Clean Cooking in Central America: Why do we Care?

Kirk R. Smith, MPH, PhD
Professor of Global Environmental Health
University of California Berkeley

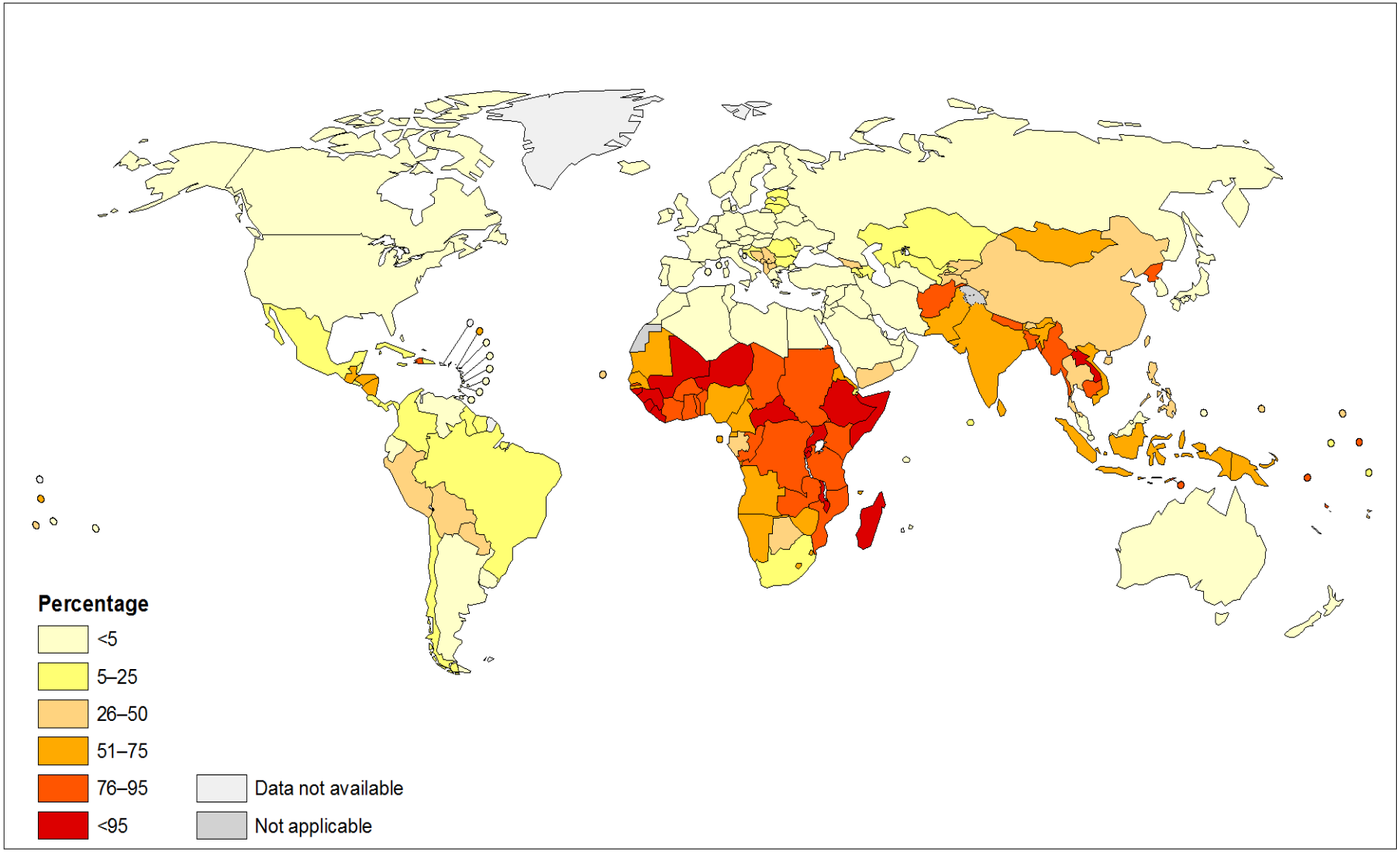
"CHALLENGES AND OPPORTUNITIES TO UNIVERSAL ACCESS TO CLEAN BIOMASS COOKSTOVES IN CENTRAL AMERICA"
Regional Workshop Organized by SICA's General Secretariat and the World Bank in Coordination with the Ministry of Energy and Mines of Nicaragua and the Secretariat of Natural Resources and Environment of Honduras.

May 24, 2013

The Environmental Health Pathway


The three major solid fuels

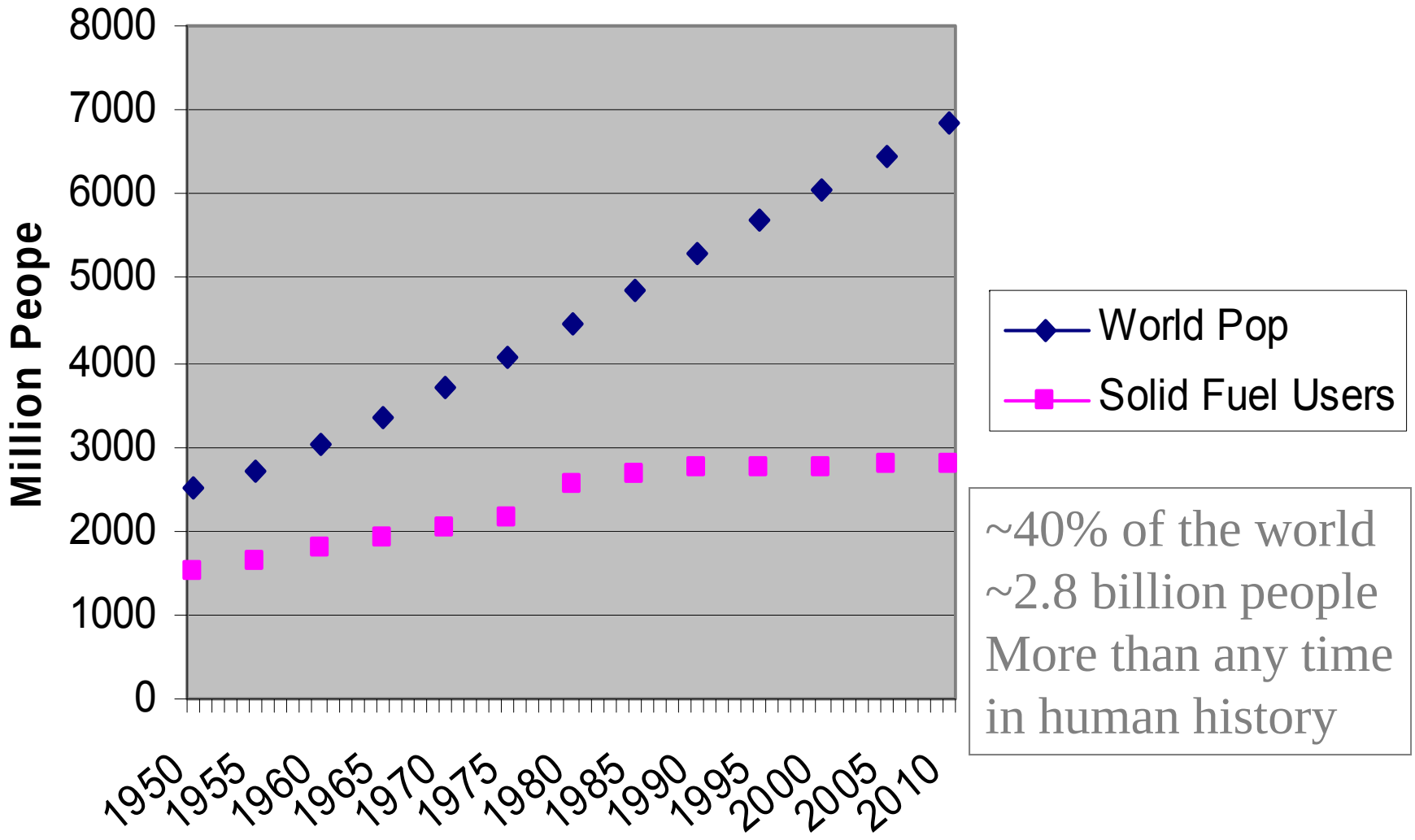
Population Cooking with Solid Fuels in 2010 (%)



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

World Health Organization

World Population Using Solid Fuels



~40% of the world
~2.8 billion people
More than any time in human history

2010 Biomass Use for Cooking in Latin America

Argentina	0 (0, 12)
Belize	12 (0, 25)
Bolivia	29 (32, 58)
Brazil	6 (0, 19)
Chile	6 (0, 19)
Colombia	14 (1, 27)
Costa Rica	6 (0, 19)
Cuba	0 (0, 22)
Dominica	1 (0, 14)
Domin Repub	7 (0, 20)
Ecuador	2 (0, 15)
El Salvador	22 (9, 35)
Grenada	0 (0, 0)
Guatemala	57 (44, 70)
Guyana	7 (0, 20)
Haiti	91 (78, 100)
Honduras	51 (38, 64)
Jamaica	11 (0, 24)
Mexico	14 (1, 27)
Nicaragua	54 (41, 67)
Panama	18 (5, 31)
Paraguay	49 (36, 62)
Peru	36 (24, 50)
St Vinc/Grenad	3 (0, 16)
Suriname	12 (0, 25)
Uruguay	0 (0, 13)
Venezuela	0 (0, 8)

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%

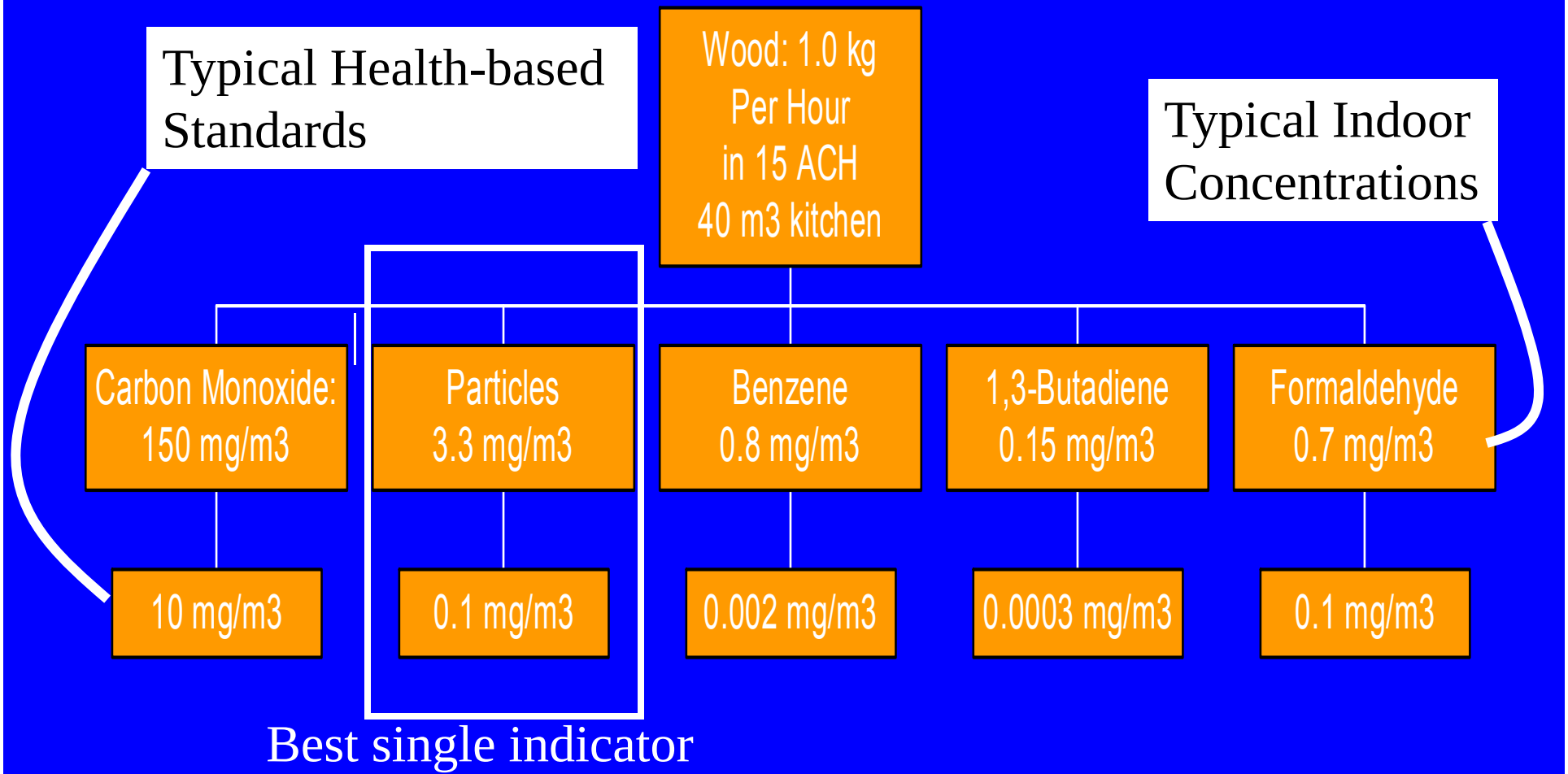
Toxic Pollutants in Wood Smoke from Simple (poor) Combustion

- 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*

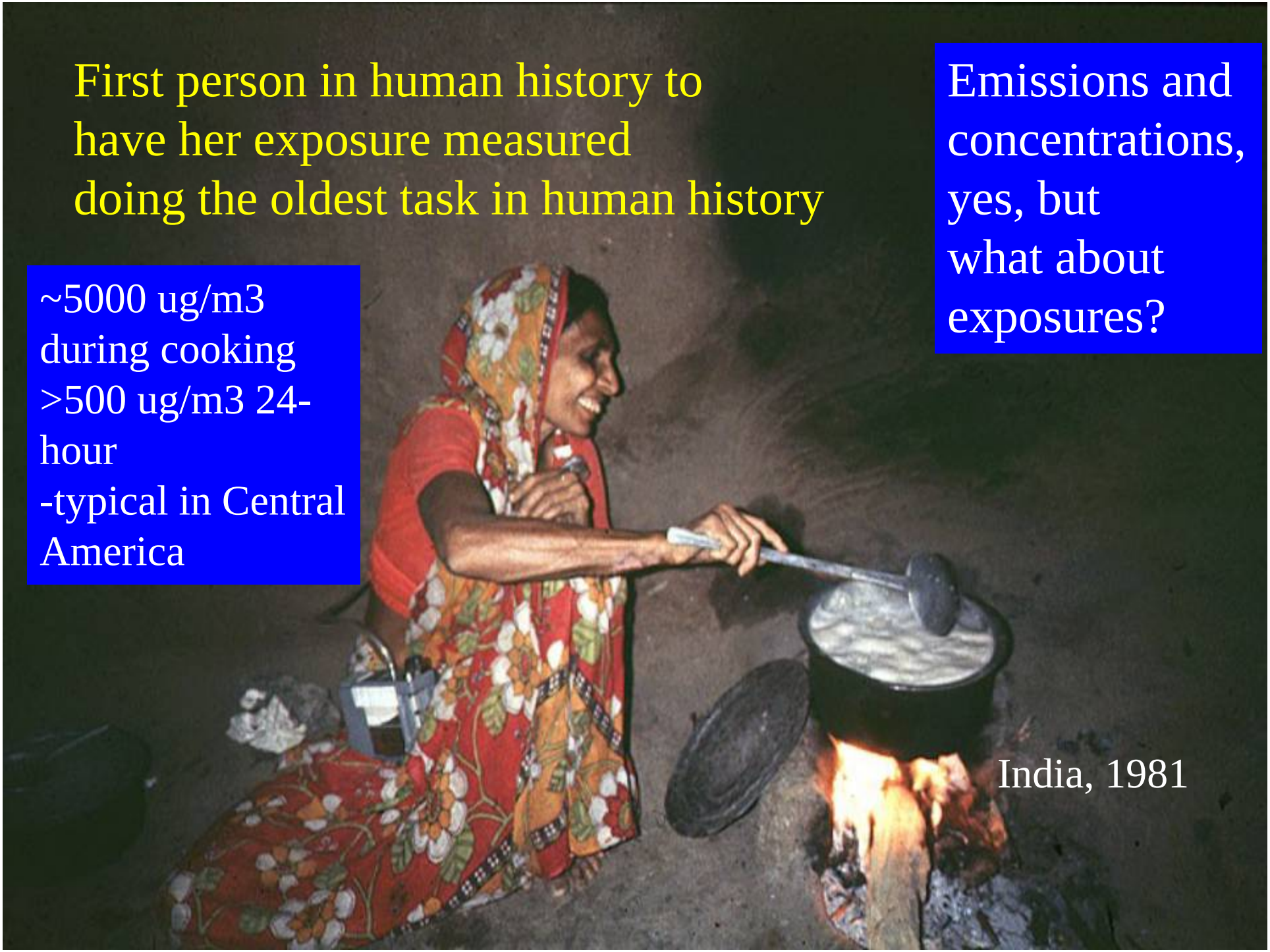
Source: Naeher et al, *J Inhal Tox*, 2007

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
Emissions and concentrations, yes, but what about exposures?
~5000 ug/m3 during cooking
>500 ug/m3 24-hour
-typical in Central America
India, 1981

The Environmental Health Pathway

How much $PM_{2.5}$ is unhealthy?

- WHO Air Quality Guidelines
  - 10 ug/m^3 annual average
  - No public microenvironment, indoor or outdoor, should be more than 35 ug/m^3
- USEPA
  - Was 15 ug/m^3 until 2012: annual outdoors
  - Now 12 ug/m^3
  - 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 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

ALRI/
Pneumonia

COPD

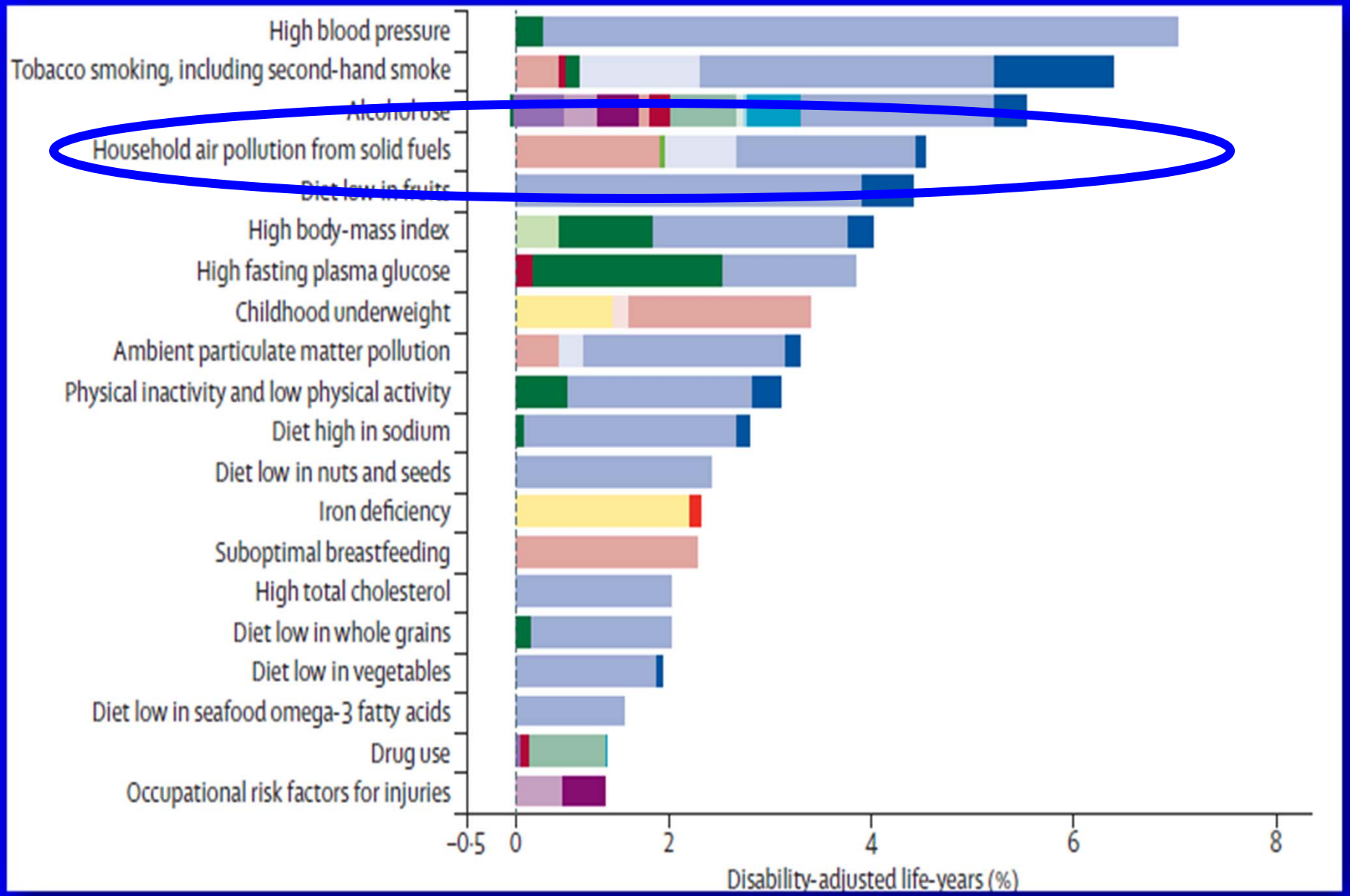
Lung cancer

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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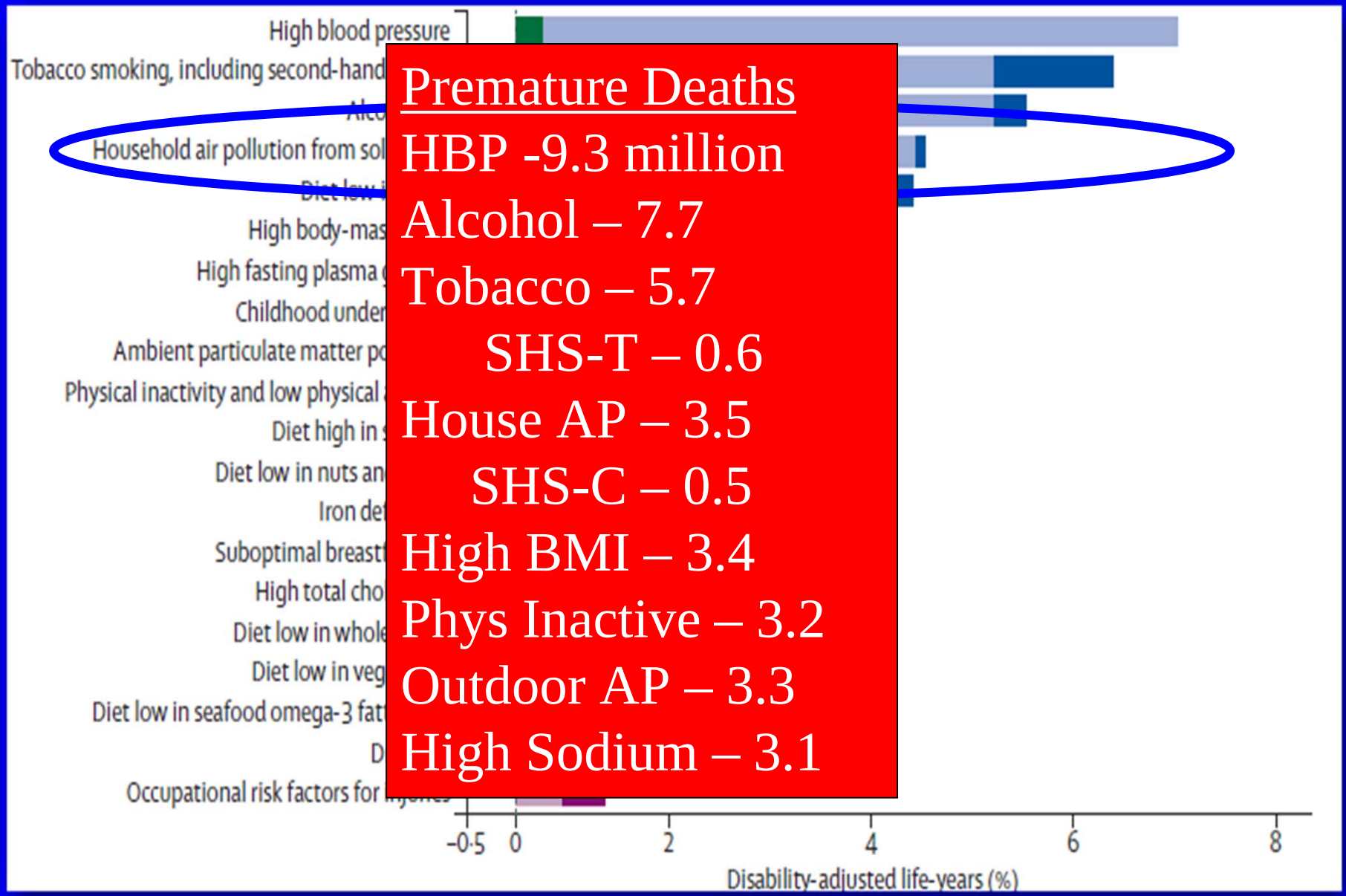


Premature Deaths

HBP -9.3 million

Alcohol – 7.7

Tobacco – 5.7

SHS-T – 0.6

House AP – 3.5

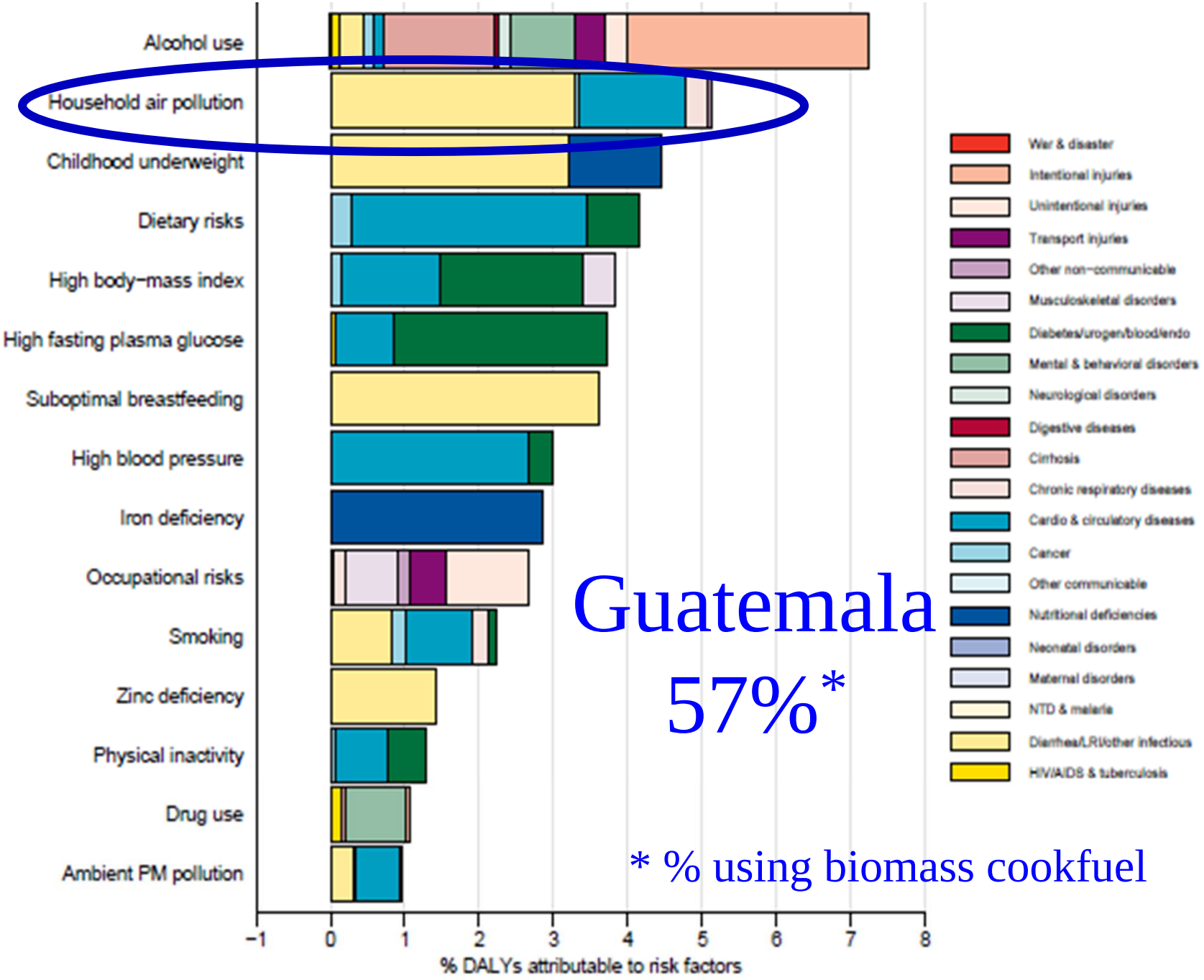
SHS-C – 0.5

High BMI – 3.4

Phys Inactive – 3.2

Outdoor AP – 3.3

High Sodium – 3.1


Alcohol use
Household air pollution
Childhood underweight
Dietary risks
High body−mass index
High fasting plasma glucose
Suboptimal breastfeeding
High blood pressure
Iron deficiency
Occupational risks
Smoking
Zinc deficiency
Physical inactivity
Drug use
Ambient PM pollution
−1
0
1
2
3
4
5
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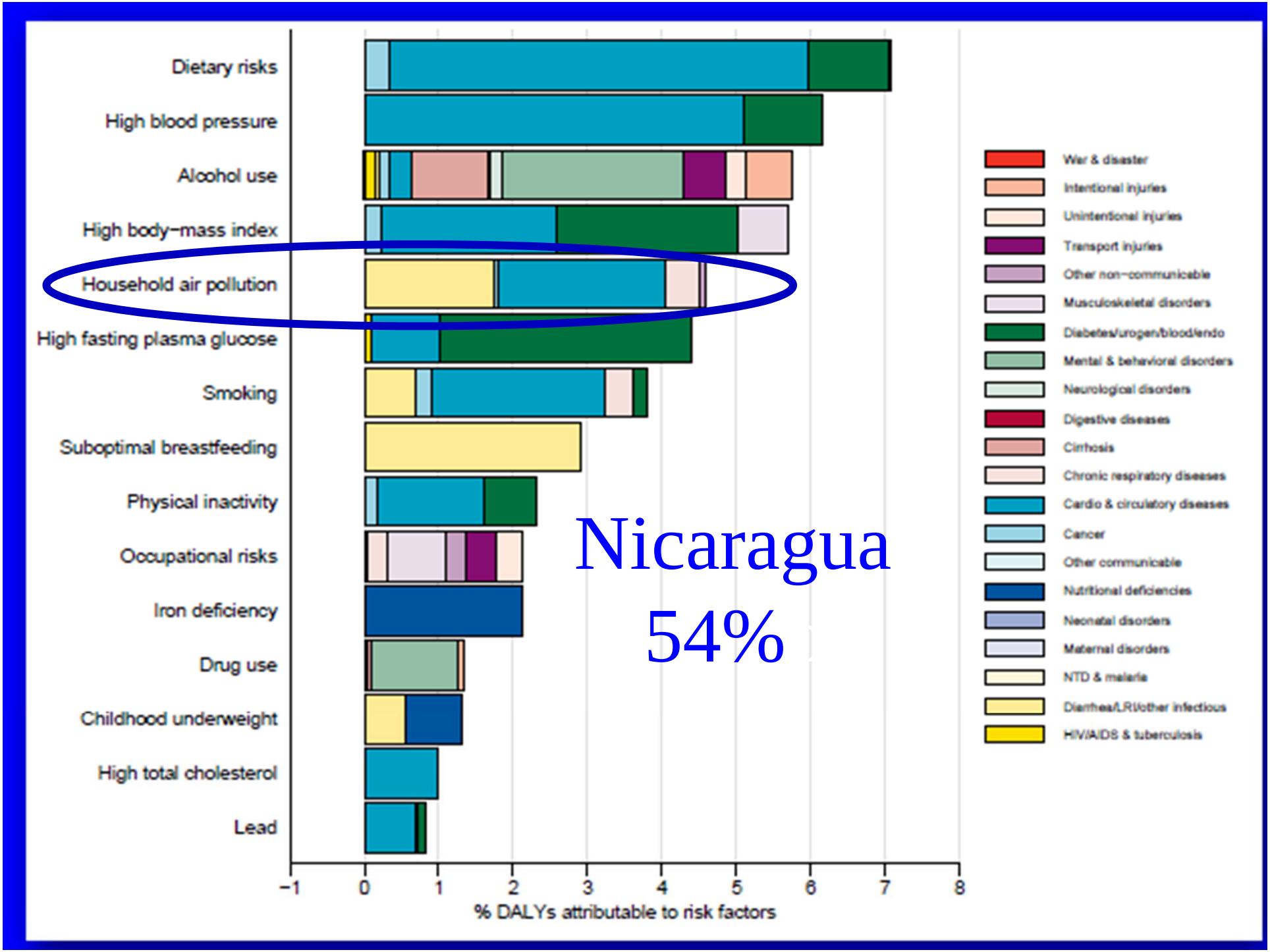
7
8
% DALYs attributable to risk factors
War & disaster
Intentional injuries
Unintentional injuries
Transport injuries
Other non−communicable
Musculoskeletal disorders
Diabetes/urogen/blood/endo
Mental & behavioral disorders
Neurological disorders
Digestive diseases
Cirrhosis
Chronic respiratory diseases
Cardio & circulatory diseases
Cancer
Other communicable
Nutritional deficiencies
Neonatal disorders
Maternal disorders
NTD & malaria
Diarrhea/LRI/other infectious
HIV/AIDS & tuberculosis
Guatemala
57%*
* % using biomass cookfuel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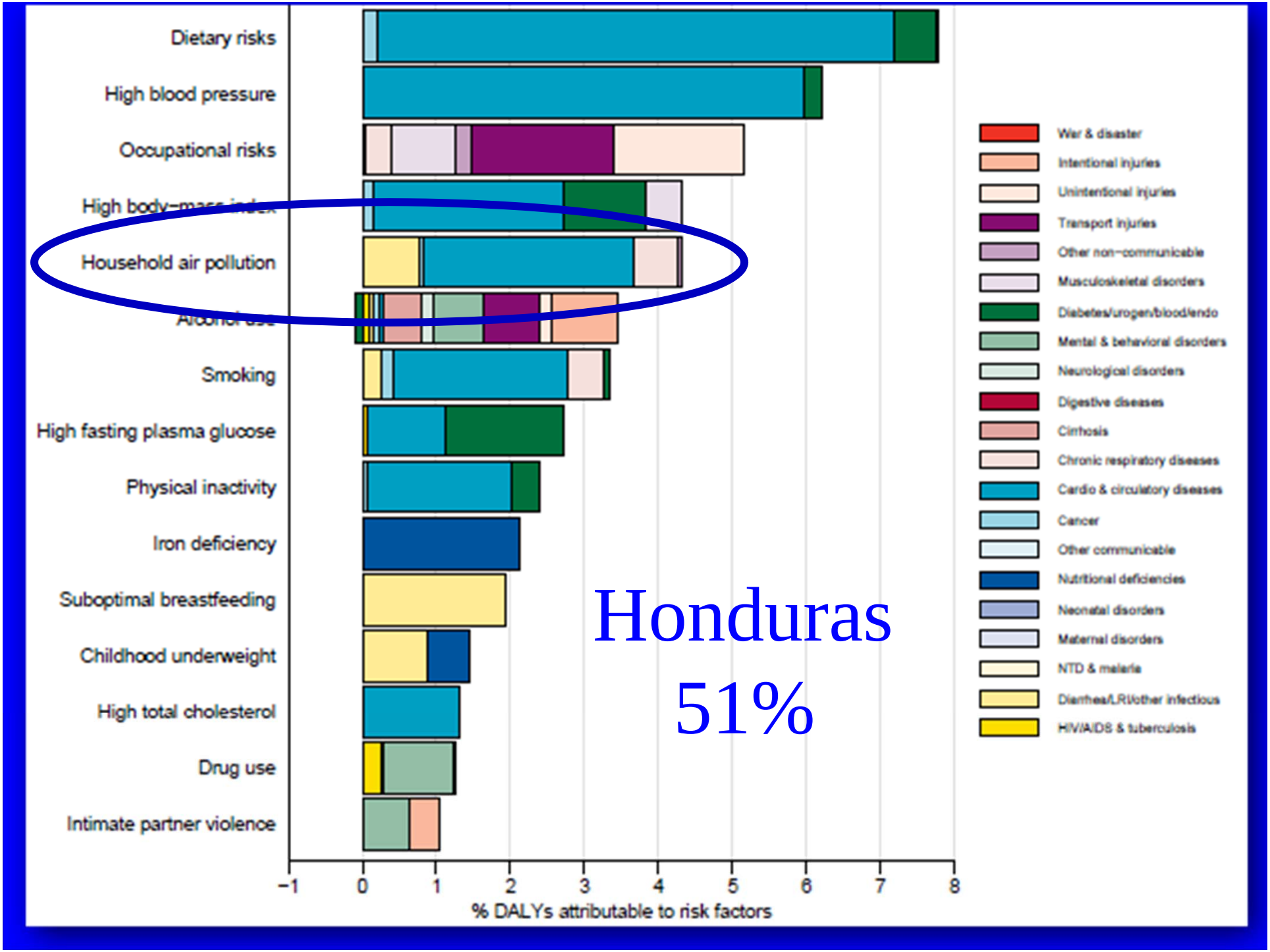
Nicaragua
54%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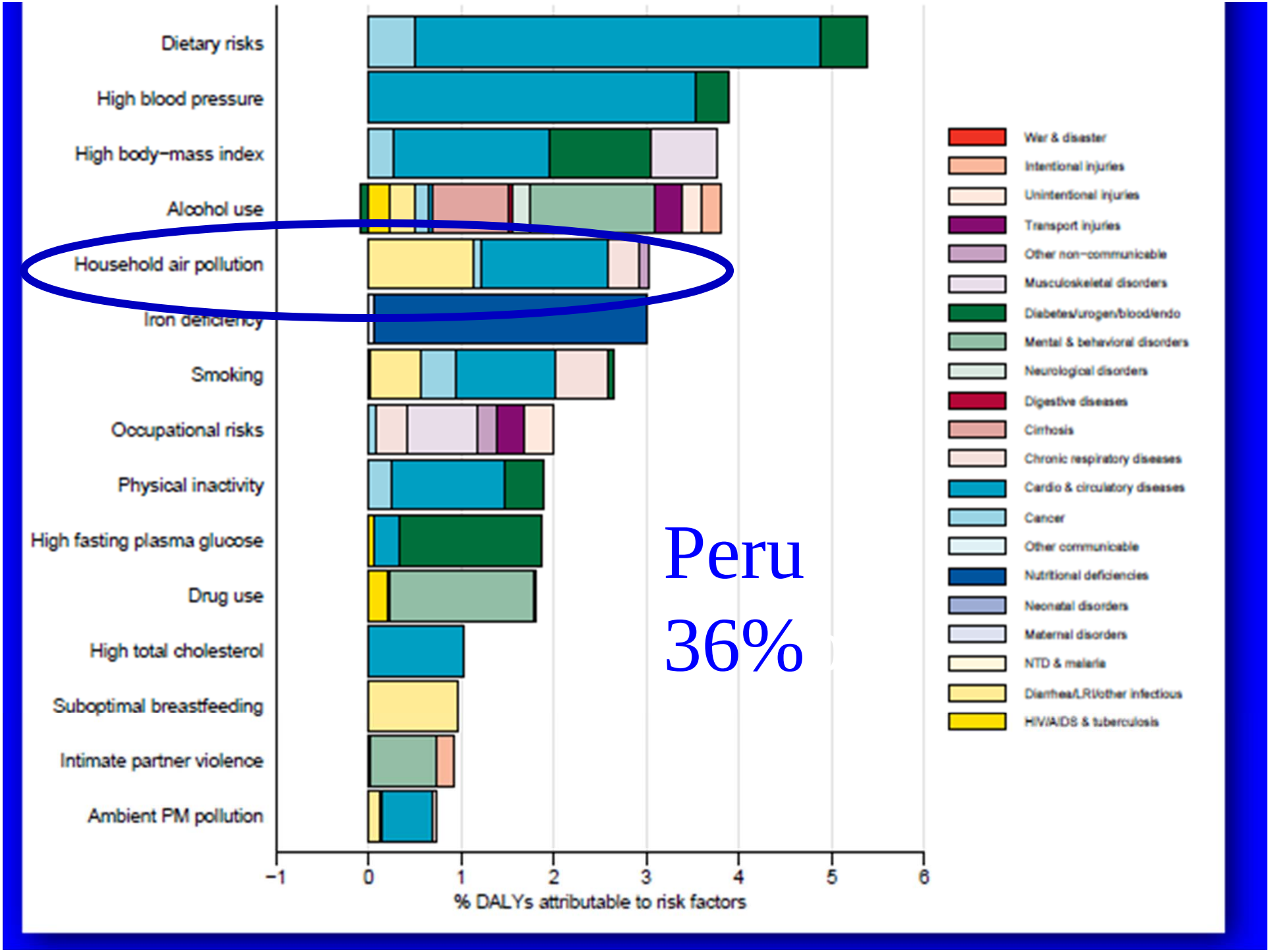
% DALYs attributable to risk factors
Honduras
51%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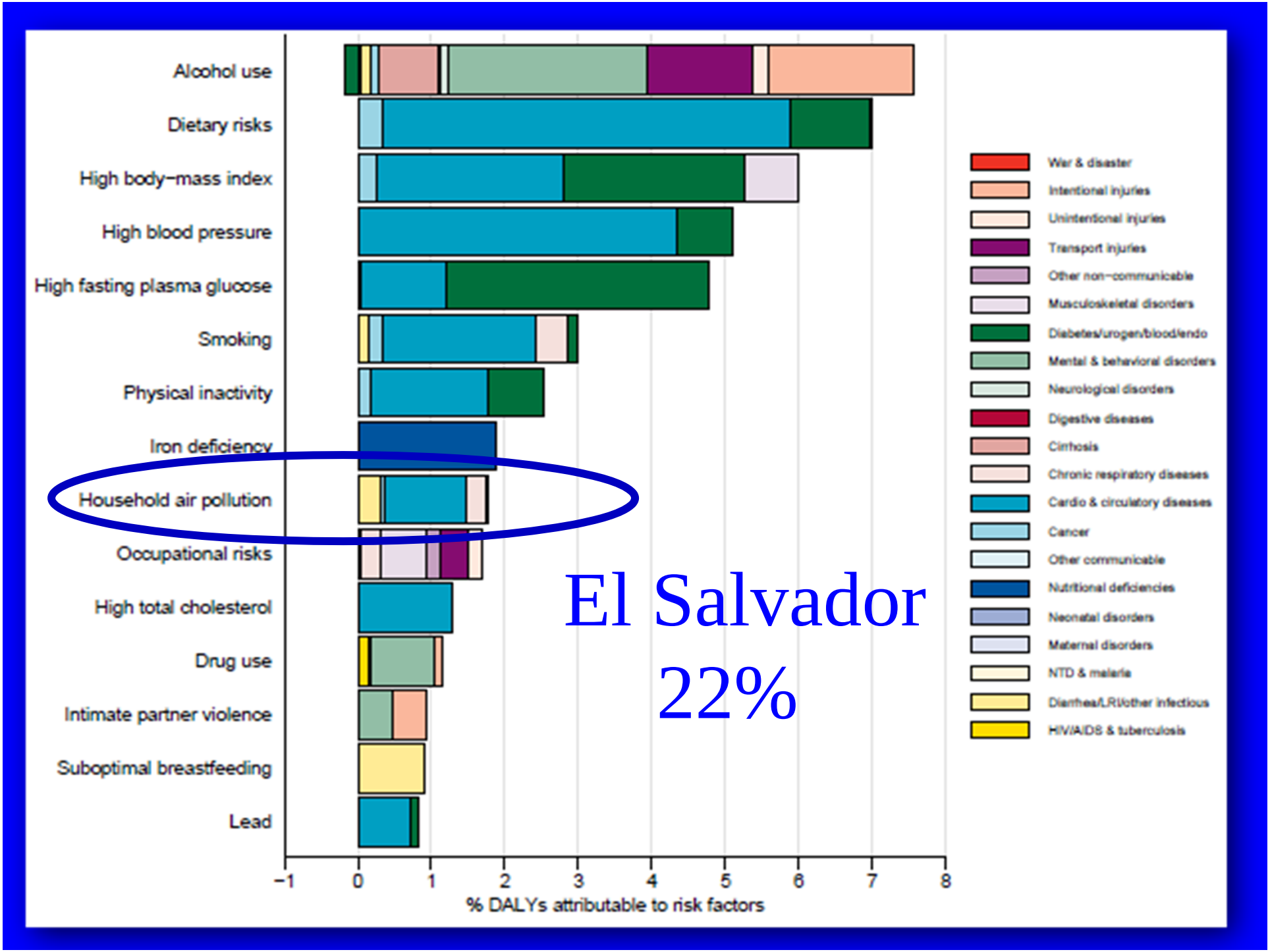
Peru
36%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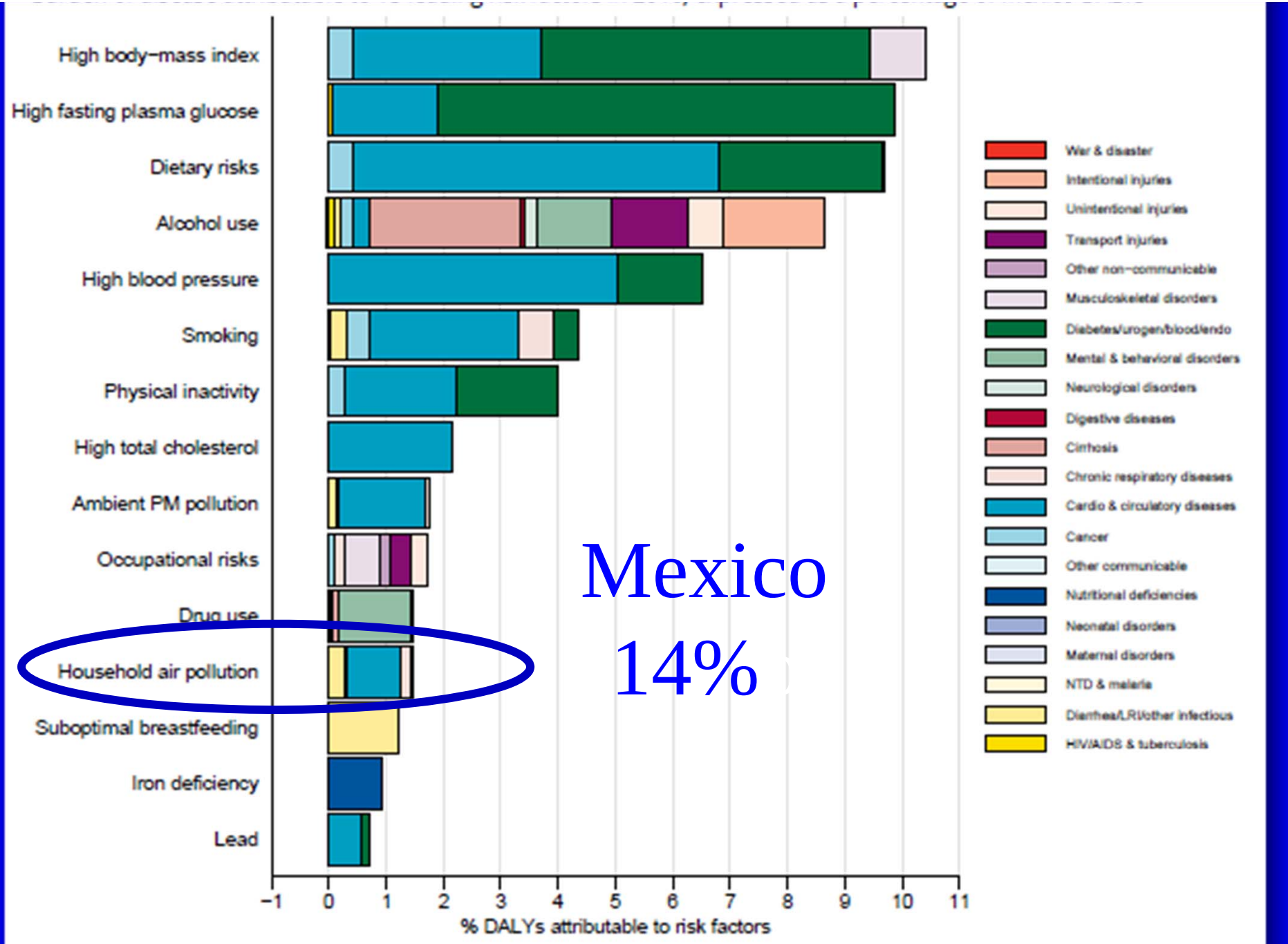
Diarrhea/LRI/other infectious
HIV/AIDS & tuberculosis
El Salvador
22%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Occupational risks
Drug use
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11
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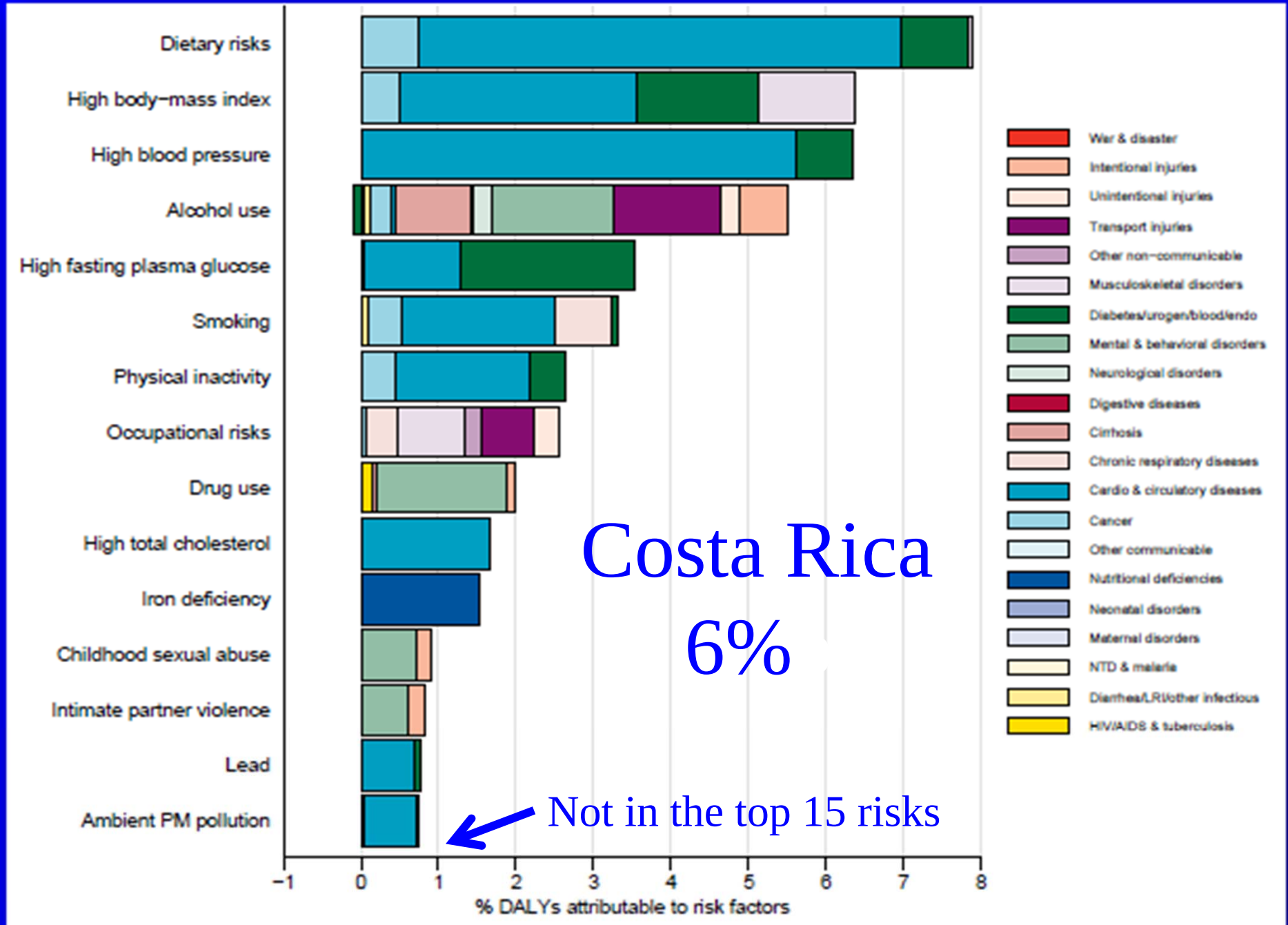
Maternal disorders
NTD & malaria
Diarrhea/LRI/other infectious
HIV/AIDS & tuberculosis
Mexico
14%


Dietary risks
High body−mass index
High blood pressure
Alcohol use
High fasting plasma glucose
Smoking
Physical inactivity
Occupational risks
Drug use
High total cholesterol
Iron deficiency
Childhood sexual abuse
Intimate partner violence
Lead
Ambient PM pollution
−1
0
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Chronic respiratory diseases
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Cancer
Other communicable
Nutritional deficiencies
Neonatal disorders
Maternal disorders
NTD & malaria
Diarrhea/LRI/other infectious
HIV/AIDS & tuberculosis
Costa Rica
6%
Not in the top 15 risks

Central America

- 37,000 premature deaths annually from household air pollution from biomass cookfires
- About 10% in children

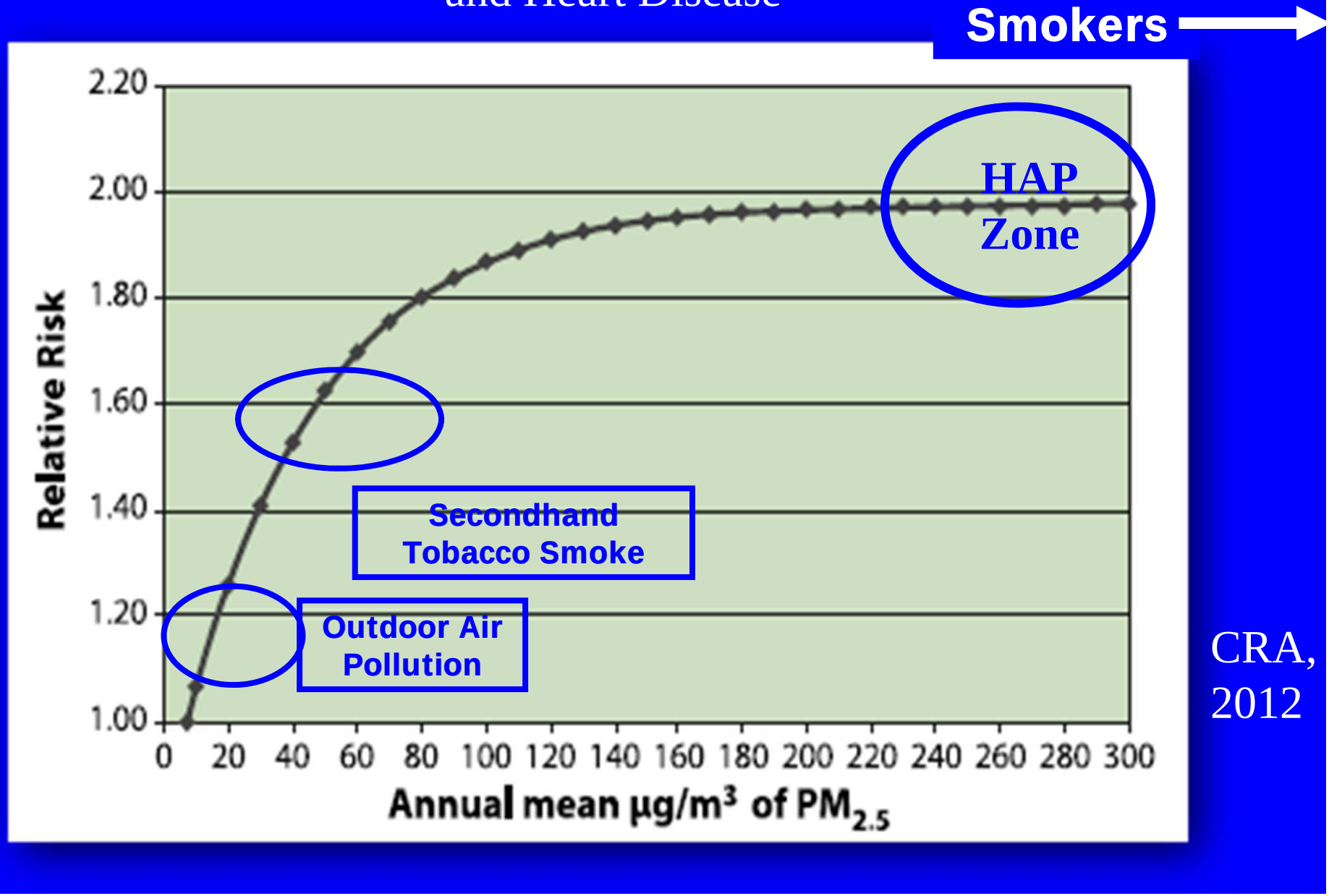
The framing

- Household air pollution from use of solid fuels for cooking
- 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.

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, 2012

Summary of CRA

- 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

Much evidence from Central America

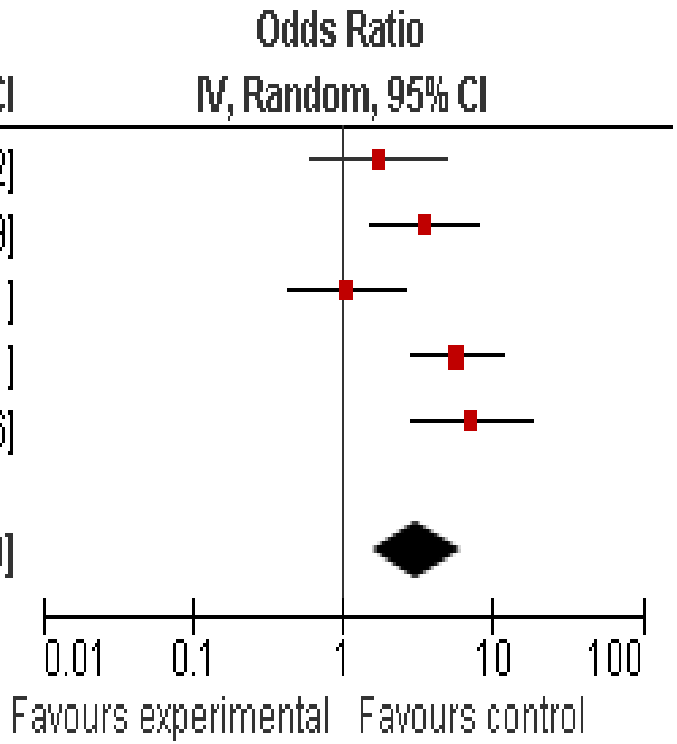
- Oldest and most productive HAP research site in the world – highland Guatemala
  - Pneumonia in children
  - Low birth weight
  - Impaired cognitive ability
  - Chronic lung disease in women
- Several studies of cervical cancer in Honduras

Cervical Cancer and Household Air Pollution

Study or Subgroup	log[Odds Ratio]	SE	Weight	Odds Ratio IV, Random, 95% CI
Ferrera 2000(a)	0.54232429	0.53624989	17.6%	1.72 [0.60, 4.92]
Ferrera 2000(b)	1.24990174	0.41614175	20.9%	3.49 [1.54, 7.89]
Velema 2002(a)	0.06765865	0.45514155	19.8%	1.07 [0.44, 2.61]
Velema 2002(b)	1.75093748	0.36626585	22.4%	5.76 [2.81, 11.81]
Sierra Torres 2006	1.98787435	0.47618897	19.2%	7.30 [2.87, 18.56]
Total (95% CI)			**100.0%**	**3.14 [1.57, 6.30]**

Heterogeneity: $Tau^2 = 0.43$; $Chi^2 = 12.71$, df = 4 (P = 0.01); $I^2 = 69\%$

Test for overall effect: Z = 3.23 (P = 0.001)



Three papers; two done in Honduras with four groups, one in Columbia

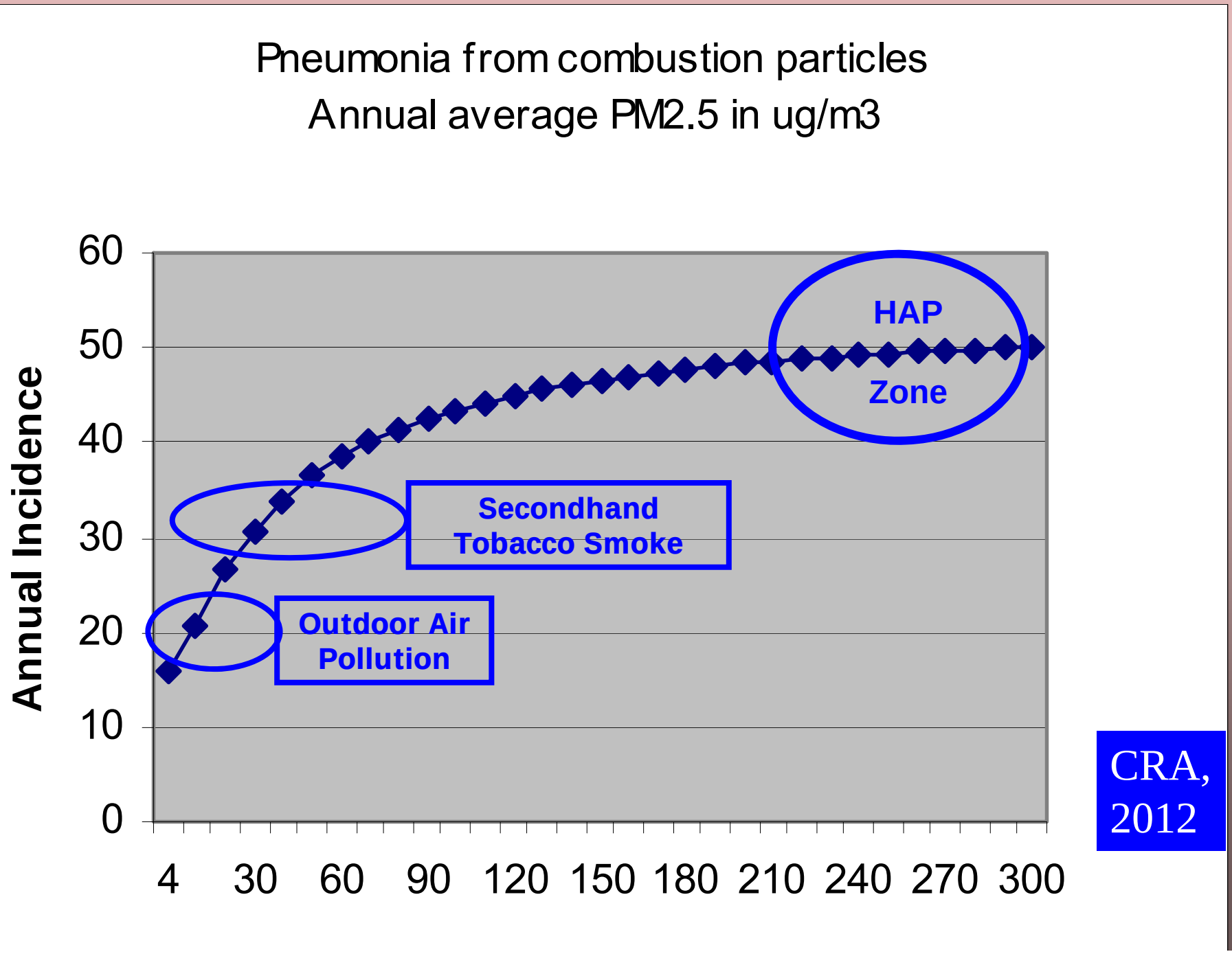
RESPIRE

Impact on pneumonia up to 18 months of age

Traditional open 3-stone fire:

Chimney woodstove, locally made and popular with households

The Plancha


Pneumonia from combustion particles
Annual average PM2.5 in ug/m3
Annual Incidence
60
50
40
30
20
10
0
4
30
60
90
120
150
180
210
240
270
300
HAP
Zone
Secondhand
Tobacco Smoke
Outdoor Air
Pollution
CRA,
2012

y Stove reduced kitchen pollution by 10x, but children exposure by only 2x

--The kids do not spend their entire day in the kitchen
--A chimney does not reduce smoke, but just shifts it outside into the household environment,
--No significant difference in bedrooms or patios

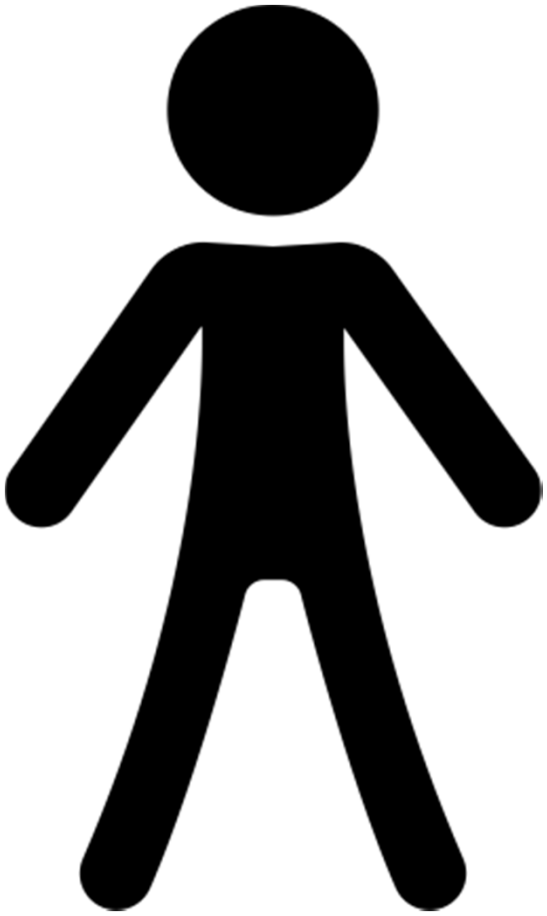
To reduce exposures more requires reducing smoke as well as moving it.

Important!

- Implied health benefit from HAP reduction only potentially achieved by shifting to clean cooking – gas & electricity
- Not achievable with a chimney alone
- Must be very clean combustion
- Can we do this with biomass fuels?
- The big question!

What is to be done?

A fresh look



World cooking in Pictograms –

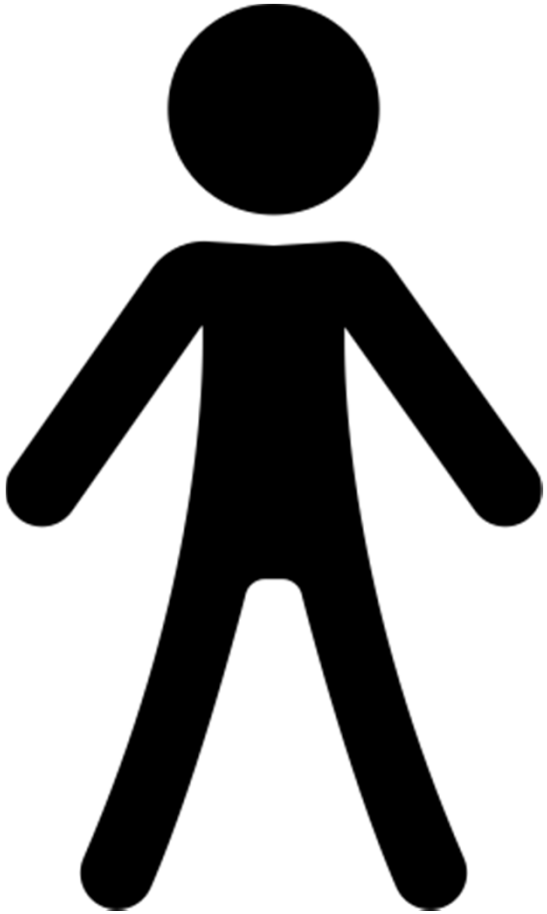
One billion people each

With apologies to
Hans Rosling at Gapminder*

*”Magic Washing Machine”

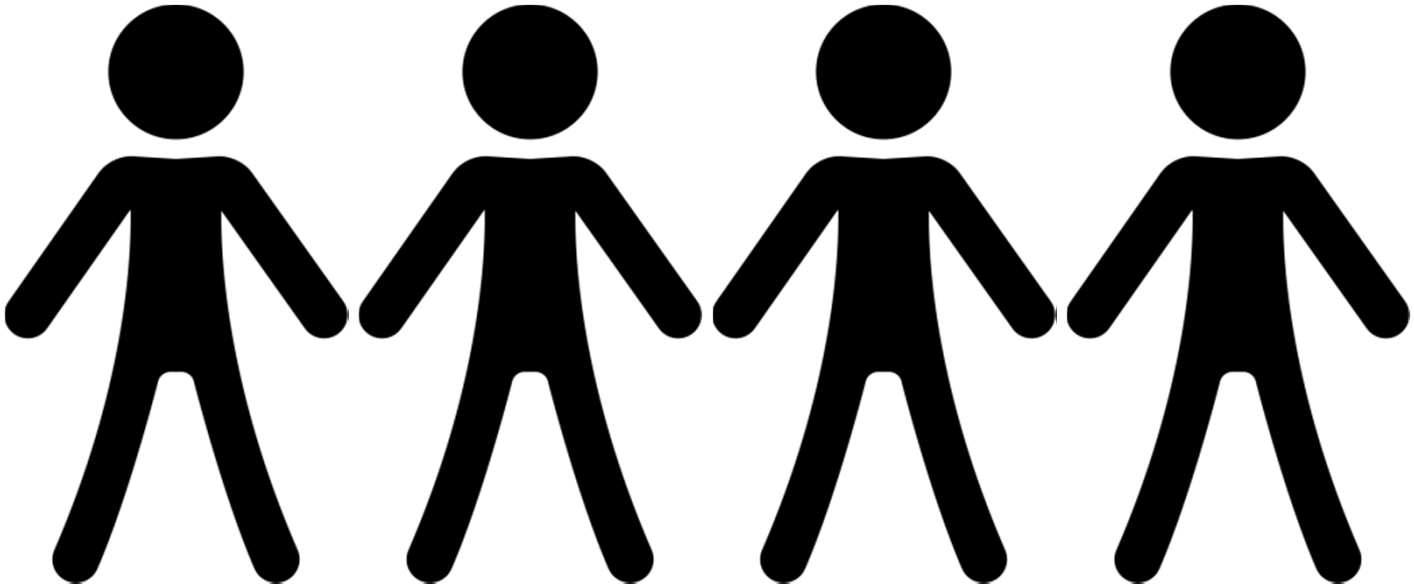
And thanks to Ajay Pillarisetti

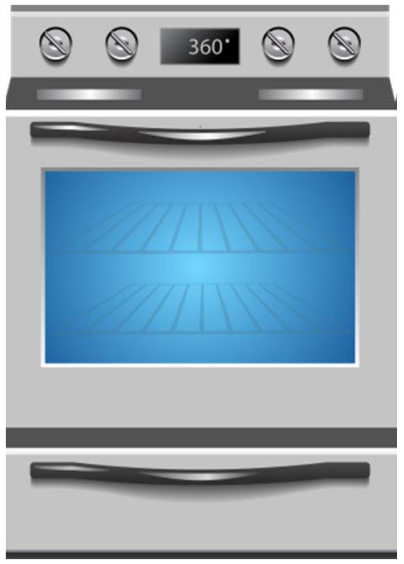
What do the richest one billion people cook with?



Gas or electric stoves

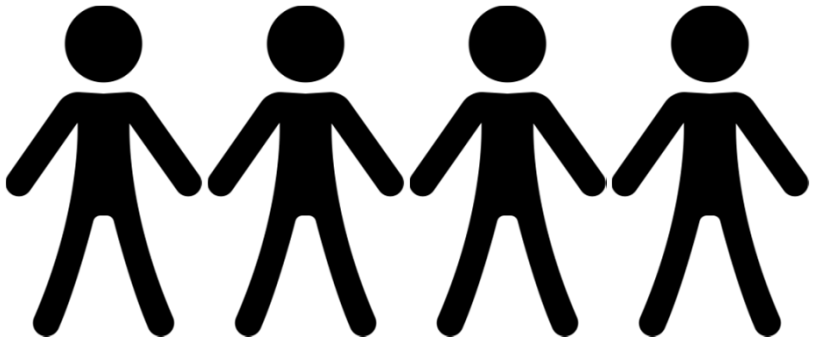
Plus





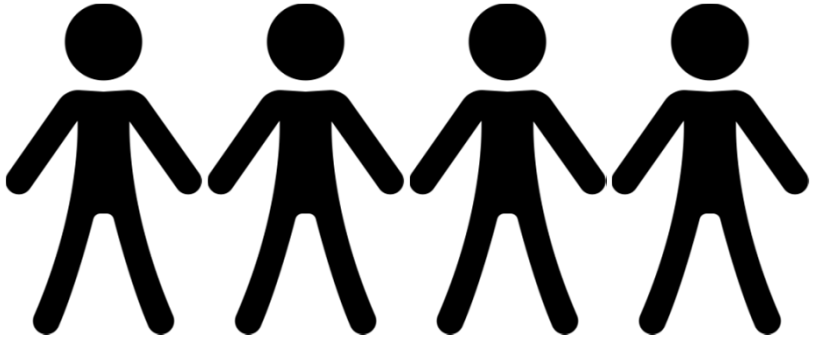
~4 billion worldwide cook with liquified petroleum gas, natural gas, and electricity

What about the other 3 billion?



SMOKING SECTION

NON-SMOKING



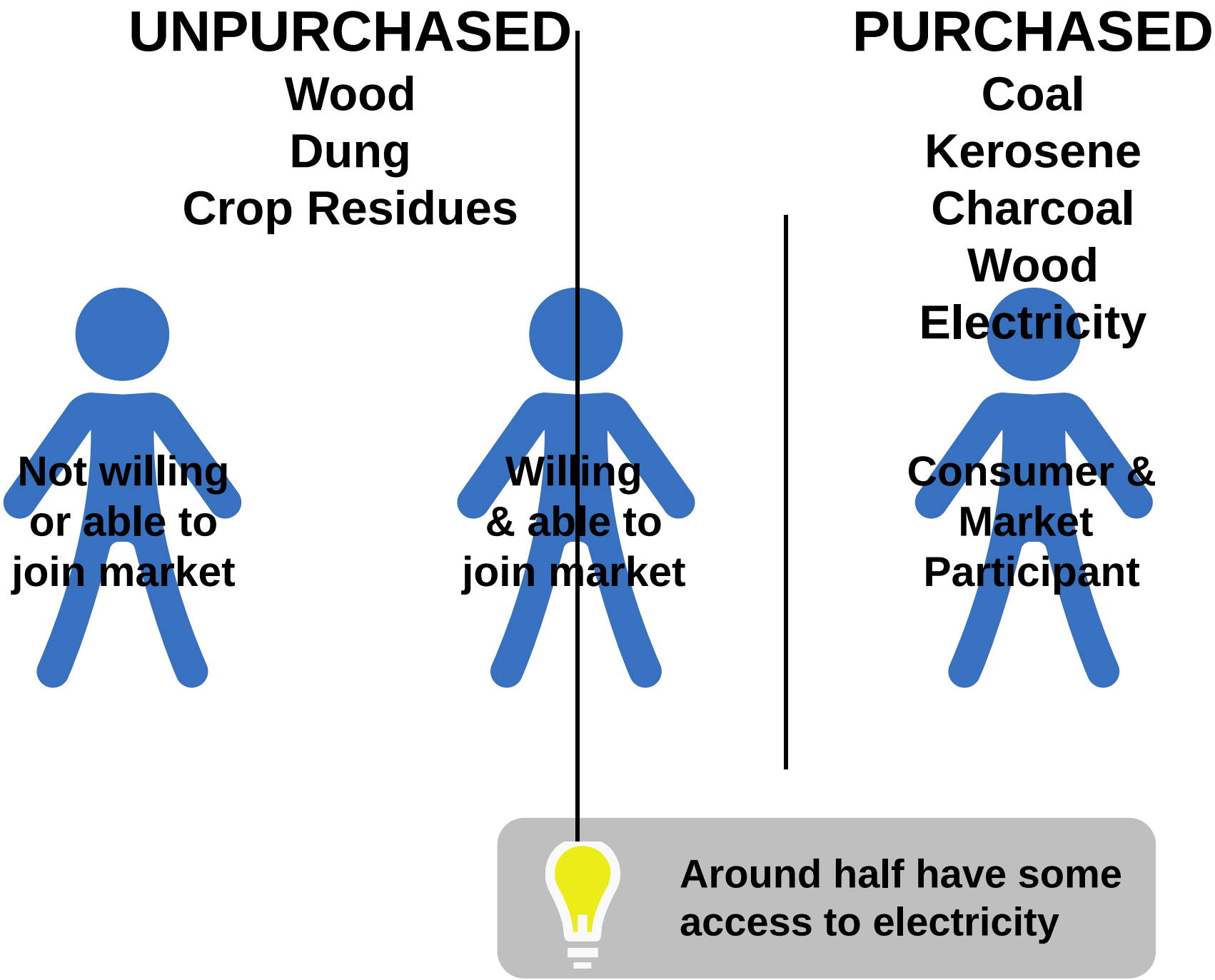
LPG

Natural Gas

Electricity

MARKET BASED OPTIONS

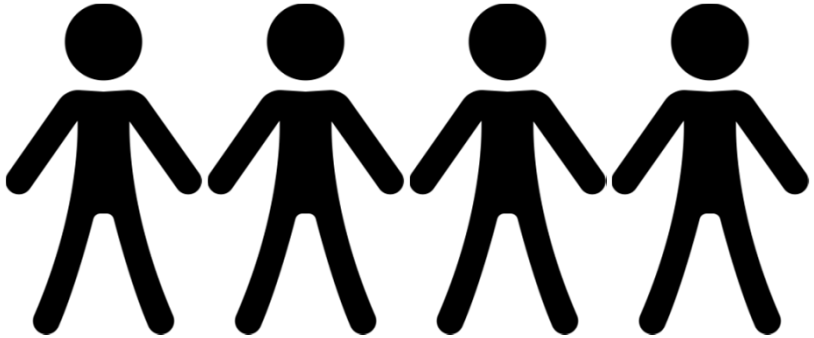
NON-SMOKING


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

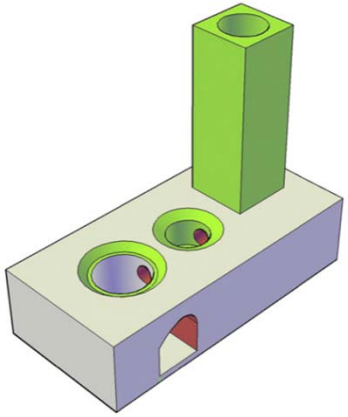
Utilize the health care system through primary health and antenatal care

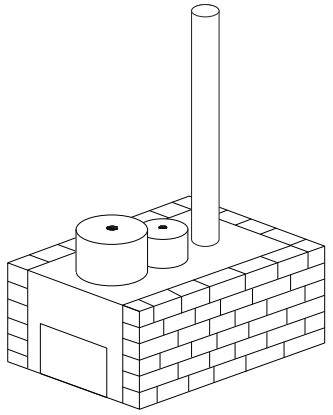
ELECTRICAL APPLIANCES

PHILIPS BLOWER STOVE

PELLETS

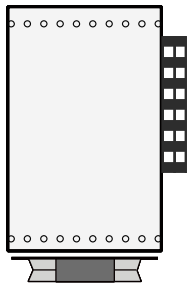
Market-ready advanced stoves + fuels



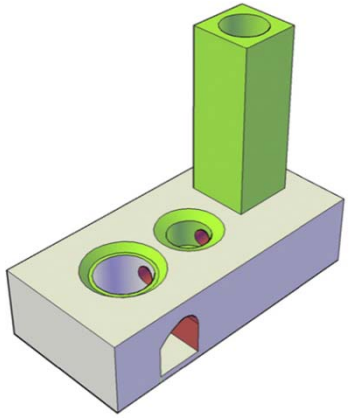


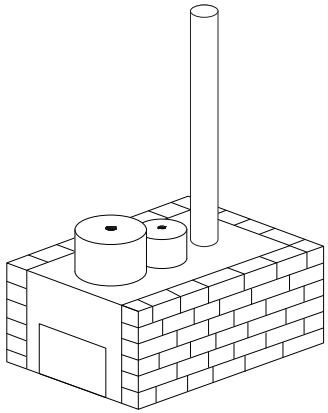
Heavily utilized but only moderately more clean

heart of the hearth



LONG-LASTING
LOW EMISSIONS
COMBUSTION UNIT





Multi-million Dollar Global Innovation Prize for a Truly Clean Biomass Combustion "Engine" for Household Stoves

Proposed by Ambuj Sagar and Kirk R. Smith,
Nature, May 2013

Newborn Stove (NBS) Project

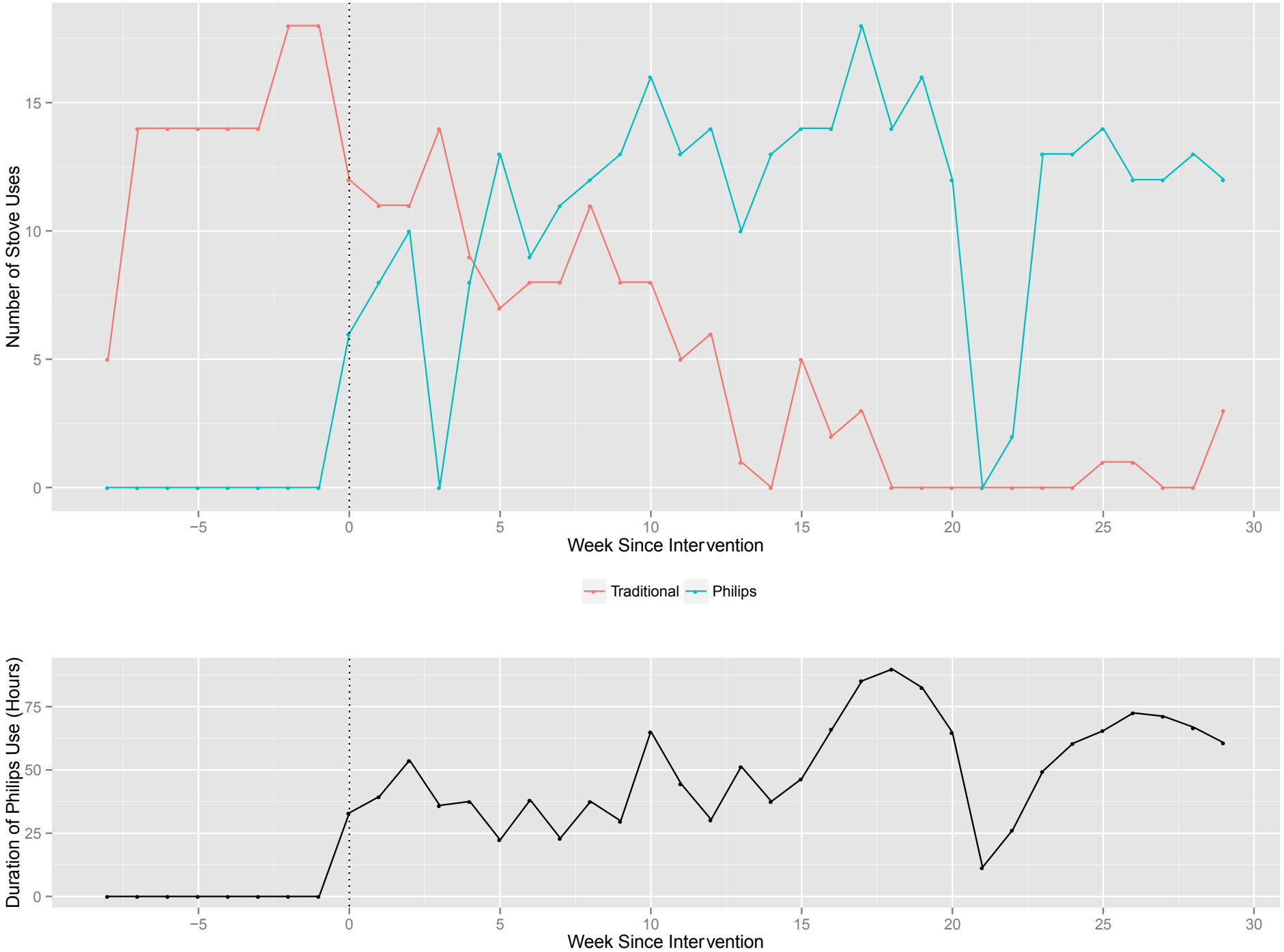
SOMAARTH Surveillance Site – Haryana ~200,000 people

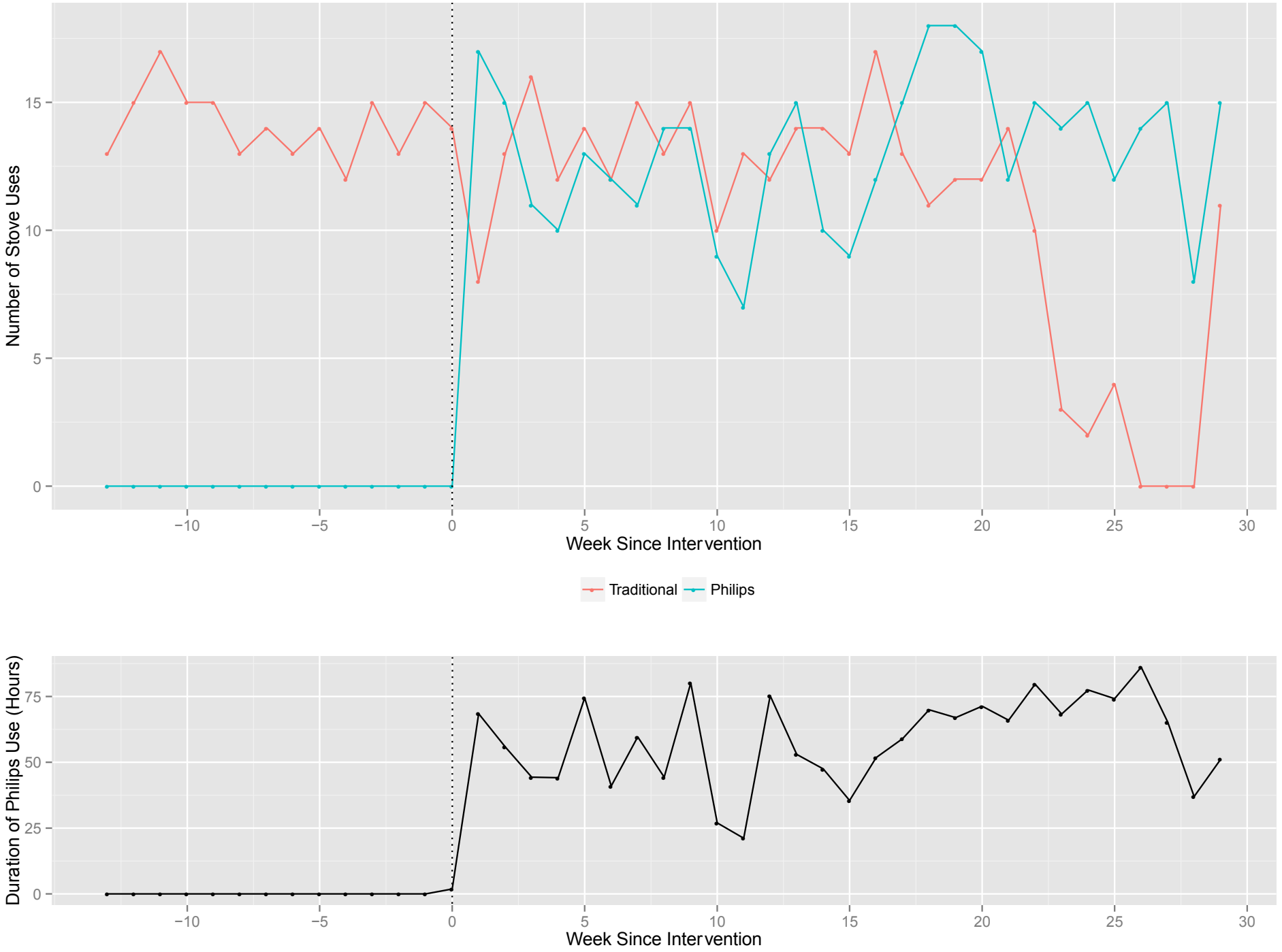
Berkeley, Columbia
INCLEN, SRU

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


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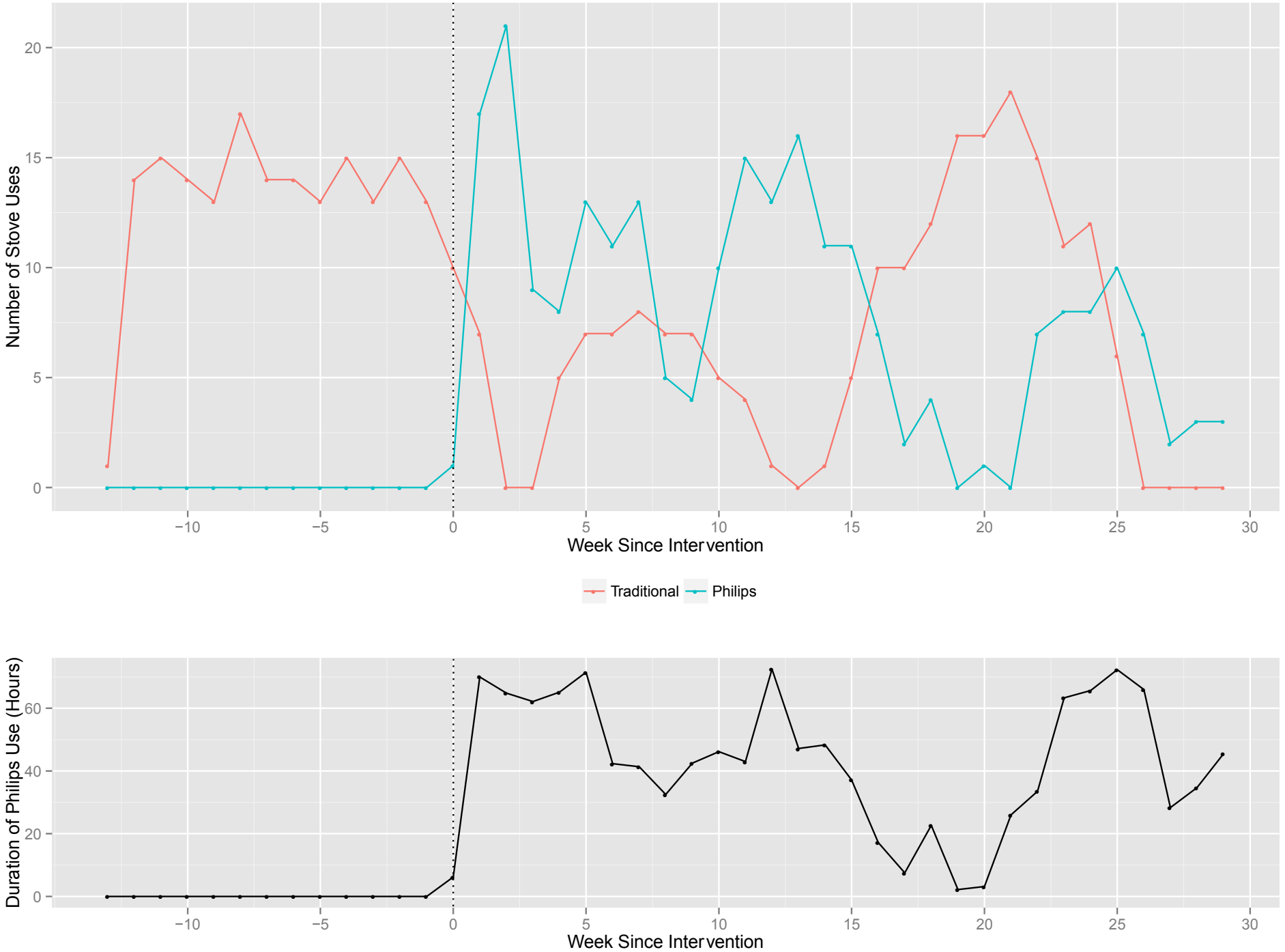
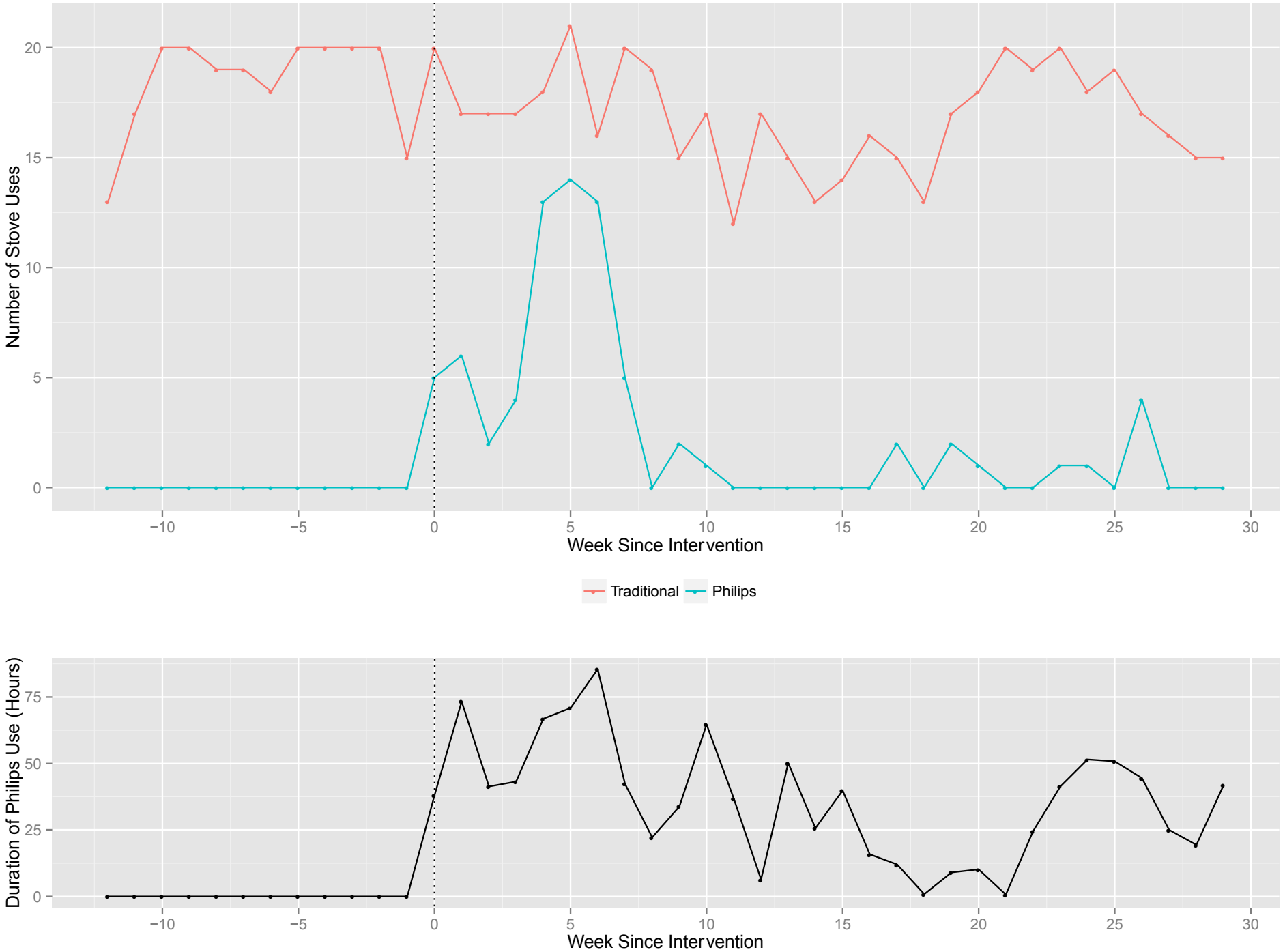
10
5
0
−10
−5
0
5
10
15
20
25
30
Week Since Intervention
Traditional
Philips
Duration of Philips Use (Hours)
75
50
25
0
−10
−5
0
5
10
15
20
25
30
Week Since Intervention


Number of Stove Uses
20
15
10
5
0
−10
−5
0
5
10
15
20
25
30
Week Since Intervention
Traditional
Philips
Duration of Philips Use (Hours)
60
40
20
0
−10
−5
0
5
10
15
20
25
30
Week Since Intervention


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

Available online at www.sciencedirect.com

SciVerse ScienceDirect

http://www.elsevier.com/locate/biombioe

Temperature dataloggers as stove use monitors (SUMs): Field methods and signal analysis

Ilse Ruiz-Mercado[a,b,*], *Eduardo Canuz*[c], *Kirk R. Smith*[b]

[a] Civil Systems, Civil and Environmental Engineering, University of California, Berkeley, 760 Davis Hall, Berkeley, CA 94705-1710, USA

[b] Environmental Health Sciences, School of Public Health, University of California, Berkeley, 50 University Hall, Berkeley, CA 94705-7360, USA

[c] Centro de Estudios en Salud, Universidad del Valle, Guatemala City, Guatemala

2012

Lesson

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

(No lográs lo que esperás, sino lo que inspeccionás)

Bottom Lines

- HAP a major health problem in poor populations
- Interventions must be very clean to make a difference
  - Exposure-response evidence – non-linear
  - Field performance does not come up to lab
  - Usage less than 100%
  - Traditional devices not given up 100%
- A very difficult problem – not amendable to simple technologies or dissemination schemes

Just because we know it's a risk, does not mean we know how to fix it

- **~1900**: Mosquito-born disease cause established, but still 1.4 million die of malaria today
- **~1890**: causation of health risk from human waste in drinking water firmly established: still today one-third of world population without adequate sanitation/water

Why is it so hard?

- What we know works, but gas and electricity (piped water/flush toilets), not “affordable” by the poor.
- Other technologies difficult and less effective and insufficient profits for private sector to enter
- Particularly difficult because of the high component of behavioral change required
- Easy unhealthy alternatives available – gathered biomass (and open defecation)
- Yet, the fact that 60% of the world is now protected, gives us reason to think we can protect the other 40%

What to do

1. Expand use of what works – gas stoves and electric cooking appliances. Top priority.
2. Develop really clean biomass stoves– close to gas performance in the lab needed
3. Deploy with chimneys where at all possible
4. Upgrade kitchens – lift cooking off the floor – change social expectations of the kitchen
5. Treat seriously – big problems require big solutions – need best combustion, materials, manufacturing, marketing, financing solutions the world can find

Problem

- Word “improved” is highly misleading.
- Should be avoided as it is relative to something usually undefined.
- Absolute terms are needed
  - High efficiency
  - Clean or low emissions
- And, very unfortunately, the two often do not go together

International Standards Process

- International Standards Organization (ISO)
  - Preliminary standards now available for emissions, efficiency, etc. (IWA)
- World Health Organization (WHO)
  - Indoor air quality guidelines
  - Total and indoor emissions limits to be published late this year
- Final ISO standards to incorporate WHO AQGs

ENVIRONMENTAL Science & Technology

Article

pubs.acs.org/est

Pollutant Emissions and Energy Efficiency under Controlled Conditions for Household Biomass Cookstoves and Implications for Metrics Useful in Setting International Test Standards

James Jetter,*[,†] Yongxin Zhao,[‡] Kirk R. Smith,[§] Bernine Khan,[†] Tiffany Yelverton,[†] Peter DeCarlo,[∥] and Michael D. Hays[†]

EPA Testing Lab, North Carolina
Only Independent Stove Lab in the World at Present
Using Modern Methods

EPA Testing Lab Results 2012

Total Emissions: Woodstoves

		CO				PM2.5			
		High Power		Low power		High Power		Low power	
Cookstove	Tier	($g/MJ_{delivered}$)	Sub-Tier	(g/min/L)	Sub-Tier	($g/MJ_{delivered}$)	Sub-Tier	(mg/min/L)	Sub-Tier
3 Stone carefully tended	0	11.2	1	0.230	0	719	1	10.0	0
3 Stone minimally tended	0	15.1	1	0.288	0	1350	0	16.5	0
Berkeley Darfur	1	5.2	4	0.093	3	277	2	4.1	1
Envirofit G-3300	1	5.1	4	0.080	4	478	1	2.7	2
Envirofit G-3300, reduced fuel feed	2	3.4	4	0.070	4	300	2	2.2	2
Onil	1	5.7	4	0.109	2	793	1	5.7	1
Philips HD4012 fan	3	1.0	4	0.015	4	62	3	0.7	4
Philips HD4008 Natural Draft	1	5.2	4	0.044	4	702	1	6.8	1
Sampada	0	8.9	3	0.072	4	623	1	8.4	0
StoveTec GreenFire	2	6.3	4	0.062	4	377	2	3.2	2
StoveTec GreenFire, reduced fuel feed	2	4.3	4	0.060	4	351	2	3.4	2
Upesi Portable	1	10.9	2	0.143	1	914	1	7.7	1

Jetter et al., 2012

Many thanks to

Guatemala Ministry of Health, NIEHS, WHO, Griffin Trust, Daniele Agostino Derossi Foundation

Publications and presentations on website – easiest to just "google" Kirk R. Smith