POTENTIAL LABOR MARKET IMPACTS OF THE CLEAN ENERGY TRANSITION

A CGE Analysis for Nine Countries in Sub-Saharan Africa

WORKING PAPER

ESMAP
Energy Sector Management Assistance Program

THE WORLD BANK
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ABOUT ESMAP

The Energy Sector Management Assistance Program (ESMAP) is a partnership between the World Bank and over 20 partners to help low- and middle-income countries reduce poverty and boost growth through sustainable energy solutions. ESMAP's analytical and advisory services are fully integrated within the World Bank's country financing and policy dialogue in the energy sector. Through the World Bank, ESMAP works to accelerate the energy transition required to achieve Sustainable Development Goal 7 (SDG7), which ensures access to affordable, reliable, sustainable, and modern energy for all. It helps shape World Bank strategies and programs to achieve the World Bank's Climate Change Action Plan targets. Learn more at: https://www.esmap.org.

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The report was prepared by Hugo Rojas-Romagosa (International Monetary Fund), Zuzana Dobrotková (Senior Energy Specialist), Claire Nicolas (Senior Energy Economist) and Sheoli Pargal (Lead Energy Economist). The work was initiated under the guidance of Rohit Khanna (Practice Manager, ESMAP) and completed under Gabriela Elizondo Azuela (Practice Manager, ESMAP), with overall strategic direction provided by Demetrios Papathanasiou (Global Director, Energy and Extractives Global Practice).

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About this Report

This working paper modeling of economywide job impacts of policies supporting the clean energy transition in selected countries in Sub-Saharan Africa was undertaken under a program of analytical work that investigates the impacts of the global transition to clean energy on the quantity and quality of jobs in low- and middle-income countries. Under the program, entitled "Estimating the Job Creation Potential of the Clean Energy Transition," the World Bank's Energy Sector Management Assistance Program (ESMAP) undertook multiple streams of analysis:

- A review of the literature and commonly used methodologies of investigation
- Case studies of the effects on employment of selected World Bank clean energy projects
- Deep dives into the impact on jobs of closure of coal-fired power plants; of productive uses of electricity associated with mini grids in Nigeria; and of the Rusumo Falls Hydropower Project.

Building on the above-mentioned steams of analysis, the program has also produced a high-level report summarizing its findings and conclusions "Jobs for a Livable Planet: Job Creation Potential of the Clean Energy Transition" and a discussion paper to support project design "Tracking Jobs in Projects Focused on Clean Energy and Productive Uses of Electricity", providing strategies for tracking and enhancing job creation that can be used in the clean energy projects.

The reports developed under this program together aim to support low- and middle-income countries in reaping greater socioeconomic benefits from the energy transition by supporting them in increasing the number and quality of local jobs generated while implementing clean energy projects. Realizing the benefits of the jobs created by clean energy interventions will depend on effective planning and preparation in the early stages of projects and sustained support during their implementation.

The reports target multiple audiences, from policy makers to development practitioners and academics. They also aim to familiarize energy specialists with the effects of energy projects on jobs and give them tools that enable them to take account of—and, where possible, maximize—the socioeconomic benefits of the clean energy transition.

The reports can be found at https://www.esmap.org/publications.

Abbreviations

CAPEX	capital expenditure
CGE	computable general equilibrium
EPM	Electricity Planning Model
ESMAP	Energy Sector Management Assistance Program
GDP	gross domestic product
GERD	Grand Ethiopian Renaissance Dam
GTAP	Global Trade Analysis Project
GWh	gigawatt hours
OECD	Organisation for Economic Co-operation and Development
T&D	transmission and distribution
TFP	total factor productivity

All currency is in United States dollars (US$, USD), unless otherwise indicated.

Executive Summary

This report presents the findings of an investigation into how the energy transition can support economic activity and contribute to the generation of jobs while advancing the global decarbonization agenda. It is part of a larger effort by the World Bank's Energy Sector Management Assistance Program (ESMAP) to understand the potential employment impacts of the energy transition.[1]

The energy transition—the transition away from fossil fuels that encompasses adoption of new technologies and models of service delivery in the sector—covers investment in renewable energy; grid strengthening to absorb variable renewable power; decentralized power generation; digitization of the energy sector; and a quantum improvement in energy efficiency in buildings, industry, and transport. Many of these investments have significant potential to create local employment and boost economic activity and job creation in the broader economy. In access-deficit countries, increased use of newly provided power for productive purposes is expected to be an important channel for these outcomes.

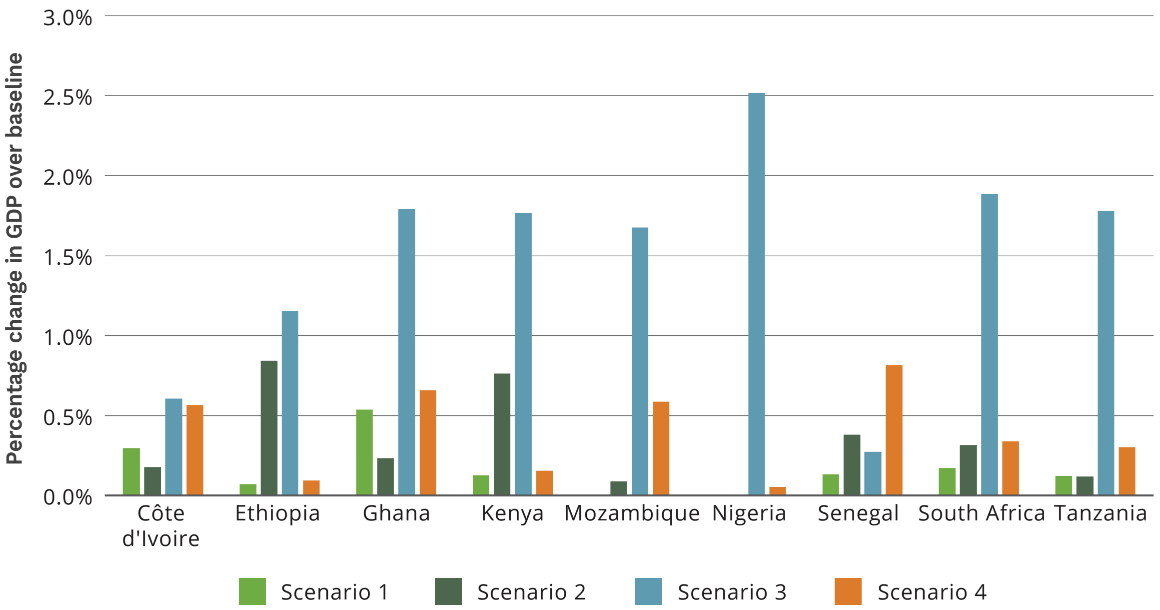
The analysis relies on computable general equilibrium (CGE) modelling of four policy scenarios that support the energy transition in the electricity sector: increases in renewable generation, deeper regional electricity trade integration, increased power reliability, and investments in energy efficiency. For each scenario, the report indicates the labor market and broader macroeconomic effects of the policies. The CGE analysis uses a global model and focuses on nine sub-Saharan African countries that World Bank teams identified as being of particular interest.

The analysis indicates that all four policy scenarios have positive effects on real GDP compared with the baseline (or business as usual) scenario. All of them increase the demand for labor and raise real wages for both unskilled and skilled workers.

The magnitude of the macroeconomic impacts differs across scenarios (figure ES.1). For all countries analyzed except Senegal, increasing power reliability through additional investments in transmission and distribution (T&D) (Scenario 3) has the largest effect on GDP. It is strongest in Nigeria where the current state of T&D network prevents efficient and effective delivery of electricity service. In Senegal, increased energy efficiency (Scenario 4) has the largest impact on GDP of the four scenarios. Changes under both scenarios boost production in the economy and stimulate aggregate demand, drawing forth additional increases in power generation, driving GDP increase. Although the other scenarios have lower impacts on GDP, they are substantial in some countries. Higher regional electricity trade (Scenario 2) generates relatively large economic gains in Ethiopia and Kenya, for example, and increasing renewable electricity generation (Scenario 1) has a significant impact on GDP in Ghana. In Scenarios 1 and 2, the GDP impacts are associated directly with the increase in total electricity generation and associated general equilibrium effects following introduction of the policy changes.

FIGURE ES.1

Real GDP Impacts of Four Policy Scenarios that Support the Energy Transition in the Electricity Sector (2030)



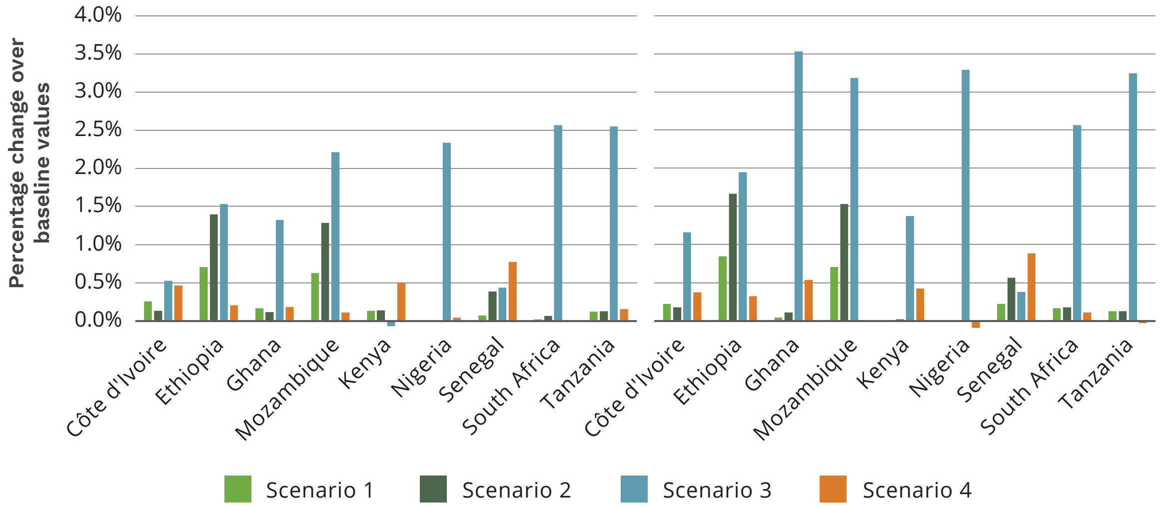
Wage gains are correlated with GDP effects (figure ES.2). Scenario 3 has the greatest potential to generate better jobs in the region, for both unskilled and skilled workers; it also has the greatest potential to generate economy-wide output gains. Scenario 4, which involves relatively low investment, yields moderate economic gains.

The analysis presented brings an understanding of the highest "returns" on investments by individual scenarios, through comparison of the required investment against the GDP gains. Analysis shows that scenarios with modest additional investment can bring relatively large economic gains and should therefore be considered a low-hanging fruit for policymakers.

It is important to highlight that the results were obtained for countries in a particular context of sub-Saharan Africa, where reliability of power supply is significantly worse than in more developed regions and where energy efficiency can liberate power for alternative uses in situations, given that quantity and quality of power is often a binding constraint in these economies. Results of similar scenarios in other regions could therefore potentially lead to different results.

FIGURE ES.2

Real Wage Effects for Unskilled (Left) and Skilled (Right) Workers of Four Policy Scenarios that Support the Energy Transition in the Electricity Sector (2030)



Endnote

1. ESMAP is a global partnership between the World Bank and development partners and philanthropic foundations to help low- and middle-income countries increase their know-how and institutional capacity to achieve environmentally sustainable energy solutions for poverty reduction and economic growth (www.esmap.org).

ONE

INTRODUCTION

This report presents a first attempt to systematically investigate how the energy transition can support economic activity and contribute to the creation of jobs while advancing the global decarbonization agenda. It is part of a larger effort by the World Bank's Energy Sector Management Assistance Program (ESMAP) to understand the potential employment impacts of the energy transition.

The energy transition—the transition away from fossil fuels through the adoption of new technologies and models of service delivery in the sector—covers investment in renewable energy; grid strengthening to absorb variable renewable power; decentralized generation; digitization of the energy sector; and a quantum improvement in energy efficiency in buildings, industry, and transport. Many of these investments have significant potential to create local employment and boost economic activity and job creation in the broader economy.[1] In access-deficit countries, increased use of newly provided power for productive purposes is expected to be a key channel for these outcomes. The benefits of expanded and improved electricity services do not depend on the fuels or technologies used or other aspects associated with the energy transition.

The analysis relies on computable general equilibrium (CGE) modelling of key policies and investments that support the energy transition in the electricity sector. It uses the ENVISAGE CGE model to assess the potential labor market impacts of different elements of a clean energy transition in nine Sub-Saharan African countries, identified by World Bank teams as being of particular interest. Focus on sub-Saharan Africa allows us to study the impact of new power production better than in other regions, since new power production in Africa typically comes as additional power in the system, while in developed countries clean power often simply displaces existing fossil-based power. The model uses data inputs from the Global Trade Analysis Project (GTAP)-Power database, which distinguishes electricity generation by source.[2] The CGE model is linked to ESMAP's Electricity Planning Model (EPM), which provides a detailed break-down of electricity generation by source, projections on how the share of generation from each source changes over time under different scenarios, and the investment costs associated with each scenario. This information was used to create a bottom-up linkage between EPM outputs, which provide detailed technical specifications for electricity production, and the CGE framework, which allows simulation of the macroeconomic effects of different energy policies.

Four scenarios were created to assess how different aspects of the clean energy transition in electricity are likely to affect each country's macroeconomic outcomes and labor markets: increases in renewable generation, the integration of regional electricity trade, improved power reliability, and investments in energy efficiency. For each scenario the report presents the impacts on macroeconomic outcomes and the labor market effects of the policies.[3]

The results of the analysis are promising: All four policy scenarios have positive effects on real GDP compared with the baseline, increasing the demand for labor and raising real wages for both unskilled and skilled workers. As GDP is higher with the same number of workers (compared with the baseline), labor productivity (output per worker) is higher. Jobs are thus both more productive and better paid.

Endnotes

1. Throughout this document, renewable generation refers to solar, wind, hydro, geothermal, and bioenergy.
2. For documentation on the GTAP and GTAP-Power databases, see Aguiar and others (2019) and Chepeliev (2020).
3. An initial suggestion was to also run simulations reducing fossil fuel subsidies and introducing carbon taxation. Several data and methodological limitations prevented the report team from conducting such analysis. Fossil fuel subsidies are not well represented in the GTAP database, and updated data are scarce. The EPM is used to perform economic optimization of the power system and hence does not address taxes and subsidies. It was therefore impossible to obtain the electricity generation projections to be used as inputs for this scenario in the CGE model. The Country Climate Development Reports (CCDR) that are being produced at the World Bank do consider carbon taxes, and some of them use CGE models. The CCDR for Ghana, for example, examines a moderate carbon tax and different carbon tax revenue-recycling options.

TWO
DATA AND MODEL SPECIFICATIONS

The power modules of the ENVISAGE model include information on electricity production by generation source and energy demand of firms is separated into demand for electricity and non-electricity sources of energy.[1] The Global Trade Analysis Project (GTAP)-Power database (version 10.1) includes 2014 generation levels for each power source and a detailed cost structure for power generation by source that includes capital, different labor types (skilled and unskilled), and several intermediate inputs. These numbers were updated and calibrated using 2019 and 2020 data from the Electricity Planning Model (EPM), reflecting actual power sector data of the countries modelled, to create a baseline for 2014–30.[2] The GTAP database includes information on 144 countries/regions and 65 sectors. It was aggregated into 18 countries/regions and 31 sectors. The nine Sub-Saharan countries of interest: Côte d'Ivoire, Ethiopia, Ghana, Kenya, Mozambique, Nigeria, Senegal, Tanzania, and South Africa, are separated out for modelling purposes. Appendix F provides details on the regional and sectoral aggregation.

The GTAP-Power database includes 12 energy sources: nuclear, coal, gas (base and peak load), hydro (base and peak load), wind, oil (base and peak load), solar, and other. The model uses six of them—hydro, coal, oil, gas, wind, solar, and other—as separate electricity generation activities ("other" includes geothermal, biomass, and nuclear).[3] All generation sources produce the same electricity "commodity," which is demanded by firms (as an intermediate input in production) and by final consumers.

Appendix C provides the underlying cost structure for electricity generation from different sources. As it shows, capital costs dominate the cost structure of renewable sources (solar, wind, and hydro). A major share of the cost of power generated from fossil fuel sources is intermediate inputs, mainly the fuel costs associated with each source. No source of electricity generation is labor intensive; increasing power generation is therefore not expected to directly increase labor demand significantly. However, cheaper and more reliable electricity helps the economy grow, an expansion that increases labor demand and wages.

The strength of CGE models lies in their ability to assess the impacts of different policies on labor demand. The models show how policy shocks translate into sectoral demand for specific worker types and thus affect the economy-wide demand for each worker type. Standard CGE models take as exogenous baseline labor supply over time by assuming that labor participation rates, informality rates, and unemployment levels remain constant and that the labor supply changes only as a result of changes in the size of the working-age population. Therefore, when policy shocks are simulated, labor supply levels are unchanged with respect to their baseline level in these models, and the estimated changes in labor demand directly translate into wage changes that clear the labor market.[4]

There are several ways to endogenize labor supply using CGE models.[5] However, in all but one of the countries analyzed in this report (South Africa), unemployment rates are low, and labor force participation rates of both men and women are high relative to international standards, albeit with widespread informality.[6,7] These features of the labor market imply that there are strict limits to increasing labor supply in these countries over time. In view of these labor market conditions, the standard CGE labor supply mechanism was retained. It assumes that the relatively low unemployment rates and high participation rates observed remain constant over time and focuses on how energy policies under each scenario affect labor demand and real wages.[8]

Although changing energy policies and associated changes in labor demand result in the creation and destruction of jobs in different sectors, the tight labor supply constraint implies that on net relatively few new jobs can be created in the economy. The structural changes that the simulated energy policies trigger create new jobs in the expanding energy sectors and other new and better-paid jobs in those economic activities that benefit from cheaper and more reliable energy supply. The direct and indirect (general equilibrium) effects of the energy policies simulated are expected to raise the productivity of workers, which will be reflected in increases in real wages.

A complication is that the investments required for electricity generation can be substantial and take years to come to fruition. The lumpiness of these investments and the delays between when expenditure is made and output increases are not well captured in the CGE framework, where additional investment typically results in an immediate increase in productive capacity and output.

A second complication is that installed capacity directly constrains generation. CGE models typically assume that output can always be expanded via the intensive margin (more inputs for a given capital stock). As a result, these models deal poorly with strict capacity constraints, increasing generation endogenously (perhaps at great cost if supply of inputs is inelastic) if electricity demand rises. The CGE model endogenously increases hydroelectric generation, for example, even if that can be achieved only by building new dams.

To overcome these limitations, this report uses the generation projections from the EPM model as inputs, based on least-cost generation values that account for future investment projects, as explained in the next section. Using EPM values also ensures that the mix of generation sources reflects the power system's technical constraints—namely the resources available in the country and the size and profile of the mix of sources that can cover power demand (the dispatchability, variability, and flexibility of different power sources come into play here) — and not only economic factors.

Calibration Using EPM Outputs

The energy data in the GTAP-Power database, based on 2014 values, were updated to reflect recent changes in the mix of power generation sources in the countries analyzed. The EPM was used to calibrate the baseline data. EPM outputs are used throughout this analysis to calibrate the energy activities in the CGE model.

The following variables are calibrated:

- The initial energy supply and mix of power generation sources are calibrated to EPM values for 2021.[9] Doing so avoided calibrating the strong fluctuations between 2019 and 2021 resulting from the impacts of the Covid-19 pandemic.

- The country-specific mix of power generation sources is calibrated to EPM values from 2021/22 to 2030.
- Bilateral electricity trade is calibrated to EPM values for 2021–30.[10]
- Investment costs related to expansion of different power generation sources between 2021 and 2030 are calibrated.

The resulting baseline draws on both the GTAP database and EPM outputs, where the electricity variables (power supply, generation mix, investments, and electricity trade) are calibrated to be as close as possible to EPM values. The CGE model also includes an additional activity—electricity transmission and distribution (T&D)—which is not part of electricity generation but is necessary to provide electricity to consumers. The EPM does not include this activity explicitly; information from the GTAP-Power database was therefore used to calibrate the values of T&D in the CGE model. The value added of electricity T&D as a share of the value added of total electricity supply was kept fixed at the 2014 GTAP levels for 2021/22. Thereafter, T&D activity levels increase proportionally to the increase in electricity generation.[11] This combination of the EPM, which provides sound, technically detailed, modelling of electricity supply, and the CGE model generates a robust modelling framework of energy activities and their interactions with the rest of the economy.

Information on the investment costs associated with each policy intervention also comes from the EPM. The additional investment associated with each scenario is estimated as the difference between the capital expenditure (CAPEX) values from the scenario and the CAPEX values in the baseline. The CGE model endogenously increases investment in sectors that expand. As renewable generation expands, for example, the model endogenously increases investment in renewable energy sectors. The CGE model thus already captures part of the additional investment needed under scenarios in which specific generation sources expand. The analysis compares the investment endogenously created in the model against the values provided by EPM. In most cases they are very similar; where they diverge, investment was adjusted to match EPM values. These additional investments were then explicitly accounted for and implicitly financed by a reduction in overall savings. The model does not distinguish between public and private investment, however. Financing is assumed to be a combination of public and private reductions in savings and future investments in other sectors—that is, investment in electricity generation is crowding out investment in other economic activities.[12]

Baseline Scenario

In the baseline (business-as-usual), simulation, the rate of growth of real GDP is calibrated to follow long-term growth projections from the OECD.[13] Labor supply growth is projected using growth of the working-age population, which is taken from United Nations (UN) population projections. Labor supply is then fixed at these baseline values, and changes in wages ensure that the labor market clears; workers can move between sectors, but the overall level of employment does not change for any given year. Real incomes change as wages adjust to match the total demand and supply of workers.[14] An increase in labor demand as a result of a shock or policy that increases overall economic activity raises wages; contractions in overall economic activity reduce wages.[15] Workers are divided into two groups, skilled and unskilled. Each group has a different wage rate, reflecting the balance between demand and supply for that kind of labor.

On the energy side, data on the electricity generation mix and the growth of electricity supply come directly from the EPM. For the baseline scenario, the EPM assumes that trade levels remain at their level in 2020 (the initial base year) through 2030, and countries build only already committed transmission lines and renewable plants.[16] Candidate plants for generation expansion over the period are restricted to thermal generators that will be brought online to meet demand growth beyond the levels that are met by committed renewable sources and transmission investments.

Endnotes

1. van den Mensbrugghe (2019) documents the technical specifications of this CGE model.
2. Appendix B provides a short description of the EPM.
3. To simplify the analysis, the CGE model does not distinguish between base and peak load.
4. Assessing labor market impacts using CGE models is complicated, because impacts depend on labor market conditions in each country (initial employment levels, labor participation rates, unemployment, level of informal jobs) and their interaction with labor market institutions (for example, labor taxes, minimum wages, unemployment benefits, the flexibility of labor contracts).
5. For instance, ENVISAGE includes a reduced-form decision process in which individuals choose between additional work (at both the extensive and intensive margin) and leisure. It implies an endogenous labor supply adjustment, which is modeled using a real wage–labor supply curve: As real wages increase, individuals find working more attractive than leisure and increase their labor supply. Lower real wages translate into a reduction in labor supply, as leisure becomes more attractive than work. The elasticity of the wage curve determines the magnitude of these changes.
6. According to World Development Indicators, in South Africa, unemployment rates are very high (around 30 percent), leaving space to increase labor supply. For the other eight countries, the average unemployment rate is around 4 percent. For all nine countries, female labor force participation rates average 61 percent, much higher than the world average of 47 percent and the Organisation for Economic Co-operation and Development (OECD) average of 52 percent.
7. It is important to note that CGE analysis abstracts from realities on the ground in developing countries: low unemployment rates in many sub-Saharan Africa countries stem from limitations to afford unemployment due to the lack of social protection and security. Consequently, individuals often find themselves trapped in informal and insecure jobs, characterized by irregular hours, underemployment, lack of protection,

and unproductive activities. Barriers to accessing formal employment are multifaceted and depend on various factors, including labor market policies, governance, and the rule of law.

8. Increased labor demand and labor productivity could also facilitate the transition from informal to formal jobs. The precise linkage is usually country specific, related to labor market institutions and state capacity. It is therefore not analyzed here.
9. Data from 2022 were used for Ethiopia and Kenya. Appendix D provides additional technical detail on the calibration.
10. Because of strong fluctuations in bilateral trade, the analysis focuses on fitting the EPM 2030 values. The report team tried to keep trade between 2021 to 2030 close to EPM values; for some countries, however, the EPM trade fluctuations are not fully replicated.
11. The CGE uses a Leontief function to model the relation between electricity T&D and the total supply of electricity.
12. The CGE model also allows for other financing options, such as increasing taxes or reducing government expenditure if it is assumed that all investments are publicly financed. Exploring these alternative options without a clear distinction between public and private financing is beyond the scope of this study.
13. Shared Socioeconomic Pathways (SSP) projections on real GDP growth from the SSP2: Middle of the Road scenario were used.
14. The fixed labor supply implies that both unemployment and labor participation rates are fixed in the long term based on their initial values. Therefore, the economy is not assumed to be working at full employment.
15. The model also assumes that workers can move freely between sectors without any short-term adjustment costs—a medium- to long-term perspective on labor market adjustments. The model does not explicitly account for adjustment costs to workers, which are implicitly assumed to be compensated by higher wages in the new job.
16. A plant is considered committed when a final investment decision has been made.

THREE
POLICY SCENARIOS AND MACROECONOMIC RESULTS

This section describes the main assumptions made for each of the four scenarios analyzed and explains how each scenario is simulated in the CGE model. It then presents the macroeconomic and labor market impacts of each scenario.

Scenario 1: Investment in Renewable Energy

Description and Implementation

This scenario takes electricity generation values directly from the EPM renewable scenario, in which trade does not change from the baseline level but (domestic) generation expands to meet the (exogenous) demand for power, which grows in line with the baseline. Generation is renewable or fossil fuel based, whichever is least cost.

The EPM assumes that electricity demand in each country changes over time based on external developments. The baseline scenario covers the years 2021/22–30. In the EPM scenarios, however, projected electricity demand is identical to the baseline projection. Hence, any change in the annual quantity of electricity supplied from a specific fuel source and/or trade must be offset by an equivalent change in the supply of electricity from other fuel sources or in net electricity trade.

The fixed-demand assumption artificially limits the economic gains from more efficient production of renewable energy. If renewable generation is expanding, it is because the cost of producing energy from such sources is falling. Lower energy production costs should be reflected in lower energy prices, which would be expected to increase energy demand. By keeping energy demand constant between the baseline and Scenario 1, the EPM does not consider the broader economic impact of these renewable technology gains.

The CGE modeling takes a more flexible approach. It allows power output from renewable sources to expand and contract per the EPM but fixes other generation sources to remain at the same level as in the baseline. This feature preserves the physical constraints of electricity generation that are implicit in the EPM, which are not considered in the CGE model, but allows lower costs in renewables to be reflected in increased supply and lower overall power prices. With this approach, the increased electricity demand caused by the lower cost of renewable technologies can be covered only by further expanding renewable electricity supply; there is no substitution between different electricity sources.

This scenario is implemented in the CGE model as a productivity increase in electricity generation for the renewable source that is expanding.[1] The CGE model requires that any expansion in electricity generation be matched by a proportional increase in T&D activity in the model in order to ensure that the increased electricity supply can reach final consumers.

In the EPM, the expansion of generation from renewable sources varies by country, reflecting each country's renewable energy resource endowments and their competitiveness with fossil fuels. Table 3.1 shows how generation from different renewable sources increases for each

TABLE 3.1

Changes in Renewable Generation Over Baseline Values in 2030 Under Scenario 1, by Country

COUNTRY	RENEWABLE SOURCE INCREASING	INCREASE IN RENEWABLE ENERGY		PERCENT OF TOTAL ELECTRICITY GENERATION	
		GWH	PERCENTAGE CHANGE OVER BASELINE	BASELINE	SCENARIO 1
Côte d'Ivoire	Solar	687	714.3%	0.60%	4.30%
Ethiopia	Hydro	1,724	5.2%	82.60%	83.30%
Ghana	Solar	1,374	2,352.9%	0.20%	4.60%
Kenya	Wind	4,126	133.9%	13.70%	22.20%
	Other	5,466	75.8%	32.10%	39.70%
Mozambique	None	0	n.a.	n.a.	n.a.
Nigeria	Solar	39	783.1%	0.00%	0.10%
Senegal	Solar	1,119	290.8%	3.30%	11.70%
South Africa	Wind	22,023	247.3%	2.80%	9.00%
	Solar	6,518	109.2%	1.90%	3.60%
Tanzania	Wind	1,632	250.0%	2.40%	7.40%
	Solar	891	250.0%	1.00%	3.00%
	Other	1,638	1,107.7%	0.50%	5.10%

Note: n.a. = Not applicable.

country. It also shows the absolute and percentage change in electricity generation in 2030 with respect to the baseline values and how the changes affect the power generation mix.

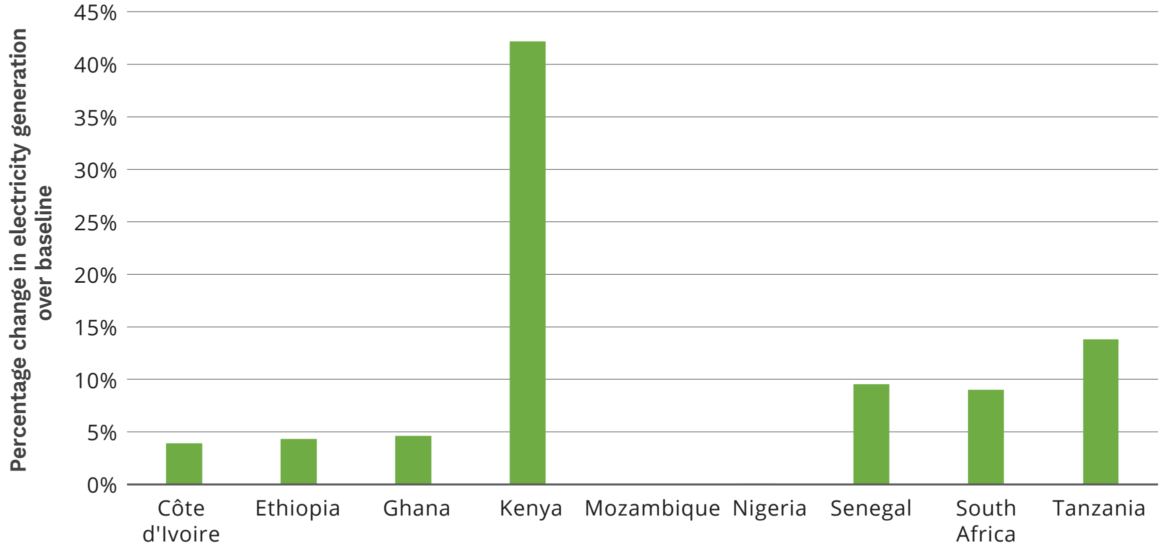
The changes in renewable generation taken from the EPM result in an initial increase in power supplied that has direct and indirect (general equilibrium) effects. This additional renewable generation is a result of lower prices of renewable power sources, which reduce the average electricity price faced by firms and households. As electricity is an important intermediate input in the production of many firms, lower electricity prices allow firms to produce more at the same cost, which increases their demand for electricity.[2]

Macroeconomic Effects

The increases in renewable generation shown in table 3.1 result in increases in total electricity generation in most countries (figure 3.1). The increase is a direct consequence of retaining the electricity generation of nonrenewable sources at baseline levels and adding the country-specific increase in renewable generation from the EPM.

FIGURE 3.1

Changes in Electricity Generation In 2030 in Scenario 1, by Country



The increase is large for Kenya, where wind and geothermal energy are significant sources of electricity and both increase substantially (by 134 percent and 76 percent, respectively; see table 3.1). In Tanzania, total electricity generation increases by almost 15 percent, thanks to large increases in wind, solar, and geothermal generation. For the other countries except Nigeria and Mozambique, total generation increases as a result of increase in renewable generation. There is no increase in renewable generation in Nigeria. Installed capacity was sufficient to cover demand, but it cannot be properly evacuated because of T&D bottlenecks; expanding generation is therefore not a priority in Nigeria. In addition, Nigeria's significant low-cost gas resources means that gas-fired power is cost competitive with solar photovoltaic generation. In contrast, Mozambique has excellent hydropower resources. Hence, even in the baseline, new hydropower plants are being developed, which is why no changes with respect to the baseline are observed in this scenario in 2030.

Figure 3.2 displays the electricity generation mix in the baseline and in Scenario 1. It reveals that even when renewable generation increases significantly—as in Ghana, for example, where solar power generation increases by a factor of about 23—substantial changes in the generation mix do not occur. This is because the initial level of renewable generation is so low that even very large relative increases do not result in significant changes in total electricity generation or the mix of generation sources. In all countries except Kenya, only small changes are observed in the shares of each generation source. In Kenya, geothermal becomes the dominant generation source; wind also becomes more important.

The increase in total electricity generation is achieved by deploying more productive (and hence lower-cost) renewable generation sources, which reduces the final price of electricity by around 5 percent for most countries (see figure E.6 in appendix E). The combination of more electricity that is cheaper also increases electricity demand, spurring overall economic activity.

FIGURE 3.2

Electricity Generation Mix in 2030 in the Baseline and Scenario 1, by Country

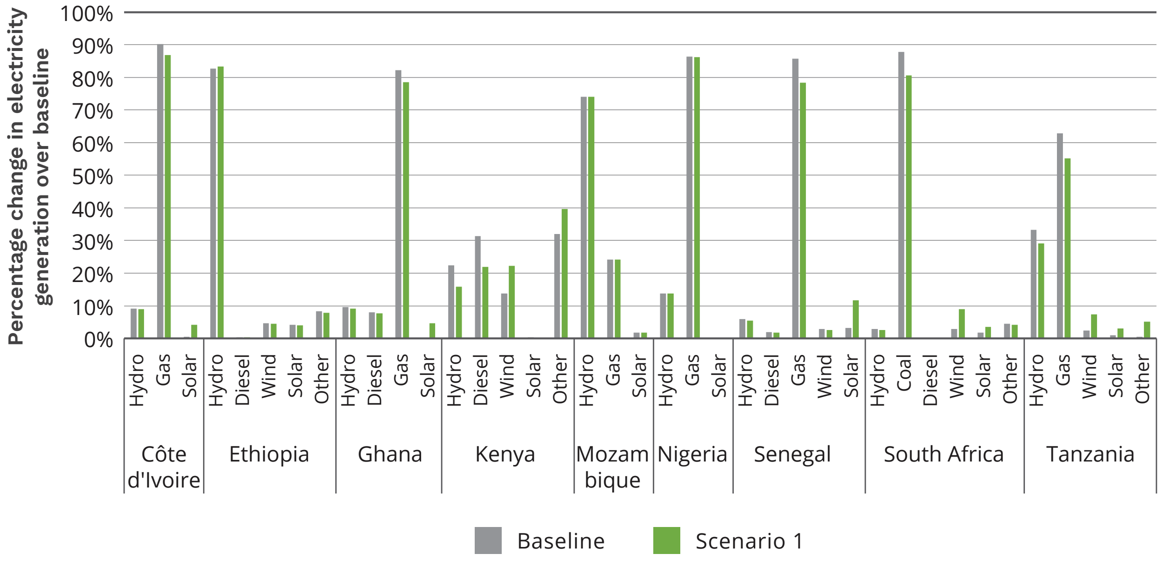
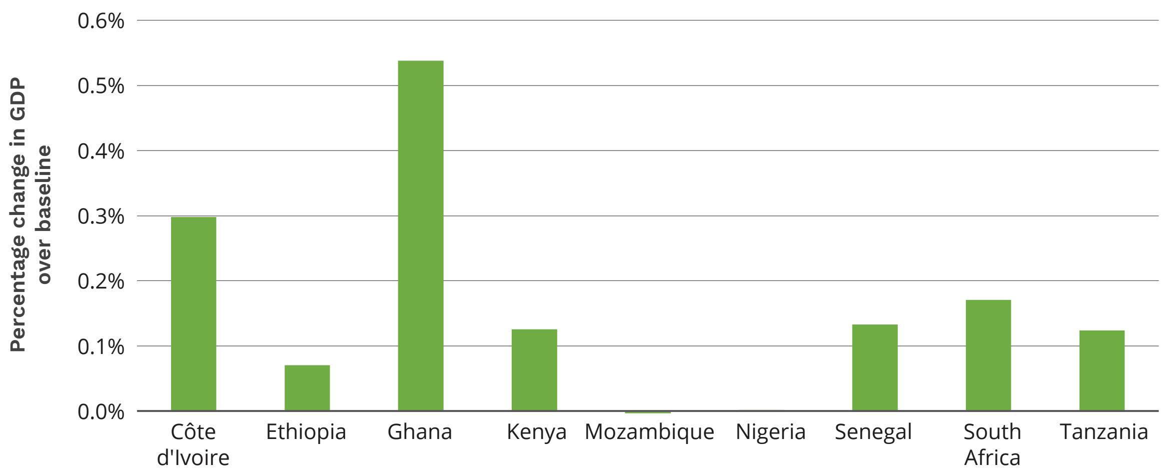


Figure 3.3 shows the changes in real GDP that result. Real GDP increases in all countries with the increase in renewable power generation. In 2030, Ghana's real GDP is around 0.5 percent above the baseline. The size of the GDP change in a country depends on the magnitude of the initial increase in renewable generation, how total electricity supply (including electricity trade) is affected, and the average electricity intensity of the country. Ghana enjoys the largest GDP impacts, because the initial increase in solar power was substantial and the share of solar in total generation in 2030 increases from 0.2 percent in the baseline to 4.6 percent in this scenario. This injection of cheaper renewable energy

FIGURE 3.3

Increases in Real GDP in 2030 in Scenario 1, by Country



provides substantial benefits to the economy. On the other hand, Mozambique and Nigeria do not have any changes in real GDP as total generation is also not changing.

Although Kenya experiences the largest increase in total domestic electricity generation, as seen in figure 3.1, it does not experience a larger GDP increase than other countries, because of Kenya's electricity trade patterns. Figure 3.4 shows the changes in electricity net exports for each country. In the baseline, Kenya is a net importer of electricity; with its large generation increase in Scenario 1, it becomes a net exporter. A large share of the new renewable generation replaces imports from Ethiopia. As a result, the domestic electricity supply does not change as much as the increase in renewable generation would suggest.

Even though overall electricity trade changes in gigawatt hours (GWh) in Kenya are not large compared with other countries, it has the largest percentage increase in net exports (figure 3.5).

Electricity exports in Côte d'Ivoire increase by more than 50 percent. In contrast, in Ghana and Tanzania, net export decline (by 113 percent and 57 percent, respectively). Ghana moves from being a net electricity exporter to a net importer. Tanzania was already a net electricity importer; its electricity imports increase further. The greater availability of affordable power drives the increase in GDP in both countries.

Real GDP levels are correlated with welfare indicators in most countries; using the change in real consumption by households as a welfare proxy yields very similar outcomes to real GDP changes. Figure E.5 (appendix E) shows the welfare effects for all scenarios.

FIGURE 3.4

Net Electricity Exports in the Baseline and Scenario 1, by Country

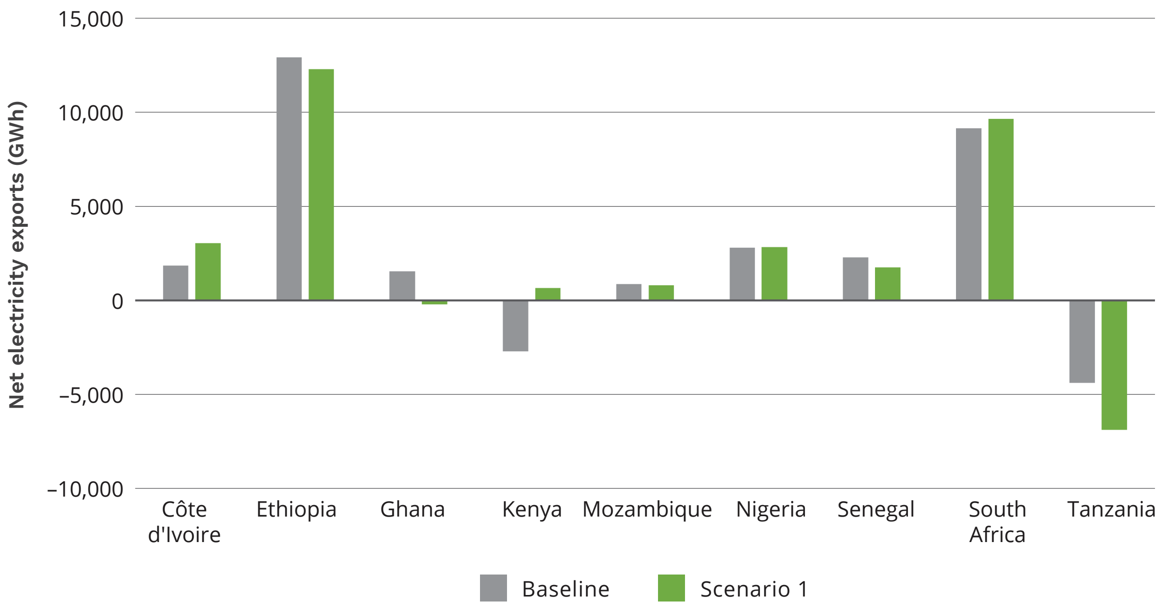
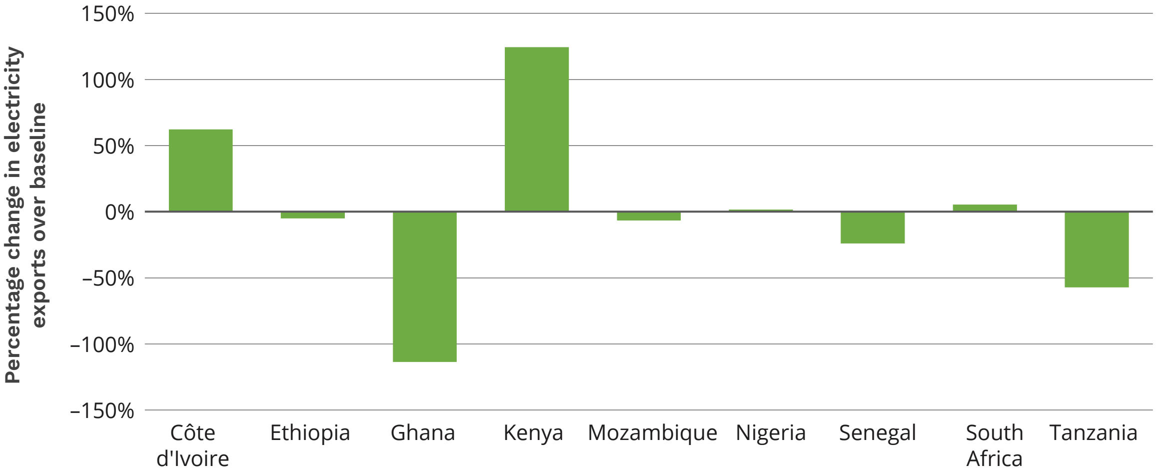


FIGURE 3.5

Changes in Net Electricity Exports in 2030 in Scenario 1, by Country



Labor Effects

All of the countries analyzed except South Africa have relatively low unemployment rates, and all countries have high participation rates, for both men and women. These figures imply that most people who are able and willing to work are already doing so and that it would therefore be difficult to increase the aggregate labor supply at the extensive margin (that is, by expanding the number of jobs). In South Africa, under-employment and informal work are prevalent; they could be addressed by an increase in the intensive margin of labor (average hours worked), but there is a lack of reliable data on hours worked. An increase in labor demand when the total number of jobs is fixed directly leads to higher real wages.

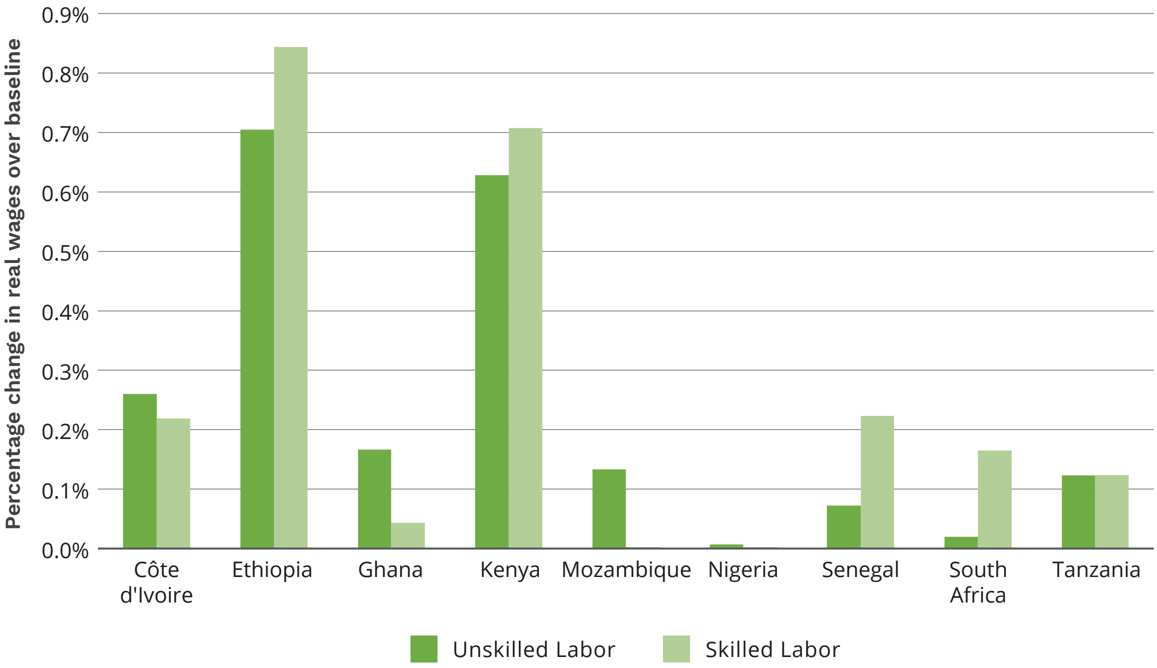
The increase in overall economic activity—captured by the increase in real GDP—is associated with an increase in overall labor demand. As the total number of workers does not change with respect to baseline values (indicating that labor productivity has risen), higher labor demand is directly reflected in higher real wages.

Figure 3.6 shows the changes in real wages in 2030 in Scenario 1 for all countries compared with baseline values. Wages increase for both unskilled and skilled workers in all countries except Mozambique and Nigeria, so the renewable energy scenario has a positive impact on wages. The increase in labor demand in this scenario could also result in formerly underemployed workers now having full-time jobs and receiving higher take-home pay at the same hourly wage as before.

In summary, an increase in the demand for labor benefits workers, with country-specific labor market conditions determining the manner in which it does so. Labor supply is determined by the number of workers, the average hours they work, and their average wage. Any combination of these factors increases the labor supply.

FIGURE 3.6

Change in Real Wages in 2030 for Unskilled and Skilled Labor in Scenario 1, by Country



Changes in electricity generation affect economic sectors differently, depending on the electricity intensity of production.[3] Lower energy prices are expected to lead to greater expansion of production in energy-intensive sectors than in non-energy-intensive sectors. These changes in sectoral production affect the demand for labor. Sectors and activities that are expanding attract more workers (that is, labor is redistributed across sectors). These effects are relatively small, and only around 0.05 percent of total workers are moving across sectors. In absolute terms, although the changes differ across countries, the largest number of workers switching sectors in any one economy is around 10,000. This figure is of the same order of magnitude as normal annual turnover in the labor market.[4]

Scenario 2: Regional Electricity Trade

Description and Implementation

Electricity generation data for Scenario 2 come directly from the EPM trade scenario, in which trade expands in each power pool relative to the baseline. In this scenario, as in Scenario 1, renewable generation expands if it is least cost; it is not fixed at the committed renewable level, as in the baseline. In Scenario 2 renewable generation expands in a different way and scale, given that thanks to new cross-boundary transmission lines power trade can increase across countries.

While renewable generation levels in the CGE model come directly from the EPM trade scenario, other generation sources are kept fixed at baseline EPM levels (as in Scenario 1). As renewable power generation increases consistent with EPM outputs, trade costs are adjusted to calibrate the trade changes to be as close as possible to EPM values.

It is difficult to model electricity trade in a CGE framework because electricity trade is significantly affected by infrastructure constraints impacting the transmission and distribution of electricity, complex electricity network dynamics, and contractual agreements. In addition, given the nature of trade in electricity, there is information only on how much each country trades on net, not on bilateral power flows in an international power pool.

Table 3.2 shows the new renewable generation values under Scenario 2. In Ethiopia, hydropower generation increases by 117 percent in the EPM trade scenario—almost

TABLE 3.2

Changes in Renewable Generation in 2030 in Scenario 2, by Country

COUNTRY	RENEWABLE SOURCE INCREASING	INCREASE IN RENEWABLE ENERGY		PERCENT OF TOTAL ELECTRICITY GENERATION	
		GWH	PERCENTAGE CHANGE OVER BASELINE	BASELINE	SCENARIO 2
Côte d'Ivoire	Solar	687	714.30%	0.60%	4.30%
Ethiopia	Hydro	20,777	62.90%	82.60%	86.80%
	Solar	422	40.20%	4.10%	3.80%
	Other	345	16.50%	8.30%	6.20%
Ghana	Solar	733	1,255.70%	0.20%	2.60%
Kenya	Wind	4,006	130.00%	13.70%	21.70%
	Other	5,714	79.30%	32.10%	41.00%
Mozambique	None	0	n.a.	n.a.	n.a.
Nigeria	Solar	39	783.10%	0.00%	0.10%
Senegal	Solar	1,873	486.70%	3.30%	16.60%
Tanzania	Wind	1,632	250.00%	2.40%	7.40%
	Solar	891	250.00%	1.00%	3.00%
	Other	1,638	1,107.70%	0.50%	5.10%
South Africa	Wind	22,023	247.30%	2.80%	9.00%
	Solar	6,518	109.20%	1.90%	3.60%

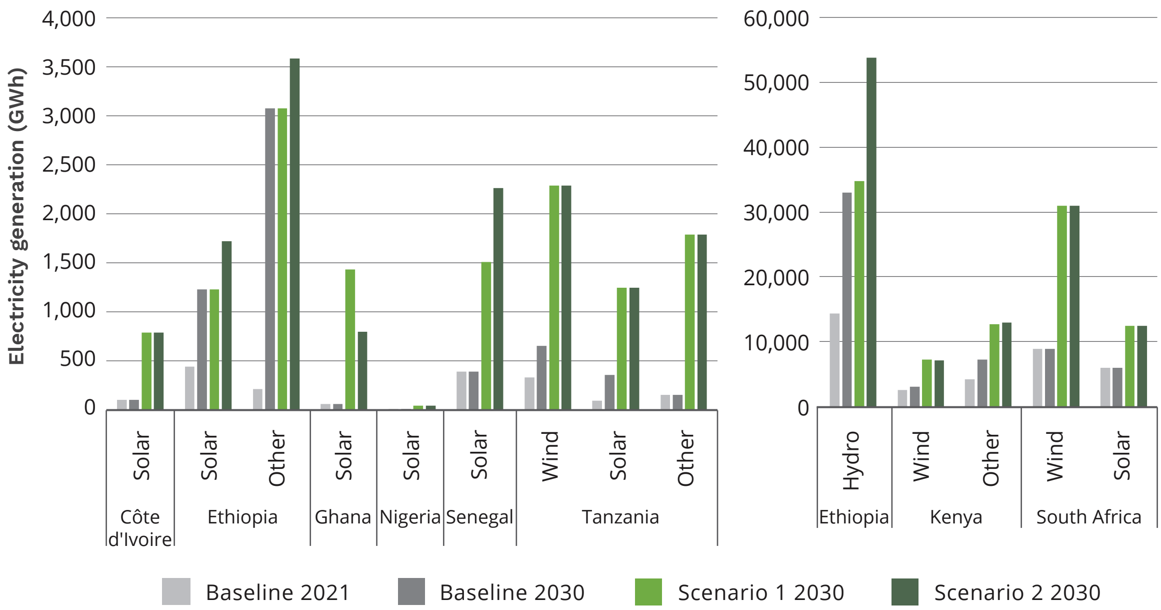
Note: n.a. = Not applicable.

twice the generation in the baseline. This very large increase in hydropower, of around 37,000 GWh, is related to the Grand Ethiopian Renaissance Dam (GERD). The CGE model is not able to simulate such a large increase. The hydropower increase is therefore limited to 75 percent of the original increase in EPM, which still results in a substantial change of around 21,000 GWh.

Figure 3.7 shows generation levels by renewable source in 2021 and 2030 in the baseline and generation in 2030 for Scenario 1 and Scenario 2. In Côte d'Ivoire, Kenya, Mozambique, Nigeria, South Africa, and Tanzania—the countries that are not newly importing or exporting renewable power in Scenario 2—renewable generation changes are the same in both scenarios. Renewable generation for Senegal and Ethiopia increases in Scenario 2 compared with both Scenario 1 and the baseline, as their costs of solar and hydropower generation are so low that exporting electricity can contribute to the least-cost generation plans of neighboring countries. Ghana is the only country in which renewable generation in Scenario 2 is lower than in Scenario 1. In Scenario 2, Ghana can import low-cost solar power from neighboring countries north of Ghana with better solar resources and therefore lower costs of solar power. As in Scenario 1, Mozambique experiences no changes in renewable generation, and Nigeria has a relatively small increase in renewable generation in 2030 compared with the baseline.[5]

FIGURE 3.7

Electricity Generation from Renewable Sources in 2021 and 2030 in the Baseline and Scenarios 1 and 2, by Country



Note: The figure is provided in two parts due to the significant differences in scale.

Macroeconomic Effects

Increased transnational interconnections lead to increased electricity trade, which in turn changes the build-out of power plants, including renewable generators in countries that are particularly well endowed with renewable resources and can generate power from them at very low cost. Ethiopia and Senegal increase renewable generation with respect to Scenario 1. Ghana reduces its renewable generation because its neighbors can produce renewable power at lower cost. Figure 3.8 presents the total energy generation increase under this scenario.

In Kenya, the increase in generation is as large as in Scenario 1. The effect is also large in Ethiopia, driven by the commissioning of the GERD, which partially serves exports. As in Scenario 1, the trade scenario results in relatively modest changes in the power generation mix in 2030 with respect to the baseline, except in Kenya and Ethiopia (figure 3.9).

Figure 3.10 shows the real GDP effects for this scenario. All countries except Nigeria have positive effects. These are generally correlated with the increase in electricity generation.[6] Ethiopia experiences the largest GDP change; Senegal also enjoys a significant increase. The GDP increases for Ethiopia and Kenya (about 0.4 percent) are almost twice as large as in Scenario 1. The difference is attributable to a combination of higher electricity generation in both countries and higher net electricity exports.

By 2030, the price of electricity is lower than its value in the baseline by around 5 percent for most countries (see figure E.6 in appendix E). A notable exception is Ethiopia, where the large increase in generation from the GERD reduces electricity prices by around 45 percent and also contributes to the large increase in electricity exports.

FIGURE 3.8

Increase in Electricity Generation in 2030 in Scenario 2, by Country

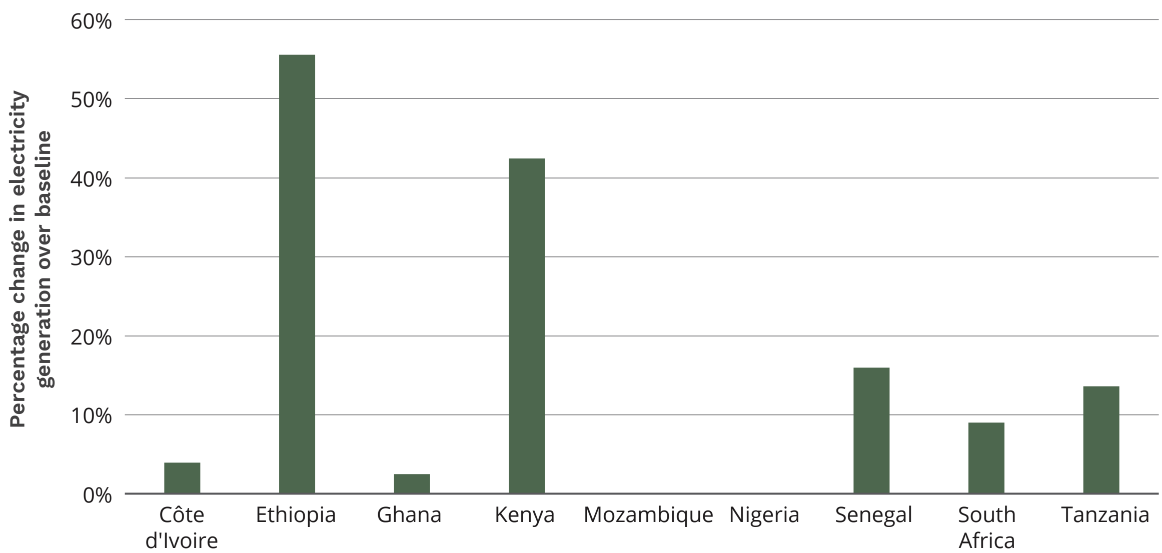


FIGURE 3.9

Electricity Generation in 2030 in the Baseline and Scenario 2, by Country

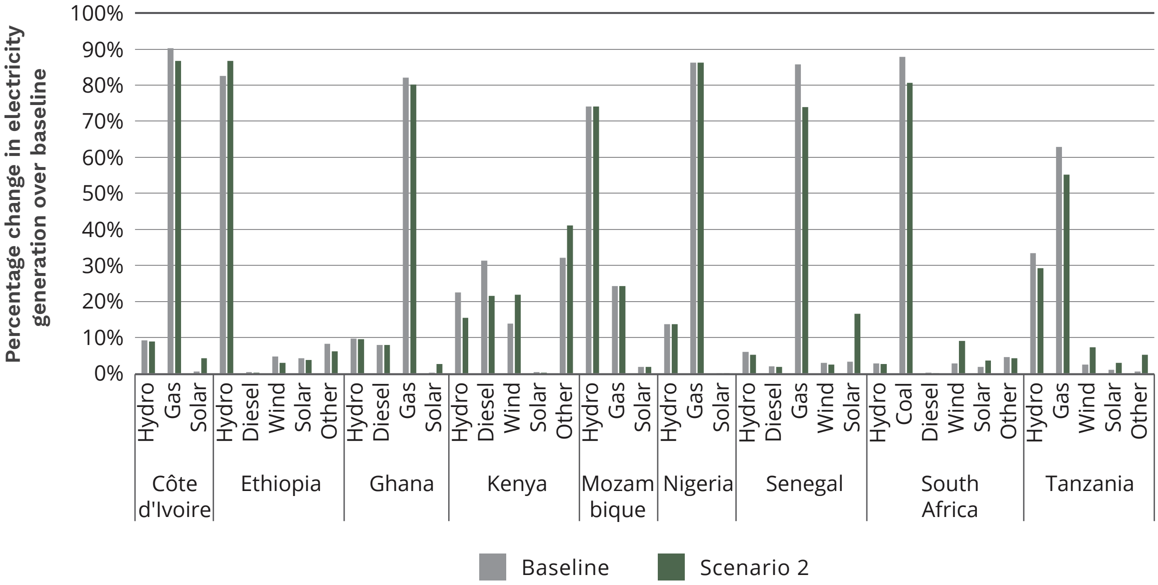


FIGURE 3.10

Increases in Real GDP in 2030 in Scenario 2, by Country

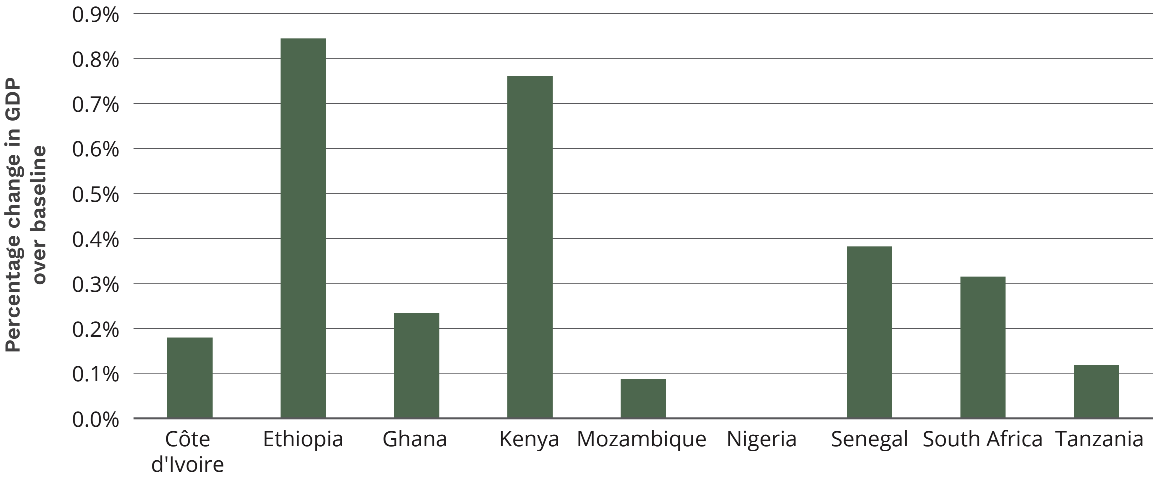
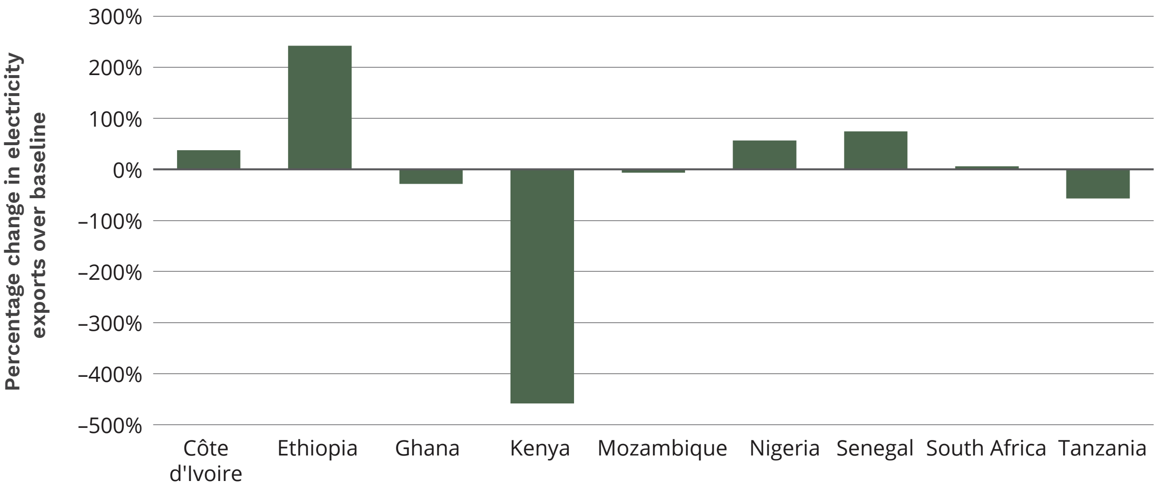


Figure 3.11 shows the percentage change in net electricity exports in 2030 over the baseline. The most remarkable change is the large increase in Ethiopia's net electricity exports, which are associated with the GERD. A large share of these exports is to Kenya, which becomes a larger net importer of electricity than before. For the other countries, the changes in net electricity exports are also substantial (around 40 percent on average).

FIGURE 3.11

Change in Net Electricity Exports in 2030 in Scenario 2, by Country

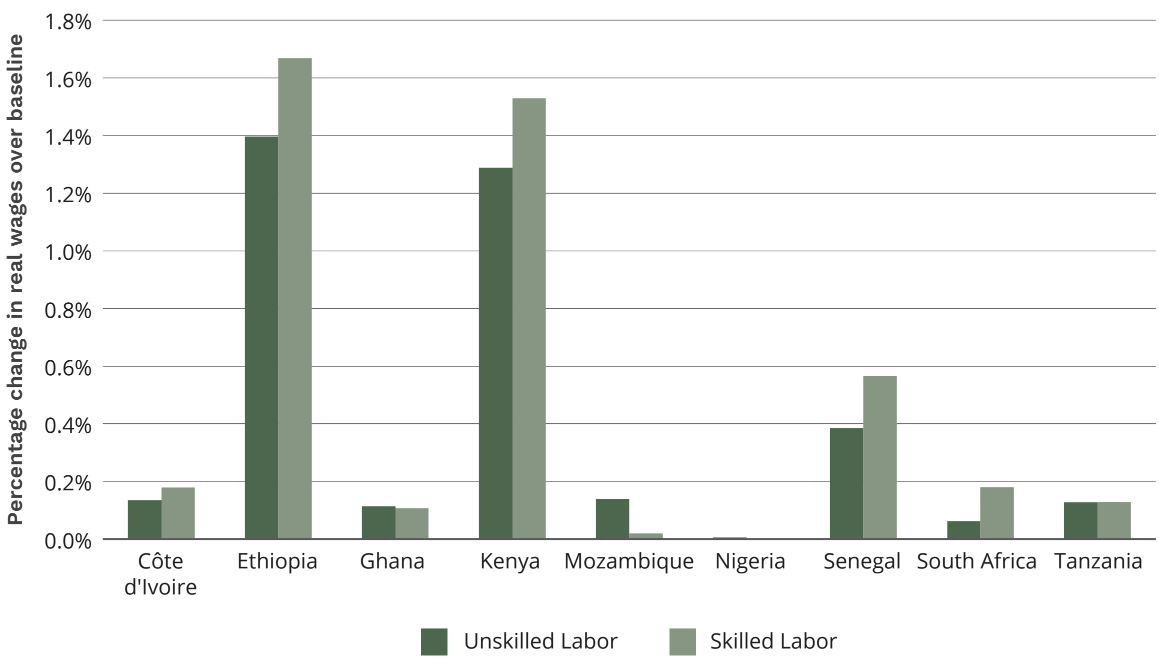


Labor Effects

Real wages are positively correlated with the increases in real GDP, as the expansion of the economy increases labor demand (figure 3.12). In Ethiopia and Kenya, wages in 2030 increase by around 1.5 percent over the baseline. This increase is almost twice the wage increase these countries experience in the renewable energy scenario. Wages also increase

FIGURE 3.12

Increase in Real Wages for Unskilled and skilled labor in 2030 in Scenario 2, by Country



in the other countries, providing a strong indication of positive employment impacts from an increase in electricity trade.

Scenario 3: Increased Power Reliability

Description and Implementation

In countries suffering from unreliable power supply (outages, intermittency, voltage fluctuations), additional investments in T&D capacity can improve power quality by increasing the volume of power delivered in a country. According to World Bank Enterprise Surveys, electricity outages substantially constrain businesses in the region and increase their production costs.[7] Improved stability and reliability of electricity is expected to increase firm productivity by reducing production shutdowns, uncertainty, and the cost incurred for expensive backup sources of power, such as private diesel generators.

Both the extent of unreliable power and its economic effects are hard to measure, particularly at the country level. Data from World Bank Enterprise Surveys indicate that around 80 percent of manufacturing firms experience outages in the nine countries studied. On average, when a firm experiences an outage, it lacks access to electricity for two hours a day (or 9 percent of the time, assuming 24-hour operation). The situation is by far the worst in Nigeria, where on average manufacturing firms are without electricity 40 percent of the time (almost 10 hours a day). Firms in Nigeria cope with this situation by relying heavily on private diesel generators, which around 70 percent of firms own or share. Outages account for a substantial share of lost sales and output.[8] Table 3.3 presents estimates of the average share of daily hours manufacturing firms experience outages[9] and of how these outages affect output.[10]

Electricity outages are a consequence of three main failures: insufficient power generation capacity; grid deficiencies (because of an underdeveloped T&D network, for example); and operational failures of the grid operator.[11] The energy generation projections from the EPM are constructed in such a way that the model deploys generation capacity to meet demand as soon as possible, as unserved demand has a high penalty cost. The energy supply projections used thus implicitly assume that the first reason for outages is addressed.[12] Operational failures that are caused by poorly managed and staffed grid networks—and can be addressed by technical and managerial improvements—are hard to directly simulate in the model. Grid deficiencies, which exist in all countries studied are therefore the main focus of this simulation.

Increased electricity stability is modelled as a result of improvements in the grid thanks to investments in electricity T&D. The EPM baseline values are employed for the electricity mix and supply levels in this scenario. Contrary to previous scenarios, there is no direct increase in renewable generation or electricity trade. However, the reductions in outages that result from the electricity T&D investments increase electricity demand and the model

TABLE 3.3

Incidence of Outages and Associated Output Losses, by Country, Latest Year Available

COUNTRY	OUTAGES (PERCENT OF DAILY HOURS)	OUTPUT LOSSES CAUSED BY OUTAGES (PERCENT OF ANNUAL OUTPUT)
Côte d'Ivoire (2016)	2.1%	4.9%
Ethiopia (2015)	5.2%	6.9%
Ghana (2013)	8.0%	15.8%
Kenya (2018)	2.5%	5.4%
Mozambique (2018)	0.6%	3.2%
Nigeria (2014)	40.4%	15.6%
Senegal (2014)	1.2%	2.8%
South Africa (2020)	2.2%	5.5%
Tanzania (2013)	6.6%	15.1%

Source: World Bank Enterprise Surveys.

allows the increase in electricity generation—proportionally for all generation sources—to match this increase.

Based on experience from World Bank projects in Sub-Saharan Africa, the investment required to significantly reduce outages is $3,000 per megawatt (MW) of installed capacity in all countries studied except Nigeria—this amounts to about a 30 percent increase in the capital stock in the T&D sector in those countries. In Nigeria, the investment required is substantially higher—at 16 times the current capital stock in the T&D sector in the model—because of the limitations of the current grid.[13] Accordingly, the quality (stability) of electricity supply in each country increases in the model in line with electricity T&D investment, which rises to the level that allows each country's grid to fully eliminate outages by 2030. In Nigeria, given the very large investment required, the model assumes that outages are reduced by 50 percent in 2030.

Data on output losses from outages are used to calibrate the manufacturing productivity increases associated with a fully functional grid that provides stable electricity supply.[14] These productivity increases are experienced only by the manufacturing sector, not services or private consumption. This assumption means that manufacturing output increases only in response to the initial shock, not also as a result of second-round general equilibrium effects.

For comparison, Fried and Lagakos (2020) also simulate the economic effects of reducing outages in Sub-Saharan Africa. Using World Bank Enterprise Surveys and additional data and survey information, they estimate that eliminating outages increases long-term labor productivity by around 27.5 percent on average in Ethiopia, Ghana, Nigeria, and Tanzania.

The implicit output effects of the labor productivity increase they analyze are very similar in magnitude to the output effects estimated here.

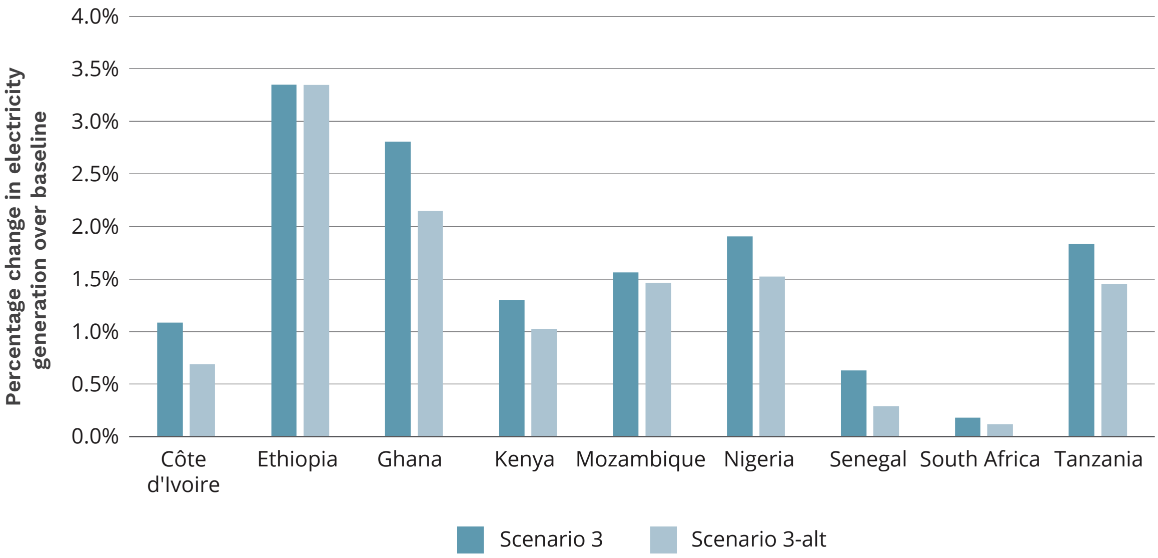
Two simulations of this scenario were run as a sensitivity check. The first (Scenario 3) assumes that all outages are eliminated for all countries except Nigeria, where only 50 percent of outages are eliminated. The second, an alternative (Scenario 3-alt), assumes that 75 percent of outages are reduced in all countries except Nigeria, where 37.5 percent are eliminated. These scenarios are simulated by increasing capital demand in the T&D sector corresponding to the investment required to eliminate (or, in Nigeria, reduce) outages in each country. Manufacturing output increases in line with the data in table 3.3.[15]

Macroeconomic Effects

Improvement in the quality of electricity supply, which increases manufacturing productivity and output, also yields second-round (general equilibrium) effects. Higher manufacturing output increases GDP and aggregate demand, which increase electricity demand across the board, bringing forth an increase in total generation (figure 3.13). The power generation mix and electricity trade remain unchanged from the baseline values (not shown), as all generation sources increase proportionally. Electricity prices do not change significantly

FIGURE 3.13

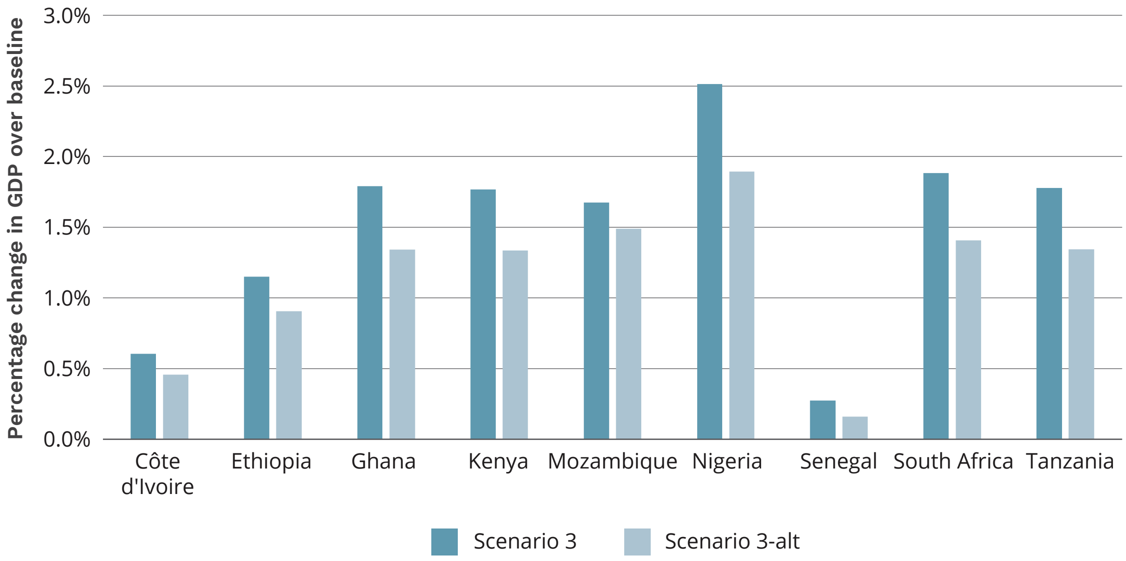
Total Electricity Generation in 2030 in Scenarios 3 and 3-Alt, by Country



Note: In Scenario 3, in all countries except Nigeria, all outages are avoided, thanks to additional T&D investments; in Scenario 3-alt, outages in all countries except Nigeria decline by 75 percent. For Nigeria, given the severity of underinvestment in its grid, Scenario 3 assumes that 50 percent of outages are avoided, while scenario 3-alt assumes that 37.5 percent of outages are avoided.

FIGURE 3.14

Increase in Real GDP in 2030 in Scenarios 3 and 3-Alt, by Country



from their baseline values (see figure E.6 in appendix E); in most countries, the increase in electricity supply is matched by higher electricity demand, which keeps prices close to baseline levels.[16]

This scenario yields significant GDP gains (figure 3.14). On average, relative to the baseline, real GDP increases by around 1.5 percent in 2030 in Scenario 3 and 1.1 percent in Scenario 3-alt. Nigeria experiences larger increases in GDP than the other countries, even though only half the number of outages is eliminated with new investment in the T&D sector, because the number of electricity outages there is particularly high (see table 3.3).

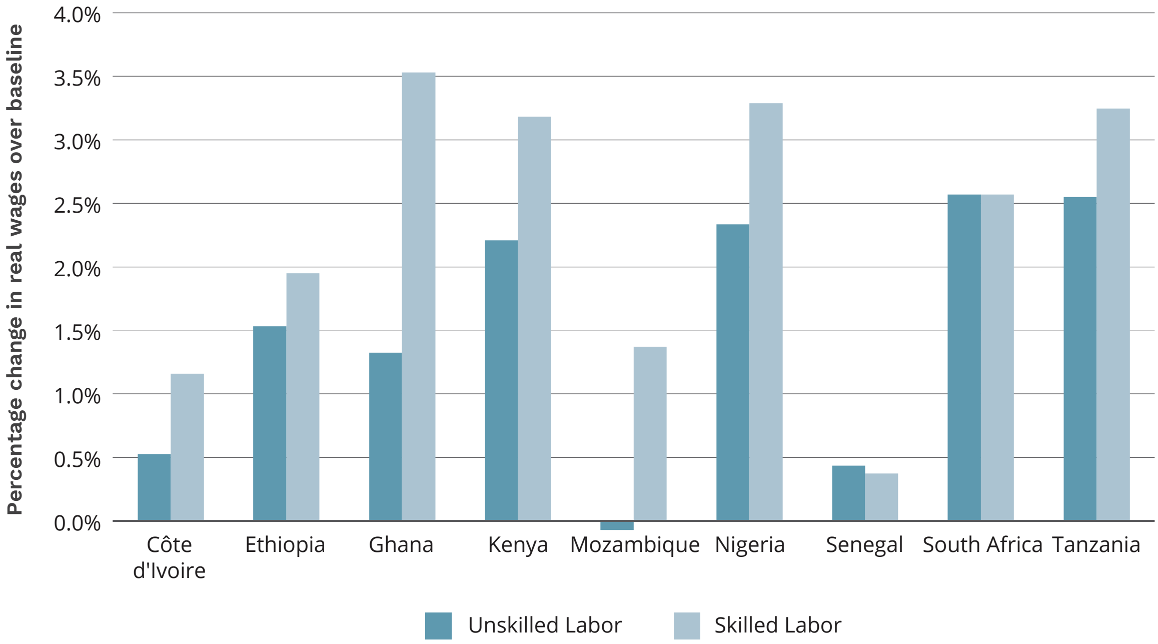
In Senegal, GDP, total electricity generation, and wages increase by substantially less than in the other countries, because it has fewer outages than they do (see table 3.3). Mozambique also has similarly low outages and output losses from outages but experiences a much larger increase in total electricity generation because of the general equilibrium effects of increased trade with neighboring countries, whose demand for power increases. As a result, GDP and wage gains are larger than in Senegal.

Labor Effects

As economic activity expands, the demand for labor increases. Wages therefore rise—by 2 percent above the baseline under Scenario 3 (figure 3.15) and by about 1.5 percent under Scenario 3-alt. Skilled labor benefits more than unskilled labor because of the expansion of the manufacturing sector, in which skilled workers are employed more intensively.

FIGURE 3.15

Increase in Real Wages in 2030 in Scenario 3, by Country



Scenario 4: Investments in Energy Efficiency

Description and Implementation

Scenario 4 models demand-side improvements in energy efficiency that allow consumers to achieve the same level of service using less energy. It is difficult to obtain precise estimates of the economic effects of different energy-efficiency investments. Although such estimates for particular energy efficiency measures exist, they are usually available for developed countries and do not cover all potential economic effects. Under these constraints, this scenario focuses on improved efficiency in residential lighting for which we have detailed estimates from Tanzania. On the other hand, the study only provides results for lighting in households, while energy-efficiency improvements in industrial processes likely have greater potential for saving electricity than efficient lighting programs. However, the data needed to model improvement in industrial energy efficiency were not available.

A study of Tanzania finds that only 10 percent of residential light bulbs there are LEDs and that these LED bulbs save around 90 percent of electricity compared with incandescent bulbs, most common in the country (CLASP 2020). To provide a broad estimate of the impact of switching to LED, this report assumed that half of average household electricity consumption in Tanzania is for lighting, given the country’s level of development. If all households switched to LED bulbs, their electricity consumption would therefore decline by 40.5 percent.[17] These electricity savings are modeled as a one-time 40.5 percent energy-efficiency gain in household electricity consumption. As estimates of LED penetration were available only for Tanzania, the same energy-efficiency gains were applied to the other eight countries analyzed.[18]

The costs of switching from incandescent to LED bulbs is relatively low. CLASP (2020) estimates that 6.3 million LED bulbs would be needed to switch universally in Tanzania, at a cost of $3 a bulb. Assuming the switching program is financed directly by the government and adding distribution and management costs of the program brings the total cost to about $23 million—around 0.01 percent of GDP or 0.04 percent of total investment. These additional investment costs are included in the CGE model as a public investment financed through an increase in public debt.[19] The analysis applies this share of investment to all countries analyzed.

This scenario is simulated by increasing the energy-efficiency parameter in the energy demand of households, so that households obtain the same consumption utility from electricity services by purchasing less electricity. As a result, households have more discretionary income to spend on other goods and services, which increases demand in different sectors. The electricity saved in lighting can also be viewed as more electricity available for other users, including firms. The initial reduction in electricity demand results in a reduction in the price of electricity, which encourages firms to use more electricity and increase production of goods and services; it encourages households to increase electricity consumption for other needs. The result is a broad expansion of consumption demand and an expansion of productive use of power by firms, which spurs GDP growth.

As in Scenario 3, the baseline electricity generation mix does not change in this scenario. The increases in renewable generation or trade modeled in the first two scenarios are therefore not included.

This simulation accounts only for the benefits of households using more LED lamps; it does not account for other sources of gains (such as energy- efficiency gains in street lighting and savings in energy for lighting consumed by firms), which could be substantial.

Macroeconomic Effects

All countries experience increases in real GDP (figure 3.16), and electricity generation (figure 3.17). As the efficiency shock is the same in each country, the GDP effects reflect the importance of lighting in domestic consumption in each country. Countries in which lighting represents a larger share of household expenditures are expected to enjoy larger GDP gains from the switch to energy-efficient lighting.

The overall effect on GDP is the result of the direct effect of households, such as having more power available for their non-lighting needs or to be used by other consumers, and the indirect (general equilibrium) effects of households switching expenditure away from lighting to other consumption goods and services, which affects production patterns and increases overall electricity demand. Using changes in real consumption by households as a proxy for welfare

FIGURE 3.16

Increases in Real GDP in 2030 in Scenario 4, by Country

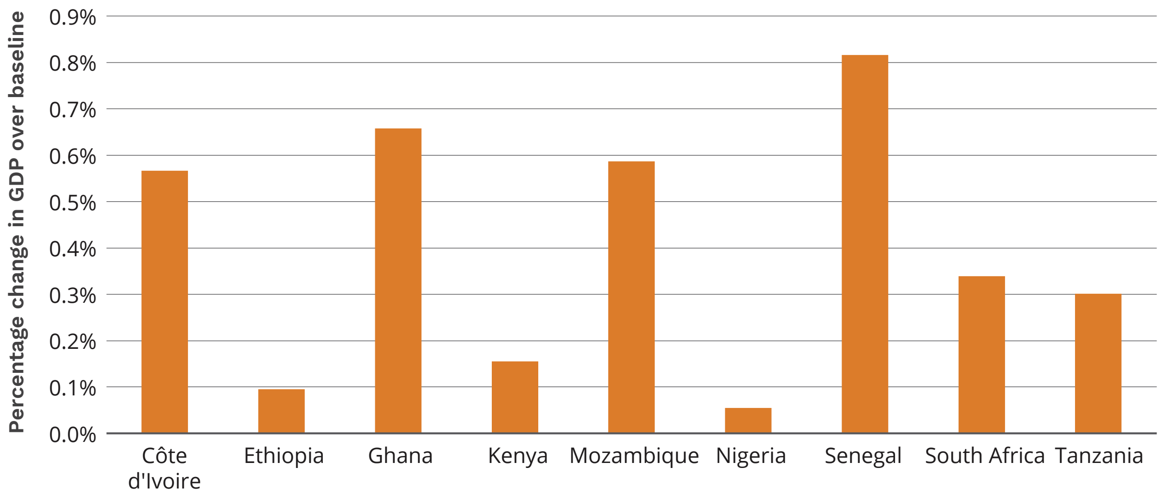
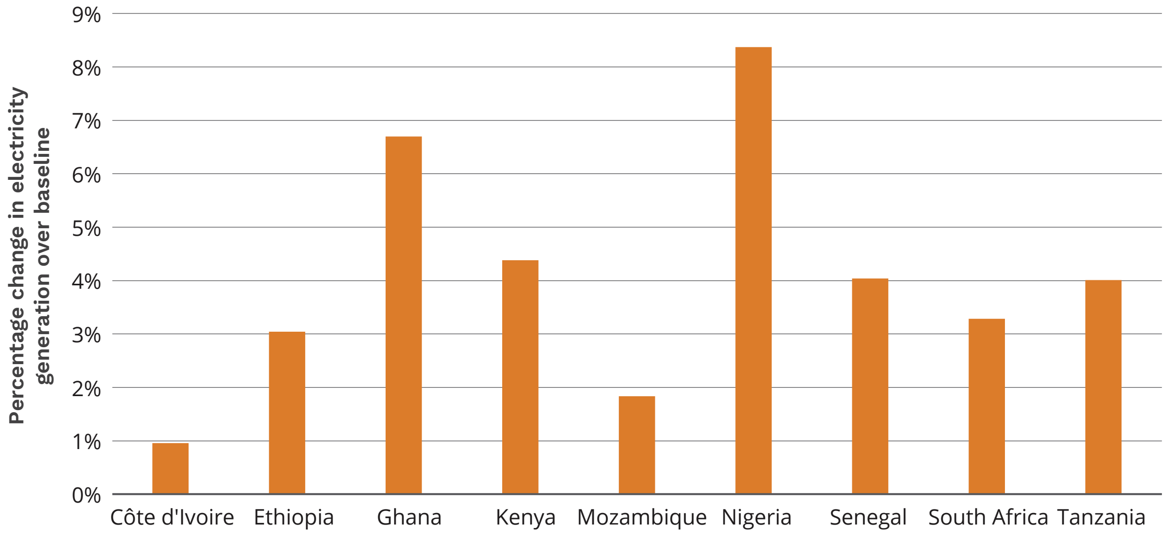


FIGURE 3.17

Increases in Total Electricity Generation in 2030 in Scenario 4, by Country



changes, however, shows that Ethiopia and Kenya experience small declines in welfare (see figure E.5 in appendix E). Both countries rely on renewable generation sources, which are more capital intensive than fossil fuel generation. The increase in power generation under Scenario 4 requires higher capital investment to increase generation capacity in these countries than it does in others. Therefore, the GDP changes for these countries are driven by relatively large increases in investment, but with small declines in consumption and hence, welfare.

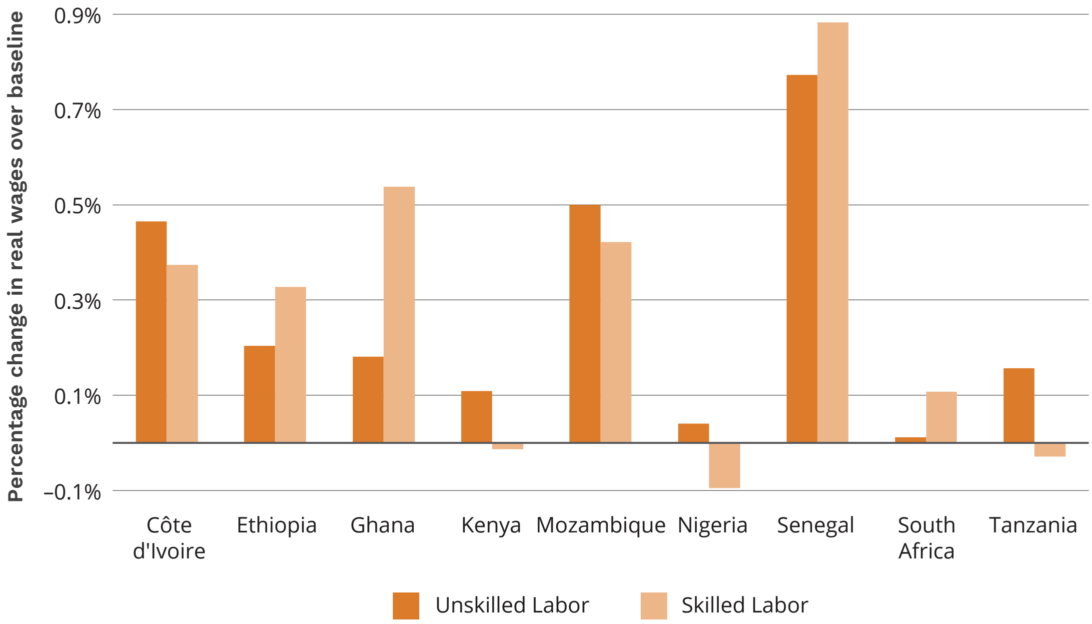
Labor Effects

As economic activity expands, the demand for labor increases. Wages therefore rise (figure 3.18) but the increase is very modest given the small size of the investment.

Real wages see a very small decrease in the countries where the service sector shrinks while the largest positive effects result from the manufacturing sector expanding while agriculture is shrinking, as in Ethiopia, Ghana and most notably in Senegal (see appendix E for sectoral analysis).

FIGURE 3.18

Increases in Real Wages in 2030 in Scenario 4, by Country



Endnotes

1. The increase in power generation also requires additional investment in the sector. Investment is endogenous in the CGE model, so the analysis does not target it to obtain the exact values provided by the EPM, also because the capital requirements for electricity generation in both models are not identical. However, once renewable generation increases, the change in capital demand in the CGE model should be similar in magnitude to the investment requirements from the EPM. If it is not, the electricity investments are adjusted to the EPM values.
2. Ideally, the changes in electricity demand in the CGE model that result from applying the first round of renewable changes from the EPM could be fed back into the EPM to generate a new generation mix based on this updated electricity demand value. Applying this feedback loop was beyond the scope of this project. It is a promising area for future work.

3. The GTAP database shows the initial structure of the economy and the electricity intensity of each sector. Both endogenously change in the CGE model, because of substitution in production between factors (labor, capital) and energy.
4. This process of workers moving to new jobs and new workers entering the labor market is usually associated with frictional unemployment. Appendix E provides figures on sectoral employment.
5. This scenario is simulated in a similar way to Scenario 1. In both scenarios, productivity increases in the expanding renewable generation source. In Scenario 2, the electricity trade values are also adjusted to reflect (as much as possible) the scenario outputs from EPM. The outputs from the EPM indicate that electricity generation using gas increases in this scenario in both Mozambique and Nigeria. Since nonrenewable generation is maintained as in the baseline in this simulation, as in the previous one, all of the economic impacts reported relate only to the impacts of increased renewable source generation.
6. Mozambique, however, has a small positive GDP effect but no increase in electricity generation, which is associated with positive trade effects from the output expansion in neighbor countries.
7. www.enterprisesurveys.org
8. Enterprise Survey data are based on self-reports by firms, which can bias the data. For instance, firms might want to exaggerate their losses for various reasons, including the need to put pressure on the government to address particular issues.
9. These figures are the product of the average share of firms experiencing outages, the number of outages in a typical month, and the average duration of a typical outage.
10. Enterprise Surveys apply only to formal firms; they do not cover informal firms. The model implicitly assumes that the effect on outages that the survey reports on formal firms applies to informal ones.
11. Insufficient capacity and grid deficiencies are a function of several factors, including subsidized and/or unpaid electricity rates that disincentivize investment, financial constraints, and political decisions regarding specific energy infrastructure investments.
12. Unless it is more expensive to meet the demand than to pay a penalty for unmet demand corresponding to the value of lost load.
13. Information on Nigeria is from the website of the Nigerian Electricity Regulatory Commission. It was compared with the investments in T&D in the model. A back-of-the-envelope calculation for other countries is as follows: Assume that the power factor across the entire transmission network is poor (for example 0.85), and estimate what it would cost to raise it to 0.95. Assuming that generators are at their limits and there are existing compensation devices, all of the compensation needed to increase power factor to 0.95 would come from new shunt capacitors. An investment of approximately $3,000 per MW is therefore required. For a 5,000 MW system, investment would be $14.5 million.
14. The calculation was made by increasing the total factor productivity (TFP) of the manufacturing sectors to reach the output increase in table 2.3.
15. This calculation was made by endogenizing TFP in the manufacturing sectors to reach the desired manufacturing output values. Doing so implies that the model does not

allow second-round effects in the manufacturing sector that could result from manufacturing being more productive and experiencing higher demand.

16. The main exceptions are Ethiopia and Mozambique, where the increase in electricity generation is larger than the increase in electricity demand, resulting in a reduction in the final relative price of electricity.
17. This value is obtained as follows: The 90 percent of households that previously did not use LED lamps save 90 percent on lighting, which represents 50 percent of total electricity consumption ($0.9 \times 0.9 \times 0.5 = 0.405$).
18. Given the level of development in South Africa, this assumption may not be suitable for it. It was adopted in the absence of other data.
19. The very low magnitude of the adjustment in investment does not affect the macroeconomic results in a significant way; how these investments are financed is not relevant.

FOUR

ESTIMATED JOB CREATION IN THE ELECTRICITY SECTOR

The CGE model estimates how labor is re-allocated to economic activities after a policy shock is introduced. Economy-wide employment is kept constant at the baseline level; sectoral employment levels can change, as labor moves from contracting sectors and economic activities to expanding ones. This section shows how employment in the electricity sector itself changes under each scenario.

Table 4.1 presents the estimated number of new jobs in electricity generation under each scenario. It reports "direct" jobs in electricity generation and the related transmission and distribution; it does not capture labor that was used to construct the infrastructure and manufacture the equipment used in electricity generation (that is, upstream activities).

TABLE 4.1

Estimated Number of Direct New Jobs in the Electricity Sector Created by Increased Electricity Generation in 2030

COUNTRY	PERCENTAGE CHANGE IN ELECTRICITY GENERATION	ESTIMATED NEW DIRECT JOBS		PERCENTAGE CHANGE IN ELECTRICITY GENERATION	ESTIMATED NEW DIRECT JOBS	
		NUMBER	PERCENT OF TOTAL		NUMBER	PERCENT OF TOTAL
	SCENARIO 1			SCENARIO 2		
Côte d'Ivoire	3.9%	2,935	0.03%	3.9%	2,935	0.03%
Ethiopia	4.3%	10,557	0.01%	55.0%	134,618	0.18%
Ghana	4.6%	5,726	0.03%	2.5%	3,056	0.02%
Kenya	42.2%	167,347	0.50%	45.3%	179,883	0.54%
Mozambique	0.0%	0	0.00%	0.0%	0	0.00%
Nigeria	0.1%	408	0.00%	0.1%	408	0.00%
Senegal	9.5%	1,315	0.02%	16.0%	2,201	0.04%
South Africa	9.0%	24,848	0.14%	9.0%	24,848	0.14%
Tanzania	13.8%	10,512	0.02%	13.8%	10,512	0.02%
	SCENARIO 3			SCENARIO 4		
Côte d'Ivoire	1.1%	809	0.01%	0.9%	679	0.01%
Ethiopia	3.3%	8,194	0.01%	3.3%	7,954	0.01%
Ghana	2.8%	3,463	0.02%	7.8%	9,563	0.05%
Kenya	1.3%	5,166	0.02%	4.5%	18,049	0.05%
Mozambique	1.6%	1,547	0.01%	0.6%	603	0.00%
Nigeria	1.9%	11,671	0.01%	7.5%	45,948	0.06%
Senegal	0.6%	87	0.00%	1.1%	146	0.00%
South Africa	0.2%	503	0.00%	3.5%	9,763	0.06%
Tanzania	1.8%	1,396	0.00%	0.8%	633	0.00%

The number of new direct jobs is proportional to the change in electricity generation under each scenario (that is, the percentage change with respect to baseline generation values) and the number of workers expected to be employed in the electricity sector in 2030 in the baseline. In most scenarios, changes in employment levels in electricity generation activities are small: New workers that move into the electricity sector usually represent less than 0.05 percent of total employment in each country. However, under scenario 2, Ethiopia and Kenya, and under scenario 1, Kenya, experience large changes in employment, associated with large hydroelectric and geothermal projects. The capital intensity of renewable power projects is relatively high; construction jobs associated with capital investment (for example, building of solar farms or hydropower plants) are accounted for under construction activities, not as electricity activities. Overall, the energy policies simulated in each scenario have significant positive labor effects, as they increase economy-wide economic activity and labor demand, which translates into better and more productive jobs that pay higher wages.

FIVE
CONCLUSIONS

All four of the policy scenarios examined have positive effects on real GDP. Higher GDP translates into higher demand for labor and higher real wages for both unskilled and skilled workers. The magnitude of the macroeconomic impacts differs across scenarios (figure 5.1).

In Scenarios 1 and 2, the GDP impacts are associated directly with the increase in total electricity generation and associated general equilibrium effects following introduction of the policy changes, but the positive impacts are generally smaller than those of the other two scenarios. Scenario 3 improves the reliability of power supply, and Scenario 4 increases demand-side energy efficiency (making additional electricity available at no additional cost). Both changes boost production in the economy and stimulate aggregate demand, drawing forth additional increases in power generation. This combination generates the largest GDP gains for most countries. (In Scenario 4, household savings from improved efficiency of use permit further expansion of consumption, adding to the increase in aggregate demand.)

Increasing power reliability through additional investments in T&D (Scenario 3) has the greatest impact on GDP, particularly for Nigeria. Increased energy efficiency (Scenario 4) has the greatest GDP impact in Senegal. Increased regional electricity trade (Scenario 2) has relatively large effects in Ethiopia and Kenya. Increasing renewable electricity generation (Scenario 1) has relatively low impacts on GDP compared with the other scenarios, although it is substantial for Ghana. These findings reflect the different mechanisms each scenario triggers under differing country-specific conditions.

FIGURE 5.1

Changes in Real GDP in 2030 in the Four Scenarios, by Country

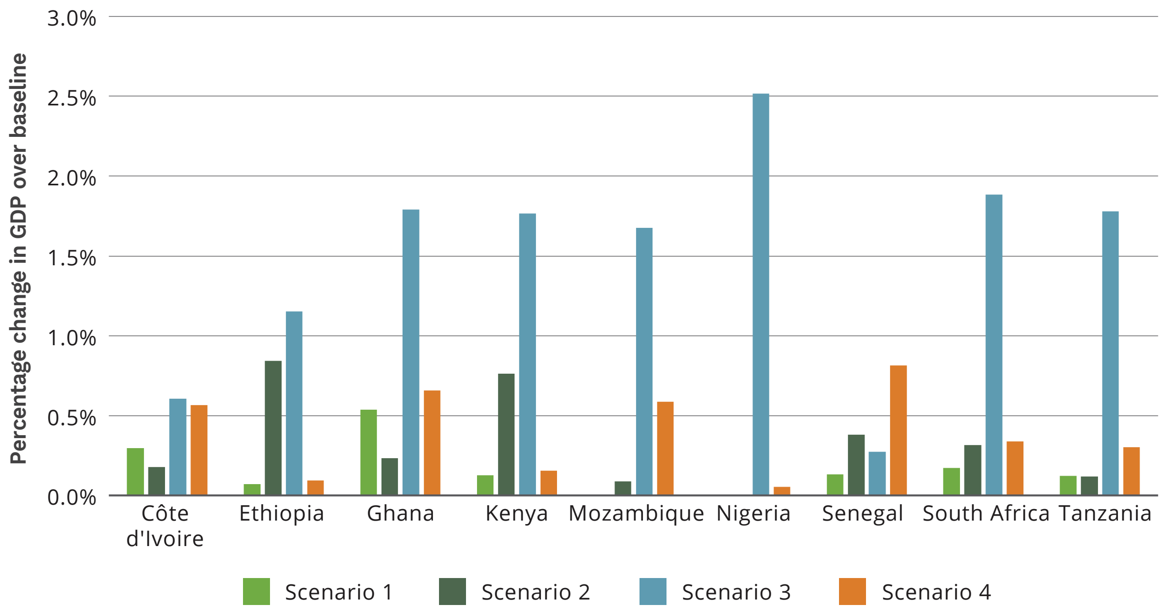


FIGURE 5.2

Effect of the Four Scenarios on Real Wages of Unskilled (Left) and Skilled (Right) Workers in 2030, by Country

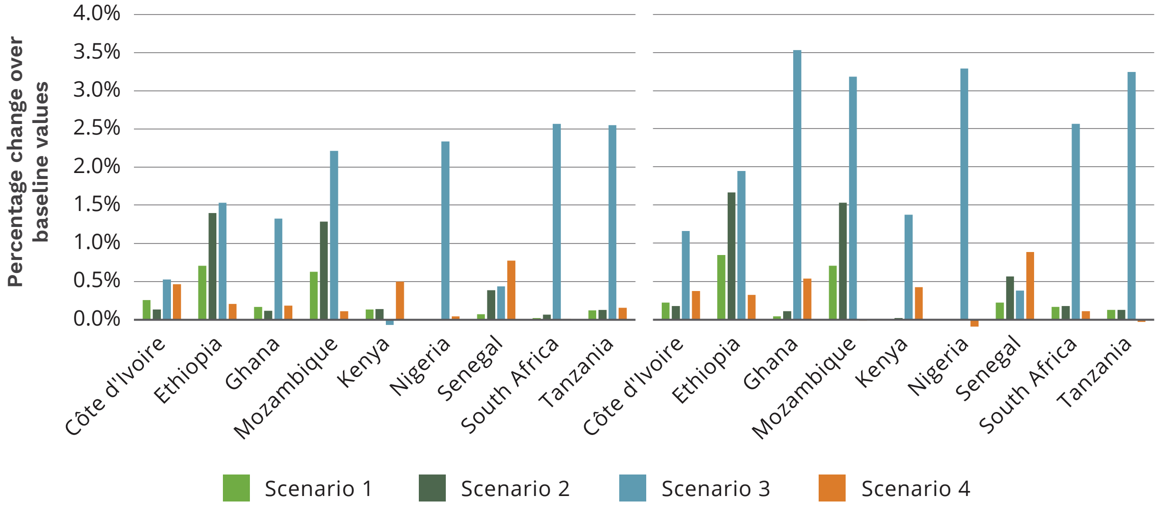


Figure 5.2 shows the real wage impacts by scenario and country. They follow very closely the GDP results presented in figure 5.1. All scenarios generate positive real wage effects, with the largest impacts associated with increasing power reliability. The relatively low unemployment and labor force participation rates in these countries imply that there is limited capacity to increase the size of the labor force (that is, create new net jobs). However, the policy scenarios analyzed improve the quality, productivity, and remuneration of existing jobs.

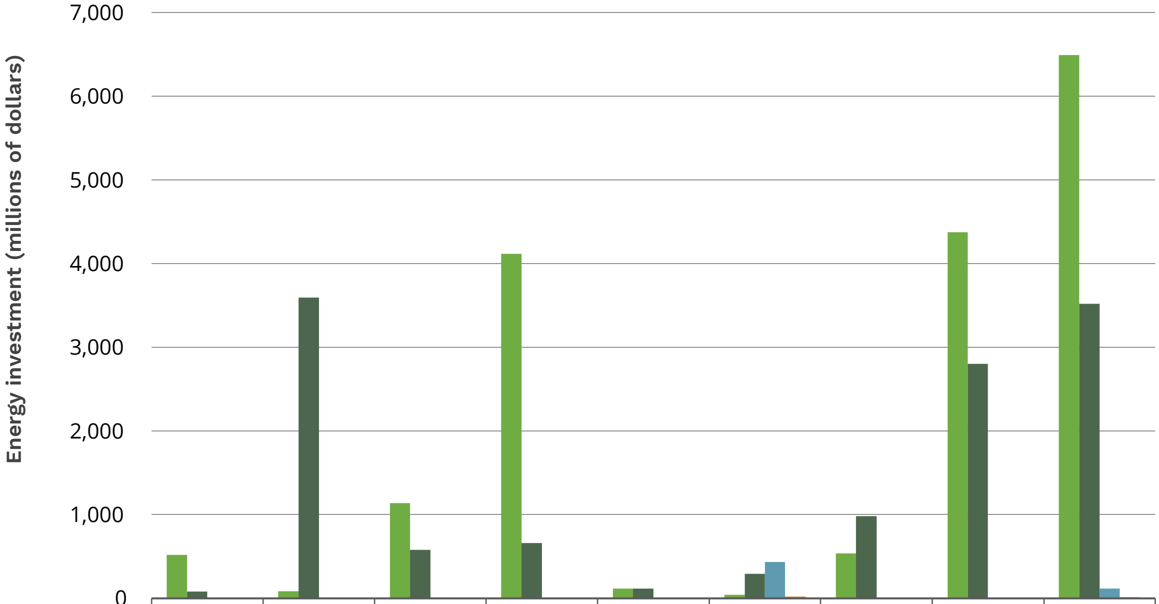
The wages of both skilled and unskilled workers increase in all scenarios, indicating increased demand for labor. Skilled workers experience slightly higher increases in real wages than unskilled workers, which will increase wage inequality. However, the overall increase in unskilled wages will help to reduce poverty rates.

Since the CGE model assumes that labor supply—the number of workers in the economy—is fixed, an increase in the demand for labor due to the increase in productivity associated with the rise in GDP results only in higher wages, not more jobs. In order to assess the implications for job creation, one option is to estimate how many more workers (with the same productivity as in the baseline) would be required to achieve the real GDP levels in the different scenarios. This concept—the "employment equivalent to real GDP changes"—provides an indirect measure of jobs created. Box 5.1 presents these results, which demonstrate a net increase in jobs in all scenarios.

Figure 5.3 shows the additional electricity sector investment in each scenario compared with investment in the baseline. Scenario 4, in which LED bulbs are adopted, has the

FIGURE 5.3

Additional Energy Sector Investment Required in the Four Scenarios



	Côte d'Ivoire	Ethiopia	Ghana	Kenya	Mozam bique	Nigeria	Senegal	South Africa	Tanzania
Scenario 1	520	85	1,138	4,116	116	41	536	4,375	6,493
Scenario 2	81	3,593	576	661	116	291	981	2,800	3,522
Scenario 3	5	9	11	6	2	434	3	7	116
Scenario 4	2	7	3	3	1	23	1	4	13

lowest investment cost. Scenario 3, in which T&D investments reduce outages, also has a relatively low investment cost. Scenarios 1 and 2 involve large investments in renewable energy plants.[1] Scenario 2 deploys renewable plants in countries with the best resources (e.g. hydropower in Ethiopia and solar in Senegal), which are then benefiting countries domestically but provide also their neighbors with least cost renewable energy power.

The positive real GDP and wage effects indicate that all four scenarios have positive economic gains. Comparison of the required investment against the GDP gains reveals that Scenario 3 has the highest "returns," followed by Scenario 4. GDP increases in Scenarios 1 and 2 are generally lower than in the others, and the initial investment required is also much larger. Scenarios 3 and 4 can be considered low-hanging fruit, with relatively large economic gains associated with modest additional investment.

BOX 5.1

MEASURING JOBS CREATED THROUGH "EMPLOYMENT EQUIVALENT TO REAL GDP CHANGES"

One of the main assumptions in the CGE simulations is that labor supply is held fixed at the baseline value. This is reasonable because the average rate of labor participation in Sub-Saharan Africa is above 85 percent for both women and men, and unemployment is less than 5 percent.[2] Thus it is assumed that most people able to work are likely doing so, even if they are underemployed.

The model shows that due to increased availability/quality of power, the productivity of labor and output (GDP) increase. Hence, the demand for labor increases. Since labor supply—the number of workers in the economy—is fixed in the model, an increase in the demand for labor means that wages must rise to clear the labor market. The wage that clears the labor market equals the new (higher) marginal product of labor. Thus, the new equilibrium is characterized by an increase in GDP, higher productivity of labor, and an increase in wages.

To assess the effect on job creation, one option is to estimate how many more workers (with the same productivity as in the baseline) would be required to achieve the new real GDP levels in the different scenarios. This concept—the "employment equivalent to real GDP changes"—provides an indirect measure of jobs created.

Box table 4.1.1 shows the GDP equivalent employment results for each scenario. When measured using this implicit employment measure, net jobs increase in all scenarios. Scenario 3 (reduction in outages) has the largest implicit job creation potential for all countries except Senegal, and Nigeria has the largest job increase in this scenario. In Senegal, Scenario 4 (increase in the efficiency of electricity consumption) has the largest job impact, because the positive impacts from Scenario 3 are not as large as for the other countries.

(*continues*)

BOX 5.1 (*Continued*)

TABLE 5.1.1

Employment Equivalent to Change in Real GDP in the Four Scenarios

COUNTRY	SCENARIO 1		SCENARIO 2		SCENARIO 3		SCENARIO 4	
	PERCENT CHANGE IN NUMBER OF NEW WORKERS	NUMBER OF NEW WORKERS	PERCENT CHANGE IN NUMBER OF NEW WORKERS	NUMBER OF NEW WORKERS	PERCENT CHANGE IN NUMBER OF NEW WORKERS	NUMBER OF NEW WORKERS	PERCENT CHANGE IN NUMBER OF NEW WORKERS	NUMBER OF NEW WORKERS
Côte d'Ivoire	0.26%	24,087	0.18%	16,482	0.60%	55,420	0.57%	51,935
Ethiopia	0.21%	134,791	0.84%	533,442	1.15%	727,511	0.10%	60,072
Ghana	0.47%	72,476	0.23%	35,904	1.79%	274,077	0.66%	100,635
Kenya	0.43%	125,162	0.76%	220,432	1.77%	511,806	0.16%	44,977
Mozambique	0.11%	17,378	0.09%	14,298	1.68%	271,420	0.59%	95,104
Nigeria	0.00%	1,288	0.00%	299	2.51%	1,772,058	0.05%	38,390
Senegal	0.13%	6,631	0.38%	19,400	0.27%	13,917	0.82%	41,399
South Africa	0.29%	48,118	0.32%	52,634	1.88%	314,296	0.34%	56,580
Tanzania	0.12%	44,158	0.12%	43,942	1.78%	656,875	0.30%	111,290

Endnotes

1. All scenarios ensure that demand is met by supply of power. In Scenarios 1 and 2, generation expands to meet exogenous power demand growth under the baseline; in Scenario 3 investment in T&D ensures outages/losses are reduced (to close to zero) so supply is able to meet baseline demand. In Scenario 4, investment in energy efficiency lowers the cost of achieving the existing level of utility or baseline "demand".
2. An exception is South Africa, where the unemployment rate is almost 30 percent (World Bank, 2022).

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APPENDIX A
Technical Aspects of CGE Model

The Cost Structure of Renewable Energy Sources

In 2014, when solar and wind development was at any early stage, several of the countries covered in this analysis had no installed renewable generation. Solar and wind were therefore not included as sources of power for these countries in the Global Trade Analysis Project (GTAP) database. To be able to incorporate them into the model, very low (close to zero) values of renewable generation in these countries were included in the model as a starting point, so that renewable generation could be expanded to the values taken from the EPM for 2020–30.

For these countries, the solar cost structure from Senegal was used. It is in line with data underlying calculations of the levelized cost of electricity generation in the 2015 International Energy Agency/Nuclear Energy Agency report, which find that around 90 percent of the overall cost is capital cost. Small values for solar generation were then assigned to Côte d'Ivoire, Ethiopia, Nigeria, and Mozambique, in order to allow for the calibration of the energy mix and the expansion of solar generation in the scenarios. A similar procedure was followed to include wind generation in Senegal and Tanzania and "other" generation in Tanzania. Once the CGE model included all the new renewable sources that were not in the GTAP database, it was possible to expand these renewables based on the EPM outputs and to update and calibrate the energy mix to 2020 values.

Phantom Taxes

To calibrate the EPM outputs that correct for the limitations of the CGE model, the study used an adjustment mechanism that employs a phantom tax. This mechanism is a technical device that does not affect government revenues or the final electricity price.[1] Phantom taxes create a price wedge between generation costs and final prices that allows the CGE to achieve large changes in energy generation from sources associated with large investment projects. These phantom taxes proxy for the capacity constraints that are implicit in the EPM electricity generation values. If an energy source cannot expand generation beyond a particular level (for example, hydropower generation is constrained by the installed capacity of hydropower in the country), then the phantom tax fixes energy supply to the generation levels in the EPM. When the tax is applied to hydroelectric generation, it increases production costs for suppliers until final generation reaches the desired level. To maintain the revenue neutrality of this tax on hydroelectric generation, the model applies an equally distributed subsidy to other generation activities, which reduces their production costs and increases their generation levels. This tax adjustment calibrates generation activities to the desired EPM levels and sets the revenue from the taxed activities equal to the subsidy paid to the remaining generation activities. Electricity consumed by firms and households is a single commodity that is generated by all sources. As a result, the phantom tax affects only the energy mix employed to generate electricity, not final electricity prices.

Although the phantom tax mechanism is very effective for calibrating the energy mix, in some cases the adjustments required are so large that the CGE model can be calibrated to the EPM values for a specific year only through gradual changes over a longer time period. Appendix D identifies and discusses the resulting calibrated generation values in the CGE model and the main challenges encountered for each country.

Electricity Demand

The CGE model determines electricity demand endogenously, based on macroeconomic conditions, changes in sectoral production and sectoral energy intensity, and changes in electricity supply and electricity trade.[2] The EPM model takes as exogenous the value of electricity demand over time, based on expert opinions (reflecting physical constraints on the speed build-out of power plants and of grid expansion) and other energy-related data (the utility demand forecast is often used). The EPM uses the same demand forecast across all scenarios. As electricity demand does not change, for any scenario in the EPM any increase in electricity supply from a specific source must be compensated by an equivalent decrease in supply from other sources or by an increase in net electricity exports. This condition imposes an artificial constraint in modeling the impact of policy changes through the CGE model, as electricity demand would also be expected to change in any scenario in which electricity is less expensive and/or more reliably supplied, because, for example, energy-intensive sectors benefit from low-cost electricity and expand, demanding even more power, and household spending on electricity declines, with the possibility that their demand for other goods in the economy increases.

Electricity Trade

Calibrating electricity trade using the EPM outputs is particularly challenging. The 2014 GTAP database does not include electricity trade for most countries (values are either zero or very small). However, the EPM outputs show relatively large electricity trade volumes (with respect to overall country generation), reflecting increased electricity trade in the various African power pools (East Africa Power Pool, Southern Africa Power Pool, and West Africa Power Pool.

To bridge this gap, the report team introduced electricity trade data in addition to the GTAP database data in the baseline, to be used from the beginning and better reflect the EPM values. This addition avoids the modelling challenge created when electricity trade disrupts the supply–demand balance of two countries simultaneously, making it hard to calibrate while keeping the constraints on the energy mix. Phantom taxes were also used to facilitate increasing electricity trade volumes in the GTAP power baseline.

Endnotes

1. These taxes are called *phantom taxes* because the revenue generated by a tax in a particular energy source is neutralized by a uniform subsidy to all other energy sources. Total revenues from the tax are therefore always zero.
2. Electricity demand is defined as domestic final consumption of electricity by households and government and use of electricity as an intermediate input for firms in all economic activities. Total electricity supply should therefore equal domestic electricity demand plus net electricity trade. This market-clearing condition is satisfied by changes in the relative price of electricity. (This is different from overall theoretical electricity demand since unserved demand exists in many sub-Saharan Africa countries.)

APPENDIX B
The Electricity Planning Model (EPM)

The World Bank Electricity Planning Model (EPM) is a power system planning tool developed by the Power System Planning Group of the World Bank. The core mixed integer (MIP) multi-zone model, implemented in the General Algebraic Modelling System (GAMS), minimizes the total discounted system costs, which include the annualized investment costs of new generation and transmission projects, fuel costs, fixed and variable operations and maintenance (O&M), import costs or export revenues of trade with external zones, and the cost of unserved energy. The model optimizes the expansion of generation and transmission in the long term as well as the underlying dispatch of generation and flows on transmission lines for existing and new transmission assets. In addition to the core decision variables on generation and transmission capacity addition (dispatch and flow), the model co-optimizes the spinning reserve provision from the generators.

The core EPM accounts for the following constraints relevant to investment and dispatch optimization:

- demand and capacity reserve requirements (meeting the demand for each load block and meeting the reserve requirement for each load condition)
- minimum and maximum generation limits for power plants
- intermittency of variable renewable resources (solar, wind) in the short, medium, and long term (inter-annual) as well as their impacts on spinning reserve
- maximum ramp-up and ramp-down rates of generators
- transmission limits between different internal and external zones
- joint capacity limit on generators for energy and reserve
- spinning reserve constraints
- transmission security constraints
- any applicable constraint on demand-side response.

The model was developed by the Power System Planning Group of the World Bank in 2015. It has been implemented in more than 80 developing countries to inform investment decisions and policy analyses. It is deployed largely for the World Bank's internal analysis and in capacity-building exercises for utilities and ministries conducted by the Bank.
It has also been adopted by some utility planning groups, through World Bank technical assistance projects. The model has been used extensively for regional markets, such as Central Asia, South Asia, the Middle East, North Africa, and the West Africa Power Pool.

APPENDIX C

Cost Structures by Generation Source

The Global Trade Analysis Project (GTAP)-Power database (version 10.1) includes 2014 generation levels for each power source and a detailed cost structure for power generated by source that includes capital, different labor types (skilled and unskilled), and several intermediate inputs. Figures C.1–C.7 provide cost structure for all electricity generation sources used in the modelling. Capital costs dominate the cost structure of renewable sources (solar, wind, and hydro). Intermediate inputs, mainly the fuel costs, dominate cost structures of fossil fuel sources. No source of energy is labor intensive.

GTAP database contains only cost structures of power generation sources that already exist in the country. Given that some of the sources get introduced to a country mix during the time horizon of the modelling, 2030, the costs structures of those sources are approximated by structures of neighboring countries, as indicated in the notes. If country does not use a particular source of energy depicted of the figure during the modelling time horizon, the country is excluded from the figure.

FIGURE C.1

Cost structure for Solar Generation, by Country

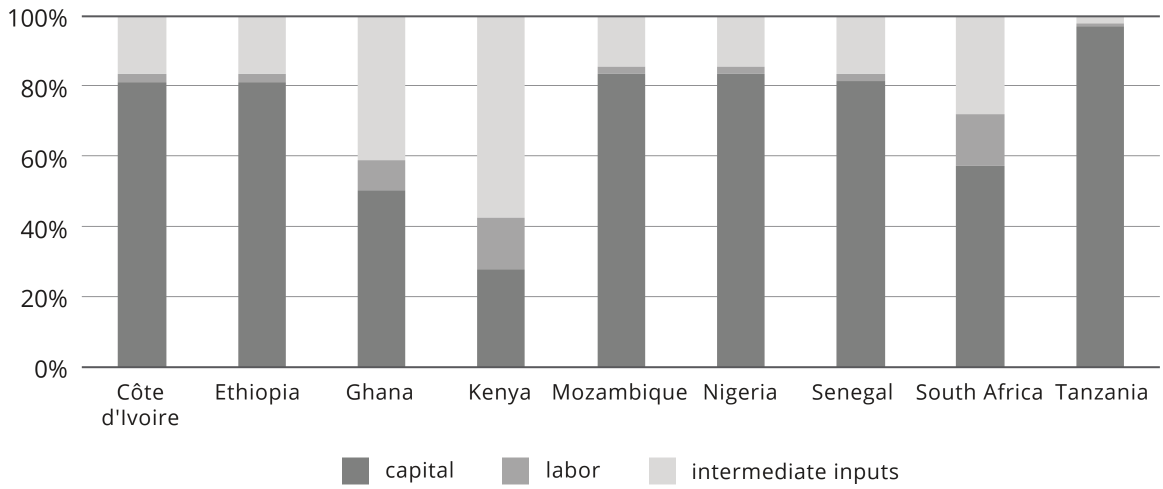
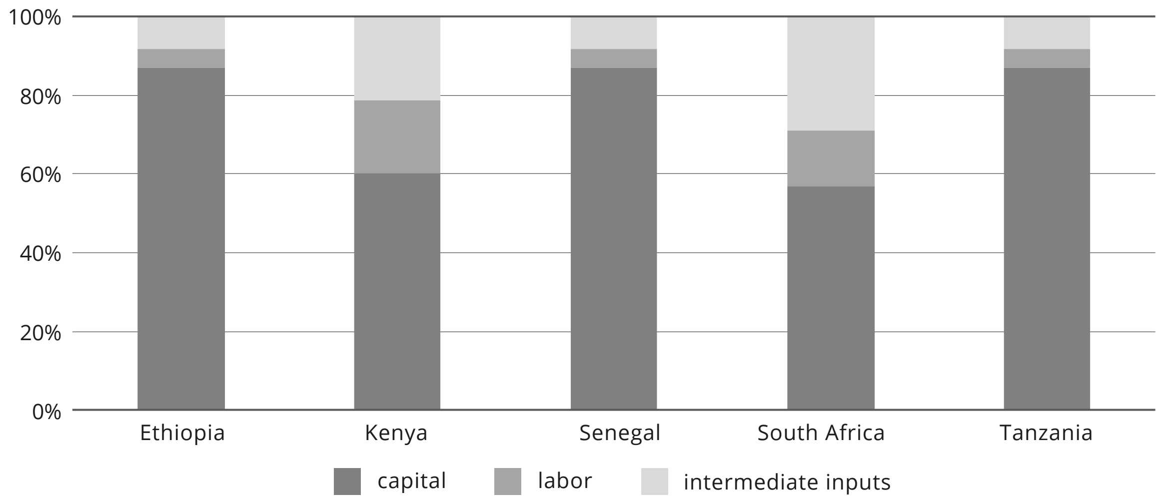


FIGURE C.2

Cost Structure for Wind Generation, by Country



Note: For Côte d'Ivoire, Ghana, Mozambique, and Nigeria, the cost structure of Senegal is used.

FIGURE C.3

Cost Structure for Gas Generation, by Country

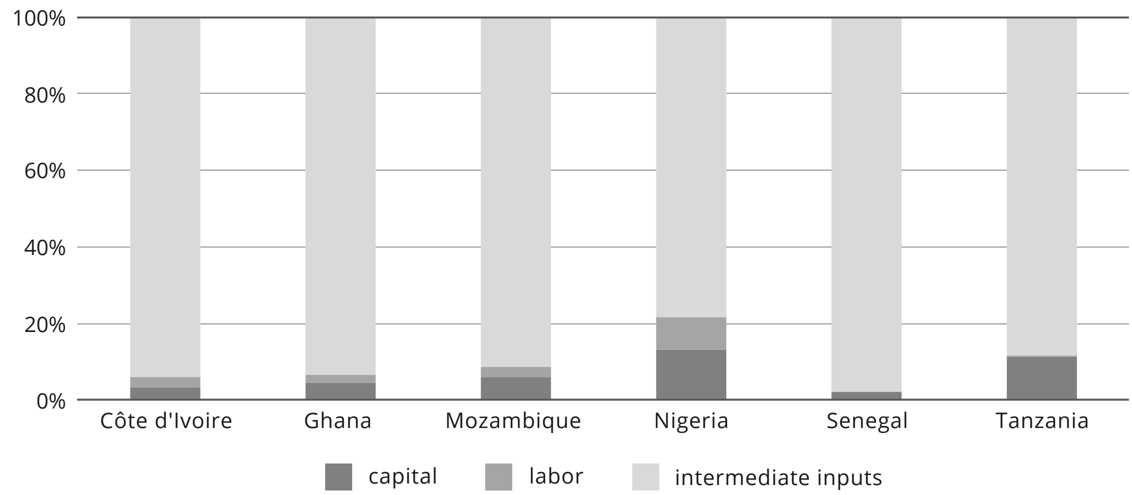


FIGURE C.4

Cost Structure for Coal Generation, South Africa

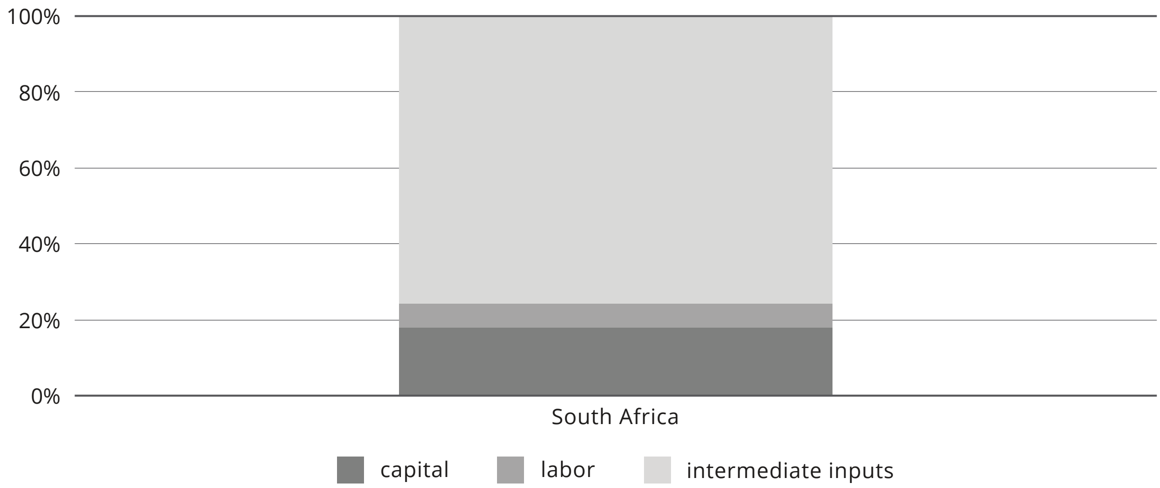


FIGURE C.5

Cost Structure for Hydropower Generation, by Country

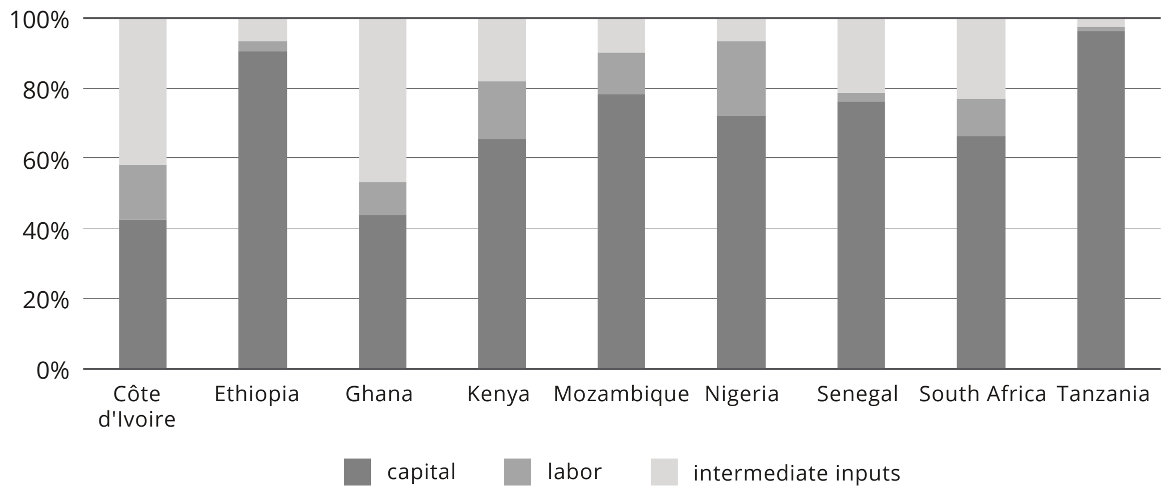


FIGURE C.6

Cost Structure for Diesel Generation

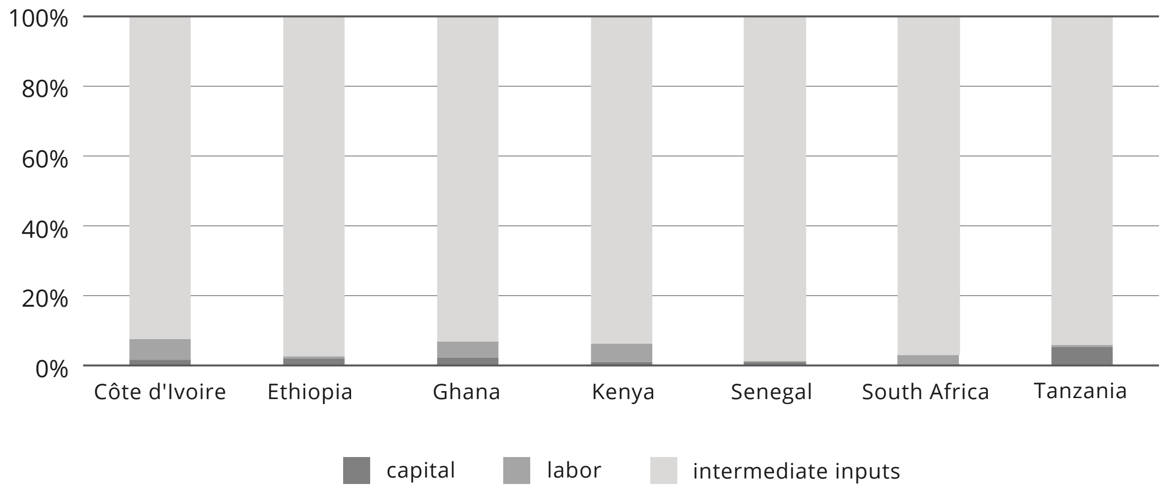
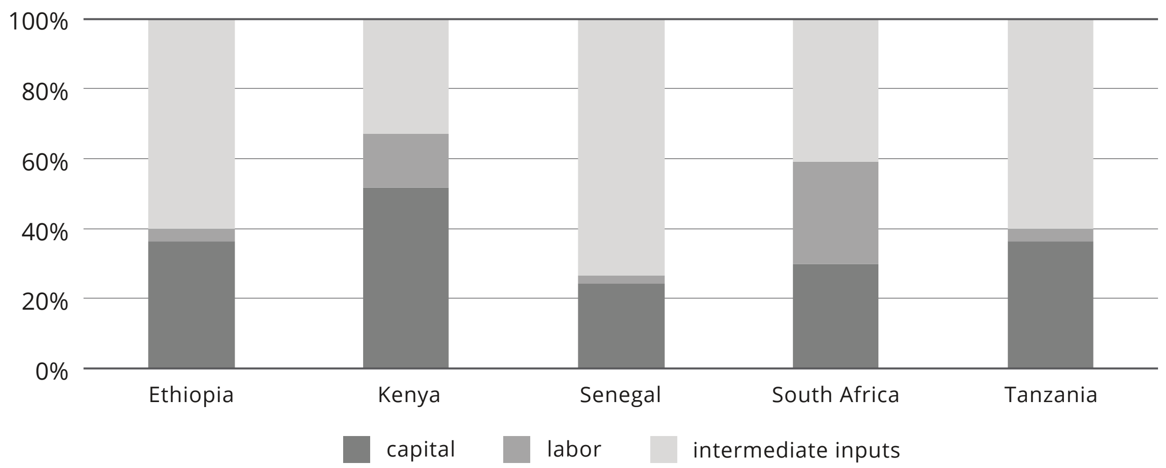


FIGURE C.7

Cost Structure for Other Generation Sources, by Country



Note: Other sources include bioenergy, geothermal and nuclear power.

APPENDIX D
Comparison of Baseline Calibration Using EPM Outputs and Initial GTAP Values

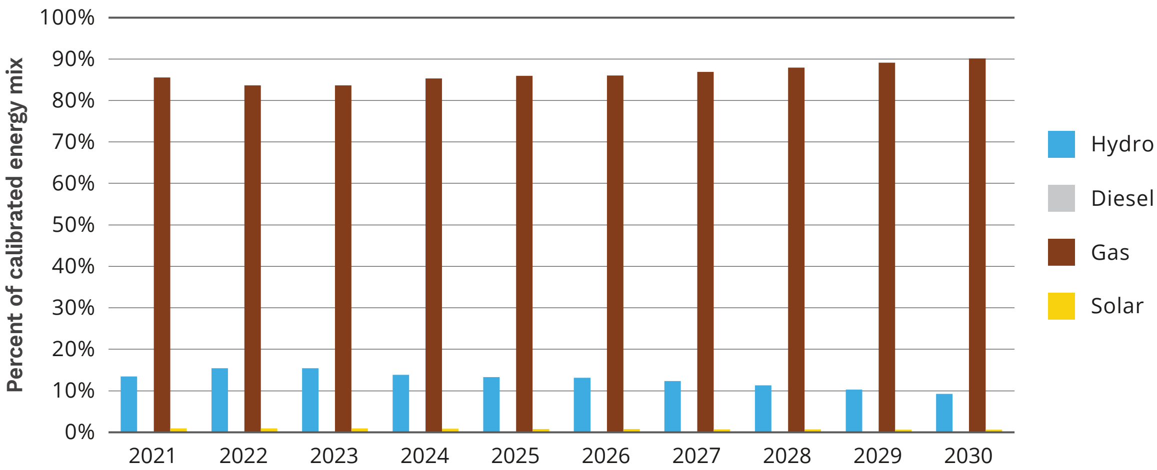
Each of the nine countries analyzed required special consideration regarding the calibration of the energy mix, the trade values, or both. This appendix provides information on each of the nine countries. Region codes appearing in the country notes are explained in appendix F.

Côte d'Ivoire

- The energy mix is well calibrated.
- The GTAP included diesel generation that was not in the EPM, so it is kept at a very low level.
- Electricity exports are mainly to Burkina Faso and Mali (region XWF) with small volume of exports to Ghana.
- Initial GTAP trade values were small but not zero; 2030 trade values are well calibrated.

FIGURE D.1

Energy Mix in Côte d'Ivoire, 2021–30



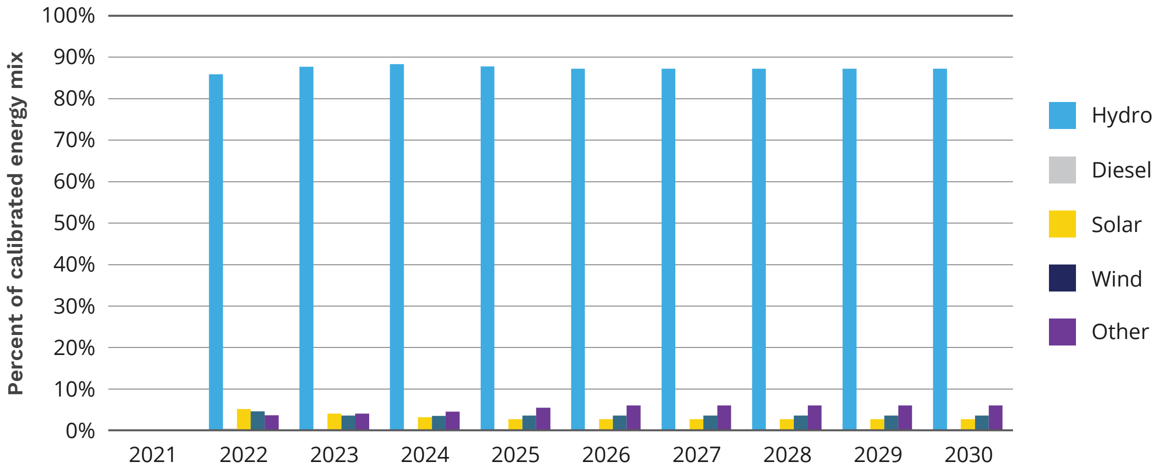
		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Calibrated	Hydro	13.42%	15.40%	15.40%	13.83%	13.24%	13.13%	12.32%	11.34%	10.23%	9.23%
	Diesel	0.05%	0.05%	0.05%	0.04%	0.04%	0.04%	0.04%	0.03%	0.03%	0.03%
	Gas	85.56%	83.65%	83.65%	85.32%	85.94%	86.07%	86.93%	87.96%	89.14%	90.19%
	Solar	0.96%	0.90%	0.90%	0.81%	0.77%	0.77%	0.72%	0.66%	0.60%	0.55%
EPM inputs	Hydro	13.43%	15.41%	15.41%	13.84%	13.25%	13.13%	12.32%	11.35%	10.23%	9.23%
	Diesel	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Gas	85.60%	83.69%	83.69%	85.36%	85.98%	86.10%	86.96%	87.99%	89.17%	90.22%
	Solar	0.97%	0.90%	0.90%	0.81%	0.77%	0.77%	0.72%	0.66%	0.60%	0.55%

Ethiopia

- The energy mix is well calibrated.
- The GTAP included diesel generation that was not in EPM, so it is kept at a very low level.
- Electricity exports are to Djibouti and Sudan (XEC region) and Kenya.
- GTAP has zero trade values, but trade values are calibrated close to EPM values for later years.

FIGURE D.2

Energy Mix in Ethiopia, 2021–30



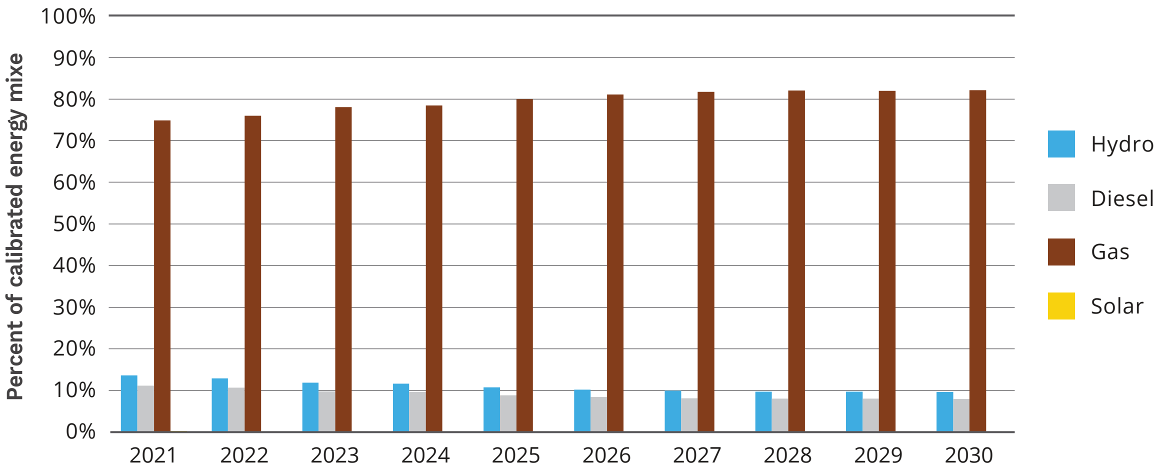
		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Calibrated	Hydro		86.17%	87.99%	88.62%	88.00%	87.52%	87.52%	87.52%	87.52%	87.52%
	Diesel		0.42%	0.33%	0.25%	0.22%	0.22%	0.22%	0.22%	0.22%	0.22%
	Wind		4.60%	3.61%	3.47%	3.60%	3.58%	3.58%	3.58%	3.58%	3.58%
	Solar		5.13%	4.03%	3.12%	2.70%	2.68%	2.68%	2.68%	2.68%	2.68%
	Other		3.67%	4.04%	4.54%	5.48%	6.00%	6.00%	6.00%	6.00%	6.00%
EPM inputs	Hydro		84.27%	89.72%	88.58%	88.73%	88.73%	88.73%	88.73%	88.73%	88.73%
	Diesel		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Wind		5.40%	3.53%	2.75%	3.44%	3.44%	3.44%	3.44%	3.44%	3.44%
	Solar		6.02%	3.94%	2.47%	2.23%	2.23%	2.23%	2.23%	2.23%	2.23%
	Other		4.3%	2.8%	6.2%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%

Ghana

- The energy mix is well calibrated.
- Electricity exports are to Burkina Faso and Togo (XWF region) and Côte d'Ivoire.
- GTAP has zero trade values, but trade values are calibrated for XWF close to EPM values for later years. Côte d'Ivoire was left with zero trade throughout, because it was difficult to make the model correctly reflect the direction of the bilateral trade.

FIGURE D.3

Energy mix in Ghana, 2021–30



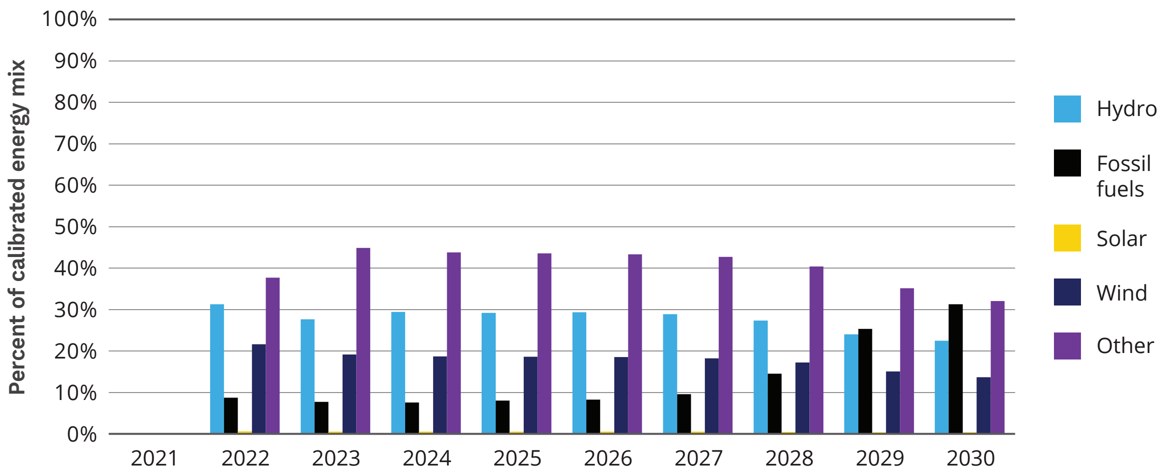
		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Calibrated	Hydro	13.59%	13.00%	11.92%	11.69%	10.83%	10.25%	9.94%	9.75%	9.77%	9.68%
	Diesel	11.22%	10.73%	9.84%	9.65%	8.94%	8.46%	8.20%	8.05%	8.06%	7.99%
	Gas	74.91%	76.01%	78.01%	78.41%	80.00%	81.08%	81.66%	81.99%	81.97%	82.13%
	Solar	0.28%	0.26%	0.24%	0.24%	0.22%	0.21%	0.20%	0.20%	0.20%	0.20%
EPM inputs	Hydro	13.59%	13.00%	11.92%	11.69%	10.83%	10.25%	9.94%	9.75%	9.77%	9.68%
	Diesel	11.22%	10.73%	9.84%	9.65%	8.94%	8.46%	8.20%	8.05%	8.06%	7.99%
	Gas	74.91%	76.01%	78.01%	78.41%	80.00%	81.08%	81.66%	81.99%	81.97%	82.13%
	Solar	0.28%	0.26%	0.24%	0.24%	0.22%	0.21%	0.20%	0.20%	0.20%	0.20%

Kenya

- The energy mix is well calibrated.
- The GTAP included diesel generation but no coal or gas generation. The EPM includes diesel until 2020, coal generation starting in 2022, and gas generation starting in 2025.
- Coal and gas generation are classified as fossil fuel generation using the existing GTAP diesel cost structure.
- Electricity exports are to Ethiopia, Tanzania, and Uganda (XEC region).
- GTAP has zero trade values, except for the XEC region, but given the large fluctuations in trade it is very hard to calibrate. Values are calibrated only for Tanzania, the only positive values for 2030.

FIGURE D.4

Energy Mix in Kenya, 2021–30



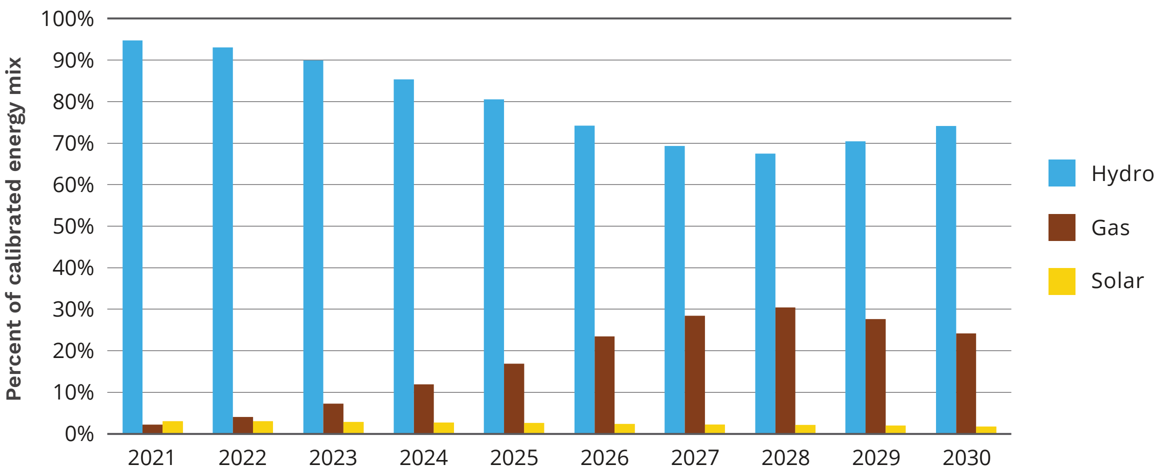
		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Calibrated	Hydro		31.25%	27.68%	29.41%	29.25%	29.34%	28.89%	27.32%	24.02%	22.52%
	Fossil fuels		8.74%	7.75%	7.56%	8.07%	8.25%	9.63%	14.56%	25.36%	31.27%
	Wind		21.64%	19.17%	18.71%	18.61%	18.53%	18.25%	17.26%	15.03%	13.72%
	Solar		0.62%	0.55%	0.53%	0.53%	0.53%	0.52%	0.49%	0.43%	0.39%
	Other		37.75%	44.85%	43.78%	43.54%	43.36%	42.70%	40.37%	35.16%	32.10%
EPM inputs	Hydro		31.25%	27.69%	29.42%	29.26%	29.34%	28.90%	27.84%	23.27%	22.09%
	Fossil fuels		8.74%	7.75%	7.56%	8.07%	8.25%	9.63%	12.92%	27.72%	32.58%
	Wind		21.64%	19.17%	18.71%	18.61%	18.53%	18.25%	17.59%	14.55%	13.46%
	Solar		0.62%	0.55%	0.53%	0.53%	0.53%	0.52%	0.50%	0.42%	0.38%
	Other		37.7%	44.8%	43.8%	43.5%	43.4%	42.7%	41.1%	34.0%	31.5%

Mozambique

- The energy mix is difficult to calibrate because of the very large increase in natural gas generation in 2025, which rises from 0 to 34 percent of total generation. The change was dealt with by increasing the value gradually over several years.
- Very small biomass generation (constant over time) was added to hydropower generation.
- Electricity exports in 2030 are only to South Africa.
- The GTAP has zero trade values. A positive value was therefore included throughout the period to reach the 2030 trade values.

FIGURE D.5

Energy Mix in Mozambique, 2021–30



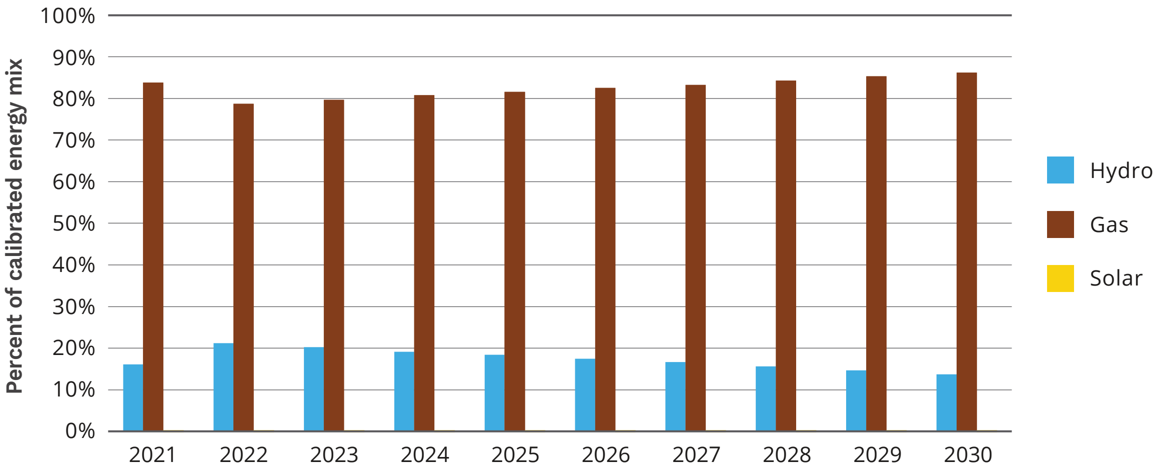
		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Calibrated	Hydro	94.77%	93.02%	89.94%	85.33%	80.52%	74.24%	69.37%	67.45%	70.44%	74.09%
	Gas	2.22%	4.02%	7.20%	11.95%	16.92%	23.40%	28.42%	30.40%	27.61%	24.20%
	Solar	3.01%	2.96%	2.86%	2.71%	2.56%	2.36%	2.21%	2.15%	1.95%	1.71%
EPM inputs	Hydro	97.08%	97.08%	97.08%	97.08%	64.44%	64.44%	64.44%	64.44%	64.44%	82.38%
	Gas	0.00%	0.00%	0.00%	0.00%	33.61%	33.61%	33.61%	33.61%	33.61%	16.66%
	Solar	2.92%	2.92%	2.92%	2.92%	1.94%	1.94%	1.94%	1.94%	1.94%	0.96%

Nigeria

- The energy mix is well calibrated.
- Electricity exports are to Niger and Benin (XWF region).
- GTAP has zero trade values, but calibrated trade values are close to those in the EPM.

FIGURE D.6

Energy Mix in Nigeria, 2021–30



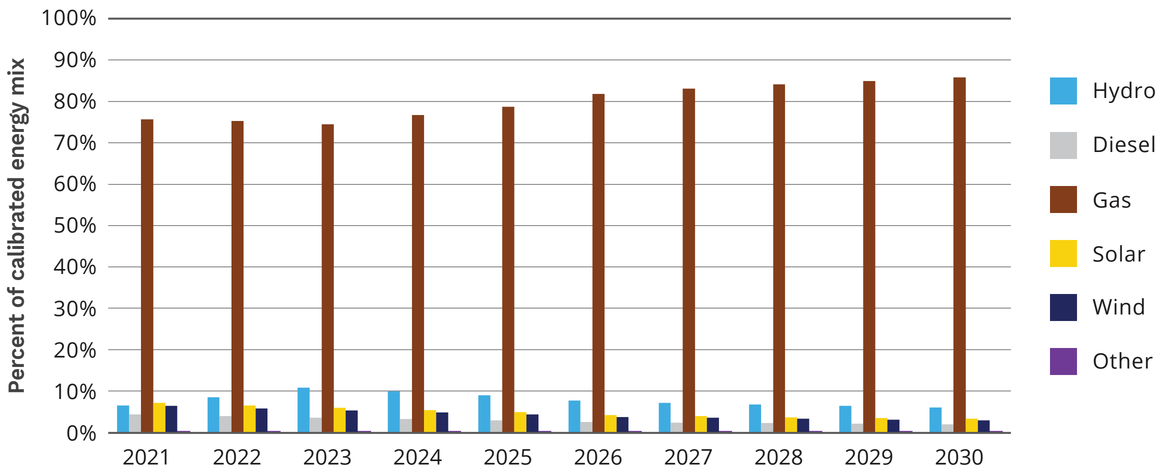
		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Calibrated	Hydro	16.12%	21.21%	20.24%	19.14%	18.37%	17.41%	16.66%	15.61%	14.63%	13.72%
	Gas	83.87%	78.78%	79.75%	80.85%	81.62%	82.58%	83.33%	84.38%	85.36%	86.27%
	Solar	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%
EPM inputs	Hydro	16.12%	21.21%	20.24%	19.14%	18.37%	17.41%	16.66%	15.61%	14.63%	13.72%
	Gas	83.88%	78.79%	79.76%	80.86%	81.63%	82.59%	83.34%	84.39%	85.37%	86.28%
	Solar	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Senegal

- The energy mix is well calibrated.
- The GTAP includes "other" generation that is not in the EPM outputs, so it is kept at a very low level.
- Electricity exports are to Mali (XWF region).
- GTAP has zero trade values, but calibrated trade values are close to EPM values in later years; differences in initial years are large.

FIGURE D.7

Energy Mix in Senegal, 2021–30



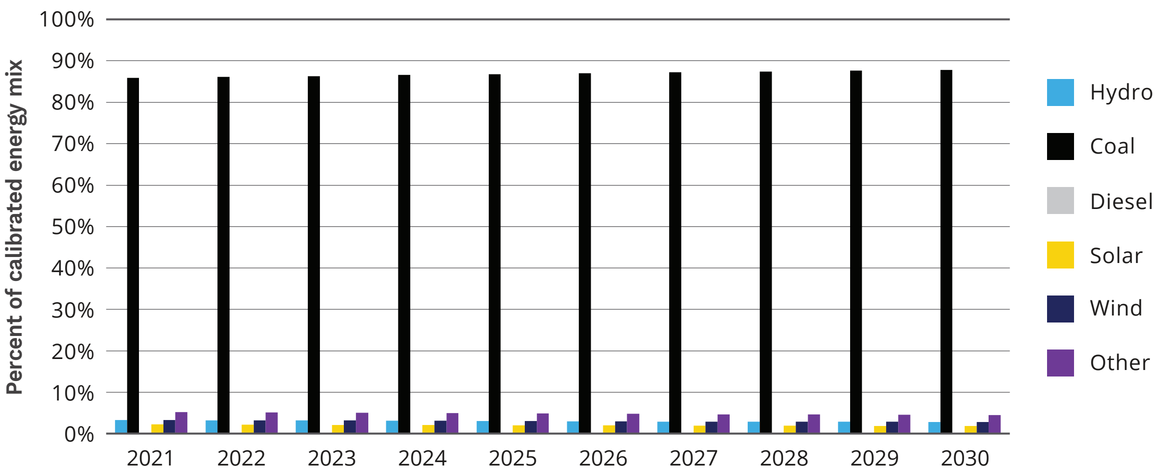
		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Calibrated	Hydro	6.51%	8.52%	10.80%	9.85%	9.00%	7.67%	7.17%	6.72%	6.36%	6.01%
	Diesel	4.27%	3.88%	3.53%	3.22%	2.94%	2.51%	2.34%	2.19%	2.08%	1.96%
	Gas	75.65%	75.27%	74.45%	76.71%	78.72%	81.85%	83.05%	84.11%	84.96%	85.78%
	Wind	6.35%	5.77%	5.25%	4.79%	4.38%	3.73%	3.49%	3.27%	3.09%	2.92%
	Solar	7.12%	6.47%	5.89%	5.37%	4.91%	4.18%	3.91%	3.66%	3.47%	3.28%
	Other	0.09%	0.08%	0.08%	0.07%	0.06%	0.05%	0.05%	0.05%	0.05%	0.04%
EPM inputs	Hydro	6.5%	8.5%	10.8%	9.9%	9.0%	7.7%	7.2%	6.7%	6.4%	6.0%
	Diesel	4.27%	3.88%	3.53%	3.22%	2.94%	2.51%	2.34%	2.20%	2.08%	1.97%
	Gas	75.72%	75.33%	74.50%	76.76%	78.77%	81.89%	83.09%	84.15%	85.00%	85.81%
	Wind	6.36%	5.78%	5.26%	4.79%	4.38%	3.73%	3.49%	3.27%	3.09%	2.93%
	Solar	7.13%	6.48%	5.90%	5.37%	4.91%	4.19%	3.91%	3.67%	3.47%	3.28%
	Other	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

South Africa

- The energy mix is well calibrated.
- The GTAP includes diesel generation that is not in the EPM, so it is kept at a very low level.
- A small share of natural gas generation (0.3 percent of total) in 2030 is added as diesel generation.
- Relatively small electricity exports are mainly to countries in the XSC region (Lesotho, Eswatini, Botswana, and Namibia) and Mozambique.
- GTAP has non-zero trade values, which made it easier to calibrate trade values to the EPM.

FIGURE D.8

Energy Mix in South Africa, 2021–30



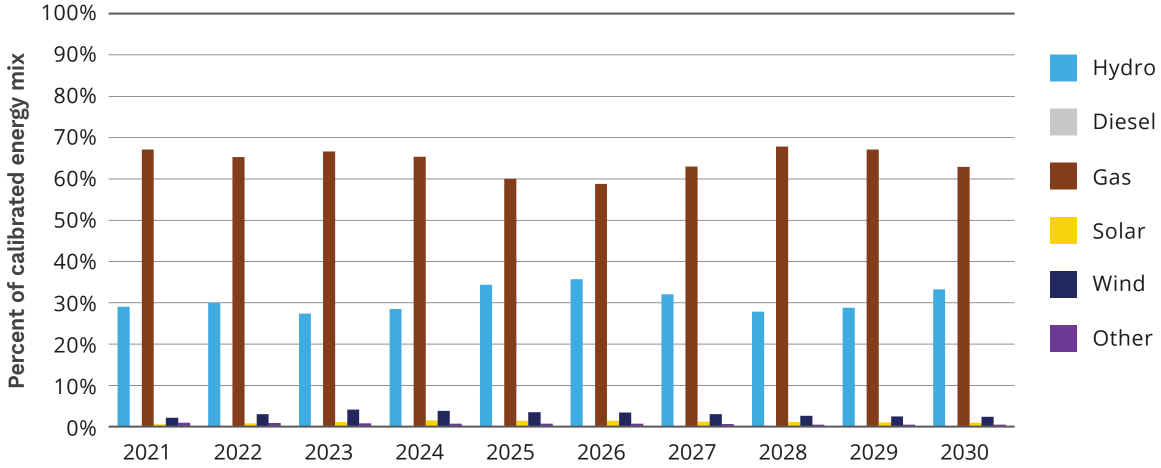
		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Calibrated	Hydro	3.28%	3.22%	3.17%	3.11%	3.06%	3.01%	2.96%	2.91%	2.86%	2.82%
	Coal	85.86%	86.10%	86.34%	86.57%	86.79%	87.01%	87.23%	87.44%	87.64%	87.82%
	Diesel	0.18%	0.18%	0.17%	0.17%	0.17%	0.17%	0.16%	0.16%	0.16%	0.17%
	Wind	3.27%	3.22%	3.16%	3.11%	3.06%	3.01%	2.96%	2.91%	2.86%	2.82%
	Solar	2.19%	2.16%	2.12%	2.08%	2.05%	2.02%	1.98%	1.95%	1.92%	1.89%
	Other	5.22%	5.13%	5.04%	4.96%	4.87%	4.79%	4.71%	4.64%	4.56%	4.49%
EPM inputs	Hydro	3.28%	3.23%	3.17%	3.12%	3.07%	3.01%	2.96%	2.92%	2.87%	2.81%
	Coal	86.02%	86.26%	86.49%	86.71%	86.93%	87.15%	87.37%	87.58%	87.78%	87.66%
	Diesel	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.36%
	Wind	3.28%	3.22%	3.17%	3.11%	3.06%	3.01%	2.96%	2.91%	2.87%	2.81%
	Solar	2.20%	2.16%	2.12%	2.09%	2.05%	2.02%	1.99%	1.95%	1.92%	1.88%
	Other	5.23%	5.14%	5.05%	4.96%	4.88%	4.80%	4.72%	4.64%	4.57%	4.48%

Tanzania

- The energy mix is well calibrated.
- Diesel generation is substantial 2020, after which it is kept at a very low level.
- Tanzania has no electricity exports in either the EPM or the GTAP.

FIGURE D.9

Energy Mix in Tanzania, 2021–30



		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Calibrated	Hydro	29.10%	29.99%	27.31%	28.53%	34.34%	35.70%	32.05%	27.88%	28.79%	33.25%
	Diesel	0.03%	0.03%	0.03%	0.03%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%
	Gas	67.10%	65.27%	66.63%	65.37%	60.05%	58.81%	63.02%	67.82%	67.13%	62.87%
	Wind	2.18%	2.99%	4.09%	3.77%	3.47%	3.39%	3.05%	2.66%	2.52%	2.40%
	Solar	0.60%	0.82%	1.12%	1.54%	1.42%	1.39%	1.25%	1.09%	1.03%	0.98%
	Other	0.99%	0.90%	0.82%	0.76%	0.70%	0.68%	0.61%	0.53%	0.51%	0.48%
EPM inputs	Hydro	29.11%	29.78%	27.21%	28.57%	34.39%	35.75%	32.10%	27.91%	28.82%	33.28%
	Diesel	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Gas	67.12%	64.81%	66.38%	65.47%	60.14%	58.89%	63.10%	67.90%	67.20%	62.94%
	Wind	2.18%	3.96%	3.62%	3.36%	3.09%	3.02%	2.71%	2.36%	2.24%	2.13%
	Solar	0.60%	0.54%	1.98%	1.83%	1.68%	1.65%	1.48%	1.29%	1.23%	1.16%
	Other	0.99%	0.90%	0.82%	0.76%	0.70%	0.68%	0.61%	0.54%	0.51%	0.48%

APPENDIX E

Additional Data on Sectoral Employment Effects

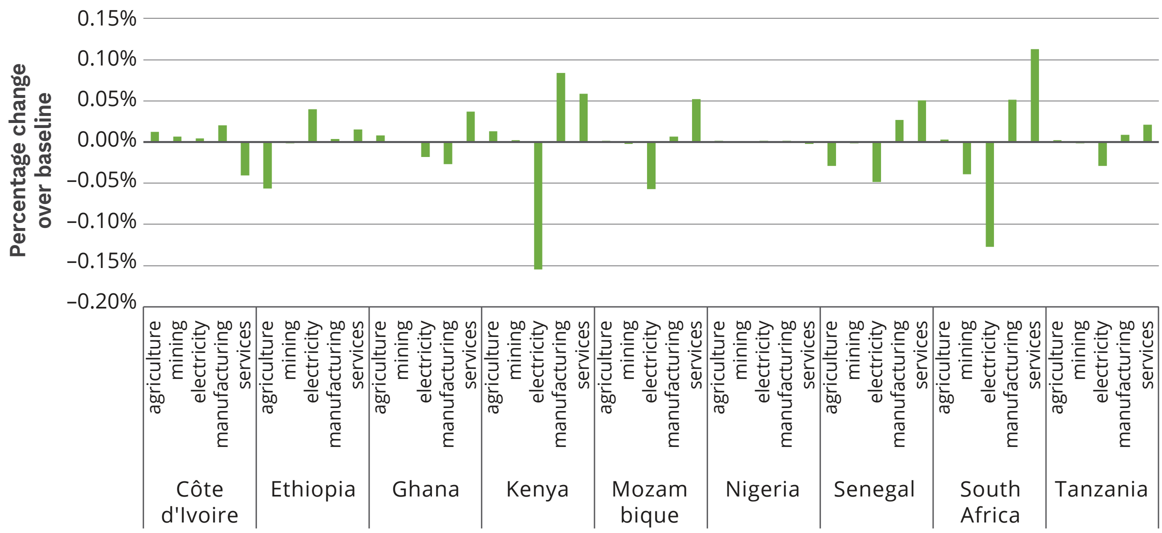
Figure E.1 shows the changes in sectoral employment in Scenario 1 with respect to the baseline values for five broad (aggregate) sectors: agriculture, mining, electricity, manufacturing, and services. These sectoral employment changes are closely related to changes in sectoral production (not shown).

No distinct pattern of change is common to all countries, as these changes depend on multiple factors, including (a) overall GDP and trade changes that affect the demand for production of different sectors and (b) the labor intensity of each sector and the substitution possibilities between labor and capital, among others. The combination of these indirect (general equilibrium) effects and the fact that electricity is not a labor-intensive sector explain why, even though the electricity sector is initially expanding, workers in some countries relocate from electricity to sectors that are also expanding but are labor intensive, such as services. (The construction jobs needed to expand the electricity sector are accounted for under the construction services.) Employment shifts between sectors cancel each other out in aggregate, as total labor supply is fixed at the baseline values each year. The employment changes observed in this scenario are relatively small.

Reductions in employment in the electricity sector are partly a direct consequence of keeping nonrenewable electricity generation fixed at EPM values; the CGE model does not allow the electricity sector to expand beyond the increase in renewable generation that is

FIGURE E.1

Changes in Sectoral Employment in 2030 in Scenario 1



initially imposed in this scenario. This condition ensures that the CGE model respects the technical and physical constraints on expansion of electricity generation specified in the EPM. Electricity employment is fixed in line with EPM technical constraints; all other sectors can attract labor as the economy expands as a result of the initial increase in renewable generation.

Figure E.2 shows the sectoral changes in labor demand for Scenario 2. The demand for labor (employment) in electricity declines, and employment in the services and manufacturing sectors increases, to varying degrees in different countries.

Figure E.3 shows the changes in sectoral employment for Scenario 3. Employment in services expands, in most cases at the expense of agricultural sector. Manufacturing employment either decreases or increases slightly, as a result of t the positive productivity effects of fewer outages on manufacturing activities, which require fewer workers to produce the same amount of goods.[1] This initial expansion of manufacturing raises total income and GDP; increases in aggregate demand induce other sectors to expand as well. These second-round effects attract workers to the expanding sectors and away from manufacturing (which cannot increase beyond the initial expansion imposed for this scenario). The final (general equilibrium) effects on manufacturing employment depend on how strong each labor effect is.

Figure E.4 shows the changing patterns of sectoral employment in Scenario 4. They reflect the changes in production that result from households changing their consumption baskets because of their energy-efficiency gains. Several general equilibrium channels are at play. First, energy-intensive activities are likely to benefit the most, as the initial lower electricity prices from households consuming less electricity, allows these sectors to use more electricity

FIGURE E.2

Changes in Sectoral Employment in 2030 in Scenario 2

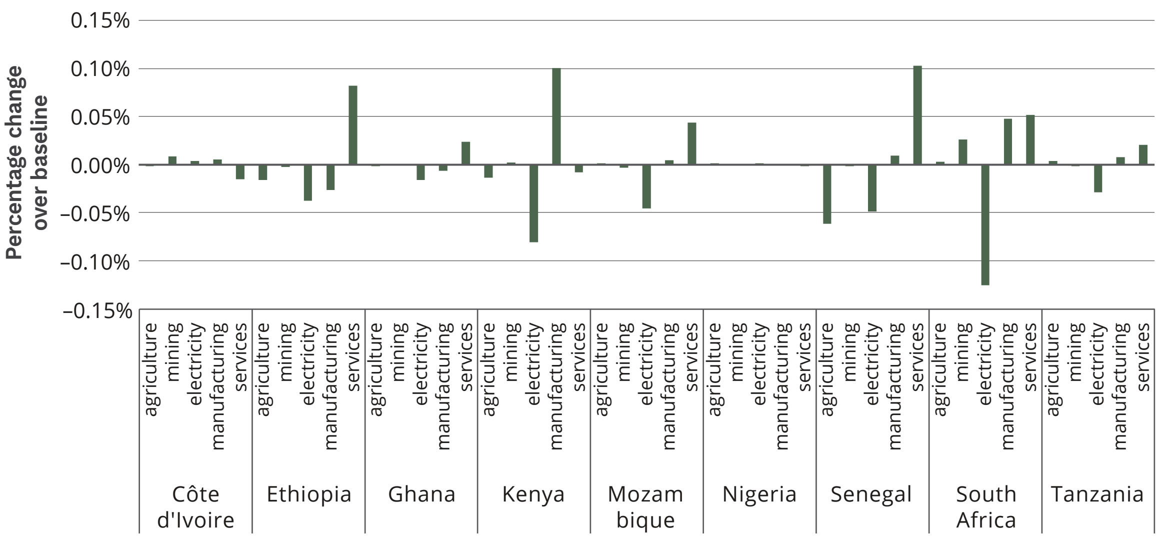


FIGURE E.3

Changes in Sectoral Employment in 2030 Under Scenario 3

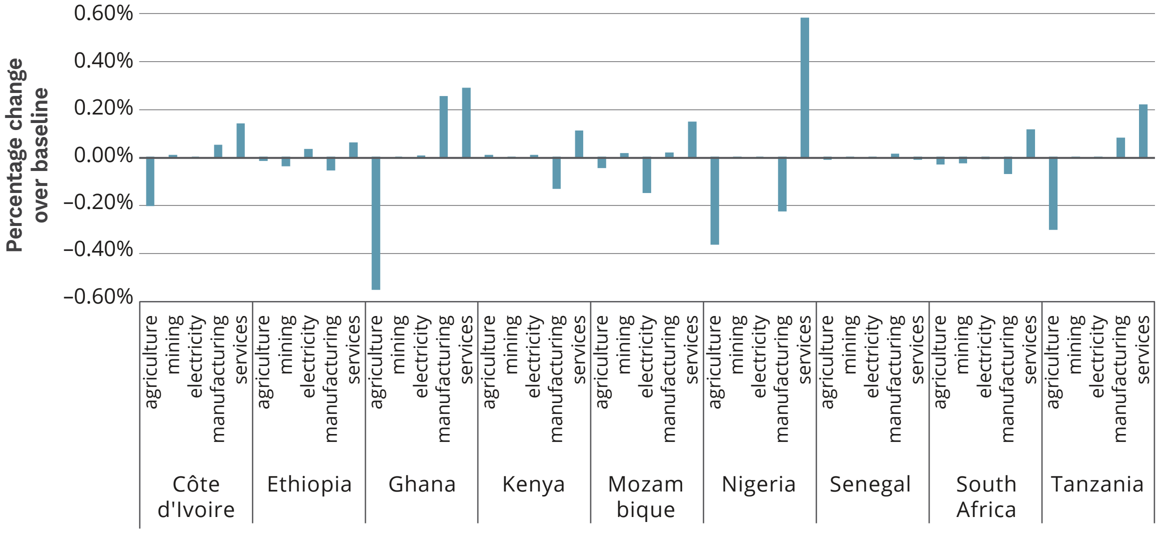
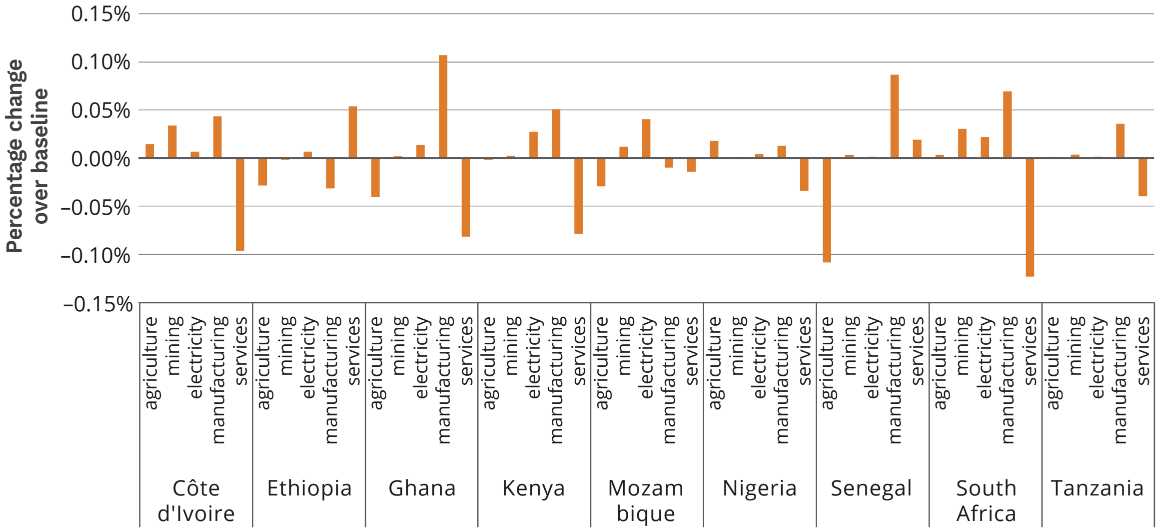


FIGURE E.4

Sectoral Employment in 2030 in Scenario 4



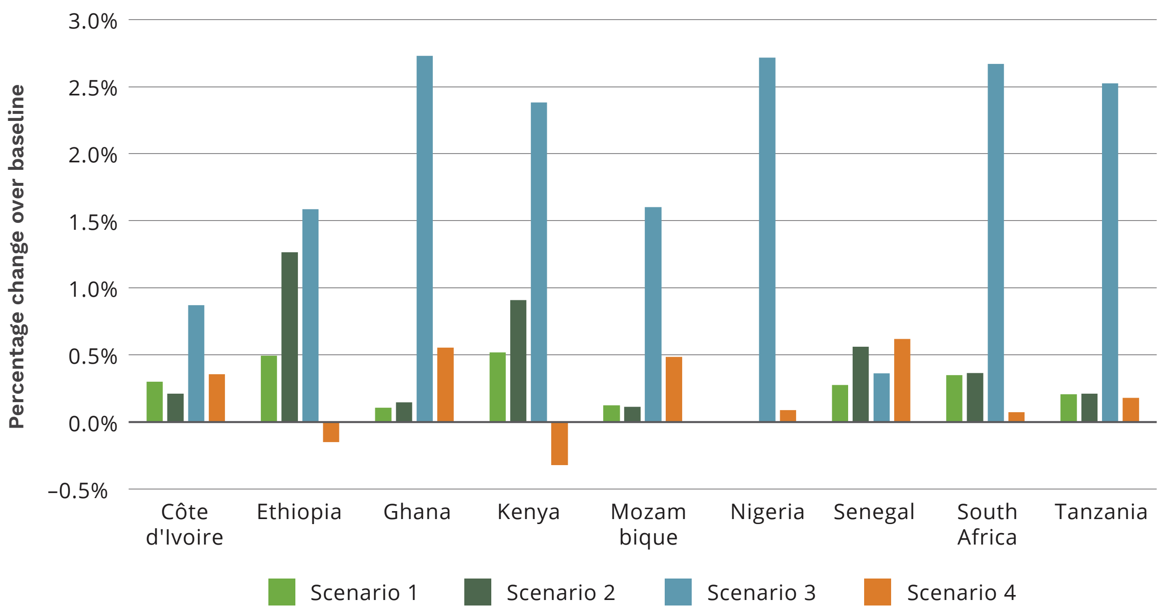
and increase production, compared with less energy-intensive sectors. Second, as households pay less for electricity consumption, they can allocate those savings to consumption of other goods and services. This consumption requires manufacturing sectors producing these (more demanded) commodities to expand. The final changes in sectoral production and employment depend on how strong each effect is for each sector in each country.

The positive GDP effects, which reflect higher overall levels of consumption and production, are also translated into higher total energy demand and higher electricity generation. The power generation mix remains unchanged from the baseline values, implying that electricity generation is expanding in proportion to the baseline shares of each power source. The electricity trade pattern also remains that of the baseline.

Changes in welfare and electricity prices are represented in figures E.5 and E.6.

FIGURE E.5

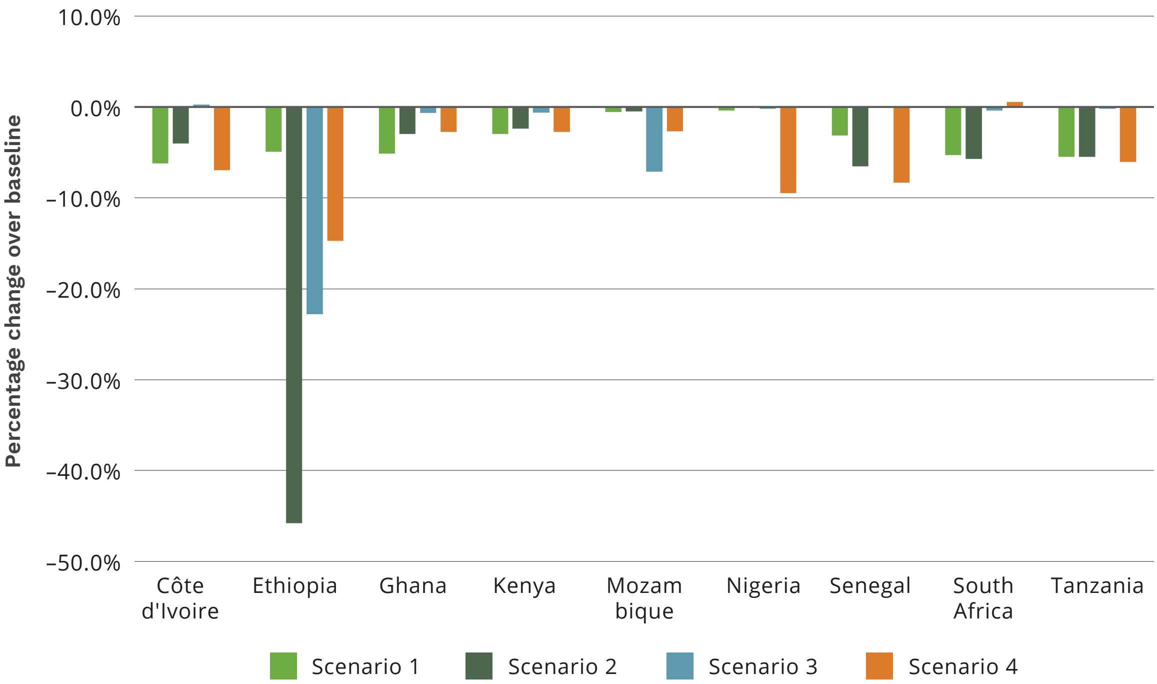
Welfare Effects in 2030 in Each Scenario



Note: Welfare is measured as the percentage change in real consumption with respect to the baseline.

FIGURE E.6

Changes in Electricity Price in 2030 in Each Scenario



Endnote

1. Manufacturing output is not permitted to change beyond the initial increase associated with the elimination of the electricity outages, because the initial increase in manufacturing reflecting the productivity gains from the elimination of outages is the exogenous shock that defines this scenario.

APPENDIX F
Regional and Sectoral Aggregation of the GTAP Database

This appendix contains a key to equivalence of codes used in ENVISAGE and GTAP databases.

TABLE F.1

Regions in the ENVISAGE and GTAP Databases

ENVISAGE REGION	GTAP REGION
Coôte d'Ivoire	Coôte d'Ivoire
Ghana	Ghana
Nigeria	Nigeria
Senegal	Senegal
Ethiopia	Ethiopia
Kenya	Kenya
Mozambique	Mozambique
Tanzania	Tanzania
South Africa	South Africa
Rest of Western Africa (XWF)	Benin (BEN), Burkina Faso (BFA), Cameroon (CMR), Guinea (GIN), Togo (TGO), Rest of Western Africa (XWF)
Rest of Central Africa (XCF)	Central Africa (XCF), South Central Africa (XAC)
Rest of Eastern Africa (XEC)	Madagascar (MDG), Malawi (MWI), Mauritius (MUS), Rwanda (RWA), Uganda (UGA), Zambia (ZMB), Zimbabwe (ZWE), Rest of Eastern Africa (XEC)
Rest of South African Customs Union (XSC)	Botswana (BWA), Namibia (NAM), Rest of South African Customs Union (XSC)
China (CHN)	China (CHN), Hong Kong (HKG)
Rest of East Asia (XEA)	Japan (JPN), Korea (KOR), Mongolia (MNG), Taiwan (TWN), Rest of East Asia (XEA)
United States (USA)	United States of America (USA)
European Union + EFTA (WEU)	Austria (AUT), Belgium (BEL), Cyprus (CYP), Czech Republic (CZE), Denmark (DNK), Estonia (EST), Finland (FIN), France (FRA), Germany (DEU), Greece (GRC), Hungary (HUN), Ireland (IRL), Italy (ITA), Latvia (LVA), Lithuania (LTU), Luxembourg (LUX), Malta (MLT), Netherlands (NLD), Poland (POL), Portugal (PRT), Slovakia (SVK), Slovenia (SVN), Spain (ESP), Sweden (SWE), United Kingdom (GBR), Switzerland (CHE), Norway (NOR), Rest of EFTA (XEF), Bulgaria (BGR), Croatia (HRV), Romania (ROU)

(*continues*)

TABLE F.1

Regions in the ENVISAGE and GTAP Databases (*Continued*)

ENVISAGE REGION	GTAP REGION
Rest of World (ROW)	Australia (AUS), New Zealand (NZL), Rest of Oceania (XOC), Brunei Darussalam (BRN), Cambodia (KHM), Indonesia (IDN), Laos (LAO), Malaysia (MYS), Philippines (PHL), Singapore (SGP), Thailand (THA), Viet Nam (VNM), Rest of Southeast Asia (XSE), Bangladesh (BGD), India (IND), Nepal (NPL), Pakistan (PAK), Sri Lanka (LKA), Rest of South Asia (XSA), Canada (CAN), Mexico (MEX), Rest of North America (XNA), Argentina (ARG), Bolivia (BOL), Brazil (BRA), Chile (CHL), Colombia (COL), Ecuador (ECU), Paraguay (PRY), Peru (PER), Uruguay (URY), Venezuela (VEN), Rest of South America (XSM), Costa Rica (CRI), Guatemala (GTM), Honduras (HND), Nicaragua (NIC), Panama (PAN), El Salvador (SLV), Rest of Central America (XCA), Dominican Republic (DOM), Jamaica (JAM), Puerto Rico (PRI), Trinidad and Tobago (TTO), Rest of Caribbean (XCB), Albania (ALB), Belarus (BLR), Russian Federation (RUS), Ukraine (UKR), Rest of Eastern Europe (XEE), Rest of Europe (XER), Kazakhstan (KAZ), Kyrgyzstan (KGZ), Tajikistan (TJK), Rest of Former Soviet Union (XSU), Armenia (ARM), Azerbaijan (AZE), Georgia (GEO), Bahrain (BHR), Iran (IRN), Israel (ISR), Jordan (JOR), Kuwait (KWT), Oman (OMN), Qatar (QAT), Saudi Arabia (SAU), Turkey (TUR), United Arab Emirates (ARE), Rest of Western Asia (XWS), Egypt (EGY), Morocco (MAR), Tunisia (TUN), Rest of North Africa (XNF), Rest of the World (XTW)

TABLE F.2

Activities in the ENVISAGE and GTAP Databases

ENVISAGE ACTIVITY	GTAP ACTIVITY
Agriculture (AGO)	Paddy rice (PDR), Wheat (WHT), Cereal grains nec (GRO), Vegetables, fruit, nuts (V_F), Oil seeds (OSD), Sugar cane, sugar beet (C_B), Plant-based fibers (PFB), Crops nec (OCR), Bovine cattle, sheep and goats, horses (CTL), Animal products nec (OAP), Raw milk (RMK), Wool, silk-worm cocoons (WOL), Forestry (FRS), Fishing (FSH)
Oil and refined petroleum (OIL)	Oil (OIL), Petroleum, coal products (P_C)
Gas and gas distribution (GAS)	Gas (GAS), Gas manufacture, distribution (GDT)
Coal (COA)	Coal (COA)
Other extraction (OXT)	Other Extraction (formerly OMN Minerals nec) (OXT)
Processed foods (PFD)	Bovine meat products (CMT), Meat products nec (OMT), Vegetable oils and fats (VOL), Dairy products (MIL), Processed rice (PCR), Sugar (SGR), Food products nec (OFD), Beverages and tobacco products (B_T)
Textiles and wearing apparel (TWP)	Textiles (TEX), Wearing apparel (WAP), Leather products (LEA)
Wood and paper products (WPP)	Wood products (LUM), Paper products, publishing (PPP)
Chemical, rubber, plastic products (CRP)	Chemical products (CHM), Basic pharmaceutical products (BPH), Rubber and plastic products (RPP)
Energy intensive manufacturing (EIM)	Mineral products nec (NMM), Ferrous metals (I_S), Metals nec (NFM), Metal products (FMP), Computer, electronic and optical products (ELE), Electrical equipment (EEQ), Machinery and equipment nec (OME)
Other manufactures (XMN)	Motor vehicles and parts (MVH), Transport equipment nec (OTN), Manufactures nec (OMF)

(*continues*)

TABLE F.2

Activities in the ENVISAGE and GTAP Databases (*Continued*)

ENVISAGE ACTIVITY	GTAP ACTIVITY
Construction (CNS)	Construction (CNS)
Electricity transmission distr. (ETD)	Electricity Transmission distr. (TnD)
Hydroelectricity (E_H)	Electricity Hydro-base (HydroBL), Electricity Hydro–peak (HydroP)
Electricity–coal (E_C)	Electricity Coal-base (CoalBL)
Electricity–oil (E_O)	Electricity Oil-base (OilBL), Electricity Oil–peak (OilP)
Electricity–gas (E_G)	Electricity Gas-base (GasBL), Electricity Gas–peak (GasP)
Electricity–wind (E_W)	Electricity Wind-base (WindBL)
Electricity–solar (E_S)	Electricity Solar (SolarP)
Electricity–other (E_X)	Electricity Nuclear-base (NuclearBL), Electricity Other-base (OtherBL)
Trade services (TRD)	Trade (TRD), Warehousing and support activities (WHS)
Road and rail transport services (OTP)	Transport nec (OTP)
Water transport services (WTP)	Water transport (WTP)
Air transport services (ATP)	Air transport (ATP)
Communication services (CMN)	Communication (CMN)
Other financial services (OFI)	Financial services nec (OFI)
Insurance, real estate services (INS)	Insurance (formerly ISR) (INS)
Other business services (OBS)	Real estate activities (RSA), Business services nec (OBS)
Hospitality services (ROS)	Accommodation, Food and service activities (AFS), Recreational and other services (ROS)
Other services (XSV)	Water (WTR), Public Administration and defense (OSG), Education (EDU), Human health and social work activities (HHT), Dwellings (DWE)

TABLE F.3

Commodities in the ENVISAGE and GTAP Databases

ENVISAGE COMMODITY	GTAP COMMODITY
Agriculture (AGO)	Paddy rice (PDR), Wheat (WHT), Cereal grains nec (GRO), Vegetables, fruit, nuts (V_F), Oil seeds (OSD), Sugar cane, sugar beet (C_B), Plant-based fibers (PFB), Crops nec (OCR), Bovine cattle, sheep and goats, horses (CTL), Animal products nec (OAP), Raw milk (RMK), Wool, silk-worm cocoons (WOL), Forestry (FRS), Fishing (FSH)
Oil and refined petroleum (OIL)	Oil (OIL), Petroleum, coal products (P_C)
Gas and gas distribution (GAS)	Gas (GAS), Gas manufacture, distribution (GDT)
Coal (COA)	Coal (COA)
Other extraction (OXT)	Other Extraction (formerly OMN Minerals nec) (OXT)
Processed foods (PFD)	Bovine meat products (CMT), Meat products nec (OMT), Vegetable oils and fats (VOL), Dairy products (MIL), Processed rice (PCR), Sugar (SGR), Food products nec (OFD), Beverages and tobacco products (B_T)
Textiles and wearing apparel (TWP)	Textiles (TEX), Wearing apparel (WAP), Leather products (LEA)
Wood and paper products (WPP)	Wood products (LUM), Paper products, publishing (PPP)
Chemical, rubber, plastic products (CRP)	Chemical products (CHM), Basic pharmaceutical products (BPH), Rubber and plastic products (RPP)
Energy intensive manufacturing (EIM)	Mineral products nec (NMM), Ferrous metals (I_S), Metals nec (NFM), Metal products (FMP), Computer, electronic and optical products (ELE), Electrical equipment (EEQ), Machinery and equipment nec (OME)
Other manufactures (XMN)	Motor vehicles and parts (MVH), Transport equipment nec (OTN), Manufactures nec (OMF)
Construction (CNS)	Construction (CNS)
Electricity (ELY)	Electricity Transmission distr. (TnD), Electricity Hydro-base (HydroBL), Electricity Hydro–peak (HydroP), Electricity Coal-base (CoalBL), Electricity Oil-base (OilBL), Electricity Oil–peak (OilP), Electricity Gas-base (GasBL), Electricity Gas–peak (GasP), Electricity Wind-base (WindBL), Electricity Solar (SolarP), Electricity Nuclear-base (NuclearBL), Electricity Other-base (OtherBL)
Trade services (TRD)	Trade (TRD), Warehousing and support activities (WHS)
Road and rail transport services (OTP)	Transport nec (OTP)
Water transport services (WTP)	Water transport (WTP)
Air transport services (ATP)	Air transport (ATP)
Communication services (CMN)	Communication (CMN)
Other financial services (OFI)	Financial services nec (OFI)
Insurance, real estate services (INS)	Insurance (formerly ISR) (INS)
Other business services (OBS)	Real estate activities (RSA), Business services nec (OBS)
Hospitality services (ROS)	Accommodation, Food and service activities (AFS), Recreational and other services (ROS)
Other services (XSV)	Water (WTR), Public Administration and defense (OSG), Education (EDU), Human health and social work activities (HHT), Dwellings (DWE)

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