Making the Clean Available: Breaking out of India's Chulha Trap

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IIT-Delhi – 2013/14

Energy Access Department, World Bank
January 30, 2014

Warnings

- This lecture is given from a health perspective, not an energy or climate perspective.
  - Put another way, health benefits for the poor trump slight net deviations from goals for global energy renewability and CO_2 emissions.
- It is from the perspective of India and may not apply well in Africa, etc
- It is a work in progress – new insights coming rapidly from the inversion in thinking – stay tuned

Road Map

- Very brief summary of health evidence
- And history of biomass stoves in India
- What has been done to deal with the issue
- And what has been happening outside the main establishment of clean stoves
- Proposition: are there “leap frog” options that might be transformational in bringing benefits to the poor?

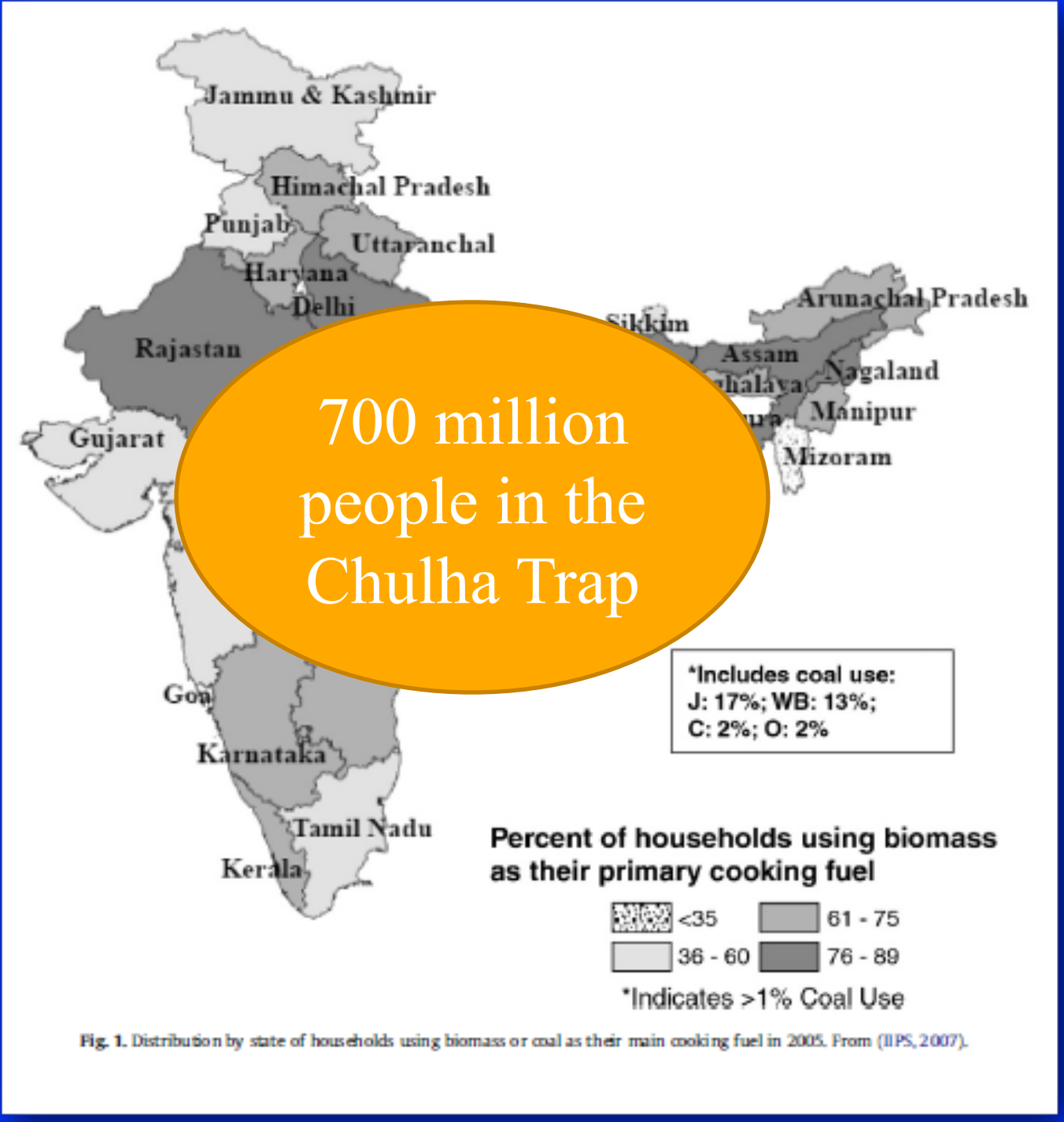


Fig. 1. Distribution by state of households using biomass or coal as their main cooking fuel in 2005. From (IIPS, 2007).

1990:
85%: 700 million people using solid fuels

2010:
60%: 700 million people

~1980
700 million people in entire country

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

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

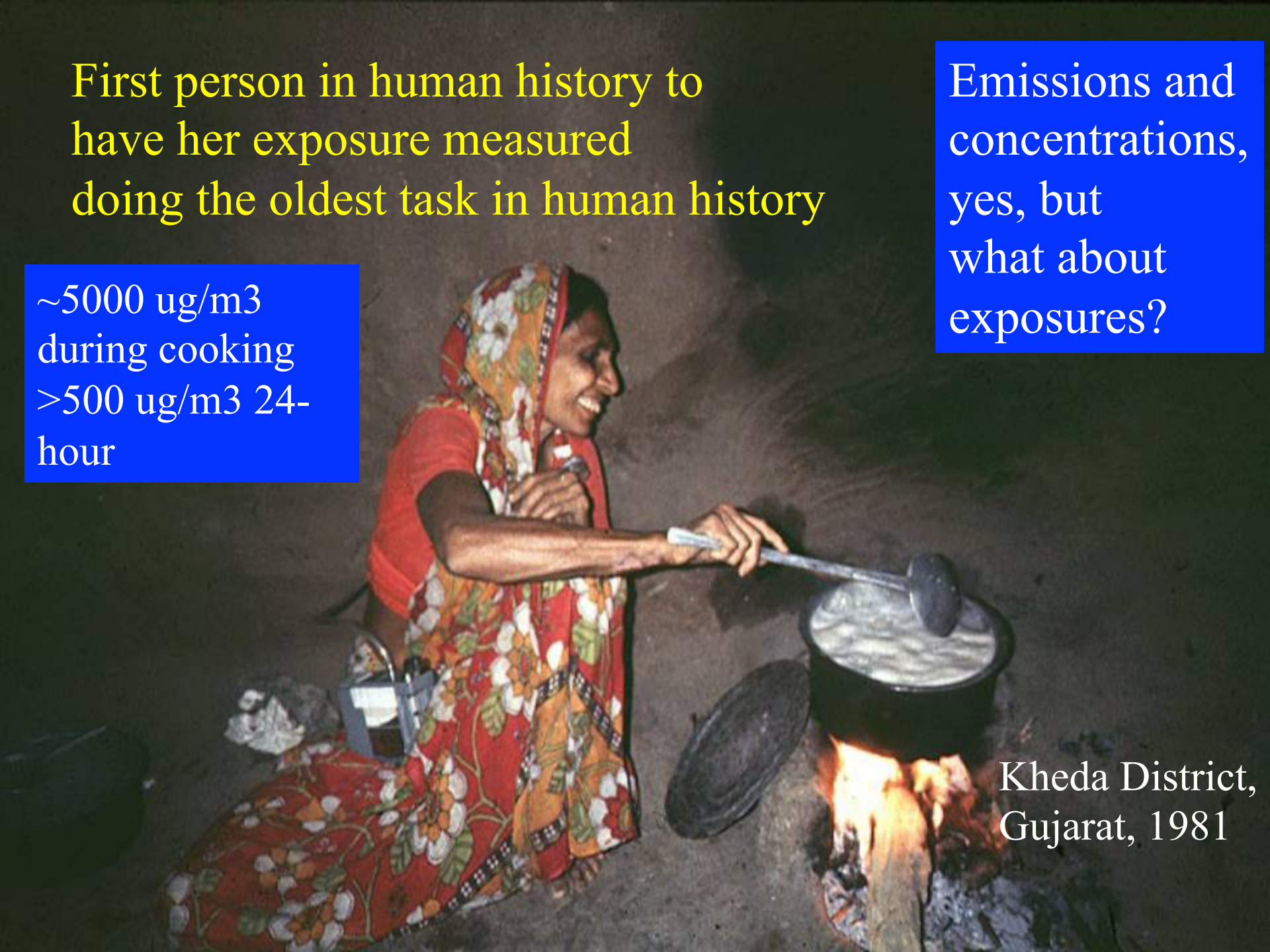
Typical chulha releases 400 cigarettes per hour worth of smoke

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

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
- National standards – annual outdoors
  - USA: 12 ug/m3
  - China: 35 ug/m3
  - India: 40 ug/m3

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*

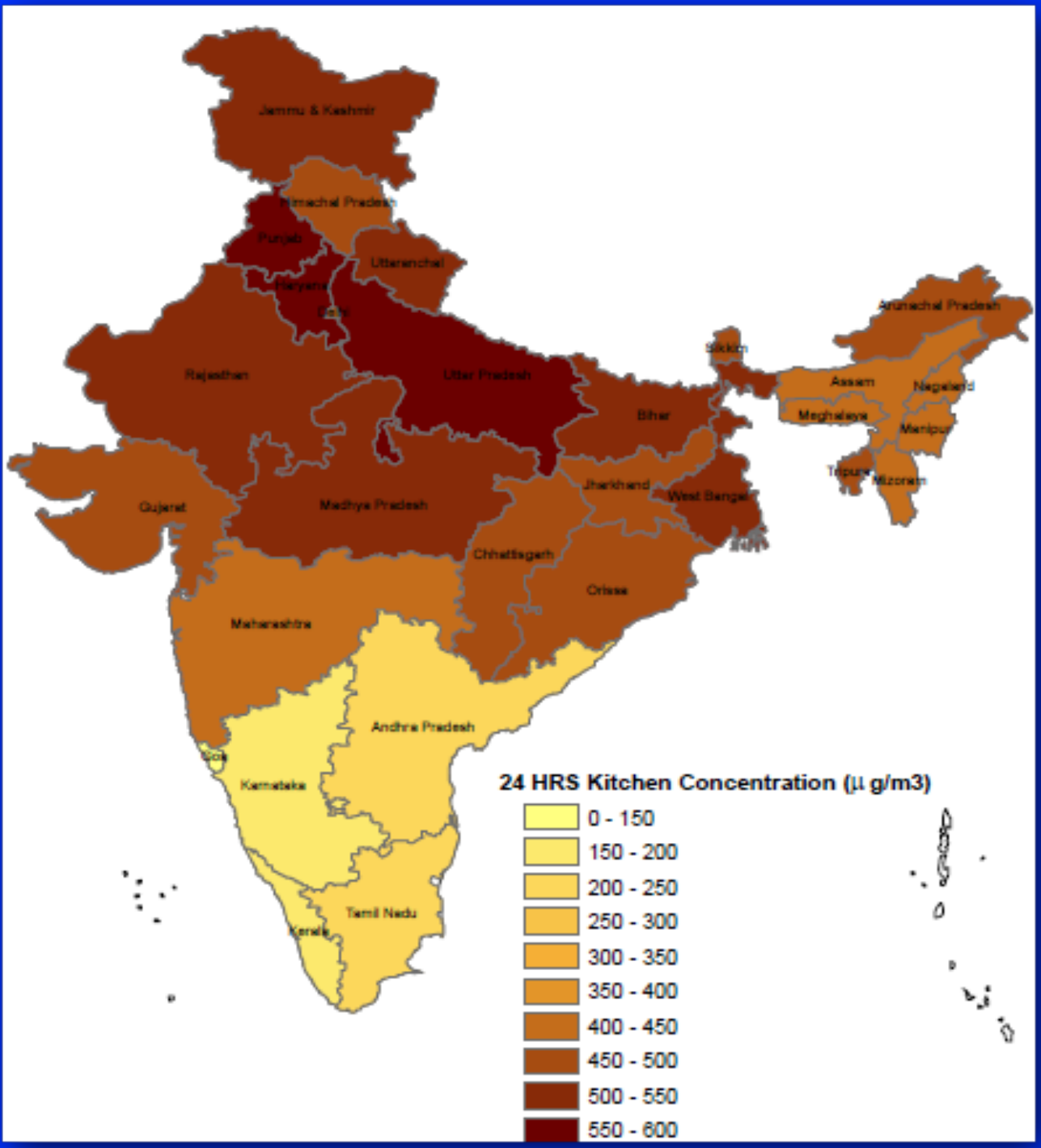
Millions Dead: How Do We Know and What Does It Mean? Methods Used in the Comparative Risk Assessment of Household Air Pollution

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]

Annual Review of Public Health, vol 35, 2014, to be published in March

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



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

Solid-fuel using households

Balakrishnan et al. 2013

ALRI/
Pneumonia

COPD

Lung cancer
(coal)

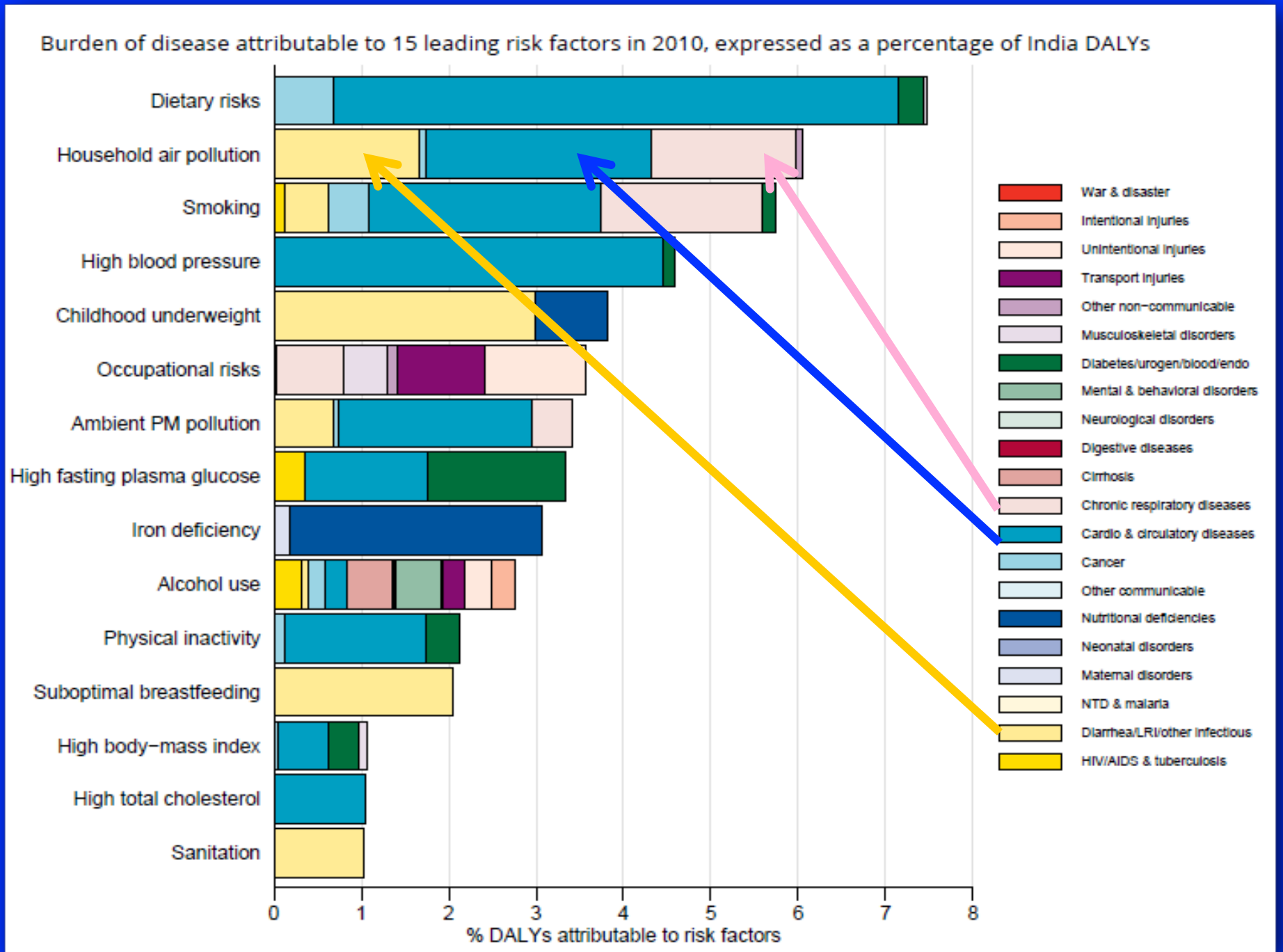
Lung cancer
(biomass)

Cataracts

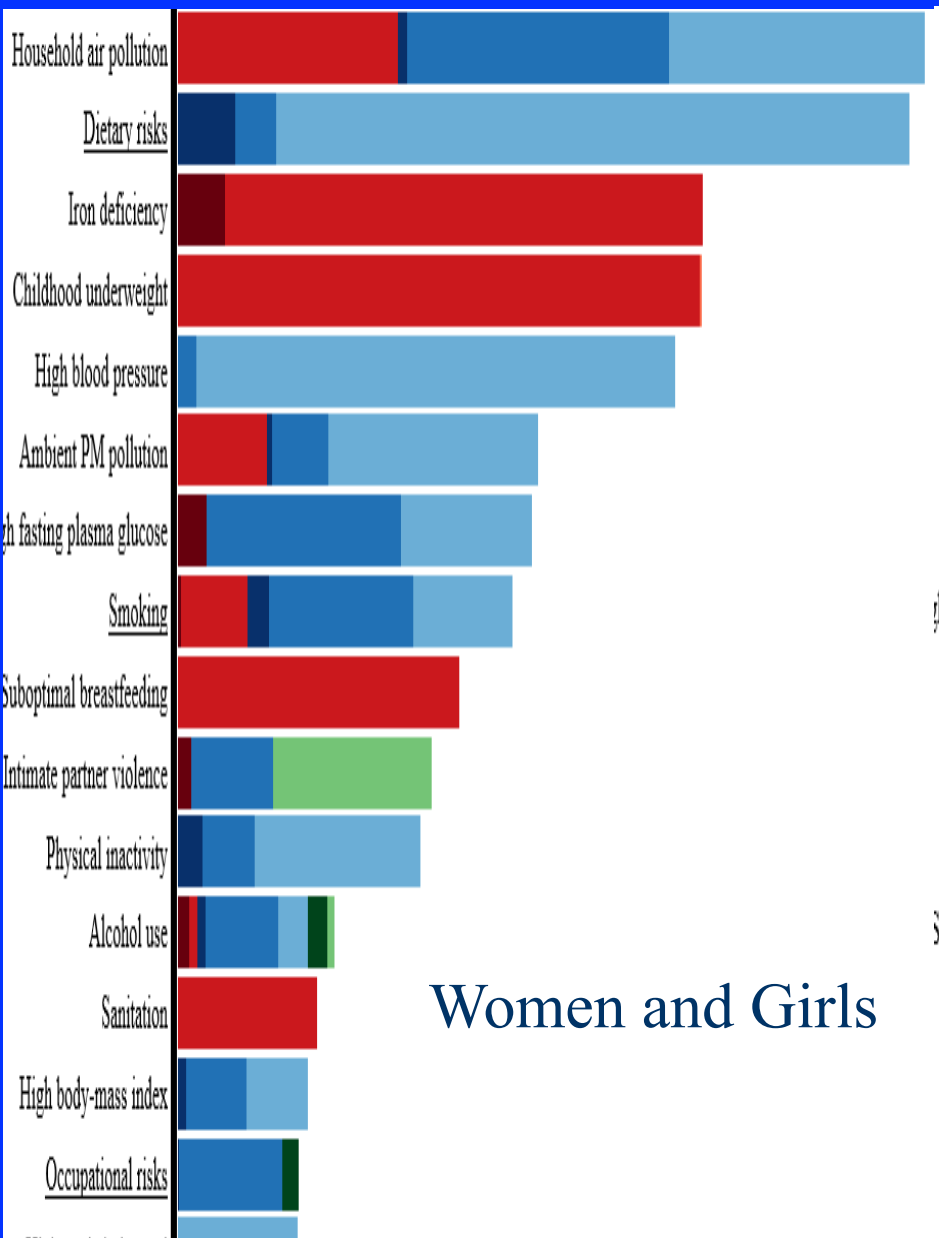
Ischemic
heart disease

Stroke

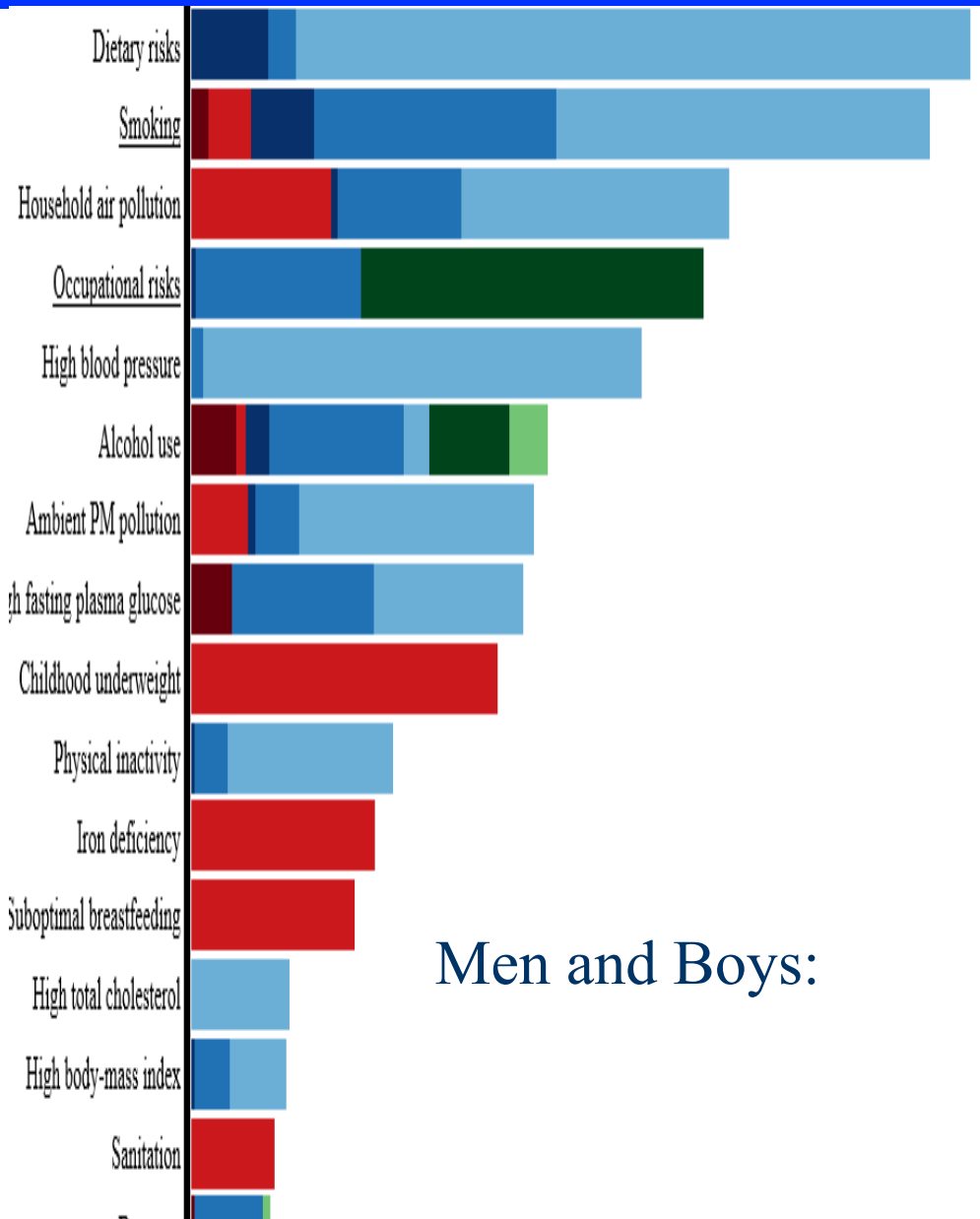
These diseases are included in the
2010 Comparative Risk Assessment (released in 2012)


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

Top 15 causes of ill-health in India (GBD/CRA 2010)
HAP Total: ~1,000,000 premature deaths annually



Women and Girls

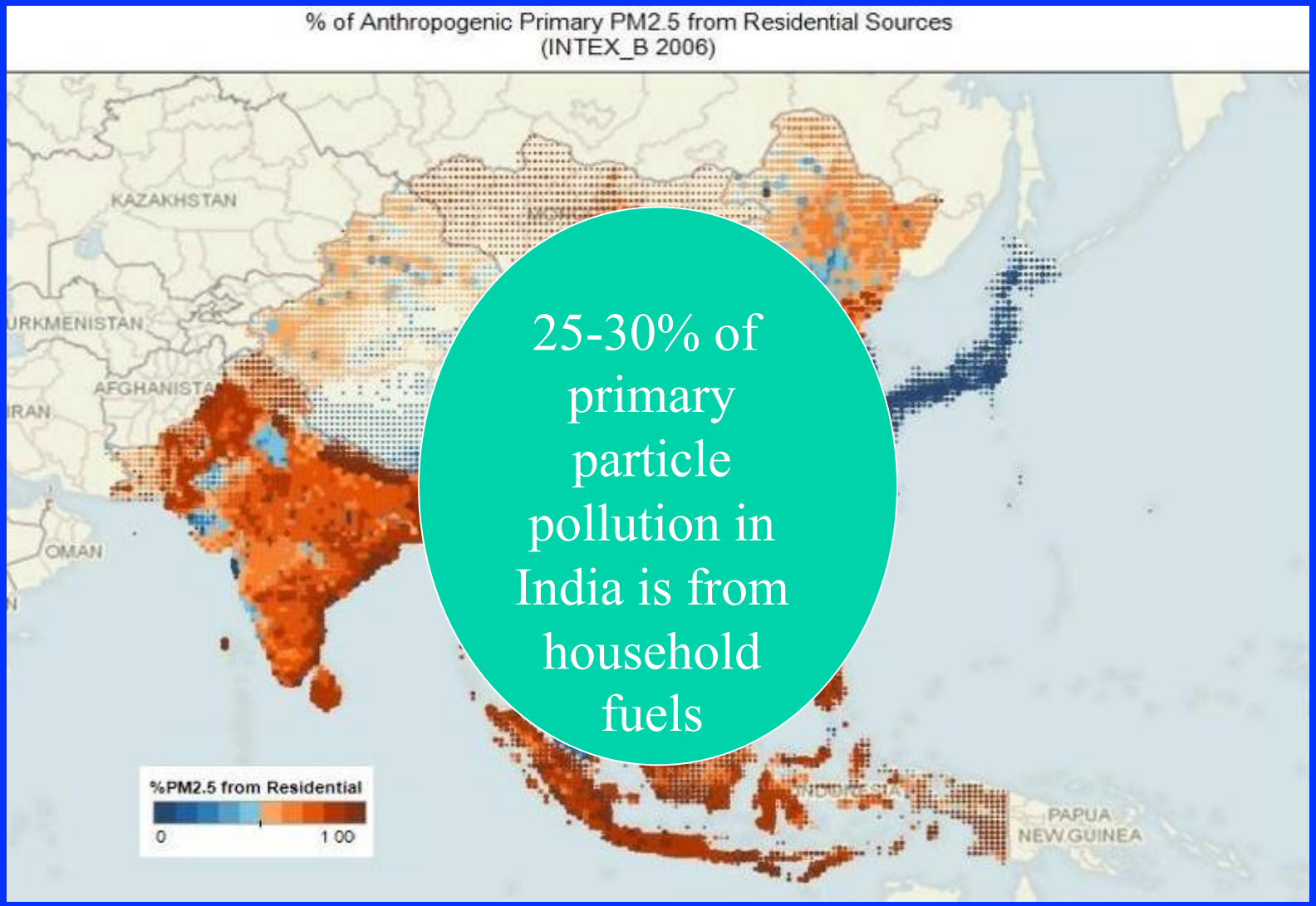


Men and Boys:

Framing.

- Not called “indoor” because stove smoke enters atmosphere to become part of general outdoor air pollution (OAP)
- HAP contributes about 13% to OAP globally, but much more in some countries
- ~25% in India
- Thus, part of the burden of disease due to OAP is attributable to cooking fuels in households

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



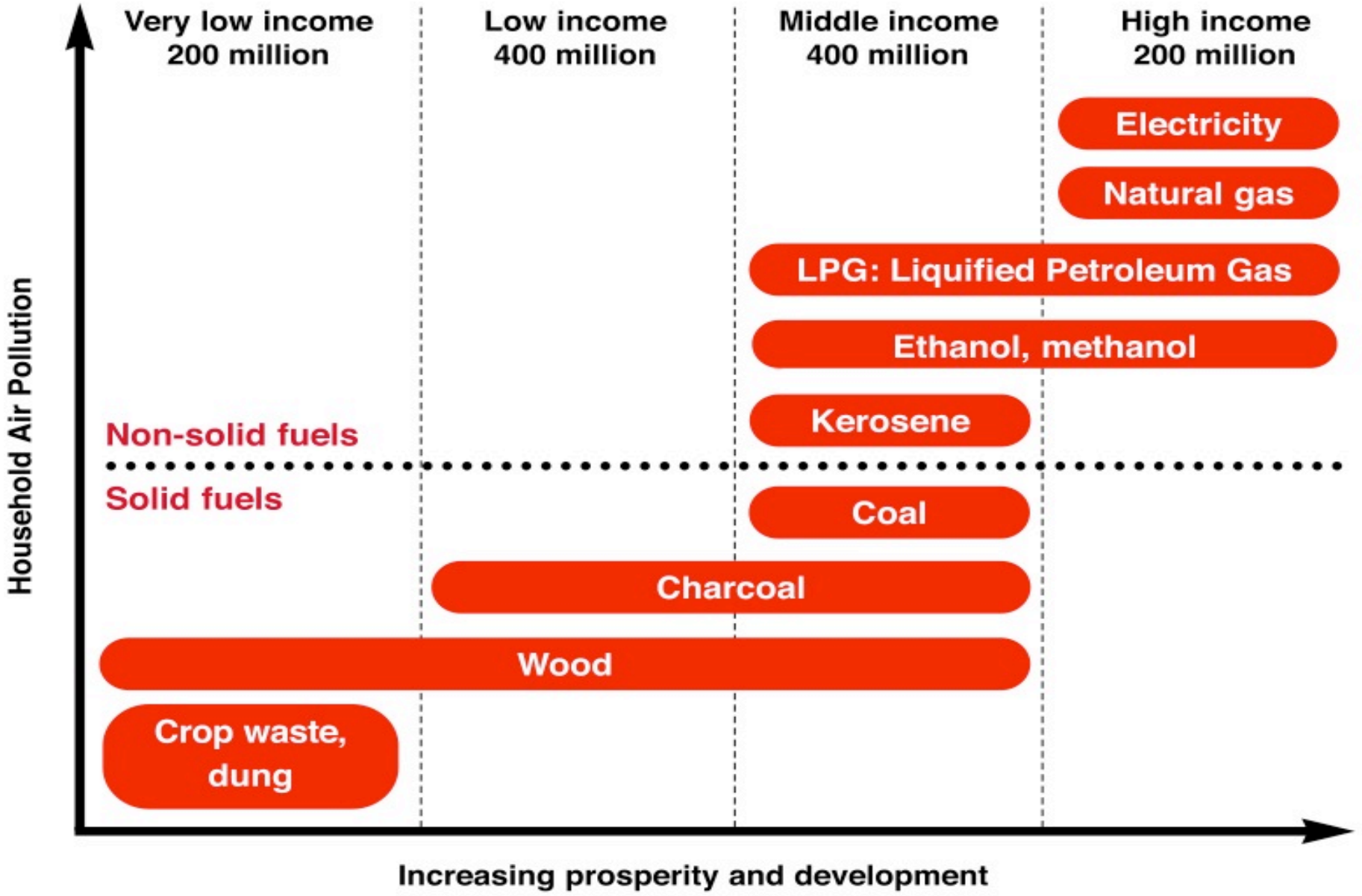
Source: Asian Emission Inventory for NASA INTEX_B 2006 (accessed 2010)

Chafe, 2010

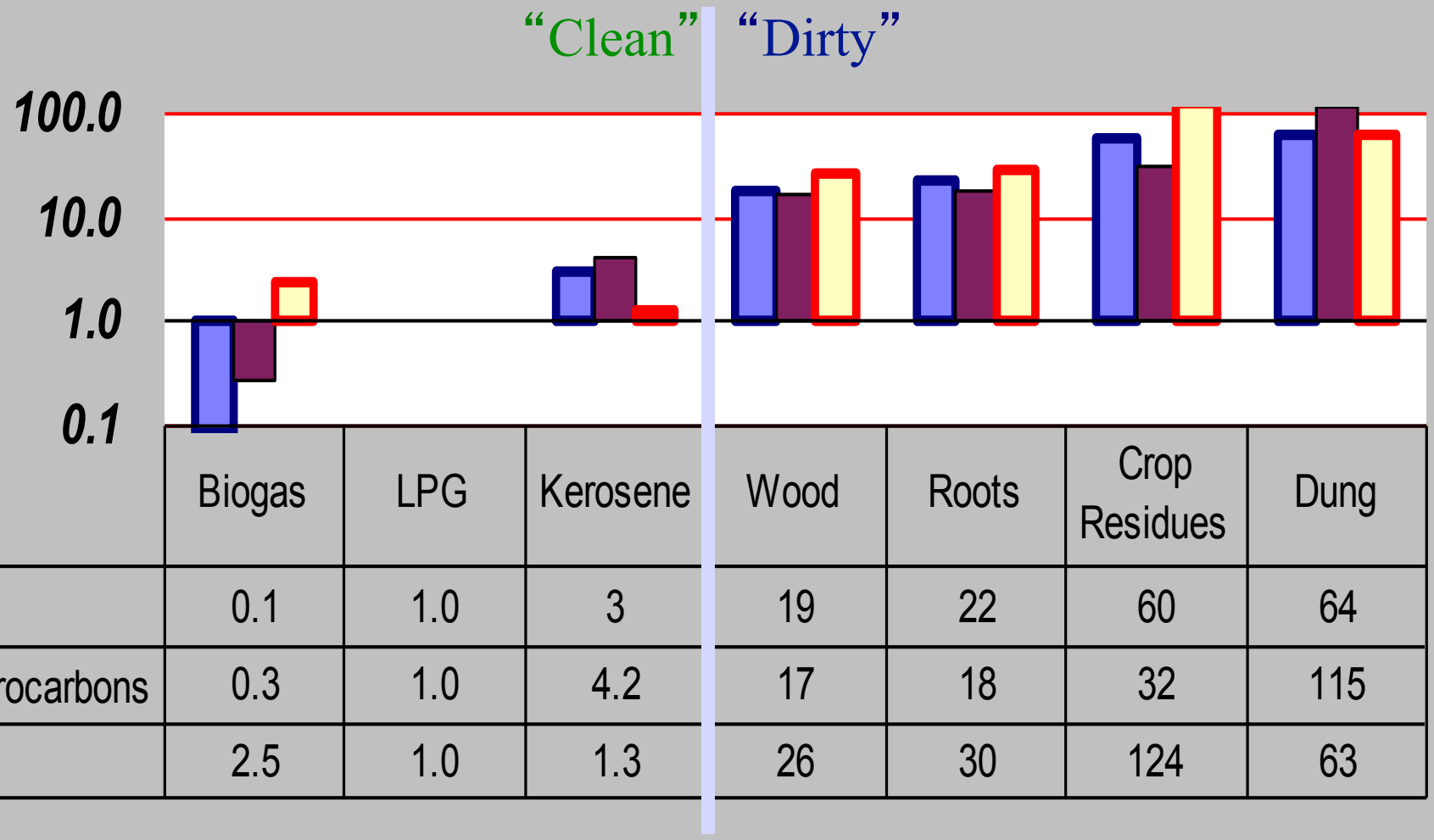
Summary

- One of the top risk factors in the world for ill-health.
- Biggest impact in adults --3 million premature deaths (two-thirds the DALYs)
- Still important for children ~500,000 deaths (one-third the DALYs)
- One million total premature deaths in India
- Biggest single risk factor of any kind for Indian women and girls
- Important source of outdoor air pollution
- Impact going down slowly because background health conditions improving
- Actual number of people affected is not going down

Indian Population in 2010

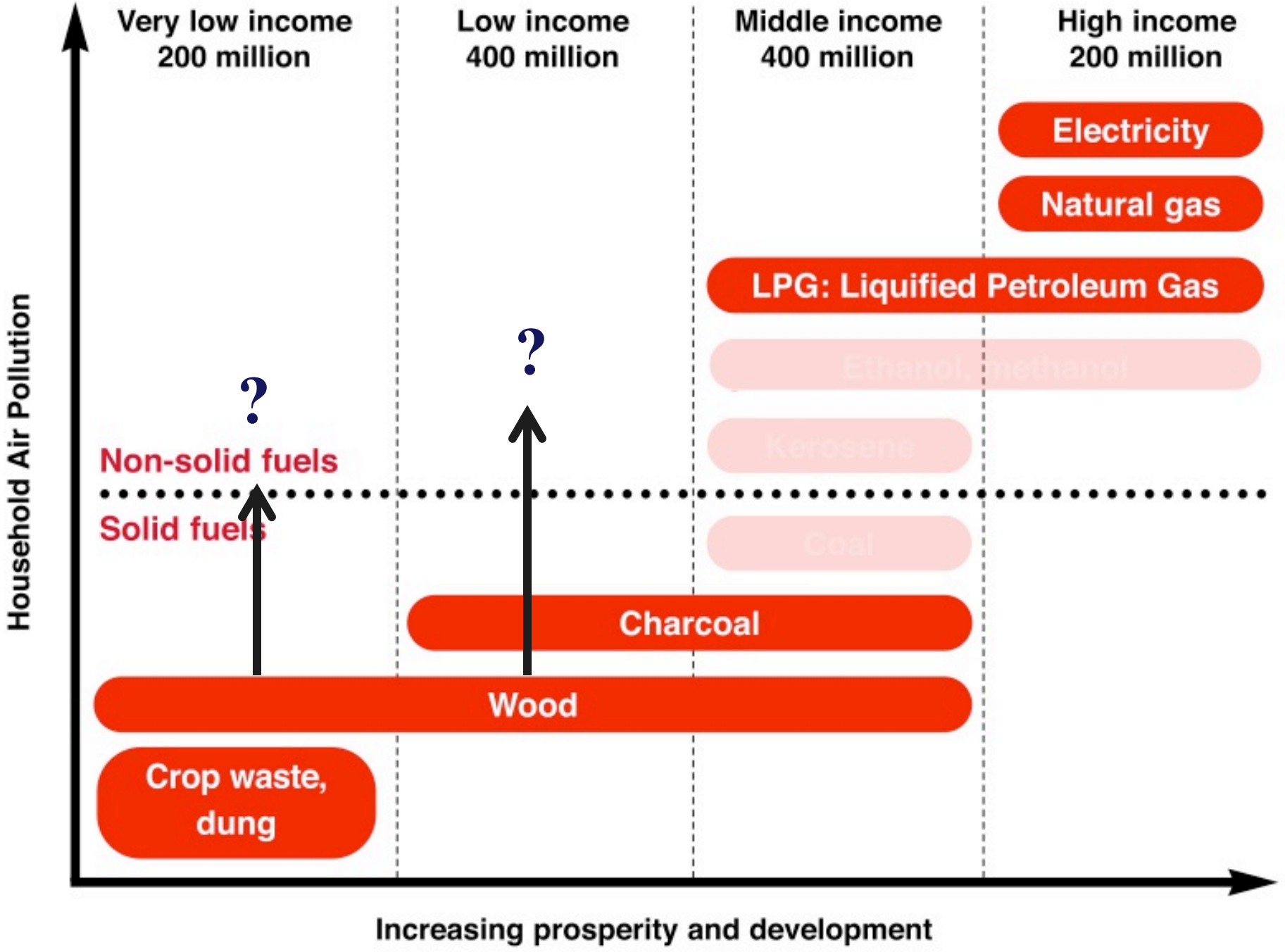


The Energy Ladder: Relative Pollutant Emissions Per Meal



	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

Smith, et al., 2005


Very low income
200 million
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High income
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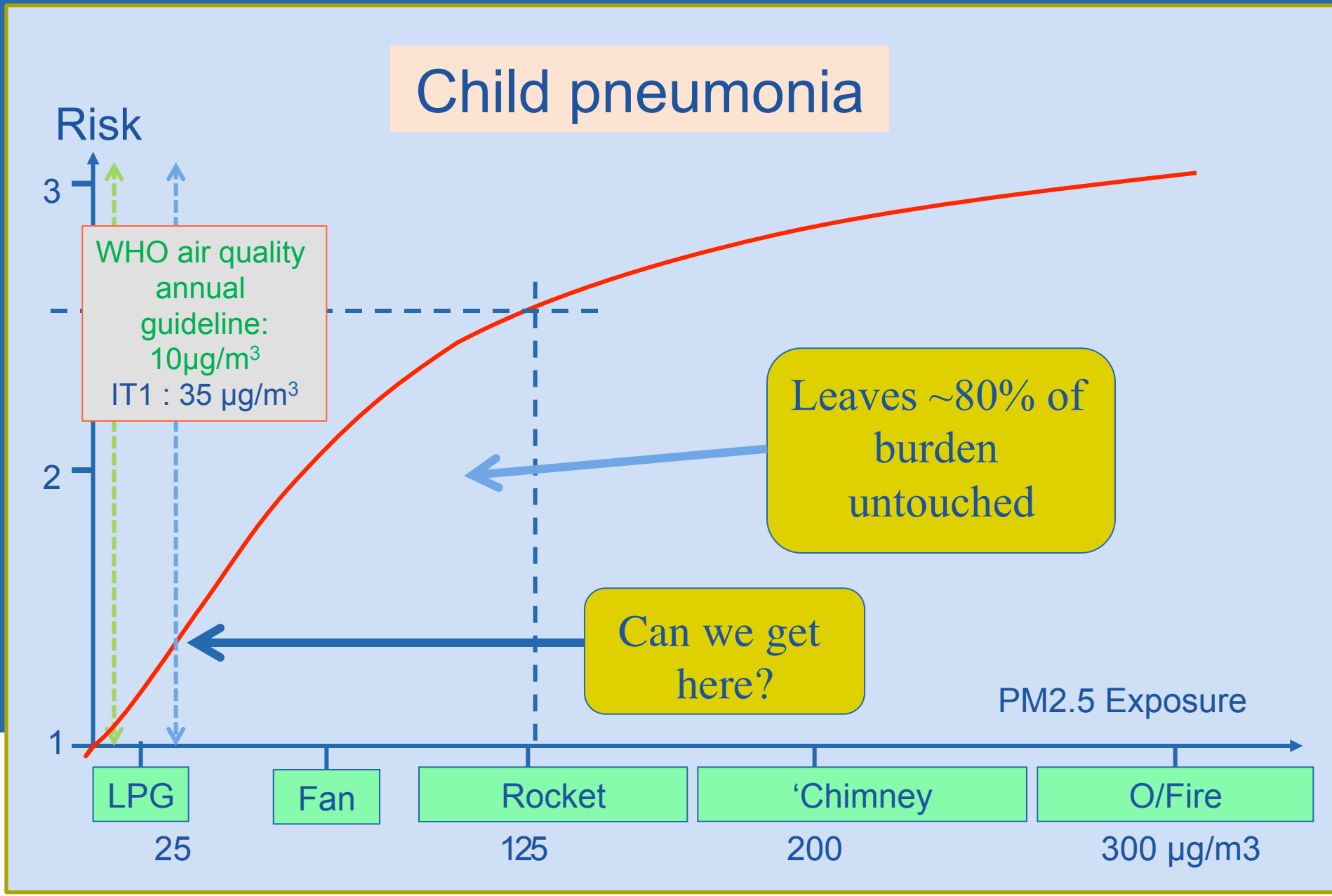
Electricity
Natural gas
LPG: Liquified Petroleum Gas
Ethanol, methanol
Kerosene
Coal
Charcoal
Wood
Crop waste,
dung
Non-solid fuels
Solid fuels
?
?
Household Air Pollution
Increasing prosperity and development

Exposure-response relationship



How close to clean enough?

- New WHO Indoor Air Quality Guidelines will be about 0.9 mg/min $PM_{2.5}$ to protect ~80% of households at AQG-IT_1, 35 ug/m^3
- Cleanest biomass blower stove tested by the USEPA is about 8 times more polluting in lab.
- But does not achieve this over time in the field
- Need to push harder to find ways to make biomass burn cleanly in inexpensive devices


Associates
तेल उद्योग सुरक्षा निदेशालय
OIL INDUSTRY SAFETY DIRECTORATE
&
Centre for Occupational and Environmental Health (MAMC)
International Conference
Occupational and Environment
13-14 December 2013, New Delhi
OIL INDUSTRY SAFETY DIRECTORATE
and
Centre for Occupational and Environmental Health (MAMC)
International Conference
on
Occupational and
Environmental Health
T.K. JOSHI
HIRAK DUTTA
KIRK R. SMITH
VIVEK RAE

Secretary Vivek Rae

- Doubled the number of new LPG distributors planned for this year
- By adjusting requirements
- 1400 instead of 700 hundred
- Each with 5000 customers
- ~20 million more people

Porous radiant burners → Porous medium combustion

- ✓ Flameless co
- ✓ Based on rec

flux

ic value fuels

Conventional L

Efficient pots ➡ lower costs ➡ more usage ➡ less pollution

GenteGas Guatemala

GenteGas Recruits Women to Become Sales Agents
* Selected through community leaders, customers, and account holders at the lending institution

GenteGas Trains Entrepreneur
* Recive sales training, and health education about toxic cook smoke

Entrepreneur Recruits New Entrepreneurs
* The entrepreneur recruits more women to be part of the sales force, she becomes their leader and generates more income

Entrepreneur Begins Finding Customers
* Potential customers recieve health education about toxic cook smoke

Family Decides to Switch to Clean Fuel
* Receives LPG safety and handling education
* Learns how to apply for and manage a loan

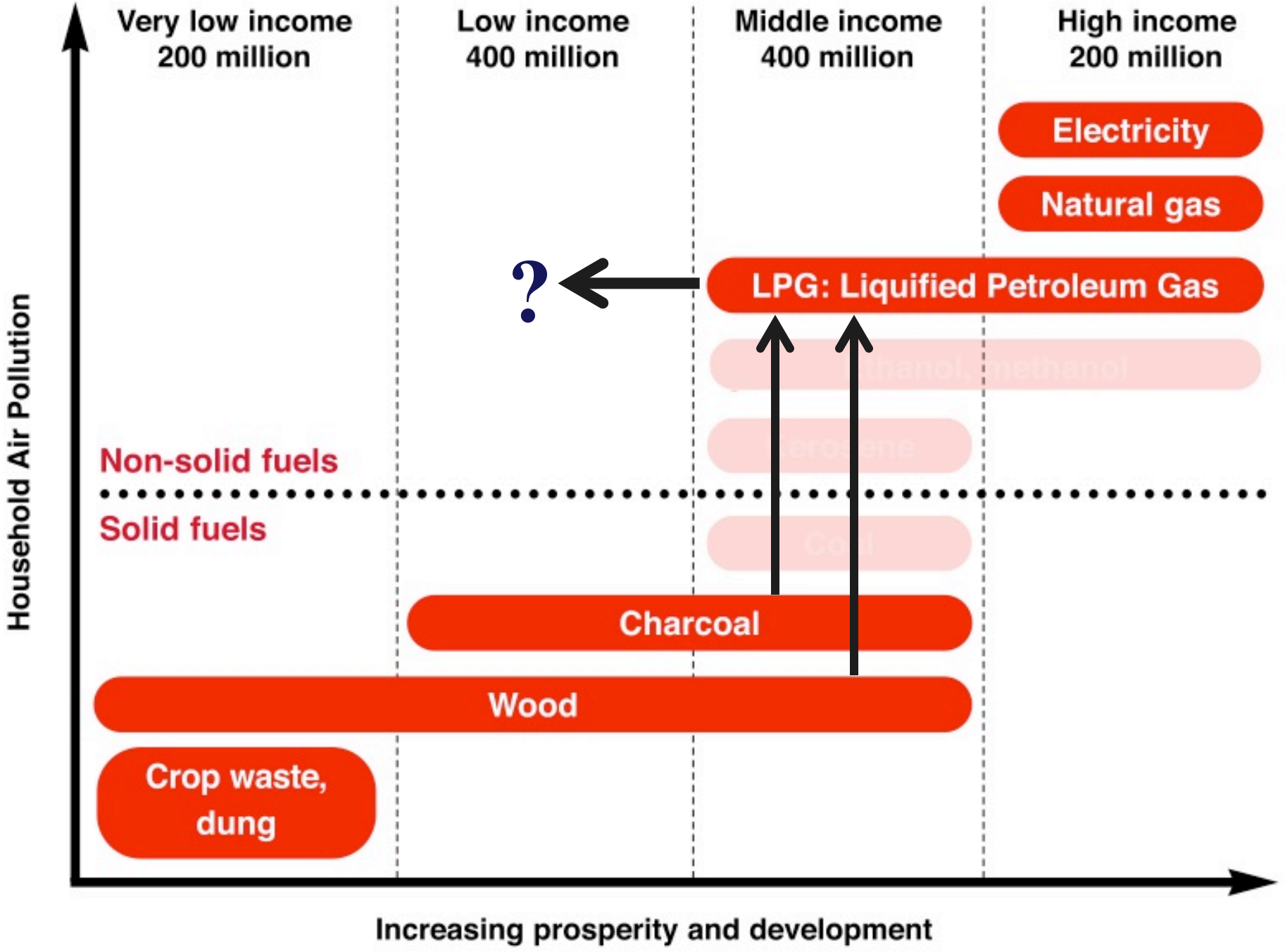
Applies for Loan through Bank Partner
* Helps family with paperwork and connects them to her loan agent

Entrepreneur Earns a Commission to Support Her Family
* She invests in education, healthcare, and better nutrition for her family

GenteGas Community Grows
*Entrepreneur network expansion
*New families using clean fuel

Family gets the health benefits of using gas
* Reduced incidence of disease and death related to toxic cook smoke

After loan approval customer recieves stove package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Electricity
Natural gas
?
LPG: Liquified Petroleum Gas
Non-solid fuels
Solid fuels
Charcoal
Wood
Crop waste,
dung
Household Air Pollution
Increasing prosperity and development

Story of Two States

Gujarat: 1981-2013

Kerala: 2005-2013

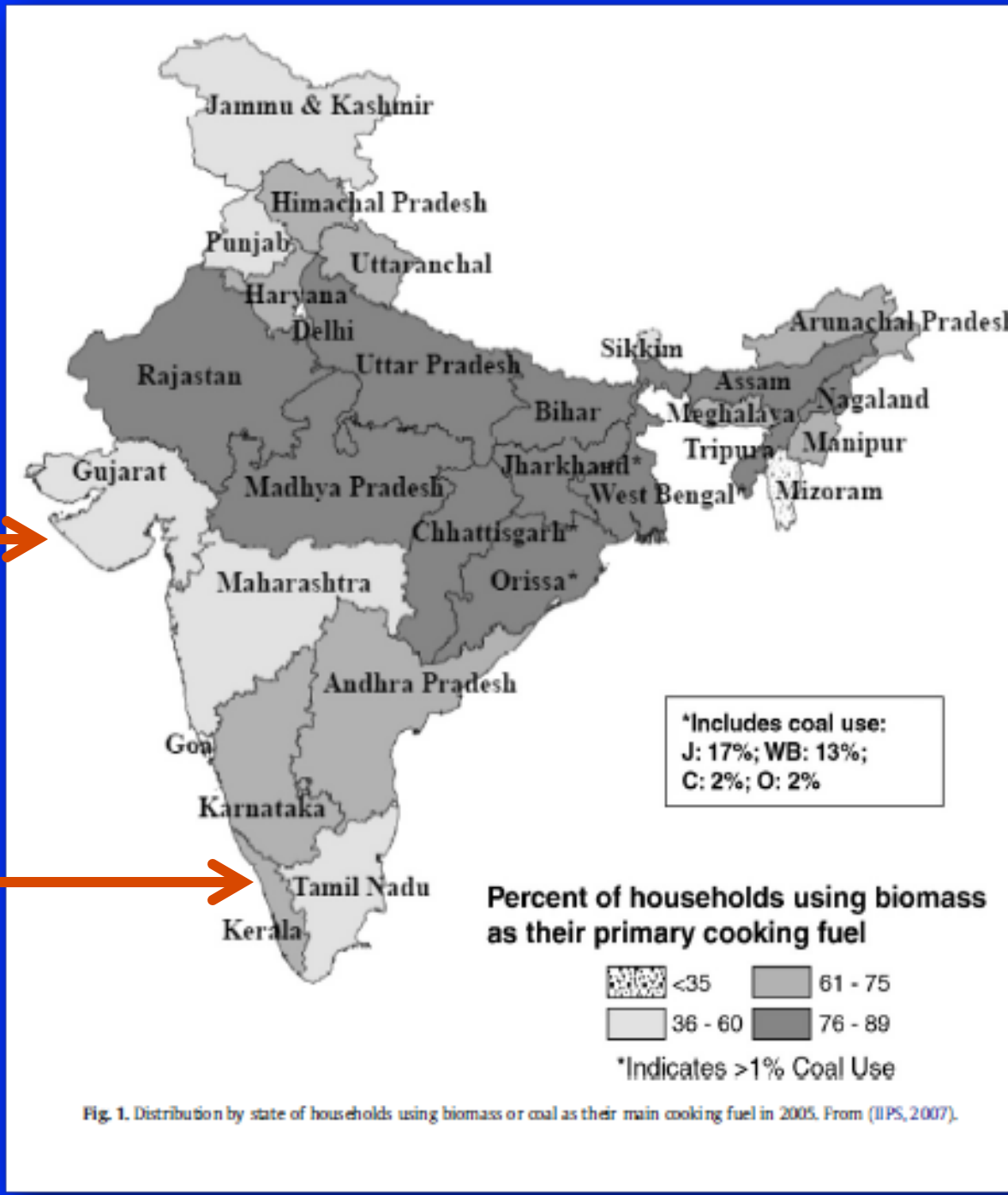

Fig. 1. Distribution by state of households using biomass or coal as their main cooking fuel in 2005. From (IIPS, 2007).

In the 1980s, the first link to air pollution science

Atmospheric Environment Vol. 17, No. 11, pp. 2343–2362, 1983
Printed in Great Britain.

0004–6981/83 $3.00 + 0.00
Pergamon Press Ltd.

AIR POLLUTION AND RURAL BIOMASS FUELS IN DEVELOPING COUNTRIES: A PILOT VILLAGE STUDY IN INDIA AND IMPLICATIONS FOR RESEARCH AND POLICY

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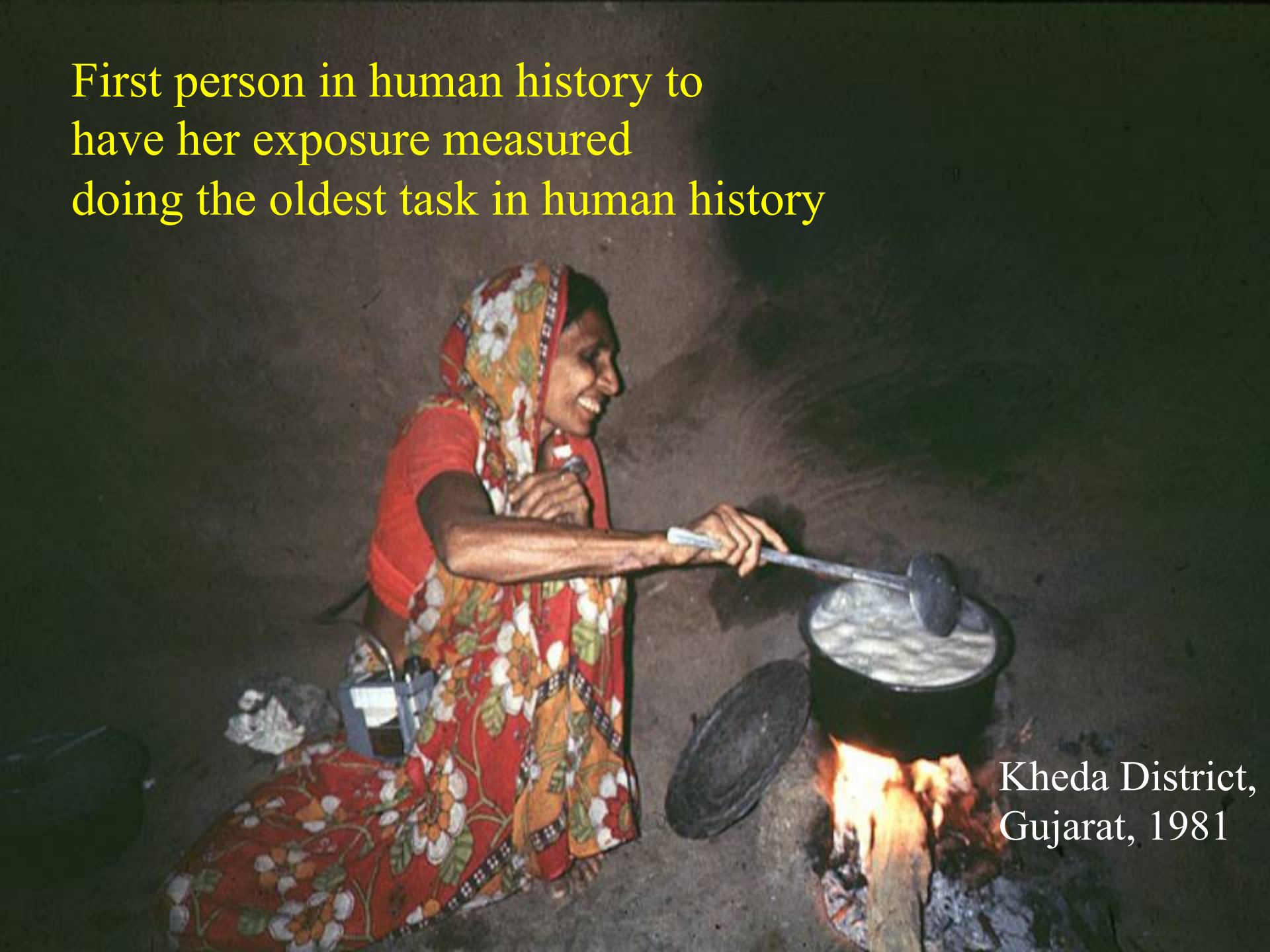
Resource Systems Institute, East-West Center, 1777 East-West Road, Honolulu, HI 96848, U.S.A.

A. L. AGGARWAL†
National Institute of Occupational Health, Ahmedabad, India.

and

R. M. DAVE✠
Jyoti Solar Energy Institute, BVM Engineering College, Vallabh Vidyanagar, Gujarat, India, 388-120.

First person in human history to
have her exposure measured
doing the oldest task in human history



Kheda District,
Gujarat, 1981

Field Team, Gujarat, 1981

Diwaliben, October 2013

Gujarati Villages since 1981

- Reliable electricity
- Piped water
- Cell phones
- Satellite TV
- Pucca schools
- More pucca houses and roads
- But still using chulhas

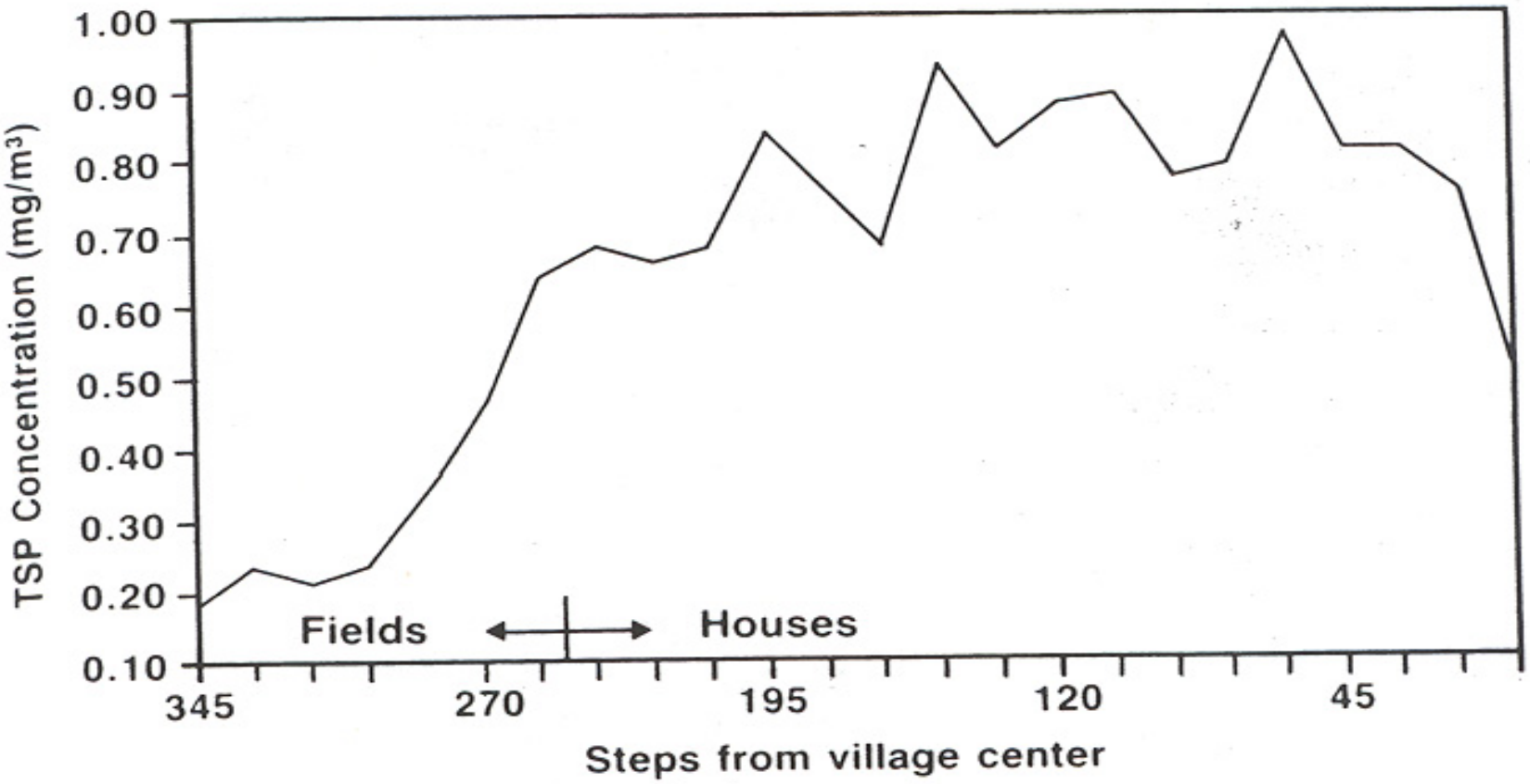
Assessment of "Improved Stoves"

Table 10. Exposure and fuel use variations due to cookstove type*

	Smokeless	Regular	Pit
TSP (mg m^{-3})			
Mean	4.6	6.4	6.2
Standard deviation	(2.9)	(4.6)	(1.9)
a.m. (mean)	3.0	4.7	7.1
p.m. (mean)	5.8	7.7	5.3

Smith, et al., 1983

Neighborhood Pollution in an Indian Village



Measurement of Neighborhood Pollution

Table 5. TSP and BaP measurements: ambient levels

Village	Height (m)	Time at start	Duration (minutes)	TSP mg m^{-3}
Meghva	2.5	7:00 p.m.	—	1.48
Denapura	2.5	6:40 p.m.	58	1.14
Denapura	2.5	6:40 p.m.	50	0.50
Rampura	3.5	6:23 p.m.	50	2.5
Rampura	1.5	5:50 p.m.	51	2.5
Vallabh Vidyanagar*	1.5	5:55 p.m.	150	0.6

* Semi-urban area.

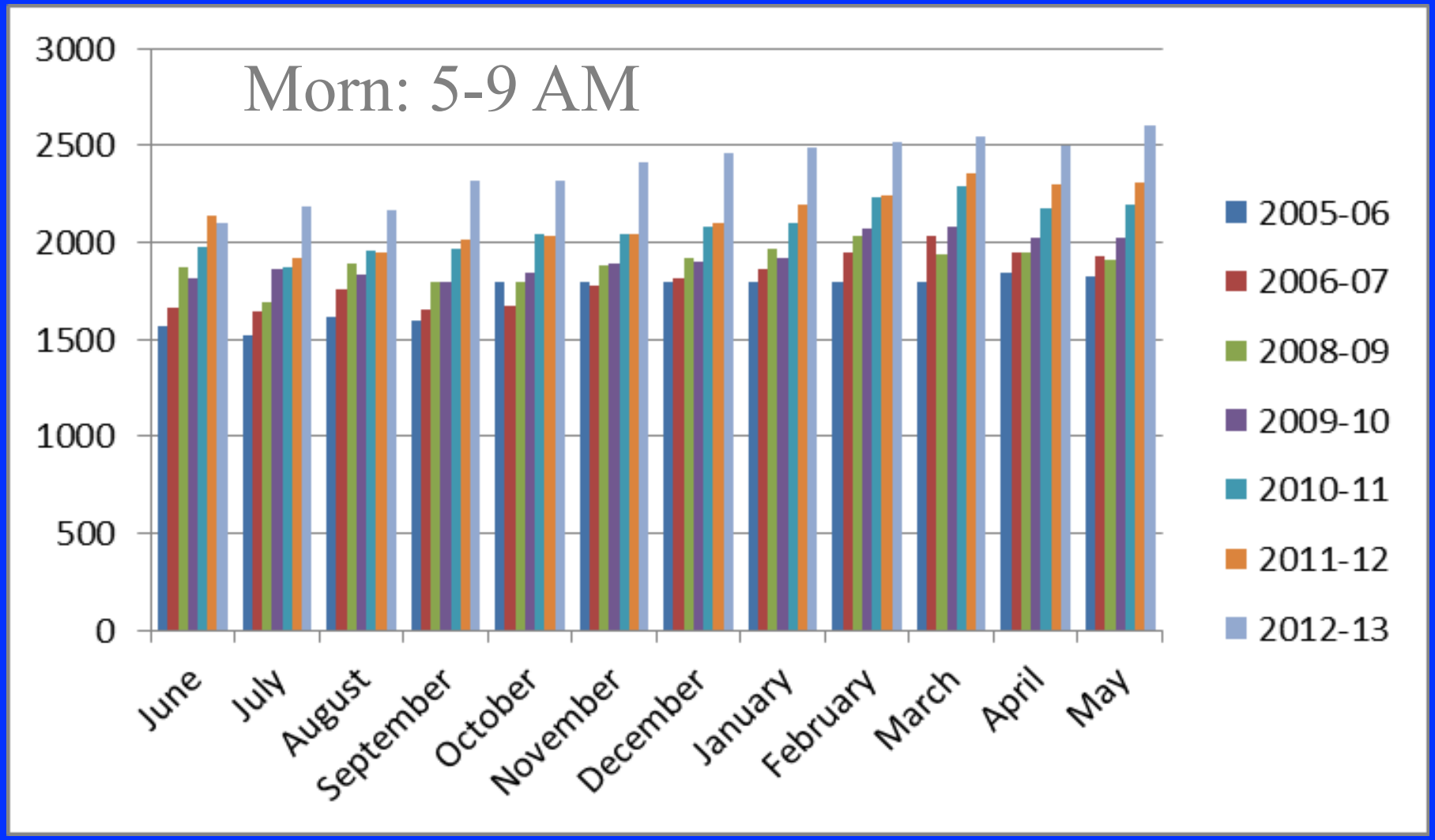
Smith, et al., 1983


NIRLEP
dane

Kerala story

- Like most of India, Kerala has had an electric peak in early evenings
- Starting after mid decade, however, Kerala started experiencing a fast-growing morning peak as well
- Reason: massive sales of induction cookstoves (ICs) were shifting demand
- Experience is that once a woman is used to an IC, she does not want to go back.

Kerala Morning Peak (MW)

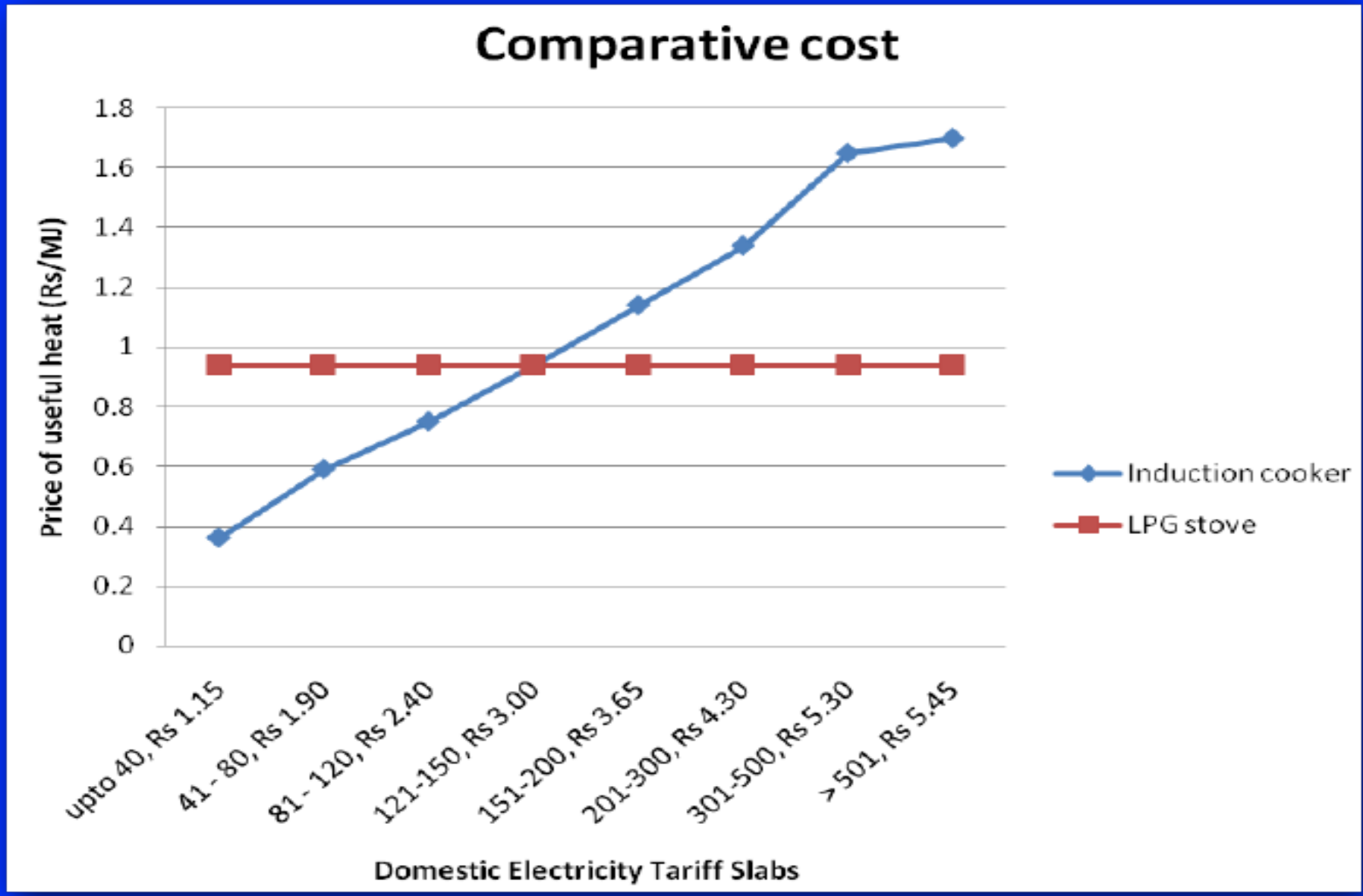


Evening Peak growing at 5.5%; Morning at 8%

KSEB, 2013

Fuel	*Calorific vale (kJ/kg)*	*Cost (Rs/kg)*	*System*	*Thermal Efficiency (%, average)*	*Price of useful heat energy (Rs/MJ)*
Fuel wood	12540	4	Ordinary cook stove	8	3.99
	12540	4	Improved cook stove	22	1.45
Kerosene	43116	25.0	Nutan wick stove	60	0.97
LPG	45837	29.3	Efficient stove	68	0.94
Electricity	3600	3.0	Induction cooker	89	0.94
	3600	3.0	Electric hot plate	66	1.26

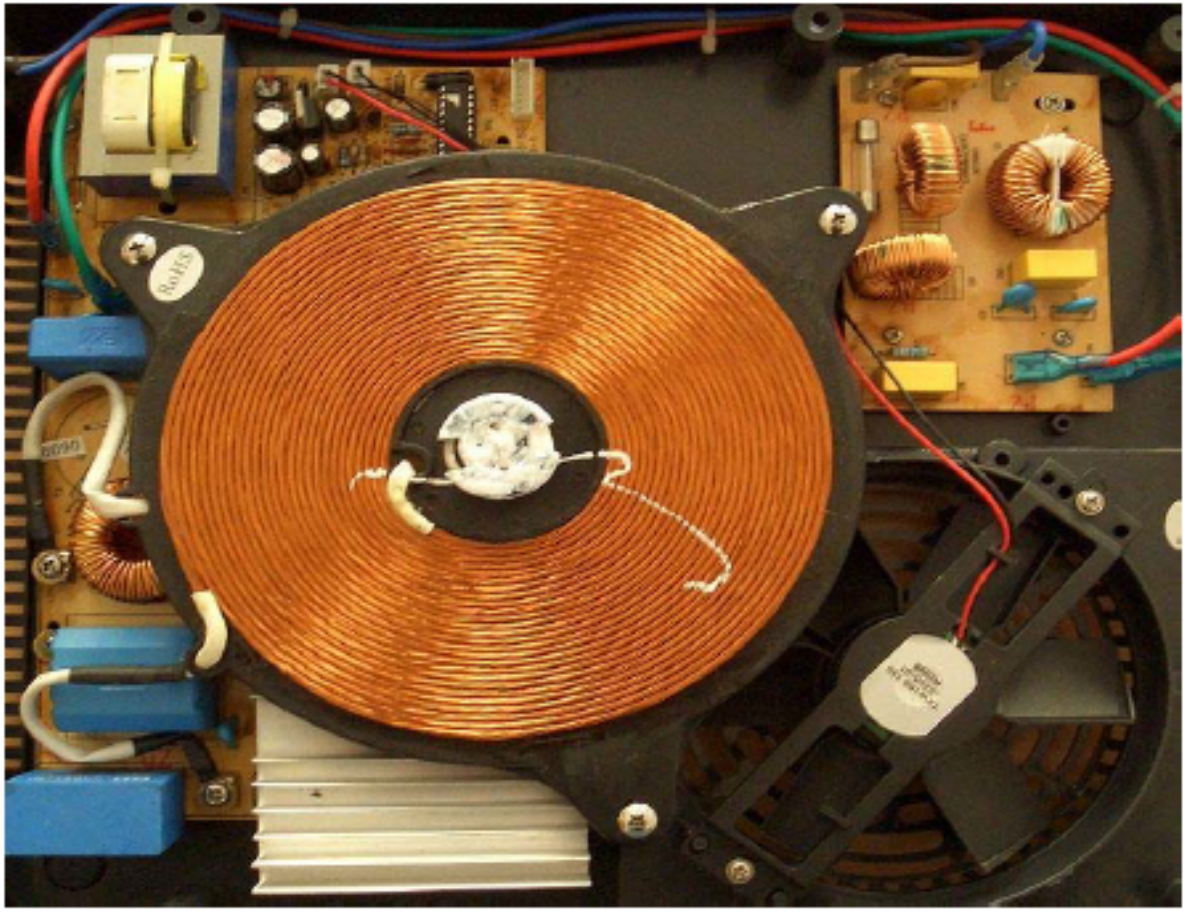
Kerala Energy Management Centre, 2011



Kerala Energy Management Centre, 2011

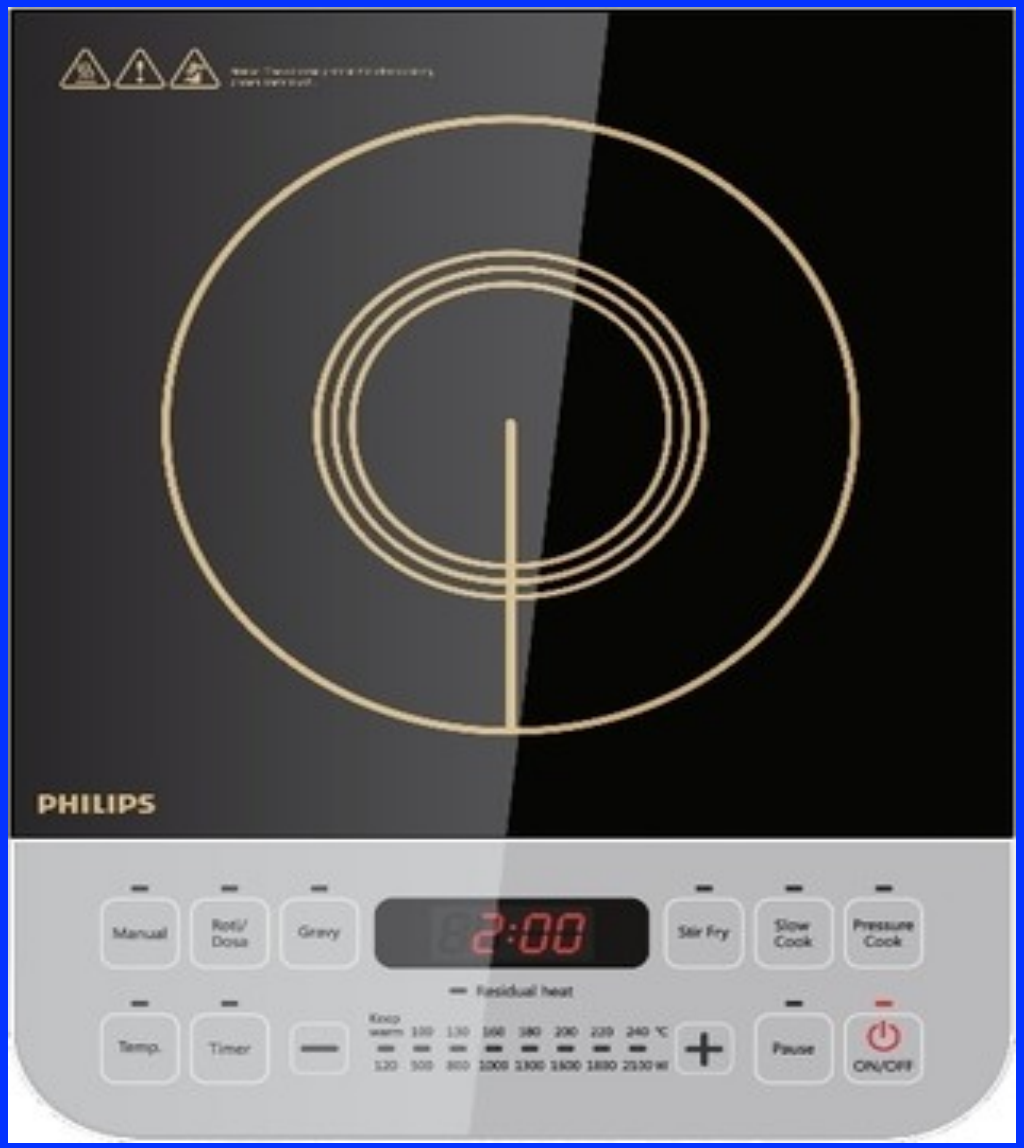
What is an induction cookstove?

- Electric, yes, but
- Entirely different technology from traditional electric stoves – high frequency magnetic field induces heat in pot alone
- More efficient ~90% instead of ~60%
- Faster cooking >1.5x
- Safer – surface is warm but does not burn or cause fires
- Long-lived, easy to clean, sophisticated controls if desired



Electromagnetic Induction: Electromagnetic induction is the production of an electric current across a conductor moving through a magnetic field. Induction heating is the process of heating an electrically conducting object (usually a metal) by electromagnetic induction, where eddy currents are generated within the metal and resistance leads to heating of the metal. Induction cooker uses induction heating to directly heat a cooking vessel. To be used on an induction cooktop, a cooking vessel must be made of a ferromagnetic metal. In an induction cooker, a coil of copper wire is placed underneath the cooking pot. An alternating electric current flows through the coil, which produces an oscillating magnetic field. This field induces an electric current in the pot. As a result, the body of the cooking pot will be heated quickly on its own, which will in turn cook the food inside.

Dozens of Models on Indian Market



Phillips Induction Stove for India

Functions include

Roti/chapati
Pressure cooker
Stir fry
Milk simmering
Etc

Induction Cooktop Market in India 2012-2016

Published: March 2013
Infiniti Research Limited

35.4% per year growth predicted: 2012-2016

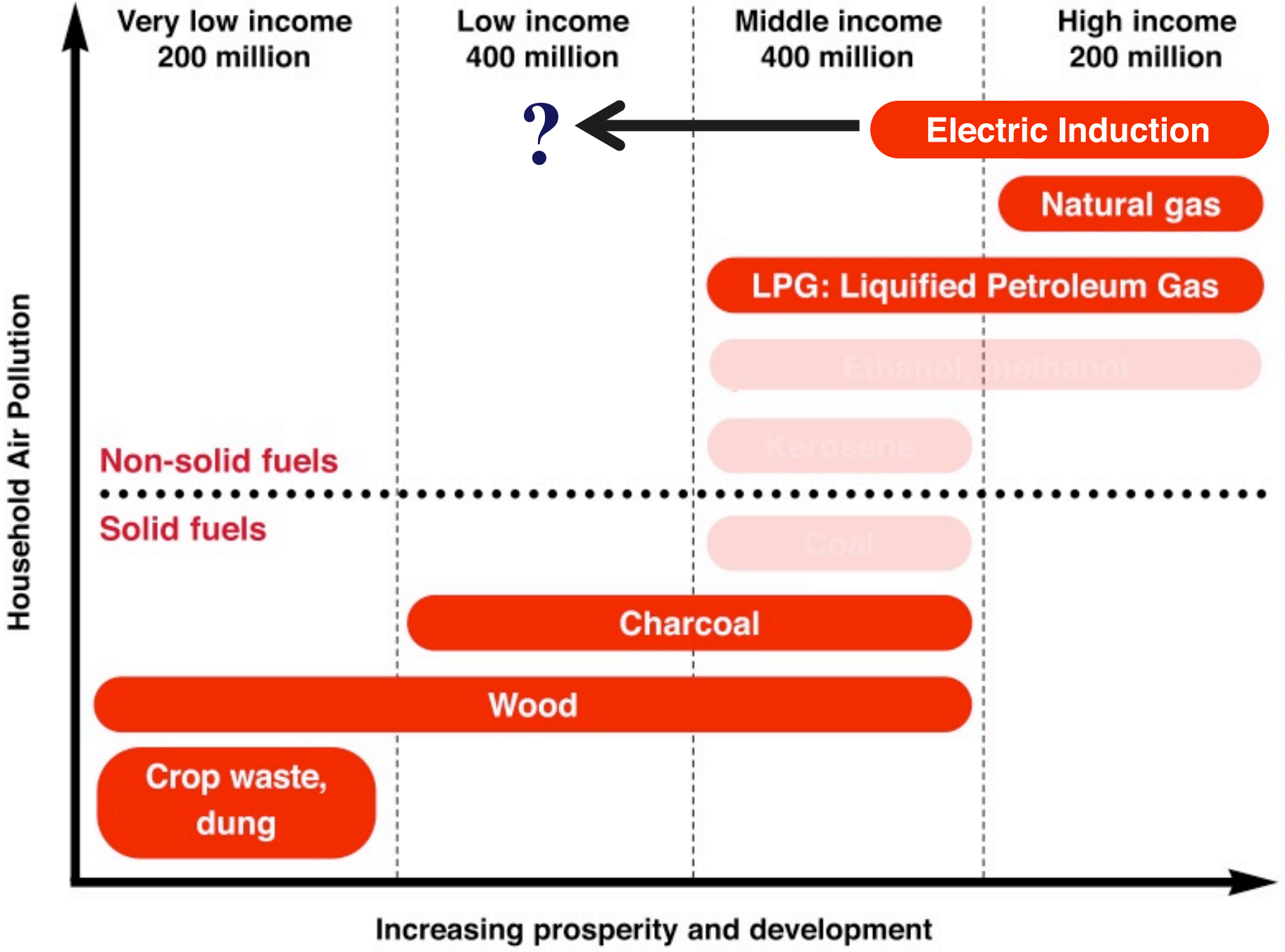
Factor of nearly five increase!

- - Bajaj Electrical Ltd.
- Compton Greaves Ltd.
- Eurolux
- - Glen Appliances Pvt. Ltd.
- Inalsa
- Jaipan Industries Ltd.
- Kenwood Ltd.
- Khaitan Electrical Ltd
- Morphy Richards
- Panasonic Corp.
- - Phillips
- Preethi Kitchen Appliances, Ltd.
-Sunflame
-TTK Prestige Ltd.
-Usha International Ltd.
-Westinghouse

Flying off the shelves in China

Considerations

- Power reliable in major cities and 2-3 full states and on the march nationally.
- Cooking would add serious additional demand, but at great benefit, and not large compared to need in general
  - E.g., for 100M households, 50 GWe peak during addition of needed 200+ in next decades
- PV microgrids are proliferating in India to supply villages without power
  - Technically doable to provide sufficient power for induction cooking, but economics uncertain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Electric Induction
Natural gas
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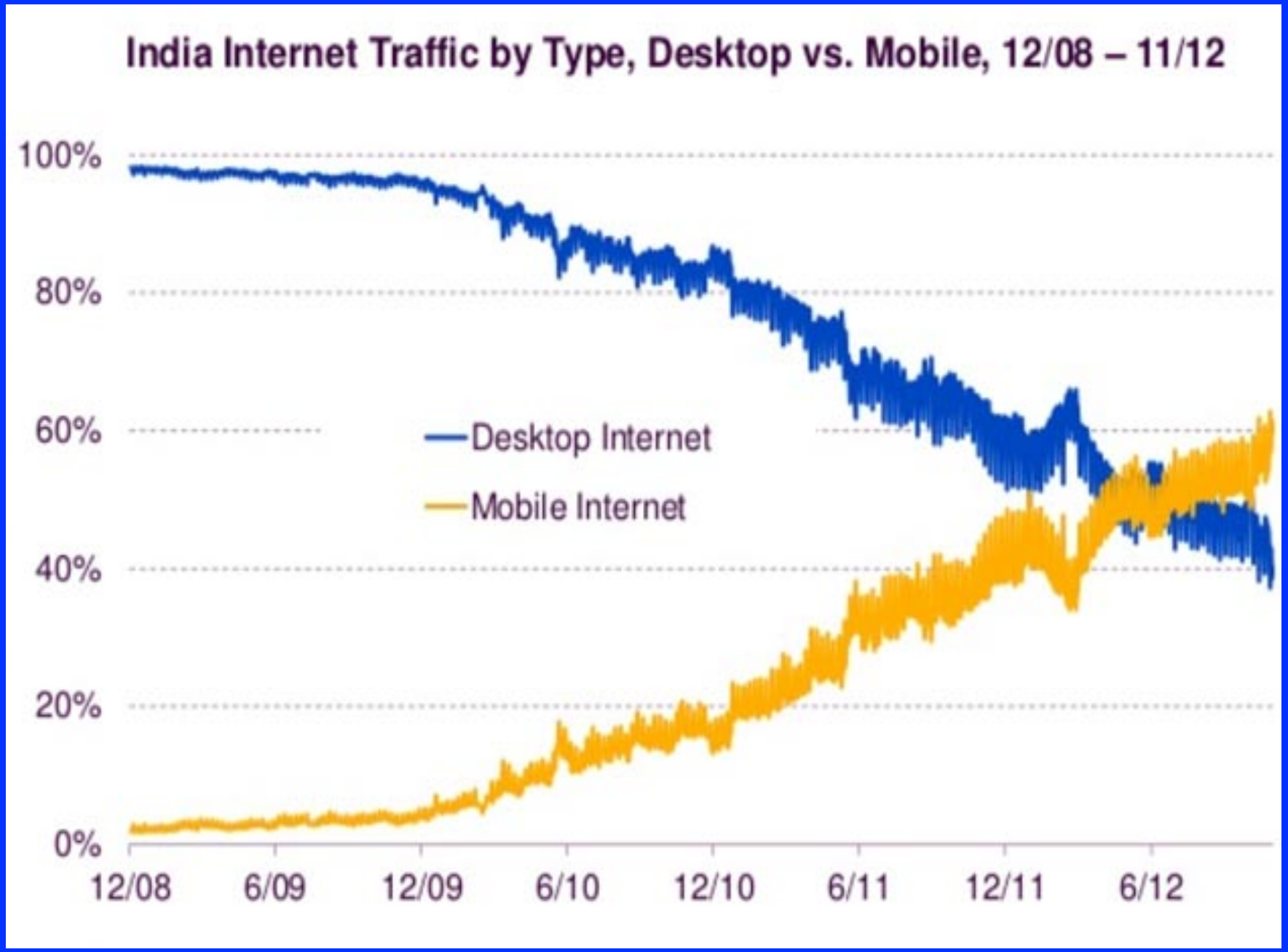
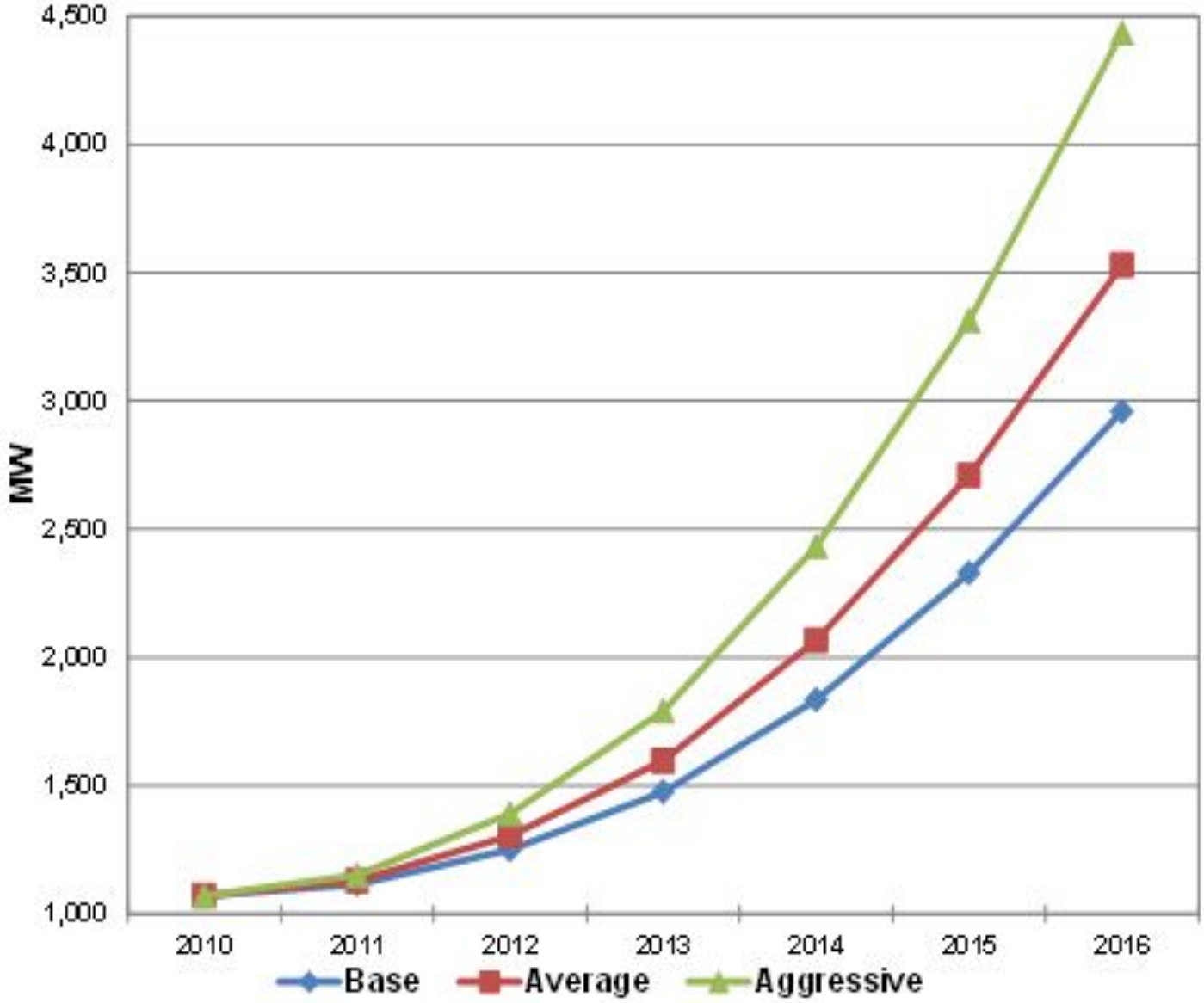
Ethanol, methanol
Kerosene
Non-solid fuels
Solid fuels
Coal
Charcoal
Wood
Crop waste,
dung
Household Air Pollution
Increasing prosperity and development

Leapfrog Technologies

- Cell phones
- Satellite TV dishes
- Smart phones
- PV microgrids


India Internet Traffic by Type, Desktop vs. Mobile, 12/08 – 11/12
100%
80%
60%
40%
20%
0%
Desktop Internet
Mobile Internet
12/08
6/09
12/09
6/10
12/10
6/11
12/11
6/12

Planned Microgrid Capacity, Base, Average & Aggressive Scenarios, World Markets: 2010-2016

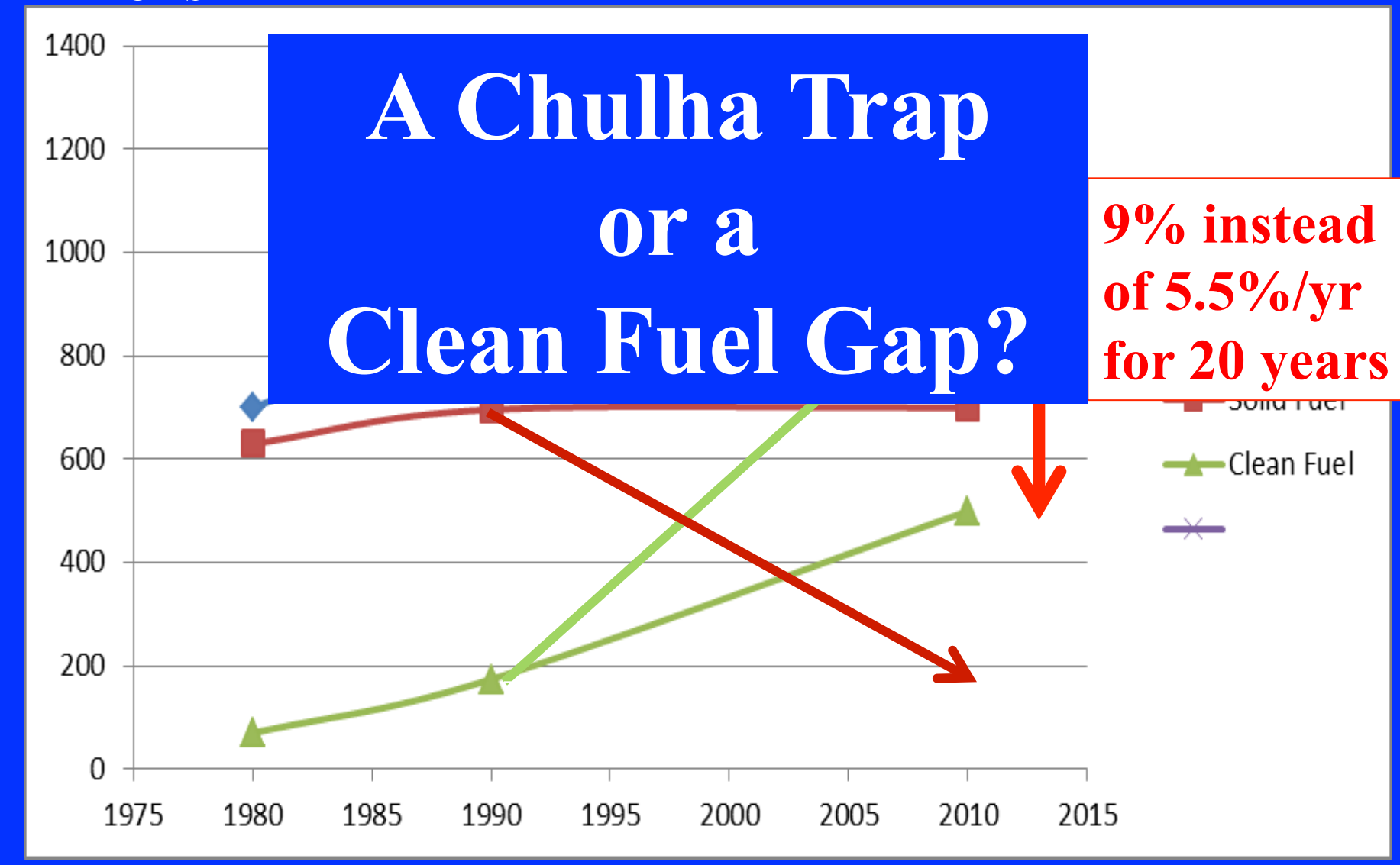


(Source: Pike Research)

Questions for consideration

- What are the full benefits of reliable electricity?
- Is there a leapfrog cooking technology that would
  - Be clean, efficient, and safe
  - Sufficiently transformational to "sell itself" and rapidly take over the market

India: What If?



Expensive?

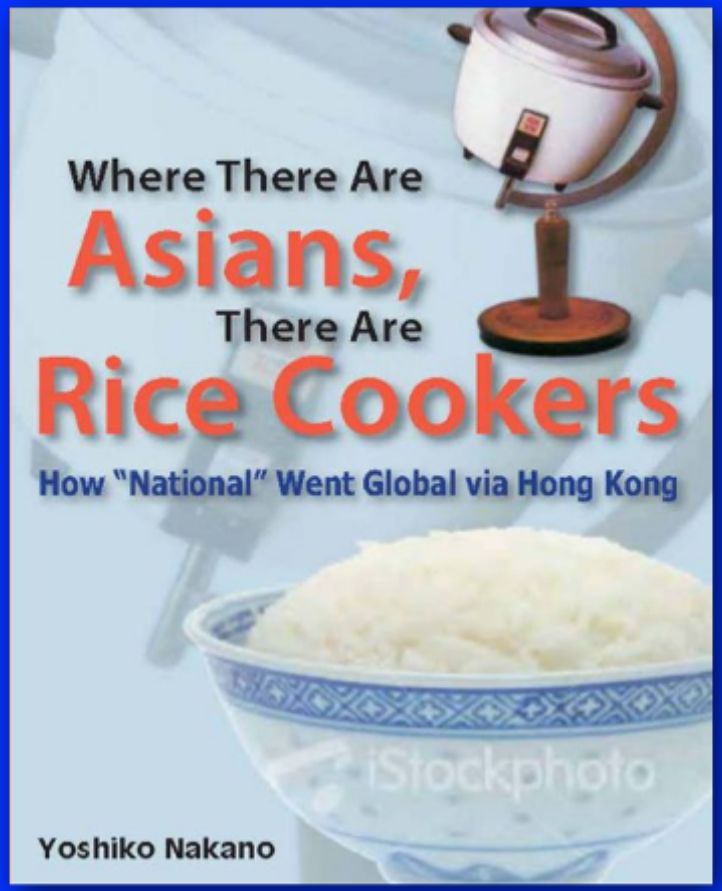
- Total funds would be large, but
- Even if fully paid by the government
  - Stove/canister and $15/mo LPG
  - Reduce $PM_{2.5}$ to 30 ug/m3
- Cost per DALY saved would be on the order of $1000.
- This is considered "very cost-effective" by WHO criteria for India (based on one annual GDP/cap per DALY) .

New Partners in India

- Ministry of Health and Family Welfare
  - First MOH in world to take on reducing HAP as a major goal. First meeting of steering committee next week to design program
- Ministry of Petroleum/Natural Gas
  - MOP/NG considering expansion of LPG as a health priority, potentially in conjunction with MOH. First meeting next week
- Ministry of Power:
  - working to bring them on board through the Bureau of Energy Efficiency

Leapfrog lessons from the past

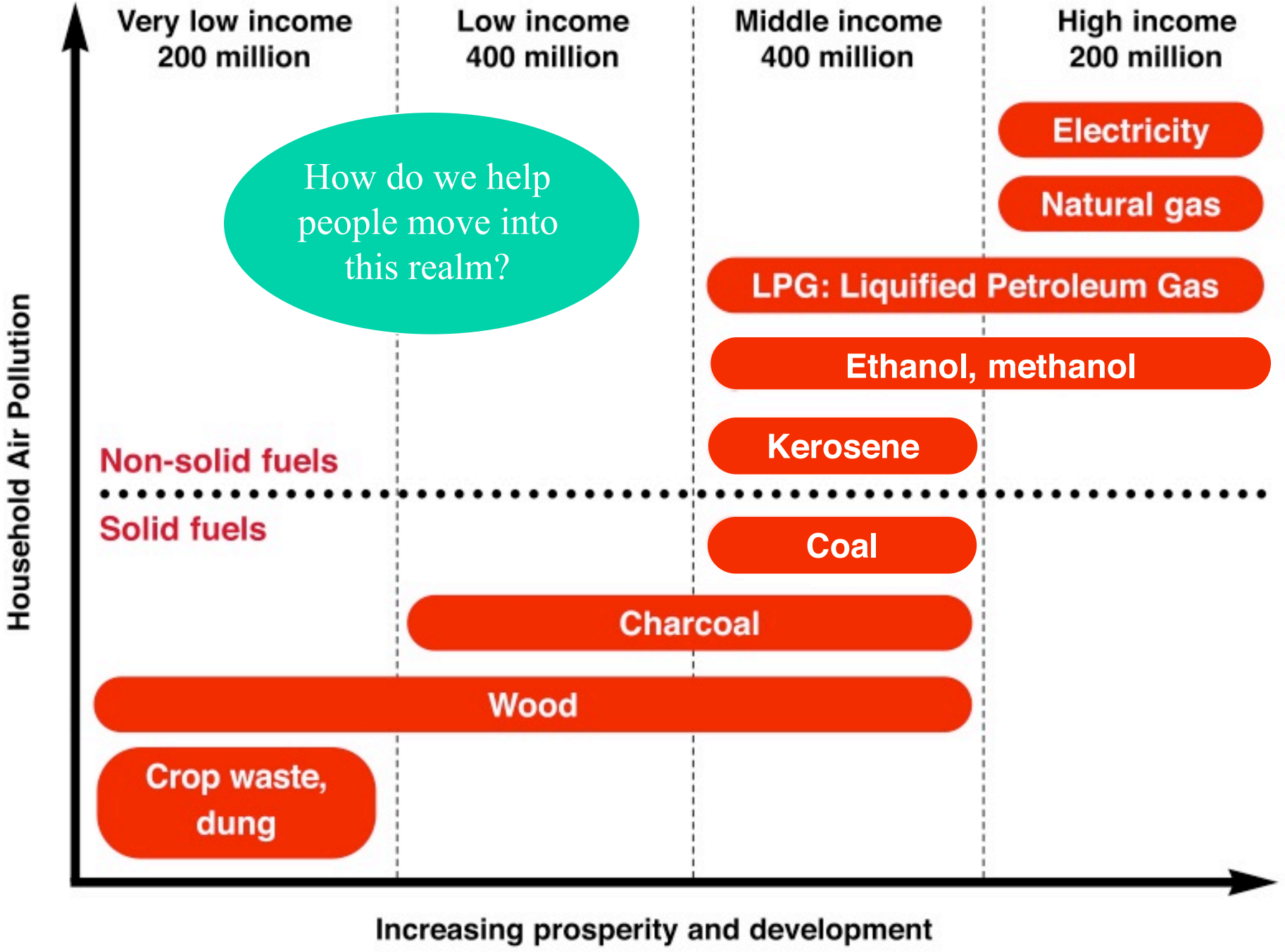
Rice Cooker History



HK University Press, 2010

Highlights

- Invented in Japan: 1955
- 90%+ households in <9 years
- Went global via Hong Kong in 1960s
- ~100 million a year now
- Careful adaption to every market
- 3rd largest fortune in HK from this industry


Very low income
200 million
Low income
400 million
Middle income
400 million
High income
200 million
How do we help people move into this realm?
Electricity
Natural gas
LPG: Liquified Petroleum Gas
Ethanol, methanol
Kerosene
Non-solid fuels
Solid fuels
Coal
Charcoal
Wood
Crop waste, dung
Household Air Pollution
Increasing prosperity and development

Bottom line

- In addition to continuing to try to

Make the available clean

- Shouldn't we also try harder to

Make the clean available?

Many thanks

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