Renewable & Appropriate Energy Laboratory
RAEL

Cookstoves, Climate & Development

Daniel Kammen

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University of California, Berkeley

COP21, December 8, 2015

UNITED NATIONS FOUNDATION

GLOBAL ALLIANCE FOR CLEAN COOKSTOVES

fondation maison des sciences de l'homme
Programmes scientifiques

Resources:

Website: http://rael.berkeley.edu

Twitter: @dan_kammen

THE PROBLEMS

“More than 1.4 billion people worldwide have no access to electricity. An additional 1 billion only have intermittent access. ”

United Nations Secretary General, 2012

“Another 2 billion have unreliable or unaffordable electricity.”

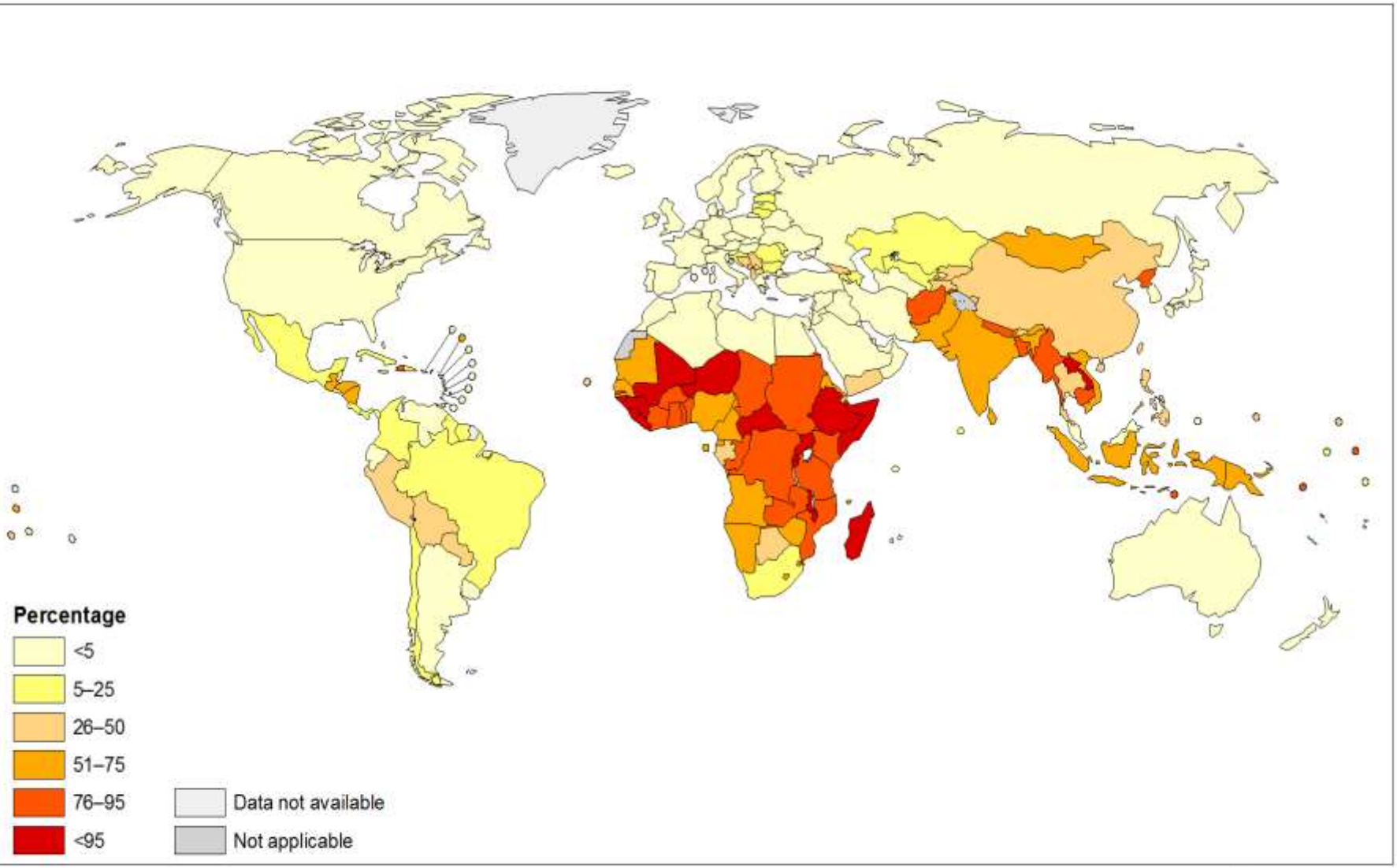
IEA, 2015

“Less than 10 nations have viable decarbonization pathways.”

RAEL, 2015

Cookstove research and activism has been the opening opportunity on both issues

Population using solid fuels (%), 2010
Total

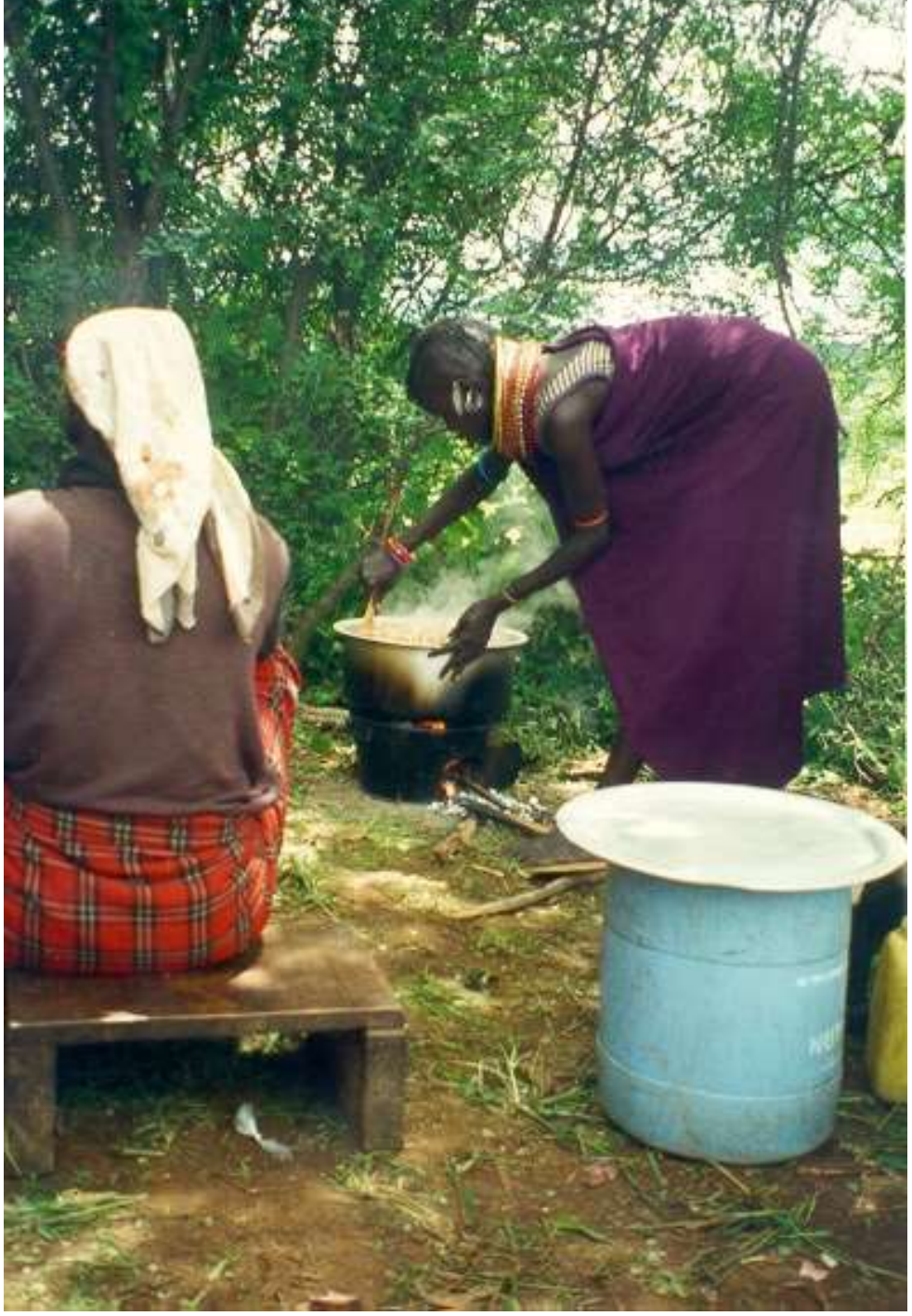


The boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted and dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

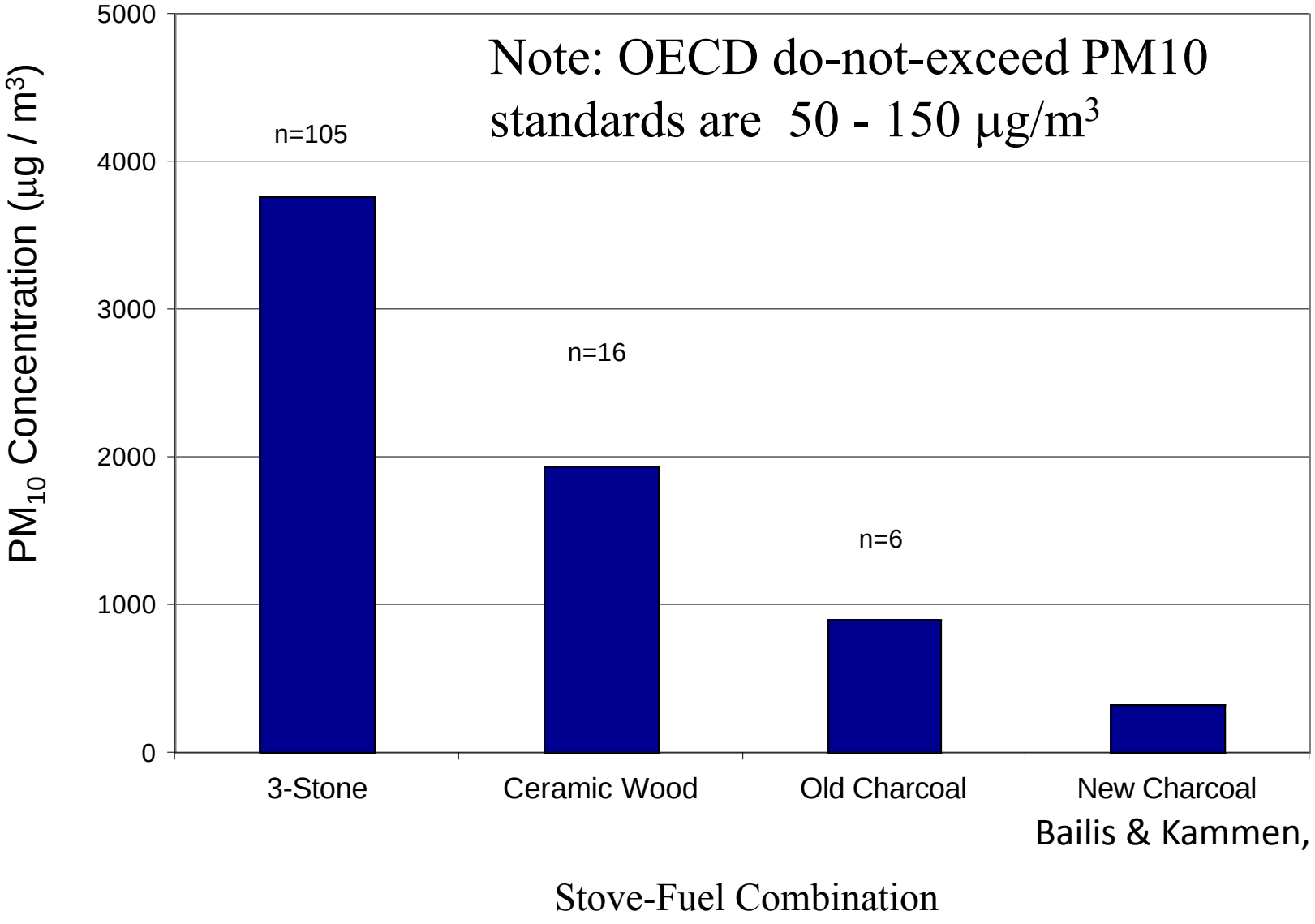
Data Source: World Health Organization
Map Production: Public Health Information and Geographic Information Systems (GIS)
World Health Organization

World Health Organization

Solid Fuel Users



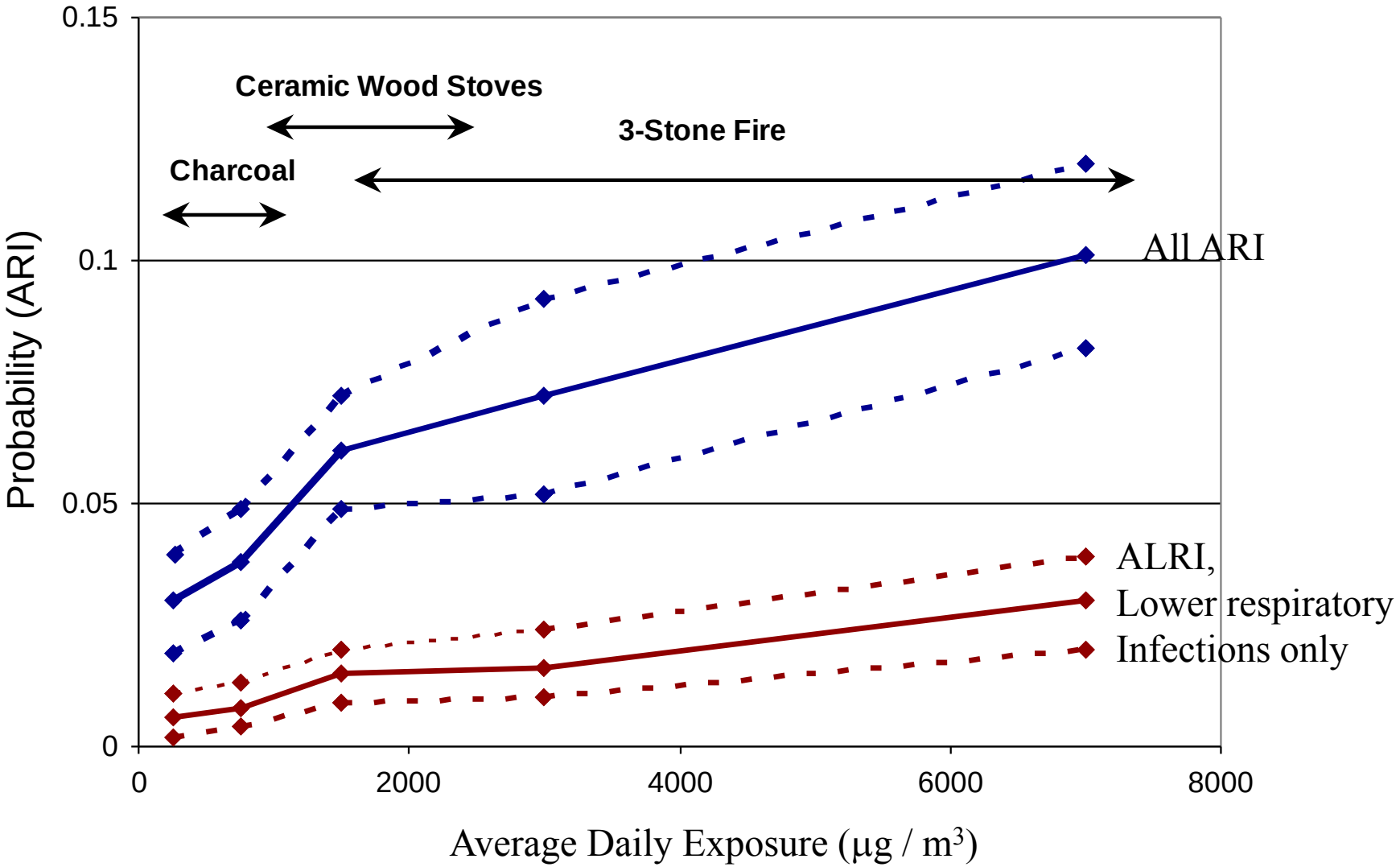
Stove and Fuel Comparison (Average Emissions)



Bailis & Kammen, ES&T, 2003

Solid Fuel Users

Illness Reduction Observed in Kenya in 500 Households (ARI = acute respiratory infection)



Kammen (1996), *Scientific American;* Ezzati and Kammen (2001) *The Lancet*

How Clean Is Clean Enough to Impact Child Survival?

More evidence along the ALRI "Integrated Exposure Response Curve"

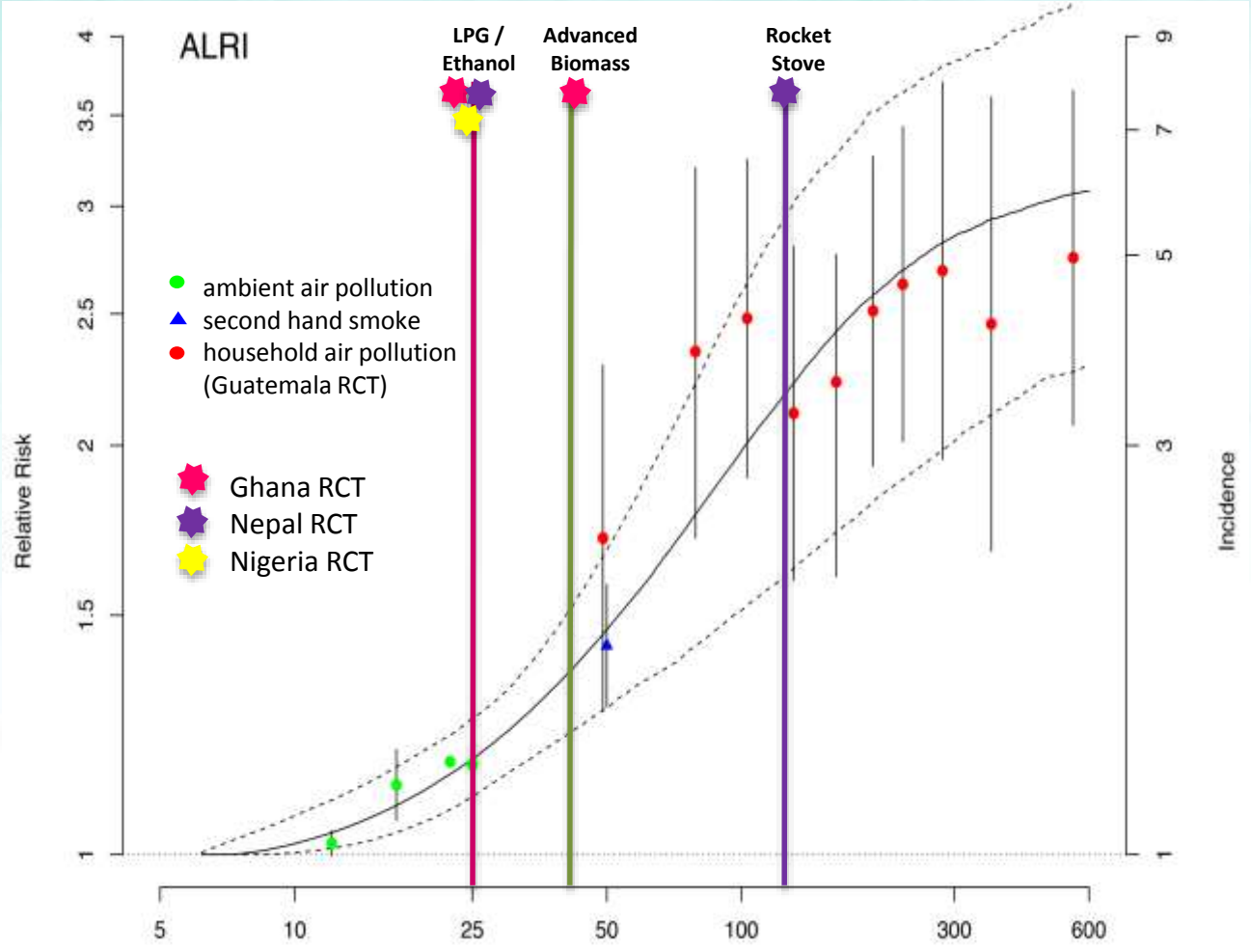
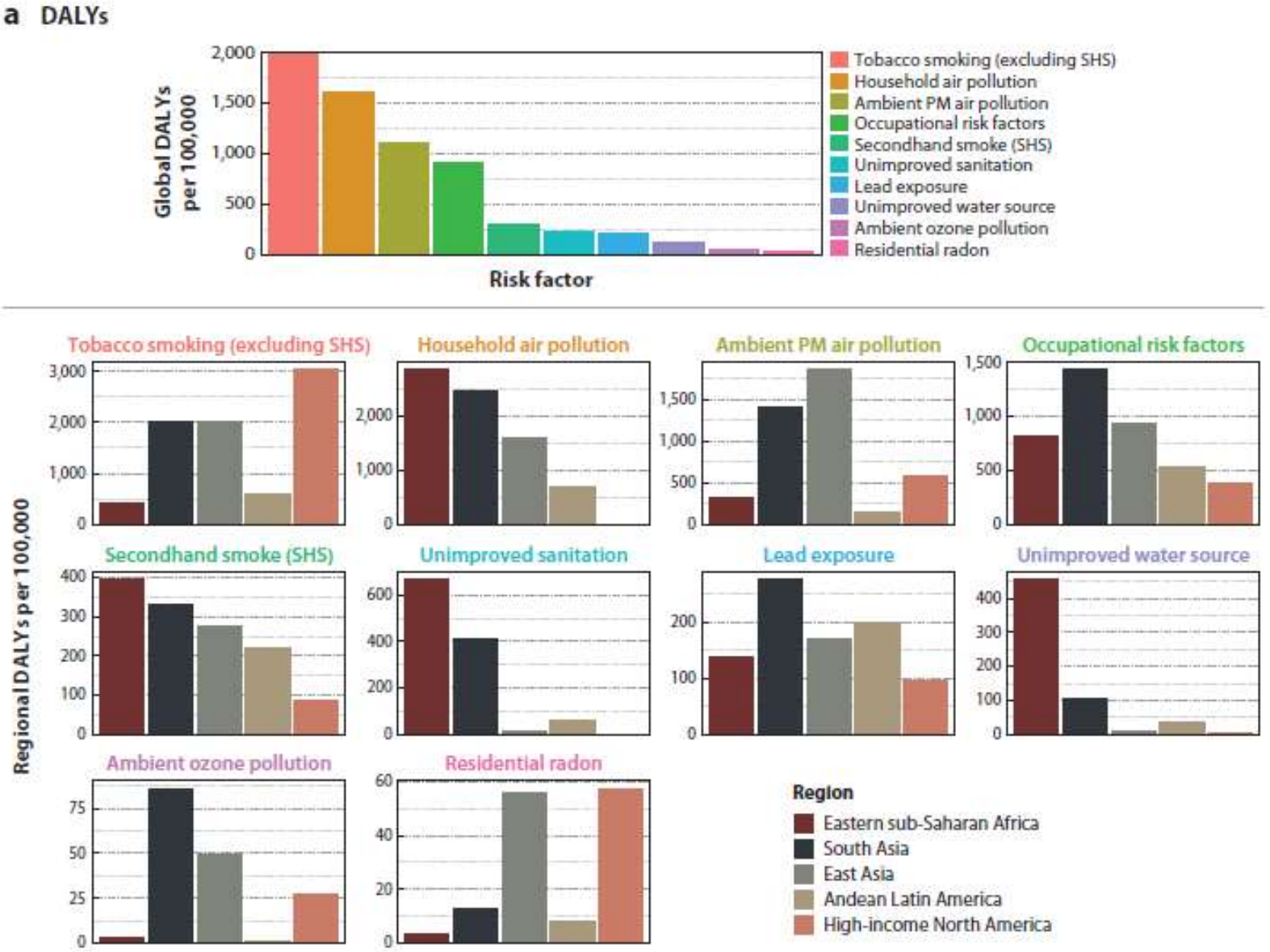


Figure 2

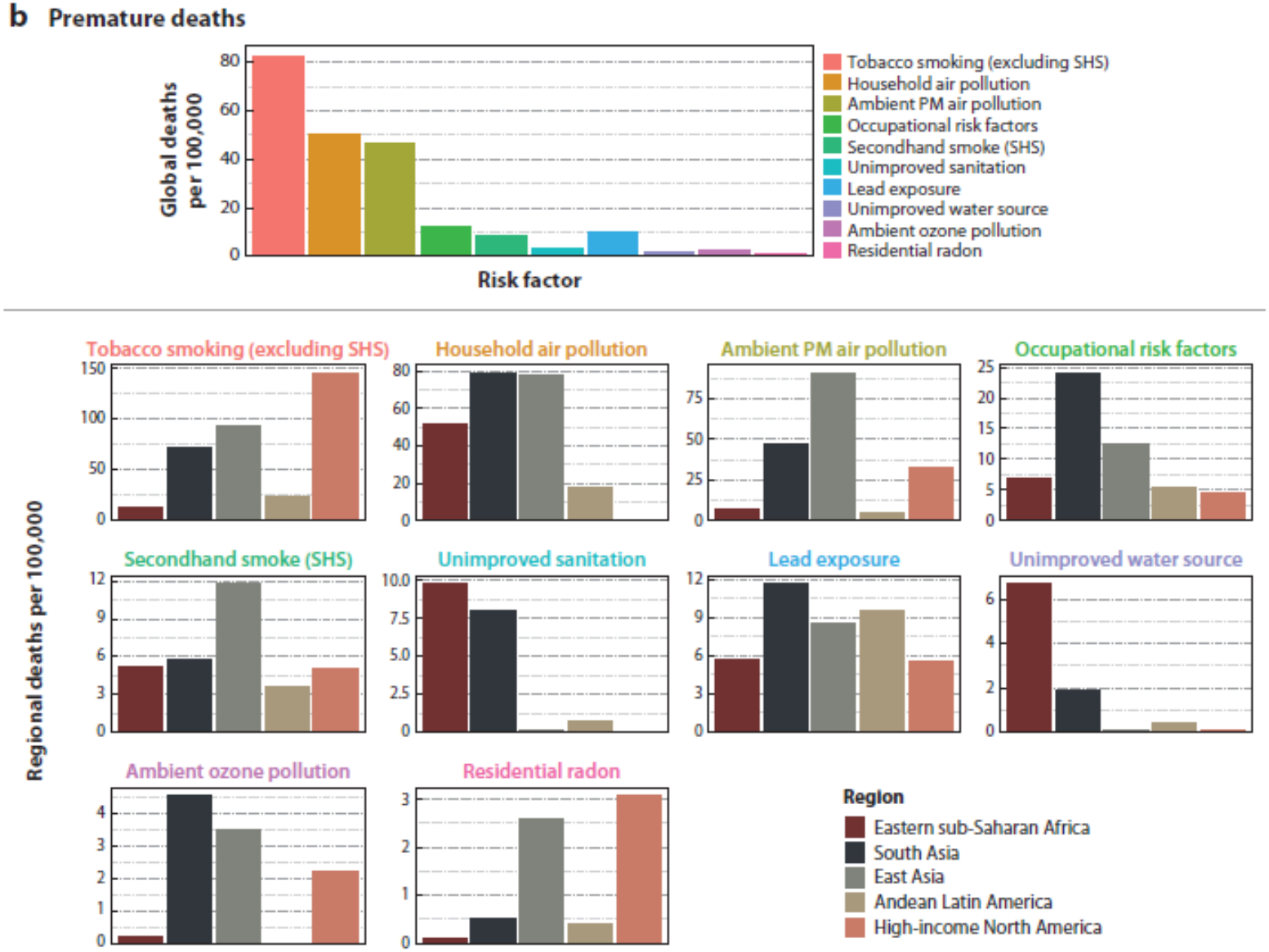
GLOBAL ALLIANCE FOR CLEAN COOKSTOVES

DALYs from household air pollution (2010)



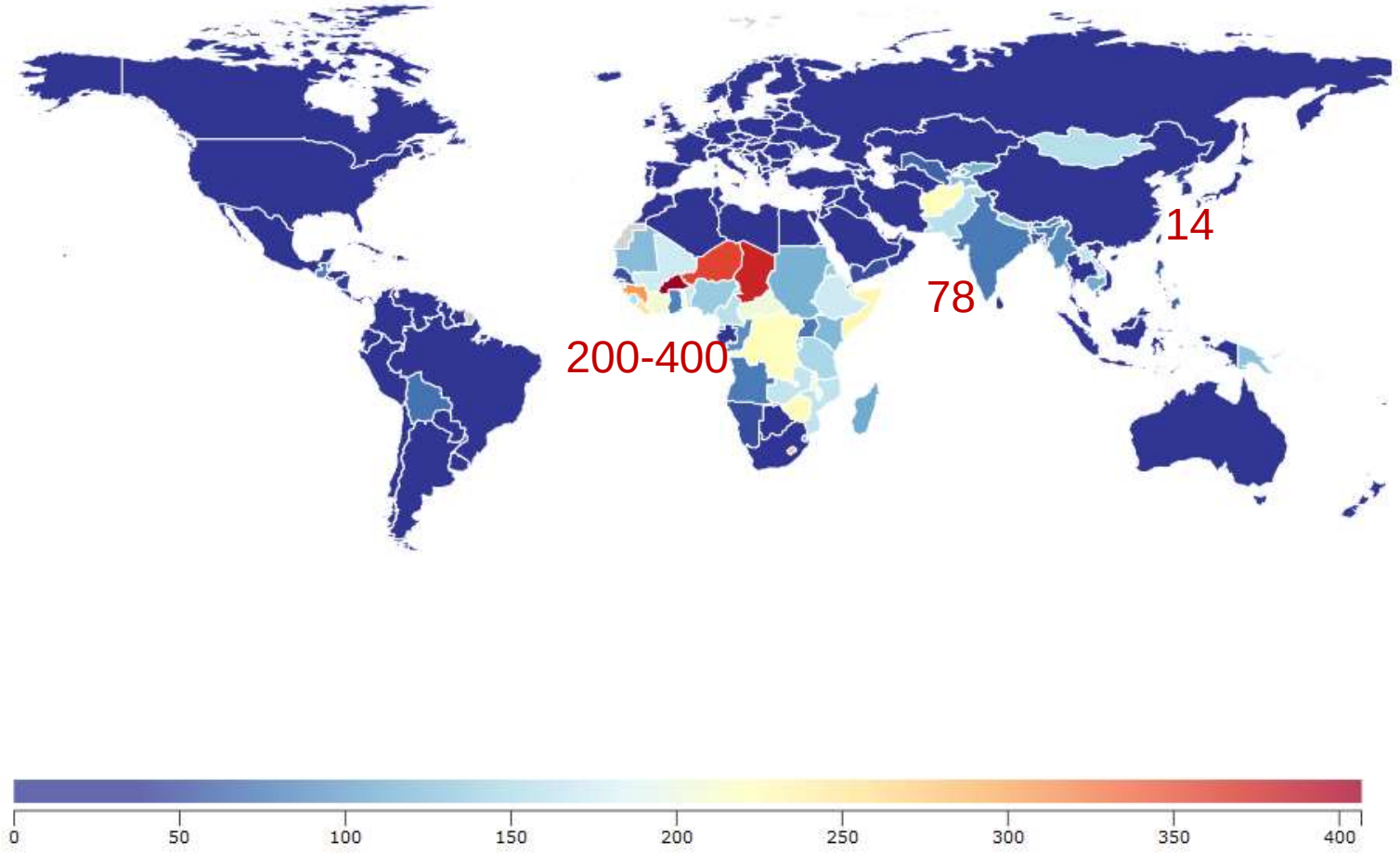
Source: Smith, *ARPH* (2014)

Deaths from household air pollution (2010)



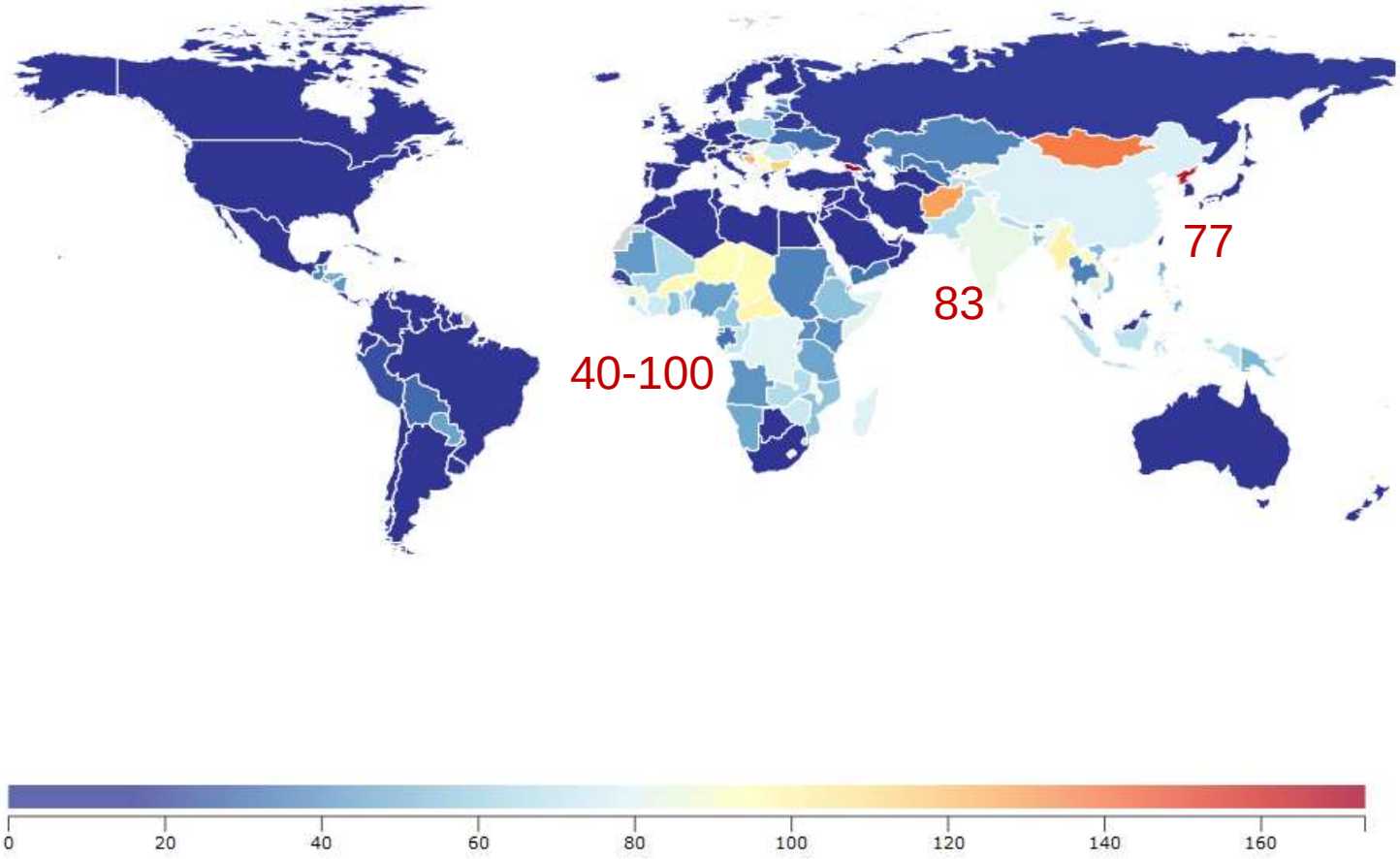
Source: Smith, *ARPH* (2014)

Household Air Pollution: Deaths <5yrs



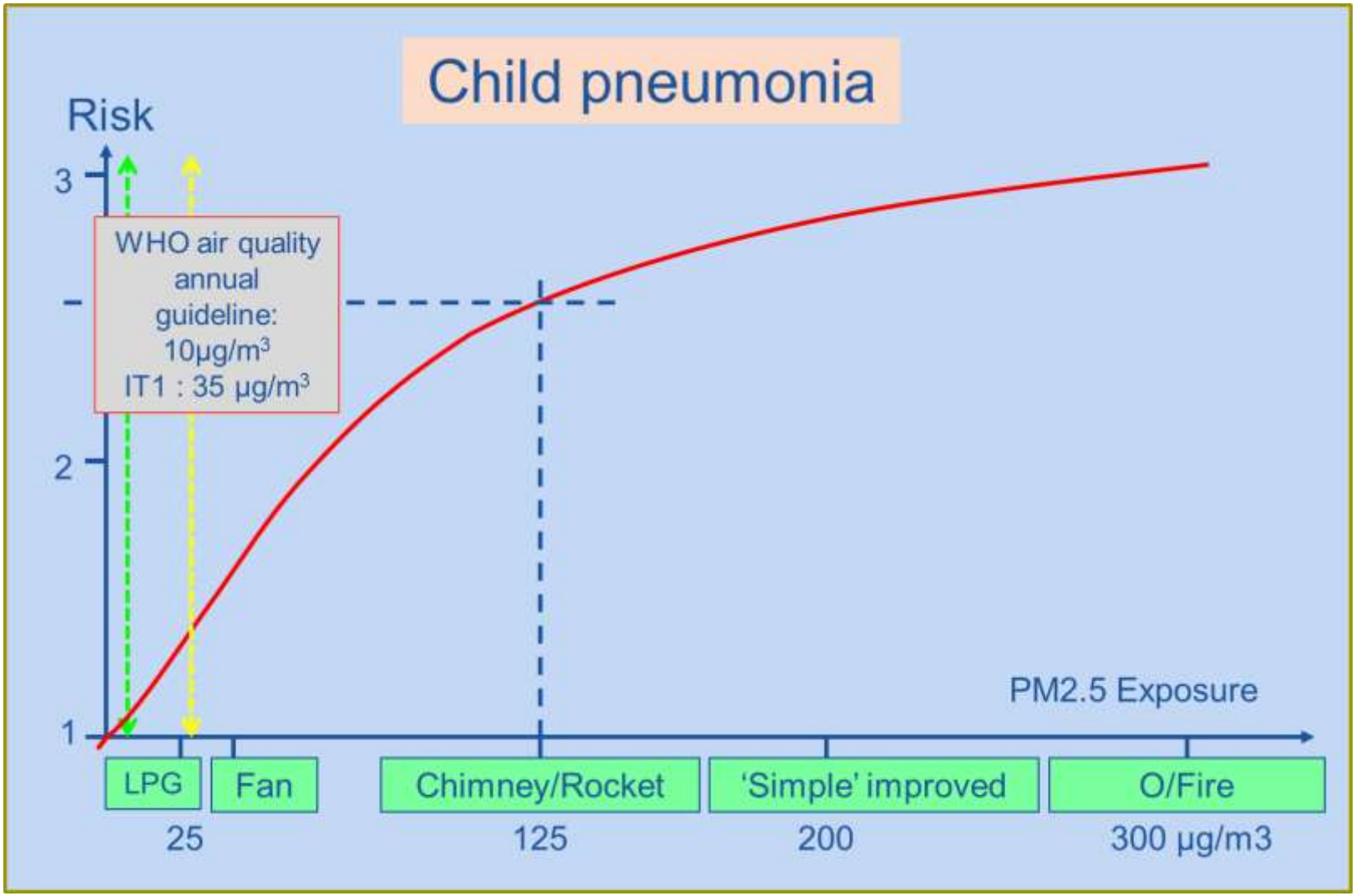
Source: IHME, Global Burden of Disease 2010 (2012)
Shows Deaths Attributable to Household Air Pollution in 2010, per 100,000

Household Air Pollution: Deaths, All Ages



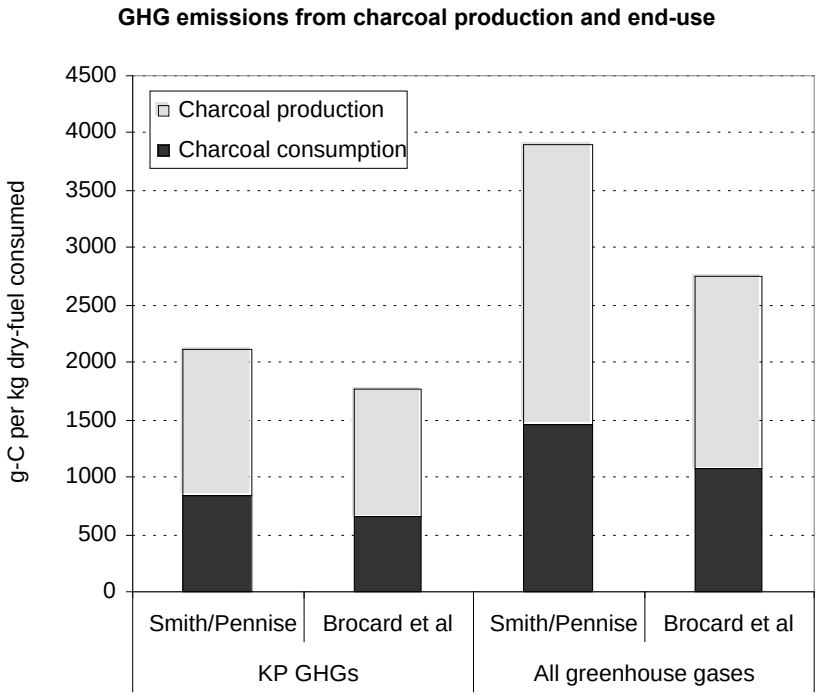
Source: IHME, Global Burden of Disease 2010 (2012)
Shows Deaths Attributable to Household Air Pollution in 2010, per 100,000

Health Co-Benefits



Source: Kirk Smith, 2012

Life-cycle comparison of Kenyan household energy technologies



Charcoal kiln in the early stages of firing, Narok, Kenya. Source: Rob Bailis & Dan Kammen

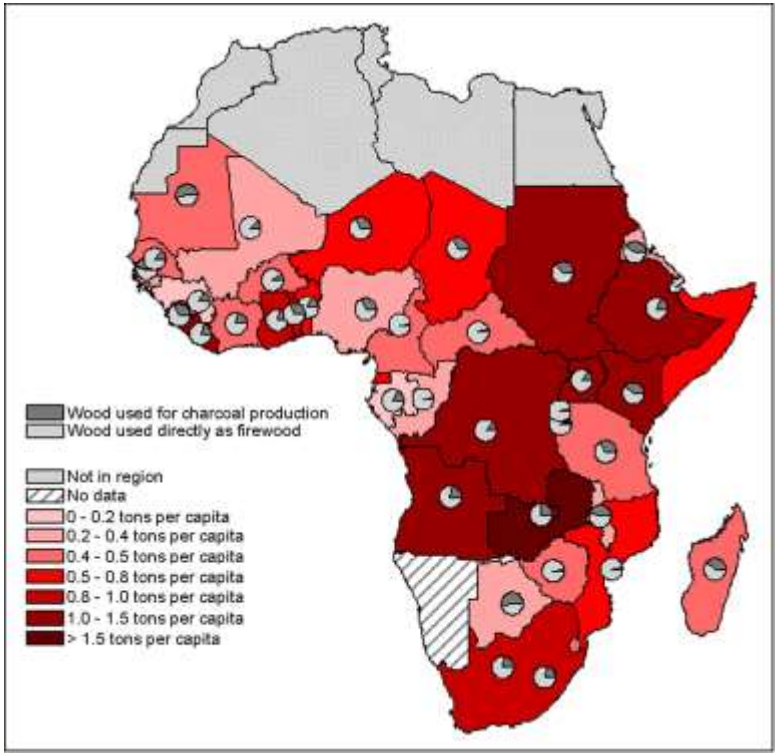
KP: Kyoto Protocol

Analyzing regional transitions

Mortality and Greenhouse Gas Impacts of Biomass and Petroleum Energy Futures in Africa

Robert Bailis,[1] Majid Ezzati,[2*] Daniel M. Kammen[1,3*]

We analyzed the mortality impacts and greenhouse gas (GHG) emissions produced by household energy use in Africa. Under a business-as-usual (BAU) scenario, household indoor air pollution will cause an estimated 9.8 million premature deaths by the year 2030. Gradual and rapid transitions to charcoal would delay 1.0 million and 2.8 million deaths, respectively; similar transitions to petroleum fuels would delay 1.3 million and 3.7 million deaths. Cumulative BAU GHG emissions will be 6.7 billion tons of carbon by 2050, which is 5.6% of Africa's total emissions. Large shifts to the use of fossil fuels would reduce GHG emissions by 1 to 10%. Charcoal-intensive future scenarios using current practices increase emissions by 140 to 190%; the increase can be reduced to 5 to 36% using currently available technologies for sustainable production or potentially reduced even more with investment in technological innovation.



Biomass fuels (wood, charcoal, dung, and agricultural residues) are vital to basic welfare and economic activity in developing nations, especially in sub-Saharan Africa (SSA), where they meet more than 90% of household energy needs in many nations. Combustion of biofuels emits pollutants that currently cause over 1.6 million annual deaths globally (400,000 in SSA) (*1*). Because most of these deaths are among children and women, biomass use is

Black carbon from household fuel use

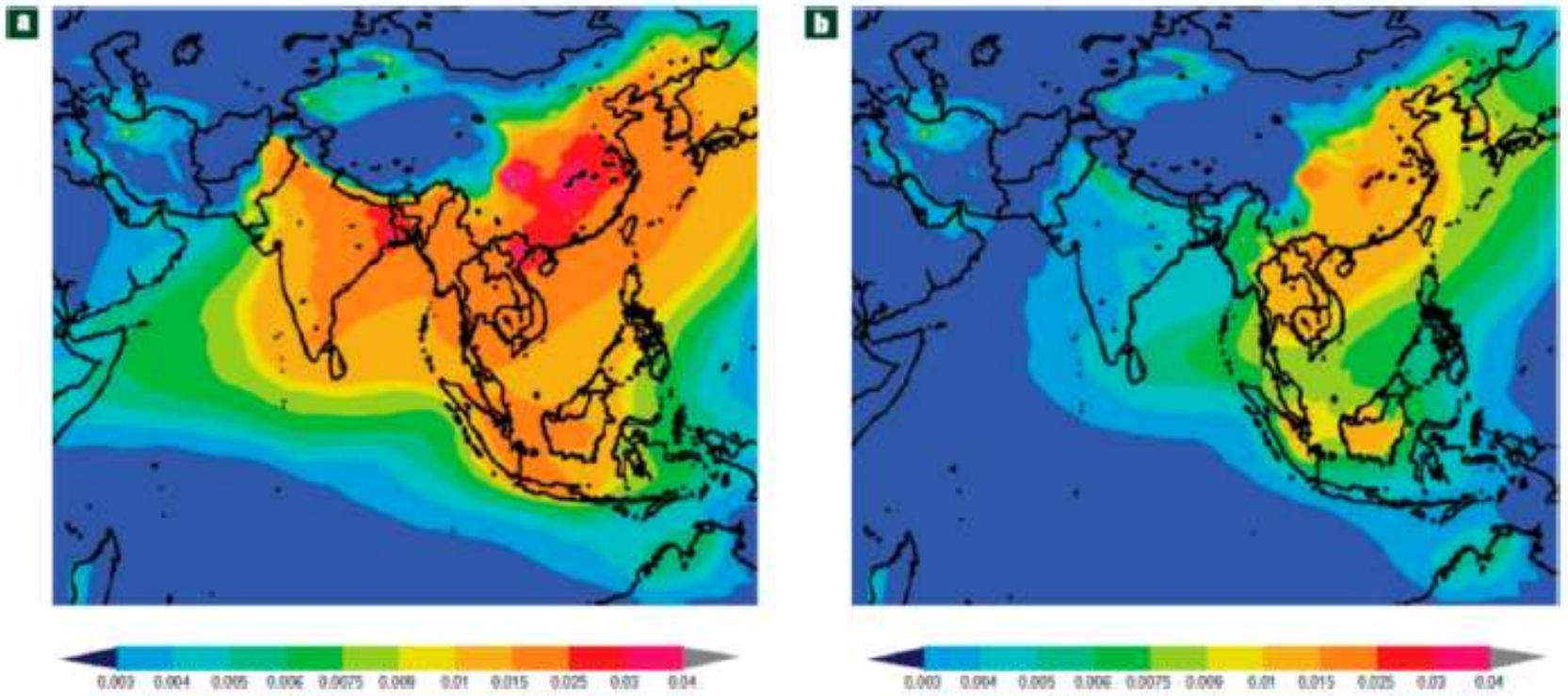
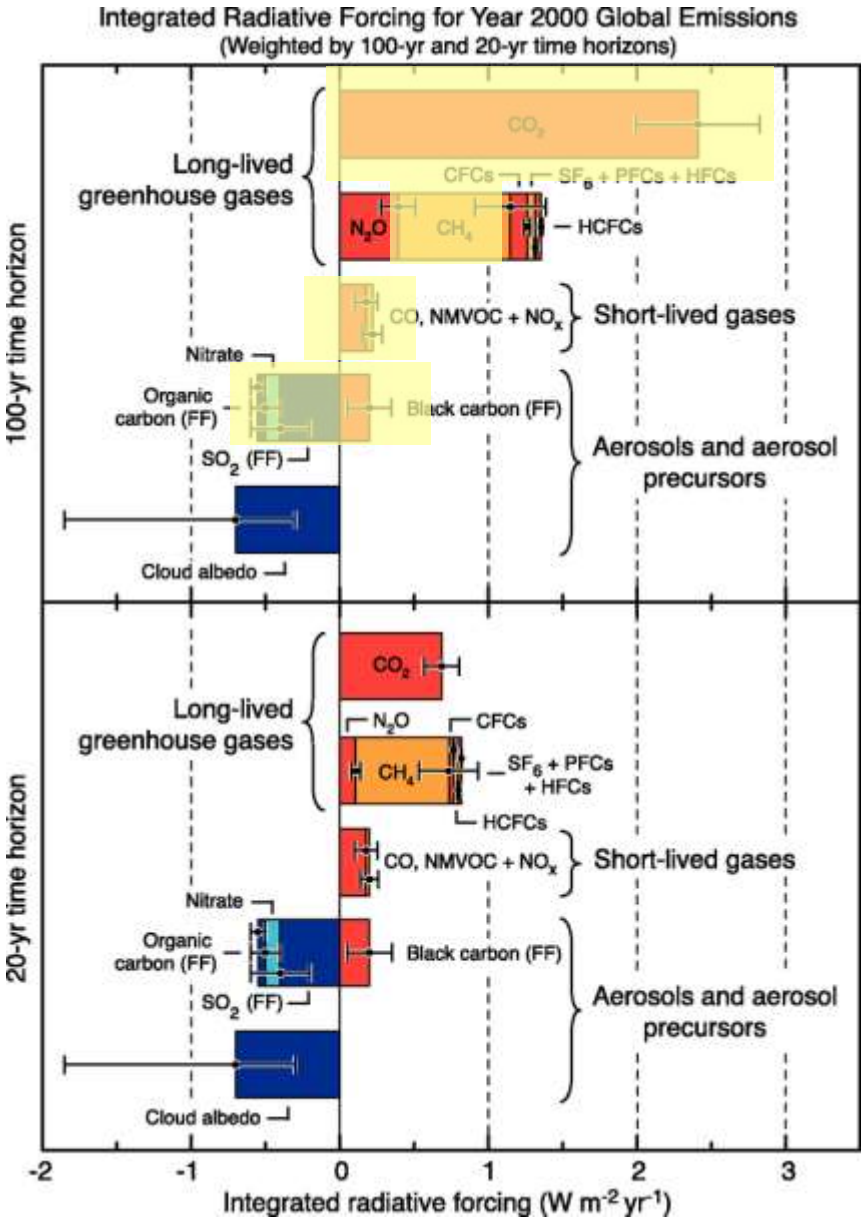


Figure 2. Effect of biofuel cooking on Asian BC loading. (a) Simulated annual mean optical depth of BC aerosols for 2004–2005 using a regional aerosol/chemical/transport model. The values include BC emissions from biofuel cooking (indoor cooking with wood/dung/crop residues), fossil fuels, and biomass burning. (b) Same as for (a), but without biofuel cooking. Reproduced with permission from ref 35. Copyright 2008, Nature Publishing Group.

Sources: Ramanathan & Carmichael, *Nature Geoscience* (2008)

Radiative forcing of GHG gases + aerosols



Source: IPCC AR4 SPM (2007)

Household Emissions in Climate Models

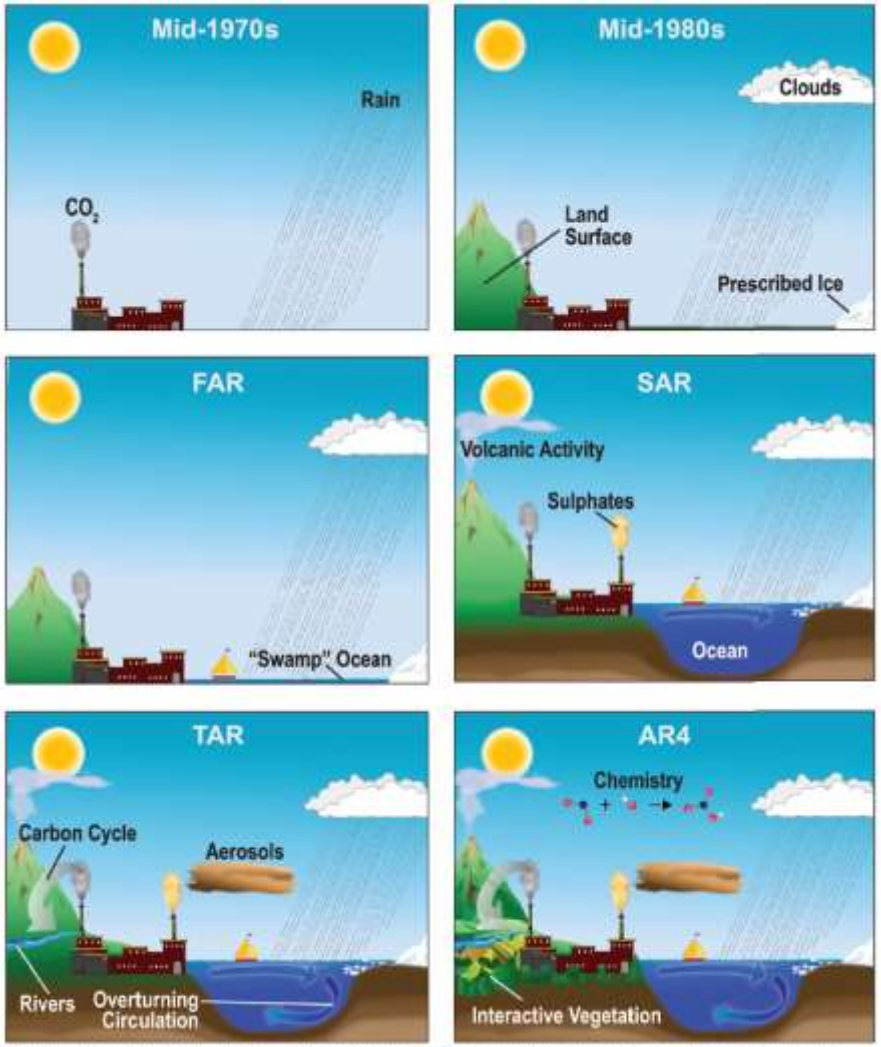
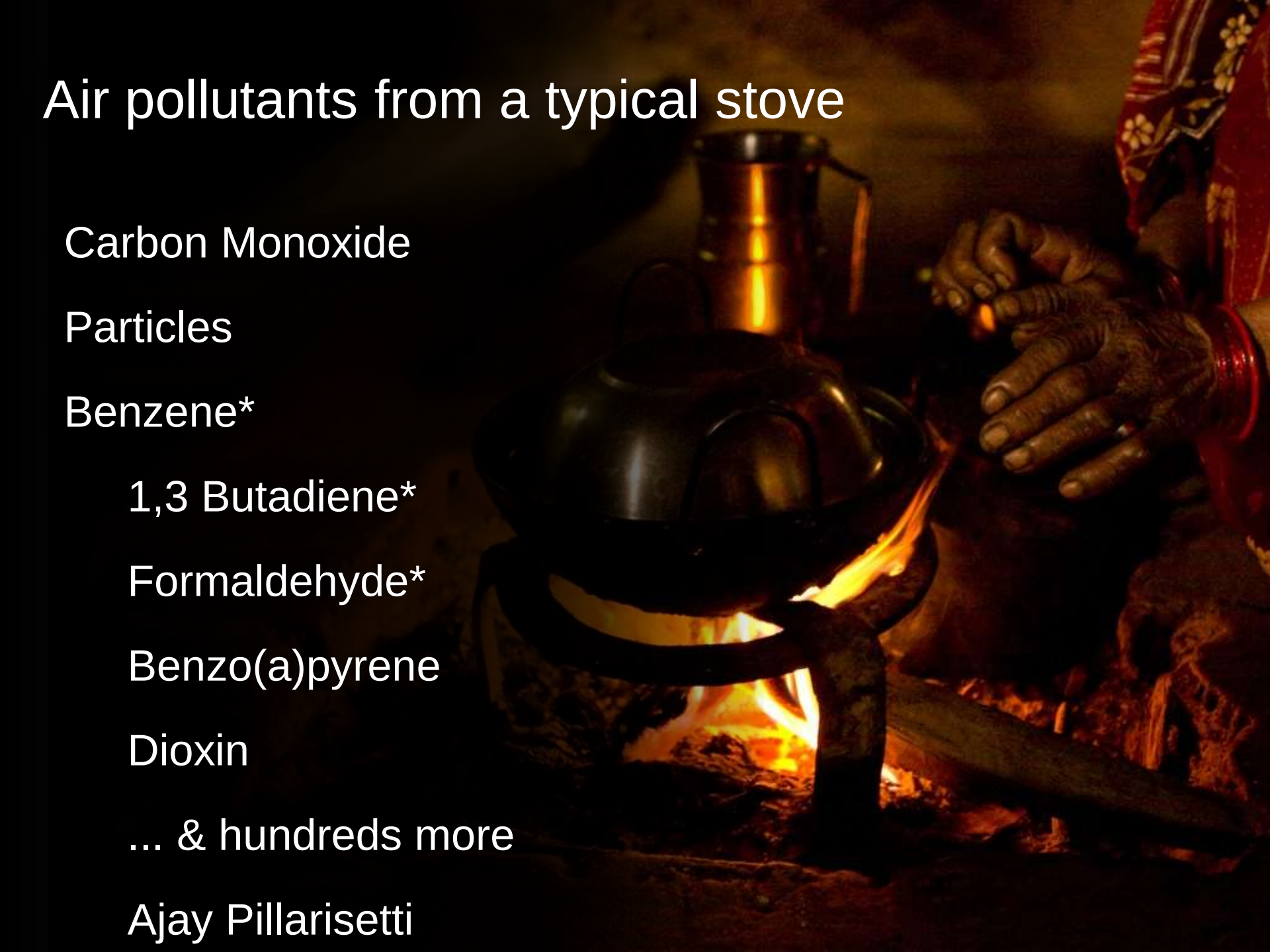


Figure 1.2. The complexity of climate models has increased over the last few decades. The additional physics incorporated in the models are shown pictorially by the different features of the modelled world.

Sources: IPCC AR4 WGI (2007)

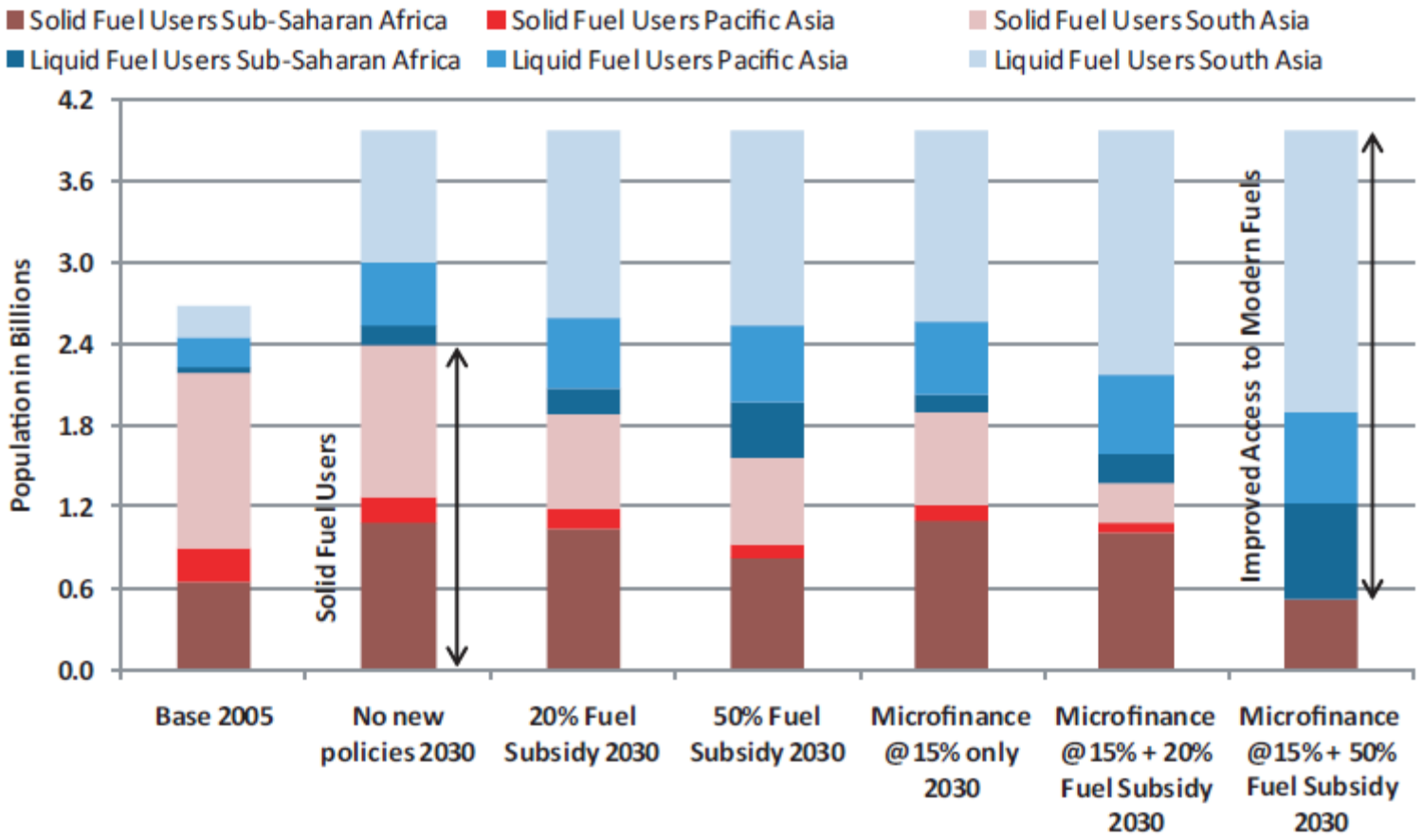
Air pollutants from a typical stove



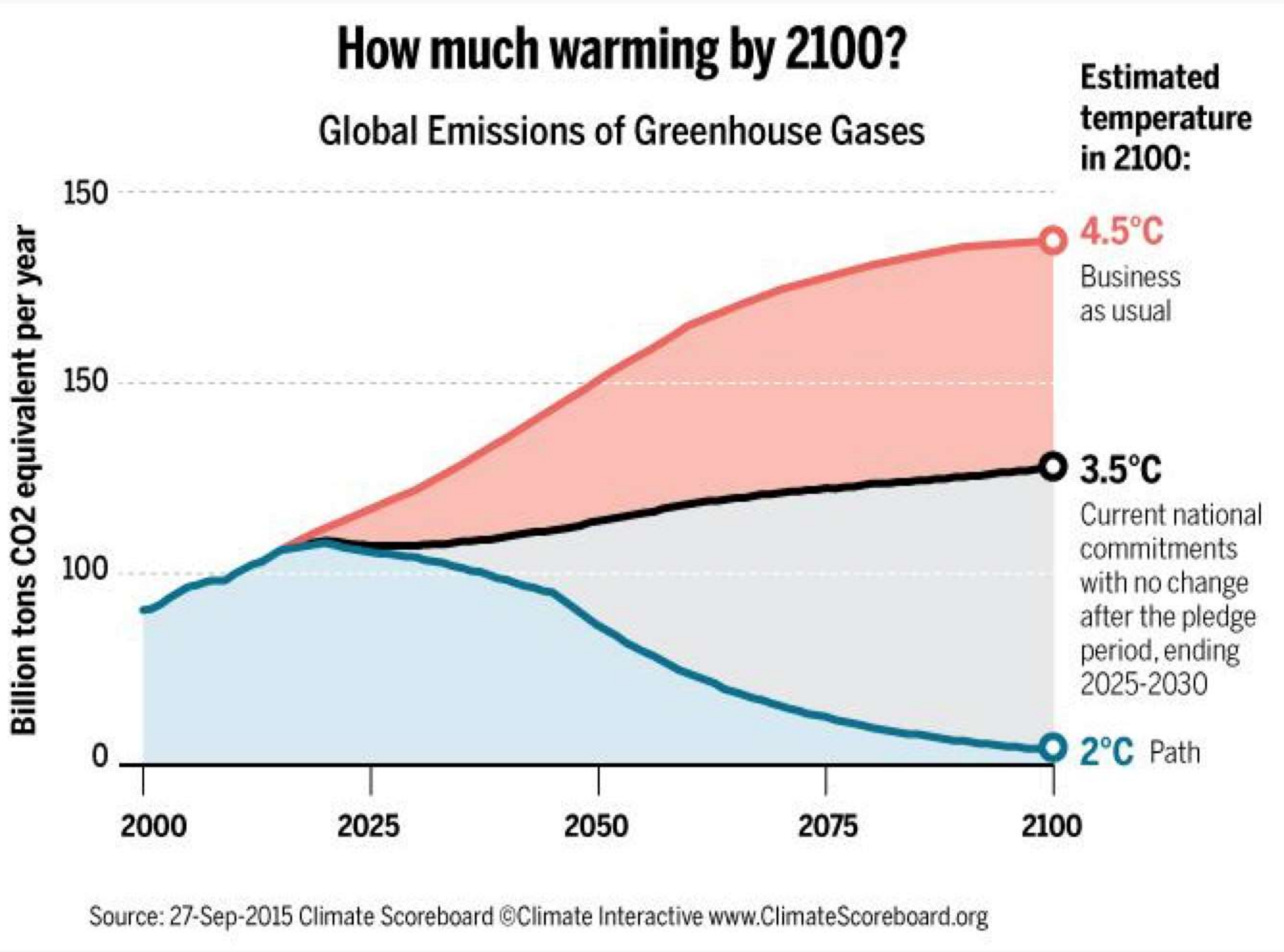
- Carbon Monoxide
- Particles
- Benzene*
  - 1,3 Butadiene*
  - Formaldehyde*
  - Benzo(a)pyrene
  - Dioxin
  - ... & hundreds more

Ajay Pillarisetti

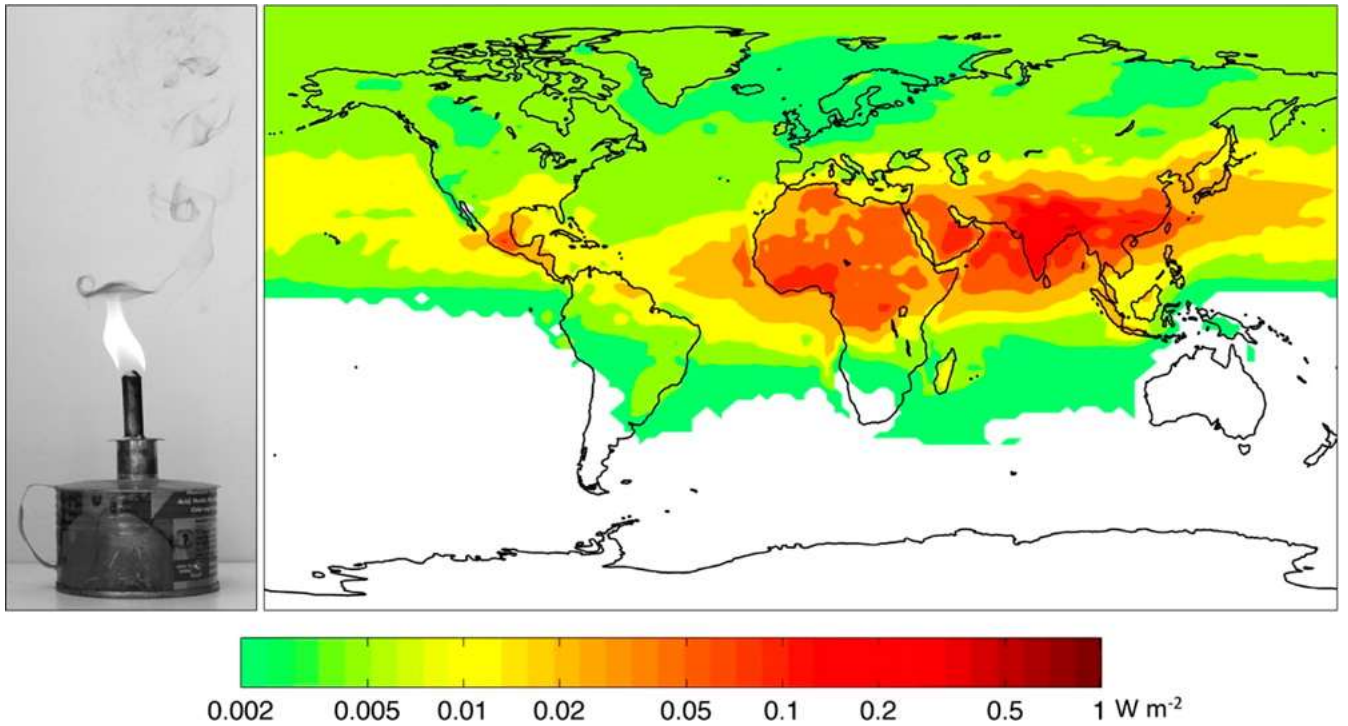
Solid Fuel Users: Clustered



Source: Global Energy Assessment (2012) www.globalenergyassessment.org


How much warming by 2100?
Global Emissions of Greenhouse Gases
Billion tons CO2 equivalent per year
150
150
100
0
2000
2025
2050
2075
2100
Estimated temperature in 2100:
4.5°C
Business as usual
3.5°C
Current national commitments with no change after the pledge period, ending 2025-2030
2°C Path
Source: 27-Sep-2015 Climate Scoreboard ©Climate Interactive www.ClimateScoreboard.org

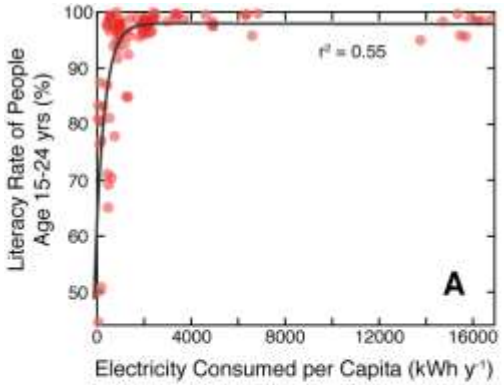
Hot Topic: Kerosene for Lighting

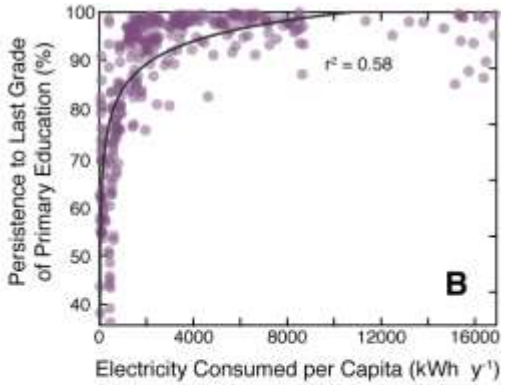


Source: Lam et al., *EST* (2012)

Quantitative Assessments: Energy and Human Development

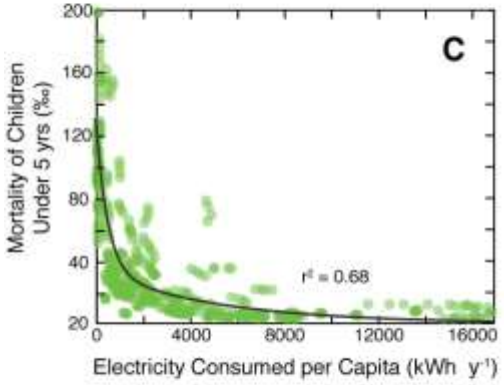
Literacy

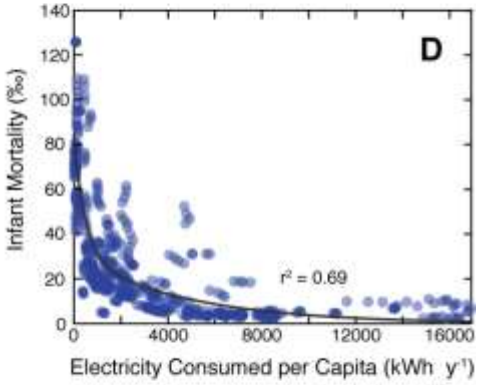




Education

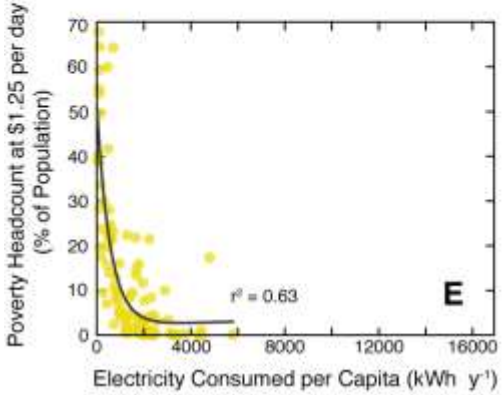
Mortality (Children)

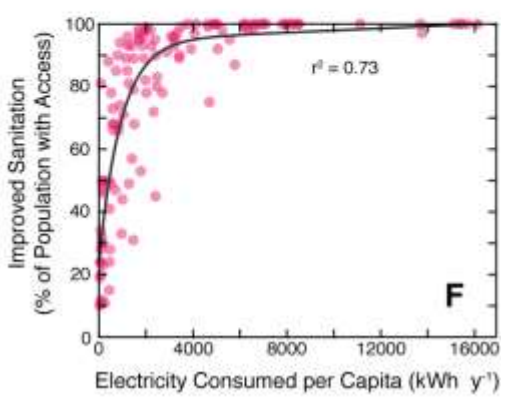




Mortality (Infants)

Poverty

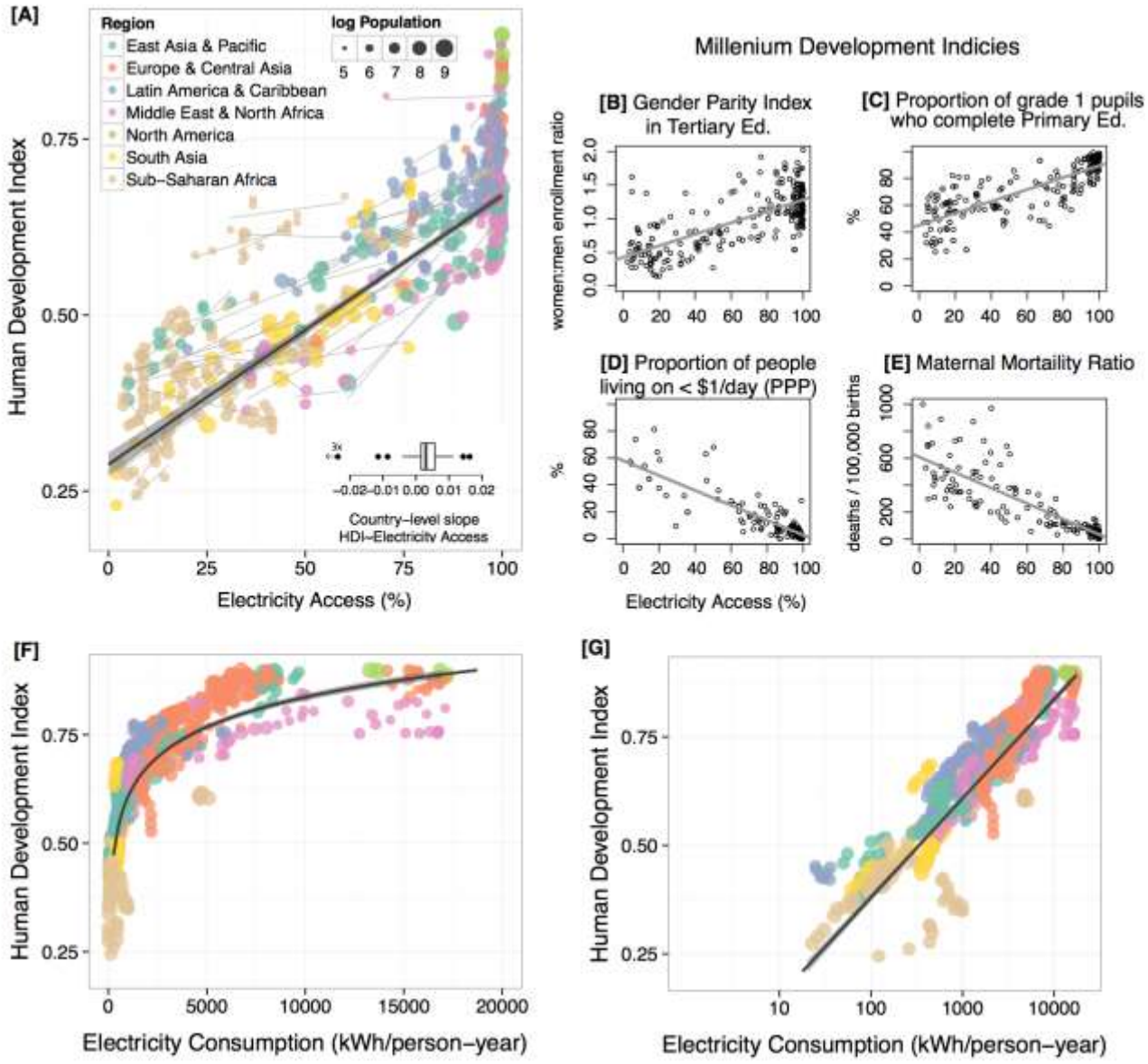




Sanitation

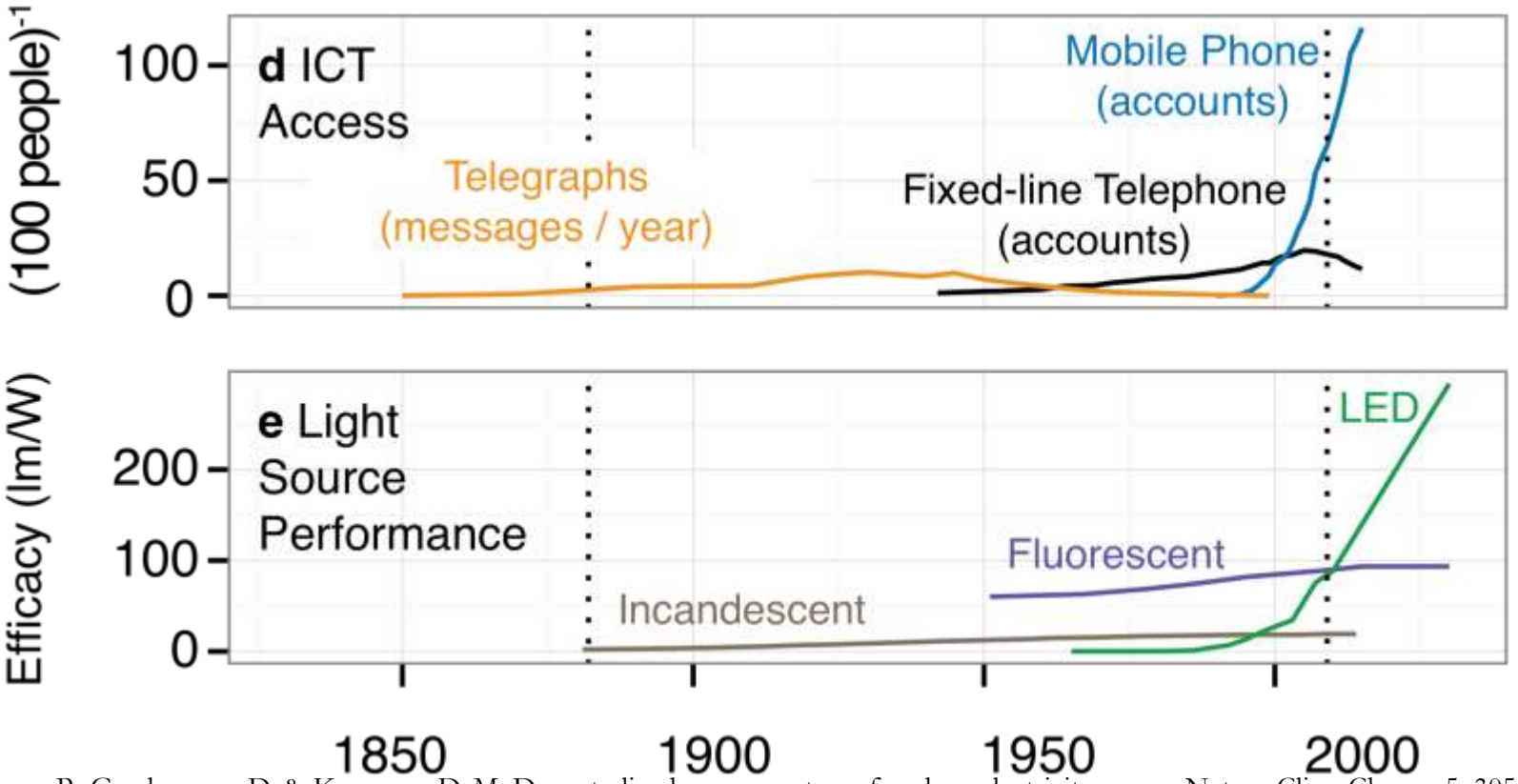
Correlation, not causation, but warrants deeper investigation

Energy Access, Opportunity & Quality of Life

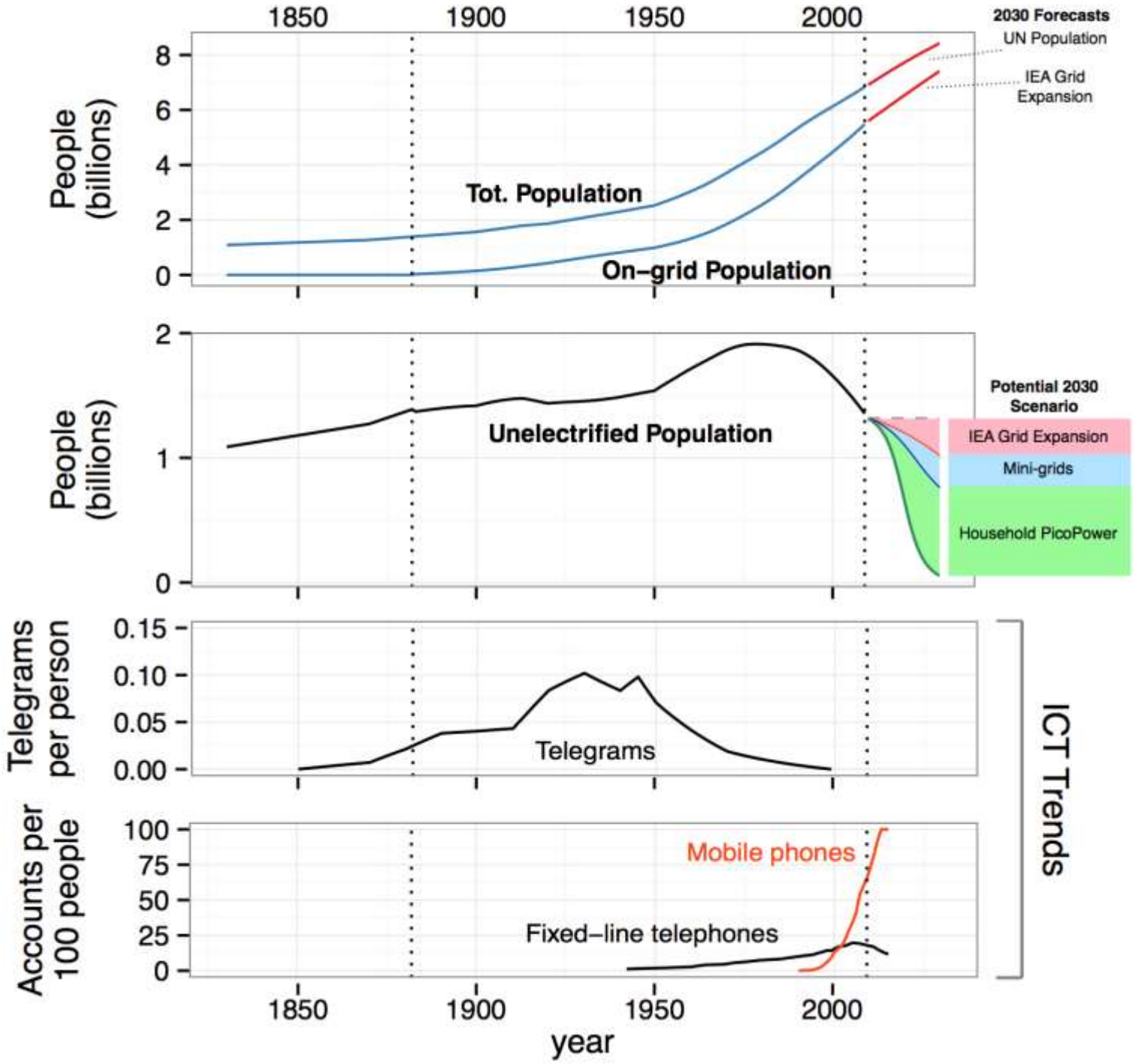


Alstone, Gerhenson, and Kammen, Nature Climate Change, 2015

A unique moment in history:
rapid shifts in ICT, end-use efficiency, and business models



Alstone, P., Gershenson, D. & Kammen, D. M. Decentralized energy systems for clean electricity access. Nature Clim. Change 5, 305–314 (2015).


1850
1900
1950
2000
2030 Forecasts
UN Population
IEA Grid Expansion
People (billions)
Tot. Population
On−grid Population
Unelectrified Population
Potential 2030 Scenario
IEA Grid Expansion
Mini-grids
Household PicoPower
Telegrams per person
Telegrams
Accounts per 100 people
Mobile phones
Fixed−line telephones
ICT Trends
year

Fuel Based Lighting is the Incumbent Technology

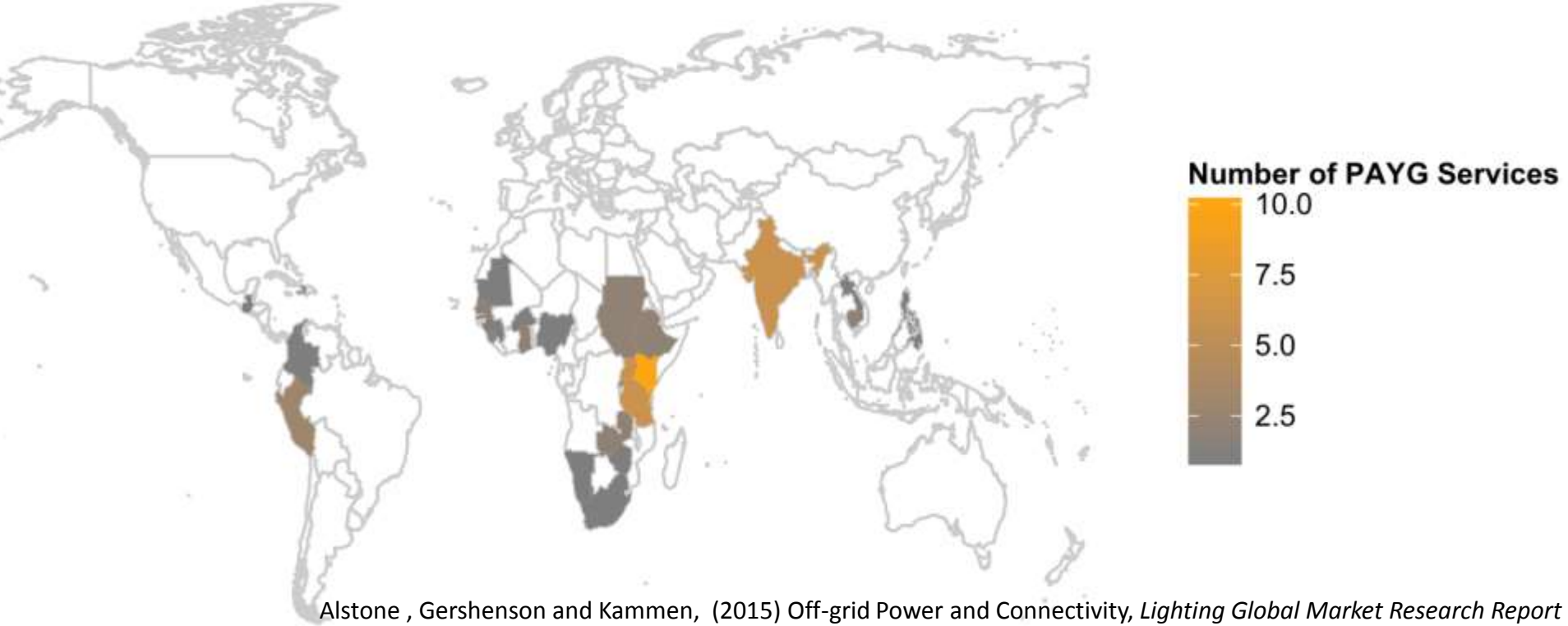
Fuel Based Lighting : Expensive, Unhealthy, and Inefficient

Kerosene for lighting is a $25 billion per year industry globally (source: UNEP, 2013)

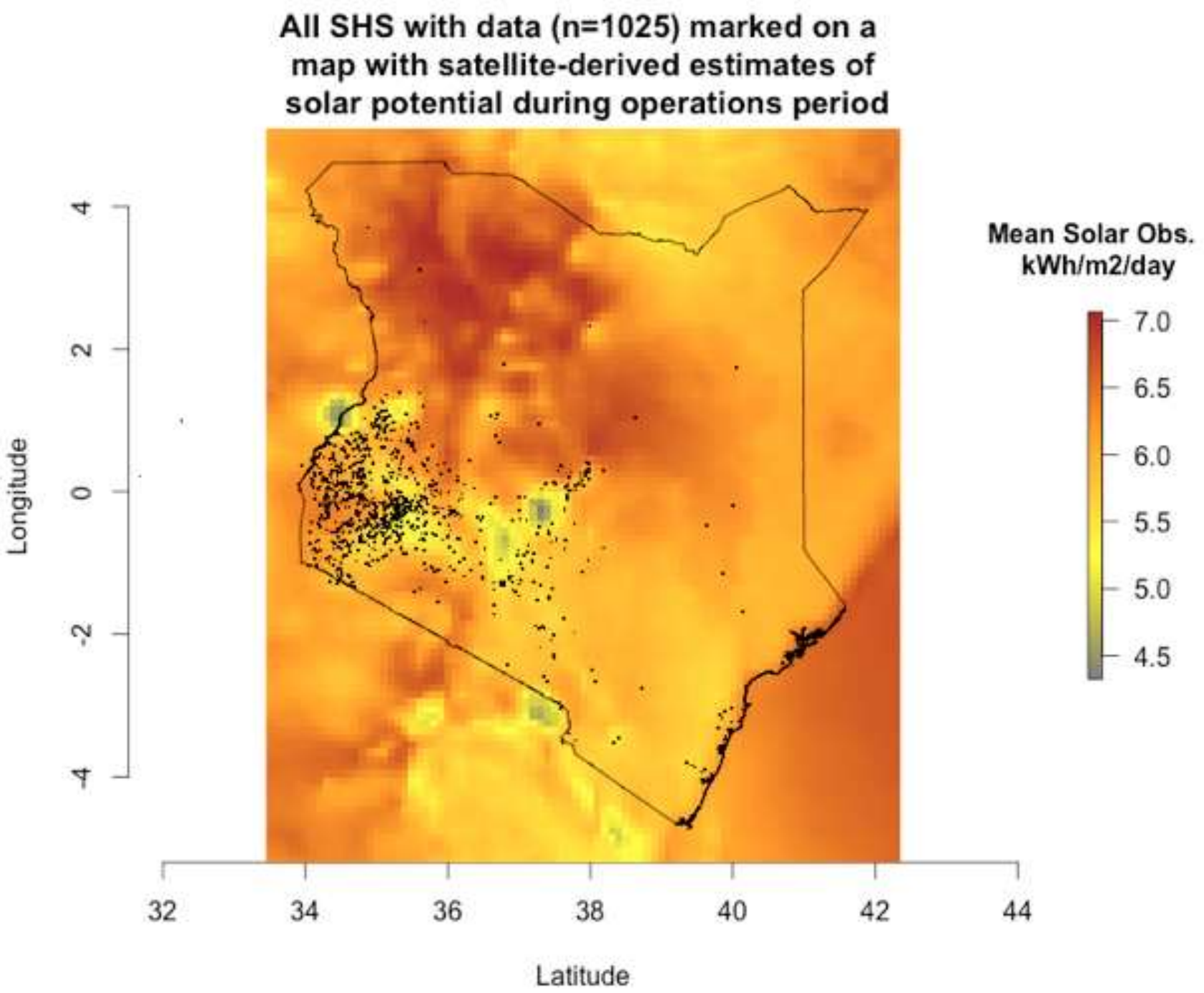
PAYG accelerates access (~2-3x higher uptake)

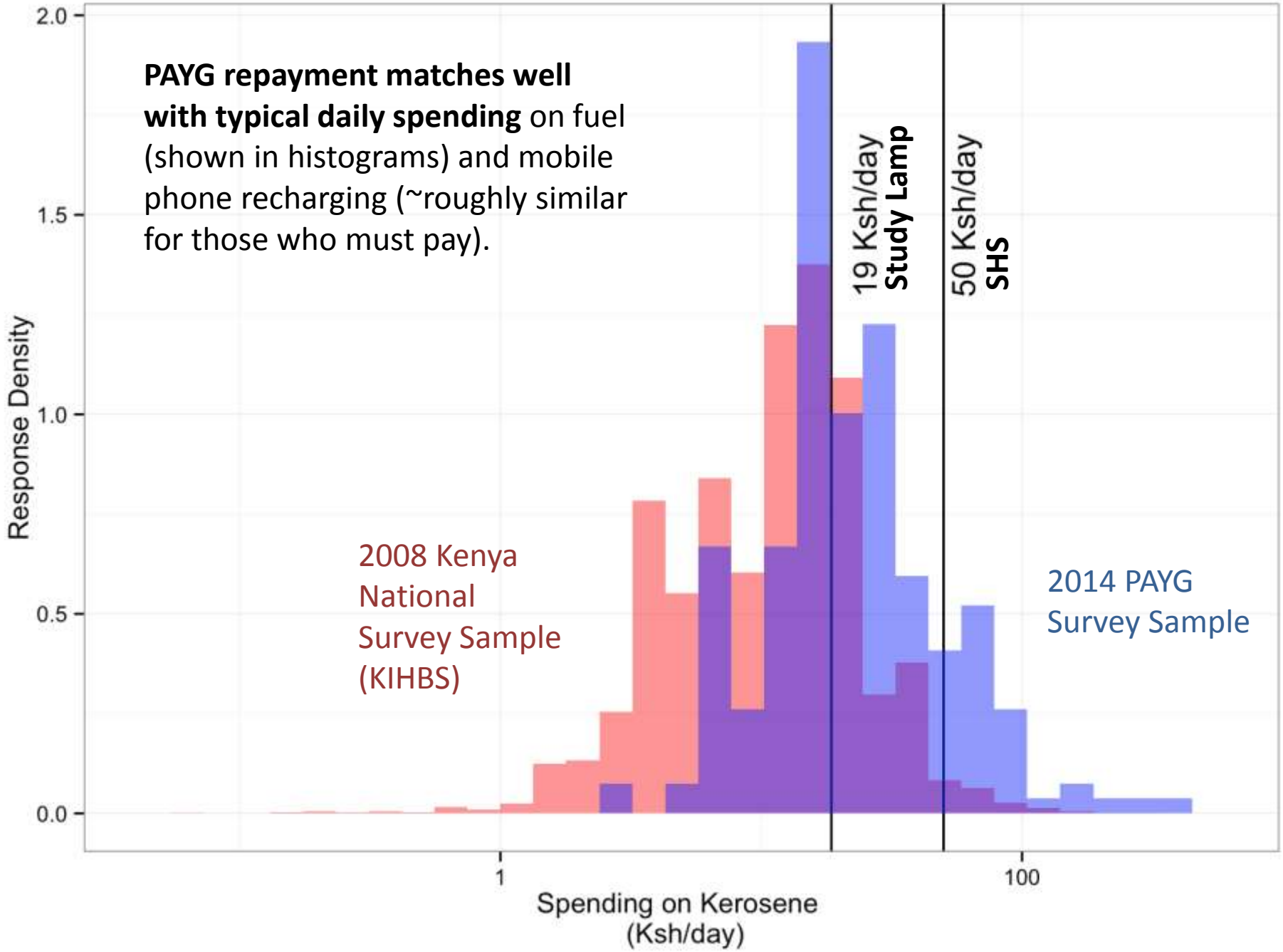
- Providing financing for customers and supply chain players
- Improving trust in off-grid power by spreading risk

Source: http://www.m-kopa.com/products/

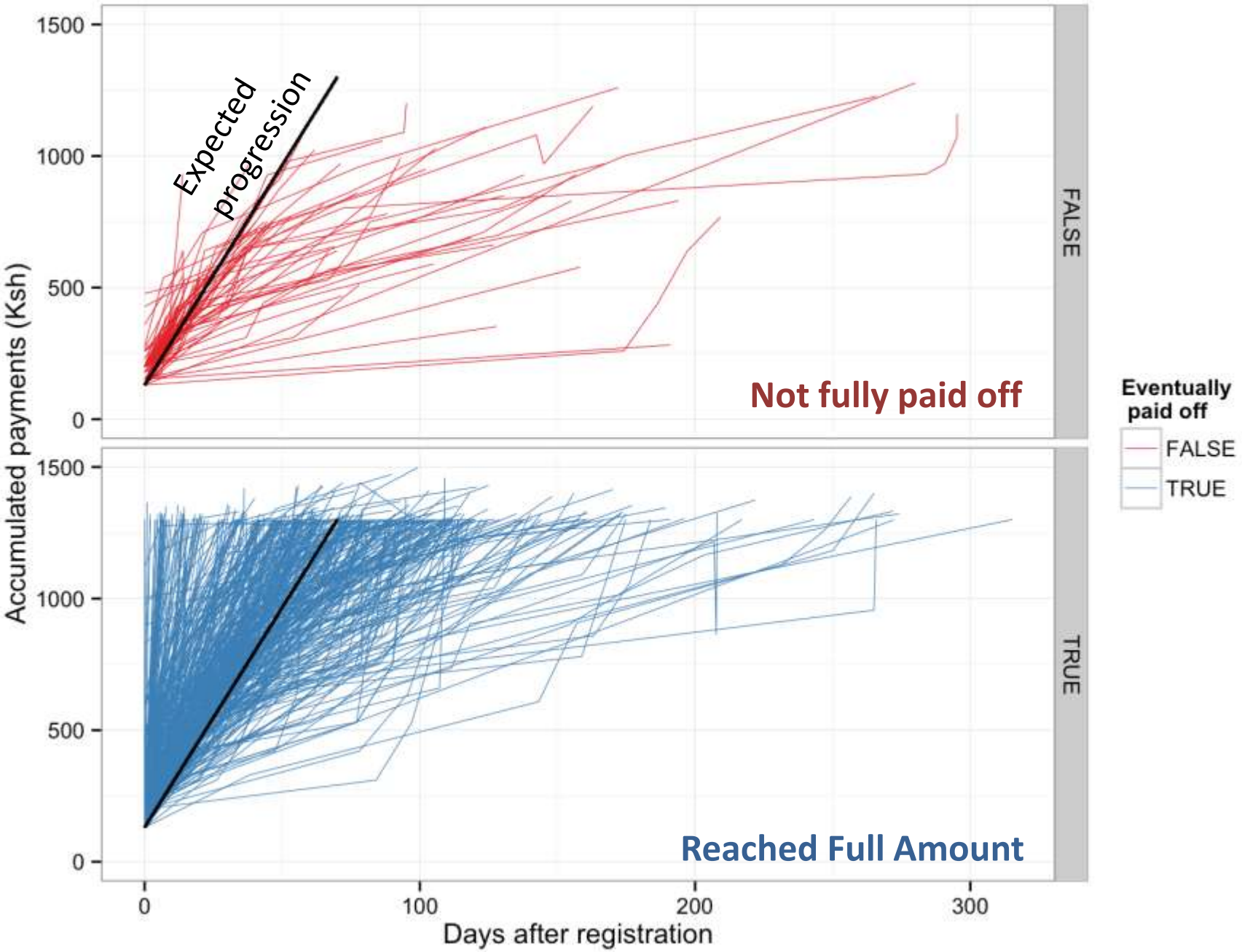


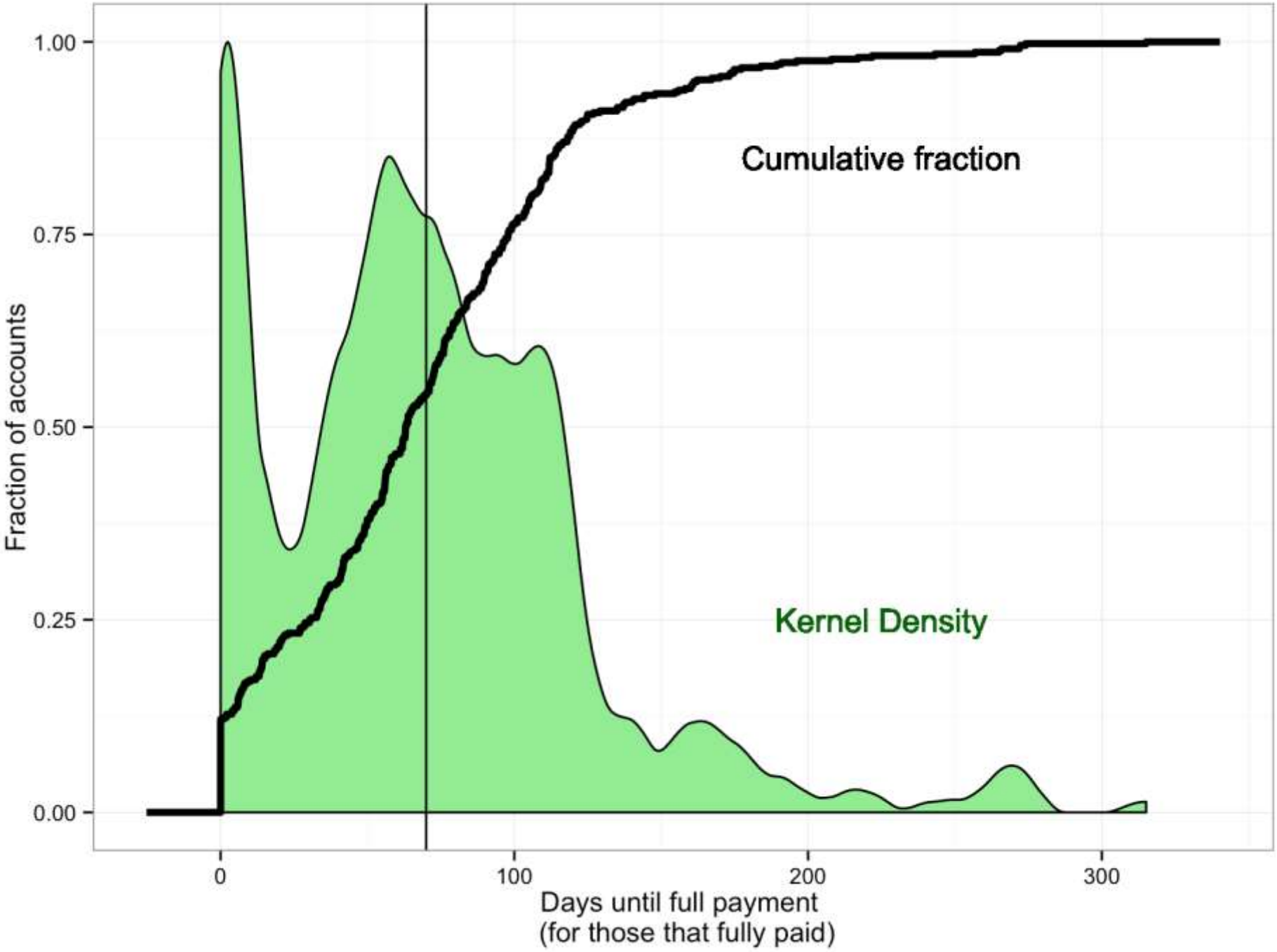
Alstone , Gershenson and Kammen, (2015) Off-grid Power and Connectivity, *Lighting Global Market Research Report*


All SHS with data (n=1025) marked on a map with satellite-derived estimates of solar potential during operations period
Longitude
4
2
0
-2
-4
32
34
36
38
40
42
44
Latitude
Mean Solar Obs. kWh/m2/day
7.0
6.5
6.0
5.5
5.0
4.5

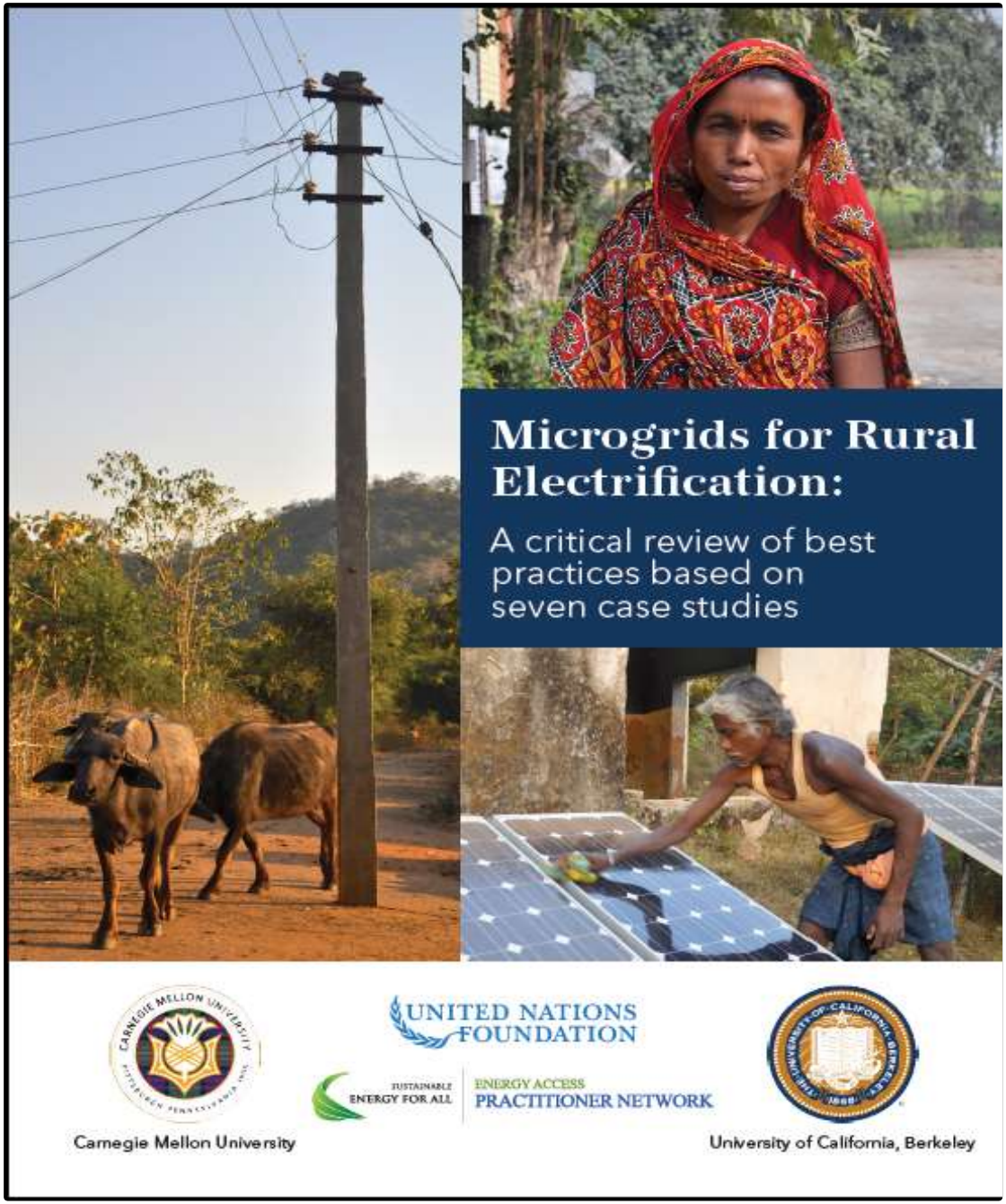

PAYG repayment matches well with typical daily spending on fuel (shown in histograms) and mobile phone recharging (~roughly similar for those who must pay).
19 Ksh/day **Study Lamp**
50 Ksh/day **SHS**
2008 Kenya National Survey Sample (KIHBS)
2014 PAYG Survey Sample
Response Density
2.0
1.5
1.0
0.5
0.0
1
100
Spending on Kerosene (Ksh/day)

Diverse paths to repayment




1.00
0.75
0.50
0.25
0.00
Fraction of accounts
Cumulative fraction
Kernel Density
0
100
200
300
Days until full payment
(for those that fully paid)

Next Wave of Off-grid products



Lessons disseminated to new micro-grid developers

http://energyaccess.org/images/content/files/MicrogridsReportFINAL_high.pdf

The GridShare solution: a smart grid approach to improve service provision on a renewable energy mini-grid in Bhutan

T G Quetchenbach *et al* 2013 *Environ. Res. Lett.* **8** 014018

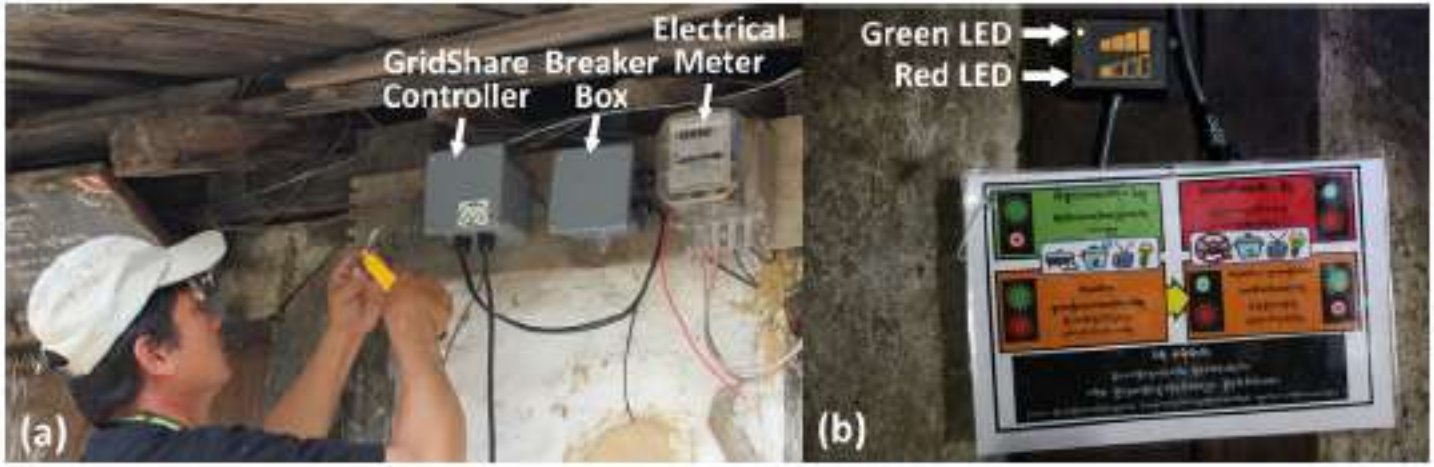


Figure 1. BPC electrician installs a GridShare and breaker box near the electrical meter (a). LED indicator lights with an instructional sign are installed near the rice cooker (b). Borrowing from familiar power-indicating graphics on cell phones, the yellow bars next to the green LED remind users that when the green light is lit, the grid is at 'full power' and any appliances may be used, while the empty bars next to the red LED suggest that the red light means the grid electricity is limited and only low power appliances can be used.

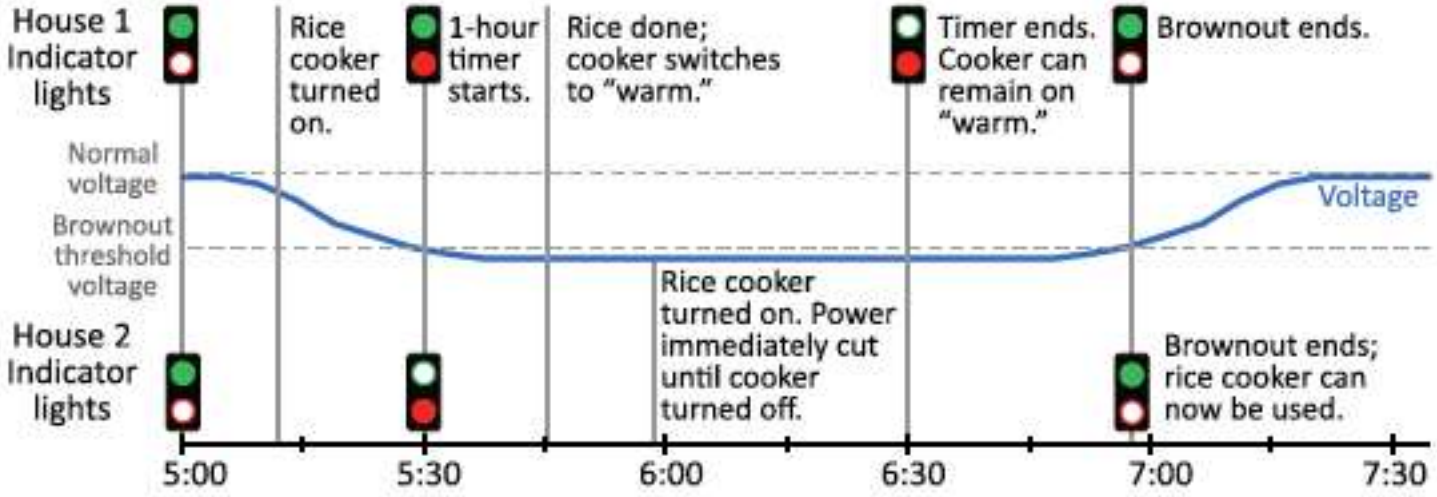
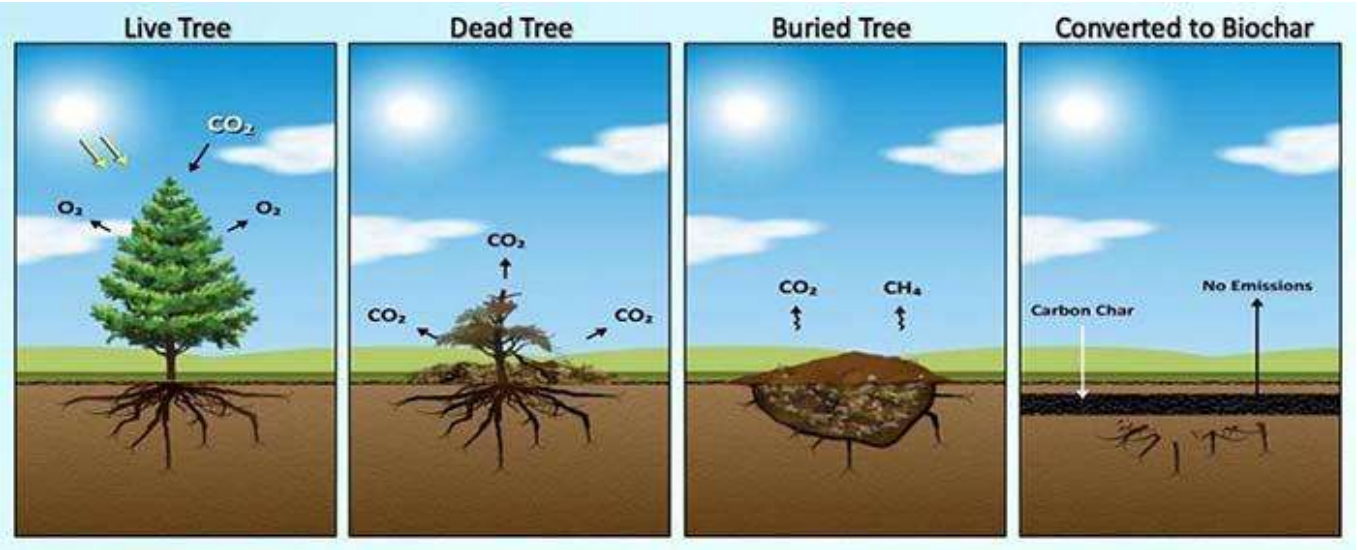


Figure 3. A hypothetical timeline of two homes in a brownout to clarify the indication and enforcement aspects of the GridShare. A rice cooker is a 'large appliance' unless on warming mode, which for a typical 600 W rice cooker requires approximately 40 W.

SOLUTION: Carbon negative energy

When gasification is combined with a biochar co-output, the total "power and products" cycle is carbon negative.



The result is an unlikely combination of wins:

1. Agricultural waste is removed from the field without burning.
2. Clean and renewable energy is delivered at low cost.
3. Plant productivity is increased through application of biochar to soils.
4. GHG is reduced by underground sequestration of carbon as charcoal.
5. GHG is reduced preventing CH4 and N20 releases from

Biochar is an attractive opportunity to draw down GHGs

EXAMPLE PRODUCT: Model history

2008	2009	2010-13	2014	2015-16
Gasifier Experimenter's Kit (GEK) APL is co-founded by Jim Mason	GEK TOTTI (Tower of Total Thermal Integration) Combination with GEK creates the GEK TOTTI	The PP10 & PP20 Power Pallet are born by integrating the GEK TOTTI w/ a Genset & Process Control Unit (PCU)	The v5.01 GEK & Power Cube are launched. CE Certification, Sound Enclosure, CHP, Emissions Control, Grid-Tie	Next steps include the development of the 100 kW Powertainer & Power Pallets w/ rice husk / ag waste capability

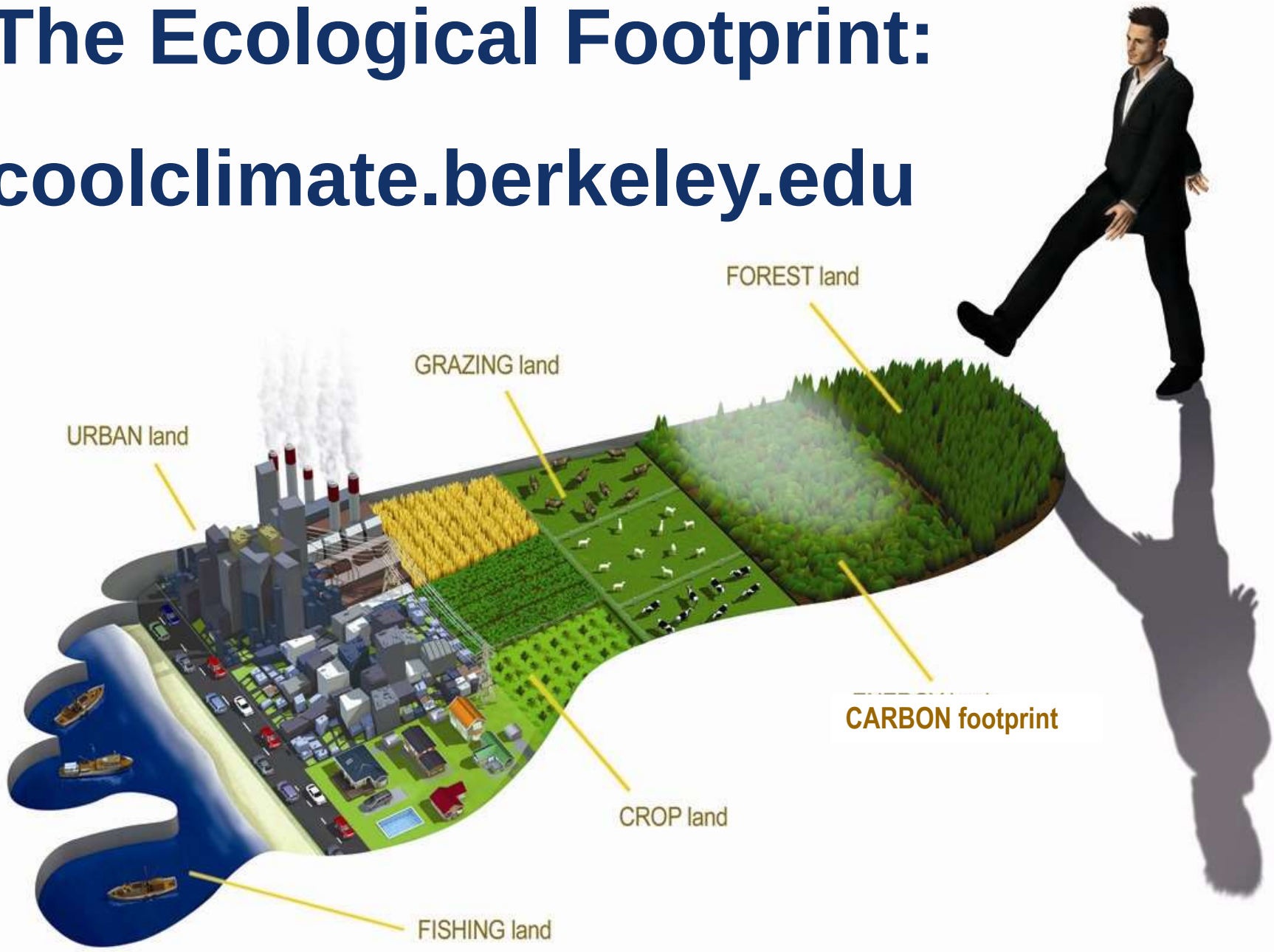
Resources:

Website: http://rael.berkeley.edu

Twitter: @dan_kammen

The Ecological Footprint:

coolclimate.berkeley.edu



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Policy Analysis

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Spatial Distribution of U.S. Household Carbon Footprints Reveals Suburbanization Undermines Greenhouse Gas Benefits of Urban Population Density

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http://coolclimate.berkeley.edu/maps

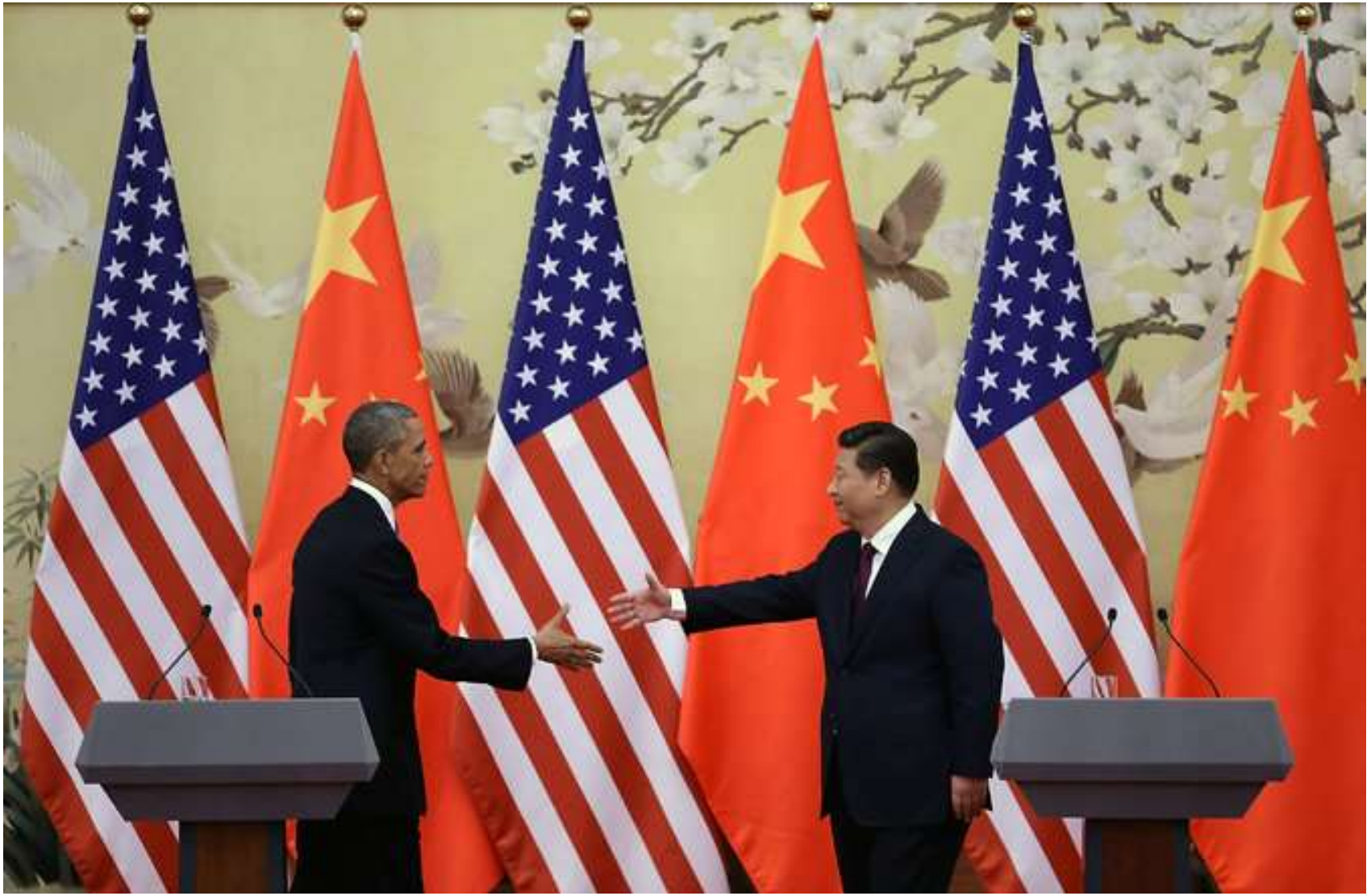
Example proposals for Paris

Transformative opportunities for Research, philanthropy & business development: Stoves and other services

$2+ Trillion US profits are "parked" overseas

☑ Apple	$138B	Cisco	$48B
☑ GE	$110B	☑ Google	$48B
☑ Microsoft	$93B	☑ HP	$38B
☑ IBM	$52B	☑ Pepsi	$34B
☑ Johnson & Johnson	$50B	☑ Oracle	$33B

U.S.-China Joint Announcement on Climate Change



Source: http://www.nytimes.com/2014/11/13/opinion/climate-change-breakthrough-in-beijing.html