# Healthier Cooking, No Veggies Required: Gas-to-Induction Stove Retrofits and Indoor Air Quality

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**ABSTRACT**

Growing attention to indoor air quality (IAQ) has highlighted the significant contribution of gas-burning appliances, particularly cooking stoves, to household pollutant exposure. To assess the potential IAQ benefits and energy savings of switching to an induction stove, the research team conducted an innovative two-year pre/post monitoring study in 11 homes with gas stovetops. Pollutants measured include $NO_2$, $CO_2$, CO, VOCs, and $PM_{2.5}$.

This paper will discuss three key methods of IAQ analysis and related results. Using aggregated time series of pollutants during cooking events, we analyze pollutant spikes, release rates, and decay curves. The average $NO_2$ spike exceeded the EPA's hourly exposure guideline during gas range use lasting 40 minutes or more. We also compare daily pollutant concentrations to site-level cooking frequency and duration. On average, $NO_2$ levels exceeded the WHO's daily exposure guideline after 50 minutes of daily cumulative gas range cooking. Additionally, we model the relative effects of cooking versus outdoor air quality on indoor $PM_{2.5}$. Outdoor air pollution was much less significant than cooking, except during wildfire events.

These findings deepen understanding of how cooking behaviors and appliance choices influence IAQ. We offer recommendations on ways this research can guide appliance upgrade decisions, support electrification programs, and inform future research.

## Introduction

### Induction Range Technology

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 stovetop. 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. These efficiency gains have motivated several existing induction range utility program savings measures and appliance rebate programs in the United States, including in Michigan, California, Massachusetts, and

Washington, DC, as well as federal rebate offerings (Michigan Energy Measures Database 2025, McCullough 2025, California Electronic Technical Reference Manual 2025, Mass Save 2025, ComEd 2025, District of Columbia Sustainable Energy Utility 2025).

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. And 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).

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 (Ball 2026). The study also assessed the health and safety benefits of gas-to-induction conversions, due primarily to improved indoor air quality (IAQ) to inform assumptions used in beneficial electrification program design. This paper focuses on these IAQ results.

## 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).

Drawing on this literature, as well as consultation with IAQ experts, this paper 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 paper does not assess direct health outcomes, and the research team does not claim medical expertise. Rather, this paper 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 paper because they are widely used benchmarks in U.S. policy.

Occasionally, this paper also references the Regenerative Ecological, Social, and Economic Targets (RESET) IAQ guidelines. This is a set of performance-based building standards developed by GIGA (a building performance organization) 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.

- **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 ($PM_{2.5}$):** Particulate matter can originate 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). The thresholds below are given for $PM_{2.5}$, the smaller-diameter designation for particulate matter, and the designation measured in 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.

    - 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)[1]

## Methods

### Recruitment and Installation

Outreach to recruit field study participants began in January of 2023.

Outreach materials directed candidate participants to a project landing page that included project information, participant requirements, and a link to a pre-screening survey. A pre-screening survey was administered to collect initial information. The research team then scheduled virtual walkthroughs with qualified candidates for additional screening to prioritize sites based on cooking and traveling habits, existing electrical infrastructure, and other factors.

After the virtual walkthroughs, the project team selected 11 participants with gas ranges. All gas ranges were in UPPCO territory, with seven natural gas and four propane powered ranges.[2] 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 reporting using their ranges 8-14 times a week.

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 (i.e. electrical circuit installation) to prepare the home for induction range installation.

In order to allow time for pre-intervention air quality monitoring, the induction range retailers installed the induction range at participants' homes one year after the initial walkthrough visit. Ranges cost ~$1,500-$1,700, including electrical cords, taxes, delivery, and installation.

Shortly after 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, potentially because of high-frequency tones emitted by the range.

[1] 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 field study likely use different reference VOC compositions than RESET in determining the pollutant's average molecular weight. These thresholds are thus not included in this paper's analysis (DigiKey TechForum 2020; RESET Air, n.d.).

[2] The terms "gas" and "gas-to-induction" in this paper refer to both natural gas and propane prior ranges.

This household is not included in analysis. There were many other participants with pets who did not experience this issue.

**Data Monitoring and Processing**

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 the field study monitored were chosen based on literature review research and conversations with pollutant and health experts.

Monitoring devices remotely transmitted data back to the research team daily throughout the field study period. For energy usage monitoring at homes with gas ranges, gas meters were installed during the pre-retrofit period and eGauge loggers and current transformers were installed within the electricity breaker during the post-retrofit period. They were removed at the time of induction range installation. For air quality metering, the research team housed the Awair Omni, Aeroqual NO2 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. Information about each monitoring device is provided in Table 1 below.

Table 1: Monitoring devices used in the field study

| 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 | 10 |
| Gas meter | Gas usage of range | Monitoring minutely flow through gas pipe into appliance | Daily push via connection to eGuage | 11 |
| 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 |
| HOBO logger, with DF Robot (CO) and Aeroqual ($NO_2$) | 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 manual Bluetooth download by participants through | 11 |

| | | | | |
|---|---|---|---|---|
| sensor attachments | | | study end (due to connectivity issues) | |

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 632 days of IAQ monitoring per site.

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.

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.

### Indoor Air Quality Analysis

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. The team 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, the team modeled daily cumulative IAQ levels as cooking minutes increased, with outdoor pollutant levels brought into particulate matter calculations. Finally, the team quantified the duration of time that pollutant concentrations exceeded health-based threshold guideline levels to assess how observed values compared with established benchmarks.

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, the study team downloaded outdoor air quality data from monitoring devices in the field study region through PurpleAir, as well as from EPA AirData monitors (United States Environmental Protection Agency 2016; PurpleAir, n.d.).

## Results

### Typical Pollutant Levels

A boxplot of measured mean daily pollutant levels per site pre-and post-retrofit is shown in Figure 1. A general reduction in average pollutant levels across sites is visible, as well as significant variation between sites for certain pollutants.

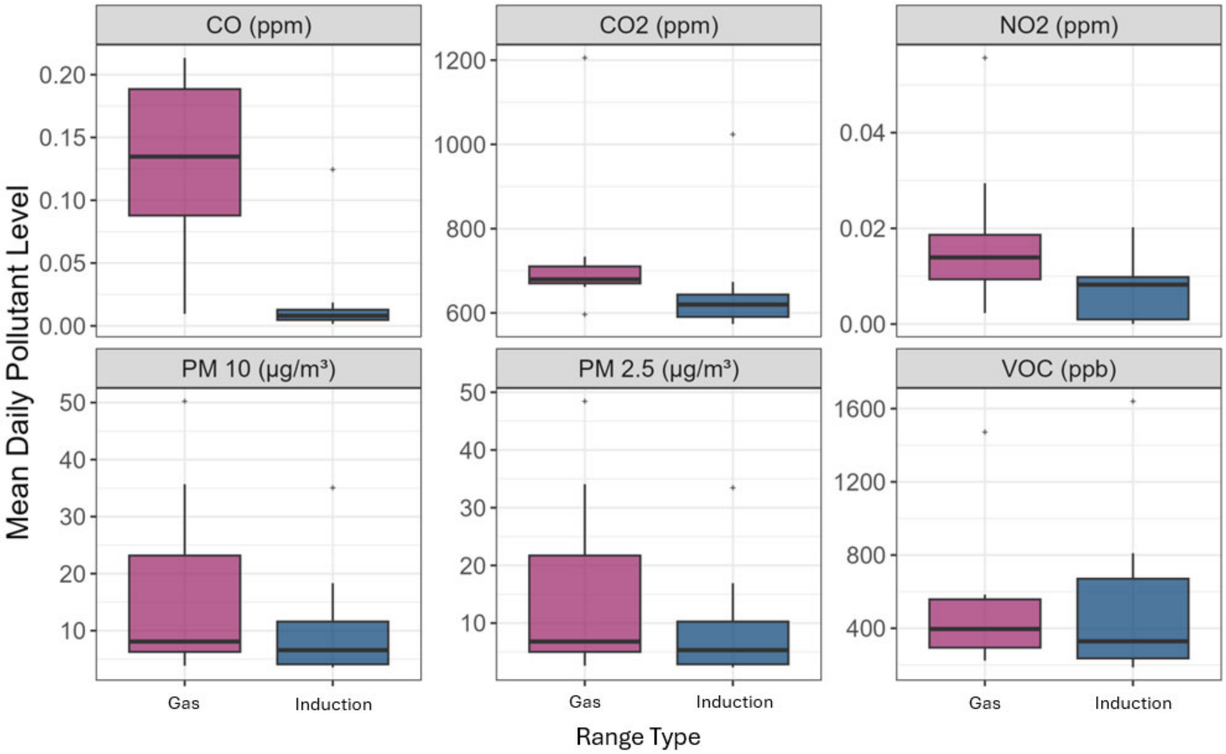


Figure 1: Mean daily pollutant values per site, gas versus induction range

The improvements in $NO_2$, $CO_2$, and CO levels are the most clearly attributable to the new range, because those pollutants are byproducts 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 particulate matter levels, improvements are at least partially due to a particularly bad wildfire season in the pre-period, as discussed further below.

**Cooking Event Analysis**

To assess the real-time effects of cooking on IAQ, the research team analyzed average cooking event timeseries. The end of a cooking event was flagged when a household turned their range on for more than a minute and then turned their range off for more than four hours. This four-hour timeframe was selected to ensure that consecutive cooking activities did not overlap, thereby reducing noise from back-to-back events, but note that there could be numerous cooking instances within one event under this definition. Average concentrations are shown for each pollutant at each minute before and after range power-off.

Figure 2 shows pollutants levels before, during, and after range use for both pre- and post-retrofit monitoring. The figures illustrate the rise to average peak pollutant levels while cooking, as well as the subsequent decay towards baseline after the cooking event.

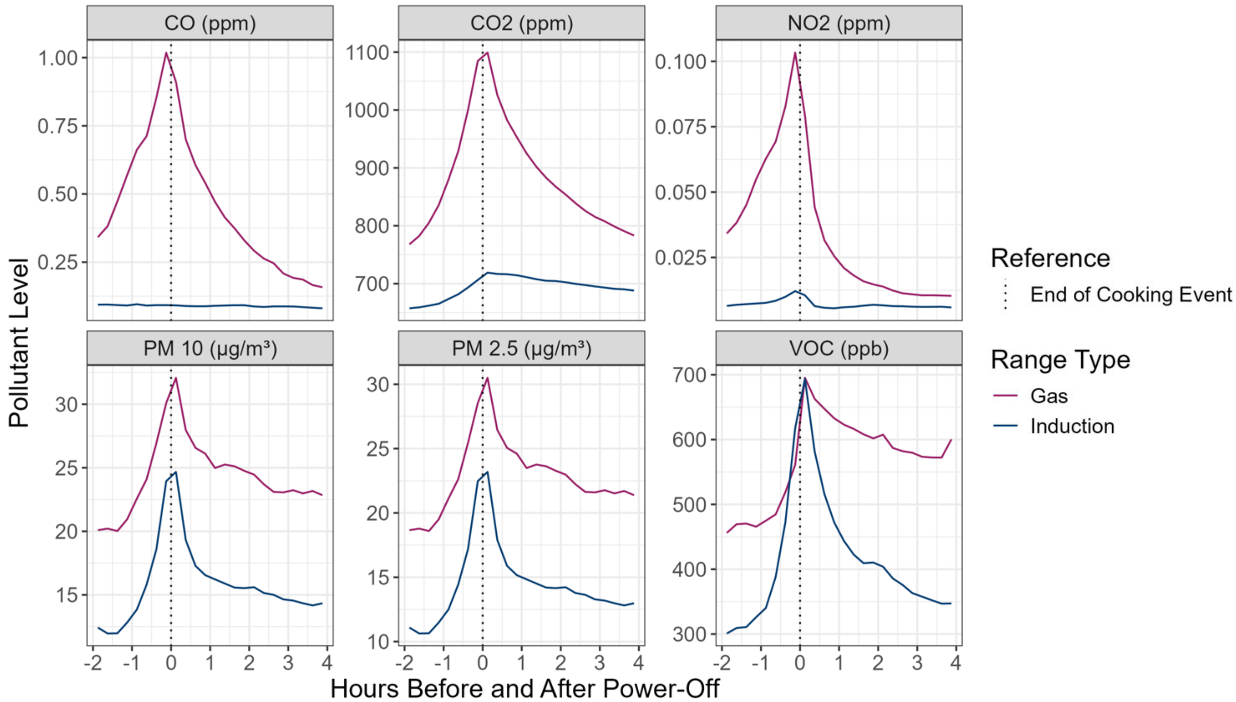


Figure 2: Average cooking event timeseries, gas versus induction

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 the field study reports total VOCs and cannot identify individual compounds, the specific contribution of combustion-related VOCs cannot be directly quantified.

Figure 3 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.

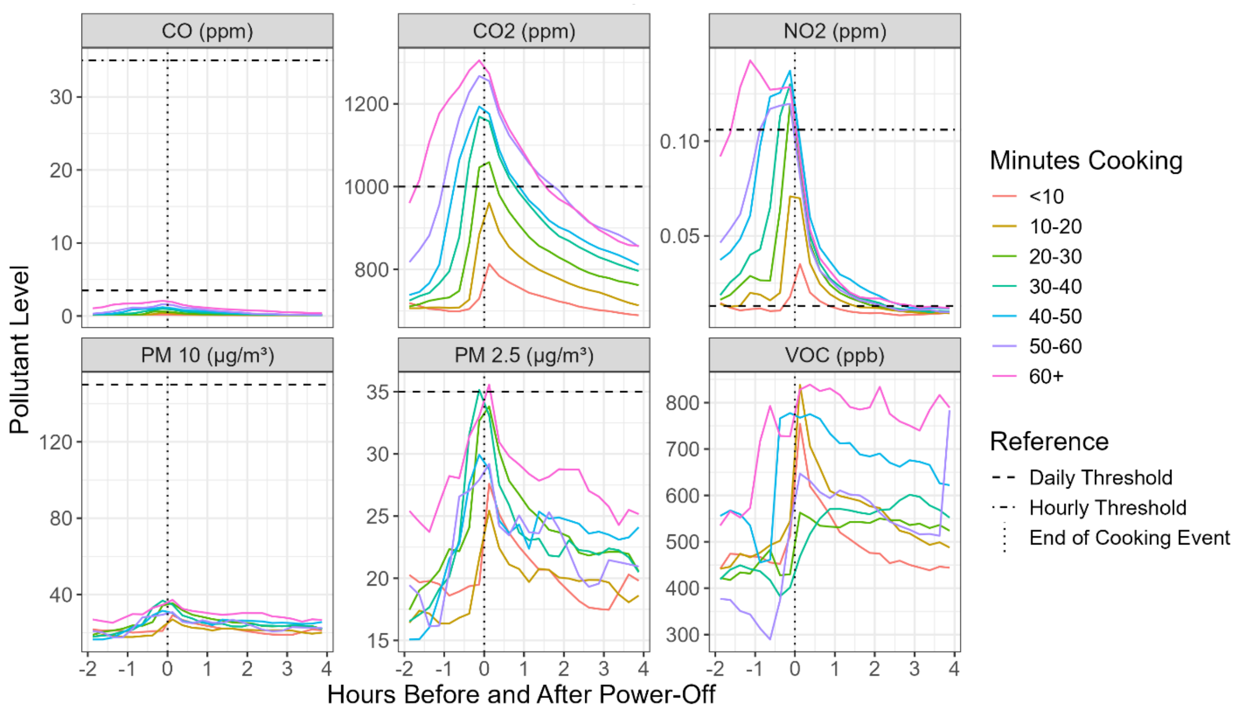


Figure 3: Average cooking event timeseries with gas ranges only, by cooking event length, with health thresholds overlaid; in the case of multiple applicable thresholds, the least strict is shown[3]

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 pre- and post-retrofit. 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.

[3] Thresholds used: 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 $PM_{10}$.

- 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 interpret indoor pollutant levels for relevant pollutants. $CO_2$, CO, and VOC levels are primarily driven by indoor sources, as described in the Introduction, 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, the team included an outdoor air PM term in the particulate matter regression models. The pre-period equation is shown in Equation 1 below.

Equation 1: 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 2 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. As $PM_{10}$ levels are estimated by the monitoring device based on $PM_{2.5}$ measurements, $PM_{10}$ modeling is not reported.

Table 2: 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 4 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.[4] Particulate matter and VOCs increase with cook time in both the pre- and post-retrofit periods due to cooking and burning food particles.

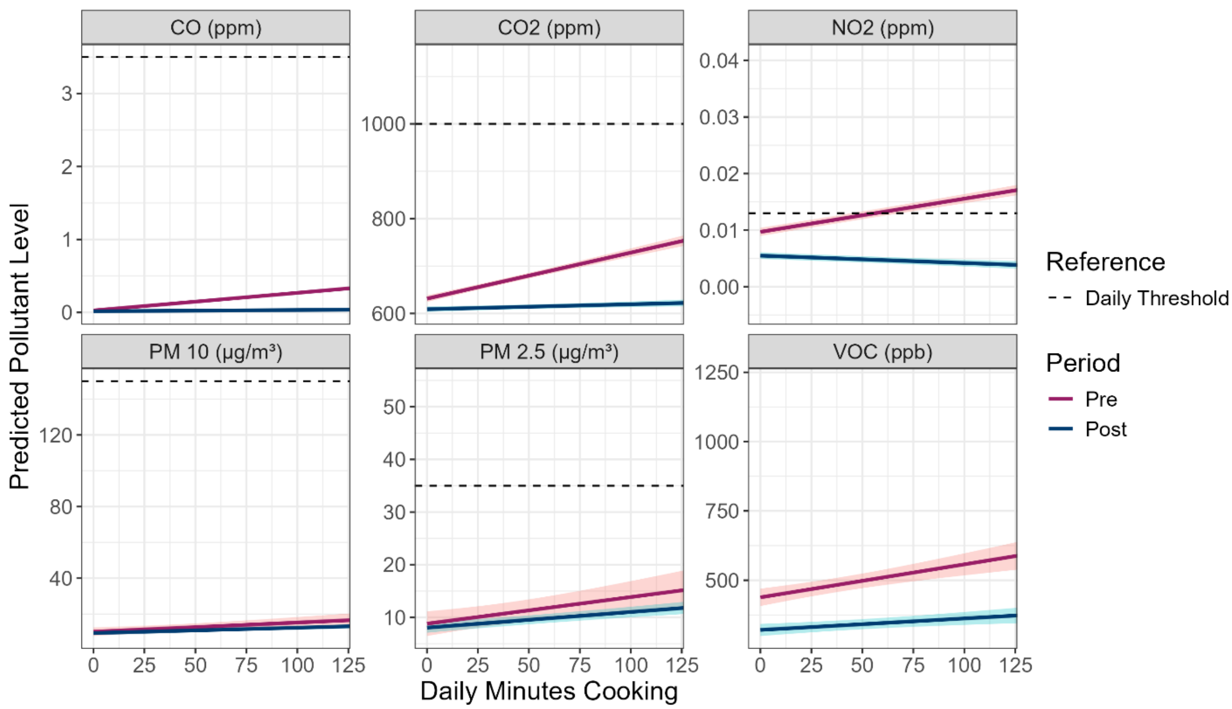


Figure 4: Modeled daily pollutant levels per daily minutes cooking, gas versus induction, with health thresholds overlaid; in the case of multiple applicable thresholds, the least strict is shown[5]

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

[4] Note that the post-period $NO_2$ coefficient is statistically insignificant, and thus the slight negative slope is likely zero in reality.
[5] 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.

explain why some households showed larger than modeled 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 3 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 green for improved time over threshold in the post-retrofit period and blue for unchanged percentages. Percentage over threshold did not increase in the post-retrofit period for any pollutant or duration metric.

Table 3: 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[6]

| 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% |

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 the 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 5 below shows the percent exceedance 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.

[6] Thresholds used: 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 $PM_{10}$.

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.

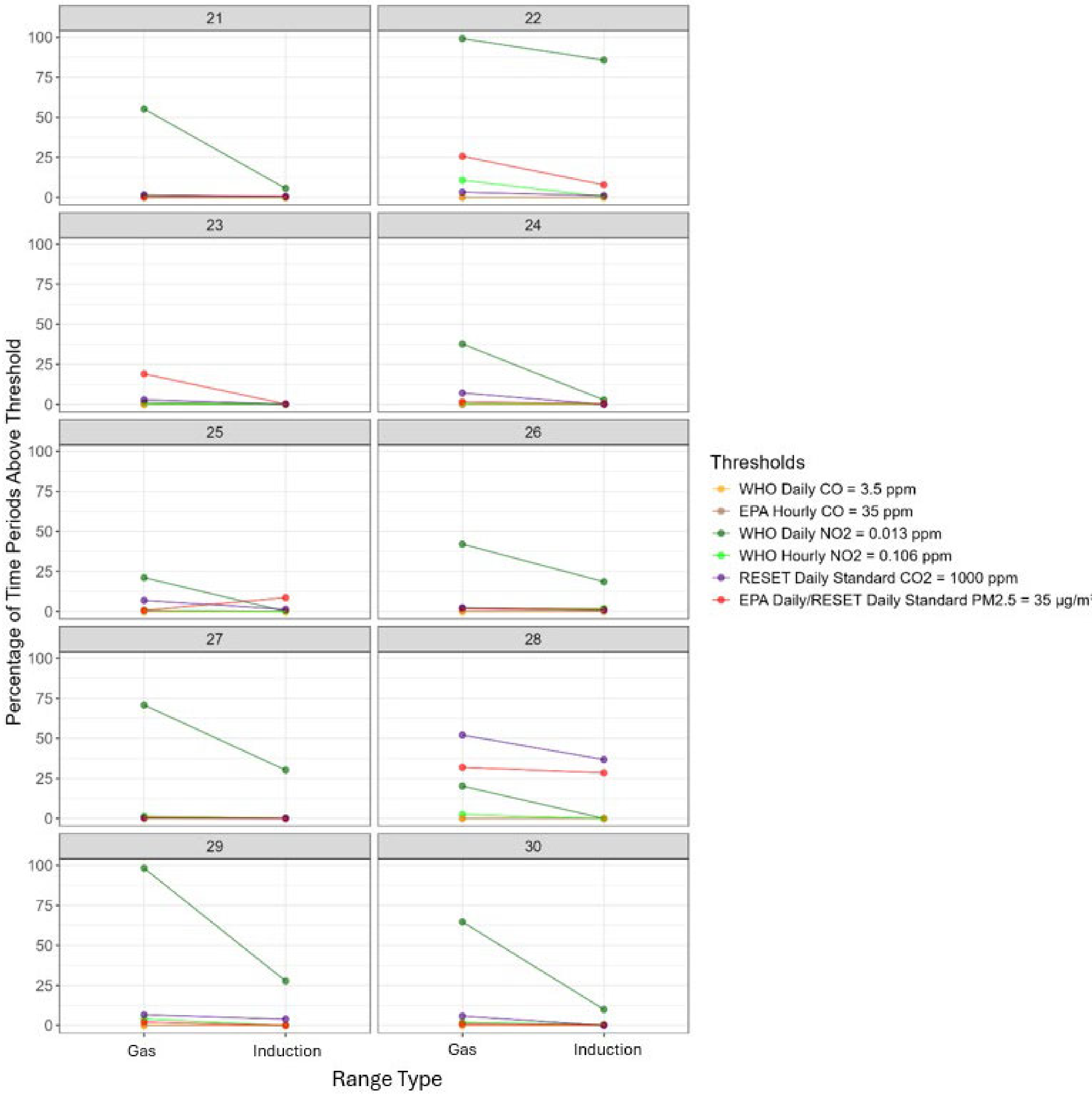


Figure 5: Percentage of total days/hours of data with an average pollutant level over certain health organization thresholds, per site, gas versus induction; in the case of multiple applicable thresholds, the least-strict is shown

## Discussion

This paper provides quantitative results regarding the effects of different range types on IAQ. While sample sizes were small, results identify IAQ benefits for gas-to-induction retrofits. 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. These IAQ benefits—particularly with respect to $NO_2$ reductions—represent meaningful non-energy impacts and may justify incentives in beneficial electrification programs.

There are several areas that were identified as important for future IAQ research during the course of the field study. 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.

Additionally, while this paper 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. Pollutant reduction and health benefit results could also be combined with existing and future range upgrade cost-effectiveness studies to evaluate the economic case for gas-to-induction retrofit incentives. Such work would provide important context for policymakers and utilities evaluating the non-energy impacts of induction adoption.

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## AI-Assisted Tools Disclosure

AI-assisted tools used: ChatGPT.
Used for: editing sentences and code.
Extent: light editing.
Human review: the authors reviewed and verified all content, calculations, and citations.