Providing Clean Cooking in Developing Countries: What's the Big Deal?

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The Environmental Health Pathway


The three major solid fuels

The Environmental Health Pathway

Woodsmoke is natural – how can it hurt you?

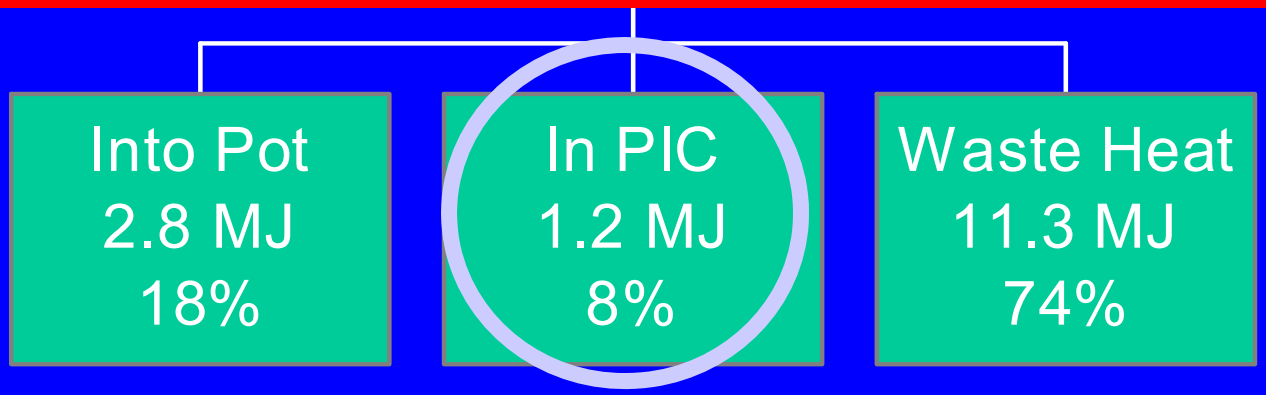
Or, since wood is mainly just carbon, hydrogen, and oxygen, doesn't it just change to CO_2 and H_2O when it is combined with oxygen (burned)?

Reason: the combustion efficiency is far less than 100%

Energy flows in a well-operating traditional wood-fired cookstove

A Toxic Waste Factory!!

Typical biomass cookstoves convert 6-20% of the fuel carbon to toxic substances



PIC = products of incomplete combustion = CO, HC, C, etc.

Source: Smith, et al., 2000

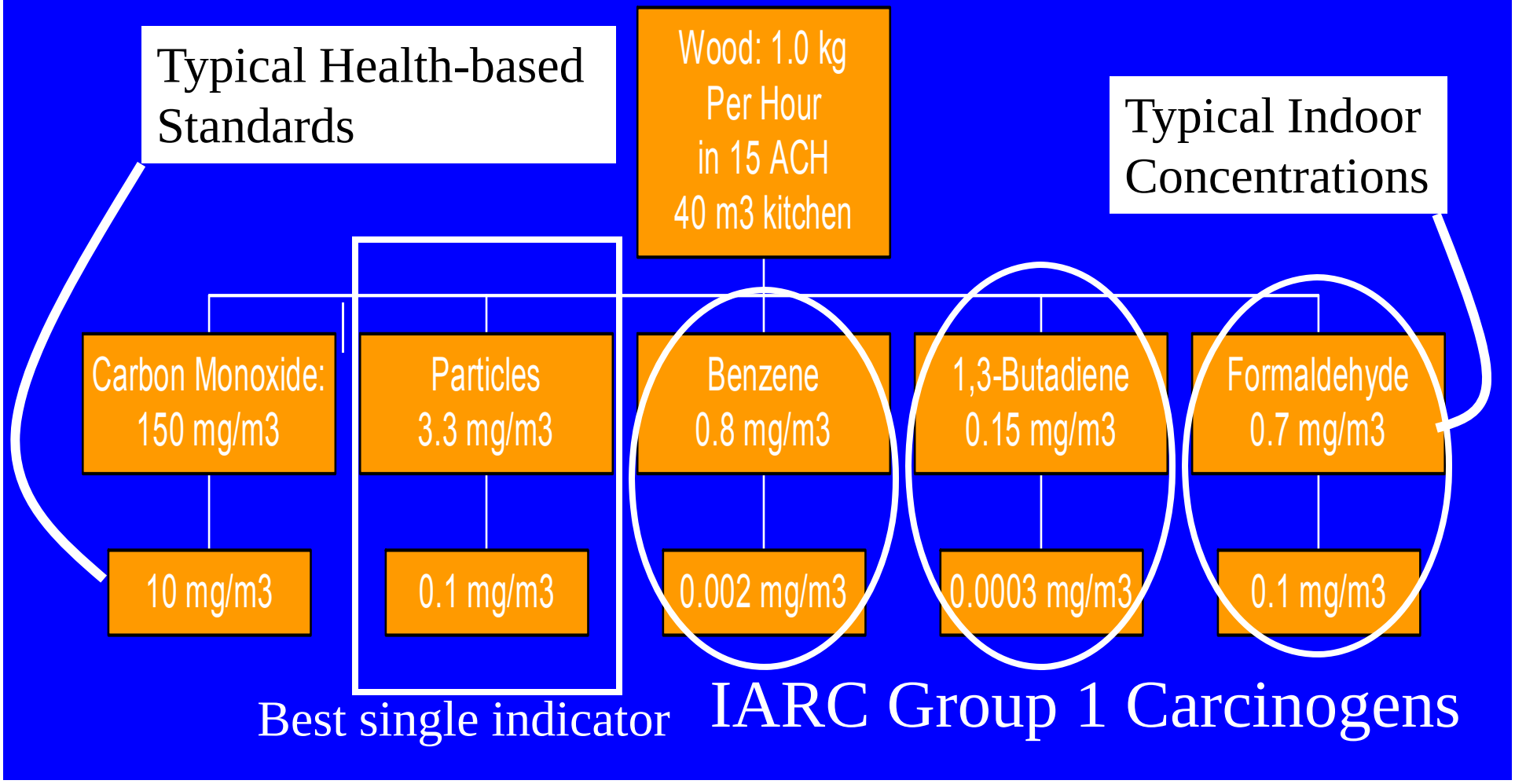
Toxic Pollutants in Biomass Fuel Smoke from Simple (poor) Combustion

- Small particles, CO, NO_2
- Hydrocarbons
  - 25+ saturated hydrocarbons such as *n-hexane*
  - 40+ unsaturated hydrocarbons such as *1,3 butadiene*
  - 28+ mono-aromatics such as *benzene & styrene*
  - 20+ polycyclic aromatics such as *benzo(α)pyrene*
- Oxygenated organics
  - 20+ aldehydes including *formaldehyde* & *acrolein*
  - 25+ alcohols and acids such as *methanol*
  - 33+ phenols such as *catechol* & *cresol*
  - Many quinones such as *hydroquinone*
  - Semi-quinone-type and other radicals
- Chlorinated organics such as *methylene chloride* and *dioxin*

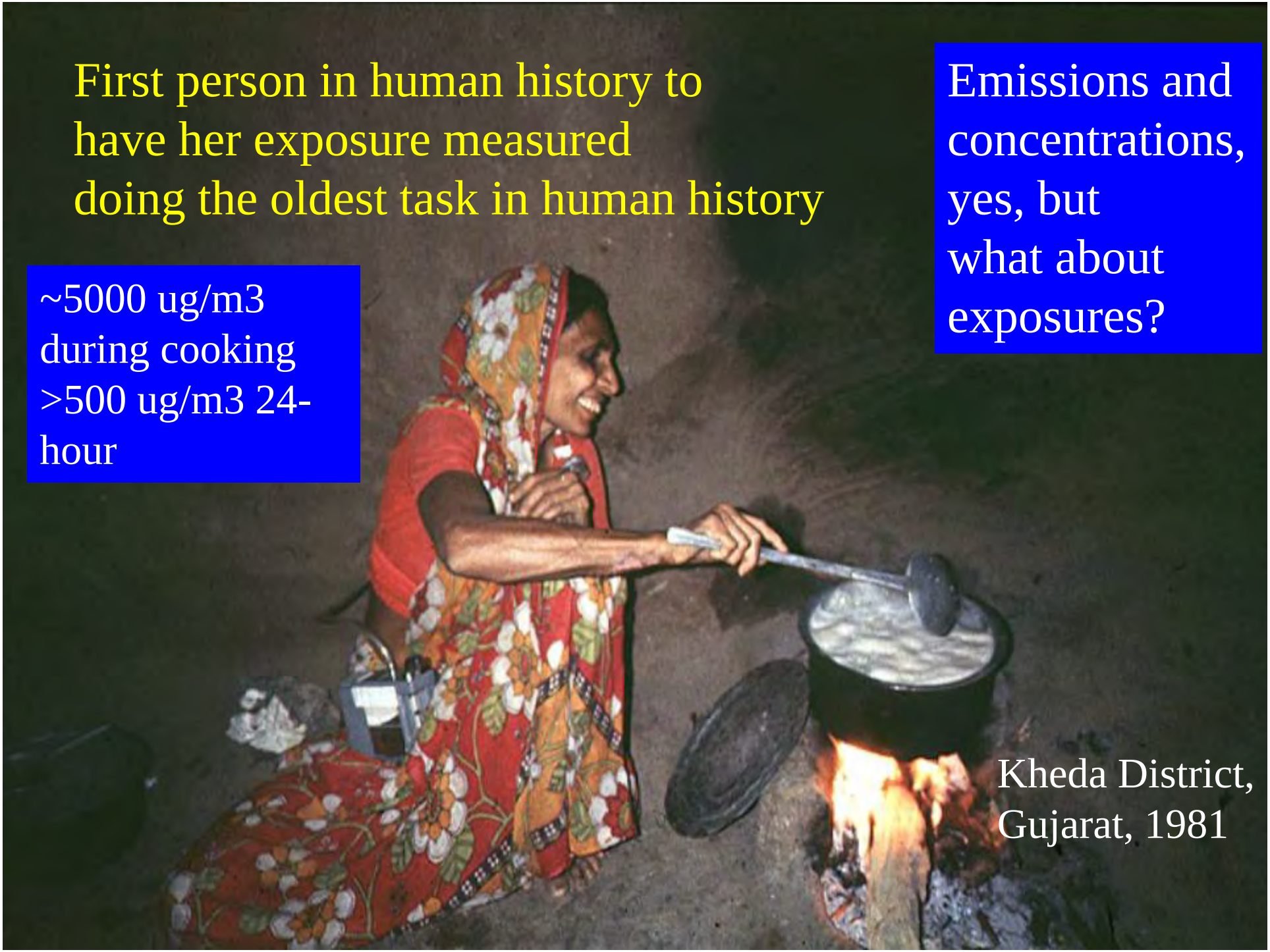
Source: Naeher et al, *J Inhal Tox*, 2007

The Environmental Health Pathway

Health-Damaging Air Pollutants From Typical Wood-fired Cookstove.



The Environmental Health Pathway


First person in human history to have her exposure measured doing the oldest task in human history
~5000 ug/m3 during cooking >500 ug/m3 24-hour
Emissions and concentrations, yes, but what about exposures?
Kheda District, Gujarat, 1981

The Environmental Health Pathway

How much PM2.5 is unhealthy?

- WHO Air Quality Guidelines
  - 10 ug/m3 annual average
  - No public microenvironment, indoor or outdoor, should be more than 35 ug/m3
- USEPA
  - Was 15 ug/m3 until 2012: annual outdoors
  - Now 12 ug/m3
  - Same as California since ~2000

A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010

Stephen S Lim‡, Theo Vos, Abraham D Flaxman, Goodarz Danaei, Kenji Shibuya, Heather Adair-Rohani, Markus Amann*, H Ross Anderson*, Kathryn G Andrews*, Martin Aryee*, Charles Atkinson*, Loraine J Bacchus*, Adil N Bahalim*, Kalpana Balakrishnan*, John Balmes*, Suzanne Barker-Collo*, Amanda Baxter*, Michelle L Bell*, Jed D Blore*, Fiona Blyth*, Carissa Bonner*, Guilherme Borges*, Rupert Bourne*, Michel Boussinesq*, Michael Brauer*, Peter Brooks*, Nigel G Bruce*, Bert Brunekreef*, Claire Bryan-Hancock*, Chiara Bucello*, Rachelle Buchbinder*, Fiona Bull*, Richard T Burnett*, Tim E Byers*, Bianca Calabria*, Jonathan Carapetis*, Emily Carnahan*, Zoe Chafe*, Fiona Charlson*, Honglei Chen*, Jian Shen Chen*, Andrew Tai-Ann Cheng*, Jennifer Christine Child*, Aaron Cohen*, K Ellicott Colson*, Benjamin C Cowie*, Sarah Darby*, Susan Darling*, Adrian Davis*, Louisa Degenhardt*, Frank Dentener*, Don C Des Jarlais*, Karen Devries*, Mukesh Dherani*, Eric L Ding*, E Ray Dorsey*, Tim Driscoll*, Karen Edmond*, Suad Eltahir Ali*, Rebecca E Engell*, Patricia J Erwin*, Saman Fahimi*, Gail Falder*, Farshad Farzadfar**

CRA published along with the other GBD papers on Dec 14, 2012 in *The Lancet*

Metrics

- Mortality – important, but can be misleading as it does not take age into account or years of illness/injury
  - Death at 88 years counts same as at 18, which is not appropriate
- Disability-adjusted Life Years (DALYs) lost do account for age and illness.
- GBD 2010 compares deaths against best life expectancy in world – 86 years

Diseases for which we have many epidemiological studies

ALRI/
Pneumonia

Low birth weight

Stillbirth

COPD

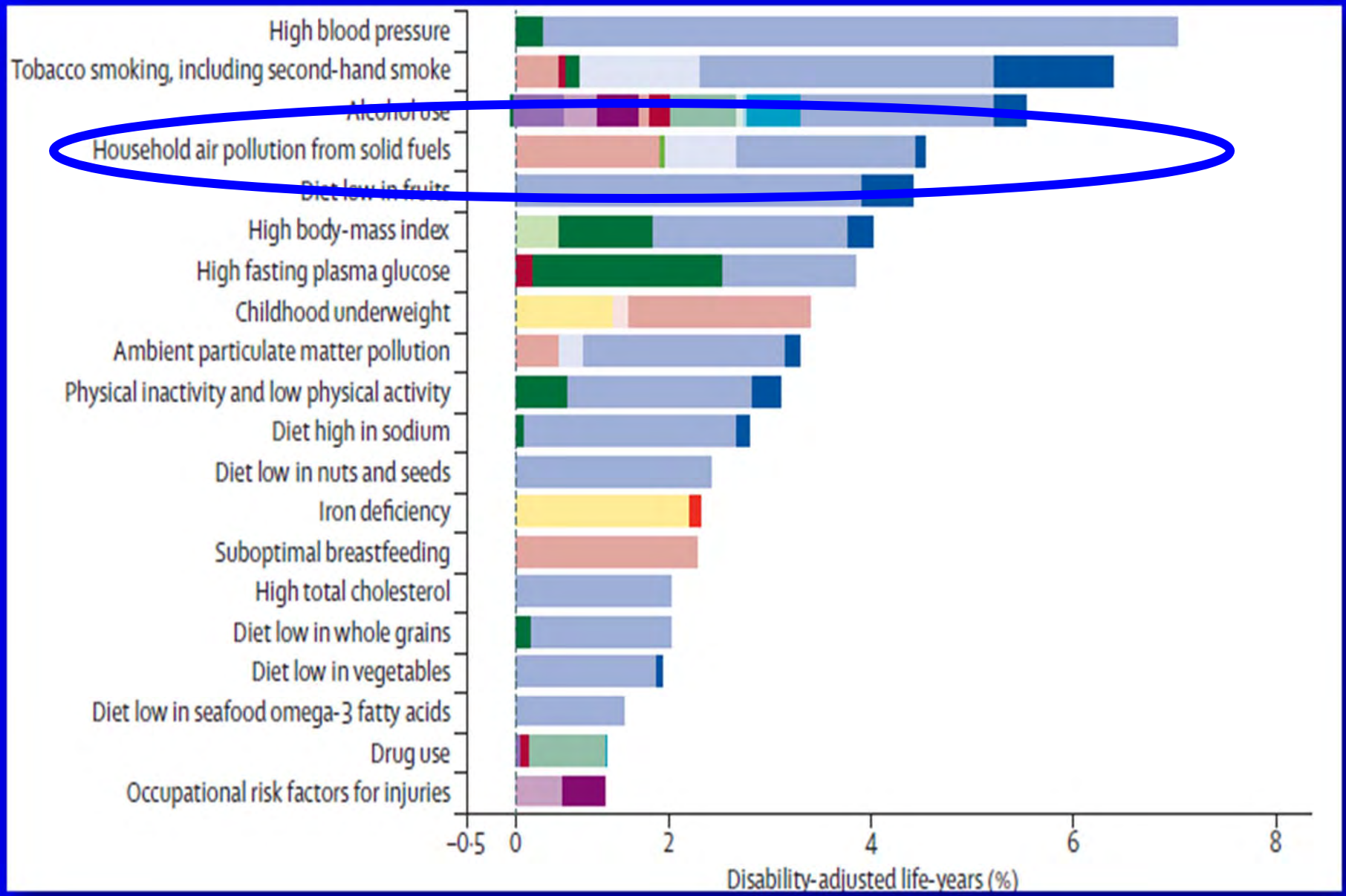
Lung cancer

Blindness
(cataracts, opacity)

Heart disease
Blood pressure
ST-segment

These diseases are included in the
2010 Comparative Risk Assessment (released in 2012)

Global DALYs 2010: Top 20 Risk Factors



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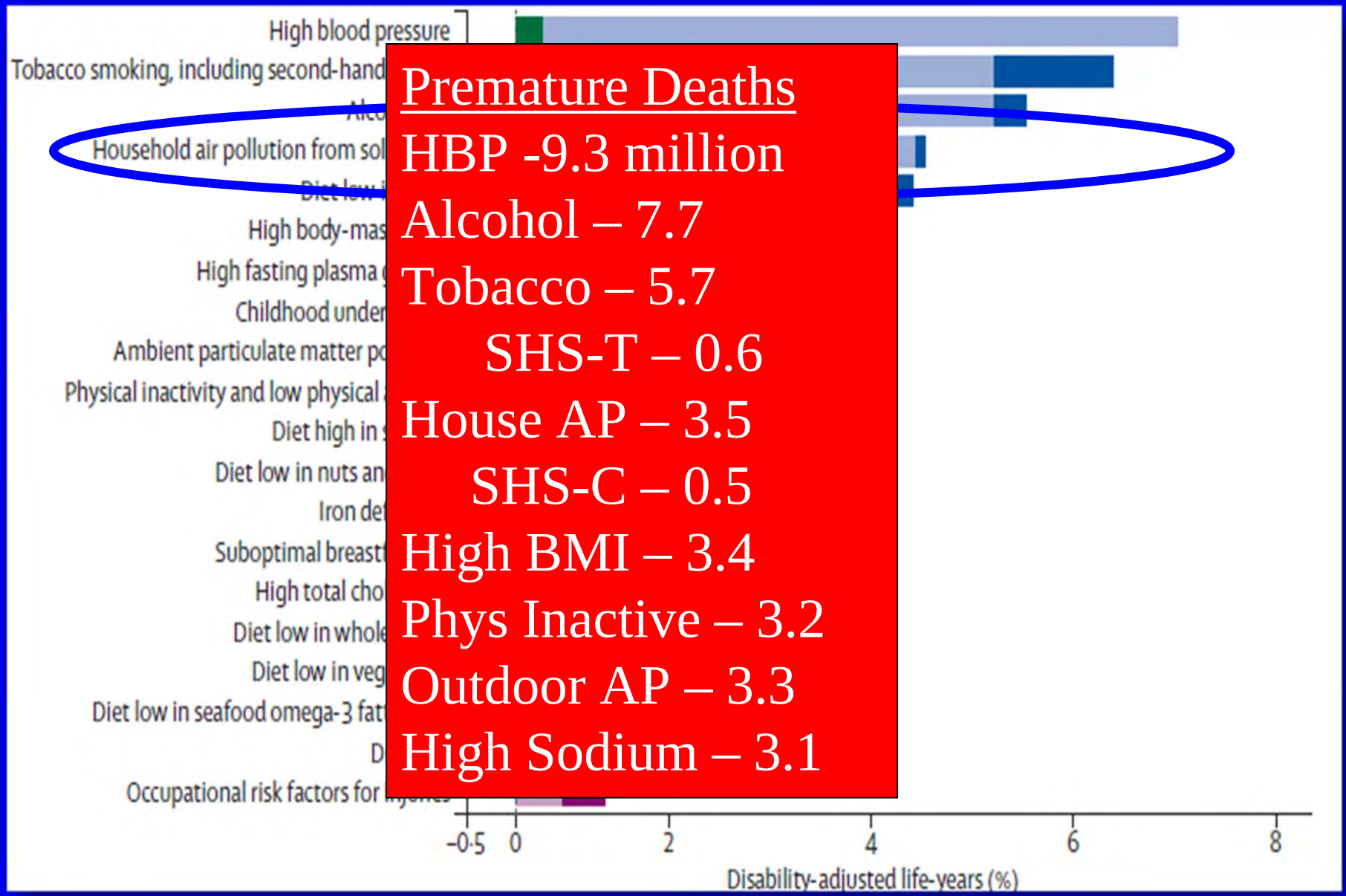


Premature Deaths

HBP -9.3 million

Alcohol – 7.7

Tobacco – 5.7

SHS-T – 0.6

House AP – 3.5

SHS-C – 0.5

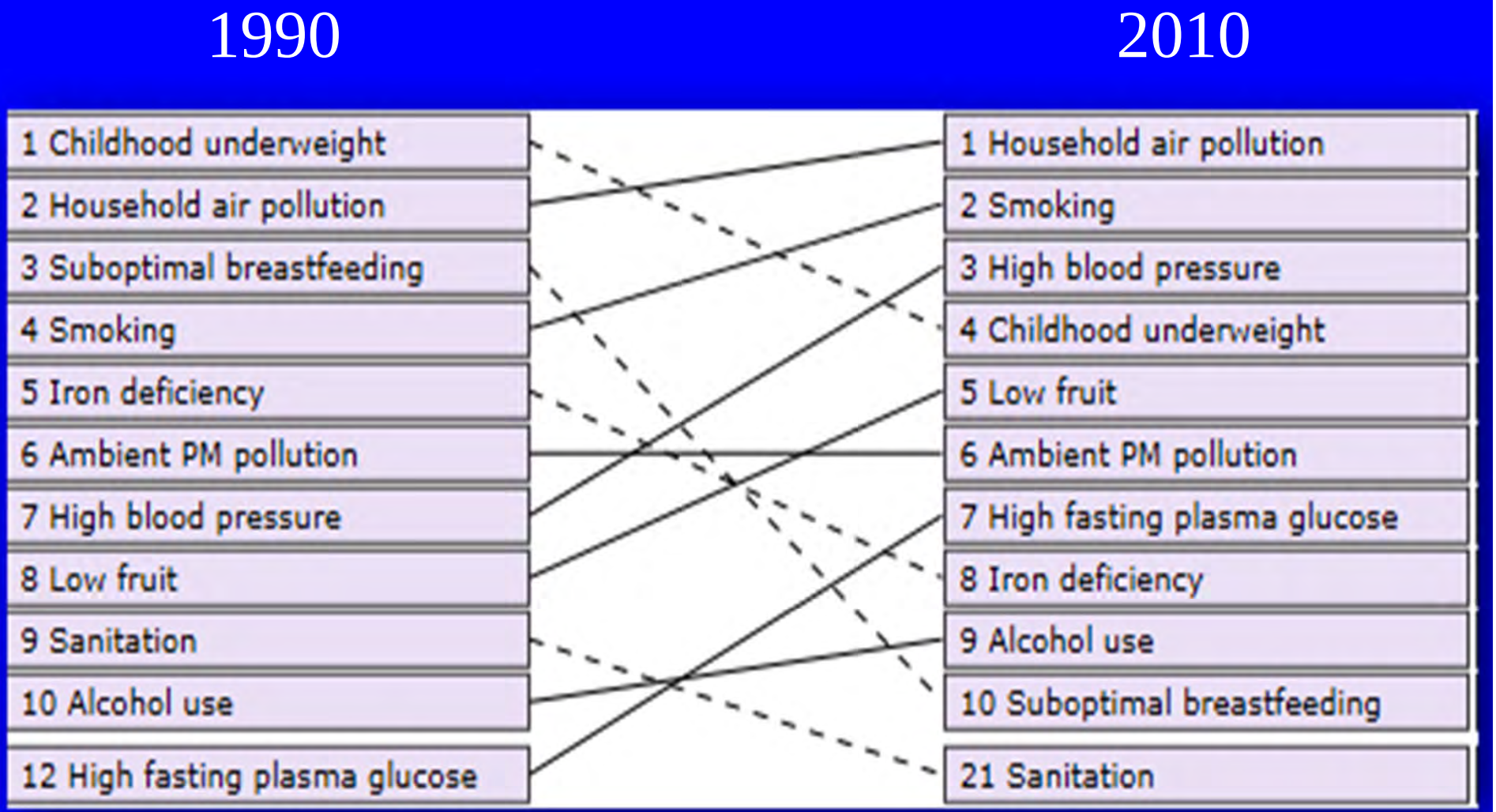
High BMI – 3.4

Phys Inactive – 3.2

Outdoor AP – 3.3

High Sodium – 3.1

DALYS. South Asia by Risk Factor



DALYS. South Asia by Risk Factor

1 Childhood under	ollution
2 Household air po	
3 Suboptimal brea	sure
4 Smoking	weight
5 Iron deficiency	
6 Ambient PM poll	ution
7 High blood press	sma glucose
8 Low fruit	
9 Sanitation	
10 Alcohol use	astfeeding
12 High fasting pl	

HAP in India in 2010
~900 thousand annual premature deaths
About one-quarter of global total

Secondhand cooksmoke
~150 thousand more

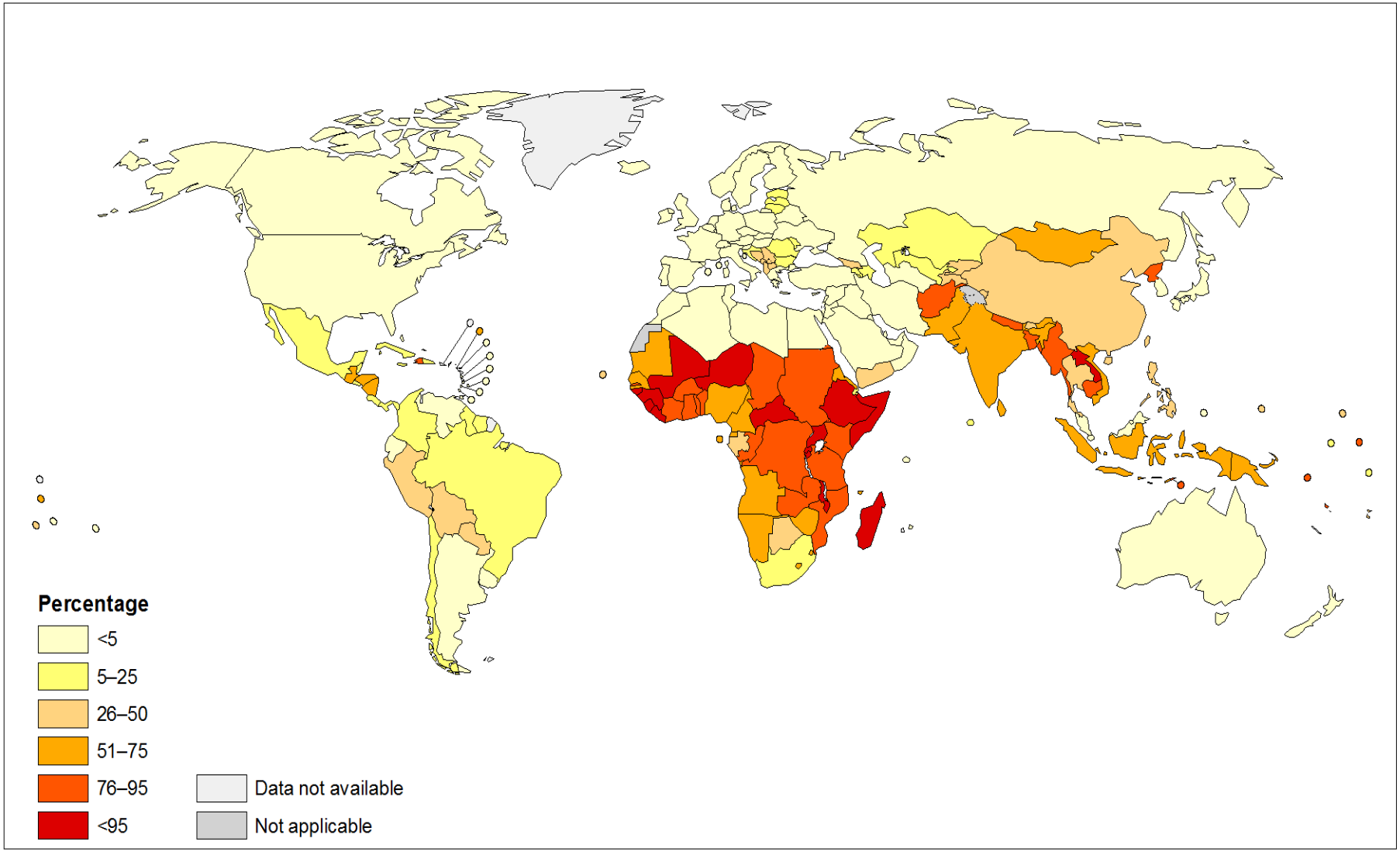
About 10% of national mortality

About the same as tobacco

The framing

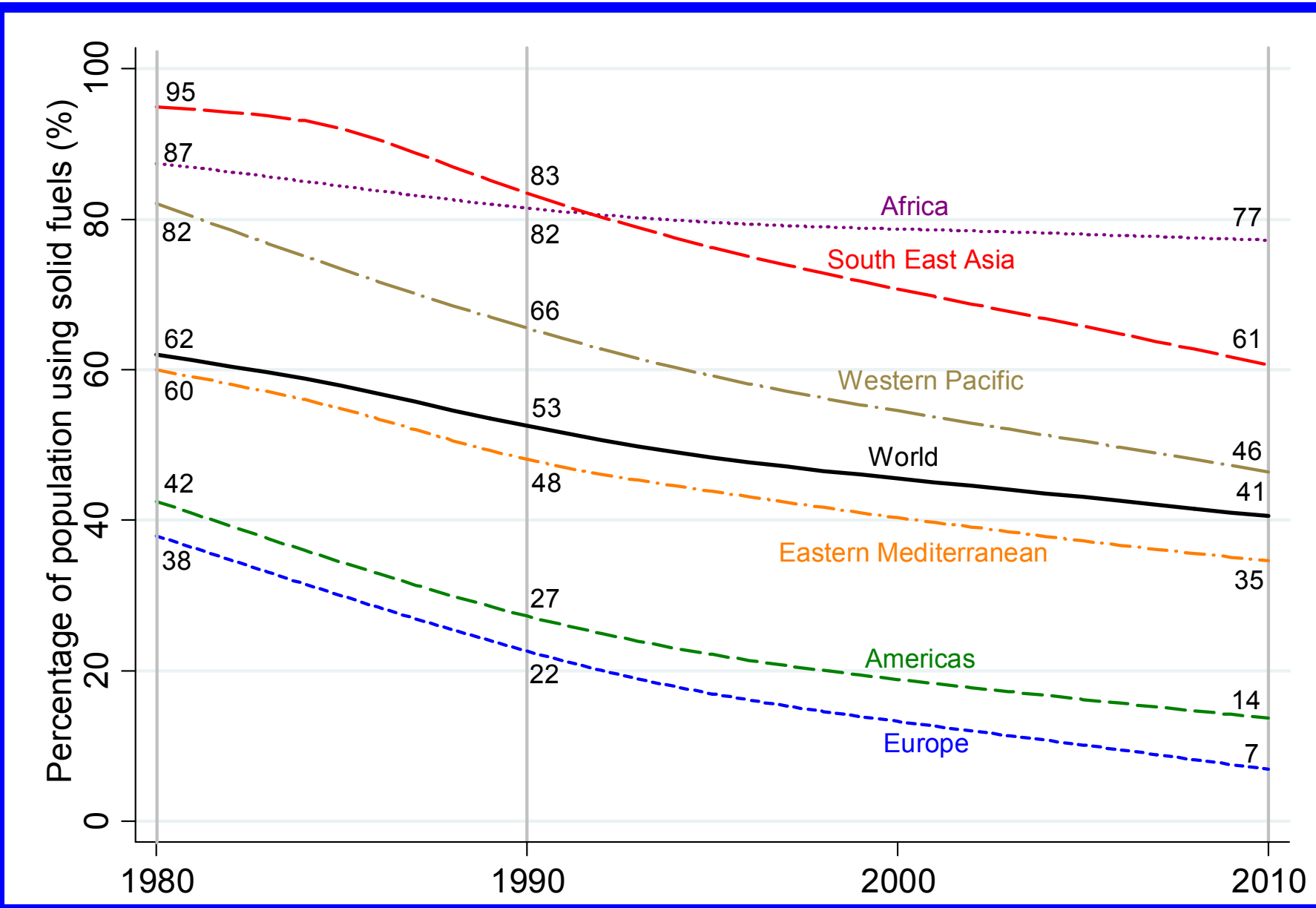
- Household air pollution from use of solid fuels for cooking
- Exposure based on percent of households using biomass or coal as their primary cooking fuel
- Country models informed now by ~600 nationally representative household surveys over 20+ years.
- Much less confusion with space heating, but not perfectly separated

Population Cooking with Solid Fuels in 2010 (%)



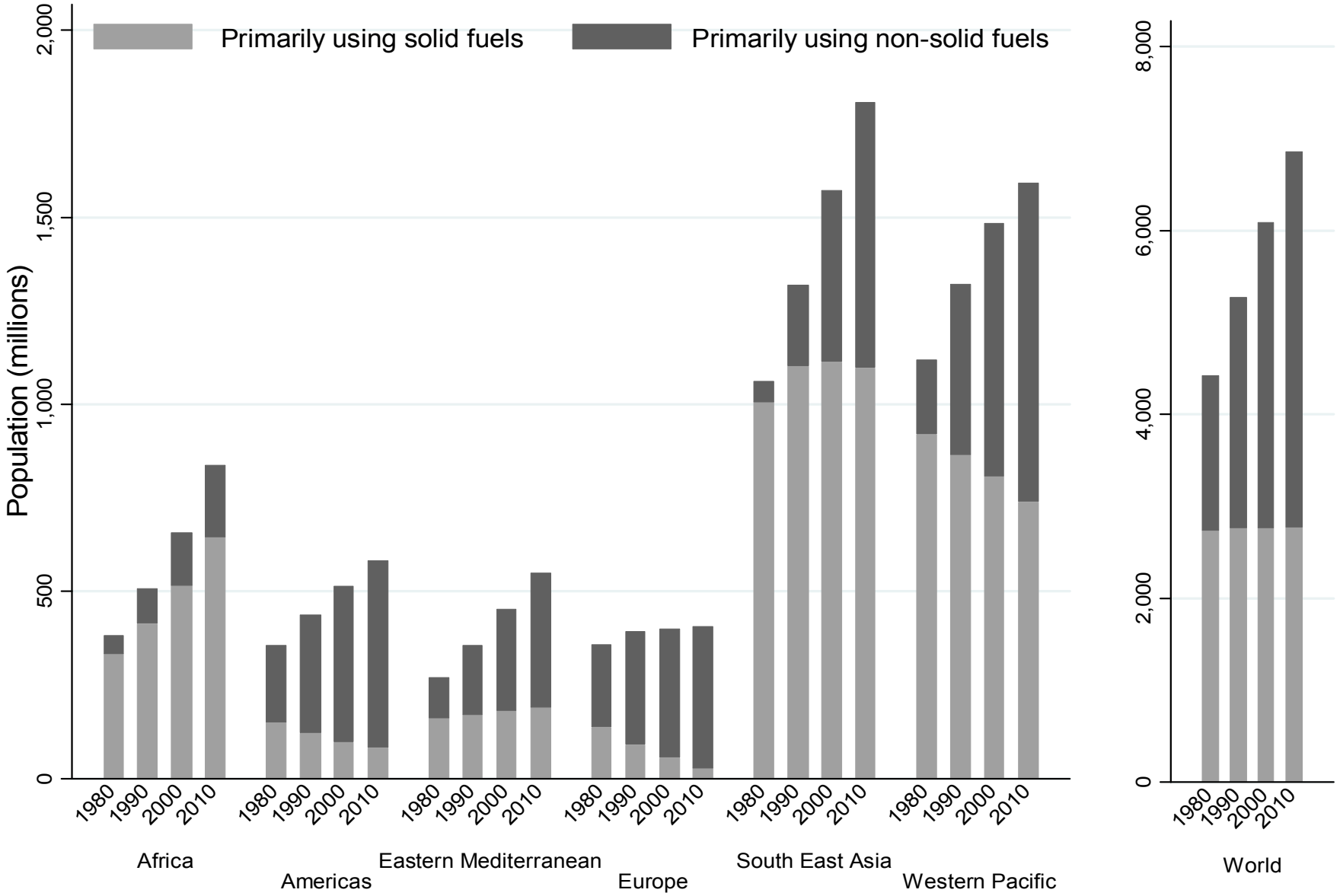
Data Source: World Health Organization
Map Production: Public Health Information and Geographic Information Systems (GIS)
World Health Organization

World Health Organization



Percent of households cooking with solid fuels by region

Bonjour et al., GBD-2010



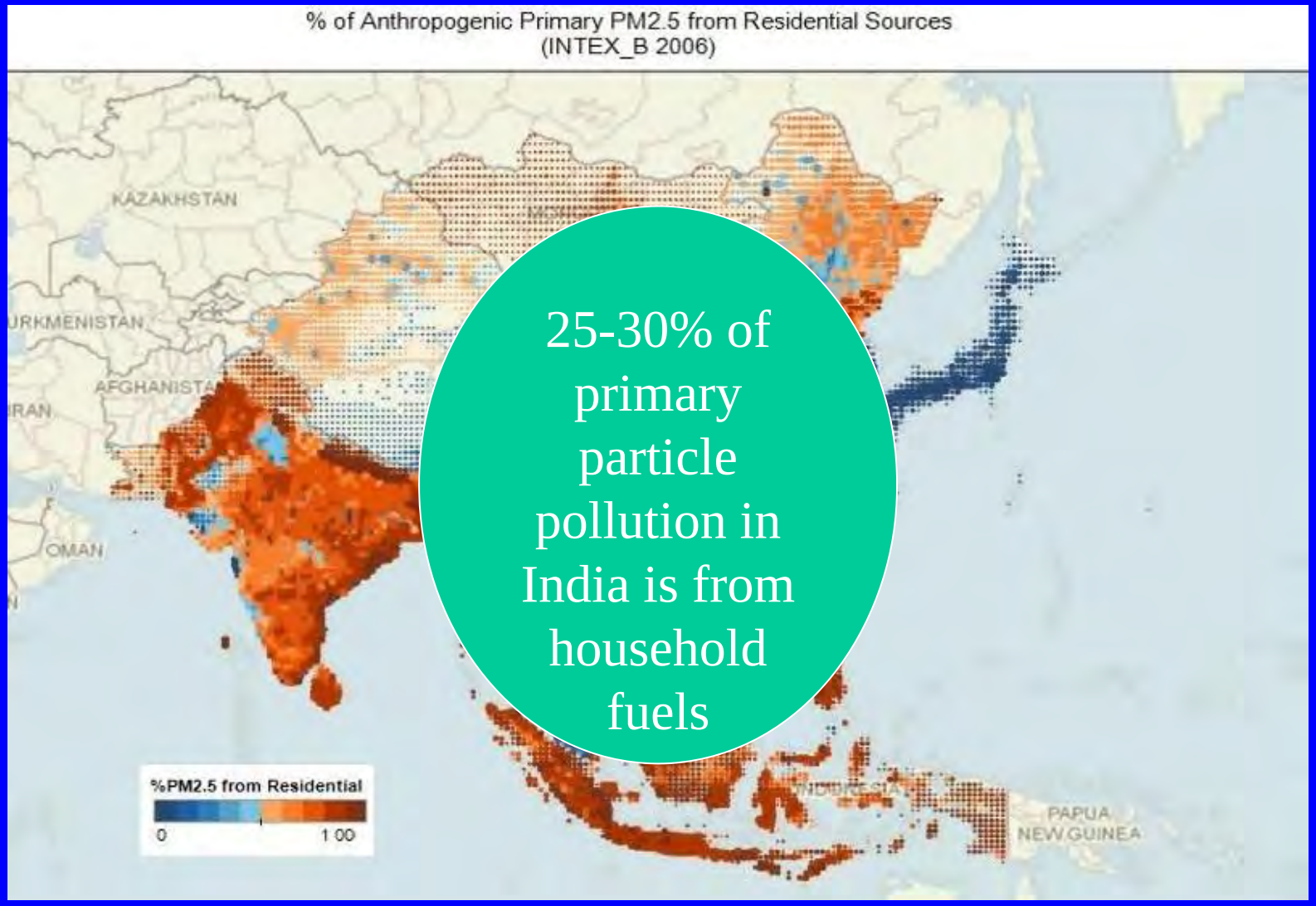
Total Population Cooking with Solid Fuels

Bonjour et al., CRA-2010

Framing, cont.

- Not called “indoor” because stove smoke enters atmosphere to become part of general outdoor air pollution (OAP)
- HAP contributes about 16% to OAP globally, but much more in some countries
- Thus, part of the burden of disease due to OAP is attributable to cooking fuels in households ~500,000 premature deaths.

%$PM_{2.5}$ from "Residential" Emissions from INTEX_B



Source: Asian Emission Inventory for NASA INTEX_B 2006 (accessed 2010)

Chafe, 2010


Delhi Jan 14, 2013
24h mean $PM_{2.5}$:
316.5 µg/m³


Rural India
24h mean $PM_{2.5}$:
195 µg/m^3

Urban Beijing
24-hr $PM_{2.5}$ (Jan 18-19): 334 µg/m^3

Source: PM data from US Embassy monitors in Beijing - https://twitter.com/BeijingAir
Photo from AP Images: http://seattletimes.com/html/nationworld/2020288471_chinapollutionxml.html

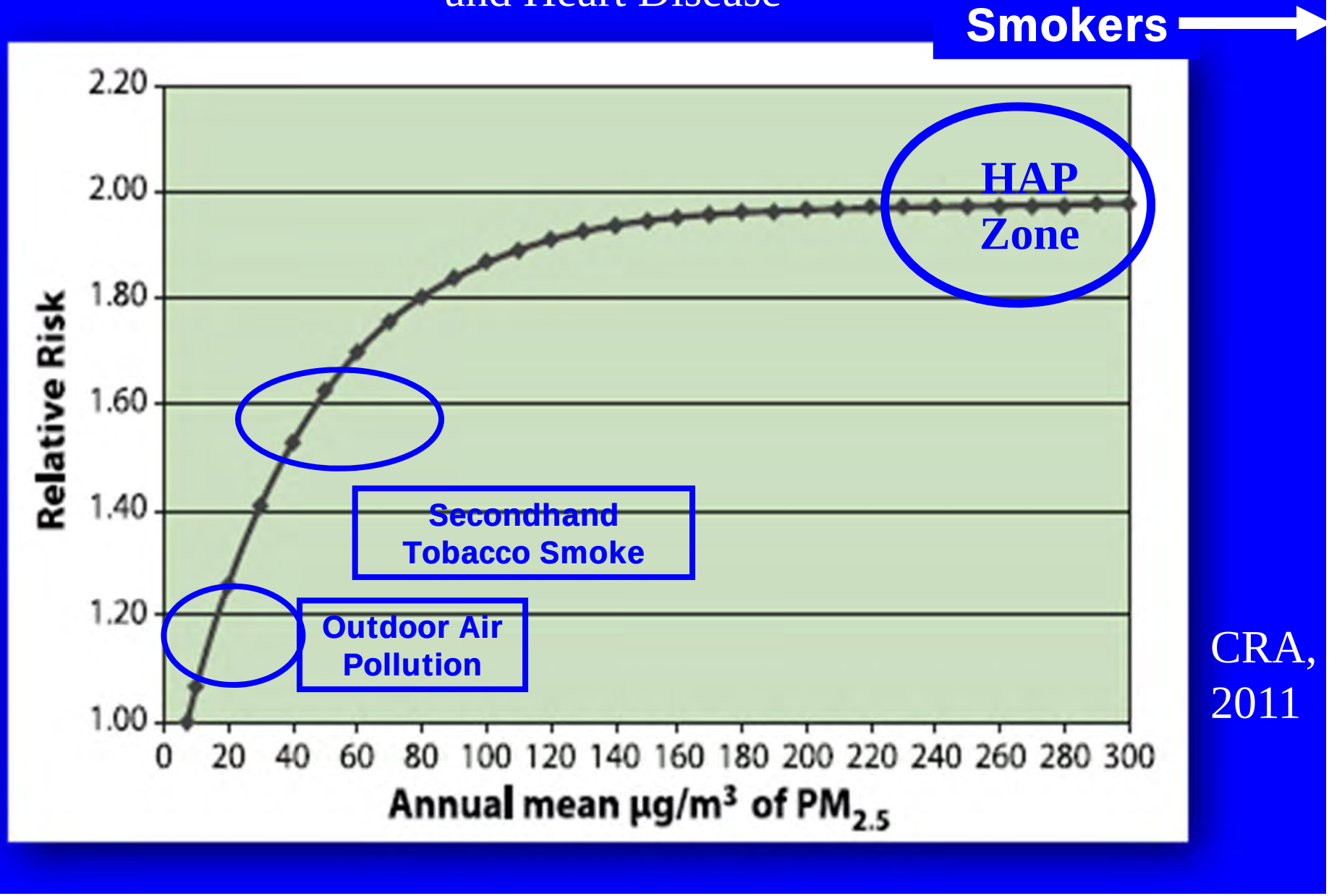
Rural Site outside Beijing
24-hr $PM_{2.5}$ (Jan 18-19): 695 $\mu g/m^3$

Source: Mean PM concentration from 2 gravimetrically calibrated DustTrak monitors on rooftops in ErHeZhuang Village, 40 km SW from central Beijing. Photos & measurements in village from Anna Zimmermann (Smith research group).

Framing, cont.

- Much effort made to make estimates consistent across the four combustion particle groups in the new GBD/CRA
- Active tobacco smoking, household air pollution, secondhand tobacco smoking, and outdoor air pollution
- HAP and OAP use the same counterfactual level for nearly all diseases: ~7 ug/m3 annual mean PM2.5 concentration
- Roughly equivalent to cooking with a vented gas stove or electricity

Integrated Exposure-Response: Outdoor Air, SHS, and Smoking and Heart Disease



CRA, 2011

Bottom Lines

- One of the top risk factors in the world for ill-health.
- Most important environmental risk factor among all examined
- Biggest impact in adults --3 million premature deaths (two-thirds the DALYs)
- Still important for children ~500,000 deaths (one-third the DALYs)
- Important source of outdoor air pollution
- Impact going down slowly because background health conditions improving
- Actual number of people affected is not going down

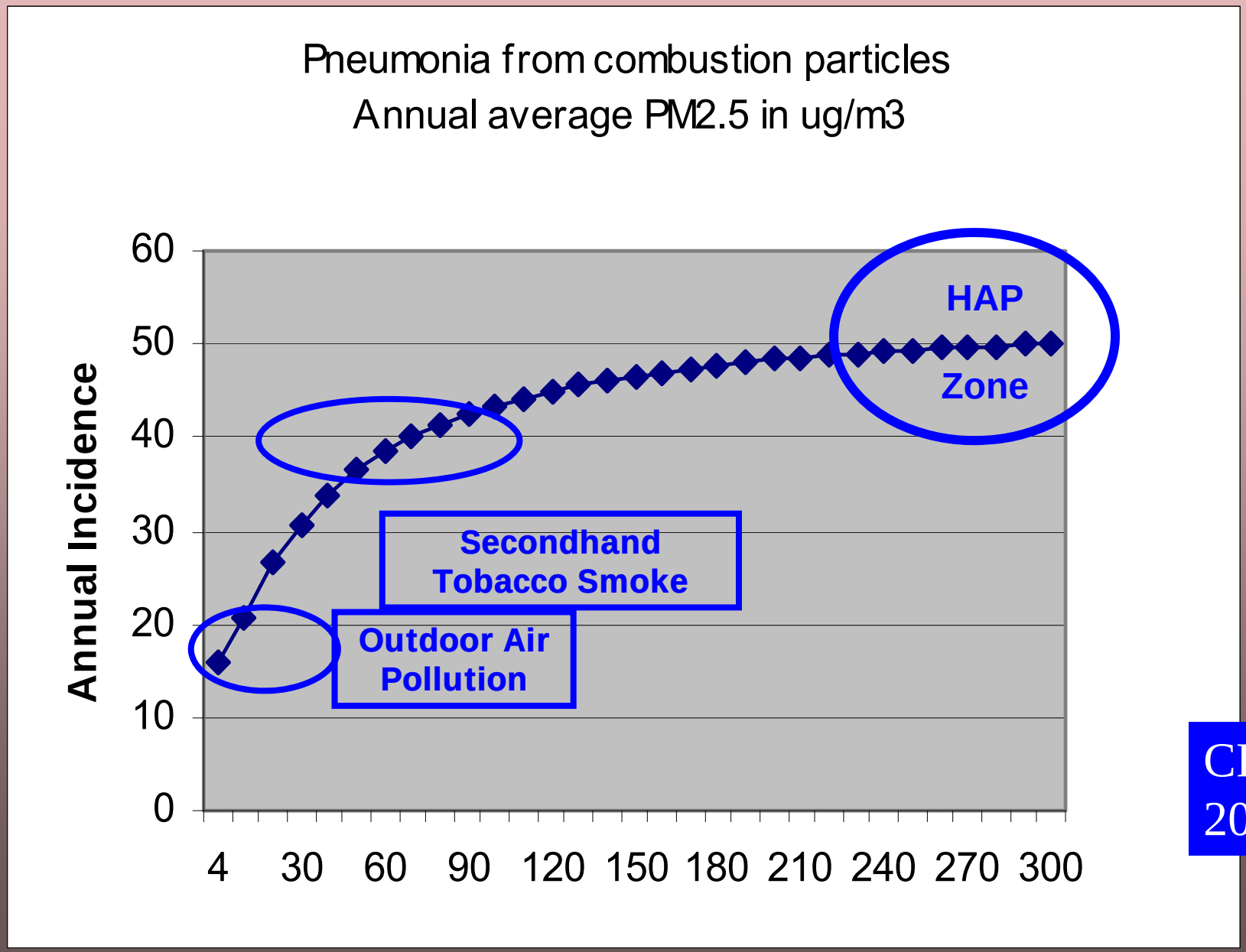
Not all diseases included

- Many with evidence not included yet
  - Low birth weight
  - TB
  - Other cancers – cervical, upper respiratory, etc
  - Cognitive effects
  - Pneumonia in adults
- Can expect that HAP effects, over time, will be found for nearly all the many dozen diseases found for smoking.
- But at lower risk levels

Important!

- Implied health benefit from HAP reduction only potentially achieved by shifting to clean cooking – gas & electricity

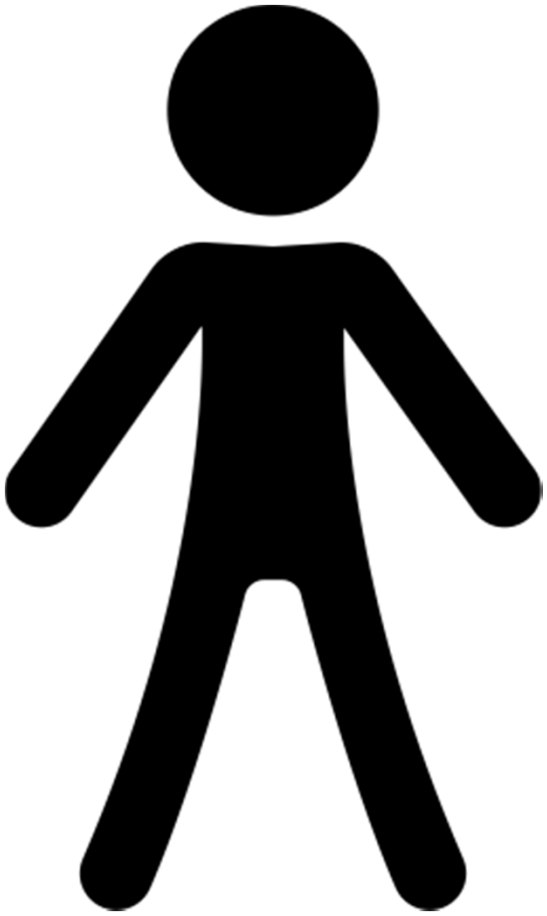
Integrated Exposure-Response: Outdoor Air, SHS, and HAP



CRA, 2010

What is to be done?

A fresh look



World cooking in Pictograms –

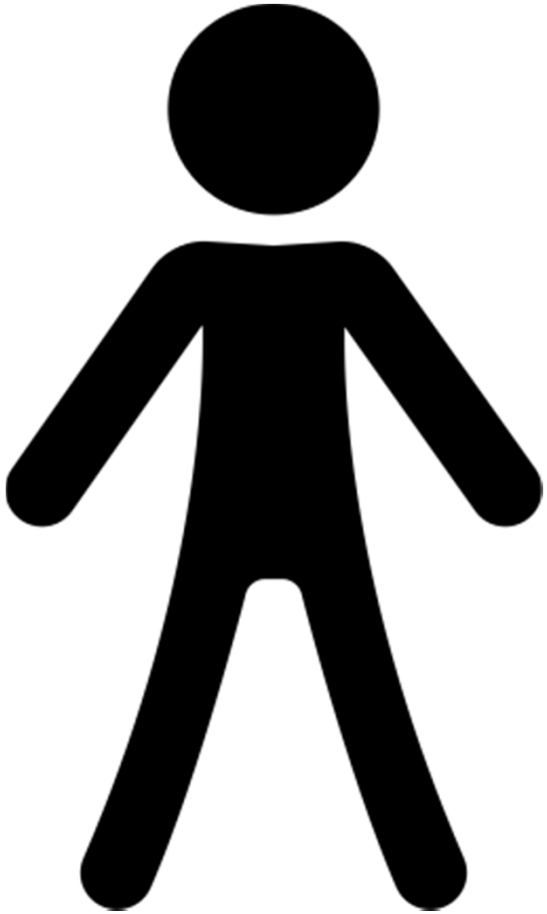
One billion people each

With apologies to
Hans Rosling at Gapminder*

*”Magic Washing Machine”

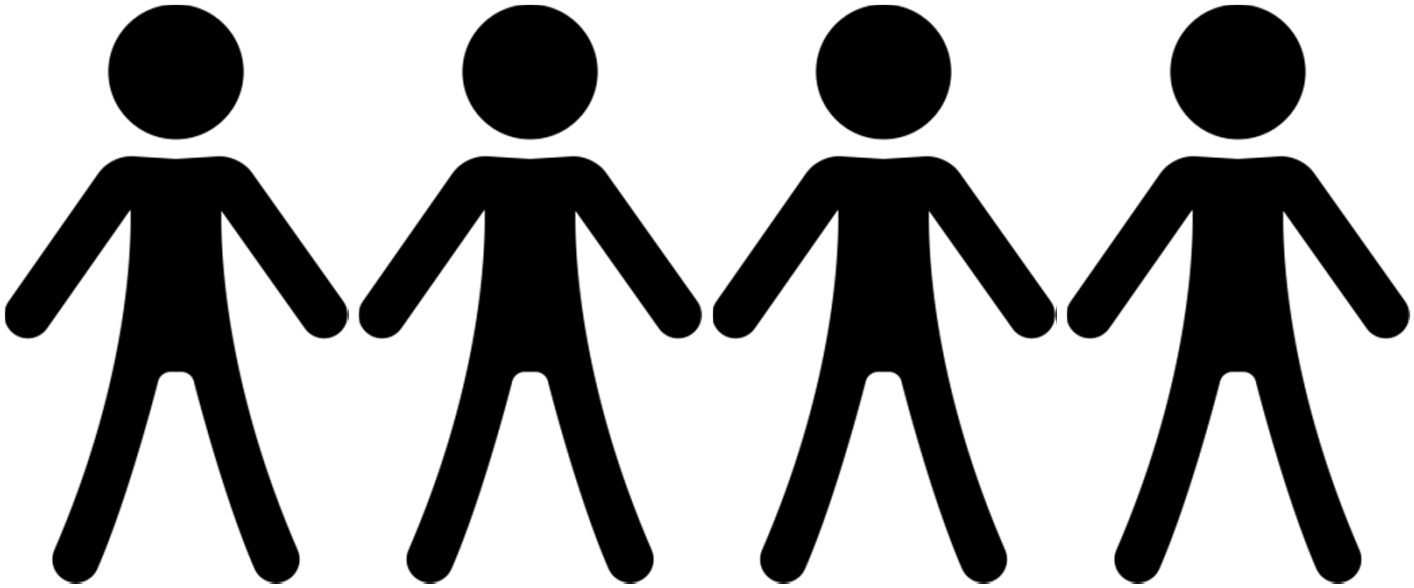
And thanks to Ajay Pillarisetti

What do the richest one billion people cook with?



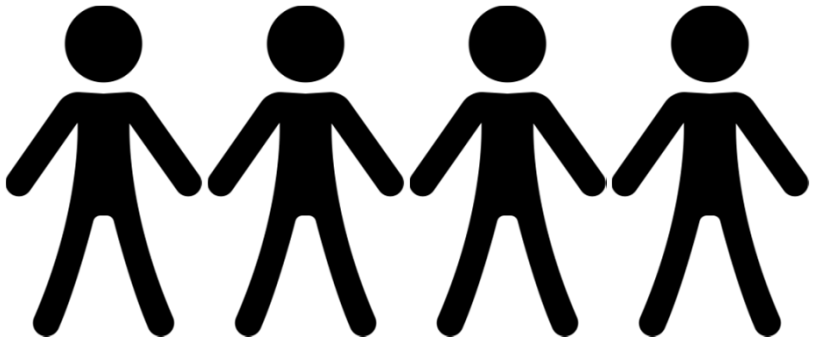
Gas or electric stoves

Plus



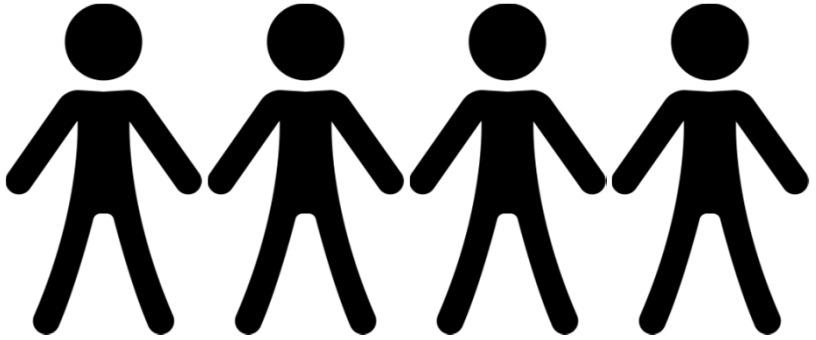
~4 billion worldwide cook with liquified petroleum gas, natural gas, and electricity

What about the other 3 billion?



SMOKING SECTION

NON-SMOKING



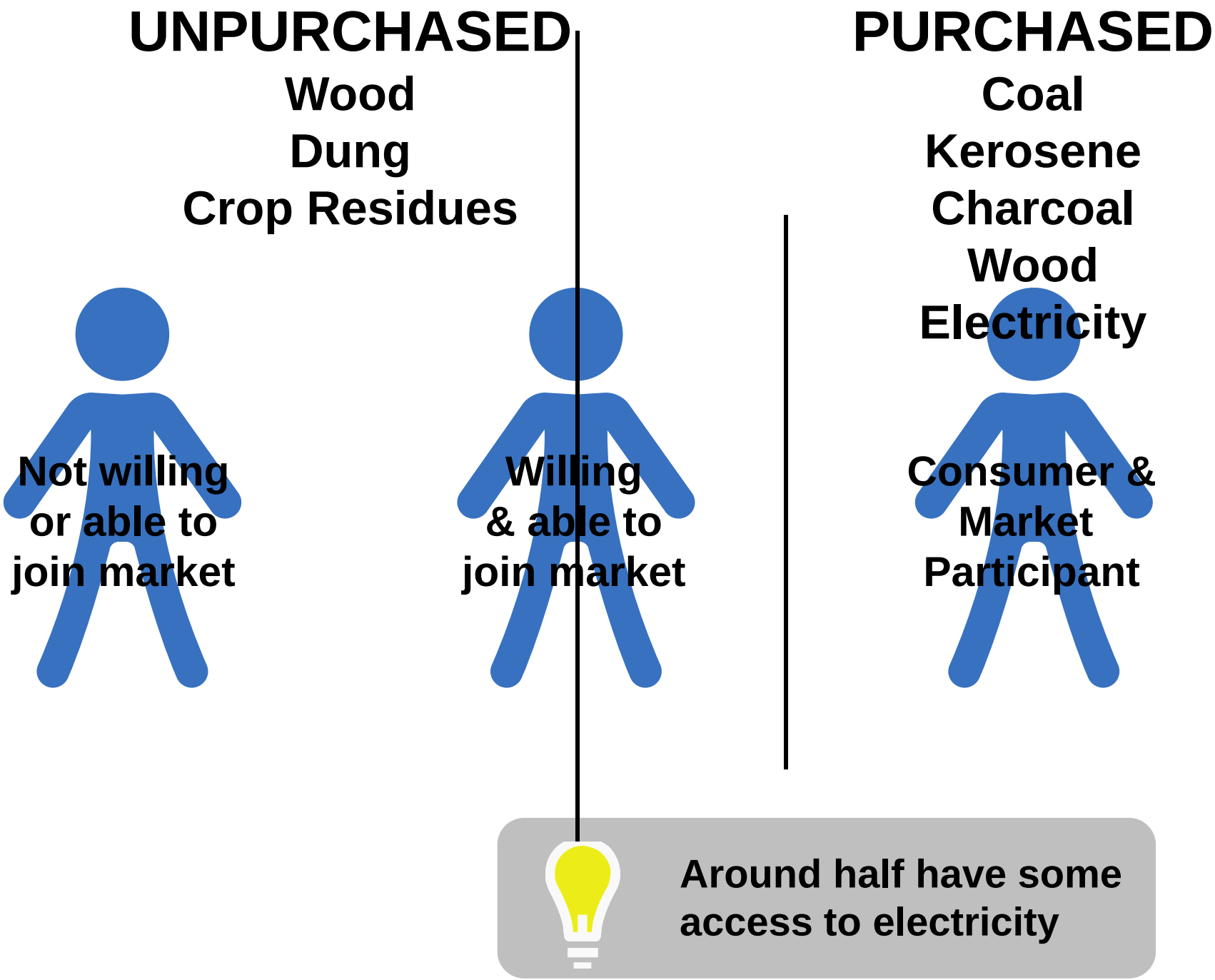
LPG

Natural Gas

Electricity

MARKET BASED OPTIONS

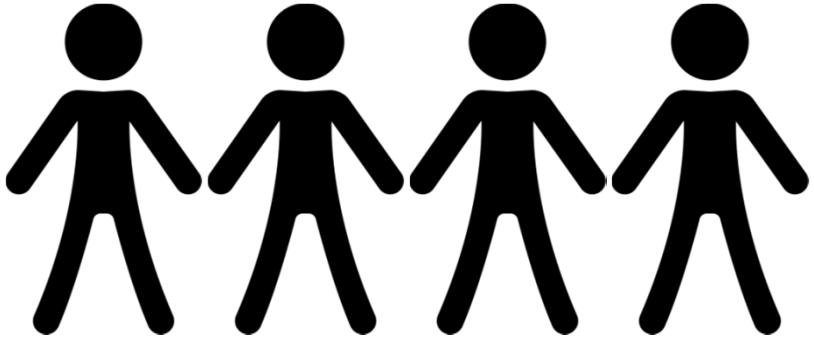
NON-SMOKING


UNPURCHASED
Wood
Dung
Crop Residues
PURCHASED
Coal
Kerosene
Charcoal
Wood
Electricity
Not willing or able to join market
Willing & able to join market
Consumer & Market Participant
Around half have some access to electricity

UNPURCHASED
NO MARKET ACCESS

UNPURCHASED
BUT WILLING TO USE THE MARKET

PURCHASED
MARKET USER



SMOKING

NON-SMOKING

UNPURCHASED
NO MARKET ACCESS

UNPURCHASED
WILLING TO USE THE MARKET

Incentives to move to new cooking technologies?
Subsidized fuel / capital cost?
Access to infrastructure and improved markets?

ELECTRICAL APPLIANCES

PHILIPS BLOWER STOVE

PELLETS

Market-ready advanced stoves + fuels

Newborn Stove (NBS) Project

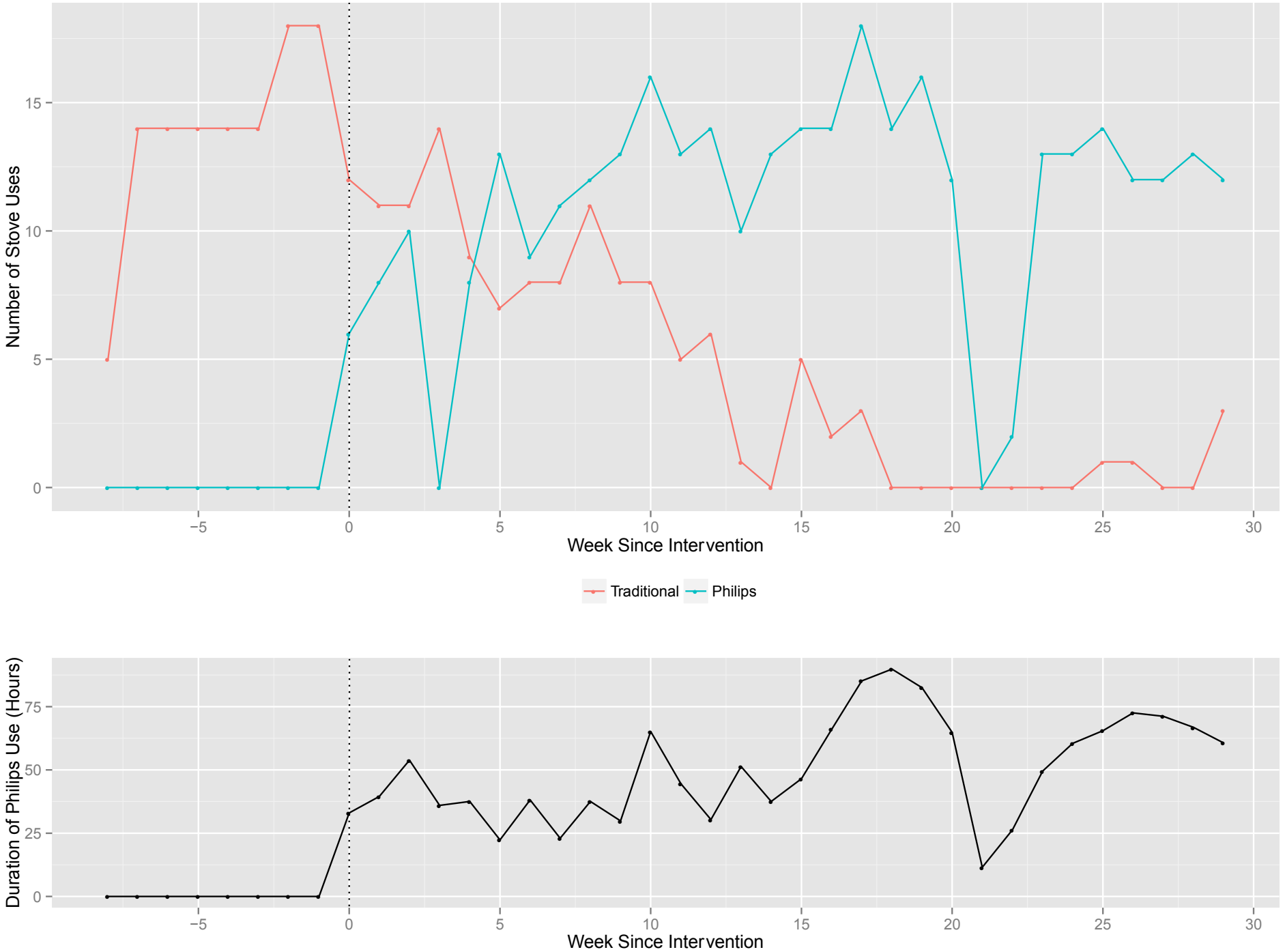
SOMAARTH Surveillance Site – Haryana ~200,000 people

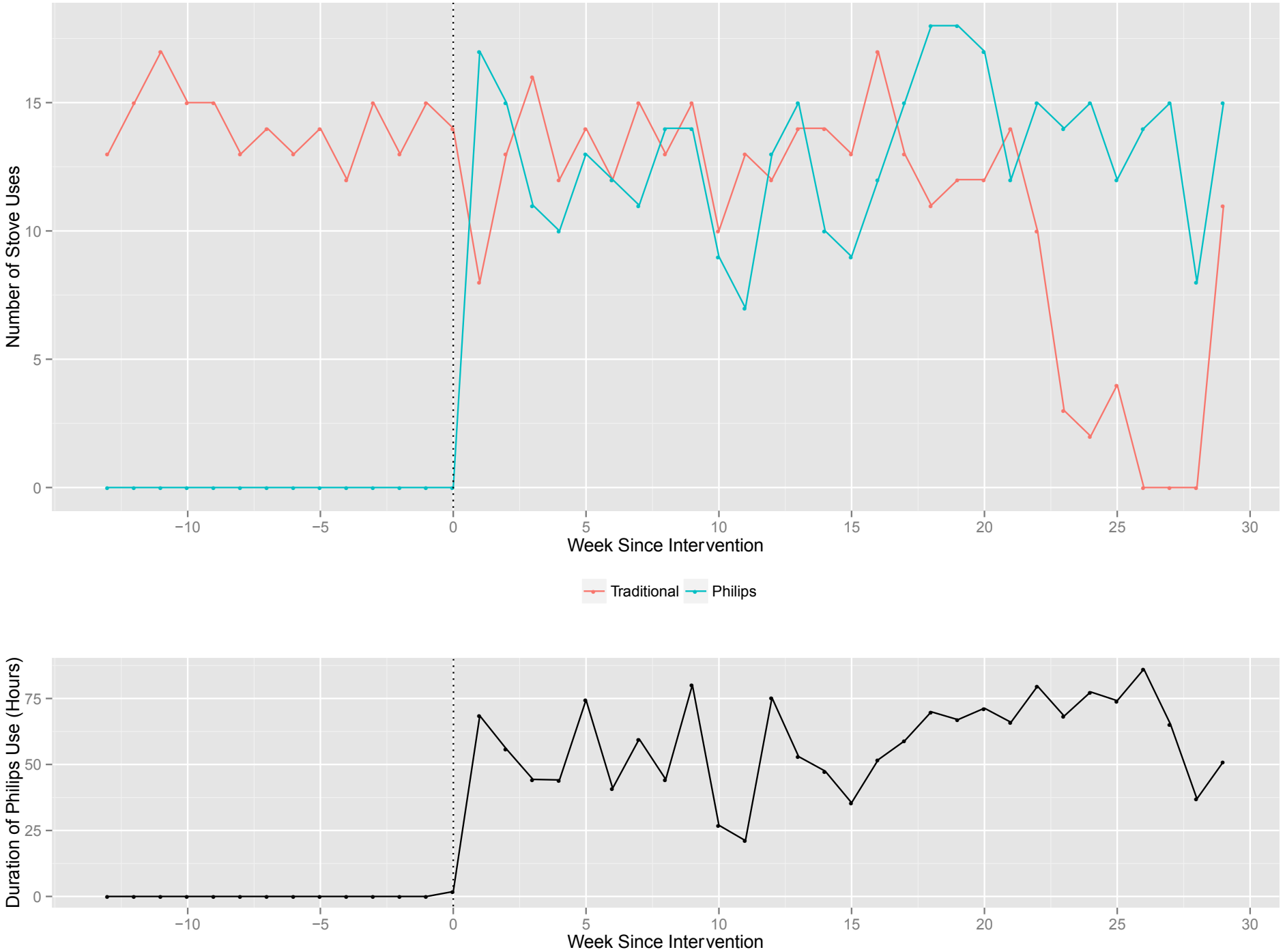
Berkeley, Columbia
INCLEN, SRU

NBS Project

Introducing advanced combustion stoves to pregnant women through the official ante-natal care system in India

Monitoring air pollution, usage, birth outcomes, and infant pneumonia


Number of Stove Uses
15
10
5
0
−5
0
5
10
15
20
25
30
Week Since Intervention
Traditional
Philips
Duration of Philips Use (Hours)
75
50
25
0
−5
0
5
10
15
20
25
30
Week Since Intervention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Traditional
Philips
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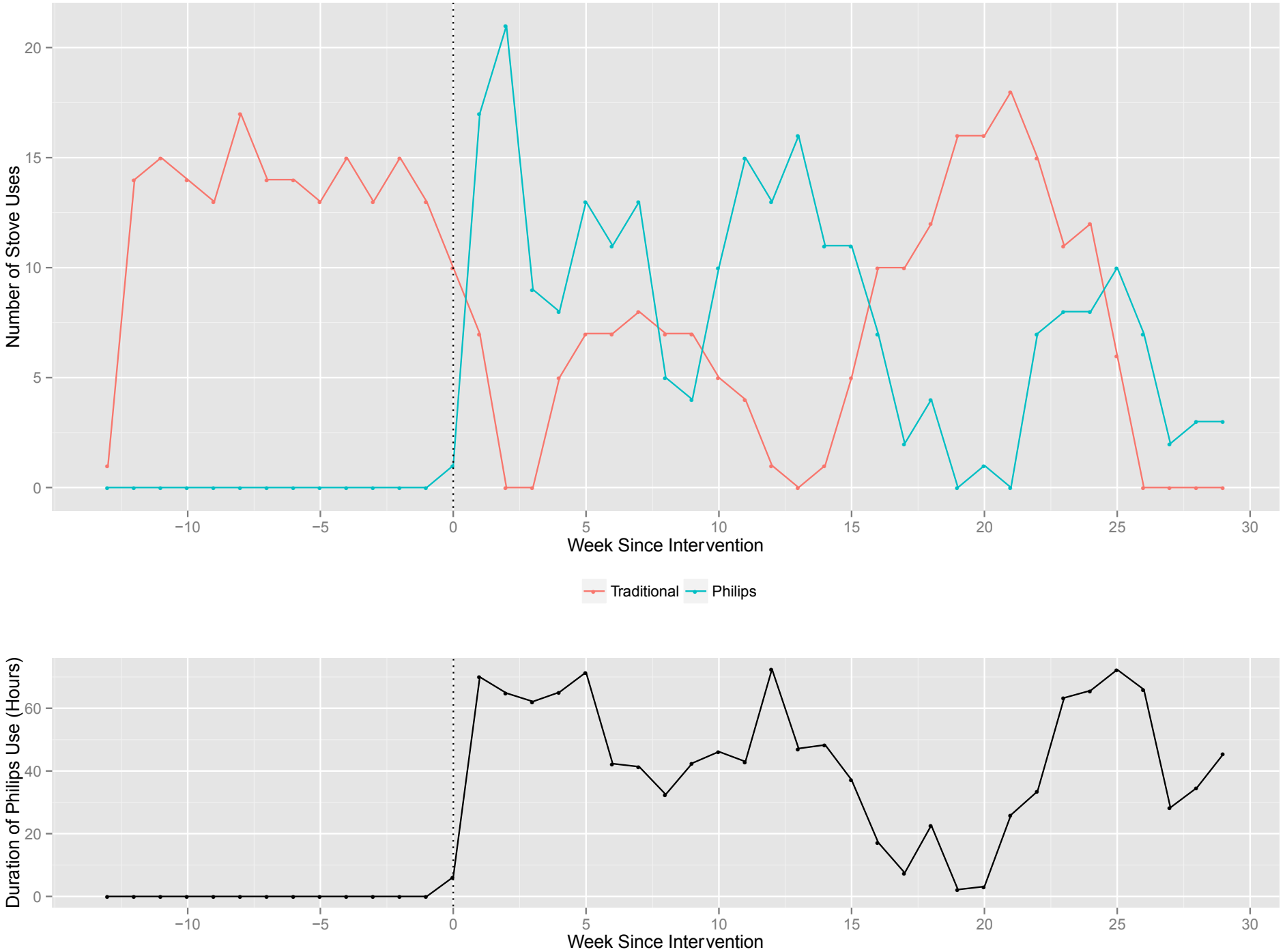
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Week Since Intervention
Traditional
Philips
Duration of Philips Use (Hours)
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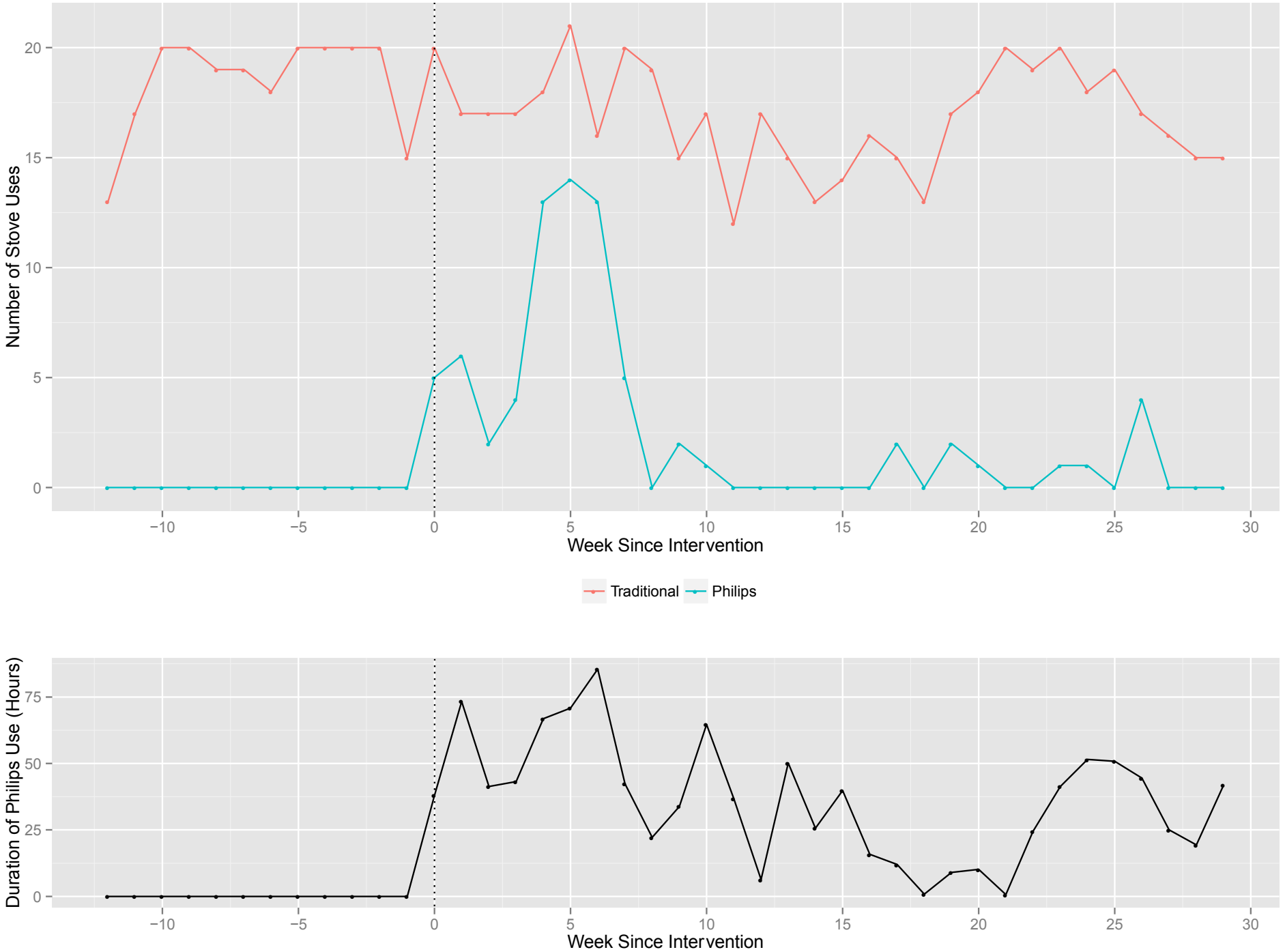
Week Since Intervention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75
50
25
0
−10
−5
0
5
10
15
20
25
30
Week Since Intervention

Bottom Line

You don’t get what you expect, but what you inspect

Many thanks

Funders for HAP CRA
USEPA
Shell Foundation
For NBS Project
World Bank
CDC/GACC
World Lung Foundation