Co-benefits of Reducing Short-lived Greenhouse Pollutants or PICs and the Poor

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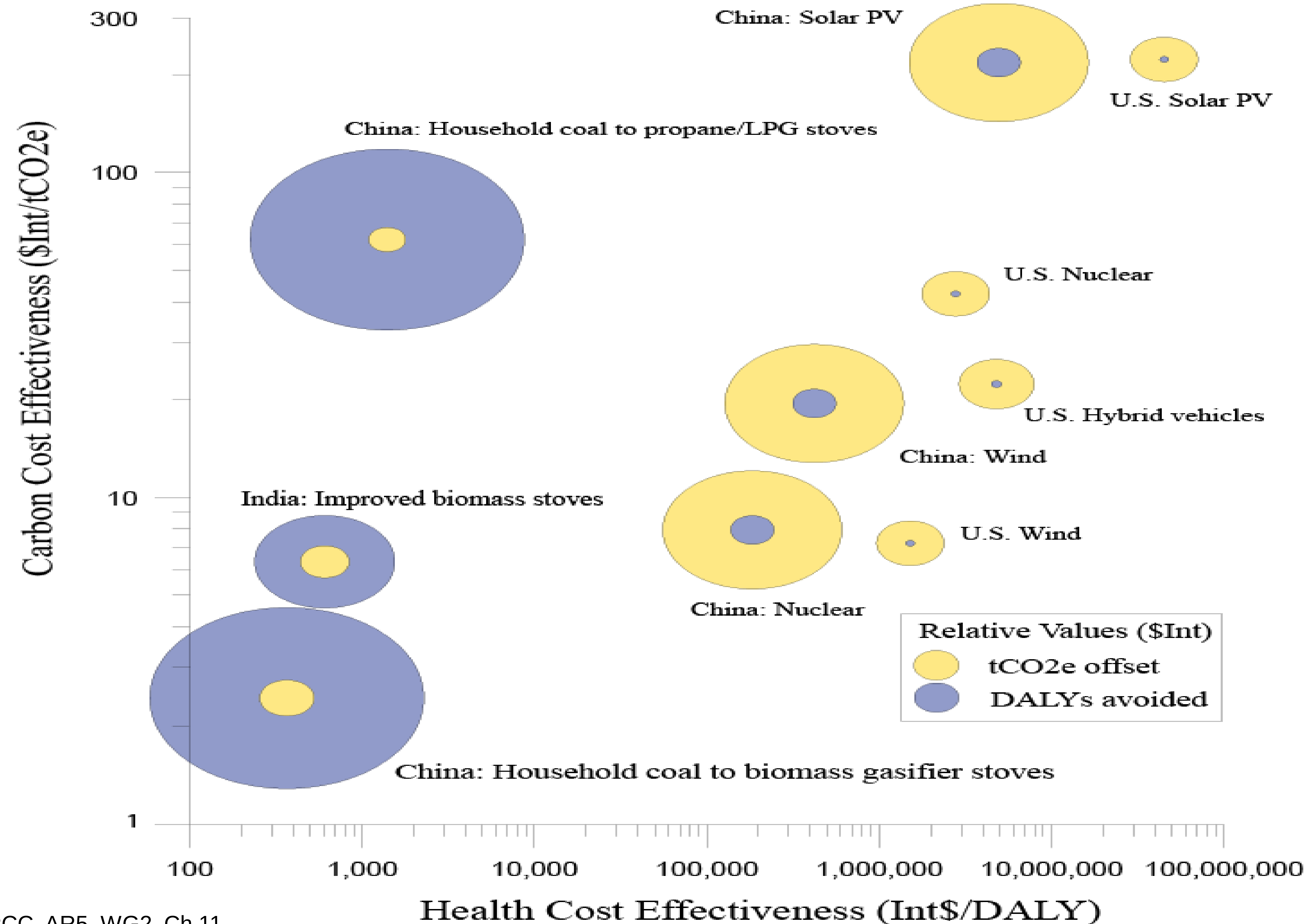
University of California, Berkeley



IPCC, AR5, WG2, Ch 11

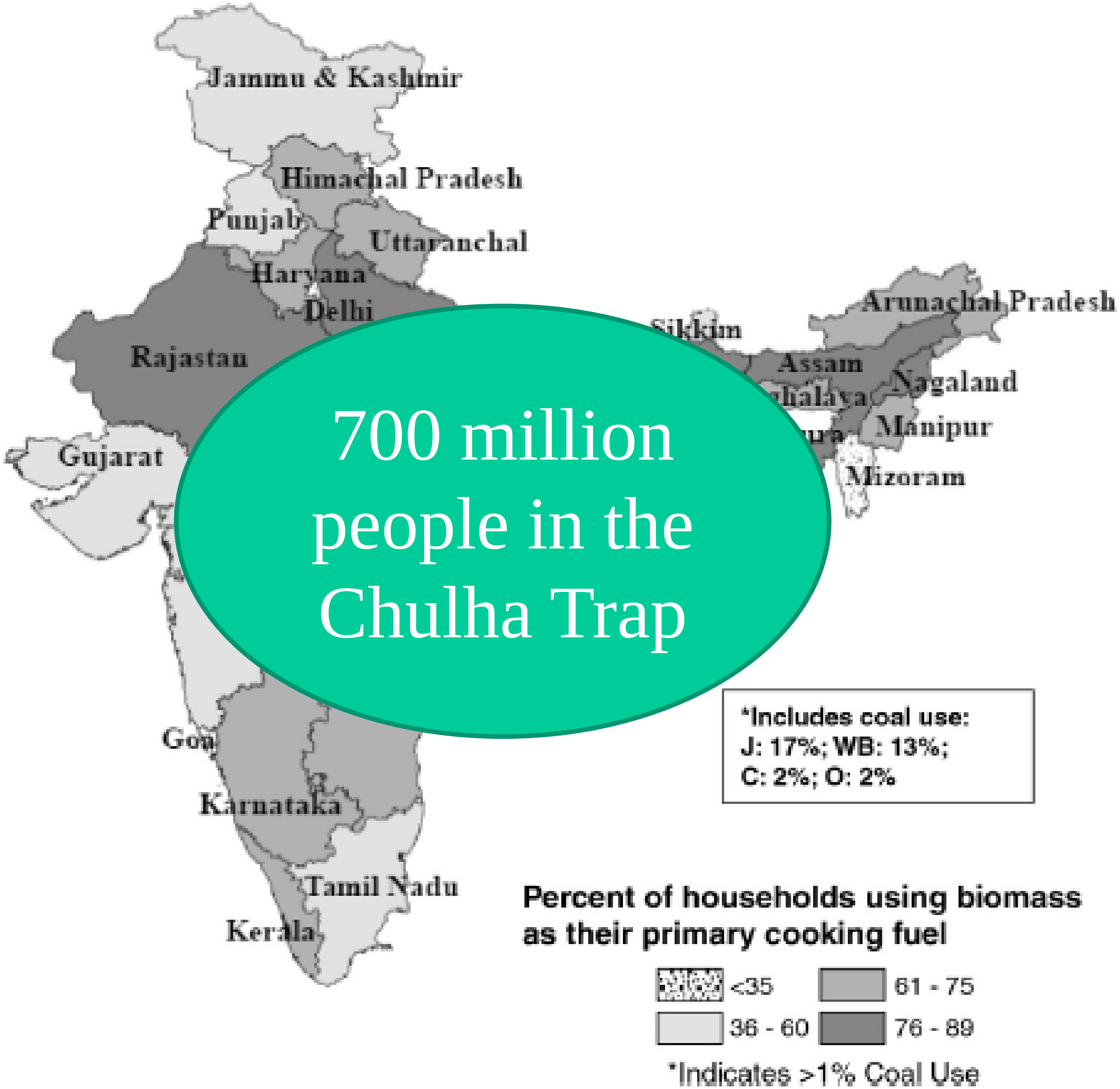


Fig. 1. Distribution by state of households using biomass or coal as their main cooking fuel in 2005. From (IIPS, 2007).

700 million people in the Chulha Trap

1990:
85%: 700 million people using solid fuels

2010:
60%: 700 million people

~1980
700 million people in entire country

Energy flows in a well-operating traditional wood-fired Indian cookstove (chulha)

A Toxic Waste Factory!!

Typical biomass cookstoves convert 6-30% of the
fuel carbon to toxic substances + methane

Into Pot	In PIC	Waste Heat
2.8 MJ	1.2 MJ	11.3 MJ
18%	8%	74%

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

Source: Zhang, et al., 2000

Nominal Combustion Efficiencies in Indian Stoves

Smith, et al., 2000

- Gas: ` 99% (98-99.5)
- Kerosene: 97 (95-98)
- Wood: 89 (81-92)
- Crop residues: 85 (78-91)
- Dung: 84 (81-89)

Recent data from Haryana households

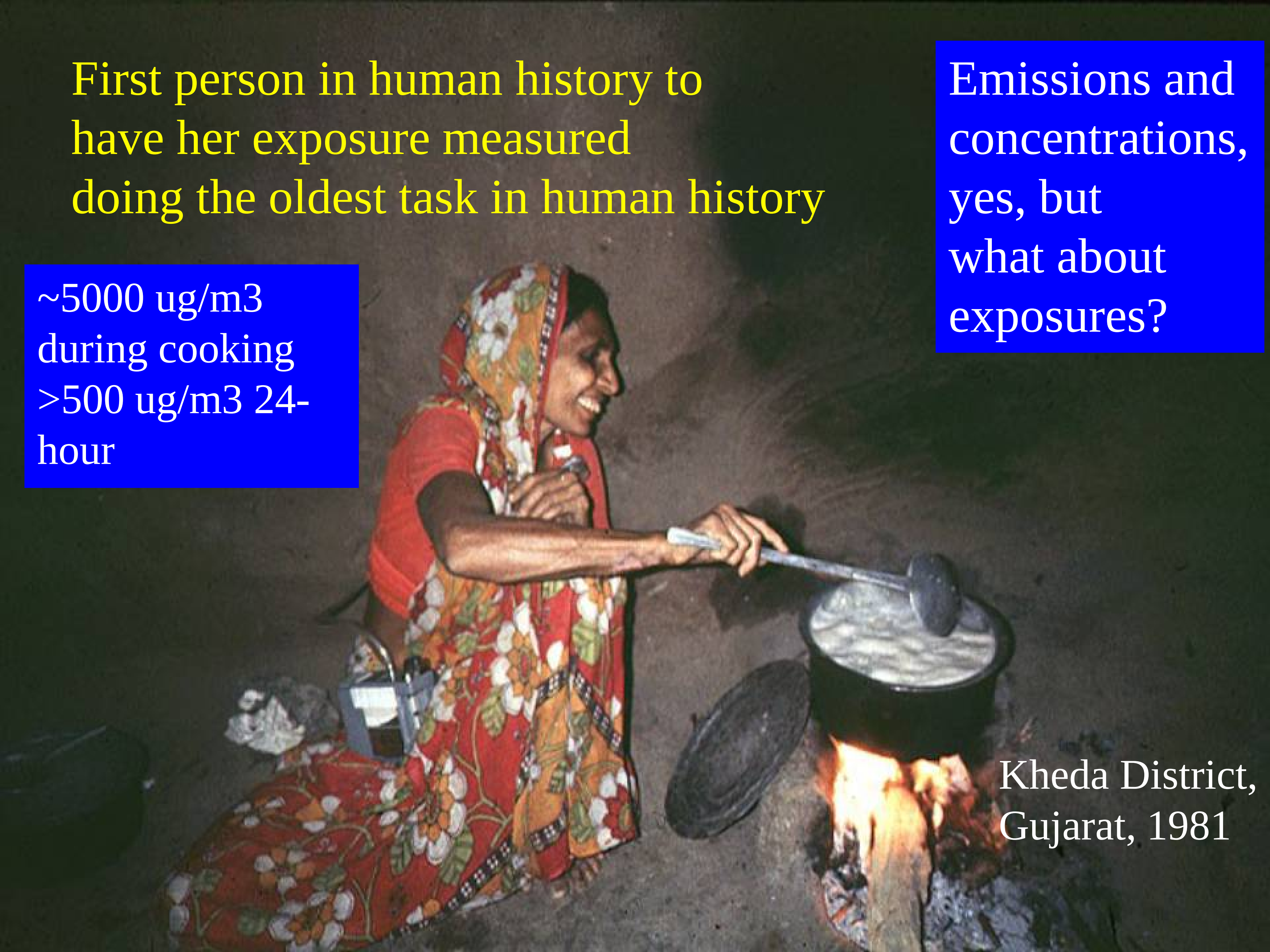
Angithi	**2**	**0.86 (±0.04)**
Fixed Chula w/o Chimney	16	0.92 (±0.01)
Haro	5	0.89 (±0.02)
Phillips	13	0.94 (±0.01)

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

- Small particles, CO, NO_2
- Hydrocarbons
  - 2
  - 4 *tadiene*
  - 2 *ne*
  - 2 *rene*
- Oxy
  - 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*

Typical chulha releases 400 cigarettes per hour worth of smoke

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


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
Kheda District,
Gujarat, 1981

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, Ab
Kathryn G Andrews*, Martin
Suzanne Barker-Collo*, Amar
Michel Boussinesq*, Michael
Fiona Bull*, Richard T Burnett
Jian Shen Chen*, Andrew Tai-
Susan Darling*, Adrian Davis
E Ray Dorsey*, Tim Driscoll*,

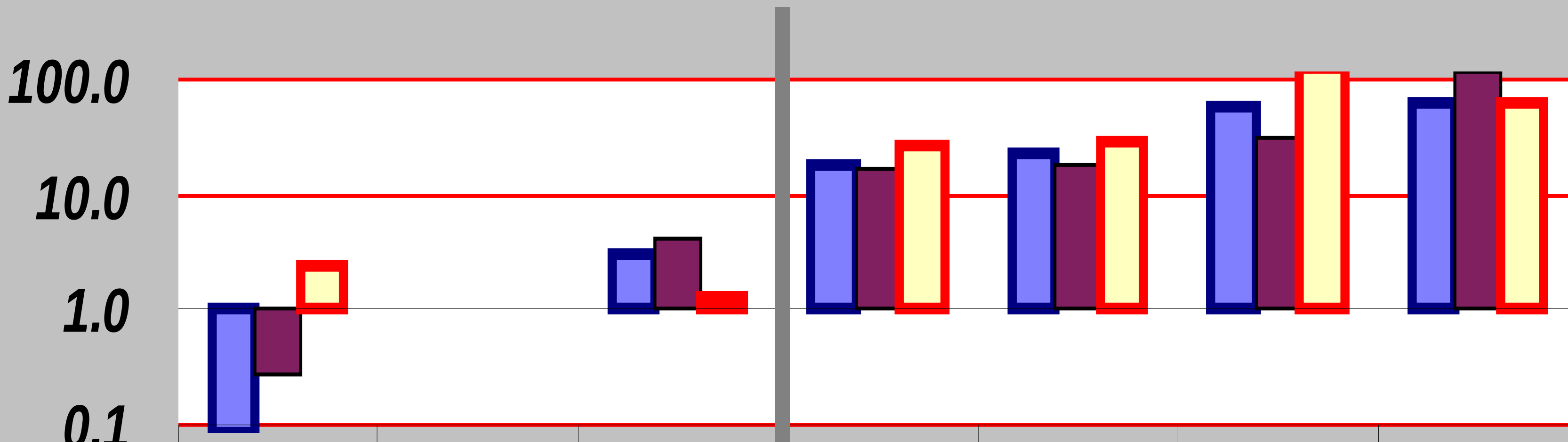
Lancet, 2012

Millions Dead: How Do We Know and What Does It Mean? Methods Used in the Comparative Risk Assessment of Household Air Pollution

Kirk R. Smith,[1,*] Nigel Bruce,[2,*] Kalpana Balakrishnan,[3] Heather Adair-Rohani,[1] John Balmes,[1,4] Zöe Chafe,[1,5] Mukesh Dherani,[2] H. Dean Hosgood,[6] Sumi Mehta,[7] Daniel Pope,[2] Eva Rehfuess,[8] and others in the HAP CRA Risk Expert Group[1]

ARPH, 2014

The Energy Ladder: Relative Pollutant Emissions Per Meal



	Biogas	LPG	Kerosene	Wood	Roots	Crop Residues	Dung
CO	0.1	1.0	3	19	22	60	64
Hydrocarbons	0.3	1.0	4.2	17	18	32	115
PM	2.5	1.0	1.3	26	30	124	63

CO Hydrocarbons PM

Smith, et al., 2005

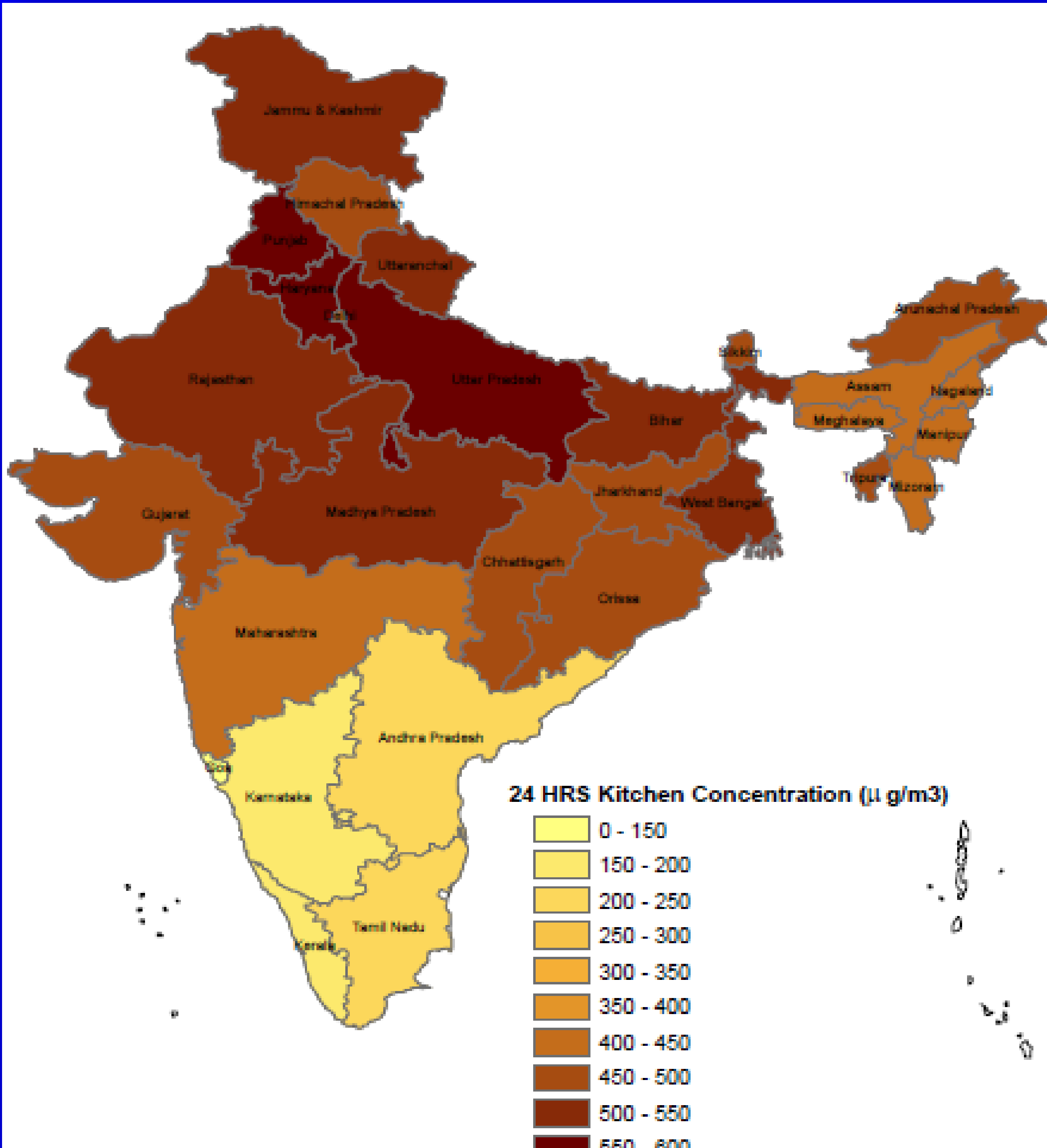
Balakrishnan *et al. Environmental Health* 2013, **12**:77
http://www.ehjournal.net/content/12/1/77

ENVIRONMENTAL HEALTH

RESEARCH Open Access

State and national household concentrations of $PM_{2.5}$ from solid cookfuel use: Results from measurements and modeling in India for estimation of the global burden of disease

Kalpana Balakrishnan[1*], Santu Ghosh[1], Bhaswati Ganguli[2], Sankar Sambandam[1], Nigel Bruce[3], Douglas F Barnes[4] and Kirk R Smith[5]

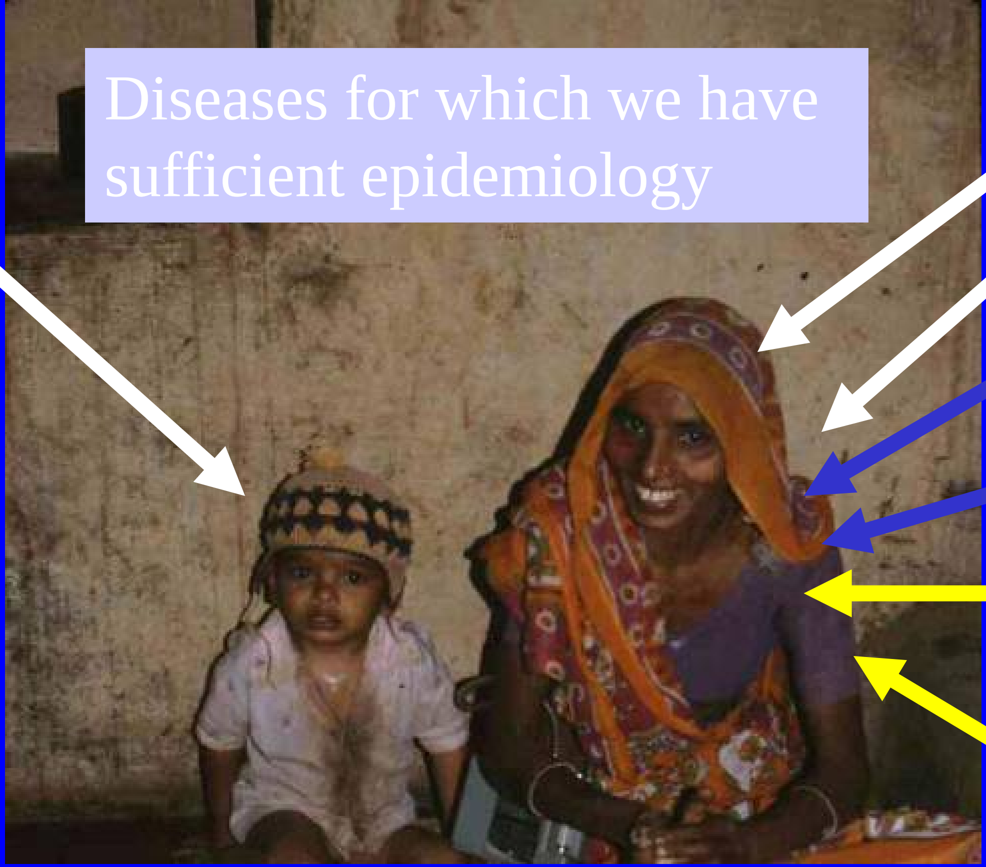


State-wise estimates of 24-h kitchen concentrations of PM2.5 in India

Solid-fuel using households

Balakrishnan et al. 2013

Diseases for which we have sufficient epidemiology



ALRI/ Pneumonia

COPD

Lung cancer (coal)

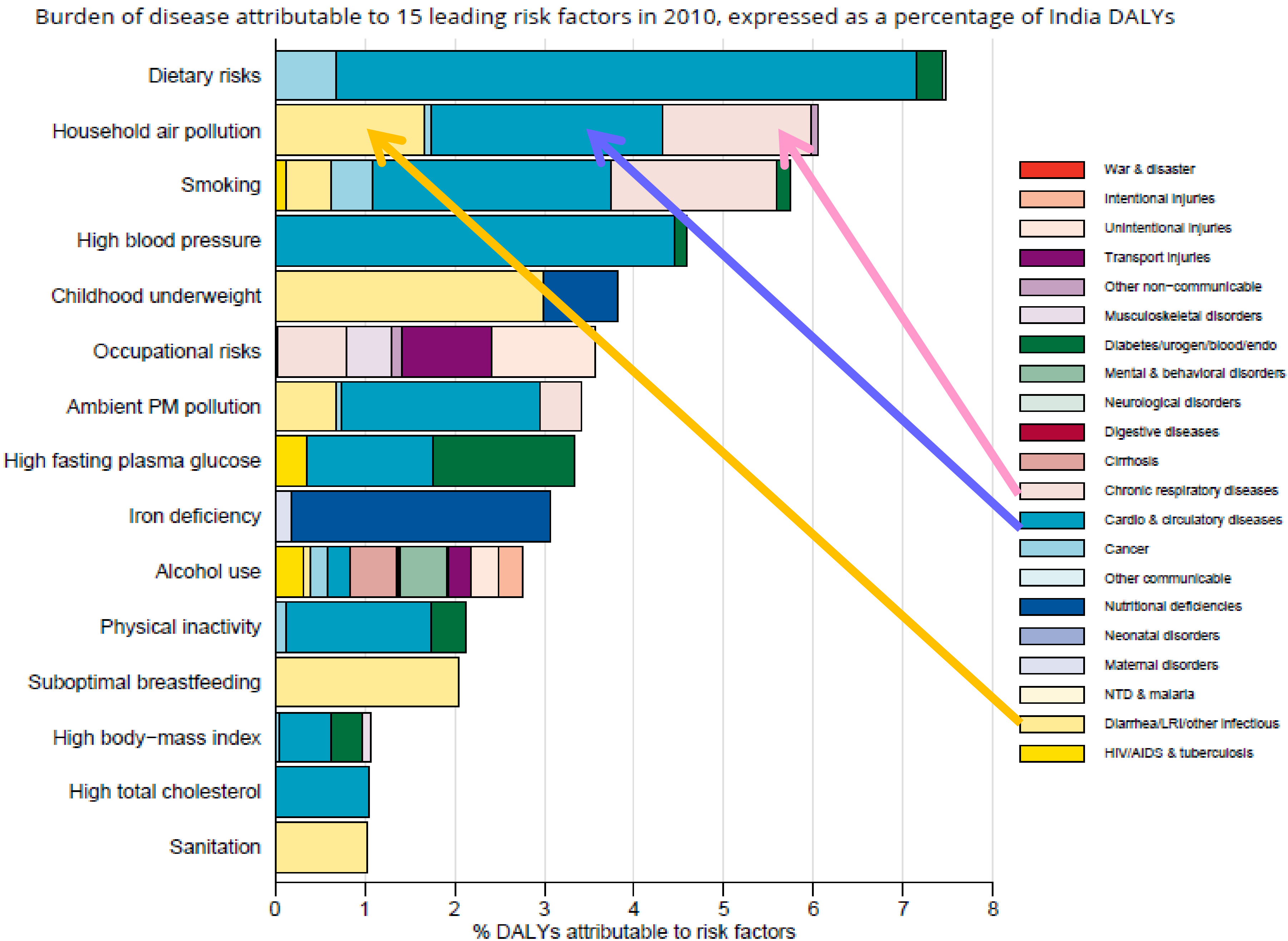
Lung cancer (biomass)

Cataracts

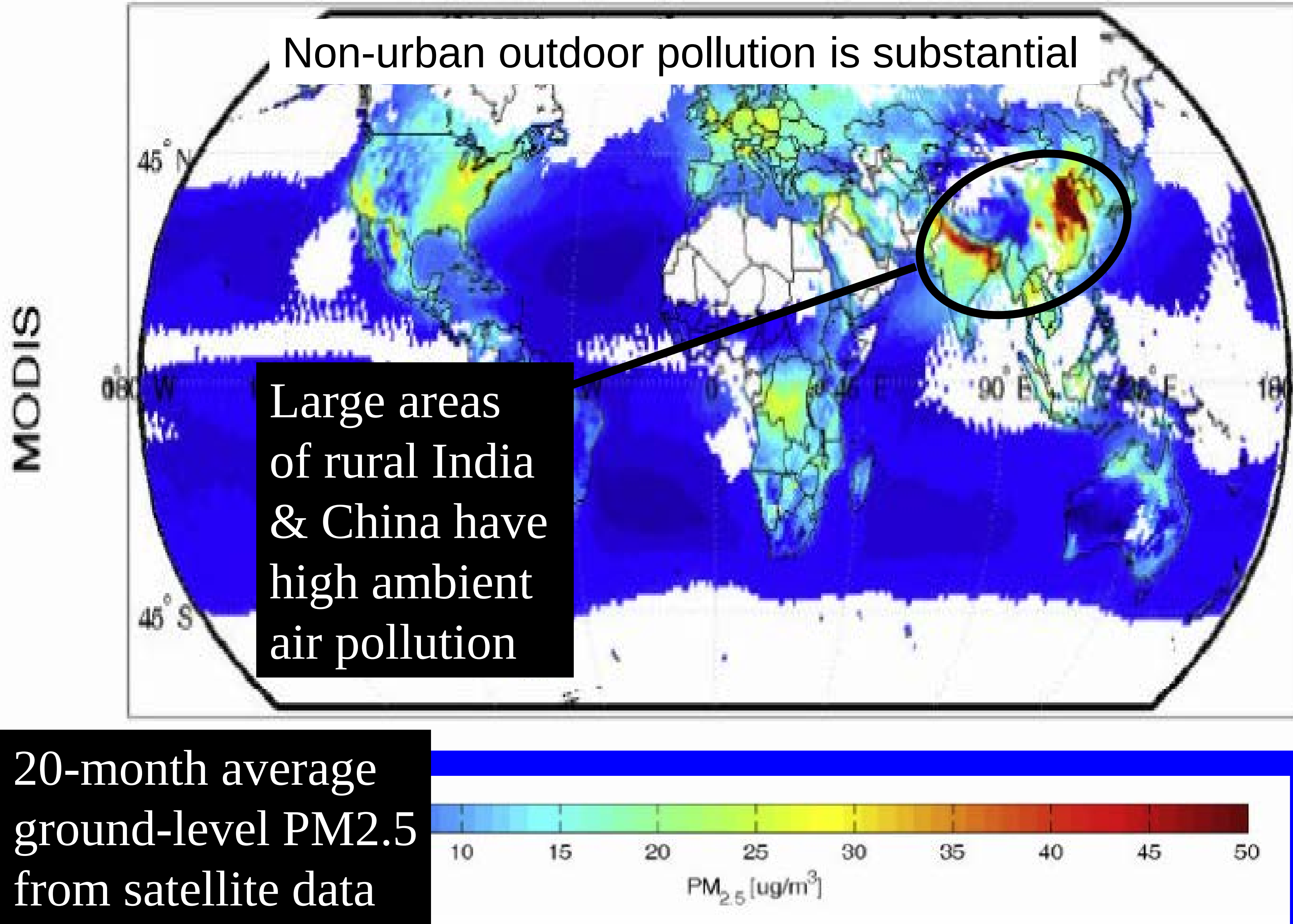
Ischemic heart disease

Stroke

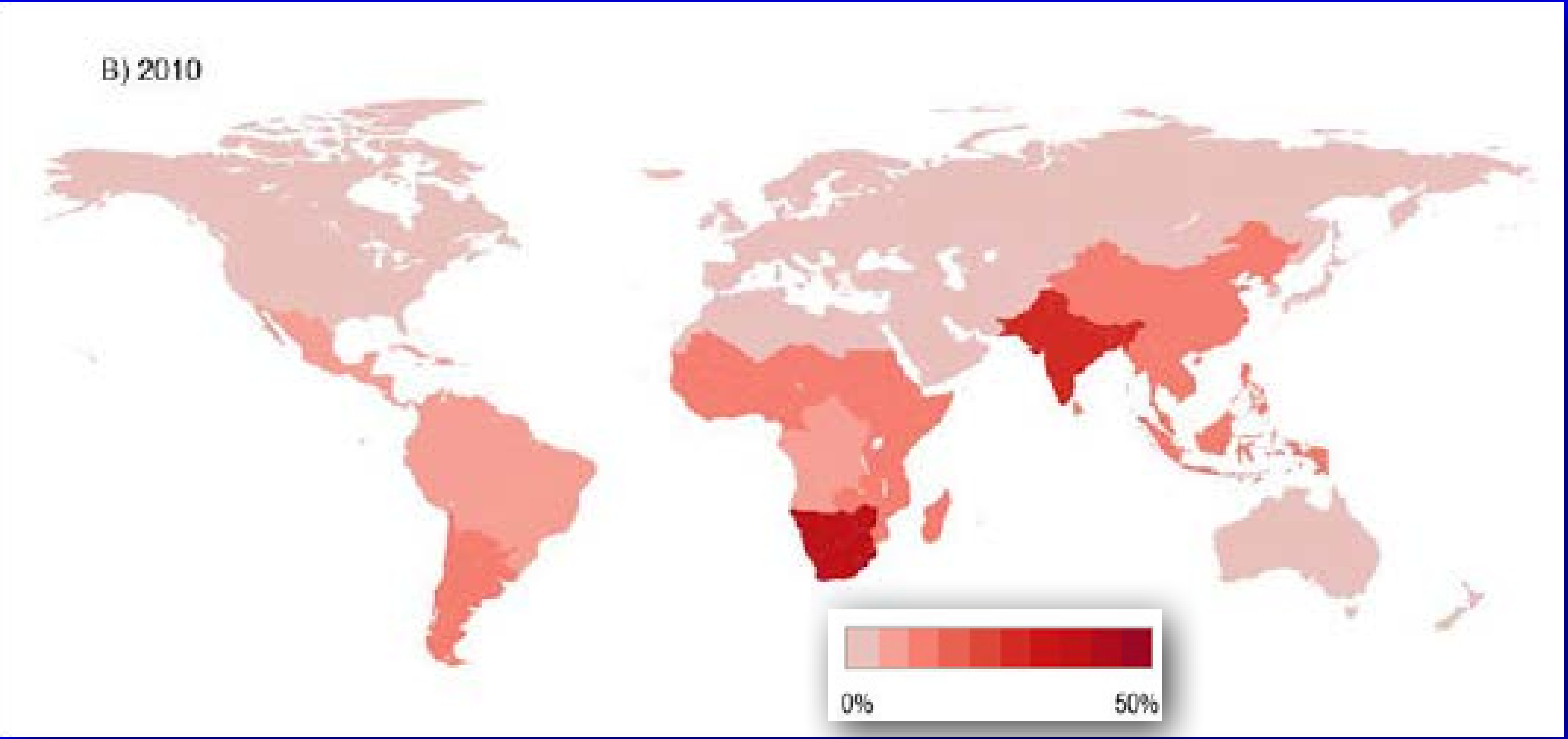
These diseases are included in the
2010 Comparative Risk Assessment (released in 2012)



Burden of disease attributable to 15 leading risk factors in 2010, expressed as a percentage of India DALYs
Dietary risks
Household air pollution
Smoking
High blood pressure
Childhood underweight
Occupational risks
Ambient PM pollution
High fasting plasma glucose
Iron deficiency
Alcohol use
Physical inactivity
Suboptimal breastfeeding
High body−mass index
High total cholesterol
Sanitation
0
1
2
3
4
5
6
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



Non-urban outdoor pollution is substantial
MODIS
45° N
45° S
90° E
Large areas of rural India & China have high ambient air pollution
20-month average ground-level PM2.5 from satellite data
10
15
20
25
30
35
40
45
50
PM2.5 [ug/m3]



Relative contribution household cookstoves
to outdoor particle pollution
~26% in India

Chafe, et al., 2014

Total Burden of HAP in India

- About 1.15 million premature deaths including the contribution to outdoor
- About twice the impact of the rest of ambient air pollution
- Considerable uncertainty, but not extending to small effects.

Chemosphere, Vol.26, Nos.1-4, pp 479-505, 1993
Printed in Great Britain

0045-6535/93 $6.00 + 0.00
Pergamon Press Ltd.

GREENHOUSE GASES FROM BIOMASS AND FOSSIL FUEL STOVES IN DEVELOPING COUNTRIES: A MANILA PILOT STUDY

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Research Triangle Park, North Carolina 27711, USA
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Dept. of Mechanical Engineering
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[5]Lawrence Berkeley Laboratory, University of California
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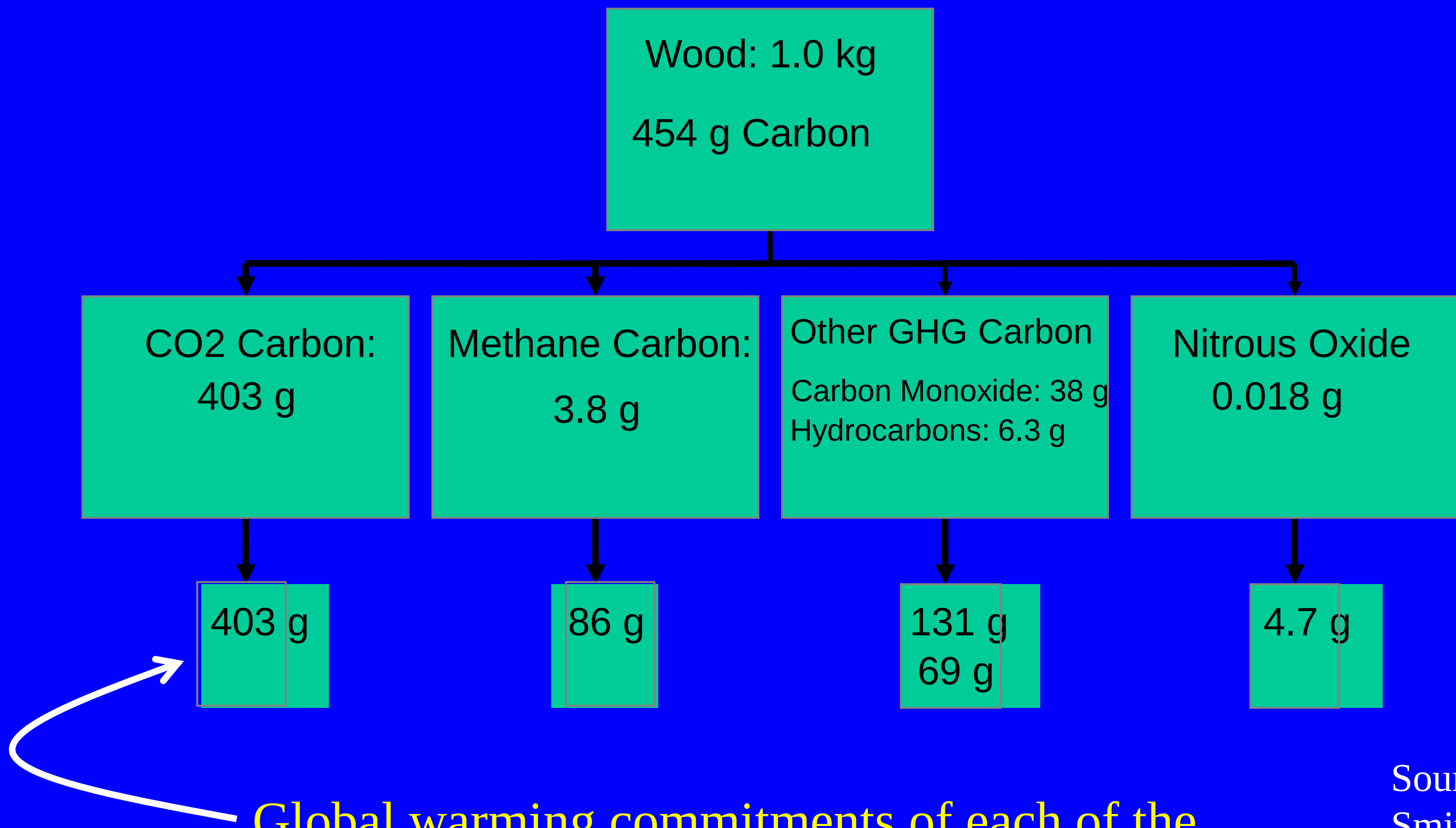
Berkeley, California 94720, USA

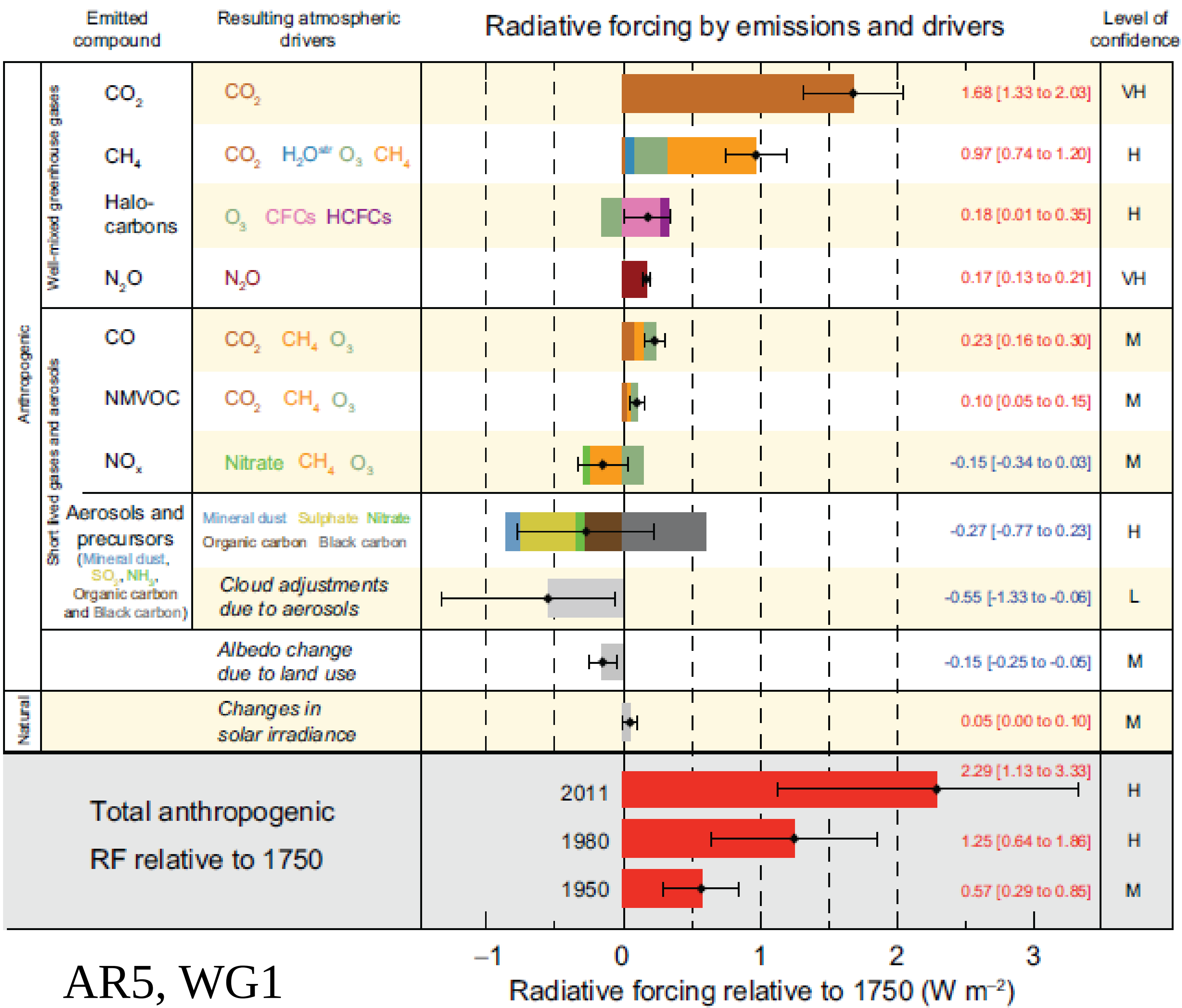
(Received in USA 26 November 1991; accepted 15 April 1992)

Greenhouse warming commitment per meal for typical wood-fired cookstove in India

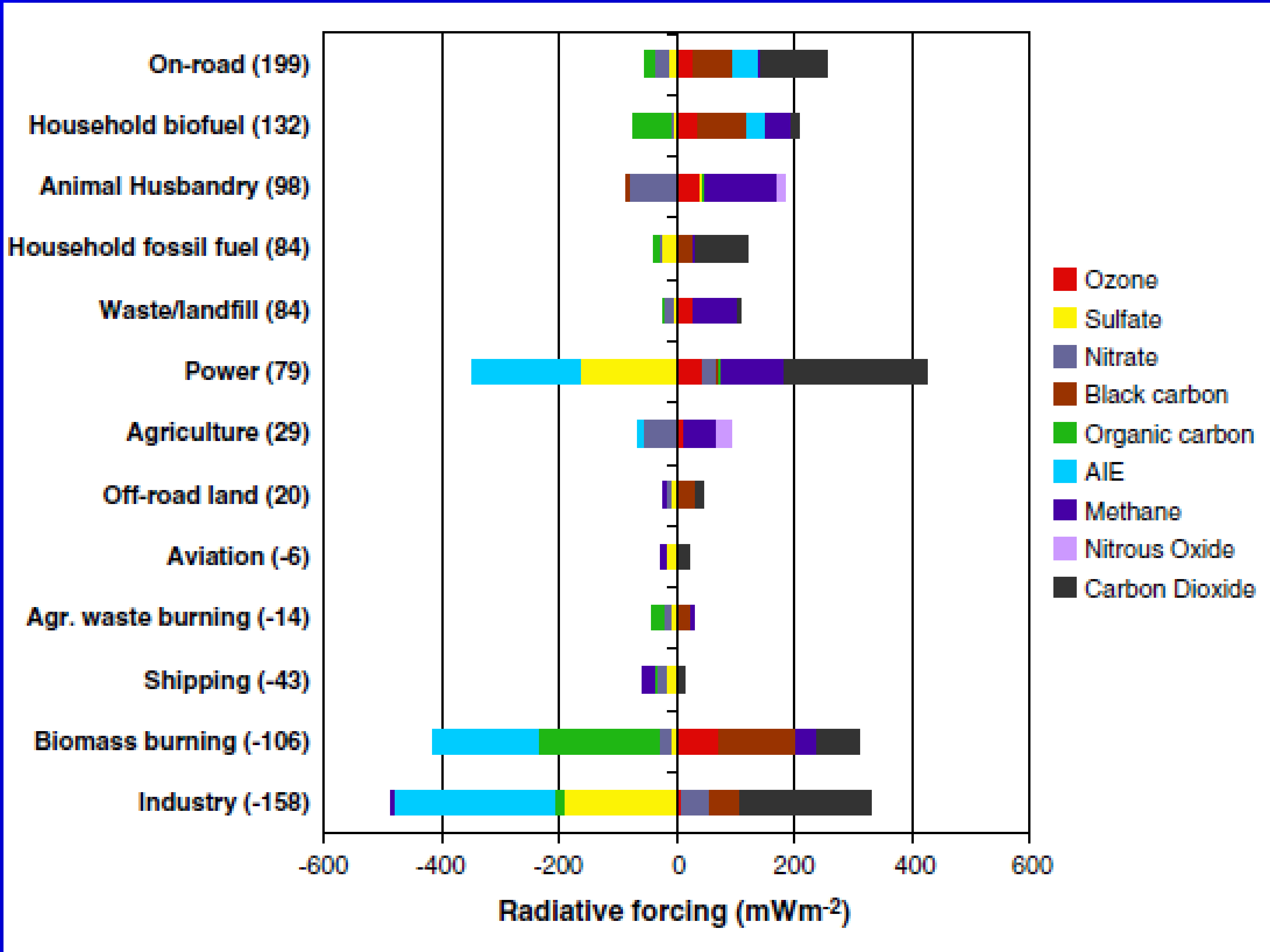


Global warming commitments of each of the gases as CO_2 equivalents

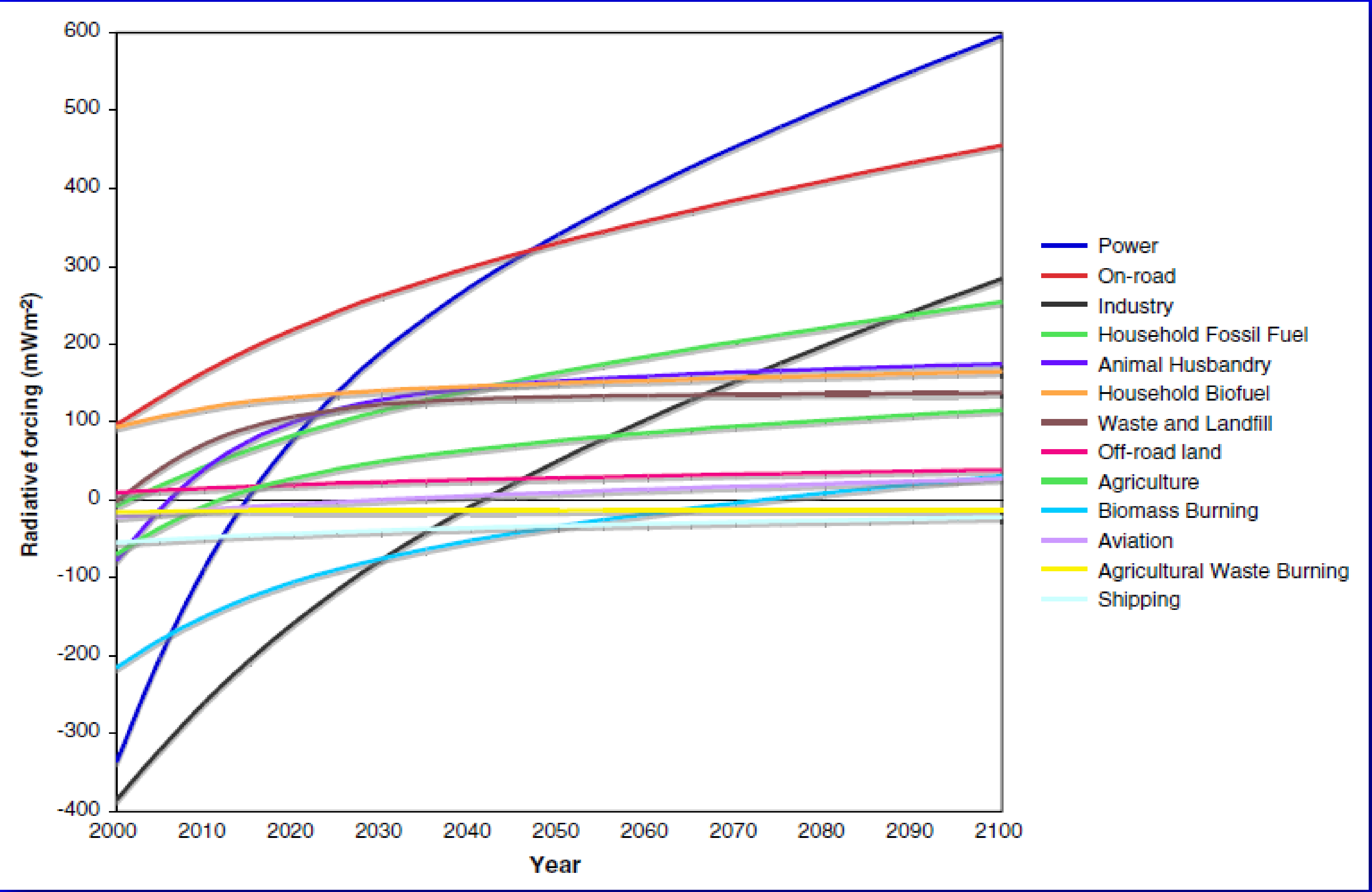
Source: Smith, et al., 2000


Emitted compound
Resulting atmospheric drivers
Radiative forcing by emissions and drivers
Level of confidence
Anthropogenic
Well-mixed greenhouse gases
CO_2
CO_2
1.68 [1.33 to 2.03]
VH
CH_4
CO_2 H_2O^{str} O_3 CH_4
0.97 [0.74 to 1.20]
H
Halo-carbons
O_3 CFCs HCFCs
0.18 [0.01 to 0.35]
H
N_2O
N_2O
0.17 [0.13 to 0.21]
VH
Short lived gases and aerosols
CO
CO_2 CH_4 O_3
0.23 [0.16 to 0.30]
M
NMVOC
CO_2 CH_4 O_3
0.10 [0.05 to 0.15]
M
NO_x
Nitrate CH_4 O_3
-0.15 [-0.34 to 0.03]
M
Aerosols and precursors (Mineral dust, SO_2, NH_3, Organic carbon and Black carbon)
Mineral dust Sulphate Nitrate Organic carbon Black carbon
-0.27 [-0.77 to 0.23]
H
Cloud adjustments due to aerosols
-0.55 [-1.33 to -0.06]
L
Albedo change due to land use
-0.15 [-0.25 to -0.05]
M
Natural
Changes in solar irradiance
0.05 [0.00 to 0.10]
M
Total anthropogenic RF relative to 1750
2011
2.29 [1.13 to 3.33]
H
1980
1.25 [0.64 to 1.86]
H
1950
0.57 [0.29 to 0.85]
M
−1
0
1
2
3
Radiative forcing relative to 1750 ($W m^{-2}$)

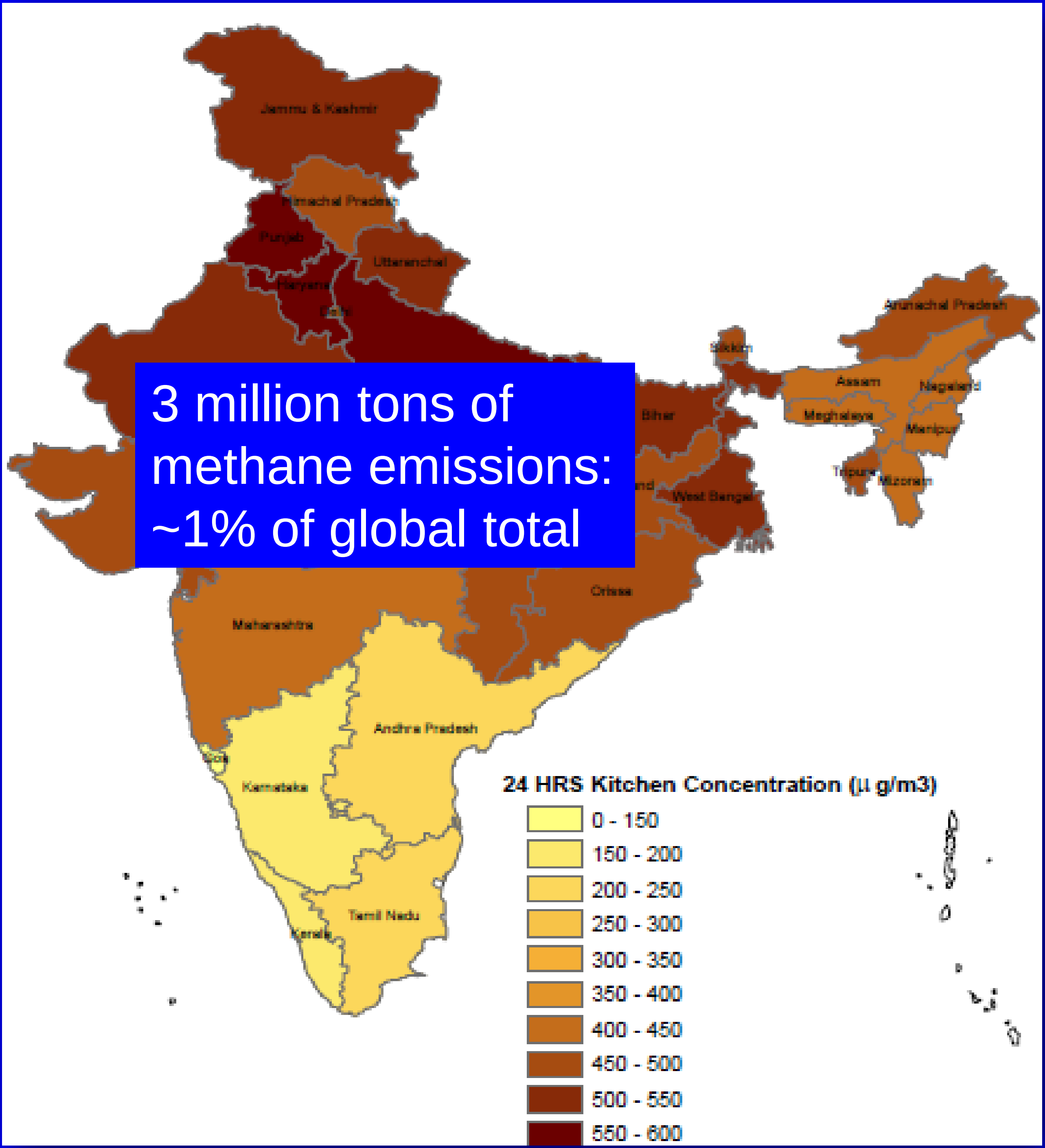
AR5, WG1



Unger et al., PNAS, 2010



Unger et al., PNAS, 2010



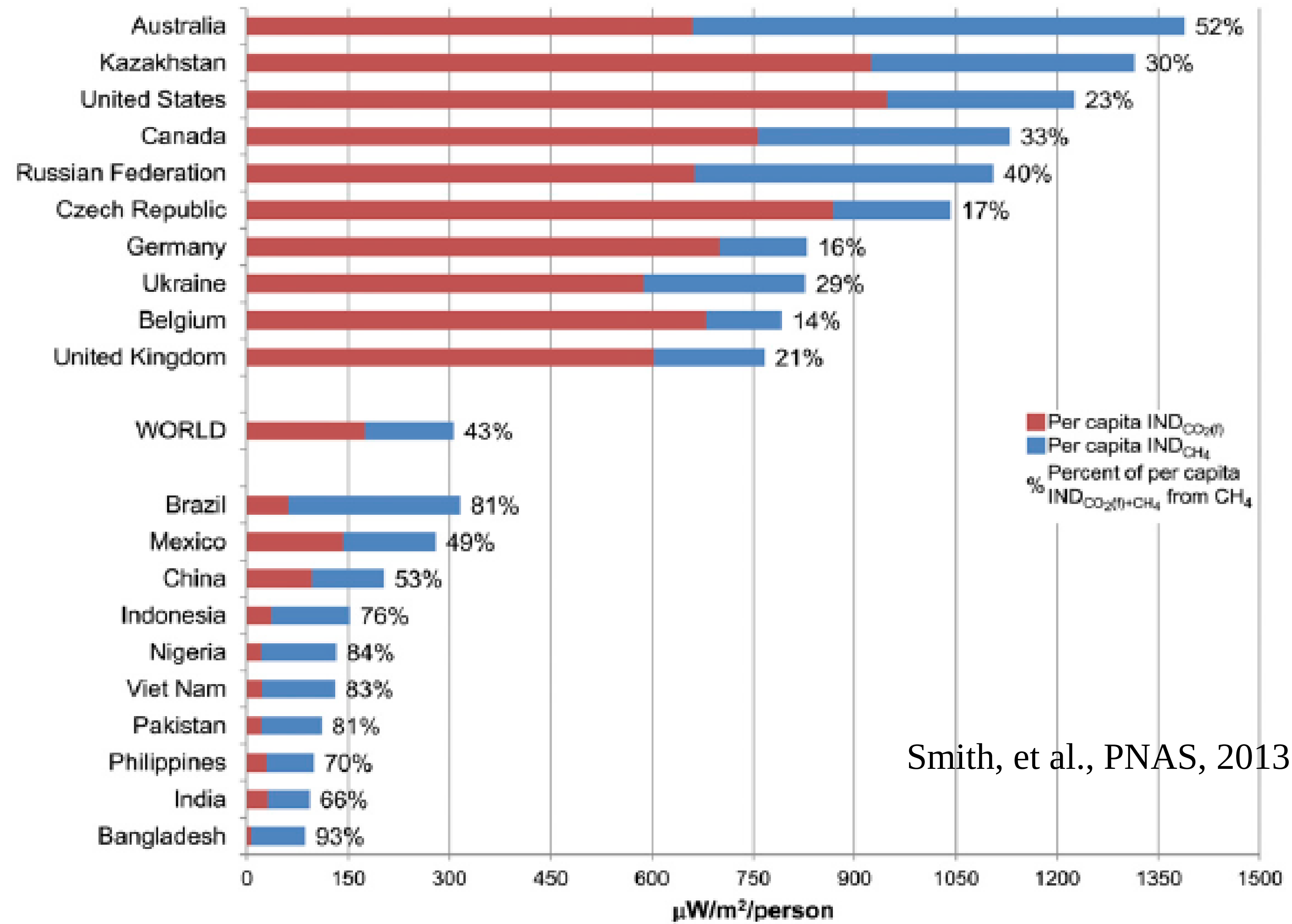
3 million tons of methane emissions: ~1% of global total

State-wise estimates of 24-h kitchen concentrations of PM2.5 in India

Solid-fuel using households

Balakrishnan et al. 2013

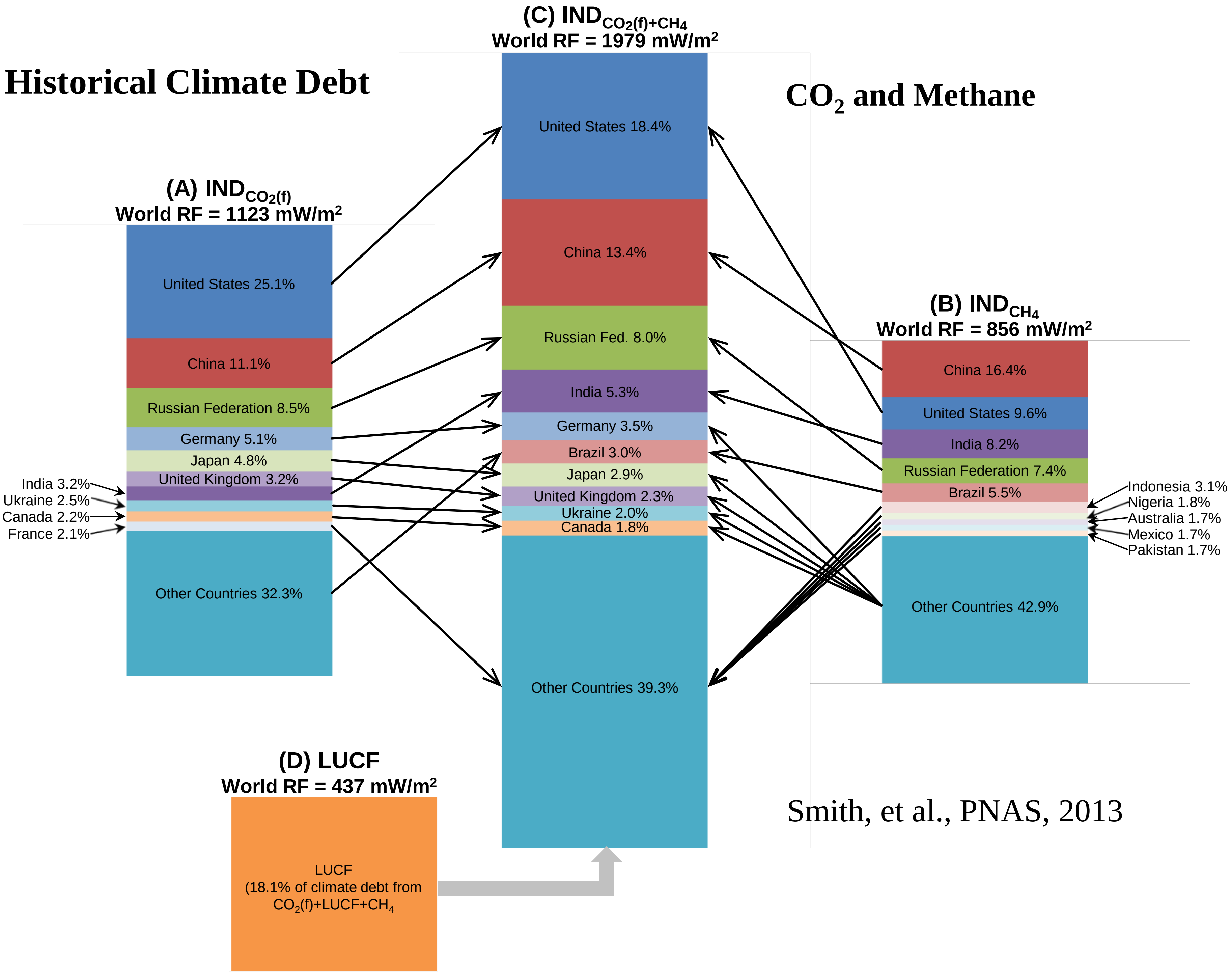
Per Capita Historical Climate Debt: CO_2 and Methane



Smith, et al., PNAS, 2013

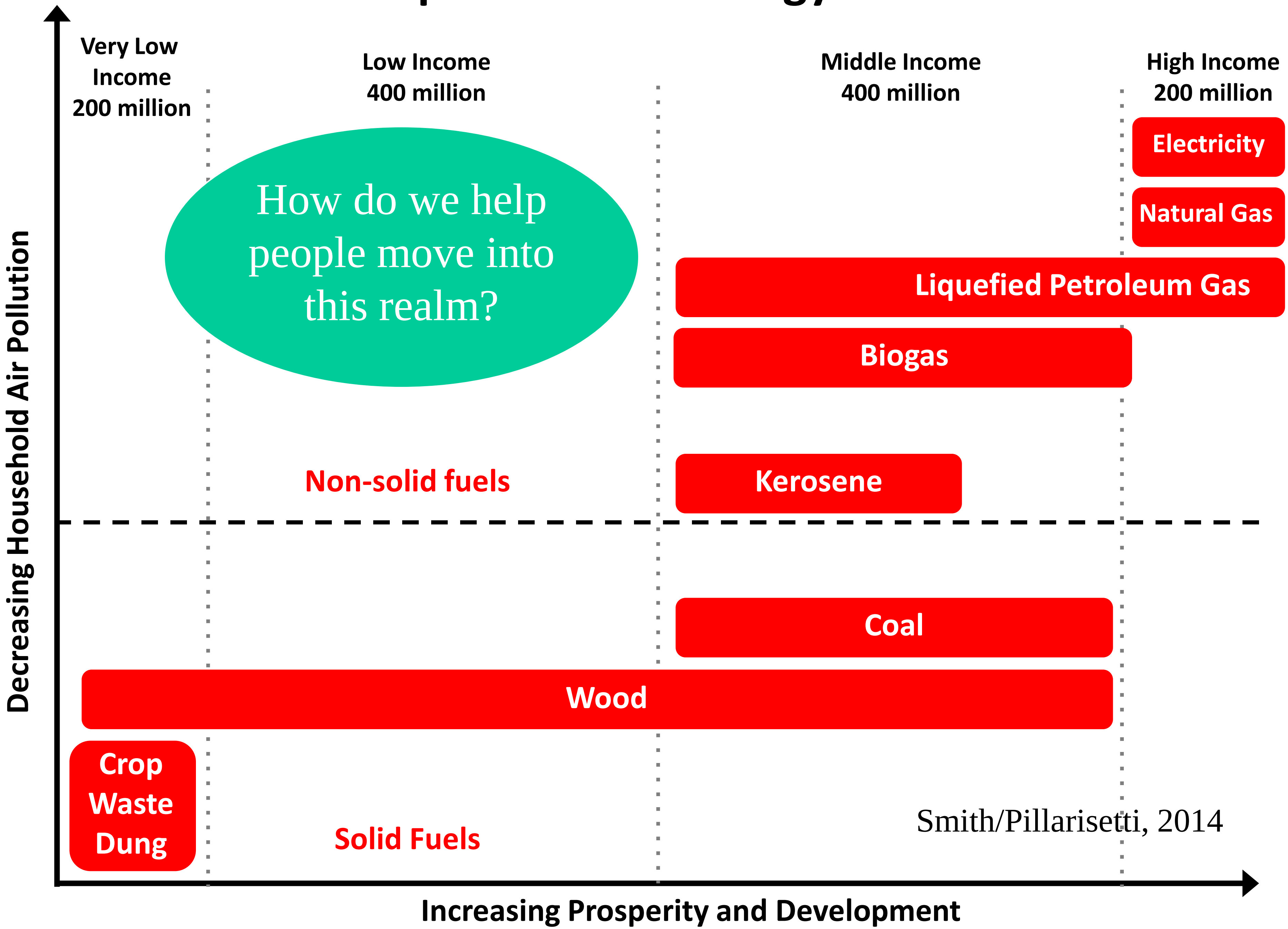
Historical Climate Debt

CO_2 and Methane



Smith, et al., PNAS, 2013

Conceptual Indian Energy Ladder

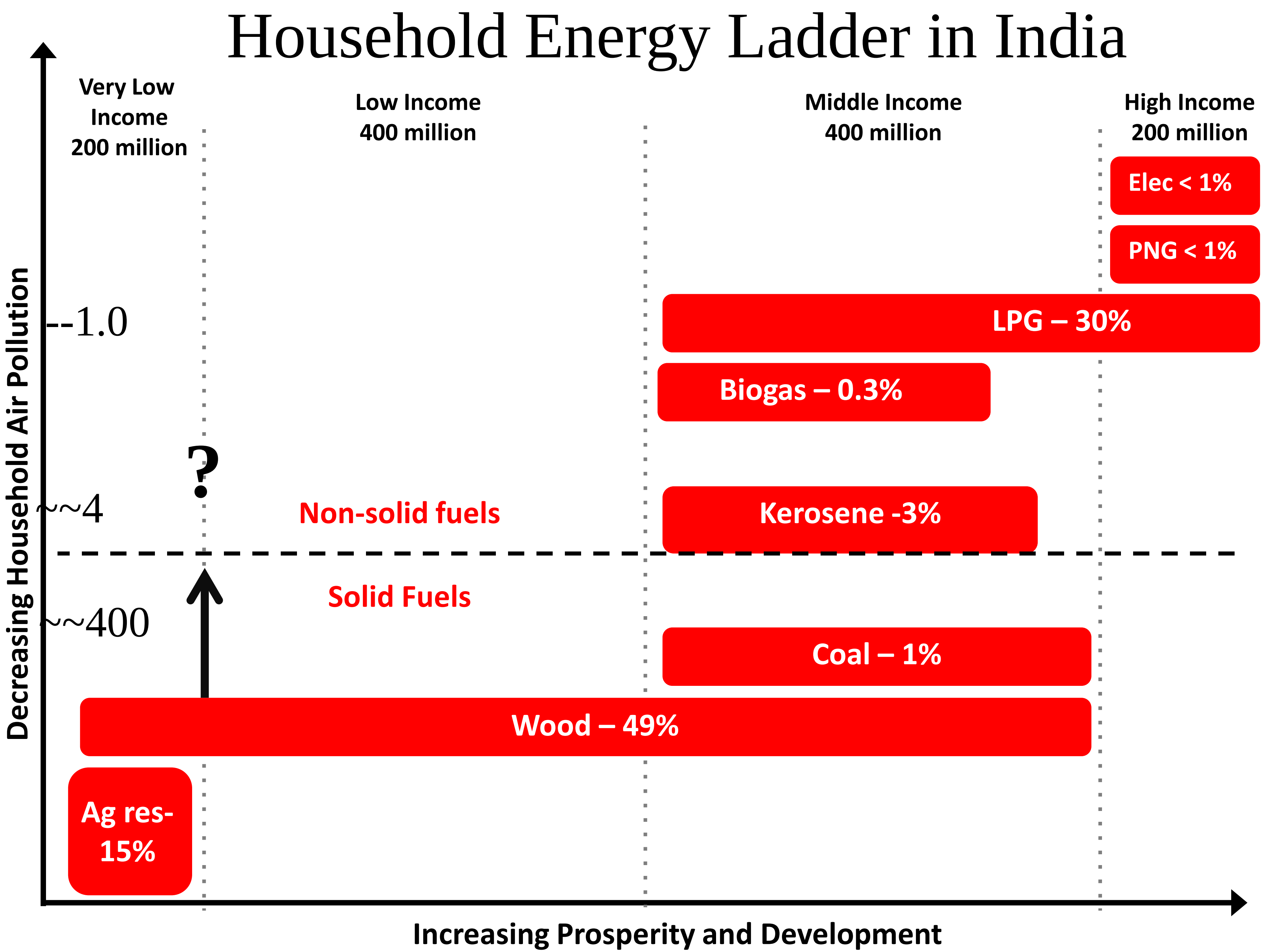


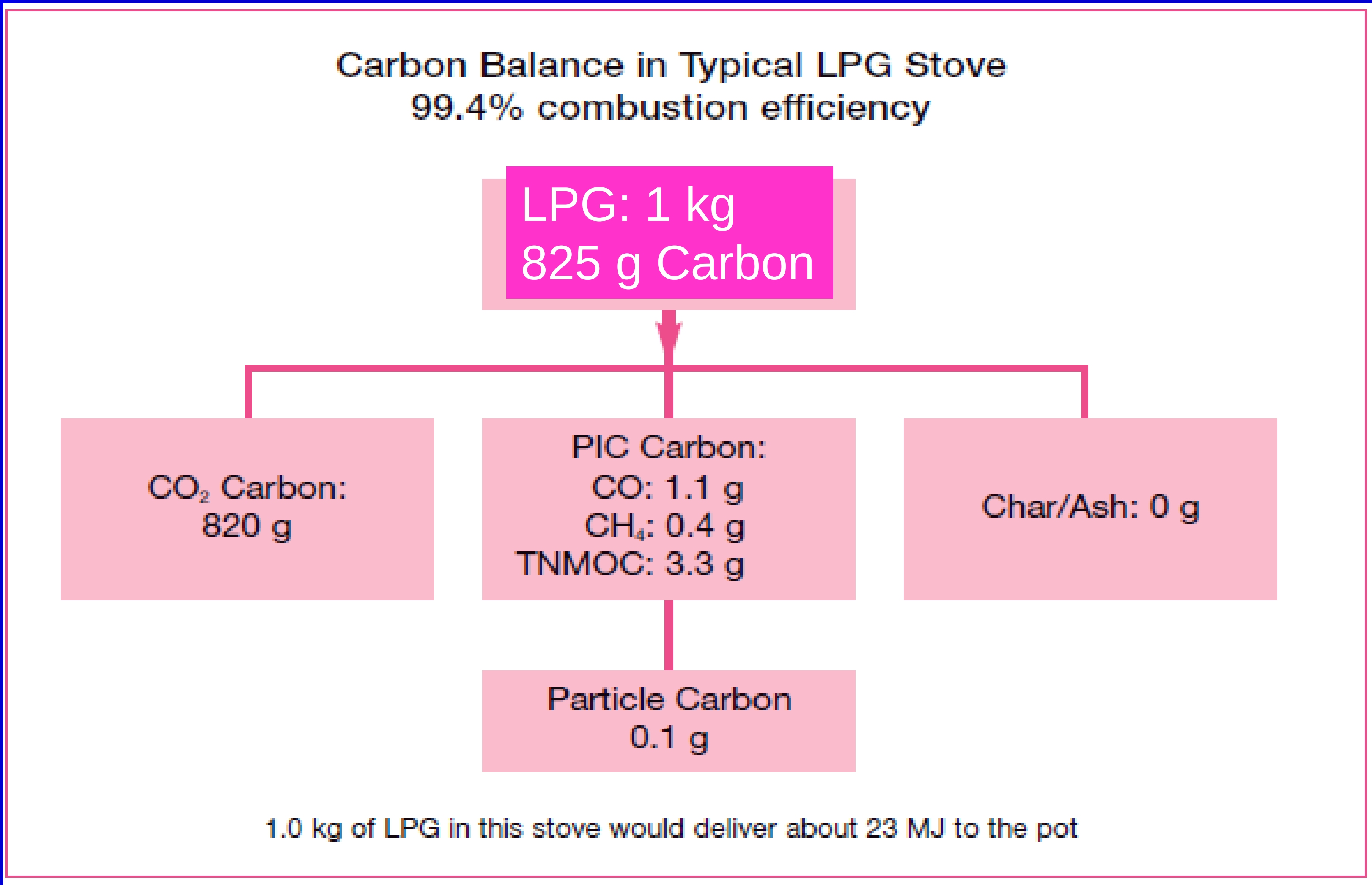
Diversity of improved cook stoves

27.0

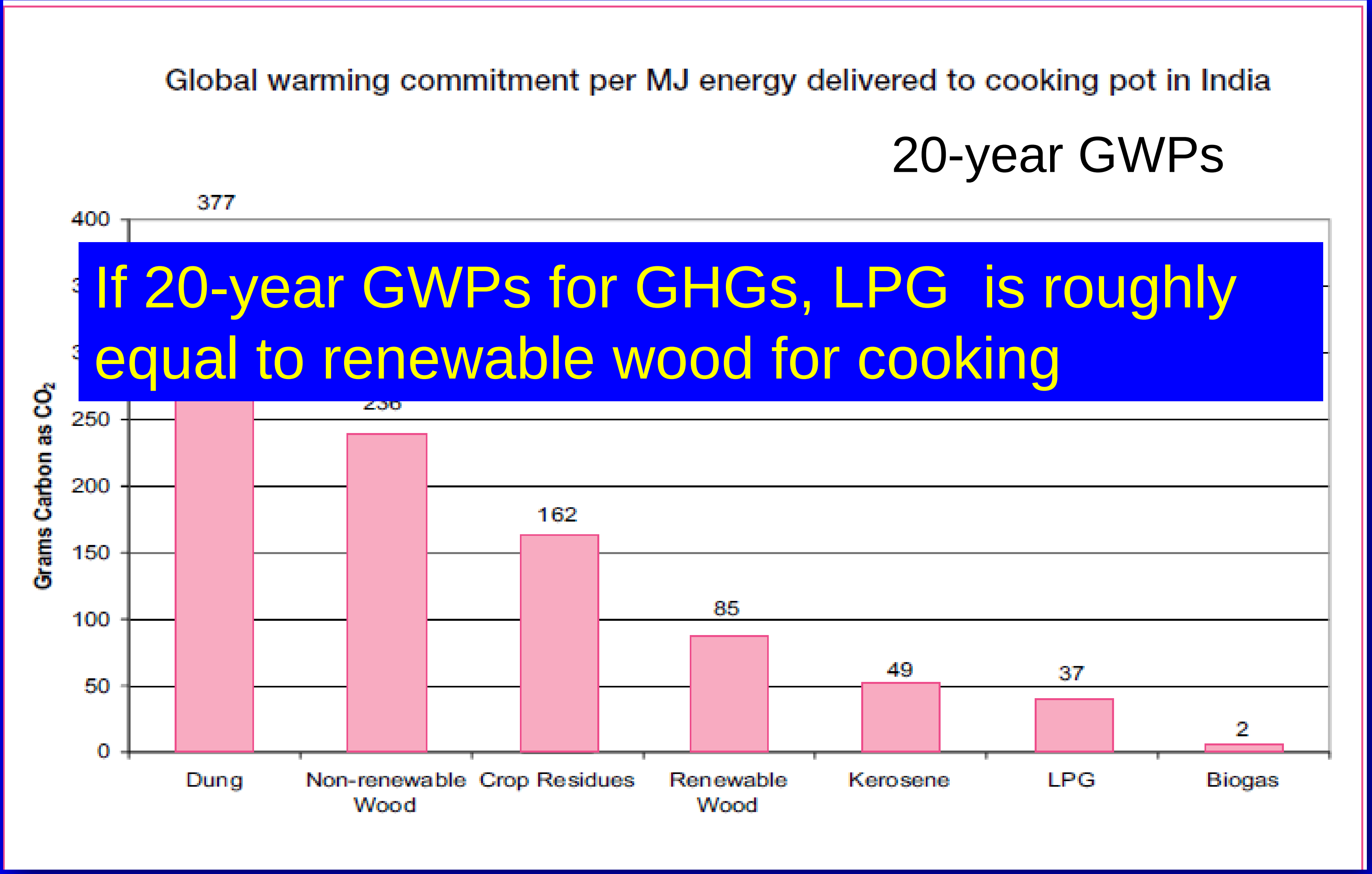
Current Health Evidence

- Shows now that even major reductions (<90%) in emissions still lead to small health improvements
- Posing a very large technical challenge to solid fuels to reach 99% or greater reductions over open fires
- This is very difficult with any solid fuel
- But still worth pursuing


Household Energy Ladder in India
Very Low Income 200 million
Low Income 400 million
Middle Income 400 million
High Income 200 million
Elec < 1%
PNG < 1%
--1.0
LPG – 30%
Biogas – 0.3%
?
~~4
Non-solid fuels
Kerosene -3%
Solid Fuels
~~400
Coal – 1%
Wood – 49%
Ag res- 15%
Decreasing Household Air Pollution
Increasing Prosperity and Development

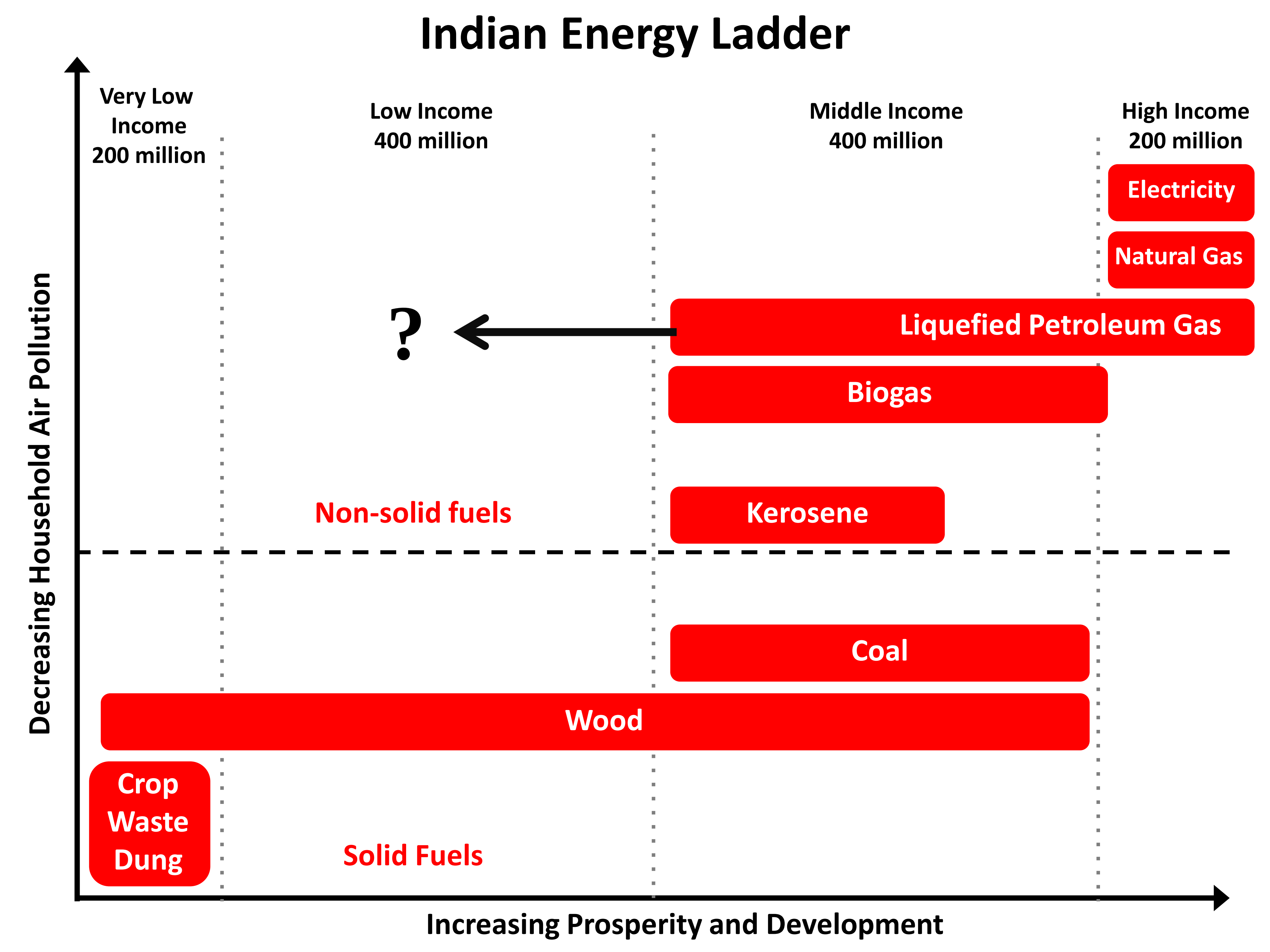


Smith et al., 2005



If 20-year GWPs for GHGs, LPG is roughly equal to renewable wood for cooking

Smith, et al., 2005


Indian Energy Ladder
Decreasing Household Air Pollution
Increasing Prosperity and Development
Very Low Income 200 million
Low Income 400 million
Middle Income 400 million
High Income 200 million
Electricity
Natural Gas
Liquefied Petroleum Gas
?
Biogas
Kerosene
Non-solid fuels
Coal
Wood
Crop Waste Dung
Solid Fuels

Making the Clean Available

- Incomplete fuel combustion is the enemy
- It has to be very low to reduce combustion particles to health guidelines
- One of the only proven ways to reach near complete combustion in small devices is with gas.
- Although non-renewable, LPG and other gaseous fuels would not add appreciably to global warming.

Conclusions

- It is difficult to burn unprocessed solid fuels completely in simple household-scale devices.
- Consequently, a large fraction of the fuel C is diverted to PIC
- Leading to inefficient use of the primary resource
- And, because of the proximity to population, the PIC seem to be responsible for much ill-health in developing countries.

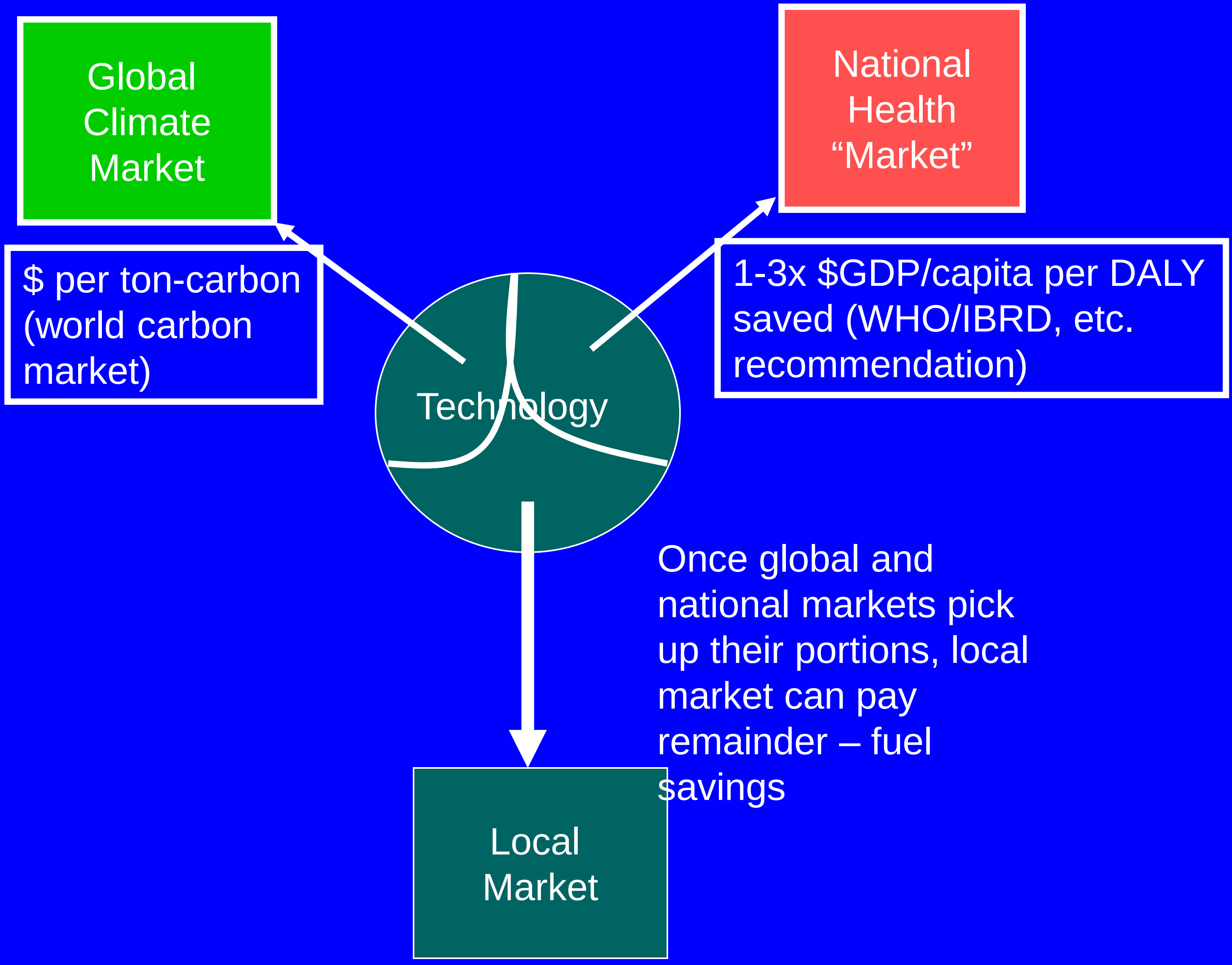
Conclusions, cont.

- Among climate active PIC, methane holds a unique niche
  - High RF and large emissions: 2nd largest total impact after CO2
  - Largest source of rising global levels of ground-level ozone
  - Relatively short-lived, but long-enough to be globally mixed – can be treated under existing frameworks
  - Two-thirds of its emissions are amenable to control measures using existing technology and policy tools, much at low cost

- Adding in shorter-lived CAPs to climate debt discussions shifts the political landscape – more responsibility to LDCs in the case of methane, but also
  - Controls in LDCs wield greater leverage for making an impact – opportunities are greater and response to them faster than in rich ones

- Plus, for household combustion, nearly all the health benefits accrue locally to the very poorest and most disenfranchised people on the planet

Paying for Rural Energy Development



Laws of Carbon-atmospherics

I. Keep all fossil and forest carbon out of the atmosphere

II. If you cannot do so, the least-damaging form to release is carbon dioxide because all other forms, gas or aerosol, are worse for climate and health.
   - If gases, they eventually turn to CO_2 but are worse than CO_2 until they do

III. Even renewable (non-fossil) carbon is damaging for climate and health if not released as carbon dioxide.

“Wood is the fuel that warms you twice” - true?

1. Once when you chop it: ~20 kJ/kg
2. Once when you burn it: ~20 MJ/kg
3. When it warms you through radiative forcing in the atmosphere: ~20 GJ/kg
4. And finally, fever from induced respiratory infection due to smoke exposure

Thus, biomass is the fuel that can warm you four times: **breaking, burning, forcing, and fever.**

Conclusion

If you have to put carbon into the atmosphere, the best form is CO_2 – anything else is worse from both climate and health standpoints

or

Get rid of PIC and you make the world a better place

Many thanks

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