Introduction
The human health and economic costs of air pollution in Africa are high and rising. Between 1990 and 2013, deaths from ambient particulate matter on the African continent rose by more than one third, and by 2013 was costing the African economy approximately USD 215 billion annually [1]. Similarly, premature deaths associated with domestic fuel combustion rose by 18% between 1990 and 2013 and cost the African economy approximately USD 232 billion in 2013 [1].

Sources of human exposure to air pollution in Africa include anthropogenic and natural sources and occur in urban, rural, industrial and residential settings. The main contributors are industry, power generation, agricultural burning, transport and traffic, the combustion of wood, coal, paraffin and dung for household energy needs (Figure 1a, b), unpaved roads and burning of household solid waste in areas not provided with regular residential waste collection services. Desert dust and wildfires are sources of particulate matter of natural origin [2].

Certain vulnerable groups may be simultaneously exposed to air pollution from multiple sources – sometimes at highly elevated concentrations [3]. For example, people living in informal settlements without a connection to the electricity grid, located close to mine tailings facilities or industrial sites, and in areas with unpaved roads (Figure 1c). In countries with high unemployment, many households generate livelihoods in the informal sector, including cottage industries (Figure 1d) such as vehicle spray painting, which may lead to increased levels of air pollutants in the immediate vicinity that frequently exceed the air quality guidelines of the World Health Organization [4, 5]. A study undertaken in Accra, Ghana showed that biomass burning accounted for 39–62% of total PM$_{2.5}$ mass in the cooking area, road dust and vehicle emissions comprised 12–33% of PM$_{2.5}$ mass, and solid waste burning was also a significant contributor to household PM$_{10}$ in low-income settlements [6]. Patriarchal systems and household power dynamics may play a role in women and children being particularly vulnerable to exposure to noxious air pollutants [7].

The Challenge of Addressing Air Pollution in Africa
Tackling air pollution in Africa is undoubtedly important but constitutes a uniquely complex challenge. Unlike many OECD countries, African efforts to curb exposure to air pollution need to be implemented alongside actions to address competing health and economic challenges, including poverty and inequality, a process of rapid urbanization currently underway, housing shortages, unsafe water, inadequate sanitation and major epidemics such as HIV/AIDS. Poor people are exposed to higher concentrations of air pollutants, have access to inferior health services, and tend to suffer disproportionately from the effects of air pollution [5]. In settings of poverty, where safe energy alternatives are not available, legislation to curb household solid fuel combustion would place additional hardship and financial burdens on poor households. While being home to 16% of the world’s population, only 3% of the world’s vehicle fleet is found in Africa [1, 8]. Traffic-related air pollution may gain in importance as a source of air pollution, given the predicted population...
and income increases in Africa in the coming decades, and
the process of rapid urbanization currently underway. The
current African population of approximately 1.2 billion is
predicted to rise to 2.5 billion by 2050, and to 4.4 billion
(or 40% of the world’s population) by 2100 [8].

In this regard, a fundamental concern is that air quality
monitoring capacity in Africa is weak. One study reported
that only 41 cities across 10 African countries measured
ambient air pollution levels, and knowledge of the
sources and pathways of human exposure to air pollution
across is limited to well-resourced countries, providing a
weak base for policy development and priority setting [9].

Harnessing Opportunities from the Global Statement
on Air Pollution
As stated in the July 2019 Air Pollution and Health State-
ment jointly issued by the Academy of Sciences of South
Africa (ASSAf), the Brazilian Academy of Sciences (ABC) and
the German National Academy of Sciences Leopoldina as
well as both the US National Academies of Medicine and
Science (USNAM and USNAS), “the costs of air pollution
to society and the economies of low- and middle-income
countries are enormous” and “can undercut sustainable
development” [10]. African countries thus have much to
lose from limited action on air pollution, but much more
to gain from heeding the Joint Call for investment in air
pollution reduction.

Signs of Hope and Success

| Box 1: Case Study |
|------------------|
| The Integrated High-Speed Train Network is a flag-
ship project of the African Union’s Agenda 2063. The
project aims to connect all African capitals and com-
mercial centers through an African High-Speed Train
Network thereby facilitating the movement of goods,
factor services and people. The increased rail connec-
tivity holds the potential for reducing transport costs,
relieving traffic congestion and lowering traffic emis-
sions [11]. Emerging low-cost air quality monitoring
technologies also provide hope for more extensive
air quality monitoring systems and the generation of
improved information for future decision-making. |

While the challenges are complex, some novel solutions
are emerging to overcome air pollution in some African
countries. In South Africa, at a regional scale, the Green-
house Gas and Air Pollution Interactions and Synergies or
‘GAINS’ model is a useful framework being considered to
identify strong linkages between air quality and climate-
relevant measures [12]. The results would provide evi-
dence for improving understanding of the cost-efficiency
of air pollution policies in line with the Statement’s
recommendation to ‘identify co-benefits among policy instruments’. Renewable energy technologies that are increasingly deployed at grid- and household-level present another opportunity for policy co-benefits by reducing air pollution and greenhouse gas emissions from large fossil fuel-fired power stations and household fuel burning.

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**Competing Interests**
The authors have no competing interests to declare.

**References**
1. **Roy R.** The cost of air pollution in Africa. *OECD Working Paper No 333*. September 2016. Available at https://www.oecd-ilibrary.org/development/the-cost-of-air-pollution-in-africa_5jlqzq77x6f8-en (Accessed 30 August 2019).
2. **Bauer S, Im U, Mezuman K** and **Gao C.** https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2018JD029336.
3. **Wernecke B, Language B, Piketh SJ** and **Burger RP.** Indoor and outdoor particulate matter concentrations on the Mpumalanga Highveld – A case study. *Clean Air Journal*. 2016; 25(2): 12–16. DOI: https://doi.org/10.17159/2410-972X/2015/v25n2a1
4. **Teare J, Kootbodien T, Naicker N** and **Mathee A.** The extent, nature and environmental health implications of cottage industries in Johannesburg, South Africa. *Int J Environ Res Public Health*. 2015; 12(2): 1894–1901. DOI: https://doi.org/10.3390/ijerph120201894
5. **Schwela D.** Review of Urban Air Quality in Sub-Saharan Africa Region: Air Quality Profile of SSA Countries. *World Bank*. 2012. DOI: https://doi.org/10.1596/26864
6. **Zhou Z, Dionisio KL, Verissimo TG,** et al. Chemical characterization and source apportionment of household fine particulate matter in rural, peri-urban, and urban West Africa. *Environmental Science & Technology*. 2014; 48(2): 1343–51. DOI: https://doi.org/10.1021/es404185m
7. **Cutter SL.** The forgotten casualties redux: Women, children, and disaster risk. *Global Environmental Change*. 2017; 42: 117–21. DOI: https://doi.org/10.1016/j.gloenvcha.2016.12.010
8. **United Nations.** Department of Economic and Social Affairs: Population Division. 2015. Available at https://population.un.org/wpp/Publications/Files/World_Population_2015_Wallchart.pdf (Accessed 30 August 2019).
9. **World Health Organization Regional Office for Africa.** Cleaning Africa’s Air would Pay for Itself in Economic Gains. Available at: https://www.afro.who.int/media-centre/statements-commentaries/cleaning-africas-air-would-pay-itslef-economic-gains-pollution (Accessed 30 August 2019).
10. **Five Academies.** Air Pollution and Health. Available at https://air-pollution.health/ (Accessed 30 August 2019).
11. **African Union.** Flagship Projects of Agenda 2063. Available at https://au.int/en/agenda2063/flagship-projects (Accessed 30 August 2019).
12. **IIASA.** The GAINS model. Available at http://www.iiasa.ac.at/web/home/research/research-Programs/air/GAINS.html (Accessed 30 August 2019).