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KEYS TO CLIMATE ACTION

CHAPTER 8: CHALLENGES AND OPPORTUNITIES OF CLIMATE CHANGE: THE CASE OF EAST AFRICA

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Abstract

Using existing evidence and new analysis of data from East Africa, this chapter shows that climate change negatively impacts economic growth through its effect on sectoral output and labor supply. Moreover, higher temperatures deter renewable energy consumption. Finally, the study investigates the implications of the transition to a decarbonized economy for East Africa that hold a promise to promote prosperity and poverty reduction while addressing the adverse effects of climate change on economic activity. In this regard, the chapter assesses the position and capacity of the region to make such a transition and marshals evidence of the opportunities and trade-offs associated with the green transition in the region.

Keywords: Climate change; Energy transition; East Africa

Introduction

No region has done less to contribute to global warming than Africa. With nearly one-fifth of the world's population, Africa accounts for less than 3 percent of the world's energy-related carbon dioxide (CO2) emissions and has lower emissions per capita than any other region (IEA, 2022). Nevertheless, Africa is already experiencing disproportionately severe and damaging impacts from climate change. Sectors like agriculture, tourism, health, and energy are all suffering. In addition to jeopardizing households' well-being and livelihoods, the impacts of climate change harm the overall economy and environment and put into question our ability to achieve sustainable development. The climate impacts often do not occur in isolation but interact and sometimes reinforce each other.

Looking forward, countries in East Africa are highly vulnerable to a future of increasing climate change (Cline, 2008; Jayne et al., 2018; Klein et al., 2014; Nyasimi et al., 2014). As climate variability and extremes such as drought will become more intense and more frequent, they are expected to affect agricultural households disproportionately; for instance, a moderate increase in temperatures will harm the production of staple crops such as maize that are mainly produced by smallholder farmers in sub-Saharan Africa (SSA) (Hörner and Wollni, 2021; Morton, 2007). Successive and ongoing climate impacts will have a cumulative effect, magnifying the imbalance in risk between wealthy and developing countries.

East Africa already confronts several development challenges. The region faces high unemployment with a narrow range of economic activities and tends to have low human development index scores along with political fragility in some countries. Underlying obstructions to growth include poor infrastructure connectivity in transport and electricity. However, East Africa has been the continent's fastest-growing region in recent years, with Ethiopia, Djibouti, Kenya, Rwanda, Tanzania, and Uganda being some of the fastest-growing economies (AfDB, 2023).

Countries are pursuing efforts to develop and diversify their economies, including the need to improve energy access given the growing population and urbanization. IEA (2019) states that the use of fossil fuels and petroleum products will be required along with the deployment of renewables as the region develops. This leaves policymakers with a perceived dilemma between energy-intensive activities to develop their economies and climate change mitigation through reduced consumption. Bhattacharya et al. (2015) state that countries should not have to choose between economic development and climate change mitigation; through sustainable infrastructure development, both can be addressed.

The failure to take climate action and continue the current climate trajectory could force about 100 million people to fall into extreme poverty by 2030 (Hallegatte, 2016). Ongoing work at the African Economic Research Consortium on growth, poverty, inequality, and redistribution shows new evidence that strong growth supplemented by targeted social protection programs will lead to poverty reduction and flattening of inequality. Thus, the main issue is how to generate strong growth amid the challenges of climate change. If fairness is the only goal, the impetus to act will lie solely with developed economies that are the big emitters who must step up their domestic climate action. Nevertheless, building the new climate economy is a once-in-a-lifetime opportunity that every African nation should prioritize and claim a stake in.

The need to respond to climate change is also an opportunity to drive the economic transformation that the region needs: Climate-resilient, low-carbon development that can boost inclusive growth, bridge the energy deficit, and reduce food insecurity and poverty (African Development Bank, 2015; Apollo and Mbah, 2021). Climate change gives greater urgency to sound, growth-stimulating policies that can withstand the climate threat. One crucial area where the climate change imperative frames an opportunity for Africa is for energy-poor countries to leapfrog straight to clean energy, avoiding decades of inefficient spending on polluting energy sources. This is important because unequal access to energy in Africa has reinforced wider inequalities linked to poverty, gender, and the rural–urban divide that have accompanied the economic growth of the past 15 years. Restructuring energy systems also levels the ground for creating low-carbon jobs, sustaining growth, improving health, eradicating poverty, and boosting government revenues through subsidy reform and carbon pricing alone (GCEC, 2018). As climate change threatens the means of production and the nutrition of the continent's people, policies centered around leveraging science and digital technology also hold the greatest promise to address food security challenges.

Delivering the benefits of a new climate economy requires ambitious action across key economic systems and sectors. While there is evidence that Africa's transition to a new climate economy is underway in many places, there is less supporting evidence that shows if the continent is well positioned to capitalize on this opportunity fully. Based on the above motivations, this chapter seeks to document the challenges of climate change and opportunities in East Africa to learn if the region can build a cleaner, more prosperous future and avoid the worst impacts of climate change, primarily created by others. The study tackles three core questions:

- What are the emergent and future climate hazards associated with climate change in East Africa?
- What is the status of the debate in East Africa regarding the green transition economy, and what are the most salient obstacles to implementing a green transition in the region?

- What are the policy areas to support to facilitate the shift into a decarbonized economy, and what are the potential benefits of such transitioning and the incentive mechanisms for adaptation?

The study focuses on 10 countries in East Africa (Burundi, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, Somalia, South Sudan, Tanzania, and Uganda) and uses insights to identify more comprehensive lessons for sub-Saharan Africa. The overall analysis is based on the premise that understanding the challenge and opportunities of climate change and identifying practical adaptation measures requires a better understanding of how society interacts with climate in the present, along with information about the nature of future climate risks, which can be set within the context of rapidly evolving livelihood systems. The study reviews the literature and conducts new data analysis to assess the challenges and opportunities of climate change and green transition in East Africa. It also identifies policy recommendations.

Impact of climate change in East Africa

East Africa is warming faster than the global average—alarmingly, almost double the 1.1°C warming the world has experienced since the industrial revolution (East Africa Hazard Watch2, 2021, as cited in ICPAC, 2021). Since early 1860, Addis Ababa, Khartoum, Dar es Salaam, Mogadishu, and Nairobi have warmed by 2.2°C, 2.1°C, 2.0°C, 2.0°C, and 1.9°C, respectively.1 Estimates from the United Nations indicate that the region's population will also double by 2050 (U.N., 2019). The rise in population is expected to aggravate the challenge of climate change through pressure on natural resources, leading to environmental degradation, worsening food insecurity, and higher regional poverty levels (Apollo and Mbah, 2021). An extensive literature also documents the direct impact of climate change on the agriculture sector in the region, which accounts for up to 40 percent of gross domestic product (GDP) and affects the livelihood of 65 percent of the region's population (see Adhikari et al., 2015, for review). As temperature increases continue, the frequency and intensity of extreme weather events are projected to increase. Thus, climate change is likely to widen the existing development gap and negatively affect welfare in east African countries. The following section highlights the key impacts of climate change in East Africa documented in the empirical literature.

Insights from empirical studies in East Africa

An array of empirical evidence considers the effects of climate change on development and welfare across Africa broadly and in East African countries in particular. Previous estimates document the huge risk climate change poses to Africa's long-term economic growth. At the regional level, the median loss in GDP per capita is estimated to range from about 9.9 percent to 16.0 percent by 2050 (AfDB, 2019). A range of other studies have considered broader impacts specific to East Africa.

Agriculture and food insecurity

Economies in East Africa are highly dependent on rain-fed agriculture, making rural livelihoods and food security highly vulnerable to climate change (IPCC, 2001). Several studies document a strong positive correlation between food insecurity and climate change due to a shift in growing seasons compounded by extreme weather events such as droughts and floods (Apollo and Mbah, 2021; FAO, 2020). One estimate suggests climate change could increase the number of

[1] East Africa Hazards Watch: https://eahazardswatch.icpac.net

undernourished people in Eastern Africa by 50 percent by the 2030s (Funk et al., 2008). A shortening of rainfall seasons and progressive moisture deficit reduces crop yields produced and consumed by subsistence farmers, such as maize (Adhikari et al., 2015; Waithaka et al., 2013). Lower production of maize, which accounts for about 33 percent of daily calories in Kenya, 26 percent in Tanzania, 20 percent in Ethiopia, 13 percent in Burundi, and 9 percent in Uganda, would significantly affect the availability of food for the growing population and aggravate food consumption gaps in the region (Apollo and Mbah, 2021). The increase in temperature also affects fisheries, influencing the abundance, migratory patterns, and mortality rates of wild fish stocks, with consequences for food access among lakeside populations (Mohammed and Uraguchi, 2013). There is already a tremendous need for emergency food assistance in Somalia, Northern and Eastern Kenya, and South Eastern Ethiopia, linked to unprecedented drought that limits household capacities to access food and income.

Extreme weather events

The socioeconomic impacts of extreme weather are well known in East African countries (Generoso et al., 2020). For example, between 1997 and 2000, floods and droughts associated with El Nino-La Nina cost Kenya about 290 billion Ksh, equivalent to 14 percent of GDP (Mogaka et al., 2009). Climate variability is impacting the frequency, intensity, and predictability of precipitation in the region (Funk et al., 2005; Gebrechorkos et al., 2019). In Sudan, a decline in precipitation is causing more land degradation and desertification (Haile et al., 2020). Meanwhile, Wainwright et al. (2021) report that the 2019 rainy season in the region was the wettest on record, causing massive landslides and floods affecting about 2.8 million people. Similarly, large swathes of Eastern Africa experienced heavy rainfall in 2020 that affected over 1.3 million people by flooding, including at least 481,000 displaced (Kassegn and Endris, 2021). Future temperature increases are projected to cause more frequent and more intense extreme weather events, such as drought, floods, and wildfires across East Africa, with the frequency varying by country (Apollo and Mbah, 2021; IPCC, 2001) Overall, studies predict that the region’s rainy seasons will get wetter over time, increasing the risk of floods, displacement, and an increase in the need for humanitarian aid (Apollo and Mbah, 2021).

Fluctuations in lake levels are also expected to worsen with projected climate variations. For example, lake levels in Lake Victoria in Kenya have already been attributed to climate variations and may become more variable over time (Birkett et al., 1999; Latif et al., 1999). Floods and high rainfall triggered by El Nino-La Nina in 1997 resulted in a surface rise of 1.7 meters in Lake Victoria and negatively affected agricultural production and pastoral systems (Lovett et al., 2005). The same climate event caused drought in another location in Kenya, significantly reducing hydroelectric power output and limiting the availability of electricity to Kenyan households (Lovett et al., 2005; Mogaka et al., 2009).

Lake level fluctuation in Lake Victoria is also increasing the frequency of floods and disrupting livelihoods in the agriculture (fishery) (Mohammed and Uraguchi, 2013) and tourism sectors in Uganda, Tanzania, and Burundi (Akurut et al., 2014, as cited in Apollo and Mbah, 2021). For the Nile region, it is predicted that the fluctuation in the annual amount of water will increase by 50 percent (Siam and Eltahir, 2017). Similar coastal effects are documented in Tanzania and Kenya due to sea-level rise, causing loss of coral reefs and mangroves and ultimately coastal erosion along the Indian Ocean (Ojoyi and Kahinda, 2015).

Human capital accumulation

Climate change significantly affects the human capital accumulation of individuals and countries in the region through its effect on health and hence economic development (Orindi et al., 2005; Tidman et al., 2021). Climate variability is expected to exacerbate the frequency and intensity of disease outbreaks and is estimated to increase the spread of diseases in some areas (IPCC, 2001). In addition to longer rainy seasons suitable for malaria spread, temperatures have also been increasing in the highlands of eastern African countries that were cooler in the past. As a result, East African highlands are experiencing a spread of malaria in populations that had not previously been exposed to malaria outbreaks (Bryson et al., 2020; Onyango et al., 2016; Patz et al., 2005; Zhou et al., 2004;). Of policy concern, the number of people exposed to malaria is expected to more than double by 2080 (Ryan et al., 2020), and the and high cost of household expenditure for malarial treatments in the region is still a major barrier for effective malaria treatment (Ezenduka et al., 2017). Similarly, Rift Valley fever epidemics are correlated to climate change in the region, threatening human health (Bryson et al., 2020; Mweya et al., 2017). For example, outbreaks in the East African highlands are correlated with higher rainfall over time. According to Patz et al. (2005), three-quarters of the Rift Valley Fever outbreaks between 1950 and 1998 coincided with high rainfall in East Africa, which is associated with El Ninõ events.

Biodiversity

Climate change is also having an impact on the dynamics of East Africa’s rich biodiversity, although there is considerable variation in species composition and diversity in each country, and the consequences of climate change will vary by species (Lovett et al., 2005; Sintayehu, 2018). In the post-glacier period, climate variability has resulted in shifts in the geographical distributions of species and ecosystems in East Africa (Orindi et al., 2005). Increasing temperature, combined with other stresses like human population growth, disrupts species’ habitat and co-existence. According to Maitima et al. (2009), East Africa is particularly vulnerable to invasive and exotic species colonization due to its sensitive fauna, resulting in numerous localized extinctions. Moreover, plant species that cannot keep up with the climate shifts, such as the shrub savannahs, are declining. Climate change is also likely to change species migration routes, such as the Wildebeests' migration from Kenya to Tanzania, leading to a general population decline (Maitima et al. 2009).

Climate change further threatens some protected areas, including ones that protect migratory species. Vegetation might also migrate to find suitable habitat requirements such as water and nutrient availability; however, this may mean that some countries' geographical range of suitable habitats will shift outside the boundaries of protected areas. Extreme weather can also affect biodiversity in more complex ways. For example, a shift in rainy and dry seasons could change relative breeding rates and genetic structures in animal populations such as African elephants (Poole, 1989). Thus, strategies for future protected area designations in East Africa must include forecasts of future climate change and associated changes in the geographic range of plant and animal species.

Water availability

Water demand is expected to rise in East Africa due to population increases and increasing needs in agriculture, livestock, industries, and hydropower (Mogaka et al., 2009). Gebrechorkos et al. (2019) estimate that during the long-rain season (March–May), precipitation will increase in Ethiopia, and Kenya and decrease in Tanzania. However, some parts of Ethiopia will be much drier than the baseline period (1961–1990) during short-rain season (June–September), suggesting seasonal shift in precipitation in the region. Less precipitation and rain during the dry season can lead to drought and increased desertification (IPCC, 2001). Changes in rainfall, desertification, and drought might ultimately affect water availability and lead to decreased agricultural production and potentially increased frequency of food shortages.

A decline in moisture required for pastoral and agricultural activities and in the availability of water for human consumption is of concern for the countries in the region. Currently, 47% of the population in Eastern and Southern Africa lack access to safe drinking water, most prominent in Ethiopia, Tanzania and Uganda (UNICEF, 2022). In Tanzania, two of three key river basins (Ruvu and Pangani) have already experienced a reduction in water flow due to decreasing regional rainfall, which caused water shortages, lowered agricultural production, increased fungal and insect infestation, decreased biodiversity, and variable hydropower production (Orindi et al., 2005). In addition, the rising sea levels discussed in Section 2.1.2 will also increase salt-water intrusion into river deltas and aquifers, thus expected to harm freshwater availability (Orindi et al., 2005).

Political economy

One important channel through which climate change affects growth is if it leads to political instability, which in turn may impede factor accumulation and productivity growth. Previous studies show that political instability (e.g., riots and protests) is more likely in warmer weather (Dell et al., 2012). Meta-analysis suggests that temperature increases and precipitation variations are linked to increased risks of conflict (Burke et al., 2015). The results of Burke et al. (2015) show that a 1 standard deviation increase in average temperature increases interpersonal conflict by 2.4 percent and intergroup conflict by 11.3 percent. The causes are often indirect, with climate change exacerbating other sources of underlying tension.

New empirical evidence

In a separate recent study (Ndung'u and Azomahou, 2023), we estimate the effect of climate change (temperature and rainfall) on economic growth (GDP growth) as well as on sectoral output growth (agricultural value added, services value added, and industrial value added), the key elements of the aggregate production function (child mortality as a proxy for labor supply), and energy use, using panel data from 10 East Africa countries over the period from 1970 to 2020.

Impacts on economic growth and sectoral output

The analysis suggests that GDP growth is affected by both temperature and rainfall but nonlinearly in an inversely U-shaped relation. The turning point is roughly at 23°C, implying that overall economic growth within the region is likely to decline when temperatures climb above an optimal average annual temperature of 23°C. Of the 10 East African countries included in this study, five have an average annual temperature beyond the estimated critical temperature threshold. This reflects the general vulnerability of the region to temperature variations and suggests that climate change would constrain the development strategy in these countries more specifically. The results suggest that lower temperatures are associated with more substantial positive effects on economic growth while higher temperature levels have negative impacts, aligning with previous studies (Acevedo et al., 2020; Henseler and Schumacher, 2019). The results also suggest a nonlinear relationship between economic growth and precipitation. As discussed below, this could be because of the effect of precipitation on agricultural output. Overall, the findings point to the need to implement adaptation policies or apply adaptive technologies to mitigate the adverse effects of climate change.

There are several channels through which climate change can influence economic growth. First, as discussed earlier, the relationship between climate change and economic growth can be channeled through direct negative effects on agricultural yield or output and other sectoral outputs, including services. Second, indirect effects can take shape when resources are allocated to compensate for the damaging effects of global warming, rather than to high return investments in physical infrastructure, research and development, and human capital. Third, extreme weather events such as droughts and floods could result in the destruction of nature and ecosystems, with long-term consequences for societal progress.

Our research suggests that temperature has a significant and nonlinear impact on agricultural output growth. The turning point is around 22°C. While the effect of temperature on agricultural output growth at lower temperature levels is positive and strong, a 1-degree higher temperature is associated with about 0.5 percent lower agricultural output growth. This compares to 0.07 of a standard deviation of annual temperatures within the sample. Our analysis also shows that temperature variability (measured as 10 years' standard deviation) negatively and significantly affects agricultural output growth. On average, a one standard deviation increase in annual temperature is linked to 6 percent lower agricultural output growth.

Agricultural output growth is also significantly correlated with precipitation shocks, again in a nonlinear relationship. At lower precipitation levels, an increase in precipitation appears to have a clear positive link to improved agricultural productivity. However, the relationship turns negative above a threshold of 875 mm per year. The link between precipitation and industrial output growth is found to be significant only at lower levels of temperature. Previous studies show that adaptation efforts may mitigate the effects substantially in the long run (e.g., Dell et al., 2012). However, the most important path to limit the long-term risks of climate change in the region is through a global effort to contain carbon emissions to levels consistent with a manageable increase in temperatures (Acevedo et al., 2020).

Health effects

One of the channels through which climate change impacts economic growth would be labor supply. To examine whether labor supply would be affected by weather fluctuations, for example, through their effect on health, we followed Acevedo et al. (2020) by using child mortality as a proxy for adult health outcomes. The results indicate that higher temperatures may reduce (future) labor supply through its influence on child mortality rates. At lower temperature levels (below the turning point which is around 26°C for the health outcome), an increase in temperature by 0.1°C is associated with a reduction in child mortality by 17.2 deaths per 1,000 live births. However, at higher temperatures (beyond the turning point of 26°C), an increase in temperature by 0.1°C is linked to an increase in the under-five child mortality rate of about 0.4 deaths per thousand live births, which is equivalent to 0.006 of a standard deviation. These results are in line with recent empirical evidence in other parts of Africa (e.g., van der Merwe et al., 2022) and could be because temperature shocks lead to lower income (and potential food insecurity), reinforcing the direct physiological impact of higher temperatures (Acevedo et al., 2020). The adverse health effect of climate change also has long-term welfare effects; it can negatively impact a child's growth and brain development, which negatively impacts children's adulthood outcomes such as education, productivity, and income (van der Merwe et al., 2022; Yitbarek and Beegle, 2019). This also sheds light on some reasons why weather shocks affect sectors besides agriculture (Acevedo et al., 2020).

Energy use

We also investigated the relationship between renewable energy use and climate change. The results indicate that higher temperature is correlated with lower renewable energy consumption. This might reflect climate change dampening demand for sustainable energy use. Given the growing demand for renewable energy, an increasing focus on higher energy efficiency, and a greater role for the carbon market, there is a need for increased investment in sectors such as energy-efficient technologies, renewable energy, public transport, sustainable agriculture, and sustainable management of natural resources are needed for the promotion of a green economy (Lohani et al., 2016). This supports the creation of a low-carbon society needs and creates new dynamic industries, more employment, and income (Meyghani et al., 2022). Access to clean fuels and technologies for cooking is very low in East Africa, particularly in rural areas, ranging from the highest level in Kenya (19.5 percent of the population) to the lowest in Burundi (0.2 percent) (WHO, 2023).

Policy response to climate change in East Africa

All sub-Saharan African countries except Eritrea have signed and ratified the 2015 Paris agreement, including its commitment to Nationally Determined Contributions and implementing national climate actions. Member states benefit from the support of the African Union Commission and Regional Economic Communities in climate strategies and action. Agenda 2063 is the main pillar of the African Climate Change strategy, outlining united efforts, self-reliance, and African finance to align continental, regional, and national climate action.

In 2009, the East Africa Community developed its own Climate Change Policy (EACCCP) to improve the region's adaptive capacity and build resilience against the adverse effect of climate change (Apollo and Mbah, 2021). Countries in the region also established the Eastern Africa Climate Smart Agriculture Platform (EACSAP) in 2014 to promote agricultural productivity, adaptation, and resilience to climate change through technological innovation (Apollo and Mbah, 2021; Price, 2018). Most of the region's adaptation policy priorities focus on livelihoods, energy, forests, agriculture and food security, disaster response, transport, and coastal zones. However, a lack of horizontal linkages across countries and policies limits regional policy coherence (Price, 2018). In the same vein, Apollo and Mbah (2021) highlight the importance of coordinating efforts between the government, the private sector, civil society, and educational institutions to promote climate change education and innovation in East Africa for maximized implementation of the existing strategies.

In parallel, most countries in the region have developed their own national climate change strategies. Table 8.1 summarizes the country-specific climate policies, their focus areas, and the action points for their implementation.

Table 8.1: Climate change policies in East Africa

Country	Policy	Main objective	Nationally determined contribution (NDC) targets to reduce greenhouse gas (GHG) emissions
Burundi	National Climate Change Policy 2012 Updated NDC 2021	Promote resilient climate development by coordinating restorative environmental activities	3 percent by 2030, or 13 percent with international support
Ethiopia	Climate Resilient Green Economy (CRGE) strategy 2011 Updated NDC 2021	Keep greenhouse emissions low	69 percent - 14 percent of which is to be an unconditional effort
Kenya	National Climate Change Action Plan 2018–2022 National Climate Change Policy 2018 Climate Change Act 2016 Updated NDC 2020	Integrate climate change into sectoral planning and implementation at all levels Promote a climate resilient and low-carbon economic development Mainstream climate change into sector functions	32 percent by 2030
Uganda	Green Growth Development Strategy 2017–2030 National Climate change policy (NCCP) 2015 Updated NDC 2022	Achieve an inclusive low-carbon economic development that observes efficient and sustainable use of natural resources and human capital Attain transformation through climate change mitigation and adaptation	25 percent by 2030
Tanzania	National Climate Change Strategy (NCCS) 2012 Updated NDC 2021	Enhance technical, institutional, and individual capacity of citizens to address climate change impacts	30–35 percent by 2030

Country	Policy	Main objective	Nationally determined contribution (NDC) targets to reduce greenhouse gas (GHG) emissions
Somalia	Somalia National Adaptation Programme of Action (NAPA) 2013 Environmental and Climate Change Policy 2012 First NDC 2021	Reduce change-induced vulnerabilities to the poorest communities who depend on natural resources Identify the key environmental challenges and opportunities.	30 percent by 2030
Rwanda	National Environment and Climate Change Policy 2019 Rwanda Green Growth and Climate Resilience: National strategy for climate change and low carbon development 2011 Updated NDC 2020	Achieve a clean and healthy environment, resilient to climate change for a high quality of life Promote climate resilience and green development through adaptation, mitigation, and poverty reduction	38 percent by 2030
Sudan	Sudan National Adaptation Plan 2014	Provide a platform for climate change policy dialogue	Sectoral actions/ reductions
South Sudan	National Environment Policy 2015–2025 Updated NDC 2021	To enhance the protection, conservation, and sustainable use of natural resources.	Sectoral actions/ reductions 110 MT reduction by 2030 with additional sequestered 45 million tCO2e

ƚ Target numbers rounded to nearest integer where relevant. NDCs are available at https://unfccc.int/NDCREG as well as https://climatepromise.undp.org/what-we-do/where-we-work.
Source: Authors' analysis and Apollo and Mbah (2021).

Most of the policy documents summarized above seem to regard climate change as a technical problem that requires specialized solutions and treat climate change separately from a broad development agenda (Addaney, 2018; Apollo and Mbah, 2021; Orindi et al., 2005). This could be due to the urgent need for the countries to reduce poverty and tackle other development challenges such as unemployment and growth rather than climate change. However, as noted in Section 2 of this study in detail, climate change would severely affect the region's sustainable development in both the short and long run. Weisser et al. (2014) argue that adaptation to climate change should not merely focus on new activities; instead, it should be mainstreamed in the existing livelihood coping strategies through knowledge and innovation.

Another key insight from Table 8.1 is that the majority of the countries in the region have defined unconditional targets in their NDCs, showing countries' own underlying commitment to tackling climate change. However, the conditionality of NDCs on international finance shows how much more could also be done within the region. Reaching these more ambitious objectives remains challenging, due to inadequate access to additional and predictable climate finance across the region (Roberts et al., 2021).

Energy transition: Opportunities and challenges

Context and opportunities for renewable energy

East African policymakers must address both energy and economic challenges while addressing climate change policies. According to the International Renewable Energy Agency (IRENA), the key to reducing energy-related CO2 emissions is to increase the share of renewable energy, coupled with gains in energy efficiency and lowering fossil fuel consumption (IRENA, 2018). The IEA (2019) states that Africa is vital to the clean energy transition worldwide, with its abundant fossil fuel reserves, solar power, and minerals, and as a key driver of growth in global energy demand. East Africa's growing population and rapid urbanization further intensify the need for a reliable and sustainable energy supply. Demographic changes will drive economic growth, requiring substantial infrastructure development and accelerating energy demand. Africa's overall energy demand growth is already twice as fast as the global average (IEA, 2019).

Achieving universal access to reliable electricity supply remains a key challenge for East Africa's economic development (IEA, 2019). In 2020, an estimated 182 million people across the region did not have access to electricity, while more than 85 percent of the population (303 million people) lacked access to clean cooking (IEA 2022). Traditional uses of biomass result in household air pollution, which the World Health Organization estimates to have cause more than 170,000 premature deaths per year in the region as of 2019, while contributing significantly to deforestation (WHO, 2022).

Within East Africa, several countries have made significant progress in providing energy access. However, current plans and efforts barely outweigh population growth (IEA, 2019). Renewable energy sources dominate the energy mix in East Africa, with 71 percent of installed capacity from renewables (IRENA, 2021). Burundi, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, Somalia, South Sudan, Sudan, Tanzania, and Uganda have invested significantly in renewable energy. IRENA (2021) forecast that, by 2030, on-grid electricity demand will grow by 250 percent in East Africa. Growth is driven by rapid access expansion since the region has the highest number of unconnected households. The most significant increases in absolute demand are expected in Ethiopia, Kenya, Tanzania, and Sudan. Robust off- and mini-grid solutions are important to expanding access. Installed capacity is expected to increase substantially by 2030, with solar power and large reservoirs playing a central role. In Ethiopia, the region expects a newly added capacity of 12,000 MW by 2025 from large hydropower plants under construction (IRENA, 2021). Considerable investment in solar power plants and batteries is expected to be realized by

2030, developing a diverse generation mix. This will allow the region to undergo significant system integration since the largest projects are already under construction.

Challenges to the energy transition

Africa holds significant renewable energy potential, including wind, solar, and hydropower. However, urbanization and population growth might require fully utilizing all available energy resources (Nalule, 2021). Due to decreasing cost of renewable technologies and the need to combat climate change, financial institutions may reduce investment in fossil fuels. While the transition to the low-carbon economy provides an opportunity to address climate change and job creation, the transition will likely intensify energy access challenges and poverty in Africa due to reduced funding for fossil fuel energy projects (Nalule, 2020).

Hydrocarbons

Nalule (2021) argues that fossil fuels will have a significant role to play in the energy transition where revenues could be used to finance clean energy investment. Many formerly energy importing African countries will become energy exporters in the coming years, often linked to oil, gas, and coal discoveries that have been made within the last decade (Kidunduhu, 2021). For example, Kenya made its first small-scale export of crude oil in 2019 and recently discovered coal and offshore natural gas deposits (Kidunduhu, 2021). Enormous natural gas resources in Africa could also play a compelling role in climate change mitigation while contributing to global energy security (Olawuyi, 2020). Natural gas is identified as an environmentally preferable product for low-carbon transitions, due to its reduced effect on human health and the environment compared to oil and coal. Between 1980 and 2014, the increased share of natural gas in the energy mix contributed to a 40 percent reduction in CO2 intensity of oil equivalence (Olawuyi, 2021). Recent discoveries in East Africa, Mozambique, and Tanzania, along with other discoveries in Egypt, Senegal, Mauritania, and South Africa, account for more than 40 percent of global gas discoveries between 2011 and 2018 (IEA, 2019).

Similarly, Muhongo (2021) states that the continued role of fossil fuels in African development cannot be ignored, as energy is vital in addressing many development challenges within Africa, such as poverty, unemployment, and gender equality (Nalule, 2018). The author argues that both fossil fuels in conjunction with renewables would play a role in achieving sustainable development goal (SDG) 7 to provide universal access to reliable, modern, clean, and affordable energy. In order to take full advantage of the energy industry lifecycle, resource-rich countries have implemented local content policies, which allow for the creation of employment, capacity building, value addition, and education and training provisions for local communities (Marcel et al., 2016). However, Tanzania, Kenya, and Uganda lack the technology, capital, capacity, and supporting industries to fully develop their oil and gas capacity (Anderson, 2016; Cannon et al., 2022; van Alstine et al., 2014). Nalule (2021) identifies three disruptions in the hydrocarbon sector in developing countries: A lack of necessary infrastructure, corruption and transparency issues, and an unreliable regulatory regime. Competition from liquified natural gas and renewables investment will likely disrupt existing hydrocarbon developments. Furthermore, corruption creates uncertainty for investors and prevents locals from accessing benefits from their resources. The region also lags behind in digitalization, which is a notable feature of the hydrocarbon sector, possibly deterring further investment (Carnegie, 2022).

The IEA (2019) states that changes in global energy dynamics indicate that development models highly dependent on hydrocarbon revenues can no longer assume that oil resources will translate into reliable future revenues. The push toward the energy transition would decrease demand and hydrocarbon prices, substantially reducing additional revenues. Policymakers are therefore faced with the dilemma of capitalizing on fossil fuel reserves to accelerate development while constraining carbon emissions (Kidunduhu, 2021).

Nalule (2021) proposes the use of "Energy progression" in order to achieve the energy transition. Energy progression recognizes the progressive nature of energy use, which implies a gradual progression from one form of energy to another. The concept allows for the role of fossil fuels to facilitate industrialization, urbanization, and meeting domestic energy demand. However, a lack of funding to capitalize on fossil fuels would delay Africa's energy transition from fossil fuels to renewables. In this respect, the author argues that different countries face different energy challenges. Africa lacks access to modern energy and technology to facilitate cleaner usage of fossil fuels.

The role of natural gas in the global energy mix is central to energy progression where natural gas replaces more polluting fuels, i.e., coal-to-gas switching. Coal-to-gas switching has saved around 500 million tons of CO2 since 2010 (IEA, 2022). In addition, natural gas provides a quick win for emission reductions in case cases where it can use existing infrastructure, compared to the time it takes to implement energy efficiency improvements and new renewables projects.

Energy security

From the viewpoint of options to promote stable supply, renewables can offer energy security. However, countries highly dependent on low-cost imports are less likely to attract additional investment in renewable energy sources to become self-sufficient (Oosthuizen and Inglesi-Lotz, 2022). While renewable energy shields against the price variability of traditional fossil fuel sources, the technology creates other import dependencies, such as for minerals and precious metals.

The initial adoption of renewable energy allows for the diversification of the energy mix; however, increased deployment can lead to domination in the energy mix, undoing diversity gains. This could expose the energy system to the characteristics of a monopoly (Augutis et al., 2014).

Due to the variability of renewable energy sources, countries will still have import dependence to smooth demand. Renewable energy sources are closely related to climate conditions, where climate change, such as changes in temperature, wind patterns, and cloud coverage, could increase the variability further (Kidunduhu, 2021). Furthermore, renewable adoption will require grid updating and investment in storage. This process requires large amounts of metals and minerals, which are depletable and endowed to a small number of countries. Renewable energy technologies also depend on the geopolitics of the supply of these minerals.

Technological barriers

Clean energy system development requires both technological and institutional innovation. Unfortunately, Africa has low levels of technology as well as research and development due to the high cost associated and lack of capacity, among others (Kidunduhu, 2021). Technological transfer to developing countries is envisioned under the Kyoto Protocol and the Paris Agreement. However, to enable successful technology diffusion, developing countries need the capacity to absorb the technology. Unfortunately, only moderate progress has been made to facilitate technology transfer from developed countries. In order to enable technology absorption, African countries require capacity development, possibly through joining technology collaborative networks such as IEAS's Networks of Expertise in Energy Technology (NEET) initiative (Kidunduhu, 2021).

Cost

Investment in the energy sector is a priority on the agenda of many African countries, regional bodies, and international funders due to the growing importance of SDG 7. Financing and investment are fundamental challenges in East Africa. Clean energy systems require significantly more capital expenditure than fossil fuel systems (Kidunduhu, 2021). The cost of financing clean energy systems determines the cost of deployment, and African projects face higher interest rates than other parts of the world. In addition, political risks, such as war, civil disturbance, currency inconvertibility, and expropriation, can adversely affect the value of investments. High risk makes financing renewable energy projects difficult and costly (IRENA, 2020).

IRENA (2020) conducted an energy resource and zoning analysis and identified high resource potential and cost-effective power generation zones for wind, solar photovoltaic, and concentrated solar power across eastern Africa. The financial viability and bankability of over 90 solar photovoltaic and wind projects have been conducted so far (IRENA, 2020). The East African Rift System holds noticeably untapped geothermal potential. Five regional African organizations and 10 African countries have joined the Global Geothermal Alliance facilitated by

IRENA to promote the development. The Global Geothermal Alliance works to overcome high upfront cost barriers, investment risk, and policy uncertainty. In East Africa, there are more than 10 ongoing initiatives with high levels of private sector involvement to accelerate the role of renewable energy and electrification (IRENA, 2020). The Clean Energy Corridor, a regional initiative to accelerate the development of renewable energy potential also assists in the facilitation of renewable power generation upscaling and cross-border electricity trading within the East Africa Power Pool.

A way forward

The evidence described above indicates that climate change creates both challenges and opportunities in East Africa. The challenges include its adverse effects on economic growth, agricultural productivity and food security, and human capital. The East African region has the opportunity to use adaption, resilience policies, and investment to strengthen their overall economy strategically. Through investments in climate-resilient and carbon-efficient agriculture, land use and forestry, and energy practices, the region can reach successful adaption and mitigation while building economic and social resilience.

But the opportunities also come with trade-offs. Based on the empirical evidence in Africa in general and East Africa in particular, this section focuses on policy recommendations:

Renewable energy and green transition

East African countries have not yet been able to effectively improve their energy mix and promote energy transition, at the same time as they are primarily dependent on imports for oil and coal consumption (Irowarisima, 2022). As a result, they have not yet locked in any form of path dependence on specific high-carbon energy sources. This differs from major coal-consuming countries such as China and India and leaves tremendous potential for making the leap from biomass to hydro, geothermal, wind, and photovoltaic energy systems (Cilliers, 2021). The East African region is rich in renewable energy endowments, including geothermal energy in the East African Rift Valley in Kenya, hydro energy in the Abbey and Omo river basins in Ethiopia, and solar energy endowment in Tanzania, etc. (Sun, 2022). However, while wind and solar energy have made a breakthrough from 0 percent to 1 percent, there is limited scope for emission reductions, and further investment is needed with the help of FDI (Sun, 2022). In the 1970s nuclear power plants spread with the oil crisis in an attempt to address flexibility needs in conventional power systems; however, because they operate at full capacity at base load, they are not fully flexible. Pumped-storage hydro plants address the flexibility problem (Impram et al., 2020). In Ethiopia, hydropower is used to internalize the intermittency of other renewable sources such as solar and wind (van der Zwaan et al., 2018).

Policymakers should actively promote access to renewable energy in particular and clean energy in general (Inglesi-Lotz, 2016). Policymakers do not have to reinvent the proverbial wheel. Instead, they have the luxury of borrowing and adapting strategies that have been used to reduce CO_2 emissions in developed countries (Njoh, 2021). Some of the most promising clean energy strategies fall under two broad categories, namely, demand focused and supply oriented (Njoh, 2021). Demand-focused strategies seek to bolster the ability of consumers to pay for renewable or clean energy. This may assume the form of government vouchers or incash assistance to consumers. Supply oriented strategies entail using market mechanisms such as tax incentives, subsidies, or subventions directed at renewable/clean energy supplying enterprises (Mac Domhnaill and Ryan, 2020). For either category, countries need to understand that the success of any strategy hinges tightly on its ability to render the cost of renewable/clean energy affordable to consumers (Njoh, 2021). Salahuddin et al. (2019) recommend rigorous efforts to stimulate converting a considerable amount of off-grid bioenergy, a significant Total Primary Energy Supply (TPES) source in the East Africa region, into modern energy services. Wind potential is another highly prospective source for transitioning to a low-carbon region (IEA, 2019). In addition, the region should build more geothermal sites to boost its geothermal energy production.

Four policy implications emerge: First, intensive investment in existing renewable energy projects and common markets can lead to significant CO2 emissions reduction and environmental relief at the regional level. Second, optimizing and creating interconnection through renewable energy projects (such as the Eastern Africa power pool) can intensively contribute to meeting energy demand in the region and result in CO2 emissions reduction (Nalule, 2021). Third, country-specific energy policies should target emissions reduction (Bhattacharya et al., 2015). Finally, enhancing East Africa power trade optimization over current cross-border connections and building other integrated power systems can lead to sustainable energy generation and contribute to the growth of national economies (Namahoro et al., 2021).

Off-grid solar dissemination

Countries in the region also need to renegotiate large-scale power plant private–public agreements (PPAs), implement operational flexibility, decrease reserve demands, and optimize energy expenses. In addition to off-grid solar energy being a relatively new industry in Kenya, Rwanda, and Ethiopia, more focus on developing technical abilities and associated capacity for project oversight, tracking, and assessment is required (Mugisha et al., 2021). In the same three countries, local private investors have less involvement in the off-grid solar business because of a lack of incentives and high upfront costs, primarily due to insufficient funds for rural electrification programs (Mugisha et al., 2021). However, a lot can be learned from Cambodia, which has been prosperous in terms of rural off-grid solar penetration, with private investors highly involved. The success story of Cambodia is a combination of sound policies that focus on the standardized approach of mini-grids, appropriate tariffs regulations that evaluate each power provider individually depending on their costs, and the availability of effective financing mechanisms to private investors (Mugisha et al., 2021). Providing incentives to private sectors and households can play a significant role in sustainable off-grid solar dissemination (Chakamera and Alagidede, 2018; Mugisha et al., 2021).

In Kenya, Ethiopia, and Rwanda, the off-grid solar sector is administered by a general government body that oversees entire sources of energy and electricity generation as a whole

(Mugisha et al., 2021). As a result, investors face lengthy bureaucratic procedures and delay in the updated reports. However, off-grid solar has been set as a pillar in these East African countries' rural electrification plans (Mugisha et al., 2021). Therefore, an office solely focusing on off-grid solar systems in planning, marketing, and implementation is also worth considering.

There is also a need for transparency and platforms in which information could be shared to prep private investors and minimize business risks (Kidunduhu, 2021). Decentralized rural electrification agencies in villages are crucial, rather than having top-down policies. Decentralization will ensure that the quality of products sold throughout the country meets standards to reduce fraud, provide updated information on customer status, map the area, and carry out risk assessment studies (Nalule, 2021). Thus, promoting transparency and decentralizing rural electrification agencies can reduce the lengthy bureaucratic processes. At its best, it will provide updated information for investors, donors, and customers (Nalule, 2021). Poverty is one of the main threats to making the off-grid solar projects economically feasible for households, especially if population increases expand the number of poor people (IRENA, 2020). Therefore, complementary income-generating opportunities can help make sure the development of the off-grid solar sector is backed by citizens' ability to afford it.

Small-scale renewable energy technologies

It is also vital for national governments in the East Africa region to formulate prudent policies and provide direct support to small-scale renewable energy technologies (SRETs). This includes the provision of financial and non-financial incentives, such as subsidies, long-term credit services, and soft loans (Wassie and Adaramola, 2019). A related priority is to ensure the technologies are operational once installed, by setting up maintenance service centers with skilled standby technicians and through proper monitoring and follow-up services (Gebreslassie et al., 2022). Furthermore, strengthening the institutional, technical, logistical, and human resource capacity of district and local level SRETs promotion and dissemination offices and staff is crucial for enabling them to create community awareness, provide training and maintenance services, and establish local experience-sharing platforms (Qadir et al., 2021). This will facilitate knowledge transfer between users, non-users, suppliers, and technicians. Establishing viable cross-sectoral integration and multi-stakeholder cooperation is important, as is involving the private sector at national and local levels if SRETs are to play a significant role in the energy regime of households in East Africa (Wassie and Adaramola, 2019).

Resource mobilization

Increasing the proportion of foreign investment in clean energy development expenditure is another crucial aspect of a way forward, including the unlocking of East Africa's major endowments of potential renewable energy. Countries should first reform their power sectors to facilitate international investments. However, the reform must also extend well beyond the power sector (Bhattacharya et al., 2015). Reducing the risks arising from macroeconomic or political instability and weak protection of contract and property rights is also paramount (Hafner and Strasser, 2018). The international public financing available for Africa's electrification should be better used to favor the scale-up of international private investments. Putting the governance of the region's energy sector in order is the starting point for expanding countries' power systems. Without such reforms, international energy companies and investors would hardly jump into SSA energy markets. The support of international public finance institutions will be vital to ensuring the progress of energy transition, notably by contributing to crowding-in private investors into SSA's power markets. International public finance institutions can provide support with direct financing, blended finance tools, or risk-sharing mechanisms (IRENA, 2020). They can provide risk-mitigation and credit-enhancement tools to cover the country's risk faced by international energy companies and institutional investors (Chakamera and Alagidede, 2018; Hafner and Strasser, 2018). Moreover, macroeconomic measures such as suspending remittances fees or temporarily removing trade barriers for imports of emergency items such as food and reconstruction equipment can help accelerate the recovery from severe impacts of extreme weather.

Reducing energy intensity and promoting energy efficiency

The industrial and transportation sectors have a considerable influence on national economies and are vital for the development of countries (Srinivasu et al., 2013). However, as energy-intensive sectors, the development of industry and transport will inevitably result in high emissions. However, Therefore, industry and transport should reduce energy intensity and improve energy efficiency rather than give up development opportunities. Governments should promote sustainable economic development by structurally transforming the manufacturing sector through high-value-added techniques and product diversification, improving the energy efficiency of transport, and developing public transport (Sun, 2022).

Overall, the Governments in the region need to improve the efficiency of the energy sector to minimize the ratio of electricity transmission and distribution losses (Edenhofer et al., 2017). While small-scale power plants (e.g., solar, small-scale hydropower) can improve electricity supply even in remote areas as off-grid systems, they lack economies of scale to reduce generation costs and losses (Chakamera and Alagidede, 2018). To enhance efficiency in the transmission and distribution of energy, proper planning and implementation, skilled personnel, and adequate research and development are among the key factors (Chakamera and Alagidede, 2018).

Prompting green innovation and information and communications technology development

African governments should focus on supporting digital technology policies and incentives to encourage investments in green technologies and improve environmental quality. Although investment incentives are needed to deploy renewables, these incentives are not enough in themselves, because other barriers to deployment must also be removed (Newell, 2021). For example, extending and promoting smart meters to help conserve and reduce energy consumption by the different industry sectors and residential areas is also crucial (Bogdanov et al., 2021). This can be achieved in various ways, such as through better asset management (since fixed assets represent a large part of operating costs), making remote maintenance possible via environmental scans, and achieving better logistics control through accurate and timely weather forecasting and precise planning (Charfeddine and Kahia, 2021). In addition, the use of Blockchain could considerably improve the accountability, transparency, and traceability of CO2 emissions (Wang et al., 2019; Xiao et al., 2020).

Recently, renewable technologies have been cost competitive with non-renewables; therefore, governments can divert fossil fuel subsidies into renewable development and reduce import tariffs on green technologies (IRENA, 2020). Additionally, authorities should establish well-defined structures to absorb knowledge spillovers from other internal power pools and international partners. Besides, rigorous economic cooperation among African regions and at the country level should be encouraged to boost the technical know-how of less developed economies (Dauda, 2021; Lin and Sai, 2022).

Strengthening regional and countries' adaptation priorities

As examined in Section 4, countries in the region have national adaptation priorities but there are no adaptation priorities at a regional level. Given the transboundary nature of a number of the region's river basins as well as forest, coastal, and marine ecosystems, regional coordination will be required to ensure long-term sustainable management of these resources. Developing a regional strategy and action plan in coordination with international and national stakeholders may serve as the foundation for regional dialogue and coordinated response to climate change impacts. A clear regional strategy will also help to inform the prioritization of projects that can be jointly marketed to donors and other potential investors.

Concerning climate change mitigation and adaptation priorities, policies need to focus on land users' needs, as they directly feel the impact of climate change. Transitioning from rainfed agriculture to irrigation crop production increases crop yield and addresses the vulnerability concern. However, this places pressure on limited water resources in the region. Other adaptation strategies include water harvesting, water catchment area management, and land and water conservation. However, the latter are not preferred adaption strategies for some land users, illustrating the need for discourse between policymakers and land users to effectively reconcile land users' needs and resources (Adimo et al., 2012). Land use and climate change significantly influence the watershed where the impact is likely to increase in coming years due to further clearance of virgin forest lands for agricultural use (Hyandye et al., 2018). Increased deforestation is projected to decrease the total water yield by 13 percent and increase evapotranspiration and surface runoff by approximately 8 and 18 percent, respectively, from the Ndembera River affecting the East African Rift (Hyandye et al., 2018). To prioritize adaption strategies, vulnerability profiles can assist in avoiding exploitative adaption, which could lead to land degradation and biodiversity loss, energy and water waste, and gradual productivity loss. Other regional priorities include improving seasonal forecasts, developing approaches and tools for vulnerability and adaptation assessment, and devising methodologies and tools for climate change monitoring, detection, and attribution.

Conclusion

Climate change has already caused enormous economic and societal costs throughout East Africa. These costs are only projected to grow as average temperatures continue to rise, precipitation patterns continue to evolve, and extreme weather events further intensify. Forestalling the impacts of climate change requires urgent implementation of adequate resilient development measures in all economic sectors across all countries in the region. In parallel, there is an enormous development opportunity embedded in the pursuit of a successful energy transition that can promote universal access to electricity and widespread deployment of renewables. East Africa's extraordinary endowments of different forms of potential renewable energy further heighten the opportunity.

Given its low GHG emissions and high prevalence of energy poverty, East Africa must be allocated a carbon space and planning horizon to define contextual transition pathways that protect its aspirations for economic transformation and poverty elimination. Climate justice requires that the region should not be denied access to the remaining global carbon budget to power its structural transformation. For instance, where the benefits of natural gas outweigh the cost, natural gas should be allowed as a transition fuel. Indeed, natural gas can and should be used alongside renewables to help overcome the intermittency of the power supply.

At the same time, a just transition in East Africa should prioritize the equitable distribution of benefits associated with the shift to low-carbon and resilient climate sectors, helping to confront energy poverty, inequality, and barriers to economic development. Development priorities should align with increased access and energy-efficient systems. Mitigation, adaption, and development should follow the same goals, in which the appropriate mix of low-carbon technologies will be context dependent. A range of complementary infrastructure, capacities, investments, and policies will define the path for East Africa's green competitive advantage.

References

Acevedo, S., Mrkaic, M., Novta, N., Pugacheva, E. and Topalova, P. (2020). The effects of weather shocks on economic activity: What are the channels of impact? Journal of Macroeconomics, 65, 103207.

Addaney, M. (2018). Climate change adaptation law and policy in the African union: Creating legal pathways for adaptation, in 5th International Climate Change Adaptation Conference Cape Town South Africa, 18–-21 June 2018, p. 2.

Adhikari, U., Nejadhashemi, A. P. and Woznicki, S. A. (2015). Climate change and eastern Africa: A review of impact on major crops. Food and Energy Security, 4(2), 110–132.

Adimo, A. O., Njoroge, J. B., Claessens, L., and Wamocho, L. S. (2012). Land use and climate change adaptation strategies in Kenya. Mitigation and Adaptation Strategies for Global Change, 17(2), 153–171.

African Development Bank (2015). The African Development Bank at The UNFCC COP21 Meeting – Africa's Climate Opportunity: Adapting and Thriving, African Development Bank Publications

African Development Bank (AfDB) (2019). Climate Change Impacts on Africa's Economic Growth. Retrieved from https://www.afdb.org/sites/default/files/documents/publications/afdb-economics_of_climate_change_in_africa.pdf

African Development Bank (AfDB). (2023). East Africa Regional Overview. Retrieved from https://www.afdb.org/en/countries/east-africa/east-africa-overview

Akurut, M., Willems, P. and Niwagaba, C. B. (2014). Potential impacts of climate change on precipitation over lake , East Africa, in the 21st century. Water, 6(9), 2634–2659.

Anderson, W. (2016). Local suppliers in Tanzania: Ready for the petroleum sector? The African Review: A Journal of African Politics, Development and International Affairs, 43(2), 51–83.

Apollo, A. and Mbah, M. F. (2021). Challenges and opportunities for climate change education (CCE) in East Africa: A critical review. Climate, 9(6), 93.

Augutis, J., Martiˇsauskas, L., Krikˇstolaitis, R. and Augutiene˙, E. (2014). Impact of the renewable energy sources on the energy security. Energy Procedia, 61, 945–948.

Bhattacharya, A., Oppenheim, J. and Stern, N., (2015). Driving sustainable development through better infrastructure: Key elements of a transformation program. Brookings Global Working Paper Series.

Birkett, C., Murtugudde, R. and Allan, T. (1999). Indian ocean climate event brings floods to East Africa's lakes and the sudd marsh. Geophysical Research Letters, 26(8), 1031–1034.

Bogdanov, D., Ram, M., Aghahosseini, A., Gulagi, A., Oyewo, A. S., Child, M., Caldera, U., Sadovskaia, K., Farfan, J., Barbosa, L. D. S. N. S. et al. (2021). Low-cost renewable electricity as the key driver of the global energy transition towards sustainability. Energy, 227, 120467.

Bourcet, C. (2020). Empirical determinants of renewable energy deployment: A systematic literature review. Energy Economics, 85, 104563.

Bryson, J., Bishop-Williams, K., Berrang-Ford, L., Nunez, E., Lwasa, S., Namanya, D. and Harper, S. (2020). Indigenous health adaptation to climate change research team neglected tropical diseases in the context of climate change in east Africa: A systematic scoping review. Am. J. Trop. Med. Hyg, 102, 1443–1454.

Burke, M., Hsiang, S. M. and Miguel, E. (2015). Climate and conflict. Annu. Rev. Econ., 7(1), 577–617.

Cannon, B. J., & Mogaka, S. (2022). Rivalry in East Africa: The case of the Uganda-Kenya crude oil pipeline and the East Africa crude oil pipeline. The Extractive Industries and Society, 11, 101102.

Carnegie Endowment for International Peace. (2022). To close Africa's digital divie, policy must address the usage gap. Retrieved from https://carnegieendowment.org/2022/04/26/to-close-africa-s-digital-divide-policy-must-address-usage-gap-pub-86959

Chakamera, C. and Alagidede, P. (2018). Electricity crisis and the effect of co2 emissions on infrastructure-growth nexus in sub Saharan Africa. Renewable and Sustainable Energy Reviews, 94, 945–958.

Charfeddine, L. and Kahia, M. (2021). Do information and communication technology and renewable energy use matter for carbon dioxide emissions reduction? Evidence from the middle east and north Africa region. Journal of Cleaner Production, 327, 129410.

Cilliers, J. (2021). Technological Innovation and the Power of Leapfrogging. In: The Future of Africa. Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-030-46590-2_10

Cline, W. R. (2008). Global warming and agriculture. Finance & Development, 45(001).

Comte, J. C., Cassidy, R., Obando, J., Robins, N., Ibrahim, K., Melchioly, S. and Davies, J. (2016). Challenges in groundwater resource management in coastal aquifers of East Africa: Investigations and lessons learnt in the Comoros Islands, Kenya and Tanzania. Journal of Hydrology: Regional Studies, 5, 179–199.

Dauda, L. (2021). Innovation, trade openness and co2 emissions in selected countries in Africa. Journal of Cleaner Production, 281, 125143.

Dell, M., Jones, B. F. and Olken, B. A. (2012). Temperature shocks and economic growth: Evidence from the last half century. American Economic Journal: Macroeconomics, 4(3), 66–95.

Edenhofer, O., Knopf, B., Bak, C. and Bhattacharya, A. (2017). Aligning climate policy with finance ministers' g20 agenda. Nature Climate Change, 7(7), 463–465.

Ezenduka, C. C., Falleiros, D. R., Godman, B. B., (2017) Evaluating the Treatment Costs for Uncomplicated Malaria at a Public Healthcare Facility in Nigeria and the Implications. Pharmaco Economics, 1(3), 185–194.

FAO, ECA, AUC (2020). 2019 Africa regional overview of food security and nutrition. Rome, Italy, FAO. https://www.fao.org/documents/card/en/c/ca7704en

Funk, C., Senay, G., Asfaw, A., Verdin, J., Rowland, J., Michaelson, J., Eilerts, G., Korecha, D. and Choularton, R. (2005). Recent drought tendencies in Ethiopia and equatorial subtropical eastern Africa. Washington DC, FEWS-NET.

Funk, C. Dettinger, M. Michaelsen, J., Verdin, J., Brown, M., Barlow, M., and Hoell, A. (2008). Warming of the Indian Ocean threatens eastern and southern Aafrican food security but could be mitigated by agricultural development. Proceedings of the National Academy of Sciences, 105 (32) 11081-11086.

GCEC (2018). Unlocking the inclusive growth story of the 21st century: Accelerating climate action in urgent times. The Global Commission on the Economy and the Climate. Washington DC. https://newclimateeconomy.report/2018/

Gebrechorkos, S. H., Hu¨lsmann, S. and Bernhofer, C. (2019). Regional climate projections for impact assessment studies in east Africa. Environmental Research Letters, 14(4), 044031.

Gebreslassie, M. G., Cuvilas, C., Zalengera, C., To, L. S., Baptista, I., Robin, E., Bekele, G., Howe, L., Shenga, C., Macucule, D. A. et al. (2022). Delivering an off-grid transition to sustainable energy in Ethiopia and Mozambique. Energy, Sustainability and Society, 12(1), 1–18.

Generoso, R., Couharde, C., Damette, O. and Mohaddes, K. (2020). The growth effects of el nino and la nina: Local weather conditions matter. Annals of Economics and Statistics, 140, 83–126.

Hafner, T. and Strasser, L. (2018). Energy investments for Africa's energy transition. In: Energy in Africa: Challenges and opportunities. SpringerBriefs in Energy. Springer, Cham. 77–96. https://doi.org/10.1007/978-3-319-92219-5_4 .

Haile, G. G., Tang, Q., Hosseini-Moghari, S.-M., Liu, X., Gebremicael, T., Leng, G., Kebede, A., Xu, X. and Yun, X. (2020). Projected impacts of climate change on drought patterns over East Africa. Earth's Future, 8(7), e2020EF001502.

Hallegatte, S. (2016). Shock Waves: Managing the Impacts of Climate Change on Poverty. Washington D.C.: World Bank Publications.

Henseler, M. and Schumacher, I. (2019). The impact of weather on economic growth and its production factors. Climatic Change, 154(3), 417–433.

Hörner, D. and Wollni, M. (2021). Integrated soil fertility management and household welfare in Ethiopia. Food Policy, 100, 102022.

Hyandye, C. B., Worqul, A., Martz, L. W. and Muzuka, A. N. (2018). The impact of future climate and land use/cover change on water resources in the Ndembera watershed and their mitigation and adaptation strategies. Environmental Systems Research, 7(1), 1–24.

IEA, (2019). "Africa energy outlook 2019," World Energy Outlook Special Report.

IEA, (2022). Retrieved from https://www.iea.org/data-and-statistics/data-product/sdg7-database#access-to-electricity

Impram, S., Nese, S. V. and Oral, B. (2020). Challenges of renewable energy penetration on power system flexibility: A survey. Energy Strategy Reviews, 31, 100539.

Inglesi-Lotz, R. (2016). The impact of renewable energy consumption to economic growth: A panel data application. Energy Economics 53, 58–63.

ICPAC, Baraibar,M., Babiker, A, S. (2021). 10 Climate Change Impacts in East Africa you didn't know about, IGAD Climate Predictions and Applications Centre, Retrieved from https://www.icpac.net/news/10-climate-change-impacts-in-east-africa-you-didnt-know-about/

IPCC (2001). Climate Change 2001: Synthesis Report, Vol. 397, Cambridge UK: Cambridge University Press.

IRENA (2018). Global Energy Transformation: A roadmap to 2050. International Renewable Energy Agency Publications. https://www.irena.org/publications/2018/Apr/Global-Energy-Transition-A-Roadmap-to-2050

IRENA (2020). Scaling up renewable energy deployment in Africa: Detailed Overview of IRENA's Engagement and Impact. International Renewable Energy Agency Publications. https://www.irena.org/Publications

IRENA (2021). The Renewable Energy Transition in Africa. Powering Access, Resilience and Prosperity. https://www.irena.org/energytransition

Irowarisima, M. (2021). African Energy Challenges in the Transition Era: The Role of Regional Cooperation. Energy Transitions and the Future of the African Energy Sector: Law, Policy and Governance, 37-72.

Jayne, T. S., Sitko, N. J., Mason, N. M. and Skole, D. (2018). Input subsidy programs and climate smart agriculture: Current realities and future potential. Climate Smart Agriculture, 52, 251–273.

Kassegn, A. and Endris, E. (2021) Review on socio-economic impacts of 'Triple Threats' of COVID-19, desert locusts, and floods in East Africa: Evidence from Ethiopia, Cogent Social Sciences, 7:1

Kidunduhu, N. (2021). Energy transition in Africa: Context, barriers and strategies, in Energy Transitions and the Future of the African Energy Sector. Springer, 73–111. https://doi.org/10.1007/978-3-030-56849-8_3

Klein, R. J., Midglev, G., Preston, B., Alam, M., Berkhout, F., Dow, K. and Shaw, M. (2014). Climate change 2014: Impacts, adaptation, and vulnerability. IPCC fifth assessment report, Stockholm, Sweden.

Latif, M., Dommenget, D., Dima, M. and Gro¨tzner, A. (1999). The role of Indian ocean sea surface temperature in forcing east African rainfall anomalies during December–January 1997/98. Journal of Climate, 12(12), 3497–3504.

Lin, B. and Sai, R. (2022). Towards low carbon economy: Performance of electricity generation and emission reduction potential in Africa. Energy, 251, 123952.

Lohani, B. N., Kawai, M. and Anbumozhi, V. (2016). Managing the Transition to a Low-Carbon Economy: Perspectives, Policies, and Practices from Asia. London, UK: Brookings Institution Press.

Lovett, J. C., Midgley, G. F. and Barnard, P. (2005). Climate change and ecology in Africa. African Journal of Ecology, 43(3), 167–169.

Mac Domhnaill, C. and Ryan, L. (2020). Towards renewable electricity in Europe: Revisiting the determinants of renewable electricity in the European union. Renewable Energy, 154, 955– 965.

Maitima, J. M., Mugatha, S. M., Reid, R. S., Gachimbi, L. N., Majule, A., Lyaruu, H., Pomery, D., Mathai, S. and Mugisha, S. (2009). The linkages between land use change, land degradation and biodiversity across East Africa. African Journal of Environmental Science and Technology, 3(10).

Marcel, V., Tissot, R., Paul, A. and Omonbude, E. (2016). A local content decision tree for emerging producers. Chatham House, The Royal Institute of International Affairs.

Meyghani, S., Khodaparast Mashhadi, M. and Salehnia, N. (2022). Long-term effects of temperature and precipitation on economic growth of selected MENA region countries. Environment, Development and Sustainability, 2, 1–19.

Mogaka, H., Gichere, S., Davis, R. and Hirji, R. (2009). Climate variability and water resources in Kenya: The economic cost of inadequate management. World Bank Group: Open Knowledge Repository, http://hdl.handle.net/10986/11736

Mohammed, E. Y. and Uraguchi, Z. B. (2013). Impacts of climate change on fisheries: Implications for food security in sub-Saharan Africa. Global Food Security, Nova Science Publishers, Inc, 114–135.

Morton, J. F. (2007). The impact of climate change on smallholder and subsistence agriculture. Proceedings of the National Academy of Sciences, 104(50), 19680–19685.

Mugisha, J., Ratemo, M., Keza, B. and Kahveci, H. (2021). Assessing the opportunities and challenges facing the development of off-grid solar systems in eastern Africa: The cases of Kenya, Ethiopia, and Rwanda. Energy Policy.150, 112-131. https://doi.org/10.1016/j.enpol.2020.112131

Muhongo, R. S. (2021). Local content policies in the energy transition era in Africa: A case study of the East African oil and gas industry. Energy Transitions and the Future of the African Energy Sector, 311–340.

Mweya, C. N., Mboera, L. E., & Kimera, S. I. (2017). Climate influence on emerging risk areas for Rift Valley fever epidemics in Tanzania. The American journal of tropical medicine and hygiene, 97(1), 109.

Nalule, V. R. (2018). Energy Poverty and Access Challenges in sub-Saharan Africa: The Role of Regionalism. In Energy, Climate and the Environment, Palgrave Macmillan, Springer Nature, Switzerland.

Nalule, V.R. (2020). Transitioning to a Low Carbon Economy: Is Africa Ready to Bid Farewell to Fossil Fuels?. In: Wood, G., Baker, K. (eds) The Palgrave Handbook of Managing Fossil Fuels and Energy Transitions. Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-030-28076-5_10

Nalule, V. R. (2021). How to respond to energy transitions in Africa: Introducing the energy progression dialogue. Energy Transitions and the Future of the African Energy Sector, 3–35.

Namahoro, J., Wu, Q., Xiao, H. and Zhou, N. (2021). The impact of renewable energy, economic and population growth on co2 emissions in the east African region: Evidence from common correlated effect means group and asymmetric analysis. Energies, 312.

Newell, P. (2021). Power Shift: The Global Political Economy of Energy Transitions. Cambridge UK: Cambridge University Press.

Ndung'u, N. and Azomahou, T. T. (2023). Estimating the long-term economic consequences of climate change in East Africa. Mimeo. African Economic Research Consortium.

Njoh, A. (2021). Renewable energy as a determinant of inter-country differentials in CO2 emissions in Africa. Renewable Energy, 172, 1225–1232.

Nuru, J. T., Rhoades, J. L. and Sovacool, B. K. (2022). Virtue or vice? Solar micro-grids and the dualistic nature of low-carbon energy transitions in rural Ghana. Energy Research & Social Science, 83, 102352.

Nyasimi, M., Amwata, D., Hove, L., Kinyangi, J. and Wamukoya, G. (2014). Evidence of impact: Climate-smart agriculture in Africa. CCAFS Working Paper no. 86. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Available at: http://ccafs.cgiar.org/publications/evidence-impact-climate-smart-agriculture-africa

Ojoyi, M. M. and Kahinda, J.-M. M. (2015). An analysis of climatic impacts and adaptation strategies in Tanzania. International Journal of Climate Change Strategies and Management, 7(1):97-115.

Olawuyi, D. (2020). Energy poverty in the Middle East and north African (MENA) region: Divergent tales and future prospects. Energy Law and Energy Justice, 254–272.

Olawuyi, D. S. (2021). Can MENA extractive industries support the global energy transition? Current opportunities and future directions. The Extractive Industries and Society, 8(2), 100685.

Onyango, E. A., Sahin, O., Awiti, A., Chu, C. and Mackey, B. (2016). An integrated risk and vulnerability assessment framework for climate change and malaria transmission in East Africa. Malaria Journal, 15(1), 1–12.

Oosthuizen, A. and Inglesi-Lotz, R. (2022). The impact of policy priority flexibility on the speed of renewable energy adoption. Renewable Energy, 194, 426-438.

Orindi, V. A., Murray, L. A. et al. (2005). Adapting to Climate Change in East Africa: A Strategic Approach, number 117. London, UK: International Institute for Environment and Development.

Patz, J. A., Campbell-Lendrum, D., Holloway, T. and Foley, J. A. (2005). Impact of regional climate change on human health. Nature, 438(7066), 310–317.

Poole, J. H. (1989). Announcing intent: The aggressive state of musth in African elephants. Animal Behaviour, 37, 140–152.

Price, R. (2018). Shared governance of climate change and natural resources issues in East Africa. K4D Helpdesk Reprot 450, Brighton, UK: Institute of Development Studies.

Qadir, S. A., Al-Motairi, H., Tahir, F. and Al-Fagih, L. (2021). Incentives and strategies for financing the renewable energy transition: A review. Energy Reports, 7, 3590–3606.

Roberts, J. T., Weikmans, R., Robinson, S. A., Ciplet, D., Khan, M., and Falzon, D. (2021). Rebooting a failed promise of climate finance. Nature Climate Change, 11(3), 180–182.

Ryan, S. J., Lippi, C. A. and Zermoglio, F. (2020). Shifting transmission risk for malaria in Africa with climate change: A framework for planning and intervention. Malaria Journal, 19(1), 1–14.

Salahuddin, M., Ali, I., Vink, N. and Gow, J. (2019). The effects of urbanization and globalization on CO2 emissions: Evidence from the sub-Saharan Africa (SSA) countries. Environmental Science and Pollution Research,26, 2699–2709.

Siam, M. S. and Eltahir, E. A. (2017). Climate change enhances interannual variability of the Nile river flow. Nature Climate Change, 7(5), 350–354.

Sintayehu, D. W. (2018). Impact of climate change on biodiversity and associated key ecosystem services in Africa: A systematic review. Ecosystem Health and Sustainability, 4(9), 225– 239.

Srinivasu, B., & Rao, P. S. (2013). Infrastructure development and economic growth: Prospects and perspective. Journal of business management and Social sciences research, 2(1), 81-91.

Stoerk, T., Wagner, G. and Ward, R. E. (2020). Policy brief—recommendations for improving the treatment of risk and uncertainty in economic estimates of climate impacts in the sixth intergovernmental panel on climate change assessment report. Review of Environmental Economics and Policy.12(2), 371-376.

Sun, Y. (2022). Emission accounting and drivers in East African countries. Applied Energy.312, 118805

Tidman, R., Abela-Ridder, B. and de Castan˜eda, R. R. (2021). The impact of climate change on neglected tropical diseases: A systematic review. Transactions of the Royal Society of Tropical Medicine and Hygiene, 115(2), 147–168.

U.N. (2019) World population prospects. Retrieved from https://population.un.org/wpp/

van der Merwe, E., Clance, M. and Yitbarek, E. (2022). Climate change and child malnutrition: A Nigerian perspective. Food Policy,113, 102281.

UNICEF. (2023). Water and environment. UNICEF Eastern and Southern Africa. Retrieved February 6, 2023, from https://www.unicef.org/esa/water-and-environment

Van Alstine, J., Manyindo, J., Smith, L., Dixon, J., & AmanigaRuhanga, I. (2014). Resource governance dynamics: The challenge of ‘new oil’in Uganda. Resources Policy, 40, 48-58.

Van der Zwaan, B., Boccalon, A., and Dalla Longa, F. (2018). Prospects for hydropower in Ethiopia: An energy-water nexus analysis. Energy Strategy Reviews, 19, 19–30.

Wainwright, C. M., Finney, D. L., Kilavi, M., Black, E. and Marsham, J. H. (2021). Extreme rainfall in East Africa, October 2019–January 2020 and context under future climate change. Weather, 76(1), 26–31.

Waithaka, M., Nelson, G. C., Thomas, T. S. and Kyotalimye, M. (2013). East African agriculture and climate change: A comprehensive analysis. International Food Policy Research Institute, Washington DC, http://dx.doi.org/10.2499/9780896292055

Wang, X., Zha, X., Ni, W., Liu, R. P., Guo, Y. J., Niu, X. and Zheng, K. (2019). Survey on blockchain for internet of things. Computer Communications, 136, 10–29.

Wassie, Y. and Adaramola, M. (2019). Potential environmental impacts of small-scale renewable energy technologies in East Africa: A systematic review of the evidence. Renewable and Sustainable Energy Reviews, 111, 377–391.

Weisser, F., Bollig, M., Doevenspeck, M. and Mu¨ller-Mahn, D. (2014). Translating the "adaptation to climate change" paradigm: The politics of a travelling idea in Africa. The Geographical Journal, 180(2), 111–119.

WHO (2022). Retrieved from https://www.who.int/data/gho/data/indicators/indicator-details/GHO/household-air-pollution-attributable-deaths

WHO. (2023). Household air pollution data. Retrieved from https://www.who.int/data/gho/data/themes/air-pollution/household-air-pollution

Xiao, Y., Zhang, N., Lou, W. and Hou, Y. T. (2020). A survey of distributed consensus protocols for blockchain networks. IEEE Communications Surveys and Tutorials, 22(2), 1432–1465.

Yitbarek, E., and Beegle, K. (2019). Fundamentals 1: Africa's Human Development Trap. Accelerating Poverty Reduction in Africa (pp. 83–90). World Bank Publications.

Zhou, G., Minakawa, N., Githeko, A. K. and Yan, G. (2004). Association between climate variability and malaria epidemics in the East African highlands. Proceedings of the National Academy of Sciences, 101(8), 2375–2380.

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