

CLIMATE ALERT

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Fire and Ice: Valuing Reductions in Short-Lived Climate Forcers



A Message from the President

Hope in the Climate Wars

John Topping, Jr., Climate Institute President



Just over six years ago, following on its twentieth anniversary Summit on Climate Stabilization about eighteen months earlier, the Climate Institute produced a thought-provoking volume: *Sudden and Disruptive Climate Change: Exploring the Real Risks and How We Can Avoid Them*. This book probed risks of accelerating climate change to the world's coastal cities and small island nations and to vulnerable populations of humans and other animal and plant life. It also examined a number of possible societal responses, among them innovative engineering defenses by coastal cities; the reduction of regulatory barriers to energy recycling that frustrate the implementation of cogeneration; and the mobilization of interfaith religious and university collaboration worldwide to foster response actions that transcend national boundaries.

The results in climate protection since 2008 have been mixed, at best. On the positive side we have seen some remarkable action by major industrial corporations and financial institutions to integrate climate change into long-term planning. Offsetting this, however, have been a number of disturbing developments, including

rapid growth in emissions in some large and rapidly industrializing countries, a relative paralysis in international climate negotiations, and a political polarization in the US Congress that has limited national action on climate change to executive agency regulation, which opponents have fought tooth and nail in the courts. Most alarming, however, have been mounting signs that sudden and disruptive climate change is not merely a legacy we are bequeathing to our grandchildren, but is in fact something that may already be well underway. A reduction since 1979 of about 80% in volume of Arctic summer sea ice may be beginning to wreak havoc on Northern Hemisphere weather systems. Although the science is still soft on this, one need not be a Hollywood screenwriter to wonder whether there might be a link between the rapid warming in the Arctic and some of the recent unusual weather events—a drought in the western US that is already evoking Dust Bowl comparisons, the wettest winter in England in a quarter millennium, and an occasional collapse of the Arctic Vortex that may have caused a meandering jet stream to produce brutally cold temperatures in much of the Lower Forty-Eight while Alaska basked in near record winter warmth. Although we have yet to experience the nightmare scenario of a climate-driven collapse of land-based food systems, we can draw no comfort from projections that overfishing may deplete fish stocks worldwide before the middle of this century. Moreover, there is mounting evidence that ocean acidification is beginning to inflict a serious toll on some species of shellfish.

In the face of these foreboding trends, there are some glimmerings of hope that humanity may be starting to piece

its way out of this fix. The focus of this issue of *Climate Alert* is on three buds of hope—an obscure US Life Cycle Assessment Standard being developed under the auspices of the American National Standards Institute (ANSI); cook stove and transportation retrofit efforts in Asia, largely driven by human health concerns; and signs that a few voluntary emission reduction credit institutions may be inclined to grant significant credit for reductions of black carbon. A perverse feature of the Kyoto Protocol-based greenhouse trading systems is that they have afforded zero value to reductions of black carbon and zero or minuscule values to reductions of tropospheric ozone compounds, despite growing evidence that reduction of these air pollutants is the most effective near and medium term means of slowing global climate change and one with special benefit in the Arctic and other ice-bound regions. Moreover, reduction of these pollutants would bring immediate health benefits. Black carbon and other air pollutants pose a grave threat to the health of people and crops in many parts of the world, particularly in South Asia. New estimates released 25 March 2014 by the World Health Organization (WHO) more than doubled projected annual global air pollution deaths to about seven million each year.

Whatever numbers health experts settle upon, local evidence of air pollution damage has helped spur some local remediation efforts. One of the most promising projects is an effort by an Australian firm, **Rotec Diesel**, to retrofit half a million Manila metropolitan area jeepneys with devices that would slash particulate emissions over 70%. The major stumbling block in this effort is that traditional carbon trading systems will grant carbon credits only for the carbon dioxide reductions from the modest fuel efficiencies from such devices. These systems provide no valuation for the much more significant

and life saving black carbon reductions. Cash-strapped jeepney driver/owners recognize the air pollution risks they and their passengers face but lack the resources to finance retrofits. Rotec, however, has cobbled together financing to do validation tests of black carbon reductions and now seems on the verge of implementing large-scale financing from some voluntary emission reduction credit groups. Having seen the emerging evidence of black carbon effects on climate and anticipating a new ANSI Life Cycle Assessment Standard that will provide robust valuation for such reductions, these emission reduction credit groups seem ready to step ahead of the greenhouse trading community and provide such credits. In coming weeks it is likely that Rotec and the Chinese Government may embark on a joint effort to retrofit about 200,000 trucks in Xi'an, capital of Shaanxi Province, to reduce particulate and black carbon emissions by over 90%.

Another air pollution reduction effort, Project Surya, founded by University of California San Diego scientist, **Veerabhadran Ramanathan**, seeks to develop black carbon reduction financing to spur transformation of cook stoves in India and elsewhere in South Asia. The transformation of tens of millions of cook stoves and retrofitting of millions of vehicles in Asia would both save millions of lives and reduce the radiative forcing that drives global climate change and melting in crucial regions, such as the Himalayas and the Arctic.

The Life Cycle Assessment Standard moving its way toward ANSI promulgation could prove to be the most significant advance in climate protection since the June 1992 signing of the UN Framework Convention on Climate Change in Rio de Janeiro. The emerging standard covers many other areas besides climate in setting out guidelines for life cycle assessment, among them air quality, water quality, and biodiversity. The proposed new standard provides for significant advances in all areas of life cycle assessment, looking much more at real

world exposures of both humans and fragile ecosystems.

Our discussion, however, centers more on its three climate-related indicators: 1) a global climate change indicator that establishes a valuation for reduction of black carbon and tropospheric ozone forming-compounds and enhances incentives for reductions of methane; 2) an Arctic climate change indicator that provides a mechanism for prioritizing mitigation actions that will slow Arctic climate change; and 3) an ocean acidification indicator that will highlight a change potentially as significant as we are experiencing in climate. Although the anticipated standard is voluntary and US-focused, it could have a global effect greater than that of any of the last dozen or so COPs. Once the standard is promulgated by ANSI and integrated by early adapting US-based multinationals into their investment planning, it will have an immediate extraterritorial effect as most would be expected to implement the new life cycle assessment guidelines throughout their supply chains. Moreover, the standard would likely nudge Kyoto-based trading platforms—created before the climate science community was fully aware of the important role of short-lived climate forcers in climate change—to provide valuation for reductions of emissions of black carbon and ozone-forming compounds. The Climate Institute has joined with two other groups to provide an umbrella for an Arctic Climate Action Registry (ACAR) to incentivize actions that would slow Arctic climate change. Once ANSI adopts a Life Cycle Assessment Standard with an Arctic climate indicator, existing climate registries would be free to integrate this into their analysis, perhaps negating the need for a stand-alone Arctic Registry.

This issue of **Climate Alert** contains four articles concerning the potential implementation of strategies to reduce black carbon and other short-lived climate forcers to slow climate change while reducing the risk air pollution

poses to human health. The first of these, jointly by **Tobias Schultz**, Life Cycle Assessment Practitioner of SCS Global Services, and **Michael MacCracken**, Chief Scientist for Climate Change Programs of the Climate Institute, applies the metrics of the Arctic climate change indicator of the emerging ANSI standard to calculate the relative radiative forcing share of the eight Arctic Council member nations and the two largest observer nations—China and India. The second article by **Thishan Dharshana**, Graduate Research Fellow and a national of Sri Lanka, explores the potential of drawing on air quality monitoring data systems across the globe to supplement data gathered by the Global Change Observation System to track trends in climate forcers. The final two articles, also by Climate Institute Graduate Research Fellows, both from India, include an article by **Shirin Bithal** exploring cook stove emission mitigation efforts in South Asia and another by **Pallavi Pant** at the University of Birmingham on vehicle emission mitigation strategies in various parts of Asia. Both highlight the advantages of adjusting the climate credit and trading systems to provide a robust valuation for black carbon reduction. Finally, we should recognize that the bulk of black carbon emissions affecting Arctic climate change are from grassland burning and forest fires, as pointed out by **Gerard Wedderburn-Bisshop**, Chief Scientist of World Preservation Foundation, in “**Burning Up the Arctic**” in the winter 2012 issue of *Climate Alert*. Much of black carbon emissions from other regions comes from such sources. Incentivizing these reductions is likely to be a much dicier proposition than the cook stove and vehicle situations, but the proposed ANSI standard lends itself to calculating such averted radiative forcing. Should the draft ANSI standard be promulgated within the next twelve months, as I profoundly hope, we may begin to gain real traction in the climate protection battle.

The Contribution to Arctic Climate Change from Countries in the Arctic Council

Tobias Schultz, SCS Global Services and Michael MacCracken, Climate Institute

This note summarizes a case study of the implementation of a new approach for estimating contributions to Arctic climate change from climate-forcing emissions. The approach used is based on the guidance and requirements of the Draft LEO-SCS-002 standard being developed under the American National Standards Institute (ANSI) process [1].



Figure 1: The scope includes the United States, China, India, Russia, and the Nordic Countries (image from Google Earth).

Using this developing metric, we calculate the contribution to Arctic climate change of emissions originating within the borders of the eight member countries and two largest observer states of the Arctic Council. The member countries include the United States, Canada, Russia, and the five Nordic countries: Denmark, Finland, Iceland, Norway, and Sweden. The two observer states included are China and India.

Methodology

The calculation method used is based on the Absolute Regional Temperature Potential (ARTP) model developed by Shindell and Faluvegi [2,3], following the requirements of Section 4.2 of Annex A of the Draft LEO-SCS-002 standard (March 2014 version).

For the purposes of this research, the Arctic is defined as the region of the Earth's surface north of 60° north latitude. The calculations account for the influences of all radiatively significant short-lived climate forcers

(SLCFs) and well-mixed greenhouse gases (WMGHGs).

Inventory (Emissions) Data

For the member countries of the Arctic Council, the emissions data are from the 2014 National Inventory Reports (NIR), which provide 2012 emissions, and from the Arctic Monitoring and Assessment Programme (AMAP) 2011 report, which provides black carbon (BC) and organic carbon (OC) emissions in 2000. For China and India, emissions for each substance are drawn from several published sources [4,5,6]. Emissions of BC, OC, and carbon dioxide (CO₂) from open burning and deforestation are from the Global Fire Emissions Database version 3 (GFED3) [10]. The BC emissions from these data sources are based on “bottom-up” inventory models that have been found to underestimate actual emissions of BC for most regions [7]; the emissions levels of BC are thus scaled to correct for this underestimate.

The significance of local emissions on climate change in the Arctic, particularly of BC, is well understood. Of all emissions occurring in or near the Arctic, emissions from forest fires are by far the largest contributor to inducing a warming influence in the Arctic; local emissions from industrial sources currently account for a negligible amount of Arctic warming influence when compared to forest fires. Emissions from forest fires occurring in or near the Arctic are characterized separately from emissions far from the Arctic. Emissions levels, by substance and country, are characterized as an expected value and upper and lower confidence bounds. These confidence bounds are used to develop a confidence interval for final results. Expected values of the emissions levels are shown in Tables 1 and 2.

Arctic Temperature Potentials

Results are based on use of Arctic Temperature Potentials, which are established for each substance considered using the ARTP model

calculated on a 20-year time horizon (ATP-20). ATP-20 is the ratio of the average change after 20 years in the Arctic surface temperature resulting from the emission of one Teragram (Tg) of a substance to the average change in Arctic surface temperature after 20 years caused by the emission of one Tg of CO₂. ATP-20s have units of Tg CO₂e per Tg of emission.

For Short-Lived Climate Forcers (SLCFs), which only cause radiative forcing in the general area of the source of emission, the region where an emission originates has a strong influence on the ATP-20; generally, SLCFs emitted close to the Arctic have ATP-20s that are larger in magnitude than for those emitted outside the Arctic. The ATP-20s for long-lived GHGs, which tend to spread evenly throughout the atmosphere because of their long their atmospheric lifetime, are independent of the location of emission.

Where possible, the ATP-20 for each substance is calculated based on mass-normalized radiative forcing and temperature response values provided in the peer-reviewed literature [10-17]. The ATP-20s are expressed as an expected value, with upper and lower confidence bounds. These confidence bounds are used to develop a confidence interval for final results. Expected values and confidence bounds for the ATP-20s are shown in Figure 2.

Due to limitations in observational data sets, the ATP-20 for brown carbon (BrC) had to be assumed. For BrC emitted from open burning far from the Arctic, the total effect is estimated to be equivalent to 25-100% of the total forcing from BC. The mean of these values (62.5%) is used for the expected value. For BrC emitted in or near the Arctic, it is estimated that the total effect of BrC from open burning in these regions is 50% of the total effect of BC from these sources [18,19].

Emissions far from Arctic	Unit	Nordic	Canada	India	Russia	USA	China
BC, energy-related	tons BC	36,000	44,000	3,800,000	320,000	440,000	3,300,000
OC, energy-related	tons OC	56,000	53,000	2,200,000	620,000	520,000	3,400,000
BC, forest fires	tons BC	Negligible	Negligible	72,000	3,200	14,000	20,000
OC, forest fires	tons OC	Negligible	Negligible	150,000	90,000	120,000	110,000
CO ₂ , industrial sources	tons CO ₂	180,000,000	550,000,000	2,000,000,000	1,700,000,000	5,400,000,000	8,300,000,000
CO ₂ , open burning and deforestation	tons CO ₂	Negligible	Negligible	62,000,000	22,000,000	34,000,000	35,000,000
Nitrous oxide (N ₂ O)	tons N ₂ O	73,000	170,000	430,000	440,000	1,300,000	2,000,000
Methane (CH ₄)	tons CH ₄	710,000	4,800,000	23,000,000	25,000,000	27,000,000	44,000,000
HFCs, PFCs	tons HFC	1,200	3,000	29,000	4,500	51,000	120,000
Nitrogen oxides (NO _x)	tons NO _x	590,000	1,900,000	4,600,000	5,600,000	12,000,000	13,000,000
Sulfur dioxide (SO ₂)	tons SO ₂	190,000	1,300,000	8,800,000	690,000	4,700,000	31,000,000

Table 1. Inventory data used, showing expected values for emissions occurring far from the Arctic.

Expected Value, in or near Arctic	Unit	Nordic	Canada	India	Russia	USA	China
BC, forest fires	tons BC	Negligible	52,000	None	140,000	14,000	None
OC, forest fires	tons OC	Negligible	820,000	None	2,100,000	220,000	None
CO ₂ , forest fires and deforestation	tons CO ₂	Negligible	160,000,000	None	460,000,000	44,000,000	None

Table 2. Inventory data, showing expected values for emissions occurring in or near the Arctic. Of all emissions in or near the Arctic, BC, OC, and CO₂ from forest fires are the dominant contributor to Arctic climate change.

Uncertainty Analysis

The uncertainty analysis incorporates the confidence intervals for both the inventory data and the ATP-20 values. Although this is a simplification, calculation of the final confidence interval, associated with each data point has been determined by setting the value for each of the two factors to its upper and lower confidence bound, with all other data points fixed at the expected value. The uncertainty value for each data point was then combined in quadrature (i.e., as a square root of the sum of squares) to determine the confidence interval for final results.

Results and Discussion

For the countries considered, the five largest contributors to warming in the Arctic, in order of significance, are China, the United States, Russia, India, and Canada; emissions from the Nordic Countries collectively account for a much smaller contribution. The results are shown in Figure 3, showing the contribution of emissions originating far from the Arctic and from forest fires in or near the Arctic.

The combined result of emissions from these countries is roughly 45 Gigatons each year (Gt) CO₂e (ATP-20); the uncertainty analysis gives

an emissions range equivalent to as high as 57 Gt CO₂e to as low as 30 Gt CO₂e per year. Of the total, China is the largest contributor, accounting for roughly 35% of the warming influence. The United States is the second largest contributor, accounting for over 20% of the warming influence. Russia accounts for roughly 20%, and India 17%. Canada and the Nordic Countries have much smaller contributions, accounting for 6% and 1% of the total. Even though it does not border the Arctic, China is the largest contributor to Arctic climate change, due to its substantial levels of BC, CO₂, CH₄, and NO_x emissions.

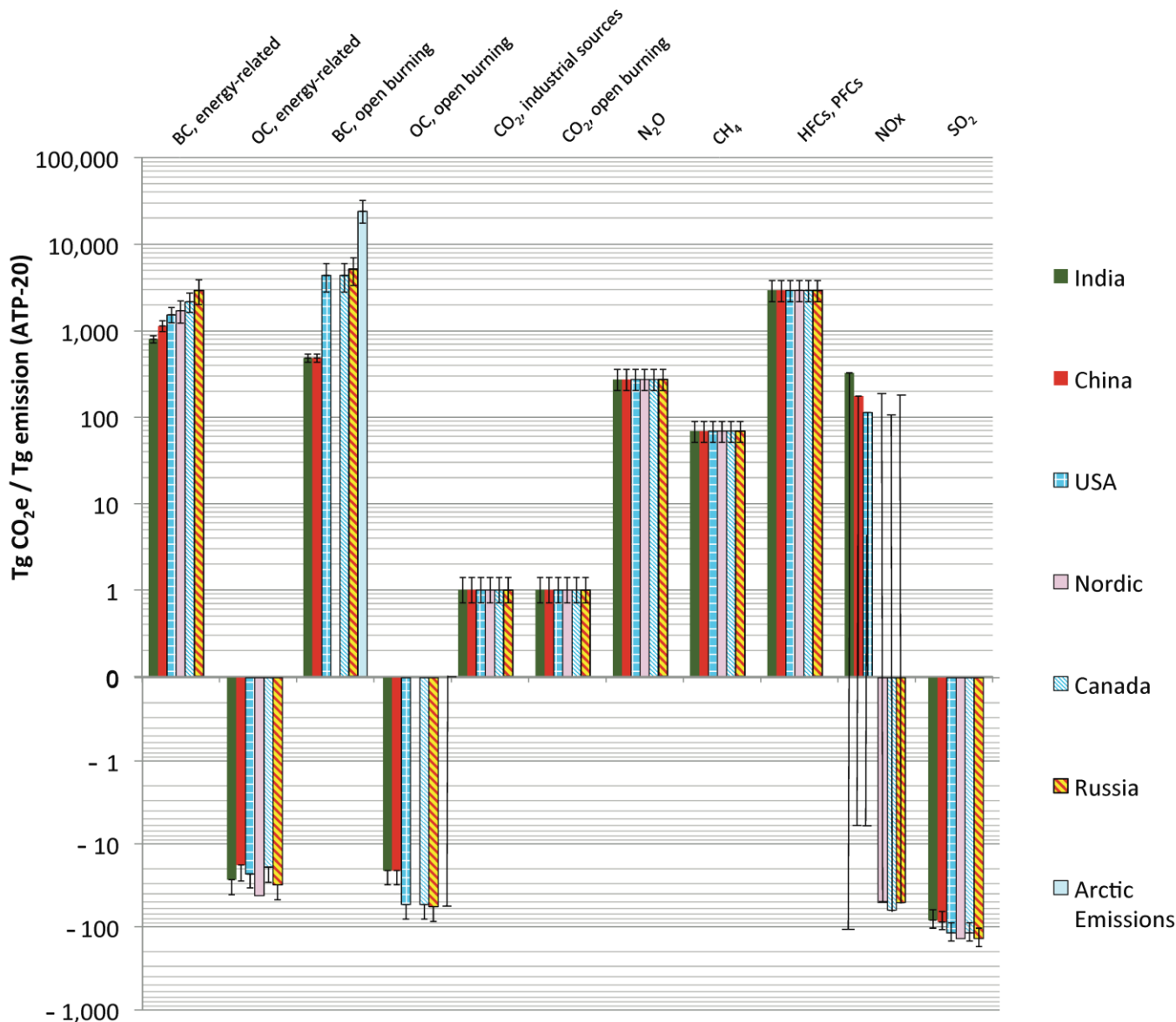


Figure 2. Arctic Temperature Potentials, by substance and region, calculated on a 20-year time horizon.

The relative ranking of these countries does not change when compared to global emissions levels calculated using the most commonly applied metric, the Global Warming Potential calculated on a 100-year time horizon (GWP-100). However, the inclusion of carbonaceous aerosols makes Russia and India much closer to the USA in terms of final results than has been previously understood. Considering the confidence intervals in the final results, there is significant overlap between these three countries.

One of the most significant differences in the Arctic climate profile, when compared to results based on the GWP-100, is the importance of forest fires in the Arctic region. Emissions of BC and BrC in this region exert a very strong warming influence in the Arctic; comparatively, one ton of BC emitted in this region exerts a warming influence, after 20 years, that is equivalent to over 23,000 times the warming influence of emitting one ton of CO₂. The net result from Russia is almost doubled when considering emissions from forest fires in or near the Arctic. In the US, forest fires in

Alaska increase the net loading of the entire country by roughly 5%. This illustrates the importance of considering the influence of all emissions that affect the Arctic and of paying particular attention to the source type of these emissions.

This is a preliminary analysis that would benefit from additional information on the characteristics and amounts of emissions within these country borders. This is a necessary step and one that would aid in the prioritization of mitigation efforts.

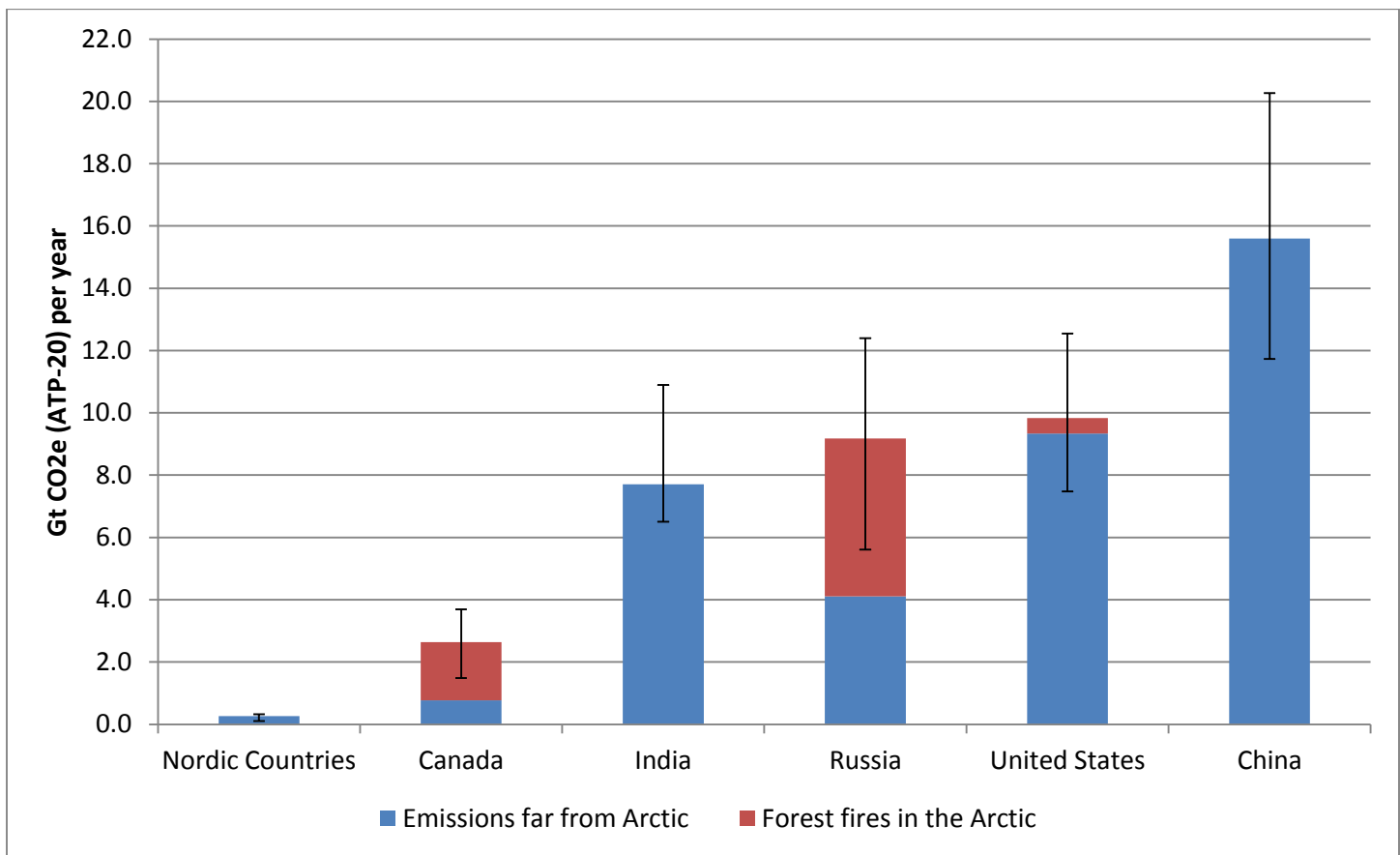


Figure 3. Results for impacts to Arctic climate change, in units of Gigatons of CO₂e (ATP-20) per year.

*Article courtesy of SCS Global Services.

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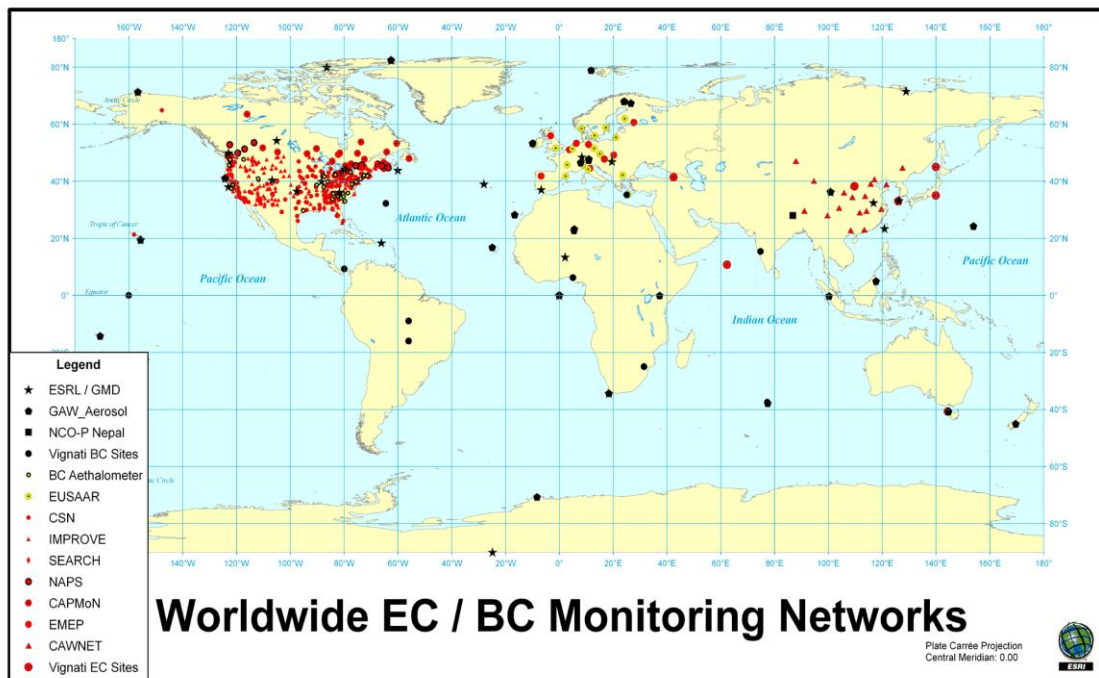


Figure 1: Ambient BC measurement locations worldwide. Light absorption measurement locations are colored black, while thermal measurement locations are colored red. Source: U.S. EPA [2]

Leveraging Air Quality Monitoring Systems to Integrate BC Emissions into Global Climate Data Systems

Thishan Dharsana

Black carbon (BC), which refers to the absorbing components of soot, has been found to play a significant role in climate change in addition to posing a threat to human health and limiting visibility. The central value of $GWP_{BC, 100} \sim 680$ means that during 100 years after emission, 1kg of BC produces as much energy as 680kg of CO_2 [1]. The fact that BC can absorb most of

intercepted visible light—while the impact of CO_2 occurs only over a limited range of IR wavelengths—supports this comparison between energy absorption.

Despite the clear importance of BC, the most significant barrier to dealing with BC is associated uncertainties. The most practical way to overcome these

uncertainties will be to build a larger database, which can be met in large part by integrating BC observations from local air quality-monitoring systems (AQMS) into a global climate data system. There are several constraints, however, that could make achieving this goal difficult, and this article outlines the most important challenges.

Table 1: U.S. 2005 emissions (in tons) and emission ratios by mega-source category. Source: U.S. EPA [8]

Mega Source Category	PM _{2.5}	BC	OC	OC/BC	BC/PM _{2.5}
Open Biomass Burning	2,266,513	224,608	1,058,494	4.7	0.1
Residential	464,063	22,807	204,160	9	0.05
Energy/Power	712,438	43,524	65,138	1.5	0.06
Industrial	219,460	6,085	16,234	2.7	0.03
Mobile Sources (Transport)	626,859	333,400	205,172	0.6	0.53
Other	1,232,123	6,743	112,967	16.8	0.01
Totals (Short Tons)	5,521,456	637,167	1,662,165	2.61	0.12
In GigaGrams (Gg)	(5,009)	(578)	(1,508)		

As evident from Fig.1, existing ambient BC monitoring locations are not evenly distributed around the globe. Most of the monitoring stations are in the United States, Canada, Europe, and China, whereas other regions have relatively few monitoring locations. While the uneven distribution of monitoring units poses one problem, a second arises because the observations are being made using two different techniques, complicating integration of BC data into a single global database.

A third difficulty is that BC's short lifetime of days to weeks makes it more of a regional pollutant than CO₂, which has a lifetime of centuries and so is globally distributed. Because of this, the climate impacts of BC depend strongly on when and where it is emitted [3]. Therefore, a global data system built on data shared from local AQMS is further encouraged because BC affects the climate differently from GHGs that are well mixed in the atmosphere [3].

Different sources of BC dominate different regions, and each source of BC has its own characteristics. For instance, a region dominated by biomass burning generates BC emissions and therefore atmospheric impacts that are different from those in a region dominated by industrial emissions [e.g., biomass burning emits substantially more brown carbon (BrC) than black carbon (BC)]. There are even substantial differences between sub-categories of BC emissions; for example, emissions from boreal forest fires are different

from emissions from savanna/grassland burning. Resolving and documenting these differences will be greatly aided by incorporating data from local AQMS into the global system.

Location of emissions can also have an important effect. Considering impacts on the Arctic, the radiative forcing (direct and snow/ice albedo only) associated with one ton of BC emitted from the region between 50N-60N exerts a three times larger warming influence than a ton of BC emitted from the region between 40N-50N, and one ton of BC emitted from the region north of 60N has seven times greater effect than one ton of BC emitted from the region between 40N-50N. Currently, nearly half of the emissions come from regions south of 50N, and most of the remainder comes from the region between 50N-60N [4]. Because different geographical regions have different land cover types and types of industry and other sources, a number of additional uncertainties can arise. These uncertainties, in turn, can influence the choice of mitigation strategies.

As shown in the U.S. EPA report to Congress on black carbon [5], global ground level loadings of BC can vary from less than 0.1 µg/m³ in rural locations to ~15 µg/m³ in urban centers. Based on data from existing monitoring locations, the same study indicates that typical BC concentrations in both urban and rural locations in China are ten times higher

than concentrations in North America and Europe.

Roughly two-thirds of global BC emissions, which total nearly 8.4 million tons, are a result of open biomass burning and residential sources (predominantly from cooking with wood stoves). Africa, Asia, and Latin America are responsible for nearly 75% of global BC emissions [6]. As shown in Figure 1, existing BC monitoring locations are widely spread in these regions (and this would be even more apparent in an equal area map). To develop a better understanding about BC effects in these regions, both additional observing stations and greater sharing of data with global climate data centers will be necessary.

Further research is also needed on how the BC to organic carbon (OC) ratio can be used to estimate climate impacts. Of all BC source types, diesel combustion creates the highest fraction of BC while open biomass burning generates the highest fraction of OC [6]. In quantitative terms, for fuel combustion, diesel PM_{2.5} consists of ~70-80% BC and ~20% OC. On the other hand, gasoline PM_{2.5} contains ~20% BC and most of the remainder is OC [7]. If these ratios can be determined for other sources and regions, as has been done for the United States (Table 1), then it would be much easier to estimate the distribution of BC and OC loadings.



Low-level flames moving through a patch of Ponderosa pine in an Arizona wildfire, 2014. Accessed at Incident Information System 12 June 2014: <http://inciweb.nwccg.gov/incident/photograph/3883/0/>

BC's impact on climate is also influenced by the seasonal "albedo" effect—the cooling effect that results from the reflection of the sun's rays back into space by snow and ice. When BC is deposited on snow/ice surfaces, it reduces the fraction reflected and thus leads to regional surface warming. The amount of BC deposited on snow/ice is a function of amount of atmospheric BC, but its relative effectiveness is affected by the amount and frequency of snowfall over a particular region [9]. Because precipitation is the main mechanism of atmospheric BC removal [10], the removal rate depends somewhat on the season, affecting the amount of BC deposited on snow/ice.

Because of BC's darkening effect on snow and ice, the Arctic experiences greater radiative forcing from BC than other regions. Both the seasonality of BC deposition and of solar radiation reaching the Arctic means that the effects of BC can fluctuate significantly throughout the year [11].

Wild fire emissions also vary greatly from year to year. In addition,

estimates of emissions can vary because of both the fire reporting system and the method used to calculate emissions [12-13]. Based on techniques being used, it is likely that fire emissions (both BC and OC) are being underestimated in many regions due to inadequate accounting for emissions from smaller fires [14].

Despite the described and other potential difficulties in adding BC data from local AQMS into a global system, it is likely that these can be overcome with time as climate scientists recognize the utility of the larger and more complete database.

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Improved Cookstove Initiatives in South Asia

Shirin Bithal



Woman in western India preparing a meal using an indoor wood stove. Image by Dan Tunstall/WRI, <http://www.worldwatch.org/node/6328>.

Until recently, carbon dioxide was considered to be the biggest contributor to climate change. However, research conducted by environmentalists and scientists has proven that short-lived climate pollutants (SLCP) like methane, black carbon, and ozone are as threatening in the short run as carbon dioxide is in the long run.

The largest sources of black carbon emission by Arctic nations (USA, Canada, Russia, Denmark, Finland, Sweden, Ireland, and Norway) include forest fires and diesel vehicles; smaller sources include household fires, off-road diesel, agricultural burning, and industrial combustion [1]. In the observer nations (India and China) and several Arctic nations, residential fires are expected to become the key contributor.

The Intergovernmental Panel on Climate Change [2] has already discussed BC as an increasing contributor to climate change and has recommended its reduction. India revealed its plans for working towards

a reduction of BC and other SLCPs at the UN climate change conference in Copenhagen in 2009 primarily because of their health impacts—another reason to prioritize reducing black carbon emissions [3].

Indoor Air Pollution

Around three billion people worldwide rely on biomass and fuels as their primary energy source for cooking and heating. Indoor air pollution affects India more than any other country. Apart from emissions of black carbon due to incomplete combustion, open fires and cookstoves do not burn their fuels efficiently, leading to increased time spent on cooking and increased exposure to harmful fumes. Over 70% of India's population lives in rural households.

As many as 2.5 million premature deaths take place around the world due to air pollution [4-5], and in India alone there have been an estimated 400,000 to 550,000 premature deaths annually due to air pollution caused by cookstoves, which leads to pulmonary and respiratory disorders in women and children under age five years. Other health effects include pneumonia, cardiovascular diseases, lung cancer, bronchitis, and sinusitis [6]. Apart from these health effects, there are additional effects associated with collecting biofuels. Women have to spend one-and-a-half to two hours on average daily in search of wood, twigs, cow dung, etc. Travelling long distances to search for these biofuels also puts them at safety risks (sexual abuse, violence), especially in unfamiliar areas.

Cookstoves in India

Rural Indian households use biomass and solid biofuels despite “modernization,” the positives of which have only affected urban households that can afford to switch to use of compressed gas. The biofuels rural women use to cook meals in cookstoves include wood, twigs, dung, and leaves. Burning these biofuels

emits black carbon that the women and their children inhale, causing respiratory disorders. According to a 2010 World Bank study on disease in South Asia, deaths from non-communicable diseases—including respiratory disorders and heart disease due to indoor pollution from stoves—are rising even as many other measures of health are improving in the region [7]. Besides causing harm to human health, the emitted soot also adds to the existing climate change problem.

In India, almost 80% of the 160 million (128 million) rural households and 50 million urban households consume solid fuels as cooking fuels [6]. In India various attempts have been made since the 1980s to distribute improved cookstoves in rural households, from the Chulha initiative taken by the Indian government in the 1980s to Project Surya funded by international NGOs in the 2000s.

Dissemination Measures in India

India has been a prime target market for cleaner cookstove models because of its diverse population, rapidly growing economy, comparatively stable policy environment, infrastructure, and economic growth. There are 75-100 million households as potential consumers [8-9]. The recent WHO report on India's air pollution has proved to be an eye opener for the public as well as government. With a new government stepping into power in May, there is pressure to take action against rising air pollution, although it is too early to comment on what steps the government will take.

A number of factors play into the acceptance of improved cookstoves in rural households.

1. **Affordability:** Subsidies may be extremely necessary before expecting someone with a disposable income of less than \$2 a day to shift to these

cookstoves, the cost of which ranges from about \$20 to \$85.

2. **Quality** of the improved cookstoves.
3. **Motivation to adopt:** Benefits of these improved cookstoves need to be explained to every household. These benefits include cost saving, time saving, and elimination of indoor pollution.
4. **Level of engagement** among the community as a whole.

The main aim of Indian government however, is not to reduce the emissions released during the incomplete combustion of fuels while cooking but to target the adverse health impacts. Under the National Biomass Cookstove Initiative, around fifteen million improved stoves will be distributed per year for the next ten years, supplying 87% of Indian households. This will lead to a reduction in the premature deaths caused by respiratory disorders and disabilities projected to occur out to 2020, saving some fifty-five million years of healthy life, according to a study in *The Lancet* cited by a Worldwatch Institute article on the program [10]. A secondary consequence of improved cookstoves would be to avoid approximately half a billion to a billion tons of carbon dioxide-equivalent gases and particulate matter.



Low-smoke chulha designed to cut down on indoor air pollution. Designed by Philips for distribution by NGOs.
www.lowsmokechulha.com.

Indian Governmental Initiatives

The National Program on Improved Chulhas (NPIC) was started by the government of India in 1985 and lasted until 2002. These improved chulhas were costlier than the traditional mud chulhas, but they were intended to last five years instead of the two-year lifespan of traditional chulhas. The harmful flue gases and smoke were supposed to be released outside the house through chimneys. As part of this project, almost thirty-five million units with over sixty designs were installed in households, aiming to achieve their goals through the use of chimneys. However, durability, high program costs, performance, delivery, maintenance, skills available, and materials used were some prominent pitfalls in this program. The program relied on subsidies from the government for its delivery mechanisms with no provisions for maintenance or repair, which led to poor adoption rates. Due to this heavy subsidization, the campaign also led to undermining of local pre-existing stove markets. Also, these so called "improved" chulhas were eventually found to have higher emissions [11].

After the failure of the National Program on Improved Chulhas, the Ministry of New and Renewable Energy (MNRE) initiated consultations to check on the status of various cookstoves being promoted and developed by NGOs, entrepreneurs, and manufacturers in 2009-10. In December 2009 these consultations gave way to the National Biomass Cookstoves Initiatives (NBCI). Its main aims were to design an efficient, cost effective, and durable device. Unlike the NPIC, this program takes lessons from its failures and successes. The program has undertaken pilot projects using existing available cookstoves with different grades of biomass. The Indian Institute of Technology, New Delhi is also involved in the new initiative for improved cookstoves, with studies on the present status of improved chulhas, their suitability, and delivery mechanisms.

The next step after the NBCI is the National Biomass Cookstove Program (NBCP) to be implemented during the

twelfth five-year plan (2013-2018). Its main objective is to expand the development and deployment of cookstoves and replace existing inefficient chulhas with improved biomass cookstoves for domestic and community cooking. It aims to mitigate drudgery faced by women and, climate change by reducing emissions. Therefore, to address health concerns, improved cookstoves will be deployed in various midday meal schemes, aaganwadis, dhabas and restaurants on national highways, hostels, rest houses, etc. This program is currently under consideration for its final nod [12].



A Sun Oven box cooker uses reflective panels to concentrate sunlight, cooking food without emissions. Accessed 12 June 2014:
http://upload.wikimedia.org/wikipedia/commons/e/e0/FOUR_SOLAIR_E_SUN_OVEN_HORNO_SOLAR.JPG.

Global Alliance

The Global Alliance for Clean Cookstoves has started to play a key role in mitigating climate and health issues related to black carbon emissions. It aims to convert around one hundred million households to cookstoves that use solar energy, electricity, or cleaner fuels by 2020. Moreover, the program aims to create awareness of improved cookstoves using print media, television, and mobile phones and to promote them as

an aspirational product. The initiative also suggests regionally specific cookstoves based on the type of food predominant in each region. According to the program's assessment, modern cookstoves will be successful if they are highly portable and durable and can be easily refueled and controlled [13].

Project Surya

Besides the efforts of the Indian and US governments, non-governmental organizations such as Project Surya and Envirofit India have also undertaken initiatives to promote clean cookstoves. Project Surya, the best known of these initiatives, is focused on both the health and climate benefits of reducing black carbon emissions. At the local level it aims to reduce deaths, at the regional level it aims to prevent glaciers from melting, and at a global level it aims to mitigate global warming. Today, black carbon, methane and ozone are responsible for approximately 30-50% effects on global warming and climate change. Landmark research by UC San Diego professor Veerabhadran Ramanathan shows that cutting black carbon emissions and other short-lived climate pollutants will benefit pollution and crop damages. His efforts and initiatives to prove the effect of non-CO₂ pollutants date back to 1975 when he showed the effect of halo-fluoro-carbons (HFC) on climate. Project Surya is the result of his collaboration with The Energy and Resources Institute (TERI) to phase out inefficient gas stoves in India [14-15].

Conclusion

Poverty is a crucial factor when it comes to transitioning from cookstoves to liquefied petroleum gas (LPG). In urban areas in India, LPG is subsidized, which enables the urban poor to afford it. Although clean cookstove initiatives are trying to reduce the prices for modern cookstove technology in order to promote more effective adoption and use in poor, rural areas, the transition to cleaner stoves may require even greater subsidies for cleaner devices, fuels, and solar energy technologies.

An alternative that government could adopt instead of fully subsidizing the cookstoves would be to increase the sponsorship of research intended to promote the health benefits of using modern cookstoves. Efficiency labels will also help promote broader acceptance of the new cookstoves.

Social marketing to make consumers aware of the benefits of cleaner cookstoves by way of village leaders or "panch" in India is another good way to promote the uptake of unfamiliar technologies. Village chiefs play a crucial role in influencing the lives and decisions of villagers. This is bound to improve the adoption rates. Bollywood actors and cricketers can also be included in this promotional list. Therefore, considering all the aforementioned factors and taking into account all the loopholes from the past initiatives, India needs to leapfrog from traditional mud chulhas to improved varieties.

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Mitigation of Black Carbon Emissions from the Transportation Sector in Asia

Pallavi Pant

Black carbon (BC), also referred to as soot, is one of the most relevant short-lived climate forcers (SLCFs) since it has far-reaching impacts affecting public health, climate, and water and food resources [1-2]. Typically released in incomplete combustion, black carbon particles can range from a few nanometres (nm) to a few micrometers (μm) in size. The effects of these particles are mostly observed at a regional scale due to a short lifetime of BC particles [3].

Transport emissions, including both on-road and off-road transportation (Figure 1) contribute nearly a quarter (23%) of the total BC emissions globally [4]. According to estimates, there is a reduction potential of nearly 1032 Gg/yr [5]. In South Asia transport contributes nearly 21% of the total BC emissions, with 11% coming solely from heavy-duty trucks [1]. In India, for example, heavy-duty vehicles (HDVs) contribute to more than half of the total sectoral emissions. According to a recent WB report, diesel engines are associated with nearly 99 percent

of the total BC emissions from road transport [6].

Several different studies have identified the potential for BC reduction in South Asia, which would serve the twin purpose of public health improvement and climate change rate reduction [1]. Anenberg et al. (2012) concluded that implementation of a range of emission control measures, including the use of diesel particulate filters (DPF) and improved cook stoves, would lead to avoidance of 0.6-4.4 million premature deaths related to BC.

In the transport sector, key strategies for BC reduction include improvement in fuel quality (i.e. use of ultra-low sulphur fuels) and after-treatment devices such as diesel particulate filter (DPF) or diesel oxidation catalysts and other measures, including retrofitting, scrapping, and stringent inspection and maintenance (I/M) programs. The World Bank has recently released a study focused on cost-benefit analysis of BC emissions reduction for a range of interventions focused on reduction of diesel engine emissions [6]. However, retrofit programs have often been unsuccessful due to the huge financial costs.

The Manila Jeepney project aims to address the cost problem, however. Jeepneys running on diesel serve as a mode of public transport in

Manila, Philippines, and emissions from these vehicles are detrimental to the health of the drivers, the larger community, and the climate. With the support of the Government of the Philippines, the world's first commercial project aimed at the reduction of BC concentrations has been initiated in Manila. It entails the repair and retrofitting of nearly 250,000 old jeepneys with a device patented by ROTEC DESIGN and will result in an estimated 25 million metric tonnes CO₂e reduction. Particulate emissions from the jeepneys are expected to decline by nearly 70%, resulting in significant health benefits. The emission credits generated through this reduction will be offered globally. The idea behind this project is to generate cash for the retrofit program by selling the emission credits generated due to the emissions reduction.

The project is supported by and is currently under international accreditation process at American National Standards Institute (ANSI). In addition to the emission reductions, the project is expected to generate significant co-benefits including improved public health (and therefore lower air pollution-associated health costs), local revenue generation, and technology transfer and training. In addition, reduction of BC in Manila will have a positive effect on ocean ecosystems and weather patterns in the region.

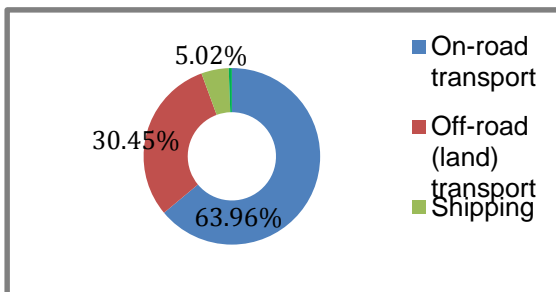


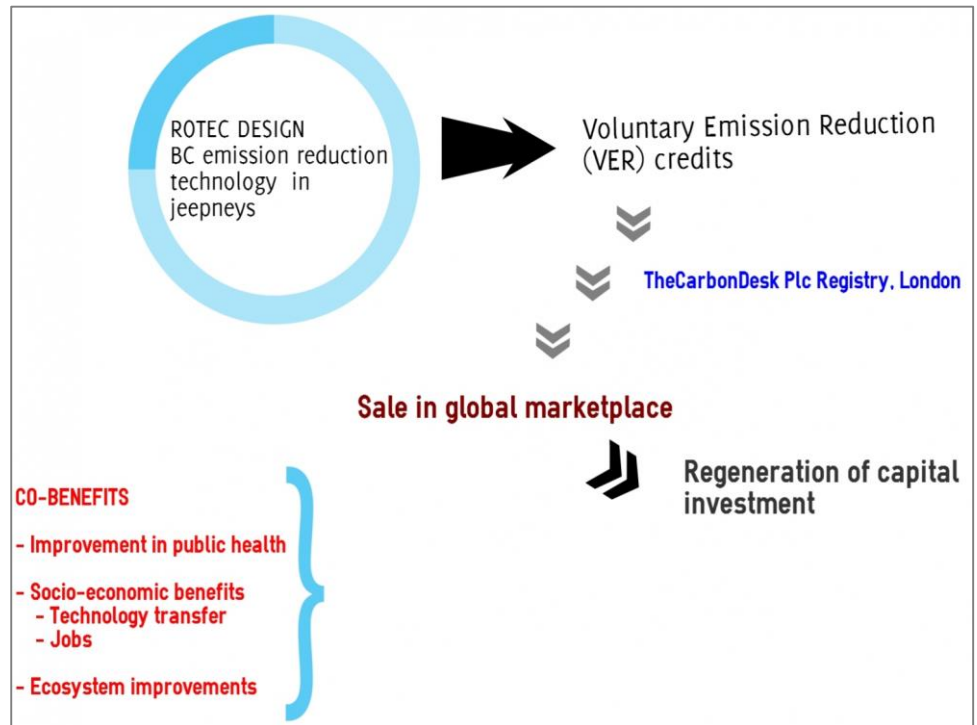
Figure 1: Contribution of the various transport sectors to total BC emissions [4]

This novel financial mechanism might lead to significant emission reductions throughout the ASEAN region, something that the company behind the project, ROTEC, envisions for the future.

In China, what started as a pilot project for retrofitting old vehicles in the city of Guangzhou has now developed into a larger project encompassing the whole province. Supported by the World Bank, the Green Trucks Pilot Project was implemented in Guangzhou (China) from 2008-2010. The project was aimed at the improvement of truck fleet fuel efficiency and the reduction of BC and other air pollutants leading to GHG savings. Simple technology changes such as the use of new tires and aerodynamic equipment on the trucks resulted in fuel savings in the range of 7-18% with a relatively short payback period. Clean Air Asia, one of the organizations involved in this pilot project, now runs a green freight and logistics program under which several projects have been initiated in China (Wuhan, Guangdong, Guangzhou) and India.

In India, the Ahmedabad Municipal Corporation initiated the municipal fleet program, which has led to conversion of the fleet (trucks and other vehicles) from diesel to compressed natural gas (CNG); replacement of the old vehicles (Euro III or IV); and initiation of a stringent vehicle I/M program and driver and operator training. More recently, the California Air Resources Board (CARB), the University of California San Diego (UCSD), and The Energy and Resources Institute (TERI) have launched the India-California Air Pollution Mitigation Program (ICAMP), which aims to generate an action agenda for a low-emission development path for the Indian transport sector. Pilot retrofit programs have also been undertaken in countries such as Brazil and Turkey.

Black carbon emissions pose a significant challenge both in terms of climate forcing and their impact on human health in Asia, and emissions reductions in the transport sector represent low-hanging fruit that could



steer us towards a cleaner environment while reducing the climate impact of human activity. Successful ANSI accreditation of the Manila Jeepney project will help create confidence in the role of such projects in the VER market and will hopefully lead to implementation of similar projects across the region. Such projects and others aimed at the introduction of cleaner cook stoves (e.g. Project Surya) in the Asian region are expected to result in significant health and climate benefits.

First image from the Manila Jeepney Project. Accessed 25 February 2014 at <http://manilajeepneyproject.com/>.

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Editor-in-Chief: Rebecca Fields Green

Climate Institute

1400 16th Street NW, Suite 430

Washington, DC 20036

info@climate.org

John Topping, President

Sir Crispin Tickell, Chairman

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