ADDIS ABABA CITY

AIR QUALITY MANAGEMENT PLAN

(2021 to 2025)

Acknowledgements

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FORWARD MESSAGE

MAYOR ADANECH ABIBEBIE

Air pollution is the most significant environmental contributor to premature death across Africa, outpacing deaths from malaria and HIV. We know that levels of harmful air pollutants are too high and present an unacceptable health burden on the people who make Addis Ababa their home. We also know that this health burden has real economic implications for the city and the nation as a whole. Health effects associated with air pollution limit healthy time that could be available for work or school and present a direct social and economic cost for healthcare to treat asthma, serious respiratory symptoms, and many other health effects, including premature death.

Through recent cooperation with the U.S. under their Megacity Partnership, local experts have calculated that our city experienced 2,700 premature deaths in 2017 from this level of pollution in our city. With no action, this will grow to 6,000 premature deaths by 2025. And we know that it's not just premature death, air pollution impacts everyone's quality of life and has many other health consequences that will only get worse if we do not take action.

I want to assure you that we can tackle this challenge together while also sustaining rapid economic growth. The idea that environmental needs counter our economic or development needs is a false choice. Advances in environmental standards can improve economic performance. In fact, without action we can anticipate harm to both health and economic development.

So, what can we do? To address this serious challenge, today I am launching an Air Quality Management Plan for the city of Addis Ababa. This plan offers a vision for our city's future that includes blue skies and cleaner air than we have today. Action is supported by the data from the U.S. monitors and satellite data to make a compelling case that the time to act is now. The plan also includes strategies for a rapidly expanding network of air quality sensors and other local data, as well as specific actions to reduce emissions.

When implemented by partners across local and federal government, the private sector and academia, this plan will help us realize the following types of air pollution reduction strategies: reduce open burning, create vehicle emissions standards, improve vehicle emissions testing and enforcement, create stronger standards for fuel quality with an emphasis on decreasing the concentration of sulfur in our diesel fuel, and expand of our air quality monitoring abilities to evaluate change over time. We cannot solve this problem overnight, but by launching this plan, I am committing to take the steps needed to clean our air and improve the health for all our residents.

The good news is that we also have support from the international community to begin to take immediate action to implement the objectives and activities outlined in the AQMP. The U.S. government support includes the U.S. Environmental Protection Agency, the State Department, NASA, and USAID. They will work in close collaboration with UNEP, C40, WRI, the World Bank, Vital Strategies, and Addis Ababa University's GeoHealth Hub along with committed representatives from the EFCCC, MoT, MoH, under the leadership of the EPGDC. I will ask the EPGDC

Commissioner to chair a steering committee to coordinate the growing efforts to improve air quality in our city. Together, we can and must make progress.

We have seen rapid growth in the number of air quality sensors in the city and will have much better data for future monitoring and action. However, there is no need to wait for perfect data to know that the air we breathe is unhealthy and people are dying from it. This AQMP includes plans for concrete steps to reduce emissions, not just measure them. We can look at large developing cities around the world to know that the air will get much worse without concrete action today to slow down the rate of emissions growth. In doing so, we can save lives, improve worker productivity with fewer sick days, improve our tourist revenues, and make Addis Ababa a city the "New Flower" that its name embodies.

EXECUTIVE SUMMARY

Indoor and outdoor pollution are currently the most significant environmental contributors to premature death in Africa, outpacing that of malaria and HIV. Yet for many African governments, addressing air pollution has only recently become a key public health concern. According to present knowledge, one in nine of today's global deaths is a result of exposure to air pollution - either (outdoor) ambient air pollution (AAP) or (indoor) household air pollution (WHO (2018a, 2018b), jointly causing an estimated 8 million deaths per year. The State of Global Air 2020 indicates that air pollution was the fourth leading risk factor for premature death in 2019 (Health Effects Institute, 2020). Without multi-pronged action, the growing rural-urban migration and increase in population being experienced in Ethiopia, and in Addis Ababa in particular, is likely to outpace and challenge the already inadequate infrastructure that exists to manage air pollution.

Ethiopia's first Air Quality Management Plan (AQMP) focuses on the Addis Ababa region for three reasons:

- Current conditions, as characterized by available ambient particulate matter data from air quality monitor readings and satellite data, present an unacceptable health burden for the population of Addis Ababa. Ambient concentration levels are estimated to be at least 2-3 times both the Ethiopian standard and WHO guidelines for air quality.
- The health burden associated with high $PM_{2.5}$ concentrations has clear economic implications for Addis Ababa and the nation as a whole. Health effects associated with $PM_{2.5}$ limit healthy time that could be available for work or school and present a direct social and economic cost for healthcare to treat asthma, serious respiratory symptoms, and many other health effects.
- Without action, economic and population growth is very likely to lead to higher air pollutant emissions in the vehicular, household and commercial open burning, and industrial sectors, which will worsen air quality over time. When implemented, this AQMP can reverse harmful emissions trends.

Common sources of ambient air pollution in Addis Ababa include vehicle emissions from fuel-inefficient, aging vehicles, incomplete combustion from diesel vehicles, unpaved roads, industrial sources, and construction. Other sources include household cooking and heating, open burning of solid waste, and transport of pollution from industrial areas outside of Addis Ababa. The health burden of these emissions is considerable. In the Addis Ababa Region, a multi-agency air quality management workgroup estimates that in 2017, 2,700 lives were prematurely lost due to the effects of air pollution, or about 21% of all non-accidental deaths in the 25- to 99-year-old age group[1]. Without action to control air pollution, by 2025 this figure is estimated to rise to 6,200 and account for 32% of deaths in this age group. Meeting existing Ethiopian ambient air quality standards can reduce those deaths by more than 75%. Additional negative health outcomes associated with air pollution, such as premature mortality among youth and children, asthma cases and missed school and work days, can also be reduced.

[1] This is the age range for which data is available. Impacts are also expected in younger ages, but estimates are not available.

The Addis Ababa Environmental Protection and Green Development Commission (AAEPGDC) and other partners developed this comprehensive AQMP for the Addis Ababa Region as the next step in addressing these problems. Key features of this plan include:

- Baseline air quality characterization and projected emission trends
- Health burden estimates
- Institutional commitment to updating and enforcing source-specific and ambient air quality standards
- Efforts to augment and standardize the air quality monitoring network
- A detailed AQMP implementation plan

The AAEPGDC expects to update this plan again in five years to take advantage of new knowledge, new technologies, and continually work to improve the public health of those who live, work and play in Addis Ababa.

1. Introduction and Background of Air Quality in Addis Ababa

As Addis Ababa grows both economically and spatially, air pollution from vehicle emissions, residential combustion, open burning of waste, and other sources is an increasing health concern in the metropolitan area. The legal basis for air quality management and general environmental policy is included in the Ethiopian Constitution, which ensures that every citizen has the right to a clean environment and that the government will prevent environmental pollution and the associated negative health effects (Tefera et al., 2014). Proclamation 295/2002 furthers the constitutional right of environmental protection by establishing a federal, independent, environmental protection authority (now the Environmental Forestry and Climate Change Commission, EFCCC), the Environmental Council, who provide high-level oversight of regulation, policy, and environmental standards (Tefera et al., 2014), and regional environmental protection authorities located in Addis Ababa and Dire Dawa (Addis Ababa Institute of Technology, 2012). This Air Quality Management Plan (AQMP) is an important step toward providing the clean and healthy environment necessary for Addis Ababa city and its residents to develop, grow, and prosper.

Under the Environmental Pollution Control Law, the EFCCC is responsible for setting environmental standards and enforcing compliance with the standards (Tefera et al., 2014). Other relevant agencies with jurisdiction over air quality management include:

- federal Ministry of Transport and Addis Ababa Transport Authority, which are responsible for monitoring and enforcement of emissions from mobile sources and collection and maintenance of statistics on the vehicle fleet,
- National Meteorological Agency, which is responsible for collecting, managing, and disseminating meteorological and air quality monitoring data,
- Ministry of Health, which has a Hygiene and Environmental Health Directorate that includes case teams focused on water quality, food sanitation, and air/climate. They rely predominantly on Health Extension Workers at the grassroots level for outreach, preventative health tips, and education of the population (Tefera et al., 2014). The Ministry of Health adopted a national framework for climate resilience (FMOH 2014).
- Addis Ababa City Administration Health Bureau, which has created the structure of the Environmental Health Department, including structure at the sub-city and woreda level where Environmental Health Professionals engage on environment-related activities. In addition, the Urban Health Extension is designed to raise awareness of the health risks including air pollution and empowerment of women and children, who experience the highest levels of exposure in their communities. Because the Environmental Health Program is yet adequately supported and lacks concrete evidence to confirm air pollution (Indoor and outdoor) associated health effects, policy decisions must rely on incomplete information.
- At the city level, the authority and responsibility to maintain a healthy and clean environment within the region of Addis Ababa city is formally held by the Addis Ababa Environmental Protection and Green Development Commission (AAEPGDC).
- In addition, the Solid Waste Management Agency, the Addis Ababa Planning and Development Commission, and the City and Federal Transportation Ministry can play particularly constructive roles in addressing air pollution.

Ethiopia has established national ambient air quality standards for various pollutants, including fine particulate matter ($PM_{2.5}$). $PM_{2.5}$ is an inhalable mixture of solid and liquid particles present in the air that measure less than 2.5 microns in diameter. There is significant evidence of the relationship between exposure to $PM_{2.5}$ and harmful human health impacts, as $PM_{2.5}$ is associated with the greatest proportion of adverse health impacts related to air pollution worldwide. Ethiopia's national standards were created with reference to World Health Organization (WHO) guideline target. WHO suggests annual average $PM_{2.5}$ concentrations not exceed 10 $\mu g/m^3$, though maintains interim targets to allow stepwise achievements in air quality management. These interim targets are meant to help countries to develop their own air quality management standards progressively and demonstrate improvement over time.

At the time of developing Ethiopian standards in 2003, there were no national baseline air quality data available. Ethiopian standards were set between WHO interim targets 1 (annual average $PM_{2.5}$ concentration 35 µg/m^3) and 2 (annual average $PM_{2.5}$ concentration 25 µg/m^3). According to Environmental Pollution Control Proclamation No. 300/2002 section 6 (4) Ethiopian law establishes the right for regional environmental protection authorities, such as the AAEPGDC, to set more stringent ambient and emissions standards than the national standards if they so choose, but the national standards establish a minimum stringency level for all parts of Ethiopia.

In Addis Ababa, both mobile (vehicle) and point (mostly industrial) emission sources contribute to carbon monoxide (CO), nitrogen oxides (NOx), ozone (O_3), sulfur dioxide (SO_2), coarse particulate matter (PM_{10}), and $PM_{2.5}$ pollution in the metropolitan area.[2] The main sources of ambient air pollution in the city are

- Vehicle emissions from fuel-inefficient aging vehicles,
- incomplete combustion from diesel vehicles,
- Dust from unpaved roads,
- Open burning of trash,
- Home heating and cooking using biomass, and
- Industrial sources.

Plans outlined in Ethiopia's Growth Transformation Plan Part One (GTPI) and Part Two (GTPII) illustrate Ethiopia's commitment to developing national, renewable energy sources for electricity generation (mainly hydropower, but also geothermal) and replacing vehicles with light rail transit and bus rapid transit systems within the city. Overall, the infrastructure projects undertaken show a significant push towards improving the efficiency and low- to no-emission components of the transport and energy sectors, which will help reduce the burden of air pollution in Addis Ababa.

In addition, despite an aging vehicle fleet, there are several policies in place and currently being drafted under the Climate Resilient Green Economy (CRGE) and Global Fuel Economy Initiative (GFEI) regarding vehicles standards. The CRGE is drafting vehicular emission standards for emissions and promoting fuel blends of ethanol, gasoline, and biodiesel through the EFCCC. Using blended fuel will reduce the country's reliance on imported fuel with high sulfur content from Sudan (other fuels are imported from Saudi Arabia and Kuwait.) Currently, every car in Ethiopia must undergo an annual inspection to ensure the vehicle meets safety standards. There are standards for vehicle exhaust emissions limits for smoke and CO, established by the Ethiopian government under the EFCCC and codified within the Transport Authority to measure compliance (Addis Ababa Institute of Technology, 2012). However, vehicle emissions enforcement is not yet happening. Recently, EFCCC altered the federal tax on vehicle imports to reduce the incentives to import older vehicles and reduce the disincentive to import newer, more fuel-efficient and cleaner vehicles. Addis Ababa city banned commercial vehicles during daylight hours and banned motorcycles from city streets in an effort to reduce congestion and improve fuel-efficiency. Other measures to control vehicle emissions and update the vehicle fleet are also being considered as part of this AQMP.

Ethiopia's standards for industrial pollution control were developed by the federal EPA in 2003 based on international best practice. At that time there were no national baseline data to guide the development of national targets. The standards require refreshing based on current national and city level air quality status as well as air quality goals. A source apportionment study conducted in 2004 concluded that between 35 and65% of PM_{10} in Addis Ababa was geologic in origin, with unpaved roads as the main source (Etyemezian et al., 2005). With an increasing number of vehicles on the road and a large unpaved road network, the concentration of suspended dust particles from unpaved roads could increase, though efforts over the past decade to pave roads within Addis Ababa city show promise in this area. Another potential area of concern is emissions from construction activity.

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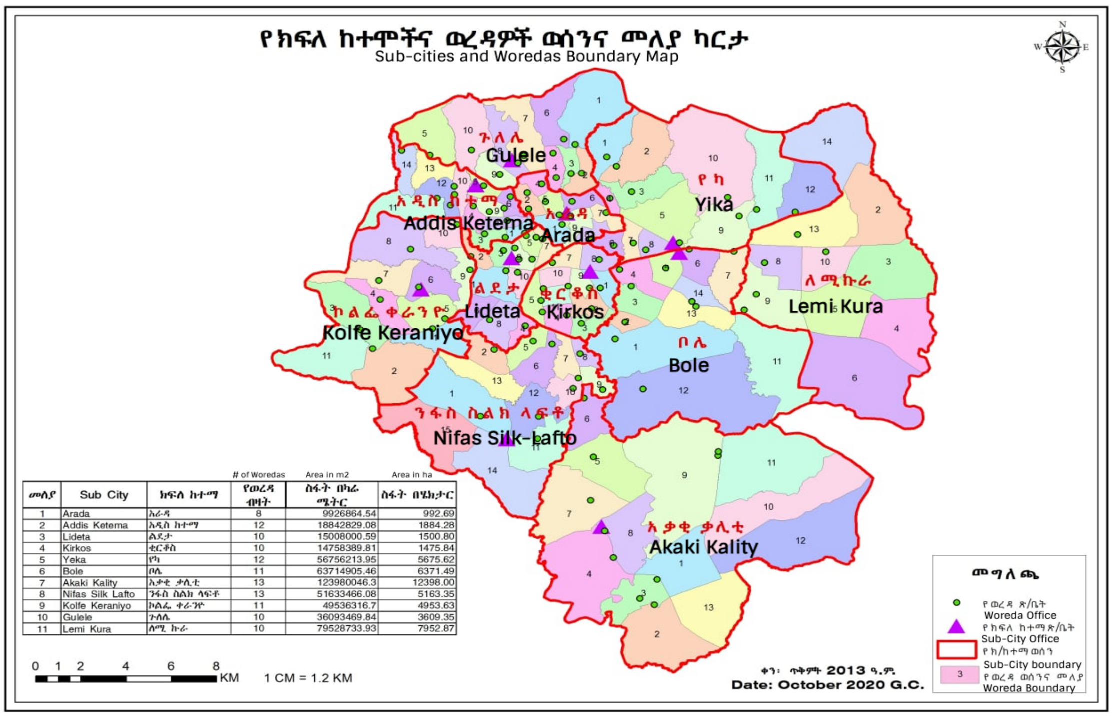
[2] Given its important relationship with harmful human health impacts, this AQMP focuses specifically on analysis of and efforts to control $PM_{2.5}$ in the city of Addis Ababa.

Open burning of waste is a common problem in Addis Ababa. Some studies have suggested that that nearly 55 percent of the population in Addis Ababa use open burning as their primary means of waste disposal, a figure slightly higher than the overall national average of the population using open burning as their primary waste disposal means (Cheever 2011).

Efforts to monitor and manage air pollution emissions, both prior to this AQMP and ongoing, have had an impact on air quality, but significant gaps remain and further progress is expected. To bridge these gaps, the AAEPGDC has developed this draft AQMP, in conjunction with other federal and city authorities, to address air quality within Addis Ababa.

FIGURE 1-1: ADDIS ABABA MAP



The goal of the plan is to reduce the concentration of hazardous fine particulate matter ($PM_{2.5}$) in the Addis Ababa region to a level that is in compliance with the national air quality standard. This first AQMP has been developed by AAEPGDC in collaboration with the United States Environmental Protection Agency (USEPA) to take advantage of USEPA's significant and broad experience in air quality management.

Ethiopia's first AQMP focuses on the Addis Ababa region for three reasons:

- Current conditions, as characterized by available ambient fine particulate matter data from air quality monitor readings and satellite data, present an unacceptable health burden for the population of Addis Ababa. Current $PM_{2.5}$ concentrations are not in line with international standards for air quality.
- The health burden associated with high $PM_{2.5}$ concentrations has clear economic implications for Addis Ababa and the nation. Health effects associated with $PM_{2.5}$ limit healthy time that could be available for work or school and present a direct social and economic cost for healthcare.
- Without action, economic growth is very likely to lead to higher emissions in the vehicular, household and commercial open burning, and industrial sectors, which will worsen air quality over time.

The focus of the AQMP is ambient particulate matter (PM) pollution in Addis Ababa. PM pollution is classified by the size of the particles—PM_{10} stands for particulate matter comprised of particles less than 10 microns in diameter and $PM_{2.5}$ refers to fine particulate matter comprised of particles less than 2.5 microns in diameter. The length of exposure and particle size a person is exposed to can cause differential health impacts; for example, $PM_{2.5}$ penetrates more deeply into the lungs and has been found to have greater toxicity at lower exposure levels than PM_{10}. Similarly, the impacts of long-term, chronic exposure to particles can differ from the impacts of exposures occurring within the course of a single day. Therefore, ambient air quality standards include different standards for PM_{10} versus $PM_{2.5}$ and daily versus annual exposure times. As noted in Section 1, this AQMP focuses on $PM_{2.5}$ specifically

2. AQMP Development Process

Section 2 of this AQMP provides an overview of the various processes that contributed to its development. More details are provided within each subsection.

2.1 Stakeholder Engagement in the AQMP Development Process

The USEPA and United Nations Environment Programme (UN Environment) worked together to support AAEPGDC in the development of actionable air quality management policies beginning in early 2018. Stakeholder buy-in is a critical part of any air quality management planning process.[3] The Megacities Partnership was launched by the U.S. Ambassador, the Ethiopian EFCCC and UN Environment. [4] Stakeholders engaged in these events included:

- Addis Ababa Transport Authority
- Addis Ababa University
- National Meteorological Agency
- Kotebe Metropolitan University
- Addis Ababa City Administration Health Bureau
- National Ministry of Health
- National Ministry of Transport
- World Bank
- Addis Ababa Driver & Vehicle Licensing & Control Authority
- Population, Health and Environment Consortium

These same stakeholders reconvened in November 2018 and again in June 2019 to continue training and to build expertise in the application of the BenMAP-CE tool, air quality management planning, and communication and public involvement strategies.

[3] The first event was organized by UN Environment on May 3, 2018. This inception workshop was designed to assess the recent, on-going and planned air quality related work in Addis Ababa. At that time, UN Environment also presented an outline of their planned situational analysis.

[4] This first workshop was followed by a joint USEPA-UN Environment training workshop in September 2018 that included a formal launch of the Megacities Partnership. The launch event included participation by a number of senior officials, press and interested members of the public. The workshop was a more detailed training event designed to build capacity within Addis Ababa to apply tools and analysis and motivate action to address air pollution. Participants learned about the current state of air quality and relevant policies, the basics of air quality management and how to design and analyze AQM strategies and policies that can improve public health. In addition, a small group of technical staff gained familiarity with both source apportionment techniques using USEPA's Positive Matrix Factorization (PMF) software; and AQMP benefits analyses using USEPA's Environmental Benefits and Mapping Analysis Program – Community Edition (BenMAP-CE) tool.

While these stakeholders received detailed training in components of AQM planning, the AAEPGDC aimed to receive additional input from external experts in the form of a Clean Air Advisory Committee. The institutions represented by members of the Advisory Committee were:

1) Said Abdella, Addis Ababa Environmental Protection and Green Development Commission
2) Gutema Moroda, Addis Ababa Environmental Protection and Green Development Commission
3) Hirut Jifara Abdi , Ministry of Health
4) Berhanu Assefa, Addis Ababa University
5) Gezahegn Bekele, National Meteorology Agency
6) Tadesse Weyuma, Kotebe University
7) Abera Kumie, Addis Ababa University/GeoHealth Hub
8) Ahmed Mohammed, PHEEC (NGO)
9) Girma Samuel, AA Transport Authority
10) Yehalem Tesera, Driver and Vehicle Licensing Control Authority

The Advisory Committee meetings were conducted as part of each USEPA mission and were chaired by AAEPGDC. They received report-outs from the individual trainings and also provided feedback on the interim products developed under the Partnership, including the inception report and workplan.

2.2 STATUS OF THE MONITORING NETWORK OR OTHER DATA SOURCES

To measure air quality, there are currently three $PM_{2.5}$ air quality monitors in Addis Ababa—one maintained by Addis Ababa University through their work with the East Africa GeoHealth Hub (though),[5] and two maintained by the United States Embassy (which are publicly available through the AirNow-International program).[6] The Addis Ababa University $PM_{2.5}$ monitor is located at the College of Health Sciences at the Black Lion Hospital and the US Embassy monitors are at the US Embassy and the Addis Ababa International Community School, respectively. When combined with recently published estimates based on remote sensing data from satellite sources, these monitors provide a broad picture of the most and least polluted areas of Addis Ababa. This initial snapshot of the air quality surface provides sufficient rationale for actions set forth in this AQMP; however, it is worth emphasizing that ground-level measurements are not routinely collected for much of the city. Expansion of monitoring will enable city officials to refine air quality estimates and better identify highly exposed populations. Future improvements to this AQMP will include important pollutants other than PM2.5, including ozone, nitrogen oxides, carbon monoxide, sulfur dioxide, and others.

The Megacities Partnership currently underway in Addis Ababa includes expansion of monitoring at more sites throughout Addis using low-cost sensor technology. As of April 2021, UN Environment has deployed 5 low cost sensors across the city to measure $PM_{2.5}$. AAEPGDC is analyzing some of the data generated through these sensors. For sustainable delivery of information, the staff needs to be strengthened around calibration, data analysis and maintenance of the sensors. Part of that deployment includes a calibration period where low-cost sensors are co-located with a reference grade monitor such as those at the U.S. Embassy or Black Lion Hospital to help identify and

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[5] These data are not publicly available and have not been shared with EPGDC or Megacities Partnership project partners.

[6] Data are publicly available through the US AirNow-International program at https://www.airnow.gov/international/us-embassies-and-consulates/#Ethiopia$Addis_Ababa_School

correct for any persistent bias in the low-cost sensor measurements. Furthermore, a citizen science civil society group Menged Lesew and Addis Air have established a network of 9 low-cost optical sensors visible at addisair.org. While the deployment of these devices is a valuable first step towards improving the mapping of air quality in Addis Ababa, planning for the future air quality monitoring network in Addis Ababa will likely require a mix of technologies to produce comprehensive and reliable real-time air quality measurements.

2.3 AQMP Development: Analytic Steps

This AQMP has been developed through a process of collaboration and consultation with stakeholders in industry and government, and support from USEPA. The process has included the following steps:

1. ***Review of the existing emissions and ambient standards***.
2. ***Analysis of emissions source contributions.***
3. ***Evaluation of AQ monitoring data.***
4. ***Estimation of current and projected future health burden of air quality.***
5. ***Establishment of goals and objectives for the plan.***
6. ***Development of a detailed implementation plan.*** Achieving the goals and objectives of the plan requires a detailed implementation plan – this is proposed in Section 6 of this plan and will be continuously updated through stakeholder engagements and as part of the ongoing monitoring and evaluation of the plan's effectiveness, which is outlined in Section 7.

3. Summary of Baseline Air Quality Characterization

The air quality baseline reflects all air pollution regulations and policies currently in effect. The baseline is thenadjusted to reflect a future economic growth scenario where emissions grow at the rate of projected population and GDP growth. The baseline reflects current emission sources, their expected trends for the foreseeable future, and current air quality. Current air quality is characterized here using three years of regulatory-grade monitor data from the U.S. Embassy monitors combined with calibrated remote-sensed satellite data for the most current available year, as described below. Projections of an air quality baseline are based on available information for current trend and available source apportionment studies, which provide a means to estimate the relative contribution of sources to ambient air quality. In general, there is limited publicly available historical data beyond the regulatory-grade monitors in Addis Ababa which monitor relatively clean areas of the city; further data are needed concerning emissions quanitities and trends particularly in the central region of the city; and further research is needed on air pollution source apportionment. For this reason, this plan also includes specific goals and measures designed to improve gradually over time the information and evidence that can be used to support air quality management. Current air quality also has implications for health status, also reviewed in this section. The baseline further includes the state of governmental air quality management capacity at the national and local level.

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3.1 Emission sources

In Addis Ababa, both mobile and point emission sources contribute to CO, NO_x, O_3, SO_2, PM_{10}, and $PM_{2.5}$ pollution in the metropolitan area. Common sources of ambient air pollution in Addis Ababa are vehicle emissions from fuel-inefficient, aging vehicles, incomplete combustion from diesel vehicles, unpaved roads, industrial sources, and construction. Other sources include household cooking and heating, open burning of solid waste, and transport of pollution from surrounding areas. Detailed future studies on speciation of the particulate will help determine the impact of these emitters. However, trends like the diurnal spikes in particulate around rush hour point toward vehicles as an important driver. Plans outlined in the Growth and Transformation Plans (GTPs I and II) illustrate Ethiopia's commitment to developing national, renewable energy sources for electricity generation (mainly hydropower, but also geothermal) and replacing vehicles with light rail transit and bus rapid transit systems within the city. Overall, the infrastructure projects undertaken show a significant push towards improving the efficiency and low- to no-emission components of the transport and energy sectors, which will help reduce the burden of air pollution in Addis Ababa.

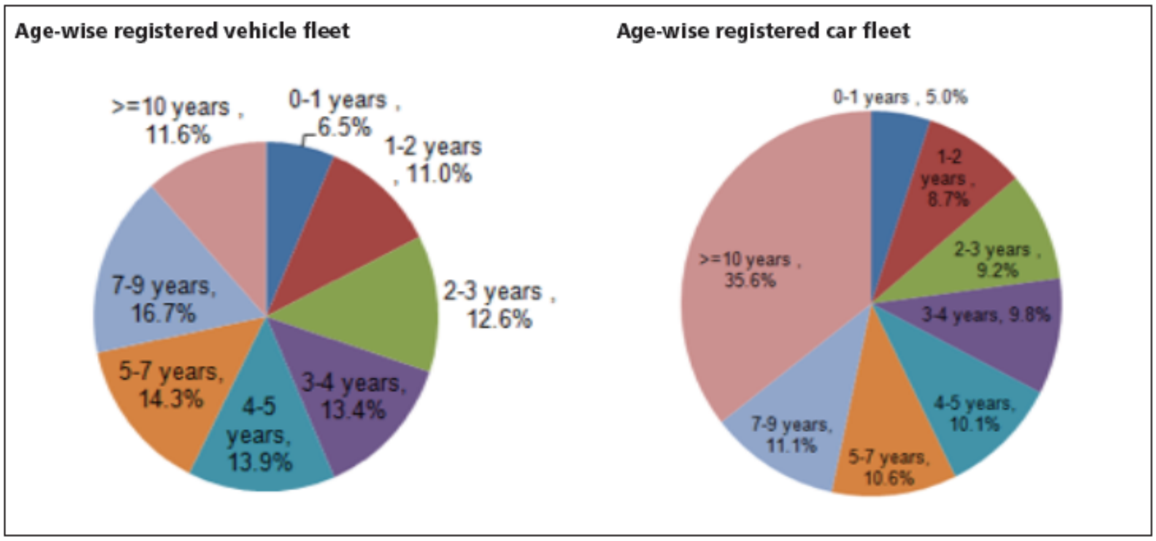
Vehicle Fleet and Emissions

Ethiopia had approximately 935,888 vehicles in use in 2018, with the number of vehicles registered growing at a rate of 16% per year (Ministry of Transport, 2019). Vehicles emit various pollutants including NO_x, CO, hydrocarbons (HCs), and PM into the atmosphere. Diesel vehicles release black carbon, and more SO_2 and PM than comparable petrol vehicles (Roychowdhury et al., 2016; Addis Ababa Institute of Technology, 2012). Older vehicles also contribute significantly to ambient air pollution from their low fuel efficiency.

Both Addis Ababa Institute of Technology (2012) and Roychowdhury et al. (2016) have done extensive research on the vehicle fleet composition and emissions in Addis Ababa. Data on the number of vehicles and types of vehicles registered were collected from the Addis Ababa Transport Authority and data on imported vehicles can be gathered from the Ethiopian Revenues Custom Authority. The Transport Authority is not responsible for private cars, but manages all public buses, public minivans, freight vehicles and private taxis in the city. Their findings show that the vehicle fleet is increasingly aged, and the proportion of diesel vehicles is rising (Roychowdhury et al., 2016). Figure 3-1, from Roychowdhury et al. (2016), shows the breakdown of cars by age class in 2014-2015.

Although the number of vehicles is increasing, around 91% of Addis Ababa's population utilizes public transportation (Roychowdhury et al., 2016). The public transportation system is based around a bus and light-rail transit system (LRT). The buses and minibuses can hold 12-24 people and travel along designated bus routes throughout the city. Most light-duty vehicles (LDVs) are imported, but Ethiopia began local assembly of vehicles between 2005 and 2008. Many of the LDVs emit substantial pollution; AACTA estimates that 31 % of the overall fleet lack catalytic converters. Because of the public's significant usage of the bus system, buses of all sizes accounted for nearly 39% of PM emission load from vehicles in 2014-2015 (Roychowdhury et al., 2016).

Figure 3-1. Breakdown of vehicles and cars by age class, 2014

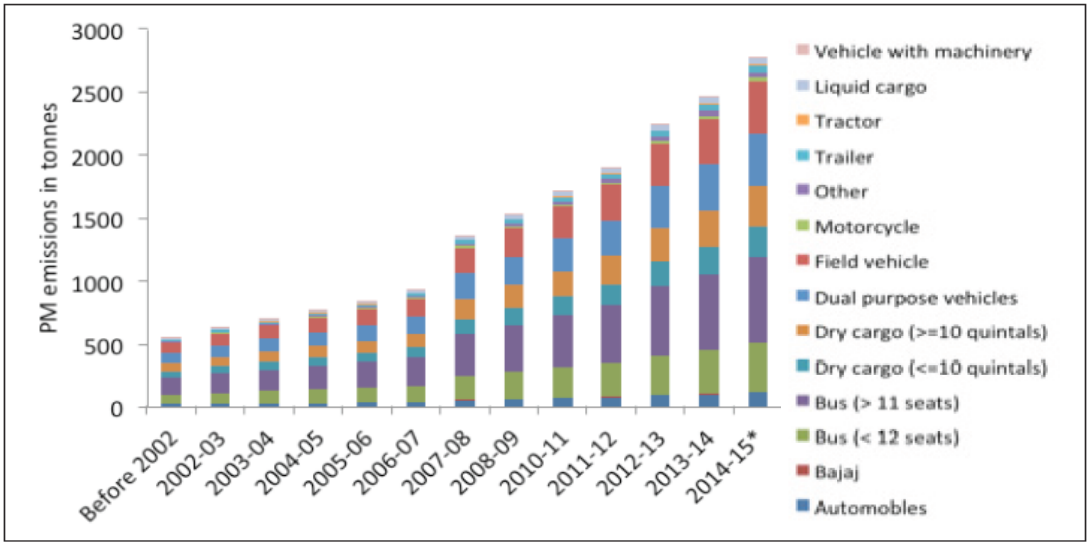


Source: *CSE based on data provided by Addis Ababa Transport Authority .*

To reduce the dependence on buses and lower emissions from public transportation, the CRGE and GTPI established measures to expand and upgrade the LRT in Addis Ababa Metropolitan Area and between Addis Ababa and Djibouti. Constructing and renovating the LRT in Addis Ababa was a substantial infrastructure project implemented under the GTPI. The LRT in Addis Ababa has since been completed and 41 additional km are planned to be constructed in GTPII. The LRT was not finished when the CSE report and Figure 3-2 below were published. The usage mix of public transportation is likely to change with the completion of the LRT. Moreover, the emissions trend line in Figure 3-2 may be outdated as people begin using the LRT over the buses as their mode of transport; however, traffic congestion created by LRT may contribute to air pollution within the city. Additional data on LRT capacity and ridership would be needed to assess potential impacts of this change.

Figure 3-2 also shows the significant contribution of PM from freight vehicles (i.e. vehicles with machinery, liquid cargo, tractor, trailer, dry cargo). Because Ethiopia is landlocked, most exported goods must be transported from Addis Ababa to Djibouti's port. Freight vehicles account for 75% of greenhouse gas (GHG) emissions in the transport sector and account for 23% of PM emissions (Roychowdhury et al., 2016; Federal Democratic Republic of Ethiopia, 2013). Construction of the LRT between Addis Ababa and Djibouti is complete and operating with some interruptions at present. Truck traffic on the road still dominates shipping volume.

Figure 3-2. Trend of Increased Particulate Matter Emission Load from Different Vehicle Types



Source: *CSE estimation based on data provided by Addis Ababa Transport Authority*

Once the train line is complete and fully operational (it began service in 2018), goods traditionally carried by diesel freight trucks will be transported via electric rail, reducing GHG and PM emissions in the future. Similarly, the proportion of PM emissions from freight in Figure 3-2 will also likely become outdated after the LRT completion.

The population's reliance on public transportation, rather than personal vehicles, can partly be credited towards the city's tax incentives to use public transportation and discourage personal vehicles. New cars specifically are taxed at 100%, where old cars are taxed at a lower rate but now the government of Ethiopia drafting policy that discourage old vehicles by increasing taxes up to 500% Excise Tax Proposed on Secondhand Cars (Ethiopian Monitor, 2019). Recently, Ethiopia banned importing vehicles older than a specific manufacturing date, which will lessen the number of aged vehicles on the road in the future (Tefera et al., 2014), but there is currently no retirement age for vehicles already registered in the country. Consequently, the high importation duties prevent people from buying new cars and leads to a large proportion of aged, inefficient, and polluting vehicles.

Despite an aging vehicle fleet, there are several policies in place and currently being drafted under the CRGE and GFEI regarding vehicles standards. The CRGE is drafting vehicular emission standards for emissions and promoting fuel blends of ethanol, gasoline, and biodiesel through the EFCCC. Using blended fuel will reduce the country's reliance on imported fuel with high sulfur content from Sudan (other fuels are imported from Saudi Arabia and Kuwait.) Currently, every car in Ethiopia must undergo an annual inspection to ensure the vehicle meets safety standards, and at that time emissions are checked in some fashion; however, we are not aware of standards established by the Transport Authority to measure compliance (Addis Ababa Institute of Technology, 2012).

Industrial Sources

At the end of the GTPI, agriculture, industry, and services shared 38.5%, 15.1%, and 46.3% respectively of the Ethiopian economy (Federal Democratic Republic of Ethiopia, 2015). Of the industrial sector, the manufacturing subsector made up 5% of the GDP and grew at an average rate of 14.6% per year. The manufacturing subsector contains garment and textile processing, leather processing, agro-processing, paint and dye manufacturing, pharmaceuticals, metal manufacturing, glass manufacturing and concrete manufacturing. There is little quality data on industrial emissions in Ethiopia making enforcement difficult. The EPGDC did succeed in banning the use of high-polluting fossil fuel in a glass manufacturing plant in Addis Ababa after neighborhood complaints of the smoke.

The construction sector is possibly the most notable growth industry. The construction subsector grew at a rate of 28% over the GTPI period and its share of GDP increased from 4% to 8.5% (National Planning Commission, 2016). The construction industry was largely driven by the infrastructure projects undertaken during the GTPI implementation. Cement creation accounted for the largest source of industrial GHG emissions. The EFCCC has set national air pollutant emissions standards for each of these industries.

Table 3-1. Emissions standards for cement manufacturing

Limit Values for Emissions to Air

Parameter	Limit value
Total particulates	150 mg/Nm^3
Sulphur dioxide (as SO_2)	1000 mg/Nm^3
Nitrous oxide (as NO_2)	2000 mg/Nm^3

Source: Provisional Standards for Industrial Pollution Control in Ethiopia

Road Network

As part of the urban development and housing section of the GTPI, almost 3,800 km of cobblestone roads were constructed in urban areas over the five-year period (Federal Democratic Republic of Ethiopia, 2015). Nationally, the paved road network expanded from 48,800 km to 63,604 km over the GTPI period, with an additional 46,810 km of unpaved roads. This spike in demand for concrete and asphalt led to a dependence on imported materials at the beginning of the GTPI period. By 2012, however, the local cement industry supplied all of the cement necessary for infrastructure projects (Federal Democratic Republic of Ethiopia, 2015).

Despite growth in local industry supporting paved roads, only 13% of the roads in Ethiopia are paved. Part of the GTPII plan is to increase the ratio of paved to unpaved roads to 16% (Federal Democratic Republic of Ethiopia, 2015). The high proportion of unpaved roads significantly impacts ambient air pollution. A source apportionment study conducted in 2004 concluded that between 35-65% of PM_{10} in Addis Ababa was geologic in origin, with unpaved roads as the main source (Etyemezian et al., 2005). With an increasing number of vehicles on the road and a large unpaved road network, the concentration of suspended dust particles from unpaved roads could increase.

Power Generation

Strategic directions of the GTPI and GTPII include increases in renewable power generation. The current electric generation capacity is 4,180 MW and will expand dramatically with renewable energy generation including the completion of the Grand Ethiopian Renaissance Dam (GERD), geothermal IPPs, solar IPPs, and wind farms. Electric capacity and expansion have important implications for electric rail transportation as discussed above. However, since most power generation is renewable, it will not contribute to air pollution. However, power distribution through transmission lines and transformers is not keeping up with the rapid population expansion of the city leaving intermittent power supply issues leading to regular use of diesel generators which impact air quality.

Opening Burning of Trash

Open burning of trash is believed to be a major issue in Addis Ababa, though minimal supporting information is currently available to characterize these emissions in a comprehensive fashion (see for example, Tefera et al. 2016). A global literature review of source attribution studies found that in Africa as a whole, the contribution of household combustion sources to ambient PM air pollution is about 34%, based on the results of four studies in Ghana, Nigeria, South Africa, and Tanzania, while traffic accounts for about 17% (Efobi etal, 2018). These results may not necessarily accurately reflect the source contribution of household burning for urban locations, and there is no information on the contribution of trash burning to this broader household combustion category. Further, there is no evidence yet available to confirm that household combustion would account for this percentage of ambient PM in Addis Ababa. The AAEPGDC nonetheless is aware of ongoing work within the GeoHealth Hub of Addis Ababa University to develop new source attribution estimates specific to Addis Ababa city, which remain under development at the time of the drafting of this AQMP.

Household Cooking and Heating

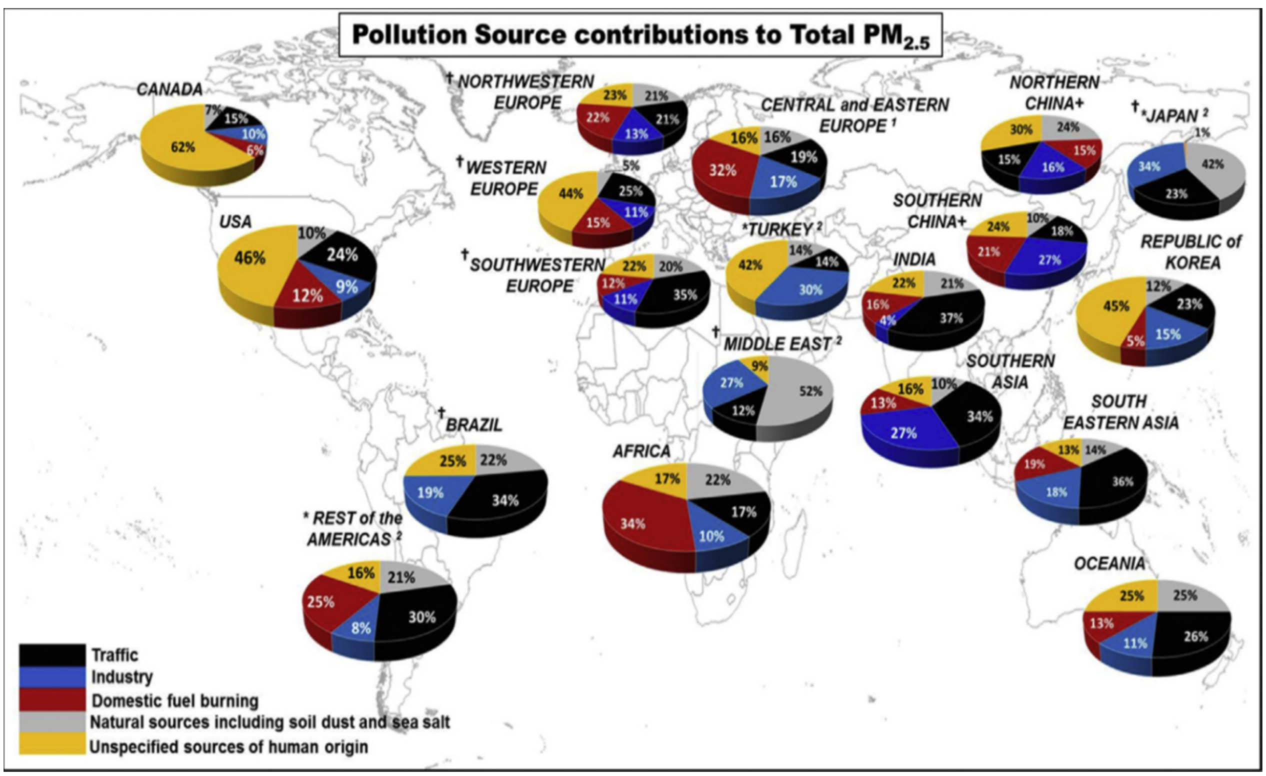
Household cooking and heating are believed to be a major contributor to health impacts from indoor air pollution exposure (CCA 2019; UN-Habitat 2017), but little information exists to clarify the role of household cooking and heating as a contributor to ambient air pollution. Etyemezian et al. (2005) concluded that the timing of particulate matter spikes over 24 hour periods suggest a major role for traffic, household cooking, and household heating in Addis Ababa, but more information is needed to confirm the specific role of household cooking and heating on ambient air quality in Addis Ababa.

Some data do exist to suggest that indoor air exposures from household cooking and heating are very high and could be significantly reduced by policies and campaigns to improve the efficiency of household cooking and heating devices, and/or to improve the fuel quality. For example, Sanbeta et al. (2014) concluded that changes in cookstove type and fuels could reduce the health burden of indoor air exposures to particulate matter by as much as 70% for households that switch from solid fuels to clean fuels. During January and February 2012, they measured the concentration of fine particulate matter ($PM_{2.5}$) in 59 households using the University of California at Berkeley Particle Monitor (UCB PM). The measurements yielded a geometric mean of 24-h indoor PM2.5 concentration of approximately 818 $\mu g/m^3$ overall, with 24-hr estimates as high as 1134 $\mu g/m^3$ for households using solid fuel; 637 $\mu g/m^3$ for households using kerosene; and 335 $\mu g/m^3$ for households using clean fuel. Additional evidence of the exposure reducing effects of changes in fuel types and cookstoves was provided by Pennise et al. (2009), who examined cookstove use and indoor exposures in low-income areas of Addis Ababa. Household surveys in Ethiopia conducted by the Ministry of Health find that in urban locations about one quarter of households utilize a location in the house for cooking (FMOH 2016). Further, households in urban locations use a range of fuels for cooking; 42.5% burn wood, 27.8% burn charcoal, and 24.2% use electricity – the remaining 5.5% employ either gas, liquid, or other biomass sources (FMOH 2016, Table 2.4, page 21).

EMISSION SOURCE ATTRIBUTION

Emission source apportionment or source attribution is a quantitative analysis that identifies the share of ambient air pollution that can be attributed to a specific class of emissions sources within a city or region. The results are expressed as percentage contributions for categories such as traffic, industry, or domestic fuel burning. An example of this type of results is provided below in Figure 3-3 from Karagulian et al. (2015), a comprehensive review of source apportionment studies conducted world-wide, in urban and rural areas, to provide a basis for comparing the relative role of emissions sources in different areas of the world. As the figure shows, for Sub-Saharan Africa as a whole it is estimated that the domestic fuel burning source accounts for the largest share of fine particulate matter in the ambient air (34%), followed by natural sources (22%), traffic and unspecified sources of human origin (each 17%), and industry (10%). The role of domestic fuel burning in Africa is much larger than in most other locations, while the role of traffic and industry is somewhat less. These results, however, do not necessarily represent urban areas of Africa, where we could reasonably expect traffic and industry to be more concentrated and to play a larger role, and domestic fuel burning to play a lesser role as a result of urban electrification and the presence of at least some centralized waste management.

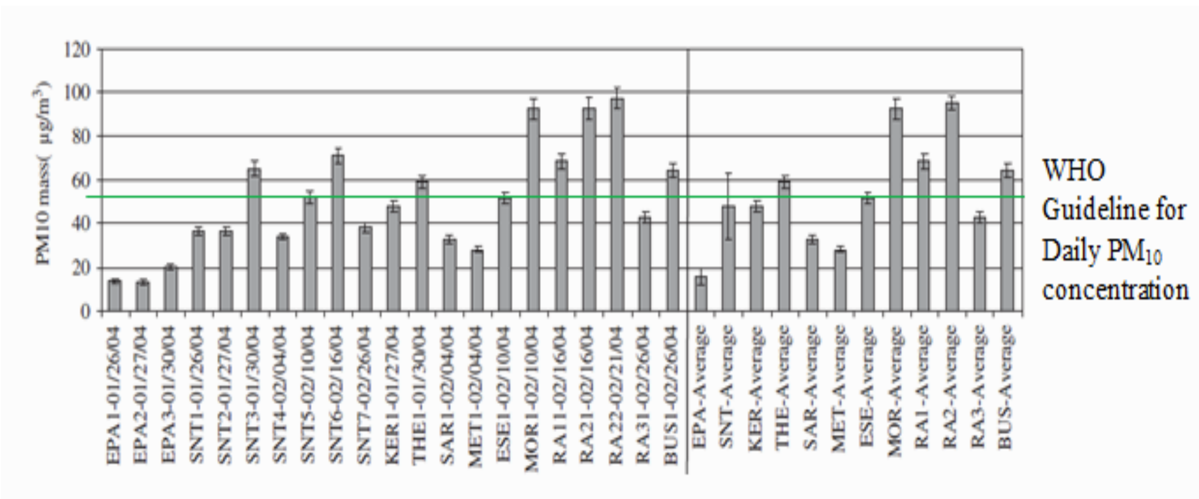
Figure 3-3. Emission Source Attribution Results Based on a Global Literature Search



Source: Karagulian et al. (2015)

For Addis Ababa, some specific information exists, but it is less specific than a rigorous source attribution study could provide. Etyemezian et al. (2005) conducted a pilot study during the dry season of 2004, which measured PM_{10}, CO, and O_3 concentrations at 12 sites throughout the city and collected 21 samples total. In addition to measuring concentration levels, the study examined the composition of the particles (using broad categories) to estimate the relative contribution of different emissions source. The 12 sites were situated in both urban and suburban locations in order to compare different concentrations and sources between the two settings. Figure 3-4 displays the PM_{10} concentrations from the 21 samples and the average concentration at each of the 12 locations. The green line represents the WHO guideline for daily PM_{10} concentrations. The study also found that the PM_{10} concentrations were made up of 30-60% geologic material, indicating that unpaved roads contributed significantly to PM_{10} concentrations – vehicle emissions and household burning are also identified as key sources of PM air pollution, based on the diurnal pattern of concentrations. The results, however, are slightly outdated—especially when considering the dramatic increase in PM concentrations from vehicles between 2004-2015 (Figure 3-2 above, showing estimated PM emissions from the transport sector).

Figure 3-4. PM_{10} concentrations from each sampling site



Source: Etyemezian et al. (2005)

3.2 EXPECTED EMISSIONS TRENDS

In many urban locations, there are six main sources of air pollution emissions: energy production, particularly electric energy from fossil fuel-fired generating units; mobile sources – vehicles including trucks, buses, and transit; industrial sources; household and open burning of biomass, waste, and heating fuel; all other man-made sources, such as construction, off-road engines, and resuspended dust from unpaved and paved roads; and natural sources. These categories are often used, for example, in source apportionment studies, such as Karagulian et al. (2015). The following analysis will examine these six sources as they relate to Addis Ababa.

In the energy sector, Ethiopia in general, and Addis Ababa in particular, has the potential to generate electric energy almost entirely from renewable sources, through use of hydropower. As a result, we would expect that the emissions trend from this source would be downward or, at worst, relatively flat. Until the electric grid reliability improves however, there remains a concern about potential growth in the use of diesel generators for backup electric power. Any efforts to mitigate air quality in this sector should target upgrading electricity transmission and distribution networks that have not kept up with the rapidly growth urban population and demand for electricity. Improving the steady supply of power will impact diesel emissions from generators.

Natural sources of air pollution in Addis Ababa are believed to be a relatively small contributor to current air quality concerns much like electricity generation.

As noted in the previous section, the transport sector has a high potential for growth, in both the number of vehicles and their potential to emit air pollution, owing largely to an aging vehicle fleet. Vehicle registrations have grown approximately 12 percent per year from 2011-2015 (CSE, based on Addis Ababa Transport Authority Data) – and more recent data suggesting a more rapid growth rate of 16 percent per year through 2018 (Ministry of Transport, 2019). With no changes to vehicle emissions rates, we could expect that transport emissions could grow at a similar rate, absent immediate action to reduce emissions. Data presented in the previous section suggest this expectation of growth in emissions from this sector is warranted, though the rate of growth is certainly subject to uncertainty, particularly in light of recent actions taken to provide stronger incentives to import newer vehicles, and reduced incentives to import older vehicles.

The trends in industrial source emissions are largely unknown – the same could be said for other man-made sources of emissions. Absent data, it is reasonable to expect that industrial and "other" sector emissions could grow at the rate of increase of economic activity. The World Bank recently estimated GDP growth from 2011 to 2016 of 10 percent per year and future projections are just below this value. Without significant improvements in monitoring and enforcement, it is unlikely that this economic growth would not increase air pollution.

The trends in emissions from open burning of waste, and household fuel use, are not well-documented, but few if any controls on these sources have been implemented. As a result, it is reasonable to expect that these sources will grow by a rate consistent with population growth. Based on the Central Statistical Agency's population projections for 2022 and 2027, it is possible that these source emissions could grow by 12 percent annually to 2022, and by 11 annually from 2023 to 2027.

There are many examples of cities and countries where trends in emissions are substantially different from trends in drivers of emissions such as population and GDP – the rate of growth can be slower, or can be negative, while population and GDP grow rapidly. Given the known factors of current emissions, it is possible to model future emissions under alternative scenarios (Figure 3-10 below, for example). The key to achieving improvements in air quality while maintaining GDP and population growth, however, is a well-established and functioning system of air pollutant emissions control and enforcement. This AQMP is an important first step toward achieving that goal.

3.3 AMBIENT AIR QUALITY

With two years of regulatory-grade air quality data it is clear that annual averages are at least two to three times higher than the WHO guideline of 10 μg/m^3. There are three $PM_{2.5}$ air quality monitors in Addis Ababa—one maintained by Addis Ababa University through their work with the East Africa GeoHealth Hub, and two maintained by the United States Embassy (Figure 3-5). The Addis Ababa University $PM_{2.5}$ air quality monitor is located at the College of Health Sciences at the Black Lion Hospital.

Data from the Black Lion monitor and ten other temporary monitors associated with a Black Lion/GeoHealth longitudinal study of children's health are not yet publicly available, though summary data for one year have been provided and are reflected in the estimates of air quality presented below. The temporary monitors are no longer in operation, but there remains a permanent monitor at Black Lion Hospital.

Of the two US Embassy monitors, one is located on Embassy grounds in the northern area of the city and the other is located at the Addis Ababa International Community School in the south (see Figure 3-6). The two monitors are called Central and School, respectively, on the USEPA AirNow-International website. The monitors began collecting data in mid-2016 at the School site, and in late 2016 at the Central (Embassy) site. Annual average $PM_{2.5}$ concentrations recorded at each monitoring station from the previous five years are presented in Table 3-2.

Table 3-2. 24-hour average and maximum measured $PM_{2.5}$ concentration

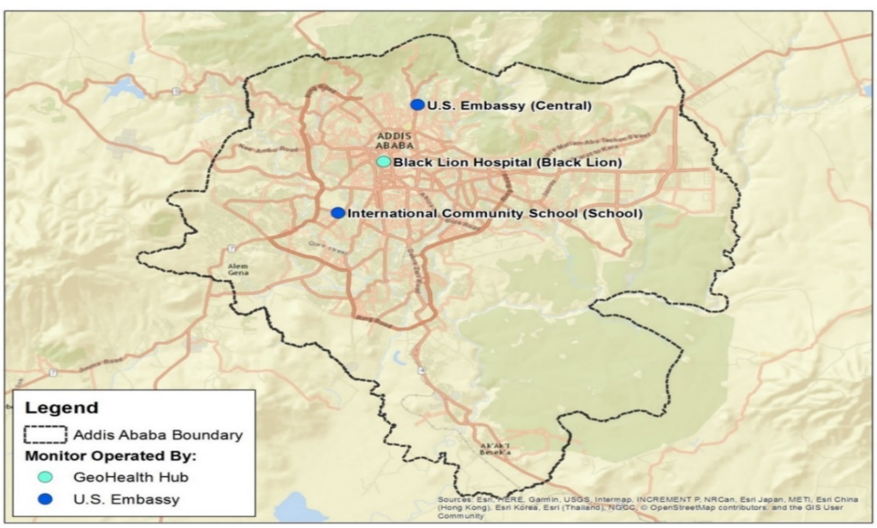
Site	$PM_{2.5}$ Concentration, $\mu g/m^3$ (n = number of hourly measurements)*					
	2016	**2017**	**2018**	**2019**	**2020**	**2021**
Central	25.1 (n = 2776)	25.6 (n = 8466)	25.6 (n = 8017)	20.2 (n = 6874)	24.4 (n = 8337)	20.3 (n = 1836)
School	36.5 (n = 2935)	33.2 (n = 5908)	37.4 (n = 3156)	Unavailable**	Unavailable**	30.8 (n = 316)

*Note: Monitoring at Central site and School site began in late-2016 and mid-2016, respectively. Annual concentration for 2021 references January – March only.

**School site concentrations are unavailable from December, 2018 through December, 2020.

Historical $PM_{2.5}$ concentrations measured at these two stations are available online from the AirNow-DOS system .[7] Since the start of monitoring in mid-2016, the mean 24-hour average $PM_{2.5}$ concentration recorded at the Central site is 24 $\mu g/m^3$ and the mean 24-hour average $PM_{2.5}$ concentration recorded at the School site is 34 $\mu g/m^3$, both of which exceed both the daily and annual $PM_{2.5}$ WHO guideline. Figures 3-7 and 3-8 below show diurnal and monthly $PM_{2.5}$ concentrations measured at each site, respectively.

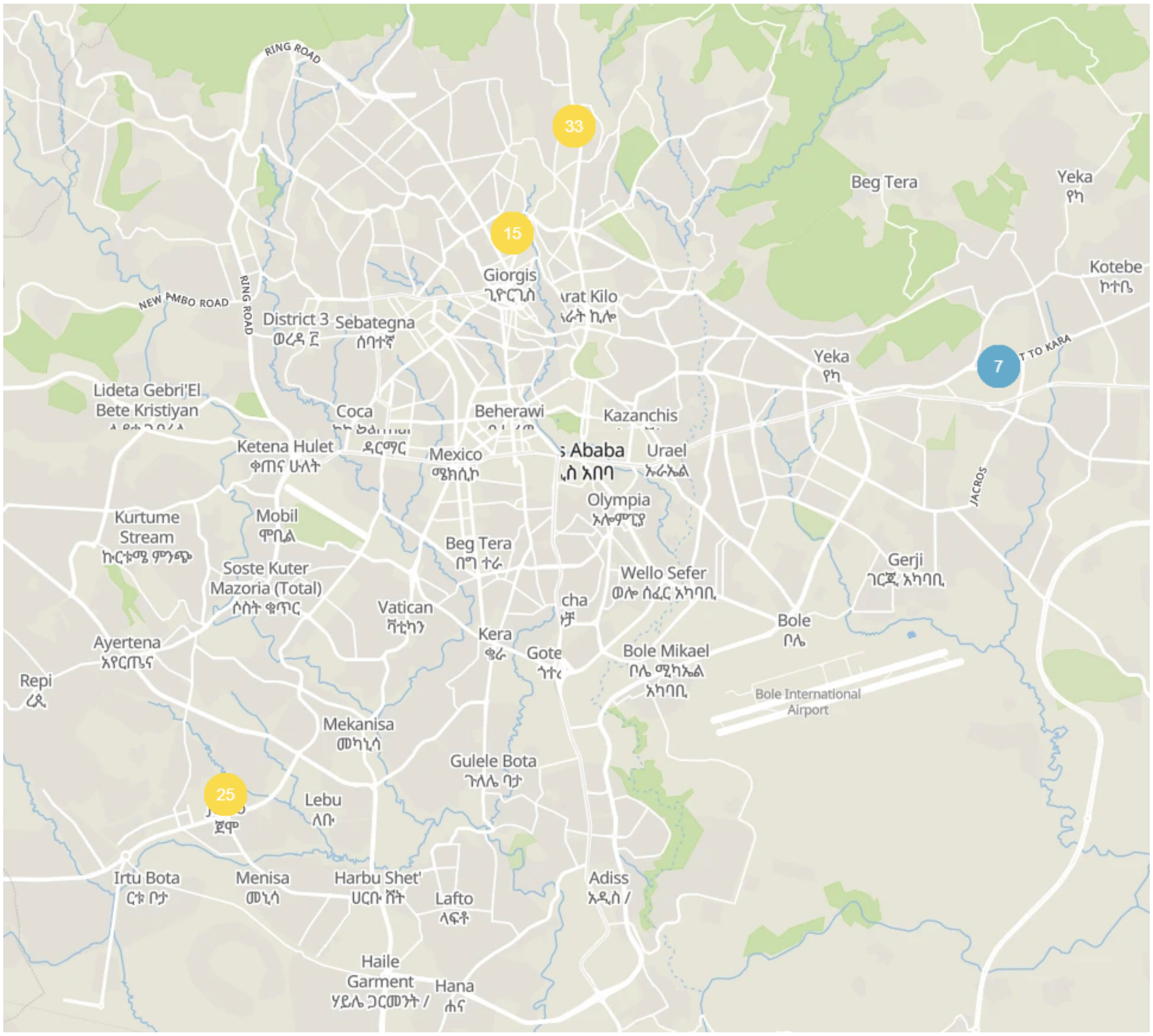
Figure 3-5 Map of Monitor Locations in Addis Ababa



Sources: Addis Ababa Boundary – Urban Planning Commission, received 2018.

[7] See https://airnow.gov/index.cfm?action=airnow.global_summary

Figure 3-6 **Monitor Locations – Google Maps and USEPA AirNow**

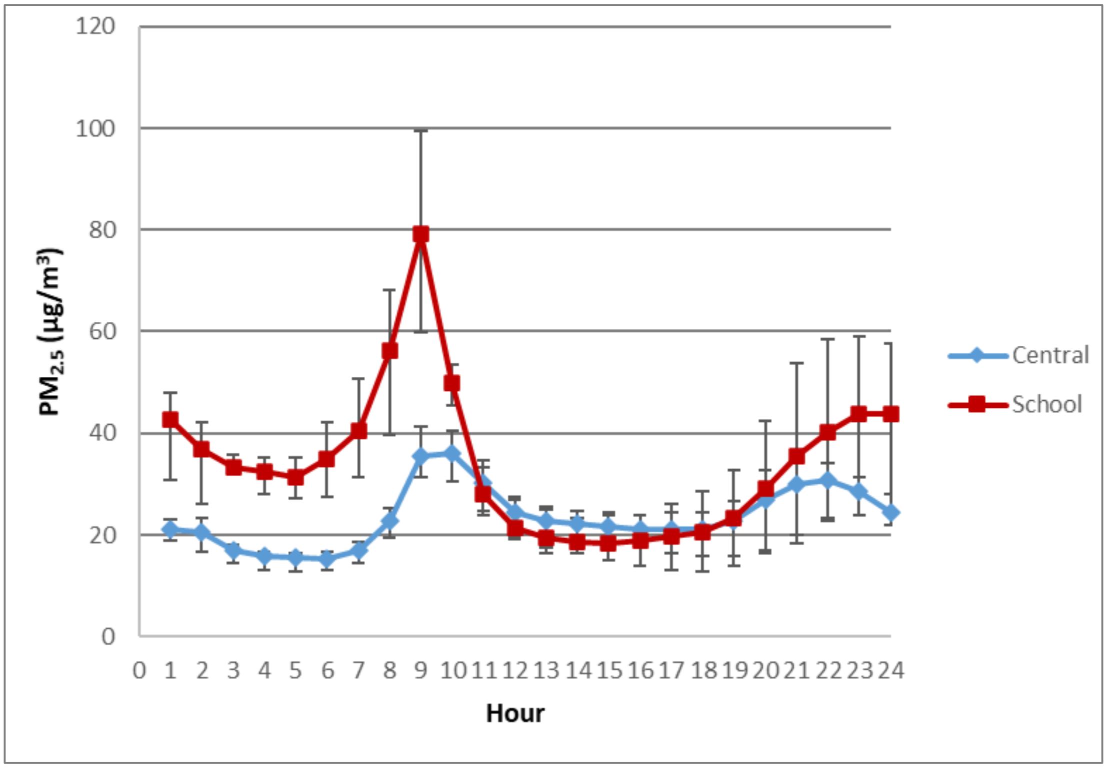


Source: AirVisual online tool shows three of the UNEP monitors that are currently online plus the U.S. Embassy monitor at the top.

Diurnal patterns at both the Central and School sites show increased concentrations during the morning and afternoon rush hours as well as possibly a temperature inversion in the morning, with concentrations at the School site higher than at the Central site. The School site shows higher concentrations overnight than during the day – this is likely related to the ventilation of pollutants during the day and trapping of pollutants overnight, and potentially due to local emissions sources near the school that are unrelated to commuting (e.g. emissions from waste burning at the local landfill). To provide additional context, the WHO $PM_{2.5}$ health guideline indicates that daily $PM_{2.5}$ concentrations should not exceed 25 $\mu g/m^3$; daily mean values depicted in Figure 3-7 at both the School and Central sites exceed this guideline. Average monthly $PM_{2.5}$ concentrations are shown in Figure 3-8.

Monthly concentrations follow the same trend at both the Central and School sites, with the highest concentrations in June through September and lower concentrations the rest of the year. These findings at first appear surprising given that June through September is the rainy season in Addis Ababa and precipitation may remove $PM_{2.5}$ from the air, reducing concentrations. These higher concentrations during the rainy season may be related to increased particles in the air associated with residential combustion for home heating, since the coldest temperatures tend to occur during this rainy season, or due to atmospheric inversions that keep particles trapped in the local atmosphere.

Figure 3-7. Average hourly $PM_{2.5}$ concentrations, 2016 - 2021 – US Embassy Administered Monitors



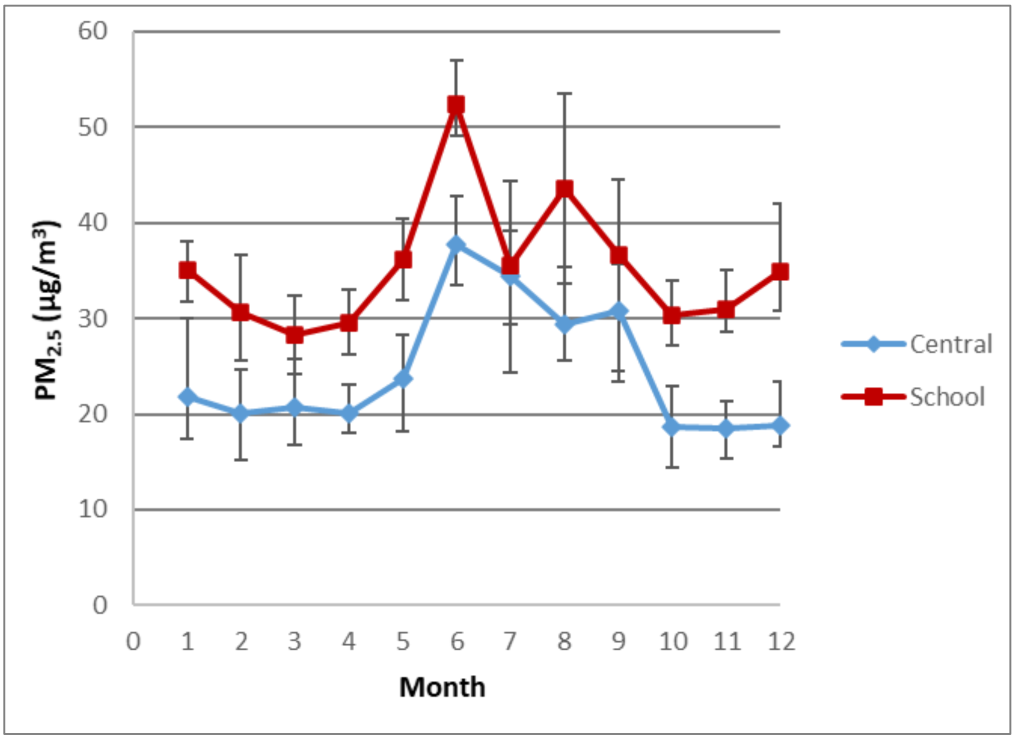
Source: USEPA AirNow DOS, https://www.airnow.gov/international/us-embassies-and-consulates/, accessed 4/7/2021

In addition to the US embassy's two $PM_{2.5}$ monitors, NMA has one real time gaseous air quality monitoring station located on the NMA campus in the southeastern area of the city. This monitor collects data on NO_x, O_3, and CO levels in the ambient environment; however, there remain concerns about the accuracy of the data collected at this site, as NMA acknowledges difficulties obtaining reference gases for calibration of the instruments. The data from this monitor is not readily available online and must be requested through the NMA. In the GTPII, NMA plans to establish a second air quality monitor, the location of which has yet to be determined.

In addition to the permanent, real-time, reference-grade air quality monitors, several studies conducted in Addis Ababa provide snapshots of ambient air pollutant concentrations. The first study (Kumie et al., 2010) was a longitudinal study that sampled CO concentrations at 40 locations on major roadways in Addis Ababa. The dataset includes the rainy season of 2007 (July 2007-January 2008) and the dry season of 2008 (March-April 2008) A second study (Etyemezian V. et al., 2005) conducted in the dry season of 2004 (January –February 2004) measured $PM_{10,}$ CO, and O_3. Another study (Gebre, G. at al., 2010) measured levels of total suspended particles and PM_{10} from

February-April 2008 and from June-July 2008. As part of the GFEI report, a researcher at Addis Ababa University (Addis Ababa Institute of Technology, 2012) focused specifically on vehicle emissions and measured $PM_{2.5}$, CO, NO_2, and SO_2 at 12 roadside locations between 8:30 am and 5:30 pm during both rainy and dry seasons. Lastly, a study conducted as input to the Global Burden of Disease report (van Donkelaar et al., 2019) used satellite imagery technique to estimate $PM_{2.5}$ concentrations globally at relatively fine resolution (1 km x 1 km), and data from this study are available in Addis Ababa. It is difficult to draw conclusions about long term trends from these data sources because the studies collected data for a specific purpose, over short time frames, and because of the lack of consistency in the metric for measuring particles. Despite this, the data summarized by these reports may help fill some gaps, due to the lack of historical PM monitor data in Addis.

Figure 3-8. Average monthly $PM_{2.5}$ concentrations, 2016 - 2021 - US Embassy Administered Monitors



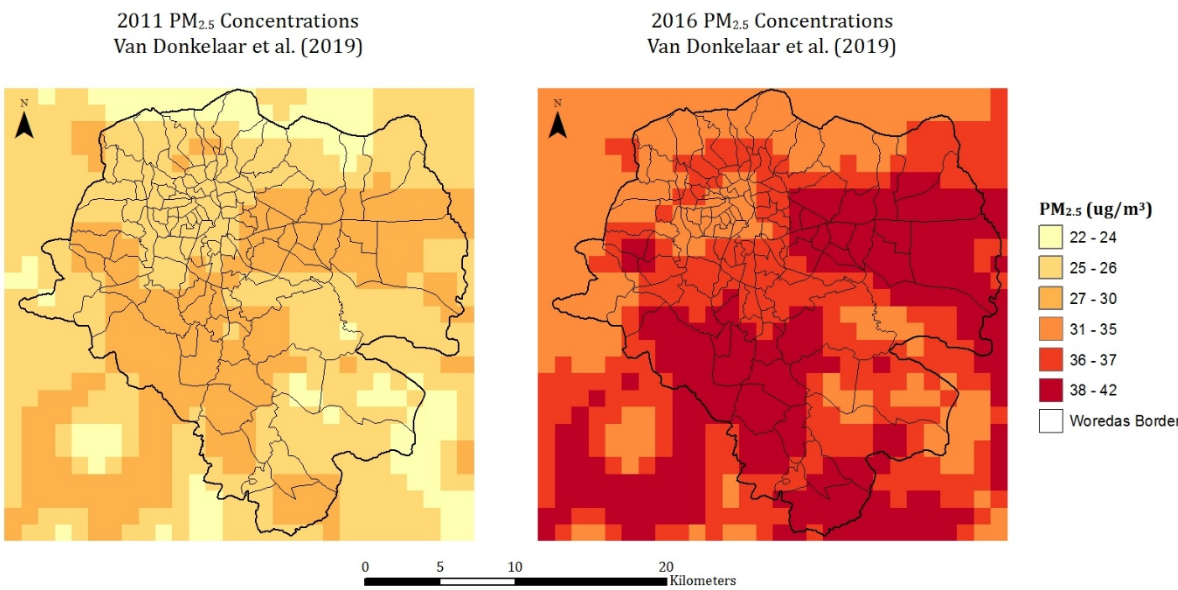
Source: USEPA AirNow DOS, https://www.airnow.gov/international/us-embassies-and-consulates/, accessed 4/7/2021

As noted above, in addition to monitored air quality data, satellite-based air quality data is available for the Addis Ababa region. Van Donkelaar et al. (2019) developed a methodology to estimate $PM_{2.5}$ concentrations using remote sensing data from satellite imagery. This technique allows for longitudinal data collection and included limited calibration of results using ground-based $PM_{2.5}$ monitors, where available.

In Addis Ababa, the Embassy-operated air quality monitors began collecting data in 2016; however, the Van Donkelaar et al. (2019) study provides a time series analysis of $PM_{2.5}$ pollution in Addis Ababa from 2011 through 2016. The satellite imagery methodology shows spatial variations in $PM_{2.5}$ within the metropolitan area. These results should be used with caution, however – while satellite-based $PM_{2.5}$ measurements have the advantage of comprehensive, consistent coverage, they may be subject to significant error, particularly at finer geographic scales.

Typically, satellite-based results are best applied in situations where they can be independently verified and calibrated with ground-based monitor measurements.

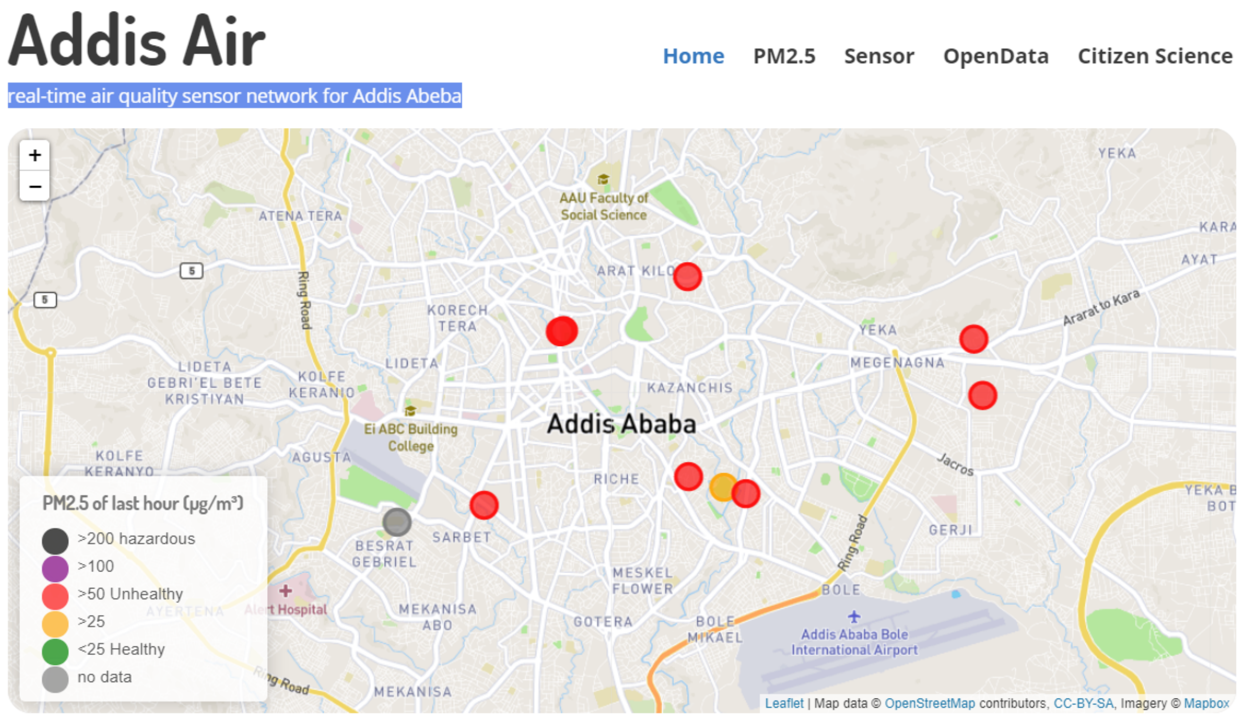
Figure 3-9. Annual Mean Concentrations of $PM_{2.5}$ based on Satellite Data



Source: van Donkelaar et al. (2019)

Additional monitoring information, derived from a sensor network, can be derived the work of a local non-profit, Addis Air, as shown in Figure 3-10 below. It is unknown, however, the extent to which these sensors have been calibrated to reliable stationary monitor readings (such as those at the US Embassy), and so the results should be interpreted with caution.

Figure 3-10 Locations of Addis Air Network Sensors



Source: www.addisair.org is a civil society organization that works with Menged Lesew who promote car-free Sundays around the city. The low-cost sensors were designed in Addis and purchased by individuals and organizations who want to track relative changes in pollution levels.

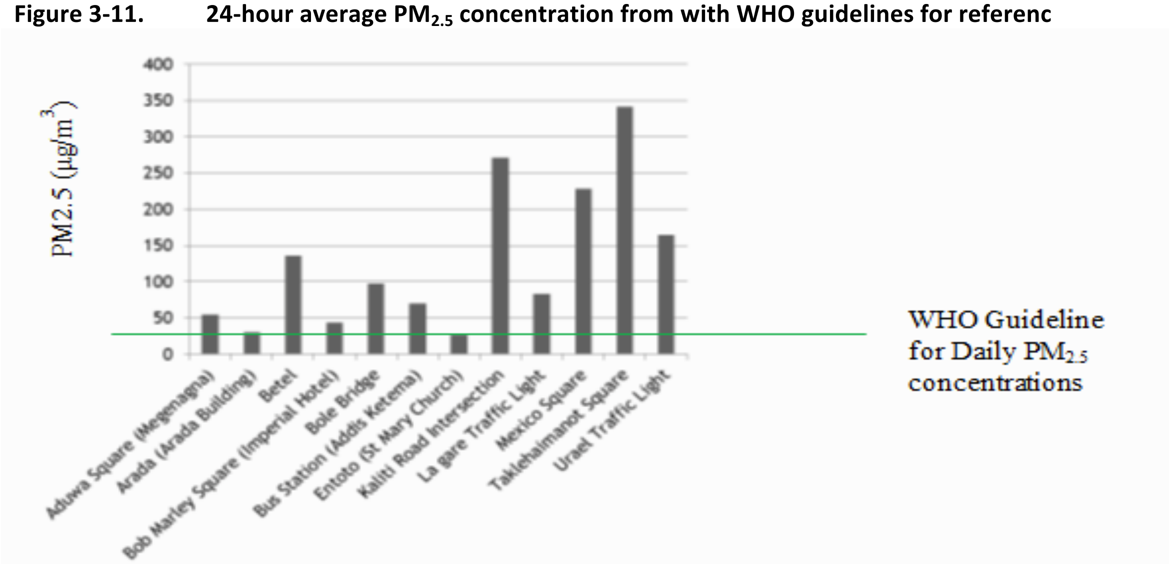
As noted above, the Global Fuel Economy Initiative study conducted by Addis Ababa Institute of Technology reported monitor results focused on understanding the impact of emissions from mobile sources. In this 2012 study, Data were collected for $PM_{2.5}$, CO, NO_2, and SO_2 at 12 roadside locations between 8:30 am and 5:30 pm. Only data for these chemical compounds were collected because they are the primary components of vehicular emissions. $PM_{2.5}$ and CO were monitored continuously throughout the study period. The 12 roadside locations were selected based on traffic characteristics; population density; meteorological conditions; and building attributes. The 24-hour average and maximum concentration of $PM_{2.5}$ measured at each of the 12 locations are shown in Table 3-3. Figure 3-11 displays the 24-hour average concentration with the WHO guidelines for reference.

Table 3-3. 24-hour average and maximum measured $PM_{2.5}$ concentration

Site		$PM_{2.5}$ Concentration, µg/m^3	
Code	**Name**	**24-hour Average**	**Maximum**
S1	Aduwa Square (Megenagna)	54.8	4471.9
S2	Arada (Arada Building)	30.7	624.0
S3	Betel	135.6	6576.4
S4	Bob Marley Square (Imperial Hotel)	43.6	511.1
S5	Bole Bridge	97.3	1982.6
S6	Bus Station (Addis Ketema)	70.4	1827.5
S7	Entoto (St. Mary Church)	27.2	808.5
S8	Kaliti Road Intersection (Traffic light)	271.4	9082.6
S9	La gare traffic light	83.5	3268.8
S10	Mexico Square	228.6	17169.3
S11	Taklehaimanot Square	342.1	2933.7
S12	Urael Traffic Light	165	1837.5

Source: Addis Ababa Institute of Technology (2012)

Figure 3-11. 24-hour average $PM_{2.5}$ concentration from with WHO guidelines for referenc



Source: Abate (2015)

3.4 Health implications of the baseline air quality scenario

Exposure to high concentrations of $PM_{2.5}$ for any length of time can cause short-term and long-term negative health outcomes, including hospital admissions due to asthma, and premature death from chronic obstructive pulmonary disease, cardiovascular disease, lung cancer, and lower respiratory infection, and work loss days, among others. Both indoor and outdoor air pollution can contribute to furthering these health impacts. Pilot studies conducted tend to focus on either indoor or outdoor pollution, while the Global Burden of Disease (GBD) study conducted by IHME provides a comprehensive picture of disease in Ethiopia.

Ethiopia has made significant progress in developing the health sector; they achieved the health-related Millennium Development Goals ahead of schedule and 98% of Ethiopia's population has access to healthcare (Federal Republic of Ethiopia, 2015). Furthermore, one of GTPII's main strategic directions is continue reducing infant mortality rates and mortality rates among children less than 5 years of age. Due to the vulnerability of these populations to negative health impacts of air pollution, improving air quality is a critical component for achieving these targets. A study found that pneumonia is the second highest cause of morbidity for children less than 5 years old (FMOH, 2011). From Tefera et al. (2014), the authors conclude that air pollution's health effects are not receiving adequate attention by stakeholders.

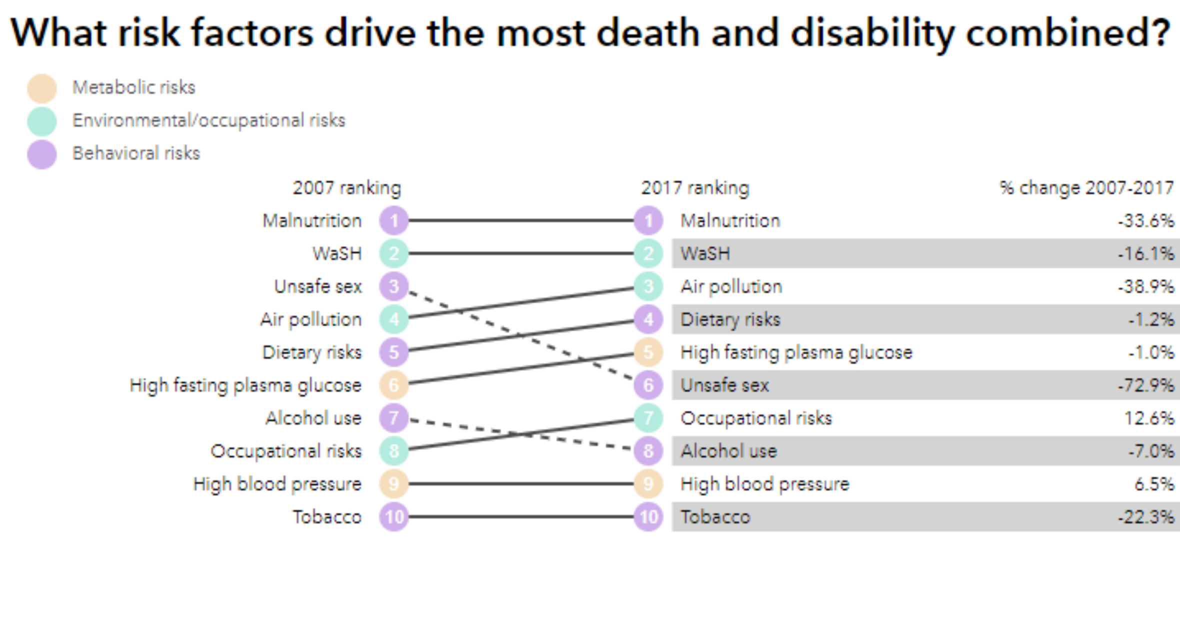
Global Burden of Disease

The Global Burden of Disease (GBD) study shows a full representation of air pollution impacts in Ethiopia, rather than cross sectional results provided by pilot studies. Where the pilot studies provide snapshots of health status and valuable insight on local health context, the GBD takes a more longitudinal approach, allowing for the tracking of national trends over time.

The GBD results are taken from 2016 and measured against a 2005 baseline. We are most concerned with health endpoints that are exacerbated by air pollution, like cardiovascular and respiratory diseases. Four of the top 10 causes of death in Ethiopia (i.e. Lower Respiratory Infection (2), Ischemic Heart Disease (3), Cerebrovascular Disease (5) and Other Cardiovascular diseases (10)) have been linked to air pollution as a risk factor. Lower Respiratory Infections and Ischemic Heart Disease are also leading causes of premature death in Ethiopia. Ischemic Heart Disease is the only top 10 cause of death and disability that has a positive percent change from the baseline year. Asthma ranks as the 8^{th} highest cause of disability in Ethiopia. From these results, the GBD estimates that air pollution is the number two risk factor for death and disability in Ethiopia.

Figure 3-12. Top 10 risks factors driving the most death and disability combined in Ethiopia

Source: IHME (2019)



Top 10 risks contributing to DALYs in 2017 and percent change, 2007-2017, all ages, number

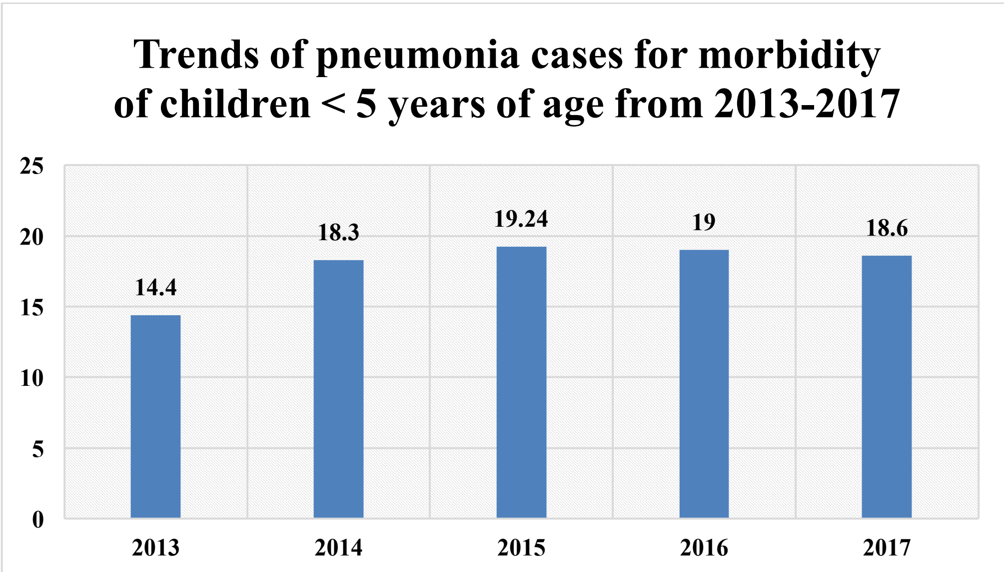
Ethiopian Health Institution Information on Burden of Disease Attributed to Air Pollution

The practice of environmental health among local Ethiopian health sector institutions is to protect and prevent health problems associated with chemical, biological or physical threats present in the different environmental media (water, air, soil, etc). Air pollution health problems are becoming the leading cause of morbidity in urban areas of Ethiopia Addis Ababa and Dire Dawa. According to the Regional Health Bureau's report, air pollution related health problems are becoming leading causes of morbidity in Ethiopia. (FMOH [HEH communication guide],2016).

The Ethiopian demographic health survey of 2016 reported that in Ethiopia, 88 in 1,000 children under age 5 die before their fifth birthday (CSA 2016). Acute respiratory infection (ARI), and particularly pneumonia, is one of leading causes of morbidity and mortality that accounts for 15% of deaths of children under 5., based on information from WHO and UNICEF (WHO 2019).

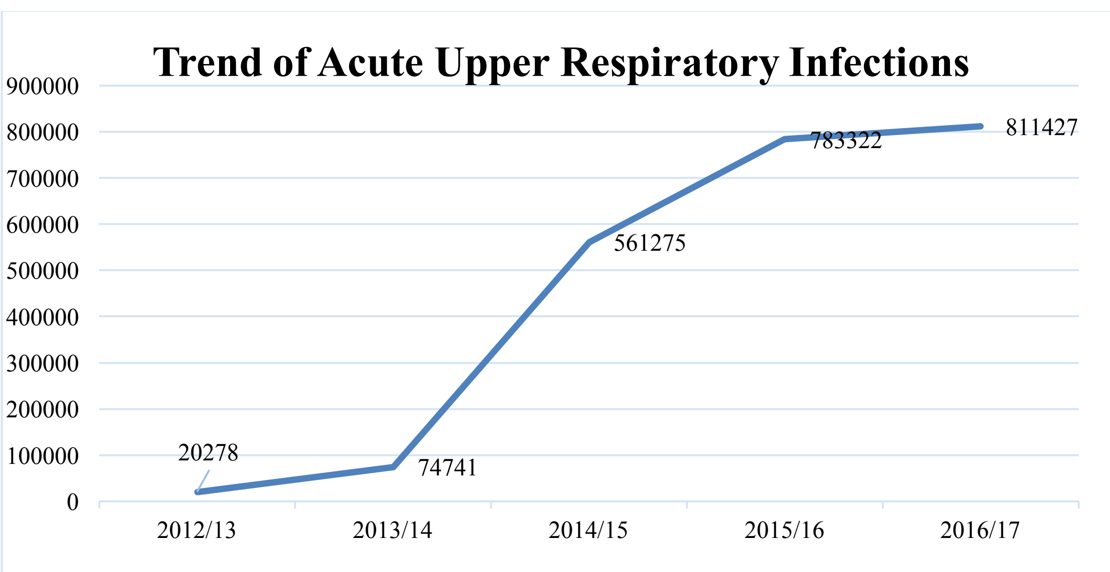
At the national level, health and health related indicators reported that pneumonia is the leading of the top ten causes of hospital admission for children < 5 years of age, and accounts for 21.9% of all cases. In addition, the trend in pneumonia cases contributing to morbidity of children < 5 years of age from 2013-2017 is also increasing, as shown in Figure 3-13 below (FMOH 2017).

Figure 3-13



At the city level, as shown in the annual reports of the Addis Ababa Health Bureau from 2013/14 -2017, the top 10 disease list indicates that upper respiratory disease is the leading cause of morbidity and the trend is also increasing over time (Figure 3-14)

Figure 3-14



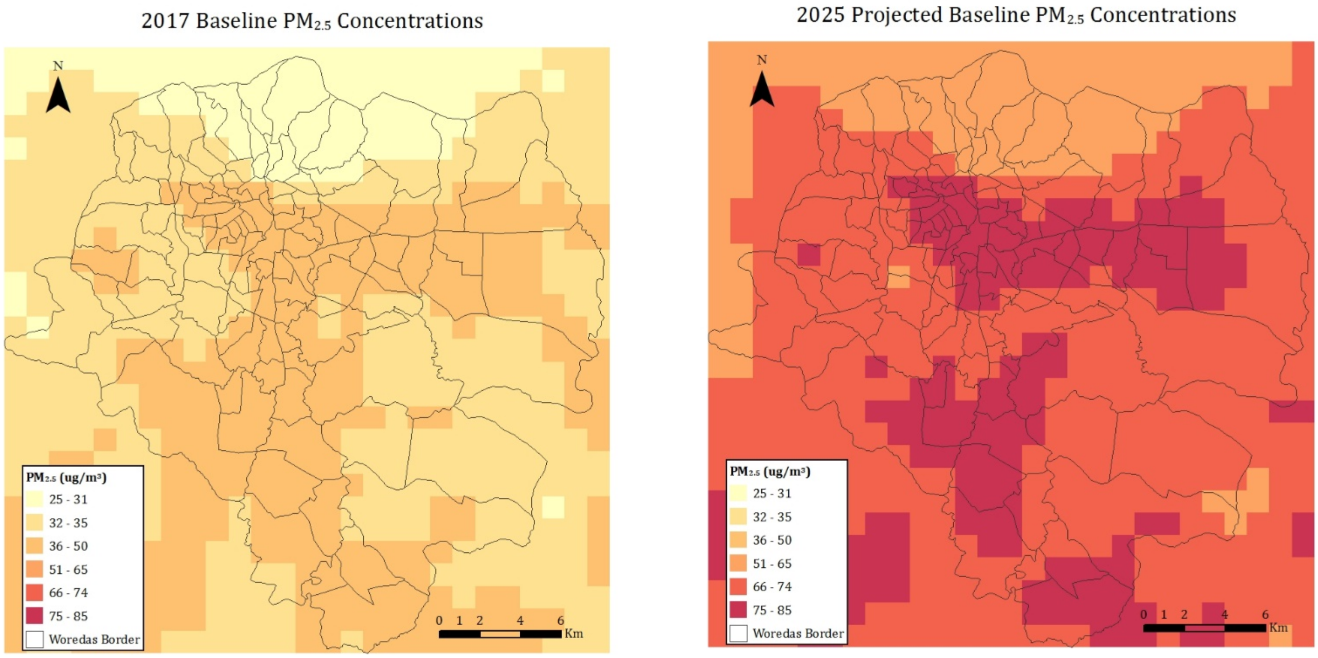
Source: Addis Ababa Health Bureau from 2013/14 -2017

Asthma is another climate sensitive non-communicable disease and allergenic effect on the upper respiratory system. Asthma aggravates with allergenic pollen that has bloomed and persisted for longer periods during warm temperature spells and as a result of increased CO_2 level in the atmosphere. Similarly, diesel exhaust can act synergistically with other allergens to aggravate asthma. Thus, asthma is more common in urban areas such as Addis Ababa. Even though the magnitude of asthma in Ethiopia is not well known, the incidence and prevalence of asthma is increasing alarmingly. (FMOH 2014). Further, the annual growth of chronic obstructive pulmonary disease (COPD) in Addis Ababa is about 53.44% (Tarekegn and Gulilat 2018).

Baseline Air Quality and Health Burden Derived from Ambient Air Quality Monitor and Satellite Data

Collaboration between the AAEPGDC and USEPA has resulted in an updated characterization of ambient air quality, human exposure, and the baseline health burden of particulate matter throughout Addis Ababa. The team used available monitor data from the three monitors identified above, and available satellite data from Van Donkelaar et al. (2019), along with a spatial calibration procedure to adjust satellite data to on-the-ground monitor readings. The result is the map on the left of Figure 3-10 below, to characterize 2017 concentrations. The team then used emissions trends forecasts for major source categories, as described in Section 3.2 above, and a source apportionment estimate for African cities from Karagulian et al. (2015), and consideration of information on source contributions in Nairobi from Gaita et al. (2014), to generate the forecast air quality map on the left of Figure 3-15, for the year 2025. A comparison of the two maps shows that, absent action to reduce emissions of air pollutants, particulate matter concentrations could grow substantially in Addis Ababa.

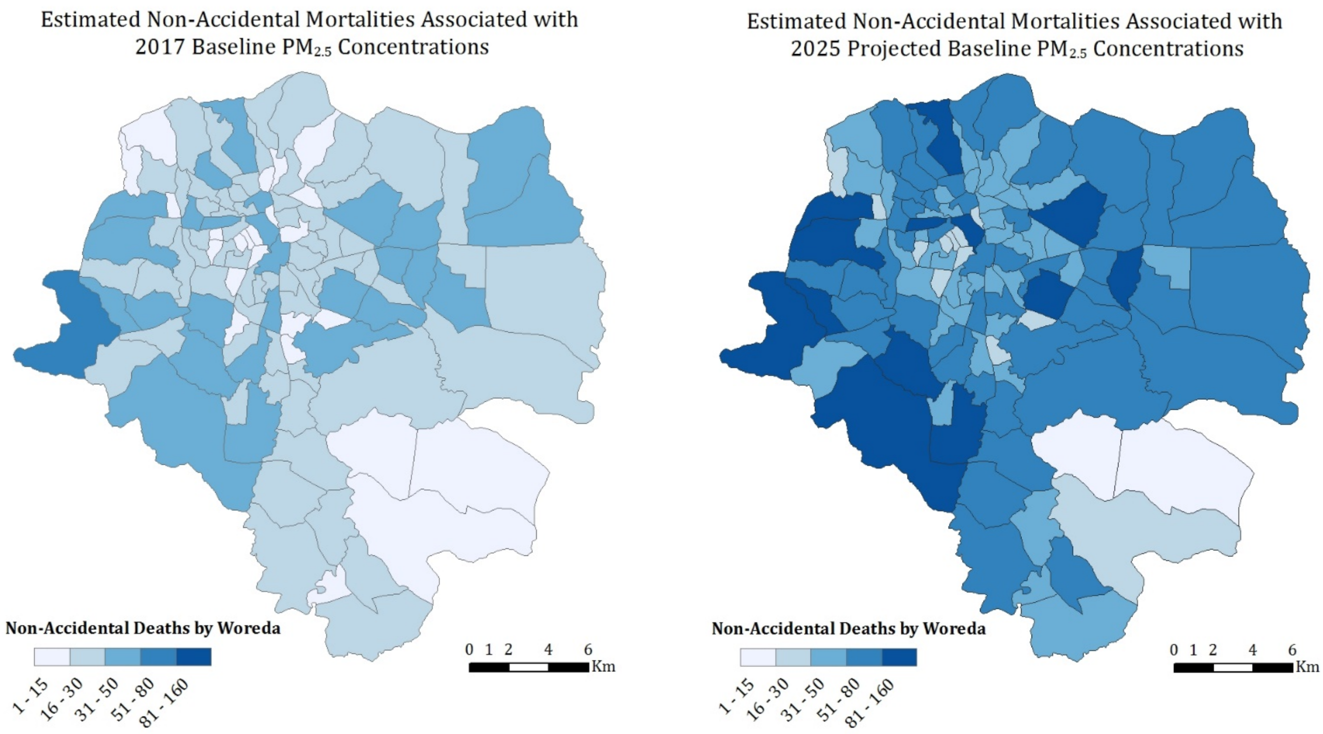
Figure 3-15: Air quality maps for 2017 and 2025 without AQMP action



Using the USEPA's BenMAP-CE tool to assess health effects, the AAEPGDC/USEPA team then combined the air quality estimates in Figure 3-15 with population data from Ethiopia's Central Statistical Agency (CSA 2013) and the Addis Ababa City Health Bureau (undated) to estimate premature mortality associated with $PM_{2.5}$ exposure in 2017 and 2025. The result is shown in Figure 3-16. Total premature adult mortality from $PM_{2.5}$ exposure in 2017 across Addis Ababa is estimated to be 2,700, or about 21% of all non-accidental deaths in the 25 to 99-year-old age group. Without action to control air pollution, by 2025 this figure is estimated to rise to 6,200, and account for 32% of deaths in this age group.

The health burden of indoor air pollution in Addis Ababa has not been assessed to date, but some estimates exist for the country as a whole. The Clean Cooking Alliance has estimated that 98% of the Ethiopian population relies on solid fuels for cooking, with 74% of urban households using solid fuels. CCA further estimates that, for Ethiopia as a whole, this leads to more than 45,000 premature deaths from indoor air pollution annually, and more than 21,000 of these are child deaths (CCA 2020). Other estimates suggest the total mortality burden from indoor air pollution in Ethiopia could be as high as 70,000 annually (UN-Habitat 2017). To our knowledge, a health burden estimate for indoor air pollution that is specific to Addis Ababa city has not yet been developed, though there is information that suggests that changes in cookstove type and fuels could reduce the health burden of indoor air exposures to particulate matter by as much as 70% for households that switch from solid fuels to clean fuels (Sanbata et al. 2014).

Figure 3-16. Estimated premature mortality from $PM_{2.5}$ exposure in 2017 and 2025



ESTIMATED IMPACT OF MEETING ETHIOPIAN AIR QUALITY STANDARD

Action to control air pollutant emissions, including those outlined in Section 6 of this AQMP, if implemented along with other measures, may have the potential to bring Addis Ababa into compliance with the Ethiopian air quality standard for $PM_{2.5}$. Achieving compliance with the annual ambient $PM_{2.5}$ standard of 15 µg/m^3 is the stated goal of this AQMP, but tools and data do not yet exist to assess whether the measures outlined in this AQMP's implementation plan will be sufficient to meet that standard. Nonetheless, it is possible to assess the level of health benefits that could be achieved if full compliance with the standard is achieved, using the BenMAP-CE tool. The results are shown in Figure 3-17 below. The left panel shows the estimated health burden in 2025 under a baseline scenario, where no action is taken to control air pollutants. The right panel shows the health burden in 2025 with full compliance. The full compliance scenario results in a reduction in total premature adult mortality attributed to air pollution across Addis Ababa from 6,200 to 1,500, and from 32% of non-accidental adult mortality from all causes to only 8% of non-accidental adult mortality. This more than 75% reduction in premature mortality, if achieved through rapid implementation and enforcement of measures in this AQMP, as well as likely additional measures needed to reach full compliance, would reverse the current trend of increasing air quality concentrations and premature mortality attributed to air pollution, and could provide substantial health and economic benefits to the residents of Addis Ababa.

Figure 3-17. Comparison of 2025 health burden for baseline scenario with full ambient air quality standard compliance scenario

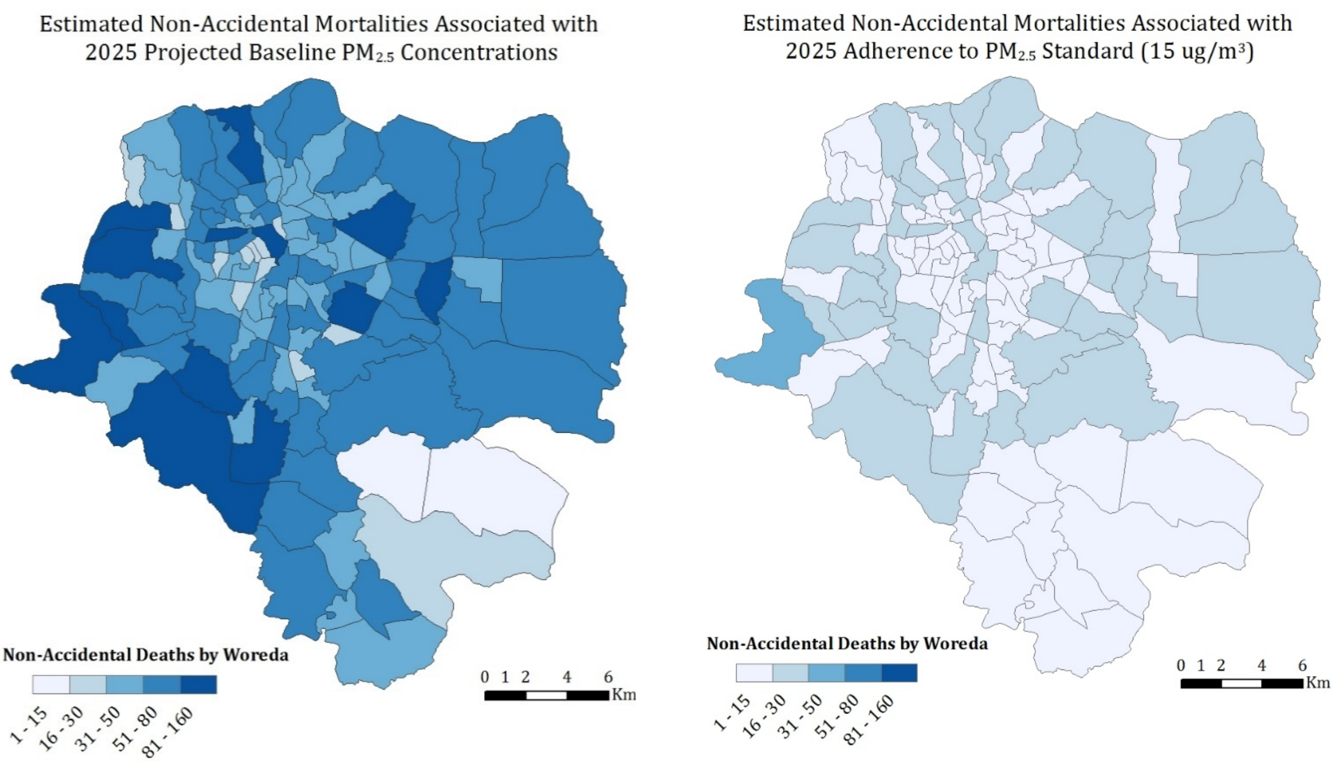


Figure 3-18 shows the difference in premature mortality, by woreda, in 2025 if the standard is achieved throughout Addis Ababa. The reduction in premature mortality, or in other words the major health benefits of achieving the standard, could be large and widespread throughout all regions of Addis Ababa, but particularly large in the more densely populated woredas.

Figure 3-19 provides another perspective on the potential benefits of achieving the Ethiopian air quality standard for $PM_{2.5}$ in Addis Ababa. As clearly demonstrated in this graph, inaction on air quality in the baseline scenario (represented by the blue line in the upper part of the figure) runs the risk of a substantial increase in premature mortality from air pollution in Addis Ababa. This outcome is the result of both the expected rapid increase in population in Addis Ababa, and the increase in emissions and worsening air quality that could result if no action is taken to implement reductions in air pollutants that contribute to high particulate matter concentrations. Achieving the standard, on the other hand, could reduce total premature mortality from air pollution by a substantial amount, even with expected rapid increases in population. Although non-mortality endpoints were not quantitatively estimated, there is evidence that the cleaner air could contribute to both better health and economic and educational prosperity for the residents of Addis Ababa, who could spend less time with air pollution-induced illnesses and more productive time at work and in school.

Figure 3-18: Difference in premature mortality between baseline and full standard compliance scenarios in 2025

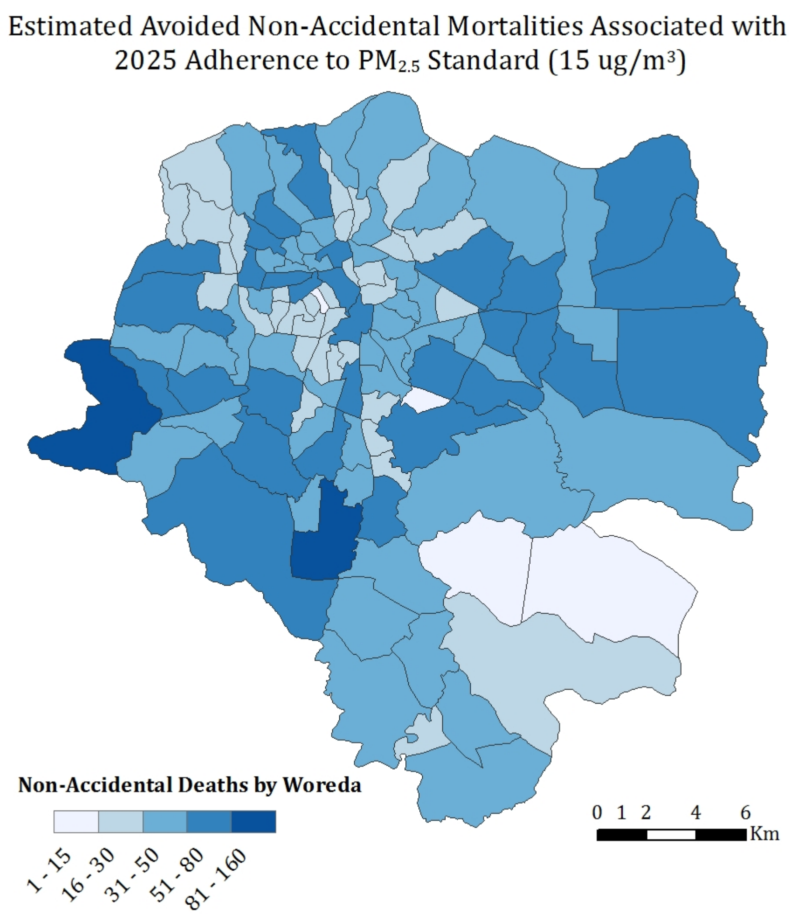
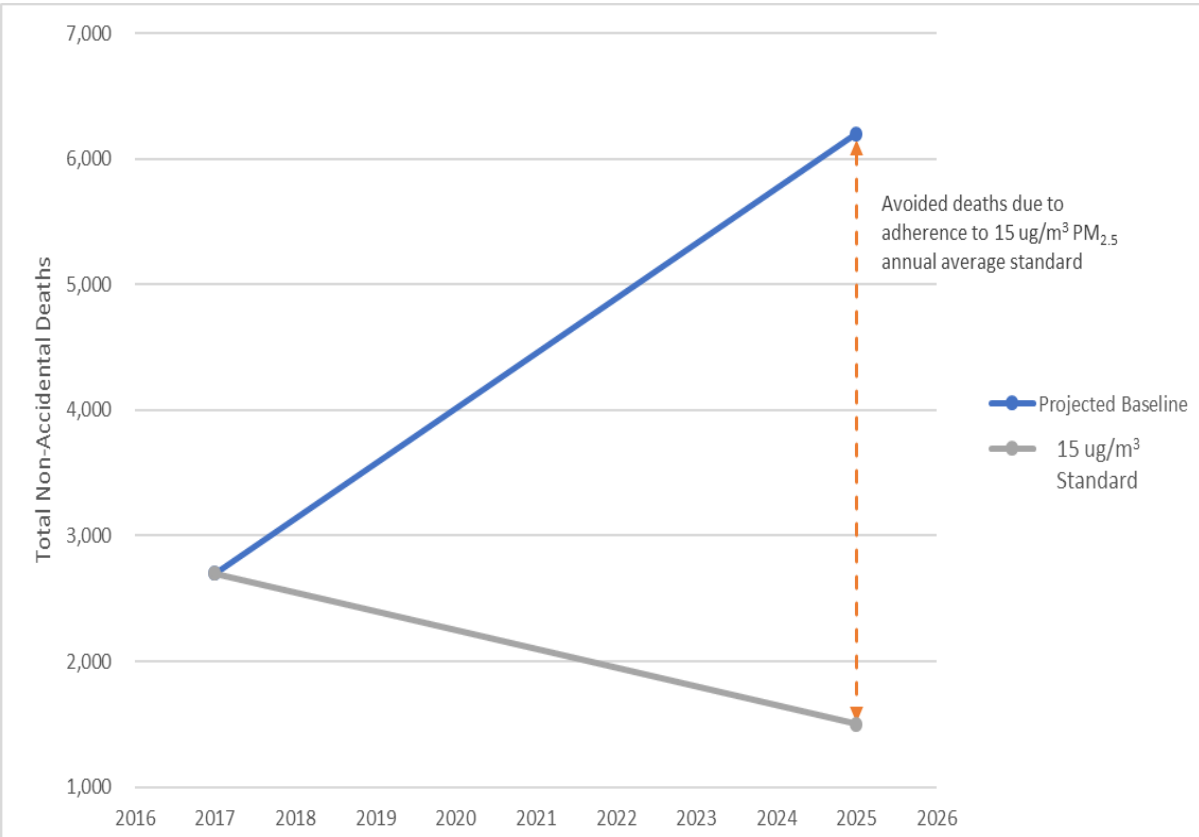


Figure 3-19. Health Impact of Achieving the Ethiopian Air Quality Standard for $PM_{2.5}$



3.5 CAPACITY ASSESSMENT

As part of the Megacity Partnership, USEPA and UN Environment reviewed air quality management capacity in Addis Ababa across multiple relevant institutions. More detail is captured in preliminary planning documents, but in general, air quality management in Addis Ababa is the jurisdiction and responsibility of the Addis Ababa Environmental Protection and Green Development Commission. Their coordinating role is complemented by Addis Ababa city institutions for public health and transport regulation, in particular, and is supported by a cooperative agreement with the Kotebe Metropolitan University. Other university and institutional roles in the execution of this AQMP, including at the national level, are outlined in the AQMP implementation plan in Section 6 of this document. The table below provides a summary of capabilities for each major component of a complete air quality management system.

Table 3-4. Available Air Quality Management Information and Capacity

COMPONENT OF AQMS	INITIAL ASSESSMENT OF STATUS	ADDITIONAL INFORMATION ON CAPACITY
Laws and Regulations	Constitution ensures every citizen has the right to a clean and healthy environment. Proclamation 295/2002 establishes the independent EFCCC and regional EPA. Environmental Pollution Control Law grants EPA legal authority over environmental standards and enforcement of standards. Emission standards set for industrial, point sources. From published online sources, current status of ambient air quality standards is in draft form. Health Policy of the transitional government of Ethiopia,1993. It prioritizes and give emphasis for environmental health. FMOH Integrated urban sanitation and hygiene strategy 2017. FMOH National Hygiene and Environmental Health Strategy (2016-2020), 2016. It has strategic initiative to increase the number of institutions emitting environmental pollutants (air, water, land and noises) below the limiting standard from zero baseline. The National Constitution of the Federal Democratic Republic of Ethiopia articles 43, 44, 90, and 92 set the direction and commitment of government related to urban sanitation management. Proclamation 200/2000 (Public Health), Proclamation 300/2002 (Environmental Pollution Control) this proclamation designed to national articles. Proclamation 661/2009 (Establishment of EFMHACA)	Not clear whether authorities could be used to address municipal burning or small-scale household emissions, if those are believed to be large sources. There is a clear implementation gap in regulation and enforcement despite the availability of regulations, guidelines, and manuals
Emission Inventory	Some estimates of mobile source emissions have been made in the literature. LEAP tool has been used to characterize energy use and to estimate carbon dioxide emissions for National Communications	It is not clear whether energy use data, and conventional pollutant data from energy sources, is available for sources located in Addis Ababa.
Ambient and Source Air Quality Monitoring	Some availability of data for key pollutants for multiple temporary monitor sites throughout Addis Ababa, based on short-term research studies. Not all data from these studies are publicly available at this time.	Speciated PM data needed for reliable source apportionment seems to be limited to short-term research studies. Any previously collected filter samples that have been properly stored could be analyzed to support this effort, but our understanding is that most data from PM

COMPONENT OF AQMS	INITIAL ASSESSMENT OF STATUS	ADDITIONAL INFORMATION ON CAPACITY
	Data are supplemented by US Embassy monitors and a permanent PM monitor at Black Lion Hospital	monitoring in Addis has been real-time, not filter-based.
Air Pollution Dispersion/Fate and Transport Modeling	None yet attempted	Should not likely be a short-term focus given lack of available data
Data Analysis and Interpretation	Currently unknown capacity	Focus could be on enhancing source apportionment, exposure assessments, baseline health effects assessments
Public Participation and Environmental Justice	Currently unknown capacity	
Control Strategy Planning and Development	Limited examples in the manufacturing sector FMOH National Health Adaptation Plan to Climate Change,2017-2020. This plan has details of action plan and budget estimation to tackle health effects due to climate change. Ethiopia’s Climate-Resilient Green Economy strategy has as its objective to identify green economy opportunities that could help Ethiopia reach its ambitious economic growth targets while keeping greenhouse gas emissions low.	Other examples may also be relevant
Compliance and Enforcement	A review of various studies coupled with interviews with relevant EFCCC and AAEPA officials reveal that the levels of air quality enforcement and compliance and are still relatively low with respect to existing legislation due to various factors as outlined.	Additional capacity building will be a focus area for the UN Environment team
Communication and Outreach	Limited efforts by certain NGO’s mostly focused on transportation FMOH National Hygiene and Environmental Communication Guidelines (2016) gives guidance for advocacy, social mobilization and behavior change, and communication activities in relation to hygiene and environment health. FMOH Hygiene and Environmental Health Message Guidance (2018) has a core message for the priority audience regarding indoor and outdoor air pollution.	Additional efforts have been coordinated by the Addis Ababa health department

4. GAPS AND ISSUES

The Advisory Committee has identified five major areas where capacity gaps can and should be addressed to further enhance the ability to implement and monitor plan and emissions reduction performance. These are described below.

4.1 ENHANCING AQ MONITORING CAPABILITIES

This AQMP was developed using the best information available at the time and includes a baseline burden analysis and health benefits assessment based on satellite measurements combined with a small number of ground-based measurements. While this offers a reasonable first step, and a sufficient basis for taking action to reduce air pollution from priority sectors, there remain significant unknowns regarding air quality in Addis Ababa. Concurrent with efforts to reduce emissions, the AAEPGDC should prioritize planning to improve the characterization of air quality in the city. Based on support from both UN Environment and the USEPA Megacity Partnership, recommendations for enhanced air quality monitoring include:

- Five air quality monitoring sensors are installed by UNEP by end of 2019. The process involved consultation with the AA EPGDC to identify a use case for each sensor (e.g., BRT, land use zoning, etc.); initial training with local government staff on deployment, maintenance and operation of the sensor network, analysis and reporting of colocation results from the November 2019 deployment. The AAEPGDC needs further hands-on capacity building for sustainable delivery of information from the existing and planned air quality monitoring sensors. These include calibration, retrieving data from the sensors, analysis and interpreting and distribution of the result
- With support from UN Environment and the USEPA Megacity Partnership, it is important to resolve data access questions with IAAF (for the sensor deployed at Addis Ababa Stadium) as part of the clear air partnership.
- A cooperative effort should be undertaken to develop and test a new approach to combining information on AQ from monitor, sensor, and satellite data to develop a fused data model of measured air quality. The timing for that product is dependent in part on timely collection of data from the sensor network.
- Based on the results of work to enhance AQ through the above efforts, the AAEPGDC, NMA, and Addis Ababa University should develop a city-level monitoring strategy for air pollution, to include expansion of monitoring locations using a combination of reference grade monitors, mid- and low-cost sensors, and other technologies (e.g., satellite/remote-sensed information). The plan should be designed to produce improved estimates of population exposures to air pollution, improve coverage in populated areas of the city that are currently unmonitored, and measure air quality changes in order to assess the effectiveness of measures undertaken as part of this AQMP. This plan should include measures for developing source apportionment capabilities as well, which will also help improve evidence-based decision-making to improve air quality and public health.
- Adding vehicle emissions testing equipment to the testing stations that already do annual inspections of cars to renew registration could be an effective next step.

4.2 IMPROVE EMISSIONS INVENTORIES

Similar to ambient AQ monitoring, an improved knowledge of source categories of emissions can enhance the overall understanding of air quality in Addis Ababa. Improved emission inventories can support a bottom up approach to air quality management but are significantly more resource intensive than the top down approach used for the analysis supporting this AQMP. Nevertheless, the AAEPGDC should consider the steps need to more systematically deploy elements of a bottom-up approach capability in emissions inventory completion. These steps include assembling data to support emissions inventory development for four emissions source categories:

1. **A mobile source inventory**. It is not practical to measure pollutants from all mobile sources, so emissions are estimated from data on the population of vehicles by vehicle class, estimates of their activity (where, when, and how far they are driven), and the emissions characteristics of those vehicles. Sometimes "non-road" sources are also included in the mobile source component of a comprehensive inventory, reflecting the activity of combustion engines in construction equipment, farm equipment, mining equipment, and other small engines (perhaps including generators). Some efforts have begun in Addis Ababa, through cooperation with C40, to better understand and measure vehicle air pollutant emissions rates.
2. **A point source inventory**. Point sources are stack emissions from major industrial and commercial facilities. The total emissions from a large point source can also include fugitive emissions from industrial plants. For example, petroleum refineries have significant emissions from stacks and flares, but also leaks around seals and from product storage containers. While some efforts have begun in Addis Ababa to monitor emissions from specific manufacturing facilities on a case-by-base basis, no efforts have been launched to systematize and manage data on an ongoing basis.
3. **An area source inventory**. Area sources are small sources of air pollution that by themselves may not emit very much but, when their emissions are added together, account for a significant portion of total emissions. Area sources are often too small or too numerous to be inventoried individually. Examples of area sources include: industrial processes such as chromium electroplating, surface coating of cans and paper, metal parts cleaning, metal recycling, small chemical manufacturing plants, and bakeries; emissions from consumer products, such as adhesives and sealants and coatings such as paints; residential heating and fuel use; prescribed agricultural burns, forest and wildfires, and structure fires; gasoline and diesel stations; dry cleaners. There are no currently known efforts in Addis Ababa to measure or estimate area source emissions.
4. **A biogenic inventory**. Biogenic emissions are emissions that originate from non-anthropogenic sources. These include sources such as forests which emit some VOCs, and sources of airborne particulates such as sea salt and crustal material.

A key next step in advancing emissions inventory capabilities is to implement a data management system for emissions data from permits, modeling, and ongoing work to characterize greenhouse gas emissions – where the relevant combustion activity factors might be used also to estimate conventional air pollutant emissions. An effort is needed to obtain and build capacity in implementing a data management system for this purpose.

4.3 IMPROVE ACCESS TO LABORATORY FACILITIES

The AAEPGDC currently has laboratory facilities focused on water and soil sampling and analysis. A critical next step for building municipal level expertise would be to inventory the capacity within the NMA, Addis Ababa University as well as Kotebe Metropolitan University to conduct a basic level of air quality monitoring analysis. This would include acquisition of $PM_{2.5}$ gravimetric devices and then equipment and training to, at a minimum, follow standard operating procedures to weigh filter samples, access to and ability to conduct gas chromatography–mass spectrometry (GC-MS) analysis to determine chemical composition of samples.

4.4 IMPROVE NATIONAL-CITY COOPERATION

While the lead agency for the Megacity Partnership was the AAEPGDC, the EFCCC was actively engaged in the training and AQMP development process. This engagement is critical because certain national level policies are required to meet the goals of the AQMP, for example limiting the age of vehicle imports and fuel economy standards, which are more commonly national policies. Identifying the role of the national ministries in the implementation plan (section 6) and obtaining their buy-in for the measures and roles identified, will be critical for the success of the AQMP.

An additional set of goals is to strengthen coordinated activities at all levels, initiate aligned and integrated planning with stakeholders, create partnership and networking with governmental, and non- government actors, such as private sector and NGOs, to enhance and scale up the desired health benefit. And, it is also very crucial to strengthen the integration of the Ministry of Health and the Regional Health Bureau with different universities, programs and initiatives across the country and at the regional level to conduct new research that strengthens the evidence base linking air pollution and health effect related health burden data.

4.5 ENHANCE EDUCATION AND OUTREACH ON AIR POLLUTION ISSUES

There is a growing awareness in Addis Ababa about the dangers of air pollution, but much more could be done to raise public awareness about the sources, the role individuals play in creating and mitigating air pollution, and the role of the public in influencing air quality policies. An informed public can advocate for the investments needed to reduce air pollution and can also be a part of certain emission reduction strategies, e.g., vehicle emission testing or cookstove change-out programs. Improving access to air quality information can inform the public of current air quality, air quality trends and the relationship between air quality and health in Addis Ababa. Publicly available air quality information is useful for raising awareness about the severity of air pollution among the public; and for helping citizens to take precautionary measures to avoid or reduce their exposure to air pollution to protect their health, for example during periods of poor air quality. In addition, sharing air quality data provides a means for strengthening accountability for air pollution control through a well-informed public.

Together with strategic investments in air quality measurement and data systems, the AAEPGDC should make commensurate investments in the following:

- Real time air quality information dissemination
- Public relations campaign regarding air pollution and health
- Communications regarding planned mitigation strategies, especially those anticipated to impact the public (e.g., vehicle testing)
- A public involvement plan for seeking input on the AQMP implementation plan

5. OVERALL OBJECTIVE AND GOALS OF THE AQMP

The overall objective of the AQMP is:

"Ambient air quality in Addis Ababa city is brought into full compliance with national and city ambient air quality standards by 2025, and the state of compliance is maintained as the city develops economically."

The individual goals by which the overall objective will be fulfilled are as follows:

- ***Goal 1: Ambient concentrations of air pollutants comply with the relevant ambient air quality standards because of planned emission reductions***
- ***Goal 2: Cooperative governance promotes the implementation of the AQMP***
- ***Goal 3: Air quality management is supported by effective systems and tools***
- ***Goal 4: Air quality decision- making is informed by sound research***
- ***Goal 5: Knowledge and understanding amongst decision-makers, stakeholders, and the general public is improved according to an education and outreach plan***

6. IMPLEMENTATION PLAN

The implementation plan outlined below is designed to fulfill the five goals for achieving the main objective of the AQMP. Each specific activity includes reference to mandatory and participatory institutional responsibility; expected time frame for completion from the formal adoption of the plan; indicators to mark successful completion; and a preliminary categorial estimate of the external funding resources needed to achieve each objective listed. The legend for the categorical entries in that column is provided below:

Symbol in "External Resource Need" Column in Tables	Meaning
ብር	External resources of $50,000 or less (approximately 1.5 million ብር or less) are needed to achieve the objective
ብር ብር	External resources of between $50,000 and $100,000 are needed
ብር ብር ብር	External resources of greater than $100,000 are needed
Unknown	Resource needs are currently unknown pending a more comprehensive scoping effort
None	Can be funded by using internal, allocated resources or previously secured funding from external sources

In addition, this implementation plan captures activities that 1) may already be underway, 2) activities that will require support from partners and donors to accelerate implementation, and 3) activities that have been identified as priorities for action, but which will require capacity building and investments from outside partners and donors to ensure success. As a result, each activity has been color coded so that potential partners and donors can see where investments are needed. 1 – Green,; 2 – Yellow; and 3- Red.

GOAL 1 AMBIENT CONCENTRATIONS OF AIR POLLUTANTS COMPLY WITH THE RELEVANT AMBIENT AIR QUALITY STANDARDS BECAUSE OF PLANNED EMISSION REDUCTIONS						
OBJECTIVES	ACTIVITIES	MANDATORY RESPONSIBILITY	PARTICIPATORY RESPONSIBILITY	TIME-FRAMES	INDICATORS	EXTERNAL RESOURCE NEED
Review the national ambient air quality standards and other relevant research and information, including other African nations and WHO	EPGDC will monitor and review the process that EFCCC is pursuing at the national level, because the Addis standards cannot be less stringent than the national standards	EFCCC	EFCCC, to communicate with EPGDC about standards development	2021-2022	EFCCC publishes findings of their review	None
Establish city-level ambient standards	Review national standard, decide whether a standard is needed at city-level.	Addis EPGDC	All members of Advisory Committee	2022-2023	Two years after completion of National ambient standard .20 decision is made about whether a new AA ambient standard is needed – if yes, then new standard is published	None
Complete pilot-level research on existing vehicle emissions	AAT Bureau will complete work with C40 to test emissions for 380 vehicles, prepare benefit-cost analysis for option of adopting Euro standards	AAT Bureau	C40, AAEPGDC, NMA, EFCCC	2021	Findings of pilot tests are published by AAT Bureau. Findings should include a specific recommendation on the type of equipment that will be used to enforce a new city-level standard	None – already funded through C40
Establish emissions standards for vehicles for Addis Ababa	Addis DVLCA and AAT Bureau develops an emissions standard proposal for review by the Addis Ababa Transport Authority and the Addis EPGDC	Addis Transport Bureau, supported by Addis EPGDC, DVLCA, Addis Transport Bureau	EFCCC, Mayor's office	2021-2022	New emissions standards are developed and published	ብር

Align national and city vehicle emissions standards	The AAT Bureau encourages the Ministry of Transport to adopt similar national vehicle emissions standards as those established in Addis Ababa	AAT Bureau and Min of Transport	UNEP	2021-2025	National vehicle emission standards	None
Enhance EPGDC's capacity to monitor vehicle emissions, including passenger vehicles, buses, and trucks	Build human and technological capacity to monitor more comprehensively.	EPGDC	EFCCC, C40	2021-2022	Improved monitoring capability evidenced by publication of emissions data by vehicle class	ብር ብር ብር
Enhance EPGDC's capacity to enforce city-level regulations for mobile sources, including passenger vehicles, buses, and trucks	Build human and technological capacity to enforce more comprehensively. Consider future revision of city-level regulations	EPGDC	EFCCC, AA Transport Bureau, DVLCA	2022-2023	Improved enforcement capability evidenced by publication of compliance data for mobile sources (e.g., emission standard fail rates)	ብር
Enhance EPGDC's capacity to monitor industrial facilities, including boilers and diesel generators	Monitor facilities in Addis, including emissions measurement. Build human and technological capacity to monitor more comprehensively.	EPGDC	EFCCC	2021-2022	Improved monitoring capability evidenced by development of internal database of industrial emissions data	ብር ብር
Enhance EPGDC's capacity to enforce national-level regulations for industrial sources, including boilers and diesel generators	Build human and technological capacity to take enforcement and compliance action more comprehensively. Consider future revision of city-level regulations	EPGDC	EFCCC	2022-2023	Improved enforcement capability evidenced by publication of compliance data	ብር

Assess the need for building construction emissions standards to be added to EIA process	Evaluate construction emissions, building on enhanced capability to monitor industrial facilities, and use the evaluation to assess whether building construction dust emission standards should be incorporated in the Environmental Impact Assessment process for new construction activity	AAEPGDC	Construction Bureau, Construction and Development Ministry	2022-2023	If assessment shows a need, publish new dust emissions control standards for EIAs	Unknown

GOAL 2: COOPERATIVE GOVERNANCE PROMOTES THE IMPLEMENTATION OF THE AQMP						
OBJECTIVES	ACTIVITIES	MANDATORY RESPONSIBILITY	PARTICIPATORY RESPONSIBILITY	TIME-FRAMES	INDICATORS	**EXTERNAL RESOURCE NEED**
Develop steering committee, chaired by the Mayor of Addis Ababa	Direct the activities of effective air quality management for the city of Addis Ababa across all governmental stakeholders; evaluate progress by Bureaus and Ministries to achieve AQMP goals.	Led by the Mayor with support of AA EPGDC and EFCCC	High-level management of city bureaus and national level Ministries, to include at least the transport, health, solid waste, industry ministries and bureau, and relevant university stakeholders,	2021	To be established in conjunction with the AQMP launch activities (tentatively June 2021).The Mayor convenes the Steering Committee and they meet regularly to direct AQMP activities.	None
Establish sector-specific working groups at staff level under the Addis Ababa Mayor's Office	Establish a cross-institutional technical working group for AQMP implementation, to include communication, air quality monitoring, and health impact assessment	AA EPGDC, EFCCC	AATB, AA Solid Waste Management Agency], Kotebe Metropolitan University, AA Planning Commission Bureau, FMHACA, MOH, WRI, many others to be clarified in subsequent activities	2021 (Within 3 months after launch)	Identify participants; set up first meeting and schedule for subsequent meetings	None

GOAL 3: AIR QUALITY MANAGEMENT IS SUPPORTED BY EFFECTIVE SYSTEMS AND TOOLS						
OBJECTIVES	ACTIVITIES	MANDATORY RESPONSIBILITY	PARTICIPATORY RESPONSIBILITY	TIME-FRAMES	INDICATORS	**EXTERNAL RESOURCE NEED**
Develop an overall air quality monitoring strategy	Develop a city-level monitoring strategy for air pollution, to include reference grade monitors, low-cost sensors, and other technologies (e.g., satellite/remote-sensed information) and data management. Include plans for developing source apportionment capabilities	EPGDC	MOH, AACAHB, FMHACA, Addis Ababa University (Black Lion), NMA, C40, UN Environment, USEPA,WRI and relevant external experts,	2021	Identification of a partner (donor) to guide EPGDC in development of the air quality monitoring strategy. Completion and dissemination of an air quality monitoring strategy	ብር
Implement the air quality monitoring strategy	Implement the strategy – procurement of equipment, implement training	EPGDC	UN Environment	2021-2022	Implementation of key elements of the air quality management strategy	ብር ብር ብር
Effectively collect, manage, and disseminate air quality data to the public	Create a public information and participation activity to share available AQ information with the public, including data management system.	EPGDC	UN Environment, C40, USEPA, WRI	2021-2022	Launch a system to share air quality data provision to the citizens of Addis Ababa	ብር ብር
Enhance source specific monitoring capabilities	Enhance the EPGDC's capacity to monitor industrial facilities. Enhance human (training) and technological (equipment) capacity	EPGDC Inspection Team	EFCCC – requires additional donor participation and funding	TBD	Identification of a partner (donor) to fund equipment procurement and capacity development. Implementation of the objective.	ብር ብር ብር

	to source-specific emissions.					
Explore options for developing a conventional pollutant (PM2.5, NOx, Sox, VOC, hydrocarbon) emissions inventory	Investigate activity being pursued in Ethiopia at national and city level to develop GHG emission inventories. Identify steps to use the activity data for conventional pollutant inventory development.	AA EPGDC	AATB, SWMA, AA Industry Bureau, AA Planning and Development Commission, with support of USEPA for coordination with Stockholm Environment Institute and SNAP initiative	2021 (6 months from AQMP launch)	Complete the exploration of options for emissions inventory [NOTE: development of an inventory would be a longer-term activity]	None

GOAL 4: AIR QUALITY DECISION-MAKING IS INFORMED BY SOUND RESEARCH						
OBJECTIVES	ACTIVITIES	MANDATORY RESPONSIBILITY	PARTICIPATORY RESPONSIBILITY	TIME-FRAMES	INDICATORS	**EXTERNAL RESOURCE NEED**
Coordinate and align public health air quality research being conducted by academia	Create TWG with different research institutes, conduct situational and problem analysis, identify priorities and design different implementation strategies, conduct researches…..	Ministry of Health EPHI	Kotebe Metropolitan University, Addis Ababa University, Center for Env. Science and Environmental Engineering, Civil Service University, GEOHEALTH	2021- 2022	Publish report, and journal articles that support the objective and encourage a focus on action	None
Utilize existing monitor information to identify patterns and trends that can inform AQMP implementation	Build capacity to assess monitor information and prepare reports on patterns and trends for policy makers and non-technical staff	AAEPGDC	UNEP	2021-2025 (One month after AQMP launch and continuing through AQMP implementation period)	Monthly reports on patterns and trends	None
Conduct research with the Black Lion PM monitor and associated GeoHealth Hub resources on air pollution links to health	Complete a children's health study (for both indoor and ambient air pollution), time series study linking air pollution data from BAM with morbidity data, and possibly source attribution analysis of PM filter samples	Addis Ababa GeoHealth Hub		2021	Drafts submitted to journals; final research and data are shared with AQMP partners in Addis Ababa	None – GeoHealth Hub already has funding from US Gov't
Establish a coordinating committee to learn about university-based air quality related research	Convene a group to interact regularly with representatives of relevant air pollution research academic	EPGDC, AATB	Kotebe Metropolitan University, Addis Ababa University, Center for Env. Science and Environmental	2021-2025 (First meetings within six to twelve months	Information on ongoing and newly completed research is shared among academic and government partners.	None

	programs to share information.		Engineering, Civil Service University	of plan adoption)		
Develop local and external capabilities to perform health impact analysis	Conduct capacity building and analytic activities to enhance the capability to revise and improve the baseline and forecast health impact estimates that derive from BenMAP modeling runs.	Kotebe Metropolitan University	Other university and government partners in a supporting role	2021-2025(Ongoing)	Kotebe Metropolitan University periodically updates the BenMAP results as new monitoring and exposed population data and information becomes available	ብር ብር
Form a monitoring and evaluation team for regularly monitoring and providing technical support.		AAEPGDC and EFCCC	UNEP in a support role	2021-2025 (Ongoing)	Periodic review and report to Steering Committee on progress of AQMP goals and objectives	None
Enhance understanding of the extent of open burning of waste, and the reasons for open burning	Develop research and surveys of the extent of open burning in Addis Ababa, and assess the health impact of this activity	AA Solid Waste Mgmt Agency	AA Health Bureau, Ministry of Health EPHI	2021-2022	Funding is secured from Ethiopian and donor support to complete the study, and the study is published and distributed among relevant decision-makers	ብር ብር ብር

GOAL 5: KNOWLEDGE AND UNDERSTANDING AMONGST DECISION-MAKERS, STAKEHOLDERS, AND THE GENERAL PUBLIC IS IMPROVED ACCORDING TO AN EDUCATION AND OUTREACH PLAN						
OBJECTIVES	ACTIVITIES	MANDATORY RESPONSIBILITY	PARTICIPATORY RESPONSIBILITY	TIME-FRAMES	INDICATORS	**EXTERNAL RESOURCE NEED**
Enhance understanding among general public about the negative health aspects of burning solid waste	Coordinate with outreach efforts in other Megacities (e.g., parallel activities being carried out in Accra, Ghana) and elsewhere to raise community awareness, consider implementing awareness raising programs	Ministry of Health EPHI, AACAHB	AA Solid Waste Management Agency	2021-2025 (Ongoing)	Communications products are developed and disseminated to educate the general public about the hazards of burning solid waste	ብር
Enhance understanding of options for technology improvement for cookstoves and home heating	Reach out to MWIE to pursue activities to identify renewable energy options as alternatives to wood, charcoal, kerosene, etc.; improved efficiency of cookstoves to reduce pollution; options for clean supplemental electric power supply options to be used during power outages	Ethiopian Federal Government, believed to be Ministry of Water, Irrigation, and Energy – to be coordinated by EFCCC		2021	Cooperation with MWIE is established to enhance understanding of options	Unknown
Enhance understanding among general public about the negative health aspects of all sources of air pollution, indoor and outdoor	Conduct impact analyses using tools such as BenMAP, data on the burden of disease, and other analyses	Ministry of Health EPHI	Kotebe Metropolitan University, Addis Ababa University	2021	Policy briefs targeted toward decision-makers	ብር

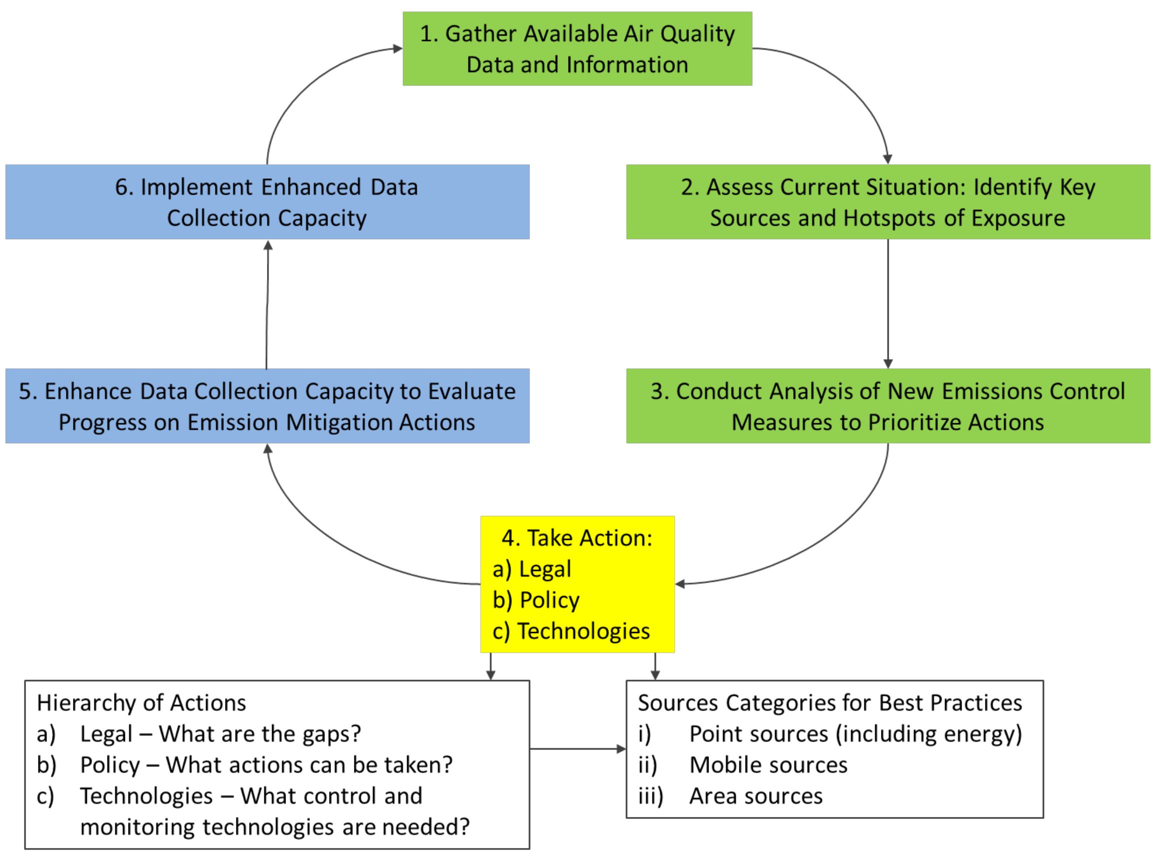
Enhance understanding of options for reducing transport emissions to meet ambient air quality standards	Assess options such as car-free days, parking restrictions, commuter plans, electric mobility, and many others in the transport sector	AAEPGDC, AATB	C40 – coordinate with options being assessed in the vehicle GHG emissions reduction action plan; UNEP for longer-term support (e.g.., electric mobility options)	2021-2022	Publish a report assessing these options	ብር ብር
Assist stakeholders and the regulated community to understand and comply with regulations under the AQMP	Provide opportunities for constructive feedback and interaction between government and regulated industry representatives	AA EPGDC, EFCCC	Representatives of regulated industries, including public transport providers	2021-2025(Ongoing)	Reports of meeting minutes are shared on relevant institution websites	None
Inform health providers about the impacts of air pollution on health	Develop programming for Public Service Air Time ("Healthy Message") to inform the public about health impacts of air pollution	Ministry of Health and EFCCC		2021-2025(Ongoing)	Messages are aired via both radio and TV media	ብር
Enhance understanding among the general public about the impacts of air pollution	Establish a media platform to communicate the status of AQMP efforts, raise awareness among the public	AAEPGDC	EFCCC	2021 (Within 6 months of AQMP adoption)	Updates are provided via the chosen media platform	ብር

7. MONITORING AND EVALUATION

Successful completion of steps to enhance AQ monitoring in Addis Ababa can provide important information to evaluate progress toward air quality goals in the city. Using these data, AAEPGDC will perform a mid-term review of progress in 2 years (at the end of 2023, and a formal evaluation of the plan's progress after 5 years. Any portion of the plan may be updated as a result of the review.

Figure 7-1 below provides a summary of the ongoing process of air quality management envisioned. Steps 1 through 3 have been used to formulate this first draft of the plan. Available air quality data and information has been used to assess the current situation and identify key sources. These results have in turn been used to prioritize actions for the key industrial point sources and for continued progress in reducing emissions from mobile sources (using both tailpipe controls and fuels content regulation). This plan represents the first step in taking action (Step 4).

Figure 7-1. Air Quality Management Process Cycle



The monitoring and evaluation process will include planned enhancements to the monitor network to expand monitoring through the sensor deployment effort, and potentially to strengthen ties to the monitoring capability available at Addis Ababa University (Black Lion Hospital). The data collected will be evaluated at the 5-year formal review to further assess whether the actions taken will be sufficient to meet the key goal of meeting the $PM_{2.5}$ standard.

Note that the review will also evaluate the state of emissions drivers, including faster or slower growth in emissions rates, air pollutant exposures, and the economy. The 5-year formal evaluation will also include an update on the availability of financing for implementation of the plan and to support meaningful changes in emissions rates and transition to new technologies, particular for point sources but also for the turnover of the mobile source fleet to cleaner technologies and the availability in retail settings of cleaner, low sulfur diesel and gasoline.

A strong monitoring and evaluation system also needs to be in place to track progress and support planning and sector investments. Therefore, to obtain the intended outputs, the planned activities must be implemented using the required resources such as human resource, materials, organizational setup, budget, etc. The outputs in turn are also expected to bring intended changes and impacts on community health. Health institutions (FMOH and AACAHB) will also record baseline information on priority air pollution related diseases, and current level of interventions and health system capacity prior to starting to adapt air pollution effects, to be best prepared to measure change after the implementation of this AQMP. The baseline information will be obtained by reviewing documents and/or conducting surveys.

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