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Bottom-Up Solutions to Mitigating Climate Change

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Significant attention has been focused on fashioning multilateral agreements to slow CO_2 emissions from fossil fuels. These efforts are essential for reducing long-term warming, but more can be done to slow near-term warming significantly by enlisting social entrepreneurs, NGOs, impact investors, and philanthropists in creating bottom-up solutions to climate change mitigation.

THE DANGERS ASSOCIATED with climate change can sound like a science fiction dystopia: melting Himalayan glaciers and a shrinking Greenland ice sheet; sea-level rise inundating coastal populations from Florida to Bangladesh and submerging sovereign island nations; rainforests succumbing and species migrating en masse; droughts leading to colossal forest fires; and more frequent, more powerful storms that show up in unusual places (like Sandy in New York).

The potential for warming to accelerate suddenly as natural tipping points are reached only adds to the surreal sense of an unprecedented challenge. Melting permafrost releases methane, and loss of the Arctic sea-ice exposes more of the open ocean to solar radiation and leads it to warm, and swell, faster.

National governments and international coalitions of governments, the traditional core of global coordination, have developed action plans, financing mechanisms, negotiating platforms, scientific panels, and other policy infrastructure to reduce greenhouse gas emissions. Many of these efforts focus on CO_2 from fossil fuels, seeking to motivate innovation and behavior change in how we produce and use energy for growth. Limiting CO_2 is the only way to prevent global warming in the long term: Even after the emissions slow or stop, the CO_2 already in the atmosphere will remain there for centuries, influencing temperature, weather, and other aspects of the ecosystem.

In spite of the urgency, national and international leaders, preoccupied by immediate economic, security, and other concerns, have been slow to act. Policy commitments to green growth, clean energy innovation, and increased efficiency are accumulating, but the investments and their impact on CO_2 emissions will take years to materialize. Decades may pass before we stabilize CO_2 levels in the atmosphere.

Although the focus must remain on reducing CO_2 emissions, another approach can yield substantial benefits. We can avert near-term warming over the coming decades to mid-century (and improve public health and agricultural yields while doing so) by reducing emissions of a group of

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Methane gas is recovered from a former open dumpsite outside of Manila, Philippines, reducing methane emissions and providing fuel for an adjacent power plant.

so-called Short Lived Climate Pollutants (SLCPs). This is where a bottom-up approach to mitigation, involving social entrepreneurs, NGOs, impact investors, and philanthropy, becomes an essential part of the response. Many of the SLCP emissions are intertwined with some of the thorniest challenges in development and regulation. We need close attention to context and responsive innovation to identify new solutions, nimbly apply funding, and quickly offer other types of support to scale up these solutions.

Black carbon in soot, lower-atmosphere (tropospheric) ozone, methane, and hydrofluorocarbons (HFCs) are responsible for up to 40 percent of the manmade warming that is being added today. Methane is about 25 times more potent than CO_2 as a climate change agent. HFCs, 100 to 4,000 (depending on the type of HFCs) times as potent as CO_2, have a negligible effect today that is due to low concentrations, but they could contribute more than 1° F warming by the end of the century if the more potent ones continue to be used to meet growing demand for refrigeration and air conditioning. Black carbon on its own is the second-largest global warmer, after CO_2.[1] It not only contributes to warming in the atmosphere, but also accelerates the melting of ice and glaciers that it lands on by absorbing additional solar energy.

None of these emissions are necessary byproducts of energy use or development. Black and brown carbon, the dark particles in smoke and engine exhaust, come mainly from diesel-fueled transport, household cooking over traditional stoves, and open burning of agricultural waste. Burning trash, diesel combustion, traditional brick-making, older coking ovens in steel production, and just about any activity that produces lots of dark smoke also contribute. Tropospheric ozone is essentially part of urban smog, a cocktail of automobile emissions mixing with smoke and other pollutants in the background air. Methane, the primary ingredient in natural gas, leaks from coal mines, oil and gas fields and pipelines, landfills and liquid manure pits, flooded rice fields, and, in a final flourish, burping cattle. It is also an important precursor of ozone. HFCs are manufactured gases used as coolants in air conditioners and refrigerators, ingredients in some types of foam, and propellants for aerosols like asthma inhalers.

Reducing black carbon, methane, and other ozone precursors (carbon monoxide and volatile organics) and eliminating HFCs could cut down near-term warming by about 1° F, about half of the increase in temperature predicted by mid-century, barring surprise cuts or a spree in CO_2 emissions. SLCP emissions reduction, combined with continued attention to CO_2, could postpone the probability of a 3.5° F warming to almost the end of the century instead of 2050.[2] The delay is significant. It could slow down the 2 to 5 feet or more of sea-level rise predicted for the turn of the next century, giving hundreds of small island nations and the 40 percent of the planet's population who live in coastal areas a few more decades to adapt.

Cutting SLCP emissions acts quickly on global warming. These substances are short-lived, in the sense that the pollutants in the air decrease drastically in a few weeks, at most a few decades in the case of methane and most HFCs.

SLCP mitigation also provides near-term human development benefits. The black carbon and other particulate matter released by traditional cooking fires, diesel engines, and industry is linked to 3.5 million premature deaths a year from indoor air pollution and 3.2 million more lives lost yearly from ambient (outdoor) air pollution.[3] The World Health Organization (WHO) recently listed diesel exhaust particulates as a carcinogen. These hazards disproportionately affect the poor and vulnerable: women and children for indoor air, and residents of poor cities and poor neighborhoods for ambient air. Ozone is also estimated to cause crop losses of as much as $18 billion per year for rice, maize, wheat, and other staples of global food security. In recognition of these benefits of SLCP mitigation, more than 25 countries, including the United States, formed the Climate and Clean Air Coalition a year ago under the United Nations Environmental Programme.

We have the technologies to cut emissions. We know how to avoid or capture methane emissions from coal mines, oil and gas fields, and landfills. We know how to grow rice without continuous flooding, and many farmers around the world already do so to save water. We have animal feed that's easier to digest. Reducing or replacing the use of solid fuels (biomass and coal) for cooking and heating and reducing particulate emissions from diesel vehicles would make the largest contribution to global black carbon emission reduction. We know how to build cleaner cookstoves, and we have pellet-based home heating systems for people who use biomass. We have filters for diesel engines that reduce particulate emissions with minimal effect on their efficiency, cleaner brick kilns, and lower-emission modern coke ovens for steel production. We have chemicals other than HFCs for cooling, making foam, and propelling aerosols.

Despite the fact that we know how to mitigate SLCP emissions, we still haven't done so. Technology is not the bottleneck. It's getting people to use it. We need new ways of attaining social ends if we are to succeed in reducing emissions quickly enough to avert mid-century warming. We believe that effective SLCP reduction requires a new form of public-private collaboration built around two pillars: bottom-up design thinking to create innovative solutions, and philanthropy and impact investing working alongside public development finance to fund the scaling up of these solutions.

The first pillar is design thinking, an approach that pays close attention to the many dimensions of the social and economic processes that produce emissions, to identify points of leverage. Many of the emissions are produced by processes that are deeply embedded in local socio-economic contexts. Unraveling these to identify cost-effective solutions that people actually want to adopt requires comprehensive understanding of not just the technology but the broader ecosystem that reinforces its use. This is the sort of knowledge that those close to the settings in which emissions are produced—NGOs, social entrepreneurs, households, and

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businesses themselves—are more likely to have than national governments.

The second pillar is philanthropy and impact investing in addition to public development finance to scale up the innovations. This is more than a call for additional funding for a cause we believe is important. It is also a request for the application of a responsive, outcomes-based funding model that can adapt quickly to evolving scientific understanding of mitigation priorities. The science of SLCPs is clear on the main point—that mitigation of methane, black carbon, tropospheric ozone precursors, and HFCs is an important opportunity to avoid near-term warming—but our understanding of the nuances is evolving. That's why it's important to have funding that can adapt quickly as new information reveals new approaches.

Mitigation Can Be Roundabout

About 65 percent of the reduction in short-term global warming will come from reductions in methane, ozone precursors, and HFCs. The science of how reductions in these gases reduce warming is reasonably straightforward. In the case of black carbon, however, the best way to attack the sources requires great care, because the sources that emit black carbon also emit other species that have complex effects on climate.

The most straightforward approach to limiting black carbon-related warming is to reduce black carbon emissions from diesel combustion. Although the co-emitted species do have some cooling effects, these are minimal. Overall, reducing black carbon emissions from diesel combustion would contribute about 20 percent of the potential reduction in short-term global warming. Reducing cookstove emissions, which contain about a third or more of anthropogenic black carbon emissions, is another important mitigation tactic. Cookstoves also emit other organic aerosols (tiny airborne particles) that have a cooling effect, but on balance, reducing cookstove emissions is highly likely to reduce near-term warming. Both warming and cooling particles disrupt regional climate: They dim the surface, leading to reduced evaporation of moisture (especially over oceans), in turn leading to reduced rainfall.

Similarly, ozone precursors (carbon monoxide, methane, sulfur dioxide, nitrogen oxides, and non-methane volatile organic compounds) are often co-emitted with each other and with other climate-affecting compounds. Because ozone is the product of their interaction, their contribution to actual ozone formation depends on the background levels of other ozone precursors. Some of the compounds play dual roles, producing ozone in some settings and catalyzing reactions that destroy it in others.

Science is also important for evaluating the effectiveness of ways to reduce methane production, particularly agricultural emissions from rice paddies and farm animals. Methane production in rice farming depends not only on the duration of flooding, but also on the variety of rice, soil quality, fertilizer, temperature, and other factors. We know that intermittent draining of fields helps, but not exactly how much. The impact of cattle feed on methane emissions depends on the animal's digestive system. These sound like trivial concerns, but they become important areas for debate in the world of climate change negotiations.

On the black carbon front, not all improved cookstoves are created equal; some emit more black carbon than others. Artisan-produced stoves (a common strategy for creating livelihoods as well as disseminating improved stoves) vary from the templates tested in the lab. People use the stoves with different fuel than intended, adjust settings, and modify parts of the design that are essential for emissions reduction.

Adding to the difficulty of devising effective solutions, the scientific understanding of regional impacts and thus regional development priorities is also evolving. Because of their short lifetimes, black carbon and ozone do not mix globally. Although some of the pollutants do move between regions, there is a basic link between the geography of production and the geography of impact. Black carbon's impact on regional climate is generally stronger closer to where it is emitted, and ozone plumes affect crops in the areas where they are formed. The regional warming intensifies rainfall in some areas, resulting in circulation change that leads to droughts elsewhere. The models are not currently reliable enough to identify which countries are the winners (more rainfall) and which are the losers (droughts, fires, and intense weather systems). Developing countries, with limited resources and infrastructure to adapt, are expected to suffer the most.

The point of bringing up these qualifications is not to suggest that we do not have a well-defined agenda for SLCP mitigation. The action items listed in the introduction are known, proven, and scientifically evaluated tactics. We simply point out why an approach based on social innovation is so important: design thinking to identify the most effective technologies given how the context in which they are actually used affects their performance; and flexible, responsive funding targeted at outcomes and taking advantage of the most recent available knowledge about means.

The Need for Social Innovation

Policy momentum and public investment will of course be important for tackling SLCPs on a global scale, but our ability to convert these efforts into emissions reduction depends on contributions from outside the traditional climate change centers of gravity. A significant part of the potential climate gains relies on many small decisions, shaped by particular factors that may not always be obvious to distant observers. Pinpointing the ways to influence these decisions and customizing solutions to particular problems require the kind of close vantage point that social entrepreneurs, NGOs, local researchers, and the people who are producing the emissions themselves have. And responding quickly to emerging science requires the kind of nimble financing system that philanthropy and impact investing have come to epitomize.

Many of the best intentions for SLCP mitigation get stuck on the last mile of technology adoption. Financial incentives to adopt cleaner technologies can be blunted by lack of information about the first steps for claiming the rewards and the complications that new technologies create for other parts of business models. Consider the challenges of reducing methane emissions into the atmosphere. Jonathan Banks, senior policy advisor at the Clean Air Task Force, found that small investments in detailed project structuring were more of a bottleneck in implementing methane capture in coal mines than were large sums of money, which were often available from selling the methane or from the United Nations' Clean Development Mechanisms program (part of the Framework Convention on Climate Change).[4]

Similarly, Ravi Maithel, Sameer Uma, and other researchers have found that many brick-kiln operators in India wanted to shift to lower-emission mechanized varieties in order to increase fuel efficiency and reduce labor dependence as fuel prices skyrocketed and labor markets tightened, but they did not know how to start. Upgrading brick production may be a cost-effective technology upgrade in some scenarios, but it also changes the economies of scale and need for other inputs such as labor and land.

Getting farmers to drain their rice fields in mid-season is a way to reduce methane emissions into the atmosphere, but it is a nontrivial adjustment to farming practice. It affects crop risks and alters the timing of income and expenditures. Similarly, urban infrastructure projects to manage solid waste and wastewater treatment for methane reduction or to develop low-emission public transport can also flounder on aspects of the local business environment that do not show up in spreadsheets. Industrial waste segregation plants in Cairo, for example, have at times competed with the city's informal garbage workers and their waste-eating pigs to obtain sufficient material for their composting plants.

Similar challenges face those trying to monitor and actually reduce other types of emissions, such as those from vehicles and cookstoves. This challenge is what one might think of as a last-mile problem. Cars and trucks move from jurisdiction to jurisdiction, whereas off-road equipment may never encounter an inspector on the road. Reducing household cookstove emissions is an important mitigation strategy, but we are just learning how to document the households' contributions in a way that enables us to reward them. Project Surya, an experiment to deploy clean cookstoves as well as empirically measure their impact on health and climate, has initiated a fund to reward people for emissions reduction as measured with cell-phone-based technology.[5] We need to move further into low-cost, targeted emissions monitoring that makes more of the SLCP emissions visible, targetable, and monitorable by communities—regulators, impact investors, and citizens concerned about health—capable of rewarding reduction.

Although monitoring is important, other initiatives fail because of poor product design. Large-scale, well-funded cookstove replacement programs have faltered because people don't like the stoves or can't maintain them. Stoves designed for energy efficiency and emissions reduction nearly always change the user experience: Families may have to process or buy fuel, stoves' heating cycle and maximum temperature may vary, and the appliance may just look different. Some of the improved stoves available today offer a single burner for families who cook in several pots; others are top-loading so that the cook needs to remove the pot in order to add more fuel. Some changes are acceptable, but others are not. Ultimately, for the cooks, it's a kitchen appliance. It has to be appealing.

To create workable solutions to these and similar challenges, we need people who both know the context for emissions in detail and can step back enough to think creatively about how to change it. We need bottom-up design thinking. This approach has been particularly successful for cookstoves. Some of the most successful initiatives, at least as defined by customer uptake and continued usage, are social enterprises that have built business models through close interaction with the households that they serve. The challenge now is to produce enough stoves to lower the costs and enable wider market penetration. We also need to make sure that the popular stoves meet the climate goals they are aiming for. There are important social spillovers: Improved cookstoves can cut fuel consumption by as much as 50 percent and reduce the burdens that foraging imposes on women and children.

Moving solutions from potential to actual requires detailed on-the-ground knowledge. Take, for example, open burning of agricultural waste. India's Husk Power Systems is a social enterprise that gasifies various forms of agricultural waste to power small-scale decentralized power plants, reducing incentives for open burning. By its own calculations, it has also saved 9,244,800 liters of kerosene (a source of black carbon) by providing electric lighting.[6] Getting this business up and running required technology innovation in biogasifiers to accommodate to local feedstock, maintenance and monitoring to be feasible in remote areas, and other adjustments to thrive in the local context.

Bottom-up design thinking has also informed larger-scale efforts. Composting and organic waste management—avoiding the accumulation in landfills—originated as small-scale community movements in the industrialized world before becoming a global business. Composting in low-income countries is rarely undertaken formally by public systems, and community efforts have often been more successful than the larger-scale plants developed in middle-income countries. Informal recyclers are increasingly recognized as critical players in access to finance and policy initiatives: Waste-picker cooperatives have gotten loans from Petrobras and Banco do Brazil in Brazil. India's SEWA (Self-Employed Women's Association), KKPKP (Kagad Kach Patra Kashtakari Panchayat) in Pune, and Chintan in Delhi are recognized globally for their contributions to waste management, among other work.

Solving these challenges at the bottom may not be sufficient for SLCP mitigation, but it is a necessary component. We need more designers who can spot opportunities for deploying new technologies and practices. We also need to create stronger links between design thinking from the bottom and global pools of talent and ideas. "Capacity gaps" is the jargon for one of the main bottlenecks for urban waste management and sustainable transport projects. In simpler terms: People may very well know the problem in detail; they are just not aware of the options. Various entities, from national governments to multilateral development banks to non-governmental expert-advocacy groups, are avidly seeking to provide the missing expertise and accelerate longer-run efforts to train a new group of professionals.

Those interested in deepening knowledge transfer could also consider investing in incentives for the science-policy dialogue to move toward linking scientists with bottom-up design thinking about solutions—to build expertise on the science of black carbon emissions into the cookstove development and design cycle, for example. A program focused on placing scientists with social enterprises and NGOs could have an enormous impact. It would also be a logical extension for existing fellowship programs placing early- and mid-career business professionals with effective organizations.

Philanthropy and Impact Investing

In addition to taking a bottom-up design-thinking approach to creating solutions, we need more money and more creative use of that money to reduce the SLCP emissions. The philanthropy and impact investing communities represent a non-trivial proportion of the financial resources currently directed at tackling global problems. International flows of private philanthropy, for example, were just under a fifth as large as the public flows from bilateral aid and the Development Assistance Committee.[7] This funding also has a demonstrated history of flexibility and creativity in responding to unfolding challenges, an attribute that is particularly important given our evolving understanding of the science of mitigation. Private contributions to meeting Millennium Development Goals in health through creative use of incentive prizes, partnerships with government, civil society alliances, social enterprise, and more are well recognized.

The diverse community—now increasingly diverse as philanthropists in emerging markets increase giving—has the structural advantage of allowing more eyes to focus on the problem, respond in different ways, and assess progress that may cut across several issue areas (such as climate change and co-benefits). Some funders may choose to act on cutting-edge science, and others may wait until a consensus view has arisen.

This form of financing also has less political baggage to cut through. Social innovation is all the more needed as SLCP policy initiatives have floundered somewhat on the shoals of climate diplomacy. The attention to black carbon in particular has been seen as an effort to divert attention from CO_2 and blame the developing world—including essential international players such as India, China, South Africa, and Brazil—for climate change. In science terms, the differences are semantic: Developing countries account for a larger share of black carbon emissions, but the United States and Europe have higher per capita emissions. In policy terms they are important.

We need to develop more ways for those who have reduced emissions at any scale to demonstrate their achievements in ways that attract more funding and make lessons more visible to others who may wish to replicate proven solutions. The power of unofficial rating systems for universities, consumer products, vacation destinations, and eBay sellers is well known. We need these same types of rating systems for brick kilns and cookstoves. Some action is under way: Global Alliance on Cleaner Cookstoves (GACC), a hybrid public-private partnership, is developing a more nuanced program of standards and certification for stoves that will clarify their likely performance under varying conditions in the field. It is also investing in building testing centers to certify stoves around the world.

We also need to make it easier to report climate change mitigation impacts in standardized systems, such as the Impact Reporting and Investment Standards (IRIS) used for philanthropy and impact investing. IRIS includes metrics for pollution prevention, energy efficiency, agricultural yield, and public health gains, but SLCP mitigation impacts could be made clearer—and more compelling for impact investors—by adjusting indicators to more effectively capture and represent the effect of SLCP mitigation on climate. Metrics for greenhouse gas emissions are measured in CO_2 equivalent, for example, which is not readily available for black carbon and ozone. The results can be misleading. Replacing petroleum with diesel, for example, may increase fuel efficiency and lower CO_2 emissions, but also may lead to higher black carbon output if filters are not used. Cookstoves burning renewable wood may look good in terms of reducing CO_2, even if their net climate impact is warming. The CO_2 equivalence metric is also problematic for HFCs, methane, and other ozone precursors, given the different time scales on which these pollutants' warming effects occur. There is also scope for adjusting indicators linking SLCP emissions to other development impacts. IRIS currently captures agricultural yield for clients of the social enterprise, but not more general agricultural yield that the social enterprise might affect through pollution reduction.

It is clear that philanthropy, impact investors, and the social innovation ecosystem can increase the potential for local innovations to diffuse horizontally by helping people disentangle general lessons from specific factors involved in success. The C40-Clinton Climate Initiative's efforts to bring city leaders together to share their experiences in waste management, for example, aims to accelerate methane mitigation through a combination of comparative city research and dialogue between mayors. Unofficial initiatives by non-state actors (perhaps semi-official in the C40 case, as it focuses on mayors) are also likely to have more flexibility to seek out crucial stakeholders without constraints of diplomatic protocol.

We do not mean to dissuade climate-conscious citizens and policymakers from continuing their efforts to reduce CO_2 emissions. Instead, we mean to summarize the importance of a broader spectrum of contributors to climate change, and more important, to highlight some of the particular ways in which social innovators at all scales can have a catalytic effect in seizing the SLCP opportunity. We live in a world where social innovators and, increasingly, non-governmental innovators have contributed to reducing global public health threats, accelerating democratization, and brokering peace in stubborn conflicts. We have an opportunity to do the same for climate change. ■

Notes

1 Veerabhadran Ramanathan and Gregory Carmichael, "Global and Regional Climate Changes Due to Black Carbon," *Nature Geoscience, 1*,2008. Mark Jacobson, "Short-term Effects of Controlling Fossil-fuel Soot, Biofuel Soot and Gases, and Methane on Climate, Arctic Ice, and Air Pollution Health," *Journal of Geophysical Research* 115, DOI:10.1029/2009jd013795. Tami Bond et al., "Bounding the Role of Black Carbon in the Climate System: A Scientific Assessment," *Journal of Geophysical Research*, 15 Jan. 2013. This study is the most recent global assessment, confirming that black carbon is the second largest contributor.

2 Veerabhadran Ramanathan and Yangyang Xu, PNAS, 2010, and UNEP/WMO, 2011, *Integrated Assessment of Black Carbon and Tropospheric Ozone*. This report also estimated that 16 actions—ranging from capture of fugitive methane from coal mining to increasing access to cleaner cookstoves—would reduce black carbon and methane emissions enough to reduce the likely mid-century temperature increase by about half.

3 S.S. Lim et al., "A Comparative Risk Assessment of Burden of Disease and Injury Attributable to 67 Risk Factors and Risk Factor Clusters in 21 Regions, 1990–2010: A Systematic Analysis for the Global Burden of Disease Study 2010," *The Lancet*, vol. 380, no. 9859, 15 December 2012. DOI: 10.1016/S0140-6736(12)61766-8.

4 Jonathan Banks, "Barriers and Opportunities for Reducing Methane Emissions from Coal Mines," Report from the Clean Air Task Force, September 2012.

5 Disclaimer: Both authors have both been involved in Project Surya, and one of us (Ramanathan) continues to lead the project as principal investigator.

6 Figure from website http://www.huskpowersystems.com/; accessed March 2, 2013.

7 Analysis based on *The Index of Global Philanthropy and Remittances*, Hudson Institute, 2012.