Co-benefits: Three Short Stories

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Main theme
Need for Standard Methods to bring Co-benefits into National and Global Policy Making

Roadmap

Landscape of Co-benefits Opportunities
Methane: Carbon on Steroids
Household Fuels in China
Why Worry about Co-benefits?

- Helps reduce the cost of mitigation by sharing cost with other sectors.
- Recognizes that society still has major goals besides avoiding climate change, such as providing acceptable levels of health protection.
- Potentially reduces political gap between developed and developing countries in international climate negotiations – early achievement of more certain benefits that directly relate to development needs (“no regrets investments”)

Air Pollution from Energy Use

- Household solid fuels
  - Large source of ill-health worldwide in poorest populations – 1.6 million premature deaths
  - Non-renewable biomass and coal carbon emissions
  - Poor combustion leads to non-CO2 GH-related emissions

- Outdoor emissions from energy systems
  - 0.8 million premature deaths
  - Most well documented benefits, climate and health

- Special advantage to eliminating black carbon, but difficult to ascertain relative climate impacts of different aerosols.

- China has the largest global impacts for both these categories of air pollution
Warming in 2005 from emissions since 1750

Note importance of methane and black carbon

IPCC, 2007
Global Burden of Disease from Top 10 Risk Factors
plus selected other risk factors

- 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

Smith et al.
2005 based on
WHO data

Percent of All DALYs in 2000

4.9 million deaths/y
1.6 million deaths/y (+/- 50%)
0.8 million death/y

4.9 million deaths/y
1.6 million deaths/y (+/- 50%)
0.8 million death/y
Maximizing the health benefits of climate change mitigation

- Buildings
  - Indoor air pollution
  - Heat and cold protection

- Industry
  - Occupational risks, mining and transport

- Agriculture
  - Nutrition, Water / vector-borne disease

- Transport
  - Air pollution
  - Traffic injuries
  - Physical inactivity

- Energy supply & conversion
  - Occupational risks; Construction and transport

- Waste
  - Occupational, chemical

Greenhouse Gas Emissions
Modifying the Built Environment

- Obesity, traffic accidents, and lack of physical activity responsible for 3+ million additional premature deaths annually
- Reduce vehicle use (air pollution, obesity, safety, etc)
- Change urban design to increase physical activity (obesity, air pollution, safety)
- Improve energy efficiency of buildings (avoid health risks of energy poverty) - great opportunity in rural China
Enhancing Biomass Carbon Storage

- Reforestation in river basins to reduce flood risks – Yangtze River Basin Commission
- Increase green space in cities and forests in rural areas – identifiable mental, livelihood, and other benefits to local populations
Redirecting Diet Preferences

- Livestock responsible for 20+% of global greenhouse emissions – methane from animal digestion plus operation of meat/dairy feed/supply systems
- Converge on lower mean global red meat consumption
  - Suggested 90 g/wk – Lancet 2007
  - Major health benefits: heart disease, stroke, obesity, bowel and breast cancer
- Similar benefits to convergence in global dairy consumption
- China has the major global growth potential
Most cost-effective GHG control device is probably a condom

- Many tens of millions of women wish to have fewer children, but do not have access to contraceptives
- Giving them access could mean 1-2 billion fewer people by 2100 – a major reduction of stress on the Earth
- Many health benefits to smaller, more planned families
Methane Reduction

- Major and probably undervalued global GHG
- Major cause of rise in global tropospheric ozone concentrations – important health-damaging and crop-damaging pollutant
- Livestock major source, as noted above
- Leaks: Coal mines, gas pipelines, etc.
- Waste management: Landfills, wastewater
  - Other health benefits here also
- Incomplete combustion: biomass and coal in households – China a main source globally
The Methane Story: CH₄
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

Atmospheric Greenhouse gas concentrations

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

Methane more than half of total from CO₂

IPCC, 2007
Methane and Global Warming

- A much more powerful greenhouse gas (GHG) than CO₂
- Partly due to its direct effect, but also because it creates ozone (O₃), another powerful GHG
- Nearly 100 times more per ton than CO₂ at any one time (73x from direct effects)
- Eventually turns to 2.75 times as much CO₂ by mass
- Methane has thus contributed a significant amount to global warming, more than half that of CO₂
- But has a much shorter atmospheric lifetime compared to CO₂
Math of GHG Decay (AR4)

• CO₂ 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 a lifetime of “many thousand years”

• Methane has a 12 y lifetime,
  – but contributes to ozone, a GHG
  – and eventually oxidizes to CO₂

*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
Natural CO2 and CH4 Depletion - 100 years

Fraction Remaining of Gas Emitted in 2008

- Carbon Dioxide
- Methane
Relative Warming from CO2 and CH4 emitted in 2008

Not equal total warming until AD 7430 (5422 years)

Not equal warming per year until 2075 (67 years)
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 CO$_2$ 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.
Methane and Time

- The current official GWPs are based on 100-year time horizons
  - Methane is 21 x CO₂ by weight (25 in AR4)
  - Equivalent to ~0.75% discount rate
- For making decisions on how to spend resources when impacts are upon us, <1% is probably 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
Relative Warming from CO2 and CH4 emitted in 2008 (one ton of each)

- 20 years – 72x
- 100 years – 25x

Carbon Dioxide
Methane
Methane GWPs and Discount Rates

- Official GWP of 21
  - ~0.75% discount rate

- At GWP=25, ~1% DR
A GWP of 48 (3% discount rate) is approximately a 40-year time horizon.
Time perspective makes a difference
Global Anthropogenic Methane Emissions ~2005
Total ~ 305 million tons

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

Expected to grow at ~1.5% per year

~47 kg/cap

USEPA, 2006
Chinese Methane Emissions in 2005

- Landfills, 5%
- Coal mining, 16%
- Solid fuel combustion, 6%
- Rice, 26%
- Livestock, 30%
- Waste water, 13%
- Manure, 3%
- Oil/gas, 1%

41 Mt = 13% of world

31 kg/capita

USEPA, 2006
Chinese methane released in 2008 creates 67% of the warming over the next 20 years as the CO2 released in 2008.
Methane and Global 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?
How much allocated to each living person from both GHGs --- our natural debts?

Warming in 2005 from emissions since 1750

More than half due to methane

IPCC, 2007
National Natural Debts:
Cumulative CO₂ emissions, depleted by natural processes

Ratio of largest to smallest emitting countries ~ 500x

This kind of calculation, however, is based only on CO₂ emissions:

Distribution of Global Natural Debt Among Top 10 Nations

CO2 only in 2005

LUC 20%
USA 21%
Other 26%
CHINA 8%
RUSSIA 6%
GERMANY 4%
JAPAN 4%
UK 4%
INDIA 2%
FRANCE 2%
CANADA 2%
UKRAINE 2%
BRAZIL 0.8%

Nb. Land-use change emissions not are parsed out by country

Smith and Rogers, in preparation
Distribution of Global Natural Debts in Top 10 Nations
CH4 and CO2 in 2005
[compared to CO2 alone; note decrease for USA, increase for China, and large increases for India and Brazil]

Other 33.2%
USA 17.1%
CHINA 10.9%
RUSSIA 6.2%
INDIA 5.5%
GERMANY 3.3%
JAPAN 2.6%
UKRAINE 2.4%
UK 2.1%
BRAZIL 2.4%
LUC 12.9%
CANADA 1.6%

Nb. National fossil fuel/cement emissions only for CO2, land-use change emissions are not parsed out by country

Smith and Rogers, in preparation
Ratio of largest to smallest emitters considering both CO\textsubscript{2} and methane
\(~40\times\)
Ranking of Carbon Emissions: The Pharmaceutical Index

- Carbon dioxide is noxious if fossil or forest derived, but benign if from renewable sources.
- Products of incomplete combustion (PIC) such as carbon monoxide and hydrocarbons are like CO₂ on caffeine – several times worse.
- Methane from any source (fossil, biologic, or incomplete combustion) is like CO₂ on steroids – dozens of times worse.
- Black carbon in particles from incomplete combustion is like CO₂ on cocaine – hundreds of times worse.
Conclusion on Methane

- Methane emissions are more important than current official weighting factors indicate because of its large effect over the next generation.
- May well 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.
- Contributes directly to global tropospheric ozone levels.
- Improving this combustion offers substantial GHG as well as health benefits in a cost-effective manner.
- Ways to control are quite different from CO\textsubscript{2}.
- And may be easier in the short term.
Methane – bottom lines?

• 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
• For some impacts, the rate of warming is as important as the total amount
• Only way to slow the rate is to immediately reduce methane emissions (and other short-lived GH pollutants)
• While working to stop CO$_2$ in the long run
Rural Energy in China: 2004

Total

Crop wastes: 33%
Coal: 35%
Biogas: 1%
Wood: 21%
Electricity: 7%
LPG: 1%
Kerosene: 2%

Households

Crop wastes: 44.3%
Coal: 12.9%
Biogas: 1.2%
Wood: 36.6%
Electricity: 3.7%
LPG: 1.2%
Kerosene: 0.1%

70% of total

Ministry of Agriculture

National Bureau of Statistics
Household Energy in China

- >65% of China’s population is rural.
- ~80% of energy use is simple solid biomass (wood, agricultural wastes)
- ~13% as coal
- Thus, it is still true to say that in China most people rely on biomass fuels for most of their energy
- A situation that has not changed since the mastery of fire by the human race
Rural energy situation is typically complex:
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
131 g 69 g

Nitrous Oxide 0.018 g

4.7 g

Global warming commitments of each of the gases as CO₂ equivalents

Source: Smith, et al., 2000
A Co-Benefits Opportunity

More than 2 million tons methane per year of the ~ 305 Mt total global human emissions from Chinese stoves
Published in late 2004, 2 vols, ~2500 pp

Available on the World Health Organization website

http://www.who.int/publications/cra/en/
Chinese Burden of Disease from Top 10 Risk Factors
Plus Selected Other Risk Factors

- Alcohol
- Blood pressure
- Tobacco
- Underweight
- Occupational hazards (5 kinds)
- Indoor smoke from solid fuels
- Overweight
- Road traffic accidents*
- Low fruit & vegetables
- Cholesterol
- Unsafe water/sanitation
- Urban outdoor air pollution
- Lead (Pb) pollution
- Physical inactivity
- Unsafe sex
- Climate change

Percent of All DALYs in 2000

420,000 deaths/year

Smith et al. 2005 (based on WHO data)
Chinese household rural energy:
A Chinese Biomass Gasifier Stove

Tests show emissions nearly at LPG levels:
Low health risk and essentially no greenhouse emissions
Recent International Collaborative Assessments Provide Much Needed for Co-benefits

- IPCC/UNFCCC: Metrics and procedures for calculating carbon credits
- Millennium Development Goals: 8 MDGs with ~30 explicit indicators and metrics
- Commission on Macro-economics and Health: established health burden metrics and standard methods for cost-effectiveness analysis
- WHO Comparative Risk Assessment: Metrics of exposure and health burden with estimated exposure–response relationships and uncertainties
DALY – international metric for lost healthy life years

Disease Priorities Project - 2006
Summary metrics for use in co-benefits scoping.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Health</th>
<th>Climate Change</th>
<th>Money</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DALYs (Disability-Adjusted Life Years)</td>
<td>GWC (Global Warming Commitment)</td>
<td>International Dollars</td>
</tr>
<tr>
<td>Unit</td>
<td>Years</td>
<td>Tons CO$_2$ equivalent</td>
<td>US Dollars</td>
</tr>
<tr>
<td>Formulation</td>
<td>Years lost from premature death plus weighted years lost to disability</td>
<td>Tons CO$_2$ plus tons other GHGs multiplied by their global warming potentials (GWPs)</td>
<td>Local currency adjusted by its capability to buy standard market basket of purchases</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Discount Rates</th>
<th>DALYs</th>
<th>GWPs</th>
<th>Benefits</th>
<th>Costs</th>
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</thead>
<tbody>
<tr>
<td>Kyoto Case</td>
<td>0%</td>
<td>100-year ~ 0.7%</td>
<td>1%</td>
<td>3%</td>
</tr>
<tr>
<td>Base Case</td>
<td>3%</td>
<td>20-year ~ 4.3%</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>Financial Case</td>
<td>3%</td>
<td>20-year ~ 4.3%</td>
<td>3%</td>
<td>6%</td>
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</table>
## Exposure Response Relationships from Global Comparative Risk Assessment

### Table 2  Risks from outdoor and indoor air pollution with example from China. Disability-adjusted life years (DALYs)/exposure will be different in other countries because of different background disease risks. Sources: References 12 and 64

<table>
<thead>
<tr>
<th></th>
<th>Population</th>
<th>Exposure metric</th>
<th>Relative risk per unit</th>
<th>DALYs/exposure&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outdoor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>Adults &gt;30</td>
<td>10 µg/m&lt;sup&gt;3&lt;/sup&gt; PM2.5</td>
<td>1.059</td>
<td>1.56E-01 3.1E-01</td>
</tr>
<tr>
<td>Lung cancer</td>
<td>Adults &gt;30</td>
<td>10 µg/m&lt;sup&gt;3&lt;/sup&gt; PM2.5</td>
<td>1.082</td>
<td>2.26E-02 4.4E-02</td>
</tr>
<tr>
<td>Acute lower respiratory infections (ALRI)</td>
<td>Children &lt;5</td>
<td>10 µg/m&lt;sup&gt;3&lt;/sup&gt; PM10</td>
<td>1.01</td>
<td>1.64E-02 3.8E-02</td>
</tr>
<tr>
<td><strong>Indoor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease (COPD)</td>
<td>Adults &gt;30</td>
<td>Solid fuel use</td>
<td>3.2</td>
<td>2.72E-02 5.4E-02</td>
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<tr>
<td>Lung cancer</td>
<td>Adults &gt;30</td>
<td>Solid fuel use</td>
<td>1.9</td>
<td>1.00E-03 2.0E-03</td>
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<tr>
<td>ALRI</td>
<td>Children &lt;5</td>
<td>Solid fuel use</td>
<td>2.3</td>
<td>1.48E-02 3.4E-02</td>
</tr>
</tbody>
</table>

<sup>a</sup>These values would be different in other parts of the world. See References 17 and 55.
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
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

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

Once global and national markets pick up their portions, local market can pay remainder DR ~40%

Technology

Economic Development
Co-benefits projects
Coal to biomass stoves
Thank you

Publications and presentations available at
http://ehs.sph.berkeley.edu/krsmith/