Michigan Induction Cooktop Field Study Pilot

Final Report

January 2026

Slipstream

Upper Peninsula Power Company

Indiana Michigan Power

Prepared by: Dani Ball, Cynthia Segura, Jeannette LeZaks

Acknowledgements: Andrew McNeally, Katie Kern, Martin Gaeta, Connor Trocke, Kevin Gries, Dan Cautley, Pat Hoody, Rebecca Sadler, Allie Cardiel

The team would also like to thank the study participants for their collaboration and contribution to this research.

Table of Contents

List of Tables

List of Figures

Executive Summary

The Upper Peninsula Power Company (UPPCO) and Indiana Michigan Power (I&M) partnered to evaluate the performance, energy impacts, and indoor air quality (IAQ) benefits of induction cooktops compared to conventional gas and electric ranges as part of their energy efficiency and energy waste reduction pilots. The two-year field study monitored 31 homes, 20 with electric ranges and 11 with gas ranges, before and after induction range installation. The results quantify changes in energy use, peak demand, cost, emissions, and IAQ, and also documents participant satisfaction and cooking patterns.

The research team conducted detailed pre- and post-period monitoring of appliance energy use at all sites. For gas-to-induction switches, pollutant concentrations of nitrogen dioxide (NO_2), carbon dioxide (CO_2), carbon monoxide (CO), volatile organic compounds (VOCs), and particulate matter ($PM_{2.5}$) were also continuously monitored. Surveys, interviews, and cooking journals were used to contextualize the monitored data with self-reported cooking habits and satisfaction.

Key Findings and Recommendations

Cooking Time and Habits

On cooking days, participants cooked for an average of 60 to 70 minutes per day. Counting only cooktop minutes (not oven), participants cooked about 50 minutes per cooking day. This time is higher than Michigan Energy Measures Database (MEMD) assumptions.

Thirty-five percent of electric-to-induction participants reported cooking more often after induction range installation, citing faster boil times and improved control. This does not affect claimable savings from increased efficiency, but should be kept in mind in the case that energy conservation is a goal.

Energy Use and Efficiency

Electric-to-induction conversions showed marginal overall energy changes due to increases in oven use habits, but demonstrated stovetop-only savings of ~15 kWh/year, consistent with MEMD assumptions of 17.6 kWh/year.

Gas-to-induction retrofits reduced total cooking energy use by approximately 45 percent, or 1,350 kBTU/year (equivalent to 396 kWh/year). Based on this research, utilities may consider this type of retrofit for future inclusion in energy savings measures.

Peak cooking energy demand occurred at approximately 5pm. Electric-to-induction stovetop switches resulted in reduced grid demand, with a coincidence factor for this peak demand of 0.83. The MEMD, in contrast, currently assumes that since induction ranges have the capacity for higher power functions, they will operate at a higher power on average, resulting in an assumed coincidence factor of -0.002. Utility programs should be structured with the knowledge that functions such as “turbo-boil” did not, in fact, increase peak demand of stovetops on the grid.

Economics

The research team calculated energy cost savings using utility-specific electric rates. Electric-to-induction participants saw no significant change in annual operating costs.

Gas-to-induction participants experienced an increase in cooking energy costs of about $100/year under UPPCO rates and $35/year under I&M rates due to higher electricity prices relative to gas. To mitigate these higher operational costs, utilities can consider allowing appliance adopters to qualify for lower electricity rates upon installation. In the case of a gas-to-induction switch as part of whole-home electrification, participants may save money if they qualify for a space-heating rate and/or eliminate their gas service fees.

Carbon Emission Impacts

Gas-to-induction switches reduced lifetime CO_2 emissions by an estimated 700 kg per appliance over a 16-year lifespan. These environmental benefits should be brought to the attention of customers by utilities, contractors, and distributors should customers be choosing an appliance with environmental goals in mind.

Indoor Air Quality

When cooking with gas for more than 45 minutes in an hour, average NO_2 levels surpassed the World Health Organization (WHO) hourly maximum pollutant concentration threshold guideline. Additionally, when cooking with gas for more than 50 cumulative minutes in a day (less than participants' average daily cook time), modeled NO_2 levels surpassed daily WHO and U.S. Environmental Protection Agency (EPA) threshold guidelines. In contrast, average and modeled NO_2 levels did not surpass these thresholds when cooking with induction. These clear IAQ benefits should be highlighted in program outreach to support beneficial electrification initiatives.

Concentrations of CO_2 and CO also decreased with the range switch, but the reductions were relatively minor in the context of existing health literature.

There are additional contributors to IAQ levels such as outdoor air quality, ventilation, cooking habits, cleaning products, pets, dust, and home improvement projects that contribute to a range of average pollutant levels across sites and time periods. These factors are especially influential for household levels of particulate matter and VOCs, where the induction retrofit yielded the least observable benefit.

Participant Satisfaction

Eighty-seven percent of participants were satisfied with their induction range, noting faster heating, easy cleaning, and improved safety.

A third of participants reported that a noteworthy level of effort was required to learn how to properly use the new induction range, largely due to the touchscreen interface and automatic safety shutoff features. Two participants reported high dissatisfaction tied to model-specific controls (not the induction technology itself). Programs should include clear setup and training resources to help users adapt to induction controls and safety features. This could improve satisfaction and minimize frustration during the transition to the new appliance.

Background

Introduction

The Upper Peninsula Power Company (UPPCO) and Indiana and Michigan Power (I&M) partnered to evaluate the potential energy savings of switching to an induction range from electric or gas appliances as part of their energy efficiency/energy waste reduction pilots. The study also assessed the health and safety benefits of gas-to-induction conversions to inform assumptions used in beneficial electrification program design.

The research team conducted an innovative two-year pre/post monitoring study in 20 homes with electric ranges and 11 homes with gas ranges. We monitored energy use at all sites, which provided metrics to analyze the energy consumption, peak energy demand, and cost and emissions impacts of the induction retrofits. We also measured pollutant levels in the gas-to-induction households. Monitored pollutants included nitrogen dioxide (NO_2), carbon dioxide (CO_2), carbon monoxide (CO), volatile organic compounds (VOCs), and particulate matter ($PM_{2.5}$). We analyzed pollutant concentrations both during cooking events and cumulative daily and compared results to health organization pollutant threshold recommendations. Additionally, we surveyed and interviewed participants to understand their experiences and satisfaction adjusting to and using the induction ranges, as well as to gain insights on cooking habits across the study sample.

This report provides background research, describes the results of the monitoring in terms of energy and indoor air quality impacts, and summarizes participant feedback. The research team offers conclusions and recommendations to integrate induction ranges into utility programs and government policies

Induction Benefits, Incentives, and Barriers

Benefits of Induction Stove Adoption

Induction stovetop technology can offer greater efficiency, precision, and safety compared to traditional gas or electric cooktops (Livchak et al. 2019). Unlike conventional methods that rely on thermal conduction from a flame or electric heating element, induction cooktops use electromagnetic fields to directly heat compatible cookware. This is achieved through a coil of copper wire located beneath the ceramic glass surface of the stove. When an alternating current passes through the coil, it generates a magnetic field that induces electrical currents (known as eddy currents) within the ferromagnetic cookware placed on top. These currents generate heat within the pot or pan itself, allowing for rapid heating and precise burner control.

There are several potential benefits of induction ranges. For one, induction cooktops are more efficient than other cooktop types. According to ENERGY STAR research, induction cooktops transfer about 85 percent of generated energy to cookware, compared to 75 to 80 percent for electric and about 30 percent for gas (ENERGY STAR, n.d.). This increased efficiency can reduce both cooking times and energy consumption. Additionally, because induction stove heat is generated directly in the cookware rather than by the cooktop, the surface does not reach the same high temperatures as electric or gas cooktops, which can lower, though not eliminate, the risk of burns from accidental contact. Lastly, while thermal conduction requires a “lag time” between when a user changes a setting and when the stovetop reaches the intended setting, induction stovetops have an enhanced ability to more precisely adjust temperature, as quantified in a Frontier Energy report (Livchak et al. 2019).

There are nuances related to these benefits that should be kept in mind. For one, though induction stovetops prove more efficient in most field and lab research, some studies have shown that at their highest efficiency, electric stovetops can compete with induction. A lab assessment done by the Electric Power Research Institute homed in on one source of this discrepancy: cookware size. While the induction stove efficiency measurements did not vary between cookware, electric cooktops performed more efficiently with larger cookware (Sweeney et al. 2014) .

Additionally, as with any home upgrade, changes in participant usage habits can outweigh raw energy savings in the field, even though the energy use in the post-retrofit period is at a higher efficiency. We will highlight several electric-to-induction households in this study whose increased oven usage led to increased total energy usage, even though we also measured an increase in their stovetop efficiency.

Induction technology continues to evolve with advances in user interface design, smart home integration, and multi-zone heating. Its growing popularity, driven by energy efficiency and modern kitchen trends, positions it as a key technology in the future of residential and commercial cooking.

Incentives for Induction Stove Adoption

Due to the above operational benefits and based on lab testing, there are several existing induction range savings measures and rebates in the United States.

Most relevant to this study, a utility program savings measure for electric-to-induction retrofits has been approved in Michigan, with a Michigan Energy Measures Database (MEMD) measure citing 17.6 kWh of yearly savings and a $736 incremental installation cost (Michigan Energy Measures Database 2025). This measure prescribes the extent to which utilities in the state can claim savings from induction range installations, allowing the creation of utility rebates for this technology in the future.

Federal Home Electrification and Appliance Rebates, rolled out as part of the Inflation Reduction Act, are also available as of 2025 in a number of states, including Michigan (McCullough 2025). Households can qualify for a rebate of up to $840 when replacing a gas range, often covering incremental installation costs (Department of Environment, Great Lakes, and Energy, n.d.).

Additionally, similar rebates are offered by utilities around the country, including:

- Various induction range rebates citing the energy savings outlined in the CA TRM, available through several CA utilities (California Electronic Technical Reference Manual 2025; Copper 2025).
- Rebates for gas-to-induction retrofits offered in MA through Mass Save (Mass Save 2025).
- A rebate for the purchase of an induction range offered in IL by ComEd (ComEd 2025).
- Rebates for a number of range efficiency upgrades, including switches to induction technology, offered in DC by DCSEU (District of Columbia Sustainable Energy Utility 2025).

Barriers to Induction Stove Adoption
There are several barriers to induction range adoption.

Firstly, induction cooktops are typically more expensive upfront than alternatives, although costs are expected to decline as more models enter the market. Available rebates improve these economics.

Secondly, certain households may require home electric upgrades during an induction range retrofit:

- Gas-to-induction: Most homes with gas ranges do not have a 30-amp dedicated circuit with an outlet available near the range for an induction range to plug into. In this case, a new circuit would need to be installed between the range's outlet and the electric panel, which is typically a $200-300 upgrade. More extensive electric upgrades may be required if the home's electric panel does not have sufficient ampacity.
- Electric-to-induction: Electric-to-induction retrofits typically do not require home electric upgrades. However, some homes may need to upgrade their range's outlet if it does not have proper grounding or cannot accommodate the induction range plug, which is a very small cost.

Thirdly, induction technology requires ferromagnetic cookware (e.g., cast iron or stainless steel with magnetic properties). Aluminum, copper, and non-magnetic stainless steel are not compatible unless modified. Upgrading cookware accordingly may require an additional upfront cost.

Lastly, pacemakers and other medical devices could be sensitive to the electromagnetic nature of induction ranges. People with these devices can often still use an induction range, but should maintain a two-foot distance between a powered-on stovetop and the device (Nhs.Uk 2017; Irnich and Bernstein 2006; Hirose et al. 2005).

Gas Ranges and Indoor Air Quality

The World Health Organization (WHO) emphasizes that even low-level exposure to common air pollutants contributes to increased mortality and morbidity worldwide (WHO Global Air Quality Guidelines, 2021). Other major public health organizations, including the American Public Health Association, the American Lung Association, and the American Thoracic Society, have identified gas range emissions as a contributor to indoor air pollution and a potential public health concern (APHA 2022; ALA 2022; Nassikas et al. 2024). These statements reflect a growing body of literature examining the relationship between indoor combustion, pollutant exposure, and respiratory health outcomes.

Residential gas ranges emit several pollutants that can contribute to indoor air quality (IAQ) degradation. Unlike furnaces or water heaters, which typically vent combustion byproducts outdoors automatically, most residential ranges release them directly into the living space. While certain range hoods can help by venting byproducts outdoors, they often are structured to vent back indoors and/or not used consistently. Pollutants can therefore accumulate indoors, with more pronounced accumulation in smaller dwellings or multifamily buildings due to limited space and shared ventilation systems. In addition, low-income households sometimes rely on gas ovens or ranges for supplemental heating, increasing pollutant exposure (Baxter et al. 2007).

Previous field studies have documented decreases in indoor pollutant concentrations following replacement of gas ranges with induction or other non-combustion appliances (Daouda et al. 2024). Such results should be interpreted in the context of the relevant housing stock, occupant behavior, and ventilation practices. Economic analyses have also explored the net household value of gas-to-induction retrofits, including estimated health benefits (NMR Group, Inc. and Three3 Inc. 2023; Chen et al. 2024), though those findings are outside the scope of this study's measurement objectives.

Drawing on this literature, as well as consultation with IAQ experts, this study focuses on the pollutants most relevant to household exposure during cooking: nitrogen dioxide (NO_2), carbon dioxide (CO_2), carbon monoxide (CO), particulate matter ($PM_{2.5}$ and PM_{10}), and volatile organic compounds (VOCs). Note that this study did not assess direct health outcomes, and the research team does not claim medical expertise. Rather, this study measures changes in indoor pollutant levels associated with gas and induction range operation and compares these concentrations with established health standards to provide context.

The WHO and the U.S. Environmental Protection Agency (EPA) both set pollutant threshold guidelines based on epidemiological and toxicological evidence linking pollutant exposure to adverse health effects. Although these thresholds are not source-specific, they provide a consistent framework for interpreting measured indoor pollutant concentrations. WHO guidelines are derived from meta-analyses of both indoor and outdoor studies. EPA standards are intended to apply only to outdoor pollutant exposure, but are referenced in this report because they are widely used benchmarks in U.S. policy.

Occasionally, we also reference the Regenerative Ecological, Social, and Economic Targets (RESET) IAQ guidelines. This is a set of performance-based building standards developed by GIGA and used globally. Though these standards are intended for commercial buildings, their CO_2 guideline, in particular, is often used for context in the absence of other threshold guidance. RESET has both Standard and High-Performance certifications; the High-Performance certification has stricter thresholds.

A summary of related health evidence and applicable threshold guidelines is provided below for each monitored pollutant. See "Appendix A: Extended IAQ Literature Review" for a more comprehensive table.

Nitrogen Dioxide (NO_2)

NO_2 is the primary pollutant of concern associated with gas range use, with numerous studies linking exposure to respiratory effects, particularly in children and individuals with asthma (Paulin et al. 2017; Gillespie-Bennett et al. 2011; Volkmer et al. 1995). In homes with gas ranges, indoor concentrations frequently exceed outdoor levels (EPA 2025b). The WHO and EPA cite causal or likely causal relationships between long-term NO_2 exposure and respiratory illness (WHO 2021; EPA 2025a). Proper ventilation can substantially reduce risk.

Thresholds:

EPA – 53 parts per billion (ppb) annual, 100 ppb hourly

WHO – 5 ppb annual, 13 ppb daily, 106 ppb hourly

Carbon Dioxide (CO_2)
Indoor CO_2 concentrations are often higher than outdoors due to human respiration and combustion (Satish et al. 2012). CO_2 is not a regulated pollutant but can potentially influence comfort and cognitive performance (RESET Air, n.d).
Thresholds:
RESET IAQ – 1,000 ppm daily standard (600 ppm high-performance)

Carbon Monoxide (CO)
CO is acutely toxic at elevated concentrations, though measured indoor levels from range use in this and similar studies remained well below health-based thresholds.
Thresholds:
EPA – 35 ppm hourly
WHO – 3.5 ppm daily, 30.5 ppm hourly

Particulate Matter ($PM_{2.5}$)[1]
Particulate matter can be from a variety of sources, including dust, cleaning products, pets, burning and cooking food, and fuel combustion. Particles can land on surfaces and be re-emitted when disturbed. $PM_{2.5}$ fluctuates with outdoor air quality, especially during events such as wildfires. Long-term exposure is associated with increased cardiovascular and respiratory risks (Chen and Hoek 2020; Orellano et al. 2020).
Thresholds:
EPA – 9 µg/m³ annual, 35 µg/m³ daily
WHO – 5 µg/m³ annual, 15 µg/m³ daily
RESET – 35 µg/m³ daily standard (12 µg/m³ high-performance)

Volatile Organic Compounds (VOCs)
VOCs are a group of organic compounds that can be released from cooking, cleaning products, building materials, and other sources. These compounds, like particulate matter, can land on surfaces and be re-emitted into the air later on. Indoor VOC levels can exceed outdoor concentrations by an order of magnitude (*Indoor Air Quality* 2025). Health impacts vary by compound, with some VOCs affecting the nervous system, liver, and kidneys (EPA 2025; WHO 2000).
Thresholds:
RESET – 500 µg/m³ daily standard (400 µg/m³ high-performance)[2]

---

[1] $PM_{2.5}$ is the smaller-diameter designation for particulate matter, and the designation focused on throughout this study. PM_{10} is a grouping of particulate matter that includes $PM_{2.5}$ particles, as well as particles with larger widths. Accordingly, the recommended maximum exposure thresholds for PM_{10} are higher. Our air quality sensors give an estimation of PM_{10} concentration based on the monitored level of $PM_{2.5}$, and when that estimate is shared in this reporting, those higher thresholds are used.
[2] The WHO and EPA do not provide threshold guidelines for general VOC levels. Additionally, the Sensirion sensors within the AWAIR OMNI devices used in the study likely use different reference VOC compositions than RESET in determining the pollutant's average molecular weight. We thus do not include these thresholds in our analysis (DigiKey TechForum 2020; RESET Air, n.d.).

Recruitment and Installation

Outreach to recruit study participants began in January of 2023. UPPCO promoted the pilot via social media, physical mailers, and a banner advertisement on their website. The website banner ads were particularly effective during storms due to customers visiting the website for power outage information. I&M's outreach used customer email blasts as the primary strategy. An example outreach FAQ page can be found in "Appendix B: Recruitment Materials".

Outreach materials directed candidate participants to a project landing page that included project information, participant requirements, and a link to a pre-screening survey. The pre-screening survey collected information to qualify and prioritize candidates. Collected data points included existing range type, annual income, frequency of cooking, presence and location of fuse box, and the candidate's intent to remain in that home for the duration of the study. A total of 191 UPPCO customers and 85 I&M customers completed the pre-screen survey and of those, 101 and 71 candidates were qualified, respectively. The research team scheduled virtual walkthroughs with qualified candidates for additional screening.

The purpose of the virtual walkthroughs was to discuss details of the study, verify candidate qualification, and provide an opportunity for candidates to ask questions. Importantly, the research team collected visual documentation of each candidate's existing range type and electric panel condition to ensure candidates did not misclassify their range type and to verify that no major electrical work would be needed during the induction retrofit.

After the virtual walkthroughs, the project team selected 31 total participants: 20 with electric ranges and 11 with gas ranges.[3] Of the electric ranges, 12 were in I&M and eight were in UPPCO territories. All gas ranges were in UPPCO territory, with seven natural gas and four propane powered ranges.[4] Final pre-screening surveys were completed in March 2023, and candidates were confirmed by May 2023.

Occupancy at selected sites ranged from two to six people, with an average of three people per home. Participants reported using their range from three to 21+ times a week, with most people responding in the 8-14 times a week range.

Once the participants were selected, the project team did a walkthrough of each home and educated the participants about induction technology and induction-safe cookware. During this initial visit, the project team, along with an electrician, installed monitoring equipment and performed necessary upgrades to prepare the home for induction range installation. Afterwards, participants signed a participant agreement.

Prior to induction range installation, induction-compatible cookware was mailed to each participant. A year after this initial walkthrough visit, the induction range retailers installed the induction range at

[3] One of these natural gas participants was added after initial recruitment. For this site, we only monitored IAQ (not energy use).

[4] The term "gas-to-induction" in this report refers to both natural gas and propane prior ranges.

participants' homes. Since necessary upgrades were made the year prior, the installation process went relatively smoothly.

Ranges cost ~$1,500-$1,700, including taxes, electrical cords, delivery, and installation. Costs were at the lower end of that range when buying in bulk in UPPCO territory, and at the higher end of that range when buying individually in I&M territory.

Participants were given the option to keep their existing range or to have the appliance technician remove it during installation. The project team communicated to participants that UPPCO and I&M would not store existing ranges, and it would be dependent on the customer to store them if desired. Three-fourths of participants chose to store their range.

Shortly after the installation of the induction range, one propane-to-induction customer returned to their propane range and dropped out of the study because their dog was barking at the induction range when in use. This household is not included in analysis. There are thus a total of 30 participants (20 electric-to-induction and 10 gas-to-induction) included in the results sections of this paper. Note that there were many other participants with pets who did not experience this issue.

Methods

Monitoring

This field study monitored appliance electricity consumption for all sites, and gas consumption for gas-to-induction sites in the pre-retrofit period. Gas sites also included IAQ monitoring of NO_2, CO, CO_2, $PM_{2.5}$, and VOCs. This monitoring setup built upon a large number of previous Slipstream power-monitoring projects, as well as several previous Slipstream IAQ field studies in the Midwest (*The Tierra Linda Passive House* 2021; *La Paz Affordable Multifamily Electrification* 2025). The air quality pollutants that we monitored were chosen based on literature review research and conversations with pollutant and health experts.

Monitoring devices remotely transmitted data back to Slipstream daily throughout the study period. Information about each monitoring device is provided in Table 1 below.

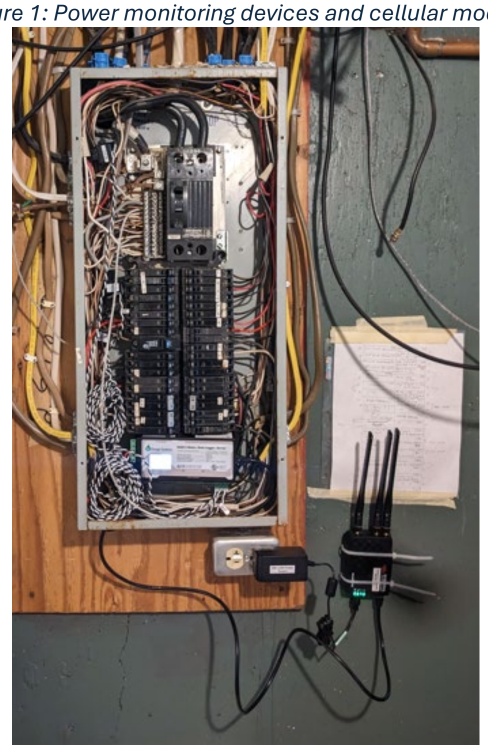
Table 1: Monitoring devices used in the field

Monitoring Device	Datapoint(s) Collected	Measurement Method and Interval	Transmission Method and Interval	Number of Homes
eGauge and current transformers	Power of range, power of microwave, power of air fryer	Current transformer devices monitoring minutely current flow and voltage from breaker to appliance and reporting to eGuage	Daily push through WiFi connection or cellular modem	30 (electric and gas ranges, except one air quality-only gas range)
Gas meter	Gas usage of range	Monitoring minutely flow through gas pipe into appliance	Daily push via connection to eGuage	11 (gas ranges)
Awair Omni	CO_2, $PM_{2.5}$, and VOC concentration, PM_{10} estimated based on $PM_{2.5}$	Monitoring pollutant concentrations through laser scattering ($PM_{2.5}$), non-dispersive infrared sensing (CO_2), or electrochemical reactions (VOCs) at a 10-second interval	Daily push through WiFi connection or cellular modem	11 (gas ranges)
HOBO logger, with DF Robot (CO) and Aeroqual	CO and NO_2 concentrations	Minutely monitoring of pollutant concentration through electrochemical reactions	Minutely push through HOBO Gateway via WiFi connection until January 2025, then monthly	11 (gas ranges)

(NO_2) sensor attachments			manual Bluetooth download by participants through study end (due to connectivity issues)	

A photo of a typical eGauge setup is shown in Figure 1 below. eGauge loggers and current transformers were installed by an electrician within the electricity breaker of each home.

Figure 1: Power monitoring devices and cellular modem



For air quality metering, the research team housed the Awair Omni, Aeroqual NO_2 sensor, DF Robot CO sensor, and HOBO logging device in a grated metal enclosure. These were installed in kitchen locations with unrestricted airflow at approximately the height of an adult's head, typically on top of a refrigerator or cabinet. IAQ monitoring boxes are shown in Figure 2.

One participant complained of an irritating noise from the Aeroqual NO_2 sensor. We remedied this by installing piece of foam near the sensor that muffled the sound, while only minimally impacting airflow through the box.

Figure 2: Typical IAQ monitoring boxes

Gas meters were installed during the pre-period at homes with natural gas or propane ranges. They were removed at the time of induction range installation. A typical gas meter is shown in Figure 3.

Figure 3: Installed gas meter

The field study consisted of one year of pre-period monitoring and one year of post-period monitoring, to capture any seasonal variations in cooking habits or home air transfer. The exact number of monitored days varied slightly per site depending on installation and removal dates. There was an average of 698 days of power monitoring per site. For gas-to-induction sites, IAQ was monitored for an average of 632 days.

Data Processing

The team ran incoming data through several quality assurance checks, flagging any out-of-range values, missing measurements (i.e. offline devices), or device warning messages. When faulty data was discovered, it was further investigated and troubleshot, adjusted, or filtered accordingly. A timeline and explanation of all device troubleshooting, as well as total days of data from each device type, can be found in "Appendix C: Device Troubleshooting and Data Quantities."

After initial checks, data from all devices was merged into one file by site name and timestamp. Further analysis proceeded at minutely, daily, and cooking-event-based intervals.

Cooking Characterization

To understand participant cooking habits, the team looked at the total time spent cooking per day per site, as well as the total cooking events per day per site.

A cooking event was flagged when a range was on (with a power reading above background power usage for clock, etc.) for more than a minute. Cooking minutes occurring within 30 minutes of one another were considered part of the same event.

Energy Use and Efficiency

While lab tests of cooking ranges isolate the power usage and heat transfer of each specific burner and oven function, the purpose of this field monitoring was to quantify observable changes in range efficiency under real-world conditions, including the influence of user habit and other sources of variability. The team took care to document participant behavior to help interpret overlapping factors affecting energy use.

We calculated energy savings using the pre-period as each site's baseline. With a year of pre-period monitoring per site, this provided a robust foundation for comparison. Cooking habits can still change site-to-site over the years for reasons both related and unrelated to the range, so we also incorporated survey responses on self-reported cooking habit changes.

We monitored microwave and air fryer use at relevant sites and observed no correlation between changes in the usage of these other cooking appliances versus changes in range use in the pre- versus post-period. Based on this, we excluded alternative appliance energy use statistics from the results

Patterns in the data revealed a relationship between energy consumption and stovetop versus oven use habits. This reporting thus breaks out energy use and cost by both whole-appliance and stovetop-only for electric-to-induction switches. This is consistent with the current MEMD framework, which attributes electric-to-induction savings only from stovetop efficiency gains, as the oven remains electric in both scenarios.

When first powered on, electric ovens heat at a consistent power for several minutes to begin warming up. To tag stove versus oven events, we first plotted all cooking events over time, and recorded the characteristics of these oven event traces in each range model. We then marked the start of each event, and checked the first fifteen minutes to see if power use corresponded with the oven warm-up trace characteristics for that model. Examples power traces can be seen in Figure 7 in the "Cooking Event Power Traces" section.

Results are given for 28 sites in this section. The power data from Site 30 proved unusable, and Site 29 was recruited late in the process, and only monitored for IAQ data.

Note that the per-site energy and cost metrics in this section filter out no-cooking days, to give the total yearly energy use or cost were somebody to use their range daily. Grid and emissions impacts include these no-cooking days to give a picture of the impact of aggregate appliance changes across the building stock.

Indoor Air Quality

For the 10 gas-to-induction sites that kept their induction stoves for the duration of the study, the research team first examined daily pollutant levels to gain an understanding of varying baselines and site characteristics. We then analyzed the IAQ impacts during cooking events using the gas range versus the induction range. This provides the clearest picture of real-time impacts of cooking on IAQ. Next, we modeled daily cumulative IAQ levels as cooking minutes increased, with outdoor pollutant levels brought into particulate matter calculations. Finally, we quantified the duration of time that pollutant concentrations exceeded health-based threshold guideline levels to assess how observed values compared with established benchmarks.

Electric-to-induction switches would not have an expected air quality impact since neither range runs on gas combustion, so no air quality monitoring devices were installed at these sites.

All 10 gas-to-induction sites had robust IAQ data and are included in the analysis of typical pollutant levels and health organization thresholds. However, Sites 29 and 30 were excluded from the cooking event analysis and the daily cumulative impact modeling; electrical data from Site 30 were unusable, and Site 29 was only monitored for air quality data, as the participant was recruited later than the rest. In addition, Site 28 experienced a substantial (>3x) spike in VOC levels, likely due to home improvement projects, approximately two weeks after induction range installation. VOC levels at this site were removed from both the cooking event analysis and the daily cumulative impact modeling.

In analysis of outdoor pollutant levels, we downloaded data from monitoring devices in the study region through PurpleAir, as well as from EPA AirData monitors (United States Environmental Protection Agency 2016; PurpleAir, n.d.).

As noted in the "Gas Ranges and Indoor Air Quality" section, total VOC concentrations were not compared to a specific threshold because neither the WHO or EPA has established threshold guideline values for total VOCs. In addition, the Awair Omni monitoring device and the RESET air quality standard likely use different assumptions for the molecular weight of VOCs.

Surveys, Interview, and Cooking Logs

Key research objectives included understanding user experience and satisfaction adjusting to and cooking on induction ranges, as well as gaining insights on cooking habits across the study sample. To support these objectives, participants completed three surveys and one interview throughout the study.

The first survey was administered prior to the first monitoring period and asked questions about households' cooking habits, cookware preferences, and satisfaction with their current range. The results from the cookware preferences were used to purchase induction-safe cookware for participants.

The second survey was administered three to four weeks after participants' induction ranges were installed. The survey aimed to understand how participants were adjusting to their new induction range.

The third and last survey was administered after monitoring equipment removal and asked questions about participants' range hoods, which was information not previously collected. This information gave the project team better insight into understanding IAQ data in the context of ventilation habits.

The interview was conducted at the final home visit, when the project team removed monitoring equipment from the participants' homes. The interview was developed to understand overall participant satisfaction with the induction range and challenges during the transition.

Seven study participants were also given notebooks to log cooking habits and events when possible. We received only four logs with detailed information. These logs were used to gain a general sense of participant range use, as well as to pull the select cooking case study timeseries that are examined in the "Participant Experience Results" section.

Range Operation Results

This section presents the quantitative results of the study. We begin with a characterization of the cooking behavior with general statistics. Energy use and efficiency results for electric-to-induction and gas-to-induction switches are provided next, followed by IAQ analysis of the gas-to-induction switches.

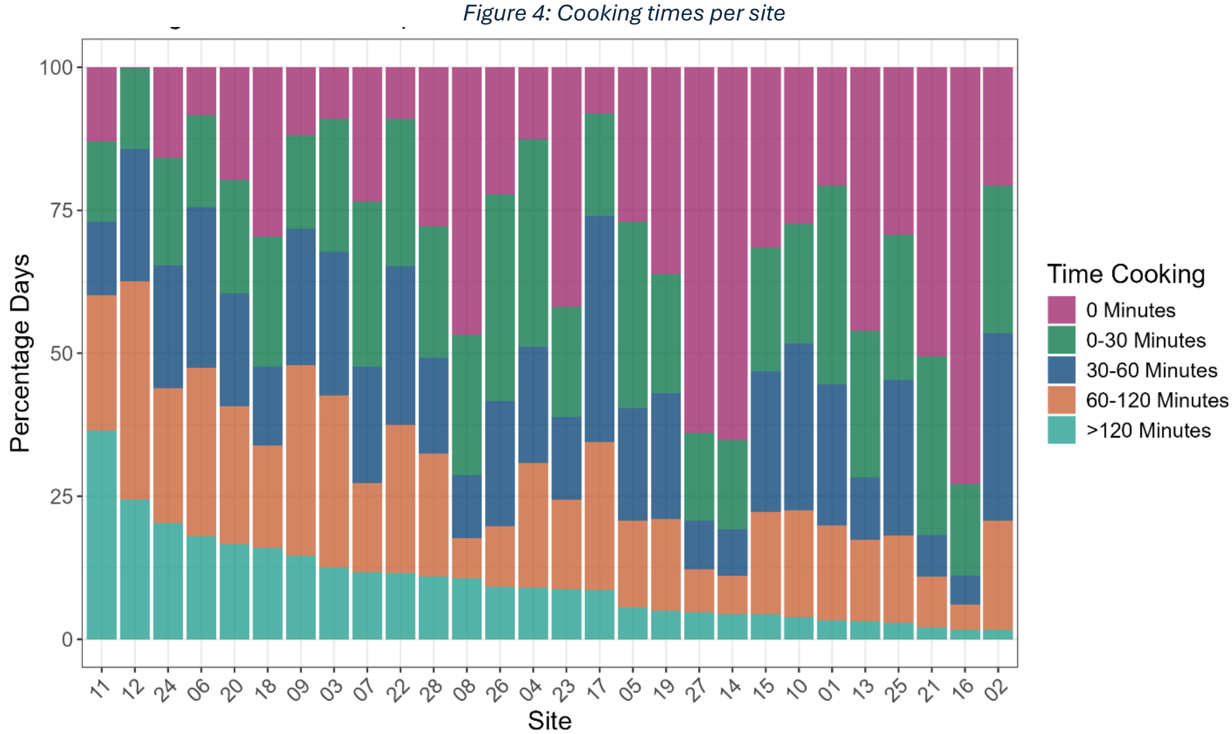
Cooking Characterization

Range Use Statistics

Home occupancy ranged from two to six people. A slight correlation was observed between the occupancy level of homes and the average range energy use, with induction ranges consuming an average of 0.4 kWh per day per person. However, there was ample deviation from this trend, with a two-person household as the highest per-day energy consumer. Several homes experienced occupancy changes during the study, increasing or decreasing by one person. These changes did not result in a predictable change in overall household cooking habits.

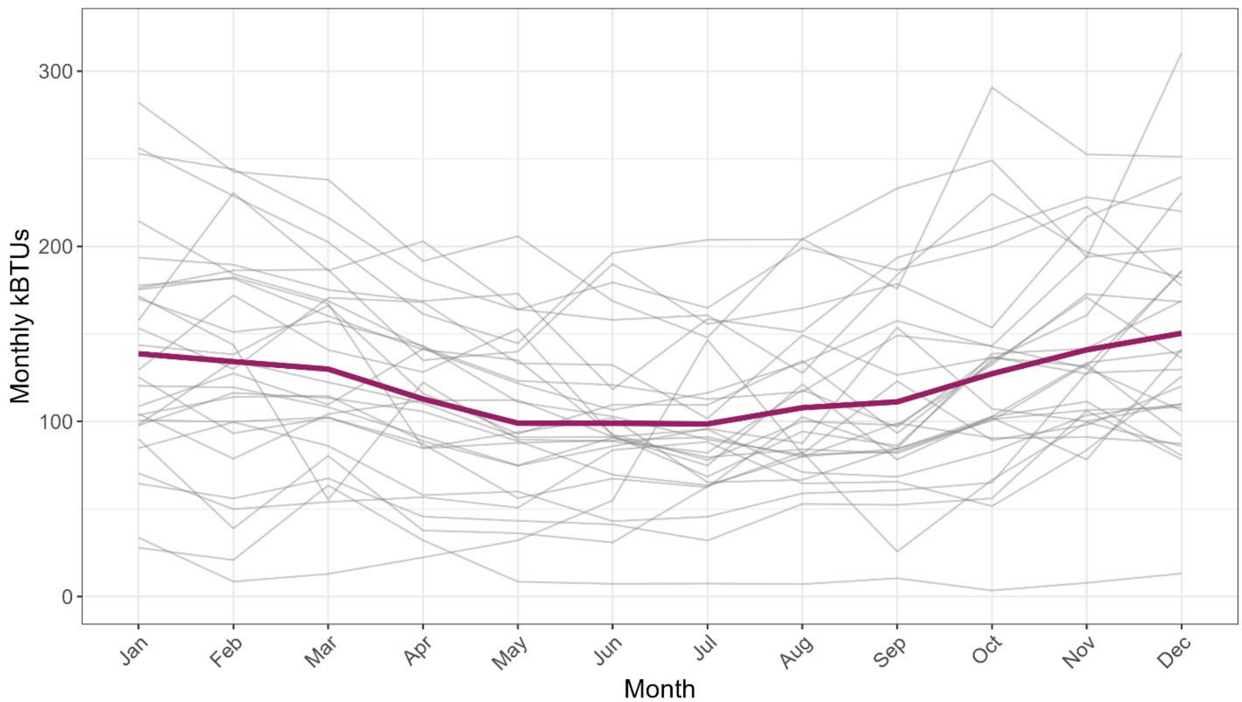
There was a wide variation in range use, illustrated by Figure 4 below, with sites cooking more than an hour on six to 62 percent of days. There was also significant variation in how many days of the year sites used their ranges at all, ranging from 25 to 82 percent.

Figure 4: Cooking times per site



In aggregate, cooking energy consumption was approximately 17 percent higher than average during the winter, with the biggest cooking month being December, and approximately 17 percent lower than average during the summer. This corresponds to survey results mentioning more summer outdoor grilling and vacations, as well as cooking journals logging holiday cooking events. These trends, as well as the spread in seasonal behavior amongst sites, can be seen in Figure 5 below.

Figure 5: Energy (kBTU) consumed per site per month, average overlaid

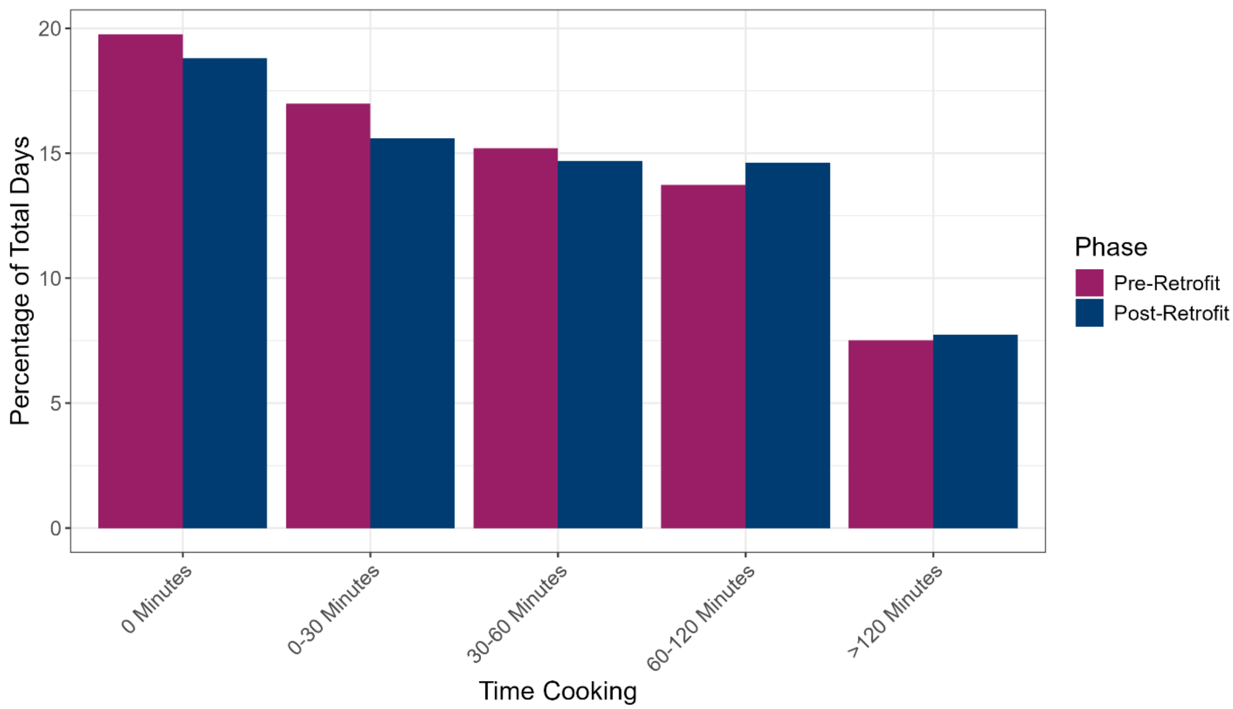


On cooking days, sites used their ranges for an average of 60 to 70 minutes over two cooking events, with an average of 50 of these minutes on the stovetop. This is 12 minutes higher than the assumed daily stovetop usage in the MEMD, which was determined based on a Frontier Energy lab study calculation that assumed about 38 minutes per cooking day (Livchak et al. 2019). Each cooking event lasted 30 to 35 minutes on average.

More than half of participants (in both the electric-to-induction and gas-to-induction groups) reported in the final interview that they were able to cook more quickly on their new induction range. However, 35 percent of electric-to-induction participants and 20 percent of gas-to-induction participants reported increased cooking habits, cooking more post-retrofit. Only five and 10 percent of these groups, respectively, reported decreased cooking habits.

Monitored results align with these interview results. Figure 6 shows the distribution of monitored daily cook times pre- and post-retrofit. There is an increase in percentage of days cooking a total of 90 to 120 minutes, as well as more than 120 minutes. Days with no cooking were slightly less common in the post-period.

Figure 6: Difference in the distribution of daily cooking minutes pre- versus post-monitoring



Even with both monitored and surveyed results, it is difficult to disaggregate changes in cook time due to the appliance itself versus changes in cook time due to habit changes, as these two metrics are often related to one another. For example, several participants stated that since they were able to cook foods like rice and pasta faster on the induction range, they made these meals more often. In addition, a monitored increase in range use may not correlate with a reported increase in range use, and many monitored cooking habit changes were not reported by participants. An analysis of the interplay between monitored versus reported changes in cook time, as well as potential reasons for these discrepancies, can be found in “Appendix D: Detailed Analysis of Cooking Habit Changes”.

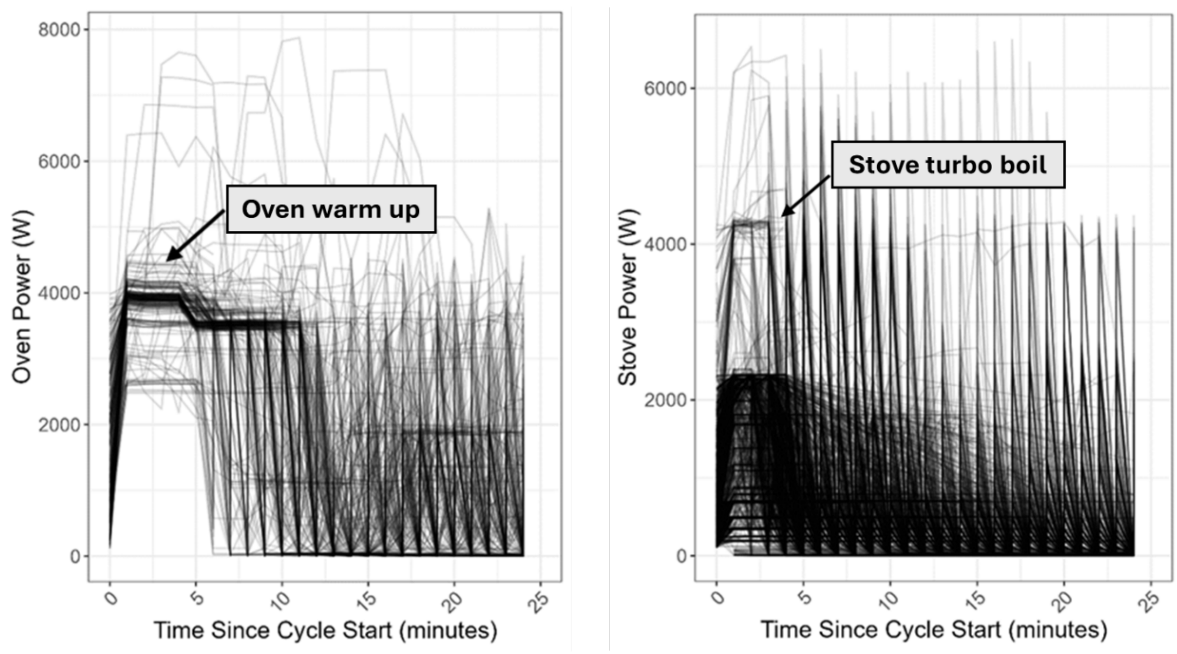
Energy Use and Efficiency

Cooking Event Power Traces

Minute-by-minute timeseries of stove and oven operation, used to distinguish between the two types of range use in electric-to-induction retrofits, are shown in Figure 7. The consistency of these power traces allowed for high confidence in disaggregating range uses. All oven events were characterized by a five or more minute warm-up, typically drawing around 4000 W. This was followed by cycling at powers between 3000 and 5000 W to maintain the desired temperature. Most stove events consisted of a five-minute warm-up at 2100 W, followed by cycling at up to 6000 W.

Many induction range models, including those in the study, have a "turbo boil" functionality (i.e. "power boost," "rapid boil," or "boost"). This function is designed to speed up tasks like boiling water by diverting extra power to a specific cooking zone to achieve maximum heat output for a short period. These are visible in the stove timeseries, and were particularly consistent in operation, with a 4200 W, three minute warm-up, and then cycling.

Figure 7: Timeseries of oven cycles (left) and stove cycles (right) for one site, oven warmup and stove "turbo boil" function indicated

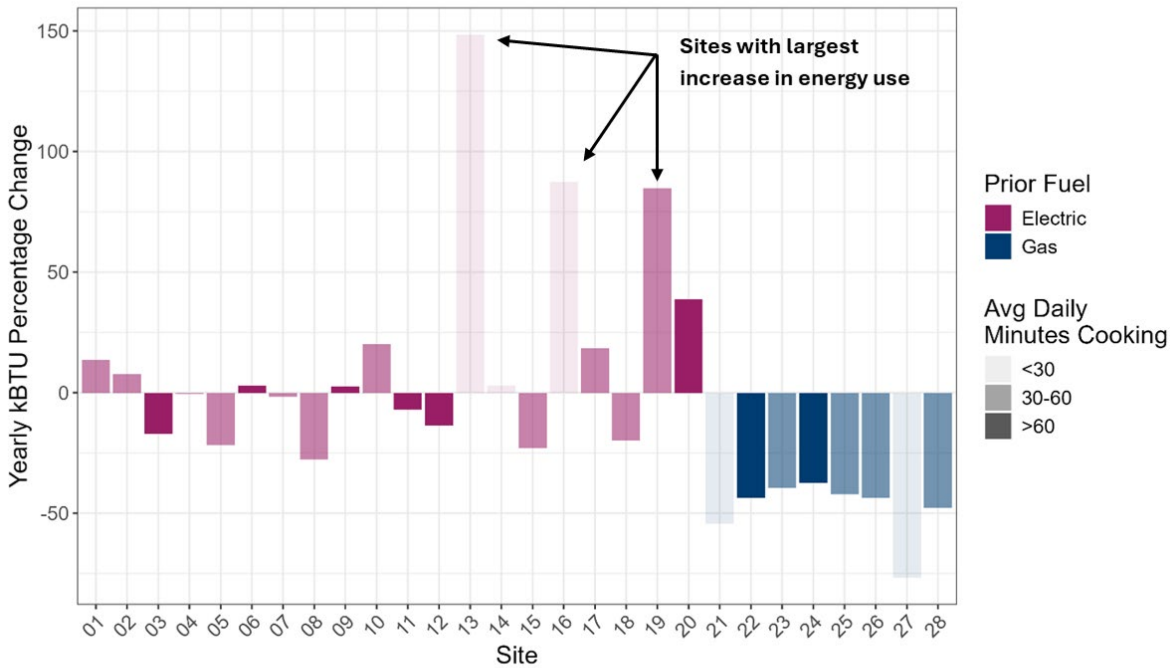


Impacts of Range Mode on Energy Consumption

In an electric-to-induction retrofit, efficiency gains come from enhanced stovetop heat transfer, while the oven is constant operationally in both pre- and post- scenarios. Relatedly, the overall energy savings of electric-to-induction participants proved to be dependent on oven use habit changes, with the induction efficiency gains only visible in stovetop-only usage data. This section documents the relationship between range energy and power metrics and range mode (i.e. oven or stovetop) at electric-to-induction sites. It concludes with modeling conducted to ensure that stovetop energy savings were statistically independent of oven usage habits.

When calculating energy savings from total range use, gas-to-induction switches decreased energy use by 32 to 75 percent, with most decreasing energy use by around 40 percent. Electric-to-induction savings, on the other hand, vary widely. There are three electric-to-induction sites with a notable jump in energy use in the post- versus pre-periods. These numbers are shown in Figure 8 below. The transparency of the bars indicates the average daily minutes cooking at each site, to give an idea of energy use sensitivity to cook time habit changes.

Figure 8: Change in yearly energy use per site, with three largest increases in energy indicated



For each site, we compared the percentage change in energy use to the change in cooking time, shown in Figure 9. These two metrics can be combined to yield average range power: the average amount of energy emitted by the range per unit of time used. Both the x- and y-axes represent rates of change, and the constant range power line sits at a 1:1 ratio between the two, marking the points where the average energy per minute of cooking remained unchanged between the pre- and post-periods.

When pre- and post-period power levels are similar, the type of cooking performed likely remained consistent. In contrast, a change in range power indicates a shift in average cooking behavior. The three participants pointed out previously significantly increased their average range power in the post-period, indicating an increase in higher-power usage, such as oven usage.

Figure 9: Percent change in cooking time versus percent change in energy consumption

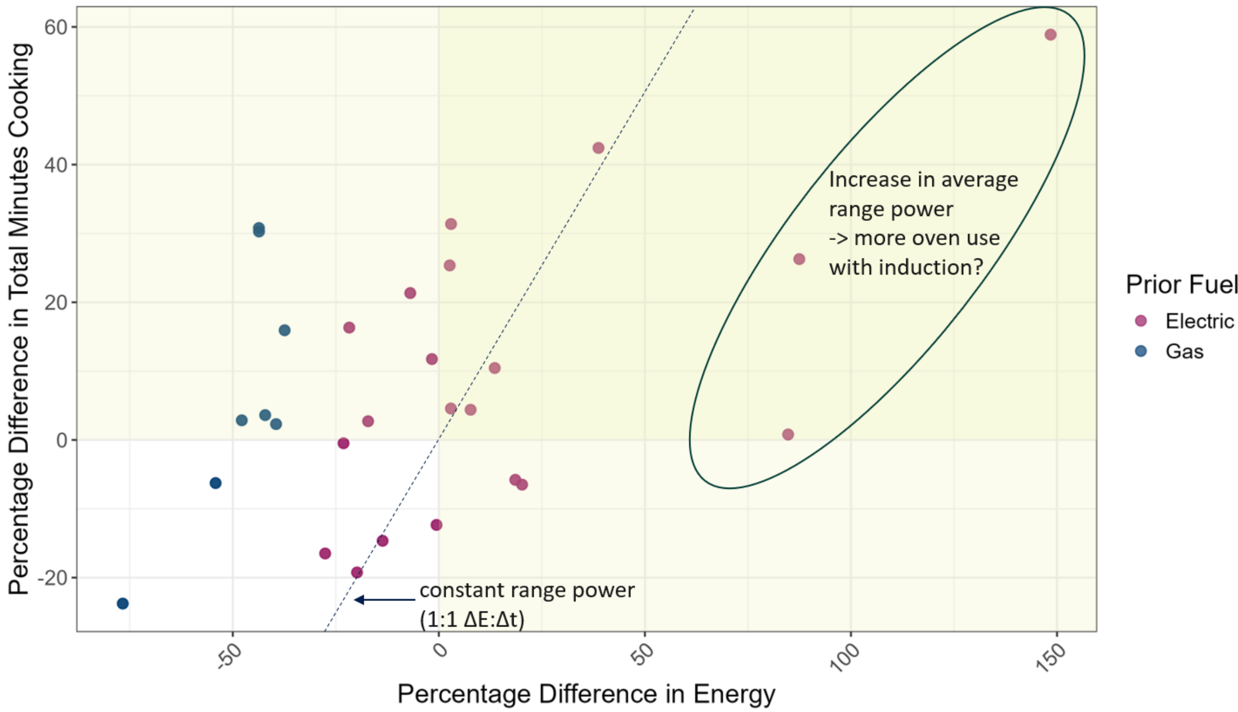
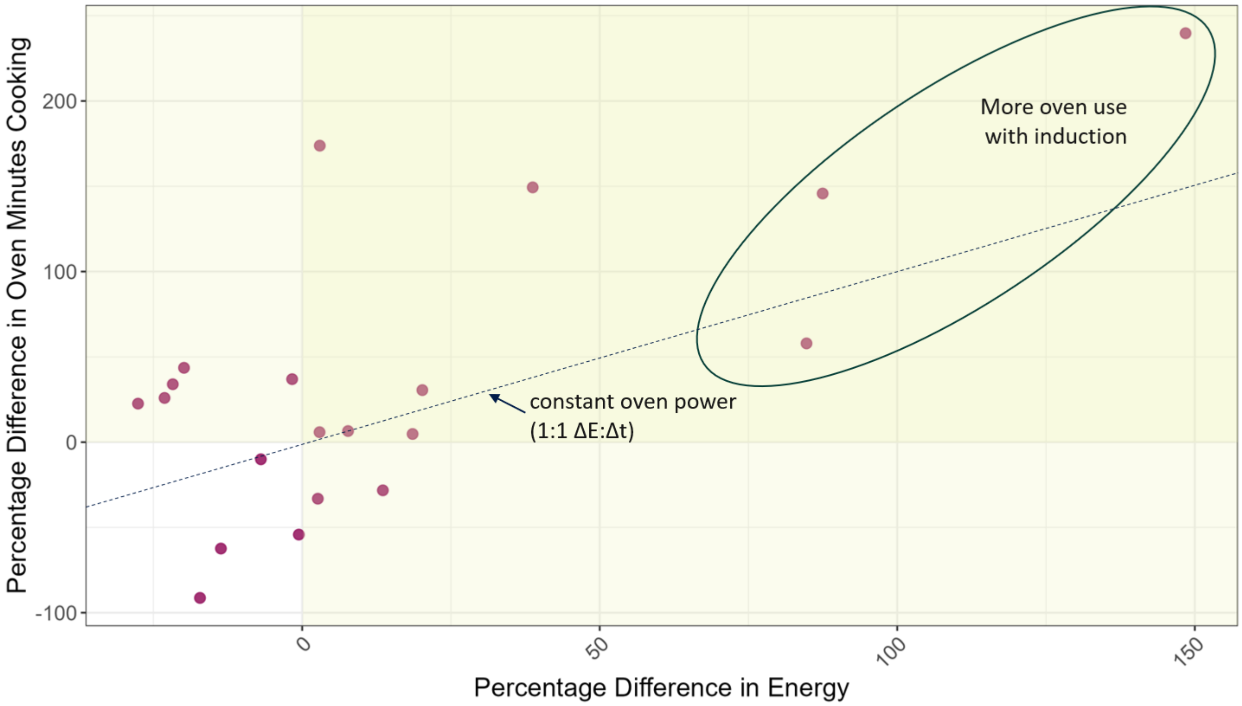


Figure 10 shows a replotted Figure 9 with oven minutes cooking rather than total minutes cooking. The three electric-to-induction sites with the greatest increase in energy use, highlighted in the discussion above and circled in both figures, indeed showed substantially greater increases in oven cooking time. These sites each increased their minutes of oven use by more than 50 percent, while their average power during oven use remained relatively constant.[5]

[5] The two other sites with more than a 50 percent increase in oven minutes decreased their average oven power, indicating an increase in lower-intensity oven uses.

Figure 10: Change in energy versus change in minutes cooking with the oven only for electric-to-induction sites



Moreover, these results align with interview responses. Two of the three circled participants specifically mentioned in their final interviews that they used the oven more after the retrofit. They attributed this increase to features such as the oven's convection, broil, and air fry functions, as well as additional functions such as the food temperature probe.

This analysis indicates that increased oven use, rather than stove use, was the primary contributor to higher energy consumption in electric-to-induction sites. To determine whether stove usage could be analyzed independently for energy use and efficiency, the project team investigated the correlation between cooktop energy savings, increased oven use, and decreased stove use. If household cooktop energy savings was highly correlated with change in oven usage, this would indicate that oven usage was replacing stove usage, and could not be separated for analysis. However, as detailed below, these phenomena proved independent of one another.

Equation 1 models daily energy savings as a function of changes in stove and oven cooking time. The regression results, summarized in Table 2, show that energy savings are primarily associated with changes in stovetop use. The intercept sits at around 67 BTUs per day (p=0.047) and represents average daily stovetop energy savings when daily cooking times remained constant. The coefficient for the stove minutes cooking term is positive and highly significant (36.2 BTUs saved per minute of decreased stove use, p<0001) indicating that reductions in stovetop cooking time were strongly correlated with increased energy savings. In contrast, the coefficient for the oven cooking time is small and statistically insignificant (0.8 BTU saved per minute decreased, p=0.7), suggesting that changes in oven use did not meaningfully affect stovetop energy savings.

Equation 1: Regression of energy savings versus stove minutes cooking and oven minutes cooking

$$\Delta E_{stove} \sim \Delta t_{stove} + \Delta t_{oven}$$

Table 2: Intercept and coefficients for Equation 1, showing the modeled impacts of stove usage and oven usage on stovetop energy savings

	Estimate/Coefficient	p value
Intercept (change in daily BTU)	67 BTUs saved/day	0.047*
Stove usage (change in daily minutes)	36.2 BTUs saved/minute decreased	<2e-15***
Oven usage (change in daily minutes)	0.8 BTUs saved/minute decreased	0.7 (**not** significant)

** = 0.01 < p < 0.05 significant*

*** = 0.001 < p < 0.01 very significant*

**** = p < 0.001 highly significant*

In alignment with the results above, the following electric-to-induction energy, cost, grid, and emissions impacts are broken out into total range use, including the increase in oven cooking, as well as only stovetop use.[6]

Energy and Cost

Compared to a gas range, the increased efficiency of an induction range cuts the energy use of the appliance in half. Compared to an electric range, there are slight energy savings when comparing solely the induction stovetop with the conventional electric stovetop, in line with the current MEMD measure. When considering the whole appliance (both oven and stovetop), energy use changes are marginal for electric-to-induction switches.

Total gas range energy usage averaged approximately 3,050 kBTU per year (equivalent to 894 kWh). Total induction range usage for these sites averaged 1,650 kBTU (485 kWh).

Total energy use of electric ranges was measured at approximately 1,850 kBTU (535 kWh) per year, including oven use. Energy use in the post-period for these sites was about the same due to the increased oven usage described above. When broken into annual usage of stovetops only, electric-to-induction households consumed approximately 1,200 kBTU (345 kWh) for electric stovetops and 1,150 kBTU (330 kWh) for induction annually, demonstrating the efficiency gains from the induction stovetop technology.

Monitored energy consumption aligned reasonably well with established electric and gas range benchmarks. The California Codes and Standards Enhancement Initiative (CASE) and the Florida Solar Energy Center provide a literature review of previous field studies used to benchmark yearly electric resistance range energy use. These papers cite numbers ranging from 250 to 800 kWh per year, placing this study's electric resistance range consumption squarely in the middle. These monitored consumption values are about 150 kWh per year higher than the final CASE benchmarking equation when estimating

[6] As noted previously, gas-to-induction switches benefit from increased efficiency from both the oven and stove functions. Because of this, we did not break out gas-to-induction switches in this manner.

consumption by occupancy (Rubin et al. 2016; Parker et al. 2010).[7] The comparisons for gas range consumption are similar. We did not identify any comprehensive induction range energy use benchmark studies. Future research on large scale induction range energy use benchmarks would thus be valuable.

Electric-to-induction participants used their range more often than gas-to-induction participants. Even when both groups were cooking on induction in the post-period, their annual energy used differed by about 59 kWh, aligning with a modest difference in average cook time (70 minutes for electric-to-induction and 67 minutes for gas-to-induction).[8] As mentioned in the "Methods" section, we break these groups out independently for calculating energy savings for each retrofit type. However, in the grid and emissions analysis, we assume that future average induction range usage will be the average of all sites (both gas and electric).

Table 3 provides an overview of the estimated effects of the retrofits on energy and costs.

Table 3: Annual change in energy and cost per range type and energy rates

	Energy per year in whole appliance (kBTU/year)	Change in cost for whole appliance ($/year)	Energy use per year for stovetop only (kBTU/year)	Change in cost for stovetop only ($/year)
Electric (UPPCO rates)	+23 (+1%)	+$1.69 (+1%)	-51 (-5%)	-$3.74 (-5%)
Electric (I&M rates)[9]		-$0.80 (+1%)		-$1.79 (-5%)
Gas (UPPCO rates)[10]	-1,364 (-45%)	+$99.22 (+427%) natural gas +$44.83 (+173%) propane	*NA*	

Gas range retrofits decreased energy use by 45 percent due to the greater efficiency of the induction appliances. However, in UPPCO territory electricity rates are relatively high and gas rates are relatively low, meaning that operational costs for natural gas customers increased by about $100 annually, and operational costs for propane customers increased by about $45. If the same households were billed under I&M electricity rates, annual operational costs for natural gas switches would increase by only $35, and propane retrofits would have roughly broken even.

Note that overall, these changes represented minimal cost differences compared to home heating and cooling needs. No homeowners reported noticing a cost increase, although this question was not

[7] For this calculation, we assume the average occupancy of this study, three people, equates to three bedrooms in the home.
[8] These differences exist even when filtering out the three electric-to-induction sites with high oven usage.
[9] I&M rates: $0.12/kWh electricity
[10] UPPCO rates: $0.25/kWh electricity, $0.76/therm natural gas, $2.34/gallon propane

explicitly asked in interviews. Also, in a whole-home electrification scenario, an UPPCO household may qualify for the utility's winter space heating electricity rate of $0.15 for all energy consumed above 500 kWh per month. This rate, especially if combined with the elimination of gas service fees, could shift the gas-to-induction economics to cost neutrality or modest savings.

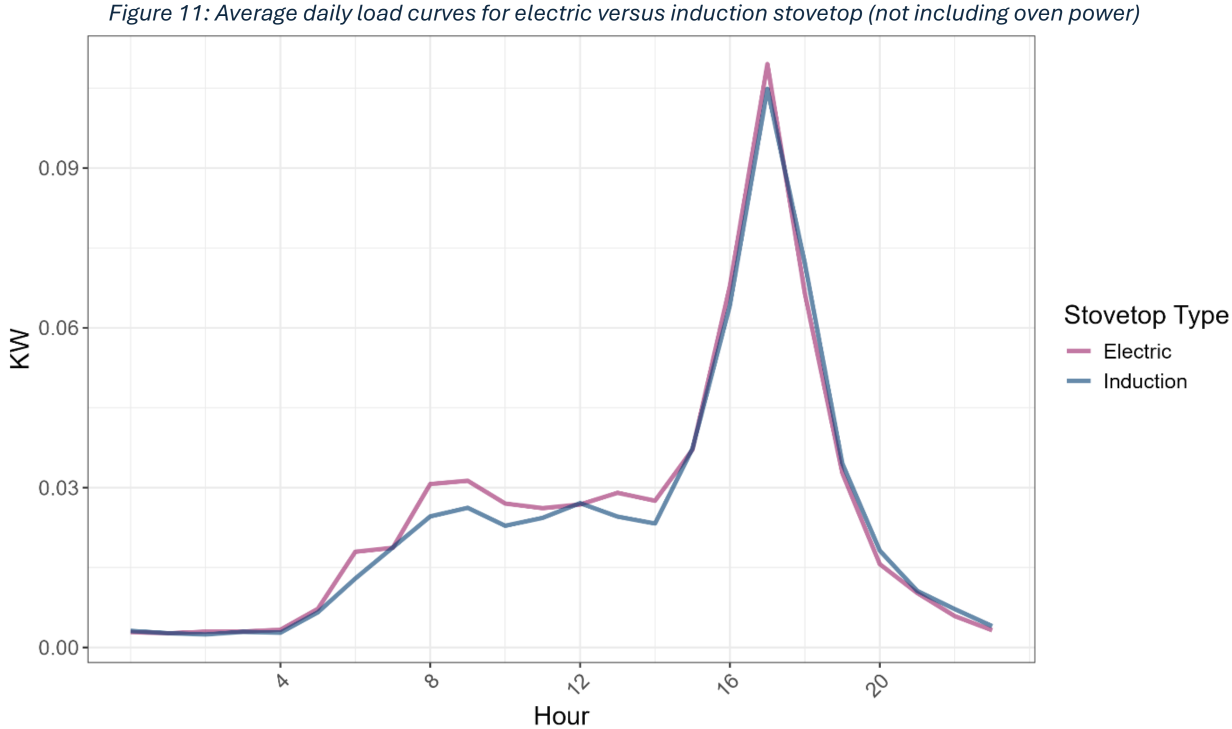
When focusing only on stovetop energy usage, there was a decrease in energy consumption of 51 kBTU, or 15 kWh, per household annually. This estimated savings is slightly below the current MEMD claimable savings from the switch, 17.6 kWh/year. Electric-to-induction switches accounting for the whole appliance resulted in a slight increase in energy usage, due to the increased oven use detailed in the previous section.

Grid Impacts

One key factor in the planning of utility programs is the aggregate demand of electric technologies on the electrical grid throughout the day.

Even with the turbo boil stove functionality and other induction stovetop settings, electric-to-induction field study sites had approximately five percent reduction in peak kWh consumption compared with their prior electric ranges. These load curves are shown in Figure 11 below. Notably, this decrease in peak power consumption occurs even with an approximately seven percent increase in average minutes of stovetop usage during peak cooking times (4-6pm), highlighting the efficiency gains of the induction technology. When whole appliance energy use is included, however, induction ranges consumed three percent more energy during peak times, likely reflecting increased oven use.

Figure 11: Average daily load curves for electric versus induction stovetop (not including oven power)



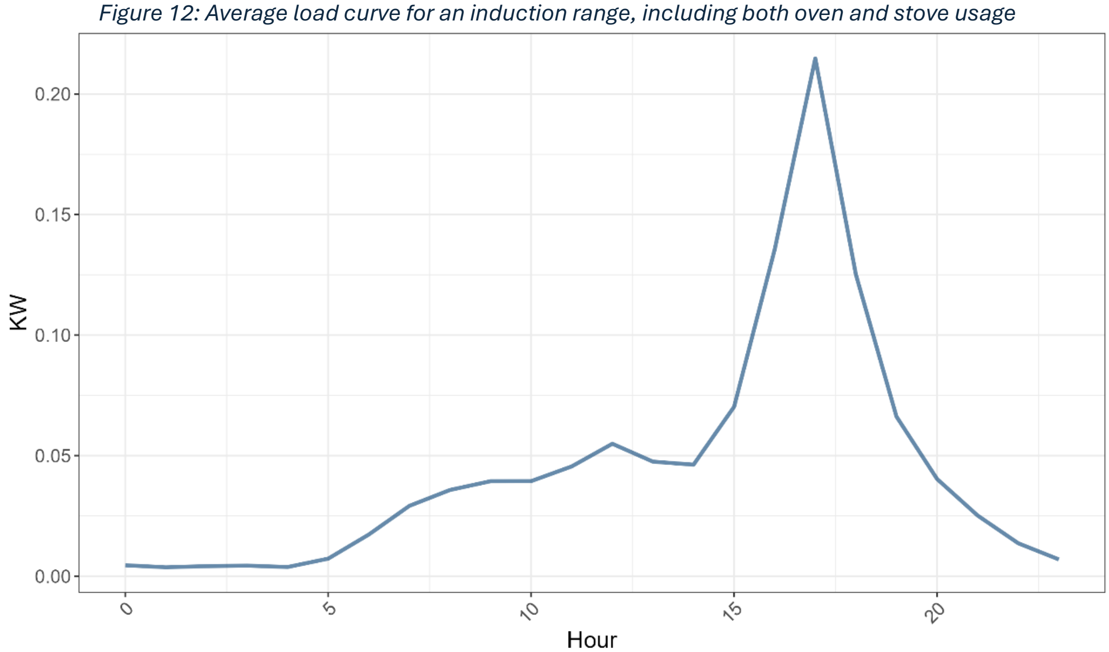
The non-coincident demand reduction for an electric-to-induction switch (i.e. the largest difference in kW demand between pre- and post-periods) is 0.006kW. With 35.7 percent of demand occurring at

MEMD peak hours between 3-6pm, the hourly load share from this field study is 0.0003. The peak coincident demand reduction is thus calculated to be 0.005kW (using our calculated yearly savings of 15kWh). The coincidence factor of the savings from this retrofit is therefore 0.83, indicating that at peak times, demand savings are 83 percent of the maximum daily demand savings.

The current MEMD induction cooktop measure assumes that because induction stovetops have the capacity for a higher power draw, they are operated at an average higher power. The measure calculates an assumed coincidence factor for the measure of -0.002. In the field, monitored data did not align with this assumption; average demand in the post-period was lower. In addition, the MEMD peak hourly load share assumption is lower than monitored in the field.

Though switching from a gas range saves total energy use, it adds demand on the electrical grid, and often this demand occurs at the same time of day across households. The average load curve of the induction range appliances (including both gas-to-electric and induction-to-electric homes) is shown in Figure 12 below. Especially as UPPCO rolls out a new electrification plan, these additional grid impacts, and potential mechanisms to shift this load to other hours of the day, are important to keep top of mind. One technology to this end that has recently entered the market is a 120V induction range with built-in batteries to decrease peak load.[11]

Figure 12: Average load curve for an induction range, including both oven and stove usage



[11] The major retail option for this type of technology as of the time of writing is Copper's Charlie range. https://copperhome.com/products/charlie

Emissions Impacts

When considering environmental impacts, an induction range provides a clear benefit over gas ranges, and a slight to no benefit compared to electric ranges.

To calculate the emissions of electric and induction range use, the average hourly annual load curve for range use throughout the study was multiplied by NREL's long-run marginal emissions rates (LMERs) from the Cambium dataset (Gagnon 2024). Emission rates were pulled from the MISO Central grid operator region,[12] and a mid-case future scenario was assumed, with central estimates for future technology cost, electricity demand, and grid infrastructure additions. For natural gas emissions, energy consumption was multiplied by the EPA's stated CO_2 equivalence per therm. Appliance energy consumption and emissions are totaled over one year, as well as the 16-year lifespan of the equipment.[13]

Table 4: Emissions impacts from natural gas, electric, and induction ranges, in kg of CO_2

Time Period	Natural Gas	Electric	Induction[14]
One year, whole appliance	**116**	**94**	**93**
16 years, whole appliance	**1858**	**1147**	**1135**

A natural gas-to-induction switch is estimated to save about 20 kg of CO_2 emissions annually using current emissions factors, and 700 kg over the lifetime of the induction range, with savings coming both from increased efficiency, as well as the cleaner energy source. Results are similar for propane-to-induction switches.

The emissions savings from switching from an electric range depend on the energy use reduction of the switch. Including the full appliance, this means that emissions remain about constant in the pre- and post-periods for the sites in this field study. When considering just the efficiency gains from the stovetop, without oven use, around 40 kg of CO_2 is avoided over the appliance's life.

For context, a mature tree absorbs about 20 kg of CO_2 per year (Franklin et al. 2024). A gas-to-induction switch thus saves lifetime emissions comparable to the carbon absorbed by a tree over 16 years, while an electric-to-induction switch saves lifetime emissions comparable to the carbon absorbed by a tree over two years.

Emissions savings add up over the lifetime of the equipment, with greater emissions savings in years further into the future. With increasing number of renewable energy projects being added to the MISO grid, the portion of electricity generated with fossil fuels is predicted to decrease.

[12] This region encompasses all of Michigan except the Western Upper Peninsula, which is part of the MISO North region. These two regions have very similar LMERs.

[13] This is the electric cooktop measure life from the DOE's Energy Efficiency and Renewable Energy Office's 2024 Lifecycle and Payback Period Analysis. The California 2024 TRM also uses a 16-year measure life.

[14] Including both gas-to-induction and electric-to-induction switches.

Indoor Air Quality

This section provides an overview of the results from the IAQ measurements for the gas-to-induction range replacements.

Ventilation Practices

Within the households who responded to the survey on range hood prevalence and usage habits, 60 percent had range hoods, with one third of those hoods venting to the outdoors. Seventy-five percent of respondents with a range hood said they used it “most of the times” or “every time” they cook. However, we did not find significant correlations between range hood type or usage and IAQ results. This may be due to the small study sample size. Participants without range hoods may also be effectively ventilating their homes through other methods (i.e. opening windows). Further research on ventilation practices across populations, and ventilation’s effect on IAQ, would be valuable.

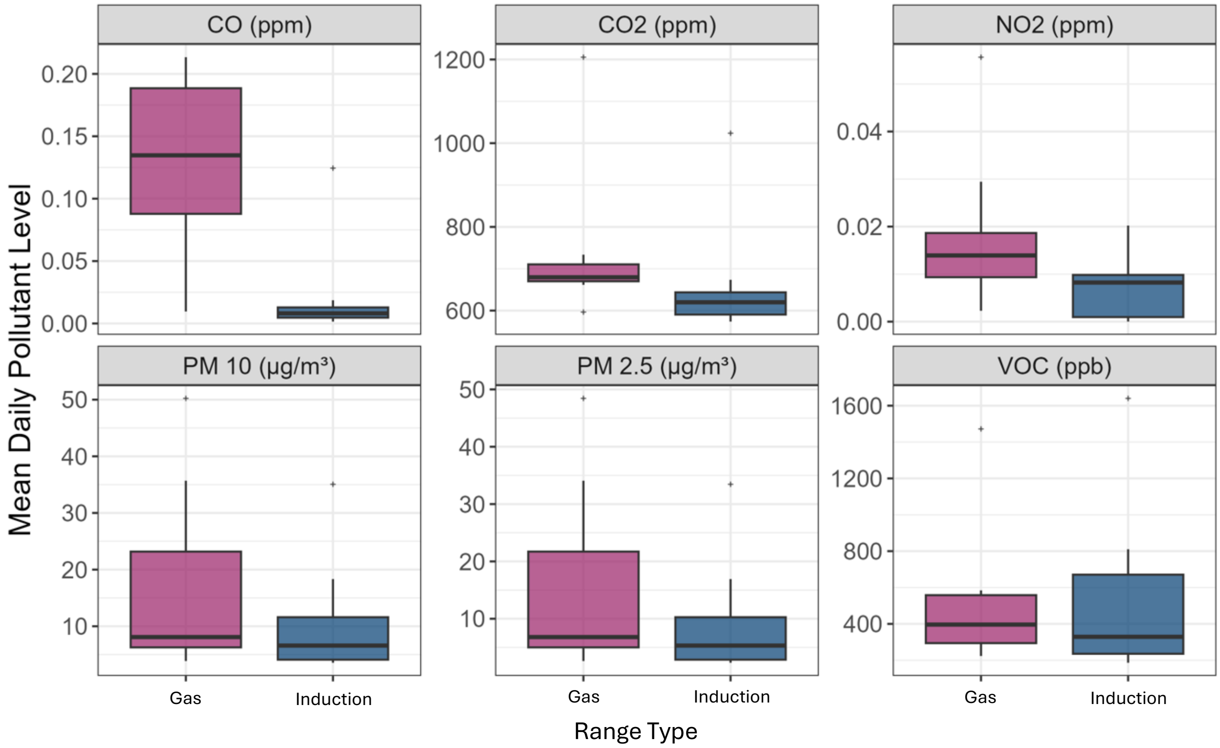
Typical Pollutant Levels

A boxplot of measured mean daily pollutant levels per site pre-and post-retrofit is shown in Figure 13. A general reduction in average pollutant levels across sites is visible, as well as significant variation between sites for certain pollutants.

The improvements in NO_2, CO_2, and CO levels are the most clearly attributable to the new range, because those pollutants are biproducts of gas combustion. Changes in VOCs and particulate matter, while likely partially due to the range, could be attributed to many other factors as well, such as food particles, cleaning products, pets, poor ventilation, smoke, mold, and certain building materials and furnishings. For monitored particular matter levels, improvements are at least partially due to a particularly bad wildfire season in the pre-period, as discussed further below.

The relationship between these pollutant levels and health organization thresholds is explored in the coming sections.

Figure 13: Mean daily pollutant values per site, gas versus induction

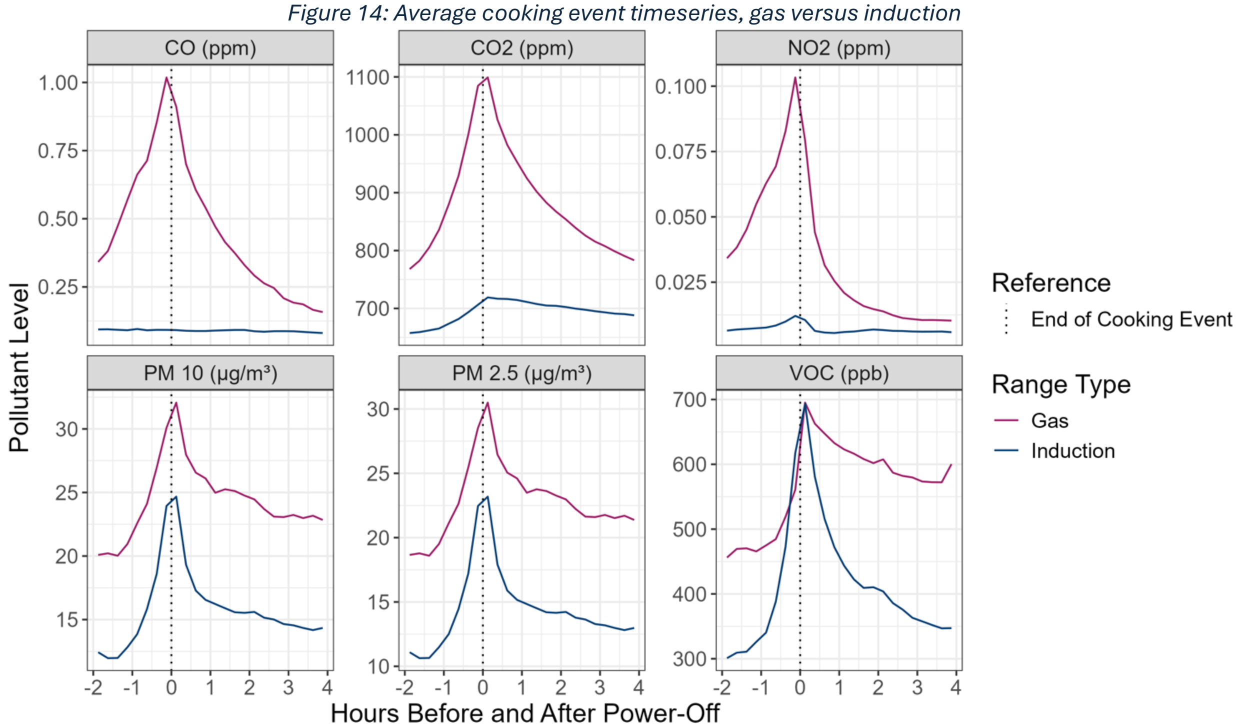


Cooking Event Analysis

To assess the real-time effects of cooking on IAQ, the research team calculated the average concentration of each pollutant at each minute before and after the range was powered off for more than four hours. These average levels were computed across all qualifying cooking events over the course of the pre- versus post-periods. A four-hour event window was selected to ensure that consecutive cooking activities did not overlap, thereby reducing noise from back-to-back events. This window differs from the 30-minute event horizon used in the energy-use analysis, which is appropriate for power-cycle behavior, but too short to isolate pollutant patterns in IAQ monitoring.

The results show pollutants levels before, during, and after range use for both pre- and post-retrofit monitoring (Figure 14). The figures illustrate the rise to average peak pollutant levels while cooking, as well as the subsequent decay towards baseline after the cooking event.

Figure 14: Average cooking event timeseries, gas versus induction



Peak pollutant levels when cooking notably decrease in the post-retrofit period for NO_2, CO_2, and CO. These three pollutants also remain at slightly elevated levels for more than four hours after range use in the pre-period when compared to the post-period.

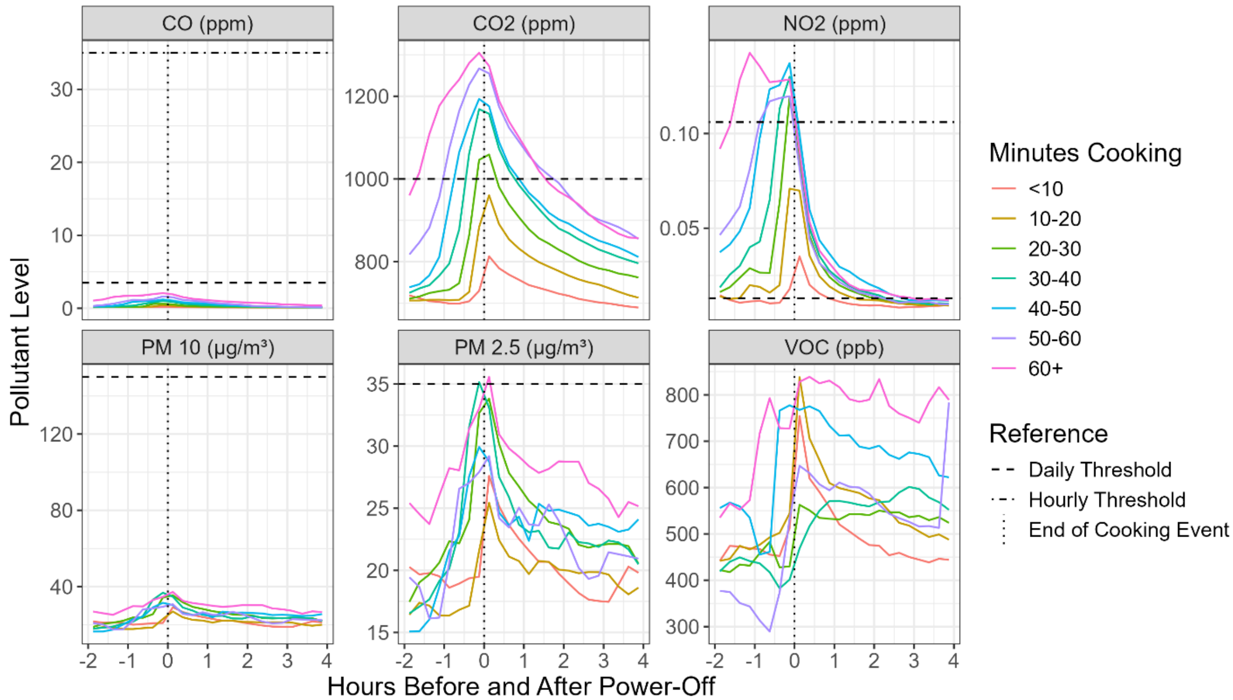
Particulate matter baselines decrease in the post-retrofit period. As discussed in the next section, this shift may reflect poor outdoor air quality in the pre-period, rather than range use. However, the relative height of the particulate matter cooking event peak decreases slightly with an induction range, which is more likely attributable to the change in range type, but this cannot be confirmed.

The decay curves of each pollutant indicate the amount of time after a cooking event that it takes for kitchen IAQ levels to return to baseline. This is quickest for NO_2. The VOCs show slower decay in the pre-period, which may be related to differences in the types of VOCs associated with gas combustion compared with those produced by cooking activities alone (Seltenrich 2024; Michanowicz et al. 2022; Zhang et al. 2023). Because the monitoring equipment in this study reports total VOCs and cannot identify individual compounds, the specific contribution of combustion-related VOCs cannot be directly quantified.

Figure 15 breaks gas range events out by cooking length, illustrating the impact of longer cooking times on peak pollutant levels. Daily and hourly thresholds from the WHO, the EPA, and RESET, are overlaid to contextualize the curves; in the case of multiple applicable thresholds, the least strict is shown.

Note that the health organization thresholds represent a maximum average hourly or daily concentration. An hourly threshold is surpassed if the average of all minutes within that hour is higher than the threshold. Similarly, for a pollutant reading to be above a daily threshold, the average pollutant concentration across the day would need to be higher than the threshold.

*Figure 15: Average cooking event timeseries with gas ranges only, by cooking event length, with health thresholds**



** Thresholds used are: WHO daily CO, EPA hourly CO, RESET daily standard CO_2, WHO daily NO_2, WHO hourly NO_2, EPA daily $PM_{2.5}$ (same as RESET standard $PM_{2.5}$), and EPA daily PM_{10}.*

In the pre-period, peak NO_2 values exceed the WHO hourly threshold for the average event lasting more than 40 minutes. Individual cooking events do not surpass hourly thresholds for other pollutants. Long cook times do result in hourly CO_2 levels exceeding the daily RESET Standard air quality threshold, suggesting that if multiple of these events occurred in a day, the average daily level could pass this threshold.

Because particulate matter and VOC concentrations are less directly tied to range operation, and can vary depending on the type of cooking activity, they are also more susceptible to re-suspension from surfaces due to contact or airflow. As a result, these event curves are noisier and show weaker correlation with cooking time.

Daily Cumulative Impact Modeling

In order to understand the effect of cook time on daily IAQ levels, the research team ran linear models of pollutant level versus cook time at each site in each study period. A model was run with each pollutant level versus daily cook time across all sites after removing the following outliers, to better isolate the impact of cooking on typical pollutant levels:

- Site 22, NO_2: This site's NO_2 levels sat at a daily level of about double that of other sites in the pre- and post-retrofit periods, potentially due to another gas combustion appliance.
- Site 24, CO: CO levels at this site were very frequently above 0.5 ppm per day, even in the post-retrofit period, while other sites were near zero. The source of these emissions are unknown. This site was notified of these elevated levels.

- Site 28, VOCs and CO_2: This site experienced a significant spike in VOC levels shortly after the start of the post-retrofit period, likely due to home improvement projects. CO_2 levels were about double that of all other sites in both the pre- and post-periods for unknown reasons.

The project team also compared the indoor data to outdoor air quality (OAQ) data to help us interpret indoor pollutant levels for relevant pollutants. CO_2, CO, and VOC levels are primarily driven by indoor sources, as described in the "Background" section, and thus these were not compared to outdoor levels. For NO_2 and particulate matter, the team incorporated EPA and PurpleAir outdoor air quality data from the region into the analysis.

For NO_2, the regression analysis of the OAQ data resulted in monitored indoor NO_2 levels being independent of outdoor levels, so no additional analysis was performed.

Indoor particulate matter, in contrast, did show a relationship to outdoor air pollutant levels. Nearby wildfires in the summer of 2023 are notably prominent in the dataset, skewing average pre-period particulate matter levels slightly higher overall. To account for this influence, we included an outdoor air PM term in the particulate matter regression models. The pre-period equation is shown below (Equation 2).

Equation 2: Regression of cooking minutes and OAQ on IAQ in the pre-period

$$IAQ_{PM2.5\ daily} \sim t_{cooking\ daily} + OAQ_{PM2.5\ daily}$$

Table 5 reports the coefficients and intercepts of each variable for $PM_{2.5}$. Because the time cooking term and the OAQ term use different units, their coefficients cannot be directly compared. Although the coefficient for cooking time is lower than the coefficient for outdoor air quality, time cooking has greater impact on indoor air quality on the average day. The average daily outdoor $PM_{2.5}$ level (6.6 $\mu g/m^3$) is skewed higher due to several large wildfire event outliers. In contrast, households cooked for 60 to 70 minutes per day on a relatively consistent basis. OAQ thus only significantly impacted IAQ during events like wildfires, when OAQ was especially poor. Results for the models for PM_{10} were similar.

Table 5: Intercept and coefficients for Equation 2, showing the modeled impacts of time cooking and OAQ on indoor particulate matter levels

	Estimate/Coefficient	p value
Intercept (baseline $\mu g/m^3$ indoor $PM_{2.5}$, no cooking)	8.8 $\mu g/m^3$	3.12e-13***
Cooking time (change in daily average $\mu g/m^3$ indoor $PM_{2.5}$ per minute cooking)	0.05 $\mu g/m^3$ increase per minute cooking	0.004**
OAQ (change in average $\mu g/m^3$ indoor $PM_{2.5}$ per $\mu g/m^3$ increase in outdoor $PM_{2.5}$)	0.26 $\mu g/m^3$ increase per $\mu g/m^3$ increase in outdoor levels	8.05e-6***

** = 0.01 < p < 0.05 significant*

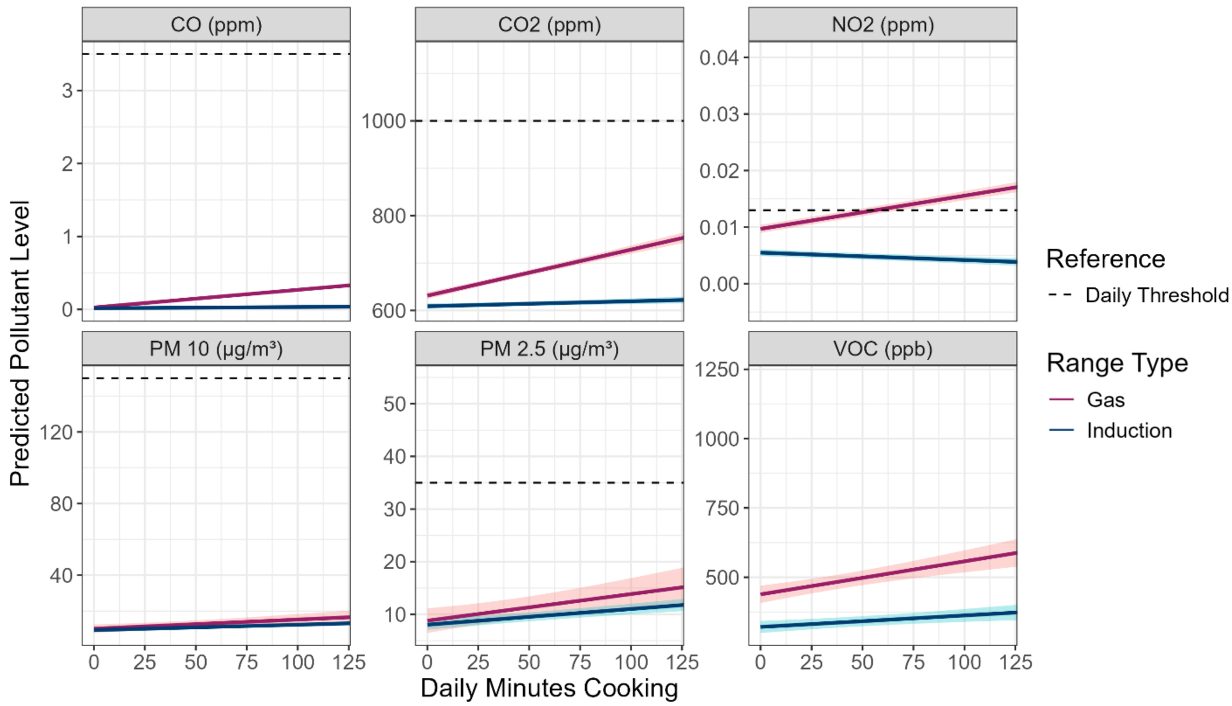
*** = 0.001 < p < 0.01 very significant*

**** = p < 0.001 highly significant*

Modeled daily levels of each pollutant with increasing daily minutes cooking can be seen in Figure 16 below. Note that these results are not raw data, but linear regressions ran on monitored daily values.

All pollutants increase with increasing cook time in the pre-period due to gas range combustion. NO_2, CO, and CO_2 levels remain at baseline regardless of daily cooking minutes in the post-period, illustrating the improvement in IAQ due to the induction range.[15] Particulate matter and VOCs increase with cook time in both the pre- and post-retrofit periods due to cooking and burning food particles.

*Figure 16: Modeled daily pollutant levels per daily minutes cooking, gas versus induction**



** Thresholds used are: WHO daily CO, RESET daily standard CO_2, WHO daily NO_2, EPA daily $PM_{2.5}$ (same as RESET standard $PM_{2.5}$), and EPA daily PM_{10}. OAQ is removed from particulate matter regressions.*

With a gas range, indoor NO_2 pollutant levels surpass the WHO's recommended daily level after about 50 minutes of cooking per day. This threshold is lower than the average of 60 minutes that gas range households cooked in the pre-period, meaning households exceeded this level on the majority of cooking days. The remaining pollutants do not approach the health organizations thresholds from cooking alone.

One nuance to consider is that these models assume typical, non-outlier baseline pollutant levels in each home. In practice, some households have higher baseline levels due to other factors such as pets, dust, burned food, and other combustion sources. In these cases, the additional pollutant load due to the gas range could push overall levels over health organization thresholds. This effect is difficult to isolate from the monitoring data. However, it could help explain why some households showed larger than modeled

[15] Note that the post-period NO_2 coefficient is statistically insignificant, and thus the slight negative slope is likely zero in reality.

reductions in overall time spent over health organization thresholds after the retrofit, as detailed in the next section.

Note that the particulate matter models above make the conservative assumption that outdoor particulate matter levels are zero, to isolate the effects of cooking. Higher outdoor levels would shift the regression intercept upward, consistent with the OAQ model above. For levels to cross the EPA recommended maximum level in less than two hours cooking, outdoor $PM_{2.5}$ would need to be around 75 µg/m³, which was relatively rare in the study periods.

Health Organization Thresholds

Table 6 below provides the percentage of varying time periods across all sites that were above hourly, daily, or annual air quality thresholds in the pre- and post-retrofit periods. Cells are colored orange for increased time over threshold in the post-retrofit period, green for improved time over threshold in the post-retrofit period, and blue for unchanged percentages.

*Table 6: Percentage of hours/days/year in the pre-period (gas range) versus the post-period (induction range) with monitored IAQ values over health organization thresholds; in the case of multiple applicable thresholds, the least-strict is shown**

Threshold Duration	NO_2		CO_2		CO		$PM_{2.5}$		PM_{10}	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Hourly	2.5%	0.3%	NA	NA	0	0	NA	NA	NA	NA
Daily	50.0%	18.5%	9.0%	4.4%	0.1%	0	23.9%	16.3%	1.8%	0.2%
Annual	10%	0	NA	NA	NA	NA	30%	30%	30%	30%

** Thresholds used are: WHO daily NO_2, RESET daily standard CO_2, WHO daily CO, EPA daily $PM_{2.5}$ (same as RESET standard $PM_{2.5}$), and EPA daily PM_{10}.*

For all daily and hourly metrics examined, pollutant metrics improved or remained constant in the post-period. NO_2 metrics improved the most dramatically. CO metrics remained about constant, and were almost always below health organization thresholds.

The total percentage of days over the EPA particulate matter thresholds decreased. This reduction was at least partially attributable to the wildfire events in the pre-retrofit period described above. However, 30 percent of sites had annual particulate matter metrics above EPA and WHO recommendations in both the pre-and post-retrofit periods. Notably, this 30 percent consists of different sites in each period, pointing to varying particulate matter levels and sources (e.g. pets, dust, burning/cooking food) over time across sites.

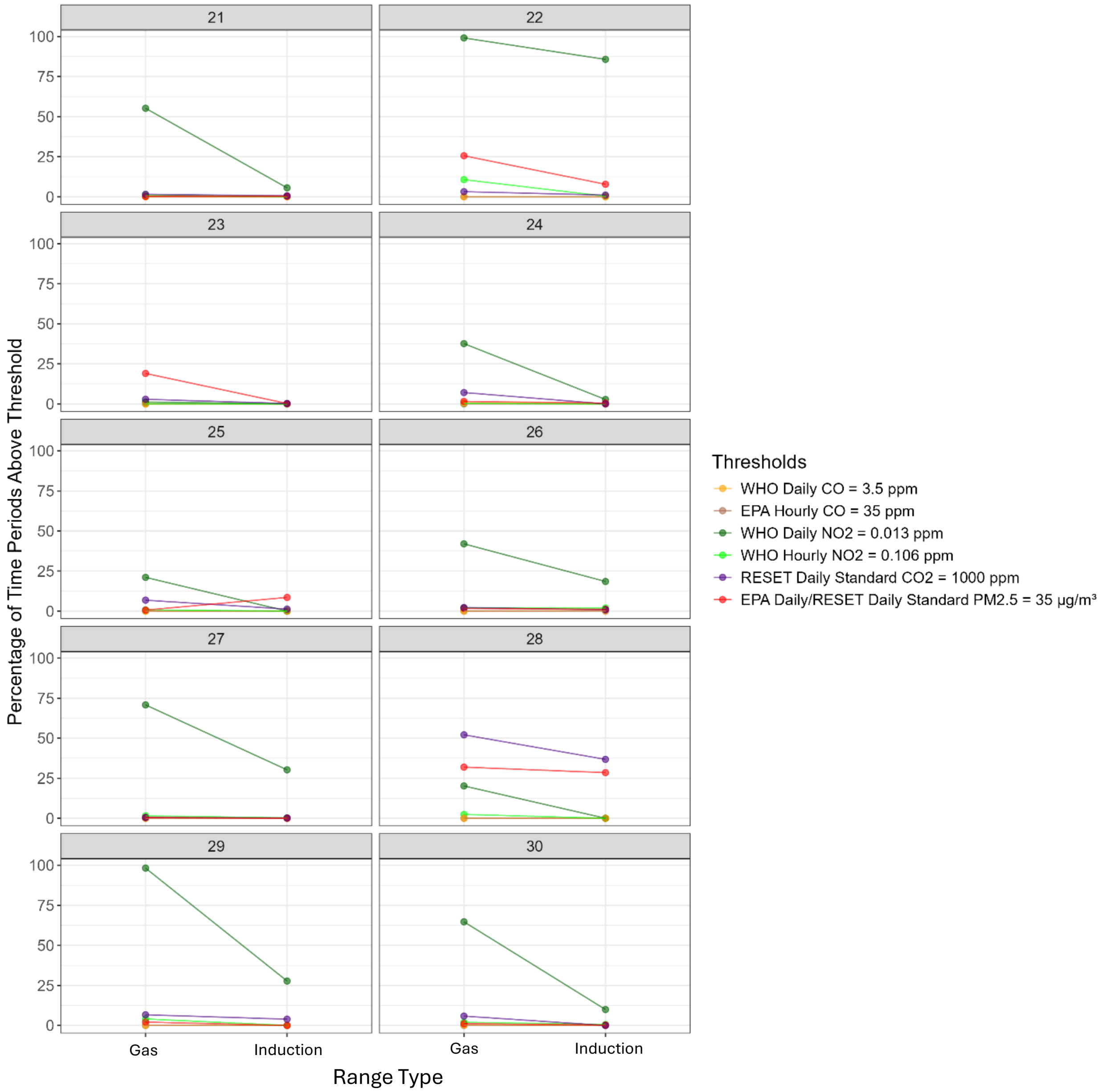
It is also important to note that cooking was often not the only factor causing households to exceed these thresholds. As described earlier, NO_2 is only pollutant likely to reach threshold levels by cooking alone. The tables here instead illustrate that, in some cases, cooking may have pushed pollutant levels above the threshold in instances when the baseline was already high, although this effect is difficult to definitively isolate in the monitored data.

Figure 17 below shows the information above broken out per site, with both hourly and daily metrics. The variation in overall pollutant metrics between sites is visible here. Hourly thresholds were crossed less often than daily.

Aligning with the above analysis, NO_2. levels exhibit the most dramatic improvement in time periods over threshold. The daily NO_2 metric, in particular, improves consistently across sites.

As mentioned earlier, changes in particulate matter metrics vary, with certain sites exhibiting an increase in time periods over threshold in the post- versus pre-period.

Figure 17: Percentage of total days/hours of data with an average pollutant level over certain health organization thresholds, per site, gas versus induction; in the case of multiple applicable thresholds, the least-strict is shown

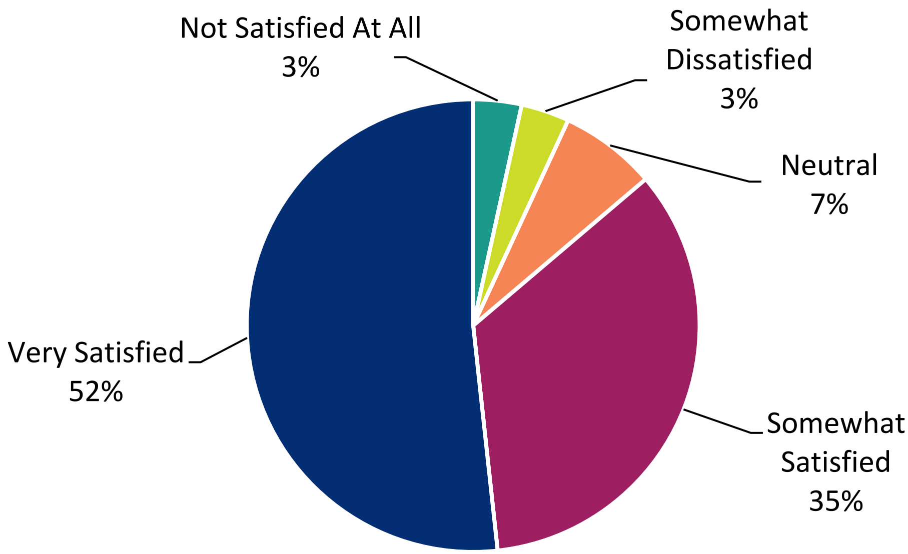


Participant Experience Results

Satisfaction

Eighty-seven percent of respondents were satisfied with their induction range, as shown in Figure 18. Participants reported satisfaction with turbo-boil functionality, fast heating and cooling-down times, the temperature gauge in the oven, dual-zone coils, and cleaning ability. Participants also found the ranges' safety features to be beneficial, especially in settings when children were present.

Figure 18: Interview responses to "How satisfied are you with your induction range?"



When comparing prior range satisfaction, asked in the first survey, with induction range satisfaction, 15 participants reported increased satisfaction levels. Seven participants, who were all satisfied or very satisfied with their previous range, ended the study at a lower satisfaction level than they began. Two of these participants ended the study dissatisfied or very dissatisfied, for reasons elaborated upon below.

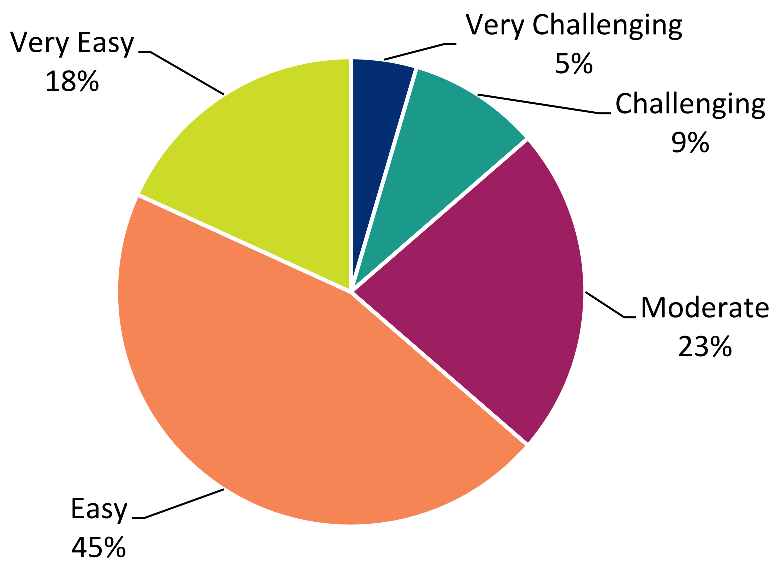
A third of participants reported that the induction model presented a learning curve in adjusting to control differences. Part of this learning curve could be attributed to the fact that most participants transitioned from a knob interface on their prior range to a touchscreen interface on the induction model.

Several participants also expressed that the safety features of the range would get in the way of their cooking, especially when the range was first installed. The stovetops shut off quickly when a pan is removed from the burner, or when a utensil is placed on the appliance, and participant habits had to be adjusted accordingly. These shut-off triggers can be changed in some models, but not the model used in the study. Certain participants reported placing heavy-duty aluminum foil on the burner to override the safety shut-off when removing the pan from the burner to sauté.

The two participants who were not satisfied with their induction range were unsatisfied enough to state that they were going to switch to a different range to regain the controls and functionalities that they missed (i.e. more flexible safety features). These participants stated that their critiques were model-specific issues, and not due to the induction technology itself.

Figure 19 breaks down stated participant experiences adjusting to the new range.

Figure 19: Interview responses to "How would you rate your experience adjusting to your new induction range?"



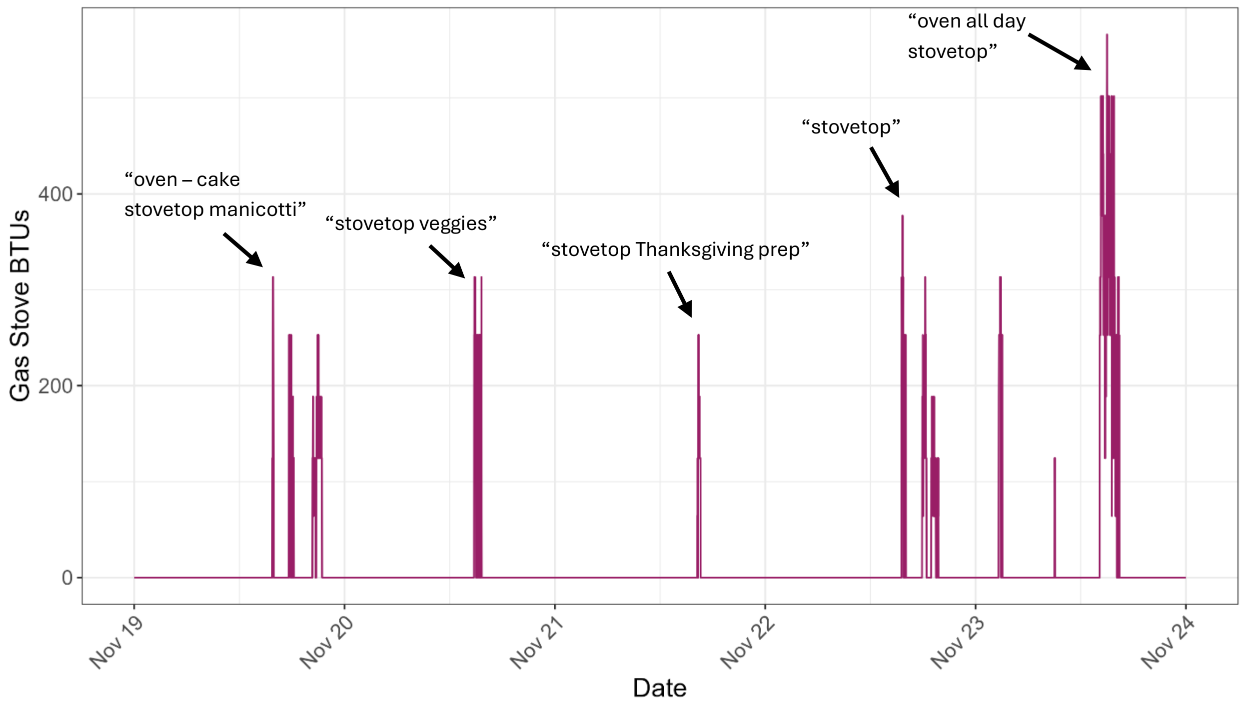
Case Studies

The team looked at several case studies within the study period, using participant logs and interviews, as well as eGuage and air quality timeseries, to pinpoint events of special interest. A few case studies are shared below.

Holiday Dinner

One participant logged their cooking activities during the week of Thanksgiving in the pre-retrofit period. Figure 20 shows the gas range usage from these days, with the logged meals indicated. There are varying cook times based on the type of meal being cooked, and the higher combined power of oven and stovetop can be seen in the November 23rd cooking event.

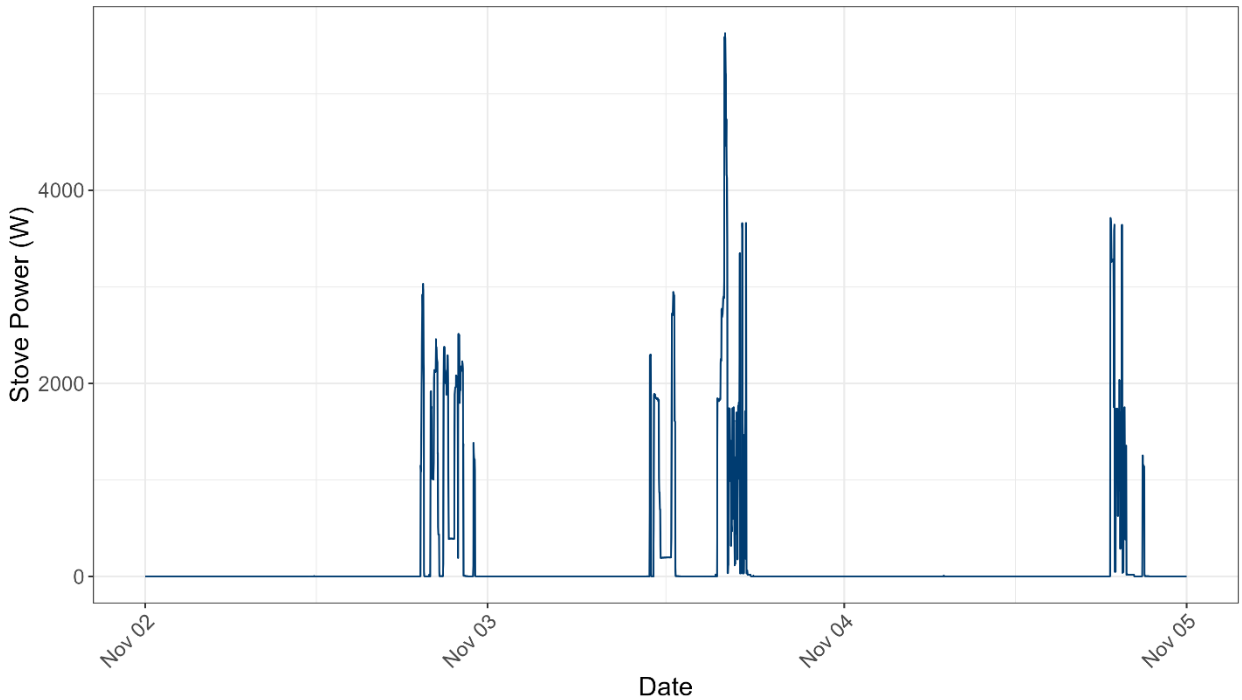
Figure 20: Week of 2023 Thanksgiving power trace, with captions pulled from participant's study journal



Canning

In the final interview, one participant said that the improved induction stovetop controls made canning garden produce easier than with their previous range. Afternoons and evenings this participant spent canning in 2024 are shown in Figure 21 below. Note the variations in stovetop power in each cooking event due to the canning process. The minutely cycles shown in the “Cooking Event Power Traces” section are averaged out at this time scale, so the modulations in power here are primarily due to changes in control setting.

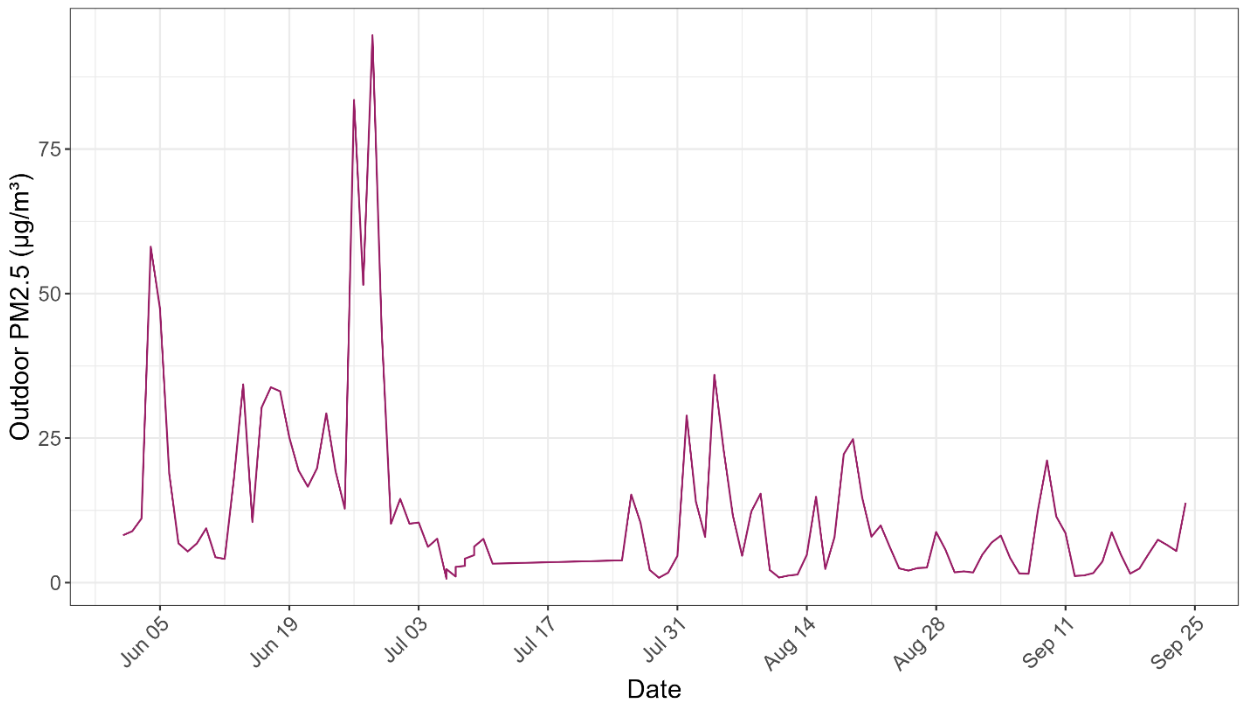
Figure 21: Power trace from several days canning garden fruits and vegetables in 2024



Wildfire

The summer of 2023 was the worst Canadian wildfire season on record, burning more than double the land area of the previous record ("Canada Wildfires, 2023 - Forensic Analysis" 2024). Smoke was very prominent in the Midwestern United States during that time. Daily averages from PurpleAir and EPA AirData monitors in the study region are shown in Figure 22 below. The peak of 95 $\mu g/m^3$ was the highest outdoor $PM_{2.5}$ concentration in the study time period, and is nearly three times the EPA daily threshold.

Figure 22: Timeseries of outdoor particulate matter levels during the summer of 2023.



Conclusions and Recommendations

This field study provides quantitative and qualitative evidence the cooking behavior, energy use, emissions, demand, and indoor air quality of participants with different range types. While sample sizes were small, results identify clear efficiency and IAQ benefits for gas-to-induction retrofits, modest stovetop-only savings for electric-to-induction retrofits, and important considerations for utility program design.

Indoor Air Quality

Gas-to-induction switches substantially reduced NO_2 concentrations, preventing exceedances of WHO and EPA guidelines observed in pre-period cooking events. CO_2 and CO reductions were modest, and PM and VOC levels varied due to multiple household and outdoor contributors.

Recommendation**:** IAQ benefits—particularly with respect to NO_2 reductions—represent meaningful non-energy impacts and may justify incentives in beneficial electrification programs.

Cooking Times and Habits

Participants cooked an average of 60–70 minutes per day on cooking days, with about 50 minutes on the stovetop. Several electric-to-induction participants reported cooking more often due to speed and ease of use, though habit changes varied widely across households.

Recommendation**:** Programs should anticipate potential increases in appliance use following installation of a new range and ensure that measure assumptions reflect realistic daily use patterns.

Energy Use and Efficiency

Isolating stovetop operation, induction saved roughly 15 kWh/year relative to electric resistance with similar minutes of cooktop operation in the pre- and post-periods. Whole-appliance energy use remained similar due to increased oven use in the post period at multiple sites. Gas-to-induction retrofits saved roughly 1,350 kBTU/year (equivalent to 396 kWh/year).

Recommendation**:** The current MEMD cooktop measure aligns reasonably well with the monitored stovetop-only savings from induction technology efficiency gains for electric-to-induction switches. Measured savings from gas-to-induction switches could be incorporated into future measures.

Peak Demand

Peak cooking demand occurred around 5 p.m. Induction stovetops reduced peak kW demand relative to electric resistance stovetops despite having higher power capability. The observed coincidence factor (0.83) differed substantially from the current MEMD assumption.

Recommendation**:** Utilities should account for the lower observed peak demand of induction stovetops when designing programs and consider technologies such as 120V battery-supported ranges when scaling gas-to-induction retrofits.

Carbon Emissions

Gas-to-induction retrofits reduced CO_2 emissions by roughly 700 kg over a 16-year appliance life. Emissions impacts for electric-to-induction retrofits were minimal.

Recommendation: Utilities and contractors should communicate emissions benefits to customers who may be selecting appliances for environmental reasons.

Cost impacts

Energy cost differences were small relative to total household energy bills. Electric-to-induction switches were cost-neutral; gas-to-induction switches increased cooking-related costs under UPPCO rates but would be closer to neutral under I&M rates.

Recommendation: For households pursuing broader electrification, eligibility for space-heating rates or removal of gas service fees may meaningfully improve range operating economics.

Participant Satisfaction

Eighty five percent of respondents were satisfied with their induction range, citing faster cooking, features such as turbo-boil, safety, and cleaning ability. Many participants found the controls unfamiliar, and two were dissatisfied with model-specific safety settings.

Recommendation: Programs should provide clear setup guidance and user training to support successful adoption and minimize early frustration.

Future Research

This study identified several areas in which further research would be valuable in enhancing understanding of the impacts of induction range retrofits at scale.

First, while this study observed some increases in range usage after induction range installation, the underlying drivers of these changes remain unclear. Additional longitudinal research could deepen the understanding of behavior-based changes and how they influence long-term energy use. However, given the relatively small magnitude of savings, a large, dedicated behavioral study is likely not necessary at this stage. Instead, ongoing energy efficiency program evaluations, which already oftentimes include site visits, participant surveys, and billing analysis, are well positioned to monitor whether the currently assumed savings for induction cooktops continue to hold in the field. If evaluators identify issues related to persistent behavior changes or unexpected oven usage patterns, those findings can inform future measure updates.

Second, a larger and more diverse sample would be valuable for improving confidence in energy, demand, and IAQ results, and for understanding variation in these metrics across household types. Such a study could be considered in the future if program evaluators or implementers observe discrepancies between assumed and realized savings, or if policymakers identify a need for more granular behavioral insights.

Third, to refine understanding of cooking IAQ impacts, future studies could incorporate more granular data on other IAQ contributors—such as pets, smoking behavior, outdoor air quality, cleaning products, and ventilation practices. This would improve the ability to isolate the specific impacts of cooking on particulate matter and VOCs, in particular, providing a clearer picture of the full IAQ benefits of induction range adoption. An IAQ characterization that assesses pollution levels across a representative sample of buildings would also provide valuable data to assess the prevalence of IAQ issues across the building stock and identify vulnerable building types.

It is important to note that the population volunteering to participate in a field study may not be fully representative of the general population. Individuals who opt into studies like this one may have higher interest in new technologies, greater tolerance for learning curves, or stronger motivations to adopt energy-efficient appliances. As a result, overall satisfaction levels, likelihood of switching to induction ranges, and IAQ-related habits may differ in this population from the general public. Future research could incorporate broader survey samples to investigate these differences.

Finally, while this study provides information on the impact of gas versus induction cooking on indoor pollutant concentrations, it does not assess any direct health impacts of those pollutant reductions. Longitudinal and large-scale studies of occupant health across different range types would provide insight on whether decreased exposure to combustion-related pollutants leads to measurable health benefits over time. Such work would provide important context for policymakers and utilities evaluating the non-energy impacts of induction adoption.

Appendix A: Extended IAQ Literature Review

Pollutant Type	Health Literature
NO_2	• NO_2 is generally the most worrisome pollutant emitted from gas ranges. This is due to links between respiratory symptoms and NO_2 exposure at NO_2 levels around the levels reached indoors when cooking on a gas range. • In homes with gas ranges, NO_2 levels often exceed outdoor levels, while in homes without combustion appliances, levels are about half that of outdoors (United States Environmental Protection Agency 2025b). • 2021 WHO guidelines cite links between NO2 exposure and all-cause, as well as respiratory, mortality (*WHO Global Air Quality Guidelines 2021)*. Likewise, as of 2016, the EPA concluded that outdoor NO_2 exposure is "causal" in worsening respiratory symptoms in individuals with asthma and "likely causal" in the development of asthma with long-term exposure (United States Environmental Protection Agency 2025a). • Meta-analyses find links between gas range use and increased risk of chronic obstructive pulmonary disease, pneumonia, and bronchitis, citing elevated NO_2 emissions (Puzzolo et al. 2024). • Studies link childhood asthma attacks and other childhood respiratory symptoms to gas range use and increased NO_2 concentrations (Paulin et al. 2017; Gillespie-Bennett et al. 2011; Volkmer et al. 1995). • Numerous studies have been done on the link between gas ranges and the development of childhood asthma. One cohort study found that children living in homes with gas ranges were 2.5 times more likely to develop asthma, even when controlling for socioeconomic factors and proximity to major roads (Han et al. 2023). Similar studies quantify that about 12% U.S. childhood asthma cases attributable to gas ranges, and estimate that gas ranges raise long-term NO2 exposure by 4ppb on average across the U.S., increasing asthma cases (Gruenwald et al. 2022; Kashtan et al. 2024). However, recent follow-up analyses caution against over-interpreting these types of causal results, as there are many other factors that contribute to the development of asthma, and risks are likely decreased by proper ventilation practices (Cox 2023; Li et al. 2023; Bédard et al. 2023; "Gas Stoves and Chronic Respiratory Illness in Children" 2015).
CO_2	• Indoor CO_2 levels are often significantly higher than outdoors, due to factors like human respiration and gas combustion (Satish et al. 2012). • CO_2 is not classified as a criteria pollutant by the EPA or the WHO, meaning that its health effects are considered less severe. • One study on office workers found that CO_2 concentrations above 1000 ppm, often reached during cooking in this study, were associated with slower cognitive performance (Allen et al. 2016).

	• The RESET IAQ building performance standard sets a daily threshold for CO_2, citing an impact on productivity and comfort (RESET Air, n.d.).
CO	• *Though CO is known to be toxic at certain exposure levels, gas range use in this study did not raise CO near those levels, so we have not included a review of CO literature here.*
Particulate matter ($PM_{2.5}$)[16]	• $PM_{2.5}$ is a classification of solid-state particles from various origins that are 2.5 micrometers or less in diameter. Household particulate matter can be from to a variety of sources, including dust, cleaning products, pets, burning and cooking food, and fuel combustion. • Particulate matter indoors can fluctuate with outdoor air quality, especially during extreme events such as wildfires (Emmerich et al. 2022). • In setting particulate matter thresholds, the WHO cites meta-analyses finding that increased exposure to particulate matter increases risk of mortality due to cardiovascular disease, respiratory disease and lung cancer (Chen and Hoek 2020; Orellano et al. 2020). • Studies show cell inflammation increasing with increased exposure to particulate matter pollution from ranges (Walker et al. 2022; Han et al. 2025).
VOCs	• VOCs are a group of organic compounds that can be released from cleaners, paints, new furniture, burning and cooking food, fuel combustion, and other sources. The same VOC level can be reached with different combinations of compounds, but monitoring usually groups these compounds together, since they tend to co-occur (Awair Support, n.d.). These compounds, like particulate matter, can land on surfaces and be re-emitted into the air later on. • Indoor VOC concentrations are generally higher than outdoor concentrations, and can be up to ten times higher ("Indoor Air Quality" 2025). • VOCs are not considered a criteria pollutant by the EPA or the WHO. However, the EPA lists health effects on its website including damage to the kidneys, liver, and central nervous system, and the WHO outlines health effects of specific compound at different levels ("Indoor Air Quality" 2025; *Air Quality Guidelines for Europe* 2000). The RESET IAQ building performance standard includes VOC targets, which are the thresholds shown to the right. • Benzene, a VOC emitted during fuel combustion, has been linked to increased rates of cancer (Kashtan et al. 2023; Garg et al. 2025).

[16] $PM_{2.5}$ is the smaller-diameter designation for particulate matter. PM_{10} is a grouping of particulate matter that includes $PM_{2.5}$ particles, as well as particles with larger widths. Accordingly, the recommended maximum exposure thresholds for PM_{10} are higher.

Appendix B: Recruitment Materials

FAQs | Induction Range Research Study

FREQUENTLY ASKED QUESTIONS

VERSION 1 | FEBRUARY 2023

How does an induction cooktop work?

When you turn on an induction cooktop, an electric current passes through metal coils under the cooktop's surface. This creates a magnetic field that directly heats pots and pans on the cooktop. This is different than a traditional electric or natural gas stove which heats up the pot by transferring heat from a flame or coil to the pot or pan. This is also why induction cooktops can only be used with pots and pans that are magnetic (more on that below).

What's different when I'm cooking on my induction cooktop?

The induction cooktop will cook food faster. For example, a pot of water will boil quicker on your new induction range.

Induction ranges reduce the risks of burns and fires because the burners only heat magnetic pots and pans when placed on the cooktop. A flammable dish towel or child's hand will not be directly heated or burned by the cooktop because they are not magnetic.

Knowing when the induction cooktop is turned on will be different because it does not have the "glow" of an electric resistance cooktop or the flame of a gas cooktop. Typically, induction cooktops have a light to indicate when they are cooking.

You might hear a buzz or a hum. This is normal! The buzz or hum is from the magnets at work.

Will my existing pots and pans work with the new induction range?

Your current pots and pans *may* not work with your new range. Magnetic cookware like cast iron or stainless steel will work with your induction cooktop, but aluminum pans will not. This is why we are providing you a new set. To check if your cookware will work with an induction cooktop, put a magnet on the bottom of your pots and pans. If the magnet sticks to the cookware, it will work with induction.

Will I get to pick out my new set of pots and pans?

You will get to choose a new set of pots and pans from options that we provide. These will include different types of pots, pans and materials (e.g. cast iron, stainless steel).

Will I get to pick out the induction range I receive?

We are still determining the make and model(s) that will be available to participants. You will be able to see the options prior to fully committing to this research.

Will it cost me more to operate my new induction range?

According to the EPA, induction cooking is 5–10% more efficient than conventional electric cooking and could reduce cooking energy costs. Although induction cooking is about three times more energy efficient than gas or propane, the cost impacts will depend on the fuel prices in your area.

Who will service my new range if I have problems after the study ends?

We are available to resolve any issues with the induction range during the research project. After we conclude the research project and remove monitoring equipment, we will no longer support any issues with the equipment.

For issues with the induction range during the study, contact Kevin Gries at kgries@slipstreaminc.org or 608.729.6878.

For issues after the study, please refer to the warranty information provided with the installed induction range.

You are monitoring my energy use and indoor air quality, will you let me know what you find?

Yes. Once the project is completed, we will share the results with all participants.

PROJECT PARTNERS

INDIANA MICHIGAN POWER — An AEP Company | UPPCO smart energy — energy efficiency | slipstream

Appendix C: Device Troubleshooting and Data Quantities

Table 7 documents the quantity of monitoring data that we successfully gathered, with notes on troubleshooting that occurred at several points throughout the study to reconnect and adjust devices.

Table 7: Data quantity per site and device troubleshooting notes

Site Number	Total Days of IAQ Data	Total Days of Power Data	Notes
1	NA	765	
2	NA	765	
3	NA	765	
4	NA	763	
5	NA	763	
6	NA	767	
7	NA	777	
8	NA	763	
9	NA	603	
10	NA	774	
11	NA	762	
12	NA	763	
13	NA	782	
14	NA	784	
15	NA	782	
16	NA	783	
17	NA	781	
18	NA	785	
19	NA	595	eGuage shut off and was replaced in February 2024
20	NA	783	
21	710	333	eGuage shut off and rebooted intermittently throughout study due to network issues.
22	707	734	
23	601	733	HOBO logger shut off and disconnected December 2024, returned to site and restarted logging in February 2025.
24	493	722	IAQ loggers shut off and rebooted intermittently throughout study due to network issues.
25	639	721	
26	693	719	
27	590	718	HOBO logger shut off and disconnected December 2024, returned to site and resumed logging in February 2025.
28	642	718	
29	590	NA	Recruited late, IAQ analysis only. HOBO logger shut off and disconnected December 2024, returned to site and resumed logging in February 2025.
30	650	440	eGuage malfunction in post-period, running but reading in blank data, IAQ analysis only.
Average	632 days	698 days	
Total	6,315 days	20,943 days	

* All HOBO loggers stopped remotely reporting data due to company changes in February 2025. We were able to recover the majority of that data through on-site downloads by the participants.

Appendix D: Detailed Analysis of Cooking Habit Changes

Cooking Changes in Gas-to-Induction Participants

For the gas range participants, there was a discernable change in cooking time pre- vs post-induction range installation, with participants cooking for on average seven more minutes per day in the post-period and 80 percent of households increasing their average daily minutes cooking.

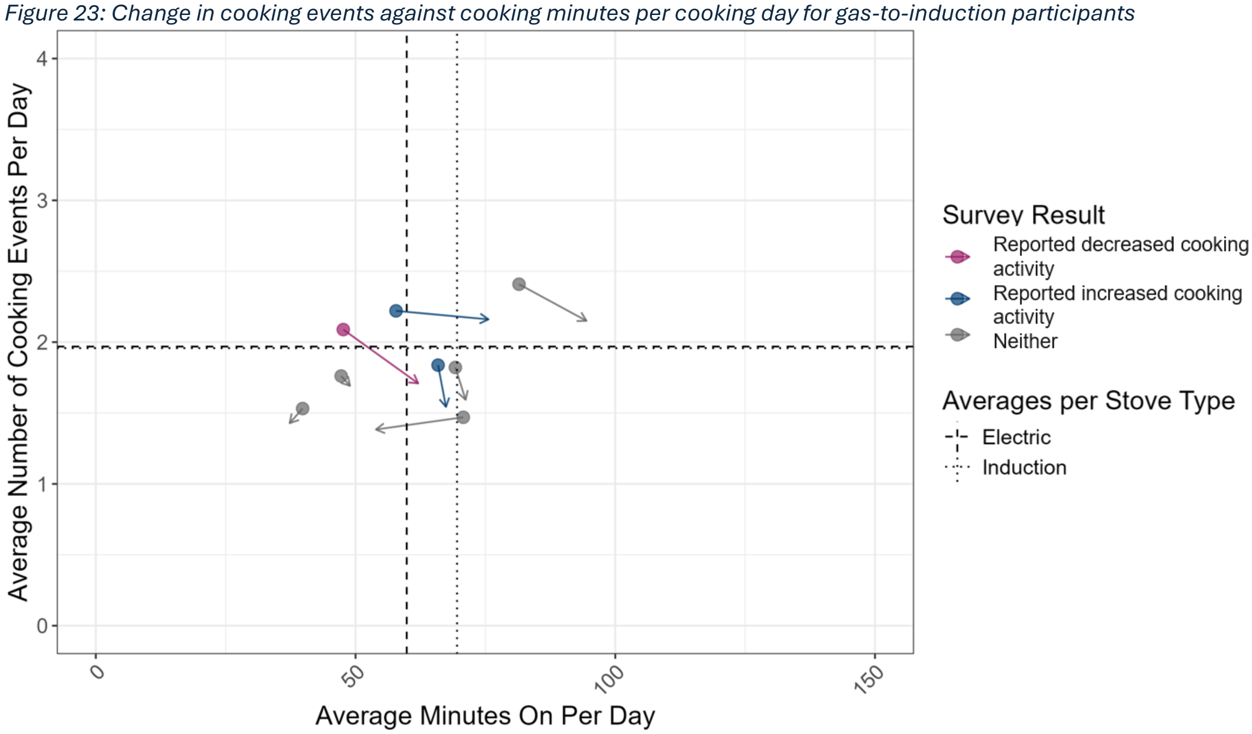
Table 8: Monitored versus reported changes in cook time and cooking habit in gas-to-induction participants

Prior Range Type	Monitored Change in Daily Cook Time	Participants' Reported Change in Potential Cook Time	Participants' Reported Change in General Cooking Habits
Gas	**80%** of households increased average daily minutes	**55%** of households mentioned ability to cook quicker	**20%** of households reported an increase, and **10%** a decrease

Although difficult to attribute precisely, the observed increase in cooking minutes is likely related to difference in energy intensity of usage (i.e. energy per time period, more time at lower settings), rather than an increased need for cooking. More than half of gas-to-induction participants reported that they felt the induction range allowed them to cook, and especially boil, more quickly. These benefits could have created a perception of shorter cooking times, with participants also using lower heat settings for longer during other types of cooking. This greater use of low-power settings (e.g., simmering) may be seen because of the induction range's more precise temperature control.

Figure 23 shows the change in average daily cooking events versus the change in average daily cooking minutes between the pre- and post-retrofit period for days with at least one minute cooking. Each arrow represents an individual household's change from gas to induction. The direction and length of the arrows indicate the magnitude and direction of change. Participants who self-reported that they cooked more or less with the induction range are color-coded by response type. These self-reports reflect perceived changes in cooking frequency or duration, while the arrows on the chart represent monitored changes based on sensor data.

Figure 23: Change in cooking events against cooking minutes per cooking day for gas-to-induction participants



An "increase" in cooking could appear in the monitoring data as an upward arrow (more cooking events per day), a rightward arrow (longer total cooking time per day), or both. Conversely, a "decrease" could appear as downward, leftward, or both. Discrepancies highlight situations where these two things differ (e.g. a household feels they cook more because they are cooking more complicated meals, but on the average, the amount of time the range is on is equal pre- and post-retrofit).

Two of the three gas-to-induction participants' self-reported changes in cooking activity are consistent with the monitored data. One household reported decreased cooking activity that aligns with monitored decreasing cooking events per day, and one household reported increased cooking activity that aligns with monitored increasing cooking minutes per day.

The third self-report, the blue point with the nearly vertical downward arrow, is also technically consistent with monitored data. However, the increase in cooking minutes, only about one additional minute per day, is marginal and likely smaller than the participant's perceived increase. This underscores the challenges of relying solely on monitored or self-reported data to capture changes in daily routines, as well as the nuanced daily habits that comprise overall energy consumption.

Overall, the figure speaks to the variability in cooking behaviors across households. Even among households who did not mention a change, the monitored results show a range of increases and decreases in cooking activity.

Cooking Changes in Electric-to-Induction Participants

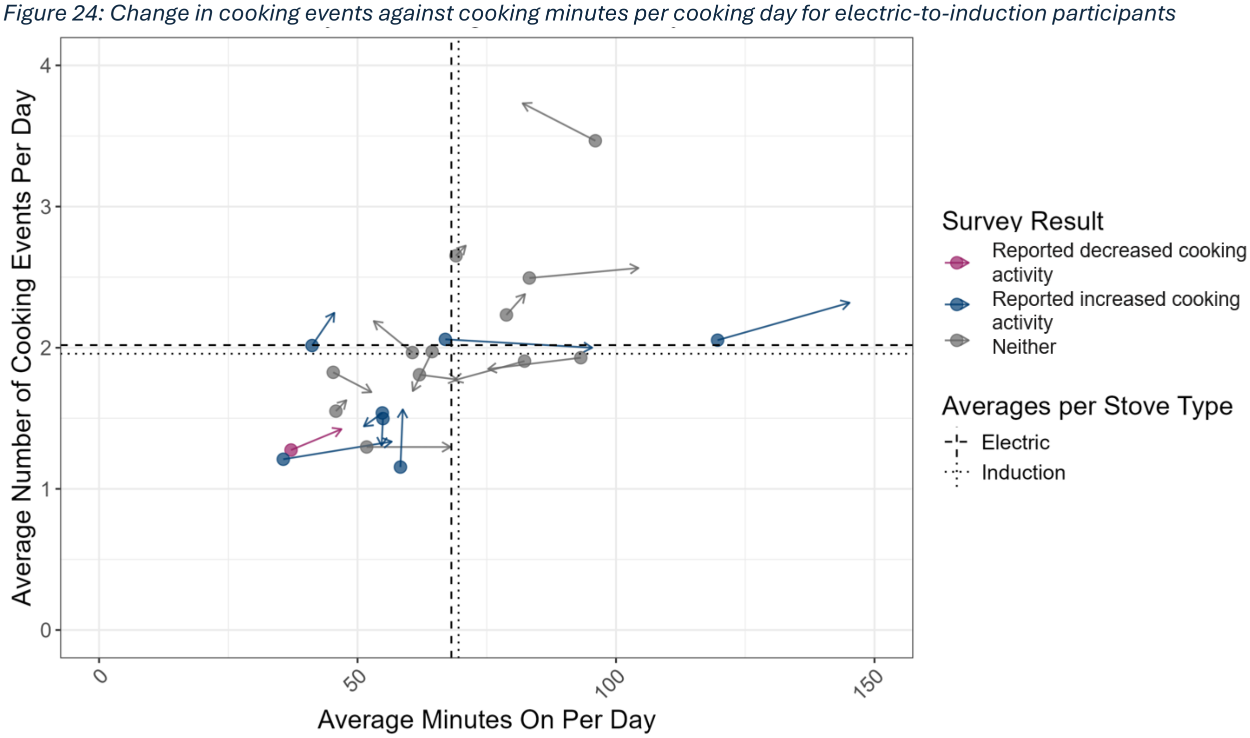
Electric range participants saw similar cook times and cooking events per day on average in the pre- versus post-period, with 40 percent of electric-to-induction participants increasing their daily average minutes cooking. Like the gas participants, more than half of electric-to-induction participants stated that they felt they had the ability to cook food faster.

Table 9: Monitored versus reported changes in cook time and cooking habit, electric-to-induction participants

Prior Range Type	Monitored Change in Daily Cook Time	Participants' Reported Change in Potential Cook Time	Participants' Reported Change in General Cooking Habits
Electric	**40%** of households increased average daily minutes	**60%** of households mentioned ability to cook quicker	**35%** of households reported an increase, and **5%** a decrease

Figure 24 shows the change in average daily cooking minutes and events per day for participants who switched from electric to induction ranges. As in the previous figure, the direction and length of the arrows indicate each household's change between the pre- and post-monitoring periods, and no-cooking days are not included. Among participants who reported a perceived change in cooking habits, 65 percent showed corresponding shifts in at least one monitored metric (minutes or cooking events). Thirty-five percent of perceived habit changes did not align with the average changes shown in monitored data.

Figure 24: Change in cooking events against cooking minutes per cooking day for electric-to-induction participants



Cooking Changes Across Study Groups

There are several takeaways from comparing the results of the two sections above, and integrating additional survey data.

First, a higher proportion of participants in the electric-to-induction group self-reported increased cooking habits compared with those in the gas-to-induction group. Within this small sample, it is unclear whether these differences reflect prior range type or random variation.

Second, all horizontal dashed lines showing daily average cooking events in Figure 23 and Figure 24 sit near two events per day. This illustrates that, on average, participants used their ranges for longer durations within each cooking event rather than cooking more frequently overall.

Lastly, all participants who reported increased cooking activity (shown in blue) in both study groups said that they were “satisfied” or “very satisfied” with their induction range. This alignment between reported satisfaction and increased perceived range usage suggests that user experience with appliance features may influence cooking frequency, though this relationship cannot be confirmed from the current data.

References

Air Quality Guidelines for Europe. 2000. 2nd ed. WHO Regional Publications. European Series, no. 91. World Health Organization, Regional Office for Europe.

Allen, Joseph G., Piers MacNaughton, Usha Satish, Suresh Santanam, Jose Vallarino, and John D. Spengler. 2016. "Associations of Cognitive Function Scores with Carbon Dioxide, Ventilation, and Volatile Organic Compound Exposures in Office Workers: A Controlled Exposure Study of Green and Conventional Office Environments." *Environmental Health Perspectives* 124 (6): 805–12. https://doi.org/10.1289/ehp.1510037.

Awair Support. n.d. "What Chemicals (TVOCs) Can Awair Omni Detect?" Accessed November 4, 2025. https://support.getawair.com/hc/en-us/articles/1500002347661-What-chemicals-TVOCs-can-Awair-Omni-detect.

Baxter, Lisa K., Jane E. Clougherty, Francine Laden, and Jonathan I. Levy. 2007. "Predictors of Concentrations of Nitrogen Dioxide, Fine Particulate Matter, and Particle Constituents inside of Lower Socioeconomic Status Urban Homes." *Journal of Exposure Science & Environmental Epidemiology* 17 (5): 433–44. https://doi.org/10.1038/sj.jes.7500532.

Bédard, Marc-Antoine, Myrtha E. Reyna, Theo J. Moraes, et al. 2023. "Association between Gas Stove Use and Childhood Asthma in the Canadian CHILD Cohort Study." *Canadian Journal of Public Health = Revue Canadienne De Sante Publique* 114 (4): 705–8. https://doi.org/10.17269/s41997-023-00779-0.

California Electronic Technical Reference Manual. 2025. Accessed November 17, 2025. https://www.caetrm.com/login/?next=/measure/SWAP015/03/.

"Canada Wildfires, 2023 - Forensic Analysis." 2024. September 17. https://www.undrr.org/resource/canada-wildfires-2023-forensic-analysis.

Chen, Jie, and Gerard Hoek. 2020. "Long-Term Exposure to PM and All-Cause and Cause-Specific Mortality: A Systematic Review and Meta-Analysis." *Environment International* 143 (October): 105974. https://doi.org/10.1016/j.envint.2020.105974.

Copper. 2025. "2025 Incentives and Rebate Information." https://copperhome.com/pages/charlie-rebates-and-incentives-information.

Cox, Louis Anthony. 2023. "The Gas Stove-Childhood Asthma Kerfuffle: A Teaching Opportunity." *Global Epidemiology* 5 (March): 100104. https://doi.org/10.1016/j.gloepi.2023.100104.

Department of Environment, Great Lakes, and Energy. n.d. "Home Energy Rebates." Accessed November 4, 2025. https://www.michigan.gov/egle/about/organization/materials-management/energy/rfps-loans/home-energy-rebate-programs.

DigiKey TechForum. 2020. "Sensirion Gas Sensor FAQ." Accessed November 4, 2025. https://forum.digikey.com/t/sensirion-gas-sensors-faq/5205.

District of Columbia Sustainable Energy Utility. 2025. "Residential Electric & Induction Stove Rebates." https://www.dcseu.com/residential-rebates/stoves?utm=.

Emmerich, Steven, Chrissi Antonopoulos, Patricia Graef, Rick Karg, Brett Singer, and Eric Werling. 2022. "Wildfire Smoke Impacts on Residential Indoor Air Quality." *NIST*, March 1. https://www.nist.gov/publications/wildfire-smoke-impacts-residential-indoor-air-quality.

ENERGY Star. n.d. "2021-2022 Residential Induction Cooking Tops | ENERGY STAR." Accessed October 29, 2025. https://www.energystar.gov/partner-resources/products_partner_resources/brand-owner/eta-consumers/res-induction-cooking-tops.

Franklin, Stephen L., Jr., and Robert S. Pindyck. 2024. "A Supply Curve for Forest-Based CO_2 Removal." MIT Center for Energy and Environmental Policy Research (CEEPR), Cambridge, MA (United States). MIT CEEPR Working Paper 2024-04. https://ceepr.mit.edu/wp-content/uploads/2024/03/MIT-CEEPR-WP-2024-04.

Pieter. 2024. "Long-Run Marginal Emission Rates for Electricity - Workbooks for 2023 Cambium Data." National Renewable Energy Laboratory - Data (NREL-DATA), Golden, CO (United States); National Renewable Energy Laboratory (NREL), Golden, CO (United States). 2 files. https://doi.org/10.7799/2305481.

Garg, Anchal, Yannai Kashtan, Metta Nicholson, et al. 2025. "Exposure and Health Risks of Benzene from Combustion by Gas Stoves: A Modelling Approach in U.S. Homes." *Journal of Hazardous Materials* 492 (July): 137986. https://doi.org/10.1016/j.jhazmat.2025.137986.

"Gas Stoves and Chronic Respiratory Illness in Children." 2015. *AAP Grand Rounds* 33 (1): 10. https://doi.org/10.1542/gr.33-1-10.

Gillespie-Bennett, J., N. Pierse, K. Wickens, J. Crane, P. Howden-Chapman, and Housing Heating and Health Study Research Team. 2011. "The Respiratory Health Effects of Nitrogen Dioxide in Children with Asthma." *The European Respiratory Journal* 38 (2): 303–9. https://doi.org/10.1183/09031936.00115409.

Gruenwald, Talor, Brady A. Seals, Luke D. Knibbs, and H. Dean Hosgood. 2022. "Population Attributable Fraction of Gas Stoves and Childhood Asthma in the United States." *International Journal of Environmental Research and Public Health* 20 (1): 75. https://doi.org/10.3390/ijerph20010075.

Han, Huishan, Xianru Peng, Minyu Huang, et al. 2025. "PM2.5 Exposure Aggravates Inflammatory Response and Mucus Production in 16HBE Cells through Inducing Oxidative Stress and RAGE Expression." *Cell Biochemistry and Biophysics* 83 (1): 941–51. https://doi.org/10.1007/s12013-024-01526-z.

Han, Yueh-Ying, Franziska Rosser, Erick Forno, Edna Acosta-Pérez, Glorisa Canino, and Juan C. Celedón. 2023. "Gas Stove Use and Asthma in a Longitudinal Study of Puerto Rican Children and Adolescents." *The Journal of Allergy and Clinical Immunology. In Practice* 11 (8): 2599-2601.e3. https://doi.org/10.1016/j.jaip.2023.04.049.

Hirose, Minoru, Mizuho Hida, Eiji Sato, Kenichi Kokubo, Masaki Nie, and Hirosuke Kobayashi. 2005. "Electromagnetic Interference of Implantable Unipolar Cardiac Pacemakers by an Induction Oven." *Pacing and Clinical Electrophysiology: PACE* 28 (6): 540–48. https://doi.org/10.1111/j.1540-8159.2005.09565.x.

Irnich, Werner, and Alan D. Bernstein. 2006. “Do Induction Cooktops Interfere with Cardiac Pacemakers?” *Europace: European Pacing, Arrhythmias, and Cardiac Electrophysiology: Journal of the Working Groups on Cardiac Pacing, Arrhythmias, and Cardiac Cellular Electrophysiology of the European Society of Cardiology* 8 (5): 377–84. https://doi.org/10.1093/europace/eul014.

Kashtan, Yannai, Metta Nicholson, Colin J. Finnegan, et al. 2024. “Nitrogen Dioxide Exposure, Health Outcomes, and Associated Demographic Disparities Due to Gas and Propane Combustion by U.S. Stoves.” *Science Advances* 10 (18): eadm8680. https://doi.org/10.1126/sciadv.adm8680.

Kashtan, Yannai S., Metta Nicholson, Colin Finnegan, et al. 2023. “Gas and Propane Combustion from Stoves Emits Benzene and Increases Indoor Air Pollution.” *Environmental Science & Technology* 57 (26): 9653–63. https://doi.org/10.1021/acs.est.2c09289.

La Paz Affordable Multifamily Electrification Monitoring and Verification. 2025. Commonwealth Edison and Slipstream. Full manuscript available upon request.

Li, Wenchao, Christopher Long, Tongyao Fan, Elyssa Anneser, Jiayang Chien, and Julie E. Goodman. 2023. “Gas Cooking and Respiratory Outcomes in Children: A Systematic Review.” *Global Epidemiology* 5 (December): 100107. https://doi.org/10.1016/j.gloepi.2023.100107.

Livchak, Denis, Russell Hedrick, and Richard Young. 2019. *Residential Cooktop Perforamnce and Energy Comparison Study*. Nos. 501318071-R0. Frontier Energy. https://cao-94612.s3.amazonaws.com/documents/Induction-Range-Final-Report-July-2019.pdf.

Mass Save. 2025. “Electric Cooktops.” https://www.masssave.com/en/residential/rebates-offers-services/appliances-and-products/cooktoprebates.

McCullough, Madeleine. 2025. *State Funding Tracker*. National Housing Trust. https://nationalhousingtrust.org/sites/default/files/documents/DOE-Rebates-State-Funding-Tracker-9-5.pdf.

Michanowicz, Drew R., Archana Dayalu, Curtis L. Nordgaard, et al. 2022. “Home Is Where the Pipeline Ends: Characterization of Volatile Organic Compounds Present in Natural Gas at the Point of the Residential End User.” *Environmental Science & Technology* 56 (14): 10258–68. https://doi.org/10.1021/acs.est.1c08298.

Michigan Energy Measures Database. 2025. Accessed November 17, 2025. https://www.michigan.gov/mpsc/consumer/energy-optimization/michigan-energy-measures-database.

Nhs.Uk. 2017. “Pacemaker Implantation.” October 20. https://www.nhs.uk/tests-and-treatments/pacemaker-implantation/.

Orellano, Pablo, Julieta Reynoso, Nancy Quaranta, Ariel Bardach, and Agustin Ciapponi. 2020. “Short-Term Exposure to Particulate Matter (PM10 and PM2.5), Nitrogen Dioxide (NO2), and Ozone (O3) and All-Cause and Cause-Specific Mortality: Systematic Review and Meta-Analysis.” *Environment International* 142 (September): 105876. https://doi.org/10.1016/j.envint.2020.105876.

Parker, Danny, Philip Fairey, and Robert Hendron. 2010. *Updated Miscellaneous Electricity Loads and Appliance Energy Usage Profiles for Use in Home Energy Ratings, the Building America Benchmark Procedures and Related Calculations*. FSEC-CR-1837-10. Florida Solar Energy Center.

Paulin, Laura M., D.'Ann L. Williams, Roger Peng, et al. 2017. "24-h Nitrogen Dioxide Concentration Is Associated with Cooking Behaviors and an Increase in Rescue Medication Use in Children with Asthma." *Environmental Research* 159 (November): 118–23. https://doi.org/10.1016/j.envres.2017.07.052.

PurpleAir. n.d. "Real-Time Air Quality Monitoring by PurpleAir." Accessed November 11, 2025. https://www2.purpleair.com/.

Puzzolo, Elisa, Nigel Fleeman, Federico Lorenzetti, et al. 2024. "Estimated Health Effects from Domestic Use of Gaseous Fuels for Cooking and Heating in High-Income, Middle-Income, and Low-Income Countries: A Systematic Review and Meta-Analyses." *The Lancet Respiratory Medicine* 12 (4): 281–93. https://doi.org/10.1016/S2213-2600(23)00427-7.

RESET Air. n.d. "RESET® Air Standard." Accessed November 4, 2025. https://reset.build.

Rubin, Eric, Daniel Young, Maximillian Hietpas, Arshak Zakarian, and Phi Nguyen. 2016. *Plug Loads and Lighting Modeling: Measure Number 2016-RES-ACM-D*. 2016 California Building Energy Efficiency Standards. https://title24stakeholders.com/wp-content/uploads/2017/10/2016_CASE-Report_Plug-Loads-and-Lighting-Modeling.pdf.

Satish, Usha, Mark J. Mendell, Krishnamurthy Shekhar, et al. 2012. "Is CO2 an Indoor Pollutant? Direct Effects of Low-to-Moderate CO2 Concentrations on Human Decision-Making Performance." *Environmental Health Perspectives* 120 (12): 1671–77. https://doi.org/10.1289/ehp.1104789.

Seltenrich, Nate. 2024. "Clearing the Air: Gas Stove Emissions and Direct Health Effects." *Environmental Health Perspectives* 132 (2): 022001. https://doi.org/10.1289/EHP14180.

Sweeney, Micah, Jeff Dols, Brian Fortenbery, and Frank Sharp. 2014. *Induction Cooking Technology Design and Assessment*. Electric Power Research Institute. https://www.aceee.org/files/proceedings/2014/data/papers/9-702.pdf.

The Tierra Linda Passive House: A Comparative Case Study Executive Summary. 2021. Commonwealth Edison and Slipstream. https://innovate.comed.com/wp-content/uploads/2023/05/ComEd-Emerging-Technologies-Passive-House-Tierra-Linda.pdf. Full manuscript available upon request.

United States Environmental Protection Agency. 2016. "Interactive Map of Air Quality Monitors." Data and Tools. August 17. https://www.epa.gov/outdoor-air-quality-data/interactive-map-air-quality-monitors.

United States Environmental Protection Agency. 2025a. "Integrated Science Assessment (ISA) for Oxides of Nitrogen - Health Criteria." Reports and Assessments. August 21. https://www.epa.gov/isa/integrated-science-assessment-isa-oxides-nitrogen-health-criteria.

United States Environmental Protection Agency. 2025b. “The Inside Story: A Guide to Indoor Air Quality.” Overviews and Factsheets. May 23. https://www.epa.gov/indoor-air-quality-iaq/inside-story-guide-indoor-air-quality.

“Volatile Organic Compounds’ Impact on Indoor Air Quality.” 2025. Overviews and Factsheets. July 24. https://www.epa.gov/indoor-air-quality-iaq/volatile-organic-compounds-impact-indoor-air-quality.

Volkmer, R. E., R. E. Ruffin, N. R. Wigg, and N. Davies. 1995. “The Prevalence of Respiratory Symptoms in South Australian Preschool Children. II. Factors Associated with Indoor Air Quality.” *Journal of Paediatrics and Child Health* 31 (2): 116–20. https://doi.org/10.1111/j.1440-1754.1995.tb00758.x.

Walker, Ethan S., Kristen M. Fedak, Nicholas Good, et al. 2022. “Acute Differences in Blood Lipids and Inflammatory Biomarkers Following Controlled Exposures to Cookstove Air Pollution in the STOVES Study.” *International Journal of Environmental Health Research* 32 (3): 565–78. https://doi.org/10.1080/09603123.2020.1785402.

WHO Global Air Quality Guidelines. Particulate Matter (PM2.5 and PM10), Ozone, Nitrogen Dioxide, Sulfur Dioxide and Carbon Monoxide. 2021. World Health Organization. https://iris.who.int/server/api/core/bitstreams/551b515e-2a32-4e1a-a58c-cdaecd395b19/content.

Zhang, Ge, Fulu Sun, Haichao Li, Yuanxin Lin, Kai Zhao, and Lei Fang. 2023. “The Content and Emission Form of Volatile Organic Compounds from Cooking Oils: A Gas Chromatography-Mass Spectrometry (GC-MS) Analysis.” *International Journal of Environmental Research and Public Health* 20 (3): 1796. https://doi.org/10.3390/ijerph20031796.