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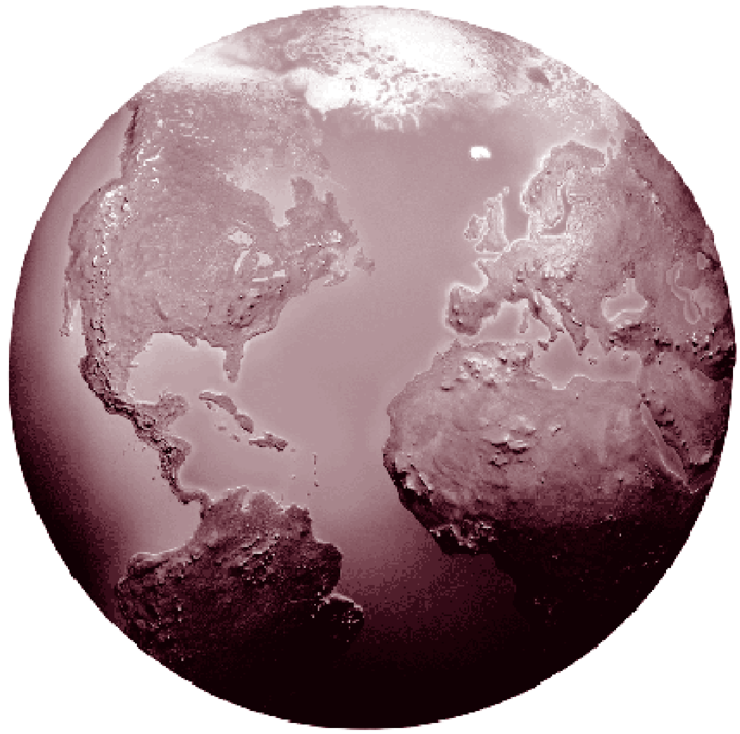

Contribution of Household Air Pollution to Ambient Air Pollution in Ghana

SUMMARY FOR POLICY MAKERS

HEI Household Air Pollution–Ghana Working Group

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ABOUT HEI

The Health Effects Institute is a nonprofit corporation chartered in 1980 as an independent research organization to provide high-quality, impartial, and relevant science on the effects of air pollution on health. To accomplish its mission, the institute

- Identifies the highest-priority areas for health effects research;
- Competitively funds and oversees research projects;
- Provides intensive independent review of HEI-supported studies and related research;
- Integrates HEI's research results with those of other institutions into broader evaluations; and
- Communicates the results of HEI's research and analyses to public and private decision makers.

HEI typically receives balanced funding from the U.S. Environmental Protection Agency and the worldwide motor vehicle industry. Frequently, other public and private organizations in the United States and around the world also support major projects or research programs. This document was made possible through support provided by Bloomberg Philanthropies (*www.bloomberg.org*). HEI has funded more than 340 research projects in North America, Europe, Asia, and Latin America, the results of which have informed decisions regarding carbon monoxide, air toxics, nitrogen oxides, diesel exhaust, ozone, particulate matter, and other pollutants. These results have appeared in more than 260 comprehensive reports published by HEI, as well as in more than 1,000 articles in the peer-reviewed literature.

HEI's independent Board of Directors consists of leaders in science and policy who are committed to fostering the public–private partnership that is central to the organization. All project results are widely disseminated through HEI's website (*www.healtheffects.org*), printed reports, newsletters and other publications, annual conferences, and presentations to legislative bodies and public agencies.

SUMMARY FOR POLICY MAKERS

Contribution of Household Air Pollution to Ambient Air Pollution in Ghana

INTRODUCTION

In 2017, 47% of the global population, an estimated 3.6 billion people, continued to rely on solid fuels for cooking. Solid fuels are a major source of exposure to household air pollution (HAP*) in the form of fine particulate matter ($PM_{2.5}$; particulate matter ≤2.5 µm in aerodynamic diameter) (Health Effects Institute 2019).

HOUSEHOLD AND AMBIENT AIR POLLUTION: A POLICY LEVER FOR ACTION

Household reliance on solid and liquid fuels is not just a problem for the households themselves; it is also a major source of ambient, or outdoor, air pollution with consequences for much broader populations (Chafe et al. 2014; Smith et al. 2014). A global analysis estimated that cooking-related HAP contributed 12% of total population-weighted ambient $PM_{2.5}$ exposure; this contribution varied substantially across the world but was disproportionally higher in low- and middle-income countries; in southern sub-Saharan Africa (SSA), the contribution was reported to be as high as 37% (Chafe et al. 2014). When all residential energy use (including cooking and heating) was taken into account, a more recent estimate put the global contribution at 21% (Weagle et al. 2018). In India and China, 24% and 19% of ambient $PM_{2.5}$, respectively, were attributed to residential solid fuel burning (GBD MAPS Working Group 2016, 2018). These estimates show that in areas where household solid fuel use is common, countries will need to address this important source in order to achieve significant improvements in ambient air quality.

The public health burden from exposures to HAP is well documented and substantial (Gordon et al. 2014; HEI Household Air Pollution Working Group 2018; Smith et al. 2014). The Global Burden of Disease (GBD) project estimated that, globally, 1.64 million deaths in 2017 were attributed to HAP from the burning of solid fuels for cooking alone (Health Effects Institute 2019). However, this estimate does not include the additional health burden linked to HAP's contribution to ambient air pollution. Therefore, it is likely to underestimate the total health

Highlights

- $PM_{2.5}$ levels in Ghana exceed the World Health Organization Air Quality Guideline for healthy air.
- Household fuel use may account for nearly 65% of total primary $PM_{2.5}$ emissions in Ghana.
- In the 2017 Global Burden of Disease study, HAP is estimated to be the seventh largest risk factor for health burden in Ghana, contributing to 9,780 deaths. However, no studies in Ghana to date have specifically estimated the additional impact of HAP on health burden via its contribution to ambient $PM_{2.5}$.
- It is critical to develop more accurate estimates of household and other source contributions to ambient air pollution and health in the near term. Ongoing studies and emerging resources (e.g., satellite data), together with expanded air quality monitoring, will serve as useful inputs into the process. In the long term, estimates of source contributions can also be used for monitoring the effectiveness of interventions over time.
- There are several near- and longer-term opportunities to advance the capacity to understand and to address household air pollution's impact on population health in Ghana and the region, including support for sustained development and improvement of emissions inventories in Ghana and West Africa, and expanded ground level and satellite air quality monitoring.

This Summary for Policy Makers is based on HEI's Communication 19, Contribution of Household Air Pollution to Ambient Air Pollution in Ghana: Using Available Evidence to Prioritize Future Action, a report by the HEI Household Air Pollution–Ghana Working Group.

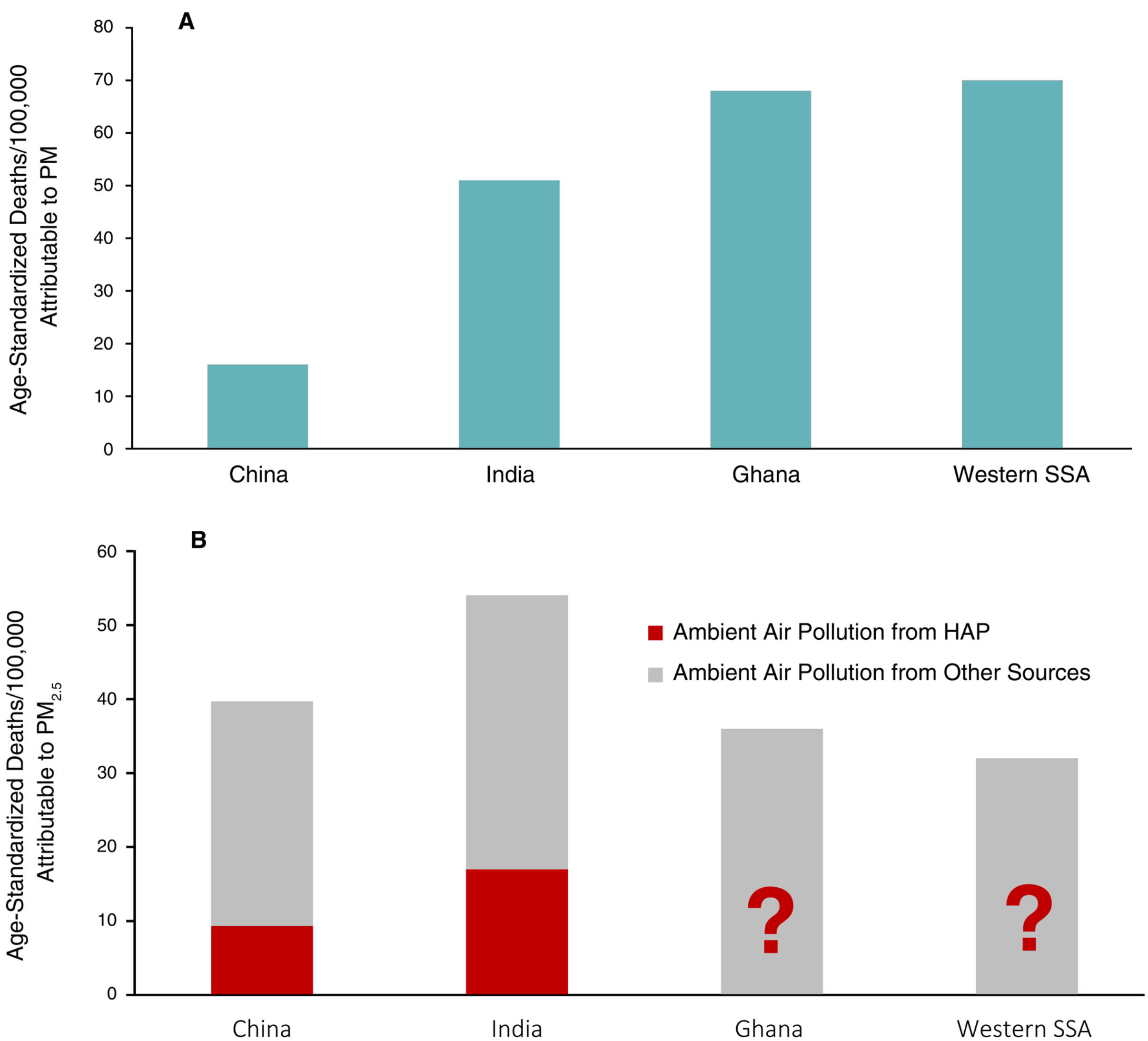
This document was made possible by funding from Bloomberg Philanthropies (*www.bloomberg.org*).

*A list of abbreviations appears at the end of this Summary.

burden associated with HAP in regions where solid fuel use is common. If we consider age-standardized death rates, a metric that takes into account the age distribution of the population, the indoor contribution of HAP to health burden is already higher in Ghana and western SSA than in China or India (Figure 1A). This is true despite the lack of estimation of the contribution of HAP to health burden via its impact on ambient air pollution (Figure 1B).

This summary of HEI's Communication 19 focuses on Ghana within the larger western SSA region, where the proportion of populations relying on solid fuels remains high (73% and 80%, respectively) (Health Effects Institute 2019), and where an increasing number of relevant studies have been conducted. In addition, a significant proportion of this population does not have access to an electric power grid, and uses biomass, kerosene, and diesel or gasoline generators for lighting. Taken together, these sources of residential energy contribute to HAP. This summary of Communication 19 synthesizes available information on the relationship between household energy use and ambient air pollution, and then compares the completeness of current estimates for the contribution of HAP to ambient air pollution and health burden. This information is intended to inform discussions on the need for more in-depth efforts in Ghana to (1) better quantify the contribution of HAP to ambient air pollution and (2) enable progress on tracking ambient air quality and the impacts of ongoing efforts in Ghana to scale up clean energy.

Beyond Ghana and western SSA, the findings and recommendations of Communication 19 are intended to inform other low- and middle-income countries where the use of solid fuels remains high and where the resources to develop estimates of the contribution of HAP to ambient air pollution are constrained.



Summary Figure 1. Contribution of HAP to age-standardized deaths per 100,000 people attributable to (A) solid fuel use for cooking (Health Effects Institute 2019; Stanaway et al. 2018); and (B) ambient $PM_{2.5}$ based on GBD 2017. In China and India, the contributions from HAP were estimated from their respective GBD MAPS studies, while in Ghana and western SSA, the fractional contribution of HAP to ambient air pollution has not been estimated (GBD MAPS Working Group 2016, 2018; Health Effects Institute 2019 ; Stanaway et al. 2018). Average $PM_{2.5}$ concentrations exceed the WHO guideline for healthy air (10 µg/m^3).

APPROACH

Starting in July 2018, HEI convened a group of experts to:

- Summarize and compare approaches that have been used to quantify the contribution of HAP and other sources of ambient air pollution for various geographic scales in Ghana.
- Discuss the current state of knowledge on the source contributions to emissions, air quality, and health and identify key knowledge gaps.
- Discuss the potential added value of other data or approaches not yet deployed fully in the region.
- Make recommendations for opportunities to improve estimates of HAP's impact on air quality and health burden for tracking progress on efforts to scale up clean energy.

KEY FINDINGS

How Have Sources of Air Pollution Been Analyzed in Ghana?

Studies of source contributions to air quality generally fall into two broad methodological categories, *top-down* and *bottom-up*, which differ in the nature and geographic detail of required inputs, the economic and technical resources required to perform them, and the nature of estimates they provide.

We examined six top-down studies that rely on the analysis of filter samples of PM_{10} and/or $PM_{2.5}$ from monitors representing local air pollution sources in the Greater Accra region and in Northern Ghana (Aboh et al. 2009; Ofosu et al. 2012, 2013; Piedrahita et al. 2017; Zhou et al. 2013, 2014).

We also examined three bottom-up analyses that use emissions inventories to model total ambient $PM_{2.5}$ concentrations and the contribution of individual sources to ambient air quality across different time spans and geographic scales. The first analysis, Diffuse and Inefficient Combustion Emissions in Africa (DICE-Africa), has provided updated, locally specific emissions inventories for several combustion sources across Africa, enabling further analysis of source contributions to ambient air quality. Two of the methods, Long-Range Energy Alternatives Planning-Integrated Benefits Calculator (LEAP-IBC) and UEinfo (Urban Emissions) (*www.urbanemissions.info/*), also offer the opportunity to explore the implications of alternative energy policies on emissions, ambient air quality, and health in Ghana.

What Do We Know about Ambient Air Pollution in Ghana?

$PM_{2.5}$ in Ghana Exceeds World Health Organization Health-Based Air Quality Guideline (10 μg/m³). Results from a range of measurement studies indicate 24-hour average $PM_{2.5}$ concentrations between 22 and 41 μg/m³. On the other hand, annual average $PM_{2.5}$ concentration in Ghana, based on satellite-derived $PM_{2.5}$ estimates, is reported to be 35 μg/m³ (Health Effects Institute 2019).

Air Pollution Is a Regional Challenge Across Western Sub-Saharan Africa. The regional annual average $PM_{2.5}$ for western SSA was 59 μg/m³ in 2017, based on the most recent GBD study (Health Effects Institute 2019). Desert dust and regional pollution sources (e.g., open fires) influence pollutant concentrations regionally and in Ghana. According to estimates generated within LEAP-IBC, approximately 65% of ambient $PM_{2.5}$ in Ghana is linked to natural emissions, which are largely comprised of desert dust emissions. This finding is consistent with a global analysis, which attributed nearly 60% of total deaths in Ghana to natural dust (Lelieveld et al. 2015).

What Do We Know About the Contribution of HAP to Ambient Air Pollution in Ghana?

Estimation of HAP's contribution to ambient air pollution requires selection of an appropriate approach and numerous inputs. For bottom-up methods, inventories for all sources — including households — that contribute to $PM_{2.5}$ emissions are required. Emissions inventories are then used as input to models that estimate how various pollutants contribute to ambient $PM_{2.5}$ concentrations, either directly or as they are formed in the atmosphere through chemical processing of other air pollutants.

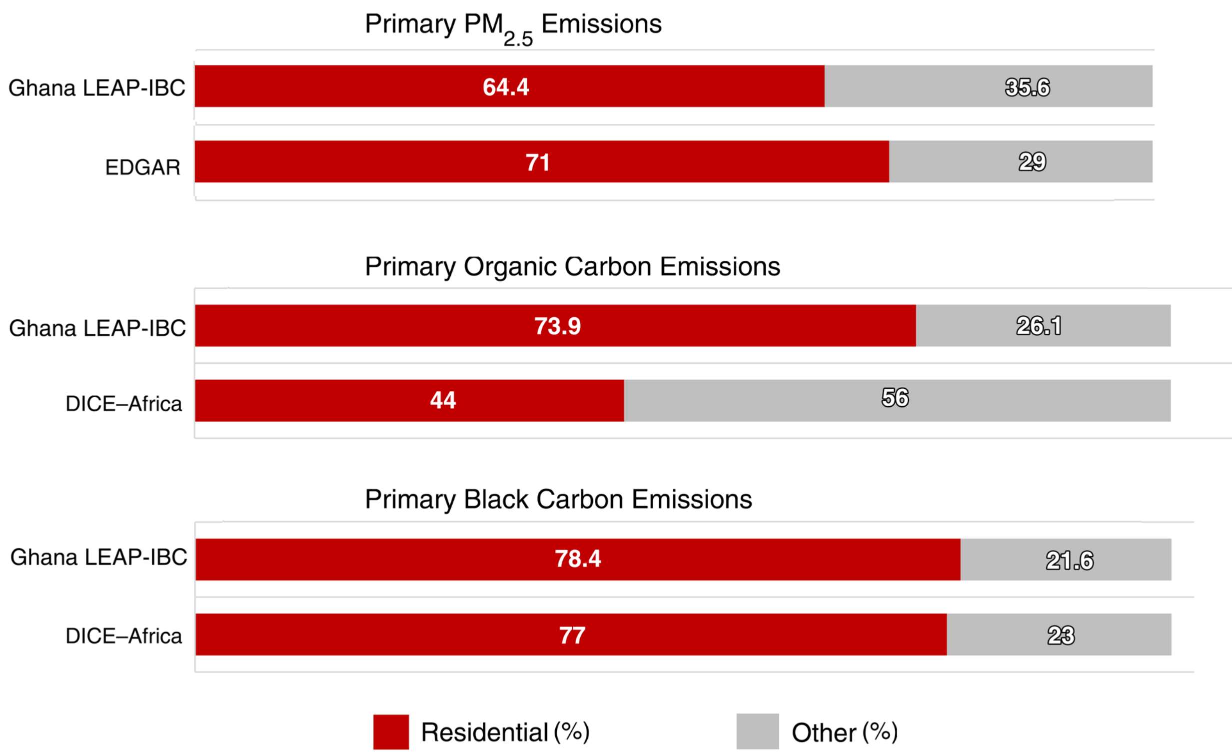
In Ghana, few studies provided a complete assessment of HAP's contribution to ambient air pollution. Some studies (e.g., DICE-Africa) were initially designed only to develop more comprehensive emissions inventories, which is an important starting point for bottom-up approaches. Although contributions of primary HAP emissions as a percentage of total emissions do not necessarily translate into the same percentage contributions to ambient $PM_{2.5}$ concentrations, both kinds of estimate are presented here to provide some perspective on the potential importance of HAP emissions for ambient air quality.

Household Fuel Use Has Been Estimated to Account for Nearly 65% of Total Primary $PM_{2.5}$ Emissions in Ghana. See Figure 2. In addition to $PM_{2.5}$, analyses of black carbon (a short-lived climate pollutant and a key component of combustion-related PM) identified residential fuel use as the largest contributor, followed by commercial biofuel use and vehicles (Marais and Wiedinmyer 2016). Other major emission sources considered include road transport, road dust, open fires, and industry.

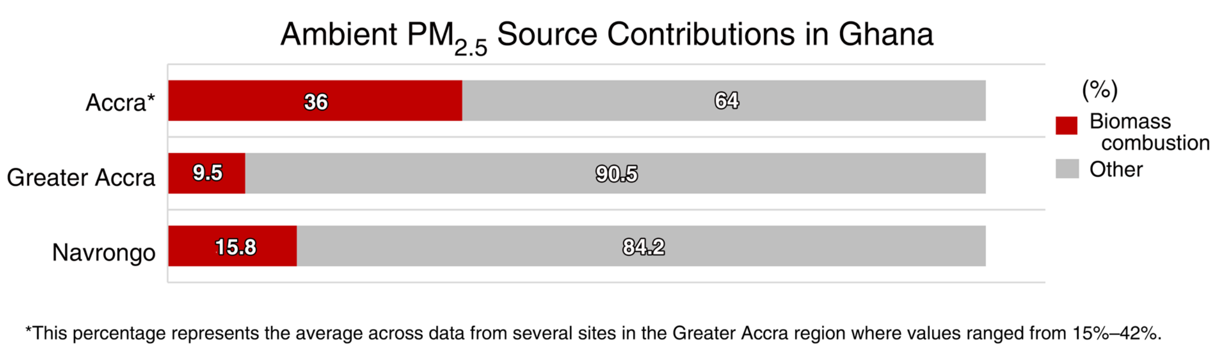
Biomass Combustion Explains 10% to 36% of Ambient $PM_{2.5}$ Concentrations in Ghana. These estimates, developed from top-down studies, are not always specific to residential use of solid fuels for cooking; they can include other forms of biomass combustion including open burning and commercial activities (see Figure 3). The other significant contributors to ambient $PM_{2.5}$ in these studies included natural and resuspended road dust and emissions from transportation and industry.

What Do We Know About the Implications of HAP's Contribution to Air Pollution for Public Health in Ghana?

No studies to date have specifically estimated the contribution of HAP to health burden via its contribution to ambient $PM_{2.5}$ in Ghana. The 2017 GBD study ranked HAP as the seventh largest risk factor based on its health burden in Ghana (Stanaway et al. 2018).



Summary Figure 2. Percentage contribution of residential emissions to total $PM_{2.5}$ emissions in Ghana. Contributions from other sources are combined and represented as “Other.” LEAP-IBC reports emissions estimates for Ghana. EDGAR is a global emissions inventory with data for the African continent. DICE-Africa is a regional emissions inventory for Africa and includes emissions estimates for Ghana (Crippa et al. 2018; Marais and Wiedinmyer 2016).



Summary Figure 3. Percentage source contributions from biomass combustion and other sources to ambient $PM_{2.5}$. (Ofosu et al. 2012, 2013; Piedrahita et al. 2017; Zhou et al. 2013, 2014).

With 73% of the population relying on solid fuels for cooking in Ghana (and where other residential fuel uses are not included), it is possible that a sizeable fraction of the ambient air pollution burden could also be attributed to HAP. In India, for example, where approximately 60% of the population relied on solid fuels for cooking, an estimated 24% of the mortality burden from ambient air pollution was attributed to HAP (GBD MAPS Working Group 2018). In Ghana, if a substantial component of the burden of disease from ambient air pollution were also attributed to residential cooking with solid fuels, HAP’s total impact would compete with premature birth to be the sixth leading risk factor for adverse health outcomes in the country.

However, there are some signs of progress. Between 2005 and 2017, the percentage of people using solid fuels for cooking in Ghana declined from 91% to 73%; by extension, the estimated number of early deaths also declined (from 11,300 to 9,780). In contrast to HAP, ambient air pollution is ranked lower (17th) in its contribution to health burden in Ghana, but sources contributing to ambient $PM_{2.5}$ have been steadily increasing due to population and economic growth (Marais and Wiedinmyer 2016).

What Other Ongoing Work Is Relevant to Ghana and West Africa?

Several ongoing projects identified in Communication 19 are improving the understanding of ambient air pollution and its sources in western SSA and provide a broader context for efforts to improve estimates of HAP's contribution to ambient air pollution. They include several ongoing projects by DICE-Africa and others that are designed to improve regional emissions inventories as well as local emissions factors. With assistance from the U.S. Environmental Protection Agency, Ghana is currently in the process of implementing a comprehensive air quality monitoring program in the Greater Accra region that includes real-time air quality monitors and facilities for chemical analyses of ambient PM filter samples.

New satellite-based methods are emerging, including:

- TROPOMI (TROPOspheric Monitoring Instrument) is a European space-based instrument designed to monitor global air quality at finer resolutions than ever before;
- NASA MAIA (National Aeronautics and Space Administration Multi-Angle Imagers for Aerosols) is an upcoming satellite program specifically intended for use in 12 urban-level health studies, including at least one African city;
- SPARTAN (Surface PARTiculate mAtter Network) is a global ground-based air quality monitoring network specifically designed both for validation of satellite data-based $PM_{2.5}$ estimates and to support source attribution for $PM_{2.5}$.

HEI's Global Burden of Disease from Major Air Pollution Sources (GBD MAPS) Global project is undertaking a worldwide estimation of sectoral source contributions to air pollution and the associated impacts on national disease burden for all 195 countries included in the GBD project. It is designed to provide consistent baseline estimates of HAP and other source contributions to ambient air pollution in individual countries across the world.

A WAY FORWARD TOWARD ACTION

Opportunities exist to apply both top-down and bottom-up methodologies to help identify the most cost- and health-effective clean energy interventions for HAP. Both top-down and bottom-up methods can be used for source apportionment and air quality management; however, both involve a substantial investment in equipment, technology, and human resources that can vary based on the scope and scale of the analysis. Targeted investments in enhanced monitoring and emissions data, coupled with refined bottom-up analyses, have the potential to capture the benefits of clean energy interventions and to motivate positive and sustained action, particularly in settings like Ghana where limited air quality data are available.

What Are the Opportunities to Spur Action on HAP and to Improve Estimates of HAP's Contribution to Ambient Air Pollution and Burden?

1. Communicating the Importance of HAP as a Contributor to Ambient Air Pollution in Ghana. The current global and national evidence reviewed in Communication 19 points to HAP from residential fuel use as an important contributor both to total $PM_{2.5}$ emissions and to ambient $PM_{2.5}$ concentrations.

In the near term, this evidence creates an opportunity for strategic communications of the results in Ghana, bolstered with additional policy and/or economic analyses, in order to influence policy action on household energy. Strategies to address HAP have two scales of broad benefit — directly to households relying on solid fuels and indirectly to others who would benefit from improved ambient air quality.

Key stakeholders to be addressed fall into two categories: (1) policy makers focused on improving ambient air quality and (2) policy makers involved in the development and implementation of the national energy plan. Other stakeholders, including academics and civil society groups can also be targeted for briefings to build broader support for the issue.

Key messages include:

- HAP is the seventh biggest risk factor for health burden — it contributed to 9,780 deaths in Ghana in 2017.
- Residential energy use is the biggest driver for $PM_{2.5}$ emissions and is among the most modifiable risk factors. Policies to address this source will have significant benefits for air quality and public health.
- Top-down studies in the Accra region indicate a significant contribution of biomass combustion to ambient $PM_{2.5}$ (15%–42%), including household solid fuel use.
- Overall, provision of liquefied petroleum gas for cooking and improving access to clean energy can help reduce air pollution.
- Air quality management plans in Accra (and more broadly, in Ghana) need to include considerations for residential solid fuel use.

This may also be an opportune time to assess public perceptions and media coverage of air pollution, its leading sources, and resulting health effects. If public perceptions and media coverage are not well correlated with the available evidence base, there may be a need to increase public awareness of the issues. The political will to promote clean household energy is likely to be dependent on a public demand for better air quality.

2. Support for Sustained Development and Improvement of Emissions Inventories for Ghana and the West African Region. Development and improvement of comprehensive inventories of emissions sources, both within countries and regionally throughout western SSA, is essential for characterizing sources and their impacts on air quality, health, and climate. All of the bottom-up analyses described in this analysis show that the accuracy, completeness, and comparability of the methods' findings depend in larger measure on the critical foundation of emissions and activity data.

In particular, there is a need for local, detailed emissions inventories focusing on key sources, including household energy use, at a fine spatial scale.

3. Support for an Expanded Air Quality Monitoring Program in Ghana. Air quality monitoring is a critical component of national and regional air quality management programs. Representative monitoring networks provide reliable information to track air quality and the effectiveness of interventions over time; they can also be used for validation and evaluation of bottom-up methods. Through the ongoing program in the Greater Accra region, Ghana is in the process of expanding its current air quality monitoring infrastructure. Future efforts could focus on expanding monitoring across the country. Detailed guidance is available for countries embarking on establishing or expanding air quality monitoring programs (Awe et al. 2018).

Data from strategically placed ground-based air quality monitoring stations can also be used to improve satellite data-based estimates for air pollutants and to support source apportionment at the national and regional levels. The SPARTAN monitoring network is currently providing data for such analyses globally. It could be expanded in Ghana, given the presence of a necessary NASA AERONET monitoring site north of Accra.

4. Harmonization of Ongoing Efforts and Better Coordination Among Researchers in the Region. While there is an increasing number of studies in Ghana and the region, there has been little or no coordination across programs. There are useful near-term opportunities to leverage existing (and ongoing) work to improve the understanding of source contributions to $PM_{2.5}$ and estimates of the air pollution-related health burden.

Sponsors of all of the efforts should gather and support (and provide resources to) a team of analysts (either from the government or from a private institution) to take the lead in coordinating and harmonizing these efforts. Some of the data gaps are being filled through the projects discussed here (i.e., DICE-Africa, the Ghana LEAP-IBC analysis, and UEinfo), as well as through other analyses. However, a more complete and harmonized assessment — led by an agreed-upon team, in collaboration with the Ghanaian government — is critical in designing national policies. The team's work should also consider steps to build local capacity for long-term sustainability of such efforts.

5. Support for Regional Action. The evidence reviewed for Communication 19 makes it clear that air pollution in Ghana is part of a regional challenge that will ultimately require regional solutions. Desert dust and pollution from surrounding countries both have substantial impacts on Ghana's air quality. Regional (western SSA) approaches to developing emissions inventories and ground-level monitoring systems may provide better value for the money than focusing on city- or country-specific analyses in Ghana alone. Such efforts would benefit from cooperation across countries in the region; Ghana could act as an anchor for a coordinated regional assessment of air pollution sources.

How Could Expanding Other Approaches in Ghana Better Inform and Motivate Action?

More comprehensive country-specific bottom-up modeling approaches can provide more realistic estimates of source contributions and analysis of the impact of policy alternatives. The GBD MAPS studies conducted in China and India (GBD MAPS Working Group 2016, 2018), and similar studies elsewhere, rely on more detailed atmospheric chemistry and meteorology as well as more geographic detail on the origins and impacts of sources on air quality and health. Like the LEAP-IBC tool, these approaches can be used to model and explore alternative energy and pollution-control scenarios, and they are very useful for both policy planning and evaluation. However, the quality of the results is dependent in large part on the quality of the detailed emissions inventories described in point 2 of the previous section.

What Does Ghana's Experience Suggest for Other Low- and Middle-Income Countries?

Ghana is currently undertaking several initiatives on air pollution and climate change. However, for countries and regions at an earlier stage in this process, Ghana's experience holds important lessons:

- In countries where no data currently exist, existing global assessments (e.g., Chafe et al. 2014; Lelieveld et al. 2015; Weagle et al. 2018) or assessments under development (e.g., HEI GBD MAPS Global, a global effort to characterize sources of air pollution) can be a good starting point for understanding and communicating the importance of residential energy contributions to ambient $PM_{2.5}$.
- Modeling tools like LEAP-IBC, which is currently being used in more than 30 countries, can be effectively used to develop local technical capabilities for building local emissions inventories that can be iteratively improved. Such tools can also be used to explore the implications of specific policies for air quality and health.
- In the long term, availability of ground-based measurement data and detailed source emissions inventories can lead to more detailed analyses of specific source contributions and the associated health burden.

Across all types of programs, collaboration with international scientists and organizations can leverage local scientific and government resources to improve the evidence base and build capacity in the long run. Although the local context needs to be considered for any of these activities, it is reasonable to assume that some of the fundamental challenges will be similar. In most cases, the investment in a comprehensive emissions inventory, together with a robust air quality monitoring network, should be seen as the first step in strengthening the local evidence base.

From the Ghana experience, it now seems clear that a more consistent and coordinated approach to building technical and resource capacity at the local and national level is not only possible but preferable for supporting data-driven policy action on household energy use. Ultimately, such efforts cannot be successful without addressing the longer-term needs for technical and financial capacity development to sustain effective in-country programs.

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ABBREVIATIONS AND OTHER TERMS

DICE-Africa	Diffuse and Inefficient Combustion Emissions in Africa
EDGAR	Emissions Database for Global Atmospheric Research
GBD	Global Burden of Disease
GBD MAPS	Global Burden of Disease from Major Air Pollution Sources
HAP	household air pollution
LEAP-IBC	Long-Range Energy Alternatives Planning-Integrated Benefits Calculator
NASA AERONET	National Aeronautics and Space Administration (U.S.A.) AErosol RObotic NETwork
PM	particulate matter
$PM_{2.5}$	particulate matter ≤2.5 µm in aerodynamic diameter (fine particulate matter)
PM_{10}	particulate matter ≤10 µm in aerodynamic diameter
SPARTAN	Surface PARTiculate mAtter Network
SSA	sub-Saharan Africa
UEinfo	Urban Emissions

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