Smoke, health, and climate: the unfinished global agenda of poor combustion

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Tyler Laureate 2012
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Jakarta
300-400 thousand years ago, hearths became a regular feature in human habitation.

The skill that many anthropologists use for defining the point when humanity switched from pre-human to human conditions was learning to control fire (e.g., Levi-Strauss 1969).

By this definition, cooking is the oldest task in human history.

How long ago was this?

“On the earliest evidence for habitual use of fire”
Roebroeks and Villa, PNAS, 2011
The three major solid fuels
Households using biomass or coal to cook

Comparative Risk Assessment (CRA) 2011- preliminary, Adair, et al.
World Population Using Solid Fuels

~40% of the world
~2.7 billion people
More than any time in human history
Indonesia Cooking Fuel Situation 2007-2010

- Number of wood users remains large and not much affected by the LPG conversion program and will still become the dominant cooking fuel in the future;
  - 49.4% to 40.1% (26.3 million to 24.5 million)

- LPG users rapidly increase after 2007, in replacement of the kerosene users
  - 10.6% to 45.6% (5.6 million to 27.6 million)

- Kerosene users decrease significantly, accounting for only 11.7% of all households in 2010. : 36.6% to 11.7% (19.5 million to 7.1 million)

Wood Users in 2010: 40% nationally

- Wood still dominates more than half of all provinces in Indonesia and these provinces are mainly distributed in the Islands of Papua, Sulawesi, and Nusa Tenggara.
- Wood continues to be the mostly used cooking fuel in 18 provinces out of 33. These provinces scatter all over the country, stretching from the west to the east.
- East Java, Central Java, and West Java remain the provinces with the largest number of wood-dependent households.
- Rate is increasing in Papua

Source: BPS 2011

YDD, 2012
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$_2$O when it is combined with oxygen (burned)?

Reason: the combustion efficiency is far less than 100%
Energy flows in a well-operating traditional wood-fired cookstove

A Toxic Waste Factory!!

Typical biomass cookstoves convert 6-20% of the fuel carbon to toxic substances

<table>
<thead>
<tr>
<th>Into Pot</th>
<th>In PIC</th>
<th>Waste Heat</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.8 MJ</td>
<td>1.2 MJ</td>
<td>11.3 MJ</td>
</tr>
<tr>
<td>18%</td>
<td>8%</td>
<td>74%</td>
</tr>
</tbody>
</table>

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

Source: Smith, et al., 2000
Toxic Pollutants in Biomass Fuel Smoke from Simple (poor) Combustion

- Small particles, CO, NO₂
- 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*
Health-Damaging Pollutants per Unit Energy Delivered
Ratio of Emissions to LPG

<table>
<thead>
<tr>
<th></th>
<th>Biogas</th>
<th>LPG</th>
<th>Kerosene</th>
<th>Wood</th>
<th>Roots</th>
<th>Crop Residues</th>
<th>Dung</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>0.1</td>
<td>1.0</td>
<td>3</td>
<td>19</td>
<td>22</td>
<td>60</td>
<td>64</td>
</tr>
<tr>
<td>Hydrocarbons</td>
<td>0.3</td>
<td>1.0</td>
<td>4.2</td>
<td>17</td>
<td>18</td>
<td>32</td>
<td>115</td>
</tr>
<tr>
<td>PM</td>
<td>2.5</td>
<td>1.0</td>
<td>1.3</td>
<td>26</td>
<td>30</td>
<td>124</td>
<td>63</td>
</tr>
</tbody>
</table>

Smith, et al., 2005
Perfect Storm for Health Impacts

• Highly polluting activity
• Half of world households
• Several times a day
• Just when people are present
• Most vulnerable (women and young children) most likely to be there
How much Ill-health?
Health-Damaging Air Pollutants From Typical Wood-fired Cookstove.

Typical Health-based Standards

Carbon Monoxide: 150 mg/m³
- 10 mg/m³

Particles: 3.3 mg/m³
- 0.1 mg/m³

Benzene: 0.8 mg/m³
- 0.002 mg/m³

1,3-Butadiene: 0.15 mg/m³
- 0.0003 mg/m³

Formaldehyde: 0.7 mg/m³
- 0.1 mg/m³

Wood: 1.0 kg Per Hour in 15 ACH 40 m³ kitchen

Typical Indoor Concentrations

Best single indicator

IARC Group 1 Carcinogens

Typical Health-based Standards

Carbon Monoxide: 150 mg/m³
- 10 mg/m³

Particles: 3.3 mg/m³
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- 0.1 mg/m³

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Typical Indoor Concentrations

Best single indicator

IARC Group 1 Carcinogens
First person in human history to have her exposure measured doing the oldest task in human history

Emissions, yes, but what about exposures?

Kheda District, Gujarat, 1981
Estimated PM2.5 indoors for all households

Estimated PM2.5 for only solid-fuel-using households

Preliminary results from the Household Air Pollution Comparative Risk Assessment, 2011

~400 ug/m3 mean
WHO guidelines = 10-35 ug/m3
Diseases for which we have epidemiological studies

These three diseases were included in the 2004 Comparative Risk Assessment Managed and published by WHO

First ever comprehensive risk assessment with consistent rules of evidence and common databases
Global Burden of Disease from Top 10 Risk Factors
plus selected other risk factors

Percent of All DALYs

~2 million premature deaths/year

1 million premature deaths/year

Underweight
Unsafe sex
Blood pressure
Tobacco
Alcohol
Unsafe water/sanitation
Child cluster vaccination*
Cholesterol
Lack of Malaria control*
Indoor smoke from solid fuels
Overweight
Occupational hazards (5 kinds)
Road traffic accidents*
Physical inactivity
Lead (Pb) pollution
Urban outdoor air pollution
Climate change

2004 CRA

~2 million premature deaths/year

1 million premature deaths/year
Global Burden of Disease Database and Comparative Risk Assessment
World Health Organization

Being completely updated
For 2011 release

For household air pollution:
New exposure assessment modeling
New outcome estimates based on meta-analyses
ALRI, COPD, Lung Cancer
Low birth weight, cataracts, cardiovascular
Diseases for which we have epidemiological studies - 2011

ALRI/Pneumonia
Low birth weight
Stillbirth

COPD
Lung cancer (coal)
Lung cancer (biomass)
Blindness (cataracts, opacity)
Heart disease
Blood pressure
ST-segment

These additional diseases will be included in the 2011 Comparative Risk Assessment

In addition, using evidence from other exposure sources, heart will be included
There is epi evidence for these other diseases, but considered insufficient to include in the 2011 Comparative Risk Assessment.

- Cognitive Impairment
- Asthma?
- Birth defects
- Tuberculosis
- ALRI
- Other cancers (cervical, NP, upper airway)
- Burns and the health/safety impacts of fuel gathering
Summary risk estimates of lung cancer associated with in-home coal use for heating and cooking by geographic region

<table>
<thead>
<tr>
<th>Study Region</th>
<th>Study Year</th>
<th>Casenum</th>
<th>Contnum</th>
<th>ES (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Sasco(2002)</td>
<td>1996-1998</td>
<td>118</td>
<td>235</td>
<td>0.74 (0.17, 3.14)</td>
</tr>
<tr>
<td>Subtotal</td>
<td></td>
<td></td>
<td></td>
<td>0.74 (0.17, 3.14)</td>
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<tr>
<td>Europe</td>
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<tr>
<td>Lissowska(2005)</td>
<td>1998-2001</td>
<td>2861</td>
<td>3118</td>
<td>1.13 (0.93, 1.38)</td>
</tr>
<tr>
<td>Subtotal</td>
<td></td>
<td></td>
<td></td>
<td>1.13 (0.93, 1.38)</td>
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<tr>
<td>North America</td>
<td></td>
<td></td>
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<tr>
<td>Wu(1985)</td>
<td>1981-1982</td>
<td>220</td>
<td>220</td>
<td>2.30 (0.96, 5.50)</td>
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<tr>
<td>Subtotal</td>
<td></td>
<td></td>
<td></td>
<td>2.30 (0.96, 5.50)</td>
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<tr>
<td>India</td>
<td></td>
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<tr>
<td>Gupta(2001)</td>
<td>1995-1997</td>
<td>265</td>
<td>525</td>
<td>1.52 (0.33, 6.98)</td>
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<tr>
<td>Subtotal</td>
<td></td>
<td></td>
<td></td>
<td>3.76 (1.64, 8.63)</td>
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<tr>
<td>Mainland China and Taiwan</td>
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<tr>
<td>Wu-Williams(1990)</td>
<td>1985-1987</td>
<td>965</td>
<td>959</td>
<td>1.30 (0.99, 1.70)</td>
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<tr>
<td>Chengyu(1992)</td>
<td>1990-1991</td>
<td>135</td>
<td>135</td>
<td>1.59 (1.22, 2.07)</td>
</tr>
<tr>
<td>Ger(1993)</td>
<td>1990-1991</td>
<td>131</td>
<td>524</td>
<td>1.44 (0.44, 4.69)</td>
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<tr>
<td>Li(1993)</td>
<td>1986-1992</td>
<td>161</td>
<td>161</td>
<td>2.08 (0.85, 5.08)</td>
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<tr>
<td>Lin(1996)</td>
<td>1985-1990</td>
<td>122</td>
<td>122</td>
<td>3.24 (1.05, 9.94)</td>
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<td>Dai(1996)</td>
<td>1992-1993</td>
<td>120</td>
<td>120</td>
<td>4.70 (1.29, 17.18)</td>
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<tr>
<td>Lu(1996)</td>
<td>1990-1991</td>
<td>102</td>
<td>306</td>
<td>6.00 (5.07, 7.10)</td>
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<tr>
<td>Ko(1997)</td>
<td>1992-1993</td>
<td>117</td>
<td>117</td>
<td>1.30 (0.29, 5.80)</td>
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<tr>
<td>Huang(1999)</td>
<td>1993-1996</td>
<td>122</td>
<td>244</td>
<td>1.92 (1.40, 2.62)</td>
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<tr>
<td>Wu(1999)</td>
<td>1997</td>
<td>258</td>
<td>258</td>
<td>1.58 (0.89, 2.80)</td>
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<tr>
<td>Lee(2001)</td>
<td>1993-1999</td>
<td>527</td>
<td>805</td>
<td>2.10 (1.19, 3.70)</td>
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<tr>
<td>Kleinerman(2002)</td>
<td>1994-1998</td>
<td>832</td>
<td>1724</td>
<td>1.29 (1.03, 1.61)</td>
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<tr>
<td>Liang(2004)</td>
<td>2001-2002</td>
<td>152</td>
<td>152</td>
<td>2.02 (1.20, 3.39)</td>
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<tr>
<td>Galeone(2008)</td>
<td>1987-1990</td>
<td>218</td>
<td>436</td>
<td>2.19 (1.08, 4.46)</td>
</tr>
<tr>
<td>Subtotal</td>
<td></td>
<td></td>
<td></td>
<td>2.28 (1.66, 3.13)</td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td></td>
<td></td>
<td>2.16 (1.62, 2.90)</td>
</tr>
<tr>
<td>Study design</td>
<td>N*</td>
<td>OR</td>
<td>95% CI</td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>----</td>
<td>-----</td>
<td>------------</td>
<td></td>
</tr>
<tr>
<td>Intervention</td>
<td>2</td>
<td>1.28</td>
<td>1.06, 1.54</td>
<td></td>
</tr>
<tr>
<td>Cohort</td>
<td>7</td>
<td>2.12</td>
<td>1.06, 4.25</td>
<td></td>
</tr>
<tr>
<td>Case-control</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cross-sectional</td>
<td>3</td>
<td>1.49</td>
<td>1.21, 1.85</td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>26</td>
<td>1.78</td>
<td>1.45, 2.18</td>
<td></td>
</tr>
</tbody>
</table>

Pneumonia – the biggest single cause of child death in the world

Effect of reduction in household air pollution on childhood pneumonia in Guatemala (RESPIRE): a randomised controlled trial

Kirk R Smith, John P McCracken, Martin W Weber, Alan Hubbard, Alisa Jenny, Lisa M Thompson, John Balmes, Anaite Diaz, Byron Arana, Nigel Bruce
First Randomized Trial
In Air Pollution History*

After a worldwide search, chose a site in the Guatemalan Highlands

* In normal populations
RESPIRE – Randomized trial (n=518)
Impact on pneumonia up to 18 months of age

Traditional open 3-stone fire:
kitchen 48-hour PM$_{2.5}$ levels of
600 - 1200 μg/m$^3$

Chimney wood stove, locally made
and popular with households
Overview of RESPIRE study design

- 530 eligible households: open fire, woman pregnant or child less than 4 months
- Baseline survey and exposure assessment

Randomize

- Keep open fire
- Plancha

Follow up till aged 18 months
- Surveillance for ALRI, diarrhoea, &c
- Detailed exposure monitoring

Compare incidence and exposure in 2 groups
- Plancha offered to ‘controls’

Year 1
- 5500 Households total

Years
- 1-3
- 3-4
MD-ALRI Hypoxaemic

MD-Xray-confirmed Hypoxaemic
<table>
<thead>
<tr>
<th>Exposure reduction</th>
<th>Overall MD-pneumonia</th>
<th>Severe (hypoxic) MD-pneumonia</th>
<th>CXR pneumonia</th>
<th>Severe (hypoxic) CXR pneumonia</th>
</tr>
</thead>
<tbody>
<tr>
<td>25%</td>
<td>0.92 (0.86, 0.99)</td>
<td>0.88 (0.80, 0.97)</td>
<td>0.84 (0.74, 0.96)</td>
<td>0.79 (0.69, 0.95)</td>
</tr>
<tr>
<td>50%</td>
<td>0.82 (0.70, 0.98)</td>
<td>0.73 (0.59, 0.92)</td>
<td>0.66 (0.49, 0.91)</td>
<td>0.56 (0.40, 0.88)</td>
</tr>
<tr>
<td>75%</td>
<td>0.67 (0.50, 0.96)</td>
<td>0.53 (0.35, 0.84)</td>
<td>0.44 (0.24, 0.83)</td>
<td>0.31 (0.16, 0.78)</td>
</tr>
<tr>
<td>90%</td>
<td>0.51 (0.31, 0.93)</td>
<td>0.35 (0.17, 0.76)</td>
<td>0.26 (0.09, 0.74)</td>
<td>0.15 (0.05, 0.67)</td>
</tr>
</tbody>
</table>

RESPIRE - Guatemala
Effect of Chimney Stove On Kitchen CO Levels

Guatemala RCT: Kitchen Concentrations

Smith, et al, 2010
Effect of Chimney Stove On Infant Exposures - 2x less

Smith, et al, 2010

1888 48-h measurements
Kitchens down by 10x, but children exposure down by only 2x, because

--Time-activity: the kids do not spend their entire day in the kitchen
--Household (or “neighborhood”) pollution: a chimney does not reduce smoke, but just shifts it outside into the household environment, where the difference between intervention and control households was less
--No significant difference in bedrooms
You have heard of secondhand smoke – from tobacco burning

But there is another kind – from cookfires
20-month average ground-level PM2.5 from satellite data

Large areas of rural India and China have high ambient air pollution – much from household fuel
NASA INTEX_B Database

Percent PM\textsubscript{2.5} emissions from households

Chafe, 2010; data from NASA INTEX_B 2006
Combustion Particles

The Generalized Exposure Response
(GER)
Heart Disease and Combustion Particle Doses

From “Mind the Gap,” Smith/Peel, 2010 and Pope et al., 2009
Intervention to Lower Household Wood Smoke Exposure in Guatemala Reduces ST-Segment Depression on Electrocardiograms

John McCracken,¹,² Kirk R. Smith,² Peter Stone,³ Anaité Díaz,⁴ Byron Arana,⁴ and Joel Schwartz¹

¹Department of Environmental Health, Harvard School of Public Health, Boston, Massachusetts, USA; ²Environmental Sciences Division, University of California, Berkeley, California, USA; ³Brigham and Women’s Hospital, Boston, Massachusetts, USA; ⁴Center for Health Studies, Universidad del Valle, Guatemala City, Guatemala

Table 3. Odds ratios (ORs) for nonspecific ST-segment depression (30-min average ≤ −1 mm, regardless of slope) associated with chimney-stove intervention compared with open fire from two study designs: between-groups and before-and-after analyses.

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Crude OR (95% CI)</th>
<th>p-Value</th>
<th>Adjusted OR (95% CI)</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between-groups</td>
<td>0.34 (0.15, 0.81)</td>
<td>0.015</td>
<td>0.26 (0.08, 0.90)</td>
<td>0.033</td>
</tr>
<tr>
<td>Before-and-after (only control group)</td>
<td>0.41 (0.24, 0.70)</td>
<td>0.001</td>
<td>0.28 (0.12, 0.63)</td>
<td>0.002</td>
</tr>
</tbody>
</table>

*Adjusted for age (quadratic), BMI (quadratic), asset index category, ever smoking, SHS, owning a wood-fired sauna, recent use of wood-fired sauna, and time of day (natural spline with 5 degrees of freedom).
Table 2. Adjusted relative risk estimates for various increments of exposure from cigarette smoking (versus never smokers), second hand cigarette smoke, and ambient air pollution from the present analysis and selected comparison studies.

<table>
<thead>
<tr>
<th>Source of risk estimate</th>
<th>Increments of Exposure</th>
<th>Lung Cancer (95% CI)</th>
<th>IHD (95% CI)</th>
<th>CVD (95% CI)</th>
<th>CPD (95% CI)</th>
<th>Estimated Daily Dose PM$_{2.5}$ (µg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACS-present analysis</td>
<td>≤3 (1.5) cigs/day</td>
<td>10.44 (7.30-14.94)</td>
<td>1.61 (1.27-2.03)</td>
<td>1.58 (1.32-1.89)</td>
<td>1.72 (1.46-2.03)</td>
<td>18</td>
</tr>
<tr>
<td>ACS-present analysis</td>
<td>4-7 (5.5) cigs/day</td>
<td>8.03 (5.89-10.96)</td>
<td>1.64 (1.37-1.96)</td>
<td>1.73 (1.51-1.97)</td>
<td>1.84 (1.63-2.08)</td>
<td>66</td>
</tr>
<tr>
<td>ACS-present analysis</td>
<td>8-12 (10) cigs/day</td>
<td>11.63 (9.51-14.24)</td>
<td>2.07 (1.84-2.31)</td>
<td>2.01 (1.84-2.19)</td>
<td>2.10 (1.94-2.28)</td>
<td>120</td>
</tr>
<tr>
<td>ACS-present analysis</td>
<td>13-17 (15) cigs/day</td>
<td>13.93 (11.04-17.58)</td>
<td>2.18 (1.89-2.52)</td>
<td>1.99 (1.77-2.23)</td>
<td>2.08 (1.87-2.32)</td>
<td>180</td>
</tr>
<tr>
<td>ACS-present analysis</td>
<td>18-22 (20) cigs/day</td>
<td>19.88 (17.14-23.06)</td>
<td>2.36 (2.19-2.55)</td>
<td>2.42 (2.28-2.56)</td>
<td>2.52 (2.39-2.66)</td>
<td>240</td>
</tr>
<tr>
<td>ACS-present analysis</td>
<td>23-27 (25) cigs/day</td>
<td>23.82 (18.80-30.18)</td>
<td>2.29 (1.91-2.75)</td>
<td>2.33 (2.02-2.69)</td>
<td>2.33 (2.03-2.67)</td>
<td>300</td>
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<tr>
<td>ACS-present analysis</td>
<td>28-32 (30) cigs/day</td>
<td>26.82 (22.54-31.91)</td>
<td>2.22 (1.97-2.49)</td>
<td>2.17 (1.98-2.38)</td>
<td>2.39 (2.19-2.60)</td>
<td>360</td>
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<tr>
<td>ACS-present analysis</td>
<td>33-37 (35) cigs/day</td>
<td>26.72 (22.58-38.44)</td>
<td>2.38 (1.91-2.75)</td>
<td>2.52 (1.98-3.19)</td>
<td>2.83 (2.28-3.52)</td>
<td>420</td>
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<tr>
<td>ACS-present analysis</td>
<td>38-42 (40) cigs/day</td>
<td>30.63 (25.79-36.38)</td>
<td>2.30 (2.05-2.59)</td>
<td>2.37 (2.16-2.59)</td>
<td>2.61 (2.40-2.84)</td>
<td>480</td>
</tr>
<tr>
<td>ACS-present analysis</td>
<td>43+ (45) cigs/day</td>
<td>39.16 (31.13-49.26)</td>
<td>2.00 (1.62-2.48)</td>
<td>2.17 (1.84-2.56)</td>
<td>2.37 (2.04-2.76)</td>
<td>540</td>
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<tr>
<td>ACS-air pol. original</td>
<td>24.5 µg/m$^3$ ambient PM$_{2.5}$</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>1.31 (1.17-1.46)</td>
<td>0.44</td>
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<td>ACS-air pol. extend</td>
<td>10 µg/m$^3$ ambient PM$_{2.5}$</td>
<td>1.14 (1.04-1.23)</td>
<td>1.18 (1.14-1.23)</td>
<td>1.12 (1.08-1.15)</td>
<td>1.09 (1.03-1.16)</td>
<td>0.18</td>
</tr>
<tr>
<td>HSC-air pol. original</td>
<td>18.6 µg/m$^3$ ambient PM$_{2.5}$</td>
<td>1.21 (0.92-1.69)</td>
<td>-----</td>
<td>-----</td>
<td>1.28 (1.13-1.44)</td>
<td>0.18</td>
</tr>
<tr>
<td>HSC-air pol. extend</td>
<td>10 µg/m$^3$ ambient PM$_{2.5}$</td>
<td>1.24 (1.09-1.41$^d$</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>0.18</td>
</tr>
<tr>
<td>WHI-air pol.</td>
<td>10 µg/m$^3$ ambient PM$_{2.5}$</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>0.18</td>
</tr>
<tr>
<td>SGR-SHS</td>
<td>Low-moderate SHS exp.</td>
<td>-----</td>
<td>-----</td>
<td>1.16 (1.03-1.32)</td>
<td>-----</td>
<td>0.36</td>
</tr>
<tr>
<td>SGR-SHS</td>
<td>Moderate-high SHS exp.</td>
<td>-----</td>
<td>-----</td>
<td>1.26 (1.12-1.42)</td>
<td>-----</td>
<td>0.90</td>
</tr>
<tr>
<td>SGR-SHS</td>
<td>Live with smoking spouse</td>
<td>1.21 (1.13-1.30)</td>
<td>-----</td>
<td>1.26 (1.12-1.42)</td>
<td>-----</td>
<td>0.54</td>
</tr>
<tr>
<td>SGR-SHS</td>
<td>Work with SHS exposure</td>
<td>1.22 (1.13-1.33)</td>
<td>-----</td>
<td>1.26 (1.12-1.42)</td>
<td>-----</td>
<td>0.72</td>
</tr>
<tr>
<td>INTERHEART</td>
<td>1-7 hrs/wk SHS exp.</td>
<td>-----</td>
<td>1.24 (1.17-1.32$^d$</td>
<td>-----</td>
<td>-----</td>
<td>0.36</td>
</tr>
<tr>
<td>INTERHEART</td>
<td>Live with smoking spouse</td>
<td>1.28 (1.12-1.47$^d$</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>0.54</td>
</tr>
</tbody>
</table>

*Adjusted RR = adjusted relative risk; CI = confidence interval; CPD = chronic pulmonary disease; PM$_{2.5}$ = particulate matter of 2.5 microns or less; SHS = second hand smoke.

Pope et al. Environmental Health Perspectives 2011, in press
Household Air Pollution and Blood Pressure In Yunnan

Baumgartner et al. Environmental Health Perspectives 2011, Oct
MD-diagnosed Acute Lower Respiratory Infection

Where we Want to Be – Really Clean Stoves

Approximate Mean PM2.5 exposure in 100s of ug/m3

RESPIRE-Guatemala
Generalized Exposure-Response: Outdoor Air, SHS, and HAP

Pneumonia from combustion particles
Annual average PM2.5 in µg/m³

Outdoor Air Pollutant

Secondhand Tobacco Smoke

Solid Fuel Zone

CRA, 2011
Biggest impacts from smoking

- Chronic obstructive lung disease
- Lung cancer
- Heart disease and stroke
- All not associated with HAP
What other cancers from smoking?

- “Traditional” smoking cancers: oral cavity, pharynx, larynx, oesophagus, pancreas, urinary bladder, and renal pelvis
- Newly confirmed cancers: nasal, sinus, nasopharynx, stomach, liver, kidney, uterine cervix, oesophagus, and leukaemia
Cervical Cancer and Household Air Pollution

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>log(Odds Ratio)</th>
<th>SE</th>
<th>Weight</th>
<th>Odds Ratio IV, Random, 95% CI</th>
<th>Odds Ratio IV, Random, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferrera 2000(a)</td>
<td>0.54232429</td>
<td>0.53624989</td>
<td>17.6%</td>
<td>1.72 [0.60, 4.92]</td>
<td></td>
</tr>
<tr>
<td>Ferrera 2000(b)</td>
<td>1.24990174</td>
<td>0.41614175</td>
<td>20.9%</td>
<td>3.49 [1.54, 7.89]</td>
<td></td>
</tr>
<tr>
<td>Velema 2002(a)</td>
<td>0.06765865</td>
<td>0.45514155</td>
<td>19.8%</td>
<td>1.07 [0.44, 2.61]</td>
<td></td>
</tr>
<tr>
<td>Velema 2002(b)</td>
<td>1.75093748</td>
<td>0.36626585</td>
<td>22.4%</td>
<td>5.76 [2.81, 11.81]</td>
<td></td>
</tr>
<tr>
<td>Sierra Torres 2006</td>
<td>1.98787435</td>
<td>0.47618897</td>
<td>19.2%</td>
<td>7.30 [2.87, 18.56]</td>
<td></td>
</tr>
</tbody>
</table>

Total (95% CI) 100.0% 3.14 [1.57, 6.30]

Heterogeneity: Tau² = 0.43; Chi² = 12.71, df = 4 (P = 0.01); I² = 69%
Test for overall effect: Z = 3.23 (P = 0.001)

Three papers; two done in Honduras, one in Columbia
Infectious disease and smoking

- pneumonia
- TB
- meningococcal disease
- otitis media
- influenza

*Archives of Internal Medicine, 2004*
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. Smith1

1School of Public Health, University of California–Berkeley, Berkeley, California, USA; 2Regional Tuberculosis Center, Ram Ghat, Pokhara, Nepal; 3Department of Community Medicine, Manipal Teaching Hospital, Manipal College of Medical Sciences, Pokhara, Nepal
## Risks from fuel use for TB in women in Pokhara

<table>
<thead>
<tr>
<th>Category</th>
<th>Source</th>
<th>Odds Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cookstove</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas</td>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td>Biomass</td>
<td></td>
<td>1.21 (0.48–3.05)</td>
</tr>
<tr>
<td>Kerosene</td>
<td></td>
<td>3.36 (1.01–11.22)</td>
</tr>
<tr>
<td><strong>Heating fuel</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No heating fuel use or electricity</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Biomass</td>
<td></td>
<td>3.45 (1.44–8.27)</td>
</tr>
<tr>
<td><strong>Main light source in the house</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td>Kerosene lamp</td>
<td></td>
<td>9.43 (1.45–61.32)</td>
</tr>
</tbody>
</table>

Pokhrel et al., 2010
Other impacts of smoking

- preterm delivery,
- stillbirth,
- low birth weight, and
- sudden infant death syndrome (SIDS)
- lower bone density in older women.
- cataracts
- IQ and cognitive impacts (SHS)

CDC, 2012
Pooled birth weight difference (low minus high exposure): Adjusted estimates (Boy and Tielsch have GA)

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Lower Exposure</th>
<th>Higher Exposure</th>
<th>Mean Difference</th>
<th>Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Total</td>
<td>Mean</td>
</tr>
<tr>
<td>Boy 2002</td>
<td>2,835</td>
<td>533</td>
<td>357</td>
<td>2,772</td>
</tr>
<tr>
<td>Mishra 2004</td>
<td>3,271</td>
<td>1,448</td>
<td>766</td>
<td>3,096</td>
</tr>
<tr>
<td>Siddiqui 2008</td>
<td>2,812</td>
<td>404</td>
<td>80</td>
<td>2,730</td>
</tr>
<tr>
<td>Thompson 2005</td>
<td>2,805</td>
<td>579</td>
<td>366</td>
<td>2,723</td>
</tr>
<tr>
<td>Tielsch 2009</td>
<td>2,819</td>
<td>453</td>
<td>646</td>
<td>2,715</td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td>2215</td>
<td></td>
<td></td>
<td>11740</td>
</tr>
</tbody>
</table>

Heterogeneity: Chi² = 2.85, df = 4 (P = 0.58); I² = 0%
Test for overall effect: Z = 6.74 (P < 0.00001)

All estimates: +96.6g (68.5, 124.7)
Excluding self-reports +93.1g (64.6, 121.6)

CRA: Pope et al., 2010
Neurodevelopmental performance among school age children in rural Guatemala is associated with prenatal and postnatal exposure to carbon monoxide, a marker for exposure to woodsmoke.

Linda Dix-Cooper, Brenda Eskenazi, Carolina Romero, John Balmes, Kirk R. Smith.

Division of Environmental Health Sciences, School of Public Health, University of California, Berkeley, CA 94720-7360, USA
Center for Environmental Research and Children's Health (CERCH), School of Public Health, University of California, Berkeley, CA, USA
Centro de Estudios en Salud Universidad Del Valle, Guatemala
Division of Occupational and Environmental Medicine, Department of Medicine, University of California, San Francisco, CA, USA

(D) Reitan-Indiana Finger Tapping

(B) Bender Gestalt-II Immediate Recall Figures Phase
Bottom Lines

- We understand the risks of combustion particles not only from a large number of studies in households, but also from studies of outdoor air pollution, secondhand smoke, and active smoking.
- Over time, we can expect that nearly every effect found in smokers will be found from household smoke, but a lower risk levels.
- We no longer refer to it as “indoor” air pollution because the exposures occur not only inside, but around the house, down the street, and indeed regionally – “secondhand cook smoke”
- Cannot solve outdoor air pollution problems in South Asia and other regions without reducing substantially household pollution.
What is the climate connection?
CO$_2$ is important for climate, but so are many other greenhouse gases create pollutants, including the ones circled that, unlike CO$_2$, also have significant health as well as climate impacts.

Several of the non-CO$_2$, greenhouse gases create a good proportion of both their climate forcing and health damage through the secondary pollutant, tropospheric ozone.

All come from incomplete combustion in households.

IPCC, 2007
Household Fuels and Climate

- Climate impacts come from non-renewable biomass and coal, i.e., from net CO$_2$ emissions
- Poor combustion also leads to other emissions such as the relatively well-understood GHGs – methane and nitrous oxide – which are “Kyoto” GHGs
- In addition, a wide range of less well-understood short-lived GH-related emissions are emitted including
  - CO and black carbon – warming agents
  - Ozone precursors – warming But also cooling agents such as sulfates and organic carbon particles
- There are also indirect climate impacts of these pollutants including
  - Reducing carbon capture of forests by ozone damage
  - Darkening of snow/ice by black carbon
Controllable Global Warming from Black Carbon Emissions

Net of OC, Forcings from IPCC, 2007: 0.25 W/m²
Inventory from T Bond Database, V 7.1.1 Feb 2009

- One-third of net black carbon and carbon monoxide emissions globally come from household fuels
- One-sixth of ozone causing pollutants
- One-twentieth of methane
Climate Warming in 2020 Under Present Trends

Unger et al. 2010

Household Biomass
Perfect Storm for Health Impacts

- Highly polluting activity
- Half of world households
- Several times a day
- Just when people are present
- Most vulnerable (women and young children) most likely to be there
Just because we know it’s a risk, does not mean we know how to fix it

- **1964**: Surgeon General’s Report but Framework Convention on Tobacco Control was 2005 and not all countries yet signed up and impacts growing
- **~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, gas and electricity, is not “affordable” by the poor.
- Other technologies difficult and less effective and no drug companies to pay for their advancement
- Particularly difficult because of the high component of behavioral change required
- Yet, the fact that 60% of the world is now protected, gives us reason to think we can protect the other 40%
- Will take a new type of research and development, however, both sophisticated and rigorous, to develop and test the interventions in ways to convince the health community
- And completely different levels of funding, for example the kinds of large intervention trials done for vaccines, water/sanitation, bednets, etc. – $10s of millions each
If it doesn’t take fifty years, it isn’t worth doing.*

• Let us hope, however, that in 2030 we are not like poor water/sanitation today, i.e., 120 years from when causation was accepted by most people, but still killing millions annually.

*Attributed to Albert Einstein
Summary

• Worst thing to do is stick burning stuff in your mouth – 5+ million premature deaths
• Next worse is burning in your house – 2+ million deaths
• Next worse is having someone else nearby sticking in their mouth – 400k+ deaths
• Even bad to have on your planet – 2+ million deaths from outdoor air pollution
• And climate change risks
• Chimneys do not help the last two– need to stop producing the pollution at all.
Many thanks

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