CHAPTER 5:

ALIGNING AIR QUALITY, CLIMATE CHANGE AND DEVELOPMENT OBJECTIVES TO PROMOTE ACTION IN AFRICA

UN environment programme

CLIMATE & CLEAN AIR COALITION TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

African Union

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CONTENTS

5.1 THE OPPORTUNITY TO ACHIEVE AIR QUALITY, CLIMATE, HEALTH AND DEVELOPMENT GOALS

MAIN MESSAGES

- The African continent has made progress towards achieving the SDGs with improvements in the number of households moving above the poverty line, improved health outcomes and mortality rates across age groups, food production and nourishment of the population, numbers of children completing primary education and the economy.
- The gains in Africa's development have been largely achieved despite environmental degradation at local, regional, and continental scales.
- In the short, medium, and long term, there is the opportunity for Africa to move along a positive development trajectory, and, at the same time, limit and reduce air pollution, GHG emissions and environmental degradation. It is possible for African countries to develop their economies successfully in the Agenda 2063 scenario – providing the same level of per capita wealth as under current development pathways, but with lower GHG emissions and reduced air pollution.
- The Assessment emphasises three distinct but interrelated factors that will determine how successfully Africa is able to achieve Agenda 2063 and its sustainable development priorities: (i) demographic and socioeconomic transitions in Africa affecting its development; (ii) global action on climate change affecting Africa's climate; and (iii) action in Africa reducing the impacts of climate change and improving air quality.

5.1.1 INTRODUCTION

Over the past two decades, the African continent has made progress towards achieving sustainable development goals. According to the United Nations, over the past decade poverty has decreased across Africa. Between 2010 and 2019, the proportion of households with income at or below US$ 1.9 per day decreased from 40.2 per cent in 2010 to 34.4 per cent in 2018, and GDP per person increased by 0.25 per cent between 2010 and 2019 (UNCTAD 2021). Health outcomes have also improved. Infant mortality rates, for children under five, have fallen by more than half since 2000, and adult mortality rates have decreased by more than 30 per cent (UNWPP 2019). Food production has increased over the last decade, with a 23 per cent rise in the production of staple cereals between 2010 and 2019, a 32 per cent increase in the production of meat, and 17 per cent growth in the production of milk and other dairy products across Africa as a whole (FAO *et al.* 2021). Between 2005 and 2019, the proportion of the population that was undernourished, i.e., not consuming sufficient calories on a regular basis to lead a normal, active and healthy life[1], decreased from 21.3 per cent to 18 per cent (FAO *et al.* 2021). Africa's economy is also broadening, with a 3 per cent reduction in the share of employment in the agriculture sector between 2011 and 2020, and increases in the manufacturing, construction and service sectors (ILO 2020). The proportion of the population completing primary education has also risen in some African countries (World Bank 2021a).

Over the past two years, however, the development gains made across Africa have been shown to be fragile. The COVID-19 pandemic erased some of the progress made on different aspects of development across the continent. Even though Africa may have experienced the lowest COVID-19 death rate relative to other world regions, the impact of the pandemic was strongly felt across the continent. In 2020, 31 million more people were estimated to be living in poverty in 2020 compared to 2019 (UNCTAD 2021); Africa's economy contracted by 2.1 per cent in 2020; and in nominal terms GDP per person fell by 10 per cent (Section 4.2.2). While these reductions were lower than in other regions of the world, Africa experienced its worst recession in 50 years in 2020 (AfDB 2021).

The gains in Africa's development have been largely achieved despite environmental degradation at local, regional and continental scales. Africa is particularly vulnerable to climate change (IPCC 2022b) and although it makes a small contribution to climate change, Africa's CO_2 emissions have increased at a higher rate than the global average, with fossil-fuel combustion CO_2 emissions increasing at 4.6 per cent per year between 1990 and 2017, compared to the global average of 2.2 per cent per year (Ayompe *et al.* 2021). Alongside this GHG increase, emissions of health-damaging air pollutants have also increased. As a result, the health burden from outdoor air pollution has increased from 164 000 premature deaths in 1990, to 383 000 in 2019, a 4.5 per cent per year increase (GBD 2019). Climate change, air pollution and their associated impacts are two of a broader range of environmental impacts that have accompanied Africa's development over the last decades, and the increased energy consumption, transport, waste generation resulting from it, has increased emissions (Chapter 2).

1. https://www.fao.org/hunger/en/

In the short, medium and long term, there is the opportunity for Africa to recover and continue along a positive development trajectory, and, at the same time, limit and reduce air pollution, GHG emissions and environmental degradation. The African Development Bank (AfDB) estimates that the economy is projected to grow at 4.6 per cent in 2022 (AfDB 2021). In the medium and long term, the African Union's (AU) Agenda 2063 has outlined a vision for how the continent can develop across multiple dimensions over the 21st Century, achieving economic growth and prosperity, improved health, zero hunger and other necessary development priorities, while improving the environment at the same time.

The focus of this integrated assessment, the intersection between sustainable development and the mitigation of climate change and air pollution, emphasises three distinct but interrelated factors that will determine how successfully Africa is able to achieve Agenda 2063 and its sustainable development priorities:

1. demographic and socioeconomic transitions in Africa affecting its development;
2. global action on climate change affecting Africa's climate;
3. action in Africa reducing the impacts of climate change and improving air quality.

FACTOR 1: DEMOGRAPHIC AND SOCIOECONOMIC TRANSITIONS IN AFRICA AFFECTING ITS DEVELOPMENT

Key demographic and socioeconomic trends will play a key role in determining Africa's future development. Its population is projected to increase by 412 million by 2030 and 1 751 million by 2063, 32 per cent and 137 per cent, respectively, compared to 2018. Africa is a young continent and it is the only region of the world in which the youth labour force, those between 15 and 24, is growing rapidly (ILO, 2020). Globally, this group comprises 23.6 per cent of the total working-age population but represents 34 per cent of Africa's workforce. This is projected to continue, with the number of 15-24 year-olds expected to increase from 120 million in 2020 to 150 million in 2030. The International Labour Organization (ILO) has identified this as a key potential resource for Africa to increase prosperity, drive economic growth and deliver key development goals (ILO 2020).

Africa's economy is expected to grow substantially by 2063, and many African countries have targeted reaching middle-income-country status by 2063, or earlier.

The projected population and economic growth across the African continent could not only support achievement of the SDGs but could also exacerbate existing pressures on resources, the environment, ecosystems and human health, compounding inequalities and limiting the achievement of sustainable development for all. By 2063, 66 per cent of Africans are projected to live in cities, the demand for passenger transport to increase by 51 per cent between 2018 and 2030, and by 294 per cent between 2030 and 2063, and freight to rise by 49 per cent between 2018 and 2030, and a further 261 per cent increase between 2030 to 2063 (Chapters 1 and 2).

To feed Africans in 2063, ensuring zero hunger will require almost three times more food than is currently consumed, and the generation of municipal solid waste could increase by 275 per cent in 2063 compared to current levels. Demand for energy could increase by 37 per cent between 2018 and 2030, and a further 164 per cent between 2030 and 2063, including a fivefold increase in requirements for electricity (Chapter 2). These changes have the potential to substantially impact the health of Africans through increased exposure to air pollution, while increasing the continent's contribution to GHG emissions, as shown in Chapter 2 that illustrates where Africa could be heading under current policies in the baseline scenario. They could also have negative impacts on other development goals, including access to clean, reliable energy, biodiversity, and other human health risks.

FACTOR 2: GLOBAL ACTION ON CLIMATE CHANGE AFFECTING AFRICA'S CLIMATE

Africa is the continent most at risk from the impacts of climate change (IPCC 2022b). The future development trajectory of the African continent, and the achievement of Agenda 2063, not only depend on decisions and action taken in African countries, but also on the collective willingness/ability of other regions responsible for the majority of GHG emissions to decarbonize and limit global temperature increases to 1.5 °C. The GDP growth figures for African countries do not take account of the impacts of anticipated climate change. This then constitutes a risk for Africa's development, but the climate change in Africa is largely dependent on the action taken by the major emitting countries that lie outside the continent (Section 3.4.1), particularly for temperature and sea-level rise. African countries are playing their part in the global effort to reduce the emissions that lead to climate change with ambitious NDC commitments in many cases, but they also need to do all they can through international negotiations to ensure action from other countries with large emissions.

This Assessment has shown that changes to emissions in Africa have a limited impact in determining global temperature increases. In 2018 Africa contributed 4 per cent of global CO_2 emissions and 13 per cent of global CH_4 emissions (Crippa *et al.* 2021) (Section 3.5.1). The trajectory of global emissions and its effect on Africa's future climate and development show, however, that it will have a considerable impact (IPCC 2022b). In the baseline scenario of this Assessment (Chapter 2) the rest of the world is assumed to follow the high-emissions scenario SSP3_7.0 of IPCC. In the Agenda 2063 scenario of this study (Chapter 3), the trajectory of emissions is similar to that for the low-emission IPCC SSP1_2.6 scenario for Africa. If it is assumed that the rest of the world follows SSP1_2.6, and Africa follows the Agenda 2063 scenario in this Assessment then these results can be compared with those of the modelling that supports the IPCC Sixth Assessment Report. In that, multiple global circulation models (GCMs) were used and they showed that under the assumptions of SSP1_2.6, in comparison to SSP3_7.0, there is a marked difference in the climate projected for 2050, summarized as follows.

Under SSP1_2.6 the temperature on average for Africa is 0.7 °C cooler during the 2050s than under SSP3_7.0, with the largest differences seen in north and south-western Africa. Changing emissions in Africa do little to change that picture as can be seen when comparing the change in temperature between the Agenda 2063 and the baseline scenarios for African emissions alone, which means that changes in global emissions dominate (Section 3.4.1). For precipitation, as is generally concluded when using global modelling, the results are less conclusive, but shows that rainfall patterns change, especially in local summer seasons when projected drying in both Northern and Southern Africa are greatly reduced by the emissions reductions in the Agenda 2063 scenario. When comparing the IPCC multi-model mean SSP1_2.6 with SSP3_7.0 modelling results, there is a large reduction in the drying that is projected for coastal North Africa, westernmost Africa and Southern Africa, as well as a reduced amount of rainfall increases in East Africa. Other than the East African rainfall increases under SSP3_7.0, however, the projected changes are generally model dependent, i.e., not robust across models.

FACTOR 3: ACTION IN AFRICA REDUCING IMPACTS OF CLIMATE CHANGE AND IMPROVING AIR QUALITY

This Assessment considered what might be achieved through action in Africa and found that substantial benefits can be achieved by the implementation of 37 measures that have been identified through the process. The degree of implementation of these measures has been agreed as plausible by the authors of the Assessment (Section 3.2.1).

The Assessment results show that air pollution across Africa is mainly caused by emissions in Africa, which means that solving air-pollution problems is under the control of African countries. For $PM_{2.5}$ concentrations, apart from contributions of pollution imported in North Africa from Europe, all of the sources are in Africa. For ground-level O_3, the sources of NOx, NMVOCs and CO are African, but precursor CH_4 emissions are global. This does mean, however, that the peak O_3 concentrations in Africa can be controlled by addressing precursor emissions in Africa. Chapter 3 shows the potential for significant reductions of CH_4, NMVOCs, NOx and CO under the SLCP and Agenda 2063 scenarios modelled out to 2030 and 2063.

Under this Assessment's baseline scenario, GHG emissions will increase three-fold, increasing Africa's contribution to global climate change. Under the Agenda 2063 scenario, Africa-wide average surface temperatures are still dominated by GHG emissions from the rest of the world – as Africa emits only a small fraction of GHGs. Chapter 3 shows that action taken in Africa under the Agenda 2063 scenario has the potential to reduce the contribution of CO_2 emissions to the atmosphere by 55 per cent in 2063 compared to the baseline, and CH_4 emissions by 74 per cent.

Despite the conclusions from IPCC and the modelling in this report, which suggest that, overall, the climate in Africa will be largely affected by global emissions, this Assessment has shown that policies in Africa can still have a considerable impact on regional temperatures and local precipitation patterns, especially in the Sahel region, East Africa and Southern Africa that will reduce further desertification, improve food security in these regions, reduce heat stress and provide economic benefits. These trends are strongly influenced by changes in the radiative balance caused by alterations in aerosol concentrations, reduced by the implementation of SLCP and air pollution

control measures. Depending on their locations and atmospheric conditions, aerosols exhibit dual features of increasing and decreasing potential precipitation. Fine-mode predominated aerosols, however, more often suppress the formation of rain-bearing clouds (Yakubu and Chetty 2022). The rainfall in the Sahel region has long been known to be sensitive to changes in radiative forcing caused by emissions of aerosols (Dong *et al.* 2014; Undorf *et al*. 2018; Westervelt *et al.* 2018) and so it is not a surprize that the modelling indicates that if these emissions can be reduced in Africa, then the patterns of rainfall will be affected.

The modelling of the baseline scenario suggests that, without further policy intervention, outdoor air pollution will get worse, killing around 930 000 people per year in 2030–2034 and about 1.6 million per year in 2063. It is also important to realize that, of these, the number of premature deaths associated with natural wind-blown dust will be 290 000 in 2030-2034 and 300 000 in 2063. The concentration of wind-blown dust is nearly the same in those years despite a slight change due to climate change, but there are more people exposed in 2063 which explains the larger number of estimated premature deaths.

By implementing the 37 identified mitigation measures, 180 000 outdoor air-pollution related premature deaths per year can be avoided in 2030–2034, including 32 per cent of deaths related to anthropogenic sources of $PM_{2.5}$, and 800 000 in 2063, including 55 per cent of deaths due to anthropogenic $PM_{2.5}$ and 76 per cent of all O_3-related deaths, compared to the baseline.

For household air pollution, in 2030, 20 000 premature deaths could be avoided from implementation of the SLCP mitigation scenario, and 80 000 in 2063, corresponding to a 12 per cent and 53 per cent reduction in disease burden in 2030 and 2063, respectively. The relatively low number of avoided deaths reflects the assumptions in the baseline about the opportunities to change cooking choices by 2030 and the assumed changes to clean cooking in the baseline, reflecting the fact that shifting to clean cooking is already a major health and development priority for Africa. This means that Africa can develop and avoid a large proportion of air-pollution related health impacts from outdoor and household exposure, which will help Africa achieve the goals of Agenda 2063.

Crop-yield changes have been calculated to account for the impact of alterations in ground-level O_3 and CO_2 concentrations, temperature and precipitation. The modelling has found that O_3 and temperature have the biggest influence on yields. At the continental level, the implementation of the identified measures in the Agenda 2063 scenario shows yield gains for maize, rice, and soy of around 4, 1 and 6 per cent respectively relative to the baseline, but no clear gain for wheat (Section 3.4.4). The results vary by region and East Africa is the only region to show yield gains for all four crops, ranging from about 6 per cent for rice to 10–12 per cent for maize and soy, and 11 per cent for wheat relative to the baseline (Section 4.5.4).

Overall, the results of this Assessment show that Africa's development can be substantially enhanced through decisions and action taken by the African countries that contribute to reductions in SLCPs, GHGs and air pollutants. The measures modelled in the Assessment have been linked to the priorities of Agenda 2063 (Section 3.2 and Table 5.1) that outlines a development trajectory for Africa that can improve the livelihoods of people and, at the same time, avoid negative consequences that often accompany development. Implementing the 37 measures of the Agenda 2063 scenario can both contribute to a large reduction in the number of premature deaths due to outdoor and household air pollution, and reduce the impacts of climate change in Africa and impacts on crop yields (Section 3.4). The emissions reductions of GHGs associated with the 37 measures can help countries achieve their international obligations under the Paris Agreement (Section 3.5.1), and also help to achieve the targets set for various SDGs (Section 3.5.2). Furthermore, the Agenda 2063 scenario developed in this Assessment allows for Africa's expected socioeconomic development for Africa to be achieved while reducing the climate and air pollutant impacts on GDP growth.

The following sections outline the potential for widespread implementation of the 37 measures in Africa that could achieve key aspects of Agenda 2063, while securing health benefits, and promoting clean development, increased prosperity and wellbeing across Africa. Section 5.2 considers the timing of implementation and mitigation potential of the 37 mitigation measures. Section 5.3 then explores the path to climate and clean air benefits under Agenda 2063 and gives examples of existing action in Africa and internationally that shows the potential for implementation. Finally, Section 5.4 outlines recommendations to increase implementation of the measures across Africa.

5.2. THE 37 MEASURES – TIMING OF IMPLEMENTATION AND MITIGATION POTENTIAL

MAIN MESSAGES

- Africa is rapidly developing and many of the 24 energy-sector and 13 non-energy-sector measures outlined in this Assessment are already being implemented in African countries at different scales.
- The 37 measures will contribute to achieving Agenda 2063 and target emission reductions in five main sectoral areas related to transport, residential energy use, energy generation and industry, agriculture and food systems, and waste management.
- By 2030, the modeling shows considerable potential to reduce SLCP emissions related to clean cooking, implement advanced emission controls for road vehicles, reduce burning of wastes, improve crop and livestock management in agriculture, and improve solid and liquid waste disposal.
- Short-lived climate pollutant measures do not affect carbon dioxide emissions as much, but progress can be made by 2030 with more development focused measures related to energy efficiency and shifting to renewable energy. The largest GHG emissions reduction potentials in the Assessment are associated with CH_4 reductions in Africa by 2030.
- Implementation of measures in the agricultural sector can potentially achieve large decreases in CH_4, N_2O and NH_3 emissions by 2030.
- By 2063, the Assessment shows greater compliance with the AU Agenda 2063 as more development focused measures are implemented, especially those related to energy generation and use, and agricultural and waste management practices.
- Progress will depend on factors such as the availability of technology, finance, uptake of renewable energy options, penetration rates, and political will.

5.2.1 THE 37 MEASURES

It is important to realize that Africa is rapidly developing and many of the 24 energy-sector and 13 non-energy-sector measures outlined in this Assessment are already being implemented in African countries. A great deal is happening already, as shown in Section 5.3 that presents some of the existing efforts to implement such measures. This section explains the assumptions in the Assessment regarding timing of implementation and the potential of the measures to mitigate air pollution and climate change individually and in combination. The 37 measures will contribute to achieving Agenda 2063 (Table 5.1) and target emission reductions in the following key source sectors – transport; households; commercial enterprises; energy transformation (electricity and charcoal production); industry; agriculture; and waste management.

Table 5.1 The 37 measures associated with priority action in the different sectors that were modelled in the Assessment

MEASURE	DESCRIPTION	SCENARIO	RELEVANT AGENDA 2063 PRIORITY AREAS
TRANSPORT MEASURES			
T1. PASSENGER ELECTRIC VEHICLES	Key to reducing road transport GHG and SLCP emissions.	SLCP	Modern and liveable habitats and basic quality services
T2. ADVANCED EMISSIONS CONTROLS FOR ROAD VEHICLES	Advanced emissions controls (which also require low sulphur fuels) can help reduce tailpipe emissions from remaining internal combustion engine (ICE) vehicles in medium term (as electric vehicles (EVs) introduced).	SLCP	Modern and liveable habitats and basic quality services
T3. HYBRID VEHICLES	Hybrid vehicles are the main measure for improving vehicle efficiency other than full electrification.	SLCP	Modern and liveable habitats and basic quality services
T4. PUBLIC TRANSPORT	Higher occupancy public transport is cleaner and more energy efficient than private cars.	Agenda 2063	Modern and liveable habitats and basic quality services
T5. NON-MOTORIZED TRANSPORT	Cycling and walking promote health and reduce energy and emissions from transport.	Agenda 2063	Health and nutrition
T6. SWITCH FREIGHT FROM ROAD TO RAIL	Rail transport is more energy efficient and easier to electrify than road freight.	Agenda 2063	Communications and infrastructure connectivity
T.7. RAIL ELECTRIFICATION	Moving from diesel to electric to reduce emissions	Agenda 2063	Communications and infrastructure connectivity
T.8. ROAD FREIGHT ELECTRIFICATION	Zero carbon freight at point of end use	Agenda 2063	Communications and infrastructure connectivity

MEASURE	DESCRIPTION	SCENARIO	RELEVANT AGENDA 2063 PRIORITY(S) AREAS
RESIDENTIAL MEASURES			
H1. CLEAN LIGHTING	Electric lighting provides better lighting conditions, avoids harmful pollutants and saves energy.	SLCP	1. Modern and liveable habitats and basic quality services 2. Health and nutrition
H2. CLEAN COOKING	Cooking is a key source of harmful indoor air pollution and traditional biomass cookstoves are placing an increasing burden on the wood resources.	SLCP	1. Modern and liveable habitats and basic quality services 2. Health and nutrition
H3. EFFICIENT AIR CONDITIONING	Although small now, as incomes grow air conditioners (ACs) will become an important contributor to overall and peak energy use. Efficient ACs can help reduce growth in demand and avoid use of dirtiest peak-load power plants.	Agenda 2063	Sustainable consumption and production patterns
H4. EFFICIENT REFRIGERATION	As with ACs, refrigerator use will grow considerably to 2063. Efficient fridges help save energy and emissions.	Agenda 2063	Sustainable consumption and production patterns
H5. OTHER HOUSEHOLD ENERGY EFFICIENCY	Efficient appliances help reduce energy demands (vital for keeping electricity demand growth manageable).	Agenda 2063	Sustainable consumption and production patterns
OTHER ENERGY SECTOR MEASURES			
E1. EFFICIENT CHARCOAL MAKING	Helps to conserve wood fuel supplies by making charcoal as efficiently as possible. Charcoal making is also a significant source of short-lived climate pollutants (SLCPs).	SLCP	Sustainable consumption and production patterns
E2. POST-COMBUSTION EMISSION CONTROLS IN INDUSTRY	Reduces non-CO_2 emissions from industry.	SLCP	1. Sustainable consumption and production 2. Health and nutrition
E3. COAL METHANE CAPTURE	Reduces methane emissions from coal mining. (Note: have not modelled the potential co-benefit of electric generation from this methane).	SLCP	Sustainable consumption and production patterns
E4. OIL AND GAS METHANE EMISSIONS	Reduces methane emissions from oil and gas operations. (Note: have not modelled the potential co-benefit of electric generation from this methane).	SLCP	Sustainable consumption and production patterns
P1. INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)	Implement Kigali Amendment to phase down hydrofluorocarbons (HFCs).	SLCP	Sustainable consumption and production patterns
E5. TRANSMISSION AND DISTRIBUTION LOSS REDUCTION	Transmission and distribtuion loss reduction helps reduce growth in demand for electricity.	Agenda 2063	Sustainable consumption and production patterns
E6. INDUSTRIAL ENERGY EFFICIENCY	Helps to reduce energy demands and emissions.	Agenda 2063	Sustainable consumption and production patterns
E7. SERVICE SECTOR ENERGY EFFICIENCY	Helps to reduce energy demands and emissions.	Agenda 2063	Sustainable consumption and production patterns
E8. REDUCE DEMAND FOR CEMENT	Cement production is highly energy and carbon-intensive. Use substitutes to partially replace cement clinker.	Agenda 2063	Sustainable consumption and production patterns
E9. CCS IN CARBON INTENSIVE INDUSTRIES AND ELECTRIC GENERATION	In some highly carbon- and energy-intensive industries (cement, iron and steel, coal-fired electric generation), carbon capture and storage (CCS) may be practical for avoiding CO_2 emissions. But still far from being commercialised.	Agenda 2063	Sustainable consumption and production patterns
E10. RENEWABLE ELECTRIC GENERATION: SOLAR, WIND, GEOTHERMAL AND HYDROPOWER	Need to pair strategies for electrifying energy demand with strong measures to decarbonize electric generation and promoting renewable energy and phasing down coal and other carbon-intensive fuels.	Agenda 2063	Renewable energy
AGRICULTURE			
A1. LIVESTOCK - REDUCE ENTERIC FERMENTATION BY INCREASING PRODUCTIVITY	Increase productivity of livestock herd to reduce emission intensity of meat and dairy.	SLCP	1. Agriculture productivity and production
A2. LIVESTOCK - REDUCE ENTERIC FERMENTATION VIA DIGESTIBILITY OF FEED	Increase digestibility of feed to reduce methane emissions from enteric fermentation.	SLCP	1. Agriculture productivity and production
A3. LIVESTOCK - MANURE MANAGEMENT	Switch to manure management systems with lower methane and nitrogen emissions.	SLCP	1. Agriculture productivity and production 2. Climate resilience
A4. CROPS - RICE	Implementation of alternate wetting and drying for flooded rice.	SLCP	Agriculture productivity and production
A5. BIOMASS BURNING	Eliminate open burning of agricultural residues.	SLCP	1. Sustainable consumption and production 2. Health and nutrition
A6. FOOD WASTE	Reduce food waste at point of consumption.	Agenda 2063	1. Poverty, inequality and hunger 2. Sustainable consumption and production patterns
A7. DIET - PROTEIN SOURCE	Shift in diets to reduce red meat consumption and increase plant-based protein sources.	Agenda 2063	Health and nutrition

MEASURE	DESCRIPTION	SCENARIO	RELEVANT AGENDA 2063 PRIORITY AREAS
WASTE			
W1. SOLID WASTE DISPOSAL - BEST PRACTISE LANDFILL MANAGEMENT TO REDUCE OPEN BURNING OF WASTE, AND METHANE CAPTURE AT LANDFILLS	Implementation of best practise landfill management to reduce open burning of waste, and methane capture at landfills.	SLCP	1. Modern and liveable habitats and basic quality services 2. Health and nutrition
W2. LIQUID WASTE - METHANE CAPTURE AT WASTEWATER TREATMENT PLANTS	Methane capture at wastewater treatment plants.	SLCP	Sustainable consumption and production patterns
W3. SOLID WASTE DISPOSAL - IMPLEMENT WASTE COLLECTION AND DEVELOPMENT OF FORMAL LANDFILL SITES	Implement waste collection and development of formal landfill sites.	Agenda 2063	1. Modern and liveable habitats and basic quality services 2. Health and nutrition
W4. SOLID WASTE DISPOSAL - DIVERSION OF ORGANIC WASTE TO COMPOSTING OR BIOGAS	Diversion of organic waste to composting or biogas.	Agenda 2063	Renewable energy
W5. SOLID WASTE DISPOSAL - REDUCE ORGANIC WASTE GENERATION	Reduce organic waste generation.	Agenda 2063	Sustainable consumption and production patterns
W6. UNIVERSAL ACCESS TO IMPROVED WATER AND SANITATION SERVICES	Universal access to improved water and sanitation services.	Agenda 2063	1. Modern and liveable habitats and basic quality services 2. Health and nutrition

It is clear that, beyond achieving air-quality and climate goals, implementing the measures also has the potential to affect the achievement of other sustainable development goals, as has been outlined in Section 3.5.2 (Haines *et al.* 2017). The full list of the 37 measures associated with priority action in the different sectors is shown in Table 5.1. These measures have different effects on emissions of the different pollutants, SLCPs and GHGs, and therefore their influence on realizing the benefits will also be different.

5.2.2 MITIGATION POTENTIAL OF MEASURES IMPLEMENTED BY 2030

Figure 5.1's heat-map shows the 37 measures and the percentage emission reductions when comparing the implementation of each measure alone against the total pollutant emissions in the baseline. Clearly, the measures to transition away from the use of traditional to clean fuels for cooking in the residential and commercial sectors – households, schools and other institutions – will provide the greatest contribution to reducing the health impacts of household exposure to $PM_{2.5}$. For outdoor air pollution, the impact of the measures on the emissions of different pollutants has been outlined in Chapter 3 and is shown in Figure 5.1 for the years 2030 and 2063. It can be seen that, whilst some measures, such as the introduction of clean cookstoves can be relatively rapidly implemented, others, for instance, the switch to electric vehicles, only really take effect later, reducing emissions after 2030–2040.

From Figure 5.1 it can be seen that in 2030, significant progress is assumed in some key sectors including a reduction of emissions from transport and residential sources. In the residential sector, clean lighting would have an impact on BC emissions, but the largest benefit would come from the assumed shift to clean cooking, which would lead to a significant reduction in the emission of primary particles – a more than 20 per cent reduction in $PM_{2.5}$, PM_{10}, BC and OC emissions – as well as a greater than 20 per cent reduction in the O_3 precursor emissions, CO and NMVOCs, and a 5 per cent reduction in NOx emissions from clean cooking compared to the baseline scenario, in which it is assumed that a lot of traditional cooking using biomass remains. Considerable progress can be made in the introduction of cleaner vehicles – mainly EURO 6 standard compliant[2] but also some hybrid and electric vehicles – which has an effect on NOx, BC, CO and NMVOC emissions.

Assumed implementation of measures in the agricultural sector also stands out with a large decrease in CH_4, N_2O and NH_3 emissions in 2030. Waste measures also reduce emissions of CH_4 from that sector by more than 5 per cent relative to the baseline scenario, and by about 8 per cent from the oil and gas sector by implementing the measures by 2030. The largest GHG emissions reduction potentials are associated with CH_4 reductions in Africa by 2030. The impact of the measures on CO_2 is not projected to be very large by then. The most significant CO_2 emissions reduction is projected from industry due to efficiency improvements, reducing the sector's emissions by about 2 per cent by 2030, relative to the baseline.

2. Euro vehicle standards https://en.wikipedia.org/wiki/European_emission_standards (accessed 17 October 2022)

5.2.3 MITIGATION POTENTIAL OF MEASURES IMPLEMENTED BY 2063

With a greater amount of time to make progress, the emissions reductions by 2063 relative to the baseline are much greater. Similar sectors and mitigation measures are highlighted, but the emissions reduction is greater, and is higher for a greater number of pollutants. Cleaner vehicle measures remain a focus, but the relative impact of measures have changed as the process of electrification proceeds.

It is important to note that the potential impact of each measure is estimated independently in Table 5.1, but the SLCP and Agenda 2063 scenarios have the integrated mixture of measures that will achieve synergies and avoid trade-offs. Clean cooking has a similar potential to reduce emissions in 2063 as in 2030 but efficient charcoal production becomes more important. Energy efficiency becomes more significant in 2063 in industry and services. The production of renewable electricity becomes much more significant in 2063. This will also interact with emissions related to the electrification of transport – leading to a larger emissions reduction overall. The potential for emissions reductions increases in the agricultural sector and the improved management of waste also leads to significant reductions, not only of CH_4 emissions but in the reduction of primary particulate emissions, as well by avoiding the open burning of waste.

It is clear from Figure 5.1 that some of the measures lead to an overall increase in some of the emissions. In 2030, these increases are all less than 1 per cent, and in 2063, the only increases greater than 2 per cent are for BC from an increase in public transport, a 3.8 per cent increase, and a 3.1 per cent increase in SO_2 due to fuel used for increasing efficiency in services (see next paragraph). The increase in BC from a shift to public transport is due to the assumption that people shift from existing petrol driven cars with low BC emissions to diesel buses that have much higher ones.

There is a slight increase in CO_2 emissions related to increasing efficiency in the service sector related to the fact that, even though the scenario assumes substantial energy efficiency, it leads to switching to electricity and away from biomass. There is also the increase in S emissions related to the fuel used for electricity generation efficiency in the service sector but the increase is small at 3.1 per cent. These increases come about because when the measures are assessed individually, they assume the electricity generation from the baseline where, for example, the CO_2 intensity of electricity is quite high and replaces biomass that has zero CO_2 intensity – accounted for under land use, land-use change and forestry (LULUCF) – and emissions go up. This situation is remedied by implementing electricity generation with renewables under the Agenda 2063 scenario (Section 2.5.3) and shows that to understand the overall effect of emissions changes related to the implementation of individual measures requires an integrated perspective as changes in a sector means switching from one situation to another, with knock-on effects on overall emissions. The measures are not, however, implemented individually in the two mitigation scenarios considered in this Assessment – the SLCP and Agenda 2063 scenarios, which consider many different measures implemented at the same time in different sectors. The effect of these on emissions is examined in the next section.

EMISSIONS REDUCTION/INCREASE IN 2030 (%)													
MEASURES	GHG	CO_2	CH_4	N_2O	BC	OC	$PM_{2.5}$	PM_{10}	NO_x	SO_2	NH_3	CO	NMVOC
Passenger Electric Vehicles - T1	0,3	0,6	0,0	0,1	0,5	0,1	0,1	0,1	2,3	0,1	0,0	0,9	0,5
High Occupancy Public Transport - T4		0,5	0,0	0,2	-0,7	-0,1	-0,2	-0,1	0,0	-0,5	0,1	1,9	0,6
Non-motorised Transport (walking and cycling) - T5	0,2	0,4	0,0	0,1	0,0	0,0	0,0	0,0	0,6	0,0	0,0	0,5	0,2
Freight Road to Rail - T6	0,1	0,2	0,0	-0,1	0,0	0,0	0,0	0,0	0,4	0,0	0,0	0,2	0,1
Advanced Emission controls for Road Vehicles (Euro VI) - T2	0,0	0,0	0,0	0,4	2,3	0,5	0,7	0,5	12,0	0,0	0,1	3,5	2,1
Passenger Hybrid Vehicles - T3	0,3	0,4	0,0	0,2	0,0	0,0	0,0	0,0	2,1	0,0	0,1	1,6	0,7
Rail Electrification - T7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Road Freight Electrification - T8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Efficient Air Conditioning - H3	0,1	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,5	0,0	0,0	0,0
Clean Lighting - H1	0,1	0,3	0,0	0,0	1,3	0,0	0,2	0,1	0,1	0,4	0,0	0,0	0,0
Efficient Refrigeration - H4	0,1	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,2	0,0	0,0	0,0
Clean Cookstoves - H2	1,8	0,4	4,2	1,7	20,0	25,4	27,3	23,5	5,7	2,3	3,4	21,6	25,4
Household Energy Efficiency - H5	0,1	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,6	0,0	0,0	0,0
Transmission & Distribution Loss Reduction - E5	0,7	1,3	0,0	0,0	0,1	0,0	0,0	0,0	0,4	2,5	0,0	0,0	0,0
Efficient Charcoal Making - E1	0,5	0,0	1,4	0,0	1,0	2,1	1,9	1,3	0,1	0,0	0,2	4,0	4,2
Industry Energy Efficiency - E6	1,0	1,8	0,1	0,1	0,6	0,6	0,6	0,6	1,0	4,5	0,1	0,4	0,4
Services Energy Efficiency - E7	0,0	-0,2	0,3	0,1	1,0	1,1	1,2	1,0	0,3	-0,5	0,1	1,4	1,3
Industry Post-Combustion Controls - E2	0,0	0,0	0,1	0,1	0,7	0,6	0,7	0,6	0,8	2,2	0,1	0,5	0,5
Coal Methane Capture - E3	0,5	0,0	1,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Oil and Gas Fugitive Emission Reductions - E4	2,7	0,0	7,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Reduce Demand for Cement Clinker - E8	0,1	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,7	0,0	0,0	0,0
Industry Carbon Capture and Storage - E9	0,6	1,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Renewable Electricity - E10	0,9	1,6	0,0	0,1	0,0	0,0	0,0	0,0	0,6	6,4	0,0	0,0	0,0
Agriculture Mitigation Measures - A1 to A7	11,9	0,0	28,1	26,0	1,8	3,4	2,5	1,8	5,3	0,2	36,7	1,5	0,2
Waste Mitigation Measures - W1 to W6	2,2	0,2	5,8	0,5	1,5	4,0	3,2	2,7	1,0	0,2	0,3	0,7	1,3

EMISSIONS REDUCTION/INCREASE IN 2063 (%)													
MEASURES	GHG	CO_2	CH_4	N_2O	BC	OC	$PM_{2.5}$	PM_{10}	NO_x	SO_2	NH_3	CO	NMVOC
Passenger Electric Vehicles - T1	4,3	8,8	0,1	1,1	8,6	2,1	2,7	2,1	24,4	1,4	0,4	13,4	9,1
High Occupancy Public Transport - T4		1,1	0,1	0,4	-3,8	-0,7	-1,1	-0,9	-1,8	-1,9	0,3	6,5	2,6
Non-motorised Transport (walking and cycling) - T5	0,9	1,9	0,0	0,2	0,0	0,0	0,0	0,0	2,1	0,2	0,1	2,6	1,1
Freight Road to Rail - T6	0,6	1,3	0,0	-0,6	-0,5	0,1	-0,1	-0,1	1,7	0,1	0,0	1,3	0,6
Advanced Emission controls for Road Vehicles (Euro VI) - T2	0,1	0,0	0,0	1,3	16,8	3,8	5,3	4,1	51,3	0,0	0,5	21,9	14,2
Passenger Hybrid Vehicles - T3	0,1	0,3	0,0	0,1	0,0	0,0	0,0	0,0	1,1	0,0	0,0	1,2	0,6
Rail Electrification - T7	0,0	0,0	0,0	0,0	0,1	0,0	0,0	0,0	0,1	0,0	0,0	0,0	0,0
Road Freight Electrification - T8	0,9	1,9	0,0	0,2	1,9	0,3	0,5	0,4	6,7	0,0	0,0	1,9	1,0
Efficient Air Conditioning - H3	0,9	2,0	0,0	0,0	0,2	0,1	0,1	0,1	0,4	2,7	0,0	0,0	0,0
Clean Lighting - H1	0,2	0,5	0,0	0,0	3,0	0,0	0,5	0,4	0,1	0,5	0,0	0,0	0,0
Efficient Refrigeration - H4	0,3	0,7	0,0	0,0	0,1	0,0	0,0	0,0	0,2	0,9	0,0	0,0	0,0
Clean Cookstoves - H2	1,0	-1,6	4,1	0,9	22,7	28,1	28,0	26,0	2,6	-1,9	1,6	25,2	27,2
Household Energy Efficiency - H5	0,5	1,0	0,0	0,0	0,1	0,0	0,1	0,0	0,2	1,4	0,0	0,0	0,0
Transmission & Distribution Loss Reduction - E5	1,6	3,3	0,0	0,0	0,3	0,2	0,2	0,2	0,7	4,0	0,0	0,1	0,1
Efficient Charcoal Making - E1	1,3	0,0	3,2	0,0	3,4	7,8	6,9	5,4	0,2	0,0	0,4	12,6	14,5
Industry Energy Efficiency - E6	5,3	10,8	0,4	0,3	6,1	5,8	6,6	6,2	4,2	17,4	0,3	4,0	4,1
Services Energy Efficiency - E7	0,1	-1,8	2,2	0,3	8,6	11,1	11,3	10,2	1,0	-3,1	0,6	12,5	12,5
Industry Post-Combustion Controls - E2	0,3	0,0	0,6	0,4	8,7	8,7	9,7	9,3	4,3	12,2	0,4	5,8	5,9
Coal Methane Capture - E3	0,6	0,0	1,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Oil and Gas Fugitive Emission Reductions - E4	1,9	0,0	4,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Reduce Demand for Cement Clinker - E8	0,3	0,6	0,0	0,0	0,1	0,0	0,2	0,1	0,2	1,6	0,0	0,1	0,0
Industry Carbon Capture and Storage - E9	2,7	5,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Renewable Electricity - E10	12,6	26,5	0,0	0,3	1,3	0,7	0,9	0,9	5,5	40,7	0,1	0,3	0,2
Agriculture Mitigation Measures - A1 to A7	25,4	0,0	52,7	36,0	1,9	3,5	2,6	2,1	9,1	0,2	62,7	1,3	0,2
Waste Mitigation Measures - W1 to W6	3,0	0,6	6,6	1,7	4,9	13,4	10,9	10,3	2,0	0,5	0,5	2,1	4,2

% DECREASE	COLOUR
<0.1	
0.1-1.0	
1-5	
5-10	
10-20	
20-25	
25-50	
50-75%	
increase	

Figure 5.1 The heat map of measures and percentage emissions reductions when comparing the implementation of each measure alone against the total pollutant emissions in the baseline, percentage reduction, negative values mean increased emissions. See Table 5.1 and Chapter 3 for descriptions of each measure.

Note: HFCs are not included, as there is only one measure which is to replace HFCs as coolants in refrigeration and air conditioning.

5.2.4 MITIGATION POTENTIALOF MEASURES IN EACH SECTOR IN 2030 AND 2063

The results shown in Figure 5.1 demonstrate the impact of applying each measure separately, quantifying emissions relative to the baseline scenario. Another way to look at the results is to consider emissions reduction by sector which shows the reductions resulting from an integration of the impact of all measures in a sector (Figure 5.2).

Using the transport sector as an example, Figure 5.2 shows the effects of implementing electrification, technology standards, public transport and non-motorized transport measures to different extents in the two scenarios in 2063. Even though the impact of a shift to electric vehicles on emissions from transport is shown, any emissions related to electricity generation required to power those vehicles is reflected in the emissions in the electricity-generation sector. It can be seen that the transport measures lead to reductions in emissions from vehicles of NOx, BC, CO and NMVOCs and also CO_2. There is, however, a difference between emissions in the electricity generation in the SLCP scenario compared to the Agenda 2063 scenario. In the former, the roll-out of renewable energy is not included as a measure, although there is extensive electrification of transport and other parts of African society. This is reflected in the increased CO_2 emission from electricity generation, but this is then turned into a net reduction in CO_2 emissions in the Agenda 2063 scenario in which renewable energy is included as a major measure.

The same logic explains why there is an increase in N_2O emission under the SLCP scenario, whereas there is a large reduction in the Agenda 2063 scenario as the latter assumes more fundamental changes in the agricultural sector.

These examples promote the importance of taking an integrated view of mitigation under the scenarios and in the development of policy generally. It is important not to view a list of measures and cherry pick favourites because there is an interaction between measures and sectors. To solve the problems associated with air pollution and climate change, and also to contribute to achieving other sustainable development goals, there is a need to address all sectors and measures in an integrated and comprehensive fashion.

SLCP MEASURES												
MEASURES IMPLEMENTED BY SECTOR IN 2063	CO_2	CH_4	N_2O	BC	OC	$PM_{2.5}$	PM_{10}	NOx	SO_2	NH_3	CO	NMVOC
Transport measures (1A3)	12,6	0,1	1,7	17,0	3,9	5,4	4,2	52,7	5,4	0,5	22,8	14,8
Residential measures (1A4a)	0,8	1,6	0,9	23,1	21,9	23,0	22,2	2,9	0,4	1,3	15,1	15,6
Commercial measures (1A4b)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Industry-related measures (1A2; 2)	0,0	0,6	0,4	8,7	8,7	9,7	9,3	4,3	11,9	0,4	5,8	21,5
Other Energy demand (1A5)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	5,9
Electricity generation, charcoal production and fossil fuel extraction (1A1; 1B)	-8,4	10,7	-0,1	4,5	11,3	9,9	7,6	-1,4	-8,4	0,5	18,7	0,0
Agriculture measures (1A4c; 3A; 3B; 3C; 3D)	0,0	23,7	-21,8	1,6	2,9	2,2	1,8	5,3	0,1	37,2	1,0	0,0
Waste measures (4A; 4C; 4D)	0,2	4,1	0,0	1,6	4,4	3,6	3,4	0,6	0,2	0,2	0,7	1,4
AGENDA 2063												
MEASURES IMPLEMENTED BY SECTOR IN 2063	CO_2	CH_4	N_2O	BC	OC	$PM_{2.5}$	PM_{10}	NOx	SO_2	NH_3	CO	NMVOC
Transport measures (1A3)	19,1	0,2	1,7	16,7	3,9	5,3	4,1	52,5	8,7	0,6	23,1	14,8
Residential measures (1A4a)	0,8	1,6	0,9	23,1	21,9	23,0	22,2	2,9	0,4	1,3	15,1	15,6
Commercial measures (1A4b)	1,5	0,6	0,4	8,7	8,2	8,7	8,3	1,6	3,8	0,5	6,2	5,5
Industry-related measures (1A2; 2)	7,6	0,7	0,5	11,1	11,1	12,6	12,0	5,7	16,5	0,6	7,5	7,6
Other Energy demand (1A5)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Electricity generation, charcoal production and fossil fuel extraction (1A1; 1B)	25,8	11,7	0,3	6,4	14,1	12,6	10,1	5,6	38,1	0,8	22,6	25,8
Agriculture measures (1A4c; 3A; 3B; 3C; 3D)	0,0	52,7	36,4	1,9	3,5	2,6	2,1	9,1	0,1	62,7	1,3	0,0
Waste measures (4A; 4C; 4D)	0,6	6,6	0,0	4,9	13,4	10,9	10,3	2,0	0,5	0,5	2,1	4,2

% DECREASE	COLOUR
<0.1	
0.1-1.0	
1-5	
5-10	
10-20	
20-25	
25-50	
50-75%	
increase	

Figure 5.2 The heat map of measures and percentage emission reductions when comparing the implementation of all measures in each sector against the total pollutant emissions in the baseline, percentage reduction, negative values mean increased emissions.

Note: that sector ID (in brackets) conforms to IPCC nomenclature.

As well as understanding the links between measures, scenarios and emissions, there is a need to understand how changes in emissions from implementing them leads to health, climate and other benefits.

Human Health

It is important to understand which emissions are mostly responsible for the $PM_{2.5}$ that most people are exposed to, as exposure to $PM_{2.5}$ from outdoor and household concentrations is the largest environmental cause of ill health in Africa. Part of the exposure of people is due to cooking and heating indoors, which is clearly linked to measures in the residential sector which can substantially reduce or eliminate these. But emissions from cooking with biomass also affect outdoor $PM_{2.5}$ concentrations to a major extent. The results of the GISS model can show the relationship between the different emissions from all sectors and outdoor $PM_{2.5}$ levels. The modelling shows that the anthropogenic emissions of OC and BC dominate the formation of $PM_{2.5}$ across Africa (Figure 5.3). These emissions are mainly associated with incomplete combustion from burning solid fuels, especially biomass in residential dwellings, as well as from commercial and industrial sector activities, waste disposal, agriculture and vehicles. Clean cooking measures to reduce the use of biomass dominates the potential reduction in BC and OC emissions in Africa (Figures 5.1 and 5.2).

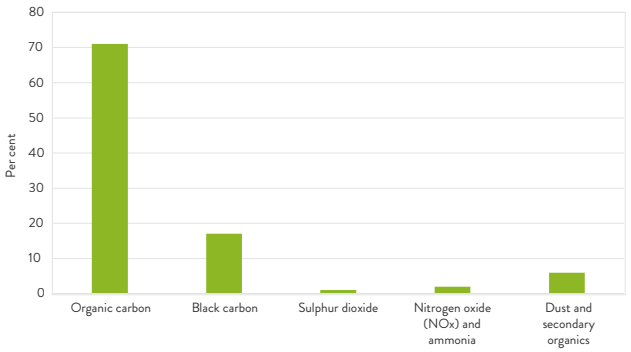

Figure 5.3 Africa, the contribution of different anthropogenic pollutant emissions to population-weighted fine particulate matter from the GISS model, 2030, per cent

From Figures 5.1, 5.2 and 5.3 it can be inferred which measures are likely to provide the largest reductions in health impacts across Africa. The impacts of $PM_{2.5}$ from household exposure is reduced by changes to the sources of the pollution, mainly by changes to clean cooking solutions in African households, schools, hospitals, etc. The results show that the shift to clean cooking also has a major impact on outdoor BC and OC emissions, and this shift is clearly a major development priority for Africa. Making a large reduction in health impacts related to exposure to outdoor air pollution, however, can only be achieved by implementing measures in all of the major sources of primary PM pollution – in the transport, residential, commercial, industrial and agricultural sectors, in electricity generation and charcoal production, and by preventing the burning of waste. There is no one silver bullet that can reduce health impacts from $PM_{2.5}$; action is required in all major polluting sectors.

Although O_3 does not have as large impacts on human health as $PM_{2.5}$, it is still an important pollutant affecting the number of premature deaths, asthma attacks and other respiratory diseases (Nuvolone *et al*. 2018) (Section 1.2.1). It is also the main pollutant affecting crop yields in Africa (Sharps *et al.* 2021a and b) (Section 1.3.2). Its formation will be affected by global CH_4 and regional CO concentrations and local peaks will be more related to the emissions of NOx and NMVOCs. From Figure 5.2 it can be seen that the measures in the transport, residential and commercial, industrial, electricity generation and charcoal production, agricultural and waste sectors will all need to be addressed to reduce these impacts. Good progress can be made by implementing the SLCP measures but the emissions reduction is greater in more sectors in the Agenda 2063 scenario. Nitrogen dioxide, which is part of NOx emissions, is particularly reduced by the transport sector measures and so will lead to health benefits, especially in areas with higher traffic volumes. The mitigation of $PM_{2.5}$ and NOx concentrations, which can be affected by vegetation fires that are decreasing in frequency in some parts of Africa (Hickman *et al.* 2021), has not been modelled in this Assessment.

The overall benefit from the measures relates to the assumptions over timing of iimplementation in this Assessment. Some of the measures are already being applied in parts of Africa and the rate of their introduction could occur more rapidly. Others have not really taken off and might require considerable infrastructure development and therefore will take a longer time to implement, and so their benefits will be likely to be felt later. To further explain this and show how the main measures have already been implemented in parts of Africa, as well as looking at progress internationally, it is possible to illustrate the potential for this change through case studies, which are included in the next section that considers implementation of the measures in different sectors.

Climate

The climate benefits described in this Assessment (Section 3.4.1) are mainly associated with CO_2 mitigation achieved by measures implemented in the transport, industrial and electricity generation sectors, in the main by using solar, wind, hydro and geothermal renewable sources, by 2063 under the Agenda 2063 Scenario. There are also considerable CH_4 emission reductions in the agricultural, oil and gas, and waste management sectors and N_2O reductions in the agricultural sector (Figure 5.1).

Achieving the climate and health benefits of Agenda 2063 is possible. The measures modelled in this Assessment show that the benefits that will accrue from implementing them at scale across the African continent will help achieve many of the key priorities of Agenda 2063 including modern and liveable habitats and basic quality services; health and nutrition; communications and infrastructure connectivity; sustainable consumption and production patterns; renewable energy; agriculture productivity and production; climate resilience; poverty, inequality and hunger (Table 5.1).

Achieving these benefits in reality will only occur, however, if there is a realistic chance that the level of implementation required will be realised. One thing in favour of achieving this is that all the measures considered have already been implemented in different parts of Africa. Therefore, in the next section examples of the implementation of the mitigation measures are described, and in the subsequent section recommendations for decision makers are provided, centred around how to promote and fast track measures related to SLCP mitigation and Agenda 2063 development priorities.

5.3 THE PATH TO CLIMATE AND CLEAN AIR BENEFITS UNDER AGENDA 2063

MAIN MESSAGES

- There are many examples of how the measures in this Assessment are being implemented via ongoing air quality agreements, initiatives, strategies, and projects across Africa:
  - **Transport:** African countries are working to decrease emissions from public transport and regional implementation of action in the transport sector is advancing. Safe, non-motorised modes of transport are becoming more central to transport policies in Africa, especially in cities that are now recognizing the integral role of walking and cycling as part of their sustainable transport system.
  - **Residential Energy:** Adoption of clean cooking options is increasing across Africa and 40 per cent of African countries have now adopted mandatory minimum energy performance standards (MEPS) for air conditioning.
  - **Energy generation and industry:** Policies recognize Africa's huge solar energy potential for energy production. In industry several African countries have pledged to significantly reduce methane emissions in the oil and gas sector by 2030 and the Kigali Agreement (to the Montreal Protocol) has seen hydrofluorocarbons (HFCs) gaining attention in African countries since 2016.
  - **Agriculture:** Measures to cut SLCPs are being implemented, such as alternate wet and drying in rice production, reduced open burning of agricultural crop residues and improved livestock nutrition management practices.
  - **Waste Management:** Innovative public-private partnerships are growing in the waste management sector in Africa.

5.3.1 MITIGATION MEASURES IN THE TRANSPORT SECTOR: CLEANER VEHICLES, PUBLIC AND NON-MOTORIZED TRANSPORT

Continental and regional transport policies in Africa

In this Assessment, multiple mitigation measures, which could enable the development of African transport systems without increasing emissions, have been modelled. Measures include the introduction of emission controls, increased electrification of vehicles, switching road freight to rail and the promotion of public and non-motorized transport. These mitigation measures are in line with key priorities of Agenda 2063, specifically the areas of communications and infrastructure connectivity, and the implementation of the Programme for Infrastructure Development in Africa (PIDA); modern and liveable habitats and basic quality services; and health and nutrition. At present, the transport sector in Africa is characterized by poor infrastructure populated with aging motor vehicles and a lack of non-motorized transport. This sector, however, provides a significant opportunity to both aid development and reduce emissions at regional and national scales.

The African Continental Free Trade Area (AfCFTA) is heralded as a vehicle for Africa's economic transformation (AUC 2017). It could create an economic bloc with a combined GDP of approximately US$ 3.4 trillion. The agreement is made more pertinent as the continent grapples with the financing and implementation of green recovery plans to regain economic growth disrupted by the COVID-19 pandemic, whilst limiting poverty, and climate and environmental vulnerability of the majority of the population (AfDB 2022). The free movement of goods and services requires a reliable transport system which includes scaling up transport infrastructure for air, maritime, road and rail modes of travel to facilitate intra-African trade. Intra-Africa trade will increase the road freight demand by 28 per cent (UNECA 2022). The largest demand for on-road transport using trucks is projected to be within West Africa, at 39 per cent, and West to Southern Africa by 20 per cent. The projected demand for rail and marine transport is also expected to double by 2030 relative to today.

Despite this projected growth in the transport sector, the implementation of AfCTA could bring climate change and air pollution benefits through advances in the Regional Economic Communities (RECs). These have the ability to implement regional systems to improve vehicle emissions and fuel standards. Africa's road fleet comprises mostly old, used vehicles from the European Union, Japan and the US. These older vehicles are a growing source of vehicle emissions in urban areas, contributing towards deteriorating air quality and GHG and SLCP emissions. Thus, these vehicles have an impact on human health, environment and climate change. Furthermore, they tend to be a safety hazard, as many have missing mechanical parts and some have had emissions-reduction devices removed (UNEP 2020).

There is a considerable opportunity to reduce emissions from the transport sector through implementing the measures for passenger journeys and alternatives for freight. African countries are starting to set emissions standards for vehicles and fuel quality. The two standards have to go hand in hand as the cleaner vehicles can only run on cleaner fuels. Europe progressed to EURO 6 standards for diesel and petrol-driven cars in 2015. In Africa, there is a move towards improving fuels and also to setting EURO-style standards for cars sold in different countries. Some countries, including Algeria, Botswana and Nigeria, have adopted EURO 3 standards (UNEP 2019a).

The regional framework on air quality agreements adopted by environment ministers in 2008/2009 in East, West and Southern Africa provides a policy basis to limit vehicle emissions by improving vehicle exhaust emissions and fuel standards (Section 4.3). These agreements encourage countries to integrate a fuel and vehicle system to coordinate the phasing out of polluting vehicles at the same time as ensuring there are cleaner fuels, diesel and gasoline, available to meet the better vehicle-exhaust standards. Subsequently, the EAC, SADC and ECOWAS have implemented different phases of the regional framework air-quality agreements with some significant success, especially for fuel standards in the transport sector as described below.

Southern African Development Community

In 2019, an SADC Regional Framework for Harmonization of Low Sulphur Fuels and Vehicle Emission Standards was agreed at a workshop, funded by the UNEP-convened CCAC, and co-organized by APINA through the Institute of Environmental Studies of Zimbabwe, UNEP and ICCT[3]. The SADC countries agreed to reduce sulphur levels in fuels to 50 parts per million (ppm) or less by the end of 2022 for importing countries and 2025 for refining countries, and then to 10 ppm from 2025–2030 for all countries. Participating countries also recommended the development of a refinery investment plan between the governments and private sector by the end of 2020 for refining countries as well as the harmonization of fuel standards and practices by 2022 through the coordination of the SADC Secretariat.

East African Community

East Africa Community Member States agreed to harmonize fuel standards in 2015 and this was implemented following the acceptance of proposed standards for low sulphur gasoline and oil products (EAC 2011). Following this, the EAC proposed harmonized vehicle standards and a road map was developed to move towards Euro 4 or higher equivalent exhaust-emission standards. The Roadmap was developed through a consultative process involving national and regional consultative meetings with various stakeholders within the East Africa sub-region (UNEP 2019a).

3. https://www.unep.org/events/workshop/sadc-regional-framework-harmonisation-low-sulphur-fuels-and-vehicle-emission

Economic Community of West African States

The environment and energy ministers of all the 15 countries of ECOWAS met in February 2020 in Ouagadougou, Burkina Faso and adopted a comprehensive set of regulations for introducing cleaner fuels and vehicles in the region. The regulations adopted by the ministers were a culmination of several years of work by UNEP to improve the standard of fuels and vehicles in the region. The ministers took an important step adopting regulations which mean that from 1 January 2021 all fuels imported by ECOWAS countries had to have a standard of 50 ppm sulphur for petrol and diesel. Local refineries have until 1 January 2025 to comply, with the expectation that this will contribute to improvements in air quality in the region. In addition, from 1 January 2021 all imported vehicles, both new and used, as well as petrol and diesel, have to comply with the minimum EURO 4 vehicle-emission standard (Afrik21 2020).

North Africa

In North Africa, progress has been made on transport issues despite the absence of a regional framework agreement. Morocco leads the field having already adopted EURO 4 standards for all vehicles sold since 2011, and in their NDC state that they will adopt EURO 6 standards by 2023. There is also an initial promotion of electric vehicles in Morocco through a reduced value-added tax (VAT) rate of 10 per cent on the import of EVs (UNECE 2021). Morocco is also starting down the path of manufacturing electric vehicles with the development of an electric battery factory in Casablanca[4]. Other countries, such as Kenya and South Africa, are also starting to import EVs, and although the numbers are small, it shows that sales have begun. Morocco and Egypt both have programmes which incentivize the scrapping of the most inefficient and polluting vehicles (IEA 2022). To date this has only been applied to taxis but could be rolled out more widely.

In North Africa, railway infrastructure is largely lacking (Elmansouri *et al.* 2020) and this has a substantial impact on the facilitation of intra-regional trade. Nonetheless, substantial railway-building and improvement plans are already underway in Algeria, Libya, and Tunisia (Elmansouri *et al.* 2020). Morocco was also the first African country to construct a 323-kilometre high-speed rail line, the *Ligne à Grande Vitesse Maroc* (LGV) – the first of its kind in Africa. An extension, adding a 1 500 kilometre high-speed network, is planned alongside a 2 700-kilometer conventional network by 2030[5].

ELECTRIFICATION OF ROAD TRANSPORT FLEETS IN AFRICA

Africa has one of the fastest growing markets for two and three wheelers, which has mostly surpassed the number of private vehicles in most urban centres in Africa (Liousse *et al.* 2014). Unlike the used car imports, the origin of two and three wheelers is mostly Asia (Ehebrecht *et al.* 2018; Mbandi *et al.* 2019). As in Asia, the use of two and three wheelers in Africa is both ferrying goods and as public service vehicles. In Africa, they are largely informal and mostly unregulated (Ehebrecht *et al.* 2018) and use diesel and gasoline. There is, however, an opportunity for this dominant form of transport to transition to a low-carbon, resilient and clean mobility through electric two and three wheelers.

There is a growing interest in manufacturing electric motorcycles in Africa (Kohli *et al.* 2022). Rwanda and Uganda have started manufacturing motorcycles and retrofitting existing ones with battery packs while Ghana and South Africa are assembling electric two and three wheelers. South Africa also has a start-up company operating electric three-wheeler taxis while multiple companies are currently investing in charging infrastructure for electric two and three wheelers. In addition, South Africa has research and development initiatives, such as the national uYilo e-mobility programme[6]. Activities include national accredited battery and material testing, battery manufacturing, recycling, second-life usage, and vehicle-to-grid technology. (Kohli *et al.* 2022).

To make progress on transitioning to resilient, inclusive and low-carbon transport in Africa, investment in mass transit systems in needed. UNEP is providing support to Côte d'Ivoire, Senegal, Seychelles, South Africa and Tanzania for soot-free buses as well as the introduction of electric buses. Kenya's Opibus and Uganda's Kiira Motors are seen as front-runners among private companies at different phases of manufacturing or assembling buses and minibuses for use in public transport. Egypt also has begun the manufacture of electric buses in partnership with the Ministry of Military Production.

4. https://atalayar.com/en/content/morocco-takes-important-step-manufacture-electric-batteries-cars
5. http://www.equipement.gov.ma/ferroviaire/TGV/Pages/LGV-Casablanca-Tanger.aspx (in French)
6. https://www.uyilo.org.za/

SHIPPING AND RAIL TRANSPORT IN AFRICA

Rail networks across Africa are generally limited. Lack of infrastructure and low levels of industrialization and regional trade contribute to the paucity of rail transport, which currently accounts for only 1 per cent of transport energy use in Africa (IEA 2022). Similarly, shipping accounts for around 5 per cent which is low in comparison to its value globally (IEA 2022). These proportions are likely to increase the transition to Agenda 2063 progresses, however, the subsequent rise in emissions can be offset by increased use of alternative fuels, i.e., the electrification of trains and the use of biofuels in shipping. South Africa has partnered with GreenVoyage2050, a project executed by the International Maritime Organization (IMO), to aid the transition to a low-carbon shipping industry (IMO-Norway 2022). The Global Industry Alliance to Support Low Carbon Shipping is a public-private partnership seeking to increase energy efficiency and reduce greenhouse gases in maritime transport[7].

NON-MOTORIZED TRANSPORT IN AFRICA

In many African urban centres, walking and cycling makes up nearly half of the modal share, and rural areas are likely to have an even greater one. At the same time, even though Africa only accounted for 3 per cent of the global new vehicle market in 2020 (UNEP, 2020), the continent has a significant problem of traffic related injuries and fatalities (Demyttenaere *et al.* 2009). These may be partially related to the poor infrastructure available for walking and cycling. Transport policy in Africa is, however, beginning to recognize the integral role of walking and cycling in any sustainable transport system (ITDP 2018).

Bicycle use is currently limited in urban Africa (Stucki 2015). In most sub-Saharan African countries, where transport is dominated by pedestrians, a transformation is occurring to accommodate the growing number of motorcycles. There is potential for the electric bicycle to provide mobility cheaply, as well as to substantially reduce pollution, decrease traffic congestion and reduce over-reliance on fossil fuels, recognized early by de Vries and Jenman (2006). In rural Uganda, as in many African regions, a case study demonstrated that when rural residents were provided with bicycles, they preferred them as they were able to save money that would otherwise be spent on transporting agricultural goods to the market, thus improving income for women and entire families (Eurist 2022).

Walking and cycling is also getting more attention and innovative approaches, see below, are being used to overcome barriers to uptake.

- The Addis Ababa Road and Transport Bureau has unveiled an ambitious ten-year non-motorized transport (NMT) strategy to create a better urban environment for all city residents that plans the construction of 600 km of footpaths and 200 km of cycle tracks. The city first undertook a data-collection project to better understand the current characteristics of the transport sector (C40 2021). The results of this exercise informed the implementation steps outlined in the Addis Ababa Climate Action Plan. These include introducing financial incentives for bicycles, launching a public awareness campaign and preparing supporting legal frameworks (Addis Ababa Environmental Protection Authority 2021). In 2019 the city also rebuilt 28 km of walkways (ITDP Africa 2019).

- Extensive stakeholder engagement helped the inclusive revised design of Lithuli Avenue that has been transformed from a congested street in Nairobi into a pleasant shopping street emphasizing pedestrian access (Cinderby *et al.* 2021; Box 5.1).

- In Cape Town, South Africa, the stated ambition of the city's Cycling Strategy is that it will become recognized and accepted as a safe, viable and attractive means of travel for all, and that cycling's mode share will increase from the current 1 per cent to 8 per cent by 2030 (City of Cape Town 2017).

3D zebra crossing in Kampala, Uganda
Source: Cinderby et al. (2021)

7. https://greenvoyage2050.imo.org/about-the-gia/

BOX 5.1 STREET INFRASTRUCTURE IN EAST AFRICAN CITIES

Many African cities suffer from road traffic issues and poor infrastructure for non-motorized transport. Two real world experiments were conducted in which creative methods were used to engage multiple stakeholders and achieve transformative urban planning, undertaken in Nairobi, Kenya and Kampala, Uganda.

A combination of complementary creative methods, such as a 3D zebra crossing in Kampala (photo previous page), on-street photography, drone imagery and virtual-reality streetscapes, were used to improve the success of road transport interventions.

Creative methods can be tailored to different stakeholders and foster innovation and transformative thinking. Interventions included pedestrianized schemes, traffic-calming schemes and road improvements with segregated walking and cycling lanes.

The creative methods and interventions incorporated multiple institutions and stakeholders including urban planners or city authorities, transport professionals, vulnerable groups, engineers and business representatives. Permanent improvements, based on the participatory co-design findings, were implemented with support from UNEP and the Nairobi City County local authority and the Kampala Capital City Authority. The installation of 3D zebra crossings has also been trialled in Lusaka by the Zambia Road Safety Trust and the installation of three permanent such crossings near school corridors were funded by a donor from the insurance sector.-

Multiple benefits were achieved including improved road infrastructure planning, increased road safety awareness and improved mobility, particularly for vulnerable groups. Better road infrastructure for non-motorized vehicles can reduce emissions. In Nairobi, reductions in motorized transport use and increased walking and cycling contributed to a 52 per cent average reduction in weekday PM_{10} measurements on Luthuli Avenue from 87.8 to 41.9 $\mu g/m^3$ after NMT improvements (Cinderby *et al.* 2021). In Kampala, the city centre NMT corridor proved particularly beneficial for urban mobility during COVID restrictions when many commuters adopted cycling rather than motorized public transport.

The participatory approach and stakeholder engagement contribute to more effective and more equitable outcomes. All these impacts are directly related, or contribute, to a number of the SDGs, such as SDG 3 Good health and wellbeing through increased road safety, and SDG 11 Sustainable cities and communities through access to transport and expanded public transport, or more broadly SDG 9 Industry, innovation and infrastructure.

There are numerous challenges in urban transformation and SDG delivery, but creative methods of engagement help to overcome some of the key barriers. For example, they can enable typically excluded groups to be engaged in the planning process.

Cinderby *et al.* (2021) found that different methods have strengths and weaknesses, and a variety of complementary methods should be utilized to increase inclusion, for example, of drivers when considering on-street approaches. Therefore, a number of alternative methods, such as digital storytelling, were used in conjunction. Development plans can, they found, also encounter barriers in terms of conflicting interests. Creative engagement can, however, increase a shared understanding among stakeholders, and innovative ways of exchanging information and empowerment help to overcome traditional planning deficits.

Top - Namirembe Road, Kampala, Uganda, pre-improvements; Bottom - the same road after improvements with segregated walking and cycling lanes.

Source: Cinderby *et al.* (2021).

5.3.2 MITIGATION MEASURES IN THE RESIDENTIAL AND COMMERCIAL SECTOR: DELIVERING MODERN ENERGY FOR COOKING, HEATING AND COOLING

Access to clean fuels for cooking and energy in residential and commercial sectors, households, schools and other institutions, varies considerably across Africa. In this Assessment, clean lighting and clean cookstoves have been modelled as measures under the SLCP scenario, and efficient refrigeration and air conditioning, and other household energy efficiencies under the Agenda 2063 scenario, relating to the priorities for modern and liveable habitats and basic quality services; health and nutrition; and sustainable consumption and production patterns in Agenda 2063 (Table 5.1; Section 3.2.3.2). Access to domestic clean energy has been a key issue in Africa for decades and, although progress has been slow, the situation has improved, albeit that recent events, such as the pandemic and war in Ukraine, have slowed progress (IEA 2022).

Clean Fuels

In North Africa the proportion of the population with access to clean fuels increased from 75 per cent in 2000 to 85 per cent in 2014, primarily due to Algeria, Egypt, Morocco and Tunisia having achieved access to clean fuels and technologies for cooking of 98–100 per cent (World Bank 2022). The situation in sub-Saharan countries is different, with the proportion of the population with access to clean cooking fuels increasing from 9 per cent in 2000 to only 18 per cent in 2020 (World Bank 2022). This also hides the situation in different countries – for example, access to clean fuels in South Africa increased from 56 per cent to 87 per cent between 2000 and 2020 and from 44 per cent to 65 per cent in Botswana. In West and East Africa, however, many countries can provide access to less than 20 per cent of their populations. In Ghana, for example, 78 per cent of the population still does not have access to clean fuel for cooking, although availability has increased dramatically from 6 per cent in 2000 to 22 per cent in 2020 (Box 5.2; Box 5.5). These are positive changes, nonetheless an estimated 900 million people in Sub-Saharan Africa have no access to clean cooking equipment (IEA 2022).

There are a number of key challenges to attaining a continental-scale transformation to clean cooking solutions. The dominant funding and financing of clean cooking solutions is through fragmented project-driven action, focussing, for example, on promoting clean, efficient cookstoves and fuels in selected countries in only one region of Africa. This can have considerable local impact but limited regional-scale benefits. Other factors are associated with air pollution management policies and standards within a country; consumer behaviour; affordability of clean cooking devices and associated clean fuels; as well as cultural cooking practices.

In some countries, including Kenya, government policies that encourage a transition to higher-tier clean cooking solutions, such as LPG gas, biogas and electricity, indicate the need for deep and extensive public education and awareness raising on their cost-effectiveness in terms of time and cash savings that can result from switching to clean cooking devices and fuels. Kenya's Ministry of Energy and the Clean Cooking Association of Kenya (2019) state that, while the use of traditional three-stone open fires remains prevalent in Africa, the uptake of LPG is one positive outcome associated with policy and legislative interventions as well as market-based innovations, similar to last-mile transportation. A survey of cooking practices of 5 600 peri-urban households in Cameroon, Ghana and Kenya (Shupler *et al.* 2021) suggests that supply-side interventions, such as shortening the

distance to LPG retail points and improving access to multi-burner LPG stoves, could help increase the use of clean cooking fuels rather than higher-polluting fuels, such as charcoal and firewood, for the benefit of public health, gender equality and environmental protection. Kypridemos *et al.* (2020), estimate that Cameroon's government target of 58 per cent of the population using LPG as a cooking fuel by 2030 could have a significant impact on population health with no adverse effects on the climate.

Although fuels and technologies such as electricity, briquettes, pellets, liquid ethanol, gel ethanol, biogas, solar cookers and fireless cookers have been promoted over several decades, their prevalence in households remain marginal. Indeed, even in households that use clean cooking, fuel stacking, the supplementing of clean cooking solutions with traditional methods, is common (Kenya Ministry of Energy and Clean Cooking Association of Kenya 2019). Implementation of clean energy measures, therefore, needs to focus on access and use, and the phased implementation of the measures recommended in this Assessment (Section 3.2.3.2) requires support if they are to succeed. As well as cost, other critical factors that should be considered include ease of use, availability of fuels, distance to fuel sources, last-mile distribution options, availability of longer-term payment plans, nature and structure of cooking area, types of food and the number of household members.

BOX 5.2 GHANA'S TRANSITION TO CLEANER COOKING

In Ghana, about 20 million tonnes of biomass are harvested each year to provide about 78 per cent of households with cooking fuel, whether wood fuel, charcoal or crop residues. This makes Ghana the fourth largest consumer of wood fuel in Africa after Ethiopia, the Democratic Republic of the Congo (DRC) and Nigeria (UN 2022). Apart from biomass, LPG consumption has increased significantly; Ghana is among the top 15 African countries in terms of the consumption of LPG (Muhirwa *et al.* 2021). At national level, LPG contributes 35.8 per cent of total urban fuel consumption and 5.5 per cent of fuel used in rural areas in Ghana (WHO *et al*. 2018). In addition to LPG, more than two-thirds of rural Ghanaian households rely primarily on kerosene for lighting compared to just one-fifth of urban households (Abdul-Wakeel Karakara and Dasmani 2019). Although 85 per cent of Ghanaians have access to electricity, there are clear challenges regarding the proportion of electricity used for cooking. Almost 100 per cent of the electricity supplied to households is used for lighting.

Many projects, studies, policies and fundraising activities have aimed to improve access to clean cooking fuels in Ghana. Through many initiatives and partnerships such as the National Electrification Project, the LPG Promotion Programme and the West African Gas Pipeline Project, the government has increased incentives, particularly for LPG transportation fees in rural and remote areas. Since 2014, the Rural LPG Promotion Programme (RLP) has been used to mainstream the use and affordability of LPG at the household level (Carrión *et al.* 2021). Biogas energy was selected as one of the clean fuel options and the government identified the technical potential for about 278 000 biogas plants (Osei-Marfo, Awuah and de Vries 2018). In 2018, biogas distribution in Ghana was 63 per cent for domestic biogas plants, 31 per cent for institutional plants and 6 per cent for community plants. Solar hybrid biomass dryers have emerged as a technology to efficiently dry biomass in the future, with minimal time and cost savings compared to the mechanical dryers originally deployed (Bosomtwe *et al.* 2019).

Further consideration was given to promoting improved, high-efficiency cooking stoves that use less firewood or charcoal and produce less household air pollution. In addition, under the Ghana Energy Development and Access Project (GEDAP), the government initiated a Solid Biomass Action Plan under the Ministry of Energy to encourage power generation from biomass.

Many public, private and foreign institutions are working together in public-private partnerships to advance the clean-fuels transition in Ghana. The government has encouraged companies and stove wholesalers to get involved in the development

of various designs of efficient wood stoves. The Council for Scientific and Industrial Research (CSIR) was established and supported to provide technology and research in the areas of biogas fuels, charcoal for biomass processing, ethanol, and solar repair, maintenance and calibration. Within the West African sub-region, of which Ghana is a member, ECOWAS has also established regional cooperatives to promote regional clean energy integration. The West African Gas Pipeline (WAGP) and West African Power Pool (WAPP) provide important opportunities for trade between nations, cross-border energy infrastructure and knowledge sharing in areas of common interest.

Ghana has put in place policies to introduce renewable energy use by 2030, with the goal of making clean and modern energy accessible to all. In its Renewable Energy Master Plan of 2019, for example, the country has set a target of having 10 per cent of the country's energy produced from renewable sources by 2030, serving more than 1 000 grid-connected communities. Concessions on the sale of stoves and fuel have been introduced for investors and entrepreneurs, and interest rates have been reduced. The Renewable Energy Sources Act (Act 832) was amended in 2020 (Act 1045) to encourage the production of energy from renewable sources.

A range of socio-economic factors such as poverty, levels of education, location of residence, number of household members, income and policies strongly impact the choices of different fuels used by households in Ghana (Twumasi *et al.* 2020; Azorliade et al. 2022). The wealth status of households and the type of fuel consumed demonstrate the energy ladder hypothesis, with the poorest households consuming biomass fuels and the richer ones using cleaner fuels such as electricity and LPG for cooking. Wood is the energy source of poor households, while 91 per cent of households using LPG belong are richer ones (Abdul-Wakeel Karakara and Dasmani, 2019). The predominant use of non-clean energy fuels has had a significant impact on environmental degradation, including massive deforestation of primary forest in Ghana, with a 20 per cent decrease in tree cover between 2001 and 2021 (GFW 2022).

Statistics on the high dependency of the Ghanaian population on biomass indicates that there is still a long way to go that requires further efforts from the government and partners. Some of the challenges mentioned are due to global issues such as the COVID-19 pandemic and rising prices of many imported commodities, including grain and fuels, which could pose a challenge for affordable and clean energy in the future (GLI, 2022).

At the national level, high population growth rates of 2.1 per cent per year combined with limited self-sufficiency in energy and end-use generation technologies could prompt many to rely on cheaper, more affordable biomass and charcoal in the future. Inefficiencies in utility operations result in high losses in the exploration, production and consumption of energy, driving up utility and distribution costs. As a result, sourcing clean cooking fuels in Ghana requires additional expertise, capacity and funding. Technologies and interventions need to be developed in current and future policy priorities and planning. Understanding local needs and purchasing power is essential in the transition to clean cooking. Increased investment in technical and feasibility assessments, construction, operation and management of renewable energy alternatives is needed, and investment that encourages public- and private-sector collaboration and participation in clean energy should be prioritized. Companies, regulators, financiers, domestic investors, and domestic energy-technology and service providers need to work together to share information, knowledge and experience in development and deployment. Energy-transition policy frameworks, policy priorities, financing and infrastructure must focus on all stakeholders and strengthen public-private partnerships (Kuamoah 2020).

Refrigeration, air conditioning and energy efficiency

In Africa, ambient temperatures are already among the highest in the world, with many locations across Africa experiencing 4 000–5 000 cooling-degree days annually, roughly an order of magnitude higher than in countries with a temperate climate (IEA 2022). Population growth, urbanization and climate change in Africa are driving up the need for cooling with a corresponding rise in demand for air conditioning. In the Agenda 2063 scenario modelled in this Assessment demand for electricity and peak loads are reduced by doubling air conditioning efficiency by 2063. This will also need to be coupled with awareness raising on how to use cooling equipment most efficiently. Promisingly, around 40 per cent of African countries have now adopted mandatory minimum energy-performance standards (MEPS), including Algeria, Benin, Egypt, Ghana, Kenya, Nigeria, Rwanda, South Africa and Tunisia, and MEPS have recently been proposed for all ECOWAS Member States and the Seychelles (IEA 2022).

As discussed in Section 3.2.3.1, energy efficiency measures will need to be combined with more efficient buildings to reduce energy demand, orientation of buildings planned to reduce cooling demand and increased green areas to cool cities and reduce heat island effects. Such measures should be complemented by development and implementation of guidelines for quality assurance and control of air conditioning and refrigeration equipment.

Africa is set to embark on one of the biggest building expansions in the world in the period to 2050, with residential building stock projected to more than double, so there is tremendous opportunity to build energy- and resource-efficient buildings adapted to local climatic conditions (IEA 2022).

Among household energy uses, as incomes rise and people gain access to electricity, demand for lighting will grow the least in absolute terms due to the rapid shift to light-emitting diode (LED) light bulbs, while demand for cooling and refrigeration will increase the most (IEA 2022). Refrigerated supply-chain infrastructure (cold chains) has now become an area of increased focus in Africa, especially since 2020 because of the refrigeration needs for Covid-19 vaccine distribution. Around 40 per cent of African countries have adopted efficiency standards and labelling for cooling equipment or are planning to do so, and around 20 per cent for refrigeration and lighting (IEA 2022).

Significantly, in terms of sustainable development, improved cold-chain infrastructure and logistics can facilitate greater supply and better quality of food, extend shelf life of food and reduce the need for imports (IEA 2022). Increased refrigeration of food can reduce post-harvest losses, thereby improving food security and reducing CH_4 emissions associated with bio-waste.

5.3.3 IMPROVED WASTE MANAGEMENT AND RECYCLING, SEWAGE TREATMENT AND REDUCED FOOD WASTE

Waste is a pertinent development issue, especially related to the management and treatment of waste in urban and rural settings in Africa (Section 1.1.2.1). Uncontrolled open burning of waste, for example, is an important source of outdoor air pollution in Africa's urban areas (Section 1.2). The importance of waste management as a source of CH_4 and BC emissions is discussed in Section 1.4.1 and its links to SDG targets and other international agreements in Section 1.4.3.

Waste generation is expected to grow rapidly over the next decades in Africa. Sub-Saharan Africa, for example, generated approximately 180 million tonnes of waste in 2016, at a rate of about 0.46 kilograms (kg) per person per day. It is the fastest growing region, with waste expected to nearly triple by 2050. Despite the large amount of waste generated, only half of the waste is formally collected (Kaza *et al.* 2018).

Managing waste is a major environmental health challenge across Africa. Over the last 20 years, African countries have been changing development approaches to adopt those that minimize the generation of waste. Green growth, cleaner consumption and production, and a circular economy are development models that are increasingly being pursued by African countries. Indeed, continental development programmes such as the Africa Union Green Recovery Action Plan 2021–2027, the Africa's Green Stimulus Programme and the Climate Change Strategy (2022–2032) signify a deliberate focus on development that results in a reduced generation of waste. These continental programmes will be pursued against a background of waste management that is challenging. The 2018 Africa Waste Management Outlook report (UNEP 2018) indicates that in 2012 Africa only recycled 4 per cent of solid waste despite an AU target of recycling at least 50 per cent of urban waste by 2023. A recent report (Mebratu and Mbandi

2022) states that of the approximately 180 million tonnes of waste generated in Sub-Saharan African countries in 2016, only about 11 per cent of the waste was disposed of in properly designed and managed sanitary landfills while more than 60 per cent was disposed of in uncontrolled landfills and open dump sites. Notably, 19 of the world's 50 biggest dumpsites in 2015 were located in Sub-Saharan Africa (UNEP 2018). Poor waste collection and improper disposal of waste often leads to residential open burning of waste, which is almost always coupled with open burning at dumpsites (Cogut 2016).

Opportunities for improved waste management in Africa are strongly evidenced by:

i. Africa's commitment to international conventions on waste management;

ii. regional commitments such as the 1991 Bamako Convention and the 2008 Libreville Declaration;

iii. national policies and legislations on waste management including regulations on extended producer responsibility; and

iv. promoting private sector investment in waste management, especially by small and medium-sized enterprises.

These opportunities link to other priorities in the area, for example, the AU is working with governments to transpose the Malabo Declaration on Accelerated Agricultural Growth and Transformation for Shared Prosperity and Improved Livelihoods, including food-loss reduction, into proper national policy and strategies in Africa. Despite these efforts, urgent action to systematically tackle waste management at a continental scale is necessary because in most African countries there are no waste recovery plants, no separation of waste at source, and no sanitary landfills or incineration plants for waste-to-energy production. One of the key improvements in living standards mentioned in Agenda 2063 in relation to waste is that by 2063 100 per cent of the urban waste will be recycled (AUC 2015a).

Of the 37 recommended measures in this Assessment, six concern waste management and of these, two propose reductions of SLCPs through the capture of CH_4 emissions from existing landfill and water treatment plants, while all six align well with the conclusions of the UNEP (2018) report that while most African countries are still very far from achieving the Agenda 2063 goals on waste, more can be achieved by focussing on:

i. the diversion of organic waste away from landfill towards composting, bioenergy recovery and higher value product recovery; followed by

ii. refurbishment, repair, reuse and recycling of mainline recyclables such as plastic, paper, metal, glass, tyres and e-waste.

This can be brought about by a typical solid waste microgrid system, consisting of source reductions; separation of different fractions of waste; on-site treatment where possible – for example, composting; and collection and transportation to recycling and resource recovery facilities. Such approaches significantly reduce the volume of waste that needs to be disposed of in sanitary landfills while also facilitating the transition of the informal waste recyclers into formal waste service providers (Mebratu and Mbandi 2022).

Systematic tackling of waste management by state and non-statal actors has huge potential to generate multiple health and environmental benefits to Africa (Box 5.3). The magnitude of the waste issue in Africa and the urgent need to deal with the GHG, air-pollutant and SLCP emissions associated with solid and liquid waste is highlighted in Chapters 2 and 3.

BOX 5.3 INTEGRATED SUSTAINABLE SOLID-WASTE MANAGEMENT EXAMPLES IN AFRICA

1: WASTE MANAGEMENT KNOWLEDGE SHARING PLATFORMS

There is a lack of data and information on waste management in Africa, rendered more acute by the informality of the sector. Information on total waste generated, the composition of waste, sources of waste and volume of waste collected is often gathered in a piecemeal manner and often there is a lack of coordination. The African Clean Cities Platform (ACCP) was established in 2017 to share knowledge on waste management in Africa and to promote the realization of SDG targets on waste management. The platform was established as an initiative of the Ministry of the Environment of Japan, the Japan International Cooperation Agency (JICA), UNEP and the United Nations Human Settlement Programme (UN-Habitat) and the City of Yokohama. As of December 2021, ACCP had 90 cities in 42 countries in Africa who are participating in the platform.

The ACCP holds regular meetings, workshops and webinars to facilitate the formulation of guidelines through knowledge sharing and networking, anchored in the promotion of the members' achievement of SDG targets related to waste and supports opportunities for investment in waste management. The platform has a wealth of open-access training material for diverse target audiences including teachers, students and citizens on topics such as 3Rs (reuse, reduce, recycle) and environmental education. The platform also has information for different key stakeholders on the basics of solid-waste management. The ACCP newsletter, produced twice a year, amplifies best practice on waste management and highlights members' activities.

2: THE ROLE OF THE PRIVATE SECTOR IN WASTE MANAGEMENT IN AFRICA

Africa's waste is increasingly seen as a resource recovery opportunity currently valued at US$ 8 billion a year (UNEP 2018). However, UNEP (2018) has estimated that of the 125 million tonnes of municipal solid waste (MSW) generated in Africa in 2012, only 4 per cent, 5.0 million tonnes per annum, valued at US$ 318.6 million, was recycled, with the bulk of the waste disposed of in dumps, often associated with open burning. As 70–80 per cent of MSW generated in African cities is considered to be recyclable (UNEP 2018), there is massive potential for the private sector to partner with governments and other key stakeholders to invest in waste management, specifically recovery, recycling and treatment. This may be an opportunity to look at ways to formalize the largely informal waste sector in Africa inclusively, where the livelihoods, health and wealth of communities reliant on waste management are protected.

EXAMPLE 1: SWITCH Africa Green is a programme developed in 2013 that supports micro, small and medium sized enterprises (MSMEs) in six African countries by building their capacity in green business and eco-entrepreneurship. This includes promoting circularity through integrated waste management and industrial symbiosis, which implies the use of waste as a secondary resource. These are the key results from the first four years of implementation supported by UNEP: 83 per cent of the surveyed enterprises reported improved business skills and 74 per cent recorded increased sales turnover; 68 per cent of the surveyed MSMEs reported that new jobs had been created during the implementation of the SWITCH Africa Green programme – survey data showed that 2 683 new jobs were created during the implementation of the programme, with 63 per cent of them through industrial symbiosis; and 70 per cent of the MSMEs implemented 3R interventions.

The environmentally-friendly activities adopted include reuse and recycling, the sale of waste, segregation at source and better disposal. In Burkina Faso, 3 700 tonnes of waste were diverted from uncontrolled dumpsites, of which 2 200 tonnes went to composting and recycling activities. In Ghana, 20 000 tonnes of e-waste were recycled, directly and indirectly benefiting around 2 100 Ghanaians living in Accra. In Mauritius, 2 677 tonnes of waste were diverted annually from landfills and used locally as raw materials. SWITCH Africa Green provides a valuable insight into the kind of support that development partners could provide in promoting the reduction and use of waste as a secondary resource. and promotion of the transition to a circular economy.

EXAMPLE 2: Zoomlion Ghana Ltd., a private company established in 2006, is a public-private partnership venture to provide waste management services and deal with the serious challenge of waste management in Ghana. In addition to mountains of waste illegally dumped and burned; choked drains were seen as a health hazard which caused major floods in Accra, in particular, and in other towns and cities. The pools of water provided a breeding ground for mosquitoes and harboured pathogenic microorganisms causing outbreaks of malaria, cholera, and typhoid.

Zoomlion Ghana Ltd. has introduced efficient and cleaner equipment and a fleet of waste collection vehicles. In addition, they supplement their truck fleet with 2 000 motorized three wheelers providing the last-mile connectivity for hard-to-reach places in order to provide the waste collection services. They also have acquired hundreds of skips, compactor trucks, mechanical road sweepers and disinfection trucks to provide services during the COVID-19 pandemic.

EXAMPLE 3: Action taken at the city scale. As part of the C40 network of mayors[8], Accra has developed a Climate Action Plan which outlines the city's ambition to achieve a waste management system with zero greenhouse gas emissions (Accra Metropolitan Assembly 2020). Priorities in Accra are to provide universal waste collection, develop effective waste treatment, and provide safe waste-disposal infrastructure.

EXAMPLE 4: Sanergy's black soldier fly larvae (BSFL) project is a private enterprise working on sanitation in urban slums in Africa offering innovative solutions for toilets and effective alternatives to sewers. The project is piloting in Nairobi, Kenya, providing animal-feed millers with protein to replace the fishmeal harvested unsustainably in Kenya's the lake region. In the pilot they have found BSFL to be one of the most efficient natural organic waste converters with an average conversion rate of around 10 per cent. BSFL not only converts, it also assimilates organic waste by storing it up in their bodies where it constitutes approximately 40 per cent protein and 25 per cent fat. This process, although conducted at small-scale, has the potential to be scaled up and incorporated to offer waste management services at community, local municipal and city.

8. https://www.c40.org/about-c40/

Action already planned or taken by several African nations is described in their NDCs through their conditional and/or unconditional contributions. For example, the NDC submitted by the Central African Republic (CAR) mentions the development of hygiene and waste action strategies for solids and liquids in rural and urban areas. This ambition is pursued within the framework of the National Water Policy (2020–2030), which has included access to water and sanitation for all by 2030 in its strategic axes. In such an approach, waste management and sustainable disposal remain major challenges for municipalities in general, and in particular, in the context of an urban population, which makes up 41.4 per cent of population and is projected to reach 48 per cent and 60 per cent respectively by 2030 and 2050. The objectives and mitigation measures relate to the treatment and recovery of municipal waste (CDN Republique Centrafricaine 2021).

Similarly, the NDC submitted by Cameroon mentions the use of waste as a way of producing electricity and further mentions mitigation measures such as producing biogas, other fuels and compost from MSW (CDN Republique Du Cameroun 2021). The NDCs of Burkina Faso and Burundi include several similar remarks, and specifically the NDC submitted by Burundi comments on the socioeconomic advantages/co-benefits of taking action to reduce waste and the emissions associated with solid and liquid waste such as increased the energy supply, improving the living conditions, saving on the import of electricity or fuel, the use of faecal sludge as composting fertilizers, the sustainable management of agricultural fertilizers, the use of compost, and the recovery of CH_4 (CDN Burkina Faso 2021; CDN Republique Du Burundi 2021).

The NDCs for the Republic of Congo and Côte d'Ivoire, mention mitigation measures such as increased waste collection and improved waste management (CDN Republique Du Congo 2021; CDN Cote D'Ivoire 2022). The DRC also describes planned national action through the 2013 National Sanitation Policy which aims to help improve access to adequate sanitation services and infrastructure. The Ministry of Environment and Sustainable Development is responsible nationally for the sanitation sector, in particular the management of municipal waste. Several departments are involved in solid waste management. These include the Ministry of Infrastructure, Public Works and Reconstruction through the Roads and Drainage Office, which is responsible for the cleaning of drains, rivers and major waste collectors. (CDN Republique Democratique Du Congo 2021).

In Ghana, two of Accra's landfill sites are more than 70km from the city, inhibiting effective waste collection. To overcome this, a transfer station has been constructed on the northern corridor of Accra, which is a location for informal waste disposal. To improve MSW management, a data collection project was conducted to accurately characterize solid waste in the city. Accra has since used this baseline waste data to inform its Climate Action Plan and planning of waste infrastructure (C40, 2021). Other examples of existing action include the implementation of a pilot project separating solid waste at a select number of institutions –scaled up to three communities and two markets, the development of a landfill with gas capture, and the implementation of public-private partnerships for waste collection which have reduced the financial burden of waste management. The Climate Action Plan also specifies a number of city-scale activities to be undertaken in the next five years and highlights how these align with commitments made in Ghana's NDC. Challenges include the lack of a market for compost, citizens' reluctance to change their behaviour, poor coordination between authorities and a lack of available space.

5.3.4 GREATER EFFICIENCY IN AGRICULTURE TO FEED POPULATIONS, MORE EFFICIENT WAYS OF REARING LIVESTOCK, PROMOTION OF HEALTHY DIETS AND REDUCED CROP RESIDUE BURNING

In this Assessment various measures in the agricultural sector relating to increased livestock productivity, manure management, reduced crop-residue burning, climate resilient practices for growing rice and reduced food waste were modelled (Section 3.2.5.2). These connect several goals and priorities under the first ten-year plan of Agenda 2063, especially ones related to the growth of agricultural production under Goal 5, which specifies doubling agriculture productivity, reducing post-harvest losses by 50 per cent and increasing climate–resilient practices in agriculture and aquaculture by 30 per cent between 2013 and 2023 (AUC 2015b). This Assessment's recommended measures also relate to Goals 1, 3 and 5 of Agenda 2063 that aim to reduce hunger and malnutrition.

In realizing the multiple benefits for the environment and human health related to agricultural practices outlined in this report, it will be important to link to Agenda 2063's CAADP and the National Agricultural

Investment Plans (NAIPS) aligned to Malabo Declaration Targets (Malabo Declaration 2014). There are also technical groupings under the UNFCCC, such as the Koronivia Joint Work on Agriculture (KJWA) and the African Group of Negotiators Expert Support (AGNES), that seek to facilitate the exchange of ideas between experts and negotiators at the international level, especially within the framework of the UNFCCC. For example, AGNES (2020a) calls for gender-sensitive strategies targeting African smallholders and identifies categories of strategies consisting of proven technologies, innovation and best-practice with the potential to deliver inclusive and climate-resilient food production at scale in Sub-Saharan Africa.

Livestock measures

Breeding programmes can be successful in increasing the efficiency of livestock systems. In the SLCP scenario, mitigation options modelled under A1 included a 33 per cent increase in calf weight, a 34 per cent increase in adult weight, a 9 per cent increase in fertility rates, and an 11 per cent reduction in the age of first calving (Section 3.2.5.2). Cross breeding or selection can be used to achieve this improved productivity by enhancing existing livestock breeds without losing their adaptive qualities. In developing countries, in which farm systems are low-input and supporting infrastructure is lacking, community-based breeding programmes offer a mechanism for improving livestock genetics. Such programmes have proved to be effective in Ethiopia and Senegal, where multiple community-based research programmes have been implemented (Box 5.4).

BOX 5.4 IMPLEMENTING LIVESTOCK MEASURES IN AFRICA

Ethiopia - An initiative was established in 2009 as a collaboration between international research institutes, the University of Natural Resources and Life Sciences and the Ethiopian national agricultural research system (Haile *et al.* 2020). The programme initially involved six communities and 8 000 sheep. Flocks were pooled and selective breeding was carried out to select for desired traits, such as lamb weight. Since the inception of the breeding programme, lamb weight at six months is up to 30 per cent higher when compared to the same breeds under station management conditions, while the number of lambs born also significantly increased in two of the three regions (Haile *et al.* 2020). Increased efficiency resulted in a 20 per cent rise in income for farmers (Haile *et al.* 2020). A key to the programme's success was the high levels of engagement from stakeholders and the incorporation of indigenous knowledge. Elected community members are involved in the selection process and breeding objectives are driven by farmers.

Senegal - Another example of a successful breeding programme is in Senegal, which initiated a National Programme for Livestock Development aiming to increase the productivity and competitiveness of the livestock sector. In an effort to increase livestock productivity, the Senegalese government promoted the use of exotic breeds through a free artificial-insemination service. This was later accompanied by the Senegal Dairy Genetics project which sought to identify the most appropriate dairy cattle breeds in terms of milk production and profitability (Marshall *et al.* 2017). Breeds which are well adapted to local conditions and are productive have proved to be much more efficient (Marshall *et al.* 2016). Under good farm management, the age of first calving is reduced by 11 per cent while milk yield in crossbred cattle increased by 150 per cent compared to indigenous breeds. This increased productivity improved the cost-to-benefit ratio for farmers, though some upfront costs, such as animal housing, may be a barrier to the adoption of crossbreeds and farmers may require incentives, such as access to credit (Marshall *et al.* 2016). In addition, farm management is key. When comparing well-managed crossbred cattle with poorly managed indigenous breeds, a 600 per cent increase in milk offtake, a 500 per cent increase in household profit, and a 70 per cent reduction in GHG intensity per kilogram of protein can be seen (Marshall *et al.* 2017).

Despite the cost-effectiveness of activities that reduce GHG emissions whilst improving the yield of livestock, significant financial and technical barriers remain. Policies to promote rotational grazing, for example, should include tenure reform, agricultural extension services, and tools to secure affordable credit (Hogarth *et al.* 2015).

Manure and nutrient management

Climate-smart agricultural techniques – composting, direct planting, agroforestry, precision application of manure and fertiliser, the use of nitrogen-efficient and nitrogen-fixing plants –require technical knowledge of local climate and soil conditions, which varies widely (Hogarth *et al.* 2015). Public research programmes can identify which techniques are most appropriate in local soil and climate types. Demonstration projects, farm tours and mobile agricultural extension services can target barriers to knowledge diffusion directly and teach farmers about the benefits of new technologies, practices and species (Hogarth *et al.* 2015). There is a growing body of practical advice on the type of manure-management improvements modelled in this Assessment. AGNES (2020b), for example, outlines how scaling up agronomic technologies and practices for nutrient use and management, developed for African farming systems, have the potential to help low-input systems become more productive while reducing emissions intensity. As 80 per cent of arable land in Africa has low-soil fertility and is degraded as a result of massive nutrient losses caused by unsustainable soil-management practices (also known as 'soil mining'), there is great potential for the application of nutrient balance approaches, as an indicator of unsustainable soil use in smallholder farming systems in Africa, to guide improvements (Kiboi *et al.* 2019). There are also co-benefits in sound manure use and management as it is important for improving agricultural yields, restoration of degraded agricultural land and promoting soil-carbon sequestration (AGNES 2020b).

Alternate wetting and drying for flooded rice

Based on water-saving experiments in irrigated rice schemes in the Senegal River valley, AfricaRice[9] has found that with alternate wetting and drying (AWD) it is possible to attain major savings of irrigation water with little loss of yield in a Sahelian environment. Irrigation water savings of 22–39 per cent are possible for rice with little or no yield loss, while maintaining high water productivity. The technology is now being tested in Burkina Faso and Côte d'Ivoire (Djaman *et al.* 2018). Using a participatory approach, AWD has been successfully validated in three climatic zones in West Africa: semi-arid in the Senegal river valley in Senegal and the Zoungou plain and the Sourou valley in Burkina Faso; sub-humid dry in Kou valley and the Karfiguela plain in Burkina Faso; and sub-humid areas in Côte d'Ivoire (CGIAR 2020). As, however, the focus of AWD implementation is often water saving rather than GHG reduction, existing and future use should be monitored to ensure optimum outcomes.

Eliminating open burning of agricultural residues

Conservation agriculture and regenerative agricultural practices, which use crop residues as a sustainable resource for improving the condition of soils and alleviating soil fertility constraints are on the rise (Giller *et al.* 2021). This and other uses of crop residue (Section 3.2.5.1) mean that there is considerable scope in Africa for crop residue burning to be reduced. A CCAC project, for example, has determined the historical and current spatial and temporal patterns of open burning in Côte d'Ivoire, Ghana and Nigeria. The project disseminates the results to local and national stakeholders, as well as potential funders of demonstration and mitigation projects[10].

The issue is complex, and Africa is home to some of the most intensive rates of residue burning per hectare of harvested land in the world, so public sector support that enables technological as well as social innovation – involving, serving and motivating stakeholders at every level – is required (Cassou 2018). Box 5.5 shows examples of how agricultural waste can be converted to commercially-viable biomass briquettes for cleaner cooking as well as biochar and fertilizers, providing employment for women and youth in developing countries.

9. https://www.africarice.org/climate-change
10. https://www.ccacoalition.org/en/activity/open-burning-mapping-nigeria-and-west-africa

BOX 5.5 MAKING THE MOST OF AGRICULTURAL CROP RESIDUES

EXAMPLE 1: Kenyan company provides an alternative to firewood using agricultural waste

BrightGreen Renewable Energy[11], is an enterprise in Kenya that partners with farmers to upcycle post-harvest waste into fuel blocks, more commonly known as briquettes. They use fibres such as sugarcane bagasse, macadamia husks and rice husks, that tend to have the lowest salvage value, to produce the briquettes. This helps reduce burning-related GHG emissions and could be scaled up to provide employment and cleaner cooking fuels.

"My grandmother, for example, had a hut that was separated from the rest of the homestead. I learnt later that this separate building was to stop the smoke from being a nuisance to the rest of the household. Around her hut, stacks of firewood were piled high and snakes and poisonous spiders would sometimes be found there. Preparing a meal was a life-threatening affair." Quote from Chebet Lesan, CEO of BrightGreen Renewable Energy[12].

EXAMPLE 2: Warm Heart - is an example of an innovative approach (Shafer 2020) that operates biochar social enterprises in, amongst others, Ghana, Kenya and Malawi. Warm Heart projects include teaching biochar production from crop waste and testing biochar-based fertilizer with subsistence crops. The African programmes are linked by WhatsApp groups that share photos, videos, information, test data and encouragement to the volunteers who manage them.

11. http://brightgreenkenya.co.ke/
12. See full blog at: https://d-lab.mit.edu/news-blog/news/kenyan-company-provides-alternative-fire-wood-using-ag ricultural-waste

Feeding Africa while reducing food waste and improving diets

Agriculture is the largest productive sector in Africa, contributing to 20–25 per cent of the overall GDP, employing between 60 and 70 per cent of the total labour force and a source of up to 50–70 per cent of household incomes (AGNES 2020a). Most of Africa's food is produced under rain-fed conditions by smallholder farmers who occupy around 80 per cent of the continent's farms and contribute about 10 per cent to global agricultural output. There is, therefore, a need for food imports on the continent, estimated at US$ 35.4 billion in 2015 (AGNES, 2020a), but the potential for Africa to produce more of its own food exists. This is hampered, however, by various barriers including climate variability and air pollution, failure to adopt and scale up proven farming technologies and practices, overused and degraded soils, poor extension services for farmers and low commercialization of agriculture (Section 1.3.2). To achieve the food security targets sustainably across varying climate change scenarios overlaying the multiple farming systems on the continent in the short to medium term, 2030 and 2050 respectively, AGNES (2020a) recommends modalities and strategies for guiding communities collaborating with the public and private sectors, as well as researchers, in selecting appropriate strategies for adoption in their particular circumstances, with high potential for impact at scale. This approach can be complemented by the measures modelled in this Assessment that incrementally reduce food waste, improve diets and enhance production by 2063 (Section 3.2.5.2). These measures, combined with improvements in refrigeration (Section 3.2.3.1) and supply chain infrastructure (Section 3.2.5) across the African continent, could go a long way to reducing food waste.

5.3.5 INCREASING THE USE OF RENEWABLE ENERGY

Africa is endowed with diverse renewable energy sources – solar, wind, hydro, geothermal, and biomass – that could be harnessed to provide centralized/off-grid electricity and clean-cooking facilities for urban and rural dwellers, while unleashing socioeconomic development in a sustainable manner. Africa is home to 60 per cent of the best solar resources globally, yet it has only 1 per cent of installed solar PV capacity (IEA 2022). It has been estimated that by utilizing solar, wind, hydropower and geothermal resources, more than 80 per cent of new power generation capacity in Africa could be provided by renewable sources in 2030 (IEA 2022). Many African governments including Algeria, Egypt, Ghana, Kenya, Morocco, Senegal and South Africa have realized that this potential exists and have established policies and targets for renewable energy expansion under their NDCs within the Paris Agreement (IRENA 2021).

Algeria now has more than 500 megawatts (MW) of renewable energy installed capacity (EQ International 2021) and aims to reach 15 gigawatts (GW) capacity of renewable power by 2035 (IEF 2021). Morocco has five new wind farms that have been developed under the 850 MW Integrated Wind Energy Project at Boujdour, 300 MW; Midelt, 180 MW; Jbel Lahdid, 200 MW; Tiskrad, 100 MW; and Tangier II, 70 MW, along with eight hydro schemes. Kenya has the 310 MW Lake Turkana wind farm and Senegal has the 158.7 MW Parc Eolien Taiba N'Diaye. The Tanzanian government has announced a 600 MW wind farm. Morocco's 500 MW-plus Noor solar complex in Ouarzazate, the world's largest concentrated solar power (CSP) plant (Box 5.6), is closely followed by Egypt's 390 MW Benban solar park and Tunisia's 360 MW solar park. In the East African Rift Valley, Kenya's 160 MW Olkaria V plant has taken the lead on geothermal power generation with Ethiopia and Uganda keen on harnessing the huge potential of one of the world's largest geothermal hotspots (African Business 2020).

According to the Africa Energy Outlook (IEA 2022), the Sustainable Africa Scenario implies that 1.3 million jobs will be created by 2030, in addition to those that result from expanded energy access. More than 60 per cent of the new jobs are related to power generation and grids while another 20 per cent are related to energy efficiency. Unlike jobs related to energy access, those related to the construction and installation of clean-energy facilities, equipment and appliances are likely to continue growing beyond 2030, as demand for energy will continue to rise. About one-third each of these jobs are in professional services, construction and manufacturing or other occupations. Most of the jobs require extensive skills, calling for specialized training and education. Around 100 000 are low skilled, offering opportunities for those that lack access to education (IEA 2022).

The AU's Agenda 2063 specifies that renewable and clean energy sources should provide the basis for expansion of Africa's energy systems to ensure energy security and decarbonization (IEA 2022). At the 26th Convention of the Parties (COP26) to UNFCCC, several African governments made commitments related to important climate and environmental goals. Seven African countries and the East African Development Bank signed the Statement on International Public Support for the Clean Energy Transition, which stipulates the end of finance for unabated fossil-fuel-based power generation by the end of 2022. Morocco has pledged not to build any new coal-fired power plants, while Egypt has committed to phase out coal-fired power stations and South Africa has also committed to decarbonizing its economy and phasing down coal use. Twelve African countries have also announced long-term net-zero emissions pledges, aiming to reach carbon neutrality between 2050 and 2070. These include several major economies, notably Nigeria and South Africa, as well as several small island developing states and least developed countries. Notably, São Tomé and Príncipe achieved climate neutrality in 1998 using carbon sinks.

BOX 5.6 RENEWABLE ENERGY DEVELOPMENT IN MOROCCO

In Morocco in 2019 electricity generation represented 40 per cent of all energy-related CO_2 emissions – a reduction from 80 per cent of emissions from this sector in 2018. The period from 2010–2020 has been characterized by a shift towards natural gas and renewables, as well as reduced coal use. Morocco is well placed to develop renewable energy and it has geographical proximity to the European market, and a proactive strategy which has already resulted in the successful development of wind and solar power. Morocco has started an ambitious energy transition project with an aim to decarbonize Moroccan electricity. The current target calls for 52 per cent of renewable energy in total installed capacity by 2030 (Morocco, Ministry of Energy Transition and Sustainable Development 2021).

The rapid and continuous decline in the cost of renewable energies and storage has supported the decision taken by Morocco to introduce ambitious decarbonization strategies, which are focussed on the production of green electricity and hydrogen. A share of renewable sources of energy in the electricity mix of 70 per cent by 2040 and 80 per cent by 2050 in terms of both generation and capacity is possible with current technologies and cost prospects. Assessments have shown that this increase in the share of renewables should not be at the expense of Morocco's competitiveness (Morocco, Ministry of Energy Transition and Sustainable Development 2021).

An important development of renewable energy investment in Morocco is related to the Noor Ouarzazate Solar Complex (Figure 5.5). Construction began in May 2013, with further development phases in 2018 and 2019. It was funded by the Moroccan Agency for Sustainable Energy at a cost of US$ 3.9 billion, funded by several investors, including the World Bank. Noor I uses Concentrating Solar Power (CSP) to produce energy – the sun's rays heat salt which is then used to generate electricity at night.

The complex has been upgraded for Noor II and III, which can store energy for up to eight hours. Noor II uses a slightly different technology: parabolic troughs to reflect the sun's rays to heat an oil that transfers the heat to electricity-generation units. Noor III has a solar tower that collects the energy reflected from the mirrors (KCL 2021).

Combined, they cover 2 500 hectares, with Noor I producing 370 GWh per year, Noor II 600 Gwh and Noor III 500 Gwh. It would take 116.5 Noor's to supply the world with renewable energy based on 2019 demand covering approximately 290 000 hectares, which is less than 0.05 per cent of the entire Sahara Desert (KCL 2021).

Figure 5.5 Part of the Noor Ouzararte Solar Complex in Morocco

Solar off-grid solutions are becoming increasingly popular in rural African communities where energy supply is unreliable or they are beyond the reach of the national electricity grid (Box 5.7). Mini-grids are increasingly deployed as a means of electrifying rural areas in Nigeria. The mini-grids are primarily powered by solar PV combined with batteries (World Bank 2017). Supported by the Nigerian Rural Electrification Agency, a successful example of a mini-grid is in Mokoloki, a rural community in Ogun State (ESI Africa 2022). The community falls within the territory of a distribution company but did not have a reliable or consistent power supply. The mini-grid provides a local power supply which is reliable and affordable for residents and businesses. Though the mini-grid is primarily powered by solar PV, it still relies on back-up diesel generators to ensure an undisrupted supply.

The IRENA is implementing multiple national and regional programmes to scale up renewable energy in Africa. The African Clean Energy Corridor aims to accelerate renewables in East and Southern Africa with the West African Clean Energy Corridor as its geographical counterpart (IRENA 2019).

BOX 5.7 SOLAR OFF-GRID SOLUTIONS – SOLAR SISTER

Founded in 2010, Solar Sister is an initiative which provides rural communities with renewable energy through empowering women (Solar Sister 2022; Figure 5.6). It is an example of community-level action operating across Nigeria and Tanzania. To date the initiative has provided more than 3 million people with clean energy. The organization provides women with the opportunity, training and support to distribute clean energy to under-served communities. Female entrepreneurs buy durable solar-powered products and clean stoves from Solar Sister and then distribute these to friends, neighbours and even institutions, such as health clinics. To date, the initiative has engaged more than 5 000 entrepreneurs, sold over 600 000 clean-energy products, and helped to provide off-grid solutions to hard-to-reach communities.

The initiative follows a social entrepreneurship framework. Female-run sales networks are established through which women use their social networks to buy and sell products. The entrepreneurs are rooted within communities and sell directly to people in need of power. This makes for an effective business model as sellers are highly tuned to their market and are able to respond to feedback and shifting demands. In addition to their own network, Solar Sister has built strong partnerships with numerous non-governmental organizations (NGOs) and businesses that are active in the region to help provide technical support, raise awareness and expand the network (Heuër *et al.* 2017).

The initiative was supported by different donors but now roughly 30 per cent of revenue comes from sales of the-clean energy products, reflecting the business model of the initiative. This means that grants can be spent on expansion rather than solely on operational costs.

Social, economic and environmental impacts

Solar Sister provides rural communities, who previously had little or no access, with affordable renewable energy. This generates direct benefits in terms of improved quality of life and increased development opportunities. The scheme empowers women, gives them employment and a source of income. It helps to make energy supply more equitable as women are more vulnerable to energy poverty.

There are economic impacts for both sellers and customers. The initiative provides women with a source of income and some financial independence, which can be invested in education and health, while customers reap the benefit of reduced spending on kerosene fuel. There are also health benefits through replacing kerosene, as that is a source of BC.

In addition to these direct ones, there are also cascading benefits. Women, for example, experience greater autonomy, develop social networks and have a greater potential for career development. There are benefits for the wider household, increased lighting, for example, allows children to read or study for longer – in a survey of Solar Sister clients, 90.6 per cent said their children's academic performance had improved since purchasing solar lanterns (Gray *et al.* 2018). There are also benefits in terms of time saved. Gray *et al.* (2018) revealed that, on average, respondents spent 1.45 hours per week travelling to purchase kerosene. Many households stopped using kerosene after purchasing solar products, meaning this time can be spent more productively. In the same vein, solar lamps effectively extend the day for the whole household, so there is more time to do household tasks, economic or leisure activities, or even start up secondary businesses.

The initiative also generates positive environmental impacts through replacing fossil fuels and reducing emissions. The organization estimates that, since 2010, the initiative has avoided 350 000 tonnes of CO_2-eq through replacing kerosene lamps with solar ones. These impacts are in line with several of the SDGs, including SDG1 No poverty, SGD3 Good health and well-being, SDG5 Gender equality and SDG7 Affordable and clean energy.

For many African countries, extending the grid to rural communities is expensive and will take a long time. Without solar products, the primary alternative to household lighting is kerosene, which is expensive, polluting and provides poor quality light. Providing off-grid solar products enables some of the poorest communities to access basic energy needs more sustainably.

Expense or high upfront costs are often barriers to the adoption of new technologies. The affordability of products and low start-up costs for entrepreneurs, however, make opting for renewable energy an easier transition. Often the introduction of new technologies is met with resistance or scepticism, but the trusting relationship fostered between customers and sellers in Solar Sister networks helps overcome these barriers to adopting new technologies (Gray *et al.* 2018). Furthermore, the training and support and repair services provided help minimize dis-adoption of solar technologies (Heuër *et al.* 2017).

Another key to the success of Solar Sister is the strong community buy-in. This is achieved through the social networks of entrepreneurs, the in-country partnerships and consulting with community leaders before expansion (Heuër *et al.* 2017). The female-focus of the initiative also helps to overcome gender barriers as women are often amongst the poorest and most-difficult-to-reach groups. In doing so it helps to address the gendered nature of energy poverty and is a prime example of how making energy supply more equitable can lead to multiple sustainable benefits for all.

Figure 5.6 Amuro Healthcare Clinic, Kogi State Nigeria. Solar Sister provided the clinic with solar home systems and lamps during the Covid-19 pandemic. Source: Solar Sister (2022)

5.3.6 REDUCING FUGITIVE EMISSIONS FROM INDUSTRY, INCREASING EFFICIENCY, REDUCING ENERGY INTENSITY

The vital importance of steep CH_4 cuts was made clear by the Global Methane Assessment (UNEP and CCAC 2021). This shows that global anthropogenic CH_4 emissions need to be reduced by 45 per cent by 2030, relative to baseline emissions, if warming is to be limited to 1.5 oC. It also outlined the measures that already exist and could achieve this level of global reductions of CH_4 emissions if implemented widely. That could avert more than 0.3 °C of global warming by 2050 and prevent health and crop-yield impacts related to O_3 pollution, as CH_4 is an important precursor of tropospheric O_3. One of the most cost-effective ways to reduce CH_4 emissions is by targeting the fossil-fuel sector. This will require a regulatory and policy environment that can enforce the scale of change necessary.

In Africa, there is a major opportunity to address CH_4 emissions reductions from fossil-fuel extraction. Much of the mitigation in this sector could be done for low or negative costs, including through strategies such as leak detection and repair of pipelines and infrastructure. There are a variety of tools and resources available to help achieve these goals. The IEA's *Regulatory Roadmap and Toolkit* (IEA 2021a) is a guide to help policy makers establish new regulations.

The IEA's *Net Zero by 2050* report (IEA 2021b) includes a global roadmap for making the drastic CH_4 cuts necessary to avoid catastrophic warming. These guides can help countries with the difficult aspects of tackling the mitigation challenge, from understanding their individual legal and political context, through developing an emissions profile, building regulatory capacity and drafting policy, to enforcing compliance and reviewing and refining policy.

In 2019, Côte d'Ivoire and Nigeria joined the Global Methane Alliance (CCAC 2022) to significantly reduce CH_4 emissions in the oil and gas sector by 2030, committing to slash the sector's emissions by 45 per cent by 2025 and 60–70 per cent by 2030. Nigeria doubled down on this pledge in its recent NDC submission to the UNFCCC by committing to cutting emissions by 60 per cent by 2031 (Box 5.8).

During UNFCCC's COP26 in 2021, the Global Methane Pledge (GMP) was adopted by more than 110 countries, including 25 African ones (GMP 2021). Through this initiative, countries will take action to reduce global CH_4 emissions at least 30 percent from 2020 levels by 2030, which could eliminate more than 0.2 °C warming by 2050. Recognition of CH_4's role in accelerating climate change is leading governments to come forward and begin tackling this issue domestically and internationally. A perspective on what countries can learn from existing initiatives to reduce CH_4 emissions from their oil and gas industries (CATF 2021) is provided in Box 5.8.

BOX 5.8 REDUCING METHANE FROM OIL AND GAS OPERATIONS – NIGERIA'S EXPERIENCE

Nigeria is working on building on its success in reducing gas flaring, which has already been reduced by 70 per cent on 2000 levels by government policies. These include the 2016 Nigeria Gas Flare Commercialization Programme, the 2017 National Gas Policy and further gas-flare regulation in 2018 that increased flaring fines. The next goal, which was included in Nigeria's NDCs, is to fully eliminate the practice by 2030.

Fugitive CH_4 mitigation is currently a major focus for Nigeria, a challenging area of intervention given the lack of domestic data and the fact that there is no policy or regulation to address CH_4 emissions. To help achieve their NDC targets, Nigeria conducted several in-country workshops to build stakeholder capacity, developed a baseline for fugitive CH_4 emissions, identified mitigation measures and took steps to develop policy to reduce CH_4 emissions in the sector. Nigeria also has guidelines to help provide direction and best practice CH_4 mitigation.

In November 2021, the Nigerian Climate Change Law came into force. Thanks to this legal instrument, a National Council on Climate Change will be established to oversee Nigeria's climate plans. Through these, Nigeria is building an institutional and legal framework which will support the nation in reducing the impacts of climate change propel its national energy transition.

In 2020, a collaboration was initiated between the UNEP; the UNEP-convened CCAC; the Federal Ministry of Environment; the Ministry of Petroleum Resources; the Department of Petroleum Resources, the oil and gas regulator; Carbon-Limits Nigeria and the Clean Air Task Force to promote adoption of CH_4 mitigation policies in the Nigerian oil and gas sector. This will ensure the inclusion of those reduction policies in Nigeria's NDC. During this collaboration, there were several lessons learnt which can be an example at continental and international levels.

Strong inter-institutional collaboration

The Federal Ministry of Environment, the Nigerian Upstream Petroleum Regulatory Commission and the Nigerian Midstream and Downstream Petroleum Regulatory Commission, have a professional working relationship and collaborate on the topics on which their competences intersect. This allows seamless coordination between government agencies and helps establish realistic energy and climate policy. Based on this positive example and the results achieved, the ministries of energy and the environment in other jurisdictions should aim to work in a joint manner on reducing CH_4 emission from the oil and gas sector.

In 2021, during the revision of its NDC, Nigeria included a conditional goal to reduce its fugitive CH_4 emissions by 60 per cent by 2031. Nigeria is showing that there are strong institutions which are ready to engage with international actors in reducing CH_4 emissions from the oil and gas industry. Fulfilling a conditional goal in the NDC is subject to support from the international community. This sets a precedent for other countries which might need assistance to take a similar approach in their NDCs.

Energy transitions linked to energy access

In developed nations, the energy transition discussions take place while most of their population enjoy high levels of access to energy and may be focussed on diversifying energy matrices and even setting a date for ending the use of fossil fuels. In the developing world, however, there is still a pressing need to provide energy access to large portions of their societies. How these sovereign nations decide to do that will be based on many factors, including, but not limited to, access to and cost of finance, technology, geopolitical reasons, qualified human resources and existing services and infrastructure. Being cognizant of these issues is necessary for the development of any energy and climate policy.

Collaboration with industry

The Nigerian authorities invited the relevant players in the industry to comment both on the CH_4 emissions reduction target for the sector and the draft regulations. Several engagements through both physical and virtual workshops were held to increase awareness, build capacity and also enhance discussion of the contents of the guidelines. It is important for all stakeholders in a sector to be given the opportunity to voice their opinions and concerns. On many occasions, this dialogue is useful in furthering an understanding of the worries of the different sides. Throughout the process of developing policies, all stakeholders should be invited to participate to promote ownership of them and therefore more acceptance in the implementation stage.

5.3.7 INCREASED EFFICACY, REDUCING ENERGY INTENSITY AND FUGITIVE HYDROFLUOROCARBON EMISSIONS FOR COOLING

As of 2016, the production and consumption of HFC refrigerants are managed under the Kigali Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer. Under the Kigali Amendment HFC phase-down schedule, African countries will freeze their consumption of HFCs in 2024 and begin phasing it down through four steps concluding in an 80 per cent reduction compared to their baseline in 2045. Emissions of HFCs, however, continue to be managed by the UNFCCC through which countries pledge their mitigation ambitions and action through NDCs under the Paris Agreement. As of 2022, the inclusion of HFCs in NDCs varies across Africa but the Kigali agreement has seen HFCs gaining attention since 2016.

Although HFCs remain absent from some countries' national reporting, others not only quantify emissions but outline mitigation options and progress. For example, Gambia's 2021 NDC states their ambition to mitigate HFC emissions from production and manufacturing and highlight its work with the United Nations Industrial Development Organization (UNIDO) to substitute HFCs with hydrocarbons for refrigeration and air conditioning. Activities include redesigning cooling products, extending the lifespan of existing ones through training technicians to handle and repair appliances and supporting governments to monitor the import and consumption of HFCs. Gambia estimates that this substitution of HFCs has a mitigation potential of 804 000 tonnes of CO_2-eq by 2030, realizing, however, that this potential is conditional on financial support and technology transfer (United Nations Climate Change 2021). Mauritius is advanced in its HFC control with the 2021 Biennial Update Report (BUR Mauritius 2021) outlining action already taken to phase out HFCs.

To tackle the challenge of imports of used, obsolete and inefficient cooling appliances, known as dumping, a growing number of countries have established anti-dumping laws. In 2013, Ghana established a ban on imports of used cooling appliances and, along with a capacity-building and awareness raising campaign supported by the Green Climate Fund, new devices made up 95 per cent of Ghana's refrigerator sales in 2019 (GCI 2020). Rwanda approved a similar ban in 2019, along with regulations requiring new cooling equipment to meet minimum energy-performance standards (Box 5.9).

In addition to direct climate benefits, mitigating HFC emissions from the cooling sector can achieve further climate and economic benefits through improvements in the energy efficiency of refrigerators, air conditioners and other products and equipment that use HFCs. As countries work to comply with the Kigali Amendment phasedown, there is an opportunity to transform markets to energy-efficient cooling equipment to achieve additional climate benefits and cost savings. Botswana, Eswatini, Lesotho, Malawi, Namibia, Tanzania, Zambia and Zimbabwe are collaborating with United for Efficiency (U4E) on Green Climate Fund readiness projects for leapfrogging to energy-efficient refrigerators. The U4E initiative helps countries implement an integrated policy approach to enable a sustainable and cost-effective transformation to energy-efficient equipment and appliances.

BOX 5.9 RWANDA'S NATIONAL COOLING STRATEGY

In 2018, to oversee the development of the National Cooling Strategy, Rwanda formed the Rwanda Cooling Initiative (R-COOL) in collaboration with the U4E initiative and support from the Kigali Cooling Efficient Programme. The aim of R-COOL is to showcase the multiple benefits of a rapid and comprehensive transition to energy-efficient and climate-friendly air conditioners and refrigerators.

R-COOL first conducted a cooling-market assessment to understand the current stock, growth projections, impacts on electricity demand and key actors in the cooling sector. The assessment estimated benefits in 2030 from transforming Rwanda's cooling market would be to save 164 GWh of electricity, save customers US$ 40 million in reduced energy bills, and avoid 109 000 tonnes of CO_2-eq emissions.

Based on this assessment, Rwanda conducted a series of consultations with government officials and stakeholders to develop the National Cooling Strategy which was published in 2019 (Rwanda Ministry of Environment 2019). The Strategy includes objectives and implementation timelines for minimum energy-efficiency standards, links to existing energy policies and the refrigerant management plan under the Montreal Protocol, and recommendations for a national product registration system. It also includes recommendations for reducing cooling demand through improved building codes, promoting alternative and passive cooling solutions, such as shading and natural ventilation, and improving operations and maintenance.

R-COOL also identified several financial mechanisms to help address some of the key barriers to purchasing clean and efficient products in Rwanda. This includes a dedicated leasing product called Coolease, the first of its kind in Africa that enables suppliers and consumers of cooling equipment to transition to the latest technology without an upfront investment (Fonerwa, 2019).

Finally, the National Cooling Strategy of Rwanda identified government entities to be responsible for oversight, coordination and implementation. The Ministry of Environment is responsible for oversight of implementation as well as development of policy guidance and strategic orientation, while the Rwanda Environment Management Authority is mandated to monitor and report on activities of the National Cooling Strategies.

5.4 RECOMMENDATIONS TO INCREASE IMPLEMENTATION OF MEASURES

MAIN MESSAGES

- To achieve greater integration of air-pollution and climate change mitigation, and achieve the emission reductions that will reduce health and environmental impacts, the 37 priority mitigation measures need to build on the following linkages:
  - Almost all of the measures are being considered in the Nationally Determined Contributions (NDCs) of African countries under the UNFCCC and are identified as contributing to achieving national climate change mitigation goals;
  - The measures are closely aligned with key priorities of AU Agenda 2063;
  - The measures align closely with the goals and targets of the SDGs;
- Actions across the five key areas involving implementation of the 37 recommended measures at scale requires partnerships to pool technical and financial resources;
- The Assessment contains recommendations across six different scales and types of action and considers relevant institutions and timelines that could promote implementation of the measures. Recommendations cover the following broad categories:

- Communication and awareness raising;
- Planning;
- Financing and resource mobilization;
- Policy development, legislation, regulation, compliance and enforcement;
- Strengthening scientific, technological and technical capacity;
- Governance and institutional coordination, including horizontal (local, national, and regional-South – South) and vertical (between sectors – integration) and South-North partnerships.

- The recommendations for implementing the 37 measures are targeted at, but not limited to the following stakeholders:
  - African multilateral institutions and policy organs;
  - Regional Economic Communities (RECs);
  - National governments of African countries;
  - Local governments and city authorities;
  - Inter-governmental organizations;
  - Non-Governmental Organization
  - The Private sector;
- The Assessment recommends the development and implementation of a continent wide:
  - Africa Clean Air Program;
  - African transboundary convention for the prevention and management of air pollution;
  - Africa program for sustainable waste management.

5.4.1 INTRODUCTION

The modelling presented in Chapters 2 to 4 of the Assessment demonstrates that there are key mitigation measures that can contribute to an improvement in human health across Africa through improved air quality, while simultaneously reducing Africa's contribution to climate change and the achievement of other Agenda 2063 priorities. The case studies highlighted in Section 5.3 demonstrate that for many of the 37 measures recommended in the Assessment, implementation has already occurred somewhere in Africa. This suggests that the significant health, climate and sustainable development benefits estimated in this Assessment need not remain as theoretical but can actually be realized. Their achievement, however, requires their large-scale implementation across the continent. To do so requires multiple institutions, organizations and initiatives working at global, continental, sub-regional, national and sub-national scales to be involved. Figure 5.7 shows a range of institutions and organizations operating across different scales, including pan-African, sub-regional, national, urban and rural. Institutions ranging from the local to Africa-wide scales, that all have different abilities and roles in promoting the implementation of the 37 recommended measures in different sectors in a way that aligns air pollution, climate change and development.

The aim of this final section of the Assessment is to outline a set of recommendations which constitute practical action that institutions at African, regional, national, and sub-national scales can take forward to promote the implementation of the 37 measures included in the Assessment. The recommendations are summarised in Table 5.2 and are disaggregated into ones specific to institutions working at different scales. Recommendations cover the following broad categories:

- communication and awareness raising;
- planning;
- financing and resource mobilization;
- regulation, policy development and legislation;
- strengthening capacity;
- coordination, horizontal and vertical institutional integration.

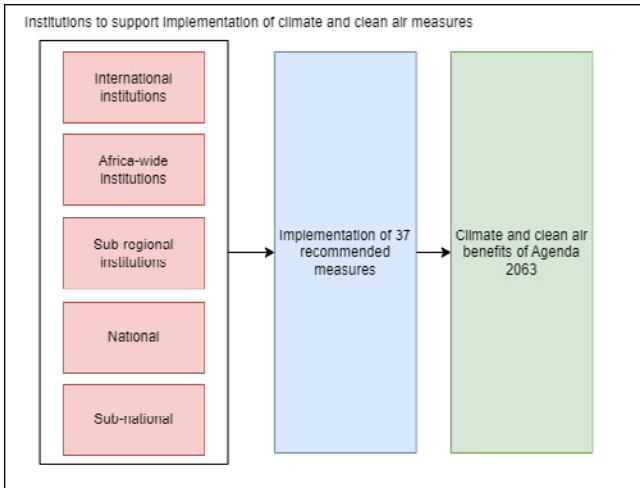

Figure 5.7 Opportunities to promote the 37 recommended measures at different scales that help achieve climate, air quality and development goals in Africa

The recommendations at different scales have been developed during the entire Assessment process and through regular engagement with the AUC and other key stakeholders and through the engagement of chapter authors, the co-chairs, UNEP and the UNEP-convened CCAC with decision makers (Table 5.2). At the African scale the AU is the key stakeholder but there are other pan-African stakeholders including NEPAD and the African Development Bank. At the regional scale there are a number of different institutions

coordinating the activities related to the countries in these regions, including EAC, ECCAS, ECOWAS, SADC and, the Intergovernmental Authority on Development (IGAD) (Table 4.3). A lot of the planning on strategies that will affect emissions in Africa and the realization of development opportunities will be at the national government level. Action will, however, be taken at the local level requiring close links between the sub-national, national and regional scales. The recommendations that have been derived as part of the Assessment are summarized in Table 5.2, and the recommendations at the different scales are further described in the subsequent sections, their rationale outlined, their links highlighted and practical examples and suggestions as to how these recommendations can be operationalized are provided. The intention is that these can then be picked up and realized by relevant stakeholders for the different scales.

Table 5.2 Overall recommendations of this Assessment to be taken forward at different scales by different stakeholders

RECOMMENDATION	RELEVANT INSTITUTIONS
1. PAN-AFRICAN: AFRICAN UNION; AFRICAN MINISTERIAL CONFERENCE ON THE ENVIRONMENT; AFRICAN UNION DEVELOPMENT AGENCY; UNITED NATIONS ECONOMIC COMMISSION FOR AFRICA; AFRICAN DEVELOPMENT BANK	
1.1 Integrate this Assessment's results into the 2nd Agenda 2063 Ten Year Implementation Plan and related plans, e.g., AU Climate Change and Resilient Development Strategy and Action Plan (2022–2032); align with the AU's Green Recovery Action Plan (2021–2027)	AU (and relevant organs, including AMCEN, African Ministerial Conference on Meteorology (AMCOMET) and specialized agencies), Ministerial Committee on Agenda 2063
1.2 Integrate this Assessment's results into existing or establish new Agenda 2063 Flagship Programmes on the mitigation measures	AU Ministerial Committee on Agenda 2063
1.3 Develop a continental programme of air quality management – the Africa Clean Air Program – bringing together countries and all concerned stakeholders to develop a continent-wide platform for the collection and sharing of data, utilizing all existing data and information sources. Also, increasing capacity and equipment for new data collection and management, monitoring and evaluation, emissions and air quality modelling, and education and communication to promote more comprehensive air quality management across the continent. All this should be combined with the development of an African transboundary convention for the prevention and management on air pollution, given the common problems and transboundary movement of polluted air in Africa	AUC
1.4 Integrate this Assessment's measures in the African Economic Outlook	AfDB
1.5 Encourage discussions on promoting the recommended measures amongst African environment ministers	AMCEN
1.6 Stimulate championing of continent-wide climate change advocacy of this Assessment 's results in Africa	Climate Action Network, C40 Cities Climate Leadership Group, Local Governments for Sustainability (ICLEI – Local Governments for Sustainability)
1.7 Integrate measures in project financing	AfDB, AUC, African Union Development Agency (AUDA-NEPAD), UNECA
2. AFRICAN SUB- REGIONS: ECONOMIC COMMUNITY FOR WEST AFRICAN STATES; EAST AFRICAN COMMUNITY; ECONOMIC COMMUNITY OF CENTRAL AFRICAN STATES; SOUTHERN AFRICAN DEVELOPMENT COMMUNITY; INTERGOVERNMENTAL AUTHORITY ON DEVELOPMENT	
2.1 Integrate measures into regional plans	RECs
2.2 Enhance capacity in regional institutions to take forward the action agenda and develop specialist centres in regions	RECs in partnership with academia, the public and the private sector
2.3 Establish regional standards/regulations/ enforcement of key measures	African Regional Organization for Standardisation (ARSO), national standards bodies (NSBs), RECs
2.4 Use regional agreements to push forward the African Assessment measures	SADC, EAC, ECOWAS, ECCAS, Arab Maghreb Union (UMA)
2.5 Finance regional processes and institutions to take forward the African Assessment findings at regional scale	AfDB, AUDA-NEPAD, multilateral development banks (MDBs), AU financial institutions

3. NATIONAL SCALE: MEMBER STATES	
3.1 Integrate recommended measures into NDCs where these are lacking but relevant	Member States
3.2 Develop integrated planning across government and fund the process	Government departments and agencies
3.3 Enhance the institutional capacity to undertake planning and follow up implementation	Relevant ministries and agencies
3.4 Integrate mitigation action into voluntary national reporting to the SDG framework	Ministries of environment, environmental management agencies
3.5 Allocate national budgets to implement recommended measures	Ministries of finance
3.6 Build effective inter-ministerial cooperation	Relevant ministries
3.7 Engage with and incentivize the private sector to mitigate emissions	Relevant ministries and private sector
4. URBAN SCALE	
4.1 Create a link between urban and national planning	Local government, ministries of environment, etc.
4.2 Integrate reduction of SLCPs and air pollution into urban planning concerning households, waste, transport and industry	Local governments, municipalities
5. RURAL SCALE	
5.1 Effective promotion of alternatives to burning	NGOs, Civil Society Organizations (CSOs)
5.2 Extend availability of alternatives to traditional biomass stoves to rural areas	NGOs and relevant ministries
5.3 Empower women to implement relevant recommended measures	Ministries of energy, NGOs, forestry agencies
5.4 Training and capacity building on the recommended agricultural measures	Ministries of agriculture, academic institutions, NGOs
5.5 Infrastructure for distribution of clean fuels and goods	National and local governments, municipalities
6. INTER-GOVERNMENTAL ORGANIZATIONS AND NON-GOVERNMENTAL ORGANIZATIONS: E.G., UNITED NATIONS DEVELOPMENT PROGRAMME, UNEP, WHO, WORLD BANK, THINK TANKS AND C40 CITIES CLIMATE LEADERSHIP GROUP.	
6.1 Provide support to access finance and allocate funds to implement the recommended measures	Intergovernmental agencies, bi-lateral and multilateral donors and NGOs
6.2 Promote best practice in planning action at national and sub-national scales	Relevant intergovernmental agencies and partnerships and NGOs
6.3 Promote uptake of key environmental resolutions	Relevant intergovernmental agencies and national governments and NGOs
6.4 Enhance human and institutional capacity related to knowledge, develop data, legal aspects, tools, methods, etc.	Relevant government and supporting institutions, e.g., universities
6.5 Harmonize and coordinate support from international organizations to maximize impact	Relevant intergovernmental agencies, national governments and NGOs

5.4.2 OPPORTUNITIES FOR AFRICAN-SCALE ACTION

At the African scale, there are opportunities to tie in with existing activities of the main pan-African organizations and initiatives, as well as initiating further activities promoting action across Africa. The AU and AMCEN provide opportunities to promote the measures outlined in this Assessment and secure their implementation. The AfDB can also play a role in highlighting the economic benefits of the mitigation measures identified as priorities in this Assessment through the African Economic Outlook. It can also provide access to finance to mobilize resources to fund projects that increase implementation of action on specific SLCPs, integrated air pollution and climate change. The recommendations as to how Africa-wide institutions can increase implementation of the 37 mitigation measures are listed in Table 5.2 and described in more detail below.

Integration into continental planning

To achieve greater integration of air-pollution and climate change mitigation and achieve the emission reductions that will reduce health and environmental impacts, the 37 priority mitigation measures need to be reflected or aligned with key continental planning documents. For example, the AU Climate Change and Resilient Development Strategy and Action Plan (AU 2022a) has been developed in alignment with the UN Agenda 2030 (the 17 Sustainable Development Goals), the Paris Agreement, commitment to the NDCs, the Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030 (actions to protect development gains from the risk of disasters), AU Agenda 2063, and other AU instruments and programmes of action devised to implement the aforementioned initiatives that are in one way or another helping in tackling the impact of climate change. Mapping of the 37 measures in this assessment with the SDGs and their targets (Tables 3.11 to 3.15) and the NDCs of Africa countries (Table 5.2) will help facilitate this process.

The AUC is the principal organization in Africa responsible for spearheading socioeconomic development, supporting the implementation of sustainable development commitments and goals set for Africa through AU structures and programmes. The AUC has been a key partner in this Assessment and is also in the process of operationalizing the African Union's Climate Change and Resilient Development Strategy and Action Plan which was developed to guide, coordinate and support the continent's response to climate change for the period 2022–2032. The Strategy is overarching and provides tremendous scope for the development of projects for specific interventions that could meaningfully link to the results of this Assessment, providing room for the adoption and implementation of the 37 mitigation measures it modelled at regional and AU Member State levels. The mitigation measures modelled in the Assessment resonate well with the Strategy's strategic intervention axes 2 and 4.

The relevant strategic interventions include enhancing climate-resilient and low carbon energy and infrastructural systems; promoting low-carbon, resilient mobility and transport systems; inclusive, low-emission and resource efficient industrialisation; building low-carbon, resilient urban areas; enhancing access to renewable energy and climate-resilient agriculture. In order to ensure the success of the Strategy, the AUC is working together with its partners, to enhance the operationalisation of the Strategy and to address any barriers to its implementation and 'domestication' by Regional Economic Communities and AU Member States.

The AUC is also in the process of rolling out the implementation of the AU Green Recovery Action Plan (GRAP) 2021–2027. This is intended to support the socioeconomic and environmental dimensions of the continent's recovery response to the devastating impacts of the COVID-19 pandemic. It seeks to achieve measurable results by coordinating interventions in five priority areas, namely, climate finance; renewable energy; nature-based solutions and biodiversity; resilient agriculture; and green and resilient cities. Several of the mitigation measures in this Assessment are included under the renewable energy priority area of the GRAP. Some of the activities support the development of credit enhancement instruments to fast track and enhance private sector investment in Africa's renewable energy initiatives; others encourage enhanced work on clean-cooking technologies and building national capacities to promote their uptake; yet more work to secure public and private investment and technology transfer in grid expansion, and improvements in energy distribution and efficiency to widen access to electricity and provide support to African countries in their just plans for transitioning away from the use of biomass and fossil fuels while providing energy for all. The AUC is in the process of engaging international partners and donors for implementation of the GRAP.

The environmental agenda in Africa is set by AMCEN, for which UNEP's Regional Office for Africa (ROA) serves as the secretariat. The Conference brings African governments, institutions and development partners together to craft policies aimed at tackling the continent's most pressing environmental issues, providing policy advice and guidance to the AU. Other ministerial bodies such as the African Ministers' Council on Water (AMCOW) and the Conference of Ministers of Agriculture of the AU complement AMCEN's activities

At its sixteenth session in June 2017, AMCEN adopted a decision on investing in innovative environmental solutions for accelerating implementation of the SDGs and Agenda 2063. The decision calls for appropriate measures to promote and invest in innovative policy interventions, including replication, to sustain and improve the productivity of natural capital to accelerate implementation of Agenda 2030, including the SDGs, as well as and Africa's Agenda 2063. It highlights the need to promote development and strengthening partnerships between governments, the private sector, NGOs, international community and other relevant parties to promote and enhance investments in innovative environmental solutions.

At its seventeenth session in November 2019, AMCEN climate change negotiators took the landmark Decision 17/2 acknowledging the importance of SLCPs, and "*the need for an assessment of the linkage between policies to address air pollution and policies to address climate change*". The Decision cemented the relationship between this Assessment and the AUC.

Continental advocacy

There is also scope for the integration of the key messages of this Assessment within continent-wide climate change advocacy, which has grown considerably in the past few years in Africa. The scope of climate change advocacy in African countries often intersects with a range of other environmental, social and political issues. The national-level impact of these advocacy initiatives is, however, not obvious. Moreover, the lifespan of such organizations is often determined by the length of their funding, which often comes from international sources. That said, these advocacy groups are a useful channel for messages to society as they employ the relevant forms of communication and interaction. Some of those that have a continental reach include the Climate Action Network (CAN)[13]. Another group of influential players on climate change in the African continent are the cities. Some of the city-focussed organizations that

13. https://climatenetwork.org/

enable tangible local government climate action and have a continental reach include ICLEI[14] and the C40 Cities Climate Leadership Group[15]. The 37 mitigation measures within this Assessment provide a practical set of activities which climate advocates and groups across the continents can integrate into their calls to action, plans and strategies.

International financing

Across the continent, substantial financing is required to implement the 37 mitigation measures included within this Assessment to achieve real-world health, climate and development benefits. This includes continent-scale financing through, for example, the AfDB. The finance for implementation of the recommended measures will be derived from both domestic and external sources. There is an opportunity for national governments in Africa to use planning and budgeting tools to provide finance for the measures within their regular budgeting processes. Financial instruments, such as sustainability bonds, tax incentives and subsidies, can be used to facilitate complementary financing from domestic private-sector actors in sectors such as energy and waste management.

External finance is also expected to play a major role in filling gaps. This includes bilateral and multilateral sources, in form of grants, loans and equity. An understanding of the current external financial landscape and its interest in air-quality management is essential in generating recommendations for directing finance to support the implementation of the clean air measures. According to analysis conducted for this Assessment, using the AidAtlas, a web-based tool that monitors development finance flows[16], the availability of finance for climate change and air-quality action is insufficient to achieve the substantial climate and clean benefits outlined in this report (Sections 3.4 and 4.5). Tackling air pollution is not considered a primary policy or programme objective of development cooperation (Clean Air Fund 2021) thereby making it difficult to track. Since air-pollution control is often tagged as a co-benefit of externally funded climate mitigation projects, AidAtlas can provide an understanding of funding trends for Africa as part of overall public climate finance, as well as targeted allocations for air pollution and addressing subsequent health issues. Development partner reporting for air pollution is also tagged using the Common Reporting Standard (CRS) code 41020 – Biosphere Protection under sector label General Environment Protection. The following overview shows the funding streams to Africa under climate mitigation as well as General Environment Protection.

From 2002 to 2019, US$ 51 billion were committed by all donors in development finance to Africa for climate mitigation. AidAtlas combines the separate Multilateral Development Banks (MDBs) dataset used to report climate related development finance and shows that of the US$ 51 billion 28.6 billion was committed by donor commitments other than the MDBs, and that of this only US$ 15 billion has been dispersed.

The funding trends have risen over time. Data from 2019 shows disbursement of more than US$ 1.4 billion in official development spending to projects with the primary or secondary objective of improving air quality (Clean Air Fund 2021).

Throughout 2002–2019, the energy sector dominates in climate mitigation funding with 54.5 per cent of funds, US$ 8 198.36 million disbursed to this sector, followed by general environment protection with US$ 2 433.55 million, 16.2 per cent of the total disbursed. Transport and storage is the second largest sector in which US$ 5.81 billion has been committed to climate mitigation. Other sectors that are shown in this Assessment to have significant opportunities for integrated climate change and air pollution benefits, such as agriculture and waste, received substantially smaller funding amounts compared to the energy sector. The leading sources of finance were France, US$ 6.47 billion; International Development Association, US$ 5.56 billion; and Germany US$ 4.36 billion. The countries receiving the most finance were Egypt, US$ 8.36 billion and Morocco, US$ 6.92 billion; with a total of US$ 4.53 billion going to other African countries.

In 2002–2019, US$ 18.1 billion were committed by all donors in development finance to Africa for general environment protection out of which US$15.2 billion have been dispersed. Of the amount disbursed, US$ 13.3 billion (87.5 per cent) was provided as ODA grants, while US$ 1.45 billion, 9.5 per cent, was provided in the form of ODA loans. The sub-sector of biosphere protection, which covers air pollution control, however, only received US$ 1.59 billion in 2002–2019. The largest sources of bilateral finance were the US, US$ 1.74 billion; Germany, US$ 1.57 billion; and European Union institutions, excluding the European Investment Bank, US$ 1.24billion; while the Global Environment Facility was the largest multilateral funding agency, providing US$ 2.12 billion.

The recommendations highlighted in Table 5.2 for the pan-African scale emphasize the importance of integrating the 37 mitigation measures into key pan-African planning documents, such as those produced by the AU. It also emphasises the

14. https://iclei.org/
15. https://www.c40.org/
16. https://www.sei.org/projects-and-tools/tools/aid-atlas/

importance of ensuring adequate access to finance for the implementation of the mitigation measures. While this is not solely achieved through pan-African institutions such as the AfDB, they play a key role in financing projects across the continent and can therefore play an important role in funding projects that demonstrate the substantial benefits that priority measures for integrated air pollution and climate change can provide when implemented across Africa.

5.4.3 OPPORTUNITIES FOR REGIONAL ACTION

Regional organizations across Africa include RECs (Table 4.3), on which the majority of regional recommendations in Table 5.2 are focused. Across Africa the RECs provide opportunities for countries within regions to act simultaneously to implement the 37 measures, for example, through common regulations and standards, or through sharing experience and best practice on implementing the mitigation measures and overcoming barriers. A key first step is to anchor and operationalize all the regional framework agreements (RFAs) on air pollution within the respective RECs, which will allow for the RFAs to be embedded in the REC's work programmes. More detail is provided on each recommendation in Table 5.2.

Some action on air pollution at regional scales is already ongoing in Africa, in particular in relation to fuel quality (Section 4.3). The EAC, ECOWAS and SADC started to make commitments to reducing the sulphur content of fuels in 2018 and 2019. In EAC countries, sulphur content in diesel is limited to 10 ppm in Kenya and Uganda, paving the way standards of 10 ppm for the whole of the EAC to be introduced in 2022; ECOWAS countries agreed to limit sulphur contents in petrol and diesel to 50 ppm by 2021; while SADC countries have agreed to reduce sulphur levels in fuels to 50 ppm or less by the end of 2022 for importing countries and by 2025 for countries with refineries, and eventually to 10 ppm between 2025 and 2030 for all countries (Stratas Advisors 2020). In addition, ECOWAS countries agreed that all vehicles that are imported, both new and used, and petrol and diesel, would need to comply with a minimum of the EURO 4 vehicle emissions standard from 1 January 2021. An age limit for used vehicles of 10 years was also agreed, with a recommendation of a five-year age limit for light duty vehicles (CCAC 2020).

There are some air quality measures for which optimal benefits are best realised through regional, transboundary policies, involving cooperation among countries within a particular region, such as on fuel quality and vehicle emission standards. The import and manufacture of other key technologies, such as clean cooking stoves, could also be developed at a regional scale by setting regional emission standards rather than each country developing their own, as is currently the case. A regional approach could help cut costs and increase the speed of implementation. Sharing best practice on developing and implementing measures between countries can also speed up implementation, as can regional access to international funds, rather than on a nation-by-nation basis.

Electricity trade between African countries could be considerably increased. This would reduce total energy costs and increase energy security. Working together would boost trade and bring benefits to the economies of participating countries and promote the socioeconomic wellbeing of their populations. It would be necessary, however, to remove existing barriers to trade to achieve this, and action must be taken to introduce the reforms that are needed to attract investment.

Regional power pools provide for more cost effective and efficient ways of managing supply and demand by building on comparative advantages of individual countries. As an example, the WAPP is trying to improve the distribution network in West Africa, given that the major sources of electricity supply are located far from the main centres of consumption. The region has, for example, more than 23 000 MW of technically exploitable hydropower capacity (World Bank 2021b) but this can only be tapped if the transmission network in the whole region improves. At the moment about 6 per cent of electricity is traded in West Africa, but this could increase with investment that is being developed under the WAPP programme. An example of progress has been the development of a transmission line between Bolgatanga in Ghana and Ouagadougou in Burkina Faso, which has had a major impact on the quality of service provided by Société Nationale d'électricité du Burkina Faso and the cost of electricity has been reduced from US$ 0.26 per kWh to US$ 0.20 per kWh and power outages have been reduced (World Bank 2021b). Additional benefits from reduced air pollution have not yet been quantified.

The recommendations for the regional scale therefore build on agreements and initiatives that are already being implemented within some RECs through the development of common standards that allow benefits from, for example, energy efficiency, fuel

quality and vehicle emissions standards to be enjoyed across regions rather than in individual countries. Secondly, many countries are already advanced in the implementation of the 37 measures, and/or overarching planning processes that integrate air pollution and climate change (Section 5.4.4). It is recommended that these examples of best practice are shared across the region, for example, coordinated by RECs to ensure that experience in one country can be utilized and benefit others where relevant.

5.4.4 OPPORTUNITIES FOR NATIONAL ACTION

The national scale is often the one at which high-level political commitment, the allocation of a budget and other necessary components of implementing SLCP, air pollution and climate change mitigation measures takes place. Almost all countries in Africa participate in international climate change policy processes through the UNFCCC, and the national scale is often where air quality legislation, regulations, plans and strategies are developed. The recommendations for national governments (Table 5.2) therefore highlight the need to integrate the 37 mitigation measures within different planning processes, especially those focussing on climate change and air pollution, and include them within national budget allocation processes. To assess opportunities and provide recommendations for national action to further the implementation of the 37 mitigation measures identified in this Assessment, the current state of inclusion of these measures and the integration of air pollution and climate change in national plans and strategies are assessed in this section.

The Paris Agreement commits all countries to submit NDCs that describe a country's commitments to reduce GHG emissions to the UNFCCC at five-year intervals. Integration of the 37 mitigation measures within NDCs is recommended because:

- it ensures that mitigation measures achieving local benefits for health and sustainable development are reflected in climate change commitments;
- it can increase national climate change mitigation ambitions, necessary to achieve the goals of the Paris Agreement;
- access to international funding mechanisms, such as the Green Climate Fund, can be facilitated through inclusion of specific measures within NDCs.

Many countries are already including the 37 mitigation measures within their NDCs, , explicitly or implicitly, and/or are highlighting the importance of local air pollution and health benefits. Analysis of these NDCs, therefore, provides a useful snapshot of how African countries are already committing to implementing the 37 mitigation measures identified in this Assessment.

Analysis of Africa's NDCs demonstrates that countries in the region are global leaders in the integration of SLCPs and air pollutants into climate change commitments. The Stockholm Environment Institute and the UNEP-convened CCAC have developed an NDC Tracker which assesses different aspects of how countries have integrated SLCPs into their NDCs (CCAC 2019). In this Assessment, the NDCs submitted by African countries between 2015 and 2022 were analysed to identify:

i. language related to SLCPs, air pollution and health;
ii. targets relevant for SLCP and air pollutant reductions; and
iii. the identification of specific measures to achieve climate change mitigation targets.

The mitigation measures included within NDCs were mapped to this Assessment's 37 mitigation measures to evaluate the extent to which these are included in existing national climate change plans (Table 5.3). Analysis of African countries' submissions shows significant integration of SLCPs and air pollutants into climate change plans already, as well as substantial potential for further integration.

Methane and HFCs, which are also GHGs, are included within the scope of overall GHG reduction targets of a large number of African countries. For CH_4, 92 per cent of African countries include its emissions within the scope of their GHG reduction target. Additionally, 43 per cent of countries include HFC emissions within their GHG reduction target. The inclusion of CH_4 and HFCs within GHG reduction targets is important because it means that the implementation of mitigation measures that reduce them will be counted towards achieving the GHG reduction target. This provides motivation to prioritize CH_4 and HFC mitigation measures.

For SLCPs, such as BC, and other air pollutants, a minority of African countries include these within their NDCs. Those countries that do, however, provide some of the most comprehensive considerations of SLCPs and air pollutants in NDCs from any country. Below are some examples of the inclusion of SLCPs and air pollutants within NDCs from African countries.

- **Acknowledging the importance of reducing SLCPs and air pollutants alongside climate change mitigation.** Several African countries included general statements highlighting the importance of achieving air pollution and SLCP reductions as part of climate change mitigation. For example, Nigeria's 2021 NDC update states "*Nigeria recognizes the importance of taking actions to reduce SCLPs such as BC,* CH_4 *and HFCs, alongside GHGs*".
- **Highlighting SLCP and air pollutant mitigation as co-benefits from NDC implementation.** This Assessment shows that the implementation of mitigation measures, particularly the 37 recommended mitigation measures, can simultaneously reduce emissions of multiple GHGs, SLCPs and air pollutants (Chapter 3). This means that policies and measures included in NDCs to achieve GHG reduction targets may also result in reductions in SLCPs and air pollutants. Several African countries have acknowledged that the policies and measures underpinning their climate change mitigation targets could achieve additional benefits through air pollutant and SLCP emissions reductions. Rwanda, for example, states that its mitigation measure to increase the efficiency of its brick kilns will "*increase resilience of the brick manufacturing industry and reduce reliance on biomass energy and related air pollution*". Meanwhile, South Africa's 2021 NDC states "*implementing the NDC will require the implementation of South Africa's Integrated Resource Plan, which contemplates a massive investment in renewable energy over the next decade. This will also result in a number of co-benefits, such as reduced air pollution in the key pollution hot spots of the country, with health co-benefits; lower water use in a water-scarce country; and rapidly adding additional electricity generation capacity to the electricity system, when it is capacity constrained*".
- **Quantification of air pollutant and SLCP reductions from NDC implementation.** To fully understand the benefits from NDC implementation on reducing SLCPs and other air pollutants requires their inclusion within the mitigation assessment that evaluates the impacts of policies and measures being considered for an NDC. While this is less common than the other types of acknowledgements, there are a few examples of African countries that have quantified the impact of implementing their NDC on the magnitude of air pollutant and SLCP emissions. In Côte d'Ivoire, for example, the impact of the mitigation measures included in its 2022 NDC would result, in addition to a 98 per cent reduction in GHG emissions, in a 30 per cent reduction in CH_4 emissions, a 58 per cent reduction in BC emissions, a 64 per cent reduction in $PM_{2.5}$ emissions and a 42 per cent reduction in NOx emissions in 2030 compared to this Assessment's baseline scenario.
- **Quantification of health benefits from NDC implementation.** The ultimate motivation for the integration of air pollution and SLCPs within climate change planning is to achieve tangible improvements in public health locally. Using health-impact assessment methodologies, Côte d'Ivoire, Ghana and Nigeria all laid out the expected health benefits that could be achieved from the reduced air pollution resulting from the implementation of their NDCs. The achievable 7 000, 2 900 and 30 000 avoided premature deaths in 2030, compared to country baselines, in Côte d'Ivoire, Ghana and Nigeria respectively, demonstrates that there are significant health benefits that could be achieved when air pollution and SLCPs are integrated into climate change planning across Africa. These countries were the first in the world to include quantified health benefits in their NDCs, demonstrating that NDCs are not only climate change plans, but can be effective tools and mechanisms to improve public health.

The broad inclusion of air pollution and climate change in multiple climate change plans demonstrates that there are already a number of African countries that are identifying, evaluating and prioritising air pollution, SLCPs and public health alongside climate change mitigation. It also provides a clear, practical example to other countries who are interested in how local air-pollution benefits can be integrated into climate change planning. In addition to the explicit integration of air pollution and SLCPs into NDCs outlined above, many other African countries have also implicitly included air pollution and SLCP reduction in their NDCs and climate change plans because of the specific policies and measures that are identified as contributing to the implementation of the plan. Table 5.3 shows all 37 mitigation measures for air pollution and climate change mitigation in this Assessment and highlights the number of countries in Africa that have included these measures in their pre-2020 NDCs, i.e., NDCs submitted after a country ratified the Paris Agreement, and post-2020, i.e., in NDCs submitted before COP26 in what was the first NDC update for most countries.

Table 5.3 Africa, countries including each of the 37 mitigation measures included in this Assessment in their pre- and post-2020 Nationally Determined Contributions

Source: Malley *et al.* (2022)

MEASURE ID	MEASURE	DESCRIPTION	NUMBER OF COUNTRIES INCLUDING RECOMMENDED MEASURES IN PRE-2020 NDCs	COUNTRIES INCLUDING RECOMMENDED MEASURES IN PRE-2020 NDCs (%)	NO. OF COUNTRIES INCLUDING RECOMMENDED MEASURES IN POST-2020 NDCs	COUNTRIES INCLUDING RECOMMENDED MEASURES IN POST-2020 NDCs (%)
T1	Passenger electric vehicles	Key to reducing road transport GHG and SLCP emissions	5	9.6	20	37.7
T2	Advanced emissions controls for road vehicles	Advanced emissions controls, which also required low sulphur fuels, can help reduce tailpipe emissions from remaining ICE vehicles in the medium term as EVs are introduced	11	21.2	16	30.2
T3	Hybrid vehicles	Hybrid vehicles are a main measure for improving vehicle efficiency other than full electrification	21	40.4	25	47.2
T4	Public transport	Higher-occupancy public transport is cleaner and more energy efficient than private cars	23	44.2	32	60.4
T5	Non-motorized transport	Cycling and walking promote health, save energy and reduce emissions from transport	23	44.2	32	60.4
T6	Switch freight from road to rail	Rail transport is more energy efficient and easier to electrify than road freight.	3	5.8	8	15.1
T7	Rail electrification	Moving from diesel to electric to reduce emissions	3	5.8	8	3.8
T8	Road freight electrification	Zero carbon freight at point of use	5	9.6	20	37.7
H1	Clean lighting	Electric lighting provides better conditions, avoids harmful pollutants and saves energy	3	5.8	5	9.4
H2	Clean cookstoves	Cooking is a key source of harmful household air pollution and traditional biomass cookstoves are placing an increasing burden on the wood resources.	33	63.5	34	64.2
H3	Efficient air conditioning	Although small now, as incomes grow, ACs will become an important contributor to overall and peak energy use. Efficient ACs can help reduce growth in demand and avoid use of dirtiest peak-load power plants	34	65.4	40	75.5
H4	Efficient refrigeration	As with ACs, refrigerator use will grow considerably by 2063. Efficient fridges help save energy and emissions	34	65.4	40	75.5
H5	Other household energy efficiency	Efficient appliances help reduce energy demand, vital for keeping the growth in electricity demand manageable	34	65.4	40	75.5
E1	Efficient charcoal making	Helps to conserve wood fuel supplies by making charcoal as efficiently as possible. Charcoal making is also a significant source of SLCPs.	11	21.2	9	17.0
E2	Post-combustion emission controls in industry	Reduces non-CO_2 emissions from industry.	0.0	0.0	0.0	0.0
E3	Coal methane capture	Reduces methane emissions from coal mining – Note: the potential co-benefit of electric generation from this methane has not modelled	1	1.9	0	0
E4	Oil and gas methane emissions	Reduces methane emissions from oil and gas operations – Note: the potential co-benefit of electric generation from this methane has not modelled	4	7.7	7	13.2

E5	Industrial processes and product use (IPPU)	Transmission and distribution loss reduction	17	32.7.	25	47.2
E6	Industrial energy efficiency	Industrial energy efficiency	30	57.7	34	64.2
E7	Services energy efficiency	Helps to reduce energy demands and emissions	32	61.5	40	75.5.
E8	Reduce demand for cement	Cement production is highly energy and carbon intensive – use substitutes to partially replace cement clinker	6	11.5	11	20.8
E9	CCS in carbon intensive industries and electricity generation	In some highly carbon- and energy-intensive industries (cement, iron and steel, coal-fired electricity generation), CCS may be practical for avoiding CO_2 emissions although it is still far from being commercialised	3	5.8	2	3.8
E10	Renewable electricity generation	Need to pair strategies for electrifying energy demand with strong measures to decarbonize electricity generation, promoting renewable sources and phasing down coal and other carbon-intensive fuels.	50	96.2	51	96.2
P1	Industrial processes and product use (IPPU)	Implement Kigali Amendment to phase down HFCs	5	9.6	19	35.8
A1	Agriculture	Increase productivity of livestock herd to reduce emission intensity of meat and dairy	10	19.2	18	34.0
A2	Agriculture	Increase digestibility of feed to reduce methane emissions from enteric fermentation	10	19.2	18	34.0
A3	Agriculture	Switch to manure management systems with lower methane and nitrogen emissions	15	28.8	18	34.0
A4	Agriculture	Implementation of alternate wetting and drying for flooded rice	10	19.2	17	32.1
A5	Agriculture	Eliminate open burning of agricultural residues	6	11.5	13	24.5
A6	Agriculture	Reduce food waste at point of consumption	0	0.0	3	5.7
A7	Agriculture	Shift in diets to reduce red meat consumption and increase plant-based protein sources	1	1.9	1	1.9
W1	Waste	Implementation of best-practice landfill management to reduce open burning of waste, and methane capture at landfills	27	51.9	42	79.2
W2	Waste	Methane capture at wastewater treatment plants	15	28.8	23	43.4
W3	Waste	Implement waste collection and development of formal landfill sites	3	5.8	6	11.3
W4	Waste	Diversion of organic waste to composting or biogas production	18	34.6	33	62.3
W5	Waste	Reduce organic waste generation	4	7.7	8	15.1
W6	Waste	Universal access to improved water and sanitation services	15	28.8	23	43.4

Table 5.3 highlights two critical aspects of how African countries are currently considering the 37 mitigation measures within their climate change planning.

1. Almost all mitigation measures are being considered in at least one African NDC. This demonstrates that across the continent, 35 of the 37 measures are currently identified as contributing to achieving national climate change mitigation goals – coal-mine CH_4 capture and post-combustion controls on industrial facilities are the exceptions. This suggests that the measures included in this Assessment are considered within the menu of options to address emissions causing climate change and air pollution. It also highlights the necessity for those countries that have committed to one or more of the 37 measures to be supported, both through the implementation of the other recommendations for national governments outlined below and through support from international and sub-national institutions.
2. There is a substantial opportunity for African countries to update their NDCs and climate change mitigation commitments through inclusion of this Assessment's 37 mitigation measures. While almost all these mitigation measures are included in at least one NDC, only increasing renewable electricity generation has near universal inclusion. Countries that have ratified the Paris Agreement are required to update their NDCs every five year. Therefore, when countries next update them before 2025, it is recommended that those that have not done so evaluate and prioritize the 37 mitigation measures to achieve substantial climate and clean air benefits.

Within a national government, there are various ministries who are responsible for different planning initiatives, legislation etc. It is clear, both from this Assessment and previous studies (Malley *et al.* 2021a) that an integrated approach to air pollution and climate change planning is essential to have maximum effect. In addition, this Assessment has also shown the potential additional co-benefits which can be achieved from measures mitigating air pollution and climate change. Consequently, air pollution and climate change planning should not be restricted to independent ministries working in silos, but rather, it is important to promote cross-governmental cooperation. This will maximize impacts and allow for higher engagement across government, resulting in a coordinated approach, which is endorsed across government, making the successful execution of air-pollution and climate change plans more likely. Furthermore, implementation of mitigation measures requires funding. It is therefore essential to incorporate the ministry in charge of finance into the planning process. Ensuring it has been involved in the planning and prioritization of air-pollution and climate change plans will make it more likely that they are implemented. The Nigerian case study for (Box 5.10) outlines how this integration was achieved within their national SLCP planning process for 2016–2019.

The UNEP-convened CCAC has supported a number of African countries to develop plans to address SLCPs. In some cases, this has resulted in stand-alone SLCP plans, but in others it has either developed air quality or climate plans or supported existing ones. Many countries have also chosen to include SLCP measures in their NDCs as described above (Table 5.3). In the end, there are a number of advantages from integrating SLCP, climate and air-quality planning and including the 37 measures identified in this Assessment in those processes. Many of the processes involved require the same building blocks, including the ability to estimate emissions scenarios and compare the emissions and their impacts between baseline and mitigation scenarios.

All countries have developed their NDCs and climate change commitments. The NDCs represent an important way by which the implementation of most of the measures outlined in this Assessment can be promoted. They are taken seriously in national planning and resources are devoted to their implementation, both from national and international sources. The inclusion of the key measures that will provide climate, air quality and development benefits identified in this Assessment then need to be encouraged. Whilst nearly all of the measures are included in NDCs in some countries in Africa, many have still not included measures outlined here in their NDCs, apart from the focus on developing renewable energy.

There is, therefore, a great opportunity to encourage the process of updating NDCs with all the measures identified in this Assessment, with the first opportunity the next submissions in 2025, and a subsequent one in 2030. Air-quality legislation is being developing in many African countries but is, in many cases, at an earlier stage than climate mitigation action. Many African countries, for example, lack legislation based upon air-quality standards, partly due to the fact that air-quality monitoring is lacking. Action is, however, being taken on climate change, in the development of NDCs, and in terms of addressing air quality, as outlined in Table 5.3, which also identifies planned action. This shows that African countries are mobilizing to reduce emissions and this can be built upon through the 37 measures recommended in this Assessment and promoted within these different national efforts.

The following country case studies provide practical examples of how the recommendations in Table 5.2 for national institutions can be achieved and air-pollution and climate change planning integrated (Boxes 5.10 and 5.11).

BOX 5.10 COUNTRY CASE STUDY 1: INTEGRATION OF CLIMATE CHANGE MITIGATION AND SUSTAINABLE DEVELOPMENT PLANNING IN NIGERIA

In 2019, the Nigerian government endorsed its National Action Plan on SLCPs, which included an integrated assessment of the mitigation potential of various measures to reduce their emissions, with associated reductions in other air pollutants and GHGs, and also provided targeted action and implementation pathways for the measures. The process that was undertaken linked various different ministries and aligned the National Action Plan with other national development priorities, which were outlined in the Economic Recovery and Growth Plan (ERGP). This was a key aspect in terms of implementation, as the ERGP provides criteria for the allocation of national budget funding.

Figure 5.8 shows the key activities, coordinating partners and relevant ministries involved in the process of developing the SLCP Plan, including planning, endorsement and implementation. The planning process was coordinated by the Climate Change Division and the Ministry of Environment and involved various activities including stakeholder engagement at multiple levels. The effect of this process, which integrated planning, placed responsibility for the process across government departments and aligned the plan development priorities, was that it increased the likelihood of endorsement at a high level. That endorsement strengthened the case for funding when the relevant ministries or departments submitted proposals to the national budget as specific measures that required funding. The implementation of the measures was coordinated by the Climate Change Division, the Ministry of Environment, the Ministry of Budget and National Planning, and the Cabinet Office. Having an integrated approach across the implementation process, meant that the prioritized action could be funded and implementation achieved more quickly.

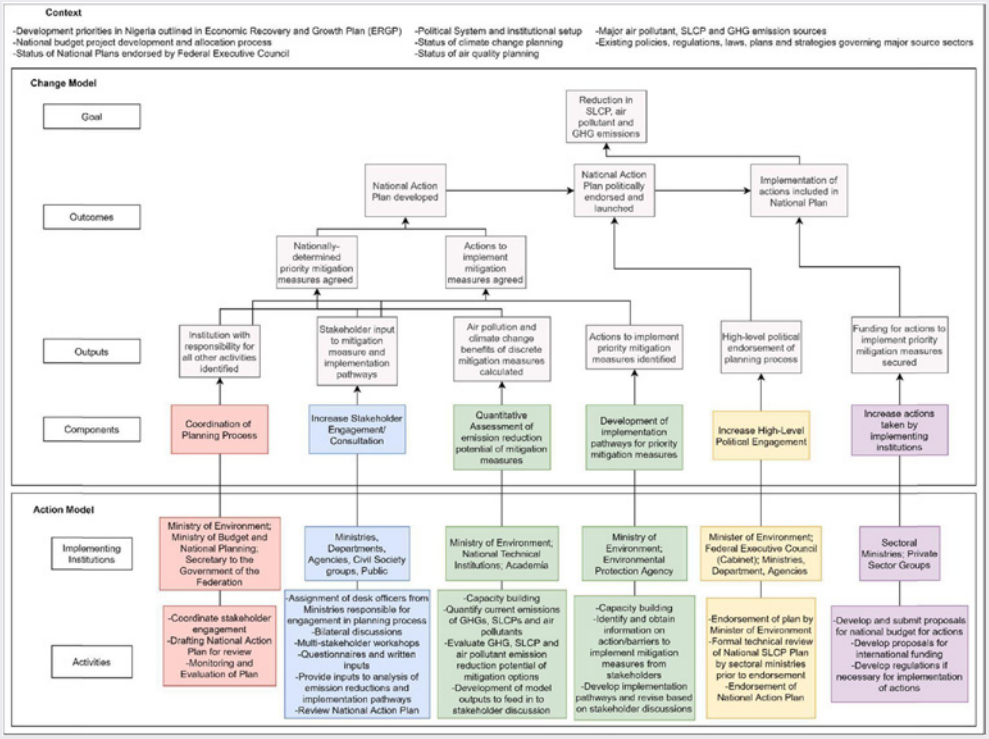

Figure 5.8 Sequence of activities, key implementing institutions and processes involved in the planning, endorsement and implementation of Nigeria's National Action Plan on SLCPs

Source: Malley *et al.* (2021a)

The process of integration and funding undertaken in Nigeria can be seen as a way in which mitigation measures can effectively move forward to implementation. **A key recommendation for implementation of this Assessment's mitigation measures is to integrate different ministries, agencies and authorities across government and other key stakeholders within both the planning and implementation process**. This will ensure engagement and endorsement from all relevant stakeholders in the development and dissemination of the information and will increase the probability of funding for the mitigation measures and that these move forward to implementation (Malley *et al.* 2021a).

In addition to the planning process, Table 5.2 identifies financing of measures as a key recommendation for the national scale. In many cases, however, government budgets are constrained and environmental protection is not at the top of those initiatives that are considered for the national budget. Allocating the necessary funding for the implementation of mitigation measures is integral to their success and there are examples of African countries now including air quality and climate mitigation in their financial planning. For example, Nigeria's 2021 Appropriation Act (Budget Office of the Federation, Federal Republic of Nigeria 2021) which outlines their national budget, includes multiple references to climate and air-pollution mitigation measures. The measures range from national scale projects to those at the state or local scale. Within the ministry of health NGN 17 million, approximately US$ 40 000, is allocated to climate change and mitigation action across the 36 states in Nigeria. Action includes monitoring and evaluating the status of air quality, airborne gases and PM that exacerbate respiratory illnesses as well as training for health workers on the use of air quality model equipment. The Ministry of Environment's budget includes a multitude of projects relating to air pollution and climate change mitigation. At the national scale, NGN 7 million, approximately US$ 15 000, is allocated to the introduction of smart air-quality monitoring, NGN 5 million, approximately US$ 11 000, is specified for the national vehicular emissions–control programme and a combined NGN 25 million, approximately US$ 55 000, is allocated to the establishment of a national GHGs inventory-management system and the development of country-specific emissions factor for the energy and AFOLU sectors in Nigeria. More localized projects include a plethora of community-based waste-management projects and solar-powered street-lighting ones.

Within the Ministry of Agriculture, NGN 146 million, about US$ 330 000, is allocated to the promotion and development of beef production while there are multiple entries for the provision of synthetic fertilizers. This has the potential to increase agricultural emissions, however, there are also significant funds specified for farmer training and equipment which could help mitigate these emissions if used effectively.

In addition to the Appropriation Act, Nigeria has also accounted for pollution-mitigation options in the Economic Sustainability Plan (Economic Sustainability Committee 2020). This outlines fiscal measures and monetary policies following the Covid-19 pandemic. Included within it is action such as the National LPG Expansion Implementation Plan which will promote the domestic use of cleaner fuels and is estimated to generate 1 million jobs in the process. Including such measures in economic planning will not only aid in the implementation of air pollution and climate mitigation action but also, for example, foster a more sustainable economy that is less dependent on oil.

Finally, the national scale is also key for the effective monitoring and evaluation of climate and airpollution mitigation to ensure that action committed to is actually implemented, and that emissions reductions are achieved. Many African countries are leaders in the integration of SLCPs and air pollutants in their national GHG inventories, the key tool used to quantify and report on GHG emissions in a country, and their changes over time. This integration allows SLCP and air pollutant emissions to be similarly tracked, to determine whether air pollutant emissions are rising alongside GHG emissions, and/or whether policies and measures intended to reduce emissions are having their desired impact. The country case study for Ghana (Box 5.11) outlines efforts made in Ghana to achieve this integration.

BOX 5.11 COUNTRY CASE STUDY 2: INCLUSION OF SHORT-LIVED CLIMATE POLLUTANTS AND AIR POLLUTANTS IN GHANA'S 2ND BIENNIAL UPDATE REPORT

For the last two rounds of reporting to the UNFCCC, Ghana has submitted a GHG emissions inventory that includes a quantification of SLCP and air pollutant emissions (Figure 5.9). This quantification was made alongside GHG emissions, ensuring that SLCP and air-pollutant emissions are estimated in a consistent way to GHGs, and minimizing the data collection needed to develop a comprehensive emissions inventory, due to the substantial overlap in activity data required to estimate GHG, SLCP and air-pollutant emissions. The quantification of SLCP emissions alongside GHGs allows all pollutants impacting climate to be included in the official GHG inventory.

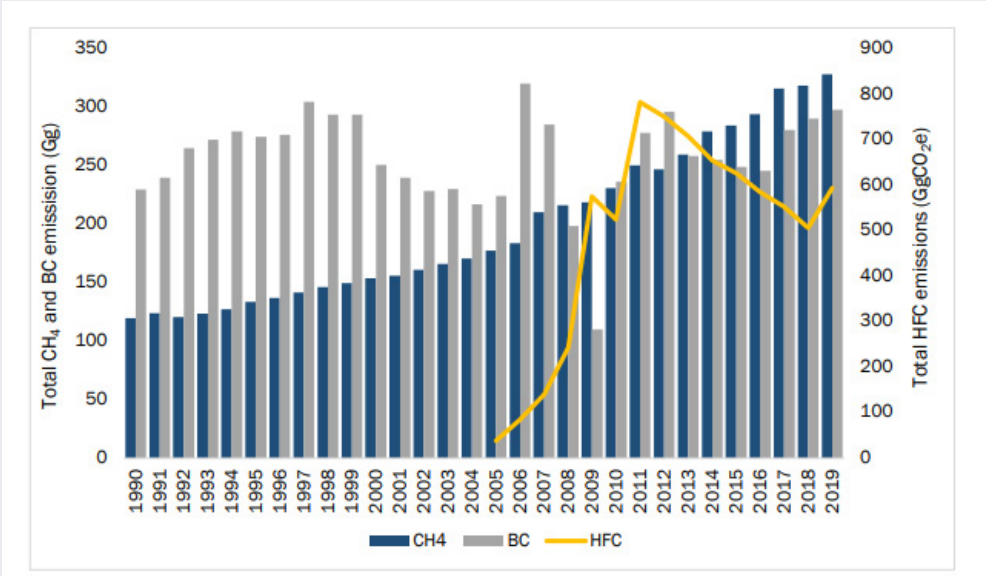

Figure 5.9 Ghana, emissions of short-lived climate pollutants, 1990–2019, Methane (CH_4) and Black Carbon (BC) in Giga grams (equivalent to a thousand metric tonnes), Hydrofluorocarbons (HFCs) in Gg of CO_2 equivalents. Source: Ghana BUR (2022).

The inclusion of air pollutants within Ghana's GHG inventory provides an efficient way of increasing capacity and knowledge on sources of air pollutants. Given the regular updating of the GHG inventory, it also ensures the provision of up-to-date information on air pollutant emissions on a regular basis.

As has been emphasized in this Assessment, the 37 measures it recommends will not only help reduce emissions responsible for climate change and air pollution but will also contribute to achieving national SDG goals. A total of 52 countries in Africa have completed their first reporting for the SDG Voluntary National Review (VNR). The SDG planning processes in each country offer an opportunity to further promote the implementation of the 37 measures. The recommendation made here is for subsequent VNRs to include reporting on the these, mapped into the SDGs and their associated Targets (Section 3.5.2).

5.4.5 OPPORTUNITIES FOR URBAN ACTION

Cities are responsible for the majority of GHG emissions globally and people living in cities are exposed to the highest levels of air pollution. In Africa, many of the drivers of future baseline increases in GHG, SLCP and air pollutant emissions will increase disproportionately within cities, such as the demand for transport (Chapter 2). Rapid population growth, combined with increased urbanization, is putting pressure on African cities and these issues are likely to be exacerbated in the future as GDP increases and populations grow. Many urban areas across the continent already face significant air pollution issues and are also impacted by the effects of climate change. Cities and urban areas often face different challenges from the surrounding rural areas. This is true in terms of both sources of air pollution and other development priorities.

The significant contribution of cities to emissions of GHGs, SLCPs and air pollutants also means that several of the levers and mechanisms to reduce them implement many of the 37 priority mitigation measures and achieve air pollution and climate change benefits within urban areas and, therefore, provide an opportunity for action to create sustainable, inclusive and healthy cities. This section considers two recommendations for action at an urban scale (Table 5.2). The first underlines the importance of creating meaningful links between urban and national planning and the second emphasizes the importance of integrating SLCP and air pollution issues related to households, waste management, transport and industry into urban planning.

Links between urban and national planning

The first recommendation highlights the need for coherence and interaction between national air pollution and climate change plans, and city-scale planning and action. The interaction between these provides a strong basis for linking the policies and plans to tackle both issues (Thambiran and Diab 2011; Tirusha and Diab 2011a and b). By creating this link between urban and national planning initiatives, cities can contribute to resolving urgent local air pollution challenges and contribute to a country's broader climate change mitigation goals. Local air quality management and climate action plans present opportunities for integration, through which measures with co-benefits for simultaneously reducing air pollution and GHG emissions should be prioritised. The need to adopt measures with such synergies should be recognized within national air-quality and climate change legislation so that opportunities for co-benefits are not overlooked when urban responses are developed.

In South Africa, for example, air-quality legislation recognizes the need to include climate change considerations and GHG pollutants are regulated as priority air pollutants. It also requires major South African cities to develop air quality management plans that align with this national air quality legislation. In other countries, such as Ghana and Nigeria, SLCPs are included within NDCs, providing multiple benefits for improving urban air quality and mitigating climate change. Establishing effective governance and legislative processes to integrate climate change and air quality is a critical step to ensuring effective links between urban actions and national priorities (Box 5.12).

Integrating households, waste management, transport and industry in urban planning

The second recommendation then recognizes the importance of cities in accelerating the implementation of many of the 37 recommended mitigation measures identified in this Assessment as essential for achieving climate change mitigation, air quality and health improvements and development goals. It follows, therefore, that, in planning for energy provision, improved infrastructure, transport and waste management, local municipalities should do so in a manner that maximizes opportunities to reduce atmospheric emissions in support of reaching national climate change mitigation goals. The key characteristics of urban areas are larger total populations and higher population density, combined with higher per person incomes. These factors combine to make certain issues in urban areas a higher priority. For example, higher incomes have been linked to higher private vehicle use, which, when combined with more people living in limited space, can lead to busy and congested roads in urban areas. Road transport is a major source of both air pollution and GHG emissions in urban areas across Africa, while congestion and road-traffic injuries also plague African cities. Consequently, implementing certain mitigation actions in the road transport sector, such as increased public and non-motorized transport, could allow not only for significant reductions in air pollutant and GHG emissions but also provide an opportunity for safer and less congested cities (Section 5.3.1). A further key issue for Africa, which most regional agreements on air pollution target (Section 4.3), is to restrict the importation of older used cars from overseas, which often have poor specifications in terms of emissions controls such as the Euro vehicle standards.

Higher incomes are also linked to higher waste generation, and this, combined with large populations, means that the total waste generated

in urban areas is substantial and is also projected to increase massively across Africa as its cities grow. The open burning of waste is a significant source of urban air pollution, while decomposition of organic waste in landfill sites is a large source of CH_4 emissions (Section 5.3.3). This means that improved solid-waste management practices and policies are a major priority in urban areas to successfully mitigate air pollution and GHG emissions. Waste collection is often more advanced and easier to roll out in urban areas due to better infrastructure, resources and higher population density. This means that policies surrounding solid-waste management in urban areas have a much larger potential to be effectively implemented if the sector is sufficiently resourced and capacity to do so is strengthened. Mitigation measures for effective management detailed in this Assessment could also have multiple co-benefits for both national and urban development. Reducing food waste, for example, would not only reduce emissions of CH_4 but could also reduce food insecurity through increasing food availability (Section 5.3.3). This could allow cities and countries to be more self-sufficient when it comes to food supply and also could help to alleviate hunger and malnutrition at both the urban and national scale. For countries/cities that are under-resourced, tapping into green/climate funding might allow for development in more sustainable ways through the financing of infrastructure projects and the strengthening of capacity to implement and monitor progress towards achieving goals.

The planning and implementation of climate change and air quality action taken within an urban area allows for progress towards building sustainability irrespective of the prevailing regional and national circumstances and policy imperatives. Local climate change action, with co-benefits for air quality and sustainable development, can help to fill the void in cities in which there is a lack of air quality management legislation, while locally legislated air quality action can have co-benefits for climate mitigation and sustainable development. The level of success in tackling these environmental and developmental issues simultaneously will, however, depend on the selection of action that maximizes opportunities for synergies whilst overcoming financial, institutional and capacity-related barriers to implementation.

Many cities in Africa are aware of these social and environmental challenges and as such have developed tailored action plans concentrated around airquality management and climate action. Additionally, many cities are making pledges towards becoming carbon neutral by 2050. The benefit of these action plans is that they also assess the needs and priorities of the city and its population while simultaneously allowing for implementation of specific policies which can mitigate against air pollution and climate change. Accra, Ghana, recently published a Climate Action Plan which transposes national commitments to mitigating and adapting to climate change to the city level, aligning them with the city's development priorities. As the Action Plan highlights, some of the policies and intended outcomes cannot be achieved solely by one urban authority but requires collaboration between others within the region, as well as at the national scale with relevant ministries and the national government. The Greater Accra Metropolitan Area also published its first Air Quality Management Plan in 2018. These city-level plans provide specific action which will reduce emissions of both air pollutants and GHGs, assign timelines and nominate responsible bodies to ensure that action is taken – increasing monitoring and inspection of vehicles, for example, to ensure emission technologies are still effective. There is significant overlap between the measures assessed in both plans highlighting that mitigation of air pollution and climate change can be tackled by an integrated approach.

Both transport and waste management are key sources of emissions in urban areas and are highlighted as priorities in both Accra's Climate Action and Air Quality Management Plans. This is not only due to their high contribution to air pollution and GHG emissions but also because management of these sectors typically falls under the jurisdiction of local authorities, which could allow for rapid and direct action at the city scale. Waste collection and management services, for example, are often managed by local authorities, while transport planning, particularly the introduction of infrastructure required for improved public transport and the development of walkways and bicycle lanes, is often performed at the city scale.

BOX 5.12 CASE STUDY: INTEGRATION OF NATIONAL AND URBAN AIR QUALITY LEGISLATION IN SOUTH AFRICA

In South Africa, many metropolitan cities have developed air quality management and climate change action plans. Air quality legislation drives the implementation and review of the types of air quality interventions proposed in air quality management plans, typically within 5-year planning periods whereas climate action planning takes a long-term view. The air quality and climate action plans are developed through consultative processes with local government officials and stakeholders and thus significantly draw on the broader development goals for the city.

In the City of Johannesburg's Climate Action Plan, for example, climate change mitigation action has significant potential to support air quality improvements through reducing $PM_{2.5}$ by 31 per cent by 2050. It is expected that 50 per cent of this reduction would be linked to the mitigation options in the transport sector that include a shift to public transport and use of non-motorized transport. This aligns with the city's broader Growth and Development Plan that seeks to promote a public transport-oriented city by 2050. The Action Plan thus seeks to build on existing interventions such as the Rea Vaya Bus Rapid Transport project, by expanding its coverage of the city. Other measures include improving vehicle fuel efficiency by, for example, retiring older vehicles, enabling the switch to EVs and promoting walking and cycling through economic and behavioural incentives. The remaining reduction in $PM_{2.5}$ was linked to interventions with co-benefits that included optimizing energy efficiency and reducing waste. Through the use of efficient lighting, rooftop PV or solar water heating, for example, it is envisaged that new buildings in the city would improve energy efficiency. In the waste sector, interventions included the diversion of waste from landfills through composting and recycling, and converting gas from landfills to energy, with the latter linking to the Sustainable Waste Management Project implemented in the city since 2007 (City of Johannesburg, 2021). The Climate Action Plan thus prioritized interventions that were closely aligned to other city-level plans and strategies to streamline the achievement of co-benefits and identified institutional responsibilities, partners, and investment needed for implementation.

The implementation of policies and measures, driven by city action, are recognized as having co-benefits (South Africa Department of Forestry, Fisheries and the Environment 2021) as the measures within city-level plans on transport, waste reduction and energy efficiency align to national priorities of the Green Transport Strategy, the National Waste Management Strategy, and the Integrated Resource Plan. Action with co-benefits taken by local governments thus also contribute to meeting the country's overall development plans and climate change mitigation targets.

It is clear that cities in Africa are at the forefront of both issues and opportunities surrounding air pollution, climate and sustainable development. Local municipalities, however, face the difficult task of justifying the allocation of public funds to climate responses rather than other development needs and risks that require management over different timescales. Integrated plans that link interventions with cross-cutting impacts are needed, along with strong monitoring and reporting systems to track implementation.

Targeted action, with clearly delineated objectives, activities and responsible groups, by local authorities is one way in which mitigation measures can be effectively implemented with benefits both at the national and local scale. As existing metropolitan areas struggle to cope with existing issues, however, other smaller cities, often known as secondary cities, are growing rapidly. These urban areas, which are yet to face some of the issues of larger cities, such as congestion and air pollution, could, by instituting better planning policies, provide a further opportunity for sustainable development in Africa through the creation of more inclusive, healthier cities. Consequently, when considering action on air quality, climate change and sustainable development in urban areas across Africa, city-scale planning could be a key priority to allow urban areas to develop, adapt to climate change and have better air quality.

5.4.6 OPPORTUNITIES FOR RURAL ACTION

There are three key issues in rural areas that, if successfully addressed at scale, could bring significant benefits to the African continent: clean cooking and lighting, agricultural production and infrastructure for moving fuels and goods efficiently.

Clean cooking and lighting

This integrated Assessment shows how the transition to clean cooking is closely linked to the move to more renewable energy and the empowerment of women and young girls, who have traditionally collected fuel wood (Box 5.7), as well reducing pressure on forests. As Section 5.3.2 explains, there are some excellent initiatives throughout the continent on clean cooking but these are often fragmented and a key recommendation of this Assessment is to accelerate the spread of measures to introduce alternatives to traditional biomass stoves and the transition to cleaner fuels and electrification (Section 3.2.3.2) to rural areas and empower women to implement measures (Table 5.2). Existing initiatives, such as the Global Clean Cooking Alliance[17] and national activities, the Clean Cooking Association of Kenya[18] (CCAK) and the Tanzania Renewable Energy Association[19] (TAREA), for example, could be coordinated and supported to scale up.

Agricultural production

Section 5.3.4 describes how most African countries show a strong correlation between agricultural growth and GDP. A major transition that Africa could make is to move away from over reliance on the importation of food and achieve the goal of the first ten-year plan of Agenda 2063 to double agriculture productivity, halve post-harvest losses and make agriculture in Africa more climate resilient. The potential for greater agricultural production is certainly there. Sub-Saharan Africa, for example, achieved the highest rate of growth in agricultural production value, for crops and livestock, of any region in the world since 2000, expanding by 4.3 per cent per year in real terms between 2000 and 2018, roughly double the rate of the prior three decades – the world average over the same period was 2.7 per cent per year (Jayne and Sanchez 2021). However, although cereal yields in Sub-Saharan Africa rose by 38 per cent in the 38 years between 1980 and 2018 that is roughly half of what was achieved in South Asia and Southeast Asia (FAO *et al.* 2021). Jayne and Sanchez (2021) discuss the conditions required on the ground in Africa to achieve the potential for further yield increases in a sustainable way. These centre around:

- the need for a switch away from an expanding agricultural area model to sustained productivity growth on existing farmland, due to the pressures of rural population growth, the limited potential for continued area expansion, and the environmental costs of expansion – biodiversity loss and destruction of natural vegetation;
- agricultural research and development, as a proven way of promoting agricultural productivity growth, is required to overcome the limitations of soils, many of which are nutrient depleted in Africa, by improving soil health and crop management through the use of appropriate mineral fertilizers, organic inputs and fertilizer-responsive seeds that are appropriate for a changing climate.

The recommendation in this Assessment (Table 5.2) is for training and capacity building on agricultural measures to implement this Assessment's recommended measures for improving agricultural practices (Section 3.2.5.2). These measures, that include improved manure management, reduced food waste and alternatives to agricultural residue burning, fit well with the needs on the ground as described above. Local adaptation of agricultural research on the diverse farming conditions found across Africa will require bidirectional learning between farmers and agricultural scientists to identify how to adapt improved management practices that fit within local resource constraints (Jayne and Sanchez 2021). Ethiopia, for example, one of the few African countries to substantially increase its spending on public agricultural research and which has half Sub-Saharan Africa's agricultural extension workers, now has the highest rate of agricultural growth of any country in Sub-Saharan Africa since 2000 (Jayne and Sanchez 2021).

There also needs to be an alignment of objectives and investment for improvements in other sectors, and between agricultural initiatives at different scales, especially those related to Agenda 2063's CAADP and NAIPS, but also with international agreements under UNEA, such as the Resolution on Sustainable Nitrogen Management (UNEP/EA.5/RES.2) (Sutton *et al.* 2021).

Infrastructure

As described in Sections 5.3.2 and 5.3.4, infrastructure for distributing clean fuels for cooking and getting food to market quickly and efficiently is a key cross-cutting issue to be addressed if many of the development aspirations of Agenda 2063 are to be realized.

17. https://cleancooking.org/
18. https://ccak.or.ke/
19. https://tarea-tz.org/projects

5.4.7 INTERGOVERNMENTAL AND NON-GOVERNMENTAL ORGANIZATIONS

The previous sections outline recommendations that organizations and institutions within Africa could undertake to accelerate the implementation of the 37 recommended mitigation measures, and air quality and climate change improvements across Africa. Intergovernmental organizations, such as United Nations organizations, the World Bank, and the WHO, and international NGOs can, however, also play supporting roles in facilitating the implementation of the 37 measures. Implementation of national climate change and air pollution policies, for example, installation-specific emission-limit values, switching to more efficient technologies and practices to reduce emissions, as well as the implementation of decisions and agreements taken at global and regional levels, require international collaboration and mechanisms for finance that can accelerate the adoption of key mitigation measures, including those identified in this Assessment. Table 5.2 highlights six recommendations through which global organizations can support the achievement of this Assessment's Agenda 2063 emissions pathway.

These recommendations firstly include supporting access to finance that directly implements the 37 recommended mitigation measures included in this Assessment. As outlined in Section 5.4.2 the financial flows necessary for implementation of these 37 measures, or action on air pollution and climate change more generally, are currently insufficient to lead to their comprehensive implementation. Multiple international funding mechanisms, including the Green Climate Fund (GCF) or bespoke agreements on specific issues, such as the agreement between South Africa and multiple donor countries to support the transition away from coal-powered energy generation (Kumleben 2021), provide mechanisms and models for providing the necessary financing for the implementation of the 37 mitigation measures. International financial institutions, such as the World Bank, the AfDB, the Global Environmental Facility (GEF) and the GCF, play major roles in project funding for cooperative implementation of control measures, such as the ones identified by this Assessment.

The second recommendation is that best practice in air pollution and climate change planning is shared. Initiatives, such as the UNEP-convened CCAC, and organizations, including UNEP, UNDP and the World Bank, have long track records in supporting air quality and climate change planning at national and urban scales, while organizations such as the C40 Cities Climate Leadership Group and ICLEI have specific expertise in city-scale air quality and climate change planning. Ensuring that this international expertise is leveraged and combined with local competence and knowledge to increase national and city-scale planning and implementation of the 37 mitigation measures is essential to ensuring that their insights are shared widely, and the implementation of the 37 measures is achieved as widely as possible.

A key contribution to/facet of intergovernmental organizations (IGOs) and NGOs achieving this recommendation is doing so in a way that enhances and strengthens existing capacity within Africa to tackle air pollution and climate change. Most African countries have had climate change departments within their ministries of the environment for decades and have built up substantial knowledge of the local circumstances related to sources of GHG emissions. Many countries also have air quality departments with mandates to tackle air pollution. It is the responsibility of IGOs and NGOs, in their engagement on improving climate change and air quality planning across Africa, to ensure that the activities, capacity enhancement and funding is directed towards locally determined priorities, and that projects are developed and executed in ways that leaves knowledge and capacity, so that efforts on air pollution and climate change mitigation can be sustained after the specific projects has ended.

Finally, this recommendation also calls for IGOs and NGOs to coordinate and harmonize their support on air quality and climate change planning to minimize the duplication of effort and ensure that projects build on one another. This means that there should be sufficient national capacity to coordinate and organize international support for air-quality and climate change planning and ensure that it meets national needs.

There are multiple international processes, mechanisms and agreements within which international support can be targeted to accelerate implementation of climate and clean air measures. Climate change planning is undertaken primarily under the UNFCCC, which today has near-universal membership. The aim of the UNFCCC is to prevent dangerous human interference with the climate system. Global multilateral environmental agreements (MEAs) which have links to air pollution are those targeting climate change, the UNFCCC; stratospheric O_3 depletion, the Vienna Convention and Montreal Protocol; mercury, the Minamata Convention; and persistent organic pollutants, the Stockholm Convention. Global legal frameworks also exist for pollution in the aviation and shipping sectors. There is, however, no global agreement on tackling air pollution, and international law on transboundary air pollution is heavily fragmented, addressed through several regional agreements and frameworks, some of them in Africa. Global action on Air Quality Management (AQM) is otherwise taken through resolutions of the UNEA, which is the world's highest decision-making body on the environment. At its first and third sessions, 2014 and 2017 respectively, UNEA adopted resolutions (UNEP/EA.1/RES.7 and UNEP/EA.3/RES.8) encouraging governments at all levels to take action across sectors to reduce all forms of air pollution, with the latter resolution urging Member States to include, as appropriate, air pollutants that are also SCLPs in national action programmes to prevent and reduce air pollution; while requesting UNEP to support countries to implement the resolutions through technical support in monitoring and assessing the quality of air; developing air pollution action plans; and providing a platform for cooperation and information sharing, building from regional cooperation, and intensifying partnerships with the CCAC and other relevant groupings.

In Africa, UNEP has, in the past, supported the development of non-binding agreements on air quality that lay out common policy goals, set regional priorities and a framework for cooperation at a sub-regional level, for example, the Nairobi Agreement in Eastern Africa; the Lusaka Agreement for Southern Africa; and the Abidjan Agreement in Central and West Africa (Section 4.3). There are ongoing initiatives to revitalize these sub-regional agreements to strengthen governance regimes and build communities of practice. Accompanied by international financing and technology transfer, these agreements could facilitate more rapid action if they specifically target pollution mitigation that maximizes air quality and climate benefits.

UNEP is working closely with AMCEN and its Bureau, as well as the AU, to ensure the effective coordination of action on the environment. A proven approach to international cooperation in Africa on air-related issues has been the development of initiatives, such as the Partnership for Clean Fuels and Vehicles[20], the Clean Cooking Alliance[21] and the CCAC. These initiatives bring together interested national governments, IGOs, private-sector companies, civil society organizations and philanthropic foundations to advance specific pollution mitigation efforts. The CCAC is working to catalyze action to decrease emissions of BC, CH_4 and HFCs.

20. https://www.unep.org/explore-topics/transport/what-we-do/partnership-clean-fuels-and-vehicles
21. https://cleancooking.org/

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ABBREVIATIONS AND ACRONYMS

AC	air conditioner
ACCP	African Clean Cities Platform
ADHD	attention deficit/hyperactivity disorder
AEC	African Economic Community
AERONET	Aerosol Robotic Network
AfDB	African Development Bank
AfCFTA	African Continental Free Trade Area
AFOLU	agriculture, forestry and other land use
AFR100	African Forest Landscape Restoration Initiative
AGNES	African Group of Negotiators Expert Support
AMCEN	African Ministerial Conference on the Environment
AMCOMET	African Ministerial Conference on Meteorology
AMCOW	African Ministers' Council on Water
AMMA	African Monsoon Multidisciplinary Analysis
APINA	Air Pollution Information Network for Africa
AOD	aerosol optical depth
ARBE	Department of Agriculture, Rural Development, Blue Economy, and Sustainable Environment (of the African Union)
ARSO	African Regional Organization for Standardisation
ART	acute respiratory-tract infection
ASAP	A Systems Approach to Air Pollution
ASD	autism spectrum disorder
AU	African Union
AUC	African Union Commission
AUDA-NEPAD	African Union Development Agency
AWD	alternate wetting and drying
BC	black carbon
BSC	Barcelona Supercomputing Center
BSFL	black soldier fly larvae
C	carbon
°C	degrees Celsius
CAADP	Comprehensive Africa Agricultural Development Programme
CAMRE	Council of Arab Ministers Responsible for the Environment
CAMS	Copernicus Atmosphere Monitoring Service
CAN	Climat Action Network
CAR	Central African Republic
CArE-Cities	Clean Air Engineering projects – Clean Air Engineering for Cities
CArE-Homes	Clean Air Engineering projects – Clean Air Engineering for Homes
CCAC	Climate and Clean Air Coalition
CCAK	Clean Cooking Association of Kenya
CCS	carbon capture and storage
CEDS	Community Emissions Data System
CIESIN	Center for International Earth Science Information Network
CH_4	methane

CI	confidence interval
CMIP	Coupled Model Intercomparison Project
CMIP6	Sixth Coupled Model Intercomparison Project
CO	carbon monoxide
CO_2	carbon dioxide
CO_2-eq	carbon dioxide equivalent
COMESA	Common Market for Eastern and Southern Africa
COP	Conference of the Parties
COPD	chronic obstructive pulmonary disease
CRS	Common Reporting Standard
CSIR	Council for Scientific and Industrial Research
CSO	civil society organization
CSP	concentrated solar power
3D	three dimensional
DALY	disability-adjusted life years
DCHS	Drakenstein Child Health Study, Western Cape, South Africa
DICCIWA	Dynamics-aerosol-chemistry-cloud interactions in West Africa
DPSIR	drivers, pressures, state, impacts and responses
DRC	Democratic Republic of the Congo
EAC	East African Community
EASFCOM	Eastern Africa Standby Force Coordination Mechanism
ECCAS	Economic Community of Central African States
ECMWF	European Centre for Medium Range Weather Forecasting
ECOWAS	Economic Community for West African States
EDGAR	Emissions Database for Global Atmospheric Research
EEA	European Environment Agency
e.g.	exempli gratia (for example)
EIP	Eco-Industrial Park
EMEP	European Monitoring and Evaluation Programme
ERGP	Economic Recovery and Growth Plan
ETSAP	Energy Technology Systems Analysis Program
EV	electric vehicle
FAO	Food and Agricultural Organization of the United Nations
FDI	Foreign Direct Investment
FEER	Fire Energetics and Emissions Research
F-gas	fluorinated gas
FINN	Fire INventory from NCAR
FRM	Federal Reference Method
GBD	global burden and disease
GCF	Green Climate Fund
GCM	global circulation model
GDL	Global Data Labs
GDP	gross domestic product
GEDAP	Ghana Energy Development and Access Project
GEF	Global Environmental Facility
GEO	geostationary Earth orbit

GEOS	Goddard Earth Observing System
GFED	Global Fire Emissions Database
GFAS	Global Fire Assimilation System
GHAir	Ghana Urban Air Quality Project
GHG	greenhouse gas
GISS	Goddard Institute for Space Studies
GMAO	Global Modeling and Assimilation Office
GMP	Global Methane Pledge
GPI	genuine progress indicators
GPPDB	Global Power Plants Database
GPW	Gridded Population of the World
GRAP	Green Recovery Action Plan (of the African Union)
GSAT	global surface air temperature
GW	gigawatt (109 watts)
GWh	gigawatt hours
GWP	Gridded Population of the World
HFC	hydrofluorocarbon
H_2O	water
hPa	hectopascal
IBC	Integrated Benefits Calculator
IBD	inflammatory bowel disease
IBS	irritable bowel syndrome
ICAO	International Civil Aviation Organisation
ICCT	International Council on Clean Transportation
ICE	internal combustion engine
ICLEI	Local Governments for Sustainability
i.e.	id est (that is)
IEA	International Energy Agency
IGAD	Intergovernmental Authority on Development
ICLEI	Local Governments for Sustainability
IGO	intergovernmental organizations
ILO	International Labour Organization
IMF	International Monetary Fund
IMO	International Maritime Organization
INDAAF	International Network to study Deposition and Atmospheric
IP	Industrial Park chemistry in Africa
IPCC	Intergovernmental Panel on Climate Change
IPPU	industrial processes and product use
IQ	intelligence quotient
IRENA	International Renewable Energy Agency
IWRM	integrated watershed resource management
JICA	Japan International Cooperation Agency
kg	kilogram
KJWA	Koronivia Joint Work on Agriculture
km	kilometre

LEAP	Low Emissions Analysis Platform
LEAP-IBC	Low Emission Analysis Platform – Integrated Benefits Calculator
LED	light-emitting diode
LGV	Ligne à Grande Vitesse Maroc
LMIC	lower middle-income country
LPG	liquified petroleum gas
LRTAP	Convention on Long-Range Transboundary Air Pollution
LRTI	lower respiratory-tract infection
LULUCF	land use, land-use change and forestry
µg	microgram
m	metre
m^2	square metre
m^3	cubic metre
mm	millimetre
MAFLD	metabolic dysfunction-associated fatty liver disease
MDB	multilateral development bank
MEA	multilateral environmental agreement
MEPS	minimum energy-performance standards
MODIS	moderate resolution imaging spectroradiometer
MOPITT	Measurement of Pollution in the Troposphere
MSMEs	micro, small and medium-sized enterprises
MVOC	microbial volatile organic compound
MSW	municipal solid waste
MVA	Manufacturing Value Added
MW	megawatt (106 watts)
N	nitrogen
NAIPS	National Agricultural Investment Plans
NARC	North African Regional Capability
NASA	National Aeronautics and Space Administration
NCAR	US National Center for Atmospheric Research
NCD	non-communicable disease
NDC	Nationally Determined Contributions (to the Paris Agreement)
NEPAD	New Partnership for Africa's Development
NGO	non-governmental organization
NH3	ammonia
NH4	ammonium
NIR	New Industrial Revolution
NMT	non-motorised transport
NMVOC	non-methane volatile organic compound
NO	nitric oxide
N_2O	nitrous oxide
NO_2	nitrogen dioxide
NO_x	nitrogen oxides
NREL	National Renewable Energy Laboratory
NSB	national standards body
O_x	containing oxygen

O_3	ozone
OC	organic carbon
ODA	overseas development assistance
OECD	Organisation for Economic Co-operation and Development
OICA	International Organisation of Motor Vehicle Manufacturers (Organisation internationale des constructeurs automobiles)
OMI	ozone (O3) monitoring instrument
PCFV	Partnership for Clean Fuels and Vehicles
PIDA	Programme for Infrastructure Development in Africa
PIQ	performance intelligence quotient
PM	particulate matter
PM_1	very fine particulate matter (with a diameter of less than 1 micron)
$PM_{2.5}$	fine particulate matter (with a diameter of less than 2.5 microns)
PM_{10}	large particulate matter (with a diameter of 10 microns or less)
POLCA	Pollution de Capitales Africaines
ppb	parts per billion
ppbv	parts per billion by volume
ppm	parts per million
PPP	purchasing power parity
PREFIA	Air Quality Prediction and Forecasting Improvement for Africa
PV	photovoltaic
QFED	Quick Fire Emissions Dataset
R-COOL	Rwanda Cooling Initiative
REC	Regional Economic Community
ReCATH	Regional Climate Action Transparency Hub for Central Africa
RFA	regional framework agreements
RLP	Rural LPG Promotion Programme
3Rs	reuse, reduce and recycle
S	sulphur
SAAQIS	South African Air Quality Information System
SADC	Southern African Development Community
SDG	Sustainable Development Goal
SEI	Stockholm Environment Institute
SEZ	Special Economic Zone
SLCF	short-lived climate forcer
SLCP	short-lived climate pollutant
SNAP	Supporting National Action and Planning on Short-Lived Climate Pollutants
SNAQ	Sensor Network for Air Quality
SO_2	sulphur dioxide
SSP	shared socioeconomic pathway
TAREA	Tanzania Renewable Energy Association
TROPOMI	Tropospheric Monitoring Instrument
TSP	total suspended particulates
TW	terawatt (1012 watts)
TWh	terawatt hour
U4E	United for Efficiency

UHI	urban heat island
UIC	International Union of Railways (Union internationale des chemins de fer)
UMA	Arab Maghreb Union (Union du Maghreb Arabe)
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UN DESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNEA	United Nations Environment Assembly
UNECA	United Nations Economic Commission for Africa
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNEP ROA	United Nations Environment Programme Regional Office for Africa
UNFCCC	United Nations Framework Convention on Climate Change
UN-Habitat	United Nations Human Settlement Programme
UNIDO	United Nations Industrial Development Organization
UN WPP	UN World Population Prospects
US	United States of America
VAT	value-added tax
VNR	Voluntary National Review
VOC	volatile organic compound
W	watt
WAGP	West African Gas Pipeline
WAPP	West African Power Pool
WDI	World Development Indicators
WEC	World Energy Council
WEPP	World Electric Power Plants Database
WEO	World Economic Outlook
WHA	World Health Assembly
WHO	World Health Organization
WMO	World Meteorological Organization
WRF	Weather and Research Forecasting


031