# New Scientific Consensus on Black Carbon: And Potential Cookstove Mitigations

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Institution</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>James L. Plummer</td>
<td>Founder, IAEE</td>
<td>President, Climate Economics Institute</td>
<td><a href="mailto:plummer@Climateeconomicsinstitute.org">plummer@Climateeconomicsinstitute.org</a></td>
</tr>
<tr>
<td>Dale T. Manning</td>
<td>Assistant Professor</td>
<td>Assistant Professor Agricultural and Resource Economics</td>
<td><a href="mailto:Dale.Manning@colostate.edu">Dale.Manning@colostate.edu</a></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Colorado State University Fort Collins, Colorado</td>
<td></td>
</tr>
</tbody>
</table>
THE NEW SCIENTIFIC CONSENSUS FROM THE GEOPHYSICAL SOCIETY

• In January 2013, the Journal of Geophysical Research: Atmospheres, the journal of the Geophysical Society, announced that it would publish a report entitled “Bounding the Role of Black Carbon in the Climate System: A Scientific Assessment.”

• The 286 page report has 31 authors from around the world and had been commissioned so that, once “accepted,” it could be considered in the IPCC Assessment Report 5 (AR5) which is due out in 2014.
BC Global Warming Potentials (GWPs)

For both direct and indirect warming effects (including effect of deposition on snow and ice). The report covers the wide uncertainties around these central estimates, but this presentation will only use the central point estimates.

20 year GWP:
Central estimate: 3200
This central estimate is used in the early slides of this presentation for physical comparisons of BC and CO2 impacts in 1 to 20 year comparisons.

100 year GWP:
Central estimate: 910
This central estimate is used in the later slides in this presentation for comparisons of the economics of mitigating BC and CO2 over a 100 year timeframe.
WORLDWIDE BC EMISSIONS

• Central estimate of 7.8 million tonnes of BC as of 2000, and the authors acknowledge a wide degree of uncertainty.

• All scenarios show an overall decline during the century — roughly a 50% decrease by 2100. That corresponds to a compound rate of annual decline of about 0.7%

• A 0.7% annual decrease would equal a 51,600 tonne decline for 2008/2009.
Global scenarios for black carbon emissions

Scenarios
- AIM - RCP 6.0
- IMAGE - RCP3-PD (2.6)
- MiniCAM - RCP 4.5
- MESSAGE - RCP 8.5

Year

Emissions (Tg/yr)

Bond et al 2013
COMPARING GLOBAL WARMING EFFECT 2008

GWP (Global Warming Potential) measures the total atmospheric heat trapping of a pollutant, compared to CO2.

For CO2 in 2008, the 29.9 billion tonnes x the GWP of 1.0 is a lifetime warming effect of 29.9 billion GWPs.

For BC, its 7.37 million tonnes (as of 2008) x the GWP of 3,200 is a warming effect of 23.6 billion GWPs.

So, the worldwide warming effects of BC are 78.9% of the warming effects of CO2, using a pollutant lifetime comparison. That is more warming effect than all the coal-fired power plants on earth.
Comparing the first year warming effects of the two pollutants

For CO2, only 2.5%* of the lifetime GWP impact is felt in the first year after the pulse. So, in 2008, 29.9 billion GWPs x 2.5% yields a first year warming effect of 747 million GWPs.

The entire 23.6 billion GWP warming effect of BC in 2008 is felt in the same year after the pulse.

**Conclusion:** In terms of the warming impact in the year of the pulse, worldwide BC exceeds CO2 by a factor of 31.6.

IS THE SIZE AND WARMING EFFECT OF BC ENOUGH TO IMPACT THE PERIOD TO PERIOD MOVEMENT IN TEMPERATURES?

• For the 15 year period from 1998 through 2012, there was no net increase in average global temperature, according to the Climate Research Center at the U of East Anglia.

• Many possible explanations have been offered, including:
  ▪ Inadequate knowledge of the level and changes of ocean absorption of CO2 and other ocean related unknowns (e.g. El Niño effects)
  ▪ Solar natural variation

• Is the annual decline in BC emissions levels enough to be a partial explanation for the pause in average global warming?
COMPARING THE FIRST YEAR CO2 WARMING WITH THE FIRST YEAR WARMING FROM THE DECREASE IN BC

For CO2, as calculated previously herein, the first year warming impact of the 29,888 million tonnes of emissions in 2008 is 747 million GWPs.

For BC, a 0.7% annual decline rate corresponds to a **cooling effect** of 165 million GWPs—22.1% of the warming effect of worldwide CO2 emissions in the first year.

**Conclusion:** The yearly decline in BC is one of the potential causes of the pause in the yearly increases in average global warming.
There are important weaknesses in the current CO2-only approach to climate policy and climate research

• Ignores the potential role of BC in the year-to-year and decade-to-decade changes in average temperatures

• Global warming depends more on what happens in less developed nations than what happens in Europe and the U.S.

• Since the GWPs from CO2 are less than the GWPs from all the other radiative forcing pollutants (BC, methane, NOx, Sox), a CO2-only approach is very incomplete.

• BC mitigation is a very different challenge than CO2 mitigation!
THE GEOGRAPHY OF CLIMATE CHANGE (including BC):

• The regions that will be most negatively impacted by global warming are in Asia, south Asia, and Africa

• Many of the non-CO2 pollutants most relevant to global warming in less developed regions (BC, methane, NOx, sulphur oxides) originate in those same less developed regions. Those pollutants have most (but not all) of their impacts within the same region.

• 75% of BC emissions are in Asia, south Asia, Africa and Latin America

• Yet, most of the action to fight climate change is in Europe and parts of the U.S. (e.g., California). Isn’t that a geographical mismatch?
CO2 v. BC: isodamages and isocosts

• The tradeoff figure on the next slide shows the isodamages lines that have a slope of -910 (the ratio of the GWP for BC and the GWP for CO2).

• If it is efficient to spend $36 per tonne of CO2 mitigation, then it would also be economically efficient to spend $32,760 ($36 x 910) per tonne of BC mitigation.

• This research attempts to quantify the benefits and costs of BC mitigation via cookstove replacement.
ECONOMICALLY EFFICIENT MIX OF BC AND CO2 MITIGATION
A transfer of $36 per tonne of CO2 avoided, and $27,300 per tonne of BC avoided
BC MITIGATION VIA COOKSTOVE REPLACEMENT (ANY KIND OF COOKSTOVE) IS A BIG BUT DIFFICULT TARGET

• BC from cookstoves makes up about 23% of all BC emissions, or about 2.15 million tons per year. That cookstove BC pollution is equivalent to about 46% of the global warming from all coal plants on earth.

• The importance of replacing traditional cookstoves was the driving force in the creation of the Global Alliance for Cookstoves, a private foundation in Washington, D.C., under the umbrella of the United Nations Foundation.

• The two most important types of cookstove replacement are:
  ▪ Replacement with more efficient woodstoves
  ▪ Replacement of traditional woodstoves with propane stoves
IMPROVED WOODSTOVE MITIGATION IN PARTS OF THE DEVELOPING WORLD WITH MUCH LOWER INCOMES

• There have been several recent field studies experimenting with improved woodstove adoption in countries with very low per capita incomes—China, India, Ghana, Guatemala and Senegal.

• The results from all of these studies are quite discouraging. Poor households did not maintain the stoves, did not operate them correctly, and retrogressed back to using their tradition woodstove for most of their cooking. Even where the stoves were installed, maintained and operated correctly, the households were strongly resistant to using the new technology.
DEFINING THE “HOLY GRAIL” IN IMPROVED WOODSTOVE S

- A stove with only the **barest** required maintenance (not even chimney cleaning)
- No electricity input requirement (e.g. to run a fan)
- Even though the fuel chamber can be partly enclosed, access to the cooking pots has to be easy.
- Increased efficiency enough that the household notices substantial (e.g. 50%) decreases in firewood collection times
- The initial capital cost of the new stove has to be subsidized at high levels (approaching 100%)
- Intensive education on indoor air pollution.

**Current technologies are far from these goals**
PROPANE REPLACEMENT MAY BE EFFICIENT IN SOME COUNTRIES

• Switching from traditional wood stoves to propane could be a good bargain in terms of climate change, indoor and outdoor pollution, and decreased forestry degradation

• But only in those areas of the world where the rural poor could potentially afford the after-subsidy initial capital outlay and the after-subsidy annual outlay for propane

• Obstacles:
  ▪ Liquidity for buying the stove or propane
  ▪ Low values of firewood collection time (i.e., cheap firewood)
  ▪ Taste of the food may be less preferable
  ▪ Gender issues: Male heads of household may suffer less health effects and be less involved in firewood collection
AN EXAMPLE FROM RURAL OAXACA, MEXICO: IS FUEL SWITCHING A COST EFFECTIVE WAY TO MITIGATE BC EMISSIONS?

RESIDENTIAL BIOMASS FUEL

- 101 kilos of firewood = a million BTUs in a traditional woodstove
- Emissions = 86.1 grams of BC and 96,634 grams of CO2.
- GWP = \(\frac{(86.1 \times 910 + 96,634 \times 1)}{1000000} = 0.175\) GWPs

SWITCH TO RESIDENTIAL PROPANE FUEL

- 20 kilos of propane = 62,300 grams of CO2 and a negligible amount of BC.
- GWP = \(\frac{62,300}{1000000} = 0.06\)

→ Propane pollutes less per unit energy than firewood.
MODEL OF GAS STOVE ADOPTION

• We consider a marginal household that has not adopted propane

• Parameter values:
  • Household energy demand: 56.9 million BTUs (assumed inelastic)
  • Propane stove cost: $105—use 70% less energy than wood
  • Annual propane cost: $465 (full adoption)
  • Health costs of propane: $43 (Jeuland and Pattanyak 2012)
  • 10-year stove life, 3% discount rate
  • Cost of wood collection: $226 (based on time valued at village wage rates)
  • Health costs of wood: $72 (Jeuland and Pattanyak 2012)
MODEL OF GAS STOVE ADOPTION

- Firewood collection has external costs
  - Deforestation
  - Conflicts associated with trespass or common property
- Firewood GWPs (100-year)
  - CO2: 5.5 GWPs for 56.9 MMBTU
  - BC: 4.5 GWPs for 56.9 MMBTU
- Propane GWPs
  - CO2: 3.5 GWP for 56.9 MMBTU, but propane stove uses less energy
POLICY EVALUATION

- Subsidy of 50% of capital and 40% of annual propane costs
- With adoption, assume propane stove is used for X % of cooking
- Net Benefit = value of time saved in firewood collection and lower social costs of firewood
- Cost is the present value of both subsidies
WHAT GWP FOR BC SHOULD BE USED?

• A body of literature exists on estimates of the Social Cost of Carbon (SCC) for CO2. The U.S. Office of Management and Budget (OMB) conducted a survey of academic literature and arrived at a SCC of $36/tonne of CO2 avoided as the standard for U.S. government programs.

• By scientific convention, CO2 has a Global Warming Potential (GWP) of 1.0.

• So, by extension the social cost of a tonne of other global warming pollutants would be its GWP x $36.

• However, this creates a potential problem for the short-lived pollutants such as Black Carbon (BC). Its 20 year GWP is 3200. Its 100 year GWP is 910. That is because beyond 20 years after emission, BC has very little warming impact whereas CO2 continues to have an impact.

• The economic life of a propane stove is about 10 years. So, one argument would be that a 20 year GWP is a lot closer to that than a 100 year GWP.

• The counter argument is that, if we are interested in knowing the full impact of an emission of a global warming pollutant, we should look at the full future impact and not be concerned with the stove lifetime.

• For purposes of this exploratory research we do the calculations both ways.
### BENEFIT-COST RATIOS FOR DIFFERENT COMBINATIONS OF PARAMETERS, USING A CONSERVATIVE 100 YEAR GWP OF 910 FOR BLACK CARBON

<table>
<thead>
<tr>
<th>% cooking with Propane stove</th>
<th>$36</th>
<th>$75</th>
<th>$100</th>
<th>$150</th>
</tr>
</thead>
<tbody>
<tr>
<td>33%</td>
<td>0.63</td>
<td>2.21</td>
<td>3.22</td>
<td>5.24</td>
</tr>
<tr>
<td>50%</td>
<td>0.74</td>
<td>2.38</td>
<td>3.44</td>
<td>5.55</td>
</tr>
<tr>
<td>67%</td>
<td>0.79</td>
<td>2.47</td>
<td>3.55</td>
<td>5.7</td>
</tr>
</tbody>
</table>
BENEFIT-COST RATIOS FOR DIFFERENT COMBINATIONS OF PARAMETERS, USING A LESS CONSERVATIVE 20 YEAR GWP OF 3200 FOR BLACK CARBON

<table>
<thead>
<tr>
<th>% cooking with Propane stove</th>
<th>Value of a tonne of CO2 reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$36</td>
</tr>
<tr>
<td>33%</td>
<td>3.16</td>
</tr>
<tr>
<td>50%</td>
<td>3.92</td>
</tr>
<tr>
<td>67%</td>
<td>3.51</td>
</tr>
</tbody>
</table>
INTERPRETATION OF B/C ANALYSIS

• Using a conservative 100 year GWP of 910, and a SCC of $36, the B/C ratio is less than 1.0 for all assumed % utilization. An SCC of 41 is required to reach a B/C of 1.0.

• If the less conservative 20 GWP for BC is used, then the B/C ratios become quite high, whatever the SCC and whatever the % utilization of the propane stove.

• All of this B/C analysis assumes a 50% subsidy of the initial stove costs and 40% subsidy of the propane cost. There would have to be creative and comprehensive regulation to prevent the formation of black markets. Or, the analysis can be redone assuming the 40% subsidy is given to all propane users, whenever they purchased the stove. And propane tanks used in cookstoves might have to be recognizable (e.g. green tanks).
PROPANE BENEFIT-COST RATIOS IN PERSPECTIVE

• This exercise can help define the conditions in which such subsidies might succeed:
  ▪ In countries where propane costs are already low or the national oil company would be willing to subsidize propane
  ▪ Where the “fracking revolution” may have large impacts.
  ▪ Areas where forestry damage from wood collection is a significant problem and/or indoor health damage from woodstoves is severe.

• These B/C ratios can also be compared with those from CO2 mitigation via subsidizing renewable energy in Germany or the rest of the EU. The 1/25/2014 issue of The Economist contained an article which quotes unnamed sources that the total cost of renewables in Germany, per tonne of CO2 avoided is 150-200 Euros ($205-$274). If that range of cost is anywhere near accurate, then the partial replacement of wood cookstoves with propane cookstoves in developing countries represents an opportunity for cost saving.
A LONG WAY FROM TAKING ADVANTAGE OF THE LARGE BC TARGET

• The worldwide GWPs from BC are nearly as large as the GWPs from CO2—though the science remains uncertain

• So, more effort should be directed toward finding ways of mitigating BC

• Mitigating cookstove BC is a natural focus, because it would alleviate both GWPs and the health effects of indoor pollution

• BUT there is not a clear pathway toward achieving large cookstove BC mitigation, and costs are high

• If technology breakthroughs occur in improved woodstoves, the B/C model structure herein could be applied