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The case for clean air in Kigali: An assessment of sources and solutions, economic impacts, and implications for policy

Egide Kalisa, Andrew Sudmant, Remy Ruberambuga, Yves Ujeneza, Jonathan Bower, and Shuyu Li

- Only 1% of the population living in urban areas in the low and middle-income countries breathe air that meets WHO air quality guidelines.Rising demand for mobility is a central cause of declining air quality, but encouraging mobility is fundamental for driving social and economic development.
- Using state-of-the-art air quality monitoring equipment, this policy brief investigates the air quality faced by commuters using different modes of transport.
- Results show that the highest air pollution exposure are experienced by those travelling by foot and by bicycle, suggesting that the disadvantaged population of Kigali may be facing a higher burden of air pollution.
- The lowest total air pollution exposure was found for those travelling by bus, emphasising that a well-functioning public transport system can not only reduce congestion, expenditure on energy, GHG emissions and air pollution but can also reduce the exposure of travellers to air pollution.
- Scenario analysis suggests that modest annual reductions in air pollution in Kigali could yield hundreds of millions of dollars of economic benefits from lives saved, workdays not lost to illness, and hospital visits avoided.

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Introduction

In low and middle-income countries, less than 1% of the population living in urban areas breathes air that meets the WHO's air quality guidelines. As a consequence, of the 6.7-8.7 million people globally who die each year from air pollution, the vast majority are in the world's developing cities.

Contributing to urban air pollution are the growth of industry, urbanisation, home heating and cooking, commercial activities, and transport. Among these, transport is not only the primary source of air pollution in most urban areas, but it is in many cases seen as one of the most intractable: While renewable energy sources are cheaper than fossil fuels across nearly all developing countries and most wealthy nations , petrol and diesel-powered vehicles still dominate urban transport.

Rwanda is leading East Africa in economic development and consequently, is facing the challenge of decoupling social and economic development from the externalities of growth, including air pollution. Previous research has identified the impact of existing government policies in Rwanda. Car-free Days, for example, are found to reduce air pollution by approximately 15% after controlling for weather and seasonal factors, leading to 200 disability-adjusted life years being saved annually (Kalisa et al., 2021). Research has also found that transport is a major source of air pollution in Kigali and that different modes of transport make significantly different contributions to urban air quality.

This research contributes to policymakers' understanding by investigating the air pollution exposure of individuals using different modes of transport. Using state-of-the-art air quality monitoring technology, data was captured on commuters walking, cycling, taking the bus and taking moto-taxis. Results find that the highest burden of air pollution is faced by walking and cycling commuters while the lowest air pollution was faced by those on the bus. However, across all commuting modes, the levels of air pollution significantly exceeded WHO limits.

These results emphasise the need for policymakers in Kigali to support the development of a multi-modal transport system in the city, particularly a system that emphasises public transport.

Policy context: Air quality in Kigali, recent literature and government policies

The urbanisation rate in Rwanda is anticipated to increase from 18% in 2020 to 70% by 2050 (Government of Rwanda, 2020), leading to a massive increase in demand for mobility. Already today the effects of growth are being felt by the transport system, with the number of vehicles in the country increasing four times between 1999 and 2019 (Bajpai & Bower, 2020) and more than 70% of these vehicles are second hand, aged more than 10 years (RRA,2017). As this pattern continues, it will lead to declines in urban air quality and growth in fuel imports, congestion, numbers of vehicle accidents and GHG emissions (Sudmantet al., 2020).

The air quality costs are particularly concerning. Air pollution can cause cardiovascular and respiratory diseases, lung cancer and strokes (Schraufnagel et al., 2019). Air pollution is one of the highest risk factors for premature mortality worldwide and the highest among environmental risk factors, leading to more than 6 million premature deaths and more than 100 million Disability-Adjusted Life Years (DALYs) annually worldwide (IHME, 2020). In addition, the World Bank has indicated that air pollution causes more than $5 trillion in welfare losses annually (World Bank, 2016). In 2021, the WHO updated its guidelines, and across nearly all pollutants, recommended exposure levels are lower than the previous 2005 guidelines. The 2021 update thus reflects evidence of how air pollution affects many aspects of health, even at what was once considered low levels.

Several academic studies have assessed air pollution in Rwanda. Kalisa et al. (2018) confirmed the government of Rwanda's analysis that wood and charcoal burning and transport activities are the primary sources of air pollution in the country. Supporting these findings, research assessing low carbon investment opportunities in Kigali attribute approximately half of the city's GHG emissions to the transport sector and suggest that transport is a primary concern for urban air quality (Colenbrander et al., 2019; Sudmant et al., 2017). Ambient PM2.5 in Kigali from 2017 to 2018 (Subramanian et al., 2020) was approximately ten times higher than the annual WHO recommended limit of 5µg/m3 (World Health Organization, 2021), emphasising the need for action and the scale of the potential benefits.

The recent analysis supported by the International Growth Centre offers insights into the impact of existing measures being taken, the sources of air pollution in Kigali, and the policy approaches government can take. Kalisa (2021*) found that Car-Free Days, a program that restricts vehicles from certain roads one Sunday of the month to allow people to exercise, socialise and receive medical advice, reduces air pollution by approximately 15%. This leads

to 150 fewer hospital visits each year, 600 fewer sick days for workers, and 200 disability-adjusted life years saved.

Kalisa et al. (2021) also helped to explore the sources of air pollution within the transport sector. Results found that the partial COVID lockdown in 2020 - which allowed cars but not motorcycles and reduced travel by 41% - reduced air pollution by around 21%. However, when motorcycles were re-introduced, air pollution remained approximately 20% lower than the pre-lockdown average. These results emphasise the role of the transport sector in urban air pollution in Kigali, and also suggest that emissions from motos, highlighted as a potential source of PM2.5 air pollution in some sources (eg REMA, 2018), may not be as pronounced as suggested.

Rwanda has been a leader in environmental action in Sub-Saharan Africa. Rwanda's Green Fund, FONERWA, is the largest environmentally-focused fund of its kind across the continent. Rwanda's government has also developed pioneering approaches, including a ban on plastic bags that have been taken up by neighbouring countries. Rwanda is also increasingly focused on environmental policy in both urban planning and the transport sector through its Green Growth and Climate Resilience Strategy, which demonstrates an aspiration to transition to low and zero carbon mobility.

Furthering Rwanda's ambitious policy vision for green and clean growth will require informed policies, which depend on high-quality data.

Under current trends, transport-generated air pollution could increase as Rwanda urbanises and develops. Research elsewhere has shown that three-quarters of air pollution in urban areas may be attributed to motor vehicle emissions (Aggarwala et al., 2011). In one of the most detailed analyses of urban air pollution, vehicles were found to account for 9 – 53% of PM10, 9 – 66% of PM2.5 and over 80% of NOx pollutants (Cyrys et al., 2012). While this research is now more than a decade old most vehicles in Kigali are second-hand. In this unique case, analysis that is approximately a decade old may therefore offer better insights than an analysis conducted on a more recent vehicle stock.

The Rwandan Environmental Management Authority (REMA) in 2018 found that vehicles imported to Rwanda before 1999 contributed 58% of nitrogen oxides (NOx) and 66% of particulate matter (PM10) (REMA, 2018). The report also implicated motorcycle taxis accounting for more than 50% of all NOx emissions in Kigali City. These results, however, relied on limited on-the-ground air quality testing and did not include air quality testing of vehicles in Kigali, emphasising the need for further analysis for the development of informed policies for addressing air quality.

Rwanda's interest in air pollution mitigation goes beyond its much-publicised Car-Free Days. In 2016, Rwanda established a "Law governing the preservation of air quality and prevention of air pollution in Rwanda", which covers the transport sector, waste incineration, industry, construction and other sources (Government of Rwanda, 2016). This law led to the Rwanda Air Quality and Climate Change Monitoring Project, which began in 2017 (FONERWA, 2016). In Kigali, the project monitors air quality from one reference station at the Meteo Rwanda headquarters and uses low-cost air quality networks in 22 sites in Rwanda.

The primary policy guiding the transport sector in Rwanda is the Transport Sector Strategic Plan (2013-2018) (Ministry of Infrastructure, 2018), which identifies the "green economy" as a priority area and focuses on public transport and non-motorised transport. This plan, however, does not explicitly mention air pollution, health or carbon emissions. A Ministerial Order from 2010 made it mandatory for motor vehicle exhaust fumes to be included in the annual roadworthiness test for vehicles (Government of Rwanda, 2010; Rwanda Standards Board, 2018), but it is unclear if motor vehicles that fail tests are being excluded from the roads. In addition, traffic police have acquired mobile and handheld emissions inspection equipment for spot checks; however, as of 2019 they were not yet in use (Nshizirungu, 2019).

Rwanda's Ministry of Infrastructure (MININFRA) prepared a National Transport Policy, which Cabinet ratified in April 2021. MININFRA is also planning to develop a new National Transport Master Plan. The terms of reference for developing this plan include focusing on green mobility, climate change and low-carbon growth (Imvaho Nshya, 2021). In May 2020, the Ministry of Environment released Africa's first updated Nationally Determined Contribution (NDC) to the IPCC and outlined electric vehicles and vehicle emissions standards as necessary mitigation measures, expected to require an investment of 900 million USD and 190 million USD, respectively (MoE, 2020). In April 2021, an electric mobility strategy released by Cabinet contained tax incentives for e-mobility inputs and lowered electricity tariffs for e-mobility users, among other incentives (Global Green Growth Institute, 2021; Office of the Prime Minister, 2021). Rwanda also plans to scale up electric buses (Nkurunziza, 2021).

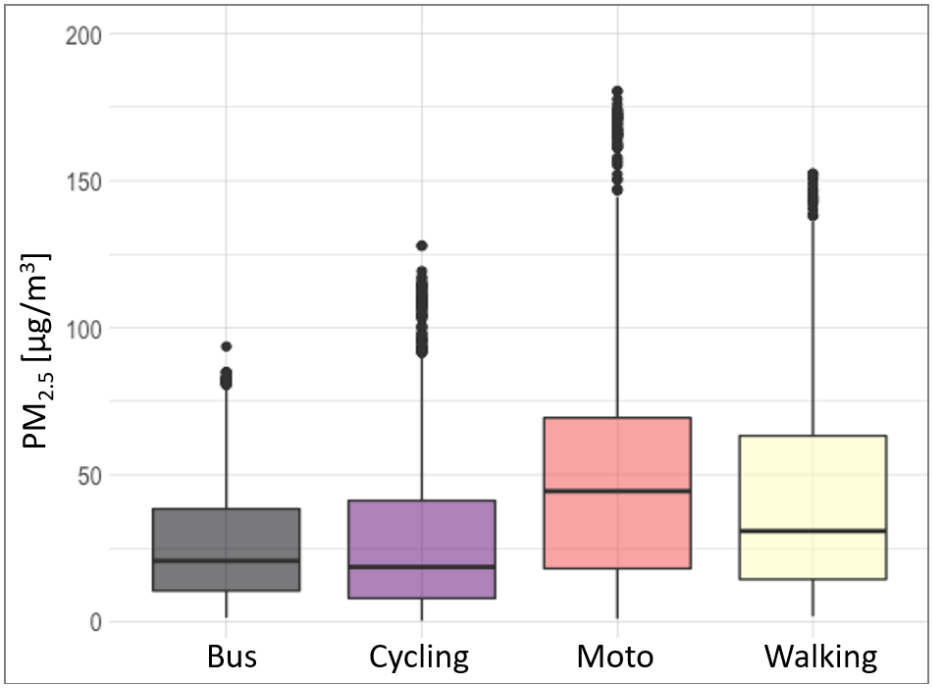
At the municipal level, Kigali has developed the Kigali Master Plan, updated in 2020, which includes transport planning, operates on a principle of transit-oriented development, and has a Green Economy pillar. This pillar consists of the following goals that are relevant to air pollution: i) develop a high-quality mass-transit system; ii) develop a road network that supports mass transit systems; iii) integrate non-motorised transport infrastructure, including cycle lanes, into the road network; iv) establish a green transportation network and

pedestrian-friendly streets in Kigali; and v) provide seamless intermodal transport connectivity. Master plans are also being developed for the six secondary cities, likely to contain similar principles. Rwanda thus has an ambitious vision to reduce GHG emissions and air pollution from the transport sector.

Air pollution by mode of travel in Kigali

Figures 1 and 2 present air pollution levels faced by commuters using different modes of transport. PM2.5 and NO2 are presented, as these are two key air pollutants on human health. The concentration of PM2.5 levels are highest for moto riders, which is unsurprising since they are in the middle of the road. The highest observations for moto passengers were likely recorded at crossings when large numbers of motos cluster while waiting for the signal to change. The lowest PM2.5 pollution was faced by bus riders and cyclists. Bus riders are significantly sheltered from the outside air (even if windows are open), and cyclists generally ride on the sidewalk or the edge of the road where PM2.5 is marginally lower.

Figure 1: The average concentration of PM2.5 pollution by different travel modes in Kigali



In Figure 2 the highest NO2 concentration was faced by cyclists. This is attributable to NO2 emissions – which disperse less easily than PM2.5 emissions – gathering at the road's edge where cyclists most frequently travel. The lowest NO2 is faced by bus riders who are protected from exhaust emissions.

Figure 2: The concentration of NO2 air pollution by travel mode

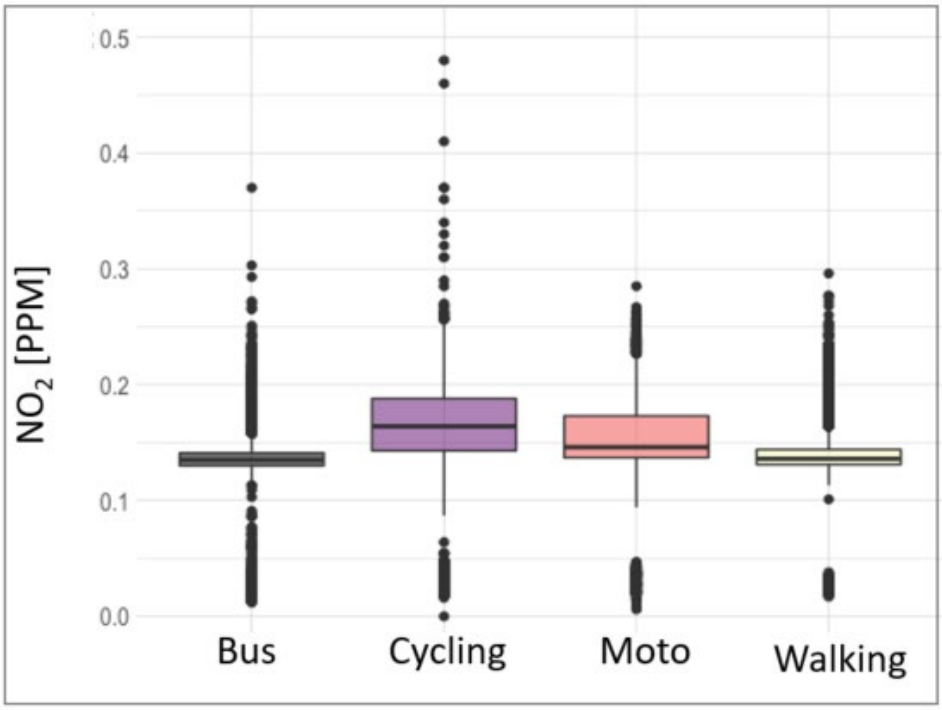


Table 1 shows average air pollution levels by mode across all pollutants investigated in the study. Mirroring the results discussed above, pollution levels are lowest for those busing and cycling, and relatively higher for those on motorbikes and walking. However, a limitation of assessing air pollution by looking at average levels is that different trips take different amounts of time and therefore expose travellers to varying levels of pollution. This issue is addressed in Table 2.

Table 1: Average air pollution levels by mode

Pollutant	Mode			
	Walking	Motoring	Busing	Cycling
O3 [PPM]	3.0	3.0	3.3	2.7
NO2 [PPM]	0.1	0.2	0.1	0.2
CO [PPM]	3.9	4.8	3.5	4.6
PM2.5 [µg/m3]	40.9	47.4	26.3	27.0
PM10 [µg/m3]	42.6	49.5	27.4	28.2

In Table 2 an index of total exposure to air pollution is presented. This index takes into account the average exposure for each mode of travel and the time each mode of travel takes for a typical trip (with the trip length standardised across modes). Results change our understanding of the modes of travel that are most and least exposure to air pollution. As a consequence of motos travelling significantly more quickly than bicycles, moto trips lead to lower or similar levels of pollution exposure as cycling trips. Walking trips face higher levels of air pollution, and busing trips face the lowest levels of total air pollution exposure across three of five air pollutants.

An implicit assumption in interpreting the total exposure results in Table 2, is that the traveller is moving to a destination (or coming from an origin) with lower air pollution than what they face during travel. If this is not the case, for example, if the traveller is travelling to a smoky factory, a faster trip that leads to more time in the factory leads to a net increase in air pollution exposure.

Table 2: Average air pollution exposure presented as an index

Pollutant	Mode			
	Walking	Motoring	Busing	Cycling
O3	1.00	0.35	0.48	0.50
NO2	1.00	0.39	0.43	0.65
CO	1.00	0.44	0.40	0.65
PM2.5	1.00	0.41	0.29	0.37
PM10	1.00	0.41	0.29	0.37

Economic impact

The economic impact of changes in the urban air quality is calculated with concentration-response functions (CRF), used in conjunction with socio-economic and health data. Table 1 provides critical data on the CRF used. Table 2 provides a summary of socio-economic and health data. It should be noted that Rwanda-specific data are not available for some variables. In these cases, least-developed country proxies are drawn from the literature.

Table 3: Concentration-response functions used to estimate the health impacts of changes in PM2.5

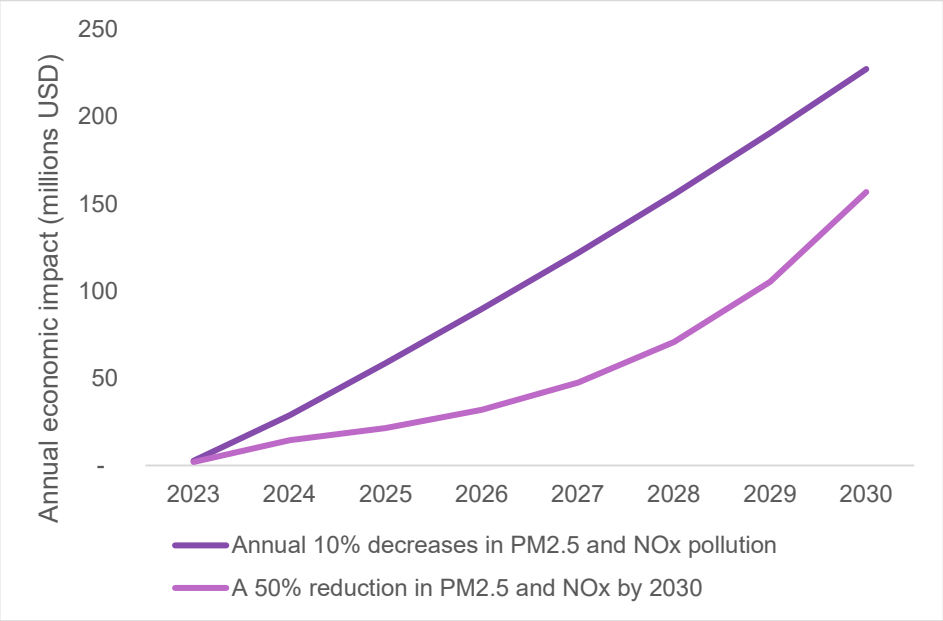
Impact Pathway	Concentration-response function	Source
Mortality	6.0%	COMEAP (2010)
Hospital admissions	1.9%	WHO (2013)
Cardiovascular-related hospital admissions	0.9%	WHO (2013)

Table 4: Key socio-economic and health data used in the analysis

Data	Value	Source
Cost of the working day lost	15 USD	Consultation
Cost of hospital bed per day	18 USD	Dagenaise et al. (2020)
All-cause mortality per 1000 person-years	13	Dagenais et al. (2020)
Respiratory hospital admissions per 1000 person-years	2	Dagenais et al. (2020)
Cardiovascular hospital admissions per 1000 person-years	5	Dagenais et al. (2020)
Working days lost per hospital admission	4	Consultation
Value of a statistical life	4.5x per capita GDP	Patenaude et al. (2019)

The value of reducing air pollution using the models and assumptions listed in Tables 1 and 2 is shown in Figure 1. Given even modest annual reductions in air pollution on the order of 10% annually, hundreds of millions of economic value could be generated. On a per capita basis, this would translate to hundreds of dollars per person. Most of these savings come from the value of lives saved, but a significant portion would also come from the direct financial benefits from workdays not lost to illness and hospital beds not used.

Figure 3: The economic benefit of reducing air pollution (PM2.5 and NOx under different scenarios)



Policy reflections

Over the last 100 years, urban, transport, and energy policies have been hugely influenced by a rapid rise in motorisation rates. In recent years, however, a dramatic shift in sentiment emerged from a realisation that for the benefits private vehicles provide for mobility, their emissions, energy use and the physical and financial capacity they require come with substantial costs. Among these costs, air pollution ranks as among the highest risk factor for premature mortality worldwide, and the highest among environmental risk factors, leading to more than 6 million premature deaths and more than 100 million Disability-Adjusted Life Years (DALYs) annually worldwide (Global Burden of Disease) (IHME, 2020).

A shift away from private vehicles also reflects the opportunity for new technologies and businesses to provide alternatives to personal vehicles. In Kigali, Ampersand, Gura, and Rwanda, Electric Motorcycles and others demonstrate that an e-mobility future can decouple economic growth from rising air pollution and GHG emissions.

Rwanda's policy goals are ambitious and now aim to shift from a transport network structured around private vehicles to one that relies on well-functioning public transport, non-motorised transport and shared low-carbon mobility options. This requires not just good intentions but investment, planning, institutional and technical capacity, and coordination. Extending Car-Free Days is not the answer, nor is assuming the current transport network can handle

significant numbers of new trips without investment. In the following, we discuss the actions that are needed.

Commit to ambitious air quality improvements

Before action comes commitment, faced with a range of development needs and the challenges of the policrisis (the combination of the crisis caused by Coronavirus, the energy crisis, inflation and wider economic and geopolitical challenges), there is a temptation to see air quality as a challenge for the future rather than today. To shift air quality to the future, however, would be to forgo substantial social and economic benefits and to make a future transition dramatically more challenging.

Joining the Clean Air Cities Declaration, led by C40 cities, offers one opportunity for Kigali to show leadership on air quality. Signatories are required to establish baseline levels of air pollution and set ambitious targets for action within two years – something that scientists in Kigali are well placed to support. Signatories are also required to establish substantive new policies and programmes to take action within five years. Developing these actions complements the city and the nation's ongoing plan to transition to 100% electric mobility by 2025, making commitments to air quality an easy decision for policymakers.

Prioritise public transport

New technologies, including electric motorbikes and cars, can support the transition away from internal combustion engines and lead to improvements in air quality. A policy approach focused on electric vehicles, however, would benefit the small number who can afford cars at the expense of the wider population.

Most trips today in Kigali are on foot, and approximately a third are by moto-taxi. Enabling this population to reach their destinations faster and easier holds the key to supporting social and economic development while improving air quality. Improving the service reliability of buses operated by private firms should be a priority in this context (Bajpai, 2014), encouraging firms to invest in cleaner and lower carbon bus technologies as part of longer-term planning. The Government of Rwanda can also work to scale up and improve public transport and implement bus lanes, plans it has committed to already. The Kigali Master Plan also contains a transport plan that includes a Bus Rapid Transit system. Considerable challenges remain, but Rwanda's policy aspirations are laudable.

Figure 4: Giving priority to public transport will enabling the Rwanda population to reach their destinations faster and easier and reduce traffic from private cars and improve air quality (Image: E Kalisa)

Investments in infrastructure towards a ‘complete streets’ approach to development

Rwanda can focus on low-cost interventions include traffic engineering, bike lanes, sidewalks, protected crossings for pedestrians, and the aforementioned allocation of road space to bus lanes and improvements to public transport. These investments can support a transition to a "complete streets" approach that prioritises public transport and non-motorised transport. More than 90% of transport infrastructure in global urban areas is public roads for private vehicles. If applied in Kigali, such an approach will likely lead to more congestion, reduced air quality, and higher fuel imports. To contribute to the planned transport-oriented development approach in the Kigali Master Plan, e-motos can provide essential 'last-mile' connectivity between bus rapid transit stations and people's homes. This requires well-placed charging stations and motorbike parking integrated into city plans.

Enforcing vehicle standards

Lowering the maximum age of imported cars to 5 years to reduce vehicles' tailpipe emissions, as has been put forward by the East African Community, could reduce tailpipe emissions (MediaMax, 2018; The East African, 2017). Given a relatively large stock of existing vehicles in the country, however, and improvement to vehicle emission technologies, the biggest opportunities may be found in addressing the emissions of existing vehicles. Aspects such as vehicle weight, mileage, engine size, fuel type, emission control technology retention, and maintenance status are key predictors of emissions (Mbandi et

al., 2019). Enforcement of emissions testing and standards for vehicle imports and the current vehicle stock could have a meaningful short-term impact on emissions in the city.

Electric mobility

The Government of Rwanda aims to rapidly transition to electric motorbikes (e-motos) and eventually to electric vehicles more broadly and recently passed an Electric Mobility Strategy through Cabinet (April 2021). Within this strategy is a set of measures developed in collaboration with the nascent electric vehicle industry, including preferable electricity rates and support for the development of industrial zones.

Effective implementation of this strategy requires long-term planning. Electric vehicles will reduce energy expenditure, air pollution and GHG emissions even under extremely pessimism assumptions about the electric grid and the efficiency of electric vehicles (Sudmant et al., 2020). However, a new peat capacity recently added to the Rwandan electricity grid will mean that air quality improvements and GHG emission reductions are dramatically less than they could be if renewable electricity was added to the grid. This exemplifies the need for coordination between transport planning to be coordinated with other aspects of economic development, not only the energy system but also urban planning (as explored in the section on ‘complete streets’), and law enforcement (enforcing vehicle standards), and private industry.

References

Aggarwala, R. T., Desai, R., Choy, B., Fernandez, A., Kirk, P., Lazar, A., Smith, T., Watts, M., & Yan, A. (2011). Climate Action in Megacities :C40 Cities Baseline and Opportunities. *Review Literature And Arts Of The Americas*, *June*, 114.

Bajpai, J. (2014). *The Role of the Government in Sustaining Mobility and Accessibility in*. *June*.

Bajpai, J., & Bower, J. (2020). A Road Map for e-Mobility Rransition in Rwanda—Policy Brief. *Igc*, *April*.

Colenbrander, S., Sudmant, A., Chilundika, N., & Gouldson, A. (2019). The scope for low-carbon development in Kigali, Rwanda: An economic appraisal. *Sustainable Development*, *27*(3), 349–365. https://doi.org/10.1002/sd.1906

Cyrys, J., Eeftens, M., Heinrich, J., Ampe, C., Armengaud, A., Beelen, R., Bellander, T., Beregszaszi, T., Birk, M., Cesaroni, G., Cirach, M., de Hoogh, K., De Nazelle, A., de Vocht, F., Declercq, C., Dedele, A., Dimakopoulou, K., Eriksen, K., Galassi, C., … Hoek, G. (2012). Variation of NO2 and NOx concentrations between and within 36 European study areas: Results from the ESCAPE study. *Atmospheric Environment*, *62*(2), 374–390. https://doi.org/10.1016/j.atmosenv.2012.07.080

Dagenais, G. R., Leong, D. P., Rangarajan, S., Lanas, F., Lopez-Jaramillo, P., Gupta, R., Diaz, R., Avezum, A., Oliveira, G. B. F., Wielgosz, A., Parambath, S. R., Mony, P., Alhabib, K. F., Temizhan, A., Ismail, N., Chifamba, J., Yeates, K., Khatib, R., Rahman, O., … Yusuf, S. (2020). Variations in common diseases, hospital admissions, and deaths in middle-aged adults in 21 countries from five

continents (PURE): A prospective cohort study. *The Lancet*, *395*(10226), 785–794. https://doi.org/10.1016/S0140-6736(19)32007-0

FONERWA. (2016). *Rwanda Air Quality and Climate Change Monitoring Project.* FONERWA. http://www.fonerwa.org/sites/default/files/Final PD Air Quality and Climate Change Monitoring Project 20th August.pdf

Global Green Growth Institute. (2021). *Rwanda E-Mobility Technology Showcase*. Youtube.

Goverment of Rwanda. (2010). *Ministerial Order No. 003/16/01 of 15/07/2010 Preventing Activities that Pollute the Atmosphere, Official Gazette nº 35 of 30/08/2010, Kigali:*

Government of Rwanda. (2016). Law No. 18/2016 of 18/05/2016 Governing The Preservation Of Air Quality And Prevention Of Air Pollution In Rwanda", Official Gazette nº 23 of 06/06/2016, Kigali: In *Government of Rwanda*.

Government of Rwanda. (2020). Vision 2050. In *Government of Rwanda*. https://doi.org/10.1007/978-4-431-09431-9

IHME. (2020). *The Lancet: Latest global disease estimates reveal perfect storm of rising chronic diseases and public health failures fuelling COVID-19 pandemic*. IHME. https://www.healthdata.org/news-release/lancet-latest-global-disease-estimates-reveal-perfect-storm-rising-chronic-diseases-and

Imvaho Nshya. (2021, February 8). RTDA: Consulting Services for Developing a National Transport Master Plan. *RTDA*.

Kalisa, E., Sudmant, A., Ruberambuga, R., & Bower, J. (2021). From car-free days to pollution-free cities: Reflections on clean urban transport in Rwanda.

Kalisa, E., Nagato, E. G., Bizuru, E., Lee, K. C., Tang, N., Pointing, S. B., Hayakawa, K., Archer, S. D. J., & Lacap-Bugler, D. C. (2018). Characterization and Risk Assessment of Atmospheric PM 2.5 and PM 10 Particulate-Bound PAHs and NPAHs in Rwanda, Central-East Africa [Research-article]. *Environmental Science and Technology*, *52*(21), 12179–12187. https://doi.org/10.1021/acs.est.8b03219

MediaMax. (2018, January 23). Clock ticks for EAC to enforce vehicle age limit. *Trade Mark East Africa*.

Ministry of Infrastucture. (2018). *Transport Sector Backward Looking Joint Sector Review Report", Kigali: Government of Rwanda*.

MoE. (2020). Nationally Determined Contribution (NDC). In *Ministry of Environment*.

Nkurunziza, M. (2021, January 26). *Transition to electric motorbikes could save Rwf9 billion annually*.

Nshizirungu, F. (2019). *Air Emissions Control and Air Quality In Rwanda*.

Office of the Prime Minister. (2021). *1/2 Statement on Cabinet Resolutions of 14/04/2021"*. Government of Rwanda. https://mobile.twitter.com/PrimatureRwanda/status/1382447988132474886/photo/2

Patenaude, B. N., Semali, I., Killewo, J., & Bärnighausen, T. (2019). The Value of a Statistical Life-Year in Sub-Saharan Africa: Evidence From a Large Population-Based Survey in Tanzania. *Value in Health Regional Issues*, *19*, 151–156. https://doi.org/10.1016/j.vhri.2019.07.009

REMA. (2018). Inventory of Sources of Air Pollution in Rwanda. In *Rwanda Environmental Management Authority* (Issue January).

Rwanda Standards Board. (2018). *Rapid situational assessment: Towards developing/revising air quality (internal combustion engine emission) standards for Rwanda*.

RRA, 2017. EAC Proposed Depreciation Schedule <https://www.rra.gov.rw/index.php?id=219>

Schraufnagel, D. E., Balmes, J. R., Cowl, C. T., De Matteis, S., Jung, S. H., Mortimer, K., Perez-Padilla, R., Rice, M. B., Riojas-Rodriguez, H., Sood, A., Thurston, G. D., To, T., Vanker, A., & Wuebbles, D. J. (2019). Air Pollution and Noncommunicable Diseases: A Review by the Forum of International Respiratory Societies' Environmental Committee, Part 1: The Damaging Effects of Air Pollution. *Chest*, *155*(2), 409–416. https://doi.org/10.1016/j.chest.2018.10.042

Subramanian, R., Kagabo, A. S., Baharane, V., Guhirwa, S., Sindayigaya, C., Malings, C., Williams, N. J., Kalisa, E., Li, H., Adams, P., Robinson, A. L., DeWitt, H. L., Gasore, J., & Jaramillo, P. (2020). Air pollution in Kigali, Rwanda: Spatial and temporal variability, source contributions, and the impact of car-free Sundays. *Clean Air Journal*, *30*(2), 1–15. https://doi.org/10.17159/caj/2020/30/1.8023

Sudmant, A., Colenbrander, S., Gouldson, A., & Chilundika, N. (2017). Private opportunities, public benefits? The scope for private finance to deliver low-carbon transport systems in Kigali, Rwanda. *Urban Climate*, *20*, 59–74. https://doi.org/10.1016/j.uclim.2017.02.011

Sudmant, A., Kalisa, E., & Bower, J. (2020). *The impact of scaling up electric motorbikes in Rwanda*. 6.

Sudmant, A., Verlinghieri, E., Khreis, H., & Gouldson, A. (2020). Chapter 19 - The social, environmental, health, and economic impacts of low carbon transport policy: A review of the evidence. In H. Khreis, M. Nieuwenhuijsen, J. Zietsman, & T. Ramani (Eds.), *Traffic-Related Air Pollution* (pp. 471–493). Elsevier. https://doi.org/10.1016/B978-0-12-818122-5.00019-3

The East African. (2017, January 26). *Second-hand cars to get more expensive in new age limit rule*.

World Bank. (2016). The Cost of Air Pollution. *The Cost of Air Pollution*. https://doi.org/10.1596/25013

World Health Organization. (2021). *WHO Global Air Quality Guidelines. Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide*.