Cows, Coal, and Cooking: the Untold Story of Methane, Climate, and Health

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Society has three basic options for responding to human-caused climate change

- **Mitigate** by working to reduce greenhouse gas (GHG) emissions from energy, agriculture, and land use or to capture them from the atmosphere in order to slow or, perhaps, reverse warming.
- **Adapt** by reducing the negative effects of climate change through protecting coastlines, moving populations away from impacted areas, increasing efforts to control climate-related vectorborne diseases, insulating cities from heat stress, etc..
- **Suffer**, i.e., given that efforts in the first two arenas above are moving slowly, there is very likely to be suffering, perhaps considerable in poorer parts of the world, because of the climate change committed already.
- We will be doing all three, but can reduce the third if we put more effort into the first two.
- Some of the suffering will occur because climate change and the ways we deal with it interfere with our other long-term health goals, such as reduction of child death.

Framework from Holdren, 2006
Two short briefings

• How do the distributions of climate change emissions and health impacts compare?

• How does this change if the special characteristics of methane are included?
Direct Impacts of Climate Change on Human Health

Human exposures
- Regional weather changes
  - Heat waves
  - Extreme weather
  - Temperature
  - Precipitation
  - Sea-level rise

Microbial changes:
- Contamination paths
- Transmission dynamics

Socioeconomic and demographic disruption

Changes in agro-ecosystems, hydrology

Health Effects
- Temperature-related illness and death
- Extreme weather-related (floods, storms, etc.) health effects
- Air pollution-related health effects
- Water and food-borne diseases
- Vector-borne and rodent-borne diseases
- Effects of food and water shortages
- Mental, nutritional, infectious-disease and other effects

Adaptation measures

Original by Patz ~1996
Published in 2004, 2 vols, ~2500 pp (available on WHO CRA website)

Global Warming Chapter: McMichael et al.,
WHO Comparative Risk Assessment
Climate Change Health Impacts as of 2000
(McMichael et al., 2004)

• Diarrhea – 2.4% of global burden
• Malaria – 2%; 6% in some regions
• 17% of protein-energy malnutrition
• 7% of dengue fever in some rich countries
• 150,000 deaths, 99% in poor countries
  (46% in South Asia)
• 0.4% of all DALYs (lost healthy life years)
• Most (88%) of impact in children under 5
• Not large today, but growing.
Health Impacts from Climate Change by Income Level across the World

Smith & Ezzati, 2005
Cumulative CO₂ emissions from fossil fuels (as depleted by natural processes)

Distribution of Health Impacts from Climate Change
(Experiencing versus Imposing)

Smith, 2008
Distribution of Health Impacts from Climate Change
(Ratio: Imposing/Experiencing)

Rich countries impose >500 times more risk than they receive.
Poor countries receive >16 times more health risk than they impose.

Smith and Rodgers
Global average surface temperature is an index of the state of the climate – and it’s heading for a state not only far outside the range of variation of the last 1000 years but outside the range experienced in the tenure of Homo sapiens on Earth.
Risk and Uncertainty

Avoidable Risk

Climate Change

Tobacco

Malnutrition

Indoor Air Pollution

Outdoor Air Pollution

Attributable Risk
The Methane Story: CH₄

Three subplots:
- Methane and global warming
- Methane and global health
- Methane and the health of the poor
Atmospheric Greenhouse gas concentrations

Anthropogenic Sources

\( \text{CO}_2 \)
Fossil fuels
Land use change
Cement manufacturing

Methane
Landfills
Rice
Livestock
Waste management
Fossil recovery

\( \text{N}_2\text{O} \)
Fertilizer
Planted N-fixers
Combustion

Figure SPM.1
IPCC 2007
Warming in 2005 from emissions since 1750

More than half due to methane

IPCC, 2007
Math of GHG Decay (AR4)

- CO$_2$ goes into four compartments:
  - 19% of total with a lifetime* of 1.2 years
  - 34% at 18.5 y
  - 26% at 173 y
  - 21% with “infinite” lifetime

- Methane has a 12 y lifetime,
  - but contributes to ozone, a GHG
  - and eventually oxidizes to CO$_2$

*Lifetime refers to the time to reach 1/e (37%) of the original amount
Natural CO2 and CH4 Depletion - first 10 years

Fraction remaining of 2008 emissions

- Carbon Dioxide
- Methane

Relative Warming of Methane and CO$_2$ from Emissions in 2008

Future Annual Warming from One Ton of Each Pollutant Released in 2008

Includes CO$_2$ produced by the methane
How can we compare projects to reduce different GHGs?

- Why not just take all future warming into account?
- This would mean that no effort would go into avoiding emissions of the shorter lived GHGs, such as methane, because CO₂ has such a long lifetime.
- It would result in spending most money to protect people thousands of years into the future and ignoring the needs of ourselves and our children.
- Thus, the IPCC established in 1996, official Global Warming Potentials (GWPs), which are weighting factors to compare the impact of different GHGs
- GWPs are built into the Kyoto Protocol, the Clean Development Mechanism, and nearly all national inventories and reduction plans, including Australia’s
Methane and Time

- The current official GWPs are based on 100-year time horizons
  - Methane is 21 x CO₂ by weight
  - Equivalent to ~0.75% discount rate

- For making decisions on how to spend resources when impacts are upon us, <1% is too low.

- The other GWP published by IPCC, has a 20-year time horizon
  - Methane is 72 x CO₂ by weight
  - Equivalent to ~ 8% discount rate
  - More compatible with financial investments

- International health investments use a 3% discount rate, which would be a GWP of ~48
Time perspective makes a difference

IPCC, 2007
Warming Contribution of Total ~2008 Emissions of Methane Compared to Total CO2 Emissions

Fraction of CO2 Warming from Methane

Methane GWPs and Discount Rates

Equivalent GWP

Annual Discount Rate - %

Official GWP of 21 ~0.75% discount rate
Methane #1: Summary

- A much more powerful greenhouse gas (GHG) than CO\textsubscript{2}.
- Partly due to its direct effect, but also because it creates ozone (O\textsubscript{3}), another powerful GHG.
- About 100 times more per ton than CO\textsubscript{2} at any one time.
- Eventually turns to 2.75 times as much CO\textsubscript{2} by mass.
- Methane has thus contributed a significant amount to global warming.
- But has a much shorter atmospheric lifetime compared to CO\textsubscript{2}.
- Thus, changes in emission rates will have a much faster impact to lower warming.
Background Ozone is Growing ...

... and Will Continue to Grow!

Historic and future increases in background ozone are due mainly to increased methane and NO\textsubscript{X} emissions (Wang et al., 1998; Prather et al., 2003).

Ozone trend at European mountain sites, 1870-1990 (Marenco et al., 1994).
Multiple Benefits of Reducing Methane

Reducing ~20% of anthropogenic methane emissions will:

- Be possible at a net cost-savings.
- Reduce 8-hr. average ozone globally by ~1 ppb.
- Reduce global radiative forcing by ~0.14 W m⁻².
- Provide ~2% of global natural gas production.
- Prevent ~30,000 premature deaths globally in 2030, ~370,000 from 2010-2030.

Mauzerall, 2007
Methane #2: Summary

- Methane is precursor to tropospheric (ground level) ozone
- Tropospheric ozone rising around the world
- Significant impact on natural ecosystems and agriculture
- WHO and other agencies lowering ozone standards/guidelines because of new evidence on mortality and continued evidence of morbidity
- Standards suggested by health protection are now at the top end of regional levels in some parts of the world, e.g., Europe
- Nowhere to hide
Global Anthropogenic Methane Emissions ~2005
Total ~ 305 million tons

- Livestock: 30%
- Coal mining: 6%
- Fossil fuel burn: 1%
- Biomass burn: 3%
- Oil/gas: 18%
- Manure: 4%
- Rice: 10%
- Landfills: 12%
- Waste water: 9%
- Other ag: 7%

Growing at ~1.5% per year

USEPA, 2006
Population: 6.102 billion
Total energy use: 10.2 Gtoe
Per capita energy consumption: 167 toe

World Energy – 2001

World Energy Assessment, 2004
Chinese household rural energy:
National Household Solid Fuel Use, 2000

Legend:
- <20%
- 20% - 40%
- 40% - 60%
- 60% - 80%
- >80%
- Household solid fuel use known
- No data
Greenhouse warming commitment per meal for typical wood-fired cookstove in India

- Wood: 1.0 kg
  - 454 g Carbon
- CO2 Carbon: 403 g
- Methane Carbon: 3.8 g
- Other GHG Carbon
  - Carbon Monoxide: 38 g
  - Hydrocarbons: 6.3 g
- Nitrous Oxide: 0.018 g

Global warming commitments of each of the gases as CO₂ equivalents

Source:
Smith, et al., 2000
Indian Households Using Biomass Fuels

2 million tons methane per year of 300 Mt total global human emissions

Smith, et al. 2000
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

- Into Pot: 2.8 MJ (18%)
- In PIC: 1.2 MJ (8%)
- Waste Heat: 11.3 MJ (74%)

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
  Plus methane

• Hydrocarbons
  – 25+ saturated hydrocarbons such as \( n\text{-hexane} \)
  – 40+ unsaturated hydrocarbons such as \( 1,3 \text{ butadiene} \)
  – 28+ mono-aromatics such as benzene & styrene
  – 20+ polycyclic aromatics such as \( \text{benzo}(\alpha)\text{pyrene} \)

• 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

Naehler, et al. 2007
First person in human history to have her exposure measured doing one of the oldest tasks in human history

Kheda District
Gujarat, India
1981
Health-Damaging Air Pollutants From Typical Woodfired Cookstove in India.

Typical Health-based Standards

- Carbon Monoxide: 150 mg/m³
  - Typical Indoor Concentrations: 10 mg/m³

- Particles: 3.3 mg/m³
  - Typical Indoor Concentrations: 0.1 mg/m³

- Benzene: 0.8 mg/m³
  - 1,3-Butadiene: 0.15 mg/m³
  - Formaldehyde: 0.7 mg/m³

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

Best single indicator

IARC Group 1 Carcinogens
Diseases for which we have epidemiological studies showing a link to household biomass use:

- ALRI/Pneumonia (meningitis)
- Asthma
- Low birth weight
- Early infant death?
- Birth defects?
- Cognitive Impairment?
- Chronic obstructive lung disease
- Interstitial lung disease
- Cancer (lung, NP, cervical, aero-digestive)
- Blindness (cataracts, trachoma)
- Tuberculosis
- Heart disease?
ALRI associated with use of solid fuels: analysis of ~12 observational studies

<table>
<thead>
<tr>
<th>Subgroup analyses</th>
<th>Odds ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All studies</td>
<td>2.3 (1.9-2.7)</td>
</tr>
<tr>
<td>Use of solid fuel</td>
<td>2.0 (1.4-2.8)</td>
</tr>
<tr>
<td>Duration of time child spent near the cooking fire</td>
<td>2.3 (1.8-2.9)</td>
</tr>
<tr>
<td>Studies adjusting for nutritional status</td>
<td>3.1 (1.8-5.3)</td>
</tr>
<tr>
<td>Studies not adjusting for nutritional status</td>
<td>2.2 (2.0-3.0)</td>
</tr>
<tr>
<td>Children aged &lt;2 years old</td>
<td>2.5 (2.0-3.0)</td>
</tr>
<tr>
<td>Children aged &lt;5 years old</td>
<td>1.8 (1.3-2.5)</td>
</tr>
</tbody>
</table>

Smith et al in WHO, Comparative quantification of health risks, 2004
Global Burden of Disease from Top 10 Risk Factors
plus selected other risk factors

Percent of All DALYs in 2000

- Underweight: 4.9 million premature deaths/y
- Unsafe sex: 1.6 million premature deaths/y
two-thirds from ARI in children
- Tobacco: 0.15 million premature deaths/y

Smith et al. 2005
A Chinese Biomass Gasifier Stove

Tests show emissions nearly at LPG levels:
Low health risk and essentially no greenhouse emissions
Health and Greenhouse Gas Benefits of Biomass Stove Options

Co-benefits in China:
~$500/life-year saved
~$6/t-CO$_2$ averted

Smith & Haigler, 2008
Smith & Haigler, 2008
Current Cost-effective Region In China

Relative Values ($Int)
- tCO2e offset
- DALYs avoided

Smith & Haigler, 2008
Economic Development

Once global and national markets pick up their portions, local market can pay remainder

DR ~40%

Rural Energy is Linked to Three Major Sectors

Paying for Rural Energy Development

Technology

Global Climate Market

$ per ton-carbon (world carbon market) – DR <1%

National MDG Health “Market”

1-3x $GDP/capita per DALY saved (WHO/IBRD, etc. recommendation) DR ~3%

High-efficiency low-emissions rural energy technology is too expensive for local markets

Economic Development

Once global and national markets pick up their portions, local market can pay remainder DR ~40%
Methane #3: Summary

- Methane is one of the constituents of products of incomplete combustion (PIC) from fuel combustion
- PIC are responsible for much burden of disease in the world’s poorest populations
- Controlling this PIC has a double benefit: health and climate
- Can potentially be done economically – low hanging fruit for both
Methane and equity

• We have seen how methane’s health impacts, direct, indirect, and associated, mostly affect the poor
• What about methane emissions: how are they distributed?
Ratio of largest to smallest emitting countries ~ 500x

This kind of calculation, however is based only on CO$_2$ emissions:

Warming in 2005 from emissions since 1750

More than half due to methane

How much allocated to each living person from both GHGs — our natural debts?
International Natural Debt Per Capita

Tons CO₂ - eq

- 100 200 300 400 500 600 700 800

AUSTRALIA
USA
CANADA
CZECH REPUBLIC
UKRAINE
RUSSIA
KAZAKHSTAN
GERMANY
BELGIUM

Ratio of largest to smallest emitters considering both CO₂ and methane ~ 40x

~55% of world pop

Smith and Rogers, In preparation
Australian Methane Emissions - 2006

- **Energy**: 26%
- **Agriculture**: 59%
- **Waste**: 14%
- **LULUCF**: 2%

5.6 Mt ~2% of global total

National GHG Inventory 2006, Dept of Climate Change, 2008
In Australia 83% of fuel cycle emissions are due to coal mining.
In Australia, 85% of agricultural emissions are due to enteric emissions from livestock.
Conclusion on Methane

- Methane emissions are more important than current official weighting factors indicate because of its large effect over the next generation
- Likely to increase in “value”, perhaps during the post-Kyoto deliberations now starting
- Developing countries have a bigger role
- Methane is emitted as part of the poor combustion process of solid fuels, which also produce much health-damaging pollution
- Improving this combustion offers substantial GHG as well as health benefits in a cost-effective manner
- Ways to control are quite different from CO$_2$
- And may be easier in the short term
Methane, cont.

- Increases of wide-scale ground-level ozone is becoming a major world problem
- A significant health-damaging pollutant
- Methane emissions are one of its causes
- Reduction of methane emissions, therefore, will help protect health worldwide in the short term
Methane, cont.

- Way to reduce warming in the next generation is to put more attention on methane (and other shorter lived GHGs)
- Once the heat enters Earth’s systems, it does not matter where it came from
- The rate of warming is as important as the total amount
- Way to slow the rate is to immediately reduce methane emissions
- While working to stop CO₂ in the long run
Being Smart about Mitigation

• **Co-benefits**: Guide mitigation measures so they help achieve other societal goals, including health protection.

• **No-regrets**: providing a short-term more certain return (health) on a long-term more uncertain investment (climate protection)

• **Political bridge** over the international divide between developed and developing countries
Thank you

Publications available at
http://ehs.sph.berkeley.edu/krsmit/