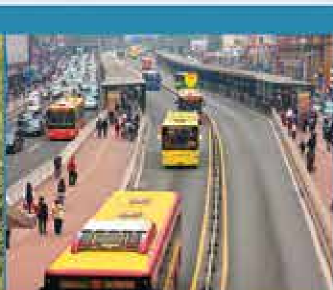
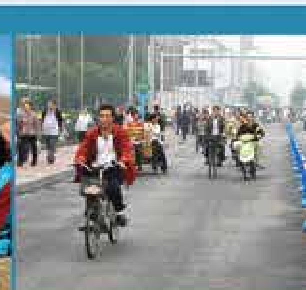
On Thin Ice

How Cutting Pollution Can Slow Warming and Save Lives

A JOINT REPORT OF

The World Bank
The International Cryosphere Climate Initiative

EXECUTIVE SUMMARY

THE WORLD BANK

INTERNATIONAL CRYOSPHERE CLIMATE INITIATIVE

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Inputs from the following modeling teams were critical to preparing this report.

Modeling Teams:

U.S. National Aeronautics and Space Administration's Goddard Institute for Space Studies (NASA/GISS)

The European Commission's Joint Research Centre (JRC)

Istanbul Technical University

University of Reading

International Institute for Applied Systems Analysis (IIASA)

Stockholm Environment Institute at the University of York (SEI-York)

University of California at Berkeley

U.S. Environmental Protection Agency (USEPA)

Glossary of Keywords and Phrases

Albedo: A measure of the reflectivity of the earth's surface. It is the fraction of solar energy (shortwave radiation) reflected from the earth back into space. Thick ice and snow have a high albedo; bare earth has a low albedo.

Alpine: Mountain regions.

Anthropogenic: Human-caused.

Baseline/Baseline Projections: Levels of greenhouse gases or warming impacts expected under the assumption that no further mitigation/reductions occur.

Biofuels: Non-fossil fuels, typically liquid or gas (e.g., biogas, biodiesel, bioethanol).

Biomass: Refers to solid organic materials, such as wood, grass, animal dung, and other agricultural wastes.

Black Carbon (BC): Black carbon is a small, dark particle that warms the earth's climate. Although black carbon is a particle rather than a greenhouse gas, it is the second largest climate warmer after carbon dioxide. Unlike carbon dioxide, black carbon is quickly washed out and can be eliminated from the atmosphere if emissions stop. Reductions would also improve human health.

Boreal: Related to or located in high northern near-Arctic ecosystems.

Carbon Dioxide (CO_2): The greenhouse gas that contributes the most to global warming. While more than half of the CO_2 emitted is removed from the atmosphere within a century, some fraction (about 20 percent) of emitted CO_2 remains in the atmosphere for many thousands of years.

Carbon Flux: Release of carbon into the environment, which can occur in different forms (i.e., methane or carbon dioxide gas).

Celsius: Unit of Temperature. One degree Celsius equals about 1.8 degrees on the Fahrenheit scale.

Cryosphere: Elements of the earth system containing water in its frozen state, including sea ice, lake and river ice, snow cover and solid precipitation, glaciers, ice caps, ice sheets, ice shelves, permafrost, and seasonally frozen ground.

Enteric Fermentation: A digestive process in ruminant animals (e.g. cows, sheep) that enables them to eat cellulose-enhanced tough plants. The process results in the release of methane emissions.

Euro-6/VI: European vehicle emission standards (Euro standards) that define the acceptable limits for exhaust emissions of new vehicles sold in EU member states (see http://ec.europa.eu/enterprise/sectors/automotive/environment/eurovi/).

Feedbacks/Feedback Mechanisms: Climate change impacts which lead to a cycle of greater warming, either by release of greenhouse gases or by changing the physical conditions for warming (e.g. albedo or ocean composition).

Glaciers/Land Glaciers: "Ice rivers" on land, built up by compacted snow over centuries or millennia, which move slowly until they melt or discharge (as icebergs) into the ocean.

Global Burden of Disease: A study to estimate the number of worldwide deaths annually from different diseases or environmental causes.

Ice Sheets: Large, continuous, old (up to millions of years), and often very thick ice (3–4 km. on Greenland or Antarctica) which may cover either land or what would otherwise be open water.

Mass Balance/Glacial Mass Balance: The difference between accumulation and melting of glaciers or ice sheets. Expressed both as volume lost (cumulative mean specific mass balance, kilograms per square meter, kg/m^2) and relative contribution to sea-level rise (millimeters sea-level equivalent, mmSLE).

Measures (Reduction Measures): For this report, refers to actions, regulations, or technologies that reduce emissions of various pollutants, including black carbon and methane. Measures are chosen to have both health and climate benefits, and only include technologies or actions already in use in some parts the world (but may not be cost-effective and applicable to all country contexts).

Methane (CH_4): A greenhouse gas that only lasts an average of 12 years in the atmosphere; it is an extremely powerful warmer during that period. One molecule of methane warms about 25 times more than CO_2 over 100 years; 72 times as much over 20 years.

Mitigation: Actions to address climate change by decreasing greenhouse gases and other climate forcing agents.

Modeling: Computer simulations of global atmospheric behavior, including temperature and complex factors and interactions between land, air, water, and the biosphere.

Monsoon: Seasonal changes in atmospheric circulation and precipitation associated with the asymmetric heating of land and sea (especially in South Asia).

OECD/IEA 450 Scenario: The progression of emissions based on energy and fuel projections of the International Energy Agency (IEA) World Energy Outlook leading to a peak CO_2 concentration of at 450ppm.

Ozone (O_3): A harmful pollutant and greenhouse gas that only forms though complex chemical reactions with other substances in the atmosphere, including methane, and can harm both human health and crops.

Permafrost: Soil that remains at or below the freezing point of water for two or more years. Permafrost traps carbon that can be released as methane, CO_2, and/or other gases upon thaw.

Radiative Forcing: A measure of the net change in the energy balance of the earth with space, that is, the change in incoming solar radiation minus outgoing terrestrial radiation. At the global scale, the annual average radiative forcing is measured at the top of the atmosphere, or tropopause. Expressed in units of warming rate (watts, W) per unit of area (meters squared, m^2).

Sea Ice: Relatively thin and young ice (a few centimeters to several meters thick, and usually less than a decade old), subject to seasonal thinning or melting.

Short-lived Forcers/Short-lived Pollutants/Short-lived Climate Pollutants (SLCPs): Substances such as methane, black carbon, tropospheric ozone and some hydrofluorocarbons which have a significant impact on near-term climate change and a relatively short lifespan in the atmosphere compared to carbon dioxide and other longer-lived gases.

Tropospheric Ozone: Sometimes called ground-level ozone, refers to ozone that is formed or resides in that portion of the atmosphere from the earth's surface up to the tropopause (the lowest 10–20 km of the atmosphere).

West Antarctic Ice Sheet (WAIS): The thick ice sheet covering over two million square kilometers of West Antarctica, with much of that region actually an ice-covered archipelago and therefore subject to some degree of instability.

Win-Win Measures: In this report win-win measures are defined as mitigation measures that are likely to reduce global warming and at the same time provide clean air benefits by reducing air pollution.

Foreword (The World Bank)

The science is settled and the problem identified. Now we must act in the smartest and most effective way we can. Our world is on thin ice.

This report is about how climate change is affecting the cryosphere—those snow-capped mountain ranges, brilliant glaciers, and vast permafrost regions on which all of us depend. It lays out 14 specific measures we could take by 2030 to reduce short-lived climate pollutants and slow the melting of ice and snow that must stay frozen to keep oceans and global temperatures from rising even faster.

Action to stabilize the cryosphere will also save lives now. By mitigating short-lived climate pollutants such as black carbon and methane, we will improve health in thousands of communities, many of them in the developing world.

If we quickly scale up just four cleaner cooking solutions, for example, we could save one million human lives every year. That is one-quarter of the mostly women and children who die from exposure from indoor and outdoor cooking smoke annually. The benefits would multiply because, with cleaner air, cities become more productive, child health improves, and more food can be grown. All the while, we would reduce the warming impact that black carbon from these cookstoves has on polar and mountain regions, especially in the Himalayas.

The Himalayan mountain ranges make up the largest freshwater source outside the poles in an area that is home to 1.5 billion people. With the surface temperature across the region now 1.5 degree Celsius higher than before the industrial revolution, the health and welfare of hundreds of millions are at stake. Today, ice and snow melting is causing catastrophic floods in one area and droughts in another—and this trend will accelerate as the planet continues to warm.

We see the same story repeated in the Andes in South America, where glaciers feed river basins on which millions depend for agriculture and electric power; and in East Africa.

Just a 50-percent drop in open field and forest burning, another leading source of black carbon, could result in 190,000 fewer deaths from air pollution. By reducing emissions from diesel transport we could avert yet another 340,000 premature deaths—while giving us some quick gains in our fight against climate change.

At the World Bank, we're taking steps to ensure more of our projects and activities reduce short-lived climate pollutants. A recent analysis for the G8 reveals that from 2007–2012, 7.7 percent of Bank commitments in energy, transport, roads, agriculture, forestry, and urban waste and wastewater—approximately $18 billion—were "SLCP-relevant" (i.e., could have an impact on the amount of short-lived climate pollutants which are released into the atmosphere). Going forward, our goal is to transform as much of the Bank's portfolio as possible into "SLCP-reducing" activities.

None of these activities will be easy, and very real barriers to implementation exist around cost, behavior, technology, and sustainability.

Also, let me be clear: The measures we are proposing in this report are not a silver bullet solution to global warming. Efforts to reduce black carbon and methane cannot replace long-term mitigation of CO_2, which requires a global transition to a low-carbon, highly energy-efficient economy. That shift will take international cooperation and decades of hard work.

By addressing short-lived climate pollutants, however, we will be reaping some significant climate benefits while at the same time meeting human development needs now.

Exploiting these win-wins while ensuring we tackle the most urgent challenges before us is how we can green growth without slowing it and how we can achieve sustainable development. We have an opportunity here, but the window for action will close soon. So let us get to work.

Rachel Kyte
Vice President, Sustainable Development Network
The World Bank

Preface (International Cryosphere Climate Initiative)

This report is a message of caution, and of hope.

Caution because rapid changes in the earth's regions of snow and ice—the "cryosphere"—daily increase the risk of changes to our global environment: changes not seen in the span of human existence. Hope, because the tools to decrease that risk are available now and would improve the lives and futures of some of the world's most vulnerable populations.

First the caution: the cryosphere is changing fast as a result of climate change, it is changing today, and those changes bring increased risk to ecosystems and human societies. This report documents how that pattern is repeated throughout the cryosphere, whether the Arctic, the Antarctic, the Himalayan "Third Pole," or the Andes: temperatures rising at twice or more the global average, glaciers receding, ice sheets showing signs of instability, permafrost thawing. The cryosphere is on an accelerated warming path, and some of those changes may drive global climate change faster and further than we are currently prepared to handle. If warming continues unabated, the risks from continuing sea-level rise, flooding, and water resource disruption rise dramatically. So too will the risk of large CO_2 and methane releases from permafrost, potentially eclipsing global efforts to reduce carbon pollution. The window to slow some of these processes may be closing rapidly.

Yet this report also carries hope, because a suite of air pollution management tools are available that can slow these cryosphere changes and at the same time bring economic benefits: improved health, higher crop yields, and greater access to energy. Anti-pollution measures aimed at sources such as cookstoves; coal and wood heating stoves; diesel; alternatives to crop burning; and capture of biogas from landfills offer direct benefits to those communities making them happen, and they are eminently achievable. Though global decreases in CO_2 cannot and should not be replaced, many communities have it in their power to at least slow snow and glacier loss nearby. The tools discussed in this report reflect a truly global solution, with actions available for both the developed and developing world: improved woodstoves for heating in Scandinavia and improved stoves for cooking in Nepal both help preserve nearby snow and ice.

The modeling in this report shows a special need to focus more urgently on cookstove pollution. Introduction of advanced cookstoves proved the one measure with recognizable climate benefits in every cryosphere region of the world, including Antarctica. The human costs of inaction are enormous: four million people die annually from cookstove pollution, greater than the annual toll of HIV/AIDS, malaria, and tuberculosis combined. It is time to consider a commensurate push to replace these polluting, health-damaging stoves using the same tools that turned around the global AIDS crisis—coordinated public/private efforts, strict monitoring and evaluation, and nimble programs adapted to local conditions.

The modeling also demonstrates how methane and black carbon emissions associated with the "front end" of fossil fuel extraction warm the earth, alongside the "tailpipe" CO_2 emissions from fossil fuel burning, underscoring the need for transition to low-carbon economies in the near future.

The result is an imperative for both protecting the cryosphere and supporting human development. Implementing these air quality measures sooner rather than later will improve the quality of life for many millions of people each year, while decreasing risks from sea-level rise and other impacts of rapid cryosphere change. Yet it cannot be overemphasized that, to realize these gains, the air quality actions modeled in this study must be accompanied by action on CO_2.

This then is the cryosphere's message of caution and hope—the new cryosphere and development imperative.

Pam Pearson
Director
International Cryosphere Climate Initiative

Main Messages

Climate change is having a disproportionate impact on areas of snow and ice known as the cryosphere, with serious implications for human development and environments across the globe. This report provides an overview of why it is so critical to slow the rate of change in the cryosphere. It also addresses how accelerating actions to decrease short-lived pollutants from key sectors can make a real difference by slowing these dangerous changes and risks to development while improving public health and food security.

Unprecedented Changes in the Cryosphere Pose Global Threats

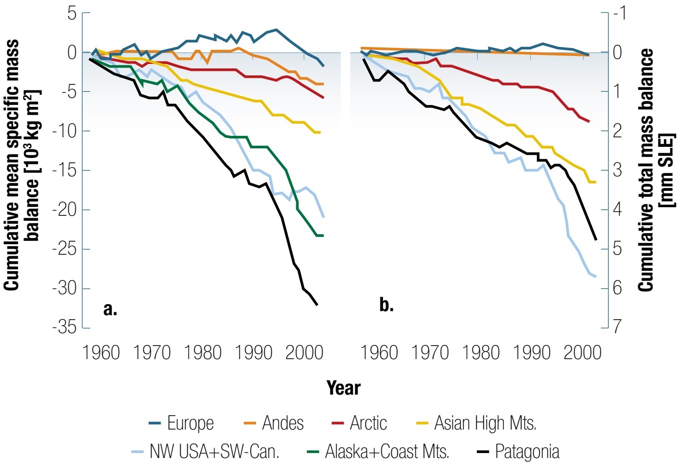
Rapid changes in the cryosphere observed during the first decade of this century are continuing or accelerating. With the exception of a one-percent increase in Antarctic sea ice extent and a very few growing glaciers, nowhere in the peer-reviewed literature is there evidence that the rapid warming documented in the cryosphere beginning in the 1990s is slowing. In most cases, warming and melting are accelerating (Figure ES1).

The high rate of warming in the cryosphere, at a pace unprecedented in the historic record, has the potential to trigger disastrous feedback mechanisms from the cryosphere into the global climate system. Examples include loss of albedo from sea ice and snow cover and loss of permafrost leading to greater carbon fluxes into the atmosphere (particularly where emissions occur as methane).

Release of carbon stores in permafrost could contribute as much as 5-30 percent more carbon to the atmosphere by the end of this century if current cryosphere warming is not slowed. This would then require even greater cuts in anthropogenic sources of CO_2 than those currently recommended to hold warming below 2 degrees Celsius.

Warming in the cryosphere poses serious threats to disaster preparedness, to water resources in some heavily populated

Figure ES 1: Land Glacier Ice Loss, Showing Cumulative Mass Lost Over Time (a) and Relative Contribution of Loss in Each Region to Sea-level Rise (b). (Source: IPCC AR4, (2007.)



regions, and to adaptation and ecosystems preservation. Intensified monitoring in cryosphere regions is needed to provide better and earlier warning of changes. Monitoring the stability of ice sheets is especially important due to their potential contribution to accelerated worldwide sea-level rise, yet large portions of polar and high alpine regions have few or no observing stations.

Mitigation Strategies in the Cryosphere Have Large and Certain Benefits

Mitigating short-lived climate pollutants (SLCPs), in the coming two decades, specifically black carbon and methane can slow these changes while benefiting human communities. Implementing by 2030 the 14 methane and black carbon reduction measures (Table ES1) modeled for this report would bring multiple health, crop, and ecosystems benefits and decrease risks to development from water resource changes, including flooding and other impacts or climate feedbacks we may not foresee today.

Climate benefits for cryosphere regions from black carbon reductions carry less uncertainty than they would in other parts of the globe and are sometimes very large. This is because emissions from sources that emit black carbon—even with other pollutants—almost always lead to warming over reflective ice and snow.

Gains would be eliminated by the end of this century if not accompanied by strong reductions in carbon dioxide (CO_2). Reductions in short-lived climate pollutants cannot be made in isolation from efforts to reduce other greenhouse gases. The role of such reductions is to slow the immediate rate of change, especially in the cryosphere, but cannot replace long-term efforts to reduce CO_2.

Certain Sectoral Approaches Offer Tremendous Benefits

Cookstove reduction measures offer by far the greatest potential benefits both to human health and to slowing cryosphere warming. Rapid scaling-up of four existing clean cookstove solutions[1] could save around one million lives annually[2] from outdoor air pollution impacts alone. Current Global Burden of Disease (GBD) estimates place total annual deaths from all household smoke exposure from cookstoves (both outdoor and indoor) at four million annually, greater than the current annual toll from HIV/AIDS, malaria, and tuberculosis combined. Effective sectoral responses, however, would need to deploy models tailored to local and cultural conditions, integrate learning from past failures, be affordable, and employ best public health practices (including independent monitoring and evaluation).

Cookstove measures delivered climate benefits for all five cryosphere regions modeled,[3] including both polar regions; the strongest benefits were in the Himalayas. Fan-assisted biomass cookstoves performed almost as well as biogas/liquefied petroleum gas (LPG) fuel stoves in modeled climate and health benefits (for outdoor exposure), but present challenges to overcome in the field.

Improved biomass (wood) and coal-heating stoves could save about 230,000 lives annually, with the majority of these health benefits occurring in OECD nations.

Just a 50-percent decrease in open field and forest burning could result in around 190,000 fewer deaths annually from related air pollution, making it the second most powerful measure from a health perspective after cookstoves. Human activity causes almost all open field and forest fires, either intentionally or by accident. Effective no-burn alternatives exist for most agricultural sector use of fire, and results in this report indicate that up to 90-percent reductions may be possible in some regions.

Reductions in emissions from diesel transport and equipment could result in over 16 million tons of additional yield in staple crops such as rice, soy, and wheat, especially in Southeast Asia, as well as averting 340,000 premature deaths. From all measures, including methane measures, the additional increase in crop yield could total nearly 34 million metric tons.

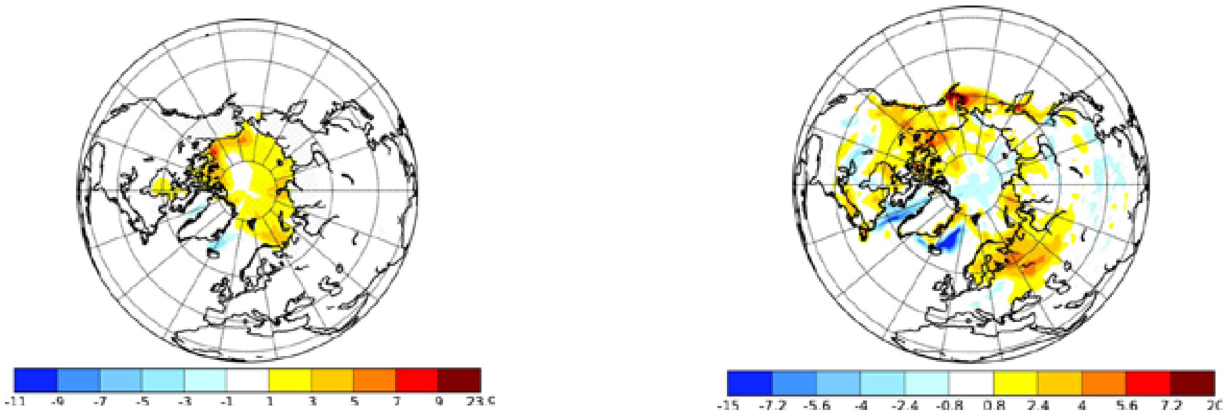
Methane reduction measures primarily target front-end emissions from fossil fuel extraction. While CO_2 emissions primarily come from fossil fuel use, significant methane and black carbon emissions arise in the production chain for oil, gas, and coal (approximately 65 percent of benefits from all methane measures), strengthening the need for conversion to low-carbon economies.

Reductions Significantly Decrease the Threat of Rapid Cryosphere Change

The black carbon and methane measures reviewed could slow warming in the Arctic by more than a full degree by 2050, resulting in up to 40 percent reduced loss of summer sea ice and 25 percent reduced loss of springtime snow cover compared to the baseline (Figure ES2). The Himalayan cryosphere might see nearly a one-degree Celsius decrease from baseline projections (though there is greater uncertainty).

This large decrease in temperature from reduction measures includes the permafrost regions of Siberia, North America, and the Tibetan region, indicating the potential for greater preservation of permafrost regions. This could reduce the risk and extent of future methane and CO_2 releases from permafrost melt.

Figure ES 2: Percentage Change in Arctic Summer Ice (left) and Boreal Spring Snow (right) in 2050 due to Full Implementation of Black Carbon and Methane Measures by 2030 (Figures not scaled for additional forcing over cryosphere; with scaling, modeling conservatively indicates two times greater reduction in snow/ice loss.)



Implementation of the black carbon and methane measures could reduce projected disruptions in water cycles, cutting the near-term projected decrease in Amazon flow by nearly half (in one model). It could also significantly decrease risk of disruption to traditional precipitation patterns in the South Asian monsoon region, the Sahel, and areas downwind of winter storm tracks (i.e., the Mediterranean).

Rates of sea-level rise might be significantly slowed by 2050, with a potential near-leveling-off in rates before the end of the century if SLCP measures are combined with CO_2 emissions held to 450ppm. This decrease in sea-level rise could range from 10 cm to half a meter or more. Perhaps more important, temperature reductions in polar regions from these measures would help minimize the risk of essentially irreversible ice sheet loss or disintegration in West Antarctica and Greenland, which could ultimately raise ocean levels by several decimeters by 2100—and by many meters over a period of centuries or millennia.

In the Himalayas, black carbon reduction measures could significantly reduce radiative forcing and help maintain a greater portion of Himalayan glacier systems. More detailed regional modeling and observational studies are needed to better understand these impacts at more local levels due to the variability of the Himalayan glacier regions.

Even Antarctica shows potentially strong climate benefits from black carbon measures, not far below the benefits in the Arctic, especially on the Antarctic Peninsula and in West Antarctica. This could decrease the risk for loss of the West Antarctic Ice Sheet (WAIS) and resulting sea-level rise. As in other regions, the primary benefit comes from cookstoves measures, likely from the southern hemisphere, decreasing the amount of airborne black carbon over Antarctica.

Climate benefits from black carbon measures in the Andes might be best addressed through observational studies. Although all alpine regions present challenges to modelers, cryosphere-specific results in the Andes proved particularly difficult because of their relative narrowness and sharp vertical rise. A more rapid and effective approach to assess impacts could involve measuring levels of black carbon reaching the glaciers and snow, though health benefits from these measures were substantial.

SLCP measures in East Africa appear highly unlikely to preserve glaciers there. The small extent (under 4 square kilometers) of the three remaining East African glacier systems makes their preservation challenging even with strong efforts to reduce black carbon. However, health benefits in that region were extremely high from black carbon measures, which also appeared to maintain precipitation levels closer to their historic pattern.

The modeling indicates urgent need for further study to better understand potential benefits. These include more precise estimates of avoided permafrost and sea-level rise impacts; more regionally-focused modeling studies, especially to better characterize precipitation and water resource impacts; improved understanding of long-range transport of pollutants to polar regions; causes of, and potential for decreasing open burning outside northern Eurasia; and benefits of cookstove measures to improve household air quality on a regional and country level.

The window for action is closing fast. This study by necessity touches only briefly on issues of implementation, local feasibility, and cost effectiveness—all significant challenges for these 14 measures, though all are currently in use in different regions around the world. This modeling assumes actions by 2030. With projections of large cryosphere impacts such as Arctic sea ice loss occurring by mid-century, speed is of the essence in addressing and operationalizing these cryosphere and development challenges.

Table ES 1: Modeled Reduction Measures

BLACK CARBON	
Road Diesel	Diesel road vehicles comply with Euro 6/VI standards (include particle filters)
Off-road Diesel	Diesel off-road vehicles comply with Euro 6/VI standards (include particle filters)
Heating Biofuel	Replacing current residential wood burning stoves and boilers with pellet stoves and boilers
Heating Coal	Replacing chunk coal with coal briquettes for residential household heating
Cookstoves	
Biofuel	Replacement of current biofuel cookstoves with forced draft (fan-assisted) stoves; or
Biogas/LPG	Replacement of current biofuel cookstoves with stoves using biogas (50%) or LPG (50%)
Open Burning	
50% Biomass Burning	Reduction of all open burning worldwide by 50 percent; or
90% Eurasian Fires	Reduction of open burning in northern Eurasia to EU levels
Flaring	Reduction of BC emissions from gas flaring at oil fields to best practice levels
METHANE	
Mining	Capture of methane, or degasification prior to the mining process
Oil and Gas Production	Capture or re-injection of fugitive methane emissions, where feasible with re-use
Oil and Gas Pipelines	Reduced leakage through improved monitoring and repair
Landfills	Recycling, composting and anaerobic digestion and methane capture for re-use
Wastewater	Upgrade of treatment to include methane gas capture and overflow control
Livestock	Anaerobic digestion and capture of methane
Rice Paddies	Intermittent aeration: fields remain continuously flooded with only occasional exposure to air

Endnotes

1 Advanced cookstoves that use biogas, liquefied petroleum gas, or ethanol; or forced-draft (fan-assisted) stoves that use biomass (wood, agricultural residue, or dung). See Chapter 3 for details.

2 This report makes the following assumptions regarding relative risk of air pollution health impacts which are different than GBD: (i) any amount of PM2.5 has health impacts, (ii) all-cause mortality is used to extrapolate health risk in other parts of the world, and (iii) linear impacts exist at high concentrations. These assumptions could lead to over- or under-estimating the final results, and are explained in greater detail in Chapter 3 of the full report.

3 The Himalayas, Arctic, Andes, East African Highlands, and Antarctica.

THE WORLD BANK
1818 H Street, NW
Washington, DC 20433
www.worldbank.org