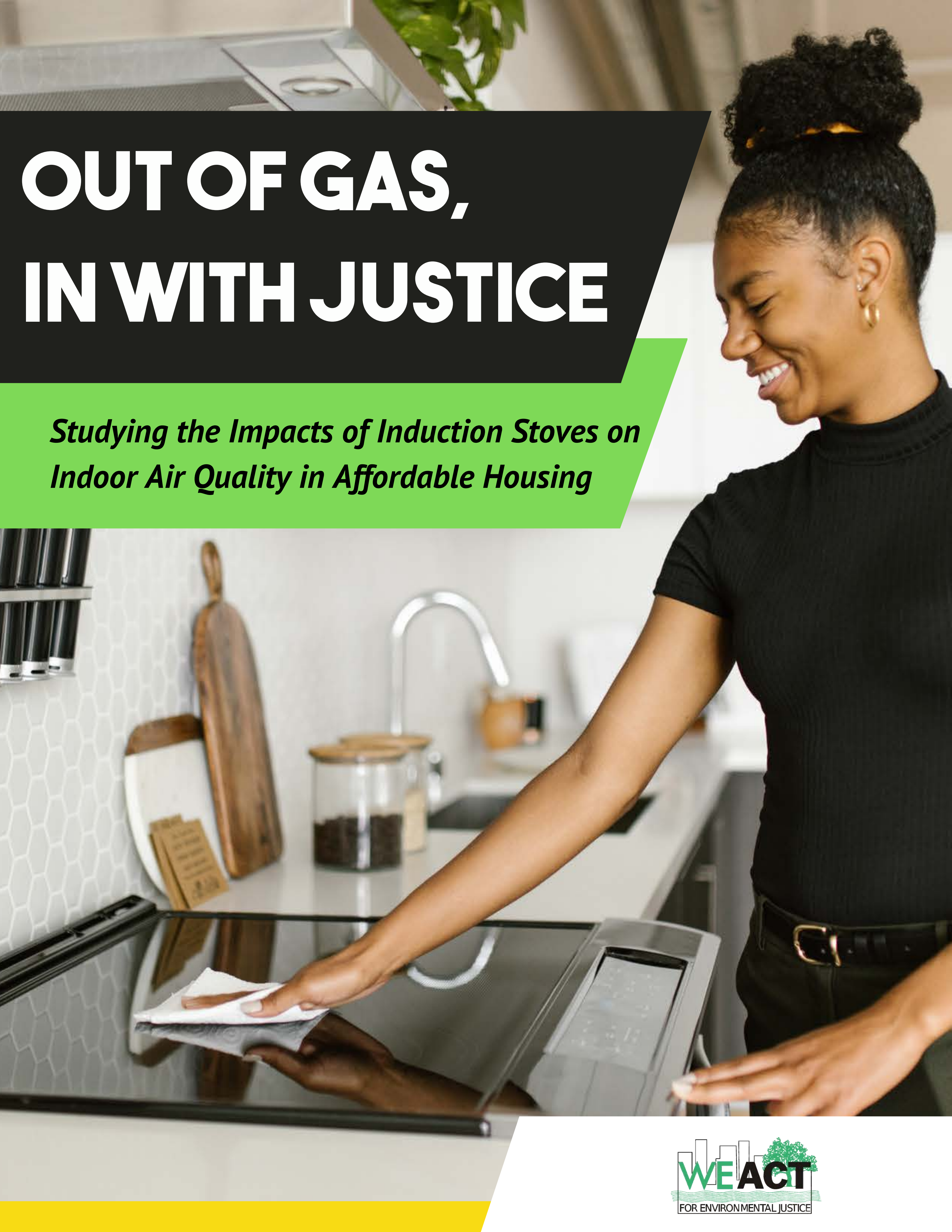
OUT OF GAS, IN WITH JUSTICE

Studying the Impacts of Induction Stoves on Indoor Air Quality in Affordable Housing



WE ACT FOR ENVIRONMENTAL JUSTICE

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Burning fossil fuels in residential buildings for cooking and heating is a significant source of pollution that contributes to climate change and negatively affects human health. Gas burning stoves are a main contributor to poor indoor air quality, emitting air pollutants like nitrogen oxides (NOx), which include nitrogen oxide (NO) and nitrogen dioxide (NO2), and carbon monoxide (CO). Long term exposure to these pollutants increases the risk of respiratory and cardiovascular illness, including asthma.

Environmental justice communities, which are low-income communities and communities of color that are already overburdened by the compounding effects of air pollution, rising energy costs, poor housing conditions, and climate change, are also disproportionately impacted by the negative health outcomes associated with gas stoves. In New York, nearly nineteen percent of childhood asthma cases can be attributed to a household's gas stove, and in New York City, Black and Latinx children and young adults make up 80 percent of hospital visits for asthma. Burning fossil fuels in buildings not only accelerates climate change, it worsens existing inequalities among environmental justice communities.

New York's landmark climate law, the Climate Leadership and Community Protection Act passed in 2019 commits New York State to 100 percent zero-emission electricity by 2040, which means electric buildings and appliances will be powered by renewable energy. This transition makes residential electrification a viable and necessary step towards reducing greenhouse gas emissions while simultaneously improving indoor and outdoor air quality for some of our most vulnerable populations. Decarbonizing, or shifting from fossil-fuel to zero-emission electric appliances powered by renewable energy sources, with priority focus on environmental justice communities, can address urgent interrelated environmental, health, and social inequities.

WE ACT for Environmental Justice's Out of Gas, In with Justice pilot studied the feasibility and benefits of electrification in New York City Housing Authority (NYCHA) by comparing improvements to air quality and participant satisfaction between ten apartments with induction stoves and ten with their existing gas stoves. It is the first study of its kind to focus on the effects of residential cooking electrification with tenants in-place in an urban public housing setting with low-income residents and residents of color. To help understand the health and social implications of changes in indoor air quality when transitioning from gas to induction cooking, this pilot reports results from three study approaches: (1) week-long air monitoring periods in each home during residents' normal daily activities; (2) air monitoring during a standardized Controlled Cooking Test (CCT); and (3) stove usability focus groups. This pilot offers lessons for policymakers, public housing agencies, and affordable housing providers on cooking electrification and its impact on indoor air quality, social acceptance of electrification measures, and infrastructure challenges for existing housing in environmental justice communities.

KEY FINDINGS

AIR QUALITY

Nitrogen Dioxide (NO2)

- Results from the Controlled Cooking Test (CCT) found that NO2 concentrations when cooking with gas stoves increased to an average of 197 ppb. This concentration level is well above the U.S. Environmental Protection Agency's (EPA) outdoor air quality level deemed "Unhealthy for sensitive groups" (100 ppb). Meanwhile, NO2 concentrations in kitchens with induction stoves remained at an average of 14 ppb, similar to background levels of NO2.
- When cooking a standardized meal on both a gas and induction stove in the NYCHA development, NO2 concentrations in kitchens with gas stoves were on average 190 percent higher than in kitchens with induction stoves.
- Over a 10 month monitoring period, households with induction stoves experienced a 35 percent reduction in daily NO2 concentrations compared to those using gas stoves, when controlling for temperature and apartment-level factors.
- While air quality improvements in induction households were significant, our pilot found that NO2 from other sources (gas-powered boiler in the basement, cars on adjacent streets, neighboring apartments with gas appliances) continued to impact household air quality.

Carbon Monoxide (CO)

- 24-hour averages of CO for households with gas stoves reached concentrations of 1.4 ppm whereas households with induction stoves had a 24-hour average of 0.8 ppm, a significant decrease.

STOVE USABILITY

- Participants unanimously loved their new induction stoves due to reasons like the ease of cooking, the time savings because the induction stove cooks faster and is easier to clean, the decreased reliance on other appliances, and the fact that the induction stove creates a safer cooking environment.
- Participants expressed relief that their safety concerns about cooking with gas, including that their home could catch on fire due to gas stove malfunctioning or leaking, were entirely alleviated with the induction stove.
- Dignity emerged as a core tenet and guiding principle in the electrification process.
- Not a single household that received an induction stove requested their gas stove back at the end of the study.

The Out of Gas, In With Justice pilot revealed compelling evidence for, as well as the challenges and limitations to, widespread adoption of induction stoves in affordable housing. Additional key findings include:

- **Air quality:** Cooking with a gas stove results in acute indoor NO2 concentrations that are harmful to one's health, particularly for sensitive groups such as those with respiratory illness, children under 18, and older adults.
- **Holistic healthy homes:** Our findings suggest that individual appliance exchanges of gas for induction stoves in multifamily housing will improve indoor air quality for individual units and prevent household exposure to the most harmful concentrations of NO2. However, other polluting systems still found in the building will continue to impact air quality, which is why transitioning entire buildings away from fossil fuels will likely have the greatest impact on improving indoor air quality.
- **Increasing awareness:** A more diverse public relations campaign for induction cooking and building electrification at large will help combat disinformation from the gas lobby and expand the audience of people willing to move away from gas appliances.
- **Electrification starting line:** It is critical to acknowledge the reality that low-income communities are more likely to live in older housing with structural deficiencies, and are more likely to need significant investments and robust tenant protections to reach the electrification starting line. Government programs that take a comprehensive approach, where several interventions are packaged into a whole-building retrofit, can maximize benefits to residents' health and expand resources for more equitable and efficient delivery of interventions.

POLICY RECOMMENDATIONS

Our pilot informed immediate and longer-term recommendations for policymakers, public housing agencies, and affordable housing providers that will help center environmental justice in building decarbonization efforts:

1) Restructure existing programs to focus on whole-home retrofits, prioritizing low-income housing.

States must create and fund complementary pre-weatherization programs that can act as an automatic referral when a household does not meet health and safety standards for existing weatherization programs.

Current weatherization and electrification programs must also expand the scope of their work to streamline access to benefits and increase participation in whole-home electrification, and they must increase funding to building owners with low-income tenants to reach deeper levels of affordability.

2) Adjust policies and programs to meet the needs of low-income renters who have limited autonomy over housing conditions.

In the absence of laws that will require landlord participation in decarbonization efforts and prevent cost-shifting, existing weatherization, energy efficiency and electrification programs need to create options available for renters that do not need landlord approval. Renters, especially in low-income neighborhoods, need tenant protections to prevent displacement as a result of investments to complete deep energy retrofits. States must commit more seriously to solutions that will ensure low-income households can afford their energy needs, including a public utility option.

3) Accelerate decarbonization in HUD-funded housing.

Funding for the U.S Department of Housing and Urban Development (HUD) needs to be more flexible to make necessary investments in decarbonization. Amendments should allow the stacking and braiding of multiple funding sources for decarbonization to help building owners make progress towards realizing safe, healthy, and climate-friendly living environments while maintaining flexibility as technology and policy evolves.

4) Pass policies that will get fossil fuels out of homes.

The evidence continues to support the fact that living with fossil fuels inside of homes is harmful to people's health. The federal government needs to set indoor air quality standards, while states like New York need to continue to pass legislation that moves our buildings away from fossil fuels.

The Out of Gas, in with Justice pilot confirms that decarbonizing our residential buildings is key to achieving a healthy home but that it must be done holistically, with a whole-building approach that centers environmental justice.

INTRODUCTION

Burning fossil fuels in commercial and residential buildings for heating and cooking is a significant source of carbon emissions in the United States.[1] In a dense urban area like New York City, buildings are responsible for 70 percent of total greenhouse gas emissions and play a key role in accelerating climate change and worsening indoor and outdoor air pollution.[2]

This has serious equity implications for communities on the frontline of the climate crisis - communities that are disproportionately people of color and low-income, and are already overburdened with a host of adverse outcomes directly attributable to structural racism in our housing and economic systems.[3] These frontline communities face higher risks from climate-related extreme weather events, such as flooding and extreme heat, and often deal with substandard housing conditions and disrepair, high energy burdens, and higher rates of chronic health problems resulting from the cumulative impacts of pollution exposure and persistent disinvestment.[4] Communities of color in the United States are exposed to nearly twice as much pollution from residential gas combustion compared to their white counterparts, which has additional health implications.[5] Recent research shows that burning all fuels (wood, biomass, gas, oil, etc.) in buildings is responsible for approximately 18,300 early deaths annually and $205 billion in health impacts in the United States.[6]

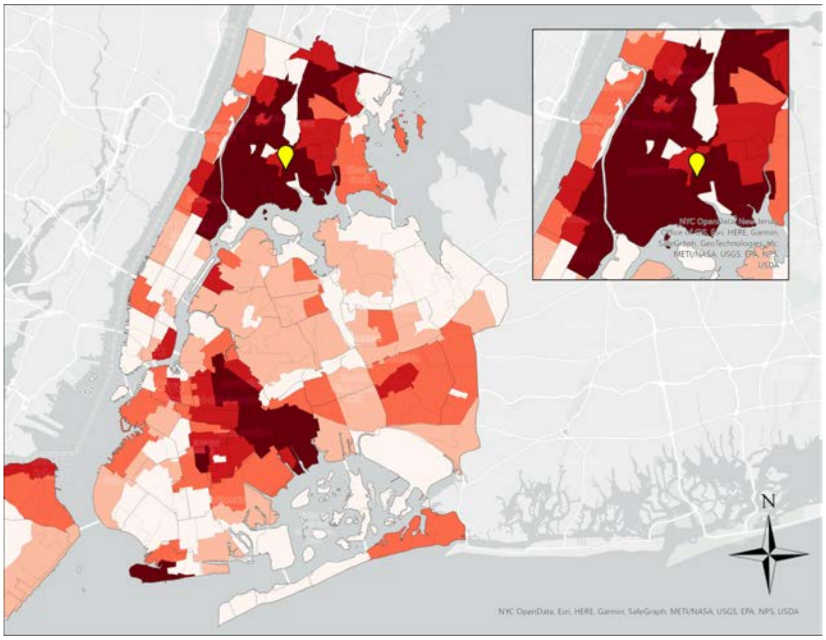
Decarbonizing our building stock, shifting from fossil-fuel powered to zero-emission electric appliances, has the potential to simultaneously address urgent interrelated environmental, health, and social inequities when low-income communities and communities of color are prioritized.

MOVING ENVIRONMENTAL JUSTICE INDOORS

The United States Environmental Protection Agency (EPA) currently has no indoor air pollution standards, despite the fact that we spend 90 percent of our time indoors. The air we breathe indoors is often two- to five-times more polluted than outdoor air – and can even be more than 100 times more polluted.[7] The gas industry embraced the term "natural gas" in the 1930's to sell the belief that naturally occurring, methane-rich, hydrocarbon fuel was clean and safe for indoor use (especially compared to the biomass fuels it replaced).[8] In reality, gas-burning stoves are a main contributor to poor indoor air quality, emitting fine particulate matter (PM2.5); nitrogen oxides (NOx), which include nitrogen oxide (NO) and nitrogen dioxide (NO2), carbon monoxide (CO); and formaldehyde (CH2O) – some of the same pollutants that come out of an automobile's tailpipe.[9] Indoor pollution levels from everyday use of gas stoves often exceed outdoor air quality standards set by the EPA, and are much higher than indoor guidelines set by the World Health Organization (WHO).[10]

Long-term exposure to these pollutants increases the risk of respiratory and cardiovascular illness.[11] Children living in a home with a gas stove are 42 percent more likely to develop asthma symptoms and are 24 percent more likely to receive an asthma diagnosis by a doctor.[12] Most recently, researchers quantified that 12.7% of current childhood asthma in the United States was attributable to gas stoves. Further, some of the most densely populated states had numbers even higher than the national average; in New York, 18.8% of childhood asthma cases were associated with gas stoves.[13]

Nationally and in New York City, asthma disproportionately affects Black and Latinx children as well as those residing in low-income neighborhoods.[14] In New York City, where nearly 10 percent of the population has a current asthma diagnosis (which is higher than the national average of 7.8 percent), 80 percent of hospital visits for asthma in children and young adults are Black and Latinx.[15] The areas of the South Bronx and Northern Manhattan, which consist of large populations of low-income residents of color, have one of the highest death and disease rates from asthma in the country.[16] Burning fossil fuels in buildings not only accelerates climate change, it worsens existing inequalities among these vulnerable populations.



Child (0 -17 years old 2012-2014) and Adult (2014 - 2016) asthma hospitalizations rate per 10,000 people in New York City. Seventeen percent of children have experienced asthma-like symptoms at some point in their lives, while children living in low-income neighborhoods are 3 times more likely to be hospitalized for asthma as children who live in wealthy neighborhoods, bearing the heaviest burden of the disease. Eighty percent of hospital visits for asthma in children and young adults are Black and Latinx in New York City.

Why Decarbonize Buildings?

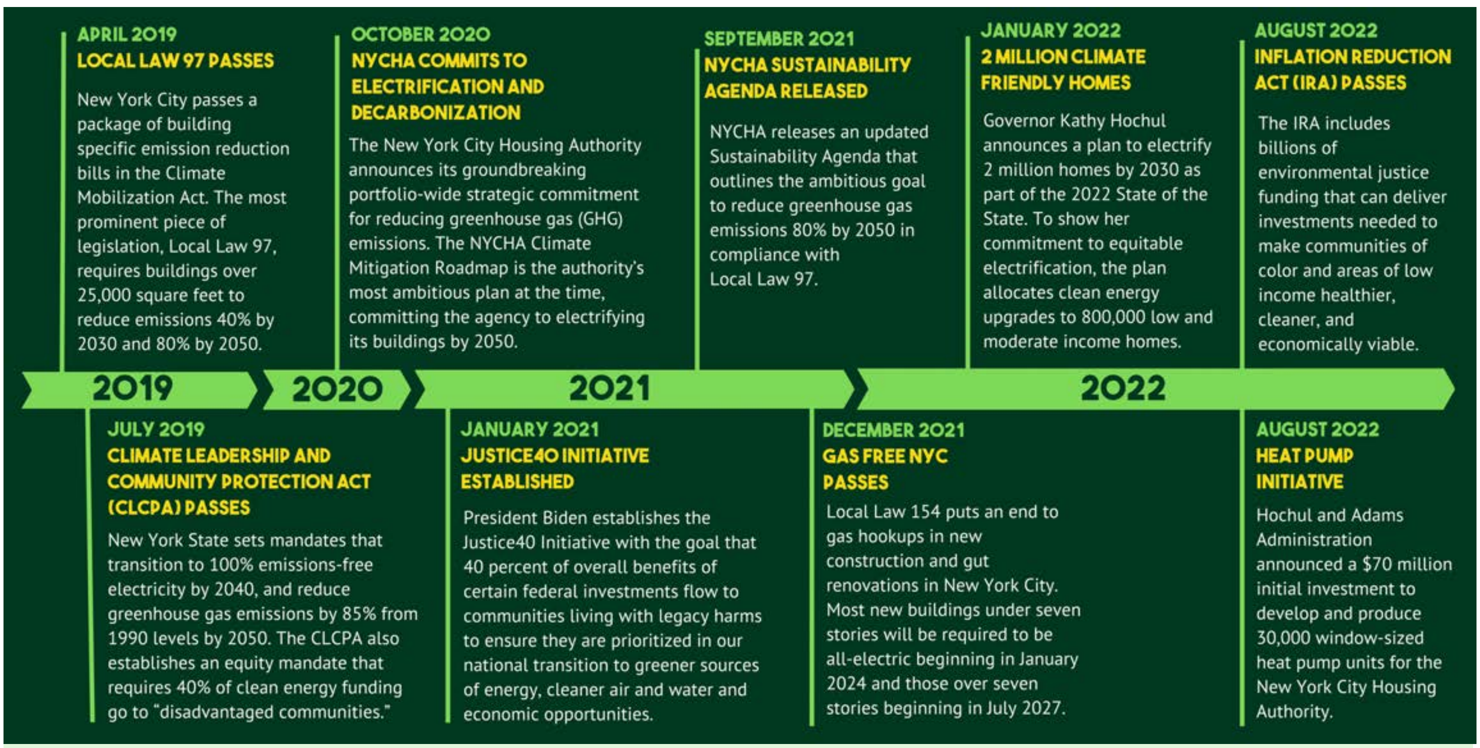
In New York, decarbonizing residential buildings provides more health benefits than decarbonizing other sectors like power generation or transportation, according to a recent simulation study by the New York City Department of Health and Mental Hygiene (DOHMH).[17] The study found that the greatest health benefits from residential electrification were in low-income neighborhoods, where asthma emergency department visits dropped 10 times more compared to more affluent neighborhoods.

Healthy Homes For All

WE ACT for Environmental Justice believes that everyone, regardless of race or income, is entitled to a healthy home, which we define as one that is free of health and safety threats, and supports physical, mental, social, economic and environmental well-being. It is becoming clear that we can only achieve ‘healthy homes' for all if we commit to policies that will decarbonize our residential building stock with the guardrails in place to prioritize low-income housing.

EQUITY IN BUILDING DECARBONIZATION

There has been more serious consideration of legislation that curbs greenhouse gas emissions over the past decade, thanks to leadership from grassroot advocates and frontline communities. Laws at the federal, state, and city levels have increased access to tools that will assist building decarbonization and electrification efforts, but vary in their commitment to equity. At the federal level, the Justice40 Initiative - modeled after New York State's climate law, the Climate Leadership and Community Protection Act (CLCPA) - ensures that a percentage of benefits from climate-related investments reach frontline communities.[18] While there are promising commitments to equity and environmental justice both federally and in New York, implementation has been lackluster, particularly in the electrification of low-income and public housing.



The Out of Gas, In with Justice pilot is the **first study to focus on the effects of residential cooking electrification with tenants in-place in a public housing setting**, and confirms that decarbonization of our residential buildings is key to realizing a healthy home. This pilot offers several lessons for policymakers, public housing agencies, and affordable housing providers on cooking electrification and its impact on indoor air quality, social acceptance of electrification measures, and infrastructure challenges for existing housing in frontline communities.

THE PILOT

Out of Gas, In With Justice Partners

WE ACT for Environmental Justice managed the New York City Out of Gas, In With Justice pilot, which took place at 1471 Watson Avenue - Sotomayor Houses, a 52 year old, 96-unit New York City Housing Authority (NYCHA) building in the Hunts Point area of the Bronx.[19] WE ACT partnered with Association for Energy Affordability to assist with participant recruitment, electrical upgrades, and stove installation in participating apartments. Berkeley Air Monitoring Group, Columbia University Mailman School of Public Health, and RMI offered expert advice and assistance on the research, analysis, and recommendations.

Out of Gas, In with Justice has an ongoing sister study in Buffalo, New York, managed by PUSH Buffalo. That pilot is working with multifamily buildings, six units or less, that are a part of the organization's affordable housing portfolio. On top of induction stoves, PUSH Buffalo plans to replace gas furnaces and boilers with air source heat pumps in participating households, and conduct identical air monitoring throughout. There are numerous benefits to air source heat pumps. They allow residents to control both heating and cooling, which eliminates the need for an air conditioner. They are also typically quieter, safer, more energy efficient, and typically have more stable energy costs compared to gas and delivered fuels. Additionally, the electrical costs can be defrayed by pairing with solar or other renewable energy sources. Air monitoring is set to begin in the Buffalo pilot in 2023.

Working With NYCHA

WE ACT selected the New York City Housing Authority (NYCHA) through a Request for Proposal (RFP) process due to their commitment to building decarbonization and the potential impact the pilot could have for residents. As New York City's largest landlord, providing homes to 339,900 low- to moderate-income New Yorkers, NYCHA has the opportunity to set precedent in equitable decarbonization for residential buildings across the city.[20]

In 2021, NYCHA released their ambitious goal to reduce greenhouse gas emissions 80 percent by 2050 in compliance with Local Law 97.[21] To achieve this goal within its existing housing stock, NYCHA needs to complete deep energy retrofits, which includes tackling health and safety concerns and deferred maintenance in buildings, and replacing gas appliances with electric ones. Rehabilitation of our current public housing stock is both desperately needed and severely under-resourced.[22] Therefore, it is critically important to understand the unique challenges public housing faces as we work towards building safe and healthy environments for all New Yorkers. NYCHA selected 1471 Watson Avenue as its first all-electric retrofit pilot, which will complement the work completed through our Out of Gas, In With Justice pilot.

Credit: Leticia Barboza, NYCHA Photographer

OUR APPROACHES TO MONITORING

To help understand the health and social implications of transitioning from gas to induction cooking, this pilot reports results from three study approaches: (1) week-long monitoring periods in each home during residents' normal daily activities, repeated three times over a ten-month period; (2) air monitoring during a standardized Controlled Cooking Test (CCT); and (3) stove usability focus groups. The goal of the long-term monitoring was to provide an indication of how daily and hourly concentrations of air pollution changed in homes which transitioned from gas to induction stoves over time, while the CCT zeroed in on impacts during prescriptive cooking events.

These approaches complement one another, characterizing how induction stoves may improve air quality at the household-level as well as isolating the specific impacts during cooking. Both approaches focused primarily on NO2 given the high emissions from gas stoves and health implications (see Background for more details). It is also important to note that, as a pilot, the goal was to demonstrate potential for air quality improvements in this context rather than provide a definitive evaluation for a larger programmatic roll-out.

Long-Term Kitchen Air Monitoring

Each week-long study used methods and equipment allowing researchers to unobtrusively capture continuous 24-hour/daily data. It required limited supervision, was noiseless, and was suitable for busy environments (such as the kitchen). The data collected over these longer periods can also provide more representative insights into the long-term average exposure concentrations needed for various health impact risk assessments.

Controlled Cooking Test

The Controlled Cooking Test (CCT) protocol was implemented to isolate impacts of cooking events on indoor air quality. As the name implies, a CCT protocol is a prescriptive and repeatable protocol. It allows researchers to compare the air quality impacts between cooking on a gas versus induction stove while controlling the food quantity, recipe, and cooking conditions.[23] Compared to a lab test, the CCT is more representative of a typical cooking event and is therefore appropriate for determining pollutant concentration in real-use settings. This protocol is especially useful as it allows researchers to more easily isolate the difference in pollutant levels from either stove as well as cooking time to prepare a standardized meal. An in-depth description of the air quality monitoring and CCT protocol is presented in the Methods section.

Stove Usability Focus Groups

Focus group discussions were held to learn about participants' experiences with the transition. Focus groups are small group discussions led by a facilitator that encourage participants to discuss their views and opinions about a shared experience. Focus groups are advantageous because they are structured and directed while being expressive, allowing for a lot of information to be shared in a relatively short amount of time.

BACKGROUND

The Out of Gas, In with Justice pilot supports a growing body of evidence that links gas stoves with significant indoor air pollution concentrations of nitrogen dioxide (NO2), carbon monoxide (CO), and methane. Exposure to elevated levels of nitrogen dioxide (NO2) can cause damage to the human respiratory tract and increase a person's vulnerability to, and the severity of, respiratory infections and asthma. Long-term exposure to high levels of NO2 can cause chronic lung disease.[24] High concentrations of CO exposure can be deadly; however, even low levels of exposure can exacerbate cardiovascular illness among people with coronary heart disease and other vulnerable populations.[25]

Households with gas stoves experience indoor concentrations of NO2 that are up to five times higher than the WHO's 24-hour guideline for indoor NO2 concentration (13 parts per billion (ppb)).[26] After only a few minutes of stove usage, some households can exceed the WHO's one-hour NO2 exposure guideline (106 ppb).[27] A physics-based simulation model of a controlled cooking test for a meal of pasta, meat-sauce, broccoli, and garlic bread predicted a one-hour maximum NO2 concentration without ventilation to be 144 ppb.[28] Over the years, studies have found that homes with gas stoves can have anywhere from 50- to more than 400-percent higher NO2 emissions than those with electric stoves.[29] A 2014 study found that replacing gas stoves with electric stoves and re-measuring air quality led to a 51-percent decrease in kitchen NO2 levels.[30] Similarly, households with gas stoves reported nearly three times higher concentrations of CO when compared to households with electric stoves, which increased in concentration with cooking duration.[31]

ENVIRONMENTAL INJUSTICE OF GAS STOVES

Indoor Air Injustice

Until recently, indoor air quality has been an underacknowledged environmental justice issue.[32] However, the few studies that have evaluated socio-economic determinants of indoor concentrations found that households that are low-income generally experience poorer indoor air quality.[33] In studies from high-income countries, homes with low educational attainment were associated with a .36 ppb increase in indoor NO2 concentrations and household occupant density increased NO2 levels three-fold.[34] Notably, in both high and middle to low-income countries, women are typically the primary household cook and disproportionately exposed to indoor air pollution.[35]

Asthma Rates in Children

NO2 emissions from gas stoves have been linked to increasing severity of asthma in children, and use of gas stoves in the home has been found to increase the risk of an asthma diagnosis over a person's lifetime by 24 percent.[36] Further, asthma disproportionately impacts Black children, with one study finding that a non-Hispanic Black child is nearly eight times more likely to die from an asthma attack compared to a non-Hispanic white child.[37] In New York City, 17 percent of children have experienced asthma-like symptoms at some point in their lives, while children living in low-income neighborhoods are three times more likely to be hospitalized for asthma as children who live in wealthy neighborhoods, bearing the heaviest burden of the disease.[38]

Gas Stoves as Heating

Low-income populations typically live in older homes that are smaller in size, have inadequate mechanical ventilation, and contain aging stoves with less efficient combustion, resulting in higher indoor pollutant concentrations.[39] Exposure to air pollution is further heightened for households that use gas stoves for supplemental heating in the winter.[40] In situations where heat in a household is insufficient, kitchen appliances are sometimes used as an alternative, which has been shown to increase time-weighted exposures to CO and NO2. National Health and Nutrition Examination Survey (NHANES) III (1988-1994) data showed that lower-income households engage in such use of combustion appliances approximately twice as often as higher-income households.[41] A study investigating the relationship between respiratory illness in children, gas stove use, and ventilation found that in homes where adults used the stoves for both cooking and heating, as opposed to solely for cooking, children had a significantly higher likelihood of being diagnosed with asthma and experiencing other respiratory symptoms.[42]

To our knowledge, no study has yet measured CO and NO2 concentrations in households transitioning from gas to electric stoves in public housing with tenants in place. Previous studies focused either on lab simulations or included cooking electrification with other healthy housing interventions.[43] Further, very few studies look at the impacts of the transition on low-income households in particular.

Our study provides needed evidence to understand the qualitative and quantitative benefits of improved indoor air quality through the adoption of induction stoves in low-income housing.

METHODS


Hot Surface
Bake
Broil
11:36
OK/
START
Self
Clean
Hot Surface
On-Off
Conv
Bake
Conv
Roast
OFF
Steam
Clean
On-Off
Conv
Convert
Quick
Preheat
1
2
3
4
5
Timer
On-Off
Add 1
Minute
Keep
Warm
On-Off
Air
Fry
6
7
8
9
0
Delay
Start
On-Off

Ethical Approvals

For both the Controlled Cooking Test and the long-term air monitoring, participants provided informed consent following institutional review board approval (Advarra, protocol number Pro00050739). The stove usability focus groups were approved by the Institutional Review Board at Columbia University. All study participants provided informed consent. Identifying information has been removed to protect the confidentiality of study participants.

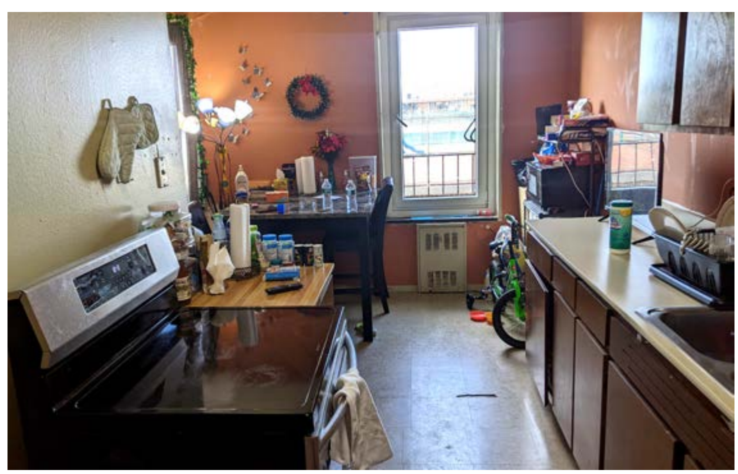
CONTROLLED COOKING TEST

Study Design

CCTs took place at 1471 Watson Avenue between November 17th, 2022 and November 28th, 2022. Six households participated in the study: three with induction stoves and three with gas stoves. A standardized meal of spaghetti, tomato sauce, steamed broccoli, and chocolate chip cookies was prepared three times in each household, totaling 18 measured cooking events.* Staff used the same cooking equipment for each test and cooked each meal according to a predetermined procedure at the same temperatures and using the same burners. For consistency, staff weighed all ingredients for identical measurements across each event. All households participating in this cooking test received $200 in compensation at the end of the study.

Indoor Air Monitoring Equipment

NO2 was measured by absorbance using a high precision sensor (2BTech Model 405). A single piece of tubing directed airflow to the sensor using a T connector. The inlet was placed at the same distance and height from the burners in use for all cooking tests. NO2 was measured concurrently before, during, and after each controlled cooking test. A fan was placed in a standardized location in each kitchen to improve air mixing conditions.**



**Due to a COVID-19 case, we were unable to complete a final cooking test in an apartment with a gas stove. As a result, we completed the cook test 17 times, three times in five households and twice in one household.*

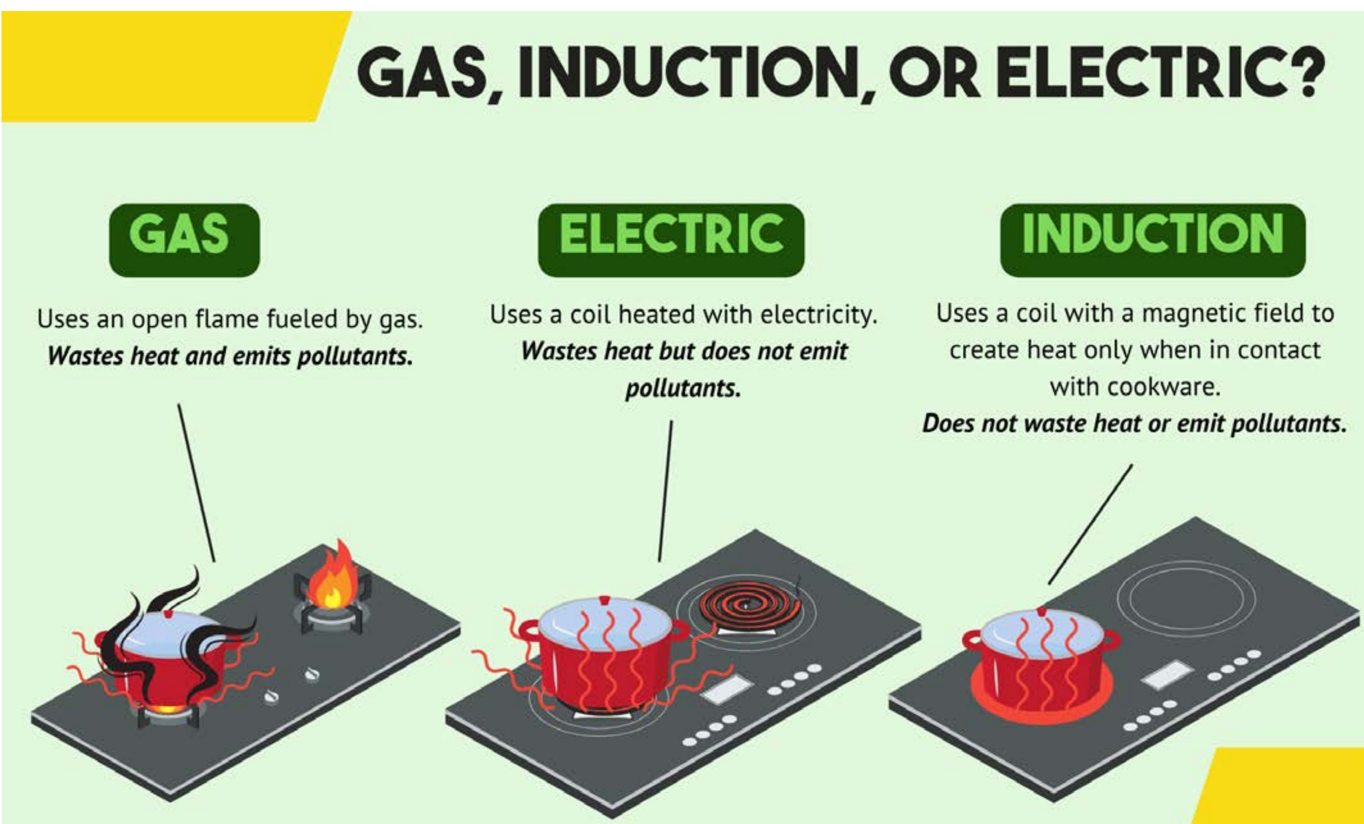
***During early tests, cooking times in gas households extended beyond what was anticipated. Staff determined that the location of the fan interfered with the flame and moved it to sit diagonal from the filter for all following tests.*

LONG-TERM AIR MONITORING

Study Design

Twenty households at 1471 Watson Avenue were randomly divided into two groups: homes that received the induction stove (intervention group) and homes that kept their gas stoves (control group). Indoor air quality measurements happened three times for one week each - once before the installation of induction stoves when all twenty households had their original gas stoves (baseline), and twice after induction stoves were installed in the households of the intervention group. Baseline air monitoring in all twenty apartments took place between October 2021 and February 2022, the first follow-up between April 2022 and June 2022, and the final follow-up between June 2022 and July 2022.

WE ACT chose electric induction ranges (Frigidaire Gallery GCRI3058AF 30" Freestand Induction Range with Air Fry feature) because of the efficiency, safety, and overall quality. Standard electric stoves heat a burner first, and some of that heat is transferred to the pot or pan above it. Induction stoves use electricity to produce a magnetic current that passes through the pots and pans themselves which causes them to heat up directly while the surrounding cooktop stays cool. This type of heating is more efficient than electric stoves, and cooks food faster and more accurately based on temperature settings. The instant a pot is removed from a burner on an induction cooktop, the heating stops. This safety feature is especially important for households with children because it reduces the possibility of accidental burns.



At the culmination of the study, the ten control apartments received the electric range, and all participating households received a complete set of induction-ready cookware. To help participants learn how to use their new electric ranges, WE ACT partnered with a local chef, Chef Sia Pickett, owner and operator of Malata Cuisines, to create a series of instructional videos - in both English and Spanish - on how to prepare affordable, healthy, and culturally relevant meals using the induction stove.[44] Participants in the pilot arm of the study were also invited to live cooking demos with the chef prior to receiving their new induction stove. All households received $500 in compensation for completing their participation in the pilot.

Building Modifications

Participating apartments needed a surface mounted double pole 40 amp breaker installed in or near the kitchen and an upgraded 209-220 volt outlet for the induction stove. Riverdale Electrical Services assessed 1471 Watson Avenue's electrical capacity in advance of air monitoring and assisted with necessary electrical work in participating apartments.

1471 Watson is six stories tall, and the electrical consultation revealed that the six apartments on each vertical line were fed by a common wire. This increased the risk of causing a power outage for all six apartments by overloading the line. Out of an abundance of caution, we only selected two apartments per line to participate in the pilot.

Indoor Air Monitoring Equipment

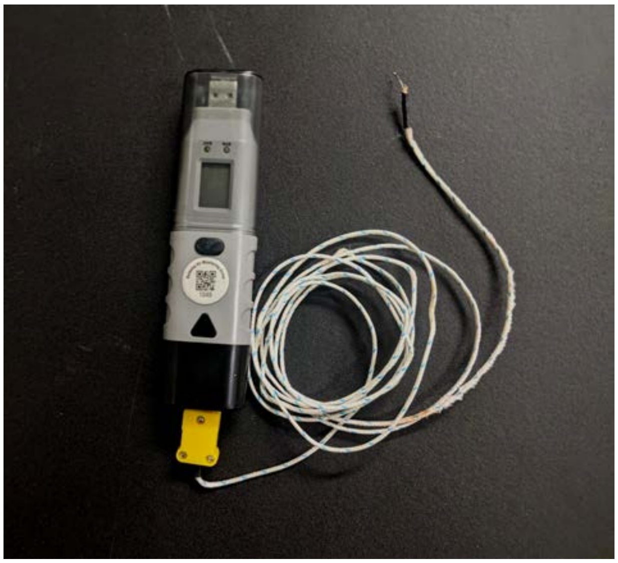
During the long term monitoring periods, the Home Health Box (Access Sensor Technologies) measured real-time NO2 and CO. The instrument was placed in the kitchen at standardized locations meant to capture air representative of what someone cooking or standing in the room would breathe. Eleven additional passive measures of NO2 using Ogawa Badges supplemented the Home Health Box measurements. EL-USB-CO monitors (Lascar Electronics) took additional CO measurements, which have a higher maximum range to capture peak events with elevated concentrations.

Filter cartridge for HHB

Home health box (HHB) with Ogawa badge

Stove Use Measurements

Temperature and electricity loggers measured participant stove usage throughout the study. Temperature loggers (Wellzion) measured gas stove usage and EL-USB-ACT electrical current loggers (Lascar Electronics) measured induction stove usage. Both temperature and current loggers collected a unique datapoint every one minute. Increases in magnitude of temperature for gas stoves and current for induction stoves helped estimate stove use events in each household.



Wellzion Logger

Lascar USB monitor

Quality Assurance and Control

The instruments in this study were subject to several quality assurance and control procedures and protocols through the duration of the pilot. The Home Health Box received frequent calibration, and data was screened for accuracy to ensure high data quality. More details on the quality assurance and control procedures, along with additional information on the air quality methods are available in Annex A.

STOVE USABILITY FOCUS GROUPS

Data Collection

The twenty households that participated in long-term air monitoring answered questions about household characteristics and cooking habits at the beginning of the pilot (Table 1). Towards the end of long term air monitoring, participants were invited to join focus group discussions to share their experiences with the pilot. Two focus groups with ten participants each were held. The first one convened on June 15th, 2022 for participants in the intervention group who had already received their induction stoves. The second focus group convened on July 11th, 2022 for participants in the control group who had not yet received their induction stove. Focus group discussions were digitally recorded and transcribed, and respondents were compensated $50 in cash at the end of the 90-minute discussion.

Data Analysis

Transcripts and field notes were systematically coded for emergent themes. First, the transcripts and field notes were reviewed several times in order to develop familiarity with the data. Then, a qualitative data analysis software (Nvivo version 12) was used to facilitate the process of categorization and coding, developing themes, and organizing data segments. Throughout the analysis, we identified emergent themes that demonstrated repeated categories of information, which were coded and linked for potential associations.

Table 1. Household Characteristics

Age of respondent	53 (18)
Household occupancy (age)	
Under 18	9 (45%)
Over 65	8 (40%)
Education of respondent	
College graduate or higher	3 (16%)
High school degree but no college degree	13 (68%)
Less than a high school degree	3 (16%)
Household size	2 (1)
Household income	
Equal to or greater than $30,000	5 (25%)
Less than $30,000	15 (75%)
Number of meals cooked on gas stove past 7 days	
Less than 7	1 (5.0%)
Between 7 and 14	12 (60%)
Greater than 14	7 (35%)
Experienced issues with gas stove preventing normal cooking in the past 6 months	4 (20%)

**Mean (Standard Deviation); n (%)*

RESULTS

CONTROLLED COOKING TEST

Results from the CCT show that households using gas stoves are exposed to acute levels of NO_2 during cooking events that are harmful for health.

Air monitoring for five minutes before the start of the controlled cooking test helped us determine background NO_2 - NO_2 that is already present in the home environment and unattributable to the CCT. Figure 1 shows that homes with gas stoves started with a median average background NO_2 of 18 ppb. NO_2 levels increased to a median average of 197 ppb during the cooking test. Comparatively, homes with induction stoves experienced negligible changes in NO_2 during cooking tests - the median average NO_2 changed from 11 ppb during background monitoring to 14 ppb during the cooking test. When background NO_2 was subtracted, the average cooking event with gas stoves experienced NO_2 concentrations 276 ppb higher than induction stoves (p-value = 0.0325).* **On average, households with gas stoves experienced NO_2 concentrations 190% higher than households with induction stoves during the CCT.**

Health Implications

What are the implications of these results on a person's health? While the United States does not have guidelines for indoor air quality, the Environmental Protection Agency's Air Quality Index (EPA AQI) offers guidelines for outdoor exposure to the five air pollutants regulated by the Clean Air Act, including one-hour exposures to NO_2. The AQI also defines the health risks associated with increasing concentrations of pollutants for specific groups of people. Every cooking event with a gas stove resulted in NO_2 concentrations greater than the AQI level deemed "Unhealthy for Sensitive Groups" (greater than 100 ppb), which puts people with respiratory illnesses, seniors, and young children at risk. Some households even experienced NO_2 concentrations greater than the AQI level deemed "Unhealthy" (greater than 360 ppb) for all individuals. By comparison, no cooking event with an induction stove exceeded the AQI's "Moderate" level (greater than 53 ppb), which could have an impact on sensitive groups.[45]

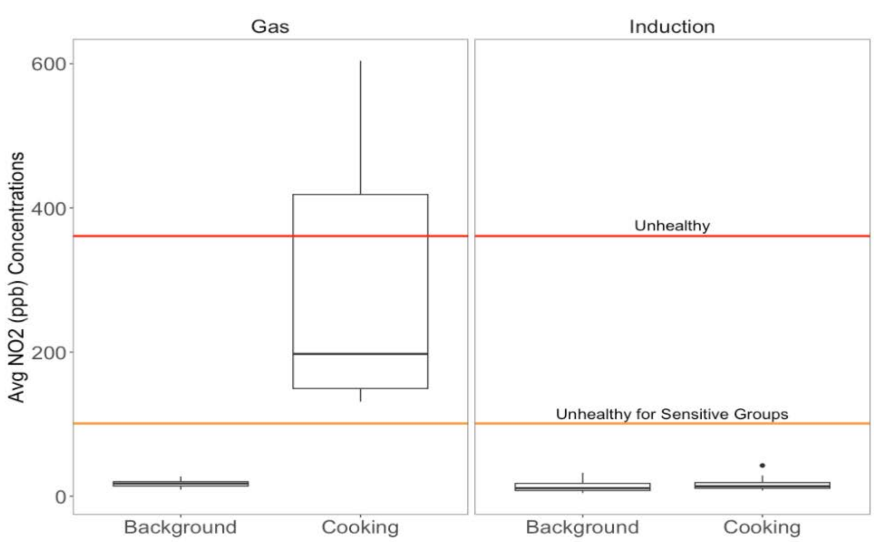


Figure 1: *Boxplot of mean NO_2 concentrations during gas and induction stove cooking tests compared to the background NO_2. The orange horizontal line (101 ppb) indicates the EPA threshold for one-hour NO_2 averages that are considered "Unhealthy for Sensitive Groups." The red horizontal line (361 ppb) indicates the EPA threshold for one-hour NO_2 averages that are considered "Unhealthy" for all individuals.*[46]

**Significance determined using a Wald test*

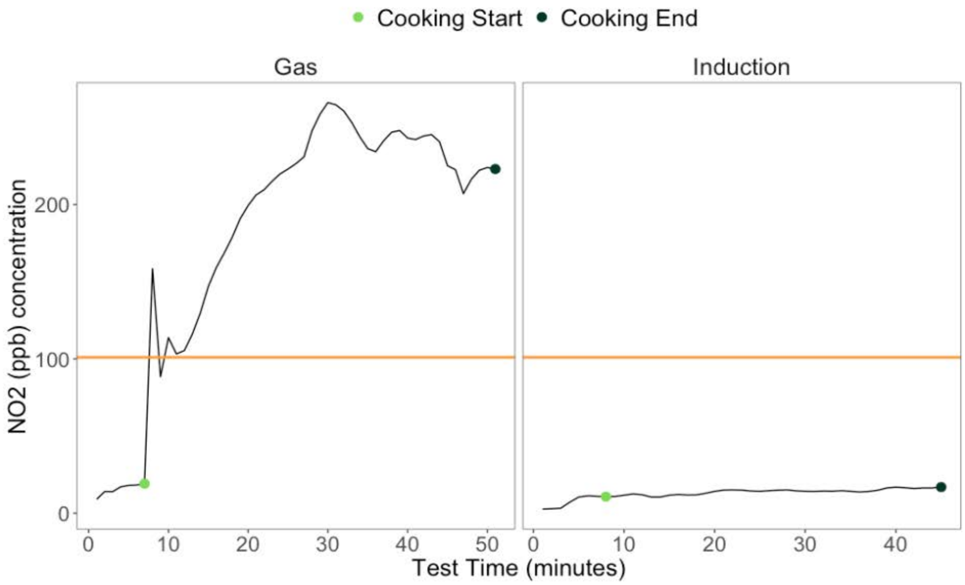


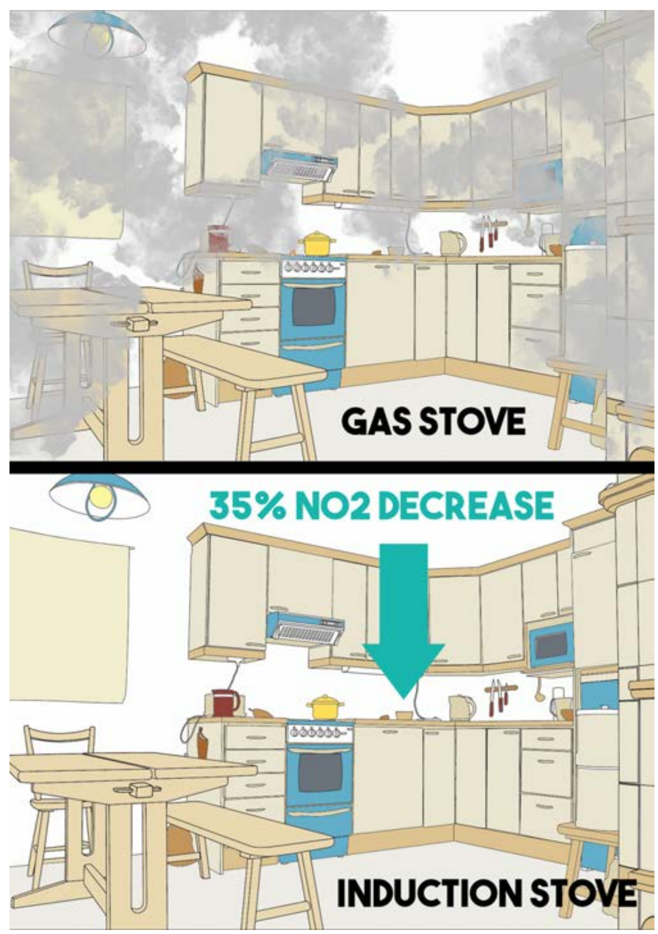
Figure 2: *Real time NO2 (ppb) concentrations during controlled cooking events with a gas and induction stove, respectively. The start of the cooking is noted with a light green dot and the end noted with the dark green dot. The orange horizontal line (101 ppb) indicates the EPA threshold for one-hour NO2 averages that are considered "Unhealthy for Sensitive Groups."*

LONG-TERM AIR MONITORING

Long-term air monitoring was designed to characterize how the gas to electric stove transition impacts day-to-day indoor air quality for participating households. Results show a decrease in daily exposure to both NO2 and CO, although impact varies.

Nitrogen Dioxide

To better measure the overall reduction in NO2 concentrations attributed to the stove transition, we adjusted our model to control for potential variables that might impact NO2 concentrations, thereby acting as confounders. These variables include outdoor temperature (which could predict whether people open their windows or not, thus affecting air exchange rates) and apartment-specific factors such as floor level and apartment orientation towards the back, side, or front of the building (as location of the unit could affect the potential infiltration of traffic-related or boiler-related NO2 in the apartments). Results from the long-term air monitoring adjusted model show that households with **induction stoves experienced a 35 percent reduction in daily NO2 concentrations compared to those using gas stoves**, when controlling for temperature and apartment-level factors.



We then modeled the impact of cooking events on NO2 concentrations in households with gas stoves and induction stoves using stove use data from the temperature and current loggers (Figure 3). Since this model does not involve a comparison between intervention and control groups, we do not adjust for the potential confounders listed above. **The results show that NO2 concentration levels were over 50 percent higher during cooking events for apartments using gas stoves,** whereas cooking events using induction stoves saw no increase in NO2 concentrations (see Figure 3).

To better understand how induction stoves could benefit health through reduced daily NO2 concentrations in each household, we looked at the percent of monitored hours bound by two thresholds - the WHO's 24-hour indoor air quality guidelines and the EPA's AQI. Since the AQI provides guidelines for NO2 one-hour outdoor exposure limits only, we decided to look at the percentage of hours with NO2 concentrations over 54 ppb, where the AQI transitions from "Good" to "Moderate," and could be detrimental to health, especially for those in sensitive groups (i.e., people with respiratory illnesses, seniors, and young children).

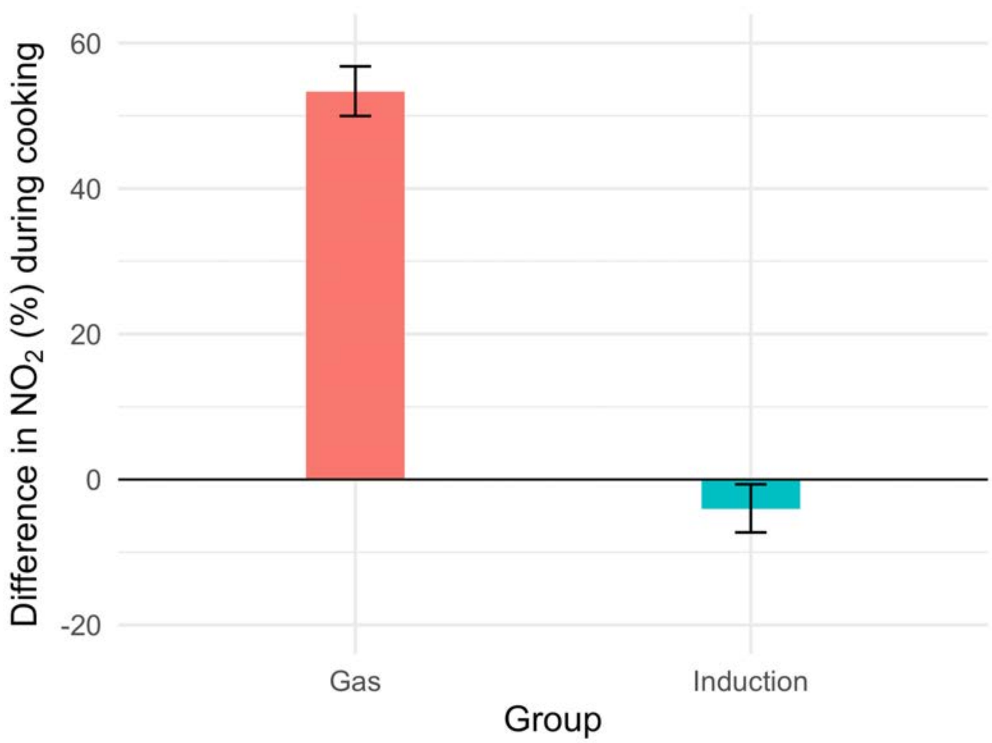


Figure 3: *Estimates of the effect of the intervention on NO2 levels during cooking. NO2 levels increase by 53.3 percent (95% CI: 50.0, 56.8%) during cooking for people using a gas stove, but only a negligible difference in NO2 levels (-4.0%, 95% CI: -7.3%, -0.7%) is observed during cooking for people cooking with an induction stove. Point estimates (dots) and confidence intervals (error bars) are derived from Model 2.*

WHAT DO THESE NUMBERS MEAN FOR YOUR HEALTH?

Chronic exposure to elevated NO2 concentrations as low as 20-40 ppb can increase mortality risk among the Medicare population (65+) by up to 3 percent.[47]

Figure 4 shows the percentage of total monitored hours in each household where NO2 concentrations exceeded the WHO guideline of 13 ppb and the EPA's AQI threshold of 54 ppb for the gas stove group and the induction stove group during both baseline (before the intervention, when all households had gas stoves) and follow-up (after the intervention when 10 households received induction stoves and 10 households continued using gas stoves).[48]

Exposure to NO2 concentrations above 54 ppb is higher for both groups during baseline air monitoring, a finding we discuss more in the Challenges and Limitations section. However, once homes receive an induction stove, hours where they are exposed to moderate levels of NO2 virtually disappear. During the follow-up period, **households with gas stoves experienced an average of 56 minutes per day above the EPA's one-hour NO2 threshold (54 ppb) whereas households with induction stoves experienced an average of only 4 minutes per day above 54 ppb**.

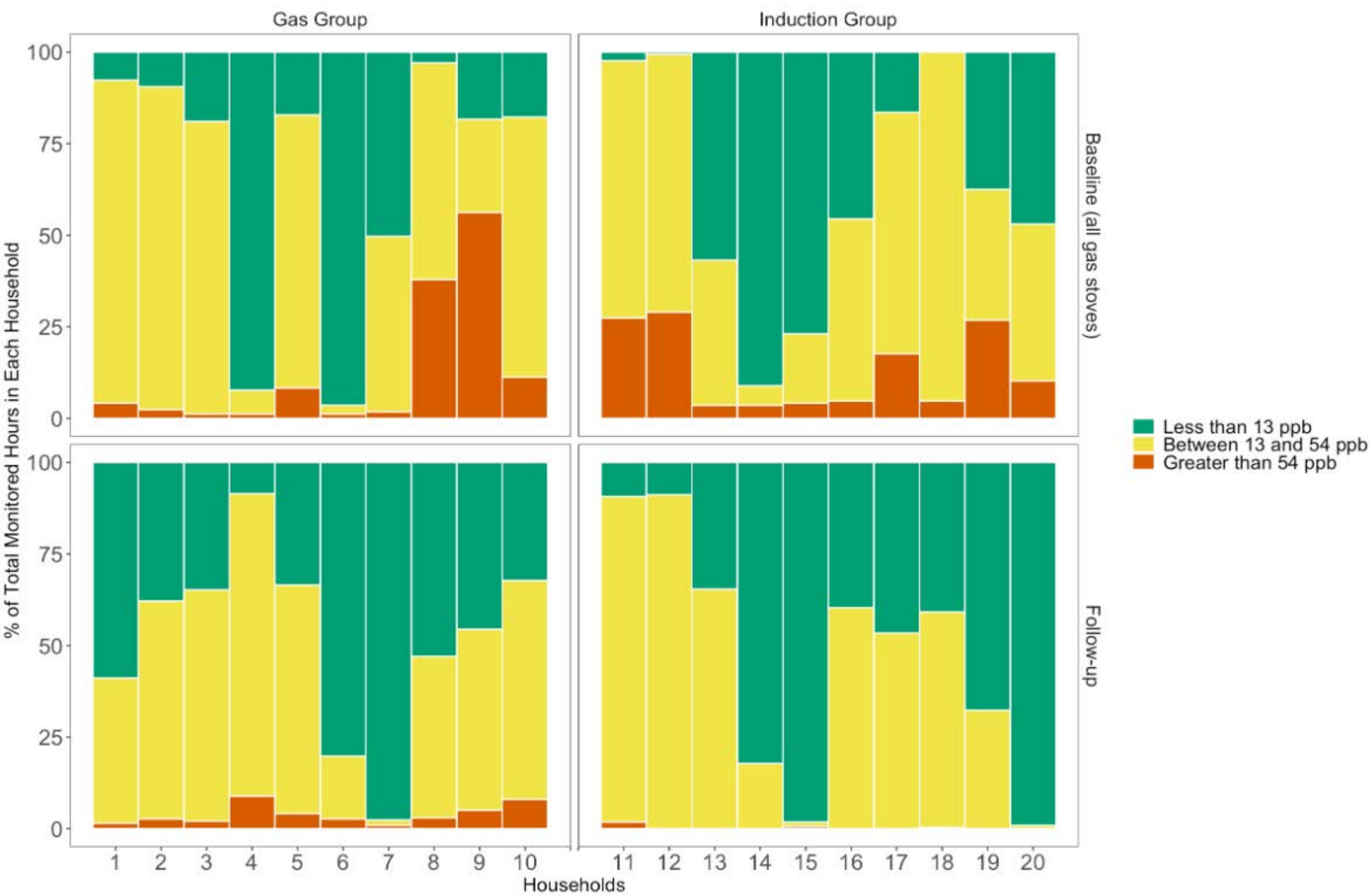


Figure 4: *Percent of monitored hours in each household spent in each category of NO2 exposure. Thirteen ppb is the WHO 24-hour average guidance for indoor NO2 exposure and 54 ppb is the one-hour outdoor NO2 exposure threshold at which EPA's Air Quality Index transitions from "Good" to "Moderate." All one-hour averages below 13 ppb are illustrated in green, all one-hour averages between 13 and 54 ppb are illustrated in yellow, and all one-hour averages exceeding 54 ppb are illustrated in red. Figure 4 shows that one-hour averages exceeding the 54 ppb threshold (the EPA AQI threshold for "Moderate" exposure) are virtually eliminated after the intervention group removed their gas stoves and started using an induction stove.*

Carbon Monoxide (CO)

Due to some complications with the CO sensors in the Home Health Boxes, household CO data was truncated at 10 ppm. Because of this, not all of the same analysis done for the NO2 data was applicable for CO data. With data from a co-located Lascar CO monitor, we were able to develop a model which allowed us to estimate the 24-hour averages within each household.

Figure 5 shows the 24-hour averages of each household in the follow-up monitoring period with households in the control group (gas stoves) having an average 24-hour average CO concentration of 1.4 ppm whereas households in the intervention group (induction stoves) had an average 24-hour average of 0.8 ppm.

This analysis shows that although induction households had a lower 24-hour CO average, neither group had a 24-hour household average that exceeded the WHO 24-hour guidance of 3.5 ppm. An hour-by-hour analysis, such as the one done for NO2 above, was not possible given the modeling approach we used to estimate daily CO concentrations.*

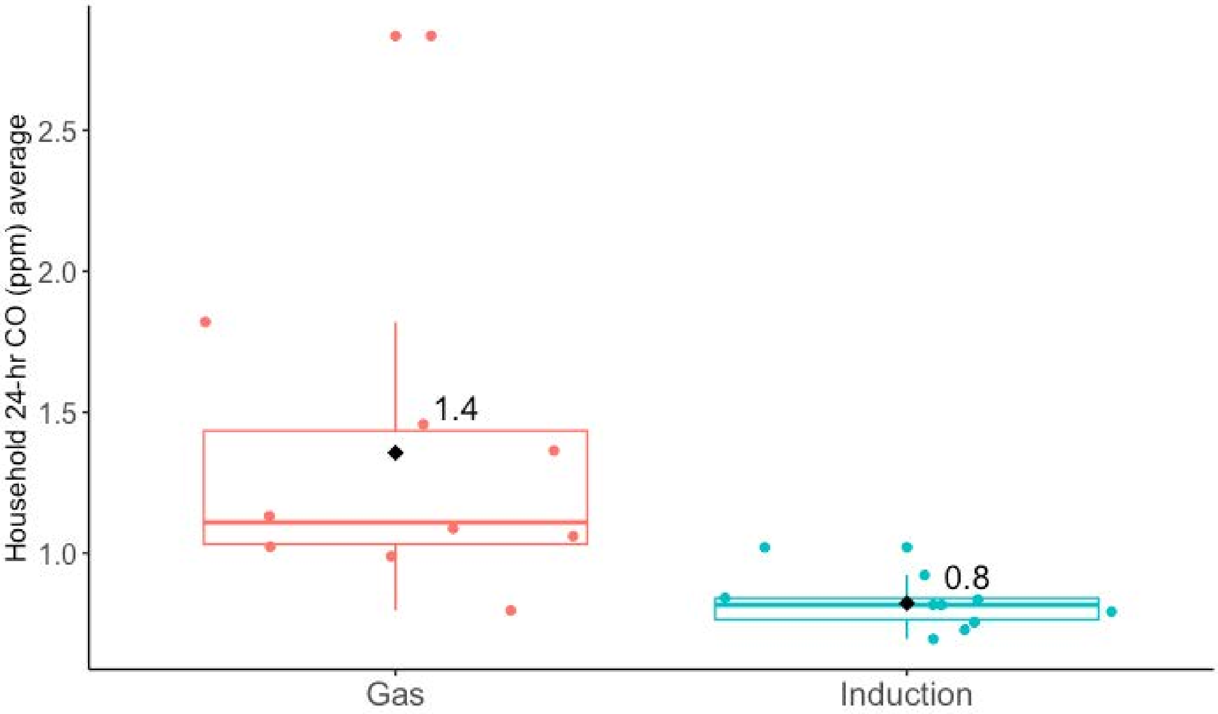


Figure 5: *Twenty-four-hour average household CO concentration (ppm) during the follow-up monitoring period.*

**The model (see Annex X) estimated daily CO averages, but not minute-by-minute estimates which were sometimes truncated at 10 ppm, and thus the data could not be analyzed for any time period shorter than one day.*

STOVE USABILITY FOCUS GROUP RESULTS

Coded transcriptions from the focus groups where long-term air monitoring participants shared their experiences with the pilot revealed observed outcomes related to satisfaction, improved cooking experience, mental health, and dignity.

Beyond Satisfied

Participants were unanimous about one aspect of the pilot: they loved their new induction stoves. They cited different reasons for preferring the induction stove to the gas stove, including the ease of cooking, the time savings because the induction stove cooks faster and is easier to clean, the decreased reliance on other appliances, and the fact that the induction stove creates a safer cooking environment. These sentiments are illustrated in the following exemplary quote:

> ***"I love the stove entirely, everything about the stove, [it] cooks fast, [I] don't have to worry about the smell of gas, [it] cleans easier than the other stove. I'm not using the air fryer that I had, I'm using the air fryer that fits in the stove. Also, [I'm] not using my microwave that much, I'm using my stove. I just love everything."***

While participants acknowledged that there was a transition period and a learning curve required to adapt their cooking methods to the new stove, they welcomed this transition phase with excitement.

This suggests that preference for cooking with their old appliance and behavior change, two commonly cited barriers to clean cooking interventions, were not as prominent in this setting. As one of the participants put it:

> ***"I am like a kid in a candy store. I wanted to learn. I tested everything. I don't even eat meat anymore, but I've been cooking steak, pork chops, crab legs for my family to practice."***

Relief: An Underappreciated Health Benefit

Participants all expressed longstanding and omnipresent concerns that at any moment their homes could catch on fire due to a gas stove malfunctioning, leaking, or being improperly turned off. Two factors were at the root of these concerns. The first is that their gas stoves were old and not properly or regularly maintained. The second is that major gas leaks (large enough to be smelled by neighbors several floors away) had become extremely common occurrences in the building. A participant described a recent gas leak that others had also experienced as a major scare:

> ***"[...] definitely safety, maybe three weeks ago there was a gas leak, was really bad, so strong that you would have probably passed out [...] strong gas odor on 6th floor, [...] God forbid if someone was in the hallway and lit a match; I would've been blown to smithereens."***

As a vivid illustration of this point, a participant who repeatedly mentioned that safety was the main driver of his decision to enroll in this pilot shared an episode with his gas stove that had deeply affected him. He had just turned his stove on when it caught on fire, which led to some of the knobs being propelled off the stove. Though he was not physically injured, he carried a fallen knob in his pocket as a reminder of the risk that the gas stove represented.

These fire safety concerns had become a source of chronic stress for virtually all the participants. Once their gas stoves were replaced, they felt relieved that they did not have to live (and cook) with this constant worry anymore. As the participant with the fallen knob summed it up:

> ***"What's important to me is that the stove is a lot safer and when I cook, I don't have to worry about a fire in the apartment. The rest doesn't matter."***

"These findings highlight a mental health pathway through which gas-to-electric conversions can additionally improve health. While the focus has been on indoor air pollution reduction as the main health-related contribution of such transitions, it is important that health be defined and evaluated holistically in future studies.

In with Justice, But What About Dignity?

Installing induction stoves in participants' homes required upgrading the electrical wiring so it could accommodate the increased electrical load. Several participants were dissatisfied with the installation process via an independent contractor, which seemed to have been done without regard to their preferences and did not prioritize aesthetics. To them, the only explanation as to why their input was not valued and the appearance of their homes not safeguarded was their status as low-income residents. The following quotes exemplify these sentiments:

> ***"Why would you bring the cable casing all the way around the house like we don't matter? Just because it's NYC housing (meaning NYCHA housing), we don't matter."***

> ***""[...] I don't like the way it looks either (referring to the wiring) [...], I wish they would have asked us and incorporated us in that decision-making."***

Though these residents are fully aware that they deserve dignified treatment like everyone else, their low-income status seemed to regularly get in the way. Dignity is increasingly recognized as a core tenet and a guiding principle of initiatives designed to improve health equity and environmental justice outcomes. Household energy interventions, such as this gas-to-electric conversion, often have permanent implications on the homes and lives of residents. As such, they should be particularly concerned with centering participants' experiences around dignity and respect and ensuring that participants are heard. Otherwise, (procedural) justice goals cannot be achieved.

KEY FINDINGS

The results from the long-term air monitoring, CCT, and participant focus groups in the Out of Gas, In with Justice pilot make a compelling case for the widespread adoption of induction stoves in affordable housing. Even more so, we believe this pilot makes a stronger case for a holistic approach to building electrification that is more ambitious than individual appliance swaps. This sections aims to unpack some of the complex findings from the pilot and identify the implications for policymakers and advocates working to advance residential building electrification in low-income housing.

Gas Stoves Pollute Our Air

The CCT results confirm that cooking with a gas stove results in acute indoor NO2 concentrations that are harmful to one's health, particularly for sensitive groups which include people with respiratory illness, children under 18, and older adults (there is no specific age when discussing risk from air pollution, but many studies cite over 65). This test only captures part of the picture since it did not investigate the time required for NO2 concentrations to return to baseline after a cooking event. Studies show that NO2 and other pollutant concentrations can remain elevated for long periods of time after a gas stove has been turned off.[49] The shortest controlled cooking test with a gas stove lasted 49 minutes, which means it is possible that NO2 levels exceeded the EPA's guidance for sensitive groups longer than one hour. It is also notable that the NO2 concentrations recorded are the result of cooking just one standardized meal, and 95 percent of participating households reported cooking more than one meal per day. This health risk is completely eliminated with the induction stove, which cooked the standardized meal in half of the time (due to its efficiency), without emitting any air pollution in the process.

Long-Term NO2 Exposure

Results from long-term air monitoring data also confirm that households with gas stoves are exposed to higher levels of NO2 and CO that again put sensitive groups at risk. This is especially true when residents are forced to use gas stoves for more than just cooking. Baseline data, collected between October 2021 and February 2022, found that some households recorded cooking events lasting 18 hours a day. This is during a season when households are more likely to use their ovens for supplemental heating (of which 85 percent of participating households surveyed reported doing so due to inadequate heating). This is partially captured in Figure 4, which shows households during baseline measurements in both intervention and control groups experiencing a larger percent of hours with NO2 concentrations above 54 ppb.

Impact for Sensitive Groups

The impact gas stoves have on air quality for sensitive groups is especially important for public housing residents and low-income communities of color, where household members are more likely to have a respiratory illness. At 1471 Watson Avenue, we did not collect health data, however 80 percent of participating households did have a permanent resident under 18 or over 65 years of age - populations that are more vulnerable to the health impacts of NO2. No apartment that participated in the pilot had a functioning range hood above the stove to help with ventilation. In addition, our results exclusively measured pollutant exposure inside of participant's homes and did not take into account the fact that majority Black and Latinx neighborhoods - such as the neighborhood in which 1471 Watson is located - live with worse outdoor air quality. A recent study found that communities of color in the United States are exposed to 17-percent higher levels of ambient PM2.5, a dangerous air pollutant that causes serious health problems, compared to the population average, with Black Americans facing 32-percent higher exposure.[50]

A CRITICAL ENVIRONMENTAL JUSTICE ISSUE

The findings expose the lived reality of low-income communities of color in multifamily buildings - **poor housing conditions such as inadequate heating, no ventilation, and outdated, inefficient gas appliances, compounded by an over-polluted neighborhood results in worse air quality and poor health outcomes.**

Removing gas stoves from low-income housing and replacing them with induction stoves can start to address some of these injustices, and residents are eager to embrace these new electric technologies. However, our pilot shows that electrification interventions can and must go farther than individual appliance swaps if we are serious about closing the public health gap that plagues low-income communities of color.

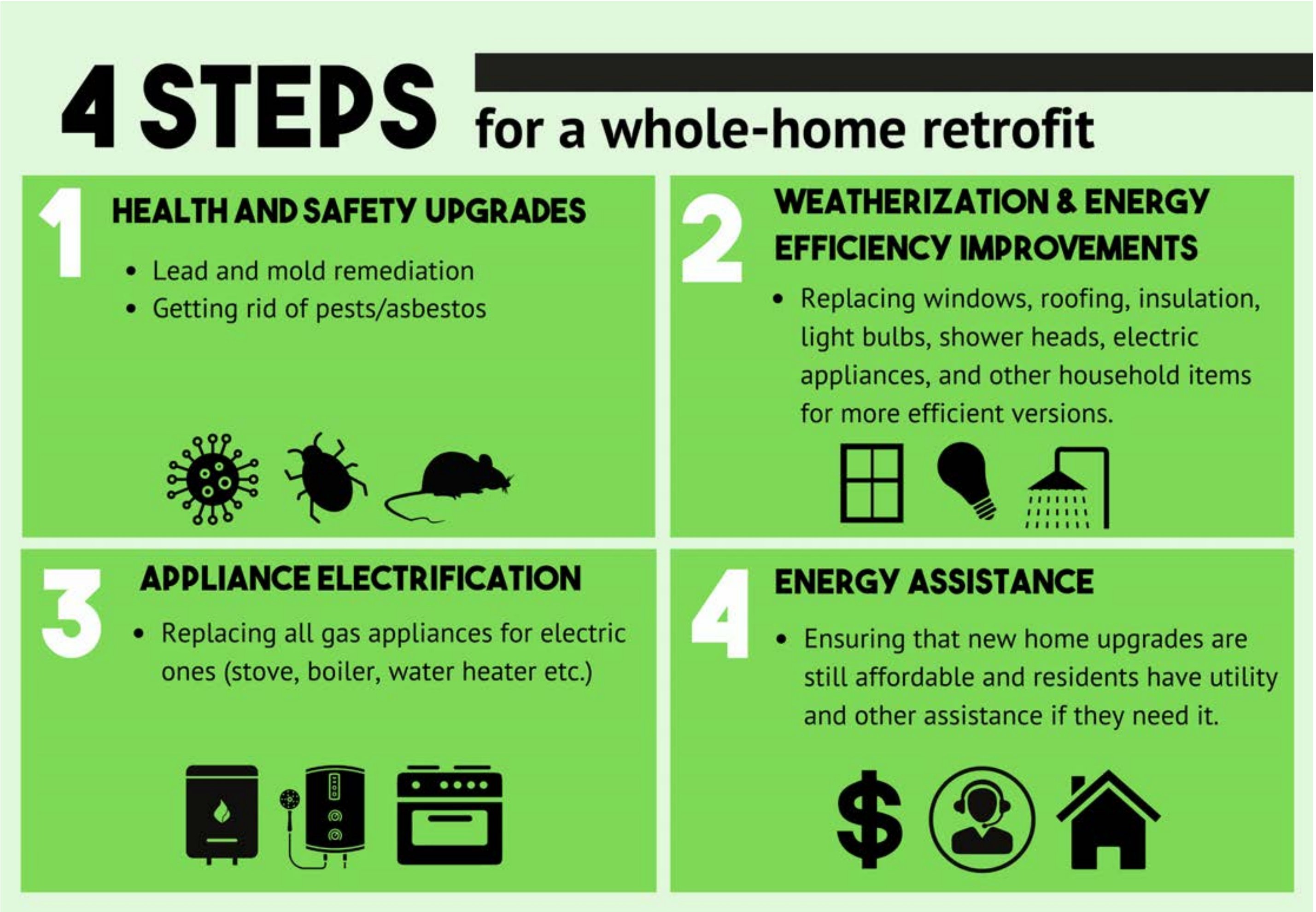
Holistic Healthy Homes

The long-term air monitoring results do show improvements to air quality when a gas stove is replaced by an induction stove. However, as Figure 4 shows, there is interference from NO2 sources beyond a household's stove that are impacting daily air quality. Our study found that average daily NO2 concentrations dropped in the intervention group by 35 percent. This reduction was similar, but slightly less than 42-51 percent reductions in NO2 reported in a similar gas-to-induction stove study in Baltimore, Maryland.[51] 1471 Watson Avenue is a 96-unit building with a central gas-powered boiler and water heater in the basement. The air quality of the ten intervention group households in our study could have been impacted by a combination of confounders, including air exchange between neighboring apartments with gas stoves, pollution from the central boiler and water heater, other gas appliances within a household, and outdoor pollutants like automobile exhaust. This interference with household air makes the health benefits of a single appliance swap less straightforward.

Individual Appliance Exchanges

Our findings suggest that individual appliance exchanges of gas for induction stoves in multifamily housing will improve indoor air quality for individual units and prevent household exposure to the most harmful concentrations of NO2. However, other polluting systems still found in the building will continue to impact air quality, which is why transitioning entire buildings will likely have the greatest impact on improving indoor air quality.

As seen at 1471 Watson Avenue, individual appliance exchanges are not always scalable because of existing conditions in the building, namely inadequate electrical capacity. It is critical to acknowledge the reality that low-income communities are more likely to live in older housing with structural deficiencies, and are more likely to face barriers to reach the electrification starting line.[52] For example, 180 of 277 NYCHA developments are 50 years and older and capital needs from deferred maintenance are over $40 billion.[53] Full electrification of 1471 Watson alone is expected to cost between $6 and $8 million.[54] Many low-income buildings do not have the financial ability to realize universal appliance exchanges without prior capital planning or government assistance, and still, more urgent health and safety concerns need to be prioritized. Building electrification needs to be holistic rather than piecemeal. A comprehensive approach, where several interventions are packaged into a whole-building retrofit, can maximize benefits to residents' health and expand resources for more equitable and efficient delivery of interventions.[55]



DISCUSSION OF THE PROCESS

Culturally Appropriate Outreach

Successful recruitment of residents at 1471 Watson Avenue was only possible because outreach staff were both representative of the neighborhood population and held pre-established relationships with residents - two factors that helped build trust with participants. Association for Energy Affordability (AEA) recently completed a number of energy saving projects at 1471 Watson through funding from the Weatherization Assistance Program (WAP), including new high performance windows, hard wire lights, and low flow shower heads and aerators in all apartments. Outreach staff at AEA proved to be reliable and professional and built good rapport with building residents. They also lived in the neighborhood surrounding 1471 Watson Avenue, spoke both English and Spanish, and helped streamline messaging around the Out of Gas, In With Justice pilot to make it digestible and relevant for the target population. Strong relationships and appropriate messaging were key to recruitment for the pilot, while respect for people’s schedules and clear communication throughout the process helped maintain positive relationships with participants.

Participants Prefer Induction Stoves

Before Out of Gas, In With Justice, the majority of our participants had never heard of an induction stove. WE ACT created opportunities to learn more about the stove, including in-person cooking classes and pre-recorded videos with a professional chef, along with curated "How-To" documents to explain the functions of the stove and best practices for induction cooking. Participants shared that our materials simplified the learning curve, and only a couple of households needed additional assistance after receiving their new stove. Overwhelmingly, participants expressed immense satisfaction with induction cooking and not a single participant asked to return to their gas stove. After the installation of the first ten stoves in intervention households, a handful of building residents that previously turned down participating in the pilot reached out to express interest. It became evident as time went on that exposure to new technology and word of mouth from trusted sources like neighbors and friends are two powerful outreach tools that complement one another.

Lessons for Future Outreach

These insights are valuable for improving outreach to low-income communities and educating individuals of different ages and cultural backgrounds on the benefits and ease of induction cooking. WE ACT aims to use materials created during the pilot to spread awareness about the health and safety benefits of induction cooking and help increase the diversity of education materials related to induction stoves. Throughout this process, we found no materials from investor-owned utilities, who play an outsized role in the energy transition, describing beneficial electrification and induction stoves. Utilities must create culturally relevant materials in multiple languages to promote induction cooking that targets a diverse population. This type of public relations campaign will help expand the audience of people willing to transition away from gas appliances.

Treating Low-income Tenants With Respect

Residents at 1471 Watson Avenue shared during focus groups a collective consensus that contractors working in apartments often seem disrespectful, which they attribute to the fact that they are residents of public housing. On the ground staff in the Out of Gas, In With Justice pilot went out of their way to accommodate people's schedules and comfort levels for the duration of the pilot, and clearly communicated the steps involved to conduct air monitoring and installation of induction stoves. For example, during the installation procedure, plumbers needed to shut off gas to all receiving units before the stoves could be swapped out. Some households did not have a functioning stove for up to two hours while our team completed other installations. However, staff communicated the date and time in advance and outlined what the process would look like so households could prepare. This type of coordination, while seemingly small, helped contribute to a positive electrification experience for pilot participants.

Despite staff efforts, there were still challenges with external contractors that completed electrical wiring, which resulted in negative interactions for some participants who felt that their opinions were not heard. This is an important lesson for landlords looking to complete electrification work in their buildings - enhanced stakeholder engagement and clear communication with both residents and external contractors will lead to a more positive electrification experience for all parties involved.

Cost Burden of Induction Ready Cookware

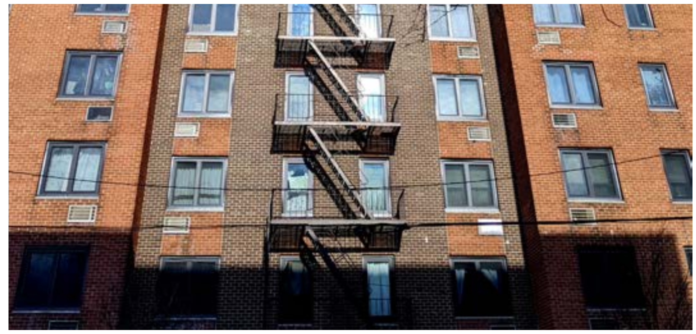
While induction stoves are coveted for their efficiency, quality, safety, and easy interface, there are additional associated costs, namely the need for induction-ready pots and pans. Low-income households and households on fixed incomes who receive an induction stove may not be able to afford the replacement of their existing cookware. Certain pots and pans that are not induction-ready may also have cultural significance and households may be reluctant to give them up. During our study, we found that the proposed solution, stainless steel stove adaptors, were inadequate and did not efficiently and safely heat non-induction pots. Providing new pots and pans to participants in our pilot proved to be an essential step for a successful transition.

Risk for Individuals with Pacemakers

Studies confirm that for individuals with unipolar and left-sided pacemakers, there is an extremely low risk, though a risk nonetheless, for interference with their device when using induction cooktops.[56] Due to this potential risk, we were unable to offer the stove to one participant, and expect that this issue will happen again in broader electrification efforts. While induction stoves are more efficient, safer, and cook food more accurately, landlords and public housing agencies should offer alternative cooktops for residents with pacemakers, namely standard electric stoves, which provide similar health benefits to induction cooking and do not pose a risk for device interference.

Dealing with the Split Incentive

The Out of Gas, In With Justice pilot focused on public housing where the property owner, NYCHA, is committed to the electrification of its existing housing stock. This is not the reality for all private landlords who own a majority of the multifamily housing stock in New York. In rental housing, the "split incentive" is a market-failure whereby neither the property owner nor the property occupant has a financial incentive to implement energy efficiency upgrades, even where those upgrades would quickly pay for themselves through energy cost savings.[57] The property owner lacks a financial incentive because they do not pay the cost of utilities and therefore do not recoup their capital investment in energy efficiency through the utility cost savings. Conversely, the occupant lacks a financial incentive to make energy upgrades to a property that they do not own, as oftentimes even cost-effective energy efficiency improvements would not pay for themselves during a one or two year lease. Government programs need to continue to improve incentives for property owners to complete deep energy retrofits and electrification upgrades as well as increase accountability for those that delay. At the same time, public programs need to be more accessible to renters, when appropriate.



Equity and Utility Bills

Understanding and responding to the impacts electrification will have on utility bills is critical for equitable building electrification. Low-income households are already forced to deal with a disproportionate energy burden due to poorly designed utility rate structures that spread fixed costs evenly without the consideration of household income. This has led to a crisis where low-income households are forced to spend up to three times more of their income on utilities.[58] At the time of this study, though induction stoves are more than two times as efficient as gas stoves, electricity remains a higher cost per unit energy than gas (gas is $0.78/therm compared to electric at $6.75/therm for supply and delivery costs combined).* The New York City arm of the pilot did not have to plan for its potential impact on utility bills because residents of the NYCHA building are not responsible for gas and electric bills. While this offered our participants long-term financial stability, especially because every participant chose to keep their stove in perpetuity, it did not allow us to implement cost-saving solutions to address this important barrier to electrification in low-income housing. Future studies, specifically the Buffalo arm of the pilot, can better measure the impact of transitioning to electric cooking via induction stove and heating and cooling via heat pump on electricity bills for tenants, along with potential cost-saving solutions.

**Supply and delivery costs calculated as averages over the duration of the study period.*

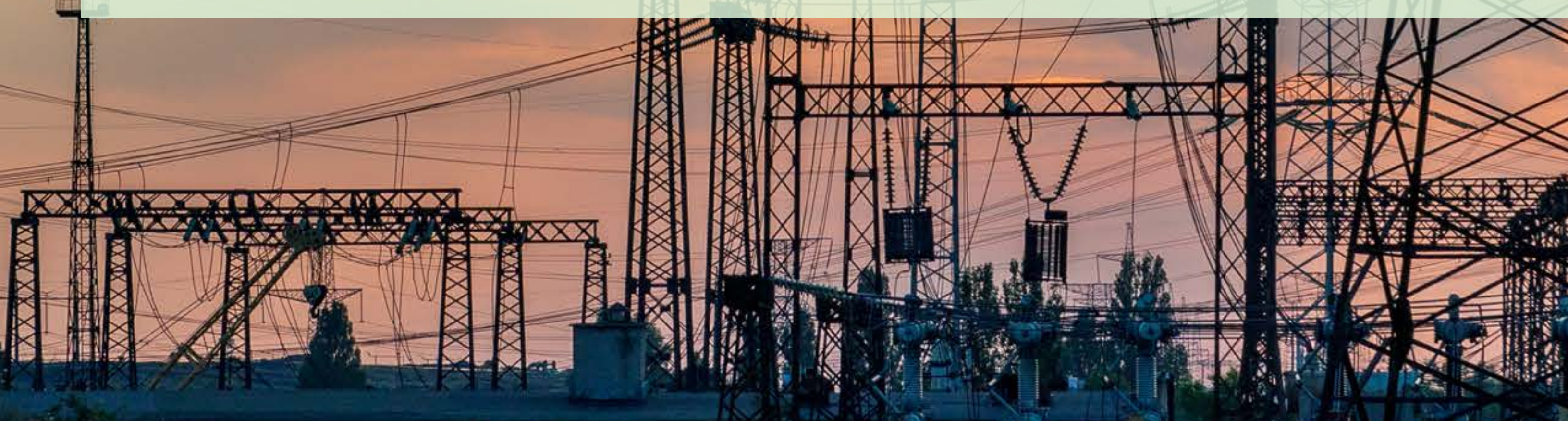
UTILITY COST ANALYSIS

Critics of electrification often cite the threat of increased utility bills as a reason to continue using fossil fuels, despite increasing evidence demonstrating the cost saving opportunity of electrification when done correctly.[59] We wanted to learn how induction cooking would impact residential utility bills using data from the Out of Gas, In With Justice pilot and utility costs from New York City utilities, National Grid, and Con Edison.

Our analysis looks at the average gas bill for a residential apartment in New York City that uses National Grid for their gas service and pays for cooking gas but not heat, which is typical of approximately 80 percent of all residential buildings in New York City.[60]

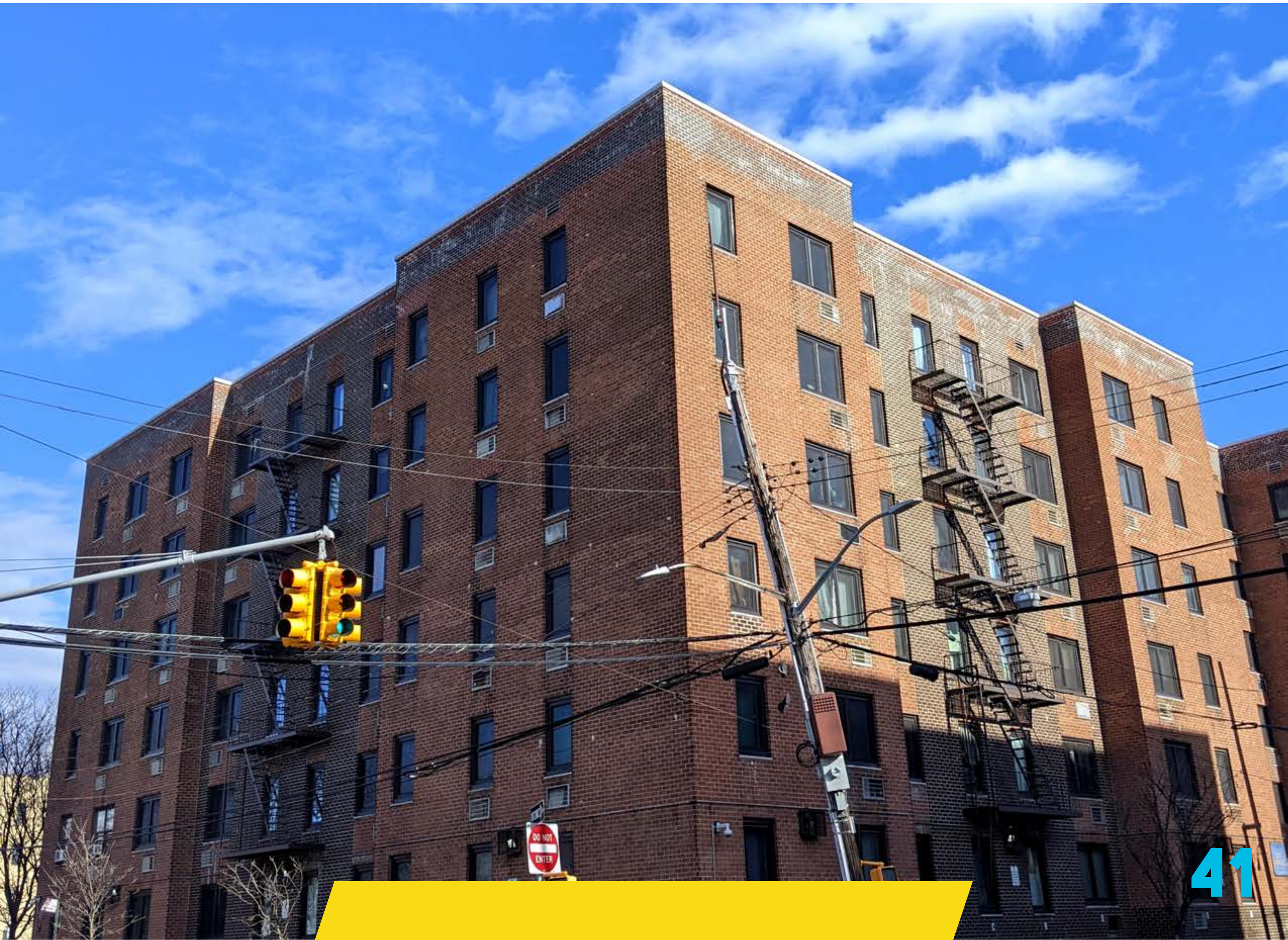
It costs around $6/month more in utility bills to operate an induction stove at usage levels similar to those monitored during this study. However, for households that only pay for cooking gas, the switch to induction could allow them to eliminate their entire gas bill, in particular the monthly minimum service charge that ranges from $16 to $18 a month. This would be a cost saving opportunity for households of approximately $11/month, or $132/year on utility bills.

See Appendix C for more details.



CHALLENGES & LIMITATIONS

As the first study to focus on the health benefits of electrification in residential cooking in a public housing setting, there were circumstances based on the design of the study that impacted our results.



Building Limitations

Due to the building's limited electrical capacity and concerns that an increase in electricity demand beyond two induction stoves per vertical line would overload the system, we were only able to enroll two apartments per line in the pilot. This limited our ability to recruit the most viable households that had participants who cooked regularly, would be home for the duration of the study, and were interested in participating.

While the Out of Gas, In With Justice pilot in Buffalo plans to swap out gas heating systems for electric heat pumps, the New York City arm made the decision to remove heat pumps from its transition due to budget restrictions and concerns that external confounders would dilute air quality results. 1471 Watson Avenue has a gas-powered basement boiler that provides heat and hot water to all 96 apartments, and would continue to operate despite the installation of air source heat pumps in the air conditioning sleeves of experimental apartments. Ambient toxins from the basement boiler in the building might still pollute the air in experimental apartments to the same extent that it would pollute the control apartments, which could weaken the association between electrification and resulting changes in air quality. Our long-term air monitoring results confirmed the hypothesis that the boiler could act as an NO2 confounder in intervention apartments facing the back of the building on lower floors.

Coordination with Participating Households

In order to complete the pilot, WE ACT and AEA staff needed to work around the schedules of twenty participating households to access air monitoring equipment and stove use loggers installed in individual kitchens. Limited access to certain apartments occasionally curtailed our ability to fix malfunctioning equipment, which resulted in lost data.

Timeline of Air Monitoring Measurements

The original research design called for a week of air monitoring at the beginning of the study (baseline), another week two months later (S1) and a final week two months after that (S2), four months from the baseline. Baseline air monitoring took significantly longer than expected. Equipment failure, participant disqualification, and a COVID-19 case surge in November and December of 2021 all delayed the outreach team's ability to complete baseline air monitoring on the planned schedule. The time between baseline and S1 varies for households due to the outsized delay in completing baseline air monitoring. The time between S1 and S2 air monitoring due to delays was limited to five to six weeks for households versus a full eight weeks.

Baseline monitoring took place in colder months (October 2021 - February 2022) compared to S1 and S2 (April 2022 - June 2022 and June 2022 - July 2022, respectively). This may have had an impact on participant stove and oven use. For example, participants reported using their ovens to heat their apartments during colder months, and temperature logging data showed instances of multi-hour cooking events, sometimes extending beyond eighteen hours. In addition, more participants reported cooking with their windows closed compared to S1 and S2 measurements. These factors may help explain why baseline NO2 and CO measurements were higher for both control and intervention apartments, and dropped for both groups in subsequent measurements.

Uneven Exposure to Possible Confounders

There was an uneven distribution of control and intervention households throughout the building which may have had an impact on long-term air monitoring results. A higher proportion of intervention households faced the back of the building where the gas boiler is located and vents out. Participants, especially in the back of the building and on lower floors, often complained about the smell of gas in their apartments. Exposure to pollution from the boiler could contribute to higher NO2 and CO emissions inside apartments. Apartments on the front and side of the building faced two-way and one-way streets, respectively. Typical of a New York City neighborhood, these streets were intermittently busy with vehicles but never experienced standstill traffic.

Overall, real-use air quality measurements are always prone to some interferences, and can be controlled for with ambient NO2 readings. They are also indicative of the many indoor and outdoor sources that can also contribute to poor air quality within the home.

Air Monitoring Equipment Limitations

After measuring baseline air quality, researchers found out that the Home Health Box limited CO monitoring at 10 ppm. To measure potential exceedance of this limit, Berkeley Air sent the air monitoring team Lascar CO monitors to run alongside the HHB. Due to the timing of this discovery as well as complications with the Lascar CO monitors, not all of the Home Health Boxes were run with colocated monitors to record spikes in CO above 10 ppm.

Study Design

While the Out of Gas, In With Justice pilot helps evaluate the impacts gas stoves have on indoor air quality for affordable housing residents, it is important to note that this is only a pilot with a limited sample size. With only twenty households participating, any fluctuations or oddities in air quality will have a direct impact on results.

POLICY RECOMMENDATIONS

There are important takeaways from the Out of Gas, In With Justice pilot that have implications for policies impacting low-income residential decarbonization. As noted in our Key Findings section, low-income communities and communities of color are overburdened by the compounding effects of air pollution, rising energy costs, poor housing conditions, and climate change - issues that lead to disproportionately negative health outcomes. Residential electrification can simultaneously address these interrelated crises, especially if policies are designed to serve the most vulnerable populations. Whole home retrofits can maximize co-benefits for low-income renters and help achieve healthy homes for all.[61]

Investments in energy efficiency measures can save New York customers more than $7.7 billion by 2025, create thousands of jobs, and improve public health.[62] Recent large-scale efforts to decarbonize our energy grid, both in New York and nationwide, make residential electrification a viable and necessary step towards reducing greenhouse gas emissions. The following recommendations address the challenges and limitations we have identified through our pilot and identify solutions that will accelerate equitable building decarbonization efforts in New York State and beyond.

Restructure existing programs to focus on whole-home retrofits, prioritizing low-income housing

Existing programs are siloed to address one specific piece of the electrification puzzle without offering flexibility to participating households. As a result, households with health and safety issues (the prevalence of toxins like mold, lead, asbestos, and pests) will typically get denied access to necessary weatherization upgrades and deep energy retrofits with little to no guidance on resources to remediate the issues. It is more likely for a low-income household or household of color to experience these poor housing conditions, thus barring them from necessary upgrades.[63] Programs that address household interventions more holistically will improve their ability to equitably serve all their residents. A whole-home retrofit typically includes four basic services: health and safety upgrades, weatherization and energy efficiency improvements, appliance electrification, and energy cost assistance. In combination, this type of intervention addresses all possible existing conditions that make homes unhealthy.

States must create and fund complementary pre-weatherization programs that can act as an automatic referral when a household does not meet health and safety standards for existing weatherization programs. Current weatherization and electrification programs must also expand the scope of their work to streamline access to benefits and increase participation in whole-home electrification. To reach deeper levels of affordability, programs need to provide tiered financial assistance for both hard and soft costs based on building size and income. Small building owners have frequently identified lack of support for soft costs, like engineering, as a barrier to participation in existing retrofit programs. Existing programs that attempt to make household electrification cost-effective need to re-evaluate their structure to ensure they go far enough to support multifamily building owners, especially those that are low-income or in predominantly Black or Latinx neighborhoods.

TITLE	TYPE	LEVEL	DESCRIPTION	RECOMMENDATION
ElectrifyNYC	**Program**	**City**	ElectrifyNYC supports 1-4 family homeowners in Queens and Staten Island with efficiency and electrification upgrades by guiding homeowners through the weatherization and energy efficiency upgrades as well as supporting the identification of appropriate incentives and financing to do the work.[64]	Additional funding should expand the program to all five boroughs, and support pre-weatherization work to address health and safety concerns that will ensure homeowners are able to reach the electrification starting line and achieve a healthy and livable indoor environment.
Energy Efficiency Equity and Jobs Act (EEEJA)	**Program**	**State**	New York State's energy efficiency programs inadequately serve people of color and low-income individuals because lead, asbestos, and mold remediation are not funded by the state as part of a pre-weatherization requirement. As a result, residents in older housing with environmental hazards do not qualify for energy efficiency retrofits.	The New York State legislature and Governor Hochul must pass EEEJA to fix the utility cost-benefit analysis so that people's health and well-being are the central consideration for targeting building retrofits. EEEJA will allow New York State Energy Research & Development Authority (NYSERDA) to fund non-energy measures in order to fix underlying conditions, like the prevalence of mold, lead, pests, and asbestos that prohibit the implementation of efficiency upgrades.
Department of Homes and Community (DHCR) Renewal Lead Abatement	**Program**	**State**	Lead impacted housing prohibits decarbonization. As the State pursues more aggressive strategies to electrify existing buildings, it is vital that lead sources are eliminated in preparation.	The state must icrease funding to DHCR by $10 million, and distribute funds to local governments through grants to landlords for lead abatement, with priority given to Primary Lead Poisoning Prevention Program participants.

TITLE	TYPE	LEVEL	DESCRIPTION	RECOMMENDATION
EmPower New York	**Program**	**State**	EmPower provides energy efficiency upgrades to low-income eligible households at no-cost to the tenant or homeowner. Upgrades include home energy assessments, high-efficiency lighting and showerheads, attic and wall insulation, heating and cooling heat pumps and replacement of inefficient refrigerators and freezers.	Expand EmPower's services to include the replacement of inefficient gas stoves with highly efficient induction stoves and induction ready cookware for households that have the infrastructure to support them.
RetrofitNY	**Program**	**State**	NYSERDA launched RetrofitNY to help existing affordable housing buildings electrify via deep energy retrofits.[65] The program, modeled after the successful European program Energiesprong, provides $40,000 per unit in "gap" funding to qualifying projects. However, this funding is often not enough to cover most soft costs, like engineering costs, which are particularly burdensome for smaller multifamily buildings.[66]	Increased funding to the program should expand financial assistance offered to smaller affordable housing buildings that need additional financial support. Households that receive induction stoves through RetrofitNY should also receive a set of induction ready pots and pans. Energiesprong provides cookware with induction stoves to participating households.
Weatherization Assistance Program (WAP)	**Program**	**Federal**	The federally funded Weatherization Assistance Program helps low-income households increase their energy efficiency and reduce energy costs.	With increased funding, WAP should expand services to assist with electrification, which includes increasing electrical capacity, installing heat pumps and induction stoves and cookware.

Adjust policies and programs to meet the needs of low-income renters who have limited autonomy over housing conditions

Low-income renters are in a difficult position when it comes to residential decarbonization due to their limited control over building participation in city, state, and federal programs despite having the most to gain from these efforts. In the absence of laws that will require landlord participation, there needs to be modifications to existing programs to create options available for renters to apply that do not need landlord approval. This can include basic upgrades like window replacement, LED lights, energy audits and more efficient air conditioners. Programs that make more substantial investments in properties, and require landlord approval, should include additional benefits for renters, including heavily subsidized induction stoves and heat pumps.

Housing Justice is Environmental Justice

It is critical to recognize that equitable building electrification for low-income renters cannot happen without strong tenant protections. While there are legal regulations for some renters, including those that live in public housing, unregulated tenants on the private market are particularly vulnerable to instability and displacement. Any investments in a housing unit including toxic remediation, weatherization, electrical upgrades, appliance swaps etc., should not be a justification for a rent increase that will displace low-income tenants, especially if that funding is subsidized by a public program.

Utilities Are a Public Service, Not a Profit Model

It is also important to remember that low-income households and households of color experience disproportionately high energy burdens while simultaneously facing worse outdoor and indoor air quality, both of which have been linked to detrimental health impacts.[67] They are also the least equipped to front the costs associated with transitioning to all-electric buildings. New York State set a goal in 2016 to cap energy costs for low-income New Yorkers at 6 percent of household income, but has yet to achieve that goal.[68] Millions of New Yorkers are severely energy burdened. In New York City alone, 25 percent of low-income households have an energy burden greater than 16.8 percent, and since the onset of the COVID-19 pandemic, utility debt in the state has climbed to over $2 billion.[69] Energy is a human right, and the commodification of such a resource has led to a crisis that causes disproportionate harm to low-income communities and communities of color. Energy systems should be controlled by publicly owned and democratically accountable entities. There is evidence that public utilities lower energy costs for ratepayers and adopt more large-scale renewable energy - a critically important component of decarbonization - than investor owned utilities.[70]

States Must Do More

In the interim, states must commit more seriously to solutions that will ensure low-income households can afford their energy needs. This includes increased funding and access to energy affordability programs, and restructuring of utility rates to fully account for income levels. Income-based fixed charges spread the cost of the system across customers based on income brackets.[71] This means that fixed system costs, such as the poles and wires to deliver electricity are distributed to customers based on their ability to pay.

TITLE	TYPE	LEVEL	DESCRIPTION	RECOMMENDATION
Clean Heat Program	**Program**	**State**	The New York State Clean Heat Program is a coordinated effort between NYSERDA, utilities, and contractors across the state to increase awareness about electric heating, build market and workforce capacity for building electrification, and subsidize costs for purchasing and installing heat pumps for heating and cooling.[72]	The program needs to target funding specifically for disadvantaged communities, and should offer technical assistance to low-income multifamily buildings to help owners identify additional incentives. Residents in buildings that participate in the Clean Heat Program should also receive induction stoves and induction ready cookware as an additional incentive. Similar to EmPower and WAP, tenants should be able to apply for the Clean Heat Program without landlord approval.
Residential Financing through NYSERDA	**Program**	**State**	NYSERDA offers low-interest loans to low-income New Yorkers looking to finance energy efficiency and renewable energy improvements through specific NYSERDA programs (Clean Heat, NY-SUN, Comfort Home, etc..).[73]	To make the programs more accessible and serve its function as a financing option for low-income New Yorkers, stringent credit requirements and debt-to-income ratios must be removed.

TITLE	TYPE	LEVEL	DESCRIPTION	RECOMMENDATION
Energy Affordability Program	**Program**	**State**	In its current form, LIHEAP supplements utility bills to help pay heating costs in the winter months, and provides a one time payment up to $800 to buy and install an air conditioner or fan in summer months.	New York State needs to expand LIHEAP to supplement utility bills for cooling costs in the summer months, especially as the intensity of extreme heat events increase and exacerbate negative health outcomes in low-income communities and communities of color in particular.
Build Public Renewables Act	**Bill**	**State**	The New York Power Authority (NYPA), the largest public power utility in the country, is the lowest-cost electricity supplier in the state, and 70 percent of its production is renewable energy. But there are major restrictions on what NYPA can do. NYPA is not legally allowed to own or build new utility-scale renewable energy projects, nor is it allowed to directly sell energy to individual households.	The New York Build Public Renewables Act would allow the New York Power Authority to own and build new renewable energy projects, including the generation, storage, and transmission of renewables.This is one of the most important first steps in achieving public power statewide and making sure that energy systems are clean, affordable, resilient, and publicly owned.
Good Cause Eviction	**Program**	**State**	New York State’s housing crisis is causing the displacement of longtime communities, and programs that will remediate toxins, weatherize homes, and provide deep energy retrofits to unregulated apartments, could price out low-income tenants if there are not strong tenant protections in place.	Good Cause Eviction gives every tenant in New York State the right to a lease renewal and protections against unreasonable rent increases. This legislation will give unregulated tenants across the state much needed stability and prevent unjust real estate speculation in low-income neighborhoods.

TITLE	TYPE	LEVEL	DESCRIPTION	RECOMMENDATION
Inflation Reduction Act	**Law**	**Federal**	The Inflation Reduction Act (IRA) signed by President Biden on August 16th, 2022 unlocks billions of federal dollars for deep energy retrofits and home electrification. As it stands, the tax credit system outlined in the IRA disqualifies low-income renters from maximizing electrification credits. However, the Department of Energy gives states autonomy over implementation of these programs, and there are steps New York State can take to improve access for low-income multifamily buildings and renters.	Allow for the flexible usage of funds from the IRA in combination with other sources of money to allow the stacking and braiding of incentives to reach deeper affordability. Use money for the Greenhouse Gas Reduction Fund to provide no-interest loans to disadvantaged communities for the purposes of healthy home upgrades, electrical work, and appliance swaps. Development of a reimbursement (refund) program instead of a tax credit program to allow lower-income residents to maximize higher credits.

Accelerate Decarbonization in HUD-Funded Housing

Remove Bureaucratic Barriers to Funding

The Department of Housing and Urban Development (HUD) provides housing support to 9.73 million low-income Americans, with nearly 1 million in public housing.[74] Funds for low-income housing need to be more available to make necessary investments in decarbonization. For example, HUD rules and regulations create bureaucratic barriers that leave available funding streams on the table to do this work. Amendments should allow the stacking and braiding of multiple funding sources for decarbonization, including the ability to use capital funds, operating funds, and reserves with Energy Performance Contract debt interchangeably. This flexibility would create opportunities inside capital programs and operating programs for decarbonization and unleash existing funding sources to a greater number of properties. Additionally, HUD needs to develop and deliver training to public housing authorities across the country on how to integrate various funding sources to achieve decarbonization goals.

Incentivize Resource Efficient Electrification, with Necessary Exceptions

For public housing authorities and other affordable housing options where capital budgets are stretched thin, Resource Efficient Electrification (REE), an incremental methodology that combines an integrated design process with strategic capital planning for whole-home retrofits, can help building owners make progress towards realizing safe, healthy, and climate-friendly living environments while maintaining flexibility as technology and policy evolves.[75] A whole-home retrofit, if done correctly, can address outstanding building issues that need investments, including deferred maintenance, inefficiencies, inadequate electrical capacity, and the presence of pests and toxins. Smart capital and asset planning through REE can prevent the renewal of a fossil-fueled energy system when the one in place has reached the end of its life cycle. REE takes into account the reality that many building owners cannot make necessary upgrades all at once. Instead, they can take advantage of programs that will help with toxic remediation, key weatherization upgrades like replacing the roof or improving the building's envelope, electrical capacity and more, so that when a gas appliance needs to be replaced the building owner is prepared to electrify.

Typically, methodologies like REE do not recommend exchanging combustion appliances out for electric ones before they have reached the end of their life cycle. Our pilot revealed that some public housing residents are using stoves that are 20-plus years old, and while technically functional, they are inefficient and result in higher concentrations of indoor air pollutants. HUD should consider REE for buildings throughout its portfolio, but it also must require the removal of gas stoves from all properties by a set date to expedite the replacement of outdated appliances. Throughout this transition, managers at HUD properties need to provide culturally appropriate educational materials that prepare residents for induction stoves and clear communication of timelines for their appliance replacement to allow residents to schedule accordingly.

TITLE	TYPE	LEVEL	DESCRIPTION	RECOMMENDATION
HUD updates to the Uniform Physical Condition Standards	**Regulation**	**Federal**	HUD needs to initiate the transition away from gas stoves due to the proven health risks and the age and inefficiency of many HUD stoves.	HUD should update the Uniform Physical Condition Standards to label gas stoves a health and safety deficiency to end the procurement of new gas-fired cooking appliances and replace all existing gas stoves with electric induction stoves starting January 1, 2026.[76]

Pass policies that will get fossil fuels out of homes

The evidence continues to support the fact that living with fossil fuels inside of homes is harmful to people's health. Currently, there is no U.S. regulatory agency tasked with monitoring indoor air quality. Individual states have the authority to regulate indoor air pollution, and while some states are exercising this authority, most, including New York State, have no indoor air quality standards. Lack of regulation has allowed the gas industry to pump toxic fuel directly into homes of people who are then forced to live with, and face the consequences of, dangerous levels of indoor air pollution. Between new available funding from the Inflation Reduction Act for building electrification and mandates set forth in the Climate Leadership and Community Protection Act (CLCPA), New York State is in a strong position to pass and implement progressive decarbonization laws.

TITLE	TYPE	LEVEL	DESCRIPTION	RECOMMENDATION
Set Indoor Air Quality Guidelines	**Guideline**	**Federal**	Where the Environmental Protection Agency (EPA) has set National Ambient Air Quality Standards (NAAQS), there does not exist any recommendations for safe, health-protective levels of pollutants indoors.[77]	EPA needs to set indoor air quality guidelines based on the current body of evidence of health outcomes.
Mandatory Performance Standards for Gas Stoves	**Regulation**	**Federal**	The Consumer Product Safety Commission has previously issued mandatory standards where doing so will improve the safety of products. The CPSC has done so related to product emissions, such as those linked to CO poisoning from portable generators.	As long as gas stoves remain in homes and are available on the market, the CPSC must issue a mandatory performance standard for gas stove emissions to make them safer.
Place Warning Labels on Gas Stoves Via the Federal Hazardous Substance Act	**Regulation**	**Federal**	The Federal Hazardous Substances Act requires labels for household products deemed hazardous by the CPSC, and prohibits the sale of products where labeling is not sufficient to protect consumers.	The CPSC can and should require hazardous labeling on all gas appliances, including gas stoves to alert consumers of the harmful pollutants those products emit.

TITLE	TYPE	LEVEL	DESCRIPTION	RECOMMENDATION
All-Electric Building Act	**Bill**	**State**	All electric new construction is the smartest way forward to avoid costly electrical upgrades down the line and is the most practical first step in wide-scale building electrification.	Following New York City's passage of Local Law 154 of 2021, New York State needs to pass legislation that will initiate all electric new construction statewide in 2023 for small buildings and 2027 for large buildings. This will jumpstart the green building economy and help facilitate the production of more efficient and affordable electrification technology.
New York HEAT Act	**Bill**	**State**	The "100-foot rule" is a New York State law that quietly incentivizes building owners to use gas for their building operations.[78] The law requires utilities to offer free hook ups to any new building within 100 feet of a gas main. While the service is free for building owners, it comes at the expense of existing utility customers who are forced to foot the bill.	To transition away from gas combustion in residential buildings, the state first needs to end subsidies that are driving the expansion of gas infrastructure, which includes ending the archaic "100-foot rule."
Implementation of the Buildings Codes and Appliance Standard Act	**Law**	**State**	Signed into law by Governor Hochul in 2022, the Buildings Codes and Appliance Standard Act will ensure that new homes and appliances are more efficient, saving families more than $15 billion dollars over the next 15 years.	The PSC must uphold this law and ensure it accomplishes its intended goal, which will phase out fossil fuel appliances in homes over the next few years.

ORGANIZATIONS

WE ACT for Environmental Justice:
As a community based organization serving Northern Manhattan since 1988, WE ACT's mission is to build healthy communities by ensuring that people of color and/or low income residents participate meaningfully in the creation of sound and fair environmental health and protection policies and practices. Annie Carforo, Climate Justice Campaign Coordinator, managed the Out of Gas, In With Justice pilot. Jennifer Ventrella, Graduate Research Assistant, provided technical assistance. Sonal Jessel, Director of Policy, and Chris Dobens, Director of Communications, offered guidance and supervision over the pilot program. Yuwa Vosper, Policy and Regulatory Manager, laid the foundation for the project to begin. Charles Callaway, Director of Workforce Development, was an integral advisor in the RFP process. Alex Ogle, Digital Design and Communications Manager, designed and formatted the report.

Columbia Mailman School of Public Health:
The mission of the Environmental Health Sciences department at Columbia Mailman School of Public Health is to understand, prevent, and mitigate the impacts of environmental exposures and climate change on human health by leading cutting-edge research, training the next generation of public health professionals and partnering with impacted communities. Misbath Daouda, a PhD candidate in EHS, led the qualitative component of the OOG pilot and supported Berkeley Air with air monitoring activities and data analysis. Darby Jack, an Associate Professor in EHS, provided guidance and supervision. Róisín Commane and Steven Chillrud provided technical guidance and generously lent air monitoring equipment and laboratory space.

Berkeley Air Monitoring Group:
Berkeley Air Monitoring Group is a mission-driven social enterprise with 14 years of experience providing independent, solution-neutral field and laboratory assessments in the energy and air pollution sectors to a range of government agencies, partner implementers, and other funders. Berkeley Air specializes in evaluating the impact of household energy transitions and has completed over 60 studies looking at the air quality impacts of heating and cooking stove interventions. Ricardo Piedrahita, former Senior Research Associate, provided remote training, troubleshooting and technical assistance to the technical team. Heather Miller, Research Associate, provided continued technical support throughout data collection as well as data management and analysis. Michael Johnson, Technical Director, procured all equipment and technical supplies, oversaw all training and technical support, and provided guidance and supervision on all analysis.

RMI (founded as Rocky Mountain Institute):

RMI is tackling the climate crisis by focusing on its main contributor: energy production and use, which represents 70% of global greenhouse gas emissions. For buildings, RMI is working to end reliance on fossil fuels to power and construct our built environment, bringing buildings to the forefront of a clean energy future. RMI believes it is critically important to prioritize the delivery of holistic, climate-aligned retrofits and new construction to overburdened and underserved families and communities, including low-income and affordable housing, to ensure the health, environmental, and economic benefits of clean energy and climate solutions are equitably deployed. Yu Ann Tan (Senior Associate), and Brady Seals (Manager), on the Carbon-free Buildings team, provided co-benefits research and techno-economic and policy analysis.

Association for Energy Affordability:

Association for Energy Affordability is a technical service provider dedicated to energy efficiency in new and existing buildings with a focus on low income housing. AEA representatives engage in a broad range of educational, technical and construction management activities and services to promote this mission and develop the industry that advances and sustains it. Michelle Feliciano, Construction Manager, led participant recruitment and managed working relationships with participants. Francis Rodriguez, Director of Weatherization, supervised building modifications and stove installations.

New York City Housing Authority:

The New York City Housing Authority (NYCHA), North America's largest public housing authority, was created in 1935 to provide decent, affordable housing for low- and moderate-income New Yorkers. NYCHA is home to roughly 1 in 16 New Yorkers across over 177,000 apartments within 335 housing developments. NYCHA connects residents to opportunities in financial empowerment, business development, career advancement, and educational programs. With a housing stock that spans all five boroughs, NYCHA is a city within a city. Supporting the efforts of WE ACT and the other participating organizations were NYCHA's Vlada Kenniff, PhD., A&CM Senior Vice President for Sustainability, Edwin Mendez, A&CM Deputy Director of Energy Programs, Keanna Julien, Program Associate for A&CM SUS Energy Programs, and Joseph Glynn, Field Inspector for A&CM Capital Programs – Project Management Operations.

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We would like to thank Daphany Sanchez of Kinetic Communities and Mike Henchen of RMI for their expert advice. And we would like to thank Rahwa Ghirmatzion, former Executive Director of PUSH Buffalo, who conceived of this pilot idea in partnership with Cecil Corbin-Mark and helped guide the vision into the present.

Dedication
We dedicate this report to the late Cecil Corbin-Mark, former Deputy Director and Director of Policy Initiatives at WE ACT for Environmental Justice. He spent his life fighting for environmental and climate justice, and was the driving force behind numerous legislative wins in New York City and New York State. He conceived the idea for this pilot shortly before he passed away on October 15, 2020. His work lives on.

ANNEX A – ADDITIONAL METHODS

Air quality sampling

The Home Health Box also measures NO2, CO, CO2, and PM2.5 in real time. The real-time PM2.5 sensor (plantower) response was normalized to each corresponding gravimetric sample. The units' NO2 and CO electrochemical sensors were factory calibrated and checked with calibration gas at the University of Columbia's Lamont-Doherty Earth Observatory Laboratory. The NO2 response was further assessed in comparison to a set of 11 integrated samples from the Ogawa Badges, which were analyzed at RTI international using the standard colormetric methods (Ogawa USA, 2006). A scatterplot showing the comparison of the Home Health Box NO2 samples versus the Ogawa badges is shown below, indicating a strong correlation.

Data Analysis

Data for the instruments were downloaded between each sample, and were checked for completeness, duration, and visually inspected for artifacts (e.g. baseline shifts). Data were analyzed using R (versions 3.6 and 4.2; R Foundation for Statistical Computing). Variables were summarized by intervention and control groups using means, medians, ranges, and standard deviations; and were analyzed for statistically significant differences between groups using a Wilcoxon signed-rank test. A p-value <0.05 was the threshold for reporting statistically significant differences between estimates.

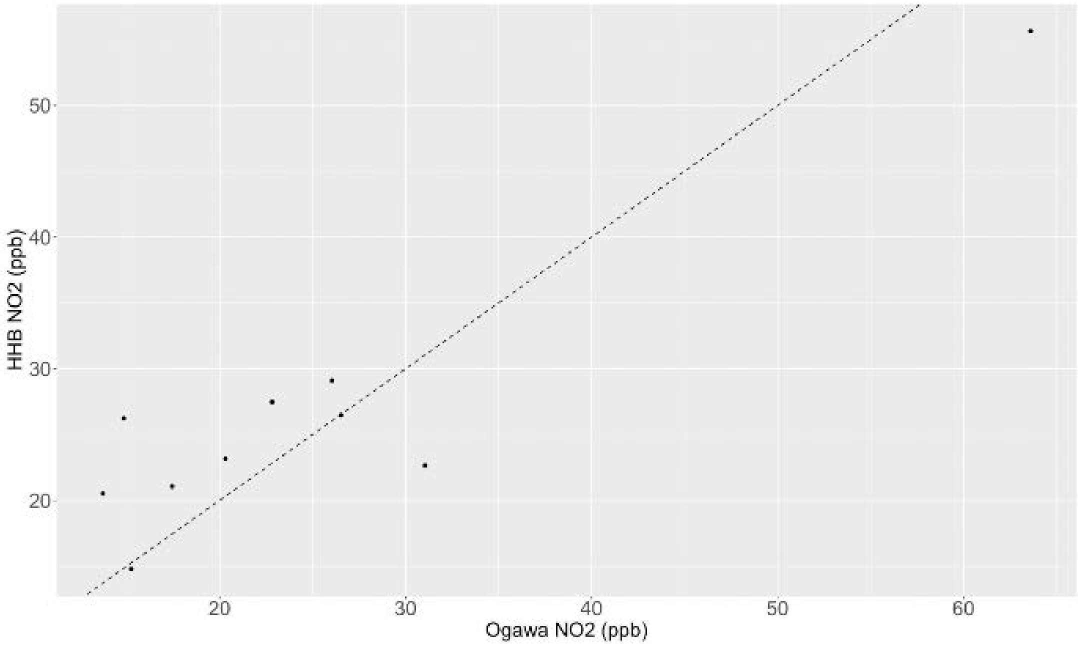

Figure A1. *Relationship between the Home Health Box and Ogawa Badge NO2 measurements*

ANNEX B – ADDITIONAL RESULTS

Air quality data analysis

In addition to summary statistics, we conducted multiple linear regression modeling to evaluate the interventions impact on NO2 concentrations results. We first log transformed NO2 concentrations to account for their skewed distribution. We then conducted two types of analyses.

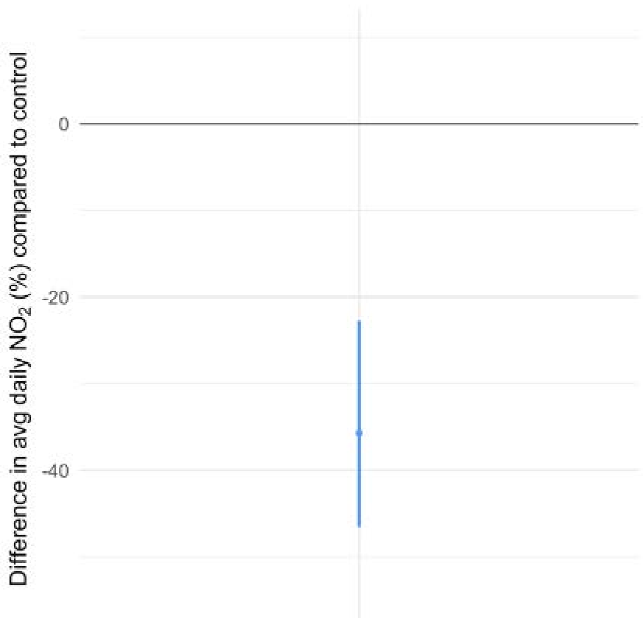

Figure B1. *Effect of the induction stove intervention on daily average NO2 exposure in a 24-hour period. Post intervention NO2 levels were 35.7% lower (indicated with the dot) in kitchens with induction stoves compared to those with the gas stoves after adjusting for outdoor temperature, apartment level, and street orientation. 95% confidence intervals were -46.5 to -22.7% (indicated with the error bars).*

CO Analysis Model

During initial stages of data collection it was noticed that the data was becoming truncated. After investigation it was discovered that the batch of CO sensors installed in the HHB had an upper limit of 10 ppm. As there was a potential that levels could rise above 10 ppm Lascar CO monitors (EasyLog EL-USB-CO) were ordered and deployed in conjunction with the HHB.

Further issues arose when it was discovered that the wrong LascarCO monitors were ordered and that the lower limit of these were at 10 ppm. Due to this confusion, it was initially thought that the Lascar CO monitors were malfunctioning and so not every HHB run was partnered with a Lascar CO monitor. At the end of the study, there were a total of 10 HHB files with matching Lascar CO files.

For the 10 HHB files with matching Lascar CO files the HHB data was replaced if the HHB read a value greater than 7.5 ppm and the Lascar CO data reading was greater than the HHB reading during the same time period. Summary statistics were then calculated for the files and it was determined that the best predictors of household average CO ppm was the 25th percentile and the % time spent over 7.5 ppm for each file.

The following model, where x is the 25th percentile and p is the percent of time spent over 7.5 ppm in each file, was applied to all files and the outcomes were used to report the daily average household CO ppm concentration.

$$\text{Adjusted Household Avg CO} = 0.184x + 0.2713p + 0.6565$$

ANNEX C – COST ANALYSIS

Table C1 summarizes the efficiency and cost values used for natural gas and electric induction used in the cost analysis.

Table C1. Efficiency and cost values for natural gas and electric induction

Measures		Natural Gas	Electric Induction**
Efficiency (%)		0.4	0.5
Cost*	Supply ($,therm)	0.74	2.75
	Delivery ($, therm)	0.04	4.0
	System Benefit Charge ($, therm)	-	0.15
	Delivery min/Service Charge ($, therm)	17.56	18.47

**Costs were averaged across the study period months (February-July 2022) using National Grid (gas) and Con Edison (electric) utility bills. Analysis reported did not include tax and surcharge fees. When calculated, analysis that included tax and surcharge fees found an even higher cost for gas utilities.*
***All costs for electric stoves were converted to $/therm using the conversion factor 1 kWh = 0.034 therms for the purpose of comparison*

Assumptions

Assuming residential non-heating (apartment not paying for heat) (Service Class 1A)

Customer uses National Grid for their gas service

Stove Usage

Induction stoves: Number of hours of cooking per day calculated via electric current loggers used in OOG study

Gas stoves: Extrapolated electric current data to gas usage through known efficiency values, corroborated with per unit usage data from a previous report [79]

COST EQUATIONS

Gas stove

$$utility\ cost_{nat\ gas} = x(cost_{supply} + cost_{delivery\ rate\ adj}) + cost_{delivery\ min}$$

- $cost_{supply}$ = supply charge ($/therm)
- $cost_{delivery\ min}$ = delivery minimum ($)
- $cost_{delivery\ rate\ adj}$ = delivery rate adjustment ($/therm)
- x = energy use (therms)

Electric Induction

$$utility\ cost_{electric} = x(cost_{supply} + cost_{delivery} + cost_{sys\ benefit}) + cost_{basic\ service}$$

- $cost_{supply}$ = supply charge ($/kWh)
- $cost_{delivery}$ = delivery charge ($/kWh)
- $cost_{sys\ benefit}$ = system benefit charge ($/kWh)
- $cost_{basic\ service}$ = basic service charge ($)
- x = energy use (kWh)

FOOTNOTES

1 *The Impact of Fossil Fuels in Buildings: A Fact Base,* Rocky Mountain Institute, 2019, www.rmi.org/insight/the-impact-of-fossil-fuels-in-buildings/.

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