rate.** Applies an equipment-specific Replacement Rate from the Appliance Stock Profile to the number of existing units. For 2020, Replacement Rate is applied to the 2020 Initial Existing Equipment Stock. For subsequent years, the Replacement Rate is applied to the Final Existing Equipment Stock from the prior year.
- **Final New Equipment Stock.** For each equipment category, the final number of new units in a year is equal to the initial number of new units that year, plus the cumulative number of equipment replacements since 2020.
- **Final Existing Equipment Stock** For each equipment category, the final number of existing units in a year is equal to the initial number of existing units in 2020, minus the cumulative number of equipment replacements since 2020.
- **Annual Home Resales:** Applies a fixed Home Resale Rate to the Number of Occupied Mixed Fuel Homes (including new homes built in prior years).
- **# Major Renovations:** Applies a fixed Home Renovation Rate to the Number of Occupied Mixed Fuel Homes.
- **Carbon Footprint:** Annual equipment stock multiplied by Unit Energy Consumption (UEC) and emissions factor. Existing equipment stock is multiplied by the Unit Energy Consumption values shown in Appliance Stock Profile. New equipment stock is multiplied by modified UECs that reflect the improvement from Baseline Efficiency to Performance Efficiency, as shown in Appliance Stock Profile.

New Construction Reach Code Impacts

Models the effect of requiring all-electric new construction as of a specified Start Year. Policy changes the number of new gas appliances installed, has no impact on the number of existing appliances. Note: this calculator focuses on existing building policies, therefore customization for a new construction reach code is not available. If the user selects a new construction ordinance, then new homes will be excluded from the housing stock applicable for existing building policies. However, if there is not new construction reach code, new homes will be applicable to existing building policies.

- **New Construction Forecast:** From BAU
- **Change in # New All Electric Homes:** Equals zero for years that precede the Start Year. Equals New Construction Forecast for Start Year and following years.
- **Number of occupied mixed fuel homes:** BAU Number of Occupied Mixed Fuel Homes minus the cumulative change in New All Electric homes.
- **New All Electric Homes:** Cumulative Change in # All Electric Homes.
- **Equipment Stock Change Relative to Business as Usual**
    - **Change in # Gas Furnace Units:** Reduces the number of furnaces by the product of New All Electric Homes and Furnace Saturation.
    - **Change in # Gas DHW units:** Reduces the number of gas water heaters by the product of New All Electric Homes and DHW Saturation.
    - **Change in # Misc. Gas End Uses:** Reduces the number of miscellaneous end uses by the number of New All Electric Homes.
    - **Change in # Central AC units:** No change since all new homes were already assumed to include central air conditioning.
    - **Change in # Heat Pump Space Heating:** Increases the number of heat pumps by the reduction in furnaces.
    - **Change in # HPWHs:** Increases the number of heat pump water heaters by the reduction in gas DHW units.
    - **Change in # Misc. Elec. End Uses:** No change since all new homes were already assumed to include miscellaneous electric end uses.
- **Final New Equipment Stock.** For each equipment category, the final number of new units in a year is equal to the BAU Final New Equipment Stock that year, plus the cumulative Change Relative to Business As Usual since 2020.
- **Final Existing Equipment Stock** For each equipment category, the final number of new units in a year is equal to the BAU Final New Equipment Stock that year.
- **Incremental Carbon Footprint:** Annual change in equipment stock multiplied by Performance Unit Energy Consumption and emissions factor.
- **Cumulative Change in Carbon Footprint:** Cumulative change in equipment stock multiplied by Performance Unit Energy Consumption and emissions factor.
- **Carbon Footprint:** Annual equipment stock multiplied by Unit Energy Consumption and emissions factor. Existing equipment stock is multiplied by the Unit Energy Consumption values shown in Appliance Stock Profile. New equipment stock is multiplied by modified UECs that reflect the improvement from Baseline Efficiency to Performance Efficiency, as shown in Appliance Stock Profile.
- **Existing Furnace only:** Number of existing furnaces in homes that lack AC, calculated as Existing # Gas furnace units plus Existing # HPWHs minus Existing # Central AC units.
- **Existing Furnace + AC:** Number of existing furnaces in homes with AC, calculated as Existing # Central AC units minus Existing # HPWHs.

Policy Tabs

1- Code Compliance

The Code Compliance option does not model energy and environmental impacts. Studies show little performance difference between permitted and unpermitted work for code minimum improvements. However, this policy will increase the impact and benefits of above-code policies as it is assumed that

above code improvements are unlikely to be undertaken without a permit. Additionally, requiring above-code improvements without enforcing permits may lead to more unpermitted construction as a means to circumvent more stringent requirements.

2-Energy Assessments

Apply assessment requirement to entire housing stock (pre- and post-2020 construction); apply electrification to entire housing stock (taking into account higher baseline efficiency of new gas equipment); apply energy upgrade assumptions only to existing housing stock with full-value UECs.

- **Number of occupied mixed fuel homes:** The final Number of Occupied Mixed Fuel Homes from NC Reach Code, subtracting the cumulative number of whole house electrifications that the Assessment requirement has triggered in prior years.
- **Number of Covered Mixed Fuel Homes**: The Number of Occupied Mixed Fuel Homes that have not yet received an assessment, multiplied by the proportion of homes that satisfy the selection criteria.
- **Number of Assessments:** Zero for years prior to the Assessment Start Year. For Assessment Start Year and subsequent years, equals the Number of Covered Mixed Fuel Homes multiplied by the Assessment Compliance Rate.
- **Number of Upgrades:** Number of Assessments multiplied by the percentage of assessments that convert to an upgrade (cell C10).
- **Electrification Changes in Equipment Stock**
    - **Change in # Existing Gas furnace units:** Number of Upgrades multiplied by (1) the fraction of Occupied Mixed Fuel Homes that have existing gas furnace units; and (2) the percentage of upgrades that include a gas furnace conversion to electric plus the percentage that converts to all-electric.
    - **Change in # Existing Gas DHW units:** Number of Upgrades multiplied by (1) the fraction of Occupied Mixed Fuel Homes that have existing gas DHW units; and (2) the percentage of upgrades that include a gas DHW conversion to electric plus the percentage that converts to all-electric.
    - **Change in # Misc. Gas End Uses:** Number of Upgrades multiplied by the percentage of upgrades that converts to all-electric.
    - **Change in # Central AC units:** The fractional Change in # Heat Pump Space Heating attributable to homes that previously lacked air conditioning, calculated as NC Reach Code ratio of # Existing Furnaces only (no AC), divided by Number of New + Existing Gas Furnace Units.
    - **Change in # Heat Pump Space Heating:** Increase equal to the reduction in gas furnaces.
    - **Change in # HPWHs:** Increase equal to the reduction in gas DHW.
    - **Change in # Misc. Elec. End Uses:** No change.
    - **Change in # New Gas furnace units:** Difference between the Change in gas furnace units and the Change in existing gas furnace units.
    - **Change in # Existing Gas furnace units:** Change in # Gas furnace units multiplied by the proportion of all remaining gas furnace units that are existing (from NC Reach Code Impacts, adjusted for existing units replaced in prior years).
    - **Change in # New Gas DHW units:** Difference between the Change in gas DHW units and the Change in existing gas DHW units.

    - **Change in # Existing Gas DHW units:** Change in # Gas DHW units multiplied by the proportion of all remaining gas DHW units that are existing (from NC Reach Code Impacts, adjusted for existing units replaced in prior years).
- **Energy Efficiency Changes**
    - **# Gas furnace unit upgrades:** The number of homes that (a) received an upgrade, (b) did not electrify their space heating, and (c) have an existing (rather than new) furnace. Calculated as Number of Upgrades multiplied by the NC Reach Code ratio of Existing # Gas Furnace Units divided by Number of Occupied Mixed Fuel Homes, plus Change in # Gas Furnace Units.
    - **# Gas DHW unit upgrades:** The number of homes that (a) received an upgrade, (b) did not electrify their DHW, and (c) have an inefficient DHW. Calculated as Number of Upgrades multiplied by the NC Reach Code ratio of Existing # Gas DHW Units divided by Number of Occupied Mixed Fuel Homes, plus Change in # Gas DHW Units.
    - **# Misc. Gas End Use upgrades:** The number of homes that received an upgrade and did not go all-electric.
    - **# Central AC unit upgrades:** The number of homes that (a) received an upgrade and (b) have an existing (rather than new) AC. Calculated as Number of Upgrades multiplied by the ratio of Existing # AC Units divided by Number of Occupied Mixed Fuel Homes, where the number of NC Reach Code # Existing AC Units is reduced by the Assessment number of AC upgrades in prior years.
    - **# Heat Pump Space Heating upgrades:** The number of homes that (a) received an upgrade and (b) have an existing (rather than new) Heat Pump. Calculated as Number of Upgrades multiplied by the ratio of Existing # Heat Pumps divided by Number of Occupied Mixed Fuel Homes, where the number of NC Reach Code # Heat Pumps is reduced by the Assessment number of Heat Pump upgrades in prior years.
    - **# HPWH upgrades:** The number of homes that (a) received an upgrade and (b) have an existing (rather than new) HPWH. Calculated as Number of Upgrades multiplied by the ratio of Existing # HPWHs divided by Number of Occupied Mixed Fuel Homes, where the number of NC Reach Code # HPWHs is reduced by the Assessment number of HPWH upgrades in prior years.
    - **# Misc. Elec. End Use upgrades:** Equal to the number of homes that received an upgrade.
- **Final New Equipment Stock**
    - **Gas end uses:** Equals the final number of new units from NC Reach Code Impact.
    - **Electric end uses**: Equals the final number of new units from NC Reach Code Impact plus the number of new units added via Assessment electrification.
- **Final Existing Equipment Stock**
    - **Gas end uses:** Equals the final number of existing units from NC Reach Code Impact plus the number of existing units removed via Assessment electrification.
    - **Electric end uses**: Equals the final number of existing units from NC Reach Code Impact.
- **Inefficient Existing Equipment Stock:** For all equipment categories, equals the final number of existing equipment stock, minus the number of upgraded units under Energy Efficiency Changes.
- **Gas efficiency gains:** For Number of Furnace, DHW, and Misc. Gas Upgrades, reduce the gas Baseline UECs by the percentage of energy efficiency improvement attributable to the assessment.

- **Electric efficiency gains:** For Number of AC, Heat Pump, HPWH, and Misc. Electric Upgrades, reduce the electric Baseline UECs by the percentage of energy efficiency improvement attributable to the assessment.
- **Electrification Change in Therms:** Product of Change in # new and existing gas furnaces and DHW units by their respective UECs.
- **Electrification Change in kWh:** Product of Change in # electric appliances by their respective UECs.
- **Incremental Carbon Footprint:** Sum of Gas Efficiency Gains and Electrification Change in Therms, multiplied by gas emissions factor, plus the sum of Electric Efficiency Gains and Electrification Change in kWh, multiplied by electric emissions factor.
- **Cumulative Change in Carbon Footprint:** Cumulative sum of Gas Efficiency Gains and Electrification Change in Therms, multiplied by gas emissions factor, plus the cumulative sum of Electric Efficiency Gains and Electrification Change in kWh, multiplied by electric emissions factor.
- **Carbon Footprint:** The final carbon footprint from NC Reach Code plus the Cumulative Change in Carbon Footprint.
- **Furnace only:** Count of homes that have gas furnaces and no central AC. Calculated as # New and Existing Gas Furnace Units plus # New and Existing Heat Pump Space Heating minus # New and Existing Central AC Units.
- **Furnace + AC:** Count of homes that have gas furnaces and central AC. Calculated as # New and Existing Central AC Units minus # New and Existing Heat Pump Space Heating.
- **Number of occupied mixed fuel homes:** Same as Final Existing # Misc. Gas End Uses.
- **Number of all electric homes:** New construction reach code all-electric homes plus the number of homes that went all electric as a result of the assessment (equivalent to the negative of the cumulative reduction in # Misc. Gas End Uses).
- **Number of occupied mixed fuel homes lacking upgrades:** Same as Inefficient Misc. Gas.

3-Time of Replacement

- **Number of occupied mixed fuel homes:** From 2-Energy Assessments: Number of Occupied Mixed Fuel Homes.
- **Number of covered furnace-only replacements:** Zero if furnace replacement is excluded from the policy scope. Otherwise, from 2-Assessments: Furnace only, the count of homes that have gas furnaces and no central AC, reduced by the number of furnace-only replacements in prior years, and then multiplied by the annual furnace replacement rate.
- **Number of covered Furnace+AC replacements:** Zero if furnace replacement is excluded from the policy scope. Otherwise, from 2-Assessments: Furnace+AC, the count of homes that have both gas furnaces and central AC, reduced by the number of furnace+AC replacements in prior years, and then multiplied by either the annual furnace replacement rate (if furnace replacement but not space cooling replacement is included within scope) or by the combined furnace+AC replacement rate (if both end uses are included within scope).
- **Number of covered DHW replacements:** Zero if DHW is excluded from the policy scope. Otherwise, from 2-Assessments: # Gas DHW Units, the count of homes that have gas DHW, reduced by the number of gas DHW replacements in prior years, and then multiplied by the annual DHW replacement rate.
- **Number of Covered Replacement Events:** The sum of covered furnace-only replacements, furnace+AC replacements, and DHW replacements.

- **Number of Inspections:** Zero for years prior to the Time of Replacement Start Year; otherwise, equal to the product of the Number of Covered Replacement Events and the Equipment Replacement Compliance Rate.
- **Electrification Changes in Equipment Stock**
    - **Change in # Furnace-only:** Zero if furnace replacement is excluded from the scope and zero for years prior to the Time of Replacement Start Year; otherwise, equal to product of the Number of Covered Furnace-Only Replacements and the Equipment Replacement Compliance Rate.
    - **Change in # Furnace+AC:** Zero if furnace replacement is excluded from the scope and zero for years prior to the Time of Replacement Start Year; otherwise, equal to product of the Number of Covered Furnace+AC Replacements and the Equipment Replacement Compliance Rate.
    - **Total Change in # Gas furnace units:** The sum of furnace-only and furnace+AC replacements.
    - **Change in # Gas DHW units:** Zero if DHW replacement is excluded from the scope and zero for years prior to the Time of Replacement Start Year; otherwise, equal to product of the Number of Covered DHW Replacements and the Equipment Replacement Compliance Rate.
    - **Change in # Misc. Gas End Uses:** Not used.
    - **Change in # Central AC units:** Counts the new heat pumps in a furnace-only replacement as an AC unit; thus, increase in # Central AC units equals the decrease in furnace-only units.
    - **Change in # Heat Pump Space Heating:** Increase in # Heat Pump Space Heating equals the decrease # Gas furnace units.
    - **Change in # HPWHs:** Increase in # HPWH equals the decrease # Gas DHW units.
    - **Change in # Misc. Elec. End Uses:** not used.
    - **Change in # New Gas furnace units:** Difference between the Change in gas furnace units and the Change in existing gas furnace units.
    - **Change in # Existing Gas furnace units:** Change in # Gas furnace units multiplied by the proportion of all remaining gas furnace units that are existing (from 2-Energy Assessments, adjusted for existing units replaced in prior years).
    - **Change in # New Gas DHW units:** Difference between the Change in gas DHW units and the Change in existing gas DHW units.
    - **Change in # Existing Gas DHW units:** Change in # Gas DHW units multiplied by the proportion of all remaining gas DHW units that are existing (from 2-Energy Assessments, adjusted for existing units replaced in prior years).
- **Energy Efficiency Changes**
    - **# Gas furnace unit upgrades:** The number of homes that (a) received an upgrade, (b) did not electrify their space heating, and (c) have an existing (rather than new) furnace. Calculated as Number of Upgrades multiplied by the 3-Time of Replacement ratio of Existing # Gas Furnace Units divided by Number of Occupied Mixed Fuel Homes, plus Change in # Gas Furnace Units.
    - **# Gas DHW unit upgrades:** The number of homes that (a) received an upgrade, (b) did not electrify their DHW, and (c) have an inefficient DHW. Calculated as Number of Upgrades multiplied by the 3-Time of Replacement ratio of Existing # Gas DHW Units divided by Number of Occupied Mixed Fuel Homes, plus Change in # Gas DHW Units.

    - **# Misc. Gas End Use upgrades:** The number of homes that received an upgrade and did not go all-electric.
    - **# Central AC unit upgrades:** The number of homes that (a) received an upgrade and (b) have an existing (rather than new) AC. Calculated as Number of Upgrades multiplied by the ratio of Existing # AC Units divided by Number of Occupied Mixed Fuel Homes, where the number of 3-Time of Replacement # Existing AC Units is reduced by the Renovation number of AC upgrades in prior years.
    - **# Heat Pump Space Heating upgrades:** The number of homes that (a) received an upgrade and (b) have an existing (rather than new) Heat Pump. Calculated as Number of Upgrades multiplied by the ratio of Existing # Heat Pumps divided by Number of Occupied Mixed Fuel Homes, where the number of 3-Time of Replacement # Heat Pumps is reduced by the Renovation number of Heat Pump upgrades in prior years.
    - **# HPWH upgrades:** The number of homes that (a) received an upgrade and (b) have an existing (rather than new) HPWH. Calculated as Number of Upgrades multiplied by the ratio of Existing # HPWHs divided by Number of Occupied Mixed Fuel Homes, where the number of 3-Time of Replacement # HPWHs is reduced by the Renovation number of HPWH upgrades in prior years.
    - **# Misc. Elec. End Use upgrades:** Equal to the number of homes that received an upgrade.
- **Final New Equipment Stock**
    - **Gas end uses:** Equals the final number of new units from 2-Energy Assessments, minus the cumulative number of new units replaced.
    - **Electric end uses**: Equals the final number of new units from 2-Energy Assessments, plus the cumulative number of new units added.
- **Final Existing Equipment Stock**
    - **Gas end uses:** Equals the final number of existing units from 2-Energy Assessments, minus the cumulative number of existing units replaced**.**
    - **Electric end uses**: Equals the final number of existing units from 2-Energy Assessments.
- **Inefficient Existing Appliance Stock.** Assumes inefficient and efficient existing appliances are replaced by electric equipment in the same proportions. Calculated as the Final Existing Equipment Stock, multiplied by the 2-Energy Assessments ratio of Inefficient to Total Existing.
- **Electrification Change in Therms:** Change in Therms attributable to reduced number of new and existing gas furnaces and DHW units. Calculated as the reduction in number of new and existing gas appliances, multiplied by each appliance's respective UEC.
- **Electrification Change in kWh:** Change in kilowatt-hours attributable to increased number of electric heat pump space heating, HPWH, and Central ACs (including heat pumps in cooling mode). Calculated as the increase in number of electric appliances, multiplied by each appliance's respective UEC.
- **Incremental Carbon Footprint:** Sum of Electrification Change in Therms, multiplied by gas emissions factor, plus the sum of Electric Efficiency Gains and Electrification Change in kWh, multiplied by electric emissions factor.
- **Cumulative Change in Carbon Footprint:** Cumulative sum of Electrification Change in Therms, multiplied by gas emissions factor, plus the cumulative sum of Electric Efficiency Gains and Electrification Change in kWh, multiplied by electric emissions factor.
- **Carbon Footprint:** The final carbon footprint from 2-Energy Assessment plus the Cumulative Change in Carbon Footprint.

- **Number of occupied mixed fuel homes:** Starting Number of Occupied Mixed Fuel Homes, plus the cumulative reduction in # Misc. Gas End Uses (which is zero).
- **Number of all electric homes:** Final number of 2-Energy Assessment all-electric homes, minus the cumulative reduction in # Misc. Gas End Uses (which is zero).
- **Furnace only:** Count of homes that have gas furnaces and no central AC. Calculated as # New and Existing Gas Furnace Units plus # New and Existing Heat Pump Space Heating minus # New and Existing Central AC Units.
- **Furnace + AC:** Count of homes that have gas furnaces and central AC. Calculated as # New and Existing Central AC Units minus # New and Existing Heat Pump Space Heating.

4-Time of Renovation

- **Number of occupied mixed fuel homes:** The final Number of Occupied Mixed Fuel Homes from 3-Time of Replacement, subtracting the cumulative number of whole house electrifications that the renovation requirement has triggered in prior years.
- **Number of occupied mixed fuel homes lacking upgrades:** The final Number of Occupied Mixed Fuel Homes Lacking Upgrades from 2-Energy Assessments, minus the cumulative number of home upgrades that occurred up through the prior year.
- **Number of Covered Mixed Fuel Homes:** The Number of user-specified annual covered homes, adjusted for the ratio of Occupied Mixed Fuel Homes Lacking Upgrades in the current year versus 2020.
- **Number of Inspections:** Zero for years prior to the Time of Renovation Start Year; otherwise, equal to the product of the Number of Covered Mixed Fuel Homes and the Renovation Compliance Rate.
- **Number of Upgrades:** Equals the Number of Inspections.
- **Electrification Changes**
    - **Change in # Gas furnace units:** Zero for years prior to Renovation Start Year. For subsequent years, equal to the fraction of renovated homes with a gas furnace, multiplied by the renovation replacement rate. The fraction of renovated homes with gas furnace equals the Number of Upgrades multiplied by the *3 – Time of Replacement* ratio of # of Gas Furnaces divided by Number of Occupied Mixed Fuel Homes. The replacement rate is 100% if either "Furnace electrification" or "Whole house electrification" is checked under Required Renovation Scope; otherwise, it is the user-entered voluntary percentage "Convert furnace to HP" plus "Convert to all-electric".
    - **Change in # Gas DHW units:** Zero for years prior to Renovation Start Year. For subsequent years, equal to the fraction of renovated homes with a gas DHW, multiplied by the renovation replacement rate. The fraction of renovated homes with gas DHW equals the Number of Upgrades multiplied by the *3 – Time of Replacement* ratio of # of Gas DHW divided by Number of Occupied Mixed Fuel Homes. The replacement rate is 100% if either "DHW electrification" or "Whole house electrification" is checked under Required Renovation Scope; otherwise, it is the user-entered voluntary percentage "Convert DHW to HPWH" plus "Convert to all-electric".
    - **Change in # Misc. Gas End Uses:** Zero for years prior to Renovation Start Year. For subsequent years, equal to the Number of Upgrades, multiplied by the whole house electrification rate. The whole house electrification rate is 100% if "Whole house electrification" is checked under Required Renovation Scope; otherwise, it is the user-entered voluntary percentage "Convert to 100% electric".

- **Change in # Central AC units:** The number of homes receiving a heat pump that did not previously have central AC. Calculated as Change in # Heat Pump Space Heating, multiplied by the *3 – Time of Replacement* ratio of Furnace Only divided by all furnaces.
- **Change in # Heat Pump Space Heating:** Increase in # Heat Pump Space Heating equals the decrease # Gas furnace units.
- **Change in # HPWHs:** Increase in # HPWH equals the decrease # Gas DHW units.
- **Change in # Misc. Elec. End Uses:** not used.
- **Change in # New Gas furnace units:** Difference between the Change in gas furnace units and the Change in existing gas furnace units.
- **Change in # Existing Gas furnace units:** Change in # Gas furnace units multiplied by the proportion of all remaining gas furnace units that are existing (from 3-Time of Replacement, adjusted for existing units replaced in prior years).
- **Change in # New Gas DHW units:** Difference between the Change in gas DHW units and the Change in existing gas DHW units.
- **Change in # Existing Gas DHW units:** Change in # Gas DHW units multiplied by the proportion of all remaining gas DHW units that are existing (from 3-Time of Replacement, adjusted for existing units replaced in prior years).

- **Energy Efficiency Changes**
  - **# Furnace upgrades:** The number of homes that (a) received an upgrade, (b) did not electrify their space heating, and (c) have an existing (rather than new) furnace. Calculated as Number of Upgrades multiplied by the 3-Time of Replacement ratio of Existing # Gas Furnace Units divided by Number of Occupied Mixed Fuel Homes, plus Change in # Gas Furnace Units.
  - **# Gas DHW unit upgrades:** The number of homes that (a) received an upgrade, (b) did not electrify their DHW, and (c) have an inefficient DHW. Calculated as Number of Upgrades multiplied by the 3-Time of Replacement ratio of Existing # Gas DHW Units divided by Number of Occupied Mixed Fuel Homes, plus Change in # Gas DHW Units.
  - **# Misc. Gas End Use upgrades:** The number of homes that received an upgrade and did not go all-electric.
  - **# Central AC unit upgrades:** The number of homes that (a) received an upgrade and (b) have an existing (rather than new) AC. Calculated as Number of Upgrades multiplied by the ratio of Existing # AC Units divided by Number of Occupied Mixed Fuel Homes, where the number of # Existing AC Units is reduced by the Renovation number of AC upgrades in prior years.
  - **# Heat Pump Space Heating upgrades:** The number of homes that (a) received an upgrade and (b) have an existing (rather than new) Heat Pump. Calculated as Number of Upgrades multiplied by the ratio of Existing # Heat Pumps divided by Number of Occupied Mixed Fuel Homes, where the number of 3-Time of Replacement # Heat Pumps is reduced by the Renovation number of Heat Pump upgrades in prior years.
  - **# HPWH upgrades:** The number of homes that (a) received an upgrade and (b) have an existing (rather than new) HPWH. Calculated as Number of Upgrades multiplied by the ratio of Existing # HPWHs divided by Number of Occupied Mixed Fuel Homes, where the number of 3-Time of Replacement # HPWHs is reduced by the Renovation number of HPWH upgrades in prior years.
  - **# Misc. Elec. End Use upgrades:** Equal to the number of homes that received an upgrade.

- **Final New Equipment Stock**
    - **Gas end uses:** Equals the final number of new units from 3-Time of Replacement, minus the cumulative number of new units replaced.
    - **Electric end uses**: Equals the final number of new units from 3-Time of Replacement, plus the cumulative number of new units added.
- **Final Existing Equipment Stock**
    - **Gas end uses:** Equals the final number of existing units from 3-Time of Replacement, minus the cumulative number of existing units replaced**.**
    - **Electric end uses**: Equals the final number of existing units from 3-Time of Replacement
- **Revised Stocks and Impacts:** Sum of new plus existing equipment stock.
- **Gas efficiency gains:** Product of Number of Upgrades, the sum of gas UECs, and the user-entered "Improve whole-house EE by (%)".
- **Electric efficiency gains:** Product of Number of Upgrades, the sum of gas UECs, and the user-entered "Improve whole-house EE by (%)".
- **Electrification Change in Therms:** Change in Therms attributable to reduced number of new and existing gas furnaces and DHW units. Calculated as the reduction in number of new and existing gas appliances, multiplied by each appliance's respective UEC.
- **Electrification Change in kWh:** Change in kilowatt-hours attributable to increased number of electric heat pump space heating, HPWH, and Central ACs (including heat pumps in cooling mode). Calculated as the increase in number of electric appliances, multiplied by each appliance's respective UEC.
- **Incremental Carbon Footprint:** Sum of Electrification Change in Therms, multiplied by gas emissions factor, plus the sum of Electric Efficiency Gains and Electrification Change in kWh, multiplied by electric emissions factor.
- **Cumulative Change in Carbon Footprint:** Cumulative sum of Electrification Change in Therms, multiplied by gas emissions factor, plus the cumulative sum of Electric Efficiency Gains and Electrification Change in kWh, multiplied by electric emissions factor.
- **Carbon Footprint:** The final carbon footprint from 3-Time of Replacement plus the Cumulative Change in Carbon Footprint.
- **Number of occupied mixed fuel homes:** Starting Number of Occupied Mixed Fuel Homes, plus the cumulative reduction in # Misc. Gas End Uses.
- **Number of all electric homes:** Final number of 3-Time of Replacement all-electric homes, minus the cumulative reduction in # Misc. Gas End Uses.
- **Furnace only:** Count of homes that have gas furnaces and no central AC. Calculated as # New and Existing Gas Furnace Units plus # New and Existing Heat Pump Space Heating minus # New and Existing Central AC Units.
- **Furnace + AC: :** Count of homes that have gas furnaces and central AC. Calculated as # New and Existing Central AC Units minus # New and Existing Heat Pump Space Heating.

5-Performance Standards

- **Number of occupied mixed fuel homes:** From 4-Time of Renovation
- **Number of occupied mixed fuel homes lacking upgrades:** Final number of homes lacking upgrades from 4-Time of Renovation, calculated as the initial number minus the number of upgrades.

- **Number of Covered Mixed Fuel Homes:** The fraction of the Number of Occupied Mixed Fuel Homes Lacking Upgrades that meet the user-specified compliance trigger, minus the number of upgrades from prior years.
- **Number of Assessments:** Zero for years prior to the Performance Standard Start Year; otherwise, equal to the Number of Upgrades divided by the Performance compliance rate.
- **Number of Upgrades:** Zero for years prior to the Time of Renovation Start Year; otherwise, equal to Number of Covered Mixed Fuel Homes divided by the number of years remaining in the performance period.
- **Electrification Changes**
    - **Change in # Gas furnace units:** Zero for years prior to Performance Start Year. For subsequent years, equal to the fraction of renovated homes with a gas furnace, multiplied by the renovation replacement rate. The fraction of renovated homes with gas furnace equals the Number of Upgrades multiplied by the 4 – *Time of Renovation* ratio of # of Gas Furnaces divided by Number of Occupied Mixed Fuel Homes. The replacement rate is 100% if either "Furnace electrification" or "Whole house electrification" is checked under Required Renovation Scope; otherwise, it is zero.
    - **Change in # Gas DHW units:** Zero for years prior to Performance Start Year. For subsequent years, equal to the fraction of renovated homes with a gas DHW, multiplied by the renovation replacement rate. The fraction of renovated homes with gas DHW equals the Number of Upgrades multiplied by the 4 – *Time of Renovation* ratio of # of Gas DHW divided by Number of Occupied Mixed Fuel Homes. The replacement rate is 100% if either "DHW electrification" or "Whole house electrification" is checked under Required Renovation Scope; otherwise, it is zero.
    - **Change in # Misc. Gas End Uses:** Zero for years prior to Performance Start Year. For subsequent years, equal to the Number of Upgrades, multiplied by the whole house electrification rate. The whole house electrification rate is 100% if "Whole house electrification" is checked under Required Renovation Scope; otherwise, it is zero.
    - **Change in # Central AC units:** The number of homes receiving a heat pump that did not previously have central AC. Calculated as Change in # Heat Pump Space Heating, multiplied by the 4 – *Time of Renovation* ratio of Furnace only divided by all furnaces.
    - **Change in # Heat Pump Space Heating:** Increase in # Heat Pump Space Heating equals the decrease # Gas furnace units.
    - **Change in # HPWHs:** Increase in # HPWH equals the decrease # Gas DHW units.
    - **Change in # Misc. Elec. End Uses:** not used.
    - **Change in # New Gas furnace units:** Difference between the Change in gas furnace units and the Change in existing gas furnace units.
    - **Change in # Existing Gas furnace units:** Change in # Gas furnace units multiplied by the proportion of all remaining gas furnace units that are existing (from 4-Time of Renovation, adjusted for existing units replaced in prior years).
    - **Change in # New Gas DHW units:** Difference between the Change in gas DHW units and the Change in existing gas DHW units.
    - **Change in # Existing Gas DHW units:** Change in # Gas DHW units multiplied by the proportion of all remaining gas DHW units that are existing (from 4-Time of Renovation, adjusted for existing units replaced in prior years).
- **Energy Efficiency Changes:**

    - **# Gas furnace unit upgrades:** The number of homes that (a) received an upgrade, (b) did not electrify their space heating, and (c) have an existing (rather than new) furnace. Calculated as Number of Upgrades multiplied by the 4-Time of Renovation ratio of Existing # Gas Furnace Units divided by Number of Occupied Mixed Fuel Homes, plus Change in # Gas Furnace Units.
    - **# Gas DHW unit upgrades:** The number of homes that (a) received an upgrade, (b) did not electrify their DHW, and (c) have an inefficient DHW. Calculated as Number of Upgrades multiplied by the 4-Time of Renovation ratio of Existing # Gas DHW Units divided by Number of Occupied Mixed Fuel Homes, plus Change in # Gas DHW Units.
    - **# Misc. Gas End Use upgrades:** The number of homes that received an upgrade and did not go all-electric.
    - **# Central AC unit upgrades:** The number of homes that (a) received an upgrade and (b) have an existing (rather than new) AC. Calculated as Number of Upgrades multiplied by the ratio of Existing # AC Units divided by Number of Occupied Mixed Fuel Homes, where the number of 4-Time of Renovation # Existing AC Units is reduced by the Performance number of AC upgrades in prior years.
    - **# Heat Pump Space Heating upgrades:** The number of homes that (a) received an upgrade and (b) have an existing (rather than new) Heat Pump. Calculated as Number of Upgrades multiplied by the ratio of Existing # Heat Pumps divided by Number of Occupied Mixed Fuel Homes, where the number of 4-Time of Renovation # Heat Pumps is reduced by the Performance number of Heat Pump upgrades in prior years.
    - **# HPWH upgrades:** The number of homes that (a) received an upgrade and (b) have an existing (rather than new) HPWH. Calculated as Number of Upgrades multiplied by the ratio of Existing # HPWHs divided by Number of Occupied Mixed Fuel Homes, where the number of 4-Time of Renovation # HPWHs is reduced by the Performance number of HPWH upgrades in prior years.
    - **# Misc. Elec. End Use upgrades:** Equal to the number of homes that received an upgrade
- **Revised Stocks and Impacts:**
    - **Gas end uses:** Equals the final number of new and existing units from 4-Time of Renovation, minus the cumulative number of units replaced.
    - **Electric end uses**: Equals the final number of new and existing units from 4-Time of Renovation, plus the cumulative number of units added.
- **Gas efficiency gains:** Product of Number of Upgrades, the sum of gas UECs, and the user-entered "Improve whole-house EE by (%)".
- **Electric efficiency gains:** Product of Number of Upgrades, the sum of gas UECs, and the user-entered "Improve whole-house EE by (%)".
- **Electrification Change in Therms:** Change in Therms attributable to reduced number of new and existing gas furnaces and DHW units. Calculated as the reduction in number of new and existing gas appliances, multiplied by each appliance's respective UEC.
- **Electrification Change in kWh:** Change in kilowatt-hours attributable to increased number of electric heat pump space heating, HPWH, and Central ACs (including heat pumps in cooling mode). Calculated as the increase in number of electric appliances, multiplied by each appliance's respective UEC.

- **Incremental Carbon Footprint:** Sum of Electrification Change in Therms, multiplied by gas emissions factor, plus the sum of Electric Efficiency Gains and Electrification Change in kWh, multiplied by electric emissions factor.
- **Cumulative Change in Carbon Footprint:** Cumulative sum of Electrification Change in Therms, multiplied by gas emissions factor, plus the cumulative sum of Electric Efficiency Gains and Electrification Change in kWh, multiplied by electric emissions factor.
- **Carbon Footprint:** The final carbon footprint from 4-Time of Renovation plus the Cumulative Change in Carbon Footprint.
- **Number of occupied mixed fuel homes:** Starting Number of Occupied Mixed Fuel Homes, plus the cumulative reduction in # Misc. Gas End Uses.
- **Furnace only:** Count of homes that have gas furnaces and no central AC. Calculated as # New and Existing Gas Furnace Units plus # New and Existing Heat Pump Space Heating minus # New and Existing Central AC Units.
- **Furnace + AC:** Count of homes that have gas furnaces and central AC. Calculated as # New and Existing Central AC Units minus # New and Existing Heat Pump Space Heating.
- **Carbon from Gas:** Fraction of the total carbon footprint attributable to gas end uses.
- **Carbon from Electric:** Fraction of the total carbon footprint attributable to electric end uses.

End of Flow

- **Cumulative Change in Gas Carbon Footprint:** Zero for years prior to the End of Flow Start Year; otherwise, equal to the negative of Carbon from Gas from 5-Performance Standards.
- **Carbon Footprint:** The final carbon footprint from 5-Performance Standards plus the Cumulative Change in Gas Carbon Footprint.

Data Sources

Housing Stock Profile

- **Number of occupied units:** From California Department of Finance's E-5 Population and Housing Estimates for Cities, Counties, and the State, 2011-2021 with 2010 Census Benchmark, Table 2: E-5 City/County Population and Housing Estimates, 1/1/2021. Occupied Units includes Single Detached, Single Attached, and Two to Four Units, adjusted for Vacancy Rate.
- **Rental units:** Calculated as Occupied Units – Owner-occupied Units.
- **Owner-occupied units:** Regional percentages applied to "Occupied Units". Percentages from American Housing Survey, 2017 San Jose MSA for Santa Clara County, 2019 San Francisco - MSA for all other counties. Table 3 provided a regional number for all occupied units; Table 15 provided a regional number for owner-occupied units. The ratio was then applied to City-specific Occupied Units from CA Department of Finance.
- **Home sales (annual):** Annual home sales were manually recorded from Zillow for the 34 largest incorporated cities in the region, as of May 14, 2021. Sales were recorded for "Houses", "Townhomes", and "Condos." Sales figures were used to derive an annual percentage of home sales as a function of total housing stock. Weighted averages were calculated for all large cities in each county and the average was applied to the unincorporated areas and the small cities. Finally, these percentages were applied to the city-specific Occupied Units from the CA Department of Finance to arrive at city-specific estimates of annual home sales.
- **New construction (annual):** Derived from California Department of Finance's E-5 Population and Housing Estimates for Cities, Counties, and the State, 2011-2021 with 2010 Census Benchmark.

Annual construction calculated as 2020 single family housing units, minus 2010 single family housing units, divided by ten.

- **Major Renovations (annual):** Regional percentages applied to "Occupied Units". Percentages derive from American Housing Survey, 2017 San Jose - Home Improvement Characteristics - Owner-occupied Units (Table 15) for Santa Clara County, 2019 San Francisco - Home Improvement Characteristics - Owner-occupied Units (Table 15) for all other counties. Percentage is the percentage of owner-occupied homes that went through "Gut Rehabilitation in the Last Ten Years". Survey value was annualized by dividing by ten.
- **Renter move rate (annual)**: An annual move rate of 21.7% was taken from https://www.census.gov/library/stories/2017/12/lower-moving-rate.html. This percentage was then applied to the number of rental units to arrive at the annual number of renters that move.
- **Electricity emissions factors** are taken from utility published Power Content Labels from 2019 or later. In cases where a utility or CCA offers customers multiple options with different emissions levels, the default option (which is generally the dirtiest) was selected.

Appliance Stock Profile

- **Equipment saturations** are regional percentages taken from from American Housing Survey, Table 0, 2017 San Jose MSA for Santa Clara County, 2019 San Francisco - MSA for all other counties.
- **Baseline Unit Energy Consumption** values by CEC compliance climate zone are derived from data provided by the statewide Codes and Standards program. Performance UECs are derived by applying user-defined equipment efficiencies.
    - Whole House baseline kWh and Therms are calculated as the simple average across measures of C&S base_kwh and base_therms by Climate Zone.
    - Furnace UEC taken as therms_savings from the measure Heat Pump at HVAC Replacement.
    - Gas DHW UEC taken as therms_savings from the measure NEEA Tier 3 HPWH at Replacement.
    - Gas Misc UEC = Whole House UEC - Furnace UEC - Gas DHW UEC
    - Elec Misc UEC inferred by assuming that climate zones 1, 3, and 5 have no AC loads. Thus, whole house UEC for those climate zones = Misc UEC.
    - For the remaining climate zones, set Misc UEC equal to the average for 1, 3, and 5; ie, 3634 kWh.
    - AC UEC - Whole House UEC = Misc UEC
    - Heat Pump and Heat Pump Water Heater UECs derived from gas UECs, assuming constant heat output. Formula is thus ElecUEC = 29.3 * GasUEC * (EFgas /EFelec)
- **Baseline energy efficiency assumption**s are based on the following sources:
    - AC baseline efficiency: National standard until 2006, when standard was increased to 13.
    - Gas DHW baseline efficiency: National standard until 2015, when standard was increased to 0.62.
    - Gas furnace baseline efficiency: National standard until 2006, when standard was increased to 0.8.
    - Heat Pump SH efficiency: consistent with E3 Pathways model.
    - Heat Pump cooling efficiency: consistent with E3 Pathways model.
    - Heat Pump Water Heater efficiency: Conservative lower bound for HPWH efficiencies for multiple manufacturers and models, consistent with E3.

- **Equipment Useful Life** (EUL) values are taken from the Database of Energy Efficient Resources (DEER), as follows:
    - Gas Furnace EUL: D08-RG-HV-EffFurn
    - Central AC EUL: D08-RE-HV-ResAC
    - Gas DHW EUL: D08-RG-WtrHt-CntLrgStrg
    - Heat Pump: D08-RE-HV-ResHP
    - Heat Pump Water Heater: D08-RE-WtrHt-HtPmp

Key Assumptions

- All new construction includes central air conditioning.
- Annual new construction is a fixed number, equal to the ten-year average of new housing units added, 2010 to 2020.
- The proportion of the housing stock made up of rental units remains constant over time.
- Existing equipment gets replaced on an annual rate equal to the inverse of its EUL. Existing equipment performs at the Baseline Efficiency level shown in the Appliance Stock Profile. New equipment performs at the Performance Efficiency level. Thus, the equipment stock naturally gets more efficient over time.