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Summary

To achieve universal electricity access and rapid economic development, sub-Saharan Africa needs to significantly accelerate its electricity generation. Despite rising real per capita incomes over the past two decades, electricity production per capita has been declining. In addition, while hydropower is prominent in some countries, solar and wind power generation has lagged other world regions, even though sub-Saharan Africa has some of the most favorable conditions, particularly in terms of solar potential.

Relying more on solar- and wind-based energy would be economically advantageous for sub-Saharan Africa because of the reduced cost of renewables and the region's geography, regardless of climate ambitions. However, a swifter shift would be needed to meet climate policy objectives.

While low-carbon energy sources have relatively low operating expenses, they require high initial capital investments. Thus, the primary challenge across sub-Saharan Africa is securing the necessary financing for renewables investment. A mix of domestic and external financing can increase both renewable electricity generation and GDP. Relying solely on domestic financing would still boost power generation but would reduce overall economic benefits because of the crowding-out effect on other sectors. Sources of domestic revenues that could be used to finance green energy investments are country-specific and range from carbon taxes, repurposing of fossil fuel subsidies and revenues from mining of minerals critical for the energy transition, among others.

Advanced economies have committed $100 billion per year to climate finance for emerging market and developing economies and a new collective quantified goal (NCQG) is expected to be set during COP29 in November 2024. In one illustrative scenario where this finance is allocated based on the relative difference between national and global per capita emissions, sub-Saharan Africa would receive about half, which in turn would have to be allocated to climate mitigation and adaptation. If, in addition, it is assumed that half of the climate finance flows received by sub-Saharan Africa are assigned to renewable energy, then renewable electricity production could be up to 24 percent higher than in the baseline scenario excluding this financing. Annual GDP growth in this illustrative scenario would be boosted by 0.8 percentage point on average over the next decade, accompanied by stronger labor demand in the electricity sector.

Policies can help catalyze climate finance. Historical data for sub-Saharan Africa shows that market reforms can attract additional concessional financing and grants for climate. An ambitious package of governance, business regulations, and external sector reforms is associated with a 20 percent increase in climate finance flows and a 7 percent increase in electricity generation over five years. Among these policy categories, governance and external sector reforms show the strongest impact. In addition, implementing climate policies is linked to increases in green foreign direct investment (FDI) announcements and green electricity production, another important source of financing for renewables deployment.

Introduction

Sub-Saharan Africa needs to boost electricity production to achieve universal access and foster sustainable development. Approximately half of the sub-Saharan African population lacks electricity, and those connected pay almost double the global rate. The region's electricity demand is set to rise with its booming population—projected to double by 2050—and with the structural transformation expected to increase the role of manufacturing and services. To meet both future energy demands and global emission targets from the 2015 Paris Agreement, the continent needs a sustainable energy transformation, instead of relying solely on environmentally harmful energy sources like coal, oil, and traditional biomass.

Renewable energy is arguably within easier reach, given significant cost reductions, and would deliver developmental benefits. The cost of solar and wind energy, as well as utility-scale batteries, has decreased markedly in recent years. Driven by lower costs, global investments in these technologies have increased exponentially (Creutzig and others 2017). At the same time, Africa has excellent conditions for renewables, especially solar energy, and auction prices for utility-scale solar power have declined steadily (Kruger and Eberhard 2023). Sub-Saharan Africa also faces a persistent electricity shortage, which acts as a major obstacle to both human development—by limiting electricity access in rural areas—and economic growth—by depriving businesses of reliable and affordable energy. Generating electricity through renewable sources, rather than fossil fuels, offers several tangible benefits, such as reducing dependency on volatile global fossil fuel markets, minimizing harmful air pollution, and avoiding the risk of stranded fossil fuel assets. In addition, in the current context of global decarbonization, international partners are likely more inclined to support investments in renewable energy rather than carbon-intensive ones. Besides efficiency considerations, green[1] technologies, like microgrids and off-grid solar energy in remote areas, provide a range of developmental benefits. These include improvements in health, access to information and communication infrastructure, and the productivity of micro-enterprises (Mugisha and others 2021), while also contributing to climate adaptation. For example, solar power allows for the use of irrigation systems and refrigeration in regions that are difficult to reach with the central grid.

Several studies highlight that the technology is available to allow Africa to scale up renewable energy. A transition to an electricity system consisting entirely of renewable energy is *technically* possible (Barasa and others 2018). Hydropower plants can be used as "virtual batteries," which jump in when electricity supply from solar and wind energy is low. The system could gain further efficiency by integrating water desalination and the production of industrial gas when renewable energy production exceeds demand. Such a system, however, would require a dense electricity network to allow for continental electricity trade.[2] Implementing this technical possibility would require time (models anticipate 20 to 30 years) and political will. However, the existing and proposed plants for renewable energy in sub-Saharan Africa could already cover a large part of total electricity needs by 2040 (Peters and others 2024).

International organizations support the case for increasing renewable energy in Africa and identify key measures for increasing investments. In an early analysis on enabling renewable energy in emerging market and developing economies, UNEP (2012) identified three key approaches: creating a level playing field between renewable energy and fossil fuels (mostly by phasing out fossil fuels subsidies), providing easy market access to private investors, and mitigating political and regulatory investment risks. The IEA (2022) developed a "Sustainable Africa Scenario," which would allow universal electricity access and fulfill Africa's climate pledges by adding renewable energy. The International Renewable Energy Agency (IRENA) and AfDB (2022) provided a comprehensive market analysis for renewable energy in Africa and identified substantial investment opportunities. Sub-Saharan Africa could also take advantage of renewable energy development with the production of minerals needed for the green transition. The IMF has recently stressed that the extraction of critical minerals could boost GDP in sub-Saharan Africa, while developing processing industries for these

[1] While the term "green" is broadly used to encompass a range of environmental issues including biodiversity, nature conservation, and climate adaptation, in this note, it primarily refers to the low-carbon and zero-carbon transition, as well as the related policies and technologies.

[2] Cáceres and others (2022) further refine the concept of fully relying on renewable energy by considering the potential effect of climate change on hydropower availability. They find that the potential loss of capacity could be compensated by other renewables.

minerals is an opportunity to climb the ladder toward more complex products (IMF 2024) and obtain revenues that could be directed to power generation investments.

While increased investments in renewable energy hold significant potential, several critical challenges need to be addressed to unlock them. Significant investments in upgrading and expanding electricity grids will be required (World Bank 2017). Solar and wind energy require complementary investments into flexibility options like interconnected electricity grids and energy storage, which are essential for balancing mismatches between electricity supply and demand. In some countries, political and expropriation risks, and barriers to the movement of capital represent constraints to private investment. Finally, managing the workforce transition from the fossil fuel sector (Ferroukhi, Reiner, and El-Katiri 2022) to the renewable energy sector (IMF 2024) will be essential to ensure a smooth and inclusive shift.

Increased investment in renewable energy requires market reforms to attract investors and sector-specific policies to improve the management and reliability of electricity systems. Poor utility performance and weak state capacity in sub-Saharan Africa are key constraints to electricity sector development (Eberhard and others 2017; Foster, Eberhard, and Dyson 2021). Electricity has become a bottleneck for development (Hardy and McCasland 2021; Mensah 2024). Hence, addressing this bottleneck is expected to deliver economic benefits. Policies aimed at improving both on-grid and off-grid supply are crucial for enhancing the overall efficiency and reach of electricity supply. Structural improvements such as increasing power reliability, boosting energy efficiency, and improving regional electricity trade would increase GDP and wages in sub-Saharan Africa (Rojas Romagosa and others 2024). Part of the solution is creating the conditions to gradually increase the role of private power investments (PPIs), which many countries in sub-Saharan Africa have already implemented in past years. Private investors are much more likely to invest in renewable energy and can be an alternative to state-owned utilities (which are typically invested in established networks of fossil fuels). Besides private sector reforms, independent regulatory agencies have an important effect on improving performance and reducing the negative effects of institutional deficiencies (Imam, Jamasb, and Llorca 2019).

Securing funding is a key challenge for Africa's electrification and energy transition and requires policies to develop bankable projects and tackle implementation bottlenecks. The funding needs for Africa's investments necessary to modernize the electricity sector are estimated at $25 billion per year by the IEA (2022). Access to funding is likely to be a more binding constraint for renewables. Fossil fuel plants have lower upfront investment costs but higher operational costs as they require the purchase of fuels with volatile prices. In contrast, renewable energy requires higher initial investments but mainly maintenance thereafter, as captured by the high capital expenditure share of onshore wind and solar photovoltaic (PV) (see Beiter and others 2024). For a sustainable shift, Africa needs diverse financing from public actors, private investors, and the international community. Climate financing will also be needed for adaptation, and a wide range of development needs compete for domestic resources. Therefore, increasing the availability of external finance is critical. Access to public and private climate finance instruments requires improving national frameworks and capacity to develop bankable projects (Arezki 2021; Belianska and others 2022), as well as addressing existing bottlenecks in project implementation (IMF 2023a), but it is threatened by geopolitical fragmentation (Bolhuis and others 2024).[3] Sub-Saharan Africa has also received substantial investment in renewable energy from China,[4] which has helped decrease greenhouse gas (GHG) emissions (Zakari and others 2022). To attract private investment, it is crucial to improve governance and regulatory frameworks. Multilateral organizations have a role in assisting both financially and with capacity building. Mission 300, a recent initiative by the World Bank and the African Development Bank, aims to provide access to at least 300 million people in Africa by 2030, marking a significant step forward (World Bank 2024).

[3] Gardes-Landolfini and others (2023) identify three main potential factors threatening the energy transition globally: (1) pullbacks in climate mitigation policies and increased carbon lock-in in fossil fuel infrastructure and policymaking, (2) lower likelihood of continuous cost reduction in renewable energy technologies, and (3) intensification of macroeconomic shocks amid increasing geoeconomic fragmentation.

[4] According to the Financial Times fDi Markets database, China has invested $4.7 billion into fossil fuel extraction in sub-Saharan Africa and $3.3 billion in fossil fuel electricity generation in the period from 2003 to 2022, compared to only $1.5 billion in renewable energy. However, none of the fossil fuel investments occurred after 2018, and renewable energy investments are increasing.

The overarching objective of this note is the analysis of the important role of renewables in increasing the availability of electricity and boosting inclusive growth in sub-Saharan Africa. The specific questions are as follows:

1. What will the sub-Saharan African energy mix look like under alternative degrees of climate ambition?
2. What economic, employment, and energy impacts can sub-Saharan Africa anticipate from improving the existing power capacity and increasingly shifting toward renewable energy for future energy needs?
3. How do these effects vary with financing options, differentiating between external finance and domestic financing, toward sustaining the capital costs for setting up new renewable capacity?
4. What reforms and policies are needed to reduce barriers to mobilize financing for renewable energy and boost renewable electricity generation?

The analysis combines data and scenarios available in the literature, novel model simulations, and new empirical findings. First, existing data shed light on the status quo of the electricity mix, while the Intergovernmental Panel on Climate Change (IPCC) scenarios provide an overview of the potential development of the energy sector under alternative degrees of climate ambition. Second, the IMF-ENV model—a global dynamic computable general equilibrium model—is used to simulate the macroeconomic impact of alternative policies to expand the electricity sector with a heavier reliance on renewables. Third, an econometric analysis investigates the effects of market reforms and climate policies in attracting (official and private) climate finance and boosting clean electricity generation.

The Current Energy Landscape and Future Scenarios

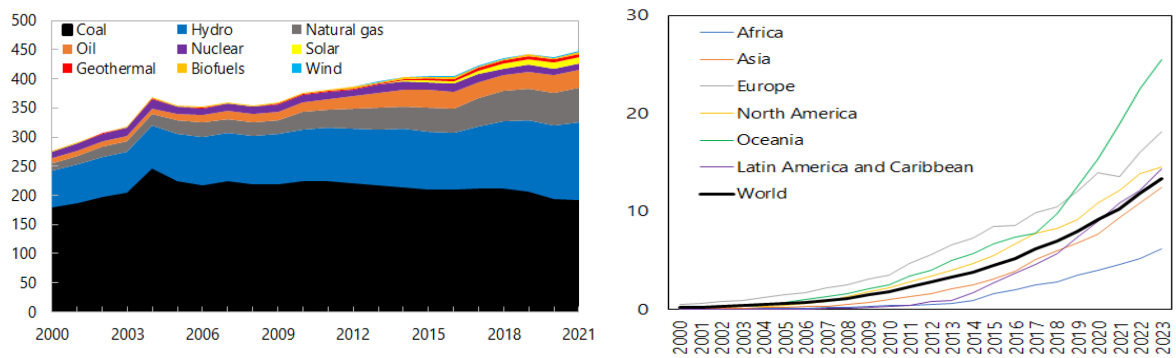
Electrification can leverage sub-Saharan Africa's solar potential to increase energy access. In 2020, the energy mix in sub-Saharan Africa was dominated by biomass, followed by oil. Biomass is used mostly for cooking and oil for transportation and heating. The next most important energy sources are coal—used for electricity generation—and natural gas—used both directly and for electricity generation. Electrification will make it possible to use renewable energy in areas like cooking, transportation, and heating, also contributing to decarbonizing energy use (Luderer and others 2022). Although emissions per capita in the region are low compared to other EMDEs, a large portion of the total CO_2 emissions in sub-Saharan Africa (except South Africa) is concentrated in the transport sector, as shown in Annex Figure 3.1. Therefore, electrification in the transport sector also presents the potential for significantly reducing fossil fuel use, and consequently emissions in most sub-Saharan African countries.

The Status Quo

The sub-Saharan African electricity mix is currently dominated by fossil fuels, followed by hydropower; but solar and wind energy are expanding rapidly. Electricity production in sub-Saharan Africa increased slowly between 2000 and 2021 (Figure 1, panel 1). Mostly used in South Africa (Figure 3), as of 2021 coal was still the predominant electricity source, accounting for 43 percent of electricity generation. Coal's contribution to the electricity mix surged from 2000 to 2004, followed by a very modest decline until 2021. Hydropower, with a 30 percent share in the electricity mix of 2021, doubled over the period covered. In parallel, the generation from oil and natural gas quadrupled in the same timeframe. Natural gas had a share of 13 percent in 2021. All other energy sources contributed less than 10 percent of electricity generation. Nuclear energy production was very small and remained approximately constant throughout the period. The milestone of 1 terawatt-hour (TWh) of electricity production using geothermal energy was reached in 2005, while solar energy reached this landmark in 2014 and wind energy in 2016. The decade from 2011 to 2021 witnessed the largest growth in electricity generation from natural gas and hydropower in absolute terms. However, in terms of relative growth, solar and wind power experienced the most dramatic increases: production from solar and wind was 78 times larger in 2021 than it was in 2011. Nevertheless, Africa remains the continent with the lowest share of solar and wind in the electricity mix globally (Figure 1, panel 2).

Figure 1. The Electricity Mix in Sub-Saharan Africa over Time

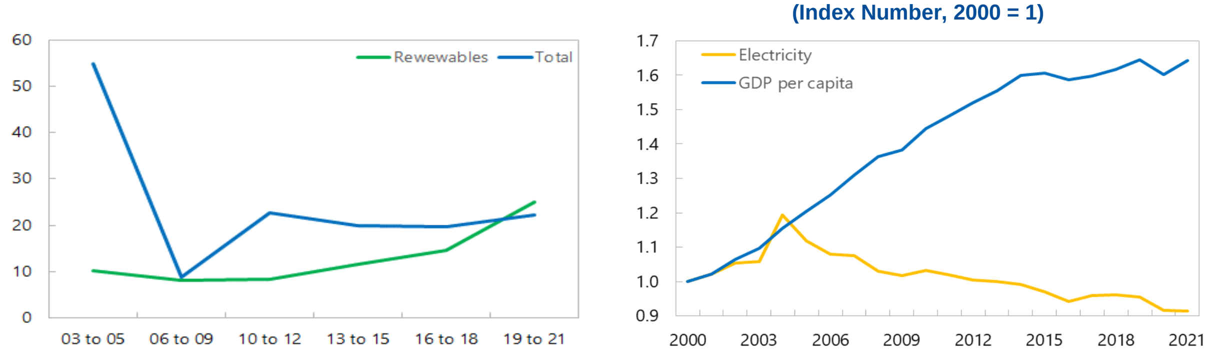
1. The Electricity Mix within Sub-Saharan Africa (TWh) — 2. The Share of Solar and Wind Energy by Continent (Percent)



Sources: International Renewable Energy Agency; Ember; and IMF staff calculations.
Note: The energy sources in the IRENA database are grouped as follows: Solar = Solar photovoltaic + Solar thermal energy, Wind = Onshore wind energy + Offshore wind energy, Hydro = Renewable hydropower + Mixed hydro Plants + Pumped storage + Marine energy, Biofuels = Solid biofuels + Renewable municipal waste + Liquid biofuels + Biogas, Geothermal = Geothermal energy, Coal = Coal and peat, Oil = Oil + Fossil fuels not else specified + Other nonrenewable energy, Natural gas = Natural gas, Nuclear = Nuclear. TWh= terawatt-hour.

Figure 2. Electricity Generation Trends in Sub-Saharan Africa

1. Net Additions to Electricity Generation (TWh) — 2. Electricity and Real GDP per Capita (Index Number, 2000 = 1)



Sources: International Renewable Energy Agency; and IMF staff calculations.
Note: The chart shows changes in electricity (total and renewable) generation computed as the average over three years less the average over the previous three years. Renewable energy is the sum of biofuels, geothermal, hydropower, solar, and wind energy. TWh= terawatt-hour.

Sources: International Renewable Energy Agency; World Bank; and IMF staff calculations.
Note: GDP per capita is in real terms using individual countries' data, weighted by GDP valued at purchasing power parity. The orange line shows electricity per capita. Both variables are normalized such that their values in 2000 are equal to 1.

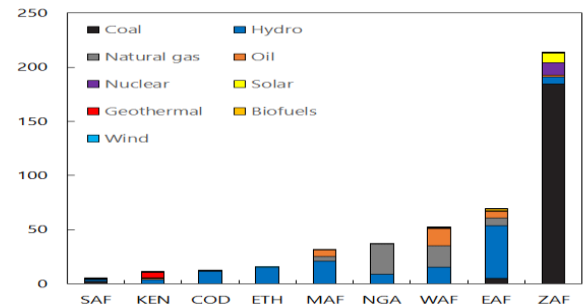
Albeit starting from a low base, sub-Saharan Africa has already embraced renewable energy to increase electricity generation; however, this is still not enough to keep up with growth. Net additions to total electricity production were higher than net additions in renewable energy sources for most of the last 20 years (Figure 2, panel 1). Since electricity production fluctuates strongly, three-year averages are reported. In recent years, renewable energy additions[5] have exceeded the increase in total electricity generation. This means that renewable electricity was used to compensate for the decrease in other electricity sources, mostly coal. Renewable energy has thus already contributed to decarbonizing electricity production. Nevertheless, power generation will have to be stepped up substantially to fuel growth. According to a "Kuznets curve" of energy intensity, sub-Saharan Africa should be expanding energy intensity (Peralta-Alva, Tavares, and Xi 2017) and yet, since 2004 electricity generation per capita has trended downward, while GDP per capita has trended upward (Figure 2, panel 2). Given these trends, per capita GDP growth is constrained by the undersupply of

[5] Of the increase in renewable energy between 2018 and 2021 in sub-Saharan Africa, 79 percent came from hydropower and 18 percent from solar energy.

electricity, as seen in load shedding in South Africa and private generators in many countries. If continued, the shortage of electricity is expected to drag more heavily on growth (Hardy and McCasland 2021; Mensah 2024).[6]

The reliance on fossil fuels for electricity generation varies across countries, with South Africa depending heavily on coal and a few subregions relying significantly on clean energy. Electricity production is distributed unequally between the subregions defined according to the United Nations (UN) classification and selected individual countries (Figure 3; see Annex Table 1.2 for details on subregions). Given that subregions are defined based on geography, some of them have significant internal heterogeneity in regard to energy use. The most striking point is that South Africa is the powerhouse of the continent, accounting for 48 percent of sub-Saharan Africa's total electricity generation. Moreover, it is notable that South Africa contributes 95 percent of coal-generated electricity across sub-Saharan Africa. Despite this heavy reliance on coal, the country distinguishes itself as the sole subregion/country within sub-Saharan Africa to generate significant quantities of electricity from solar and nuclear sources. More than two-thirds of electricity production from oil and natural gas is also present in certain subregions within sub-Saharan Africa.[7] However, clean energy is already a strong component of the electricity mix in several other subregions. In four countries or subregions (DR Congo, Ethiopia, "Middle other," and "Eastern other"), more than half of the electricity generation comes from hydropower. Kenya leads in the use of geothermal power, from which it sources half of its electricity generation.

Figure 3. The Electricity Mix in Sub-Saharan Africa across Regions (TWh)



Sources: International Renewable Energy Agency; and IMF staff calculations.
Note: Energy sources as in Figure 1 (panel 1). Refer to Annex Table 1.2. for the regional abbreviations. Data labels in the figure use International Organization for Standardization (ISO) country codes.

The Future Electricity Mix

Solar and wind energy are the only low-carbon energy sources that can be scaled sufficiently to power Africa's expected development. Until the mid-2010s, scenarios for the future electricity mix in sub-Saharan Africa strongly relied on carbon capture and storage, as well as biofuels. During the 2010s, two major developments changed scenario results. First, the cost for solar energy declined by 89 percent between 2010 and 2022 and the cost of onshore wind energy declined by 69 percent in the same period (IRENA 2023). Second, the technology for balancing the intermittency of these two sources matured (see Pietzcker and others 2017, among others). As a result, projections of the future electricity mix now rely very strongly on solar and wind power. Given excellent natural conditions, solar energy is expected to dominate electricity generation across the sub-Saharan African region (Bogdanov and others 2019). Studies now argue that the entire African electricity system can be based on renewable energy (Barasa and others 2018; Sterl and others 2021; Bamisile and others 2023).[8]

The future pathway of electricity systems in sub-Saharan Africa can be explored with the IPCC scenarios generated with high-quality models. Scenarios of global climate mitigation that would keep the average temperature increase below 1.5°C and 2°C are compared with a 3°C case. While the first two cases represent very and moderately ambitious climate policies, respectively, the last case broadly represents

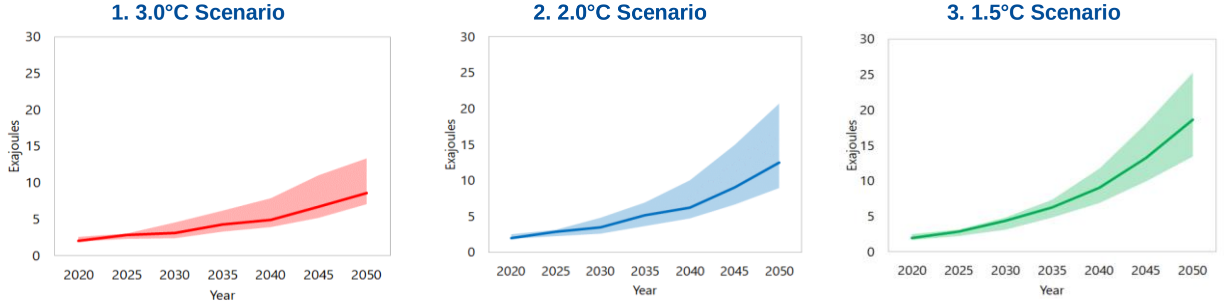
[6] By contrast, access to electricity (26 percent in 2000 and 51 percent in 2021 in the World Bank data) and clean cooking fuels (9 percent in 2000 and 19 percent in 2021) developed more favorably, while the heterogeneity within sub-Saharan Africa remains large. Further, off-grid solar has strongly contributed to increasing rural electrification from 17 percent to 28 percent between 2010 and 2020 (Babayomi and others 2023).

[7] Specifically, Nigeria and "Western other" regions are the principal areas where these energy sources are utilized for electricity generation. These are also the subregions with major oil and natural gas exports.

[8] Nuclear fusion (Nicholas and others 2021) and nuclear energy (Laureto and Pearce 2016; Muellner and others 2021) suffer from high costs and technical challenges. Carbon capture and storage (Fuss and others 2018), biofuels (Jha and Schmidt 2021), and hydropower (Xu and others 2023) can play a role but cannot be scaled up to satisfy the total electricity demand because of limited capacity.

warming that is likely to be reached with unchanged climate policies.[9] The IPCC is deliberately inclusive in its coverage of models. Scenario results from many models are included in the database.[10] The temperature targets refer to the global temperature increase. Models generally let advanced economies decarbonize first, but reaching net zero emissions globally requires all regions, including sub-Saharan Africa, to decarbonize.

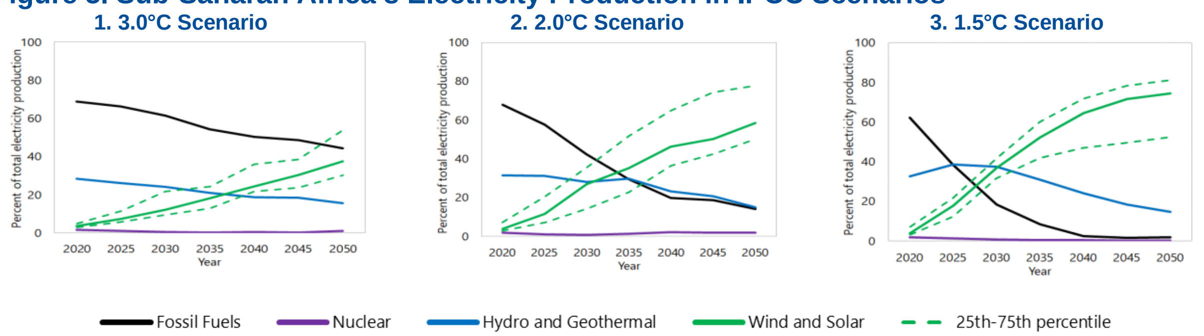
Figure 4. Sub-Saharan Africa's Total Electricity Production in IPCC Scenarios



Sources: Byers and others (2022); and IMF staff calculations.
Note: The bold line shows the median scenario. The shaded area shows the range between the 25th and 75th percentile. Total electricity production refers to secondary energy produced from all primary energy sources. IPCC = Intergovernmental Panel on Climate Change.

Stronger climate ambition would require accelerated electrification in sub-Saharan Africa, so that electricity production is expected to increase to a larger extent under tighter temperature goals. Electrification allows phasing out the direct use of fossil fuels, for example, in transportation (Luderer and others 2022) and cooking.[11] As a result, the amount of electricity production would have to increase to a larger extent under more ambitious climate policy. Figure 4 shows the total electricity production for the three global mitigation goals. For each of them, the bold line indicates the value in the median scenario for each year. The shaded area shows the range of results between the 25th and 75th percentile of the whole distribution of results. In all cases, scenarios project a rapid growth in electricity production.[12] While electricity production in 2020 was at about 2 exajoule (EJ), scenarios predict it to have median values of 8.5 EJ for an average temperature increase of 3°C, 12.5 EJ for 2.5°C, and 18.6 EJ for 1.5°C by 2050.

Figure 5. Sub-Saharan Africa's Electricity Production in IPCC Scenarios



Sources: Byers and others (2022); and IMF staff calculations.
Note: The bold line shows the median scenario. The dashed green lines show the 25th percentile and 75th percentile for solar and wind energy. IPCC = Intergovernmental Panel on Climate Change.

[9] In December 2023, it was estimated that the implemented policies would lead to warming between 2.2°C and 3.4°C with a median estimate of 2.7°C (CAT 2023). The 3°C scenario thus represents a no-policy scenario, where countries do not take action beyond what they already did.

[10] Not all models submit scenario results for each temperature category. There are 97 scenarios in the 1.5°C category, 310 scenarios for 2°C, and 96 scenarios for 3°C.

[11] Note that the United Nations Environment Programme is already implementing programs on electric mobility in Africa (UNEP 2022).

[12] GDP and population pathways follow the assumptions of the SSPs, as defined in section 2.1 of Riahi and others (2017). GDP growth in low-income countries in the SSP2 scenario, for example, is assumed to be 3.7 percent between 2010 and 2040 and 3.3 percent between 2040 and 2100 (Leimbach and others 2017). In SSP2, the population in Africa would grow from 1 billion in 2010, to 2 billion in 2050, and to 2.6 billion in 2100 (KC and Lutz 2017).

Even under less ambitious climate goals, IPCC scenarios project a transition from fossil fuels to solar and wind energy. Figure 5 shows median values of electricity generation from four groups of energy sources: (1) nuclear energy, (2) fossil fuels, (3) hydropower and geothermal energy, and (4) solar and wind energy. The scenarios under the 3°C category show that nuclear energy is not expected to play a material role. The role of fossil fuels (which risk becoming stranded assets, as shown in Gardes-Landolfini and others 2023), as well as of hydropower and geothermal energy, is expected to decrease gradually. The decline in the weight of these last two sources is due to the limited technical potential (Elbarbary and others 2022; Xu and others 2023). The fact that, even in the 3°C category, solar and wind are expected to gain market share steadily until 2050 in sub-Saharan Africa demonstrates the technical and economic potential of these energy sources for the continent.

Greater climate ambition at the global level would require an acceleration of the transition from fossil fuels to solar and wind energy also in sub-Saharan Africa. In the 2°C category, the pace of the decline in the share of fossil fuels is expected to be significantly more pronounced than in the 3°C category and the fossil fuel share would decrease below the share of hydropower and geothermal energy already in 2035. Nuclear energy remains insignificant across all scenarios and categories, because of high cost (Lovering, Yip, and Nordhaus 2016; Wealer and others 2021). Hydropower and geothermal energy are expected to double or triple total production, but given the much stronger total electricity growth, their share in total production is expected to decline. This amount of growth in hydropower use is possible in a sustainable and cost-effective manner (Xu and others 2023), despite the effect of climate change on water availability (Cáceres and others 2022). The share of solar and wind is expected to increase at a much faster pace than in the 3°C category, primarily because neither source has a limited technical potential, their prices are expected to fall, and the technology for handling intermittency is expected to improve.[13]

The Macroeconomic Implications of Increased Power Generation

Increased power generation holds the potential to benefit sub-Saharan African economies, but effects will differ significantly depending on the design and execution of relevant policies. This section leverages the IMF-ENV model to explore a variety of scenarios pertaining to the expansion of power generation and its associated macroeconomic effects. For this analysis, the model has been calibrated to reflect sub-Saharan African subregions in line with the UN classification, in addition to specific countries selected for focused analysis (for a summary of the model, its calibration, and the sub-Saharan African subregions under consideration, refer to Annex 1).[14]

Increase in Power Generation under Baseline Assumptions

Under baseline assumptions, electricity production would increase, characterized by an expanding contribution of solar and wind energy within the generation mix (Figure 6, Panel 1). The baseline scenario is shaped by long-term GDP growth rates, demographic trends, energy efficiency gains, and key energy and climate policies in large economies (see Annex 1). Compared to the year 2021, total power generation in sub-Saharan Africa would increase by a factor of 1.7 by 2035, aligning with the range of the 3°C IPCC scenarios presented in the previous section. Compared to 2021, solar and wind generation would increase the largest, by a factor of 5.6, followed by a 2.2-times increase in other non-fossil fuel–based technologies,[15] and lastly fossil fuel–based technologies would grow by a factor of 1.3. The increase in the share of solar and wind energy generation is supported by the implementation of all policies governments have already announced, alongside a continued global reduction in the costs of solar and wind energy technologies. This shift would result in the share of all renewable energy sources climbing from 31 percent in 2021 (as reported by IRENA) to 47 percent

[13] In the 1.5°C category, these developments are expedited even further. The median share of solar and wind energy would increase to almost 75 percent of the electricity mix by 2050. The share of fossil fuels would fall even more rapidly reaching nearly zero by 2040. Hydropower and geothermal energy would increase further in absolute terms than in the other temperature categories. However, given the higher total electricity production, their share is similar across temperature categories, especially toward the end of the simulation horizon.

[14] The availability of detailed data prescribes the initial year of the simulations, which start in 2017 with key historical macroeconomic and energy sector trends replicated until 2022. Simulations extend through 2035.

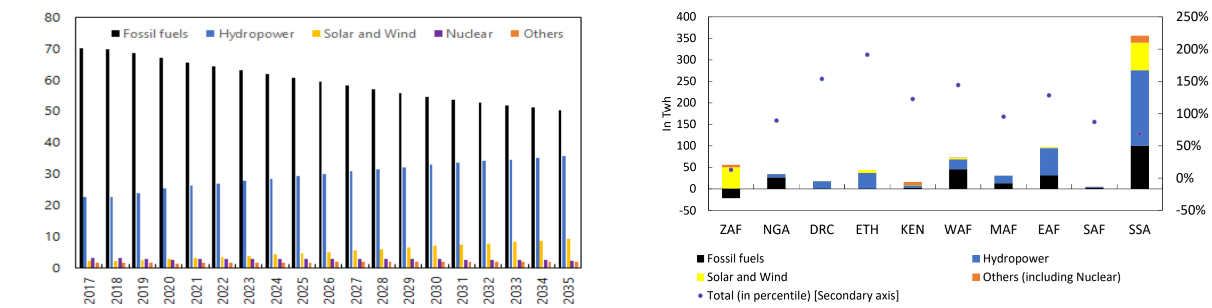
[15] This includes an increase in hydropower by a factor of 2.3 and in nuclear generation by a factor of 1.4. Note that nuclear generation is part of the electricity sector only in South Africa, and between 2021 and 2030, the share of nuclear generation falls from 3 percent to 2 percent in the baseline scenario for sub-Saharan Africa.

by the year 2035. In absolute terms, total electricity generation would increase from 520 TWh to approximately 880 TWh within the same timeframe, with hydropower playing the most significant role (300 TWh in 2035).

Figure 6. Electricity Sector Trends for Sub-Saharan Africa in the IMF-ENV Baseline Scenario

1. Sub-Saharan Africa: Power Generation Shares (Percent)

2. Sub-Saharan Africa: Change in Composition of Electricity Generation from 2021 to 2035



Sources: International Renewable Energy Agency; and IMF staff calculations using IMF-ENV model.
Note: Data from the IRENA is used to calibrate IMF-ENV model between 2017 and 2021. The left axis displays changes in production (measured in TWh) across various power generation technologies, whereas the right axis shows the overall change in total electricity generation (measured in percentage). Refer to Annex Table 1.2. for the regional abbreviations. Data labels in the figure use International Organization for Standardization (ISO) country codes. pct = percent; TWh= terawatt-hour.

Under the baseline scenario, substantial heterogeneity is expected to persist in the composition of power generation technologies across sub-Saharan African economies through 2035 (Figure 6, Panel 2). Throughout the period from 2021 to 2035, total electricity generation would increase across all sub-Saharan African regions, with this growth being accompanied by a change in the composition of generation technologies. In South Africa, a reduction in coal generation is expected, underpinned by the effective enforcement of carbon pricing and Eskom's decommissioning plans for coal plants.[16] This move toward less carbon-intensive sources is primarily driven by an increase in the generation from solar and wind technologies. In Nigeria, and across three aggregate sub-Saharan African subregions—Eastern Africa, Western Africa, and Middle Africa—natural gas is the main driver of the increase in fossil fuel–based electricity generation and is followed by generation from oil (diesel) sources in the latter three regions. Moreover, hydropower generation would expand in Eastern Africa, Western Africa, Middle Africa, as well as Ethiopia and the Democratic Republic of Congo.[17]

Paths to Scaling Up Renewables: Domestic and External Financing

Given the high capital expenses, securing appropriate financing is crucial for the expansion of renewable energy capacity. This section explores the trade-offs involved in three strategies for funding the growth of renewable energy: (1) utilizing domestic resources, (2) seeking international financial support, and (3) a mix of these two strategies. The restricted fiscal capacity in most sub-Saharan African countries presents a significant obstacle to diverting adequate domestic funds to the renewable sectors, resulting in insufficient investment despite the considerable potential. International financing can address this challenge by alleviating the trade-offs with other competing developmental needs. As an illustration, the three scenarios—*domestic, mix*, and *international*—are designed such that total annual new investments in solar and wind sectors are 0.5 percent of baseline GDP higher annually until 2030 (in addition to the accumulated capital stock amounting to 0.5 percent of sub-Saharan Africa's GDP in renewable electricity sectors under the baseline).[18] If both solar and

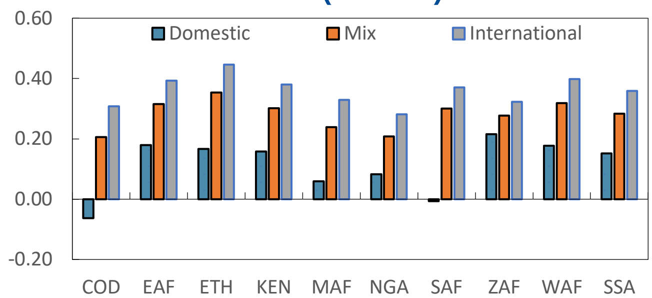
[16] Following the Integrated Resource Plan 2023 published by the Ministry of Mineral Resources and Energy, part of the coal fleet will be decommissioned; see Electricity Regulation Act: Integrated Resource Plan 2023 (www.gov.za).

[17] Overall, hydropower generation in sub-Saharan Africa would increase by a factor of 2.3 between 2021 and 2035 in the IMF-ENV baseline scenario. Xu and others (2023) estimate that unused and profitable potential for expansion in hydropower generation in sub-Saharan Africa is about four times the developed hydropower and, therefore, an expansion in hydropower generation is allowed in the model simulations. Moreover, the IEA also expects hydropower capacity to almost double between 2020 and 2030 under its Sustainable Africa scenario (IEA 2022) indicating the potential for growth in the sector.

[18] According to IEA (2022), 48 African countries have requested more than $1,200 billion in climate financing with almost 60 percent of it for climate mitigation. Half of this financing request comes from six African economies, five of which are in sub-Saharan Africa—Ethiopia, Nigeria, Cameroon, South Africa, and Somalia. 0.5 percent of GDP investment shock in our simulations is equivalent to annual spending of about $12 billion in total in sub-Saharan Africa by 2030, which is a fraction of the finance requested in the NDCs.

wind sectors are present in a country, then the investment is equally shared between the two sectors. If only one of these two-generation sectors is present, then the full investment is channeled into it. This keeps the aggregate shock comparable across sub-Saharan African economies. In the *domestic* scenario, the new investments are entirely funded by reallocating domestic resources that would otherwise be allocated to other sectors.[19] Differently, in the *international* scenario, new investments are covered by financing coming from abroad.[20] In the illustrative *mix* scenario, 50 percent of investments are assumed to be funded through domestic sources and the rest through international funds.[21] Importantly, increased electrification and improved reliance of electricity can unlock productivity gains in sub-Saharan Africa (Alam et al. 2018; Rojas-Romagosa et al. 2024). Estimates of long-term labor productivity improvements from eliminating power outages by (Fried and Lagakos 2023) average 15 percent across four significant economies in sub-Saharan Africa. Here, simulations conservatively assume that investments sufficient to modernize the electricity sector (estimated at $25 billion per year by IEA 2022) would lead to a 5 percent improvement in productivity by 2035. In each scenario, productivity shocks are rescaled proportionally to the increase in renewable investment.

Figure 7. Average Annual GDP Growth Impacts between 2025 and 2030 (Percent)



Source: IMF staff calculations based on IMF-ENV model.
Note: Refer to Annex Table 1.2. for the regional abbreviations. Data labels in the figure use International Organization for Standardization (ISO) country codes.

Macroeconomic benefits would be greater the higher the share of external resources used to finance investment (Figure 7). As a result of the diversion of resources from other sectors, if investment policies were pursued exclusively using *domestic* financing, most sub-Saharan African regions would experience lower GDP gains compared to the mix and international scenarios, while some would face small GDP loses relative to the baseline.[22] In the *domestic* scenario, between 2025 and 2030, annual GDP growth in sub-Saharan Africa would increase by 0.15 percentage point relative to the baseline, with some regions facing relatively more pronounced gains, like an increase of 0.2 percentage point in South Africa and Eastern Africa while DR Congo and Western Africa would face small GDP losses. In the *international* scenario, all sub-Saharan African economies would realize gains in annual GDP growth (relative to the baseline) ranging from about 0.3 to 0.45 percentage point with overall GDP growth in sub-Saharan Africa rising by 0.4 percentage point. Under the *mix* scenario, sub-Saharan Africa's GDP would increase by approximately 0.3 percentage point. Therefore, the *mix* scenario illustrates that a financing strategy where both external and domestic sources cover a fraction of the investment needs can yield higher GDP levels than those achievable with the *domestic* scenario. This is because the economic benefits of increased power generation are accompanied by a smaller crowding-out of investments in other sectors.[23]

In the *mix* scenario, the increase in GDP is driven by higher investment and private consumption, while net exports decline relative to the baseline scenario. As shown by the decomposition of the change in GDP for the *mix* and *domestic* scenarios, external financing allows for higher overall investment levels across sub-

[19] These model simulations are agnostic on the policy instrument used to drive the resources reallocation. The increase in renewables investment is matched by a reduction in investment in all other sectors of the economy. In practice, different policy instruments, including fiscal measures, may lead to different macroeconomic and distributional effects.

[20] For simplicity, these financial flows are modeled as transfers, as the model does not allow for debt financing. The latter, together with equity investments, grants, and government revenues, will be an important component of the financing mix. Potentially, international funding could crowd out domestic investments in these sectors; however, this is not modeled in the scenario.

[21] The share of 50 percent is illustrative. In many sub-Saharan African countries, the role of domestic financing, especially public, is very limited. Therefore, in those cases, the likely scenario would be one with an even larger share of external financing.

[22] In practice, domestic financing may encounter two additional constraints: (1) it can be more costly, potentially affecting debt sustainability; (2) due to the capital- and import-intensive nature of renewable energy investments, it may exert more pressure on reserves or the exchange rate compared to external financing.

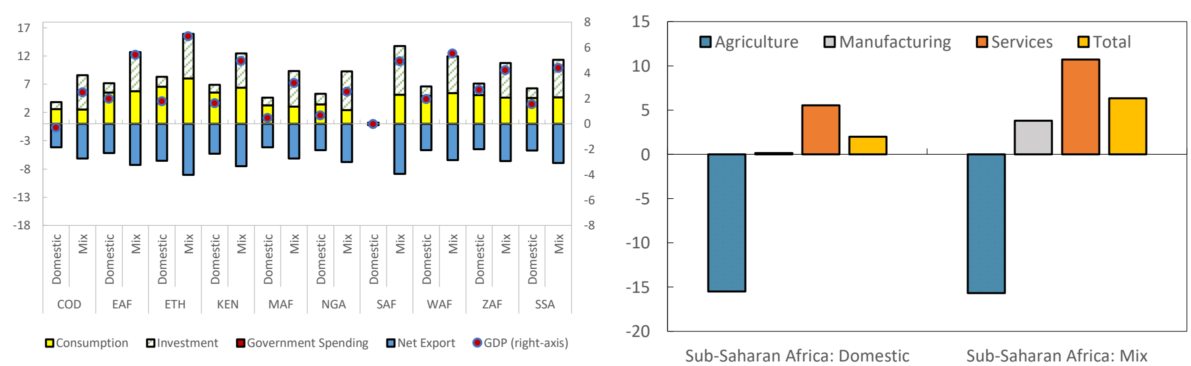
[23] Reliable access to electricity is a big concern in sub-Saharan African economies and productivity gains above and beyond the labor productivity gains included in the simulations could be unlocked with increased access and strengthened reliability of the electricity sector (Alam et al. 2018; Rojas-Romagosa et al. 2024) . Absent granular estimates about these additional productivity gains, the simulations are intentionally conservative.

Saharan African economies, contributing more prominently to the increase in GDP (Figure 8, panel 1). Wages also increase to a larger extent under the mix scenario, and higher incomes allow for higher private consumption. In the *domestic* scenario, as a result of the crowding-out of other sectors, the aggregate change in investment is more limited.[24] Real net exports contribute negatively to GDP in both scenarios, owing to a larger increase in import volumes relative to the increase in exports.[25]

Especially if supported by external financing, higher electricity supply would contribute to boosting output in manufacturing and services. Under the *mix* scenario, higher electricity supply would bolster production in the energy-intensive manufacturing and services sectors, with an overall domestic production increase of approximately 6 percent in sub-Saharan Africa by 2030. Specifically, output in manufacturing would increase by 4 percent, while services (including electricity) would increase by 11 percent. This shift would be accompanied by a decline in the agriculture sector by about 15 percent. Although magnitudes vary, this pattern of structural change is consistent across all sub-Saharan African economies. With only *domestic* financing, the overall domestic production would increase by only 2 percent, and there would be only a marginal increase of 0.2 percent in manufacturing and a modest increase of 6 percent in the services sector. The decline in the agricultural sector is very similar across the two scenarios.

Figure 8. Decomposition of GDP Impacts under the *Domestic* and *Mix* Scenarios (Percent)

1. Demand Side (2030)   2. Supply Side (2030)



Source: IMF staff calculations using IMF-ENV model.
Note: Results are calculated as percentage change relative to the baseline. In panel 1, the change in government consumption (*G*) is fixed to baseline levels in IMF-ENV (closure rule); therefore, the change in *G* relative to baseline is zero. The secondary axis shows the changes in GDP levels relative to baseline in 2030. In panel 2, services include the electricity sector. Output of the services sector, excluding electricity sector, increases by 2 percent and 5 percent, respectively, under the *domestic* and *mix* scenarios. Data labels in the figure use International Organization for Standardization (ISO) country codes. Refer to Annex Table 1.2. for the regional abbreviations.

Model simulations are subject to important caveats. The first is the conservative calibration of the productivity channel associated with increased electricity supply, which is likely to lead to an underestimation of the GDP gains. In addition, although levelized costs of renewables have been falling over the last decade, and this is captured in IMF-ENV through falling prices of renewables, other barriers like frictions to borrowing, political resistance, inefficiencies in the power market structure and lengthy bureaucratic processes exist. These are not captured in the model. Removing these barriers could further accelerate the pace of renewable development and start a virtuous cycle with improved productivity gains. Moreover, the model does not allow for debt financing, which together with equity investments, grants, and government revenues, will be an important component of the financing mix, once market reforms and climate policies are adopted to address structural constraints. Finally, the model does not distinguish between government and private investments, which are

[24] IMF-ENV has a savings-driven investment closure, a standard closure rule in the computable general equilibrium models. Regional savings rate (as a share of GDP) is exogenously defined, and this determines total investments in the subsequent period. Therefore, absent additional savings, total domestic investments are affected in a limited manner because of changes in GDP under the *domestic* scenario in Figure 8.

[25] In IMF-ENV, the external closure fixes the current account as a share of GDP to the baseline values in the policy simulations. Under the mix and international scenarios, foreign savings of each sub-Saharan African country/subregion increase by the amount of the transfers received.

instead captured as an aggregate quantity. The government, domestic and international private investors, as well as bilateral and multilateral lenders and donors, have all a role to play in the sub-Saharan Africa renewable energy development.

Enhanced International Cooperation and the $100 Billion Goal

Climate finance will be pivotal in promoting green investments, particularly in economies constrained by limited fiscal space. The concerted efforts to mobilize both official and private climate finance are crucial for accelerating green investment initiatives in emerging market and developing economies (Black and others 2022). As part of the Copenhagen Accord in 2009, high-income countries pledged to mobilize at least $100 billion per year in climate finance from 2020 onward. The pledge, however, did not clarify the exact modalities (Weikmans and Roberts 2019). In 2015, it was decided as part of the Paris Agreement to extend this commitment to 2025 and to set a new collective quantified goal (NCQG) before 2025. Advanced economies exceeded the $100 billion annual goal for the first time in 2022, mobilizing $103.6–$115.9 billion, depending on available estimates (OECD 2024; Mitchell and Wickstead 2024). However, sub-Saharan Africa typically receives a relatively small share. Of the climate finance flows disbursed by advanced economies during 2016–20, only a quarter went to Africa, including North Africa (OECD 2022). The definition of the NCQG is planned for COP29, which will be held in November 2024.

Figure 9. Illustrative Climate Finance Contributions: $100 Billion (2035)

Source: IMF staff calculations using IMF-ENV model.
Note: This is an illustrative scenario and not a policy recommendation. All sub-Saharan African countries/subregions are marked in green bars. The bars (left axis) represent the share of transfers in billions of $, whereas the dots (right axis) display these shares as a percentage of GDP in 2035. The allocation rule underlying these calculations is based on the proposal by Raghuram Rajan, which states that countries either contribute to or receive funds in proportion to the difference between their per capita emissions and the global average. This is further adjusted by an emissions price and the size of the regional population. Data labels in the figure use International Organization for Standardization (ISO) country codes.

Annual flows of $100 billion starting in 2025 are assumed, with the allocation being determined according to the difference between national and global per capita emissions. Given that the NCQG is still to be decided, the assumed flows are kept at the level of the Copenhagen Accord. A previous IMF work has discussed different rules that could be used to allocate climate finance from advanced economies to emerging market and developing economies, while maintaining global equity in mitigation efforts (see Black and others 2022). This note borrows one illustrative scenario from Black and others (2022), namely the framework proposed by Raghuram Rajan[26] to design the distribution of the climate finance flows, because it incentivizes all countries to decarbonize. This allocation rule envisions that countries either contribute to or receive funds to an extent proportional to the difference between their per capita emissions and the global average, adjusted by an emissions price and the regional population size. Based on this proposal, at the aggregate level, sub-Saharan Africa would receive about half of the total funding flows by 2035 (Figure 9).[27] Except for South Africa, all other sub-Saharan African regions would remain beneficiaries, given their relatively low per capita emissions

[26] See https://www.project-syndicate.org/commentary/global-carbon-incentive-for-reducing-emissions-by-raghuram-rajan-2021-05.

[27] In terms of economic size, contributions from advanced economies toward the $100 billion goal would represent about 0.1 percent of their GDP, while sub-Saharan Africa would collectively receive funds equivalent to 1.6 percent of its GDP in 2035. The analysis of Black and others (2022) is conducted until 2030 and models alternate allocation options in which the sub-Saharan Africa share would vary from 17 to 30 percent, with the highest share being realized under the Rajan proposal. To compare, the 2030 allocation share toward sub-Saharan Africa in this note is 38 percent, with updates in baseline emission projections being the primary drivers of the increased share of financing allocated to sub-Saharan Africa under the Rajan proposal.

compared to the global average.[28] Recognizing that a significant part of these financial flows should be allocated to climate adaptation, the following illustrative simulations assume that $25 billion per year (half of the about $50 billion flowing to sub-Saharan Africa) will be assigned to the renewable energy sector. Clearly, countries may have different preferences regarding the funds' allocation. For simplicity, these simulations also assume that these flows are in the form of transfers. In practice, they will be a combination of debt instruments (which may have a grant component), grants, and equity. The transfer-based nature of these flows likely leads to an overestimation of the GDP impact. This will be more muted the smaller the grant component in overall financing.[29]

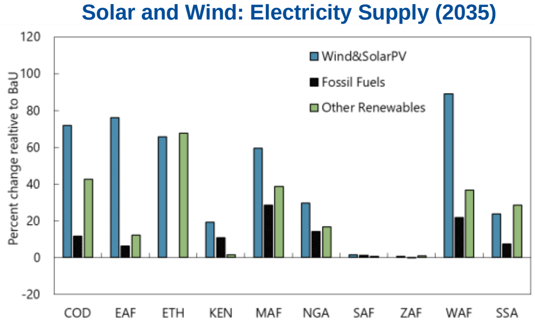
The allocation of climate finance within the power generation sector is envisaged to follow three alternative investment strategies:

1. *Solar & Wind*: In this scenario, the funds are exclusively allocated toward investments in the solar photovoltaic (PV) and wind generation sectors.
2. *Transmission and distribution (T&D)*: Beyond the investments in solar PV and wind generation, this scenario extends the use of funds to investments in the T&D sector, which is a critical input for scaling up power generation capacity across any technology.
3. *Energy Efficiency*: This scenario envisages that new investments will not only bolster the solar PV, wind, and T&D sector but will also contribute to improvements in energy efficiency.

In the *Solar & Wind* scenario, funds finance the new capital invested in these two sectors and the distribution of funds is proportional to the share of investments these two sectors receive under the baseline scenario. In the *T&D* scenario, the allocation of investments across the three sectors—solar, wind, and T&D—is determined based on their respective shares of investments in the baseline scenario. The share of investments going jointly to the wind and solar sectors is reduced substantially under this allocation because of the large share of existing capital stock in the T&D sector.[30] Moreover, investments in the T&D sector are technology-neutral within the model, given that an efficient T&D infrastructure is essential for the deployment of all power generation technologies. Finally, in the *Energy Efficiency* scenario, the same level of output can be produced with less energy inputs relative to the baseline scenario. The energy efficiency improvements are designed to be unbiased toward any specific power generation technologies, thus benefiting both fossil fuel–based and renewable energy sectors.

Figure 10. Change in Total Electricity Supply in Sub-Saharan African Regions (Percent Change Relative to baseline)

Solar and Wind: Electricity Supply (2035)



Source: IMF staff calculations using IMF-ENV model.
Note: The results for scenario *T&D* and *Energy Efficiency* are like that for scenario *Solar and Wind*. Annex Figure 1.5 shows the complete results for all three scenarios. Refer to Annex Table 1.2. for the regional abbreviations. Data labels in the figure use International Organization for Standardization (ISO) country codes. T&D = transmission and distribution.

The allocation of climate finance toward solar and wind sectors, along with the expansion of transmission and distribution networks, would substantially boost electricity supply (Figure 10). Total

[28] In the illustrative scenario, a country's role as a donor or recipient in climate finance is influenced by its decarbonization pace relative to the global average. South Africa, heavily reliant on coal, emits more per capita than the global average until 2032, making it a donor until it becomes a recipient post-2033. This shift could occur sooner if South Africa accelerates its decarbonization or if global efforts slow. Additionally, initiatives like the Just Energy Transition Partnership, established during COP26, where wealthy nations pledged $8.5 billion to aid South Africa's coal transition, highlight how climate finance can address specific national challenges and encourage decarbonization at different levels.

[29] Although the effect on electricity generation and energy sector employment remains constant across financing scenarios, given equal investment levels, the broader macroeconomic outcomes will vary by financing mix. Allocating half of climate funds to mitigation in sub-Saharan Africa equates to an annual $25 billion investment or about 1% of the region's GDP by 2035, doubling the investment rate to 0.5% of GDP annually by 2030 as seen in previous simulations. The increased investment and extended analysis to 2035 mark the primary distinctions between these scenarios, influencing the magnitude of projected outcomes.

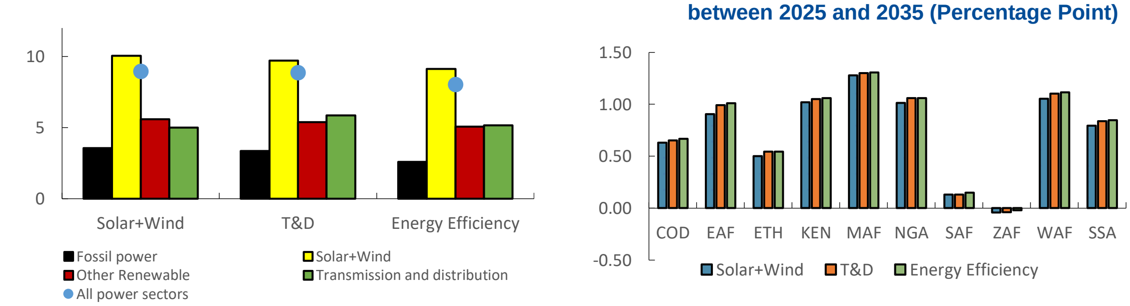
[30] Based on the GTAP data, apart from South Africa and Kenya, in the rest of the sub-Saharan African economies, over half of the capital stock within the electricity sector (all power technologies including T&D) exists in the hydropower sector. In South Africa and Kenya, most of the capital stock is in coal generation (74 percent) and geothermal generation (48 percent), respectively. On average, a quarter of the investments in electricity sector go to the T&D sector in sub-Saharan African countries.

electricity generation in sub-Saharan Africa would increase by about 17 percent to 18 percent across scenarios relative to the baseline scenario, with solar and wind generation increasing by 24 percent. The generation from solar PV and wind sources would see a boost in all sub-Saharan African countries. However, the composition of electricity generation varies based on which electricity sector is targeted for investments. Among the three policy scenarios, the *Solar & Wind* scenario, which channels the most substantial investments into solar and wind energy generation, showcases the largest increase in electricity generation relative to the baseline. The increase in wind and solar PV is as high as 76 percent to 90 percent in the Eastern and Western African regions. In the electricity sector, within the IMF-ENV model, T&D sector is recognized as an essential input for power generation. Therefore, even when funds are exclusively allocated to renewable power generation sectors, additional investments in the T&D sector take place. This explains the increase in fossil fuel and other renewables-based generation under both the *Solar & Wind* and *T&D* scenarios even though these sectors are not directly targeted by investments.[31] As a result of this mechanism, the expansion of the T&D sector benefits all power generation technologies by enhancing the overall efficiency and reach of the energy grid. The expansion of the grid is likely to expand access.[32] In the *Energy Efficiency* scenario, the growth in power generation sectors is marginally lower as a result of the reduced energy requirements for generating output given higher efficiency of energy inputs (see Annex Figure 1.5).

Figure 11. Impact on labor demand and GDP growth in Sub-Saharan Africa

1. Labor Demand in the Key Sectors (Percent)

2. Average Annual GDP Growth Impacts between 2025 and 2035 (Percentage Point)



Source: IMF staff calculations using IMF-ENV model.
Note: Both charts show percentage changes relative to the baseline. Regional abbreviations as in Annex Table 1.2. Refer to Annex Table 1.2. for the regional abbreviations. Data labels in the figure use International Organization for Standardization (ISO) country codes. T&D = transmission and distribution.

The *Solar & Wind* scenario amplifies employment within the renewable energy sector the most (Figure 11, Panel 1). All three investment strategies would contribute to an overall increase in labor demand within the electricity sector, which would increase by about 8 percent to 9 percent by 2035 under each of the three investment options, with the *Solar & Wind* scenario registering the most pronounced overall growth. Labor demand in renewable generation rises by 15 percent to 17 percent, and a smaller increase of 3 percent to 4 percent is also seen in the fossil generation sectors as these sectors also gain from improved grid structures, through expansion of the T&D sector, regardless of the investment focus.[33] To ensure that the domestic labor pool can meet the increased demand for specialized skills in the renewables sector, policy support for workforce development, including training and education programs, would be essential (Alexander and others forthcoming). Increased electricity supply supports the expansion of the manufacturing sector, which increases its labor demand by about 9.5 percent relative to the baseline. Employment falls by 18 percent in the fossil

[31] Higher generation from other renewables does not necessarily reflect expansion of capacity but could also result from higher utilization rates because of improved grid infrastructure.

[32] The link between higher electricity generation (with scaling up of the T&D sector) and electricity access is not directly modeled in IMF-ENV. The literature shows that the electricity demand of newly connected households will be low at the beginning and therefore, the impact of new connections on overall demand will remain small in the early years (Valickova and Elms 2021). Therefore, rather than increase in demand for electricity, we can use the expansion in the T&D sectors as a proxy for improvement in access. Population density and local grid characteristics play a key role in determining the cost-effectiveness of standalone and mini-grid solutions. Existing studies for Nigeria and Ethiopia show that scaling-up of grid-based solutions would be the least costly option for improving access for most households (see Nerini and others 2016), especially given the high population density in urban areas.

[33] On average, in sub-Saharan Africa (excluding South Africa), almost half of the labor in the electricity sector is employed in T&D sector (based on the GTAP data for the year 2017).

mining sector (with a small increase in other mining activities) and 4 percent in all services sectors (excluding the electricity sector). However, given the low labor intensity of the mining sector, the reduction in labor demand in the services sector remains the substantial source of new labor in the manufacturing sectors.[34]

These climate finance flows would result in higher GDP growth across most sub-Saharan African economies (Figure 11, Panel 2). Collectively, sub-Saharan Africa would benefit from a GDP boost of about 9 percent by 2035, compared to the baseline scenario, across all three scenarios. In other words, 0.8 percentage point would be added every year to GDP growth on average. The most significant gains would be observed in the Eastern, Middle, and Western African regions, which would receive a substantial portion of the $100 billion flow according to Rajan's rule. As South Africa would transition from a contributor to a recipient only between 2032 and 2035, the country would see a slight decrease in the GDP level.

The Impact of Market Reforms and Climate Policies on Financing Flows and Power Generation

Market reforms and climate policies have a role to play in reducing barriers and creating incentives to mobilize financing for renewable energy in sub-Saharan Africa. This section uses econometric approaches to investigate this hypothesis, analyzing data covering the past two decades. The analysis focuses on the effects of market reforms affecting business regulations, governance, and the external sector, as well as climate policies, on official climate finance, announced foreign direct investment (FDI) inflows, and power generation, including from solar and wind.

Empirical Strategy and Data

The analysis uses standard econometric methodologies applied to a sample of 39 sub-Saharan African economies over the period 2000–21. The data includes the number of climate policies implemented and structural indicators covering areas of governance, business regulations, trade, and external finance. Consistent with the previous literature on the economic impact of market reforms in emerging market and developing economies (EMDEs) (for example, Dabla-Norris, Ho, and Kyobe 2016, IMF 2019, Budina and others 2023), the local projection method developed by Jordà (2005) is adopted to estimate the dynamic effects of reforms on outcome variables. To show potential gains from reforms, the results are illustrated for major historical reforms—defined as episodes for which an improvement in the relevant indicator is at least as large as two standard deviations of the distribution of annual changes in the relevant indicator across the whole sample.[35] When analyzing the impact of market reforms and climate policies on announced FDI inflows, the local projection method is no longer adequate because of the large prevalence of zeros in the data, especially for nongreen projects.[36] Instead, and consistent with previous IMF works (Hasna and others 2023; Pienknagura 2024), the relationship between reforms and announced FDIs is estimated using the pseudo-Poisson maximum likelihood estimator.[37]

Sub-Saharan Africa continues to lag its peers in many areas of market reforms and climate policies. As discussed in previous IMF works, first-generation reforms (governance, external sector, business regulation) can boost economic activity in the short and medium term by increasing labor productivity, competition, and investor confidence and fostering investment, especially when reform gaps relative to the frontier are particularly large as is the case in sub-Saharan Africa (Budina and others 2023). These policies also help with the green transition, by both reducing the GHG emission intensity of output and enhancing the response of the economy

[34] The labor supply elasticity in sub-Saharan Africa is set to 0.1. With an increase in wages, labor supply increases by an average of 2.5 percent in sub-Saharan Africa. This increase in overall labor, along with reallocation from other sectors (mostly fossil mining), drives the increase in employment in the electricity generation sector.

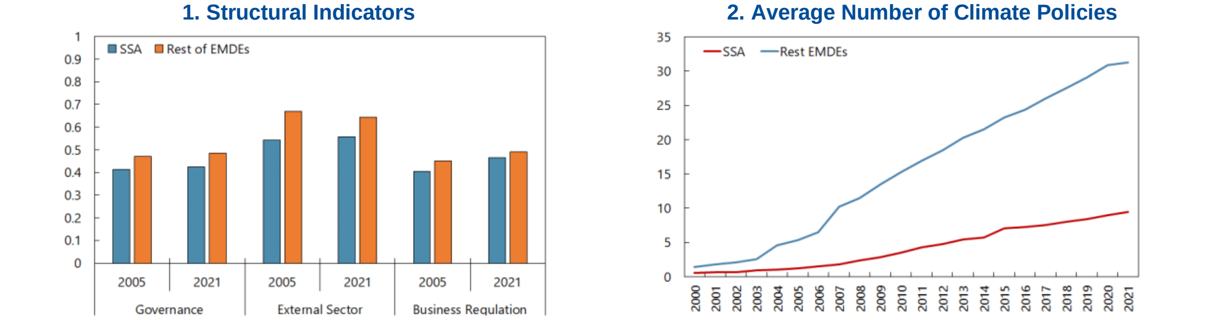
[35] This definition is consistent with previous work, for example, Budina and others (2023) and IMF (2019). Examples of major structural reforms include Rwanda's governance reforms during the late 2000s, which involved a complete overhaul of regulatory quality and government effectiveness, and Zimbabwe's post-2008 exchange rate reforms to combat long-standing hyperinflation, allowing the adoption of foreign currencies (including the US dollar and the Euro) as official currencies.

[36] This is because there has been no new FDI announcement for some countries in some years.

[37] Compared to OLS, this estimator is robust to heteroskedasticity and provides a natural way to deal with zeroes in the FDI data (Silva and Tenreyro 2006). The coverage of climate policies is comprehensive, ranging from carbon prices to subsidies, regulation, information and education, and climate targets, among others. A limitation of this data is that while capturing the number of policies implemented, it does not measure their quality.

to green policies such as energy taxes (Budina and others 2023). Despite some progress made in the past decade, on average, the region is still experiencing gaps compared to the rest of EMDEs, especially in areas of governance and external sector reforms, as well as in the number of climate policies implemented (Figure 12), thus calling for greater attention to these policy areas. The next subsections present and discuss empirical results on the impact of these policies on official climate finance, FDI, and power generation.

Figure 12. Policy Gaps in SSA

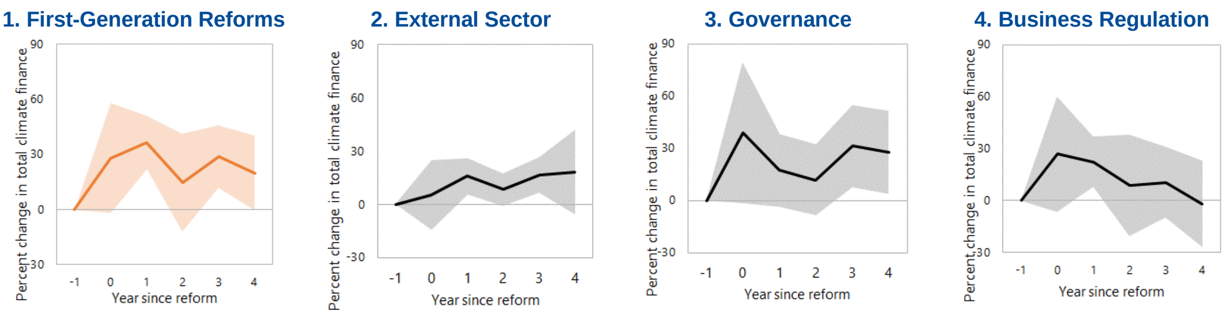


Sources: Climate Policy Database; Fraser Institute; World Bank; and IMF staff calculations.
Note: Structural indicators range between 0 and 1, with higher values implying better perceived quality of institutions (that is, governance) and greater degree of liberalization (that is, external sector and business regulation). External sector reforms comprise capital and exchange rate controls, tariffs and nontariff barriers, financial openness, and freedom of foreigners to visit. The Climate Policy Database is the most comprehensive available data set on climate policies, but it is not complete for emerging market and developing economies (EMDEs). SSA = sub-Saharan Africa

Official Climate Finance

Securing greater access to climate finance is critical for sub-Saharan Africa's sustainable development. Sub-Saharan Africa received $15.7 billion of concessional climate finance in 2020, falling short of the region's needs, which are estimated for all of Africa at $50 billion per year until 2050 for adaptation, and $190 billion per year until 2030 for mitigation (IMF 2023a). These gaps emphasize that, besides concessional sources, all other available instruments should be leveraged. This includes a wide range of financial instruments such as multilateral development bank's risk-sharing mechanisms, sustainability-linked bonds, public-private partnerships, and other financing solutions to mobilize the necessary resources for both adaptation and mitigation (Belianska and others 2022).

Figure 13. Impact of First-Generation Reforms on Official Climate Finance



Source: IMF staff calculation.
Note: $t = 0$ is the year of the shock. The lines denote the response to a major historical reform (two standard deviations). The first-generation reform package is a simple average of governance, external sector, and business regulation reforms. The shaded areas denote 90 percent confidence bands. Sample of 39 sub-Saharan African countries, 2000–21.

First-generation reforms are associated with an increase in official climate finance inflows in sub-Saharan Africa (Figure 13). Results indicate that a major first-generation reform bundle, which includes governance, business regulations, and external sector reforms, is associated with a 20.1 percent increase in climate finance through grants and concessional debt (amounting to about $28–$318 million for the countries at the 25th and 75th percentile of the distribution of climate finance, respectively) over five years.[38] More granular results indicate that, over the medium term, governance and external sector reforms present a stronger statistical association than business regulation reforms with official funding flows. As shown in Figure 12, these

[38] These results are robust to excluding South Africa from the sample. See Annex Figure 2.1.

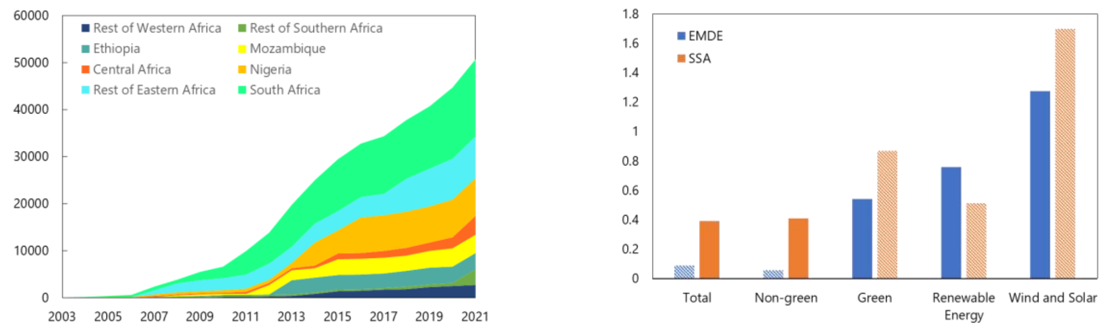
policies are those for which the gap between sub-Saharan Africa and other EMDEs is the greatest. Therefore, there is room to advance market reforms in these areas and potentially enhance climate finance flows to sub-Saharan Africa.

So far, the implementation of climate policies has not been significantly associated with increases in climate finance inflows in sub-Saharan Africa.[39] Sub-Saharan African countries have adopted and implemented fewer climate policies than other EMDEs over the past two decades: a total of 10 per country, on average, versus more than 30 per country in other EMDEs (Figure 12). A caveat is that coverage of climate policies for some sub-Saharan African countries may not be exhaustive. In addition, providers of official financing may be driven by many other motives, including developmental ones, in their decision to extend concessional loans and grants, which would weaken the correlation between climate policies and finance inflows. As sub-Saharan African countries converge to the level of climate action of other EMDEs, it is possible that the international community may respond with a more decisive increase of official climate finance flows.

Figure 14. Green FDIs in SSA

1. Cumulative Announced Green FDI Inflows (Real Terms, Million $)

2. Impact of Climate Policies on Greenfield FDIs (Levels, Real Terms)



Sources: fDi Markets; and IMF staff calculations.
Note: In Panel 1, the chart shows the cumulative greenfield FDI inflows related to green activities in sub-Saharan Africa (SSA). FDI = foreign direct investment. In Panel 2, Sample of 115 EMDEs (39 SSA countries), 2003–21. The bar chart shows the estimated coefficients from the pseudo-Poisson maximum likelihood regression, which can be interpreted as elasticities of FDI inflows in response to a percentage change in the stock of climate policies. Solid bars denote statistically significant results at the 1 percent level for EMDEs and at the 10 percent level for sub-Saharan Africa (SSA). EMDEs = emerging market and developing economies; FDI = foreign direct investment.

Foreign Direct Investments

FDI will likely play a major role in sub-Saharan Africa's transition toward a greener, more productive economy. In the context of a steady decline in official financing flows to sub-Saharan Africa, official climate finance will not be enough to cover the region's financing needs for the climate transition. Therefore, support from the international community and development partners needs to be accompanied by increased private climate finance flows. As countries develop, they typically rely more on FDI to finance their investment needs (IMF 2023b). Scaling up green FDI would allow sub-Saharan African countries to diversify their funding mix and accelerate their green transition. Over the period 2003–21, cumulative announcements of green FDI toward sub-Saharan Africa amounted to $50.7 billion ($ in 2000), approximately 4 percent of the region's GDP in 2021. They accelerated after 2011, and almost a third of these announced green FDI were directed to South Africa (Figure 14, panel 1). Other large recipients were Nigeria (16 percent), Mozambique and Ethiopia (7–8 percent each), and the rest of Eastern Africa (18 percent).

Focusing on EMDEs, empirical results indicate that climate policies are associated with an increase in the dollar amount of green FDI announcements (Figure 14, panel 2). Econometric estimates along the lines of Jaumotte and others (forthcoming) show that a one-percent increase in climate policies is associated with a 0.5 percent increase in US dollar amount of green FDI announced in EMDEs during the following year. The sub-

[39] Information on the climate policy data is provided in the "Market Reforms and Climate Policies Data" section in Annex 2. Policies included in the database are a combination of policies with explicit climate mitigation objective (that is, reduce emissions), energy policies that help decarbonize energy supply/reduce energy demand, and policies that aim to introduce low-emissions practices and technologies.

Saharan Africa-specific estimate is about 0.9 percent, but it is not statistically significant, regardless of the inclusion of South Africa, the main recipient, in the sample.[40] These results are in line with those of Hasna and others (2023), which uses bilateral data and finds that in EMDEs, green FDI inflows increase after climate policies are adopted (or trade barriers reduced), particularly those consisting in government expenditure, such as R&D subsidies and feed-in tariffs, and government revenue measures, such as emissions trading systems. Climate policies in EMDEs are even more strongly associated with announced FDI related to renewable energy, especially solar and wind, as a 1 percent increase in these policies is associated with a 1.3 percent increase in FDI announcements supporting solar and wind activities. Jaumotte and others (forthcoming) suggest that closing the climate policy gap between the average EMDE and the average AE would triple the green FDI to GDP ratio in the average EMDE and would close 40 percent of the private renewable investment gap in EMDEs excluding China (see Box 1 for successful cases of climate policies in attracting FDI). Structural reforms aiming at promoting private investment could foster FDI in sub-Saharan Africa, as in other EMDEs (Budina and others 2023) and make green FDIs more responsive to climate policies (Devine and others 2021 discuss these reforms and provide policy recommendations).

Box 1. Climate Policies and Green FDI: Successful Cases

The experience of successful EMDEs suggests that there is an association between climate action and green FDI inflows. Attracting green FDI requires specific policy effort and favorable preexisting conditions, such as progress in structural reforms and geographical potential for renewables (Jaumotte and others forthcoming). Early adopters of climate policies, such as Chile, Uruguay, and Mexico, have seen considerable inflows in renewable energy FDI thanks to sustained efforts in developing a broad climate policy portfolio for the electricity sector. Successful cases share a similar sequencing of climate policies, starting from expenditure-generating policies—such as subsidies, feed-in tariffs, power purchasing agreements—to create a domestic market for renewables and strategic planning (target setting, incentives, and so on), followed by regulation (such as energy efficiency policies), and finally, revenue-generating policies such as carbon pricing or emissions trading systems.

Failure to sustain these efforts may result in the reversal of green FDI as observed in Mexico, which has seen a decline in renewable energy FDIs in recent years, after the removal of the power sector auctions in 2019, accompanied by a surge in fossil fuel generation. The ability to attract green FDI may also differ across countries because of structural factors. For example, although Nigeria has been active on the climate policy front, passing 12 climate policies between 2007 and 2019, which included feed-in tariffs, strategic planning, and procedures for renewable energy auctions, it has not been able to attract enough FDI, potentially because of policy uncertainty, weak financing mechanisms and other structural weaknesses such as the existence of a parallel exchange rate market in recent years. Sub-Saharan Africa can learn from the experiences of successful EMDEs and close the most binding structural gaps, by promoting good governance, trade and capital accounts openness, as well as product market reforms.

This box was prepared by Andrea Medici.

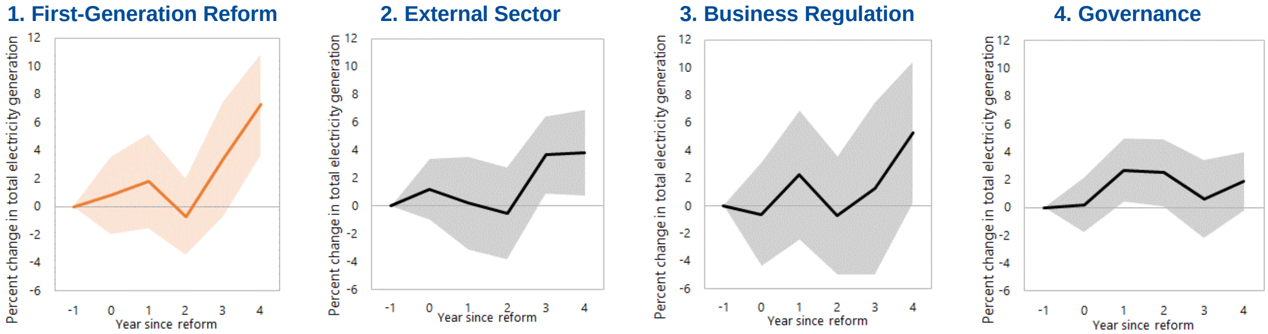
Power Generation

Increased renewable power generation is one of the main goals of official climate finance and FDI inflows. While the previous results show that market reforms and climate policies may help attract climate finance, this subsection tests whether these policies may specifically help boost power generation in sub-Saharan Africa. In what follows, green power refers to power from solar and wind sources.

As the sub-Saharan African population grows and economies expand, the region needs to increase electricity production to meet a growing demand and foster its development. So far, the increase in power generation has not kept pace with population growth, and even less with output per capita (Figure 2). This issue represents a major headwind to sub-Saharan Africa's development since the lack of electricity leads to higher production costs and hampers labor productivity and human capital accumulation (Lawal and others 2020; Mensah 2024). Increasing green power generation will be a critical component of the region's climate transition and will also have broader positive developmental effects.

[40] A signaling effect might explain the statistically significant response of nongreen FDIs in sub-Saharan Africa: following the adoption of climate policies, international investors anticipate a policy environment compatible with sustainable development, which increases local demand in the medium to long term.

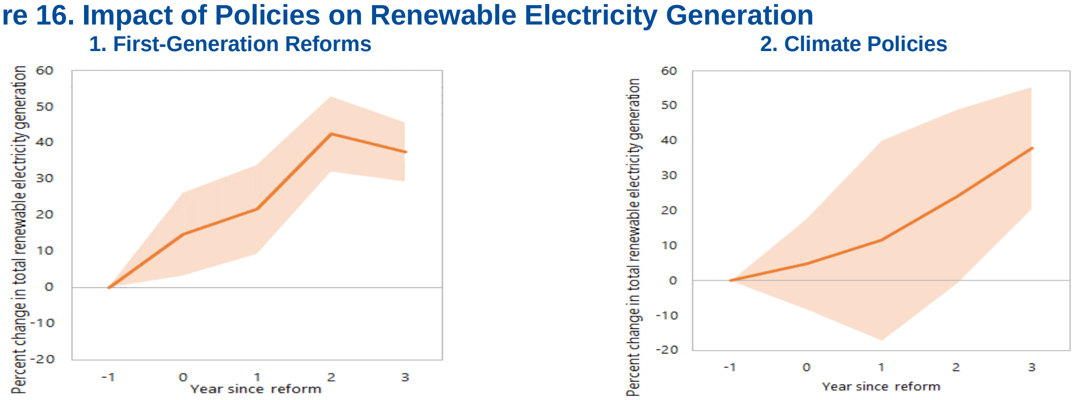
Figure 15. Impact of First-Generation Reforms on Total Electricity Generation



Source: IMF staff calculations.
Note: *t* = 0 is the year of the shock. The lines denote the response to a major historical reform (two standard deviations). The first-generation reform package is a simple average of governance, external sector, and business regulation reforms. The shaded areas denote 90 percent confidence bands. Sample of 39 sub-Saharan African countries, 2000–21. The regression includes a country-specific time trend: see the "Baseline Empirical Framework" section in Annex 2 for the detailed specification.

First-generation market reforms, which cover measures in governance, business regulations, trade, and external finance, are associated with an increase in total power generation in sub-Saharan Africa (Figure 15). The implementation of a major first-generation reform is followed by a 7.2 percent increase in power generation (representing about 3,400 GWh) over a five-year period.[41] This positive effect is mainly driven by external sector reforms and business regulation reforms. One plausible transmission channel is a direct effect: by removing bottlenecks in the energy sector, first-generation reforms incentivize sectoral investments, which lead to an increase in energy supply. An indirect effect is also at play: by enhancing economic activity, first-generation reforms lead to an increase in energy demand, which in turn incentivize greater energy supply. In contrast, climate policies do not show a statistically significant association with total power generation. This result may be explained by the small share of renewables (that is, those sectors that are most likely to respond to climate policies) in the region's total power generation (Figure 1).

Figure 16. Impact of Policies on Renewable Electricity Generation



Source: IMF staff calculation.
Note: *t* = 0 is the year of the shock. In panel 1, the line denotes the response to a major historical first-generation reform (two standard deviations). The first-generation reform package is a simple average of governance, external sector, and business regulation reforms. In panel 2, the line denotes the response to a two-standard deviation increase in the stock of climate policies. The shaded areas denote 90 percent confidence bands. Sample of 39 sub-Saharan African countries, 2010–21. The regression includes a country-specific time trend: see the "Baseline Empirical Framework" section in Annex 2 for the detailed specification.

Both first-generation reforms and climate policies have been recently associated with an increase in renewable power generation in sub-Saharan Africa (Figure 16). The adoption of major policies is on average followed by an increase of about 40 percent in renewable power generation over a four-year period.[42] The effect of first-generation reforms is mostly explained by business regulations reforms and, to a lesser extent, by external sector reforms. The greater magnitude of the effect on renewable energy is likely because of

[41] These results are robust to excluding South Africa from the Sample. See Annex Figure 2.2.

[42] The local projections horizon has been restricted to four years since the data with significant renewables presence covers only the period 2010–21.

the base effect, since solar and wind still represent a limited share of sub-Saharan Africa's energy mix, but declining costs and a relative abundance of wind and sunlight might also explain the marked response of renewable electricity generation to these policies. Regarding climate policies, energy sector reforms are generally followed by larger renewable power generation increases than transport sector reforms.[43] Box 2 presents two country examples of renewable energy development.

Box 2. Boosting Renewable Energy in Sub-Saharan Africa: Two Country Cases

Tanzania is among the sub-Saharan African countries that increased electricity access the most, from 9 percent of the population in 2000 to 46 percent in 2022 (World Development Indicators). The rapid electrification relied on grid extension initiatives such as the Tanzania Rural Electrification Expansion Program, financed by the government and the World Bank, and also on decentralization and developing mini-grids, which doubled in number since 2008 to reach 135 in 2023. About 80 percent of mini-grids rely on solar and hydropower technology, although 50 percent of mini-grids' total installed capacity uses diesel as an input (35 percent uses solar and hydro). Private sector involvement has been incentivized by the Small Private Producers Framework adopted in 2008: about 75 percent of mini-grids were privately held in 2023 (Lecaros and others 2024).

Namibia has swiftly expanded its solar photovoltaic production in recent years, from 2 percent of total installed capacity in 2015 to 42 percent in 2022 (BloombergNEF), relying on regulatory support, such as the 2015 Renewable Energy Feed-in Tariff program and decentralized systems to reach off-grid populations. To benefit further from its abundant sun and wind endowment, the recently adopted Green Hydrogen Project targets a production of 10–12 million tons of green hydrogen by 2050. This effort involves the private sector, international support including grants, and a financing vehicle, SDG Namibia One, that will raise funds from local and international investors. This is also part of a larger strategy to achieve economic diversification, which includes investment in infrastructure and green industrial policy (IMF 2023c).

This box was prepared by Thibault Lemaire.

Conclusion

Renewables have an important role to play in sub-Saharan Africa's electricity supply. Several sub-Saharan African countries already have low-carbon electricity mixes, mainly based on hydropower and, to a lesser extent, on geothermal energy. For both these countries and for those that are currently relying on fossil fuels, renewables can play an important role in their future energy and green growth strategies. As evident in the results of the IPCC scenarios, energy-economy models identify solar and wind as important drivers of electricity generation in the region, given its geographical advantage. Hydropower can play a crucial supporting role. By sending the right signals and creating economic incentives, climate policies may help accelerate the green electrification process.

Boosting electricity generation through renewable energy sources will significantly affect growth, but sub-Saharan African countries cannot achieve this relying solely on domestic resources. Scaling up renewable energy generation requires significant investments because of its capital-intensive nature. Thus, securing sufficient financing and implementing complementary reforms is crucial. A mix of domestic and external financing can lead to sizable increases in both renewable electricity generation and GDP. Conversely, relying solely on domestic financing would still boost power generation but would dampen overall economic benefits because of the crowding-out effect on other sectors of the economy. Sources of domestic revenues for financing green energy investments are country-specific and diverse. These sources can include, but are not limited to, carbon taxes, the repurposing of fossil fuel subsidies, and the mining of minerals critical for the energy transition.

Climate finance is crucial for supporting green investments, especially in economies with limited fiscal space. The commitment under the Copenhagen Accord by advanced economies to mobilize at least $100 billion annually in climate finance for emerging market and developing economies is expected to be revisited during COP29 in November 2024. The objective is setting an NCQG. Absent information on the new goal, this note explores scenarios with an annual target of $100 billion starting in 2025, based on an allocation rule where countries either contribute or receive funds proportional to relative per capita emissions. Under these conditions,

[43] These results are robust to excluding South Africa from the Sample. See Annex Figure 2.3.

sub-Saharan Africa would receive approximately half of the total funding flows. Contributions from advanced economies would amount to about 0.1 percent of their GDP, while sub-Saharan Africa would collectively receive funds equivalent to about 1.6 percent of its GDP, which could be used for climate adaptation and mitigation. As an illustration, if half of the funds received by sub-Saharan Africa were primarily directed to green power generation, renewable electricity production would increase by up to 24 percent relative to a scenario excluding these financing flows, boosting annual GDP growth by an additional 0.8 percentage point, and contributing to an overall rise in labor demand within the electricity sector over the next decade.

Market reforms and climate policies can play a vital role in removing obstacles to securing financing for renewable energy projects, and thereby increasing green electricity generation. One notable category of reforms is comprised of measures tackling fundamental constraints to the proper functioning of markets, such as governance, business regulations, and external sector reforms. In historical sub-Saharan African data, a major bundle of these reforms is associated with a 20 percent increase in climate finance flows through grants and concessional debt, and by a 7 percent increase in power generation over a five-year horizon. Notably, governance and external sector reforms show the strongest link with official climate finance flows. Climate policies can play a significant role in attracting environmentally friendly investments. In EMDE data, a 1 percent increase in the number of climate policies is associated with a half percent increase in green FDI announcements during the following year. Big pushes to market reforms and climate policies are both strongly linked to significant increases in power generation from renewables in sub-Saharan African data.

In sum, with its geographical advantages, sub-Saharan African countries have the potential to significantly boost renewable electricity generation, paving the way for sustainable economic growth and a greener future. Governments and the private sector can leverage both domestic and international resources to finance investments in green electricity generation, as both sources play an essential role in supporting these initiatives. A more robust power supply and increased use of renewables, including off-grid solutions that reach rural communities, would not only boost economic growth but it would also support development goals by bringing universal access to electricity closer to reality. By removing structural barriers and adopting climate policies, African policymakers can attract climate finance flows and green investments. Defining the NCQG at COP29 represents an invaluable opportunity for the international community to make a significant contribution to both African sustainable development and global climate objectives.

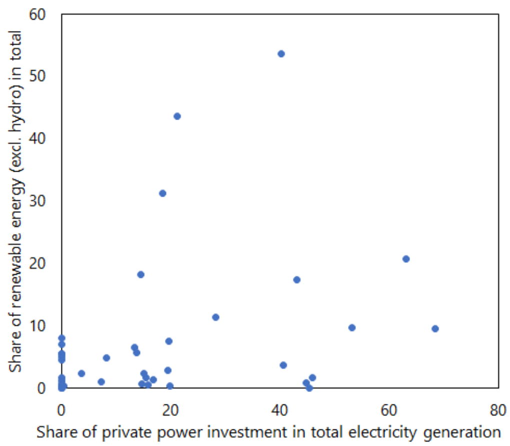
Annex 1. Further Results and Details of the Stylized Facts and Model Analysis

Further information and results on the Current Energy Landscape and Possible Future Scenarios

The official database of the sixth assessment report of the IPCC (Byers and others 2022) contains all scenarios included in the report. Inclusion criteria require publication in a peer-reviewed journal or recognition by the IPCC as eligible gray literature. The scenarios are created with integrated assessment models, which combine macroeconomic modeling with detailed representations of various emission sources, including the energy sector. The integrated assessment models do not provide sectoral and employment effects of changes to the energy system. This aspect is covered in the computable general equilibrium analysis used in this note.

Private power investments (PPIs)

Annex Figure 1.1. PPI Electricity Capacity versus Renewable Energy Electricity Generation (Percent)



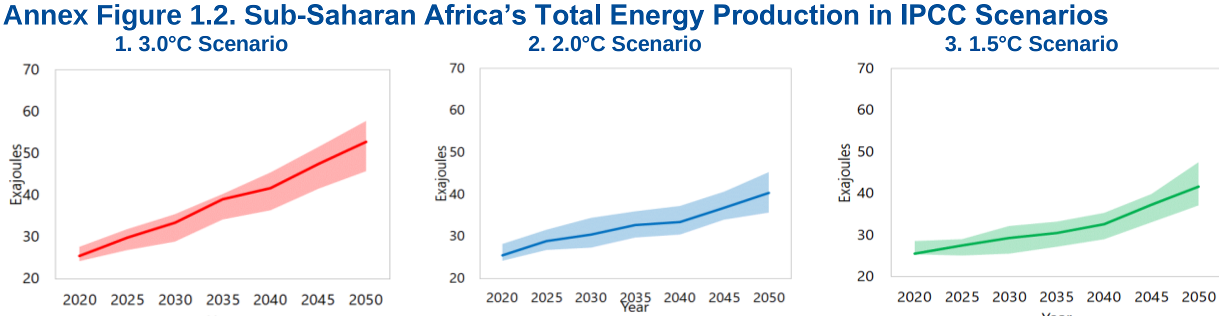
Sources: International Renewable Energy Agency; Kruger and Alao (2023); and IMF staff calculations.
Note: In panel 2, 18 countries have zero PPIs, and of these, 9 also have no capacity in non-hydropower renewable energy. Data labels in the figure use International Organization for Standardization (ISO) country codes. Refer to Annex Table 1.2. for the regional abbreviations. PPI = private power investment; TWh= terawatt-hour.

Private power investments (PPIs) have an important role in supporting the production of renewable energy. There is a correlation between the share of electricity capacity constructed between 1995 and 2022 by PPIs and the share of total electricity capacity in 2022 (Annex Figure 1.1). The share of PPIs is compared to the share of renewable energy (other than hydropower) in total electricity production. The chart shows that some countries have achieved a high level of PPIs, while having low levels of non-hydropower renewables. The reverse, however, is not true: of the 18 countries with zero PPI, only half have achieved more than 0.5 percent non-hydropower renewables and none was able to exceed 8.1 percent. This is consistent with evidence that since 2008, PPIs have been directed almost completely to renewable energy (Foster, Eberhard, and Dyson 2021). In many countries, state-owned utility companies invest very little in renewable energy other than hydropower.

Energy efficiency

Stronger climate ambition would also incentivize energy efficiency, which would reduce energy needs. Energy consumption is expected to increase in all temperature scenarios and in all models because sub-Saharan Africa is assumed to converge to the output and energy use levels of high-income countries by the end of the twenty-first century. A more ambitious climate policy, however, would incentivize higher energy efficiency, for example by phasing out fossil fuel subsidies. As a result, the increase in total energy consumption is lower in more ambitious climate scenarios (Annex Figure 1.2). Electricity consumption, however, increases with the degree of climate ambition (Figure 4). Therefore, the share of electricity production in total energy is 16.2 percent in the 3°C median scenario, 30 percent in the 2°C scenario, and 44.6 percent in the 1.5°C scenario in 2050.

Annex Figure 1.2. Sub-Saharan Africa's Total Energy Production in IPCC Scenarios



Sources: Byers and others (2022); and IMF staff calculations.
Note: The bold line shows the median scenario. The shaded area shows the range between the 25th and 75th percentile. Total energy production includes primary energy consumption from all sources. IPCC = Intergovernmental Panel on Climate Change.

Technical Description of the IMF-ENV Model

The IMF-ENV model is a recursive-dynamic neoclassical, global, general equilibrium model, calibrated primarily with a database of national economies and a set of bilateral trade flows (Chateau and others forthcoming). The model describes how economic activities and agents are interlinked across several economic sectors, as well as countries and world regions. The central input of the model is version 11 of the Global Trade Analysis Project (GTAP) database (Aguiar and others 2023). The database includes country-specific input-output tables for 160 countries and 65 commodities, as well as real macroeconomic flows. It also captures world trade flows comprehensively for a given starting year. The currently used version 11 is based on data from 2017.

The model captures the activities of key economic actors: representative firms by sector of activities, a regional representative household, governments, and markets. Firms purchase inputs and primary factors to produce goods and services, optimizing their profits. Households receive factor incomes and, in turn, buy the goods and services produced by firms; households' demands result from standard welfare optimization under budget constraints. Markets determine equilibrium prices for factors, goods, and services. Frictions on factor or product markets are limited, except for some features described in the following. The model is recursive-dynamic; that is, it is solved as a sequence of comparative static equilibria. The fixed factors of production are exogenous for each time step and linked between time periods with accumulation expressions, similar to the dynamics of a Solow growth model.

Output production is implemented as a series of nested constant-elasticity-of-substitution functions to capture the different substitutability across all inputs. International trade is modeled using the so-called Armington specification, which posits that demands for goods are differentiated by region of origin. This specification uses a full set of bilateral flows and prices by traded commodity. In contrast to intermediate inputs, primary factors for production are not mobile across countries. Model closures assume real government expenditure and current account to be constant to baseline values. While the capital market is characterized by real rigidities, the labor market is not.

One major characteristic of the model is that it features vintage capital stocks in such a way that the representative firm's production structure and behavior are different in the short and long term. In each year, new investment is flexible and can be allocated across activities until the return to the "new" capital is equalized across sectors; the "old" (existing) capital stock, on the contrary, is mostly fixed and cannot be reallocated across sectors without costs. Therefore, short-term elasticities of substitution across inputs in production processes (or substitution possibilities) are much lower than in the long term and make adjustments of capital more realistic. In contrast, labor (and land) market frictions are limited: in each year, labor (land) can shift across sectors with no adjustment cost until wages (land prices) equalize, and the labor (land) supply responds with some elasticity to changes in the net-of-taxes wage rate (land price).

The model also links economic activity to environmental outcomes. Emissions of GHGs and other air pollutants are linked to economic activities either with fixed coefficients, such as those for emissions from fuel combustion, or with emission intensities that decrease (nonlinearly) with carbon prices—marginal abatement cost curves. This latter case applies to emissions associated with non-energy-input uses (for example, nitrous oxide emissions resulting from fertilizer uses) or with output processes (like methane emissions from waste management or carbon dioxide emissions from cement manufacturing). In the very long term, the model may overestimate the cost of decarbonization, since it does not consider radical technology innovations that could materialize at this longer horizon (for example, hydrogen, second generation of nuclear, biofuel, and carbon capture and storage technologies). While some of these new technologies are at an experimental stage, it is difficult to include them in the model at the moment because of a lack of information about their future costs if they were deployed at industrial scale.

Annex Table 1.1. Key Model Parameters Calibration

Parameter	Values
Substitution between process emissions bundle and net-of-emissions output	Specific values per gas and sector; positive values for GHG emissions; zero for air pollutants
Substitution between intermediate demand and value-added bundles	• 0.2 for agricultural sectors • [0.4; 1.0] for manufacturing and services sectors • [0.1; 0.81] for energy sectors • Always 0 for old vintage technologies
Substitution between intermediate goods and services	• 0 for agricultural sectors • [0.1; 0.4] for manufacturing and services sectors • 0.2 for energy sectors
Substitution between capital and specific factor	• 0.2 for new and 0 for old vintage technologies
Elasticity between electricity and non-electricity energy bundle	• 0.125 for old vintages, 1 for new vintages in all nonenergy sectors • 0.025 for old vintages, 0.22 for new vintages in non-electric energy • 0.05 for all vintages in electricity
Elasticity between coal and non-coal bundle	• 0.0625 for old vintages • 0.55 for new vintages
Elasticity between energy inputs in liquids bundle	• 0.125 for old vintages • 1.1 for new vintages
Armington trade elasticity, domestic versus imports	Varies from 0.9 to 5 depending on the sector, identical across regions. GTAP data are used
Armington trade elasticity, import origins	Value equals from 0.9 to 10, generally twice higher than Armington trade elasticity for domestic versus imports

Source: IMF-ENV model.
Note: The elasticities are based on the assumptions in the IMF-ENV model. GHG = greenhouse gas; GTAP = Global Trade Analysis Project.

The model can be used for scenario analysis and quantitative policy assessments. For scenario analysis, the model projects an internally consistent set of trends for all economic, sectoral, trade-related, and environmental variables up to the year 2050. In this context, the model can be used to analyze the economic impacts of various drivers of structural changes like technological progress, increases in living standards, and changes in preferences and in production modes. A second use for the model is quantitative economic and environmental policy assessment for the coming decades, including scenarios of a transition to a low-carbon economy. In this case, the model assesses the costs and benefits of different sets of policy instruments for reaching given targets like GHG emission reductions. Annex Table 1.1 reports key parameters for the calibration.

Model Regions

There are two major approaches for dividing Africa into regions: one from the African Union[44] and the other from the United Nations.[45] While both approaches share the region names (Northern, Western, Central, Eastern, and Southern) and there is considerable overlap, there are a few differences. Angola, Burundi, Mauritania, Mozambique, Sudan, Zambia, and Zimbabwe are in different regions. In this note, we follow the UN geoscheme for Africa, because it is also used by GTAP, which is the main data source for country data in the IMF-ENV model. Annex Table 1.2 shows which model region and UN geoscheme region each country belongs to. For consistency, these country groupings are used also in other sections of the note.

[44] See https://au.int/en/member_states/countryprofiles2.
[45] See https://unstats.un.org/unsd/methodology/m49/.

Annex Table 1.2. Definition of Model Regions in Sub-Saharan Africa

Country	UN Geoscheme Region	Model Region
Nigeria	Western Africa	NGA
Benin	Western Africa	WAF
Burkina Faso	Western Africa	WAF
Côte d'Ivoire	Western Africa	WAF
Ghana	Western Africa	WAF
Guinea	Western Africa	WAF
Mali	Western Africa	WAF
Niger	Western Africa	WAF
Senegal	Western Africa	WAF
Togo	Western Africa	WAF
Cabo Verde	Western Africa	WAF
Gambia	Western Africa	WAF
Guinea-Bissau	Western Africa	WAF
Liberia	Western Africa	WAF
Mauritania	Western Africa	WAF
Sierra Leone	Western Africa	WAF
Democratic Republic of the Congo	Middle Africa	DRC
Angola	Middle Africa	MAF
Cameroon	Middle Africa	MAF
Central African Republic	Middle Africa	MAF
Chad	Middle Africa	MAF
Congo	Middle Africa	MAF
Equatorial Guinea	Middle Africa	MAF
Gabon	Middle Africa	MAF
Sao Tome and Principe	Middle Africa	MAF
Ethiopia	Eastern Africa	ETH
Kenya	Eastern Africa	KEN
Madagascar	Eastern Africa	EAF
Rwanda	Eastern Africa	EAF
Tanzania, United Republic of	Eastern Africa	EAF
Uganda	Eastern Africa	EAF
Burundi	Eastern Africa	EAF
Djibouti	Eastern Africa	EAF
Eritrea	Eastern Africa	EAF
Seychelles	Eastern Africa	EAF
Somalia	Eastern Africa	EAF
South Sudan	Eastern Africa	EAF
Comoros	Eastern Africa	EAF
Malawi	Eastern Africa	EAF
Mauritius	Eastern Africa	EAF
Mozambique	Eastern Africa	EAF
Zambia	Eastern Africa	EAF
Zimbabwe	Eastern Africa	EAF
South Africa	Southern Africa	ZAF
Botswana	Southern Africa	SAF
Eswatini	Southern Africa	SAF
Namibia	Southern Africa	SAF
Lesotho	Southern Africa	SAF

Source: IMF staff.
Note: Beyond sub-Saharan Africa, the G20 economies are represented individually while the rest of the world is aggregated into four model regions (Other Eurasia, Other Latin America, Other East Asia and New Zealand, Other Organization of the Petroleum Exporting Countries and Middle Eastern and North African countries).

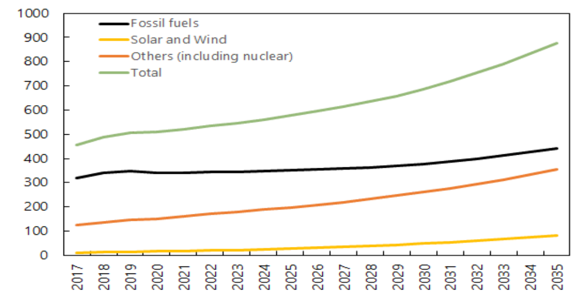
Scenario Assumptions

Baseline: Carbon prices included in the baseline (based on the effective carbon rates database of the Organisation for Economic Co-operation and Development and the South African government's tax proposal) are:

- Kenya: Fuel excise taxes resulted in an effective carbon price of $18.72/tCO2e in 2021 and this rate is held constant in the baseline.[46]
- South Africa: Carbon price starts in 2021 and is set to increase to $30/tCO2 by 2030 (Qu et al. 2023).[47]

For other sub-Saharan African countries and regions, emissions follow projections from the Climate Policy Assessment Tool CPAT until 2030 and are then driven by model dynamics until 2035. Macroeconomic trends between 2024 and 2029 are based on the IMF's World Economic Outlook 2024 database. The post-2029 GDP growth projections are based on shared socioeconomic pathways (SSP) database, which provides narrative pathways for future population and GDP. We use the SSP2 scenario, which is characterized as a scenario with intermediate challenges. Population growth is also taken from the SSP2. Electricity mix between 2017 and 2021 is calibrated using data from the IRENA (see Annex Figure 1.3), while GHG emissions are calibrated using data from the United Nation Framework Convention on Climate Change.

Annex Figure 1.3: Power generation for SSA in the IMF-ENV baseline scenario (in TWh)



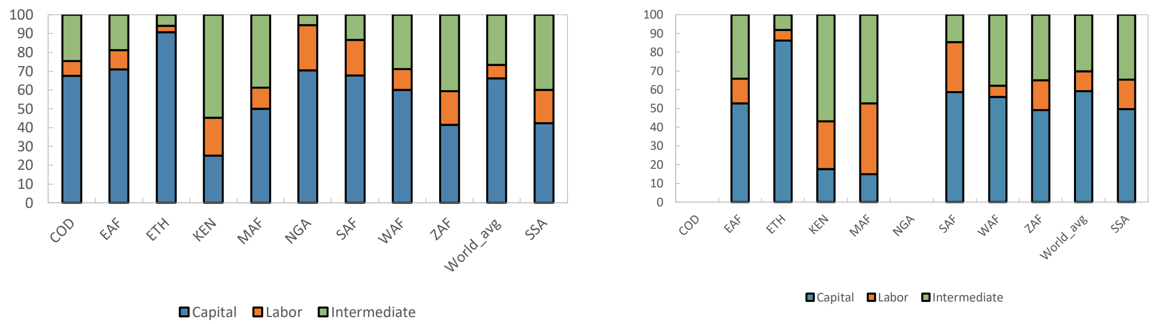
Scaling up renewable energy capacity requires significant investments because of its capital-intensive nature (Annex Figure 1.4). On a global scale, in 2017, capital expenses accounted for an average of 60 percent to 65 percent of the overall input costs for solar PV and wind technologies (from Global Trade Analysis Project (GTAP) Power V11 database, see Aguiar and others (2023)). The composition of intermediate costs largely includes electricity, services, and metal and mineral inputs, leading to regional variations in their cost share, influenced by the availability and pricing of each of these inputs. In many sub-Saharan African countries and regions, capital inputs represent over half of the total input costs for both solar PV and wind technologies, with some variability in cost structures. For instance, in Ethiopia's solar PV sector, capital costs are the predominant expense, whereas in Kenya intermediate inputs, primarily business services, and manufacturing make up more than half of the total costs. In South Africa, the costs of capital and intermediate inputs (mostly services) each contribute around 40 percent to the total. In the wind sector, intermediate costs are especially significant in Kenya and the Middle Africa region, with the largest cost share attributed to the business services sector.

[46] Excise tax rates for specific commodities including energy commodities were introduced in Kenya through the Excise Duty Act of 2015 and are periodically revised. This effective tax rate assumption is based on the OECD effective carbon rates database for the year 2021 and is one element of the baseline scenario but should not be interpreted as a policy recommendation.

[47] Revenues collected in FY2021/22 showed that policy enforcement was low because of tax-free allowances and exemptions (see Qu 2023). The baseline assumes that, by 2030, policy enforcement would be improved; therefore, the effective tax rate would be the same as the official tax rate.

Annex Figure 1.4. Cost Shares for Generation of Solar PV and Wind Sector (Percent)

1. Solar PV Power **2. Wind Power**



Sources: IMF staff calculations using IMF-ENV and GTAP Power data V11.
Note: Intermediates include inputs like machinery and equipment, services, metals, electricity, and fossil fuels (for fossil power technologies). See Chepeliev (2023) for details on the cost share estimation techniques used in the GTAP Power database. Refer to Annex Table 1.2. for the regional abbreviations. Data labels in the figure use International Organization for Standardization (ISO) country codes. GTAP = Global Trade Analysis Project; PV = photovoltaic.

Green Investments: New sectoral investments in solar and wind sectors are targeted and annually increase by a total of half percent (denoted by μ) of the region's GDP, in addition to the baseline investments in the sector. If a region has only one of the two sectors, then the entire half percent of GDP investment is allocated to the sector, otherwise it is split equally between the two sectors. Thus, the shock in investments across sub-Saharan African economies is comparable. $kv_{\text{policy}}^{\text{new}}(r,a,t) = kv_{\text{Bau}}^{\text{new}}(r,a,t) + \mu * gdp(r,t)$

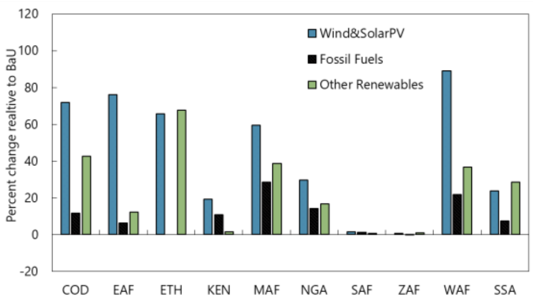
All investments are assumed to be publicly financed (*rsg*). The key difference between the three simulations lies in the shares of domestic financing (rsg_{Bau}) and external financing (ext_inv) that is used to reach the targeted increase in investments, captured by parameter θ. External financing represents any type of investment flow that do not draw down from the domestic investment pool. The value of θ is set to 0 in *domestic* policy, 0.5 in *mix* policy, and 1 in *external* policy simulations, respectively. $rsg_{\text{policy}}(r,t) = rsg_{\text{Bau}}(r,t) + \theta * \text{ext\_inv}(r,t)$

Climate Finance: The Rajan rule is implemented as described in the proposal where transfer denotes the amount of contributions provided (negative value of transfers) or collected (positive value of transfers) by country r, GCI denotes the global carbon incentive, population is denoted by pop, and per capita emissions by emi_pc. GCI is calculated by dividing the targeted global climate finance goal, in this case 100 billion, by the transfers that would be realized in the reference scenario.

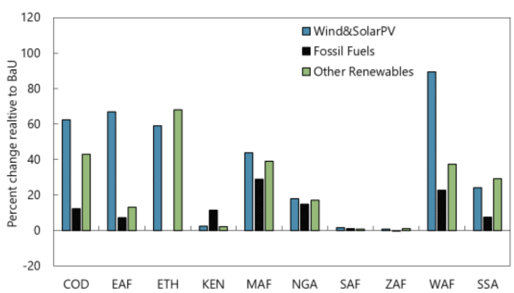
$$\text{Transfer}(r) = GCI * pop_{\text{domestic}}(r) * \left[emi_{pc(r)\text{baseline}}^{\text{global}} - emi_{pc(r)\text{baseline}}^{\text{domestic}} \right]$$

Additional results from IMF-ENV

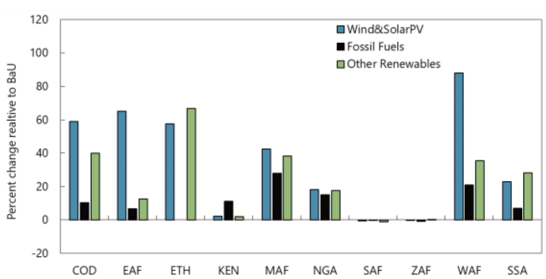
Annex Figure 1.5. Change in Total Electricity Supply in Sub-Saharan African Regions with Policies (Percent Change Relative to baseline)



2. T&D: Electricity Supply (2035)



3. Energy Efficiency: Electricity Supply (2035)



Source: IMF staff calculations using IMF-ENV model

Note: Refer to Annex Table 1.2. for the regional abbreviations. Data labels in the figure use International Organization for Standardization (ISO) country codes. T&D = transmission and distribution.

This sub-section presents the impact on electricity supply for all three investment scenarios using climate finance – *Solar and Wind, T&D* and *Energy Efficiency* (Annex Figure 1.5).

Scaling up renewables could lower electricity prices in many sub-Saharan African economies. Renewable generation is a capital-intensive activity in most sub-Saharan African economies (Annex Figure 1.4). Climate finance helps channel capital in the sector, which reduces its cost, but the scaling-up of production also causes an increase in the demand for labor and intermediate inputs, affecting their prices. Higher labor demand in the recipient countries increases wages. In addition, there is a mixed impact on prices of intermediate inputs, with prices in construction and services rising but those of energy-intensive inputs falling. The combination of these price movements ultimately determines the net effect on the change in electricity prices. Altogether, these would decline in DR Congo (13 percent), Ethiopia (20 percent), South Africa (4 percent), Western Africa (1 percent), Middle Africa (7 percent), and Southern Africa (5 percent),[48] while they would increase in other regions (with a range between 5 and 10 percent).

[48] Price declines may not occur in countries where electricity prices are artificially kept below production prices.

Annex 2. Technical Details of Empirical Analysis

Country Coverage

Annex Table 2.1 reports the country coverage featured in the empirical analysis.

Annex Table 2.1. Sub-Saharan Country Coverage

Country	Income Group	Country	Income Group
Angola	EM	Liberia	LIC
Benin	LIC	Madagascar	LIC
Botswana	EM	Malawi	LIC
Burkina Faso	LIC	Mali	LIC
Burundi	LIC	Mauritius	EM
Cabo Verde	EM	Mozambique	LIC
Cameroon	LIC	Namibia	EM
Chad	LIC	Niger	LIC
Congo, Democratic Republic of the	LIC	Nigeria	LIC
Congo, Republic of	LIC	Rwanda	LIC
Côte d'Ivoire	LIC	Senegal	LIC
Eswatini	EM	Seychelles	EM
Ethiopia	LIC	Sierra Leone	LIC
Gabon	EM	South Africa	EM
Gambia, The	LIC	Tanzania	LIC
Ghana	LIC	Togo	LIC
Guinea	LIC	Uganda	LIC
Guinea-Bissau	LIC	Zambia	LIC
Kenya	LIC	Zimbabwe	LIC
Lesotho	LIC		

Source: IMF staff.
Note: EM = emerging market; LIC = low-income country.

Market Reforms and Climate Policies Data

Governance

Consistent with the literature (IMF 2019; Budina and others 2023), the governance index employed in this SCN is computed as the simple average of the six components of the widely used Worldwide Governance Indicators:

- Voice and accountability: This aims at measuring the citizens' perception of government transparency in each country (that is, elections, freedom of speech).
- Political stability and absence of violence/terrorism: This measures the likelihood of politically induced violence.
- Government effectiveness: This measures the quality of public services and policy formulation and implementation, as well as the degree of independence from political pressures.
- Regulatory quality: This captures the ability of governments to formulate and implement regulations that can promote private sector development.
- Rule of law: This captures the extent to which market participants feel confidence in the protection of property rights, the quality of contract enforcements, and the police force.
- Control of corruption: This aims at capturing perceptions of the level of corruption in a given country.

These indicators were drawn from the Worldwide Governance Indicators database, which reports aggregate and individual governance indicators for more than 200 countries over the period 1996–2022. These indicators summarize the views of various counterparts, from citizens to enterprises and expert survey respondents. The Worldwide Governance Indicators are based on a variety of individual sources, including survey institutes, think tanks, nongovernmental organizations, international organizations, and private sector firms.

External Sector

External sector reforms—a composite indicator capturing the degree of economic freedom in trade and external finance—describe the extent to which countries can freely exchange goods and services, as well as ideas. Excluding indicators derived from the discontinued World Bank Doing Business Database, the external sector index is computed as the simple average of four sub-indicators: (1) tariffs, which aim to measure to what extent tariffs can be a barrier to trade freely internationally (tariff revenues, tariff rate and volatility of tariffs); (2) nontariff trade barriers; (3) black-market exchange rate, which aims at capturing the disparity between the official and the parallel (black-market) exchange rates; and (4) control of the movement of capital and people, which encompasses a country's degree of financial openness, restrictions to visitors, and whether capital controls are in place.

Business Regulation

This indicator measures the extent to which regulations and bureaucratic processes in each country might hamper private sector activity by restricting entry and decreasing competition. Excluding indicators derived from the discontinued World Bank Doing Business Database, the business regulation index is the simple average of three main components: (1) bureaucracy costs, which measure the risk of normal business operations becoming more costly because of the regulatory environment; (2) administrative requirements, which measure the extent to which reporting, or the issuance of permits and licenses, can be burdensome; and (3) impartial public administration, which accounts for the degree of nepotism and discrimination in public administration. Apart from the governance index, the rest of the structural indicators summarized in the previous section (that is, external sector and business regulation) were sourced from the Fraser Institute's Economic Freedom of the World Database, which gathers data from third-party sources, including the International Country Risk Guide and the Global Competitiveness Report. The aggregate indicators are normalized over a sample of 161 economies, ranging between 0 and 1.

Climate Policies

Climate policy counts, from the Climate Policy Database, include policies with an explicit climate change mitigation objective, such as GHG emissions reduction strategies; energy policies that help to decarbonize the energy supply and/or reduce energy demand; and policies that aim to introduce low-emissions practices and technologies to nonenergy sectors, such as agriculture and land use. A policy can be a law, a strategic document, a target, or any other policy document that results in a lasting reduction of the country's emissions intensity (see Nascimento and others 2022). The main advantage of this measure, which has been used widely in scientific publications, is its comprehensive coverage of policy actions, both from an instrument and sectoral perspective. This is particularly important in a context where countries have resorted to sectoral policies and regulations and subsidies instead of economy-wide carbon pricing. One drawback of this measure is that it does not capture the intensity of each policy. For example, an economy-wide carbon price has the same weight as a regulation in a specific sector. In addition, the raw policy count does not account for the enforcement of these policy instruments.

Baseline Empirical Framework

Regression Specification

The analysis employs the local projection method proposed by Jordà (2005) to estimate the effects of structural reforms on climate finance and electricity generation in a sample of 39 sub-Saharan African economies over the period 2000–21. This same method has been used extensively in the literature to estimate the impact of macro structural reforms on various macroeconomic outcomes (see Duval, Furceri, and Jalles 2022; Romer and Romer 2017, among many others). The use of the local projection approach is motivated by its strong empirical properties, which include the generation of accurate impulse responses (Auerbach and Gorodnichenko 2012; 2013) without requiring economic priors or dynamic restrictions (Plagborg-Møller and Wolf 2021), as well as by the flexibility to estimate nonlinear effects.

Specifically, our baseline panel LP model takes the following form:

$$y_{i,t+k} - y_{i,t-1} = \alpha_i + \gamma_t + \beta_k SR_{i,t} + \boldsymbol{\theta X'}_{i,t} + \epsilon_{i,t} \ , \qquad (1)$$

where $y_{i,t}$ is the log of the variable of interest (for example, climate finance through grants and concessional debt), and α_i and γ_t denote country and year fixed effects, which help control for unobservable cross-country heterogeneities as well as common global factors (for example, oil prices, global business cycle), respectively. β_k is our coefficient of interest and captures the (cumulative) impact on $y_{i,t}$ following the introduction of a given structural reform, $SR_{i,t}$. $\boldsymbol{X}_{i,t}$ is a vector of control variables, including lags of the dependent variable, past economic growth, and past reforms. Two lags of the dependent variable and the shock series are included in each estimation to control for autocorrelation, following Montiel, Olea and Plagborg-Møller (2021).Time and country dimensions are indicated by t and i, respectively, while $k = 0,1,2, \ldots 4$. Equation (1) is estimated using ordinary least squares and impulse responses for the estimated coefficients of interest, β_k, are generated using the associated Driscoll and Kraay (1998) robust standard errors.

When estimating the impact of reforms on electricity generation, especially renewables, it is important to account for the high growth of renewable power generation trend present in the data (Figure 1, Panel 2). This trend can be heterogenous across countries as these differ in technology adoption. To this end, equation (1) is modified slightly to include country-specific linear trends, $\gamma_i t$, in addition to country fixed effects. The modified equation is as follows:

$$y_{i,t+k} - y_{i,t-1} = \alpha_i + \gamma_i t + \beta_k SR_{i,t} + \boldsymbol{\theta X'}_{i,t} + \epsilon_{i,t} \ , \qquad (2)$$

The empirical section not only focuses on the impact of reforms in attracting official climate finance through grants and concessional debt but also devotes attention to the role of private sector FDIs. We use data on announced green-field FDIs, sourced from fDi Markets covering a sample of 115 EMDEs from 2003 to 2021, which are categorize as “green” or “non-green” following the methodology of recent IMF analyses (Hasna and others 2023; Pienknagura 2024). Because greenfield investments are recorded as announcements, and many countries do not receive private FDIs on a consistent basis, the data set has a large prevalence of zeros, leading us to consider alternative econometric approaches to estimate the impact of reforms on private sector FDIs. Following the methodology of these recent contributions, the relationship between market reforms and FDIs using the pseudo-Poisson maximum likelihood estimator is estimated, and the equation is as follows:

$$Y_{i,t}^{h} = exp\{\alpha_i + \gamma_t + \beta log(CP_{i,t-1}) + \boldsymbol{\theta X}_{i,t-1}\} + \epsilon_{i,t}, \qquad (3)$$

where $h \in \{total, \ non-green, \ green, \ renewable\ energy, \ wind\ and\ solar\}$, $Y_{i,t}^{h}$ is the real dollar value of greenfield FDI inflows of type h in country i in year t, α_i is a country fixed effect, γ_t is a year fixed effect, $log\ (CP_{i,t-1})$ is the natural logarithm of the stock of climate policies in year t-1, $\boldsymbol{X}_{i,t-1}$ is a set of covariates including trade over GDP, the log of the capital stock per employee, the log of GDP per capita and GDP growth.

Robustness checks – Excluding South Africa from the sample

This section presents the main findings relating to the impact of market reforms and climate policies on climate finance and power generation for a sample of sub-Saharan African economies, excluding South Africa. Annex Figures 2.1 to 2.3 show that the findings displayed in the main text hold even when South Africa is excluded from the sample.

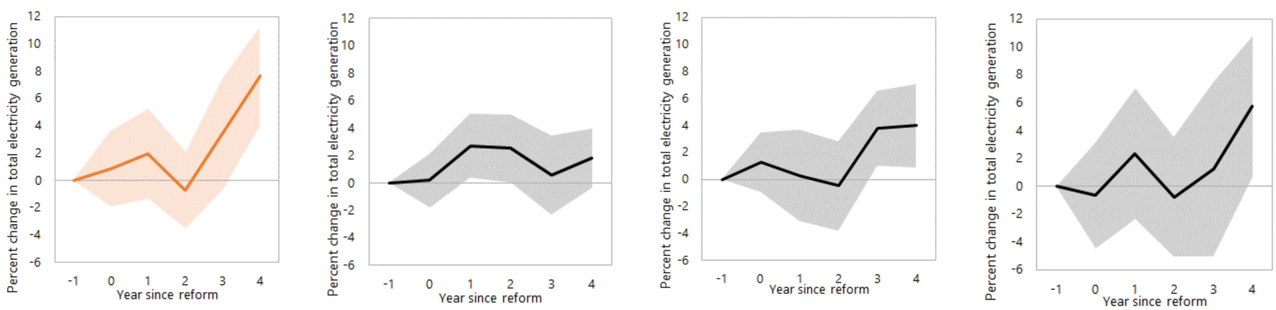
Annex Figure 2.1. Robustness Check: Impact of Market Reforms on Climate Finance Excluding South Africa

1. First-Generation Reform | 2. Governance | 3. External Sector | 4. Business Regulation

Source: IMF staff calculations.
Note: *t* = 0 is the year of the shock. The lines denote the response to a major historical reform (two standard deviations). The shaded areas denote 90 percent confidence bands. Sample of 39 sub-Saharan African countries, 2000–21. The sample average climate financing received through concessional grants and debt is equal to roughly $150 million per year ($ in 2021). A major first-generation reform is associated with a 17.5 percent increase in climate finance, or equivalent to a $130 million increase over five years, on average, compared to a no-reform scenario.

Annex Figure 2.2. Robustness Check: Impact of Market Reforms on Total Electricity Generation Excluding South Africa

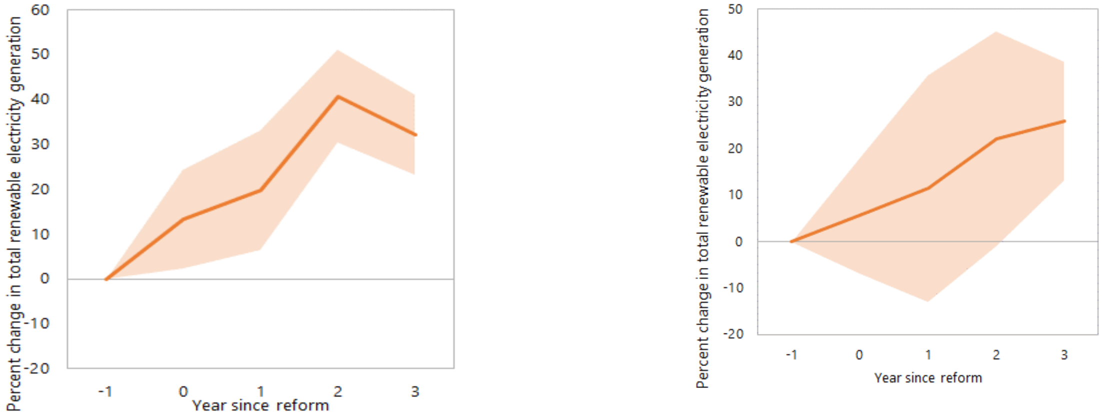
1. First-Generation Reform | 2. Governance | 3. External Sector | 4. Business Regulation



Source: IMF staff calculations.
Note: *t* = 0 is the year of the shock. The lines denote the response to a major historical reform (two standard deviations). The shaded areas denote 90 percent confidence bands. Sample of 38 sub-Saharan African countries, 2000–21. The sample average electricity generation is equal to roughly 9,567 GWh per year. A major first-generation reform is associated with a 7.6 percent increase in total electricity generation, or equivalent to an additional 3,635 GWh over five years, on average, compared to a no-reform scenario.

Annex Figure 2.3. Robustness Check: Impact of Market Reforms and Climate Policies on Renewable Electricity Generation Excluding South Africa

1. First-Generation Reforms | **2. Climate Policies**

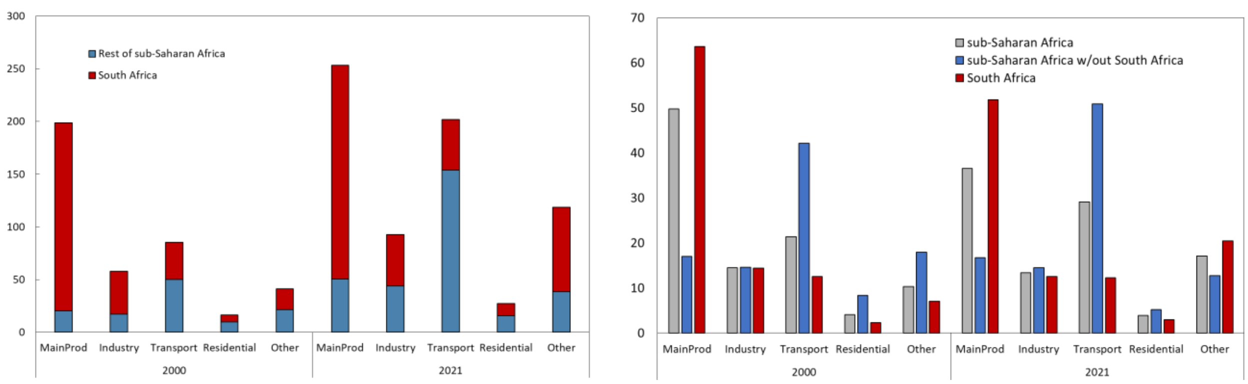


Source: IMF staff calculations.
Note: *t* = 0 is the year of the shock. The lines denote the response to a major historical reform (two standard deviations). The shaded areas denote 90 percent confidence bands. Sample of 38 sub-Saharan African countries, 2010–21. Renewable electricity is defined as solar and wind generation. The sample average renewable electricity generation is equal to roughly 132 GWh per year. A major first-generation reform is associated with a 32 percent increase in renewable electricity generation, or equivalent to an additional 170 GWh over four years, on average, compared to a no-reform scenario. Similarly, significant climate action can boost renewable electricity generation by 26 percent, or equivalent to 137 GWh over four years, on average, compared to a no-reform scenario.

Annex 3. CO_2 Emissions in SSA

Annex Figure 3.1. CO_2 Emissions in SSA by Sector

1. Total CO_2 Emissions by Sector (Mt CO_2) | **2. CO_2 Emissions Shares by Sector (Percent)**



Source: IEA.

Note: MainProd = main activities producer electricity and heat; Other = agriculture/forestry, fishing, commercial, and public services, other energy industry use and other CO_2 emissions from fuel combustion not elsewhere specified. SSA= sub-Saharan Africa.

As illustrated in Annex Figure 3.1, South Africa contributes to the majority of CO_2 emissions of the sub-Saharan African region (roughly 56 percent in 2021), largely coming from main activities related to the production of electricity and heat. CO_2 emissions from the rest of the region are more concentrated in the transport sector (roughly 50 percent), with total CO_2 emissions increasing threefold since 2000.

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