Evaluating household energy transition in communities and its impacts on air quality and health

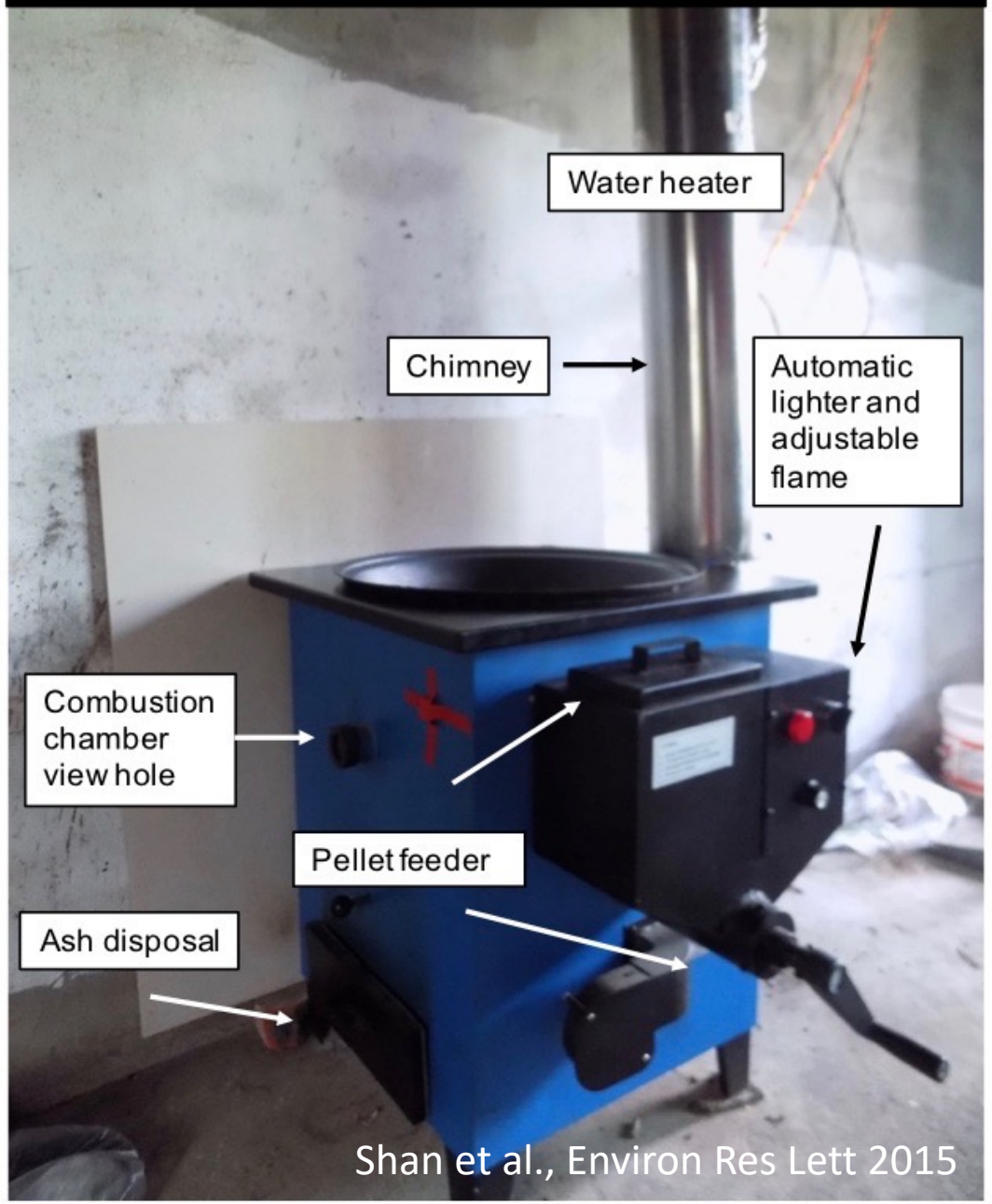
EPA STAR study: Improving air quality, health and environment through household energy interventions in the Tibetan Plateau

Jill Baumgartner, McGill University

ASHES Seminar

May 20, 2021

Semi-gasifier stove features



Shan et al., Environ Res Lett 2015

Pellet production process

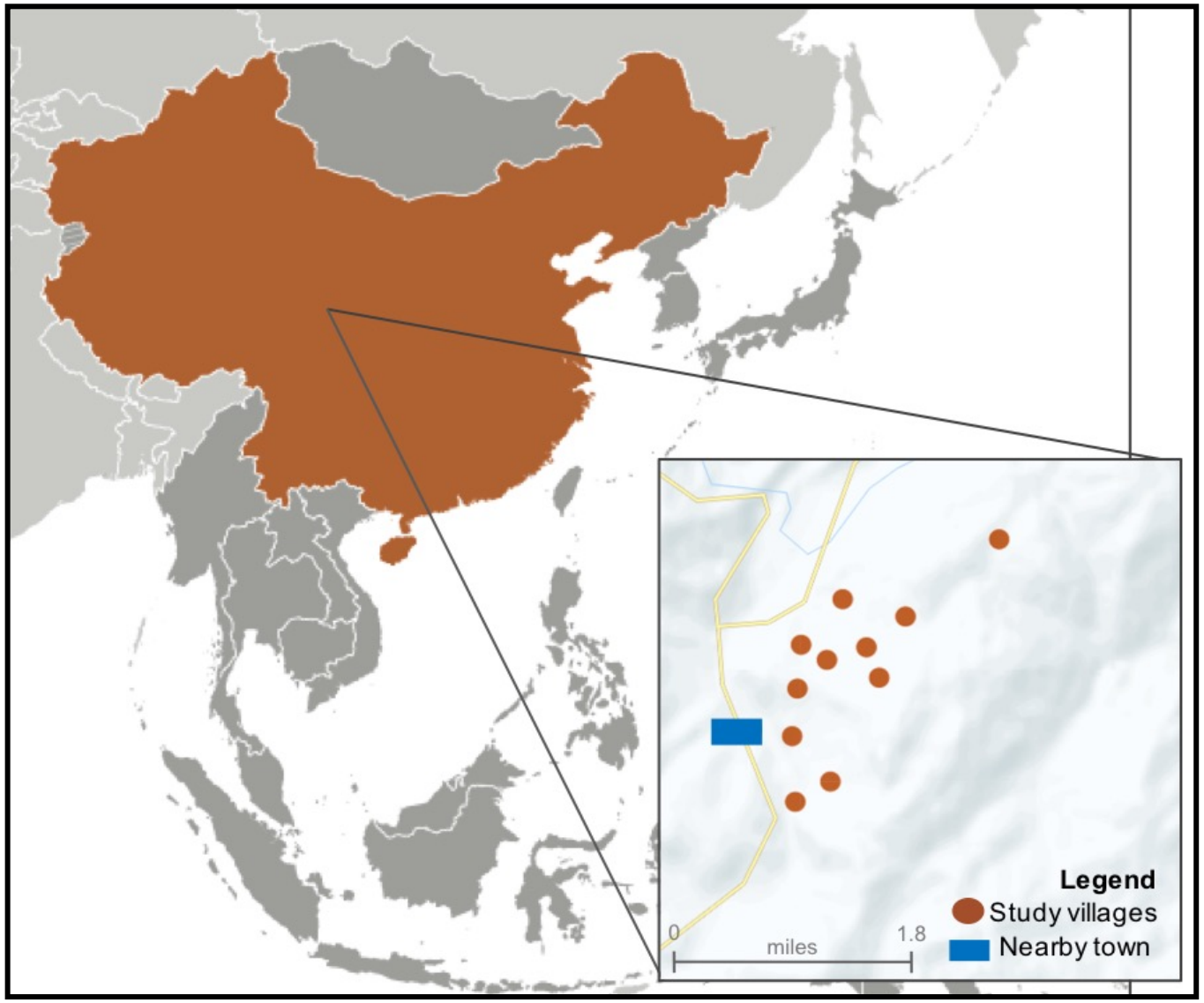
Raw wood biomass

Dried wood chips

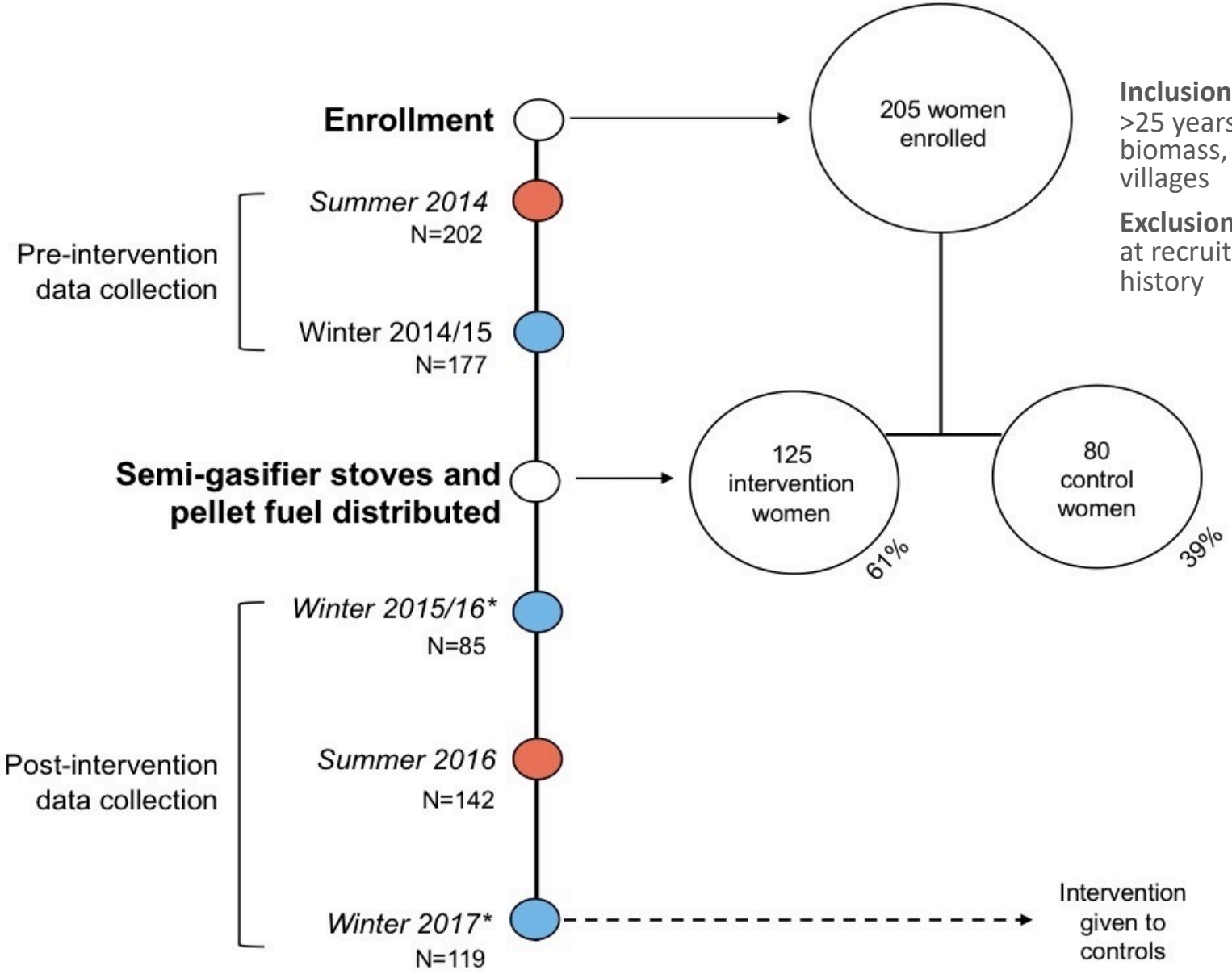
Processed wood pellets

Study site in Sichuan, China

Location of government-supported rural energy program



Study enrolment and timeline



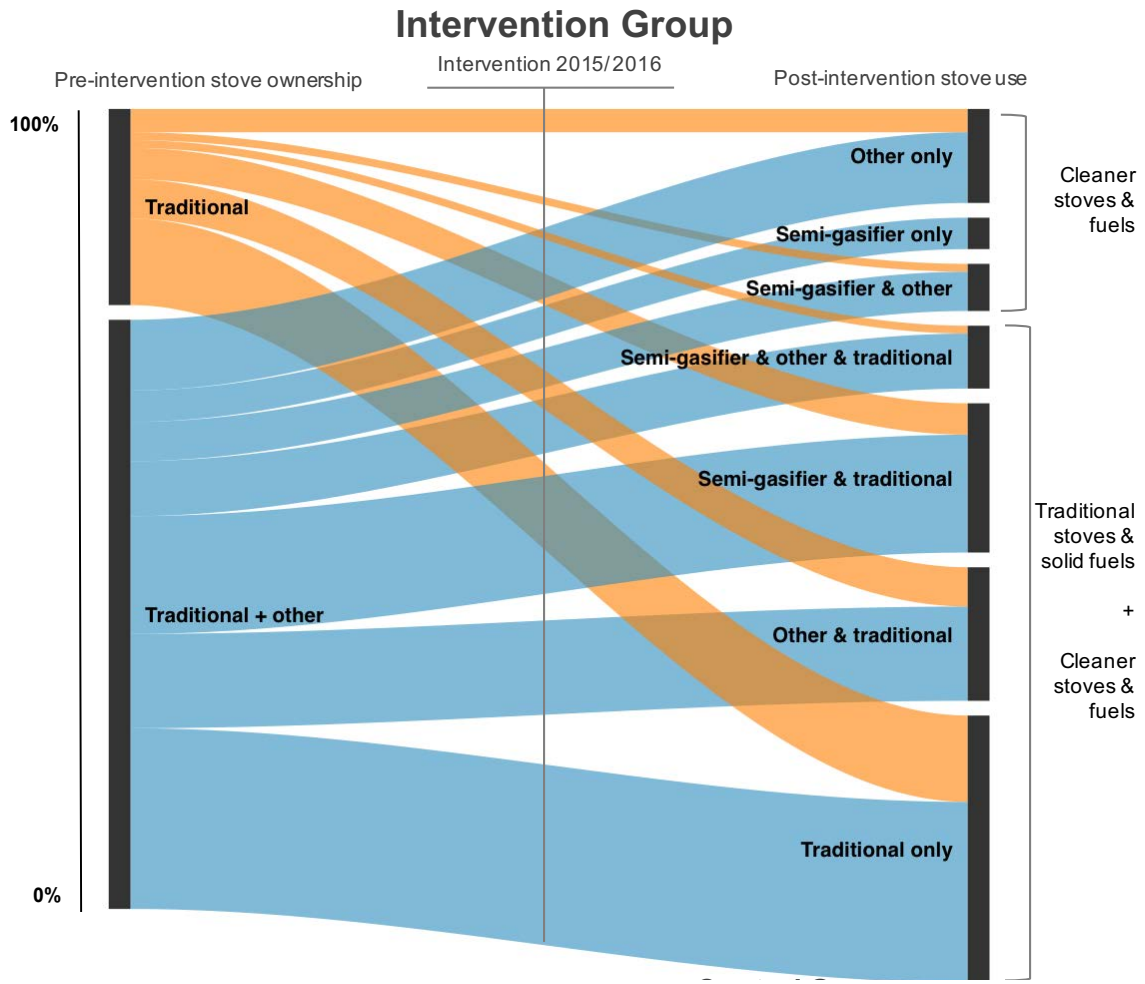
Inclusion criteria: Female; >25 years old; cook with biomass, live in the study villages

Exclusion criteria: Pregnant at recruitment; smoking history

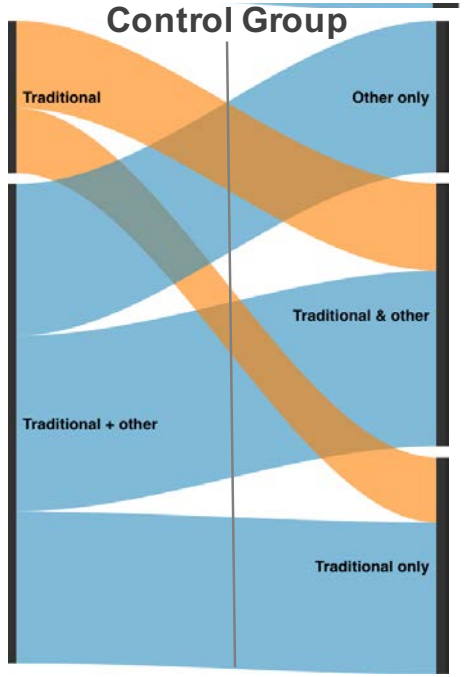
Study Measurements

- Questionnaires
- 48-hr indoor air quality and exposure ($PM_{2.5}$, BC, chemical composition)
- Outdoor air quality
- Stove emissions
- Stove use
- Blood pressure, arterial stiffness, biomarkers

Uptake and adoption was high (75-90%), but energy package only modestly contributed to overall energy use



– 2 years after installation, the energy package was used ~40% of days during a month, on average

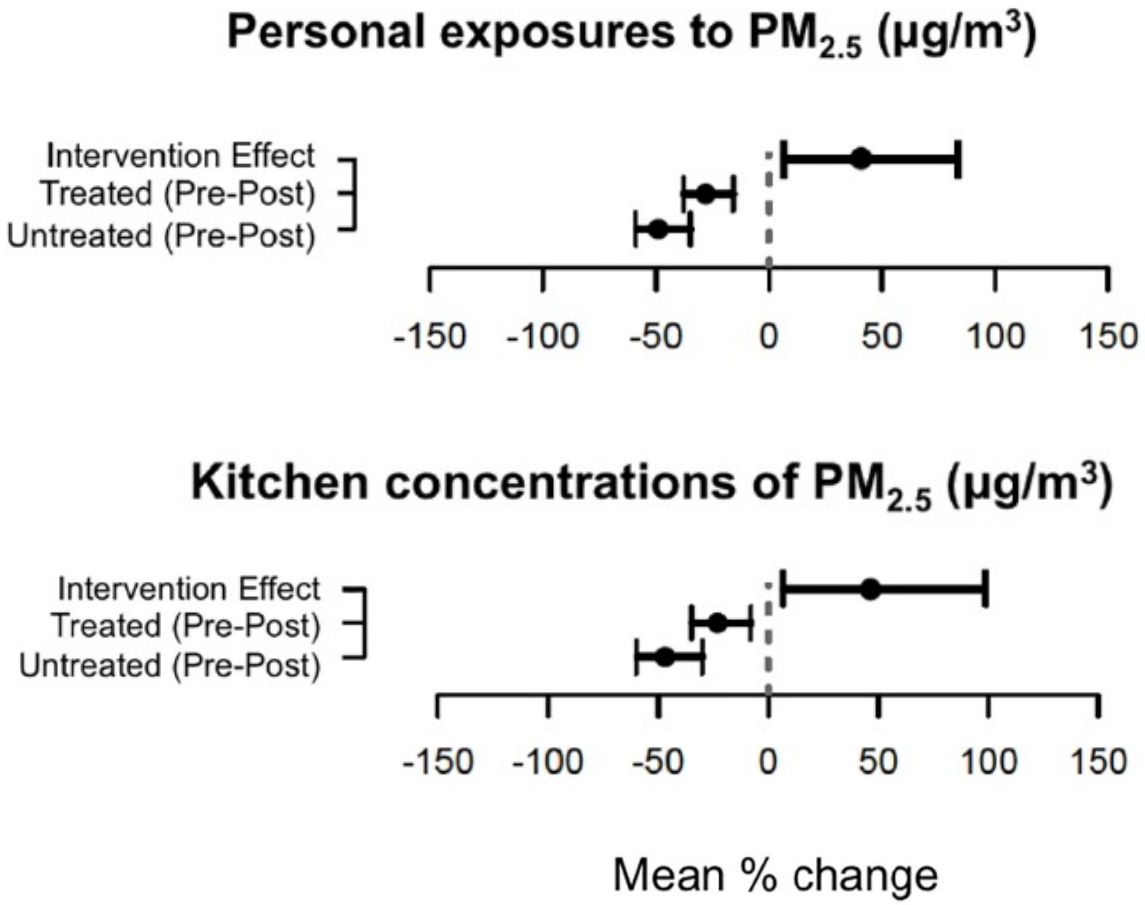


Clark, Environ Res Letters, 2018

Reduced air pollution in homes with energy package, but greater reductions in homes that did not receive it

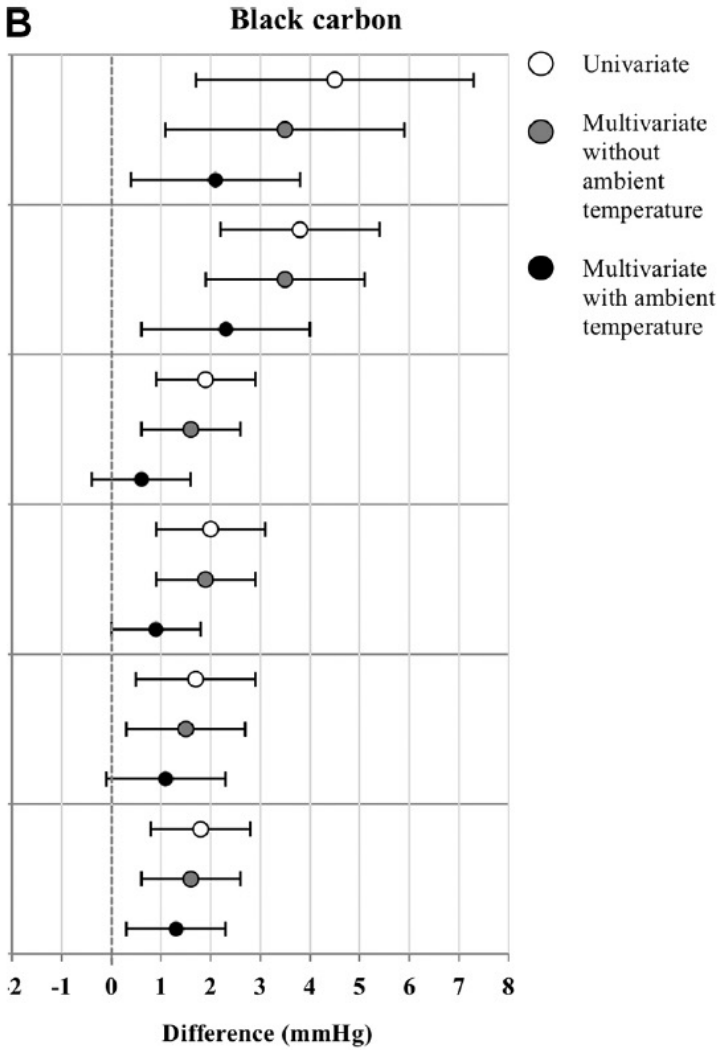
Effects of the energy package intervention on air pollution.

Results from multivariable difference-in-difference models.

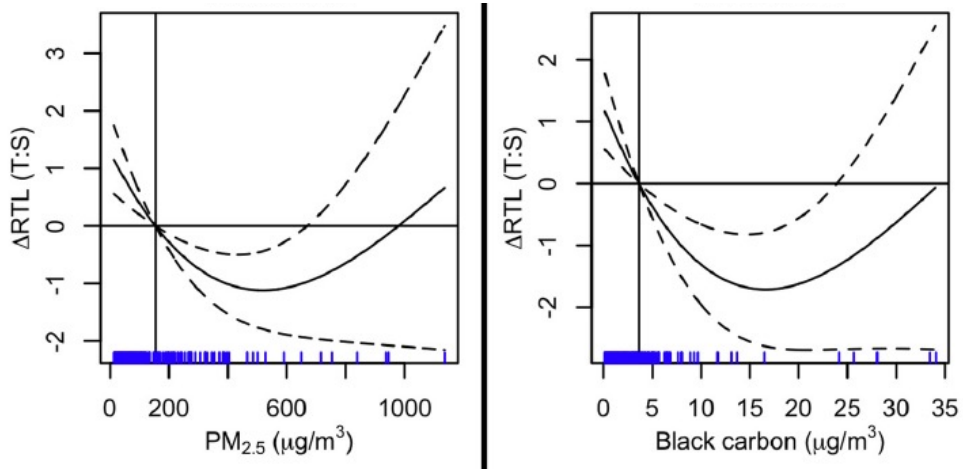


Baumgartner, Environ Sci Technol, 2019

Exposure to household air pollution was associated with worse health (blood pressure, shorter telomere length, and differences molecular markers in dried blood spots)



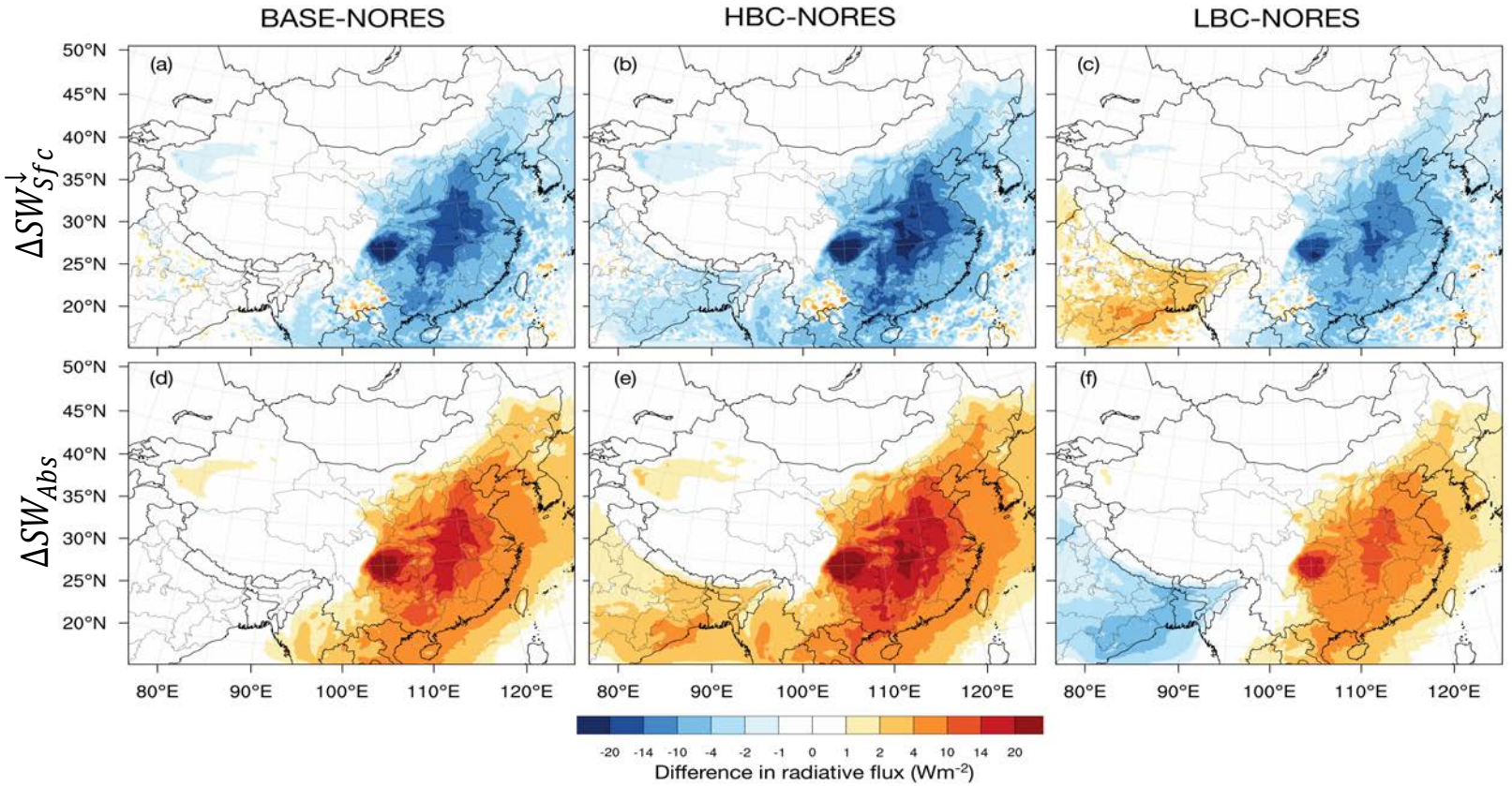
Associations between relative telomere length(T:S) and exposures to PM2.5 and black carbon



Baumgartner, Heart, 2018; Li, Env Health Perspect 2019

Household energy use contributes to outdoor PM2.5 and early mortality in China, and has a positive effect on radiative forcing

Difference in downwelling shortwave (SW) radiation at surface with and without residential heating and cooking (Archer-Nicolls, J Geophy Res, 2019)



Lessons learned for future studies

- Need to understand *how* energy interventions work
- Little knowledge of the factors that influence to solid fuel use and suspension
- Transition to clean energy is happening; leverage for real-world evaluation
- Distributional effects and unintended consequences of clean energy programs

ENVIRONMENT & HEALTH

In fight against smog, China bans coal in 28 cities

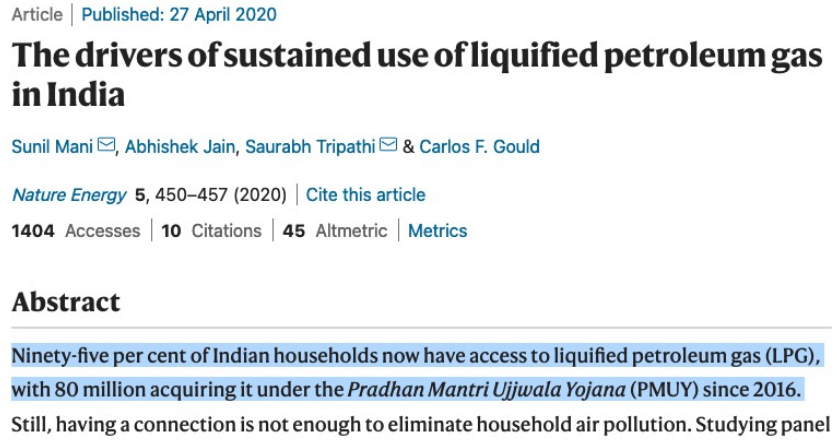
14 October 2017 10:30 · Global Voices · 6 min read

Donate

By Oiwan Lam

As winter approaches, Beijing is gearing up to fight against smog, and a large number of cities in northern China have issued a ban on coal.

Different from the previous efforts coordinated by the Ministry of Environmental Protection in past years, the Coal Ban, as it is being called, has become an economic policy supervised by a coalition of top authorities. Concrete targets on air quality level — and the number of coal-free districts — have been handed down to 28 cities in northern China.



Article | Published: 27 April 2020

The drivers of sustained use of liquified petroleum gas in India

Sunil Mani, Abhishek Jain, Saurabh Tripathi & Carlos F. Gould

Nature Energy **5**, 450–457 (2020) | Cite this article

1404 Accesses | **10** Citations | **45** Altmetric | Metrics

Abstract

Ninety-five per cent of Indian households now have access to liquified petroleum gas (LPG), with 80 million acquiring it under the *Pradhan Mantri Ujjwala Yojana* (PMUY) since 2016. Still, having a connection is not enough to eliminate household air pollution. Studying panel

Full list of publications:
https://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.abstractDetail/abstract_id/10203/report/0

University of Minnesota
Jill Baumgartner (PI)
Ellison Carter (Postdoc)

McGill University
Graydon Snyder (Postdoc)
Sierra Clark (MS Student)
Matthew Secrest (MS student)
Sabrina Li (RA)

NCAR
Christine Wiedinmyer (Co-PI)
Scott Archer-Nicholls (Postdoc)
Forrest Lacey (Postdoc)

Imperial College London
Majid Ezzati (Co-I)

University of Wisconsin - Madison
James J. Schauer (Co-PI)
Alex Lai (PhD student)
Collin Brehmer (RA)

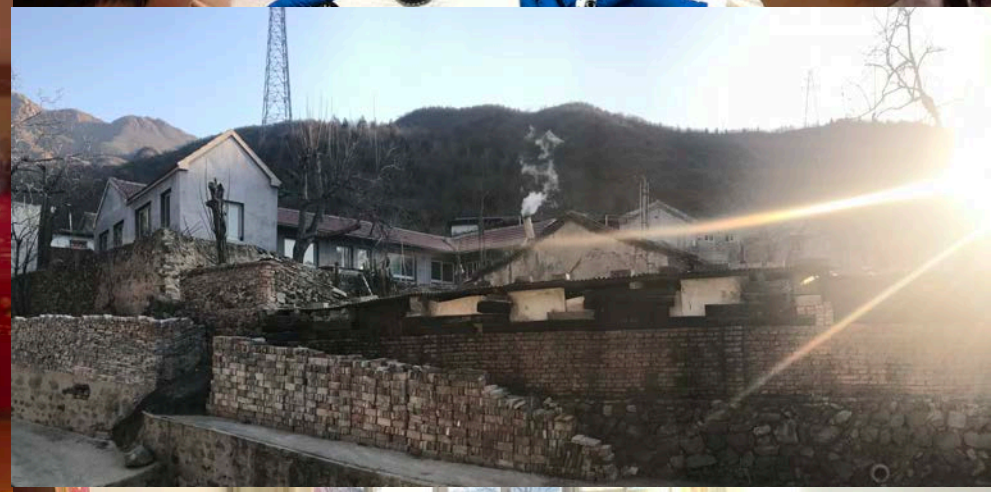
Tsinghua University
Xudong Yang (Co-PI)
Kun Ni (Postdoc)
Ming Shan (Postdoc)
Mengsi Deng (PhD student)
Project manager + field staff

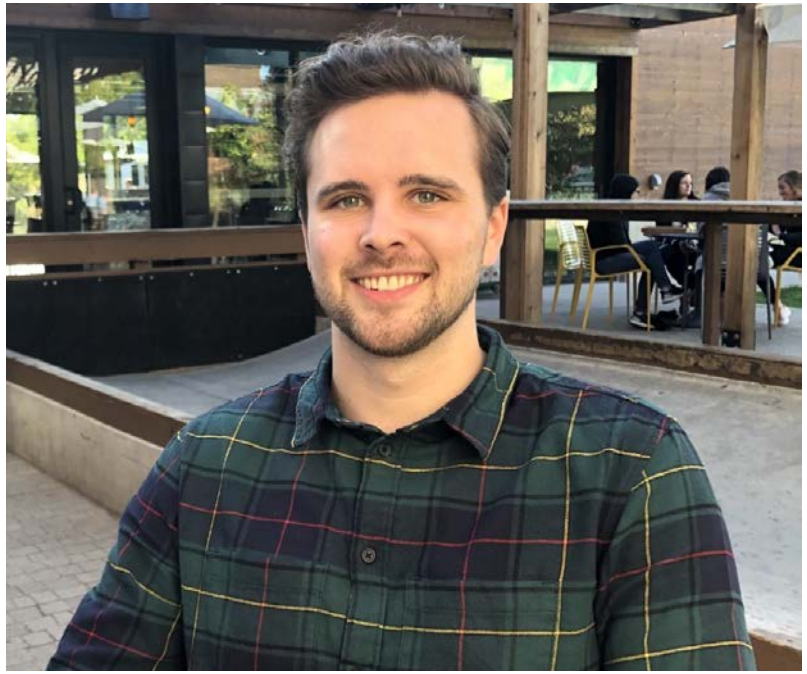
University of the Chinese Academy of Sciences
YuanXun Zhang (Co-I)
Yuqin Wang (PhD student)

Household Transitions to Clean Energy: Studies Across China

Ellison Carter and Research Team

20 May 2021 | ASHES Seminar

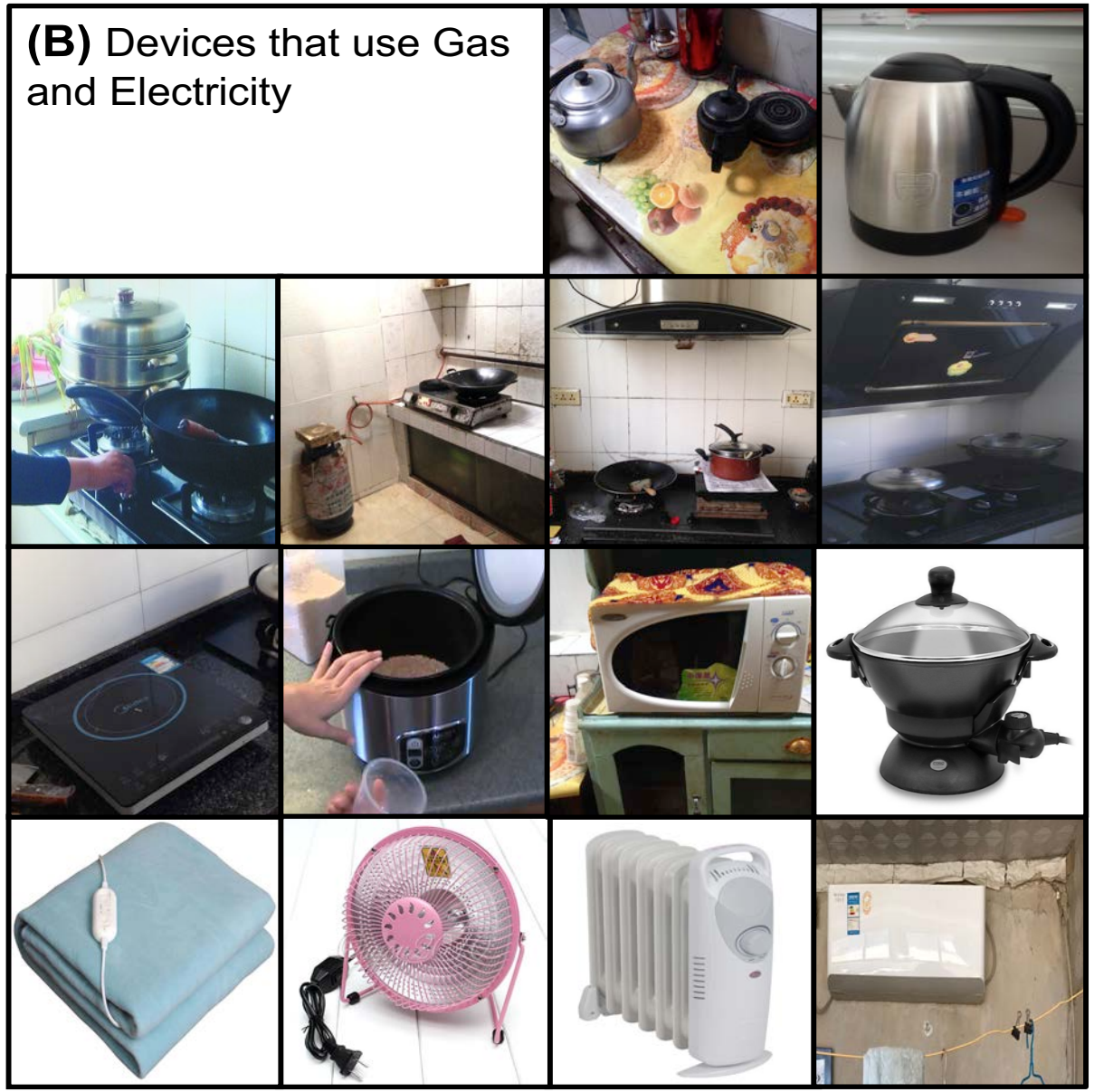




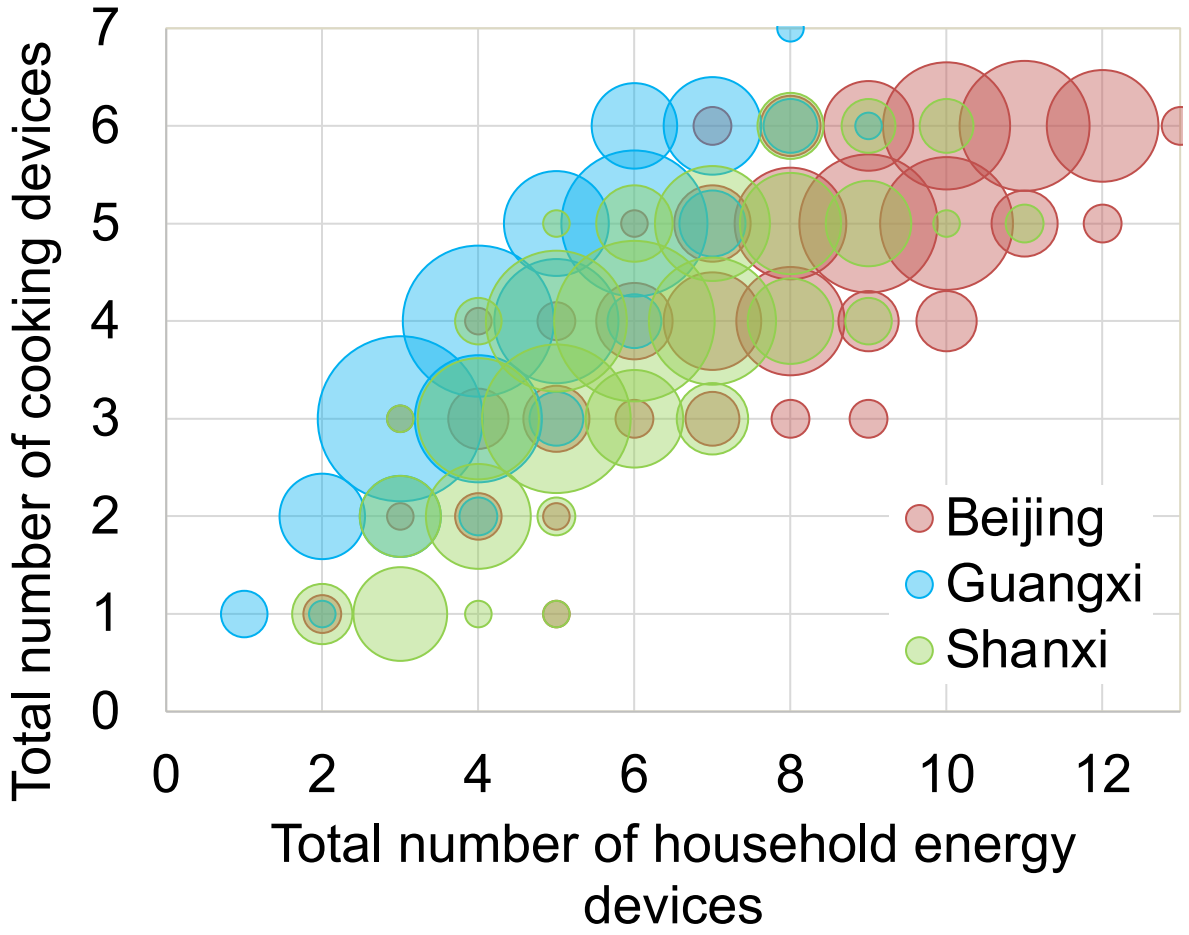
Cooking and Heating Fuels and Stoves Are Diverse

(A) Devices that use Solid Fuels

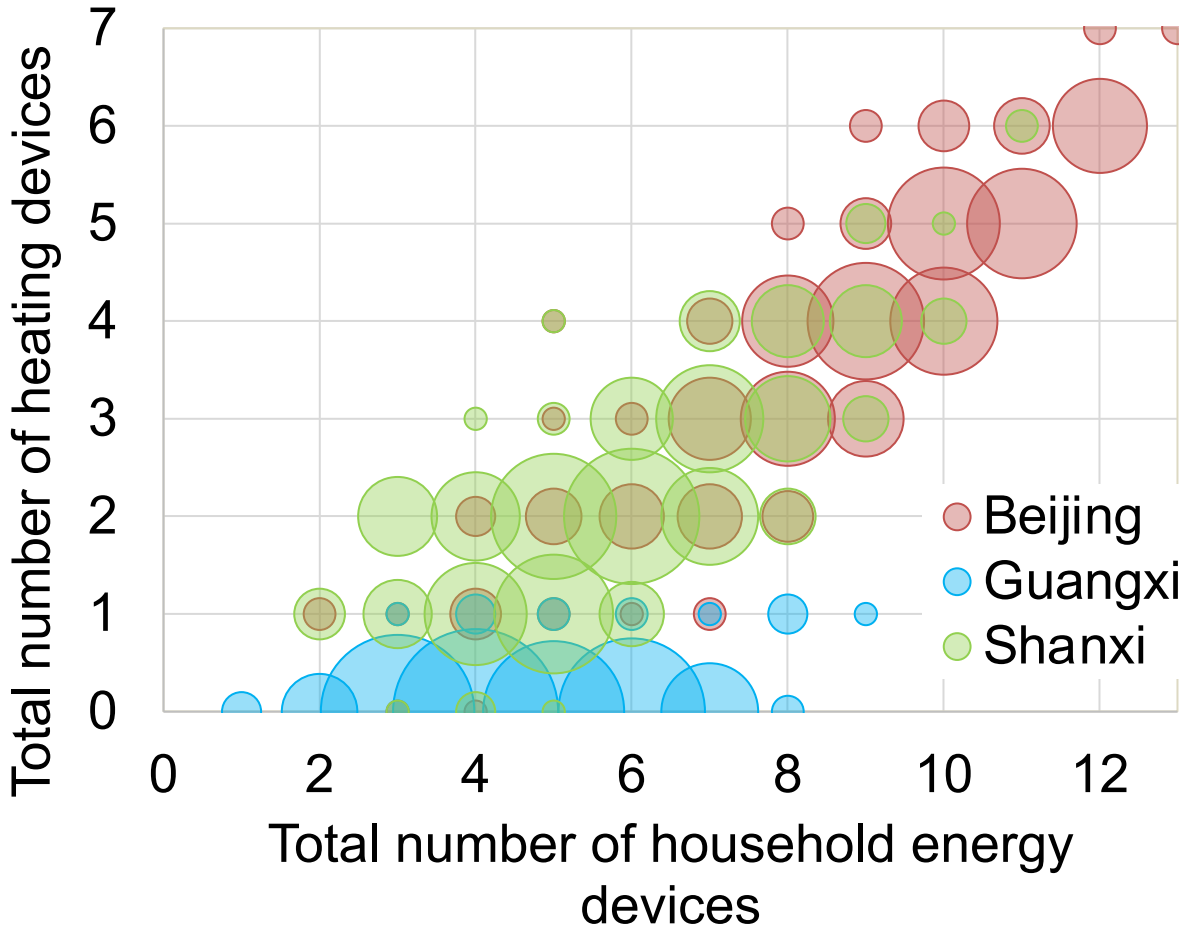
(B) Devices that use Gas and Electricity



Cooking Fuel

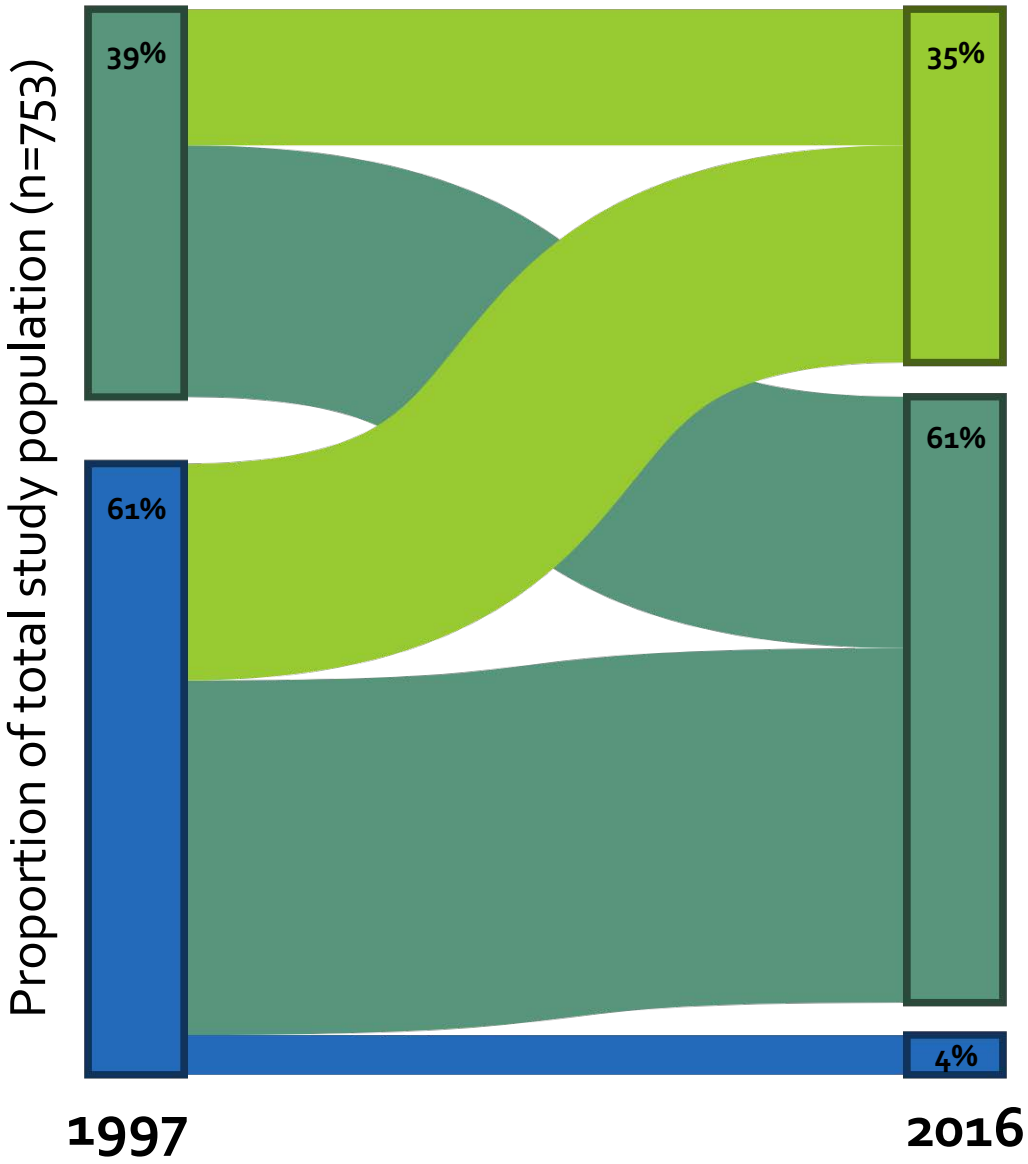


Heating Fuel

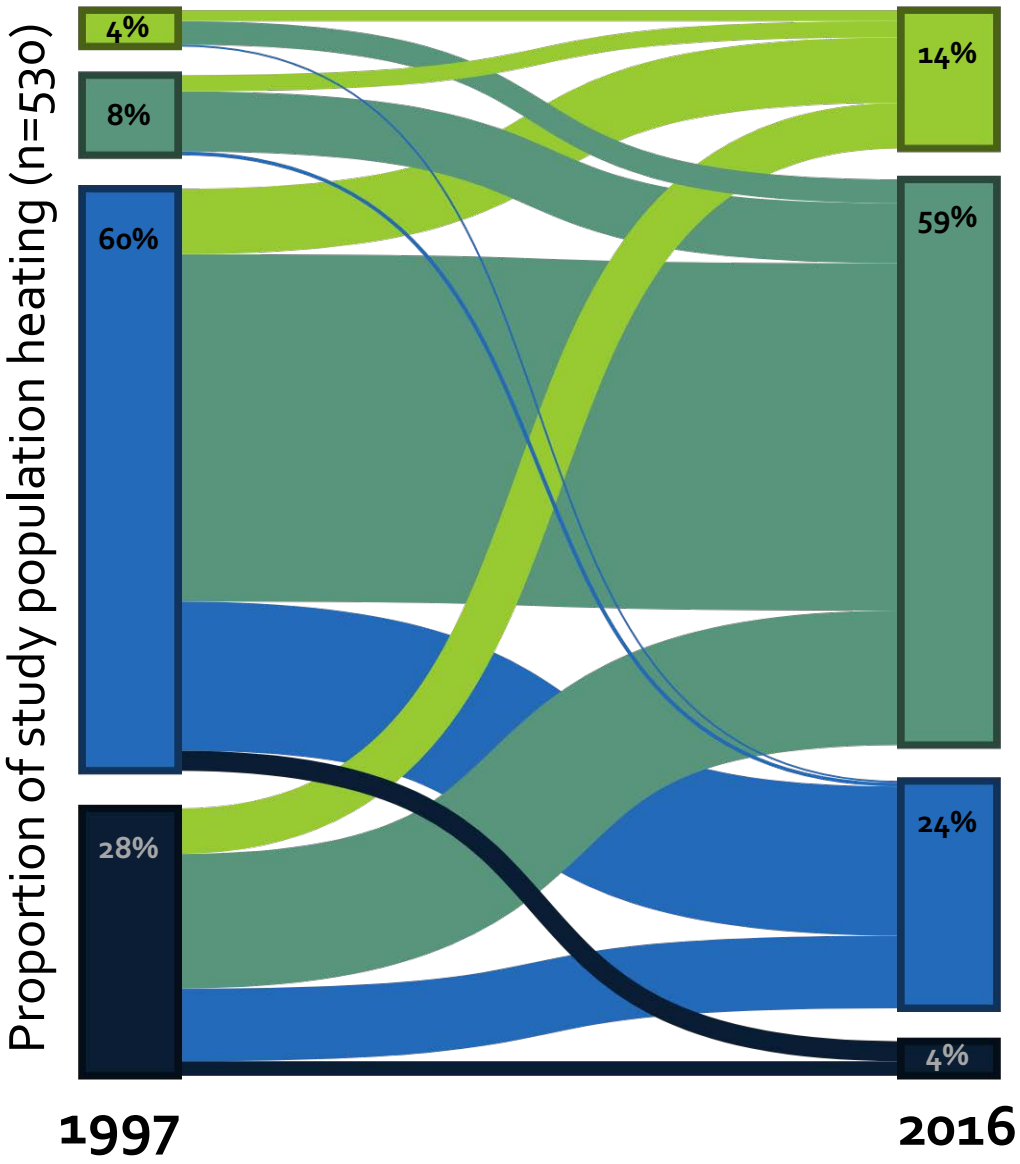


Carter et al., 2020. *Nature Sustainability*

Cooking Fuel



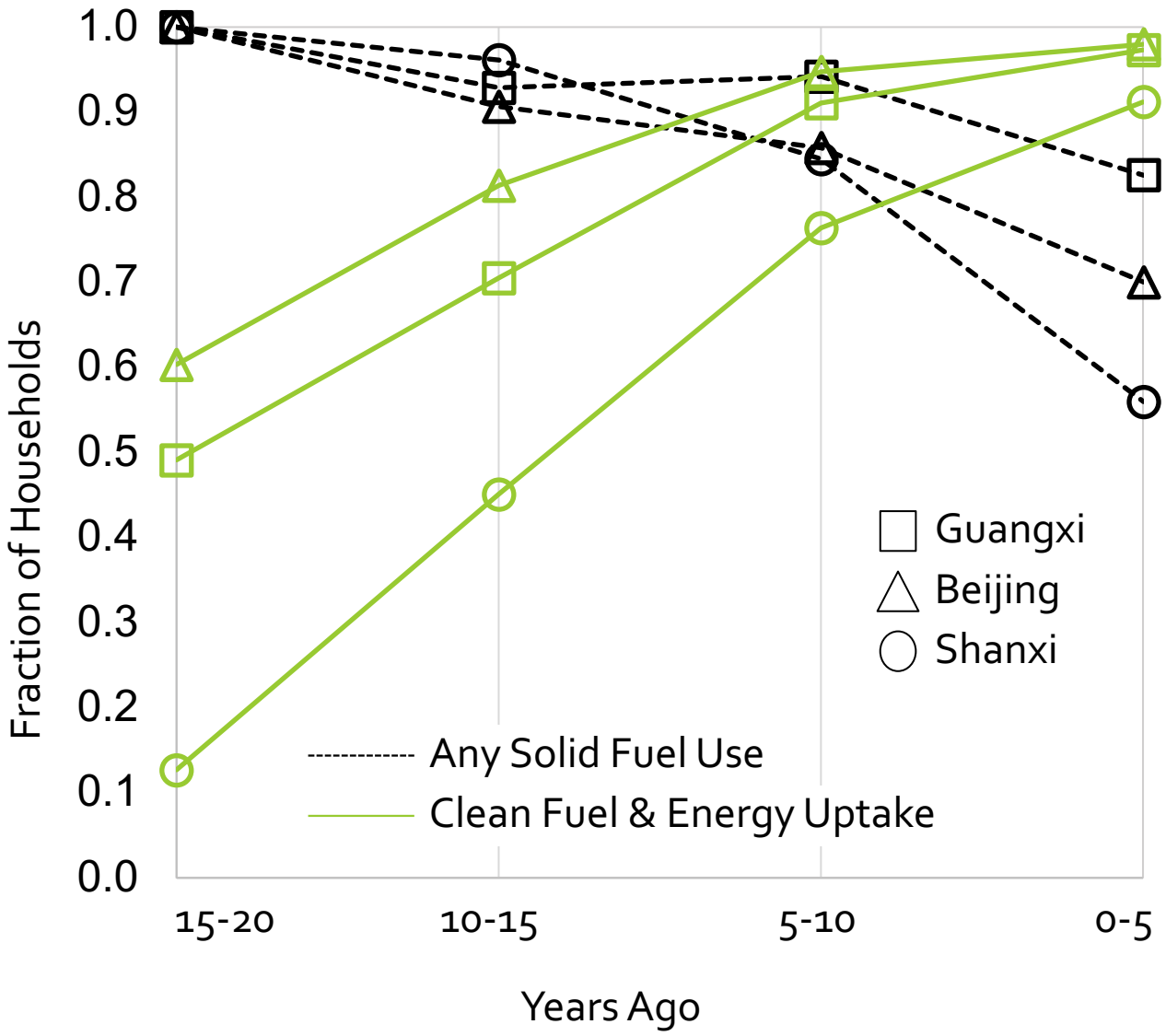
Heating Fuel



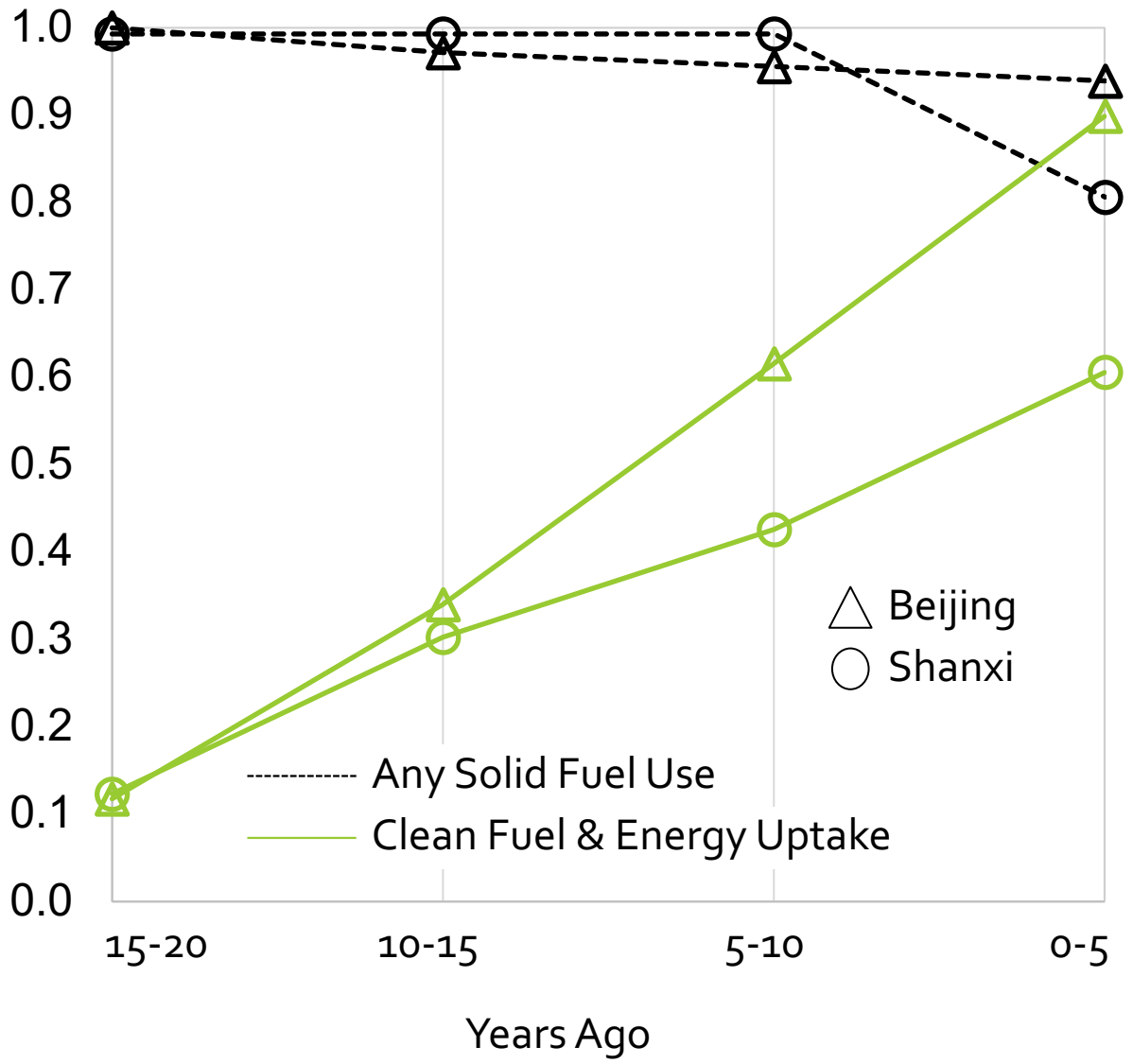
Clean fuels only | Solid/Clean mix | Solid fuels only | No active devices

Carter et al., 2020. *Nature Sustainability*

Cooking Fuel



Heating Fuel



Carter et al., 2020. *Nature Sustainability*

Whether A Change Happened

Variables	Cooking		Heating	
	Uptake	Suspension	Uptake	Suspension
Age	(-)	(-)		
Household membership	(-)			
Income				
2,500-4,999	(+)			
5,00-9,999	(+)			
10,000-19,000	(+)			
20,000-34,999	(+)			
>35,000		(+)		
Marital Status (ref: widow)		(-)		
Education (ref: none)			(+)	
Occupation (ref: retired)	(-)		(-)	
Self-reported Health (ref: excellent)				

When A Change Happened

Variables	Cooking		Heating	
	Uptake	Suspension	Uptake	Suspension
Age		(-)		
Household membership				
Income				
2,500-4,999			(+)	
5,00-9,999			(+)	
10,000-19,000			(+)	
20,000-34,999			(+)	
>35,000	(+)			
Marital Status (ref: widow)				
Education (ref: none)		(+)		
Occupation (ref: retired)				
Self-reported Health (ref: excellent)				(+)

Policy Context (2017 to present)

China does U-turn on **coal ban** to avert heating crisis
BBC News - Dec 7, 2017
China's government has allowed some northern cities to burn **coal** in a temporary

China plans to cut **coal** heating again, but can it avoid another crisis?
Unearthed - Jan 10, 2018
While the smog in **Beijing** often grabs the **headlines**, **household** fuel ... The

In China's **Coal** Country, a **Ban** Brings Blue Skies and Cold Homes
New York Times - Feb 11, 2018
Eager to impress **Beijing**, officials in this province of 37 million people have .... A

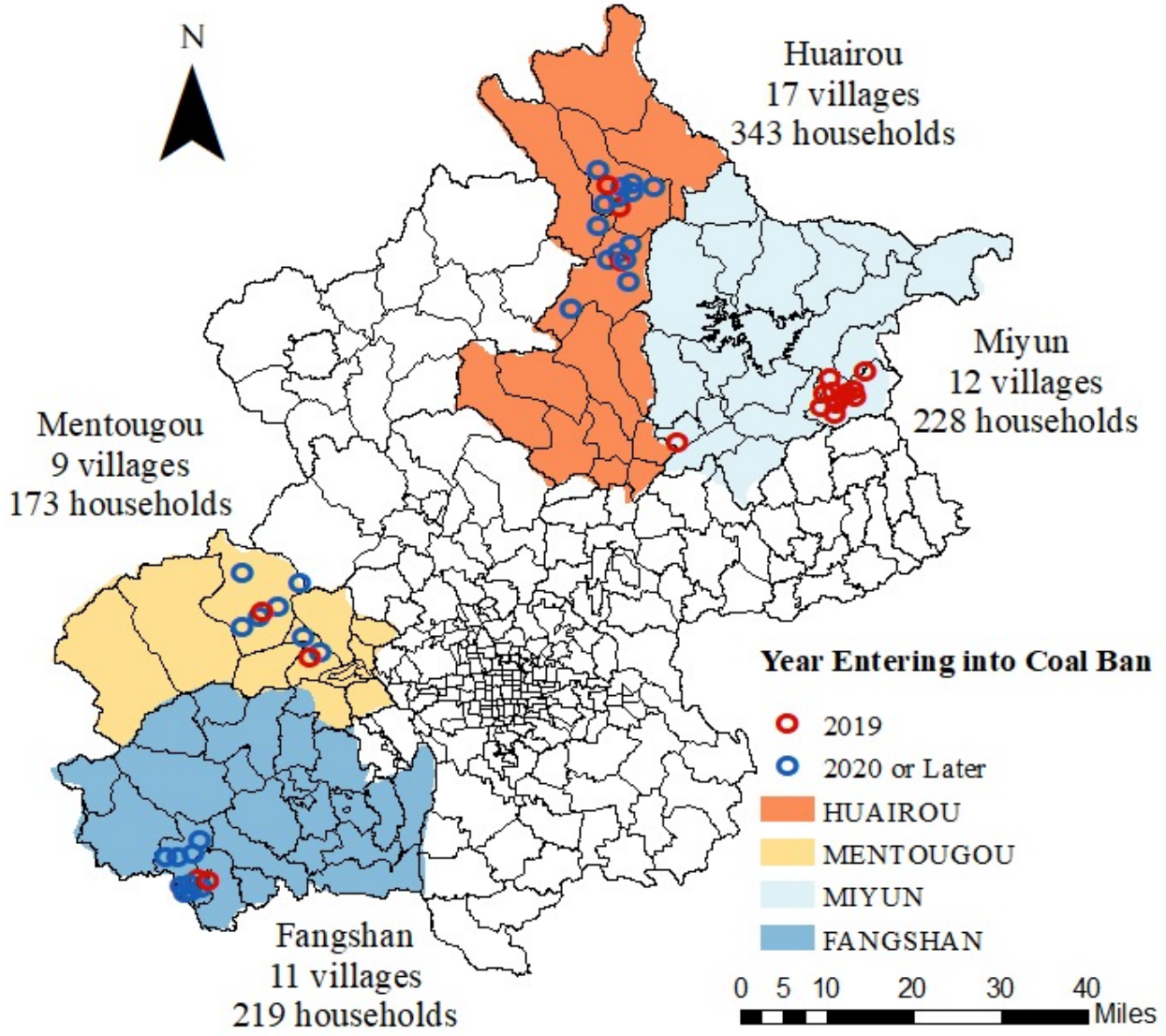
Plans to Move **Households** to Clean Energy Face Challenges Again ...
Caixin Global - Nov 8, 2018
In 2018, the push to move away from **household** use of **coal** — part of ... a further 3.62 million **households** in **Beijing**, Tianjin, and the provinces of Hebei, ... on

In China, replacing **coal** and biomass stoves has saved lives
Ars Technica - Nov 21, 2018
The resulting **household** pollution has contributed significantly to China's poor air

A very cold winter for the poor: The unintended consequences of ...
Scroll.in - Dec 9, 2018
China's air pollution dominated **headlines**, and then its strong ... In **Beijing** alone, 140,000 **households** across 336 villages bid farewell to **coal**. ... In Hebei they

It's Cold in China, And Environmental Central Planning Has Turned Of...
Forbes - Jan 23, 2019
The rural areas surrounding **Beijing** get cold during the winter, with an average ... But the **coal**—especially **coal** burned in a **home** furnace—came at the cost of air ... People can no longer afford to **heat** their **homes**, even with ...

Beijing Household Energy Transitions Study



Objectives

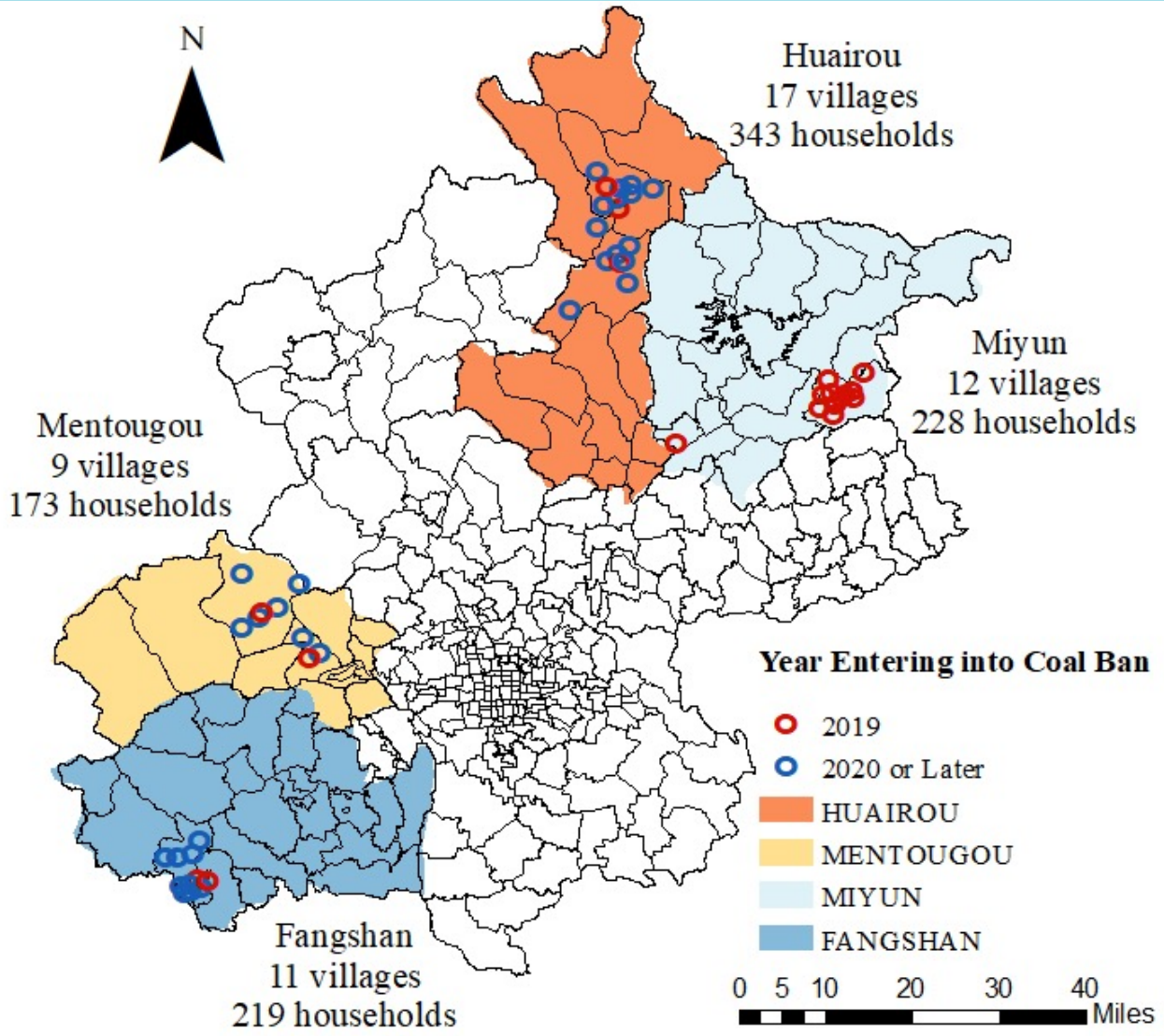
1. Estimate the total effect of the household energy policy on: (a) community, indoor, and personal air quality; (b) indoor temperatures; (c) health outcomes; (d) household energy use; (e) well-being.
2. Estimate how much of the policy's overall effect on health can be attributed to its impact on changes in PM2.5;
3. Quantify the contribution of changes in the chemical composition of PM2.5 to the total effect on health outcomes.

CIHR IRSC
Canadian Institutes of Health Research | Instituts de recherche en santé du Canada

SSHRC
Canada

HEI
HEALTH EFFECTS INSTITUTE

Beijing Household Energy Transitions Study



Measurements

50 villages, ~20 participants/village

at baseline, all using coal

extensive questionnaire

personal $PM_{2.5}$ exposure (50%)

outdoor $PM_{2.5}$ mass (2-4 months)

outdoor continuous $PM_{2.5}$ (optical)

indoor continuous $PM_{2.5}$ (optical)

indoor temperature (winter)

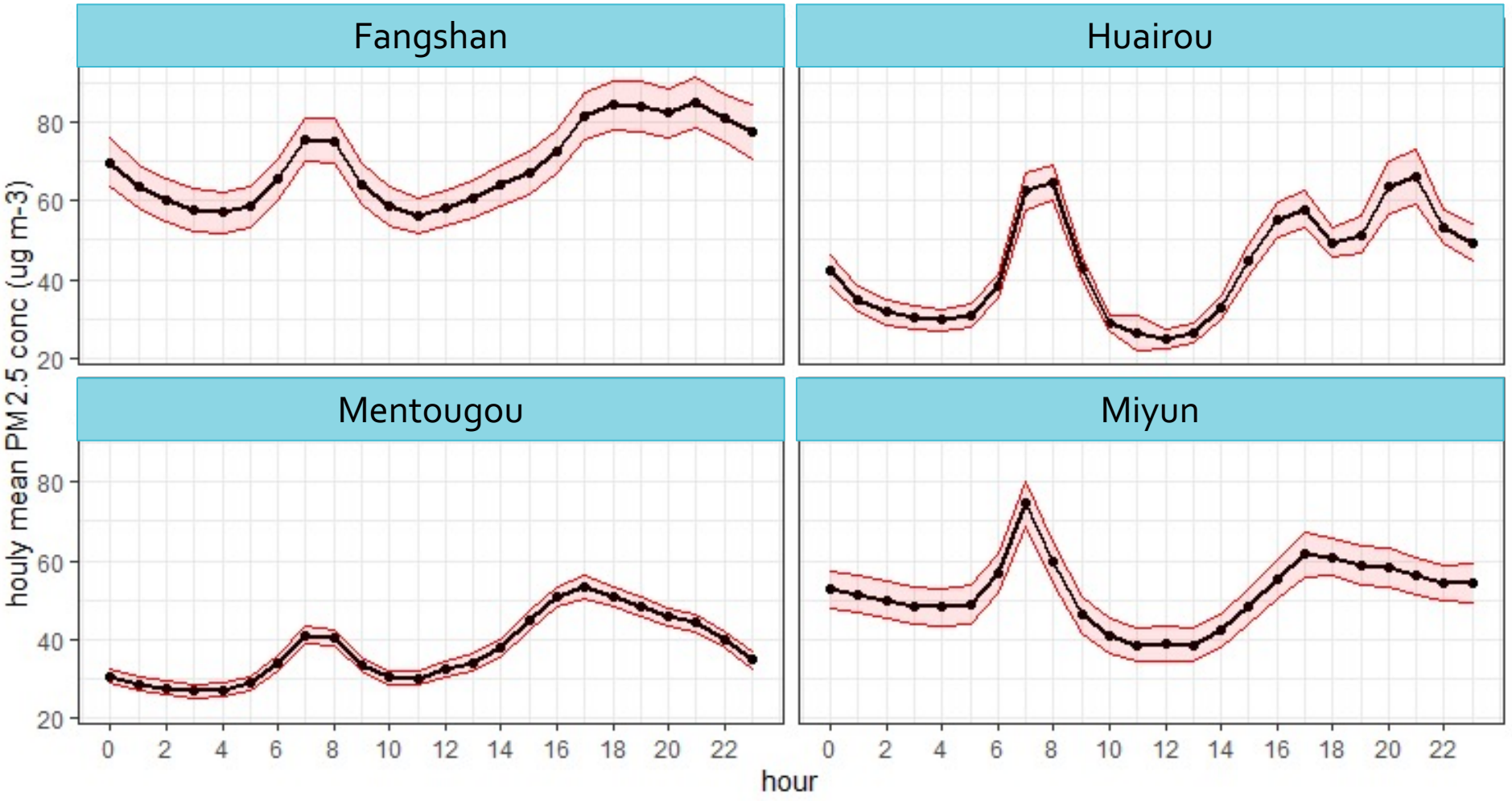
stove use monitoring

multiple measures of
cardiovascular / respiratory health

~Nov/Dec – March/April campaigns

Season 1
2018-19

Diurnal patterns of wintertime community air pollution in rural Beijing

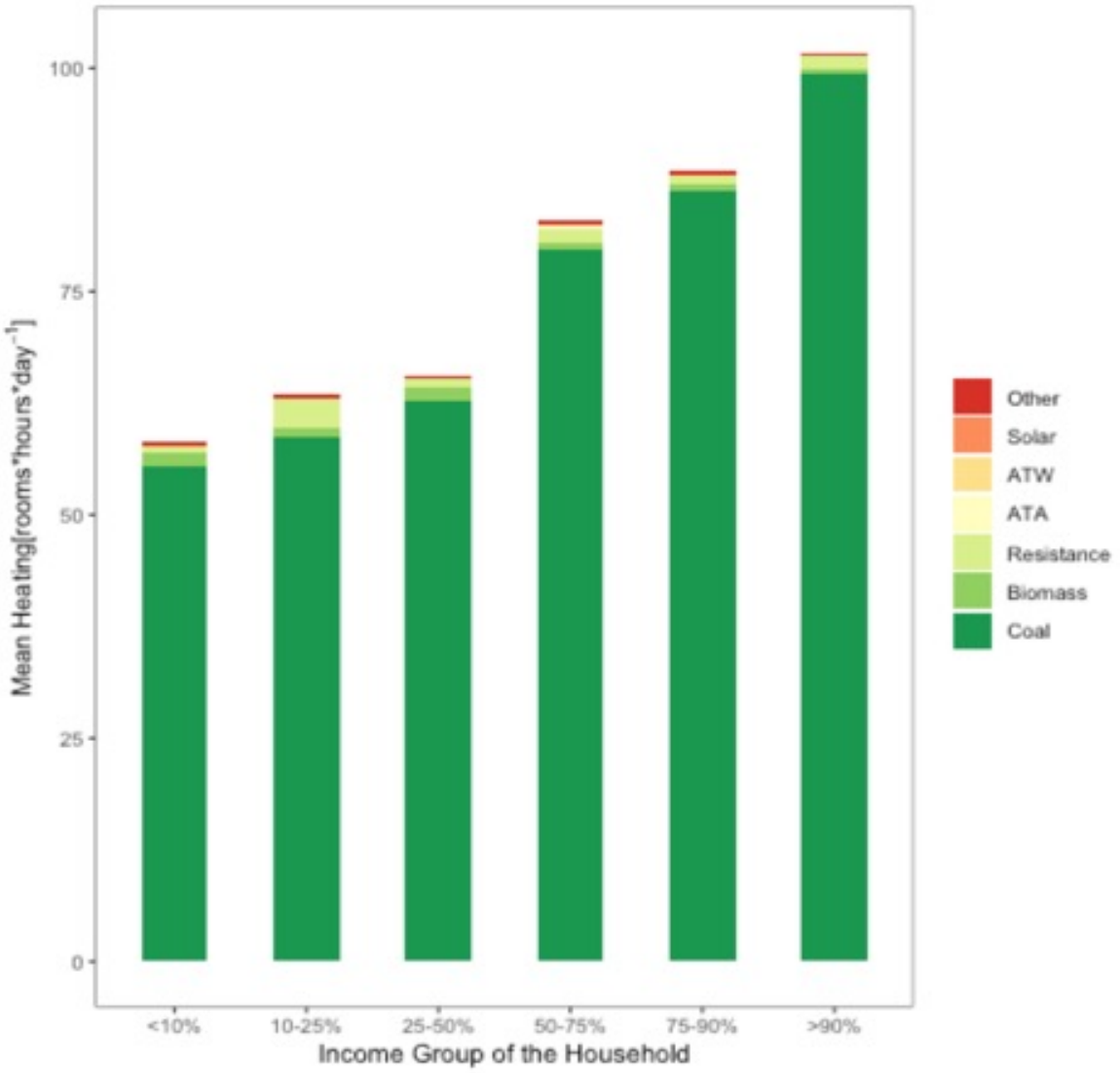


Diurnal community-level pollution ($PM_{2.5}$) patterns reflect morning and evening space heating behaviors.

Season 1

2018-19

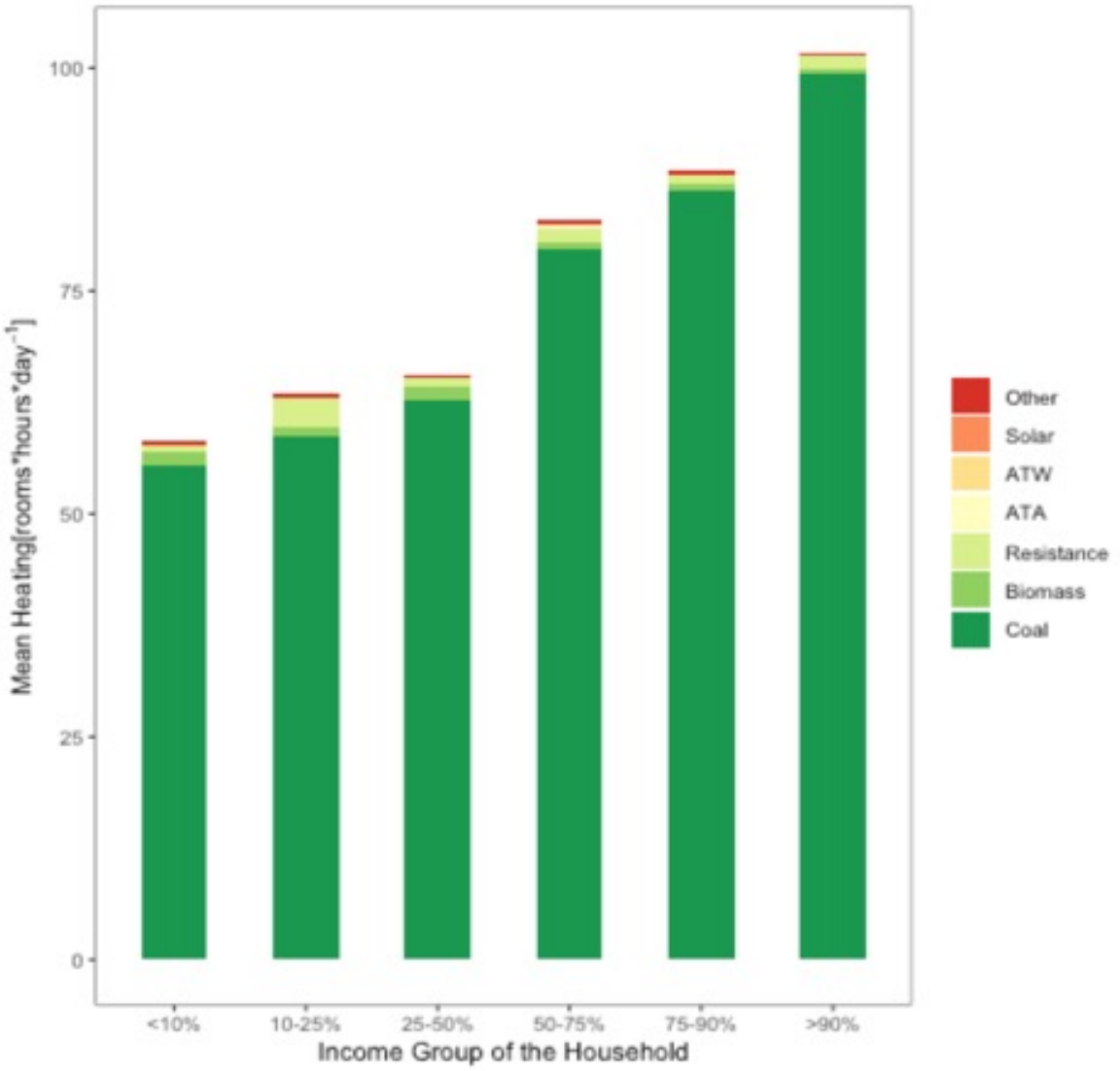
Mean Heating Hours per Day by Energy Source and Income group (based on questionnaires)



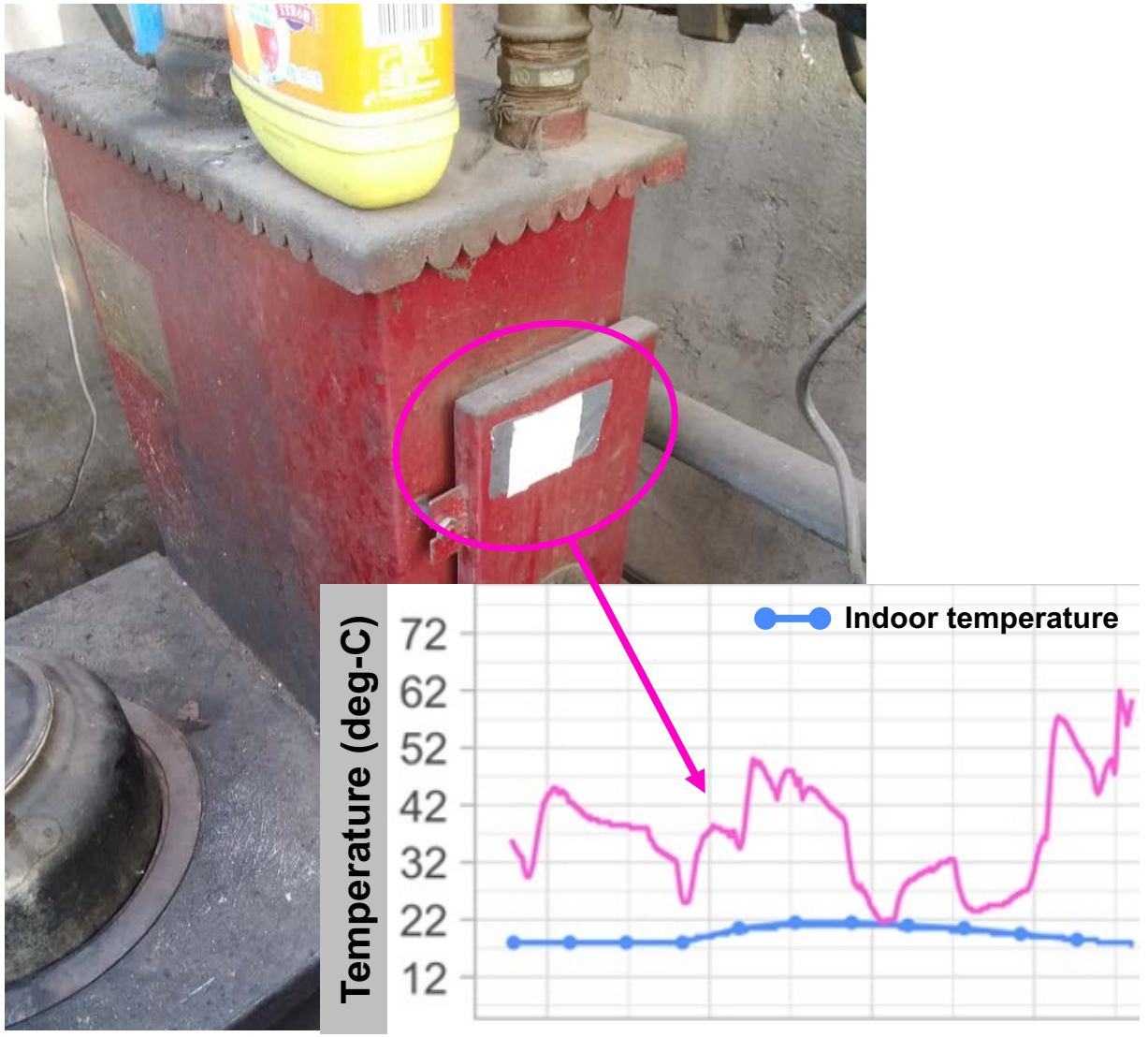
Season 1
2018-19

Season 2/3/4
2019-21

Mean Heating Hours per Day by Energy Source and Income group (based on questionnaires)



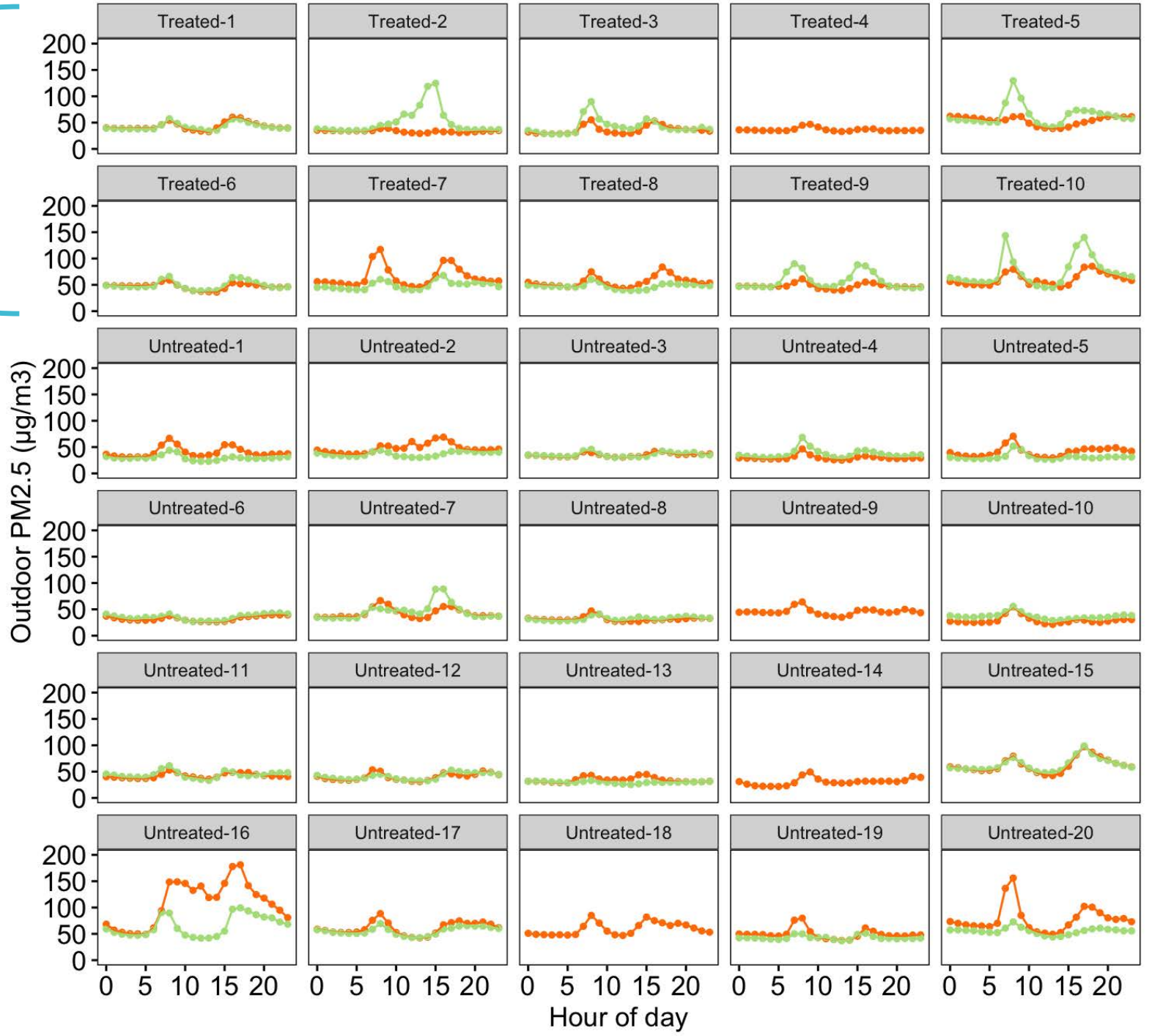
Stove Use Monitoring with Small Temperature Sensors



Season 2
2019-20

Diurnal outdoor $PM_{2.5}$

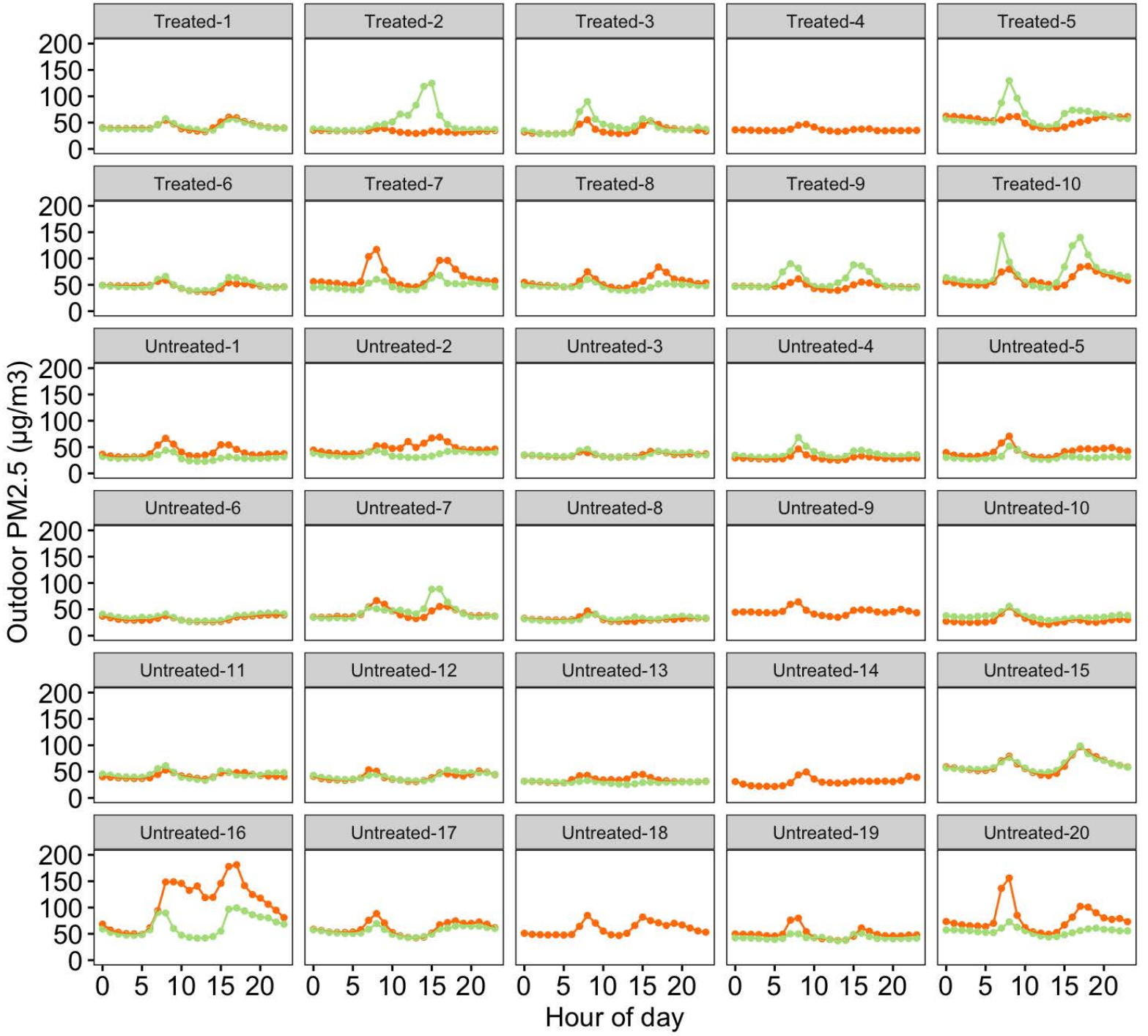
Treated villages in Season 2
N=10 among two of the four districts



Season 2
2019-20

Diurnal **community-level pollution** ($PM_{2.5}$) patterns in treated villages still reflect morning and evening solid fuel space heating behaviors.

Chinese Kang Heating Bed



TAKEAWAYS

1. Household energy policy is effectively reducing rural residential use of coal for wintertime space heating.
2. Too soon to determine the extent to which changes in source-activity (i.e., coal-burning) impact air quality.

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Impact of household energy transition on personal, indoor and outdoor air quality in Northern China

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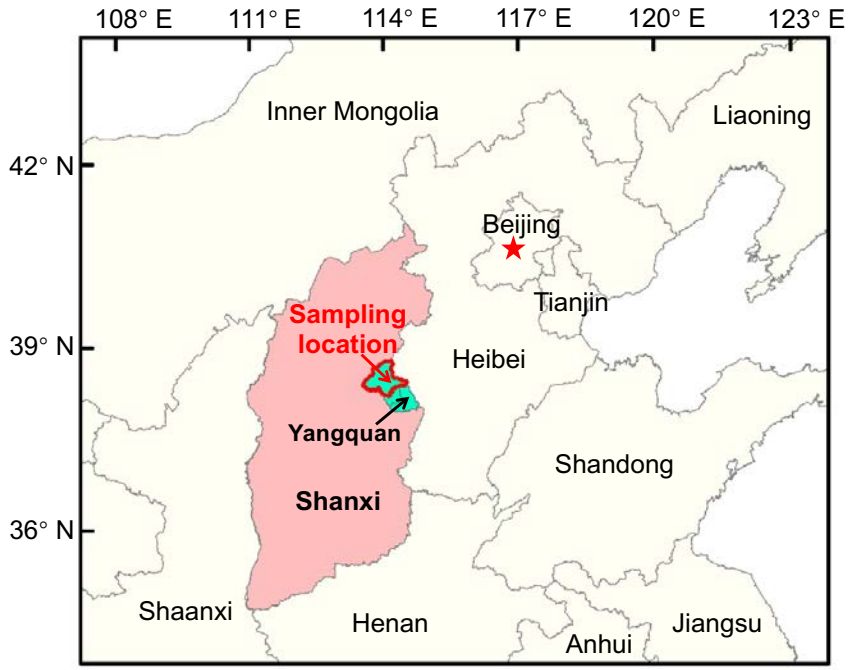
Department of Civil and Environmental Engineering, Colorado State University

2021-05-20

Household energy transition

- Not only in Beijing area, but also Northern China
- Replace coal stove, but keep *Kang*
- Substitute by electricity or natural gas, depending on energy source availability.

Field study in Shanxi



Gas village

Coal village

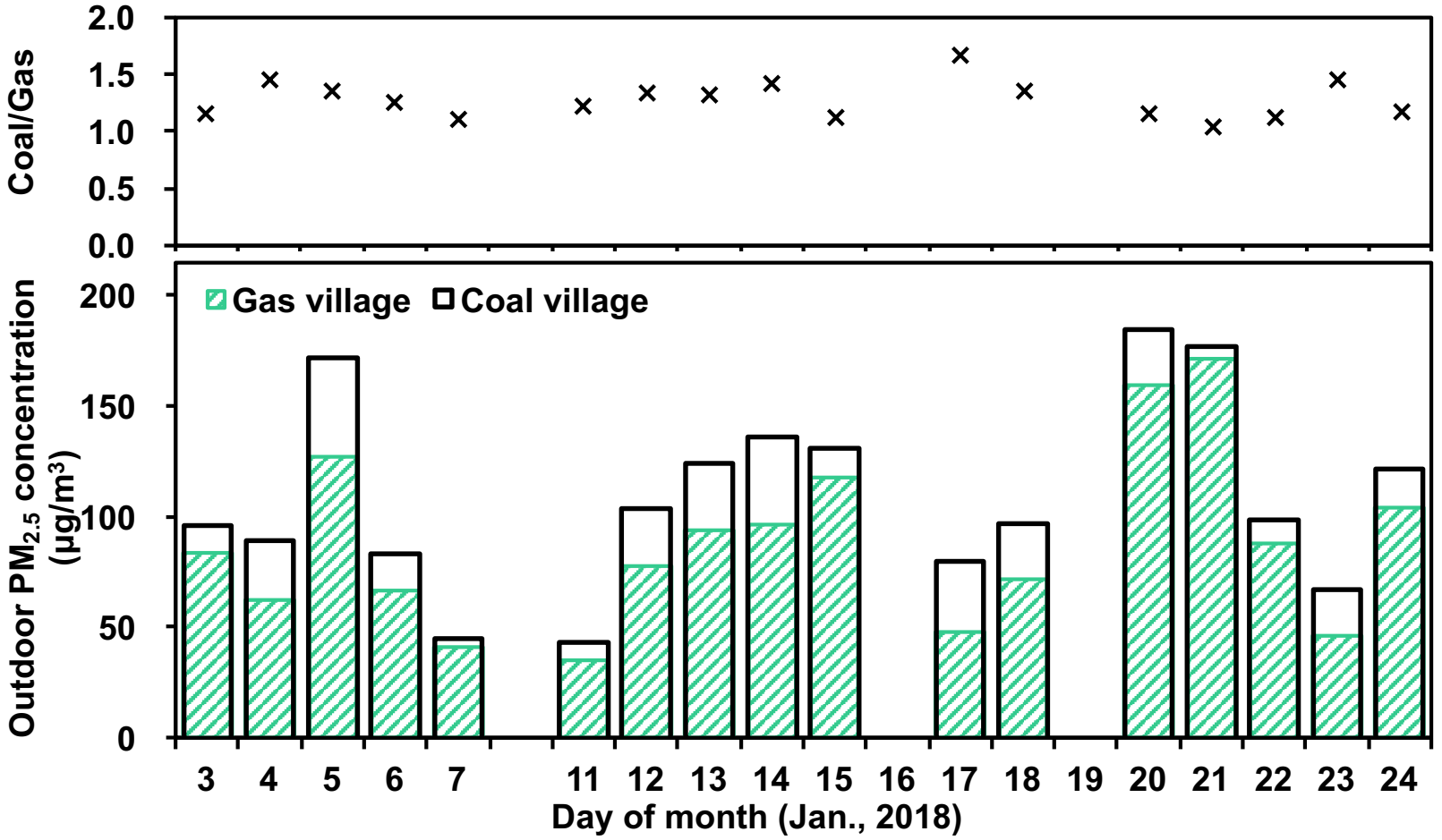
Filter-based measurements

Outdoor: 24-h (repeated for one month)
Indoor: 48-h (once per household)
Personal exposure: 48-h (once per person)

Chemical analyses:

Organic Carbon (OC)
Elemental Carbon (EC)
Black Carbon (BC)
Water-Soluble Organic Carbon (WSOC)
Water-soluble ions (e.g., SO_4^{2-}, NO_3^-, NH_4^+)
Elements (e.g., S, Fe, Se, Ca, Si)

Outdoor $PM_{2.5}$ in the gas and coal village



- Coal village > Gas village
- 1.3 ± 0.2 times

Personal exposure levels

Coal village < Gas village

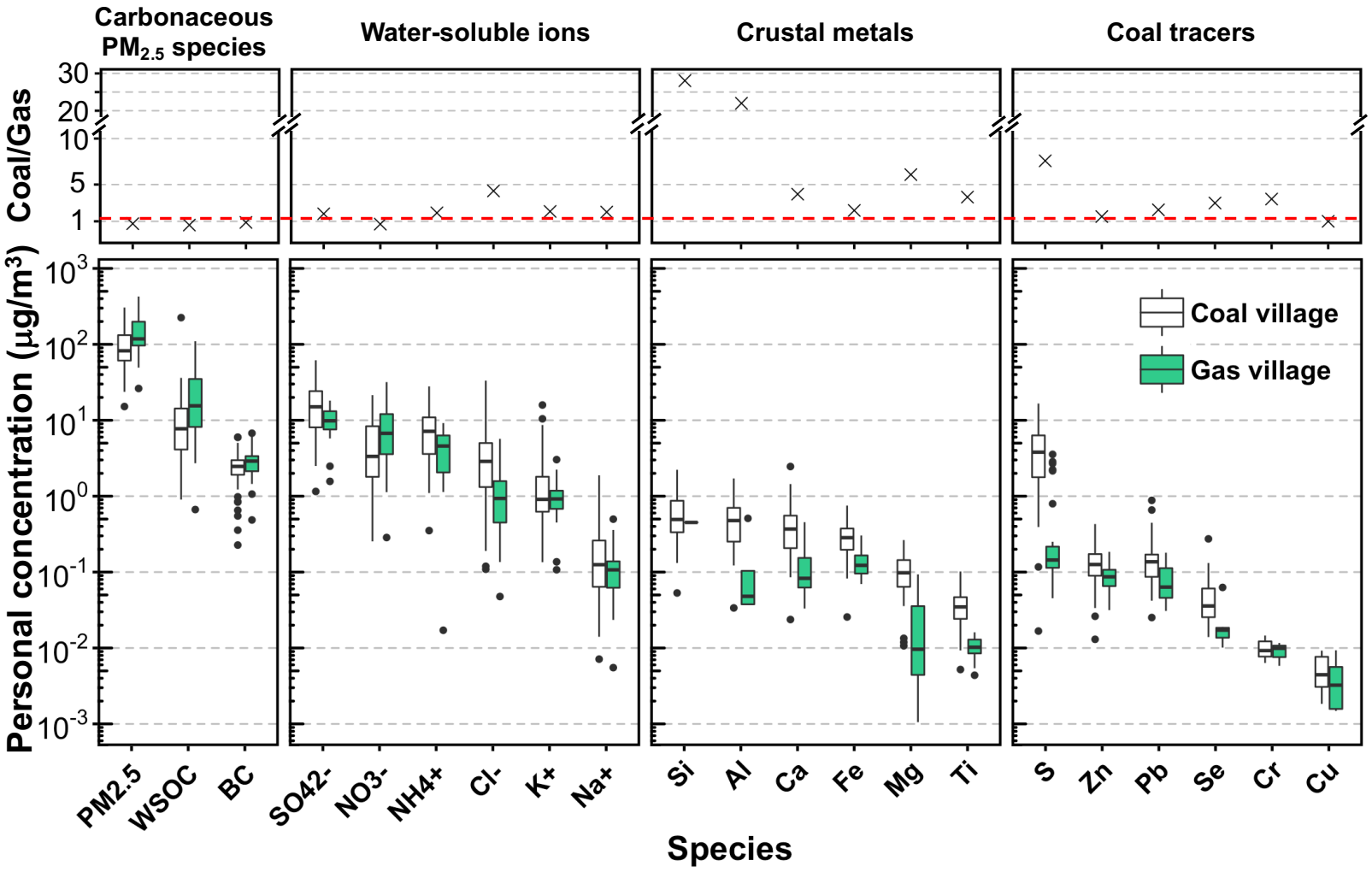
- $PM_{2.5}$, WSOC, BC
- Over 1/3 higher for $PM_{2.5}$

Coal village > Gas village

- Coal tracers: e.g., S, Se, Pb
- Crustal metals: e.g., Si, Al, Ca

In gas village,

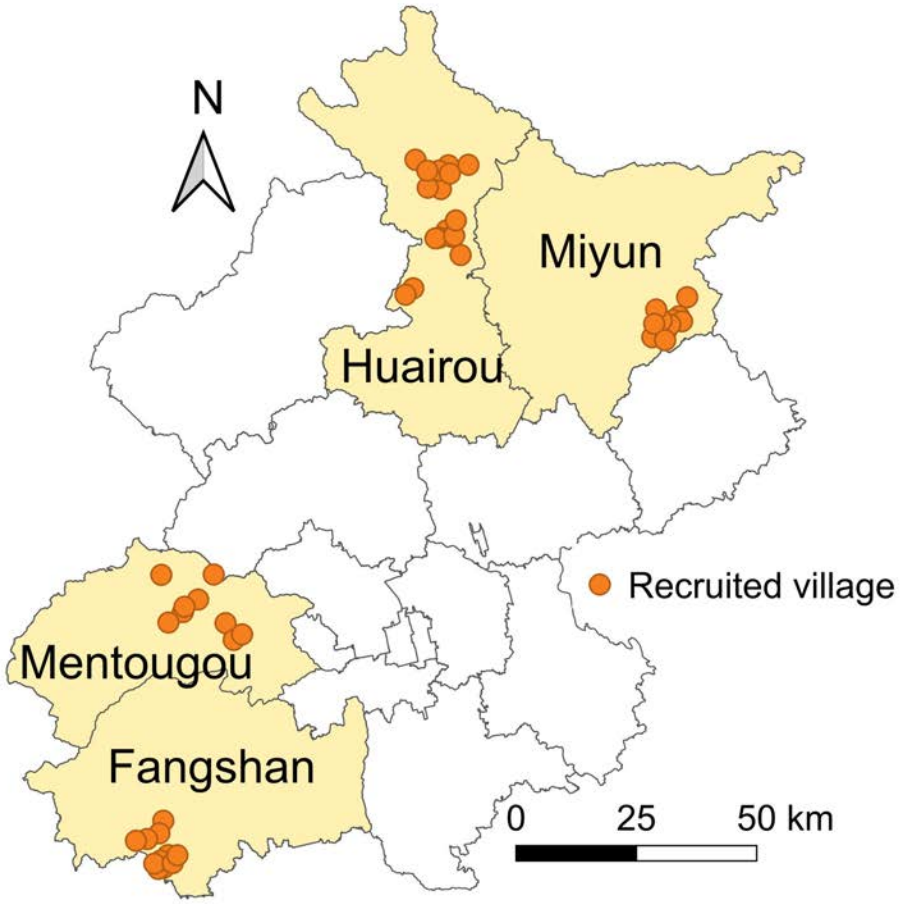
1. New-built, more airtight houses
2. No indoor coal combustion



Summary

1. Outdoor air quality was better in gas village compared to coal village.
2. Personal $PM_{2.5}$ exposures were higher in gas village compared to the coal village; however, crustal and coal tracer species were lower.
3. Indoor emissions and house construction are important drivers of personal exposure.

Field study in Beijing



Participants

- 50 villages in 4 districts
- 20 participants from 20 households
- Age>40 years old, mean= 60
- Rely on coal or biomass for heating at baseline

Air pollution measurements

Instruments: UPAS/PEM + Plantower sensor

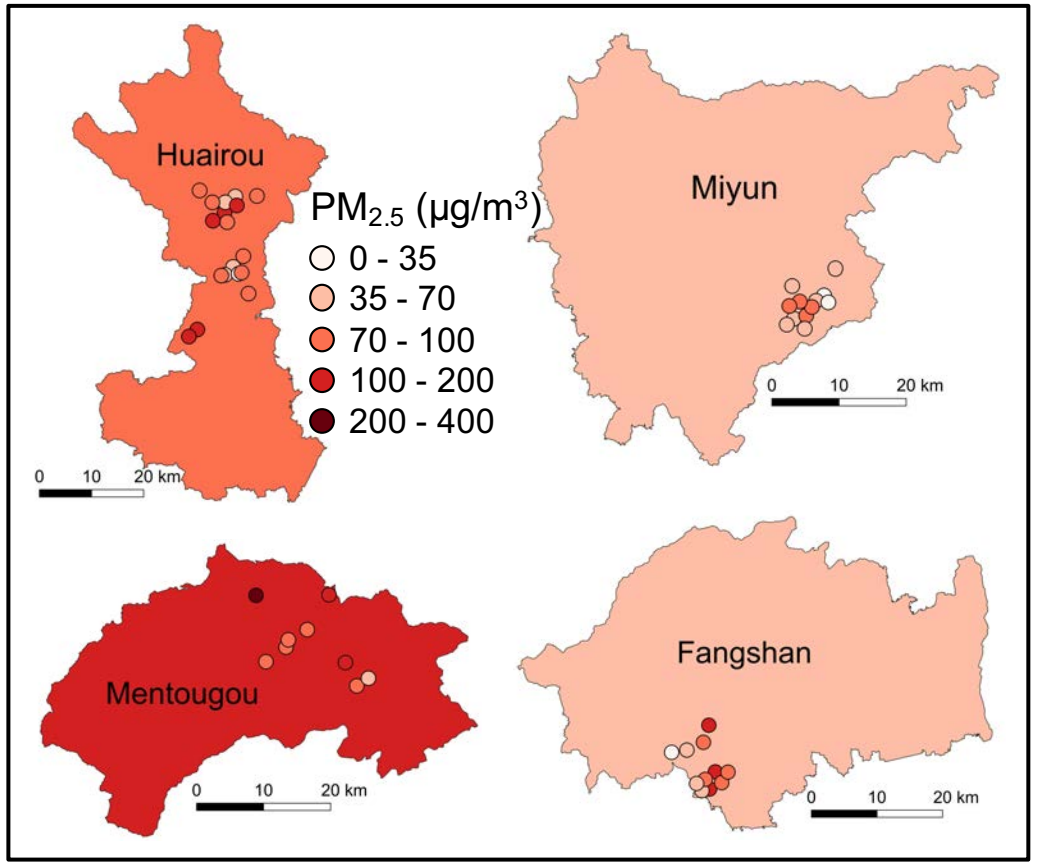
✓ Personal exposure: 24-h, ~10 per village

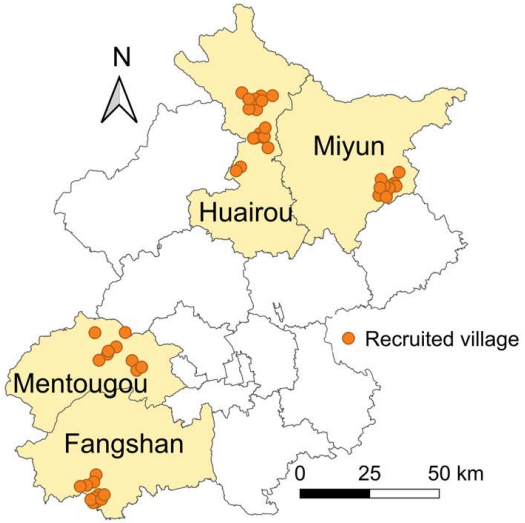
✓ Outdoor: >=1 sensor per village + 1 UPAS

✓ Indoor: 1 sensor in 6 homes per village,

1 UPAS in 3 homes per village

Personal exposure to $PM_{2.5}$ at base-line





- Personal $PM_{2.5}$ exposure in Mentougou is highest; lowest in Fangshan and Miyun.
- Within district, personal exposure to $PM_{2.5}$ varied by villages.
- The highest village-averaged personal $PM_{2.5}$ exposure was over 200 $\mu g/m^3$.

Distribution of personal exposure by socioeconomic status (SES)

Wealth index (stand for SES) estimation

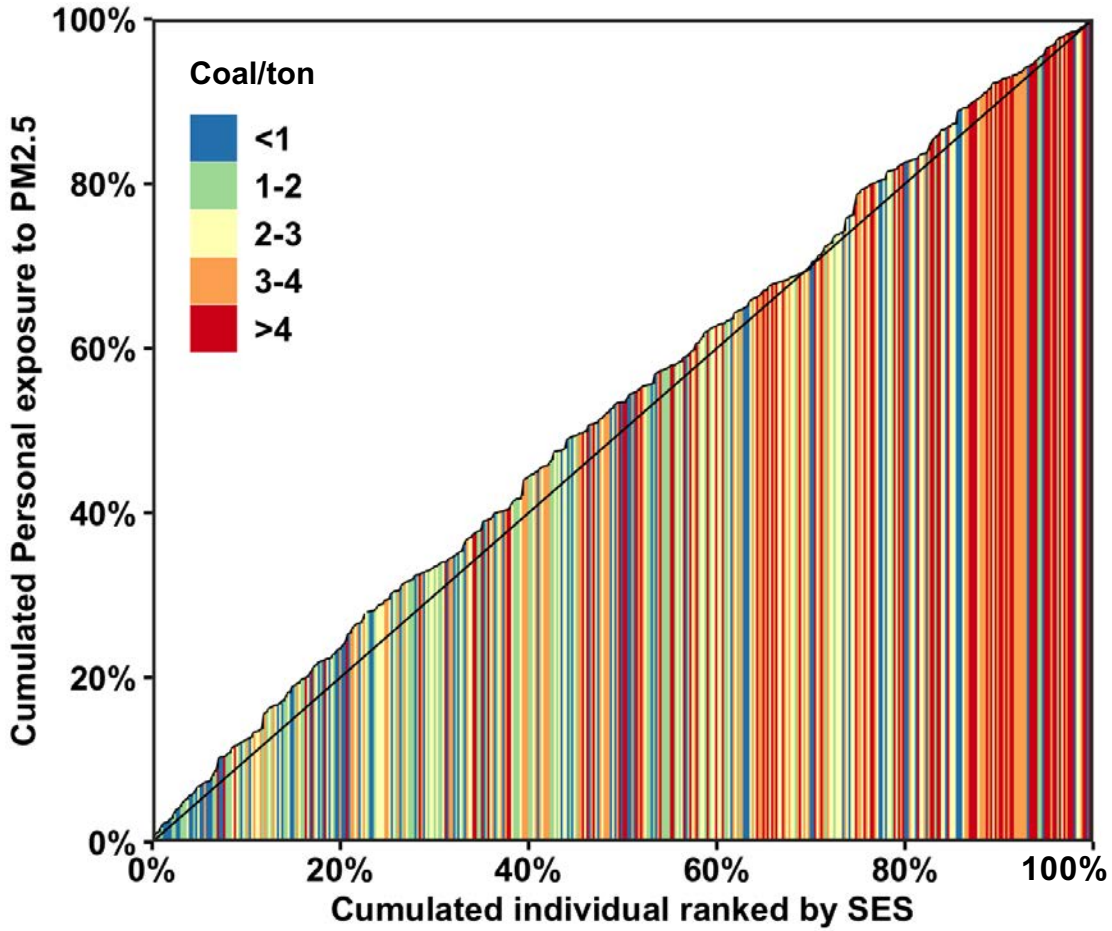
Applied Principle Component Analysis (PCA) with household assets (proxies of long term household wealth)

- Concentration curve above the 45° line (equality line):

  less wealthy households experience disproportionately higher air pollution exposures than wealthier households.

- Concentration curve lies below the equality line:

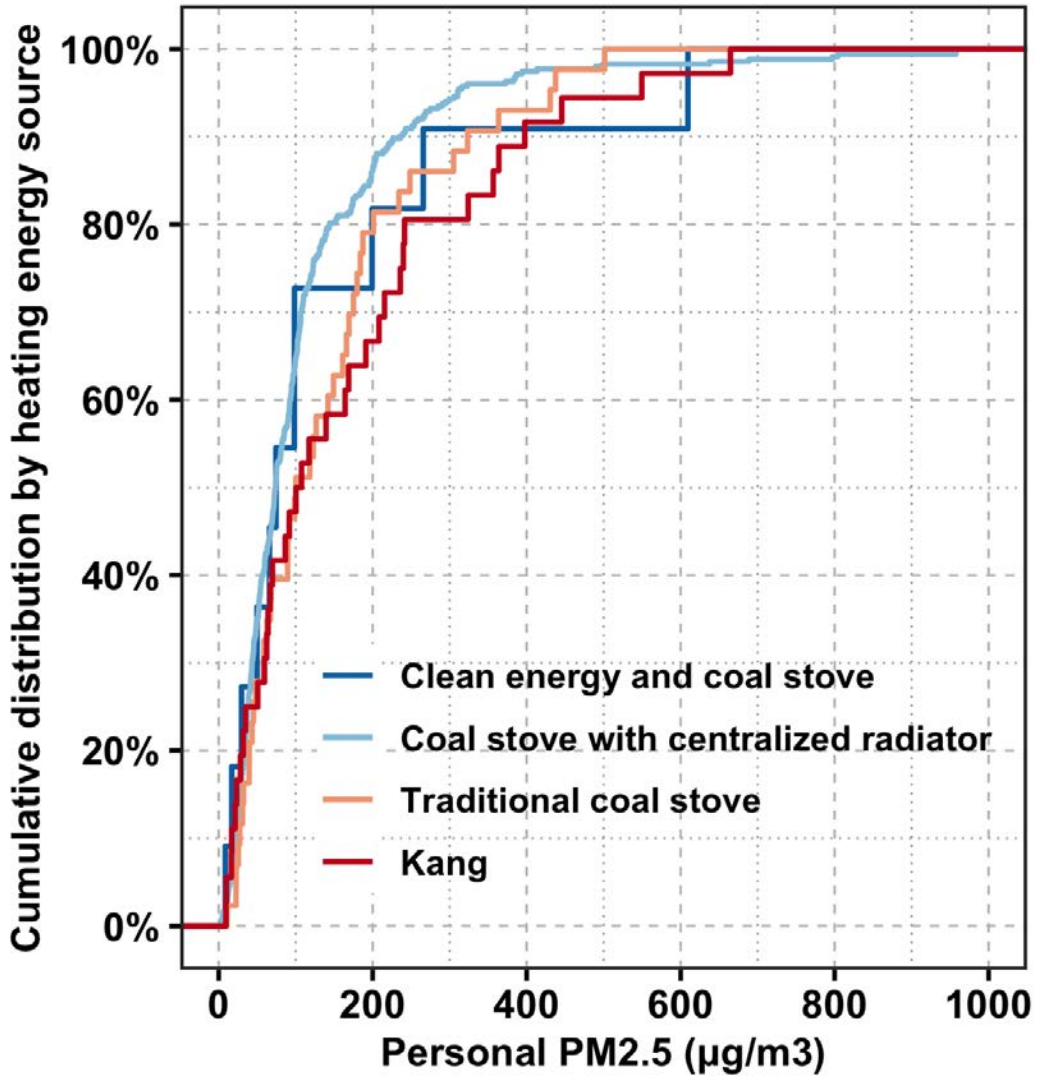
  wealthier participants have higher exposures.



1. Personal $PM_{2.5}$ did not demonstrate pronounced inequality by SES.

2. As wealth increased, people tended to use more coal for space heating.

Distribution of personal exposure by socioeconomic status (SES)

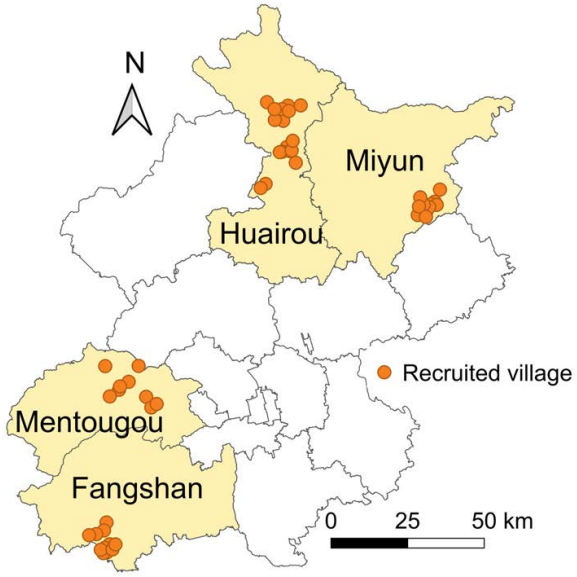


SES	coal (ton)	LPG (tank)	Biomass (ton)
Low	2.1 (1.5)	2.4 (1.5)	2.2 (5.9)
Middle	3.0 (1.6)	2.4 (1.4)	1.3 (1.8)
High	3.5 (1.9)	3.3 (3.4)	1.2 (1.5)

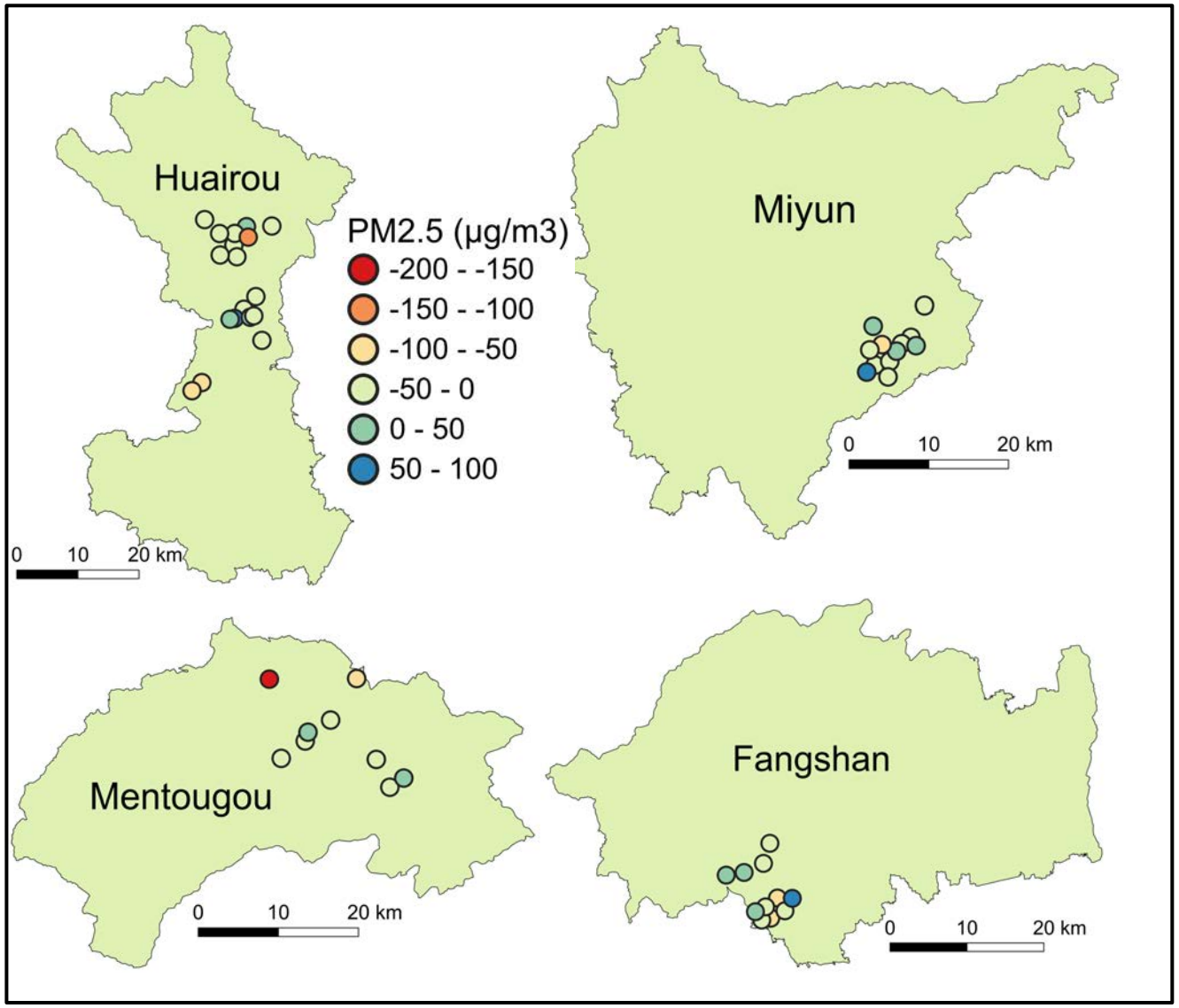
1. Personal $PM_{2.5}$ did not demonstrate pronounced inequality by SES.
2. As wealth increased, people tended to use more coal for space heating.
3. Less wealthy households were fuel-limited and tended to use less expensive and highly-polluting biomass fuel.

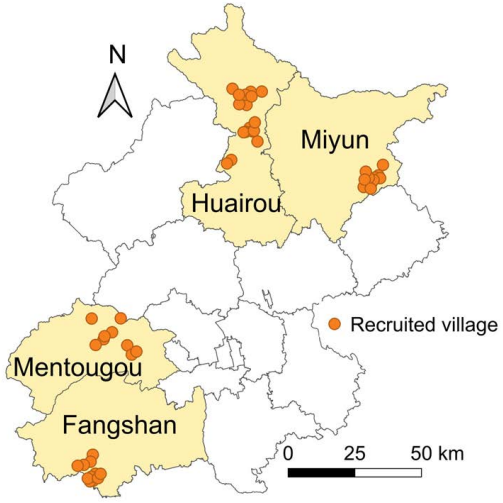
Year-2

1. Ten out of 50 villages became involved in household energy transition program.
2. Households in these villages ceased to use coal for cooking and heating, but continued to use their *Kang* for sleeping.
3. These ten villages were distributed among two of the four study districts; namely, in Huairou and Miyun.



Changes of personal exposure between Year-1 and Year-2



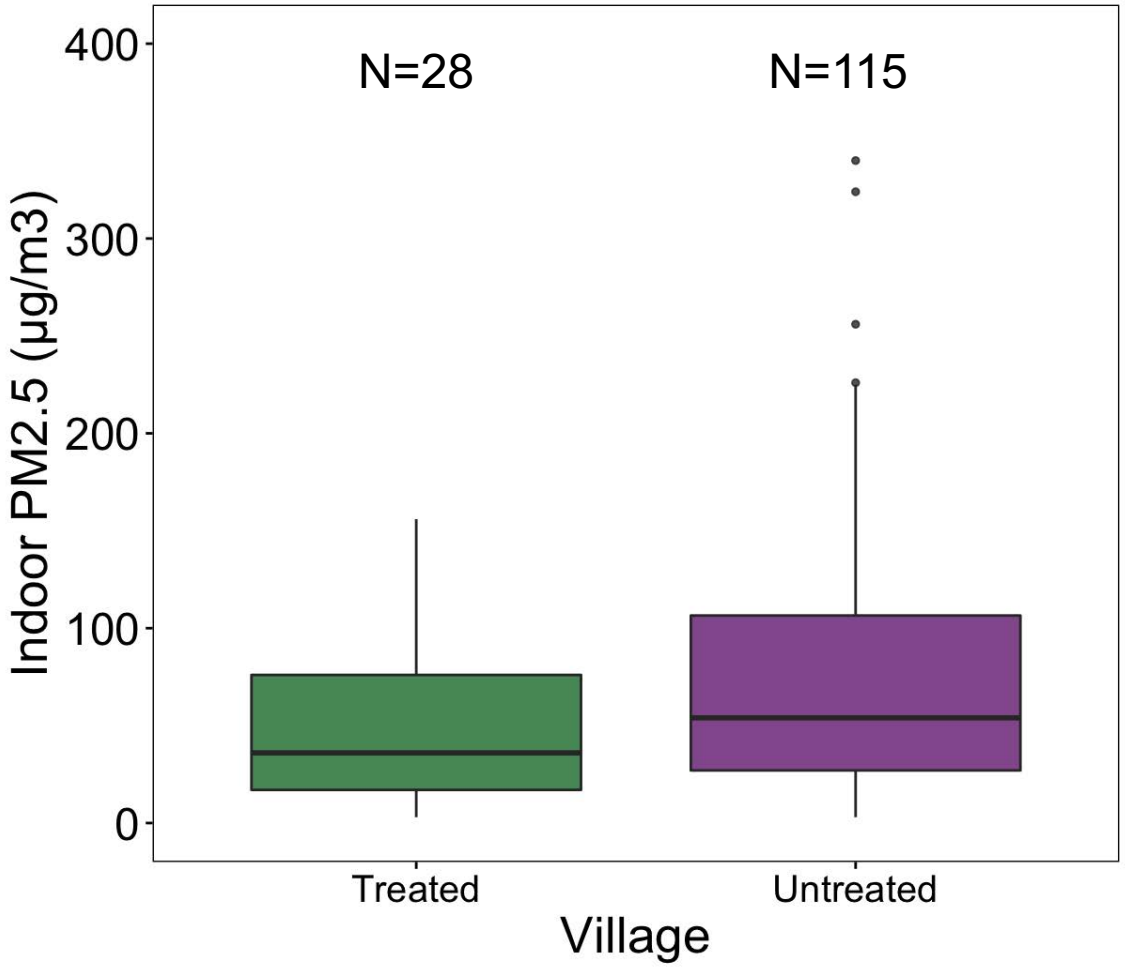


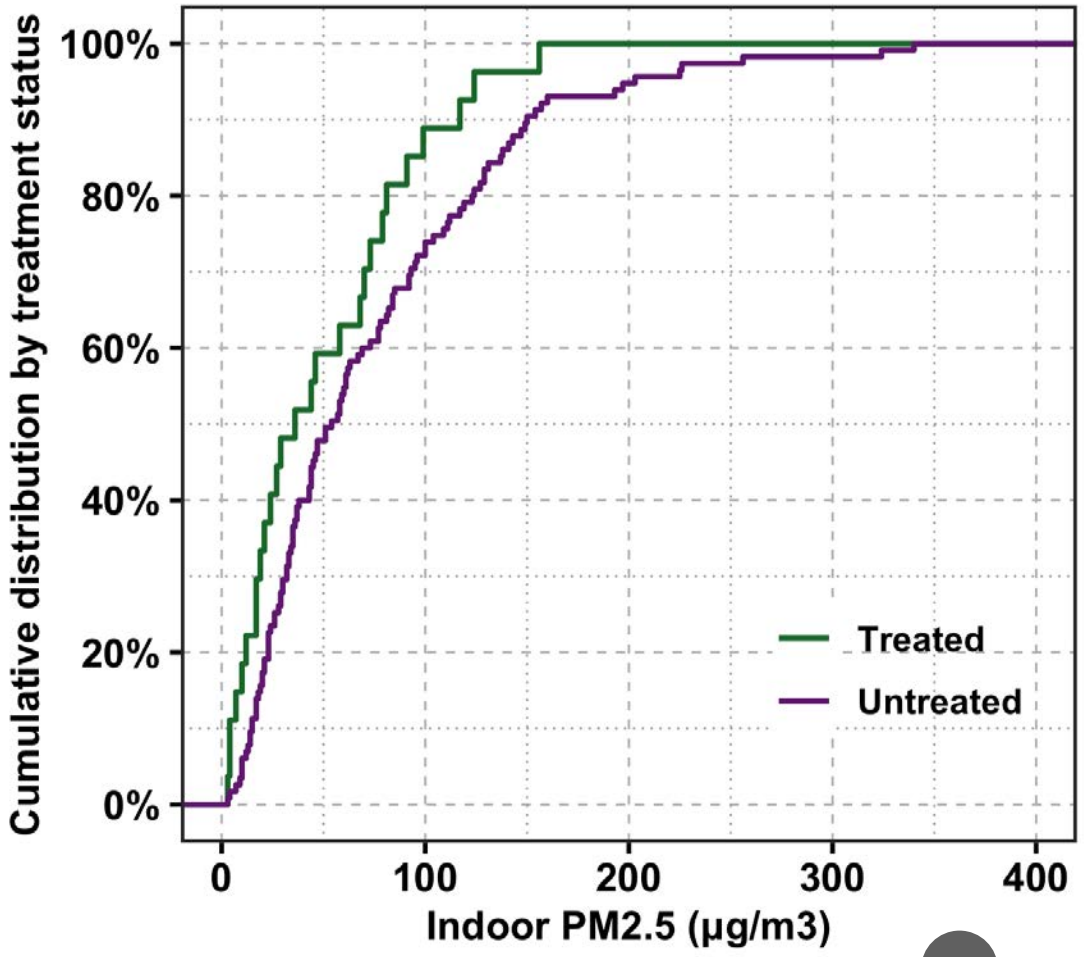
1. On average, personal exposure decreased in each districts in Year-2.

2. In most villages, the reduction of personal $PM_{2.5}$ was within 50 $\mu g/m^3$.

24-h indoor $PM_{2.5}$ in treated and untreated villages in Year-2

Treated villages =10; Untreated villages =40





Summary

At baseline,

1. $PM_{2.5}$ exposures were variable across villages and districts.
2. $PM_{2.5}$ exposure distributions in rural Beijing did not reveal pronounced inequality by SES.
3. Wealthier households tended to use more coal for space heating while the less wealthy households tended to use more biomass.

In Year-2,

1. Unadjusted personal $PM_{2.5}$ exposures decreased in Year-2 compared with Year-1.
2. Unadjusted indoor $PM_{2.5}$ concentrations appeared a trend that treated villages were lower compared to untreated villages.

Thank you!

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