



# Burning Fossil Fuels: Impacts on Air Quality & Health

Brady Seals, RMI  
June 12, 2024



**Transforming the global energy system to secure a clean, prosperous, zero-carbon future for all.**





# AGENDA

1. Impacts: climate and health
2. Solutions and strategies:  
individual & policy
3. Identifying gaps
4. Moving forward





# 1. Impacts

# Overlooked Source of Climate Pollution

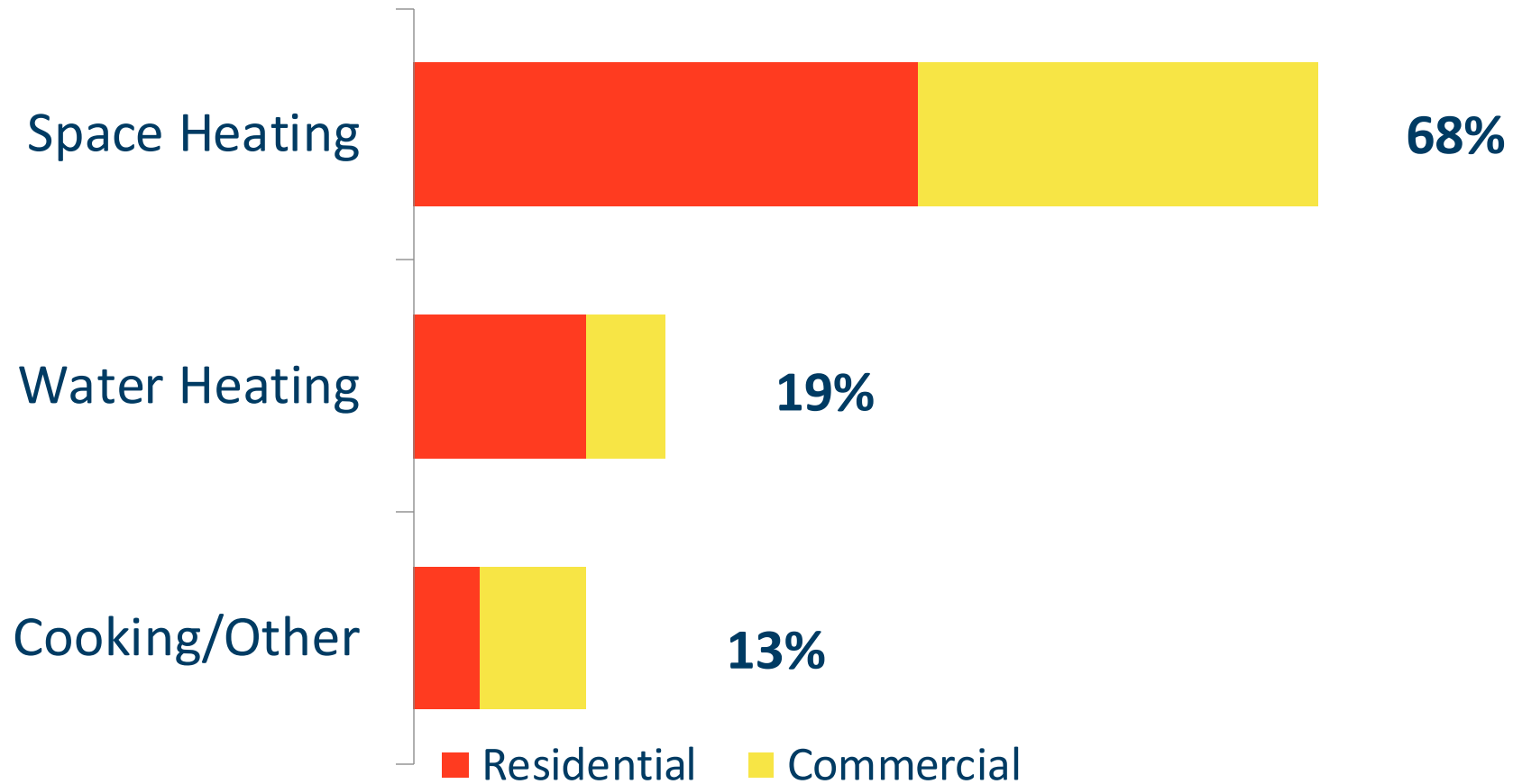


Burning fossil fuels in buildings  
is responsible for

**10%** of US greenhouse gas  
emissions.

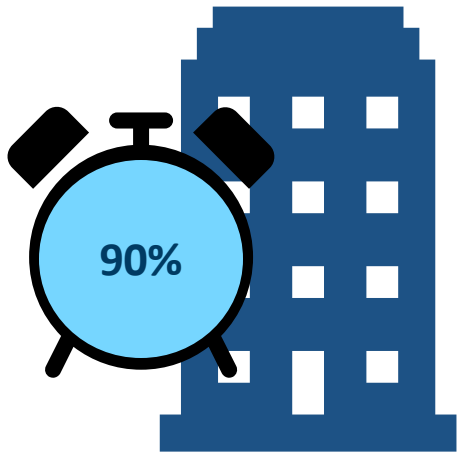
# 70 Million US Homes and Businesses Burn Fossil Fuels

## Direct buildings GHG emissions by end use and sector

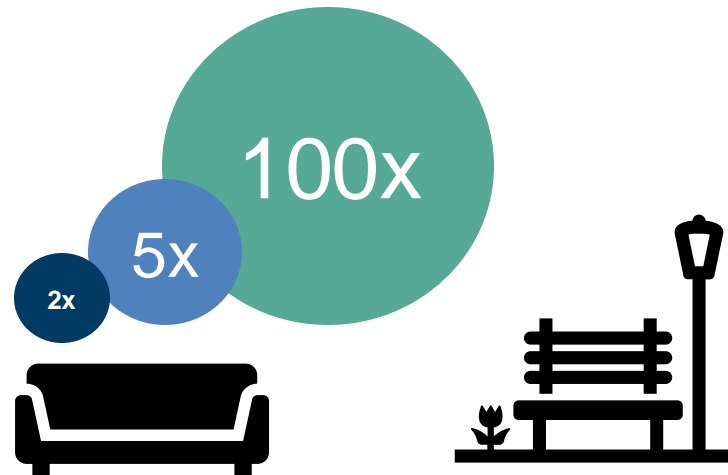


# Indoor Air Quality is Often Worse than Outdoor

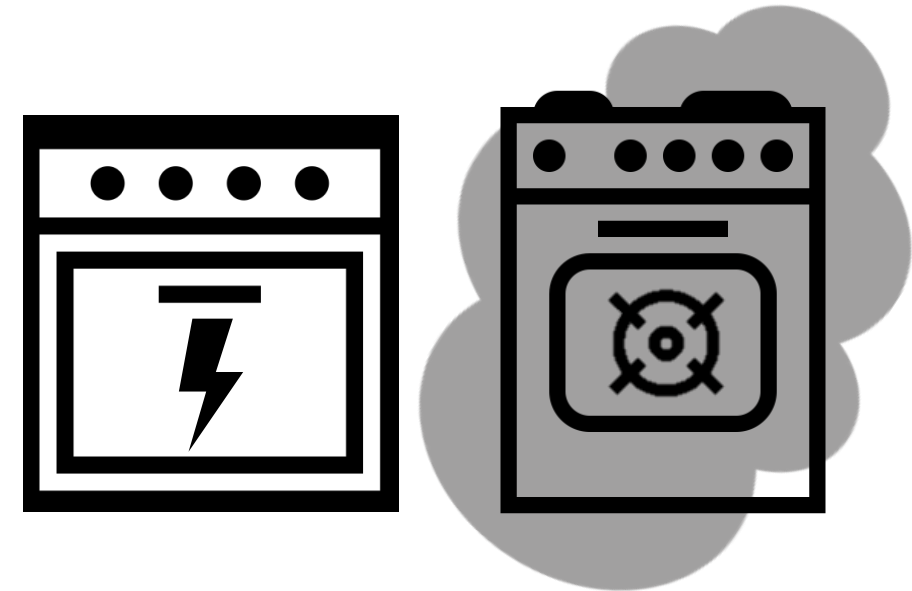
We spend up to **90%** of our time indoors



EPA states indoor pollutant levels may be **2 to 5** and as much as **100 times** higher indoors than outdoors



Homes with gas stoves have **50 - 400%** higher NO<sub>2</sub> emissions than homes with electric stoves



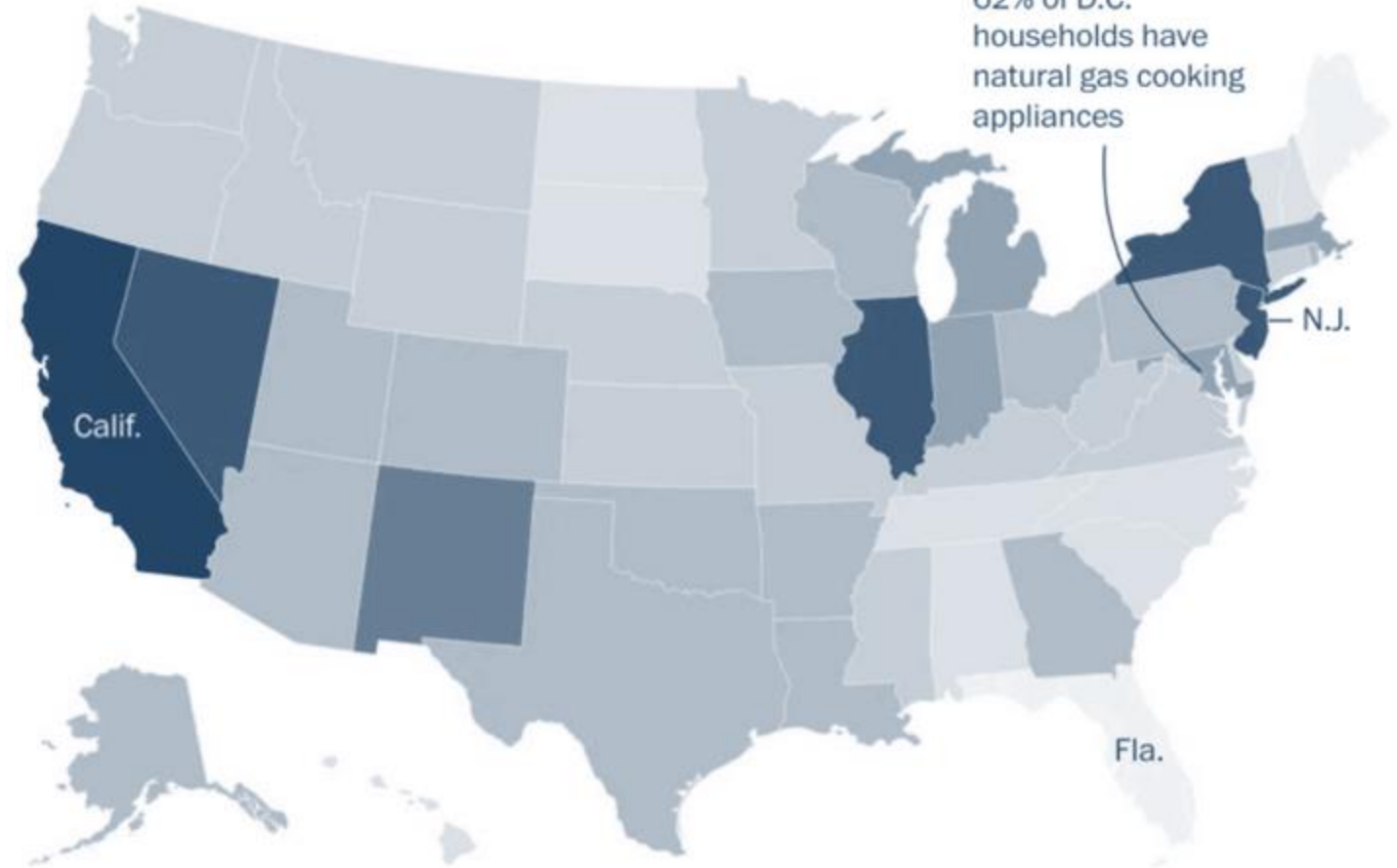
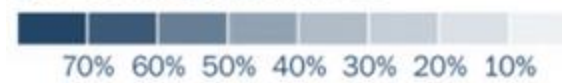
# Gas Stove Use Varies by State

National average: 38%

California: 70%

Florida: 8%

Share of households with natural gas cooking appliances



Note: Outdoor grills were not counted in the survey.

Source: 2020 Residential Energy Consumption Survey

JOHN MUYSKENS / THE WASHINGTON POST



# Gas Stoves are an Overlooked Health Concern



Release similar pollutants  
as cars



50+ years of health studies  
showing the risk of cooking  
with gas



Not universally required to  
be vented outside



Lower-income households  
likely at higher risk



42% increased risk of asthma  
symptoms for children in homes  
with gas stoves



Similar to the asthma risk of  
kids living with a smoker



## 2. Solutions

# Going Electric in the Kitchen Helps



Eliminates combustion pollutants (NO<sub>2</sub>, CO, etc.)



Eliminates benzene leak risk



Pair with ventilation outdoors for cooking



Safer and saves energy



Other co-benefits (ease of cleaning)



Stoves being developed with 120v & batteries

# What if You Can't Change Your Gas Stove?



Use other electric appliances like toaster oven or kettle.



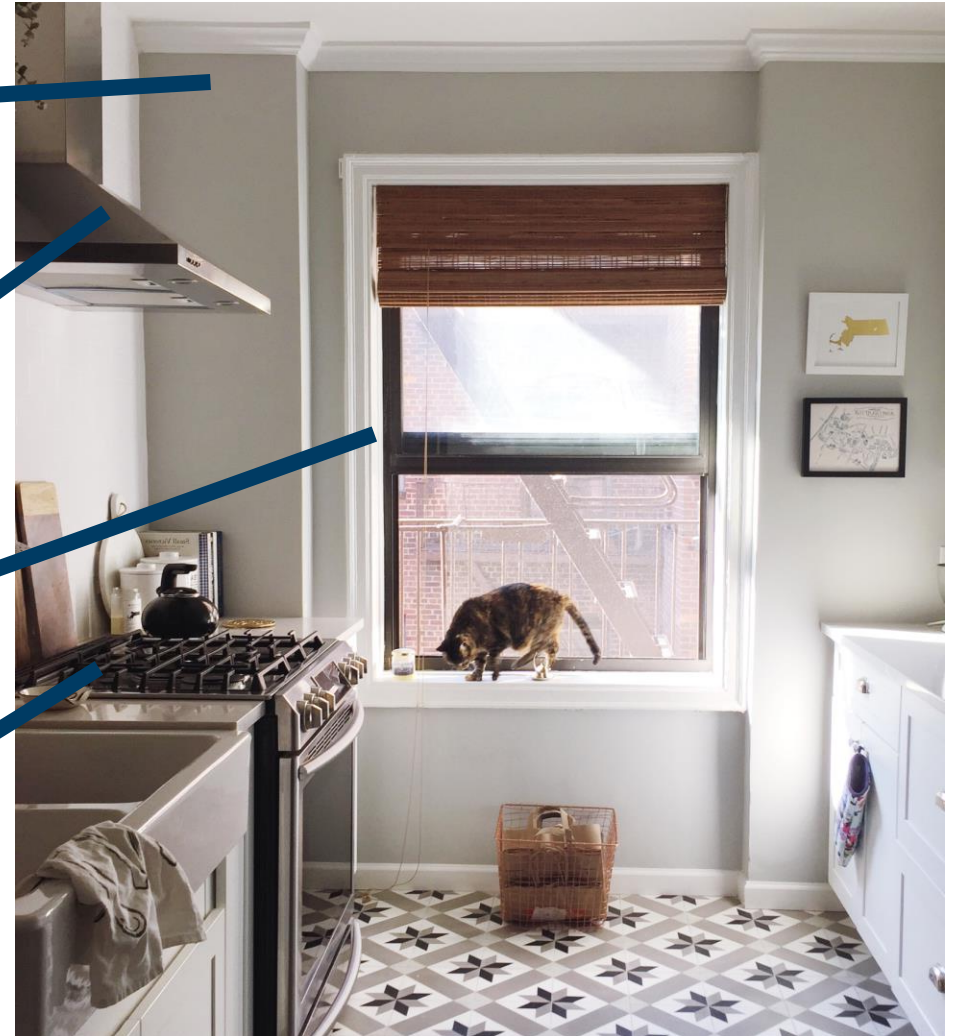
Try a plug-in induction stove (\$60)

Install & maintain a CO detector

If available, run your exhaust hood while cooking

Open a window while cooking

Cook on the back burners



# 1 in 10 People in the U.S. live in a city or county with a building electrification policy

**141** U.S. Jurisdictions

**6** Statewide Policies

**12** States with Local Government Action







## 3. Gaps

# Some common challenges



Cost (existing buildings)



Electricity supply & grid "greenness"

- Ability to leapfrog to cleanest cooking & heating fuels



Industry pushback



Extreme weather & climate disruptions



Low awareness across "supply chain" (e.g. contractor training)



Competing priorities



# 4. Moving forward

# How Do We Get Healthy Electric Buildings?

## Codes & Standards

- IAQ protections
- Ventilation
- All-electric baselines
- Policies: new construction, retrofits
- Appliance regulations

## Incentives & Financing

- Lower upfront costs
- Affordable: low interest
- Accessible: low credit scores, capital to cover upfront costs
- Target contractors & builders
- IRA

## Educational Campaigns

- Health & consumer voices
- Warning labels
- Research to action partnerships



# Thank you!

Contact [bseals@rmi.org](mailto:bseals@rmi.org) with any questions



# The Benefit to Children of Decarbonizing on a National Scale: We are Investing in Our (Their) Future

Kevin Kennedy



Healthy Indoors Consulting, Lawrence, Kansas

1

## The impact of home environments is greater on children

Jeremy just wants to grow up  
and be a contributing part of  
his community



Children's Environmental Health, CDC.gov



Jeremy's long-term  
well-being is directly  
impacted by the home  
he grows up in



Healthy Indoors Consulting, Lawrence, Kansas

<https://www.pexels.com/creative-commons-images/> Pexel photos are free for use

2

# Little Jeremy ≠ Big Jeremy: The impact is Greater on Children

Per pound of body weight, children:

- Eat more food
- Have a higher metabolism
- Drink more liquid
- Breathe more air
- Have higher respiration rate



≠



Children more susceptible to exposure:

- Natural defenses are less developed
- crawl and play close to the ground- different breathing zone
- More likely to put their hands in their mouths – a lot
- Have more years of life to develop disease than adults

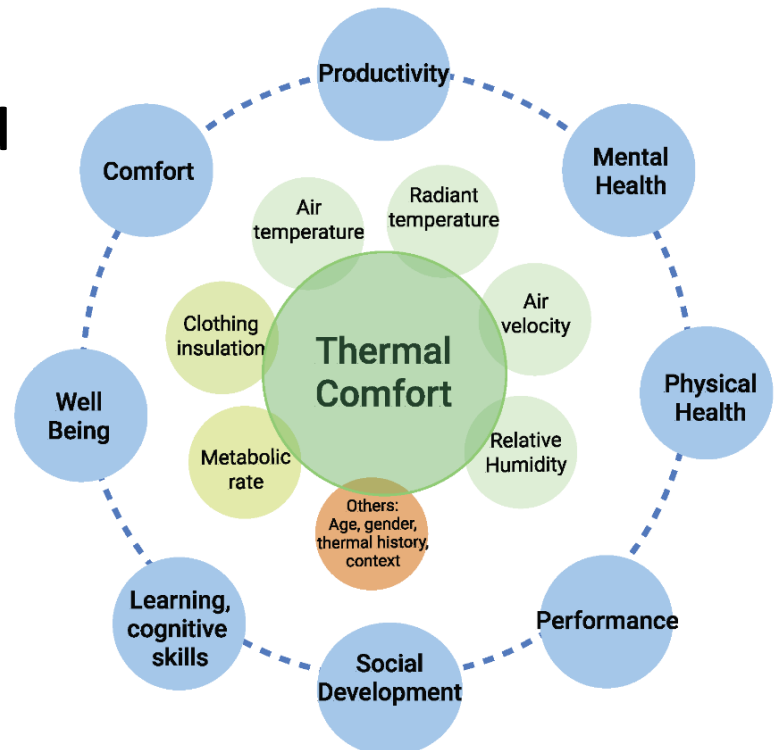
Children's Environmental Health, CDC.gov



Healthy Indoors Consulting, Lawrence, Kansas

<https://www.pexels.com/creative-commons-images/> Pexel photos are free for use

**Jeremy's comfort in his home is more complicated involving a large interaction of a combination of factors**

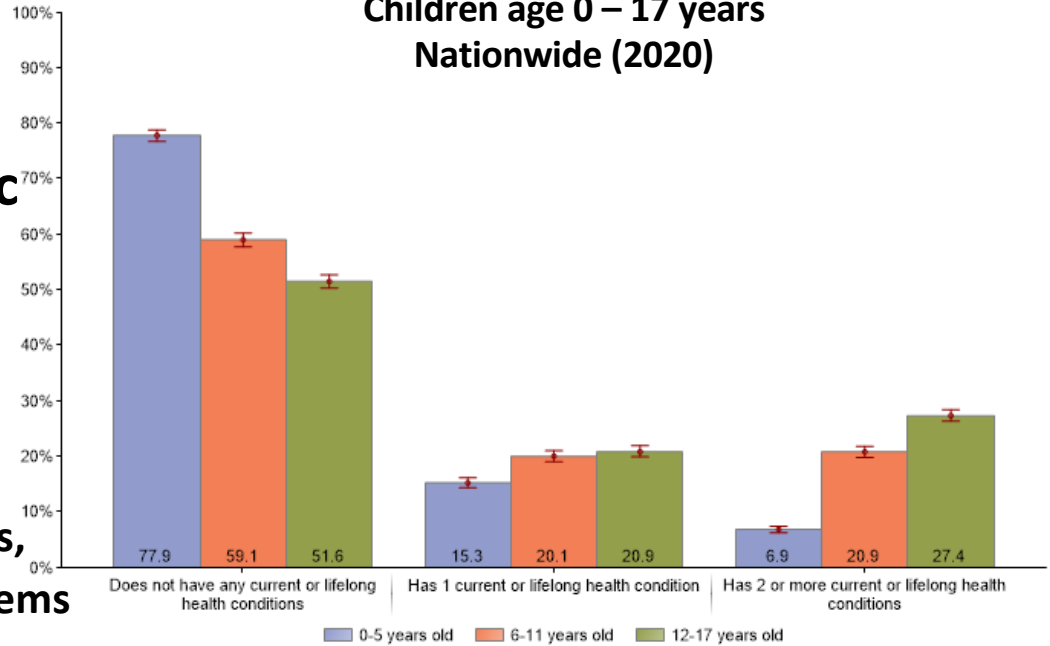


Lala, Betty and Aya Hagishima, A Review of Thermal Comfort in Primary Schools and Future Challenges in Machine Learning Based Prediction for Children, Buildings 2022, 12(11), <https://doi.org/10.3390/buildings12112007>

A model representing the factors affecting the thermal comfort of children

**~40% of school-aged children and adolescents have at least one chronic health condition**

**Number of current or lifelong health conditions  
Children age 0 – 17 years  
Nationwide (2020)**



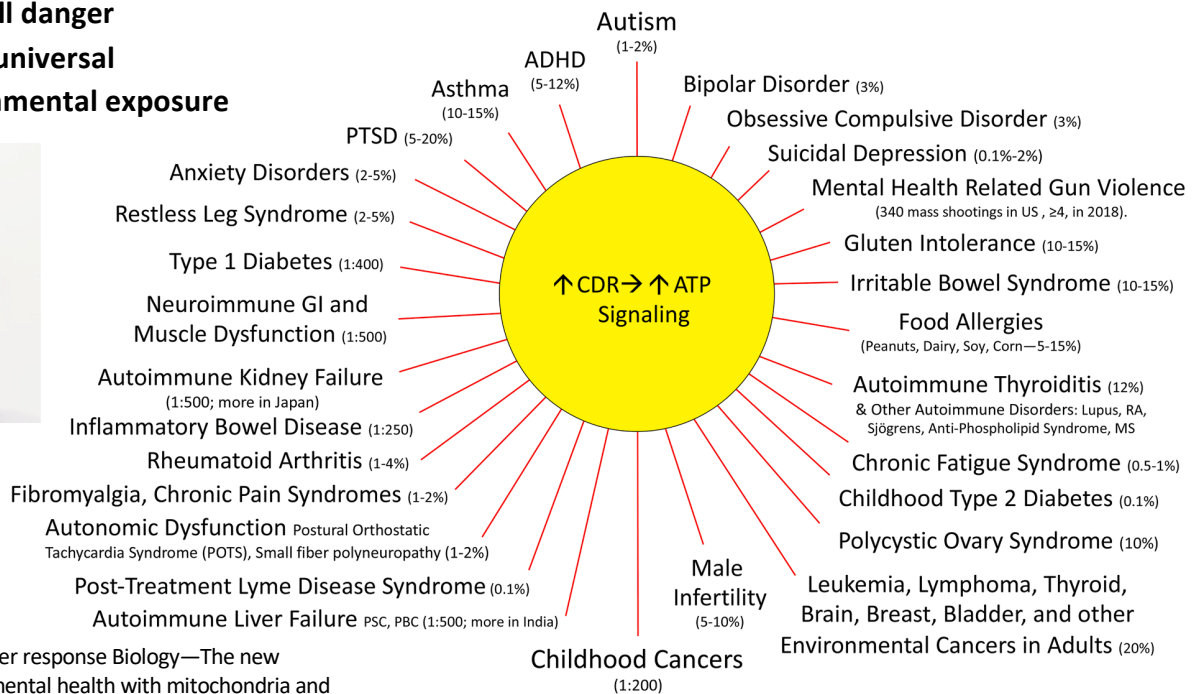
**Asthma  
Obesity  
Diabetes  
other physical conditions,  
behavior/learning problems**

Child and Adolescent Health Measurement Initiative. 2020-2021 National Survey of Children’s Health (NSCH) data query. Data Resource Center for Child and Adolescent Health supported by the U.S. Department of Health and Human Services, Health Resources and Services Administration (HRSA), Maternal and Child Health Bureau (MCHB). Retrieved [06/08/24] from [www.childhealthdata.org].



**Chronic Health Disorders that have Increased 2-100 times since the 1980s**

**A description of “cell danger response” (CDR), a universal response to environmental exposure**



Naviaux, Perspective, Cell danger response Biology—The new science that connects environmental health with mitochondria and the rising tide of chronic illness, Mitochondrion, 51 (2020) 40–45

# Potential Health Effects of Combustion Pollutants on Jeremy

- Carbon monoxide (CO)
- Nitrogen oxides (NOx),
- Particulate matter (PM),
- Air toxics- (ammonia, formaldehyde, polycyclic aromatic hydrocarbons (PAHs), and volatile organic compounds (VOCs)

The Health Impact of Combustion in Homes. American Lung Assoc. 2023



**If Jeremy's family is low-income, the impact is even greater**

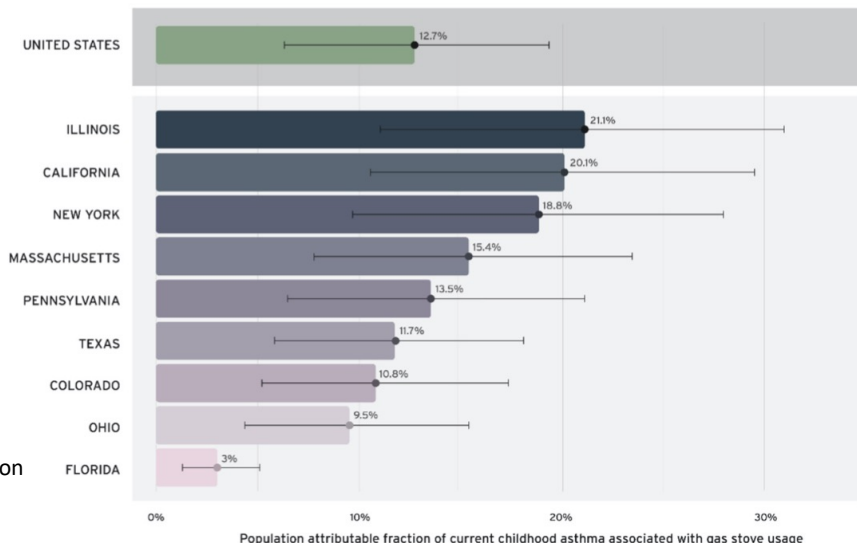
- CO- Poisonous gas and cardiovascular risk
- NOx- make children sick, especially those with asthma and allergies. It worsens asthma symptoms and wheeze and may also increase lower respiratory tract infections and reduce lung function
- PM- irritation to eyes, nose and throat, and respiratory effects in children. Also asthma, cancer, autoimmune conditions
- Air toxics- can cause cancer, birth defects and other serious health harms

Healthy Indoors Consulting, Lawrence, Kansas

# Natural gas and gas stoves – What we know

- Combustion byproducts have always been hazardous
- The unburned methane entering homes contains many hazardous chemicals
- Gas stove use associated with increased risk of asthma in children

Gruenwald, T.; Seals, B.A.; Knibbs, L.D.; Hosgood, H.D., III Population Attributable Fraction of Gas Stoves and Childhood Asthma in the United States. Int. J. Environ. Res. Public Health 2023, 20, 75.



# Preliminary Assessment of health impacts of indoor air contaminants using Daily Adjusted Life Years (DALY) Metric

DALY: Disability Adjusted Life Year:

-Sum of years of life lost and time lived with a disability attributable to a cause

-One DALY represents the loss of the equivalent of one year of full health

Est. value about \$700,000 by EPA and HHS

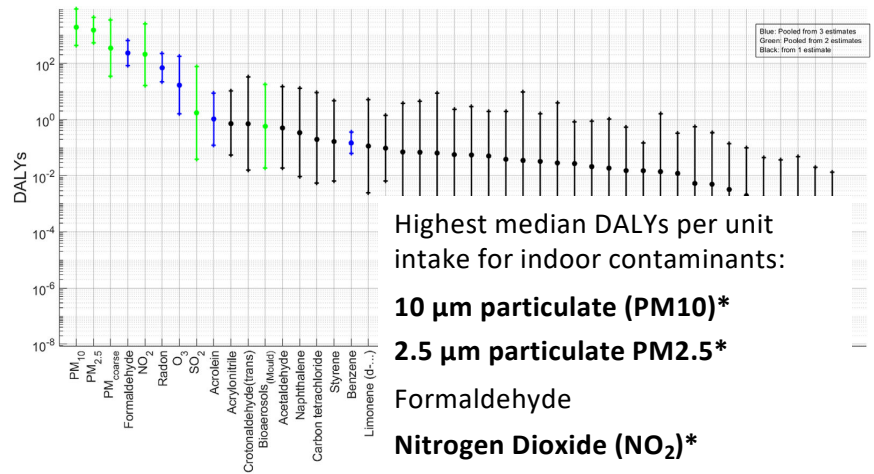


Figure 3. Pooled DALYs. Highest to lowest median. Contaminants listed from highest to lowest median DALYs: PM<sub>10</sub>, PM<sub>2.5</sub>, PM<sub>coarse</sub>, Formaldehyde, NO<sub>2</sub>, Radon, O<sub>3</sub>, SO<sub>2</sub>, Acrolein, Acrylonitrile, Crotonaldehyde(trans), Benzocyclopentadiene, Acetaldehyde, Naphthalene, Carbon tetrachloride, Styrene, Benzene, and Limonene (d-...).

Highest median DALYs per unit intake for indoor contaminants:

**10 μm particulate (PM<sub>10</sub>)\***

**2.5 μm particulate PM<sub>2.5</sub>\***

Formaldehyde

**Nitrogen Dioxide (NO<sub>2</sub>)\***

Radon

Ozone (O<sub>3</sub>)

**Sulfur Dioxide (SO<sub>2</sub>)\***

**Acrolein\***

**\*Generated through combustion**

Gioberti Morantes, Benjamin Jones, Max Sherman & Constanza Molina (2023) A preliminary assessment of the health impacts of indoor air contaminants determined using the DALY metric, International Journal of Ventilation, 22:4, 307-316, DOI: [10.1080/14733315.2023.2198800](https://doi.org/10.1080/14733315.2023.2198800)

## Jeremy Accumulates Risk

Lives in poverty

Mom works 2 jobs

Lead paint in his bedroom

Highway runs through neighborhood

Home has roaches

Does not have access to fresh produce

Squalid neighborhood

Nearest park is 5 miles away



<https://www.pexels.com/creative-commons-images/>  
Pexel photos are free for use

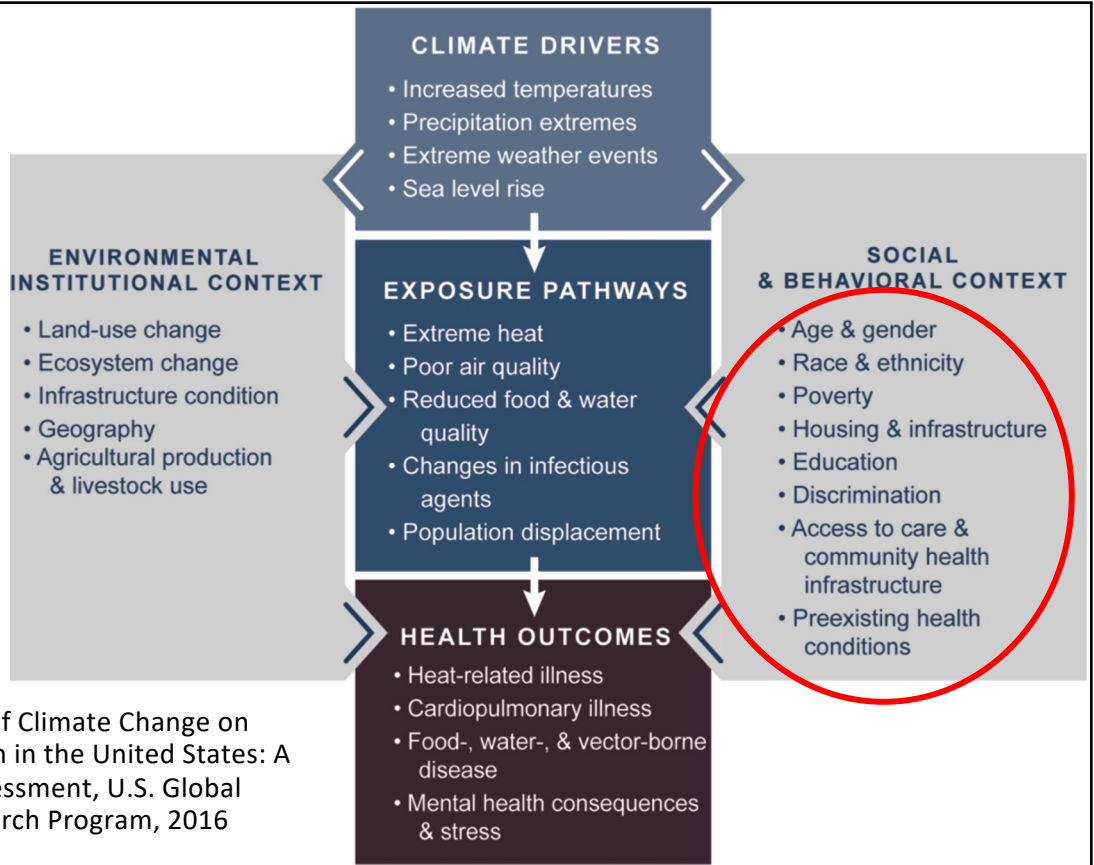
Children's Environmental Health Tracking:  
<https://ephracking.cdc.gov/showChildEHMain.action>

Child Opportunity Index:  
<https://www.diversitydatakids.org/maps/>





**Climate change planning shows the long-term impacts will disproportionately impact low-income people, communities of color, and especially children of these populations and seniors with limited resources**



The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment, U.S. Global Change Research Program, 2016



**The conversion to a decarbonized economy will provide immense benefits to the millions of children like Jeremy**

Less exposure should lead to fewer children:

- born preterm or with low birth weight
- with cognitive and behavioral disorders
- with mental-health problems
- with risk of asthma and other respiratory illness
- with long-term risk of cardiovascular disease
- with risk of developing cancer



Our focus should be making the future better for Jeremy

***These health benefits translate into improving children's ability to learn and contribute productively to society***

Frederica Perera, Pollution from Fossil-Fuel Combustion is the Leading Environmental Threat to Global Pediatric Health and Equity: Solutions Exist, Int. J. Environ. Res. Public Health 2018, 15, 16; doi:10.3390/ijerph15010016

# We need access to LARGE historic health data sets to effectively evaluate health outcomes. We've started one in Kansas City

Large historic records data base (2000-2019) combining community data and pediatric health system and public health dept. data from a large metropolitan area (Kansas City)



Images from KC Health CORE Research



Geodatabase is part of community info. system to study health disparities

Maps from KC Health CORE (KC Health Community-Organized Resource Exchange) files

Children's Mercy Kansas City, Environmental Health; Center for Economic Information, UMKC; Kansas City, Missouri Dept. of Public Health



## at the ADDRESS LEVEL:

Asthma acute care visits –

~300,000+ records

Lead testing data –

~400,000+ records

Injury events –

~1,000,000+ records

With 230,000 Neighborhood Housing Conditions Surveys

# Impact of a Weatherization Program on Asthma Outcomes in Children- A Quasi-Experimental Study

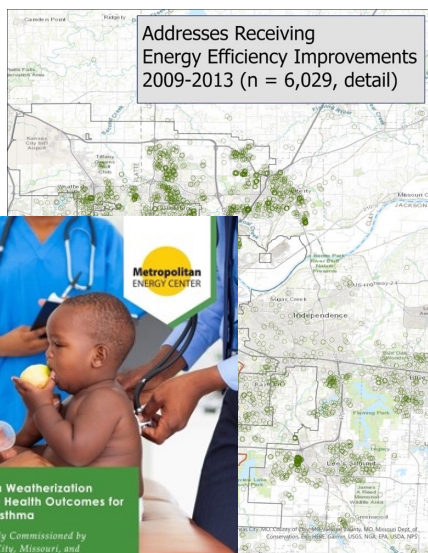
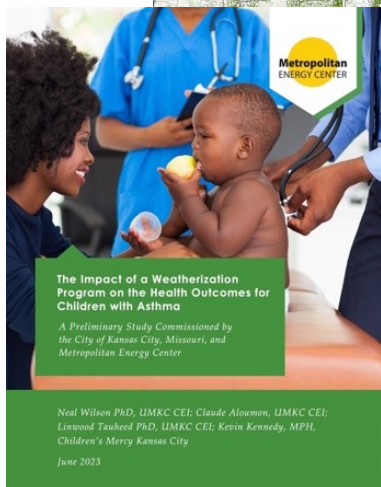


Table 6: Weatherization Improvements for all program participants and for those homes with asthmatic children as residents

Improvements	MEC Address	Asthma Encounters at MEC Address
AIR SEALING; INSULATION	2,270	101
AIR SEALING (only)	1,315	77
INSULATION (only)	1,179	37
AIR SEALING; INSULATION; WINDOW(s)	185	13
WINDOW(s) (only)	477	8
AIR SEALING; WINDOW(s)	92	7
AIR SEALING; INSULATION; DUCT SEALING	58	3
DUCT SEALING (only)	91	3
INSULATION; WINDOW(s)	56	3
AIR SEALING; DUCT SEALING	43	1
AIR SEALING; INSULATION; DOOR(s)	19	1



# Impact of a Weatherization Program on Asthma Outcomes in Children- A Quasi-Experimental Study

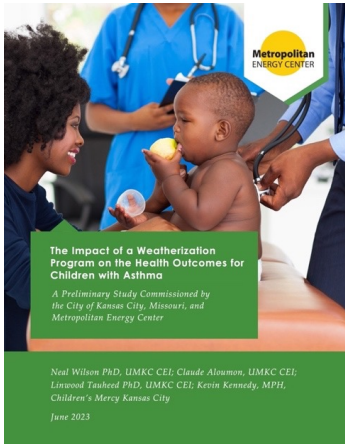


Table 13: Associations between Weatherization and Severe Asthma Encounters (1)

	Model 1		Model 2	
	IRR	95% CI	IRR	95% CI
Weatherization	.66	.53 - .82	.66	.53 - .83
Kansas City			1.05	1.01 – 1.09

Models 1 & 2: Observations = 17,002. IRR: Incident Rate Ratio. CI: Confidence Interval

The estimated effect of weatherization (model 1) shows the incident rate ratio (IRR) associated with weatherization is 0.66. This means that there were 34% fewer acute care visits for a child in a weatherized home (other things held constant) per year than those who lived in un-weatherized homes.

In this model a confidence interval  $\leq 1$  is significant and indicates that weatherization activity is strongly associated with a significant drop in the rate of pediatric asthma acute care visits. A confidence interval  $\geq 1$  implies no statistical difference.

Impact of a Weatherization Program on the Health Outcomes for Children with Asthma, A Preliminary Study Commissioned by the City of Kansas City, Missouri, and Metropolitan Energy Center, 2023

## Questions

Kevin Kennedy

[kkennedy740@gmail.com](mailto:kkennedy740@gmail.com)

<https://www.healthyindoorstraining.com/>



# Non-Energy Impacts with Electrification

Paul Francisco

Director, Indoor Climate Research & Training, CC Regional Planning Commission

Sr. Research Associate, Energy Institute, Colorado State University



# Non-Energy Impacts (NEIs)

- Any impact from a measure we do related to energy that is not the energy impact
- We are often now thinking of a couple of NEIs
  - Indoor Air Quality-related health
  - GHG reductions





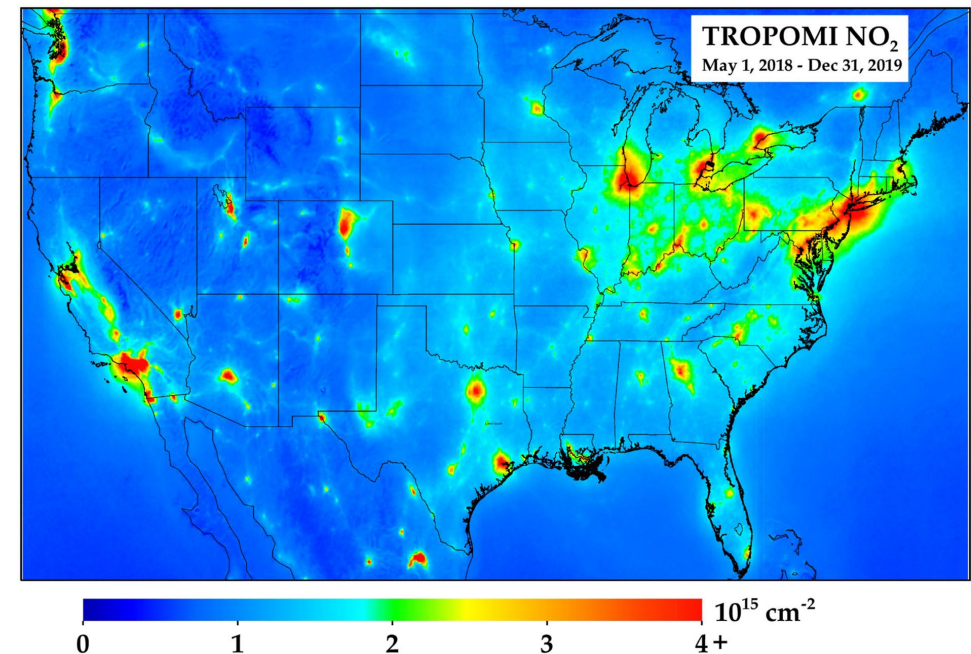
# Non-Energy Impacts (NEIs)

- There are many others
  - Jobs
  - Indoor Environmental Quality
  - Nutrition
  - Mental Health
  - Other health-related topics
  - **Comfort**
  - **Costs**
  - **Stability**
  - **Earning Potential**
  - **Resiliency**
  - **Home values**

**Not all impacts  
may be benefits!!**

# Electrification in homes

- Focus tends to be on replacing gas appliances with electric
- Also consideration of outdoor air



Goldberg et al *Earth's Future* (2021)

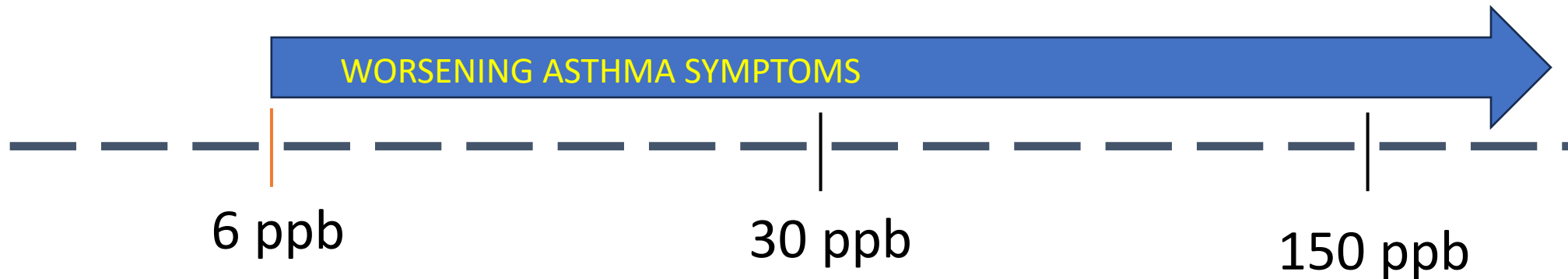
# Residential gas appliances

- Furnaces and water heaters (vented)
- Cooking (unvented)
- Unvented space heaters



# Key Contaminant of Interest

- Every 5-fold increase in NO<sub>2</sub> exposure above a threshold of 6 ppb was associated with an increase in risk of higher children's asthma severity score, wheeze, night symptoms, & rescue medicine use (Belanger et. al, 2013)



# Furnaces and water heaters

- Vented, so nominally do not contribute (much) to indoor levels
- If there is a problem, can be corrected with maintenance/repair





# Ranges

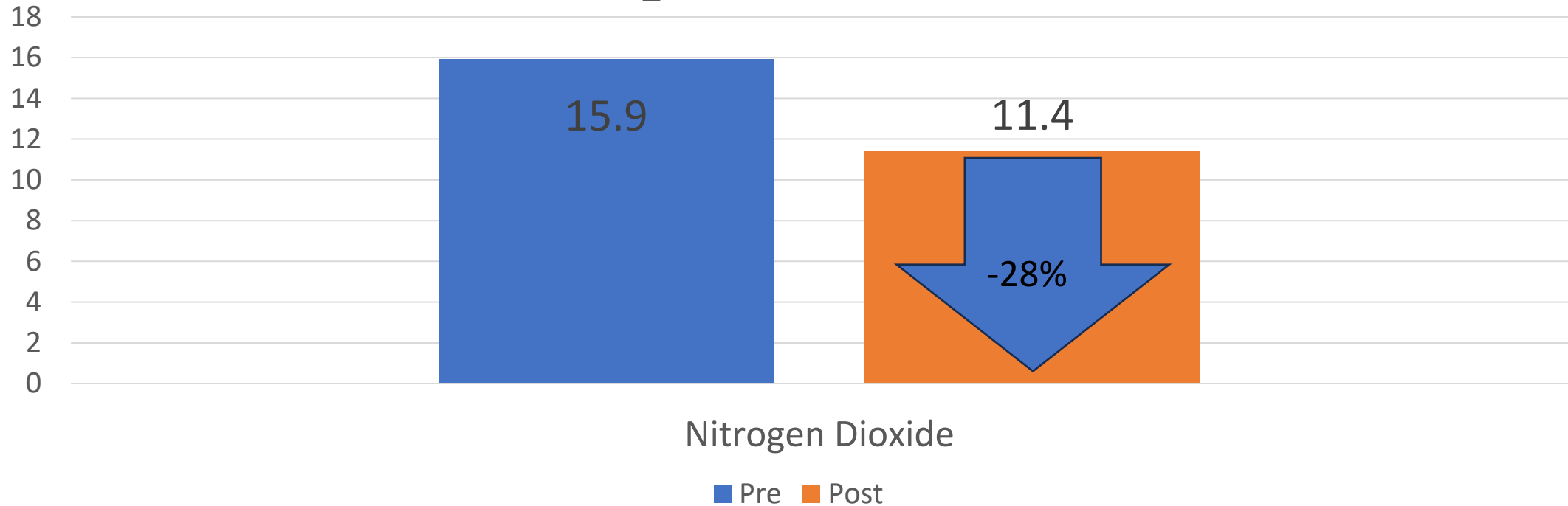
- Not vented
- Range hood fans can remove contaminants
  - People have to use them
  - They have to be vented to outside
  - They have to have good capture efficiency



# Range hood project (HUD-funded)

## Change in NO<sub>2</sub> with continuous range hood

Average ppb over sampling period



# Range hoods

- Can address much of cooking contaminants
- Many hoods are recirculating
- Many retrofit homes do not have practical way to install

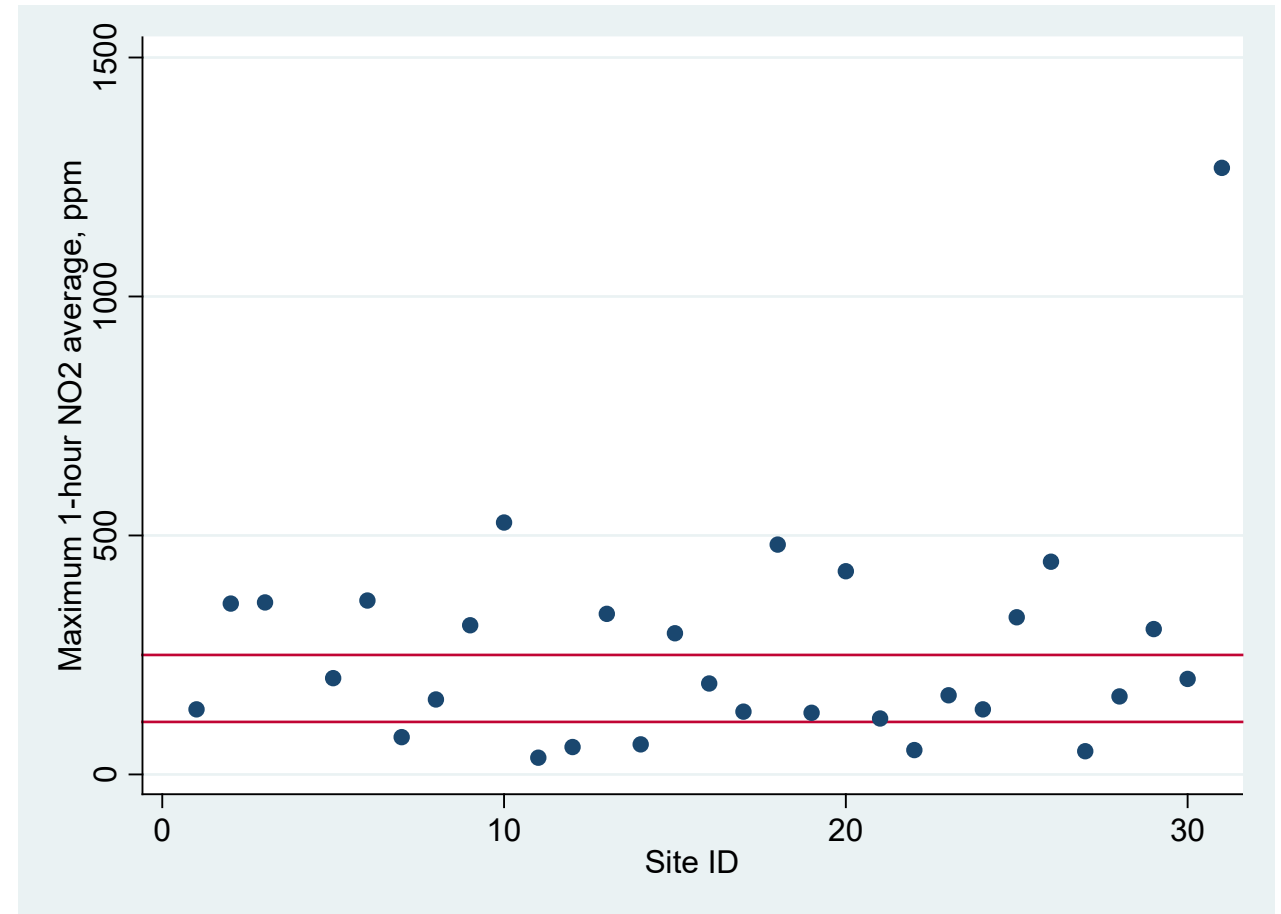
# Unvented space heaters

- Nominally only used as “supplemental” heat
- Many homes have them as primary/only heat
  - Especially in moderate climates



# Unvented space heaters (HUD-funded) - NO<sub>2</sub>

80% had a one-hour average  
NO<sub>2</sub> level of greater than 100 ppb





# Unvented space heaters

- For homes where they are only heat source, perfect opportunity for ductless minisplit heat pumps



Source: U.S. DOE

# Costs as NEI?

- For heating, often hard to reduce costs compared to natural gas furnaces
  - Especially if the heat pump is installed on bad ducts or the control strategy compromises the compressor efficiency
- Economics are much better compared to propane or oil
  - Great target for electrification projects!

# Thank you!

- For additional follow-up, contact me at:

- [paul.francisco@colostate.edu](mailto:paul.francisco@colostate.edu)

or

- [pfrancisco@ccrpc.org](mailto:pfrancisco@ccrpc.org)