Household Energy, Health, and Climate: the Kerosene Story

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and
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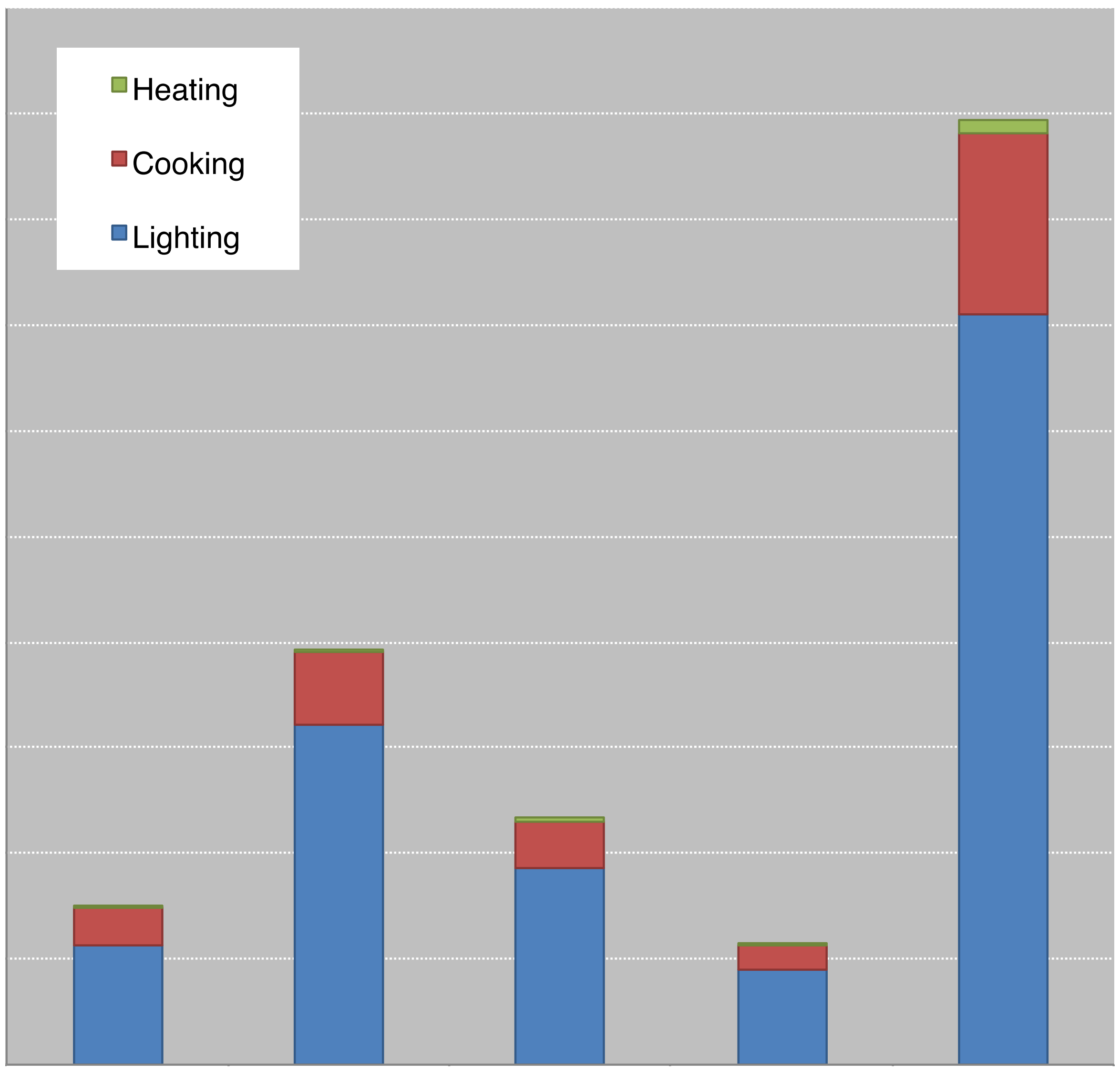
Kerosene Fuel | A True HH Energy Source

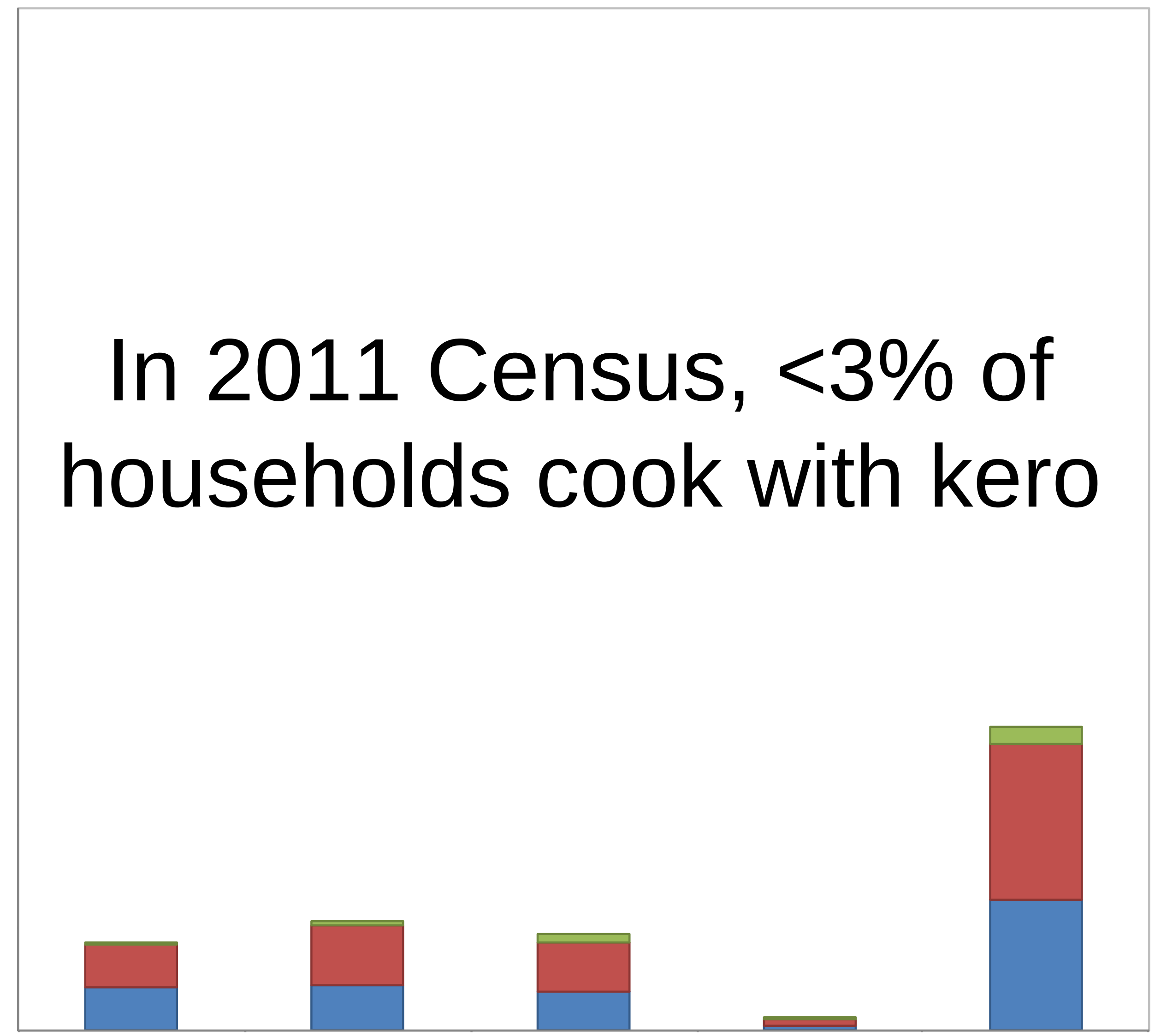
Heating (developed)

Lighting (least developed)

Cooking (less developed, urban)

How Kero Consumption Varies by Rural and Urban Income Groups in India





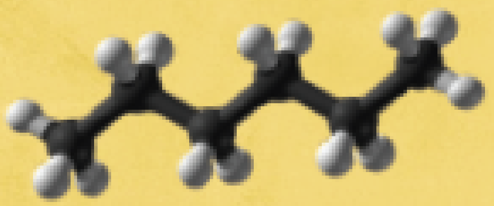
(Data: IHDS 2005; Summarized in Lam 2015)

Kerosene Fuel | Properties

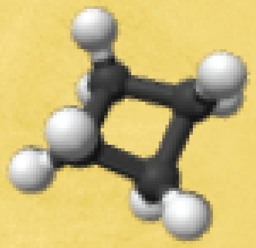
Background

Middle distillate of the petroleum refining process
(BP: 145-300C)

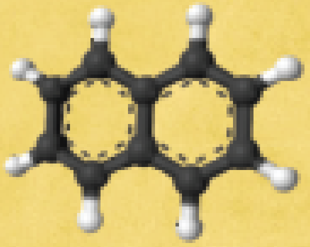
Physical properties make it versatile
composition similar to diesel



1. Paraffin (6-16C)



2. Naphthenes: 41%



3. Aromatics

Health risk before combustion (e.g. benzene, PAH, n-hexane)

Aromatics and sulfur increase potential for PICs (particle potential)

Why is this potentially bad for health and environment?

Particulate Matter | Black Carbon (BC)

Background 1

Black colored particles, often called soot, elemental carbon

greenhouse *pollutant*

Emitted from combustion sources: diesel, coal, solid fuel use

Very efficient at absorbing sunlight = warms the planet

900 times more warming than CO_2 over 100 years (GWP)

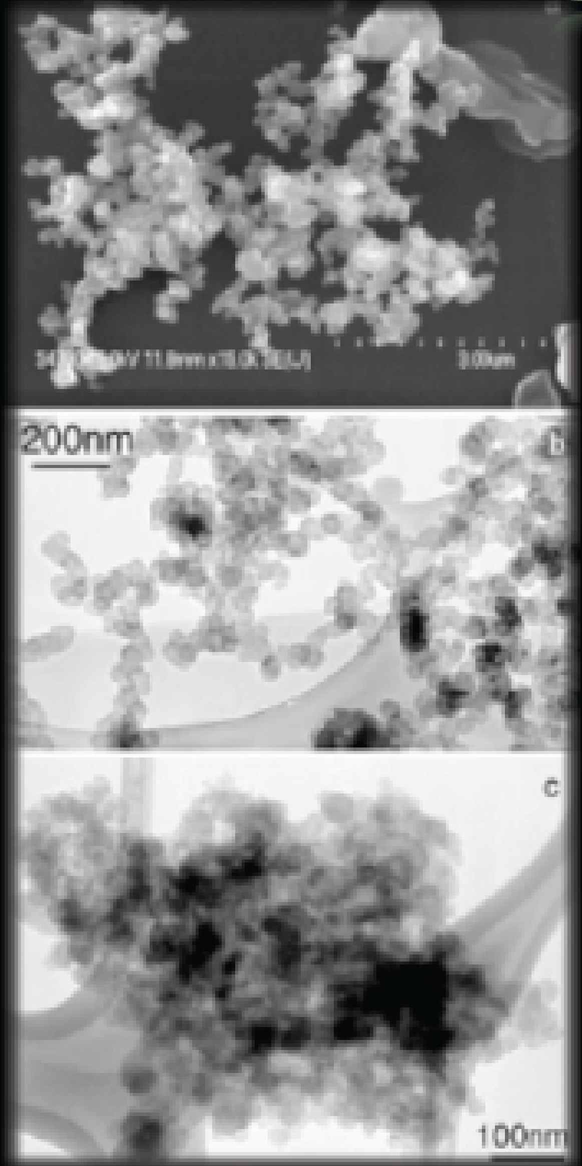
Second biggest human contributor to climate warming in atmosphere today, after CO_2 (Bond et al. 2012)

Atmospheric lifetime on order of days = benefits now

"Short-lived greenhouse pollutant"

Measures to limit BC would reduce climate warming and early mortality *(Shindell et al. 2012)*

Lets get rid of ALL sources of BC Now!!



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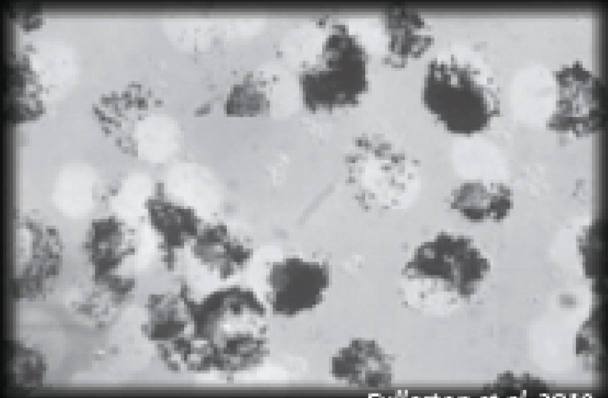


Fullerton et al. 2010

Particulate Matter | Black Carbon (BC)

The Catch...

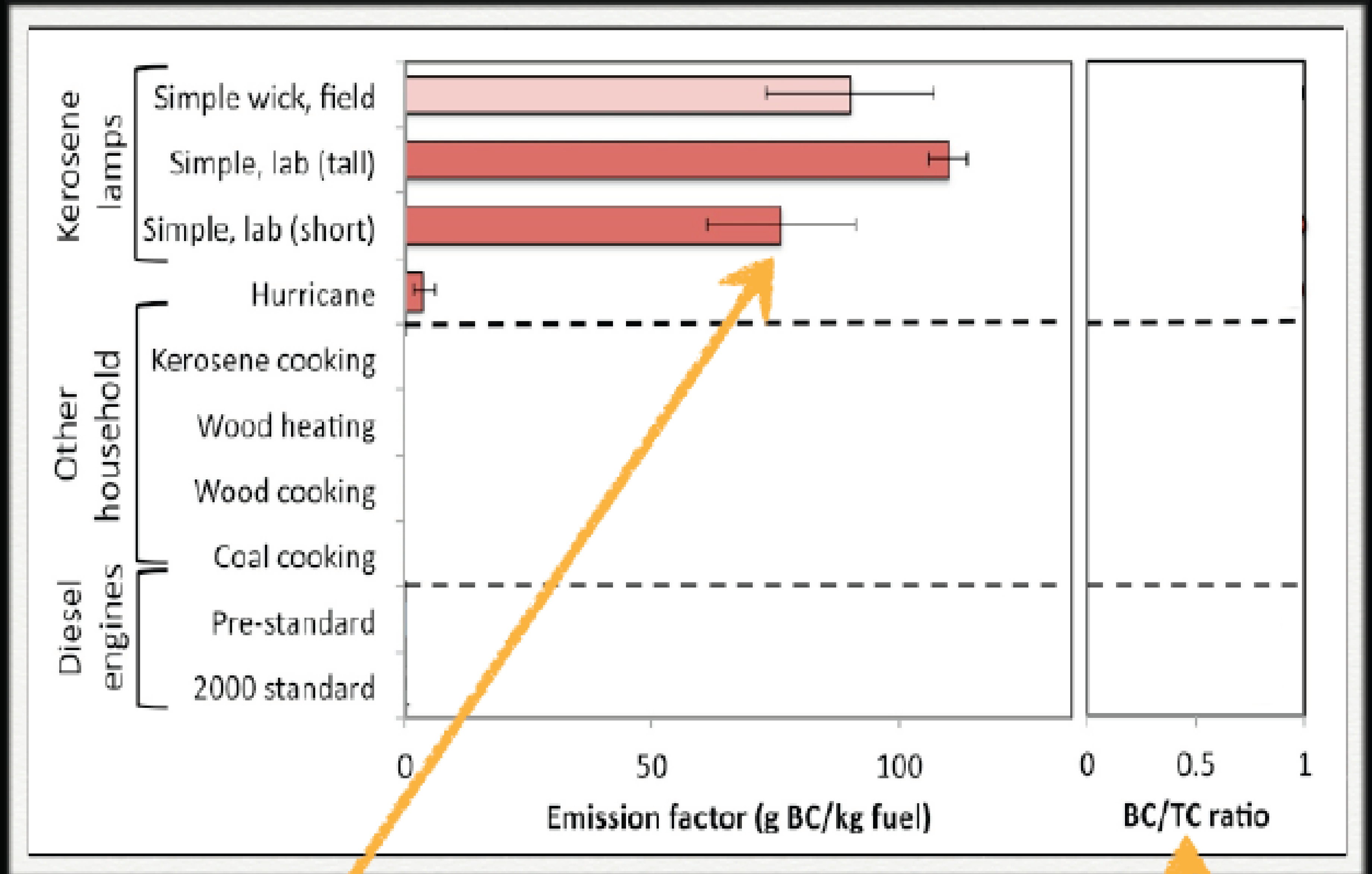
Sources emit a mixture of pollutants, not always warming

- Organic carbon (OC) is co-emitted with BC (think light and dark particles)
- Some co-emitted pollutants, like OC, are **cooling** and can offset the warming of BC

What is the net effect of the mixture from the source?

So...lets get rid of all BC sources that emit BC but in pollutant mixtures that are net warming!

Emission Factors |



BC = 76 ± 15 gBC/kg kerosene (7-9%)

OC = 5 gOC/kg kerosene

Optical Properties of Pure BC (not shown)

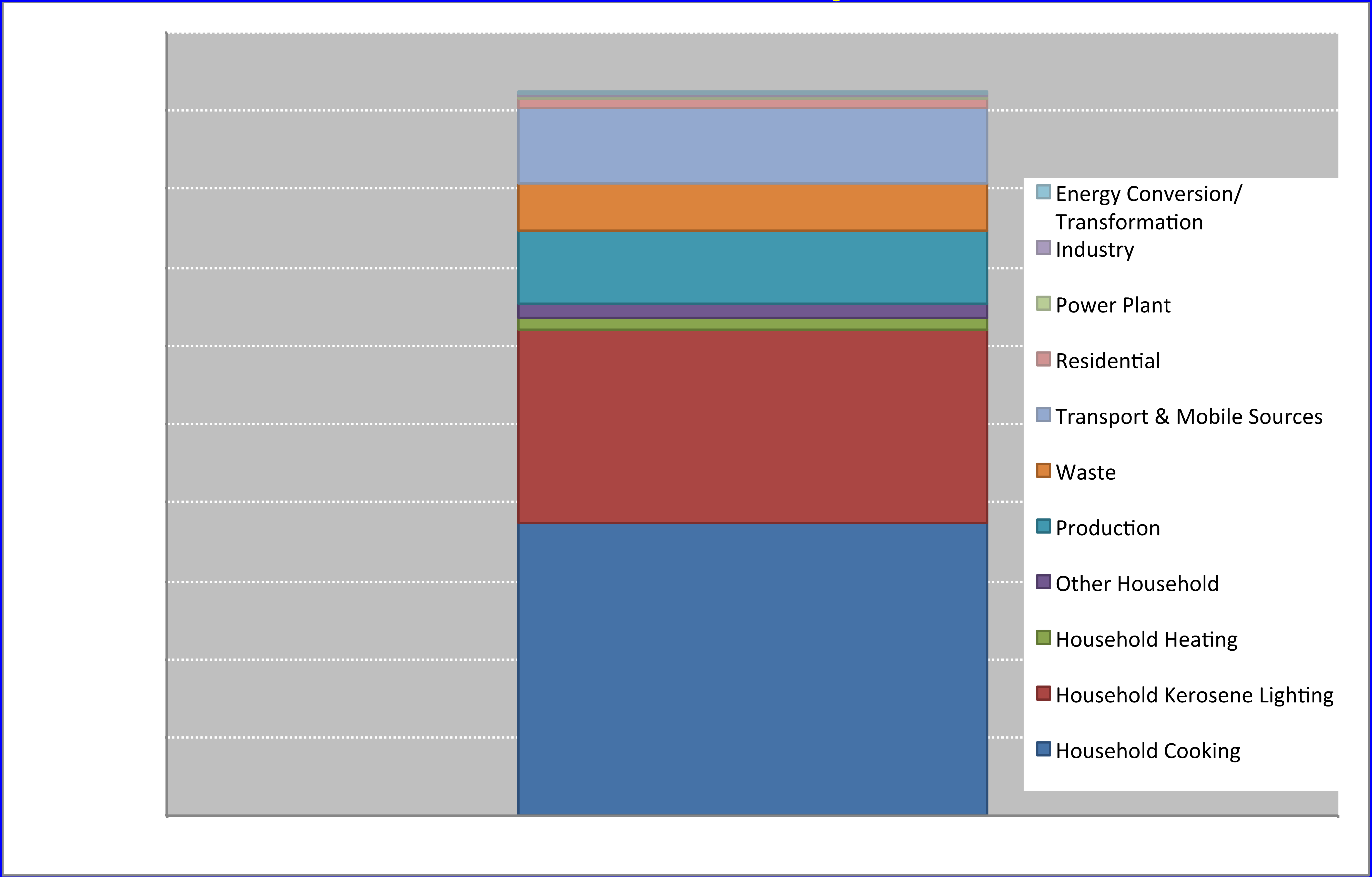
(Bond and Bergstrom, 2006)

Almost no Co-emitted cooling species (not shown in figure)

OC + BC = TC

BC 25x times more warming than the CO_2 emitted by the same lamp during 100 years.

Indian BC Emissions by Sector



IIASA (GAINS), Forthcoming

Emission Rates and Impacts | Regional & Global

270 GgBC/yr
(90%CI: 110, 590)

Update

Based on UNEP
600-670
GgBC/yr

The BC emissions from lamps:

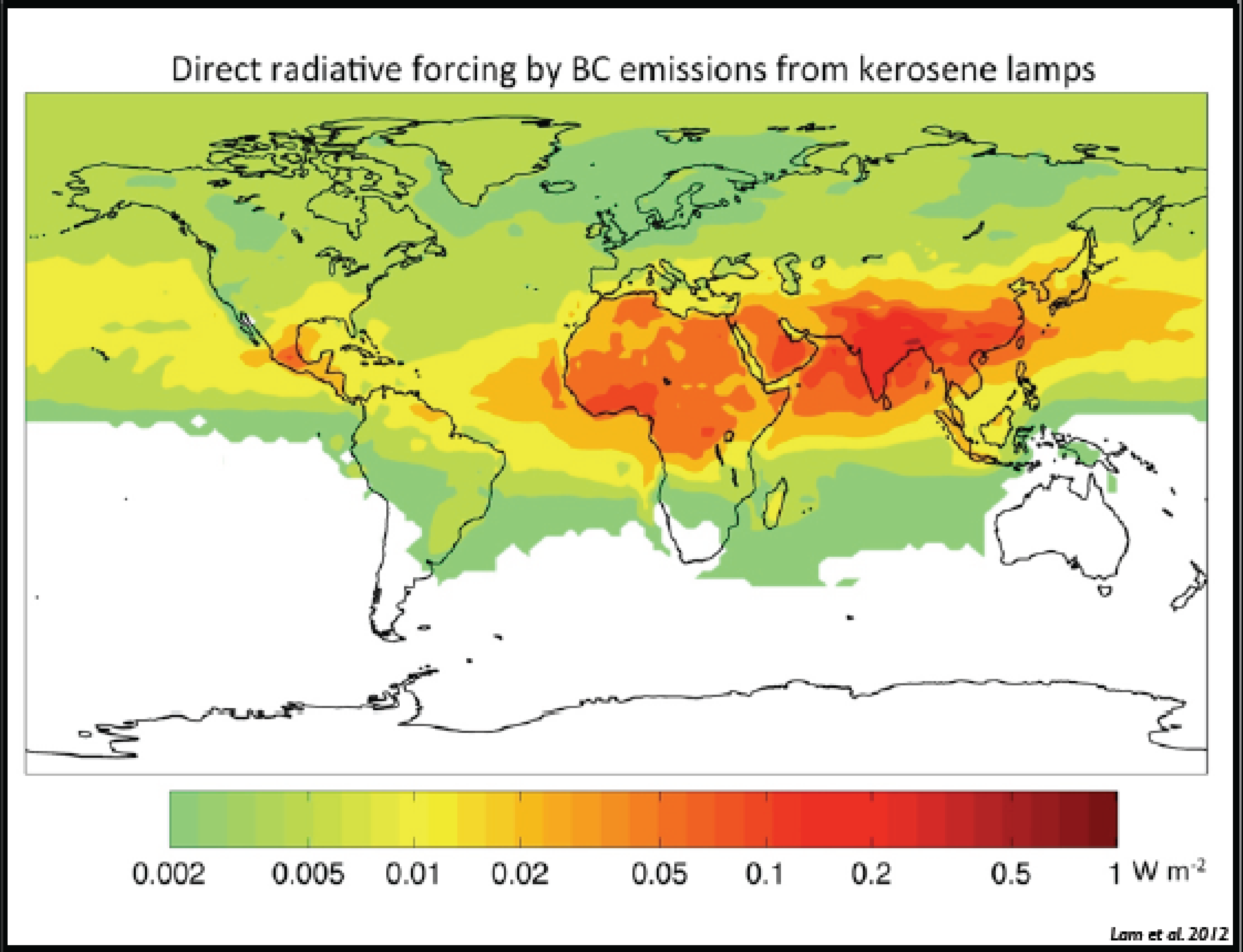
20-25% of the global BC emissions of diesel
10-15% of BC from residential solid fuel use

Equivalent to 240 million tonnes of CO_2
4.5% of US and 12% of India's annual CO_2 emissions

	Black carbon emissions[a] (EM_{BC})
	Gg/year
Canada	0 (0, 0)
USA	0 (0, 0)
Central America	13 (0, 41)
South America	3 (0, 10)
Northern Africa	19 (0, 35)
Western Africa	32 (0, 132)
Eastern Africa	12 (0, 25)
Southern Africa	0 (0, 0)
OECD Europe	0 (0, 0)
Eastern Europe	0 (0, 0)
Former USSR	0 (0, 0)
Middle East	1 (0, 4)
South Asia (excl. India)	40 (3, 79)
India	116 (23, 291)
East Asia (excl. China)	0 (0, 0)
China	13 (4, 18)
Southeast Asia	14 (0, 43)
Oceania	0 (0, 0)
Japan	0 (0, 0)

Lam et al. 2012

Impacts | Climate Forcing



7% of global BC forcing from all energy-related emissions

Globally averaged forcing
20 mW/m2
(CI: 8, 48)

Comparison :
Biomass: 60
Diesel: 85

1.5 mW/m2
on snow

Negative Forcing by OC offsets by only 0.5%

Health Studies in South Asia

- Acute lower respiratory infections in children
- Cataracts
- Tuberculosis
- Adverse pregnancy outcomes
- China: cancer

Tuberculosis and Indoor Biomass and Kerosene Use in Nepal: A Case–Control Study

Amod K. Pokhrel,[1] Michael N. Bates,[1] Sharat C. Verma,[2,3] Hari S. Joshi,[3] Chandrashekhar T. Sreeramareddy,[3**] and Kirk R. Smith[1]*

[1]School of Public Health, University of California–Berkeley, Berkeley, California, USA; [2]Regional Tuberculosis Center, Ram Ghat, Pokhara, Nepal; [3]Department of Community Medicine, Manipal Teaching Hospital, Manipal College of Medical Sciences, Pokhara, Nepal

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Table 2. Multivariate logistic regression model for fuel use in relation to TB in women in Pokhara, Nepal (log likelihood = –118.73, R^2 = 0.44).

Variable	OR (95% CI)[a]
Cooking	
Gas	1.00
Biomass	1.21 (0.48–3.05)
Kerosene	3.36 (1.01–11.22)
Heating fuel	
No heating fuel use or electricity	1.00
Biomass, coal, or kerosene	3.45 (1.44–8.27)
Main light source in the house	
Electricity	1.00
Kerosene lamp	9.43 (1.45–61.32)

Acute Lower Respiratory Infection in Childhood and Household Fuel Use in Bhaktapur, Nepal

Michael N. Bates,[1] Ram K. Chandyo,[2] Palle Valentiner-Branth,[3] Amod K. Pokhrel,[1] Maria Mathisen,[4] Sudha Basnet,[2,5] Prakash S. Shrestha,[5] Tor A. Strand,[2,6,7] and Kirk R. Smith[1]

Table 3. Exposure-related variables in final conditional multivariate logistic regression model for ALRI, in Bhaktapur children, 2–35 months of age.

Variable	OR[a] (95% CI)
Primary stove fuel	
Electricity	1.00
Gas	1.71 (1.08, 2.72)
Kerosene	2.33 (1.40, 3.86)
Biomass	2.13 (1.34, 3.41)

Environmental Health Perspectives • VOLUME 121 | NUMBER 5 | May 2013

Pokhrel et al. Atmos Environ, forthcoming

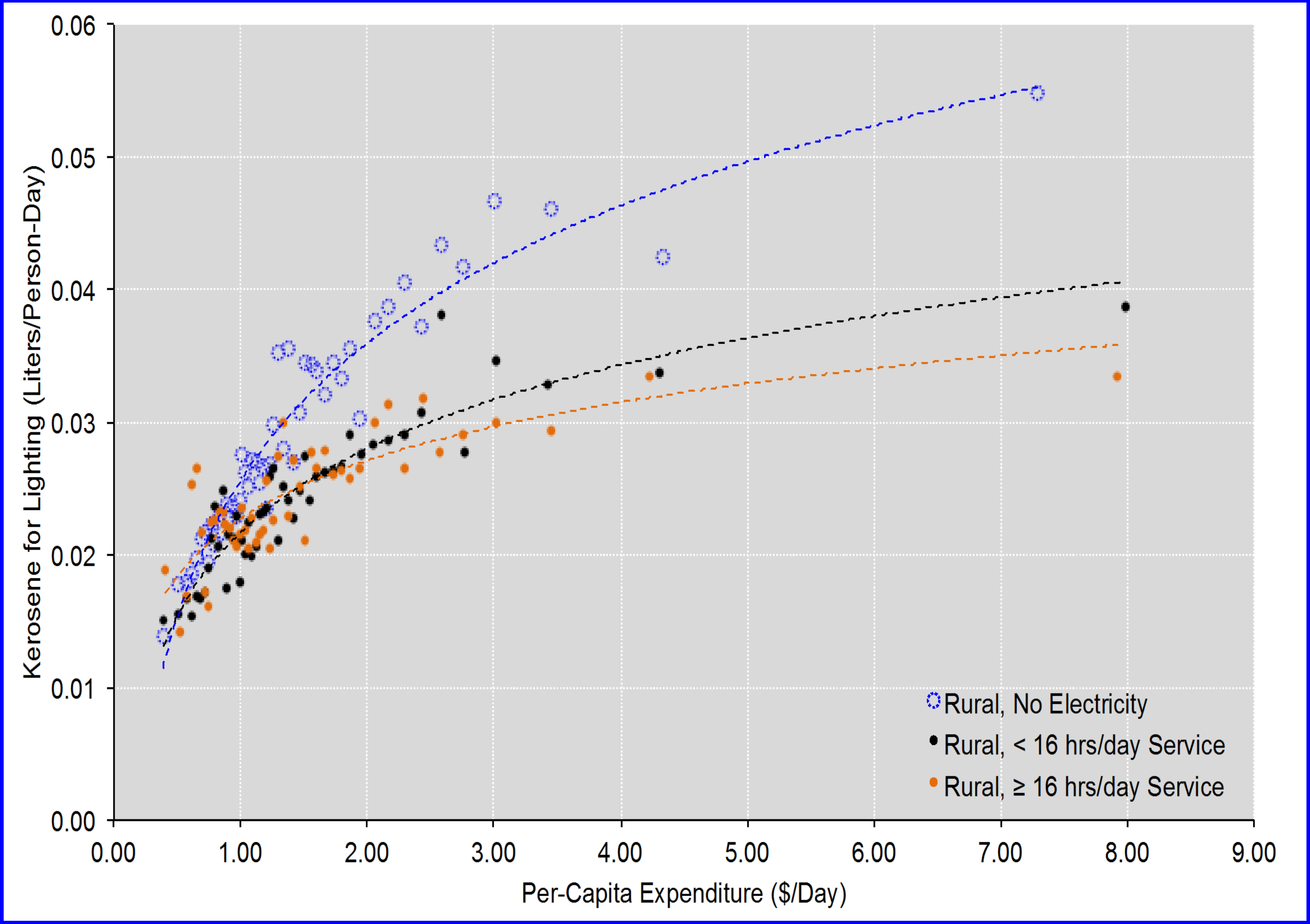
Stove fuel type	N (%) of households	Arithmetic mean kitchen $PM_{2.5}$ concentration in µg/m^3 (SD)
Primary fuel stove type		
Wood	174 (21)	630 (908)*
Rice husk	44 (5)	759 (988)
Biomass (Wood+Rice husk)	218 (26)	656 (924)*
Kerosene	187 (23)	169 (207)
LPG	238 (29)	101 (130)
Electric stove	181 (22)	80 (103)

Table 2. Characteristics of Major BC Sources and Associated Mitigation Opportunities

source category	fraction of global BC emissions[a]	annual BC emissions (Gg)[a]	major coemissions[b]	potential interventions[c]
kerosene lamps	3%	270 (110, 590)	None	LED or more efficient fuel-based lamps (e.g., pressure, hurricane)
diesel engines	17%	1320 (530, 2400)	NO_x (−)	particle traps, retrofit, standard introduction
residential solid fuel	24%	1880 (480, 5300)	OM (-)	efficient stoves, improved combustion, fuel switching
industrial coal	12%	740 (160, 2800)	SO_2 (-)	process modernization
open biomass burning	40%	2750 (980, 12000)	OM (-)	suppression, controlled burning with capture

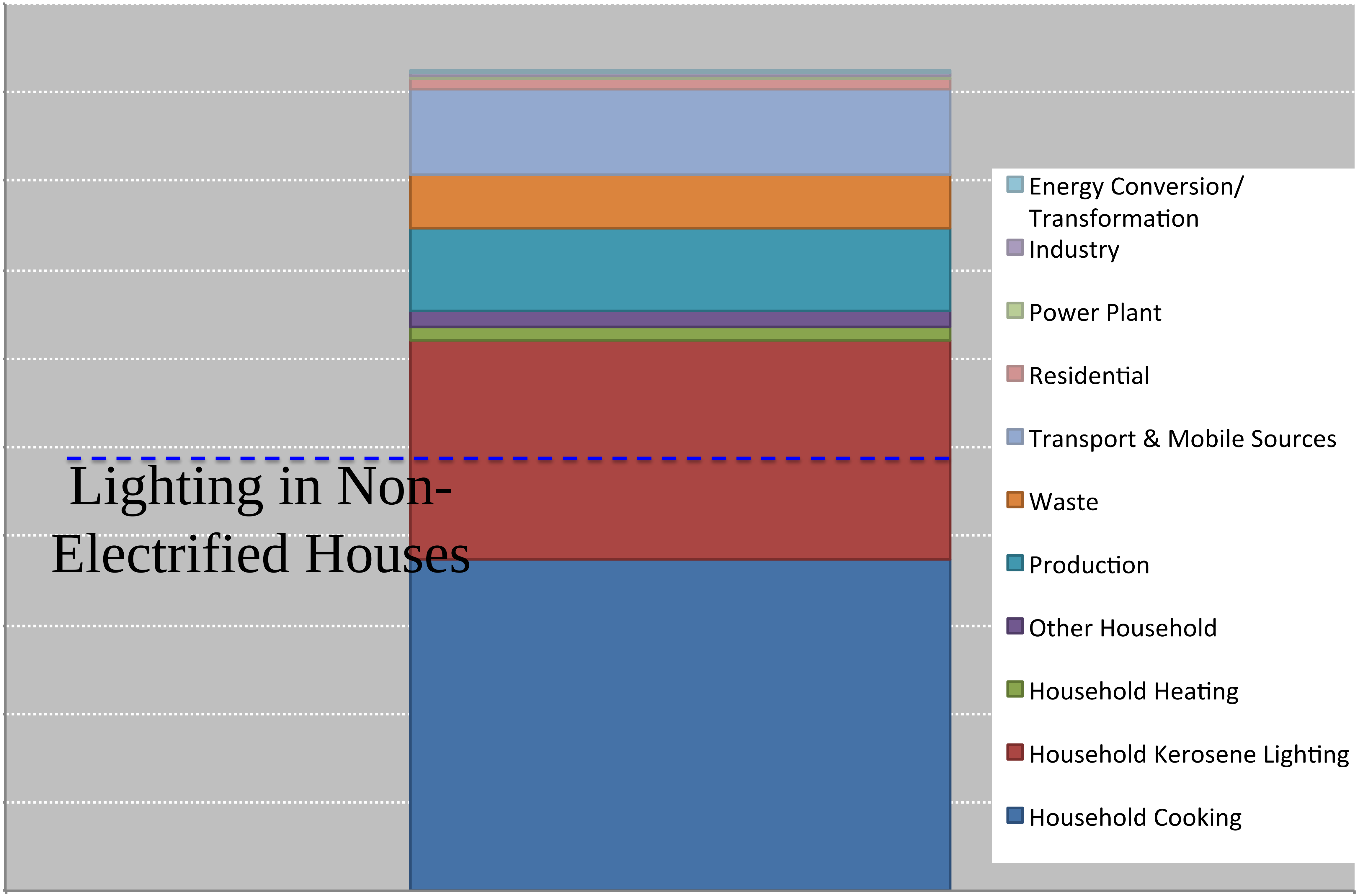
Lam et al., EST, 2012

How does per-capita demand change over electricity category and income in rural India?



Lam 2014

Indian BC Emissions by Sector



IIASA (GAINS), forthcoming

Kerosene Bottom Lines

- 7–9% of kerosene in wick lamps is converted to PM that is nearly pure BC.
- Aerosol climate forcing on atmosphere and snow from this source is estimated to be 7% of BC forcing by all other energy-related sources globally
- Nearly half this kerosene BC comes from India
- The net effect on climate is definitively positive forcing as co-emitted organic carbon is low.
- Evidence is increasing that household kerosene emissions are particularly damaging to health

WHO Indoor Air Quality Guidelines: Household Fuel Combustion

Review 9: Summary of systematic review of household kerosene use

Kerosene Bottom Lines – cont.

- Although declining, this year India will still be spending ~$2 billion (12000 cr) to subsidize kerosene
- Kero cooking has largely disappeared -- mainly lighting now
- ~40% is diverted to non-household uses – very "leaky"
- Good alternatives available
  - solar LED lights
  - increasing electrification
  - Even LPG
- No other major BC source has such readily available alternatives, definitive climate forcing effects, and co-benefits.
- Complete replacement of kerosene lamps should have high priority for programs that target short-lived climate forcers.

Thank you

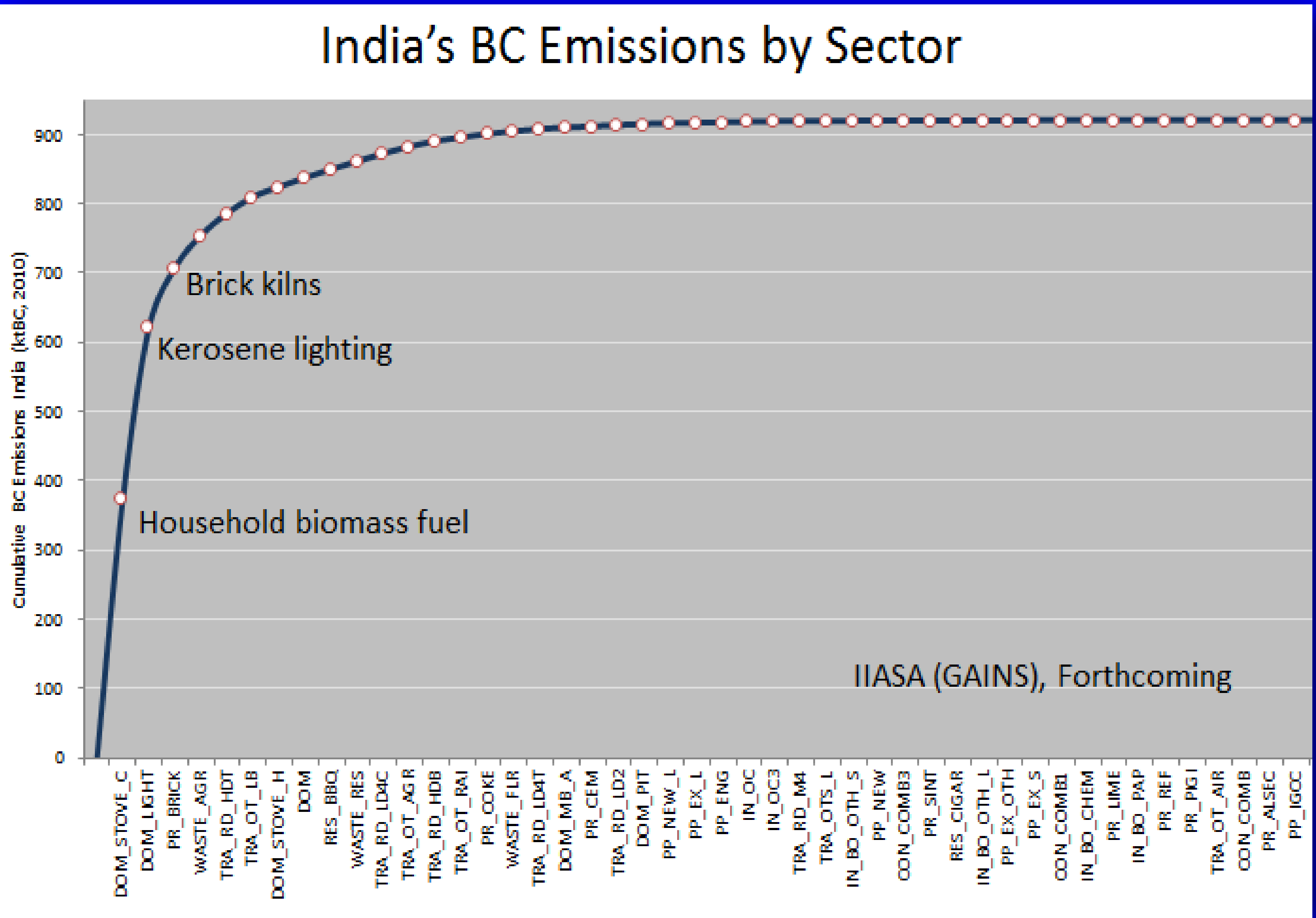


Photo Credit: Ajay Pillarisetti