Health-e Communities Pilot Evaluation and Final Report

July 2026

Dan Bertoldi
Electrification Programs Manager

Table of Contents

Figures

Tables

Executive Summary

Ava Community Energy's Health-e Communities Pilot ("Pilot") was a residential stove electrification pilot program for low-income customers. The Pilot set out to improve participants' indoor air quality by replacing gas stoves with induction stoves. This Pilot used a direct install program model, where Ava covered costs associated with the installation (equipment and labor) and at no cost to the participant. Ava also coordinated the temporary installation of an indoor air quality (IAQ) monitoring device in each home. Monitoring was conducted before and after each installation of an all-electric induction stove to measure indoor air pollution impacts within the participant's kitchen.

Ava partnered with Franklin Energy Services ("Franklin") as the Pilot implementor to coordinate the stove installation services, as well as the site visits and IAQ monitor installation. Franklin sub-contracted and coordinated with qualified electrical contractors to perform the installation work. Berkeley Air Monitoring Group ("Berkeley Air") provided air quality analysis services.

Applications for the Pilot ran for approximately one year, from October 2024 to September 2025. The total cost of the Pilot was $1.27 million, with $1.15 million spent on implementation of the Pilot installation services and approximately $120,000 on air quality monitoring. Ava received a grant from the Energy Foundation to support the air quality monitoring component of this Pilot.

Marketing efforts included email outreach by Ava to approximately 56,000 income-qualified Ava customers living in high asthma rate areas to meet the goal of installing up to 200 electric induction stoves. 162 projects were successfully completed with an average cost of over $7,000 per project.

Participant attrition rates were high throughout the Pilot. Approximately 64% of eligible applications did not result in a successful installation. Retaining interest was challenging throughout the Pilot, as many participants changed their minds about participating, or were unresponsive to communications following their approved enrollment. Additionally, many projects were cancelled due to electrical or panel issues or ineligible equipment (e.g. pre-existing electric stove or countertop ranges). A disproportionate rate of renters and residents of multifamily housing dropped out during the process, indicating additional barriers to participation in this customer segment.

On average, projects took approximately 90 days to complete from application to final site visit. This was in large part due to local permitting timelines and participant-installer scheduling. Approximately half of the completed projects required additional measures (e.g. tandem breakers, subpanel, etc.) to support electrification that were beyond the "standard" project measures (circuit install, permit, stove equipment), adding more cost to projects. Despite high attrition rates and an average 90-day timeline to complete work, overall participant satisfaction remained high for successful projects, with an average score of 9.9/10 across all satisfaction metrics.

Analysis of air quality pollution concentration showed significant and consistent reductions in nitrogen dioxide (NO_2) in households following the intervention. Ninety-eight percent (98%) of participating households with a successful IAQ measurement (n=135) experienced a substantial decrease in the number of minutes per day that NO_2 concentrations exceeded US EPA standards for sensitive groups - a median decrease of 13 minutes/day to 0 minutes/day. This measurement highlights the dangerous presence of gas stoves within the home and the significant advantage that induction/electric stoves have over gas alternatives. Observed reductions in carbon monoxide (CO) were small but statistically significant. The impacts of electrification on carbon dioxide (CO_2) remained relatively stable, suggesting household ventilation behaviors did not change throughout the study. However, results for Fine Particulate Matter ($PM_{2.5}$) were variable, suggesting $PM_{2.5}$ fluctuations were influenced by factors beyond stove fuel, such as cooking practices or outdoor infiltration. These findings confirm that removing gas cooking appliances can improve indoor air quality by reducing combustion-related air pollution within the home. However, more intensive research is needed to understand the human health impacts of electrification.

At the end of the Health-e Communities Pilot, Ava staff concluded that it did not demonstrate a scalable delivery model given the low conversion rate, the high equipment and administration costs, long installation timelines, and limited budget. With these findings, it's indicative that adding more invasive research procedures at a larger scale for the advancement of health-based research is not feasible.

While Ava is not continuing its work on the Health-e Communities concept, this study helped staff identify key barriers to electrification projects that go beyond stove electrification, such as permitting and electrical panel constraints. Staff plan to apply these learnings to future program design and development to enhance Ava's Local Development programs portfolio, and to provide more effective programs and services to Ava customers.

Introduction

Overview

Ava Community Energy's Health-e Communities Pilot ("Pilot") offered qualifying Ava residential customers with an opportunity to replace their gas range with an all-electric induction range. The Pilot used a direct install program model, providing the induction range and installation at no cost to the customer. As part of each project, indoor air quality ("IAQ") was monitored before and after installation to measure the impacts of electrification on air pollution within the kitchen. Applications for the Pilot were open for approximately one year (10/1/2024 - 9/17/2025).

Ava Community Energy partnered with Franklin Energy Services ("Franklin") to provide implementation and stove installations services to support the Pilot. Ava partnered with Berkeley Air Monitoring Group ("Berkeley Air") to facilitate the indoor air quality monitoring and to perform the air quality impact analysis. Ava led the program design, marketing and recruitment, and provided oversight of both Franklin and Berkeley Air.

Pilot Objectives

- Complete up to 200 induction stove retrofit projects over approximately one year
- Develop and refine effective program recruitment and enrollment tactics for a direct install program
- Gain insights into direct install program management strategies for electrification
- Solicit Pilot feedback from all participants
- Conduct analysis of indoor air pollutant concentrations and impacts of cooking electrification for all participants
- Inform on larger programmatic effort linking electrification and health

Methodology

Applicant Eligibility

To qualify for the Health-e Communities Pilot, applicants had to meet the following requirements:

- Be an active Ava customer for electricity service
- Active enrollment in the California Alternate Rates for Energy (CARE) or Family Electric Rate Assistance (FERA) programs, or reside in designated affordable housing
- For renters, provide property owner permission to participate in the Pilot

Project Eligibility

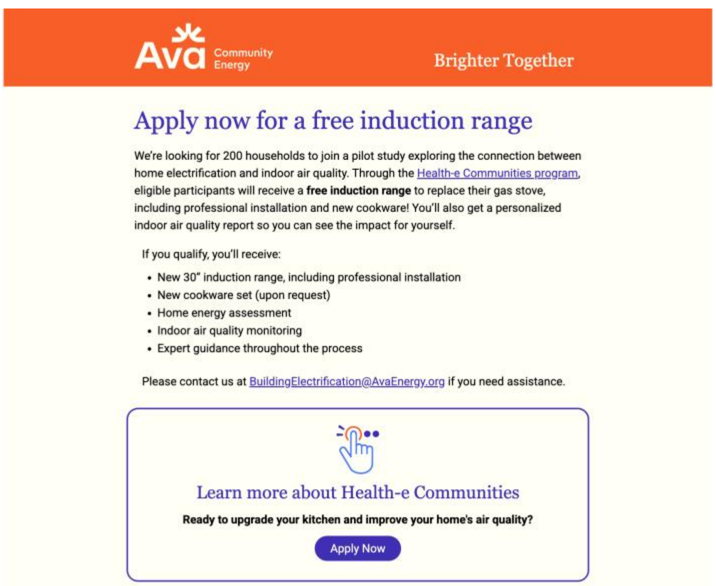
Eligible applicants could receive a free induction stove installation as long as the installation site met the following project eligibility requirements:

- Single-family home or (small) multifamily dwelling with 4 units or less
- Have an existing 30" natural gas range (cooktop and oven combined)
- Have an electrical panel without an open manufacturer recall, that could safely accommodate a dedicated circuit for the new induction range

Customer Outreach

Ava was responsible for marketing, outreach, and recruitment of Pilot participants. Ava staff used email ("campaigns") offering a free induction range and the chance to join a pilot study on indoor air quality. Emails, as well as the Pilot website and application form, were provided in both English and Spanish.

Figure 1: Sample outreach email for the Health-e Communities Pilot

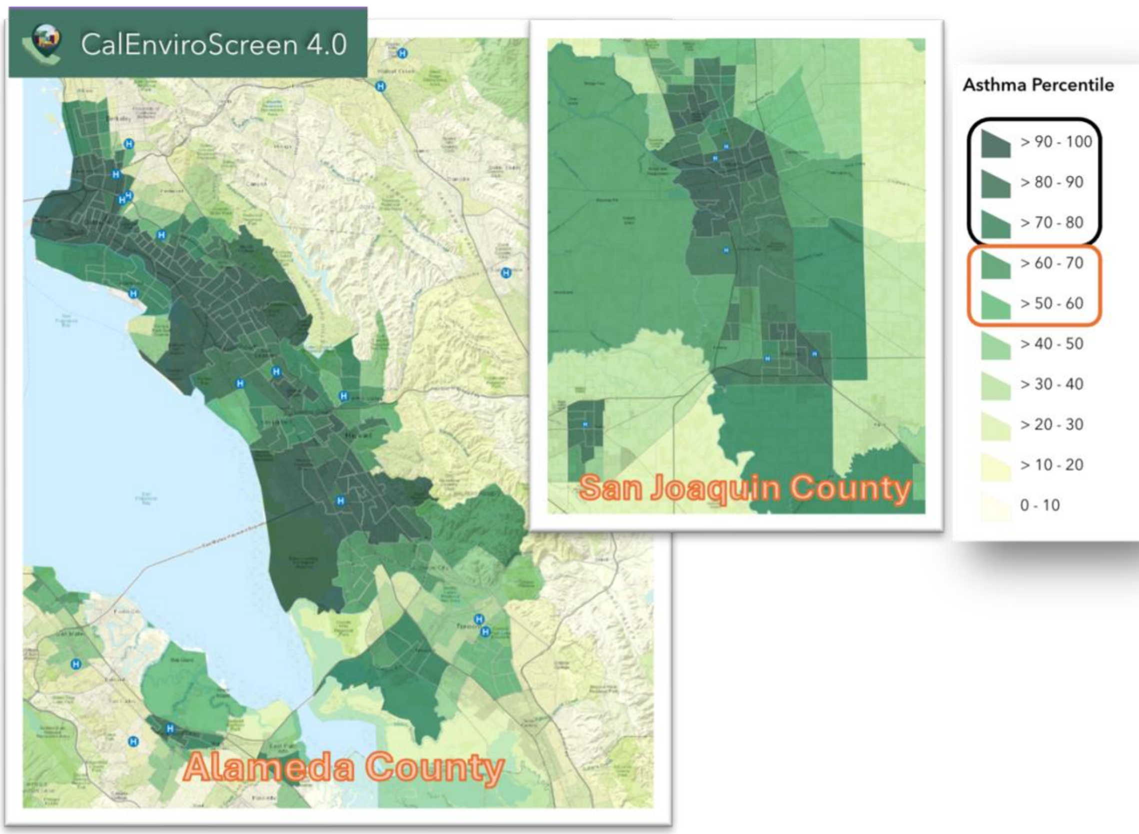


Because there are known linkages between fuel combustion in the home and respiratory illness, such as asthma[1], Ava sought to target customer segments that could benefit most from the Pilot. Ava sent the email campaign to income-qualified customers living in areas with the highest asthma rates across Ava's service area. This was done by using a

[1] Kashtan et al., Nitrogen dioxide exposure, health outcomes, and associated demographic disparities due to gas and propane combustion by U.S. stoves (2024)
Gruenwald et al., Population Attributable Fraction of Gas Stoves and Childhood Asthma in the United States (2023)

combination of Ava's internal customer account data (to identify active CARE and FERA customers enrolled in Ava's service as the approach for income qualification) along with CalEnviroScreen 4.0 ("CES 4.0") data to identify customers living in high asthma rate census tracts. Staff utilized the *CES 4.0 Asthma Indicator* set to the 75th percentile and above. As the program progressed, staff extended outreach to target customers living in the 50th percentile and above to increase the number of targeted customers.

Figure 2: Maps showing CalEnviroScreen 4.0 Asthma Percentile indicators



Ava used a cautious approach to outreach to avoid creating long wait times for participants. Due to the complex and time intensive nature of each site visit, as well as the limited availability of IAQ monitors required to measure air quality before and after installation, a large influx of applications would overwhelm the project team's ability to schedule with participants and coordinate site visits in a timely manner. In the beginning of the Pilot, emails were distributed to tranches of 2,500 – 5,000 customers for each campaign. Towards the end of the Pilot, customers were sent a "last chance" email. In total, Ava reached out to approximately 56,000 residences up to four times, for a total of approximately 200,000 individual emails distributed.

Direct Install Model

While Ava led program design and handled participant recruitment and applications, Franklin was the Program Implementor. Franklin served as a central hub between the participants, qualified electrical contractors ("installers"), and Ava. Franklin was responsible for scheduling all visits of qualified participants, site assessments, and installation and removal of the air quality monitors. The installer performed the installation of the induction stove and the supporting measures.

Supporting measures are listed below, and although "standard" measures such as capping a gas line were included in every project, others ("non-standard") such as ventilation and hood modifications were only implemented on an as needed, project-specific basis.

Table 1: Supporting Measures

Installation Measure	Standard or Non-standard
Capping Gas Line	Standard
Permit Facilitation	Standard
240V Circuit Run	Standard
Tandem Breaker	Non-standard
Drywall Repair	Non-standard
Circuit Sharing	Non-standard
Sub-Panel Replacement/Installation	Non-standard
Ventilation/Hood Modification	Non-standard

Customer Journey

Figure 3: Health-e Communities Pilot Customer Journey

Customers applied to the program through an online form hosted on Ava's website. Once a customer applied and was deemed eligible to participate, a Franklin Energy Advisor provided an in-home site assessment to confirm the project's feasibility. Projects that cost more than $7,500 for installation required Ava staff approvals. If the project was feasible, the customer signed a Program Participation Agreement with Franklin, which provided a detailed scope of work, as well as terms and conditions of the Pilot (see Appendix B).

Franklin would then install the IAQ monitor and provide the customer with a handoff packet detailing the next steps of the Pilot and educational materials for induction cooking. Following the initial site visit, participants were asked to choose between three 30" induction range models from different manufacturers. Manufacturer and model choices were updated throughout the Pilot based on availability and range performance. All models required 240 volts and 40 or 50 amps.

After at least one week of IAQ monitoring, the installer, coordinated by Franklin, would install the induction range and other associated measures, and properly dispose of the used gas range. At least one week after installation, Franklin returned to the home to retrieve the IAQ monitor and conduct an exit survey.

Data Collection

Five sources of data were tracked during the Pilot to inform on engagement approach, residential electrification needs, indoor air quality monitoring, and customer satisfaction with both the program and equipment installed. A sixth, bill data, is being analyzed as of July 2026.

Marketing Analytics

Ava tracked email campaign metrics through the Ava's Customer Relationship Management platform (Salesforce) and email distribution system (MassMailer).

Site Assessment

Upon the initial site visit, Franklin's Energy Advisor collected project-specific site and user information with a questionnaire, as well as visually inspected the kitchen and the home's service panel and wiring requirements for installing the induction range (**see Appendix A**).

Air Quality Monitoring

The IAQ study portion of the Pilot consisted of measuring the concentration of four pollutants in the kitchen: **nitrogen dioxide (NO_2)**, **fine particulate matter ($PM_{2.5}$)**, **carbon monoxide (CO)**, and **carbon dioxide (CO_2)**. Indoor air quality monitors were placed in participating customers' kitchens for at least one week before and after each installation. Additionally, participant stove use habits and other observations were collected via an exit survey. Participants were provided with a personalized IAQ report at the end of each successful monitoring period. More detail on the methodology of the air quality analysis is provided in **Attachment 1**.

Exit Survey

Following the stove installation and at least one week of post-installation air quality monitoring, the Fraklin Energy Advisor would return to the home to remove the IAQ monitor and conduct an exit survey, which included a customer satisfaction questionnaire.

Follow-up Survey

In May 2026, Ava sent a follow-up survey to Pilot participants to collect qualitative feedback, quotes about their experience with their induction range, and the impact it's had on their lives and households.

Bill Data

Ava is in the process of analyzing energy consumption and cost data. An addendum to this report will be released when ready.

Results and Analysis

Email Campaign

The total number of unique customers targeted in the marketing campaign was approximately 56,000. Ava's email campaign resulted in high open rates and was the primary source of applications and enrollment for this program. The email campaign was intentionally delivered at a measured pace to ensure that wait times for site visits were relatively short. Email campaign metrics are found in Table 2 below:

Table 2: Email Campaign Results

Total Emails Delivered	212,930
Email Open Rate	24,555 (11%)
Email Click-Through Rate	1,410 (0.66%)
Email Unsubscribes	837 (0.39%)
Email Bounces	4.3k (2%)
Total Customers Targeted	56,154
Average Number of Emails per Customer	3.8
Campaign Member Applications	395
Campaign Member Successful Installations	138

Key Takeaways

- ◊ Less than 1% of the customers targeted in the email campaign applied after 3–4 email attempts.
- ◊ Approximately 11% of the individual emails were opened at 0.66% of emails were clicked through. The overall application rate per individual email sent was 0.18%.
- ◊ Broader outreach campaigns or marketing partnerships would have likely overwhelmed the Pilot and created significant backlogs, given the limited number of air quality monitors and logistics required to enroll participants.

Applicant Attrition and Project Success

A total of 518 applications were submitted to the Pilot. Out those submitted applications, 451 were eligible and 67 were ineligible. Another 289 dropped out or were cancelled. A total of 162 projects were successfully completed. The total attrition rate for eligible participants was 64%.

Of the total eligible applicant pool, 127 applications were cancelled before a site visit due to nearly one-third of eligible applicants losing interest or changing their mind before meeting with an Energy Advisor. Of the 324 participants that received a site visit, 50% were cancelled for various reasons, including unsafe electrical panel, insufficient panel capacity, ineligible equipment, loss of interest, or were not responsive. A breakdown of final project status, representative of project success and attrition, is in Figure 4 below.

Figure 4: Sankey diagram showing breakdown of Pilot applications by final status

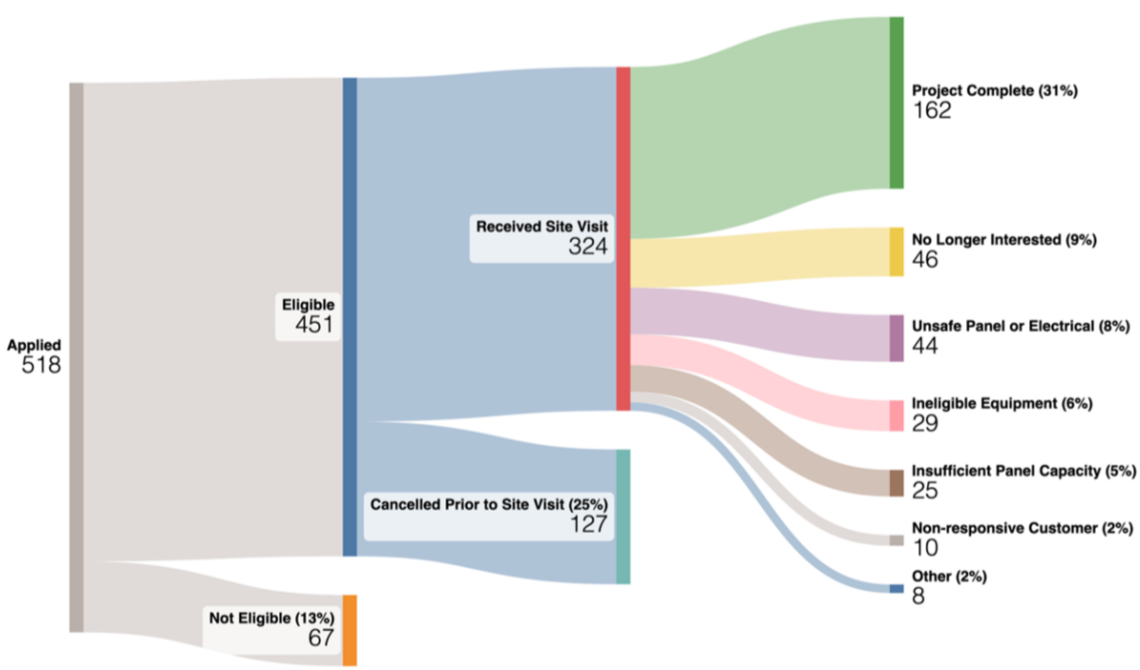


Table 3: Pilot Applications Received and Projects Completed by Jurisdiction

Jurisdiction	Approved Applications	Completed Installs	Percent of Completed Projects
OAKLAND	156	58	35%
STOCKTON*	115	33	20%
FREMONT	29	17	10%
HAYWARD	36	14	9%
SAN LEANDRO	24	13	8%
BERKELEY	26	11	7%
UNINC ALAMEDA CO	21	5	3%
TRACY	17	3	2%
UNION CITY	7	3	2%
EMERYVILLE	3	1	1%
LATHROP*	7	1	1%
NEWARK	6	1	1%
ALBANY	2	1	1%
PLEASANTON	1	1	1%
DUBLIN	1	0	0%

*Pilot made available to these cities in May 2025

Key Takeaways

- ◊ A total of 162 projects were successfully installed out of the goal of 200 (85% of the goal).
- ◊ Attrition was 64% among eligible customers who applied.
- ◊ 50% of participants dropped out after receiving a site visit.
- ◊ Even with a high-value offering ($5,000 value to the customer), the Pilot faced lower-than-anticipated interest and high attrition.
- ◊ While specific reasons for participant dropout were often documented, some customers did not provide a reason. Additional market research could be useful to better understand why participants are not interested in a high-value offering.

Pilot Costs

The total cost of the Pilot was **$1.27 million** for both implementation ($1.15M) and indoor air quality analysis ($120,000). This analysis looks at implementation costs, which are split into two categories: 1) *Direct Project Costs,* which were calculated from the total unitary measure costs - Franklin charged flat rates for measures - that include both equipment and associated labor; and 2) *Administration Costs,* which were flat rate fees for soft costs (e.g. Franklin call center operations).

The analysis below provides a breakdown of total calculated Pilot-wide implementation costs, which were calculated based on invoices paid. To estimate the cost of successfully completed projects, total Pilot expenditures were disaggregated to separate costs associated with completed projects from those attributable to cancelled or otherwise incomplete projects. Administrative costs associated with completed projects were estimated by applying the calculated administrative cost per site visit to each completed project.

Table 4: Total Calculated Pilot-wide Implementation Costs

These figures demonstrate the total "all in" cost for Pilot implementation on a per project basis and total spend. Note that expenditures for projects that did not move forward (i.e., cancelled projects) are included in these calculations.

Implementation Cost	Avg. Project Cost (Pilot-wide)	Total Cost
Direct Project Costs*	$5,050	$818,155
Administration+	$2,062	$334,024
Total	**$7,112**	**$1,152,179**

*Includes all costs for equipment, labor, assessments, and cookware
+Includes total admin costs program-wide

Table 5: Estimated Implementation Costs for Completed Projects

These figures provide a breakdown of costs for individual completed projects and the aggregate total for all completed projects.

Implementation Cost	**Avg. Completed Project Cost** (Completed Projects only, n=162)	Total Cost for Completed Projects
Direct Project Costs*	$4,968	$802,552
Administration Cost Estimate+	$1,031	$167,012
Total	**$5,999**	**$969,564**

*Includes all costs for equipment, labor, assessments, and cookware for completed projects only.
+Admin cost estimate based on the average administrative cost per site visit (total cost of admin divided by 324 site visits) and omits admin costs that did not result in a successful install.

The estimated cost of attrition is based on the difference between total Pilot costs and the estimated successful project costs:

(Total Pilot Costs – Total Cost for Completed Projects) ***= Estimated Cost of Attrition***
($1,152,179 - $969,564) ***= $182,615***

Key Takeaways

- ◊ The average cost per project for all labor, equipment, and administration was $7,110.
- ◊ The customer benefit value was approximately $5,000 on average for direct labor and equipment.
- ◊ The total cost of attrition was estimated to be $182k, approximately 15% of the total cost of the pilot.

Project Scope Analysis

To better understand the installation scope of work necessary for projects within the Pilot, staff examined measures that were deployed to support stove electrification beyond a "standard" project. This was done by calculating the frequency of deployed measures on an individual basis, as well as grouping measures and calculating the frequency of "standard," "above standard," or "below standard" projects. "Above standard" installations are projects that included the standard measures plus one or more additional measures. "Below standard" installs are projects that required fewer than the standard measures.

Table 6: Count and Rate of Installation for All Measures Implemented in the Pilot

Project Measure	Standard or Non-standard	Count	Install Rate (%)
Capping Gas Line	Standard	162	100%
Electric Induction Range	Standard	162	100%
Permit Facilitation	Standard	159	98%
Add Circuit	Standard	159	98%
Tandem Breaker	Non-standard	48	30%
Drywall Repair	Non-standard	23	14%
Circuit Sharing Device	Non-standard	18	11%
Sub-Panel Install	Non-standard	6	4%
Ventilation Modifications	Non-standard	1	<1%

Table 7: Count and Percent of Total Projects Categorized as Standard, Above Standard, or Below Standard

Project Type	Count	% of Total Projects
Standard Installs	84	52%
Above Standard*	75	46%
Below Standard*	3	2%

Key Takeaways

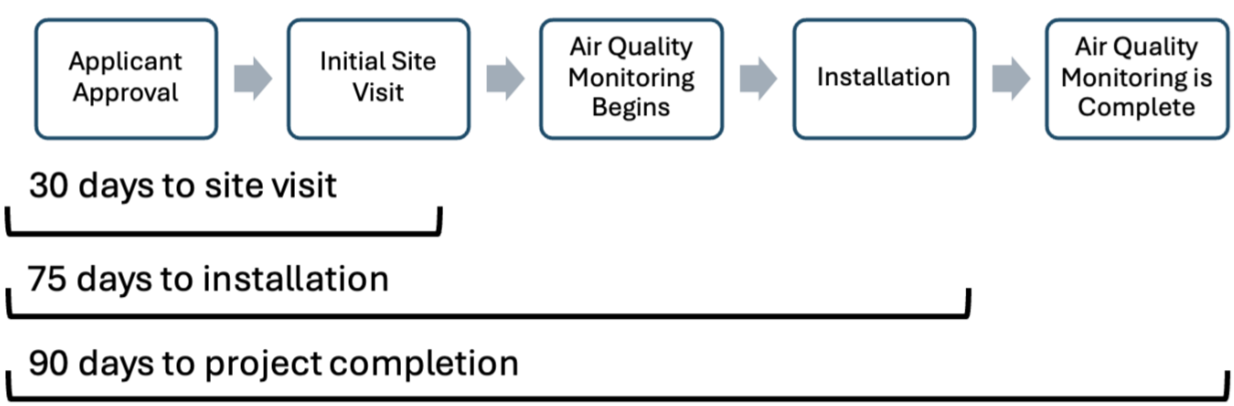
◊ Just over half of the projects were considered standard projects, which includes the induction range, permit facilitation, capping of the gas line, and the installation of a 240V circuit.

◊ Nearly half of all projects required installation measures beyond "standard project", meaning installers had to provide other install services in support of the induction range installation, circuit run, and permit (i.e. tandem breakers, circuit sharing devices, etc.), resulting in higher program costs.

Project Timelines

Timelines were impacted by several factors, including permitting wait times, customer scheduling, installer scheduling, and availability of IAQ monitors to deploy one week before an installation. These factors added logistical complexity to each project and required significant staff time and attention to ensure project progression. Average wait times across the customer journey are provided below in **Figure 5**.

Figure 5: Customer Journey and Average Project Milestone Timelines



Staff observed a high degree of timeline variability across jurisdictions when looking at the average number of days to reach project completion, ranging from 62 days (Stockton) to 140 days (Berkeley). The main contributing factor impacting project timeline variability was permitting associated with each jurisdiction, which is further analyzed in this evaluation.

Key Takeaways

- ◊ The average installation took approximately 75 days to complete, from application approval to install.
- ◊ The average project completion took approximately 90 days, from application approval to final site visit and exit survey.
- ◊ There was a high degree of timeline variability between jurisdictions showing the impact that permitting has on project completion.

Permitting

Nearly all projects (except for three) supported by the Pilot required an electrical permit to be issued by the local authority having jurisdiction (AHJ). Generally, permits are required from all AHJs to run a 240-volt circuit to support the induction stove. Permits were facilitated by the licensed electrical contractor assigned to a given project. Applications for the circuit were submitted shortly after the initial site assessment. Table 7, below, provides permit issuance timeline details.

Table 8: Permit Timelines

This table shows the average number of days it took for an AHJ to issue a permit after permit applications were submitted, as well as the number of permitted projects analyzed, the minimum number of days, and the maximum number of days to issue a permit. Some projects were omitted from this analysis due to extenuating circumstances.

Jurisdiction	Avg. Days to Issue Permit	No. of Permits Issued	Minimum No. of Days	Max No. of Days
Berkeley	31	10	7	58
Albany	30	1	30	30
Newark	29	1	29	29
Fremont	27	12	3	65
Pleasanton	22	1	22	22
Union City	14	3	0	26
Emeryville	9	1	9	9

Jurisdiction	Avg. Days to Issue Permit	No. of Permits Issued	Minimum No. of Days	Max No. of Days
Lathrop	9	1	9	9
Uninc. Alameda Co.	9	3	6	15
Hayward	8	16	0	30
Stockton	6	30	1	20
Fremont	3	17	0	28
Tracy	1	3	1	1
Oakland	1	58	0	20

Permitting times vary by jurisdiction, even with the same permit request. Installers working on the Pilot reported the following reasons for potential increases in permit wait times:

- Varying levels of complexity and information requirements needed to complete the same type of permit application. This resulted in increased communication between permit center staff and electrical contractors and the frequency with which information was missing from a given application packet, requiring additional time to remedy
- Existing building requirements to issue permit (e.g. ventilation requirements, seismic shutoff valves, etc.), which were not always directly related to the work being performed
- Permit center backlogs
- Internal AHJ application review processes and timelines
- Existing code compliance issues that need remediation before permit issuance and closeout (e.g. panel too close to the ground)

Key Takeaways

◊ The Pilot-wide average waiting period to issue an electrical permit across all AHJs was approximately 8 days.

◊ There was a high degree of variability between AHJs, ranging from an average of one day to one month.

◊ Permitting was the largest contributor to project timelines and increased the complexity of program logistics.

Customer Experience

Overall customer satisfaction scores (taken from the exit survey provided during a follow-up site visit) averaged 9.9 out of 10 across all satisfaction survey questions. A total of 161 (out of 162 completed projects) program participants submitted the exit survey.

Table 9: Customer Satisfaction Scores (n = 161)

Question	Avg. Score
How satisfied are you with your interactions with your Energy Advisor?	9.96
How satisfied are you with the Assessment report received?	9.95
How satisfied are you with the assessment experience?	9.94
How satisfied are you with the communication process prior to your assessment?	9.94
How likely are you to recommend this program to a friend, family member, or colleague?	9.93
How satisfied are you with your experience scheduling the assessment?	9.93
How satisfied are you with the installation experience?	9.91
How satisfied are you with your experience scheduling the installation?	9.90
How satisfied are you with the communication process prior to your installation?	9.89
How satisfied are you with the Induction unit received?	9.88
How satisfied are you with your interactions with your Trade Ally?	9.84

While the Pilot received high average satisfaction scores, staff noted issues that required special attention by Ava staff, Franklin, and the installer, included the following:

- Pre-existing code violations that were discovered upon inspection
- Louder than normal/optimal noise emanating from the induction range
- Malfunctioning stovetop burners
- Delays in response from manufacturer technicians to repair under warranty
- Workmanship concerns from customers

Following the close of the Pilot, Ava reached out to participants to collect qualitative feedback on their experience with induction. A summary of participant sentiment is provided below:

- **Initial hesitations** centered on cooking performance, temperature control, electricity costs, unfamiliar technology, cookware compatibility, and concerns about electrical upgrades.
- **Cooking performance exceeded expectations**, with the most common feedback being that induction heats much faster than gas, especially for boiling water.

- **Easy to adapt.** While many expected a steep learning curve, most reported becoming comfortable with the new technology relatively quickly.
- **Improved cooking experience.** Participants frequently praised the precise temperature control, even heating, and ease of cleaning.
- **Health and indoor air quality benefits were widely recognized.** Many participants reported feeling better about eliminating gas combustion indoors, noticing reduced gas odors, and believing their home's air quality improved.
- **Safety was a major perceived benefit.** Participants appreciated eliminating open flames, automatic shutoff features, and reducing concerns about gas leaks, particularly in households with children.
- **Electricity cost concerns were largely unfounded.** Many respondents noted that their electric bills increased little or not at all, contrary to their expectations (Note: Ava is in the process of evaluating cost impacts using participating customer bill data).
- **Most participants would not return to gas.** Several explicitly stated they now prefer induction and would never switch back.
- **The program itself received high praise.** Many participants expressed gratitude for the free installation, complimented the installation crews, and said they could not have afforded the upgrade otherwise.
- **Participants expressed interest in additional electrification programs**, including support for replacing other natural gas appliances.
- **A few improvement opportunities emerged, including:**
    - Long installation timelines for some participants
    - Preference for physical knobs over touch controls
    - Desire for a broader selection of eligible stove models
    - Better education on power settings and the initial learning curve to avoid overcooking or burning food
    - Minor usability concerns with some stove interfaces and control layouts

Key Takeaways

◊ Even though project wait times were longer than anticipated, customer satisfaction across all metrics was high immediately following the installation, showing that customers appreciated the service and technology.

◊ In the follow-up survey, participants overwhelmingly viewed the induction range as a worthwhile upgrade, citing faster cooking, easier cleaning, improved indoor air quality, enhanced safety, and minimal operating cost impacts.

◊ Negative feedback focused primarily on the installation process and certain appliance interface preferences rather than the induction technology itself.

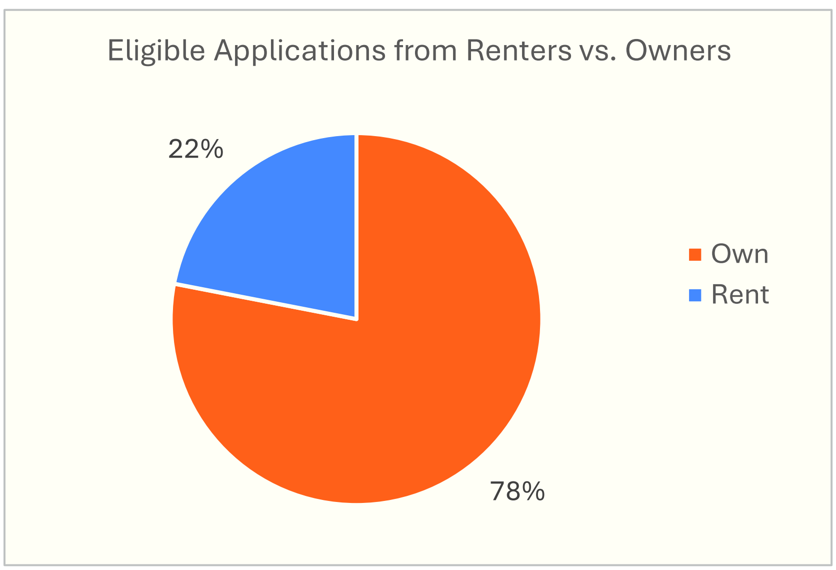
Equity & Accessibility

Eligibility guidelines for the Health-e Communities Pilot required low-income (CARE, FERA, or affordable housing) status to participate. While all Pilot participants met at least one of these criteria, this report looks at alternative equity indicators to better gauge performance within Ava's low-income customer segment and provide insights into future program design.

Renters vs. Homeowners

Lower-income households are more likely to experience housing cost burdens and are disproportionately represented in rental housing[2]. Equity programs should be well-positioned to include and encourage renter participation. The direct install model is viewed as an ideal delivery method for renters, as it addresses the split-incentives barrier, which occurs when the party who owns the property is not the direct beneficiary of the program benefits, and therefore have less to gain from participation and any additional investments beyond what is supported by program incentives. A direct install program model, as in the case of the Health-e Communities Pilot, covers all upfront costs of the program measures; however, landlord/property owner permissions are required for participation.

Figure 6: Eligible Applications from Renters vs. Owners



[2] **Source:** U.S. Department of Housing and Urban Development (HUD) Comprehensive Housing Affordability Strategy (CHAS) data; Alameda County Consolidated Plan; San Joaquin County 2023–2031 Housing Element Update. Available at: https://archives.hud.gov/reports/plan/ca/alamedca.html; https://www.sjgov.org/docs/default-source/community-development/planning/other/housing-element-update---workshop-presentation.pdf; https://www.sjgov.org/docs/default-source/community-development/planning/other/housing-element-public-review-draft.pdf

Figure 7: Homeowner vs. Renter Attrition Rate

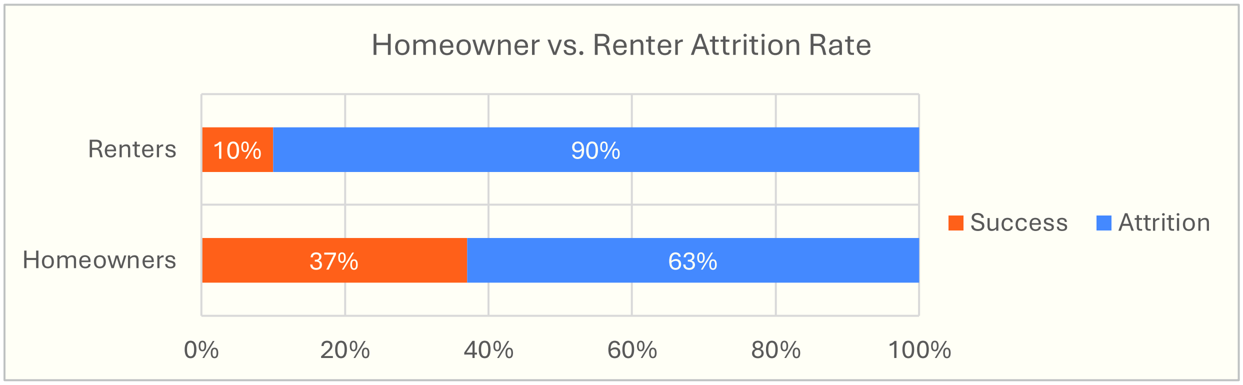
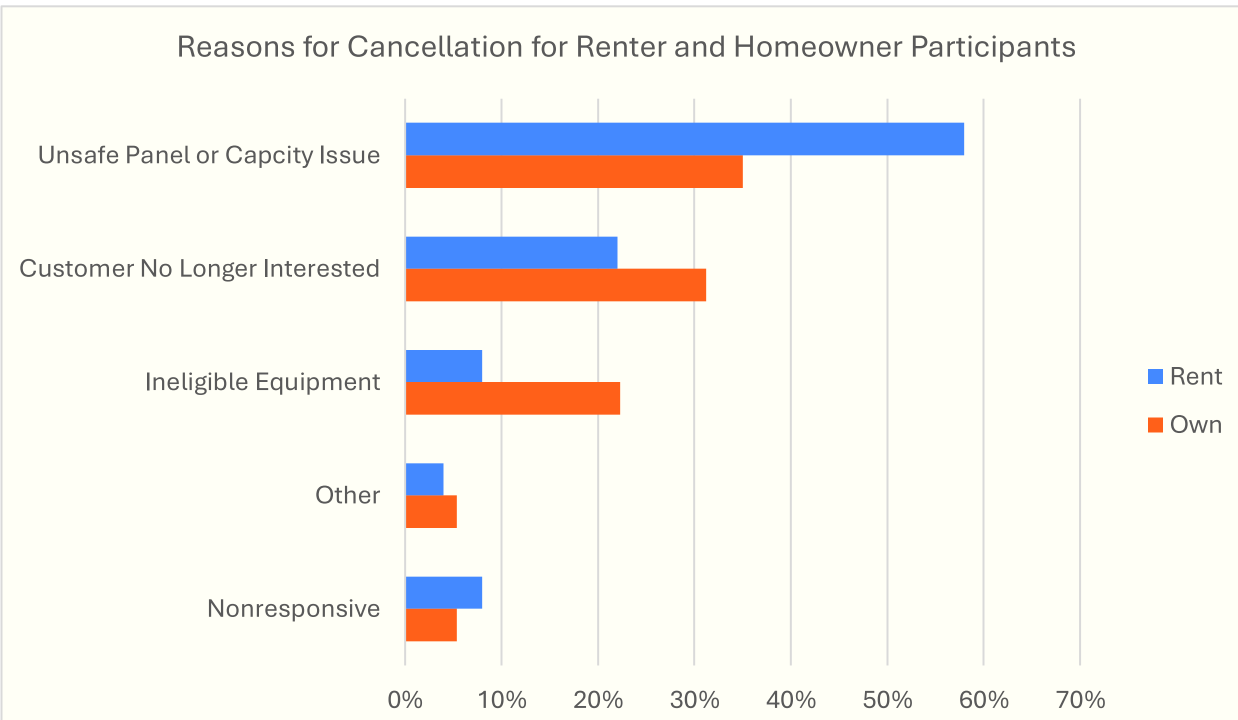


Figure 8: Reasons for Cancellation for Renter and Homeowner Participants as a Proportion of Total Cancellations



Multifamily vs Single-family Homes

Another metric that was tracked at the time of application was the building type at the project site, defined as multifamily (four units or less) or single-family homes.

While living in a multifamily home is not indicative of income status, multifamily housing is a primary housing type for accommodating lower-income households and expanding affordable housing opportunities. Both Alameda and San Joaquin County Housing Elements identify higher-density residential and multifamily development as key strategies for accommodating the region's lower-income housing allocation[3]. As a result, multifamily properties represent an important opportunity for delivering equity programs and services.

This analysis looks at application rates, attrition rates, and reasons for cancellation of customers living in multifamily versus single-family homes.

Figure 9: Eligible Applications from Customers Living in Multifamily vs. Single-family Homes

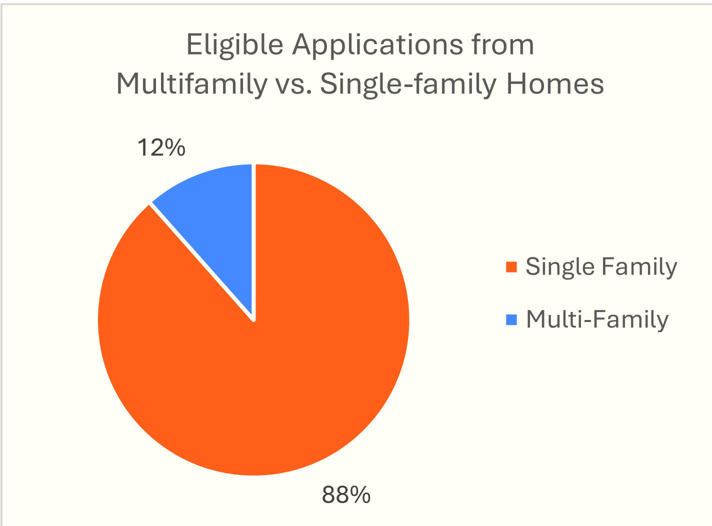
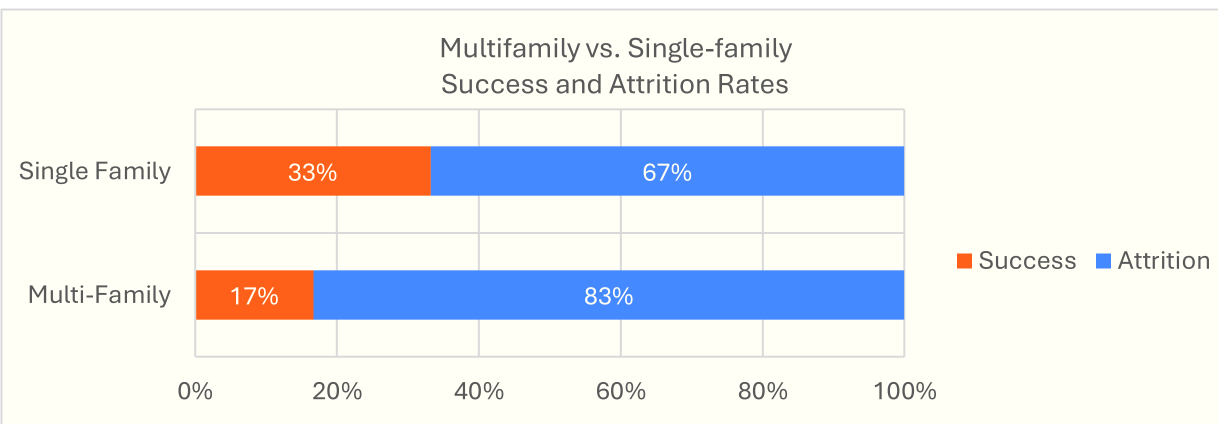
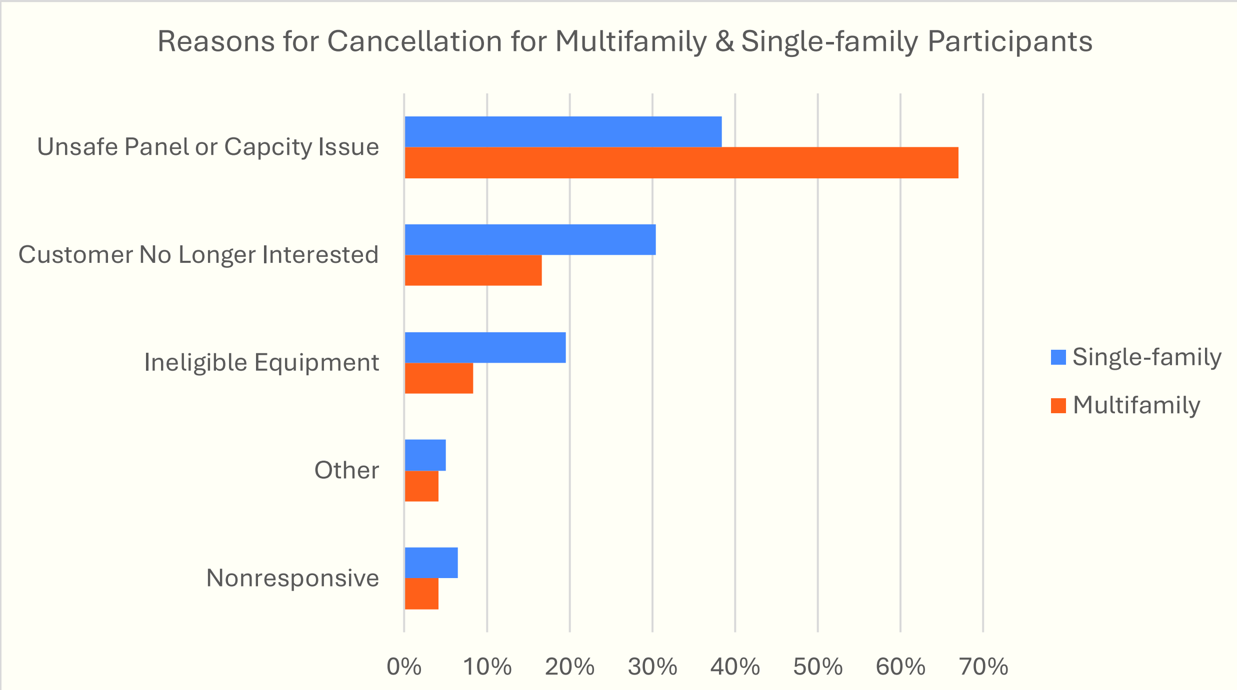


Figure 10: Multifamily vs. Single-family Participant Success and Attrition Rates



[3] **Source:** Alameda County 2023–2031 Housing Element: https://www.acgov.org/cda/planning/housing-element/housing-element.htm; San Joaquin County 2023–2031 Housing Element Update: https://www.sjgov.org/commdev/cgi-bin/cdyn.exe/file/Planning/Other/Housing%20Element%20Update%20-%20Workshop%20Presentation.pdf

Figure 11: Reasons for Cancellation for Multifamily and Single-family Participants as a Proportion of Total Cancellations



Key Takeaways

- ◊ Interest in the Pilot was higher among eligible homeowners vs. renters, as well as customers living in single-family vs. multifamily homes.
- ◊ Attrition rates were higher if a participant was a renter or they were living in a multifamily home.
- ◊ It was more common for a project to be cancelled due to unsafe panel or electrical capacity issues if a participant was a renter or they were living in a multifamily home.
- ◊ There is a greater need for panel replacements to support electrification for these customer segments.

Electric Readiness

This Pilot set out to study the existing electrical infrastructure of program participants. While this Pilot did not support panel replacements, the Energy Advisor and the installer were instructed to look for opportunities to optimize the existing electrical panel and infrastructure. This was done through the reorganization of circuits and breakers, as well as the installation of sub-panels, tandem breakers, and circuit switches.

As noted in previous sections, panel issues were a leading reason for project cancellation. In all, 21% of homes assessed by the Energy Advisor (69 out of 324) had either unsafe electrical system components, unsafe panel conditions or insufficient panel capacity. This was especially prevalent among multifamily and tenant-occupied homes.

Unsafe Panel/Electrical

Of the homes assessed, 14% (44) had an unsafe panel and/or unsafe electrical conditions. Electricians will not work on a project that involves a recalled panel or electrical infrastructure that fails basic safety inspections unless the necessary replacements are made to remedy the panel and/or electrical systems.

Manufacturers of recalled panels that were encountered during the Pilot include Zinsko, Stab-Lok, Sylvania, and Federal Pacific. Other safety conditions of note included pest infestations, fuse box/panel location too close to the ground (requiring relocation), melted breakers, missing panel enclosures, and unsafe wiring throughout the home.

Panel Conditions

Upon assessing each home, the Energy Advisor inspected the panel's condition and assigned a rating of good, fair, poor, or failed.

Table 10: Panel Conditions (n=218)[4]

Panel Condition	All Data Collected	% of Total	Installed Projects	% of Installed Projects
Failed/Needs Repair	12	6%	0	0%
Poor	26	12%	0	0%
Fair	3	1%	17	10%
Good	177	81%	145	90%

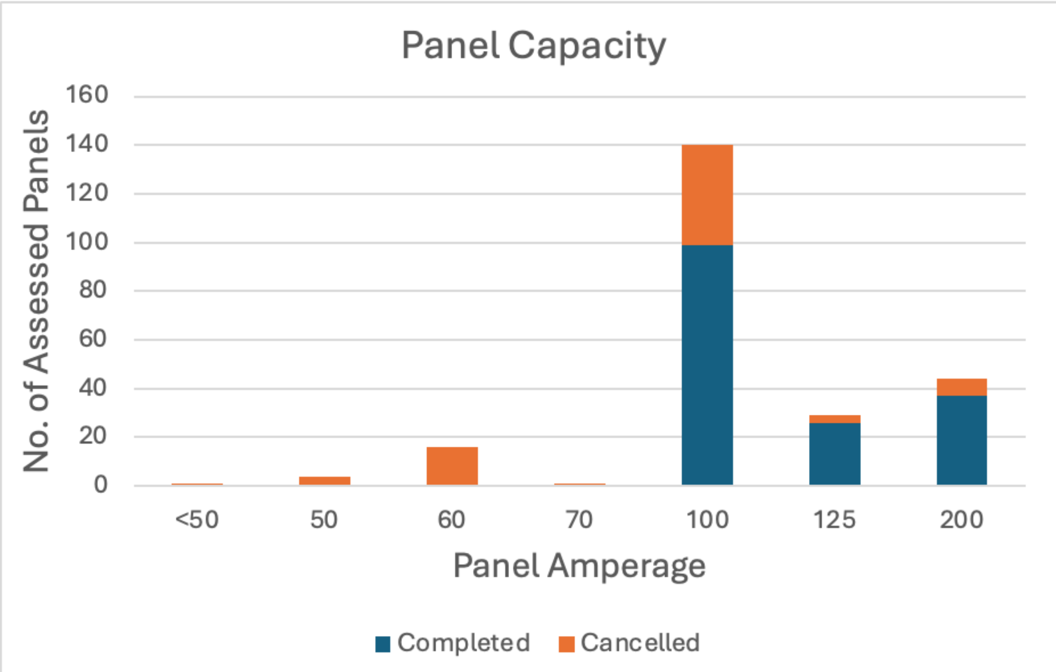
Panel Capacity

Panel amperage data was collected by the Energy Advisor during most site visits. While it is widely accepted that most homes do not utilize the full capacity of their panel under normal conditions, the induction range required 40 to 50 amps, a sizable percentage of

[4] Due to a system data collection failure at the beginning of the Pilot, some panel data was not properly captured for cancelled projects. This issue was corrected during the Pilot to ensure as much data was collected as possible. This analysis utilizes what data was made available.

available capacity for most panels. Panel optimization measures were utilized to increase project viability for capacity-constrained panels.

Figure 12: Panel Capacity (in Amps) for Completed and Cancelled Projects (n=235)[5].



Note: Cancellations in this analysis were not necessarily related to panel capacity.

Key Takeaways

- ◊ All completed projects were done on 100 amps or greater.
- ◊ Panels that had less than 100 amps could not be sufficiently optimized to accommodate an additional 40 or 50 amp circuit.
- ◊ Recalled or unsafe panels requiring replacement were a common occurrences for this Pilot.
- ◊ While Panel conditions were mostly “good” to “fair”, nearly 20% of panels were categorized as being in poor condition, or failed the inspection altogether. No projects moved forward under these conditions.

[5] Due to a system data collection failure at the beginning of the Pilot, some panel data was not properly captured for cancelled projects. This issue was corrected during the Pilot to ensure as much data was collected as possible. This analysis utilizes all available data.

Air Quality

The air quality results were analyzed by Berkeley Air. The full analysis is found in the *Indoor Air Quality Assessment for Health-E Communities Pilot Program: Final Report* (see Attachment 1). Key findings are summarized below.

Key Takeaways

- ◊ Considerable reductions in nitrogen dioxide (NO_2) with most homes experiencing some level of NO_2 decrease.
  - o The overall median concentration decreased by 70%, suggesting that large improvements were common across participants, not driven by a small number of outliers.
  - o 98% of the study homes experienced a decrease in the number of minutes per day – **a median decrease from 13 minutes/day to 0 minutes/day** - that NO_2 concentrations exceeded 101 parts per billion (ppb), the US EPA threshold above which exposures are considered unhealthy for sensitive groups, including children.
- ◊ Reductions in carbon monoxide (CO) were moderate, showing an overall median CO concentration decreased by 17%.
- ◊ Carbon dioxide (CO_2) remained stable.
- ◊ Changes in particulate matter ($PM_{2.5}$) was variable, with a slight observed increase, although results were not statistically significant.
- ◊ With the significant reduction in NO_2 observed in the Pilot and given the latest research linking NO_2 to pediatric asthma, a positive health outcome is likely attributable to stove electrification. However, more research is needed to understand the true impacts of human exposure to gas stoves.

Key Lessons Learned

This section outlines the lessons learned that could be leveraged for scaling a larger, more impactful electrification program beyond induction stove replacements.

- ◊ One possible way to avoid electrical capacity, project eligibility, and potential issues that will create permitting challenges is to **consider virtual in-home assessments at the beginning stages of each project.** This could reveal unsafe or insufficient panels, ineligible equipment, or other factors that would prevent a project from moving forward and reduce the amount of staff time on projects that are ineligible.
- ◊ Permitting for a 240V circuit run/range installation was highly variable across permitting agencies in terms of requirements, contractor effort, and timelines. **Ample buffer time should be included in forecasting project timelines to allow for permit timeline flexibility.** A sophisticated approach could include forecasting permit wait times by jurisdiction, considering past permitting experiences, and known permit requirements and processes. Alternatively, **working directly with permitting agencies to streamline permitting timelines and standardize requirements** for electrification projects could significantly reduce barriers.
- ◊ When permits are required, there should be **consideration that additional code compliance issues—unrelated to the scope of the program—could be uncovered** at homes/sites during inspection. This can trigger project delays and increased costs for both the program administrator and/or the customer. Additionally, communication with participants should be clear regarding this potential outcome.
- ◊ Site-readiness issues, including panel capacity and unsafe electrical/panel conditions, were common and should be considered during program design and when planning for attrition or delays, especially when targeting low-income communities. **Adding a panel replacement measure would substantially decrease attrition, but at a significantly higher cost.** This would also increase project viability of multifamily buildings and tenant-occupied homes.
- ◊ While the scale and scope of this Pilot did not require marketing and outreach tactics beyond email, as targeted email outreach to eligible customers generated sufficient demand to keep the Pilot pipeline full, a larger effort could benefit from working with community-based organizations and other public agencies to gain trust and broaden outreach efforts, especially in low-income communities.
- ◊ Further market research could be conducted to understand perceived customer hold-ups and hurdles to adopting induction technology. These insights could be used to better maintain customer interest.

Conclusion

While the Health-e Communities Pilot did not demonstrate a scalable, cost-effective model that could serve a broader segment of Ava's customers, it did provide important learnings to support Ava's Local Development program planning and design. The Pilot demonstrated that barriers to electrification need to be overcome for a similar delivery model to be successful at a significantly larger scale, as indicated throughout the key takeaways and lessons learned detailed throughout this report.

Many issues identified in this report related to timelines and project complexity can be overcome with good program design and execution; however, increasing customer interest and awareness of induction technology—especially within the low-income customer segment—will take significant time and effort. Additionally, more emphasis should be placed on increasing project viability for multifamily and tenant-occupied homes in future efforts.

While the scope and scale of this Pilot did not necessitate partnering with community-based organizations for outreach, leveraging partnerships with local organizations should be considered in larger program efforts to increase customer interest and trust.

Finally, it should be noted that the air quality analysis was successful in measuring impacts on indoor air pollution from electrification and obtaining statistically significant results. However, the scope and depth of the analysis need to be broadened, and cooperation with healthcare providers is likely needed before expanded insights between electrification and health can be achieved. Further understanding would require significant additional resources, logistical complexity, and customer burden for each project, which would also contribute additional challenges to the scalability of a direct install program for induction stoves.

Appendix A:
Site Visit Data Collection Questions and Fields

Customer Information:

- Have you experienced any particularly long power outages in the last year?
- How many people live in the home?
- Is the customer interested in learning more about financing?

Electrical:

- Additional Slots w/Sub Panel
- Circuit throttling/pausing device
- Circuits to Be Shared
- Existing circuit behind oven?
- Existing circuit behind range/cooktop?
- Existing Subpanels
- Main Panel Shutoff Breaker Capacity
- Overhead or Underground
- Panel Condition
- Panel Location
- Panel Manufacturer
- Panel Type
- Service Size
- Sub Panel Amps
- Total # Available Slots
- Total # Slots
- Wire type

Home Information:

- Age of Cooling System
- Age of Heating System
- Age of Water Heating System
- Condition of the Cooling System
- Condition of the Heating System
- Condition of the Water Heating System
- Cooktop burner type
- Cooktop Fuel Type:
- Current cooling technology(ies)
- Current heating technology(ies)

- Dryer Fuel Type:
- Heating Fuel
- Heating Location
- Kitchen Style
- Location of Water Heating System
- Number of bedrooms in house
- Number of floors in house (including basement)
- Oven baking type
- Size of house
- Type of cooktop/oven
- Type of Heating System
- Type of Water Heating System

Appendix B: Program Participation Agreement

FRANKLIN ENERGY™

Health-E Communities Program

Program Participation Agreement

Enrolled Date: ___________________________

Property Resident Name: ____

Property Address: ____

City: ____ Zip: ________________ Phone Number: ___________________________

Email Address: ____

Property Owner Name (if different from Property Resident's Name): ________________________________ Phone Number: __________

Acknowledgement

I hereby understand and agree to the following provisions:

a. I agree to the Health-E Communities Program ("Program") Eligibility Requirements and other Terms and Conditions, below.
b. I agree to allow the Health-E Communities measures listed below ("Measures") to be installed at the Property listed above.
c. These Measures are free of charge and are under the Property Owner's ownership upon installation.
d. All proposed Measures are subject to change until time of installation.
e. The Measures shall remain operational and unaltered in the Property for a period of at least one (1) year.
f. The parts and labor are under warranty with the installing contractor(s) ("Installer(s)") for a period of one (1) year. AVA and Franklin Energy make no representation or warranty, express or implied, regarding the design, installation, or use of the Measures.
g. I agree to allow all installed Measures to be inspected and checked by Ava Community Energy ("AVA") or an AVA-approved third-party inspection entity upon request.
h. In no event shall AVA, Franklin Energy, or the Installer(s) be liable for failure of the Measures to achieve energy savings. Property Resident and/or Property Owner waive any and all claims against AVA, Franklin Energy, and/or the Installer(s) arising out of Property Resident and/or Property Owner's participation in the Program.
i. Property Owner certifications:
   - I certify that I own the Property listed above.
   - I certify to the best of my knowledge I have not previously received a rebate or free installation for measures installed at the Property.
j. By signing this Form, I authorize the Installer to enter the Property for the purposes of installing any Measures agreed to in this Form, inspecting installed Measures, and evaluating the performance of the Measures. I authorize AVA and/or Franklin Energy to enter the Property for the purposes of evaluating the performance of Measures and conducting quality assurance and quality control inspections as needed.

Under penalty of perjury, I certify that the information provided is true and accurate to the best of my knowledge, and that I understand and agree to the terms.

Property Resident Signature: ____ Date: ____________________

Property Owner Signature (if different from Property Resident): ________________________________ Date: ____________________

Installer Signature: ____ Date: ____________________

Health-E Communities Measures Scope of Work

	MEASURE NAME
1	
2	
3	
4	

	MEASURE NAME
5	
6	
7	
8	

Health-E Communities Program Eligibility Requirements and Terms and Conditions

The Health-e Communities Program is a direct-install program for customers with chronic pulmonary diseases to replace their existing gas stoves with an induction stove. AVA will conduct a pilot phase of the program ("Pilot") to understand and inform design of a larger program. The Pilot will also serve as a research opportunity to further understand the linkage between electrification and indoor air quality, exposure to natural gas, and human health.

1. **PARTICIPANT ELIGIBILITY:** Participant must be the homeowner – or – if tenant occupied, property owner must be party to this Agreement and provide authorization for work to commence. If tenant occupied, the homeowner/property owner will serve as primary point of contact for any construction related approvals or communications.

   Must be an active customer of Ava Community Energy.

   Customer/site must be enrolled in CARE, FERA, or have obtained designation as affordable housing. Acceptable forms of affordable housing documentation include:

   - Welfare tax exemption
   - Low-income housing regulatory agreement
   - Copy of recorded deed-restriction

2. **QUALIFYING MEASURES:** Qualifying Measures include electric measures identified as eligible for installation by AVA's implementation contractor Franklin Energy, or Franklin Energy's subcontractor ("Installer"), based on the in-home assessment and/or on-site inspection. Qualifying Measures do not include any electric or gas measures or energy-efficient equipment or services purchased, contractor for, or installed prior to the Form Completion Date.
3. **WORK AUTHORIZATION AND PROJECT WORK PLAN:** Installer will meet with the Property Owner and/or Resident to discuss individual property objectives, provide information on options, discuss process, and create a work project and schedule. Installer will schedule and/or monitor the Measure installation.
4. **PROPERTY RESIDENT INFORMATION:** Property Resident agrees that AVA may provide their information including Property Resident's name, account number, electric, gas, and/or water consumption data and electric, gas, and/or water savings to a third party evaluation contractor (which will be selected by either the California Public Utilities Commission [CPUC] Energy Division or by PG&E) and/or to the local water district for Program evaluation purposes. The third-party evaluation contractor will keep this information confidential. Property Resident information may also be provided to the CPUC. Any Property Resident information provided to the CPUC will be aggregated and not personally identifiable. The Property Resident agrees that AVA, Franklin Energy, and Installer(s) may review the property's historic and future energy usage to evaluate, measure, and verify actual energy savings, which includes the use of EPA's Portfolio Manager and the Property Resident-provided utility account information.
5. **TAX LIABILITY and CREDITS:** Neither AVA, Franklin Energy, nor Installer are responsible for any taxes which may be imposed on the Property Resident as a result of the Measures installed under this Program.
6. **DISPUTES:** Except where otherwise limited by law, AVA reserves the right, at its sole discretion, to make the final determination regarding any disputes related to
the Program.
7. **PROGRAM CHANGES:** AVA reserves the right to change, modify, or terminate this Program at any time without any liability except as expressly stated herein. Installer(s) will honor all written commitments made in the Scope of Work provided to Property Resident prior to the date of any change, modification, or termination of this Program, provided that Measure installations are fully completed within the time specified in a Scope of Work.
8. **PROGRAM EXPIRATION:** This Program will expire upon the earliest to occur: (i) December 31, 2025; (ii) when funds are depleted; or (iii) when the Program is terminated.
9. **DISCLAIMER:** AVA and Franklin Energy make no representations or warranties, express or implied, and does not guarantee that implementation or use of the Measures purchased or installed pursuant to this Program will result in energy cost savings.
10. **SOLE RECOURSE:** Upon execution of this form, Property Resident and/or Property Owner's sole recourse for any remedy related to installation or use of the Measures is with the Installer. Property Resident and/or Property Owner waive all claims against AVA and Franklin Energy.

Attachment:
Final Report by Berkeley Air Monitoring Group

Indoor Air Quality Assessment for Health-E Communities Pilot Program: Final Report

Prepared by Berkeley Air Monitoring Group for Ava Community Energy

December 2025

Table of Contents

Authors and Acknowledgements

Report authors: Katie Kearns, Mafe Aragon, Sydney Jones, and Michael Johnson

Funding: This pilot project was funded by Ava Community Energy.

Acknowledgements: We first want to express our greatest appreciation for the participants, who graciously welcomed us into their homes for this study. We are thankful for staff at Franklin Energy Services for managing monitoring equipment installations, retrievals, and data collection. We appreciate the electrical contractors who managed the induction stove installations. We would like to acknowledge Ricardo Piedrahita for designing, troubleshooting, and generating the customer feedback reports. Finally, we extend our appreciation to Ava Community Energy for funding and implementing the Health-e Communities pilot, and for the Energy Foundation for funding this study.

1) Executive Summary

Program Overview

Ava Community Energy's Health-E Communities program provided free induction stoves, cookware, and electrical upgrades to low-income households to assess how replacing gas with induction stoves affects indoor air quality. Berkeley Air Monitoring Group, in partnership with Ava and Franklin Energy, conducted a pilot study using the following design to evaluate changes in indoor pollutant levels attributed to switching from gas to induction cooking:

- Air quality monitoring in **162 households** across Alameda and San Joaquin Counties in California;
- **Before-and-after design**, with approximately one week of monitoring pre-installation and one week post-installation;
- Four key pollutants – nitrogen dioxide **(NO_2)**, fine particulate matter **($PM_{2.5}$)**, carbon monoxide **(CO)**, and carbon dioxide **(CO_2) –** measured in kitchens; and
- **Individualized air quality reports** provided to each participating household, translating scientific measurements into accessible, household-specific results to support a community-based research approach.

Key Findings

- **Significant and consistent reductions in nitrogen dioxide (NO_2)** were observed after households switched from gas to induction cooking. 98% of the study homes experienced a decrease in the number of minutes per day (from 13 minutes/day to 0 minutes/day) that NO_2 concentrations exceeded 101 ppb, the US EPA threshold above which exposures are considered unhealthy for sensitive groups, including children.
    - This finding confirms the removal of a major indoor combustion source with known health impacts.

- **The observed reductions in CO** were small (from 0.6 ppm to 0.5 ppm, which are well below health-based guidelines); nevertheless, these findings indicate a decrease in another combustion-related pollutant related to cooking.
- **Carbon dioxide (CO_2)**, a marker of ventilation rather than combustion, **remained stable**, suggesting household ventilation behaviors did not change throughout the study.
- **Changes in $PM_{2.5}$ were mixed**.
  - This pollutant is more heavily influenced than NO_2 by cooking practices, ventilation, outdoor air infiltration, and other non-gas combustion-related sources, such as burning incense.

Why These Findings Matter

- **NO_2 is a well-established respiratory irritant** linked to asthma and other adverse health outcomes.
- The observed NO_2 reductions demonstrate that **electrification delivers tangible indoor air quality benefits**.
- Integrating air monitoring into energy-efficiency programs demonstrates a **data-driven approach** for evaluating health impacts.

Future Opportunities

Building on the results of this pilot, community-based electrification programs can expand impact in cost-effective and scalable ways:

- **Scale health evaluation at a low cost**
  - Compact, low-cost air monitors enable meaningful indoor air quality evaluation without complex or expensive infrastructure.
- **Increase return on investment**
  - Measuring NO_2 reductions captures health co-benefits alongside energy savings, strengthening the overall value of electrification investments.
  - Pairing electrification with low-cost, low-burden interventions – such as encouraging range hood use, providing portable air cleaners, or

integrating smart filtration devices – offers an opportunity to further reduce non-combustion-related $PM_{2.5}$ to maximize indoor air quality benefits.

- **Target high-impact households**
    - Future efforts can prioritize households most likely to benefit from reductions in combustion-related pollutants, including:
        - Homes with gas stoves and limited ventilation;
        - Older or smaller housing units; and
        - Households with children or individuals with asthma or other respiratory conditions.

2) Background and Objectives

Cooking with gas is common in U.S. homes but has important implications for health. Burning gas indoors releases pollutants, such as nitrogen dioxide (NO_2), fine particulate matter ($PM_{2.5}$), and carbon monoxide (CO), which can worsen indoor air quality and increase the risk of respiratory and cardiovascular disease.[1–5] Research has consistently shown that homes with gas stoves have higher levels of NO_2, a pollutant linked to asthma and other respiratory conditions, particularly in children.[3,6–11]

Despite growing awareness of these health risks, few real-world studies have measured the impact of replacing gas stoves with electric or induction models in occupied homes. Early evidence suggests that transitioning away from gas can substantially reduce indoor pollutant levels, especially NO_2, but more data are needed to understand these benefits across diverse households and living conditions.[4,12–17]

Across the U.S., there is increasing momentum to transition households toward cleaner, more efficient energy use. Many states and cities have adopted or proposed measures to reduce fossil fuel reliance in buildings, and utilities are offering new incentives for households to upgrade to electric appliances.[18–22] Yet, the up-front cost of new equipment and electrical upgrades can make these opportunities inaccessible for lower-income households, who are often most affected by poor indoor and outdoor air quality due to proximity of lower-income neighborhoods to pollution sources (e.g., major roads, power plants), respiratory health impacts such as asthma, and higher energy burdens.

Ava Community Energy's Health-E Communities Program helped close this gap by providing free induction stoves, cookware, and electrical upgrades to vulnerable households. In partnership with Ava, Berkeley Air Monitoring Group conducted a pilot study to characterize how replacing gas stoves with induction stoves affects indoor air quality. This collaboration aimed to generate practical, community-based evidence on the potential health benefits of electrification, helping to inform future programs and policies that promote clean and healthy homes for all residents.

3) Study Design and Methods

Study Population and Recruitment

Participants were recruited through Ava Community Energy's Health-E Communities pilot program, which offers free induction stoves, electrical upgrades, and cookware to income-qualified households within Ava's service area. Franklin Energy Services was contracted by Ava to provide implementation support services for stove installation, including subcontracting with electrical contractors. Outreach for recruitment was conducted directly by Ava to its customers through email and digital newsletters. The Health-e Communities pilot process is illustrated in **Figure 1**, below.

Figure 1. Health-e Communities Pilot Process

All households selected for the air quality monitoring component were those eligible for stove replacement and who consented to participate in the monitoring study.

A total of 162 households were initially enrolled for the pilot study. These homes represent a diverse cross-section of Ava's service area, spanning urban and suburban neighborhoods across Alameda County, California and the cities of Tracy, Stockton, and Lathrop in neighboring San Joaquin County, California.

Monitoring design

Each participating home was monitored for at least one week before and one week after induction stove installation. Instruments were installed in kitchens by trained electrical contractors following standardized placement protocols to minimize disruption to regular household activities. Field technicians from Franklin Energy and Berkeley Air checked and prepared the instruments before deployment to ensure proper function and data quality.

Instrumentation

Homes were monitored in the kitchen using either the Personal Air Monitor (PAM) (2Btech, USA; **Figure 2**) or the Atmocube (Atmotech Inc., USA; **Figure 3**). Both are small, nearly silent, portable, and easy-to-use instruments. They use a suite of time-integrated sampling and time-resolved sensing technologies[1] to measure $PM_{2.5}$, NO_2, CO, and CO_2, which are relevant to housing quality, combustion, and ventilation as follows:

- **Nitrogen dioxide (NO_2):** A gas emitted by gas stoves and other combustion sources; linked with asthma symptoms and respiratory irritation.[2,7,8,23]
- **Fine particulate matter ($PM_{2.5}$):** Small particles from combustion, cooking activities (especially frying and searing), dust, and other sources.
- **Carbon monoxide (CO):** A safety-related pollutant generated by incomplete combustion.
- **Carbon dioxide (CO_2):** An indicator of ventilation and indoor airflow; elevated levels can signal poor circulation or overcrowding.

An example real-time plot from the PAM is provided in Annex A.

[1] **Time-integrated measurements** reflect average pollution levels over longer periods, whereas **time-resolved measurements** record rapid changes in pollutant levels over time.

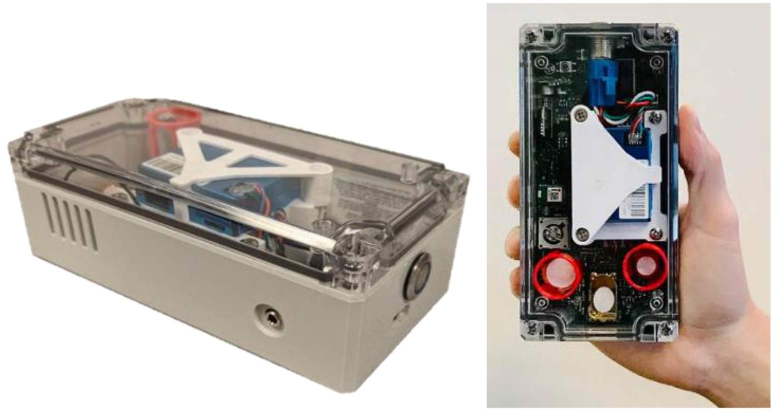


Figure 2. Personal Air Monitor (PAM) by 2Btech

Figure 3. Atmocube by Atmotech Inc.

Quality Assurance and Control

Quality assurance and control procedures were built into every step of the monitoring process to ensure that the air quality results are reliable and meaningful.

Before deployment, each PAM was checked, factory-calibrated, and programmed by Berkeley Air staff to ensure consistent performance across all devices. The monitors were verified for accurate time settings, battery life, and data recording.

During installation, trained field technicians followed standardized placement guidelines so that monitors were positioned in comparable locations within each kitchen (approximately 1 meter horizontally from the stove and 1.5 meters in height), typically near the stove but away from windows or vents. This consistency helped ensure that the "before" and "after" measurements could be directly compared.

After collection, all data files were reviewed by Berkeley Air scientists for completeness and consistency. Timestamps were standardized to local time, and any files with missing data or irregularities were flagged for further review. All files underwent "sense checks" to check for extreme or unrealistic values. Files were flagged if the duration was less than 48 hours.

All air quality measurements were reviewed for data quality before analysis. Extremely low or negative values—known to occur occasionally with air sensors—were treated as zero so that they did not affect overall results. Nitrogen dioxide (NO_2) was handled separately for Atmocube monitors, which estimate elevated NO_2 levels indirectly rather than measuring them directly as the PAM does (see Conversion of raw sensor readings to hourly/daily averages).

Finally, all cleaned and validated data were saved in a structured format by household ID, ensuring that each file could be traced back to its original measurements. These quality assurance and control (QA/QC) steps helped guarantee that the final dataset reflects true differences in indoor air quality before and after the induction stove installations, rather than artifacts from equipment limitations or data handling.

Handling of outliers and missing data

Occasional equipment malfunctions or power interruptions led to missing data in the "before" or "after" monitoring period, or rarely, both. If data were missing only for the "after" period, homes were resampled when scheduling permitted. Households with missing "before" data were excluded, since a complete paired comparison was not possible.

During the post-processing phase of the data, plots were generated to visualize and check for extreme outliers. Only one outlier was observed, which had a mean NO_2 concentration approximately an order of magnitude higher than the rest of the data points. After closer inspection of the full sampling period, data for that household were removed due to unusually high levels of instrument noise (high variability in minute-to-minute NO_2 readings).

Conversion of raw sensor readings to hourly/daily averages

Unlike the PAMs, the Atmocube monitors do not directly measure nitrogen dioxide (NO_2). Instead, they report an "NO_x index," which reflects *changes* in nitrogen oxides detected near the stove, rather than absolute concentrations. To interpret these index values, it is common practice to co-locate low-cost sensors with research-grade instruments, allowing index-based readings to be meaningfully related to NO_2 concentration spikes.

We conducted a comparison test using a research-grade reference NO_2 monitor[24] co-located with the Atmocube for several weeks. This allowed us to detect when the Atmocube readings corresponded to elevated NO_2 levels on the research-grade instrument, specifically our set threshold of 101 ppb, the level above which concentrations are considered unhealthy for sensitive groups.[25,26] The cleaned and interpreted data were summarized for each household and linked with survey responses and other monitoring results. These steps helped ensure that the reported NO_2 findings reflected true differences in air quality rather than sensor noise or data errors.

Data analysis

We evaluated changes in indoor air quality associated with the stove replacement by comparing measurements collected before and after the transition from gas to electric cooking. Each household's pre- and post-installation samples were paired using a unique household identifier, allowing for direct comparisons for each home.

Only households with valid measurements in both time periods were included in paired analyses for a given pollutant. As a result, sample sizes vary slightly across pollutants depending on data availability.

Statistical summaries and significance testing

For each pollutant ($PM_{2.5}$, NO_2, CO, and CO_2), we evaluated air quality levels in each household before and after the induction stove installation, and summarized the results to provide the mean and median levels during the sampling period.

In addition to average pollutant levels, we also examined how much time each day a given pollutant's concentrations exceeded levels commonly used in health and air quality safety guidance.[26] We summarized the average minutes per day above these thresholds before and after the stove replacement to measure changes within homes and across the study population.

For $PM_{2.5}$, NO_2, and CO, indoor air quality was evaluated using concentration thresholds corresponding to the Air Quality Index (AQI) category "Unhealthy for Sensitive Groups (AQI 101-150).[27] The AQI as the threshold provides a familiar, health-relevant reference point for interpreting short-term indoor pollutant levels. AQI values are a unitless scale, with lower levels indicating better air quality and higher levels indicating worse air quality. The air pollutant concentrations that correspond to lower threshold for the "Unhealthy for Sensitive Groups(AQI 101), are indicated in **Table 1** below.

For CO_2, we referenced the American Society for Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE)'s Standard 62.1, which provides informative guidance on indoor CO_2 levels relating to human comfort and ventilation, which is not enforceable or health-based, but can be used to contextualize indoor ventilation conditions.

These analyses provide a clear picture of how indoor air quality changed following induction stove installation, with a focus on conditions most relevant to health.

Table 1. Pollutant concentration thresholds used for analysis. Air Quality Index (AQI) levels are from the US EPA.[27]

AQI category	Pollutant	Lower-bound concentration for AQI category (AQI 101)
Unhealthy for Sensitive Groups	$PM_{2.5}$	35.5 μg/m^3
Unhealthy for Sensitive Groups	NO_2	101 ppb
Unhealthy for Sensitive Groups	CO	9.5 ppm
Not included in AQI (contextual indoor air quality metric informed by ASHRAE)	CO_2	1100 ppm

Participant Air Quality Reports

Household air quality reports were generated and shared with each participating household following completion of monitoring (an example report from this study is provided in Annex B). These reports translated the air monitoring data into summaries designed for a non-technical audience and provided participants with direct feedback on indoor air quality conditions in their own homes.

Each report summarized kitchen air quality measurements collected before and after the induction stove installation for the four pollutants. Results were presented using bar plots showing the average number of minutes per day that pollutant concentrations met or exceeded the thresholds provided in Table 1.

In addition to household-specific results, the reports included brief explanations describing why each pollutant is important, what factors can influence indoor concentrations (e.g., cooking practices, ventilation, and infiltration of outdoor air pollutants), and how to interpret changes observed before and after the stove replacement.

By providing air quality results directly to participants, this study prioritized transparency and community engagement, helping households understand how electrification affected their indoor environment. Participants were encouraged to reach out to Berkeley Air scientists directly with questions about their results, creating opportunities for communication and clarification. In addition, participants completed surveys related to household characteristics cooking practices, and ventilation behaviors during the household visits with the field technicians, which provided important context for interpreting their air quality measurements during analysis. Together, this approach supports community-based research principles by translating scientific measurements into meaningful, actionable information and helping participants contextualize the health relevance of clean energy interventions within their own homes.

4) Key Findings

A total of 162 participants were recruited to the study. Due to technical issues (e.g., instrument power-offs during the sampling period, SD card malfunctions), data from 22 households were not available. An additional 5 households were dropped due to QA/QC failures (including the one with notably high NO_2 noise), and the other four homes' sampling durations were too short. The final sample size, based on available data, was 135.

Air monitoring results are presented for the individual pollutants in the following sub-sections, and are later presented together in Combined Pollutant Results.

Survey Results

Survey responses provide context for the air quality findings and describe participant cooking and ventilation behaviors (**Table 2**). Stove use frequency and range hood use remained largely unchanged before and after induction stove installation, **supporting the interpretation that the observed reductions in NO_2 were driven primarily by the stove transition.**

Most range hoods vented exhaust outdoors, while a smaller proportion vented back into the kitchen or had unknown venting configurations (i.e., the field technician was not able to confirm whether the exhaust was vented outdoors or back into the kitchen). Although nearly 20% of participants reported that they “almost always” use their range hood when they cook, 25% reported that they never used it, which **may help explain why non-combustion emissions from cooking (e.g., $PM_{2.5}$ from frying) did not consistently decline** after switching from gas to induction.

Window use during cooking was also generally limited. Most households reported keeping windows almost always closed, with relatively few households regularly opening windows during the day, highlighting the importance of source control and mechanical ventilation in reducing indoor air pollution.

Basic household characteristics provide additional context for interpreting indoor pollutant concentrations and ventilation potential across homes. Households had a median of 3 occupants (interquartile range [IQR], defined as the 25th–75th percentile: 1–4), typically with 3 bedrooms (IQR: 2–3) and a single floor (IQR: 1–2). Most homes had either a dedicated kitchen or an open kitchen layout, with fewer households reporting a galley-style kitchen.

Table 2. Household characteristics and self-reported cooking and ventilation behaviors among participating homes.

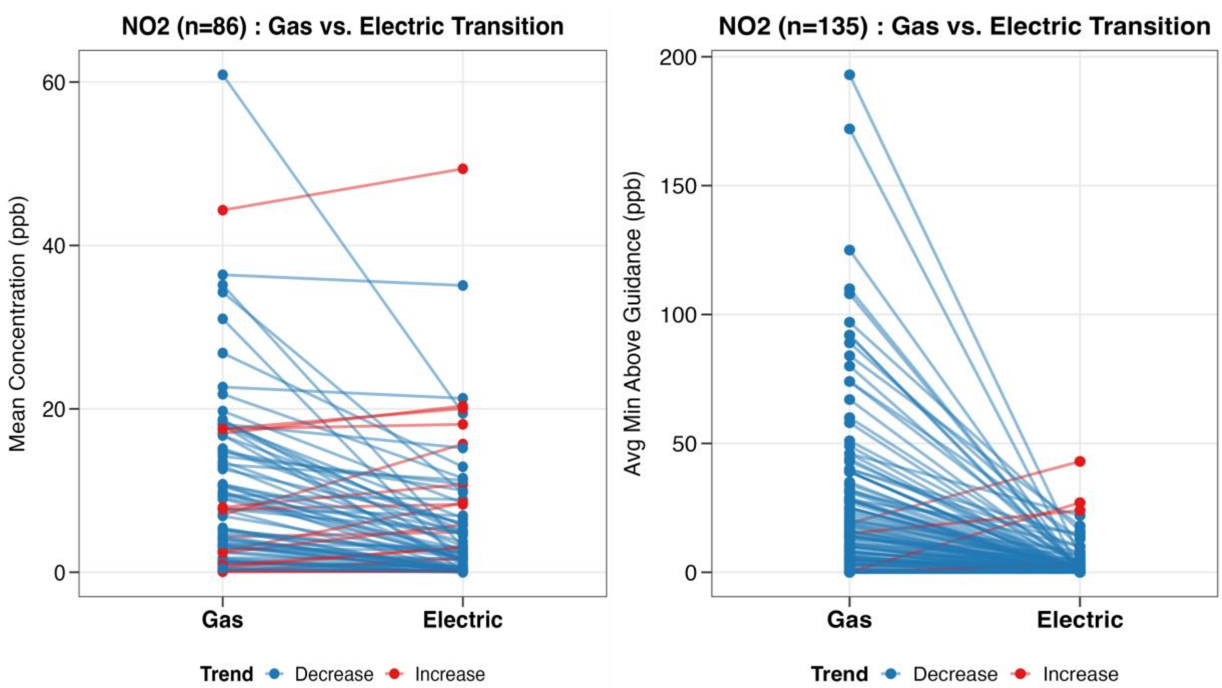
	n	%
Size of house		
1000 or less sq ft	26	19.4
1000-2000 sq ft	98	73.1
2000-3000 sq ft	9	6.7
3000 or more sq ft	1	0.7
Kitchen style		
Open	52	38.8
Galley	21	15.7
Own Room	61	45.5
Typical stove use – Gas		
Once or less per day	40	32.0
2-3 times per day	76	60.8
4+ times per day	9	7.2
Typical stove use – Induction		
Once or less per day	39	31.0
2-3 times per day	79	62.7
4+ times per day	8	6.3
Range hood vent flow		
Outdoors	101	75.9
Back into the kitchen	12	9.0
Unknown / Could not confirm	20	15.0
Typical range hood use		
Never	31	24.6
Occasionally	70	55.6
Almost always	25	19.8
Range hood use since stove swap		
Less	32	25.4
The same	92	73.0
More	2	1.6
Window use		
Almost always closed	117	92.9
Open during day, closed at night	7	5.6
Open at night, closed during day	1	0.8
Almost always open	1	0.8

Percentages may not sum to 100 due to rounding. Denominators may vary due to missing responses.

Nitrogen Dioxide (NO_2)

NO_2 levels decreased substantially after the switch from gas to induction.

Median nitrogen dioxide (NO_2) **concentrations decreased by 70%,** from 7.7 ppb with gas stoves to 2.3 ppb after electrification ($p < 0.0001$). Improvements were also evident in peak, health-relevant concentrations. Median time above the NO_2 threshold of 101 ppb declined from **13 min/day during gas cooking to 0 min/day after electrification ($p < 0.0001$)**. Of the 135 homes with NO_2 data, 132 experienced fewer NO_2 exceedances after the stove swap, while only three homes showed an increase.



These findings suggest that the intervention was highly effective in reducing health-impacting NO_2 exposures.

Figure 4. Mean NO_2 concentrations during gas versus electric cooking (left) and average minutes per day with NO_2 concentrations exceeding the 101-ppb threshold (right). Blue bars indicate a reduction following the induction stove swap, while red bars indicate an increase. NO_2 concentration data are from the PAM only, as the Atmocube does not directly measure NO_2.

Carbon Monoxide (CO)

CO concentrations also declined following the transition, with median concentrations **decreasing by 17%** (from 0.6 ppm to 0.5 ppm; $p < 0.0001$). Although baseline CO concentrations were generally low, these reductions reflect the removal of another combustion-related pollutant from the kitchen.

Median time above the CO threshold of 9.5 ppm **declined from 1 min/day before electrification to 0 min/day** afterward ($p < 0.0001$), indicating reduced potential for short-term peak exposures during cooking events.

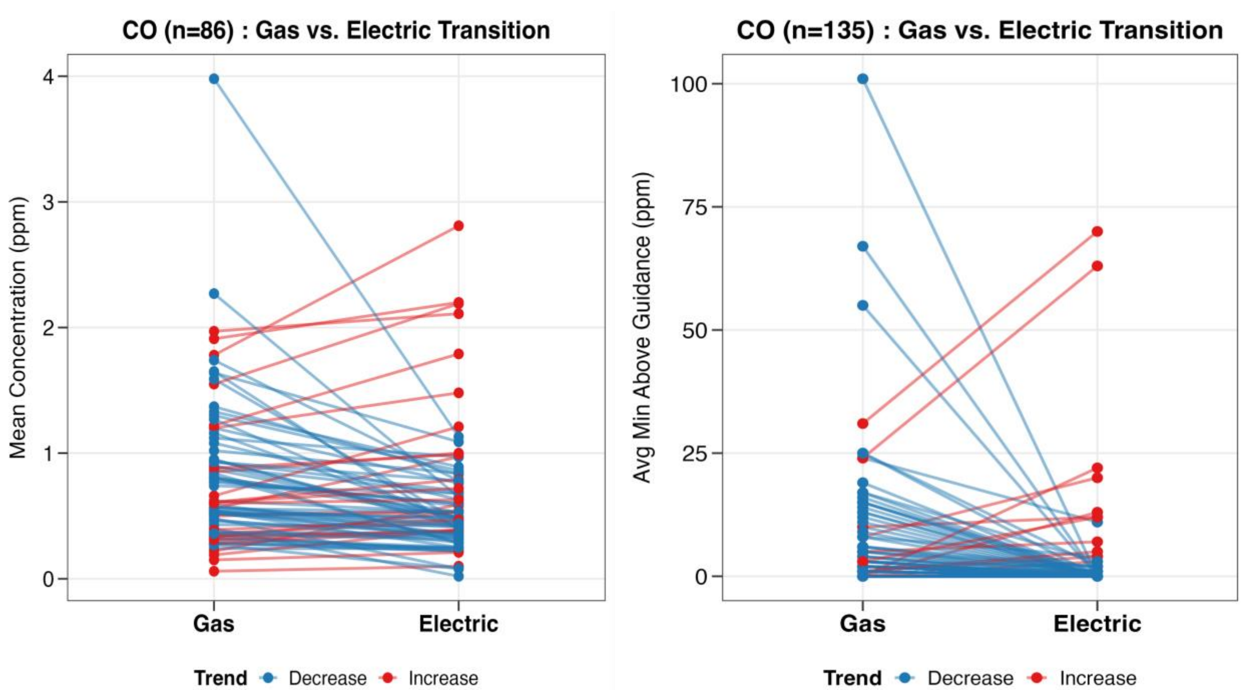


Figure 5. Mean CO concentrations during gas versus electric cooking (left) and average minutes per day with CO concentrations exceeding the 9.5 ppm threshold (right). Blue bars indicate a reduction following the induction stove swap, while red bars indicate an increase. Concentration data are from the PAM only, as the Atmocube has an upper threshold of 10 ppm.

Fine Particulate Matter ($PM_{2.5}$)

Changes in fine particulate matter were more variable across homes. Median $PM_{2.5}$ concentrations increased modestly after electrification (a **22% increase**), though this change was **not statistically significant** ($p = 0.117$). Median minutes above the threshold (35.5 µg/m³) increased from **14 min/day** before electrification to **15 min/day** after the transition, corresponding to a **7% increase**, which was not statistically significant ($p = 0.16$).

This variability is consistent with $PM_{2.5}$ being influenced by factors beyond stove fuel, including cooking practices, ventilation, and outdoor air infiltration.

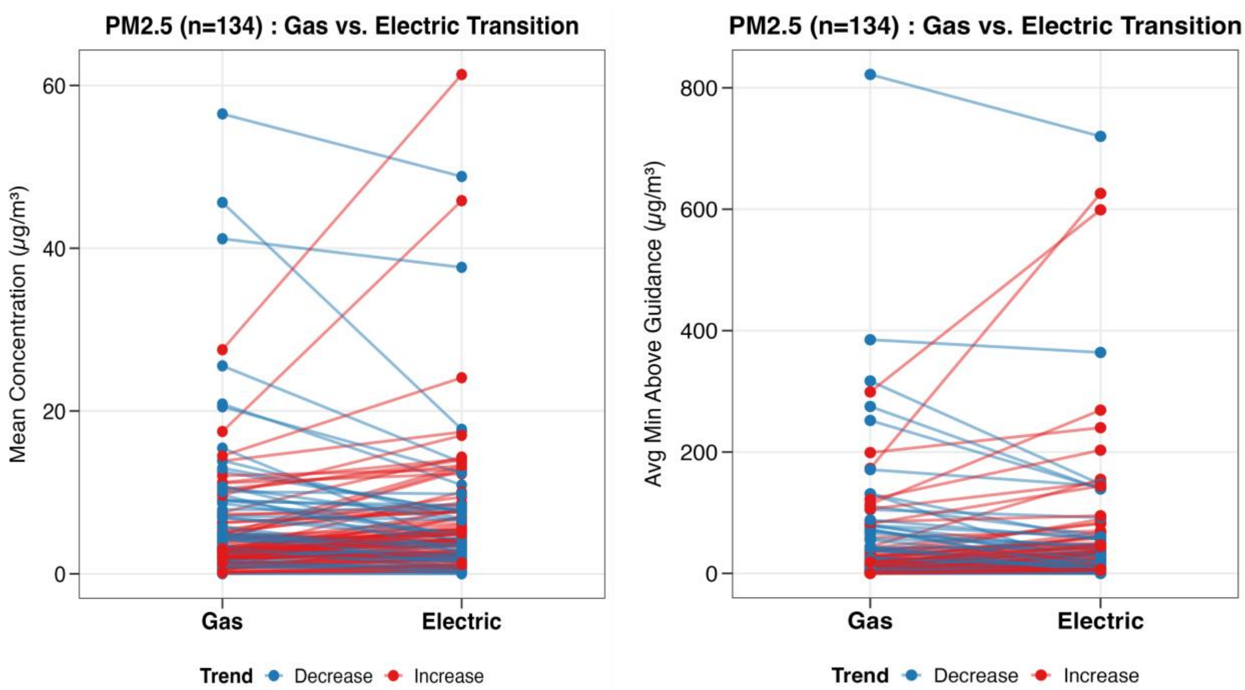


Figure 6. Mean $PM_{2.5}$ concentrations during gas versus electric cooking (left) and average minutes per day with $PM_{2.5}$ concentrations exceeding the 35.5 µg/m³ threshold (right). Blue bars indicate a reduction following the induction stove swap, while red bars indicate an increase.

Carbon Dioxide (CO_2)

Carbon dioxide concentrations remained largely stable following the stove transition. **Median CO_2 concentrations decreased slightly (4%)**, and this change was statistically significant ($p = 0.016$).

In contrast, time above the CO_2 threshold (1100 ppm) declined substantially. Median minutes above this threshold decreased by **75%**, from **61 min/day** before electrification to **15 min/day** afterward ($p = 0.01$). These findings suggest reduced combustion-generated CO_2 from cooking without major changes in household ventilation behavior.

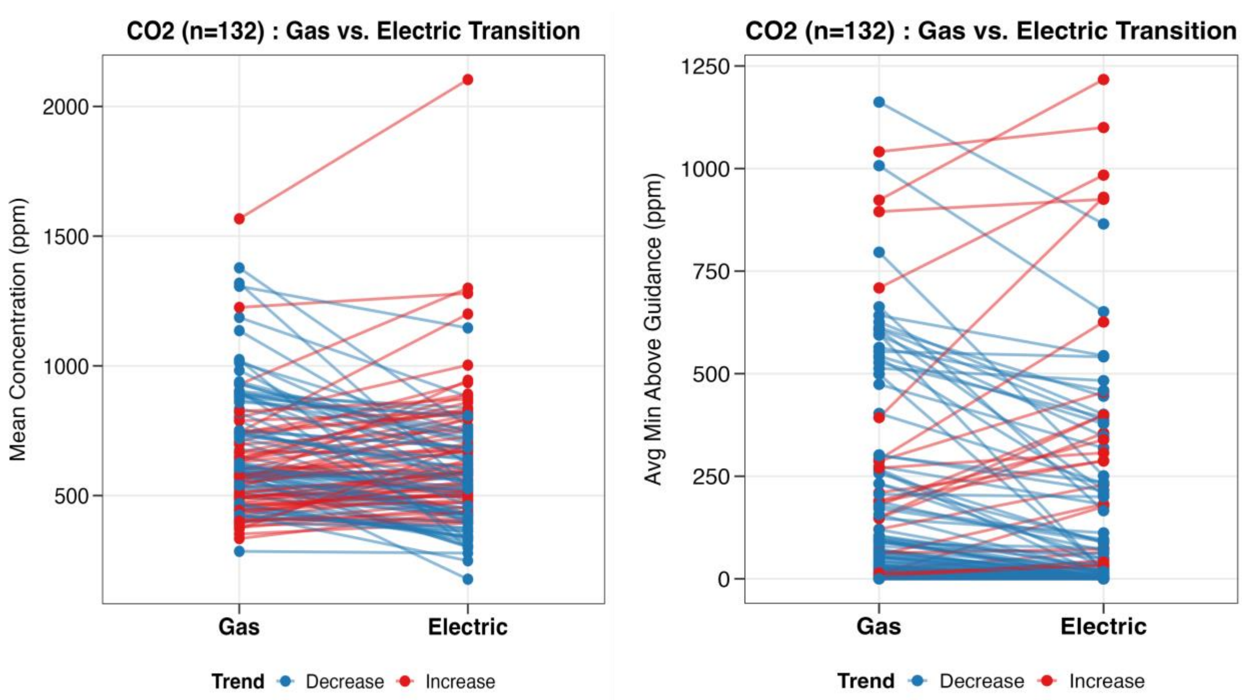


Figure 7. Mean CO_2 concentrations during gas versus electric cooking (left) and average minutes per day with CO_2 concentrations exceeding the 1100 ppm threshold (right). Blue bars indicate a reduction following the induction stove swap, while red bars indicate an increase.

Combined Pollutant Results

Pollutant summaries were combined to provide a holistic picture of how indoor air quality changed following electrification. Indoor air pollutant concentrations measured before and after the transition from gas to electric cooking are presented in **Figure 7** and **Table 3,** and **Figure 8** and **Table 4** summarize the minutes per day indoor air pollutant levels were above health-based thresholds before and after induction stove installation.

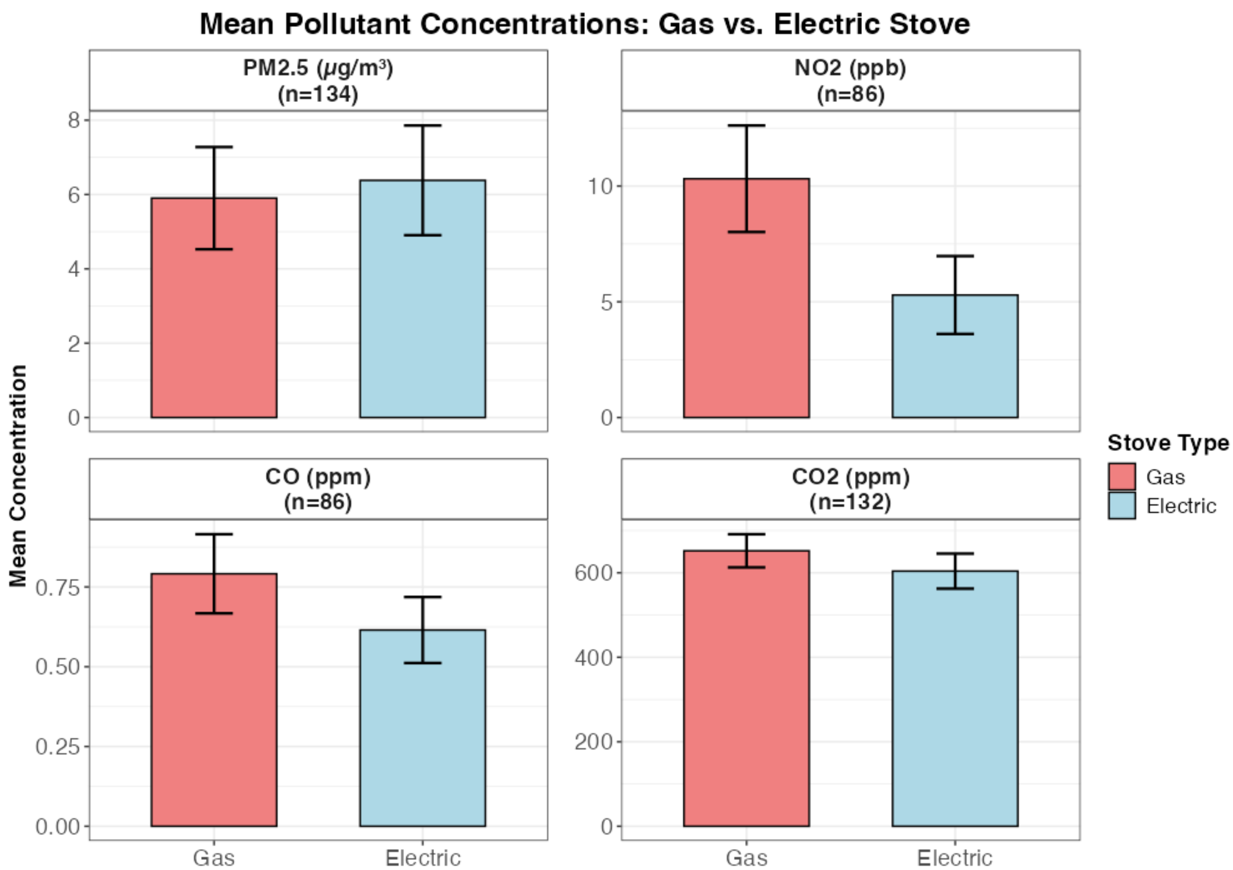


Figure 8. Mean pollutant concentrations for $PM_{2.5}$, CO, NO_2, and CO_2 by stove type. Bars show mean concentrations across homes with valid pre- and post-installation measurements; error bars indicate 95% confidence intervals. NO_2 and CO results are shown for PAM monitors only, as the Atmocube reports an NO_x index rather than NO_2 and has an upper CO measurement limit of 10 ppm.

Table 3. Summary of indoor air quality measurements in homes before and after switching from gas to electric cooking. P-values indicate whether changes were statistically meaningful (e.g., p-values < 0.05 are considered statistically significant and are shown in bold). Given that the Atmocube device does not directly measure NO_2 and has a maximum cut-off value of 10 ppm for CO, data for those pollutants are summarized for the PAM only.

	$PM_{2.5}$ µg/m³	**NO_2 ppb**	**CO ppm**	**CO_2 ppm**
BEFORE (GAS)				
n	134	86	86	132
Mean (SD)	5.9 (8.1)	10.3 (10.9)	0.8 (0.6)	652 (230)
Median (IQR)	3.2 (1.9-6.9)	7.7 (2.5-15.1)	0.6 (0.4 - 1.0)	592 (490-748)
AFTER (ELECTRIC)				
n	134	86	86	132
Mean (SD)	6.4 (8.7)	5.3 (8.0)	0.6 (0.5)	604 (243)
Median (IQR)	3.9 (2.1-7.6)	2.3 (0.3-6.5)	0.5 (0.3-0.7)	571 (436-715)
Difference in medians (%)	22 ↑	70 ↓	17 ↓	4 ↓
p-values	0.117	**<0.0001**	**<0.0001**	**0.016**

Notes: SD = standard deviation; IQR = Interquartile range (75% of the data is contained between the lower and higher number)

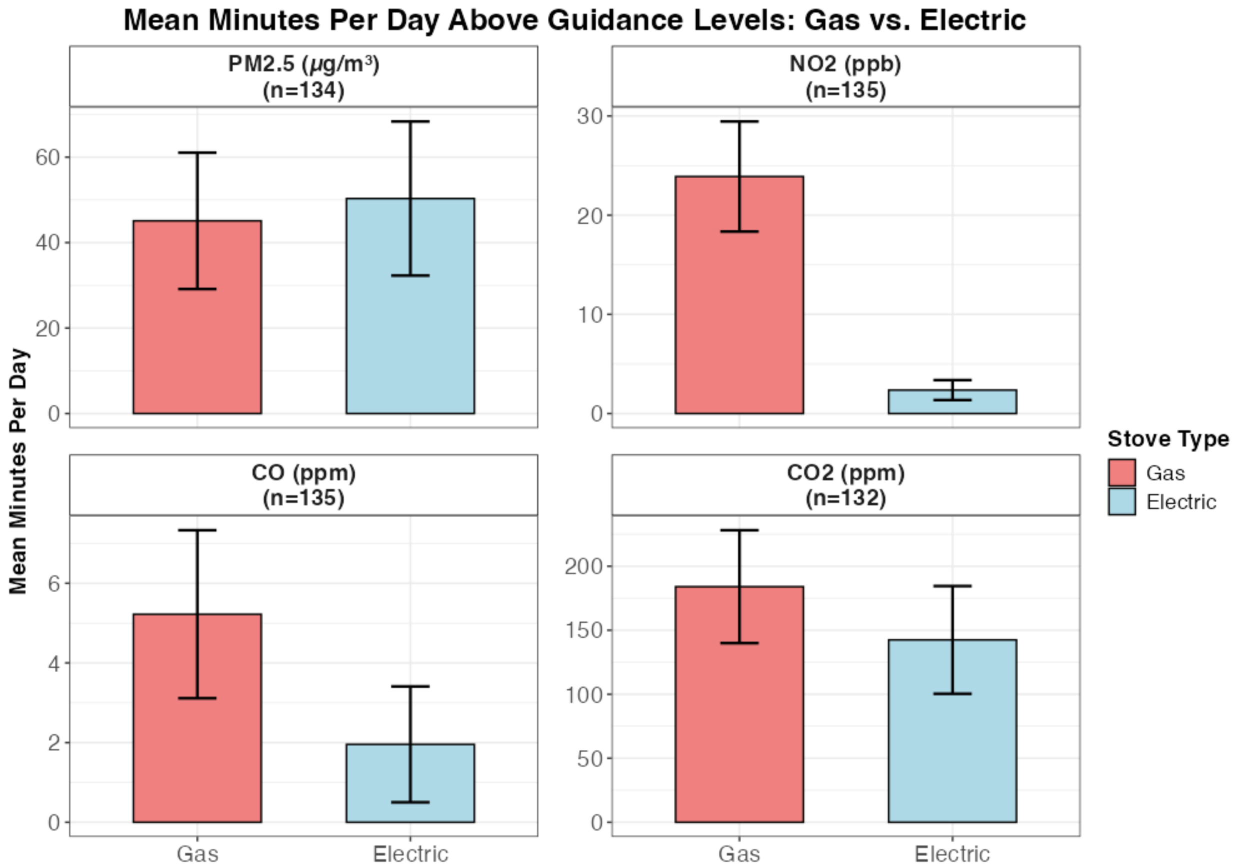


Figure 9. Mean minutes per day above guidance levels for $PM_{2.5}$, CO, NO_2, and CO_2 by stove type. Bars represent mean household-level minutes across 135 homes; error bars represent 95% confidence intervals. Comparisons illustrate substantial reductions in time above guidance levels for combustion-related pollutants (NO_2 and CO) following the transition to electric stoves, while changes in $PM_{2.5}$ and CO_2 were smaller and more variable.

Table 4. Summary of the number of minutes per day that indoor air pollutant measurements exceeded health-based guidelines. The concentration equivalent for each pollutant's threshold is given in the table below. P-values indicate whether changes were statistically meaningful (e.g., p-values < 0.05 are considered statistically significant and are shown in bold).

	$PM_{2.5}$	NO_2	CO	CO_2
Threshold	**35.5 µg/m^3**	**101 ppb**	**9.5 ppm**	**1100 ppm**
BEFORE (GAS)				
n	134	135	135	132
Mean (SD)	45 (94)	24 (33)	5 (13)	184 (258)
Median (IQR)	14 (4-42)	13 (3-30)	1 (0-4)	61 (12-259)
AFTER (ELECTRIC)				
n	134	135	135	132
Mean (SD)	50 (106)	2 (6)	2 (9)	142 (247)
Median (IQR)	15 (6-47)	0 (0-1)	0 (0-0)	15 (0-208)
Difference in medians (%)	7 ↑	100 ↓	100 ↓	75 ↓
p-values	0.16	**<0.0001**	**<0.0001**	**0.01**

Notes: SD = standard deviation; IQR = Interquartile range (75% of the data is contained between the lower and higher number)

Overall Takeaways

The transition from gas to electric cooking resulted in **clear and consistent reductions in combustion-related indoor air pollutants**, particularly NO_2. Both average concentrations and peak exposure metrics showed improvements for NO_2 and CO, while changes in $PM_{2.5}$ were smaller and more variable. Together, these findings demonstrated that **replacing gas with induction stoves effectively reduced the pollutants most directly related to combustion in the study homes.**

5) Interpretation of Results

Our results show a clear reduction in NO_2 concentrations after households replaced their gas stoves with induction units. Gas stoves are a major source of indoor NO_2, so the observed reductions reflect that switching to electric cooking effectively removes this emission source. Lower NO_2 levels represent a meaningful improvement in indoor air quality and suggest a potential reduction in health risks, particularly for respiratory outcomes such as asthma, which have been linked to long-term NO_2 exposure.[2,6,8,9] For example, a community-based study in New York City observed large and sustained reductions in indoor NO_2 concentrations after gas stoves were replaced with induction – findings that helped inform local efforts to address indoor air quality through building and electrification policies.[12]

In contrast, changes in $PM_{2.5}$ were more variable across households. While some homes experienced modest reductions, others showed little change or increases following electrification. This pattern is consistent with prior electrification and clean cooking studies, which have found that indoor $PM_{2.5}$ levels are influenced by a combination of factors beyond stove fuel, including cooking practices, ventilation, and outdoor air infiltration. Although $PM_{2.5}$ remains an important pollutant for overall health, NO_2 serves as a more direct indicator of indoor emissions from gas combustion. The substantial and consistent reductions in NO_2 therefore provide particularly strong evidence of the air quality benefits of stove electrification.

CO levels also declined following the transition to electric cooking, reflecting the removal of another combustion-related indoor pollutant. Although baseline CO concentrations were generally low, the reduction in time spent above health-relevant thresholds indicates an additional improvement in household safety, particularly during cooking events when short-term CO exposures can occur.

CO_2 concentrations showed smaller changes after electrification. Because CO_2 is not itself considered harmful to health at typical concentrations, but instead serves as an indicator of ventilation, these results suggest that overall household ventilation conditions were broadly similar before and after the stove replacement. Modest reductions in CO_2 above guidance levels may reflect changes in cooking-related combustion rather than major shifts in ventilation behavior.

Together, these findings support ongoing efforts to promote clean electric cooking as both an energy and public health intervention. Reductions in indoor NO_2 and CO exposures have particular relevance for respiratory health, especially among children and other sensitive populations, and align with broader goals related to decarbonization and improved household safety.

6) Limitations

Some limitations should be considered when interpreting these results:

- Monitoring captured a snapshot of conditions before and after the stove replacement, and pollutant levels may vary over longer time periods or across seasons as ventilation patterns change. Additionally, detailed information on building characteristics – such as window sealing, air leakage, and mechanical ventilation rates – were not in the scope of this study. These factors can influence ventilation effectiveness and indoor air pollutant accumulation.
- The study monitors were lower-cost, providing indirect, non-reference-grade measures of the pollutants. While the relative changes observed before and after the gas-to-induction stove swap-out provide a clear indication of air quality

improvements, the absolute magnitude of the concentrations and improvements is less certain.

- $PM_{2.5}$ concentrations can be influenced by non-cooking activities, such as cleaning, candle use, or infiltration of outdoor pollution. These activities were not directly measured and may have contributed to observed variability in $PM_{2.5}$ results.
- While the pollutants measured here are among those most commonly measured in similar contexts, future studies could additionally measure compounds such as volatile organic compounds (VOCs) or ultrafine particles, which have been found in fugitive and combustion emissions of gas stoves, though studies characterizing their health risks in these contexts have not yet been rigorously assessed.

Despite these limitations, the consistency of NO_2 reductions across the study, combined with evidence of other research on the indoor air quality impacts of electric cooking, strengthens confidence in the primary conclusions.

7) Conclusions and Recommendations

This pilot study demonstrates that replacing gas stoves with induction cooktops can substantially reduce indoor NO_2 concentrations, a pollutant closely linked to respiratory health. The magnitude and consistency of NO_2 reductions observed across homes indicate that cooking electrification is an effective strategy for reducing combustion-related indoor air pollution, even without changes in cooking frequency or ventilation behavior.

Although changes in $PM_{2.5}$ were more variable, the clear decline in NO_2 highlights the importance of directly targeting combustion sources to achieve meaningful indoor air quality improvements. Together, these findings reinforce the value of electrification as both an energy and public health intervention, particularly in homes with gas stoves and limited ventilation.

Beyond pollutant reductions, this pilot also demonstrates that meaningful, health-relevant indoor air quality evaluation can be conducted at relatively low cost using compact monitoring technologies paired with household surveys. Data collection was integrated into the stove installation process and carried out by trained field technicians, eliminating the need for dedicated air quality field personnel. Incorporating targeted indoor air quality monitoring (particularly NO_2) into residential electrification programs, therefore, represents a practical and scalable approach for capturing health co-benefits alongside energy savings and strengthening the overall return on investment of these interventions.

While this monitoring approach is well-suited for routine program evaluation, more intensive research-level efforts are needed to fully characterize how electrification affects personal exposures and health outcomes. Incorporating personal exposure monitoring and health-focused questionnaires alongside kitchen-based measurements would enable researchers to more accurately capture how reductions in cooking-related emissions translate into changes in individual exposures and respiratory health indicators. These additions require specialized instrumentation, laboratory analysis, and trained personnel, and are therefore best supported through dedicated research investments that complement, rather than replace, routine program monitoring.

Together, routine program-level monitoring and targeted research-grade studies play complementary roles: the former enables scalable evaluation of health co-benefits across electrification programs, while the latter provides the depth needed to advance scientific understanding and inform long-term policy and investment decisions.

This pilot also demonstrates the value of community-based research approaches that prioritize transparency and participant engagement. Individualized air quality reports were provided to each participating household, translating monitoring results into accessible, household-specific information. Sharing results directly with participants can help build trust, support informed decision-making, and ensure that scientific findings are meaningful and actionable for the communities most affected.

The results further point to opportunities for targeting future interventions to households most likely to benefit from reductions in combustion-related pollutants, including homes with poor ventilation, smaller or older housing units, and households with children or individuals with asthma or other respiratory conditions. Incorporating indoor air quality monitoring, exposure assessment, and participant-facing reporting into community-based electrification programs can help prioritize resources, demonstrate co-benefits, and support equitable implementation.

Overall, this pilot provides strong proof of concept that household electrification can deliver measurable improvements in indoor air quality. Ongoing and planned research efforts, including multiple studies currently underway by the California Energy Commission, offer important opportunities to build on these findings at larger scales. By combining scalable monitoring approaches, targeted exposure and health assessments, and clear communication of results to participating households, future programs can more fully characterize and maximize the public health benefits of clean energy transitions.

References

1. Gordon SB, Bruce NG, Grigg J, et al. Respiratory risks from household air pollution in low and middle income countries. *Lancet Respir Med*. Published online September 2014. doi:10.1016/S2213-2600(14)70168-7

2. Ezratty V, Guillossou G, Neukirch C, et al. Repeated nitrogen dioxide exposures and eosinophilic airway inflammation in asthmatics: a randomized crossover study. *Environ Health Perspect*. 2014;122(8):850-855. doi:10.1289/ehp.1307240

3. Lebel ED, Michanowicz DR, Bilsback KR, et al. Composition, Emissions, and Air Quality Impacts of Hazardous Air Pollutants in Unburned Natural Gas from Residential Stoves in California. *Environ Sci Technol*. 2022;56(22):15828-15838. doi:10.1021/acs.est.2c02581

4. Logue JM, Klepeis NE, Lobscheid AB, Singer BC. Pollutant Exposures from Natural Gas Cooking Burners: A Simulation-Based Assessment for Southern California. *Environ Health Perspect*. 2014;122(1):43-50. doi:10.1289/ehp.1306673

5. Seals BA, Krasner A. Health Effects from Gas Stove Pollution. *Rocky Mt Inst Physicians Soc Responsib Mothers Front Sierra Club*. Published online 2020:38.

6. Belanger K, Gent JF, Triche EW, Bracken MB, Leaderer BP. Association of Indoor Nitrogen Dioxide Exposure with Respiratory Symptoms in Children with Asthma. *Am J Respir Crit Care Med*. 2006;173(3):297-303. doi:10.1164/rccm.200408-1123oc

7. Docherty R, Gill M, Shankar S, Turner S, Dick S. Update of a systematic review on associations between environmental exposures and asthma control and exacerbations in young children. *BMJ Open*. 2025;15(8):e091855. doi:10.1136/bmjopen-2024-091855

8. Belanger K, Holford TR, Gent JF, Hill ME, Kezik JM, Leaderer BP. Household levels of nitrogen dioxide and pediatric asthma severity. *Epidemiol Camb Mass*. 2013;24(2):320-330. doi:10.1097/EDE.0b013e318280e2ac

9. Solanki N, Bruckman D, Wang X, Tang A, Attaway A, Khatri S. Nitrogen dioxide, an EPA parameter, may forecast the incidence of asthma exacerbations across urban areas: An observational study. *Pediatr Pulmonol*. 2023;58(1):262-270. doi:10.1002/ppul.26194

10. Jaffe DA, Creekmore A. Emissions and exposure to NOx, CO, CO2 and PM2.5 from a gas stove using reference and low-cost sensors. *Atmos Environ*. 2024;331:120564. doi:10.1016/j.atmosenv.2024.120564

11. Gruenwald T, Seals BA, Knibbs LD, Hosgood HD. Population Attributable Fraction of Gas Stoves and Childhood Asthma in the United States. *Int J Environ Res Public Health*. 2023;20(1):75. doi:10.3390/ijerph20010075

12. WEACT. *Out of Gas, In With Justice: Studying the Impacts of Induction Stoves on Indoor Air in Affordable Housing*. WE ACT for Environmental Justice, Columbia Mailman School of Public Health, Berkeley Air Monitoring Group, RMI, Association for Energy Affordability, New York Housing Authority; 2023. https://www.weact.org/campaigns/out-of-gas/

13. Garrett MH, Hooper MA, Hooper BM, Abramson MJ. Respiratory Symptoms in Children and Indoor Exposure to Nitrogen Dioxide and Gas Stoves. *Am J Respir Crit Care Med*. 1998;158(3):891-895. doi:10.1164/ajrccm.158.3.9701084

14. Dėdelė A, Miškinytė A. Seasonal variation of indoor and outdoor air quality of nitrogen dioxide in homes with gas and electric stoves. *Environ Sci Pollut Res*. 2016;23(17):17784-17792. doi:10.1007/s11356-016-6978-5

15. Mullen NA, Li J, Russell ML, Spears M, Less BD, Singer BC. Results of the California Healthy Homes Indoor Air Quality Study of 2011–2013: impact of natural gas appliances on air pollutant concentrations. *Indoor Air*. 2016;26(2):231-245. doi:10.1111/ina.12190

16. Jaffe D, Nirschl D, Birman S. Occurrence and Mitigation of PM2.5, NO2, CO and CO2 in Homes Due to Cooking and Gas Stoves. *Atmosphere*. 2025;16(7):882. doi:10.3390/atmos16070882

17. Lebel ED, Finnegan CJ, Ouyang Z, Jackson RB. Methane and NOx Emissions from Natural Gas Stoves, Cooktops, and Ovens in Residential Homes. *Environ Sci*. Published online 2022:11. doi:10.1021/acs.est.1c04707

18. Buonocore JJ, Salimifard P, Michanowicz DR, Allen JG. A decade of the U.S. energy mix transitioning away from coal: historical reconstruction of the reductions in the public health burden of energy. *Environ Res Lett*. 2021;16(5):054030. doi:10.1088/1748-9326/abe74c

19. Adebayo TS, Alola AA. Drivers of natural gas and renewable energy utilization in the USA: How about household energy efficiency-energy expenditure and retail electricity prices? *Energy*. 2023;283:129022. doi:10.1016/j.energy.2023.129022

20. Bassett E, Shandas V. Innovation and Climate Action Planning: Perspectives From Municipal Plans. *J Am Plann Assoc*. 2010;76(4):435-450. doi:10.1080/01944363.2010.509703

21. California Energy Commission. Equitable Building Decarbonization Program. current-date. Accessed September 29, 2025. https://www.energy.ca.gov/programs-and-topics/programs/equitable-building-decarbonization-program

22. California Energy Commission. Clean Energy and Pollution Reduction Act - SB 350. Clean Energy and Pollution Reduction Act - SB 350. Accessed January 31, 2024. https://www.energy.ca.gov/rules-and-regulations/energy-suppliers-reporting/clean-energy-and-pollution-reduction-act-sb-350

23. Belanger K, Gent JF, Triche EW, Bracken MB, Leaderer BP. Association of indoor nitrogen dioxide exposure with respiratory symptoms in children with asthma. *Am J Respir Crit Care Med*. 2006;173(3):297-303. doi:10.1164/rccm.200408-1123OC

24. Model 405 nm NO2/NO/NOx Monitor | 2B Tech. Accessed January 6, 2026. https://2btech.io/items/other-monitors/model-405-nm-no2-no-nox-monitor/

25. Environmental Protection Agency. National Primary and Secondary Ambient Air Quality Standards. 40 C.F.R. pt. 50. Published online 1971. Accessed January 5, 2026. https://www.ecfr.gov/current/title-40/part-50

26. US EPA O. NAAQS Table. April 10, 2014. Accessed August 14, 2021. https://www.epa.gov/criteria-air-pollutants/naaqs-table

27. AQI Breakpoints | Air Quality System | US EPA. Accessed September 4, 2025. https://aqs.epa.gov/aqsweb/documents/codetables/aqi_breakpoints.html?utm

Annex A: Example real-time plots

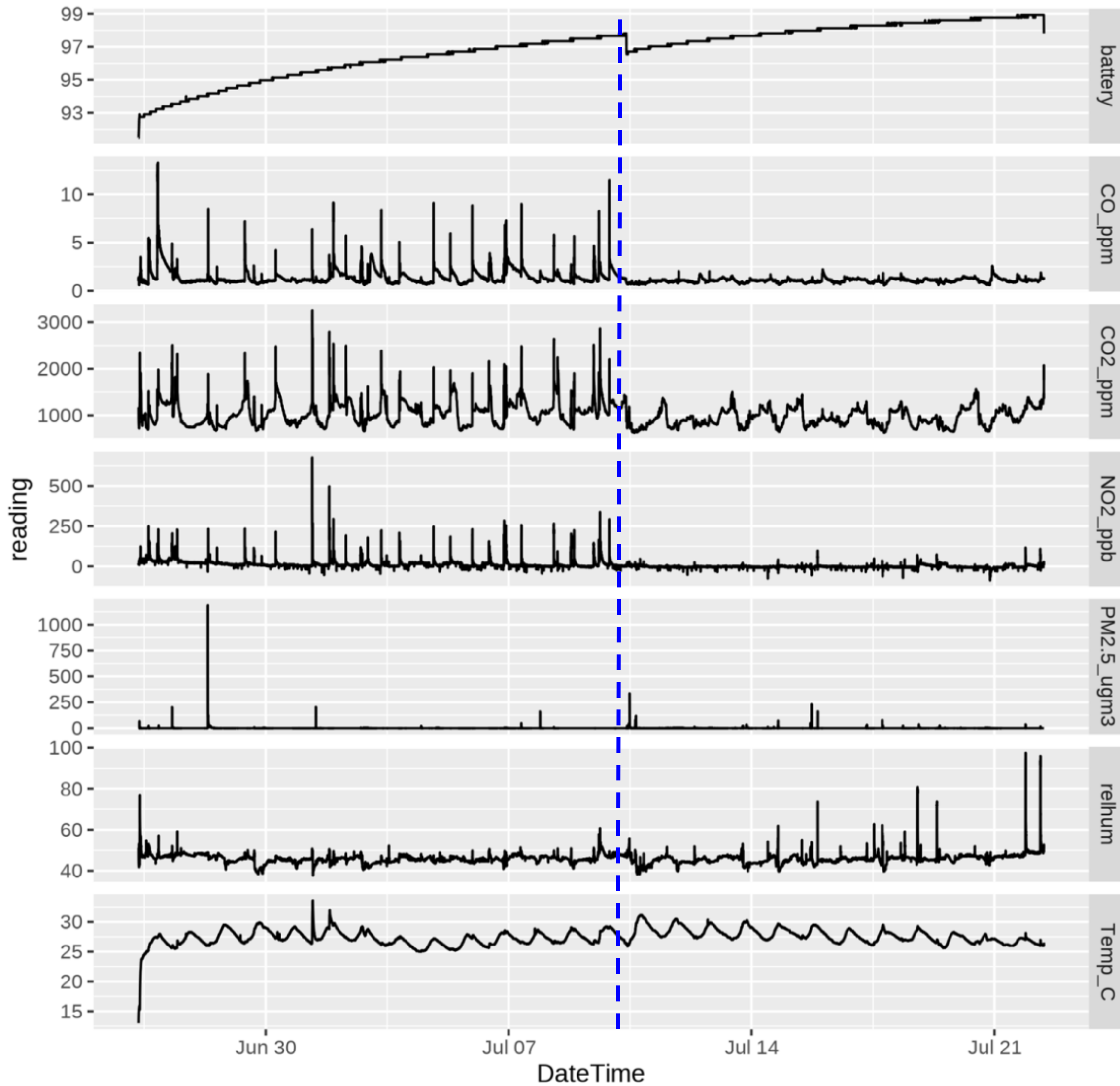


Figure A1. Time series of indoor air quality and environmental measurements from a representative household, including battery level, CO, CO_2, NO_2, $PM_{2.5}$, relative humidity, and temperature. The dashed blue vertical line indicates the timing of the induction stove installation. Pollutant concentrations and combustion-related peaks are visibly reduced following the stove swap.

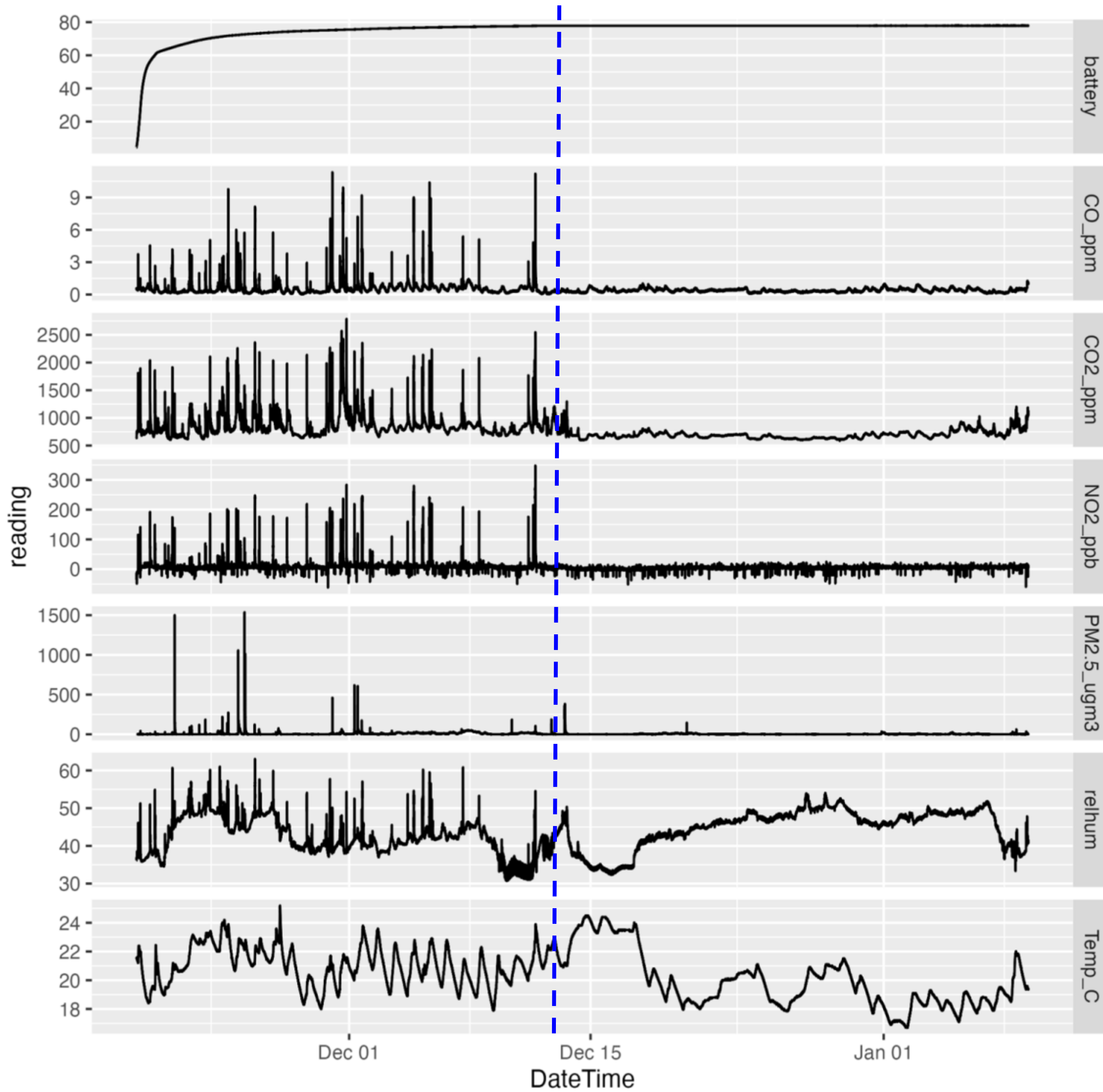


Figure A2. Time series of indoor air quality and environmental measurements from a representative household, including battery level, CO, CO_2, NO_2, $PM_{2.5}$, relative humidity, and temperature. The dashed blue vertical line indicates the timing of the induction stove installation. Pollutant concentrations and combustion-related peaks are visibly reduced following the stove swap.

Annex B: Example air quality report

Ava Community Energy Health-E Communities

Pilot Study - Household Air Quality Report

Dear Participant,

Thank you for participating in Ava Community Energy's Health-E Communities pilot study! This report presents the results of the indoor air quality monitoring conducted in your home before and after the replacement of your gas stove with an induction stove. The pollutants measured in your home were carbon monoxide (CO), carbon dioxide (CO_2), nitrogen dioxide (NO_2), and particulate matter ($PM_{2.5}$). This report includes brief explanations of why each pollutant is important and the results for your home.

Your Results

The results below show the concentrations of pollutants measured in your home before and after the replacement of your gas stove with an induction stove on 2025-09-05. For each pollutant, we calculated the average number of minutes per day during which concentrations met or exceeded thresholds. For CO, NO_2, and $PM_{2.5}$, we used the Air Quality Index (AQI) threshold for 'Unhealthy for Sensitive Groups.' For CO_2, we referenced the American Society for Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE)'s Standard 62.1, which provides informative guidance on indoor CO_2 levels relating to human comfort and ventilation, which are not enforceable or health-based. After switching from your gas to induction stove, we found that CO decreased by 100%, CO_2 decreased by 26%, NO_2 decreased by 100%, and $PM_{2.5}$ decreased by 31%.

Average Minutes per Day Above Guidance Level for Each Measured Pollutant

Pollutant	Before Installation	After Installation	% Change
CO	58	0	-100
CO_2	1179	868	-26
NO_2	111	0	-100
$PM_{2.5}$	13	9	-31

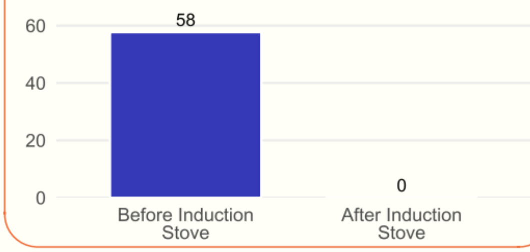
Note:
1. CO, CO_2, NO_2, and $PM_{2.5}$ concentrations are reported as normalized values to enable consistent comparison across the monitoring period.
For more information on air quality standards, visit https://www.airnow.gov/aqi/aqi-basics/
2. While ASHRAE Standard 62.1-2022 does not provide a specific CO_2 threshold, earlier guidance (Technical FAQ35) suggests that indoor CO_2 levels 700ppm above measured outdoor levels are often associated with adequate person-based ventilation.
Outdoor levels are assumed to be 400 ppm, providing us with a benchmark of 1100 ppm for indoor levels. This value is a guideline for understanding ventilation—not a health-based limit.
For more information, please see the following link for free access to ASHRAE's position document on Indoor Carbon Dioxide in English or Spanish: https://www.ashrae.org/about/position-documents

Understanding Your Air Quality Results

Carbon Monoxide (CO)

CO is an odorless, colorless gas produced by combustion. Exposure to high levels of CO can lead to headaches, dizziness, and, in severe cases, poisoning. These extreme cases are exceptionally rare and unlikely to be associated with gas stove use. The CO levels we measured are compared against the AQI category starting at 101, which corresponds to concentrations of 9.5 ppm and above.

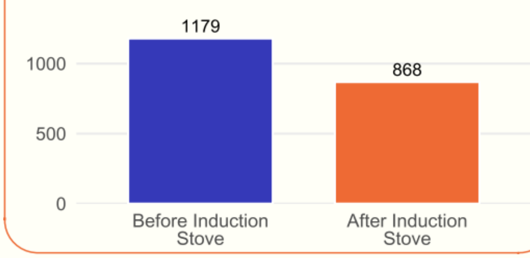
CO (Minutes Above Guidance Level)



Carbon Dioxide (CO_2)

CO_2 is a gas produced from combustion. CO_2 is not directly harmful at typical indoor levels; however, elevated concentrations can indicate poor ventilation, which can make indoor air feel stuffy and contribute to fatigue. Lower CO_2 levels after the stove switch could result from no longer burning gas for cooking. The CO_2 levels we measured are compared to an ASHRAE guideline of 1100 ppm.

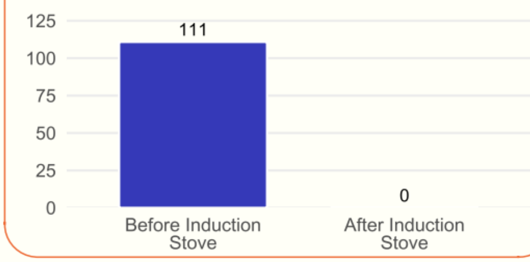
CO_2 (Minutes Above ASHRAE Guidance)



Nitrogen Dioxide (NO_2)

NO_2 is a gas produced primarily by combustion processes, such as those occurring in gas stoves. Exposure to elevated NO_2 levels can aggravate respiratory diseases, including asthma, and reduce lung function, particularly in children and older adults. The NO_2 levels we measured are compared against the AQI category starting at 101, which corresponds to concentrations of 101 ppb and above.

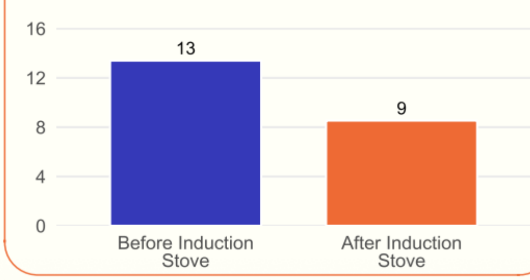
NO_2 (Minutes Above Guidance Level)



Particulate Matter ($PM_{2.5}$)

$PM_{2.5}$ consists of tiny suspended particles generated from combustion and other sources such as dust. Most $PM_{2.5}$ comes from cooking the food, not from burning fuel. $PM_{2.5}$ can be inhaled deep into the lungs, potentially leading to cardiovascular and respiratory impacts. $PM_{2.5}$ concentrations are measured against the AQI category starting at 101, which corresponds to concentrations of 35.5 µg/m³ and above.

$PM_{2.5}$ (Minutes Above Guidance Level)



Interpreting the Results

The data in the charts above show what we measured in your kitchen before and after your gas stove was replaced with the induction stove. With any study, the results may or may not be what you expect. Even if induction stoves generally reduce emissions of pollutants into homes compared to gas stoves, every home is different and other factors can affect the results. For example, having your window open during peak traffic events may cause indoor NO_2 concentrations to increase regardless of stove type. Similarly, $PM_{2.5}$ levels are often more influenced by cooking activities and outdoor air quality than by stove type. Ventilation patterns, weather conditions, and other indoor activities can all impact indoor air quality measurements. It is also important to note that these results are a snapshot in time from just before and after you had your gas stove replaced, and the results could be different if we measured for longer or at different times of the year. You may also have some results that were not available because the instrument did not work properly or the data did not pass quality checks.

Thank you for your participation in this study! If you have any questions or need further clarification, please do not hesitate to contact us.

Contact us: info@berkeleyair.com

Figure B1. Example of an individualized air quality report provided to a study participant, summarizing indoor air quality before and after induction stove installation.