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Generating Meaningful Energy Systems Models for Africa

Bringing expertise, data, and model development "home" to African countries is interrelated and mutually reinforcing with achieving electrification, development, and climate goals on the continent.

About 77% of the 770 million people living without access to electricity today reside in sub-Saharan Africa (SSA). Increasing access to energy in the region could raise prospects for the 431 million residents there who live in poverty, while also advancing global climate goals. But the process of electrification has been hobbled by lack of data and one-size-fits-all energy system models that do not adequately reflect SSA's reality. Global institutions, as well as African governments, must begin to invest in the creation of national and regional energy models, data collection, and local expertise.

Most of the energy models applied to Africa are built and run by analysts in industrialized countries. As a result, the input of African analysts and local data can be limited, which results in poorly informed assumptions. For example, in 2015, the International Energy Agency (IEA) energy balance showed that Nigeria's household electricity consumption was 14 TWh. However, using Nigeria-specific data, a bottom-up energy modeling study conducted by Nigerian analysts in collaboration with the International Renewable Energy Agency (IRENA) showed that Nigeria's household electricity consumption in 2015 was 43 TWh. The estimate tripled because the IEA didn't adequately capture how many households had diesel and gasoline generators to back up the unreliable grid. Energy models contain many implicit assumptions, some of which—like gross domestic product (GDP), as we discuss below—are biased toward the expectations and priorities of industrialized countries, making them inappropriate for the SSA context.

Appropriate energy system models are essential for planning because they can be used to explore future energy demand and supply trajectories, incorporating projections of population, economic growth, and energy prices. Crucially, models can provide insights into how different policy and technological pathways could influence outcomes, including environmental sustainability and economic development. And they are often used by policymakers to make decisions about infrastructure development, investment, and trade-offs.

To perform their function well, models should be designed for local conditions, but the 48 diverse SSA countries are often lumped together. And even then, nearly three-quarters of studies published about modeling Africa's energy transition in the last two decades have used frameworks repurposed from other parts of the world. These one-size-fits-all models are further vexed by a lack of local data. In my (Michael Dioha's) own work on Nigeria, I'm often compelled to adapt foreign data. For my research on sustainable energy transitions, for example, I had to use foreign air pollutant emission factors because there were no data from Nigeria.

Inadequate modeling and insufficient data for SSA countries raise the risk that countries will make poor investments that lock them into expensive and polluting energy pathways, jeopardizing global climate goals as well as local development. A 2017 study noted that limited local data meant that many countries in the region were more likely to invest in coal and other fossil fuels because they couldn't recognize attractive renewable opportunities such as solar or wind. And a recent report from the Energy for Growth Hub (where we work) found that many countries in Africa are excluded from global net-zero plans due to a lack of accurate local data and appropriate modeling.

Expanding modern energy access to all in Africa requires models that enable forward-looking decisionmaking to achieve the goals of the people and governments of the region. Building such models requires understanding the challenges inherent in electrifying these countries, including taking a nuanced approach to measuring economic activity, considering special geography and the features of individual nations. Finally, there is a need to reconcile the implicit objective of most global energy system models—decarbonization—with the African continent's need to rapidly ease poverty through economic development.

Using data that are up to the task

Poor energy modeling capacity has already inhibited SSA countries' ambitions. In 2011, the United Nations Secretary-General launched the Sustainable Energy for All Initiative. Since then, 44 African countries have joined, and most have performed a gap analysis, but just 11 have developed an action agenda and investment prospectus. While these plans are commendable, only Kenya and Uganda managed to expand electricity access faster than population growth between 2010 and 2020.

But even in Kenya, efforts to expand access have been hampered by limited data. Although electricity access was previously defined as a grid connection, a closer look shows this definition can downplay significant gaps in electrical service. For example, some parts of Nairobi and some rural areas experience frequent blackouts and changes in voltage, which shut down local businesses and health care centers. Only by installing monitoring equipment and gathering open data can decisionmakers gain an understanding of what infrastructure needs to be installed to fix these problems.

Inability to model market behaviors has prevented other countries from meeting their objectives. Nigeria's Vision 30:30:30, for example, which aims to achieve 30 gigawatts of generation by 2030, with renewable energy contributing 30% of the energy mix, is far behind its targets. As of 2022, the country still had not met the benchmarks for 2017. The financial portfolios of the utilities—including the need to build and maintain excess capacity and the fluctuating fuel costs—were not factored into the planning process. In spring 2022, power companies began to curtail generation because they could not balance their books.

Deficiencies in modeling and data lead to mismatches between investments and outcomes, and between resources and demand.

In general, deficiencies in modeling and data lead to mismatches between investments and outcomes, and between resources and demand. In rural areas where access to electricity is limited, small-scale isolated solar mini-grids might be installed instead of larger, more efficient grid-connected systems, making electricity unaffordable in these areas. By contrast, overestimating how much energy a hydroelectric dam can produce may result in overinvestment and waste. And if the potential for solar or wind power generation is underestimated, it can lead to underinvestment in these sources, squelching opportunities to expand access to clean energy in Africa. Combining sloppy data with poorly conceived models will result in plans that are drastically inadequate for countries that need to develop their economies and energy resources.

Modeling Africa's diverse economies and geographies

The economic metrics used in African countries' energy models require attention to local knowledge and geography. Energy models in industrialized countries use GDP and per capita GDP as driving factors for energy demand. However, in African countries the usual methods of calculating GDP frequently underestimate true economic activity, especially where informal employment is common. The International Labour Organization estimates that 85% of employment in SSA is informal. When Nigeria rebased its GDP in 2013 to include some informal sectors, that measure increased by over 60%, from $270 billion to $510 billion, revealing that Nigeria's economy was larger than that of South Africa's. This implies that models relying on GDP to forecast Nigeria's energy demand before 2014 could have underestimated the country's energy needs, leading to inadequate energy plans.

Another challenge in applying global energy system models to Africa is spatial representation. Today, the 54 sovereign countries in Africa have natural resources, systems of government, and levels of foreign dependency that vary widely. Despite these differences, energy models tend to aggregate African countries into a single region—occasionally with the Middle East—or into several regions. For example, in the Integrated Model to Assess the Global Environment (IMAGE), Africa is represented as five regions: Northern Africa, Western Africa, Eastern Africa, South Africa, and Rest of Southern Africa.

The aggregation masks the substantial heterogeneity among African countries. Over time, as the continent's population is projected to expand from 17% of today's total world population to 40% by 2100, this aggregation may magnify inequalities in data collection and modeling capacity. The Western Africa region in the IMAGE model, for instance, consists of around 25 countries. The population of Nigeria, a single country in that aggregated region, is projected to be larger than the combined population of Canada and the United States (represented in the same model as two separate regions) by 2100. The spatial structure of these models assumes that energy use will remain low, and it does not take into account the very different development trajectories of African countries. These assumptions, in turn, perpetuate bias in scenarios that greatly undervalue future energy demand and emissions, resulting in lower investments.

Lack of country-specific models also hampers planning for changing balances between rural and urban populations and proximity to grid-based power. In some SSA countries, particularly those with lower levels of electricity access, off-grid solutions such as solar home systems, mini-grids, and solar lanterns have helped to improve energy access at the subsistence level. However, many households, given the opportunity, would prefer to be grid-connected because its electricity is cheaper and more reliable and can potentially support larger equipment. With an appropriate local integrated electrification planning framework, decisionmakers could plan for a convergence of off-grid and on-grid services as the grid grows and populations shift. At local and national levels, deployments of off-grid, decentralized, renewable energy systems affect present and future power demand on the grid. Despite this fact, most of the existing energy system modeling studies and plans do not have a comprehensive strategy for grid convergence.

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Models for development versus decarbonization

One of the most important distinctions between energy models for industrialized countries and those for developing countries in Africa relates to intent. Industrialized countries must focus on decarbonizing their energy systems. But in Africa, these models must advance socioeconomic development in a carbon-constrained world. To do this, SSA countries must urgently increase energy consumption. Thus, any model mapping energy transition plans for African countries needs to adequately capture how the region's socioeconomic and development priorities influence its future energy trajectories while being faithful to climate commitments.

Many existing energy models assume that the energy trajectory of Africa can be predicted based on Europe's and North America's development narratives. However, this implicit assumption is flawed. Africa's priority is development, and these models often lack inputs relevant to that priority, including income levels, weak infrastructures, fragile institutions, and informal markets. Likewise, decarbonization-focused models that use a country's current per capita greenhouse gas emissions as benchmarks are not appropriate for places where socioeconomic development is an immediate priority.

Even models that do factor in socioeconomic development often assume that electricity access lifts communities out of poverty, but that cannot be taken as a given. Case studies in Nigeria demonstrate that for electrification projects to create meaningful increases in income, they need to consider a community's ability to pay electricity bills, as well as its credit availability and market development. However, few energy models explicitly capture this process, thus creating unrealistic projections for Africa's future energy demand. A 2015 model-based study for Nigeria estimated that a total investment of $34.5 billion could bring electricity access to all in Nigeria by 2030; but the only trade-offs explored were infrastructure and technology, without considering how different financial supports for users would further affect implementation and affordability.

India offers an example of how Africa-focused models might improve. Many extant models use GDP per capita as the primary indicator of development and thus use GDP, combined with population and energy intensity, as a driver of energy demand. In contrast, the Sustainable Alternative Futures for India (SAFARI) model does not use GDP as the main indicator of progress and welfare. Instead, it uses the achievement of developmental goals, along with food, housing, health care, education, power, water, and transportation, to anticipate growth in energy demand. For policymakers, this kind of analytical framework can capture and reflect synergies, while limiting trade-offs among objectives.

An action agenda to improve energy modeling for Africa

Currently, there are few Africans in the energy modeling space. A recent study by researchers from the Clean Air Task Force showed that the majority of energy transition studies about Africa are written from afar. Nearly two-thirds of the research was produced without an author based on the African continent. National governments in Africa must build a pool of local experts for their own countries by facilitating partnerships between local academic institutions in Africa and relevant experts from developed countries.

Such partnerships should be used to further build the capacity for data collection. At the moment, SSA nations' statistical offices and energy agencies lack the technological, economic, and human resource capacities to collect, process, and disseminate the required data. Institutions including the World Bank, United Nations, and IEA should improve on their current efforts to provide reliable African data, which many local and international analysts already draw on. But these agencies should also recognize that much important detail is overlooked by regional or continental datasets, and so should support nations to develop the capacity to use local data.

At the same time, African analysts need to embrace new technologies to bridge data gaps. Innovations such as machine learning and artificial intelligence might be used to improve energy modeling studies in Africa by filling in data gaps, improving accuracy, and identifying patterns.

There is also a need for existing African institutions involved in energy modeling and planning to pursue partnerships with various international institutions—establishing regional dialogues, facilitating the exchange of technical advice, and assisting African researchers to learn from best practices in energy modeling globally. One initiative, the Energy Modeling Platform for Africa, already ties together several hundred energy modelers, and it could be scaled up to engage other global platforms. International organizations such as the IEA, IRENA, International Atomic Energy Agency, and International Institute for Applied Systems Analysis, among others, should work with these efforts to promote energy modeling, and energy modelers, in Africa.

Funding remains a significant bottleneck, and there is a great need to build a mixture of funding from governments, international agencies, and the private sector. We believe that overreliance on external financing has limited the capacity of African energy modelers and analysts, as well as the questions that models explore. Self-reliance for funding would give African institutions the leverage to address questions really pertinent to them rather than the questions their funders prioritize. Of course, continued support from international development agencies and financial institutions is necessary, but it should be well targeted and transparent. Just as energy modeling is performed by private sector companies, including utilities, in the United States and Europe, African companies should partner with governments and international organizations to finance energy modeling capacity in Africa.

Bringing funding, expertise, and model development "home" to African countries will advance electrification and development goals, a synergy that should be explicitly recognized. Energy models that draw on expertise from scientists, policy analysts, historians, lawyers, artists, and economists can all help bring Africa-specific features into models. Input from local communities will ensure that energy solutions suit local conditions. This would, in turn, increase buy-in and ownership of energy projects that have resulted from the energy modeling and planning process. One-size-fits-all energy system models will hobble sustainable electrification in Africa. Locally owned, internationally integrated approaches are essential to advance it.

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RECOMMENDED READING

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