

APPENDIX B: TECHNICAL APPENDIX

BACHI will deliver short-term GHG reductions by decarbonizing 1,500 homes and long-term GHG reductions by removing barriers to enable successful and accelerated compliance with the Bay Area Air Quality Manage District's Zero NOx appliance rules.

Magnitude of GHG Reductions from 2025 through 2030 and 2050

Measure	Short-term GHG Reductions (cumulative 2025-2030)	Long-term GHG Reductions (cumulative 2025-2050)
Holistic Building Decarbonization	12,560 metric tons CO ₂ e	3,422,000 metric tons CO ₂ e

Short-term GHG reductions will result from Task 1's decarbonization of 1,500 homes. Long-term GHG reductions will result from Task 2 increasing the effectiveness and impact of the Air District's Zero NOx Appliance Rule by supporting more homeowners and rental housing owners to install compliant appliances.

Short-Term GHG Reductions (Cumulative 2025-2030)

BACHI will decarbonize 1,500 homes through a holistic mix of upgrade measures that will depend on the needs of each home. The GHG reduction potential from eliminating gas combustion in these homes is estimated based on the baseline gas consumption in Bay Area homes. The added electricity load is estimated based on the anticipated installation rates of efficient electric appliances for each end use. The emissions factor for grid electricity is based on the region's investor owned utility, Pacific Gas & Electric.

The basic calculation for the **annual** emissions reduction for Implementing Action 1 to decarbonize 1,500 homes is $(Gas_h \times EF_g - Elec_h \times EF_e) \times Homes$, where:

Table B-1. Short-Term GHG Reduction Calculation Inputs

Variable	Description	Value	Source
Gas_h	Average therms eliminated per home decarb	411 therms	CEC Gas Usage Data
EF_g	Emissions factor for gas (MTCO ₂ e/therm)	0.0053 tons CO ₂ /therm	EPA
$Elec_h$	Average electricity added per home	3,185 kWh	<i>See discussion below</i>
EF_e	Emissions rate for electricity (MTCO ₂ e/kWh)	0.0254÷1000 tons CO ₂ e/kWh	Pacific Gas & Electric

Based on this calculation, the average emissions reduction per home decarbonized =

- **2.07 metric tons CO₂e** (MTCO₂e) for the majority of homes (1,370 of the 1,500 homes)
- **2.18 MTCO₂e** for the small subset of homes that also receive solar plus storage (130 homes) which accounts for replacing the carbon intensity of grid electricity with renewable electricity.

These emissions reductions per home are multiplied across the total number of homes served by BACHI since the program inception. BACHI will decarbonize 1,500 homes total through 2028, starting with 100 homes in 2025, and adding 265, 500, and 535 homes respectively in years 2026, 2027, and 2028. Because these emissions reductions are durable once the retrofit is completed, the emissions reduction from homes decarbonized in 2025 will persist annually until the end of life of appliances. The retrofits will target accelerated replacement of appliances that would not have otherwise been decarbonized before 2030. Cumulative emissions reduction between 2025-2029 is derived by summing the annual emissions reductions since 2025.

Table B-2. Annual and Cumulative Short-Term Reduction

Year	Homes = Total Number of homes cumulatively served since 2025	<i>Number of homes reducing 2.07 metric tons CO₂e</i>	<i>Number of homes reducing 2.18 metric tons CO₂e (solar+storage)</i>	Annual GHG Reduction (metric tons CO₂e)
2025	100	100	0	207
2026	465	435	30	968
2027	965	885	80	2,010
2028	1,500	1370	130	3,125
2029	1,500	1370	130	3,125
2030	1,500	1370	130	3,125
Cumulative				12,560

Gas_h

The average gas combustion removed by decarbonizing a Bay Area home is estimated to be **411 therms**. This estimate was derived from residential gas consumption data from the California Energy Commission for each of the 9 counties, averaged across the homes in each of those counties. Table B-3 shows the average gas consumption by homes in the Bay Area with an estimation of the share of gas consumption by end use. This baseline reflects the extent of the GHG emissions problem, and the maximum reduction potential for decarbonizing homes.

Each appliance decarbonized will remove the corresponding amount of gas consumption, and each fully decarbonized home will remove the total amount of gas consumption. **Replacing gas appliances does increase a home's electricity consumption**, so the net GHG reduction potential calculation must include an assumed emissions increase for the new electricity load appliance-specific usage estimates, and was determined to be **conservative** in comparison, and is a better reflection of the mix of existing appliances, some of which are already electric.¹

¹ 2019 Residential Appliance Saturation Survey

Table B-3. Residential Gas Consumption for Bay Area Counties (single family and multifamily)

County	2022 Residential Gas Consumption (CEC)	Total Homes (2010 Census)	Therms per Home	Gas Tons CO2 per Home
Alameda	210,402,354	568,865	370	1.96
Contra Costa	170,832,890	367,002	465	2.47
Marin	47,695,244	98,743	483	2.56
Napa	20,274,155	49,218	412	2.18
San Francisco	128,019,010	311,374	411	2.18
San Mateo	114,172,972	246,625	463	2.45
Santa Clara	234,060,687	602,328	389	2.06
Solano	68,919,828	145,953	472	2.50
Sonoma	57,058,157	170,110	335	1.78
Total	1,051,435,297	2,560,218	411	2.18

Table references the latest available (2022) gas data at ecdms.energy.ca.gov. 2010 census data is used throughout this application for consistency with CEJST data. When 2010 CEC data were used for comparison, the average therms per home were higher; 2022 data results in a more **conservative** estimate of GHG reduction potential. Emissions factor = 0.0053 tCO₂e/therm.

Comparison with other sources of per-appliance reduction potential quantification

This top-down methodology yields similar reduction potential as the per-measure quantifications for existing ratepayer and state funded programs and research. The table below compares three other sources of data which confirm that 411 therms per home is a reasonable estimate for gas consuming appliances. These were used to triangulate and ensure that the assumed value for the calculation was realistic and conservative. The kWh usage is used to estimate Elec_h.

Table B-4. Comparison of Appliance Energy Use in California

Appliance	BAAQMD PCAP Technical Appendix C. (conducted by ICF)		2019 Residential Appliance Saturation Survey (RASS)*		TECH Clean California data portal (3/6/24) Climate Zone 3 avg, single family	
	Therms	kWh	Therms	kWh	Therms	kWh
Water Heating	146	1709	259	2071	194	1515
Space Heating	272	2242	207	1163	216	1069
Cooking	29	318	22	344		
Dryer	25	743	13	511		
Total	472	5012	501	4089	410	2584

Note: These sources do not show a total in the source material, but were summed for the purpose of this table. **The green highlighted cells are used in the example scenarios below.** * RASS presents average unit energy consumption (UEC) for each type of appliance and fuel (the values here are from PG&E's service territory). It does not compare gas vs. electric appliances within a category as shown here. It also does not show GHG emissions.

Electricity

The average electricity to be added to decarbonizing homes is estimated to be **3,185 kWh**.

This is based on a sum of the heat pump kWh consumption reported through the TECH Clean California program for heat pump space and water heating appliances, and the electric appliance unit energy consumption (UEC) reported by the 2019 RASS for cooking and dryer appliances, less the reduction from efficiency measures as estimated in BAAQMD's PCAP Technical Appendix C.

Anticipated mix of retrofit scopes for BACHH projects

The retrofit scope required to decarbonize each home depends on the existing appliances. Table B-5 represents the typical profile of anticipated BACHH home retrofit scopes.

Table B-5. Sample Decarbonization Retrofit Scenarios

Relatively Simple	More Comprehensive	With Solar + Storage
Existing condition of targeted homes		
Home is partially insulated Has electric stove and dryer Ductless heating or has good ducts	Needs attic + wall insulation Has gas stove and dryer Ducts are in poor condition	Needs attic + wall insulation Has gas stove and dryer Ducts are in poor condition Expected to increase bills
Upgrades needed		
Weatherization and additional insulation Heat pump space heating Heat pump water heater	Attic and wall insulation Heat pump space heating Heat pump water heater Stove and dryer replacement Duct replacement or sealing	Attic and wall insulation Heat pump space heating Heat pump water heater Stove and dryer replacement Duct replacement or sealing Solar plus storage
Gas reduction (therms)		
410 therms	445 therms	445 therms
Electricity addition (kWh)		
2,584 kWh for appliances* - 126.7 kWh for efficiency** = 2,457 kWh added EF = 0.0445 tons CO ₂ e/kWh (PG&E 2021)	3,439 kWh for appliances* - 253.5 for deep efficiency** = 3,185 kWh added EF = 0.0445 tons CO ₂ e/kWh (PG&E 2021)	3,439 kWh for appliances* - 253.5 for deep efficiency** = 3,185 kWh added EF = 0 tons/kWh due to solar plus storage
Per-home GHG Reduction		
2.06 tons CO ₂ e	2.22 tons CO ₂ e	2.36 tons CO ₂ e

Note: Only energy related scopes are listed in this table. The cost tables in the Budget Narrative include scopes related to health remediation and electrical capacity, which are not part of the GHG calculations.*The additional electricity use values are from the The efficiency gains of insulation are captured as a reduction to space heating electricity use after the space heating appliance has been electrified. These values are taken from Technical Appendix C of the BAAQMD PCAP for weatherization and deep efficiency respectively.

These examples are provided to illustrate that the 2.07 and 2.18 tons CO₂e per home decarbonized used in the final quantification are reasonable and conservative. The **highest value** in the table above for kWh addition (**3,185 kWh**) are used to account for the additional electricity consumption in the final quantification. The therms reductions in the table above are higher than the values of 411 therms used to calculate the GHG reduction potential for the final quantification.

EF_g

The emissions per therm is **0.0053 tons CO₂e/therm**.

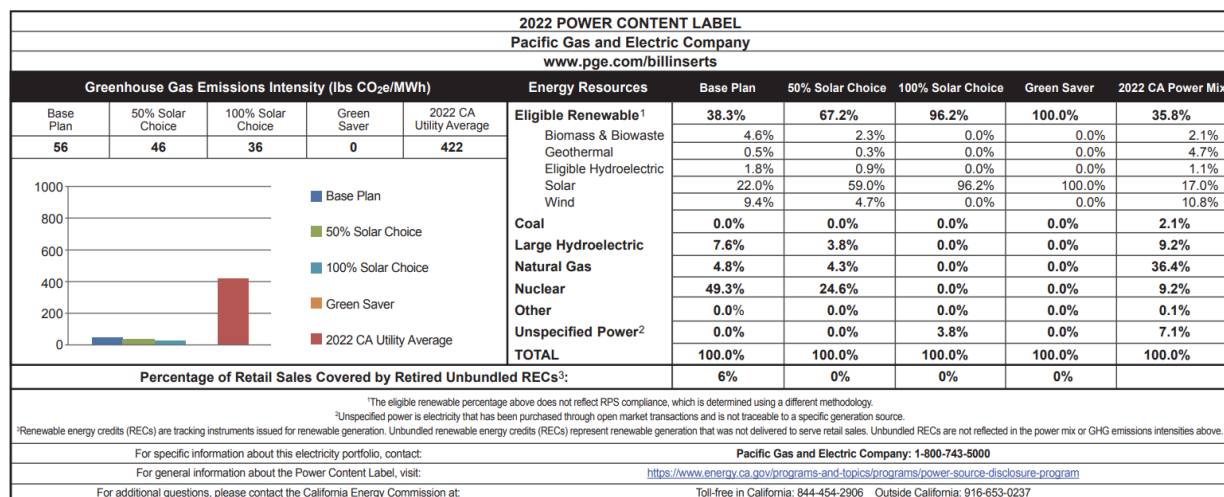
This value is a constant and consistent with EPA's calculation methodology documentation for the GHG Equivalencies Calculator.²

EF_e

The emissions per kWh is **0.0254 tons CO₂e/MWh**.

The electricity emissions factor reflects PG&E's 2022 power mix for their "base plan" (56 lbs CO₂e/kWh), and is applied as a constant across the years. This is the highest emissions intensity within PG&E's portfolio of products, and is also a conservative emissions factor compared to aggregating the emissions factors from the CCA's across the Bay Area, and does not take into account PG&E's commitments to continuously reduce their emissions factor over time. Because retrofits will span the Bay Area across multiple CCA's, PG&E's emissions factor is used as the common denominator.

Figure B-1. PG&E 2022 Power Content Label and Emissions Intensity



Note: Figures on this Power Content Label can only include RECs generated in 2022. To achieve 100% solar supply in 2022 for customers enrolled in 100% Solar Choice and Green Saver, PG&E retired additional RECs generated in 2021, in accordance with the Green-e Renewable Energy Standard.

In the case of projects that include solar plus storage, the electricity emissions are assumed to be zero, because the intent of these distributed energy resources (DER) is to offset the need to draw electricity from the grid, particularly during peak times when the electricity is sourced from emitting sources.

Long-Term GHG Reductions (Cumulative 2025-2050)

BACHI will remove systemic barriers to scaling decarbonization, and ensure that the Air District's Zero NO_x Appliance Rules have the intended magnitude of impact. The Rules will affect space and water heating appliances at natural time of replacement by prohibiting the sale and installation of NO_x

² <https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references>

emitting models in the Bay Area. The Rules' full potential impact at 100% compliance would result in 100% of homes in the Bay Area having Zero NOx (non-combusting) space and water heating appliances by 2045. BACHI's Task 2 is designed to contribute to this full potential impact by removing barriers related to permitting, funding, and rental housing dynamics.

The basic calculation for the **annual** emissions reduction for Task 2 to remove systemic barriers is $(Gas_{w+s} \times EF_g - Elec_{w+s} \times EF_e) \times Homes_{p+r}$ where most of the variables are consistent with the calculations for the short-term GHG reductions in the previous section.

Table B-6. Long-Term GHG Reduction Calculation Inputs

Variable	Description	Value	Source
Gas_w	Average therms eliminated per residential water heater	194 therms	TECH Clean California
Gas_s	Average therms eliminated per space heater	216 therms	TECH Clean California
EF_g	Emissions factor for gas (MTCO2e/therm)	0.0053 tons CO2/therm	EPA
$Elec_w$	Average electricity added per residential Zero NOx water heater	1,515	TECH Clean California
$Elec_s$	Average electricity added per residential Zero NOx space heater	1,069	TECH Clean California
EF_e	Emissions rate for electricity (MTCO2e/kWh)	0.0254÷1000 tons CO2e/kWh	Pacific Gas & Electric
DHW_p	Water heaters that comply due to permitting barriers removed by BACHI	12,268 units	<i>See discussion below</i>
$HVAC_p$	Space heaters that comply due to permitting barriers removed by BACHI	7,865 units	<i>See discussion below</i>

Based on the above calculations, the GHG reduction per appliance is:

- 0.99 MTCO2e per water heater. Over a 13-year estimated useful life, this is 12.9 MTCO2e.
- 1.12 MTCO2e per space heater. Over an 18-year estimated useful life, this is 20.1 MTCO2e.

Homes that are able to comply due to barriers removed by BACHI ($Homes_p$ variable)

BACHI proposes to improve local building permit processes across the Bay Area because permitting cost, delays, and complications have been identified as hindrances to compliance with the California Energy Code which applies to similar appliance replacements. The California Energy Commission (CEC) and California Public Utilities Commission have studied permitting obstacles since or before 2011. In the 2021 Integrated Energy Policy Report, CEC summarized the background and latest findings, including a working group conclusion that 10% of installation projects have pulled the required building permits.³

³ See 2021 IEPR Volume I - Building Decarbonization, available as of March 2024 at this Website:

<https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2021-integrated-energy-policy-report>

Other studies estimate a range of up to 30% compliance with permitting requirements. Because the Air District’s Rules also affect sales of appliances, it will likely effectively reach a higher percentage of installations than only those permitted. However, some leakage into the region from out-of-region (and even out-of-state if California also adopts similar appliance rules) is to be expected. Table B-7 shows the variables used to estimate the targeted impact for BACHI Task 2 permitting improvements.

Table B-7. Estimate of total appliances effected

Appliance	Estimated Useful Life ⁴	Gas Appliance Share	Bay Area Units per Year	Potentially Unpermitted	Targeted BACHI Enabled Units/year
Water Heater	13 years	89%	175,262	122,683	12,268
Space Heater	18 years	79%	112,356	78,649	7,865

The total number of units included in this estimate is 2.56 million single family and multifamily units. Units per year = total applicable units divided by estimated useful life. The potentially unpermitted share is estimated at 70%, which is based on the more conservative end of the range of research findings that 30% of installations are permitted. BACHI targets increasing compliance among these potentially unpermitted installations. Among these units are 1.07 million renter-occupied units, which will additionally be targeted with BACHI’s task to address challenging rental housing dynamics which prevent rental housing owners from maintaining code compliant conditions. BACHI will also facilitate connection to non-energy funding sources including home rehabilitation funding and indoor air quality health care funding to replace NOx emitting appliances. Together, these strategies target 10% of the potentially unpermitted appliance replacements.

The need to improve permit compliance rates to realize the full intended impact of appliance and energy regulations is well known and documented. California’s state legislature introduced (but did not pass) Senate Bill 795 in 2023 to attempt to resolve this issue statewide. The bill language references the low permit compliance rates and a target of increasing rates to 90 percent compliance.⁵ BACHI will implement the key interventions recommended by the CEC and CPUC, yet the target is set at a conservative percentage target. Although the modeled contribution is small compared to the larger problem, the initiative is designed to create a replicable model that can have a larger impact statewide.

Cumulative GHG reduction potential (2030-2050)

The emissions reduction potential per appliance is extrapolated for its estimated useful life and multiplied by the number of units enabled by BACHI interventions through the end of their useful life or the year 2050, whichever is sooner. For example, a water heater installed in 2032 due to BACHI’s removal of barriers will accrue a reduction of 0.99 MTCO₂e per year through 2045; a space heater installed in 2040 will accrue a reduction of 1.12 MTCO₂e per year until 2050 (only 10 years).

If fully effective, the Air District’s Rules will have reached every appliance as it is naturally replaced based on estimated useful life schedules. In reality, ABAG and its BayREN program implementers have observed many appliances remain in place far beyond their estimated useful life. However, for conservative estimation of cumulative impacts, BACHI’s impact is only calculated on water heaters

⁴ Estimated useful life of 13 years for water heaters and 18 years for space heaters is consistent with the Air District’s quantification methodology for the NOx reduction impacts of their Rules.

⁵ SB 795 text: https://leginfo.ca.gov/faces/billNavClient.xhtml?bill_id=202320240SB795

installed prior to 2040 (13 years after the NOx Rules of small water heaters in 2027) and on space heaters installed prior to 2047 (18 years after the NOx Rules on space heaters in 2029). Figures B-2 and B-3 show the extrapolation from annual to cumulative emissions for water heaters and space heaters respectively. The impact of BACHI's long-term strategy is calculated from the end of the grant period through 2050.

Combined, the cumulative impact on these two appliance categories is **3.4 million MTCO₂e**.

Appliance	Appliance Units Included in Cumulative Impact	Cumulative GHG Reduction
Water Heating	134,951	1,699,905
Space Heating	141,568	1,722,411
Total	276,519	3,422,315

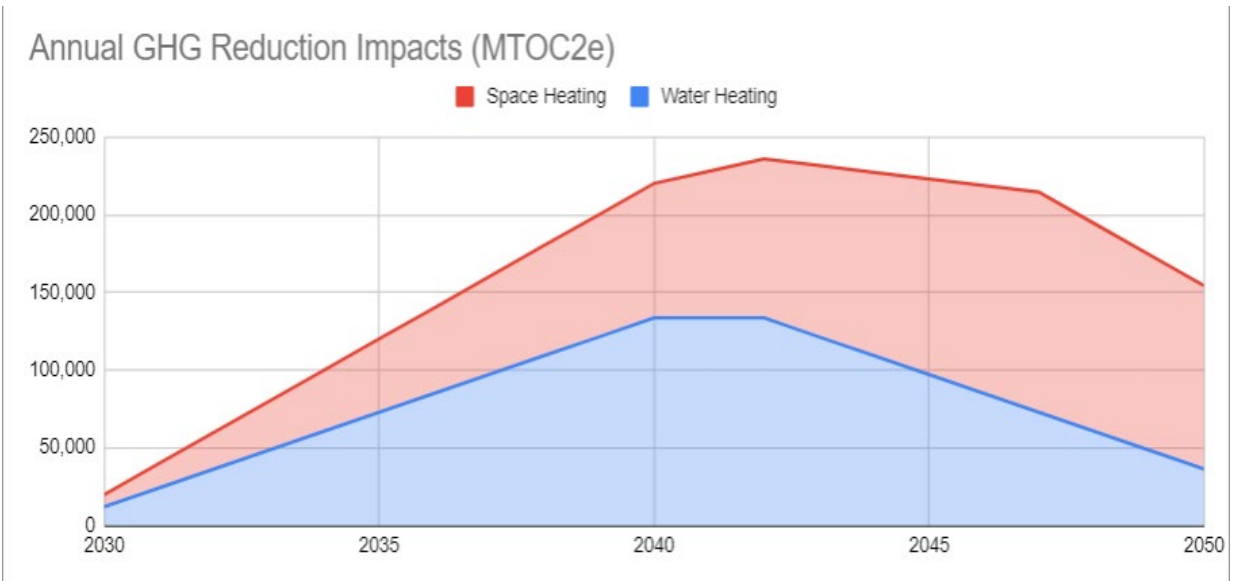
Through Task 2, the Air District will connect with building departments, including introducing permit digitization and shareable databases that will enable more visibility and insights into the permitting practices and compliance rates across participating Bay Area jurisdictions. From this data, the BACHI team will be able to assess changes in permitting rates and monitor the uptake of appliances that comply with the Zero-NOx Rules, including heat pumps and other decarbonizing technologies. These monitoring tools will enable the team to track progress toward the projected outcomes and long-term GHG reductions.

Figure B-2. Projected cumulative impacts of water heaters enabled by BACHI removing barriers

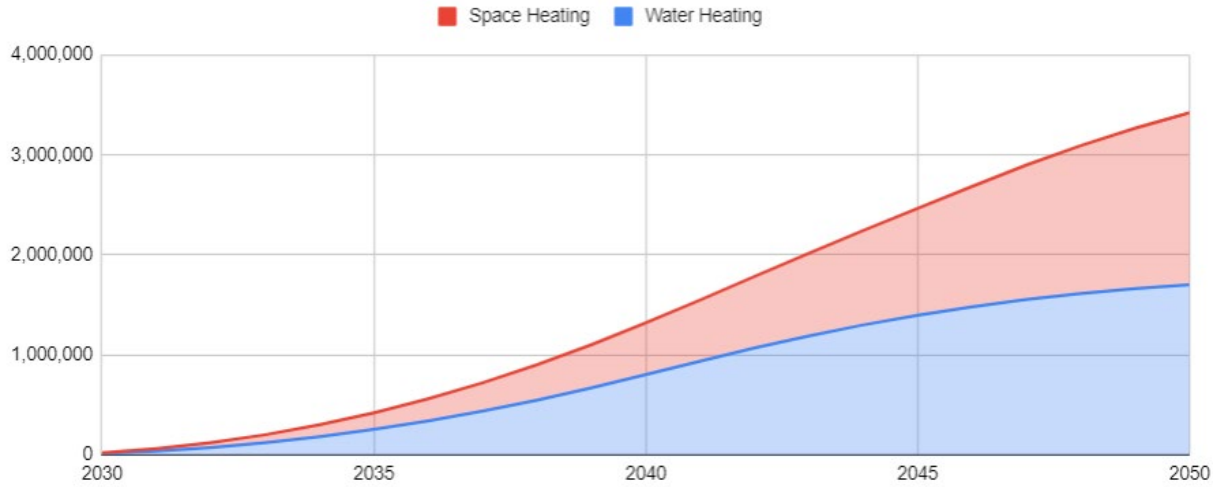
Water Heaters		Installation Year												
Emissions Year	Total	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040		
2030	12,142	12,142												
2031	24,284	12,142	12,142											
2032	36,427	12,142	12,142	12,142										
2033	48,569	12,142	12,142	12,142	12,142									
2034	60,711	12,142	12,142	12,142	12,142	12,142								
2035	72,853	12,142	12,142	12,142	12,142	12,142	12,142							
2036	84,995	12,142	12,142	12,142	12,142	12,142	12,142	12,142						
2037	97,137	12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142					
2038	109,280	12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142				
2039	121,422	12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142			
2040	133,564	12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142		
2041	133,564	12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142	
2042	133,564	12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142	
2043	121,422		12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142	
2044	109,280			12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142	
2045	97,137				12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142	
2046	84,995					12,142	12,142	12,142	12,142	12,142	12,142	12,142	12,142	
2047	72,853						12,142	12,142	12,142	12,142	12,142	12,142	12,142	
2048	60,711							12,142	12,142	12,142	12,142	12,142	12,142	
2049	48,569								12,142	12,142	12,142	12,142	12,142	
2050	36,427									12,142	12,142	12,142	12,142	
Cumulative Total	1,699,905													

Figure B-3. Projected cumulative impacts of space heaters enabled by BACHI removing barriers

Space Heaters		Installation Year																	
Emissions Year	Total	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047
2030	7,865	7,865																	
2031	15,730	7,865	7,865																
2032	23,595	7,865	7,865	7,865															
2033	31,460	7,865	7,865	7,865	7,865														
2034	39,324	7,865	7,865	7,865	7,865	7,865													
2035	47,189	7,865	7,865	7,865	7,865	7,865	7,865												
2036	55,054	7,865	7,865	7,865	7,865	7,865	7,865	7,865											
2037	62,919	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865										
2038	70,784	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865									
2039	78,649	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865								
2040	86,514	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865							
2041	94,379	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865						
2042	102,244	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865					
2043	110,108	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865				
2044	117,973	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865			
2045	125,838	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865		
2046	133,703	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	
2047	141,568	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865
2048	133,703		7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865
2049	125,838			7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865
2050	117,973				7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865	7,865
Cumulative Total	1,722,411																		



Cumulative GHG Reduction Impacts (MTCO₂e)



Cost Effectiveness of GHG Reductions

Measure: Holistic Building Decarbonization	Short-term (cumulative 2025-2030)	Long-term (cumulative 2025-2050)
Total Measure Budget	\$98,195,472	
GHG Reduction	12,560 metric tons CO ₂ e	3,422,000 metric tons CO ₂ e
Dollars per MTCO ₂ e	\$7,818 per metric tons CO ₂ e	\$29 per metric tons CO ₂ e