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livewire
APRIL 2024
2024/131
A KNOWLEDGE NOTE SERIES FOR THE ENERGY & EXTRACTIVES GLOBAL PRACTICE

Adapting Spatial Frameworks to Guide Energy Access Interventions in Urbanizing Africa

The bottom line. The extension of electricity into rural areas has been the main focus of efforts to achieve universal access to reliable, affordable, and modern energy by 2030. On the African continent and elsewhere, however, rapid urbanization has produced new patterns of human settlement that blur the distinction between rural and urban. As a case study of Kenya demonstrates, access metrics aggregated at the rural or urban level do not equip governments and their partners to properly identify or target sites for electrification. Spatialized frameworks and data that define space along a rural–urban continuum or as urban catchment areas can improve policy makers' understanding of the specific barriers to access that communities face.

Why is categorizing areas as simply rural or urban insufficient for planning electrification?

Official statistics based on a simple rural-urban distinction fail to capture the complexity of Africa's urbanization patterns

Labeling locales as either urban or rural assumes that there are clear and measurable differences between the two types of spaces. This idea is losing empirical meaning, given the rapid and sustained urbanization occurring across human societies.

In Sub-Saharan Africa, the urban population grew by a factor of more than 20 between 1950 and 2015 (OECD, UNECA, and AfDB 2022). Between now and 2050, it will grow by 560 million to reach 1.3 billion (UN DESA 2022).

Patterns of urbanization on the African continent are rapid, unevenly distributed, and complex. Contrary to popular belief, African urbanization is not simply migration from a rural area to a primary city. Informal and spontaneous urbanization has also become the norm in many African cities (Awan 2023). Examples of observed urbanization trends include:

- ✓ The *in situ* emergence of new cities and town centers (OECD, UNECA, and AfDB 2022)
- ✓ Growth and densification in urban peripheries (McGee 2021)
- ✓ The emergence of satellite cities and urban corridors (OECD, UNECA, and AfDB 2022)
- ✓ The merging of existing urban centers into dense, polynucleated conurbations/mega-agglomerations (OECD, UNECA, and AfDB 2022).

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Statistics that are spatially aggregated into rural or urban categories level do not characterize these newly urban and urbanizing communities, for several reasons (Brenner and Schmid 2014). The official definition of *urban* varies from country to country, and most projections are based on data from censuses conducted in the 1990s or 2000s. It can take decades for national governments to recognize new cities and towns administratively. During this time, many experience rapid growth without the support and resources that an "urban" designation would provide.

Informal settlements are also often omitted from or underrepresented in official statistics (Mitlin and Satterthwaite 2013). It is unclear how peri-urban communities are captured within a rural-urban division; their needs tend to be different from those of both their urban and rural counterparts. A significant number of communities are thus hidden in or missing from official statistics—by design or because they are obscured within data aggregated along a binary rural-urban categorization (Van Duijne 2019; Onda and others 2019).

Improving the ability to measure and track urbanization effects is important because urban areas—and the infrastructure that powers them—play a crucial role in economic development and poverty reduction. Thanks to economies of agglomeration, these areas facilitate the efficient provision of basic services, the concentration and specialization of labor, innovation, and the availability of a wider range of goods and services (UN-Habitat 2011). These benefits extend far beyond the formal boundaries of the city. Linkages between urban areas and their surroundings provide opportunities for employment and income diversification as well as access to services deep in the countryside (Satterthwaite and Tacoli 2002). Spatial frameworks that capture these dynamics can guide efforts to provide basic infrastructure to where it can best support broader urban societal and economic transitions.

In a period of rapid urbanization and demographic transition, barriers to energy access are evolving in ways that do not cleanly map to binary rural-urban divisions.

How does the classification of an area affect efforts to electrify it?

A coarse classification may not allow policy makers and researchers to spot barriers to energy access, model and evaluate appropriate technologies, or support the effective governance of electrification

A rural-urban binary framing limits electrification efforts by making it difficult to:

- ✓ Understand the barriers to energy access and the energy transition pathways of diverse communities
- ✓ Adapt electrification strategies that better meet communities' present and future needs
- ✓ Perform accurate geospatial energy modelling
- ✓ Establish coherent institutional jurisdictions.

Understanding barriers to energy access

According to the SDG 7 Tracking Report, in 2021 over 83 percent of the 674 million unelectrified people in Sub-Saharan Africa were rural (IEA and others 2023). The general understanding is that the main barrier in rural areas is that the grid does not reach them (Fall and others 2008). In contrast, urban environments are viewed as well-electrified (albeit with recognized challenges with service quality), because of the density of grid infrastructure (Blimpo, Postepska, and Xu 2020).

There is a rural bias in the understanding of how and where energy poverty manifests itself (Castán-Broto and others 2017; Singh and others 2015b). This argument does not imply that rural communities do not face pressing challenges in accessing electricity that deserve to be addressed. Rather, it highlights that many "rural" communities are actually in locations that are newly urban, densifying, within the urban periphery, or strongly linked to neighboring cities. The patterns of electricity access in these spaces between, within, and around cities are complex (Silver 2023). Understanding these broader processes of urbanization can be instructive in understanding the nature of the energy access challenges these communities face.

In urban areas, households are thought to transition from traditional biomass-based energy sources to electricity and gas through several stages as their incomes rise and cleaner sources become more readily available (Barnes, Krutilla, and Hyde 2004). These transitions take place haltingly and unevenly, however, especially for the lowest-income subset of the urban population (Aung and others 2022; Fall and others 2008; Mahumane and Mulder 2022). Lack of affordability is the most widely recognized barrier. One study finds that urbanization is correlated with more energy consumption and higher levels of access to clean fuels—but with increased energy poverty in terms of energy expenditures as a percent of total income (Mahumane and Mulder 2022).

There is considerable spatial variation in the challenges that unelectrified or under-electrified populations in Sub-Saharan Africa face in accessing electricity (Falchetta and others 2019). Within cities, infrastructure tends to be concentrated in commercial districts, high-income residential zones, and other formal areas (Lall and others 2017). The quality and coverage of services also worsen moving down the urban hierarchy; electricity may not be available at all in smaller cities or towns. The electricity access challenges of informal or "slum" communities within cities are also substantial but often underrepresented (Buyana 2022). Bureaucratic requirements to prove land tenure are a documented barrier in these communities (Singh and others 2015b).

Access to infrastructure declines rapidly moving into the urban periphery (Lall and others 2017). In some peri-urban areas, communities that lack electricity, sewerage, and piped water access exist alongside formally planned neighborhoods that have access to full modern services (Silver 2015). Other peri-urban communities are "under grid," and their barrier to access is not the physical availability of distribution infrastructure but the high cost of domestic wiring and the connection application (Lee, Miguel, and Wolfram 2020).

Many others are connected but face issues with reliability or power quality that limit when and how electricity can be used (Ayaburi and others 2020; Jacome and others 2019; Klugman and others 2019). Connections are sometimes precarious, meaning that an intermediary can disconnect the end user. In Kampala's informal settlements, for example, landlords can and often do disconnect their tenants because of unpaid rent, personal conflicts, or as a way to control costs. Intermediaries sometimes impose limitations on when electricity is available and the types of appliances that can be used (Kersey and others 2023; Yaguma and others 2024).

In a period of rapid urbanization and demographic transition, energy access barriers are evolving in ways that do not map cleanly into simple rural-urban divisions. Statistics and narratives that rely on these designations poorly equip practitioners to understand—and efficiently address—these challenges. As more and more of the population in Sub-Saharan Africa moves to or is born in urban and urbanizing areas, their needs will be increasingly difficult to understand and meet without a more spatially informed understanding of their challenges.

The ability to better spatialize economic and demographic dynamics and model their trajectories can help governments and their partners make strategic decisions about how to prioritize and target electrification resources.

Adapting electrification strategies to urbanization patterns

Urbanization produces fundamental transformations in the socioeconomic structure of communities. Areas of high population density benefit from agglomeration economies, which are associated with increased incomes, better access to health and education, and increased economic productivity. Surrounding areas benefit from rural–urban linkages, through which goods, people, finance, and other resources flow.

Energy is a critical input to these processes. Provided at the right quantity, quality, and price, electricity can provide a clean, low-carbon development pathway for these emerging economies (Goldemberg and others 1985). Spatialized economic and demographic data can help policy makers make strategic decisions about how to prioritize and target electrification resources.

A designation of rural or urban does not yield insight into the following factors, which are interlinked with urbanization dynamics and consequential for electrification efforts:

- ✓ The types of productive economic activities communities engage in
- ✓ The scale of these activities and expected changes over time
- ✓ The existence and strength of linkages with nearby urban centers.

In urbanizing areas, demand for electricity will grow as livelihoods improve and become more diversified. Electricity systems must be able to support the shifting demand growth of their users. Unreliable or poor-quality supply can constrain economic growth and create or increase reliance on expensive and polluting fuel sources. How demand grows—which will depend in large part on the nature of localized economic activities—has implications for the types of systems that will best meet users' needs. A recent study argues that the electricity demand of agricultural activities has been overlooked and that its inclusion could significantly alter current least-cost electrification planning (Korkovelos, Koo, and Malik 2022).

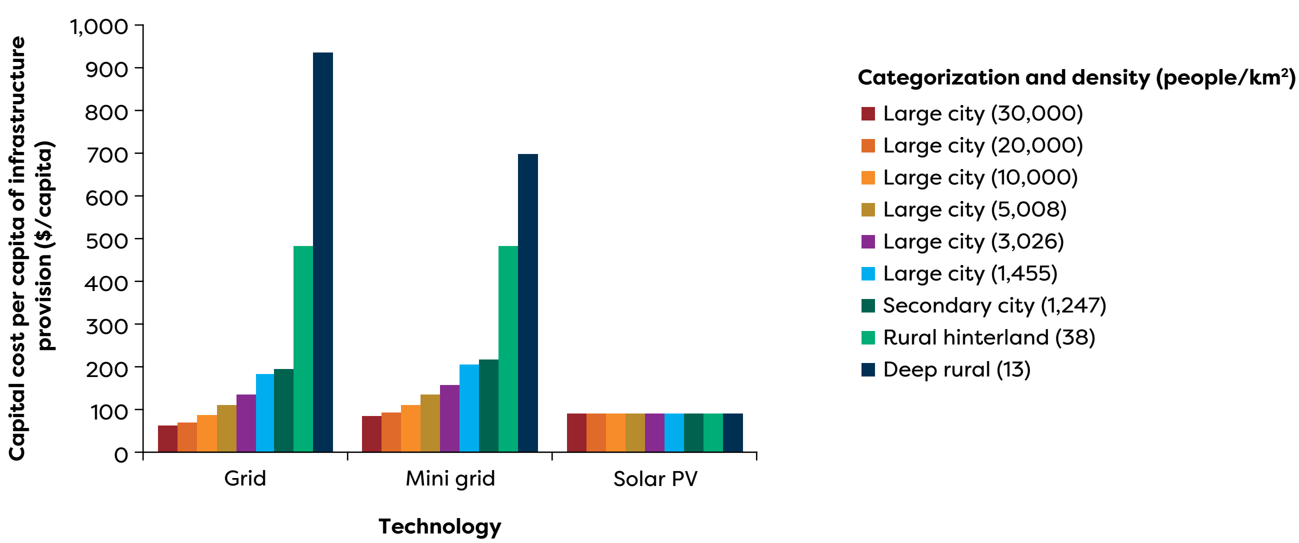
Extending this argument to the context of urbanizing communities, local economies are rapidly growing and diversifying into manufacturing, service, and trade. How these transitions are occurring, and the extent to which they can be electrified, affects the rate of demand growth and the shape of the demand profile. Both are consequential for selecting technologies and business models capable of matching output to time of use and accommodating future growth (and shifts) in demand while remaining financially sustainable. These dynamics are well-understood by mini grid developers, who often seek urbanizing sites with niche industries, such as light manufacturing and agricultural processing, with high daytime loads that can serve as anchor customers (Guillou and Girard 2022).

The Utilities 2.0 Twaake pilot in Uganda is an example of a mini grid whose business model is premised on realizing the latent demand of economically diverse peri-urban communities. The objective of the pilot is to demonstrate that mini grids can be used to stimulate demand before the arrival of the central grid.

Under Twaake, a 40 kilowatt (kW) peak mini grid was constructed in the village of Kiwumu. The livelihoods of residents there are strongly linked to commerce in Kampala, which is 45 minutes away by truck or bus. Over half of business customers received dedicated asset financing for commercial and agricultural productive-use appliances. The mini grid was connected to the central grid in June 2023. Despite early challenges with institutional coordination, this model appears to have been effective in improving the cost economics of electrification (Rockefeller Foundation 2021).

From the supply side, the cost-effectiveness of technology options is strongly influenced by the form and density of human settlement patterns. The cost of electrification per capita varies significantly depending on the technology type and population density (figure 1).

Figure 1. Capital cost per capita of electrification via a central grid, mini grid, and solar home system, based on settlement density



Source: Adapted from Foster and Briceno-Garmendia (2010).

Mini grids are often assumed to be a relevant option for isolated and unelectrified rural areas. In higher-density areas, they are also cost-competitive with grid expansion. Through fieldwork in India, Senegal, and Tanzania, Guillou and Girard (2022) find that mini grid developers "tend to favor larger villages and places that, though officially rural, have economic and social dynamics that bring them closer to urban areas." This finding is consistent with a growing body of work that advocates for the potential of under-grid mini grids and other hybridized or grid-interactive systems to improve access in areas where the grid will soon reach or is present but offers poor service (Graber, Mong, and Sherwood 2018).

Energy demand, the cost of service provision, and urban growth patterns are interlinked processes. While we have discussed matching energy services to fit the needs of urbanizing areas, the reverse – shaping planning to enable high-efficiency forms of urban living – is also possible (Madlener and Sunak 2011). Urban planning can be an important tool in promoting growth patterns that are energy and cost-efficient. Healthy urban expansion is a particular area of concern. Urban sprawl often leads to the inefficient use of resources and a rise in the per capita cost of service delivery. Doubling urban density has been estimated to reduce the per capita cost of infrastructure improvements by about 25 percent (Foster and Briceno-Garmendia 2010). These findings underscore the need to increase coordination between entities responsible for urban planning and electricity service provision. Through effective urban planning, cities can grow in ways that minimize the costs of basic service provision, avoid lock-in of high-carbon fuel sources, and align with other objectives of sustainable urban growth.

Modeling least-cost electrification accurately

Most electrification models explicitly or implicitly incorporate rural-urban binary classifications. Depending on how these assumptions factor into the model, they may yield recommendations for technologies that are inappropriate to the on-the-ground realities of urbanizing communities.

Demand estimation is highly sensitive to forecasting methods and input assumptions, which can produce dramatic differences in modeling outcomes (Kemausuor 2014). Two of the most commonly used least-cost electrification models base several key demand modeling assumptions on a rural-urban split (table 1). In some of the early applications of the Open Source Spatial Electrification Tool (Onset), for example, demand was based on estimates of per capita rural and urban consumption (Moksnes and others 2017).

Table 1. Assumptions in least-cost electrification models that are informed by binary rural-urban classifications

Model	Urban classification	Assumptions that depend on rural or urban designation	Technology output options	Source
Network Planner	User defines threshold below which an area is considered rural and above which it is considered urban.	Population growth rate,[a] average household size, fraction of total demand during peak hours	Grid, mini grid, off-grid	Kemausuor and others (2014); Ohiare (2015)
Reference Electrification Model (REM)	No explicit urban-rural assumptions within modeling parameters, but some input assumptions are informed by national datasets that are disaggregated by rural or urban.		Small home solar, mini grids, grid-connected systems	Ciller and others (2019); Borofsky (2015)
Open Source Spatial Electrification Tool (OnSSET)	User defines threshold below which an area is considered rural and above which it is considered urban.	Average household size, population growth rates, access tiers[b]	Grid connection, mini grid systems, stand-alone systems	Mentis and others (2017); Korkovelos and others (2019)

a. After a "rural" community surpasses the set threshold, it upgrades to "urban" growth rates.
b. Demand estimation has improved as these models become more sophisticated and higher-resolution socioeconomic data become more widely available. The Global Electrification Platform, for example, which is based on OnSSET, allows for a bottom-up estimation mode that uses a spatialized poverty index and income data to estimate demand.

Rural-urban assumptions also enter demand forecasting algorithms as average population growth rates and/or household size. These assumptions are often based on averaged historical values and usually do not account for the location-specific dynamics that drive these demographic shifts. Population growth is usually much higher in "rural" areas that are near large cities. Areas may also experience population declines as people resettle in areas with more economic opportunity or political and environmental stability (Black and others 2008). Models that do not account for these dynamics may not be able to identify areas of high potential growth and densification and could therefore recommend systems that are not well-suited to local economic trajectories.

A diverse ecosystem of electricity provision models now exists, including the central grid, mini grids, mesh grids, metro grids, and solar home systems. Many of these systems are commercially available at sizes and price points that are increasingly tailored to income-constrained users. Most models include just three possibilities: solar home systems, mini grids, and grid extension. They do not incorporate evolving hybrid technologies such as mesh grids and under-grid mini grids, which may be cost-effective in densifying rural and peri-urban communities or areas that are grid-connected but experience poor reliability and service quality (Menon 2022). Future iterations of these models could introduce penalties for poor grid reliability and quality and allow grid-tied or under-grid systems to compete against grid extension within optimization algorithms.

Establishing coherent institutional jurisdictions

Rural-urban designations can present a challenge to effective governance of electricity provision. In many countries, a rural electrification agency or similar institution is tasked with expanding access into rural areas. Within cities, the municipality or the utility is often responsible for electrification. Peri-urban areas may not fall cleanly under the jurisdiction of either institution. Emerging urban zones must wait until the next census cycle to be formally incorporated and receive the resources necessary to plan and administer urban services. These and other rapid demographic shifts have gone largely unrecognized in the official statistics that are used for planning and policy making.

Senegal provides an extreme example of this institutional disconnect. In the 1990s, a reform in the electricity sector designated a new electrification agency, the Senegalese Rural Electrification Agency (ASER) for rural areas; urban areas remained under the jurisdiction of the national utility, SENELEC. Under this framework, peri-urban areas fell into neither rural nor urban classifications and were not targeted by either agency's policies (Singh and others 2015a).

Reevaluating Kenya's Multi-Tier Framework Survey: What insights does a continuum approach offer?

Spatial disaggregation of Kenya's Multi-Tier Framework Survey reveals large access deficits in peri-urban communities, driven primarily by high connection costs

Rural-urban as a continuum

Several established datasets can be operationalized in lieu of a binary rural-urban classification. Table 2 outlines four of the most widely used or recently developed datasets; figure 2 shows images based on them.

The analysis presented here uses the Urban-Rural Catchment Area (URCA), which disaggregates space into 30 categories. A particular strength of the URCA methodology is its ability to identify economic linkages. URCA is based on Central Place Theory, which posits that people living closer to a city or town have better access to its goods, services, and opportunities and that bigger cities offer a broader range of urban benefits (Christaller 1933). Under the URCA framework, space is understood as a catchment area surrounding an urban center (Cattaneo, Nelson, and McMenomy 2021). Catchment areas are defined by the length of time it would take someone living in that area to reach the nearest city or town of a particular size. It is estimated by calculating the least-cost path over a cost surface. This cost surface quantifies the ease and speed of travel over different routes, accounting for transport networks, land cover data, and international borders (Weiss and others 2018). An important limitation is that this algorithm does not explicitly account for the mode of travel. Catchment area designations may vary across country and regional contexts, as different contexts favor different transportation modes.

Table 2. Features of datasets that can be used in geospatial analysis and planning

Dataset	Description	Type	Area covered	Years covered	Custodian	Dataset address
Africapolis	Provides extents of urban agglomerations; includes statistics on population and settlement density.	Vector	African continent	2015, 2022	OECD	https://oecd.us4.list-manage.com/subscribe?u=5aa4680998eddebe5f4ce7065&id=17db0c31dd
Degree of Urbanisation (DEGURBA)	Classifies space as cities, towns and suburbs, and rural areas based on a combination of geographical contiguity and population density. This first level of the classification may be complemented by a range of more detailed concepts, such as metropolitan areas, commuting zones, dense towns, semi-dense towns, suburban or peri-urban areas, villages, dispersed rural areas, and mostly uninhabited areas.	Raster	Global	1975–2030, at five-year intervals	European Commission (UN endorsed)	https://ghsl.jrc.ec.europa.eu/download.php?ds=smod
Open Buildings	Includes outlines of buildings and characterizes the density of settlements; footprints of buildings are determined from high-resolution satellite imagery via a deep learning model.	Vectors and points	Central and South America, Africa, Indian Subcontinent, Southeast Asia	Varies by location (based on availability of satellite data)	Google	https://sites.research.google/open-buildings/#download
Urban-Rural Catchment Area (URCA)	Thirty categories show catchment areas around and cities and towns, defined in terms of travel time to closest city or town (less than 1 hour, 1–2 hours, 2–3 hours, more than 3 hours) of different sizes.	Raster	Global	2015	Authors	https://figshare.com/articles/dataset/Urban-rural_continuum/12579572

Sources: Florczyk and others (2019); OECD, UNECA, and AfDB (2022); Sirko and others (2021); Cattaneo, Nelson, and McMenomy (2021).

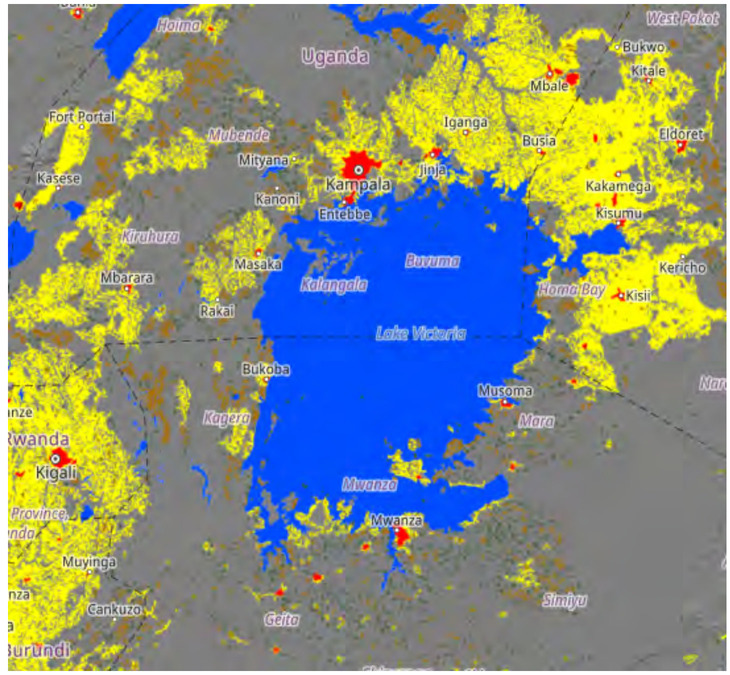
The URCA framework segments populations into categories with similar socioeconomic demographics and quality of infrastructure services. This type of spatial disaggregation is necessary to understand and address the needs of population groups across an increasingly urban global landscape.

This analysis re-evaluates the results of Kenya's Multi-Tier Framework (MTF) survey using an adapted version of the URCA framework. The objective is to reveal the additional insights that a more sophisticated spatial framework can offer in interpreting the MTF results.

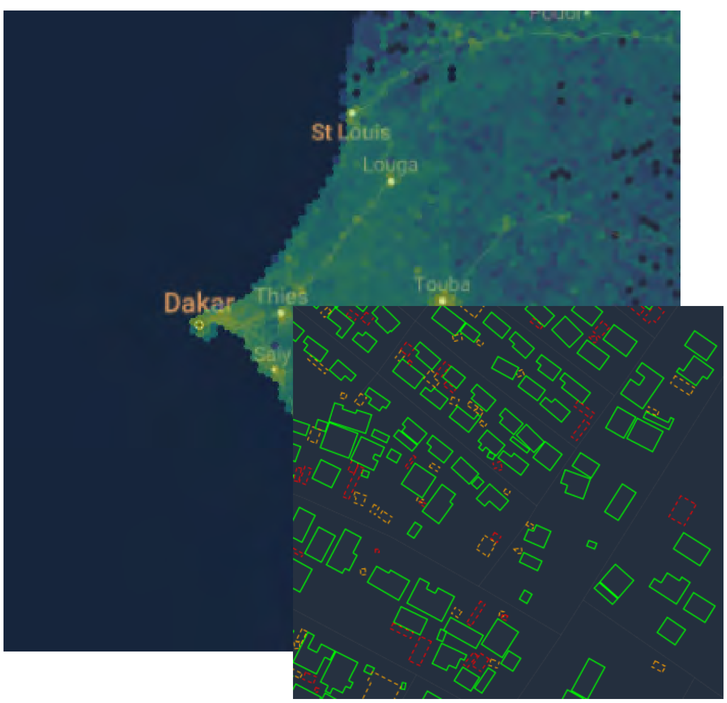
Figure 2. Representative images from four datasets used to analyze development challenges and progress

a. Africapolis

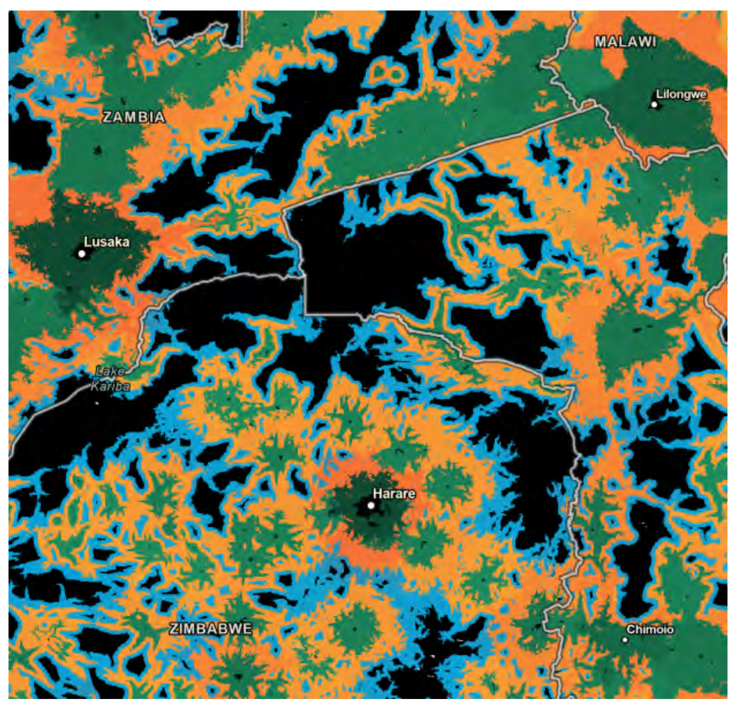
b. DEGURBA (Degree of Urbanisation)



c. Open Buildings



d. URCA (Urban-Rural Catchment Area)



Sources: Authors, using data from respective dataset.

The MTF survey is a nationally representative sample of energy access metrics, conducted in 2016. The adapted URCA framework used here contains the five categories shown in table 3. They were derived by aggregating the 30 URCA categories into new categories, each of which contains at least 100 of the original MTF survey points. Figure 3 shows a map of Kenya using the adapted URCA framework.

The aggregation of the original URCA categories into the adapted framework is a necessary limitation of this study that is rooted in the spatial distribution of the underlying sample points. In particular, peri-urban communities within one hour of a city or town are not sufficiently disaggregated within the adapted or original URCA framework. Future work could disaggregate these populations based on 15-, 30-, and 45-minute commute times.

Spatial distribution of people without access to electricity

Panel a of figure 4 shows the distribution of Kenya's population across the five categories of the adapted URCA framework in terms of their electrification status.[1] About 69 percent of Kenya's population lives within an hour's travel of a large, medium-size, or small city or town; they make up 81 percent of the unelectrified.

Panel b shows how these survey points are categorized in the original survey, which uses a binary rural/urban classification. Across these three categories, 57 percent of the population is considered urban. This means that when survey results are aggregated by rural or urban, the characteristics of the populations represented by these three categories are not well represented within either.

Areas less than one hour from a large or medium-size city contain roughly half of the population (51 percent). These categories correspond to the peri-urban zones surrounding Nairobi, Kisumu, Kisii, and Nakuru, shown in figure 3. This distribution makes sense given recent demographic trends in Kenya. In 2022, an extensive geospatial analysis of urbanization on the African continent identified Kisii and Kisumu as "spontaneous mega-agglomerations," with over 3.5 and 5.0 million inhabitants, respectively (OECD, UNECA, and AfDB 2022). Both are part of a rapidly densifying conurbation in

1. For the purposes of this analysis, respondents are considered electrified if they have a grid connection.

Table 3. Definition of urban catchment categories

Category	Description
City or town	City or town with 20,000–5 million inhabitants
Less than one hour to large city	Locale within one hour travel time to a city of 250,000–5 million inhabitants
Less than one hour to medium-size city	Locale within one hour travel time to a city of 100,000–250,000 inhabitants
Less than one hour to small city or town	Locale within one hour travel time to a city or town of 20,000–100,000 inhabitants
Non-urban	Locale more than one hour travel time to a city or town of any size

Source: Dubey and others 2019
Note: Definitions are adapted from the Urban-Rural Catchment Area framework.

Figure 3. Map of Kenya based on the adapted URCA framework

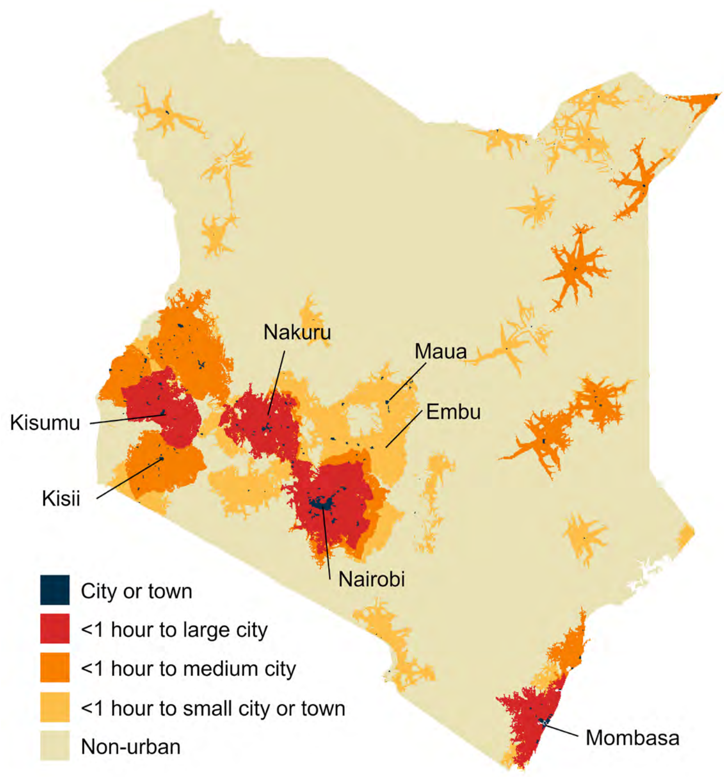
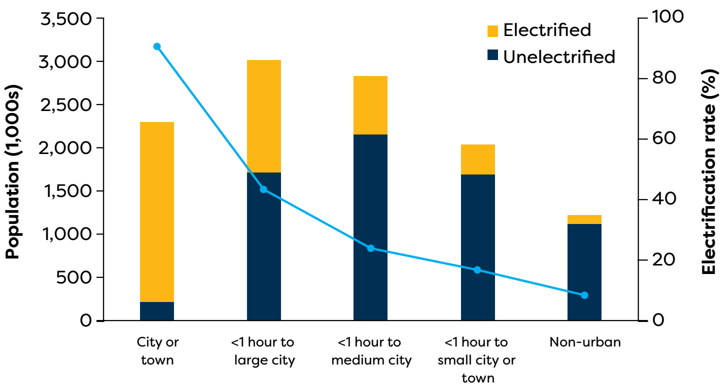
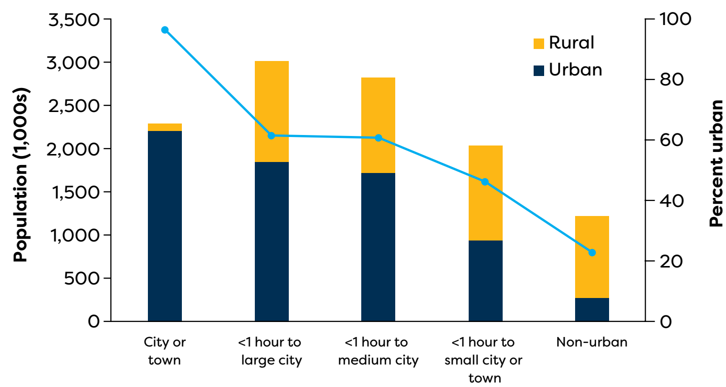


Figure 4. Grid electrification status of Kenya's population

a. Based on adapted URCA framework



b. Based on original categorization as rural or urban in the Multi-Tier Framework survey



southwestern Kenya whose linkages extend into neighboring Uganda and Tanzania. Figure 5 shows the population density of the unelectrified population in Kenya by adjusted URCA category.

Socioeconomic indicators and the choice of technology

Disaggregating household economic indicators from the MTF survey using the adapted URCA framework also yields insights into socioeconomic characteristics relevant to electrification planning. Conventionally, living conditions and socioeconomic status (such as income or occupation) are assumed to be similar among rural and urban households. Figure 6 shows annual household income and the percentage of heads of household participating in farm and non-farm sectors by spatial category.

Rates of employment in the non-farming sectors are highest in urban areas and decrease steadily with distance from a city or town. Employment in farm sectors is highest in more remote areas but still significant in areas close to cities, suggesting that these populations are engaging in significant agricultural activities, likely driven by demand from nearby urban centers. The significant amount of non-farm income shows that economic activities are diversified in these areas.

Annual household income is highest for people living in cities and towns and decreases steadily as the distance from the nearest urban center increases. The correlation between income levels and electricity consumption is well-established. It can reasonably be assumed that communities located less than an hour from a large city, for example, would have greater willingness and ability to pay for electricity than non-urban populations.

These dynamics are apparent in Kisumu, in both the city (Kenya's third-largest) and the surrounding county. As Kenya

Figure 5. Density of unelectrified population in Kenya (people per km²)

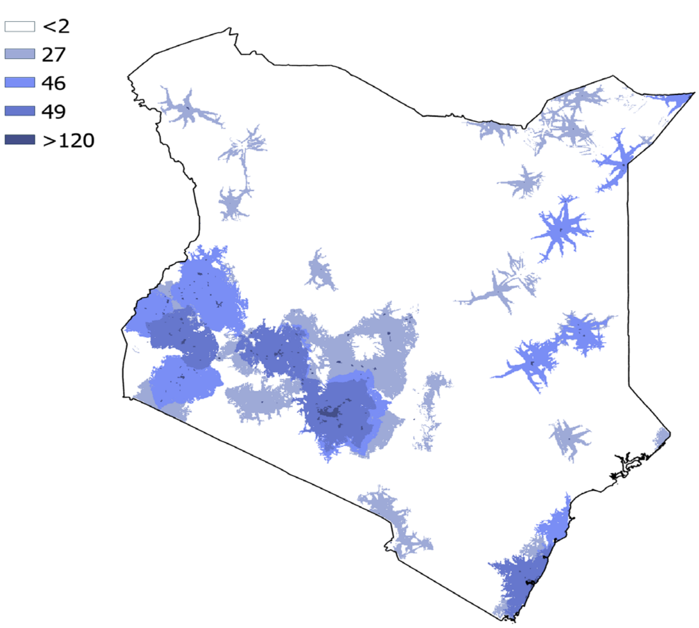
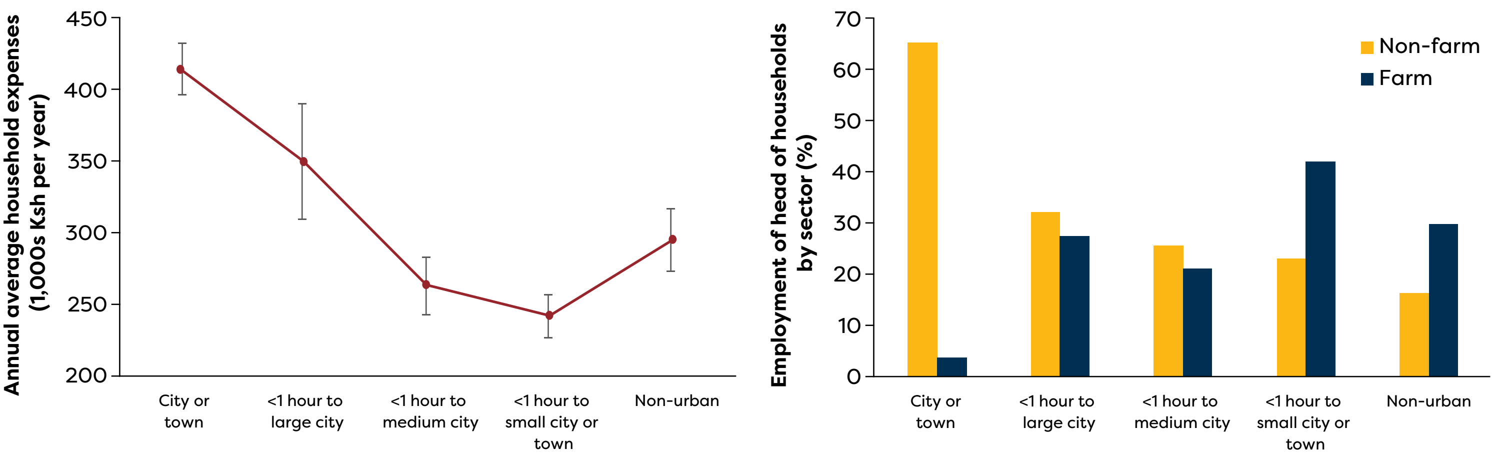


Figure 6. Annual household income and employment in farm and non-farm sectors in Kenya, by distance from city

a. Annual household income **b. Employment in farm and nonfarm sectors**



Note: Categories are based on the URCA framework.

has become denser and its population has grown, its economy has expanded from traditional fishing and agricultural activities to industrial activities, such as paint manufacturing, sugar processing, and soft drink bottling and distribution. Electricity access rates are just 53 percent, well below the national average of 75 percent (Buma 2020; Dubey and others 2019). The National Electrification Strategy has slated Kisumu for grid extension and densification. Off-grid developers have seen this combination of low electrification rate and high economic activity as an opportunity, and several mini-grids have been deployed across the county of Kisumu (Ministry of Energy 2018; Powerhive n.d.; Kenya GMG Facility 2021).

Identifying barriers to energy access

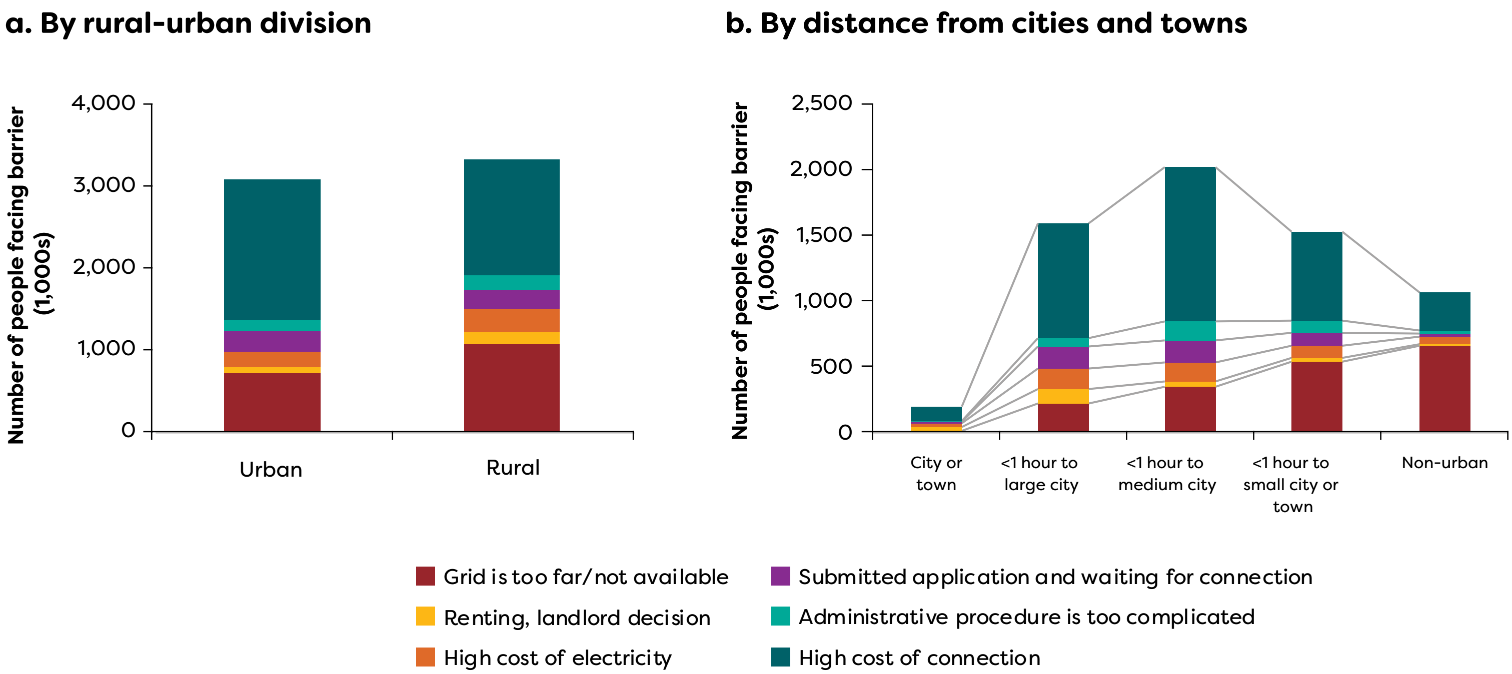
Effective and well-targeted interventions hinge on understanding the barriers different demographic groups face to accessing and using electricity from the grid. Spatial analysis of these barriers can be helpful for programmatic planning and implementation.

Figure 7 shows the main barriers to grid connection across the five adapted URCA categories in Kenya. For people living within an hour of a city or town, the high cost of connection, rather than the physical availability of grid infrastructure, is the primary barrier to electrification. Of the estimated 3.1 million people in Kenya who cite connection cost as the reason for non-connection, 87 percent live within an hour of a city or town.

These findings align with local policy realities. In 2015, Kenya announced the Last Mile Connectivity Project, which sought to electrify four million under-grid households (Ministry of Energy 2018). The program targeted communities that were physically close to the existing grid but not yet connected to it. It reached its target number of connections. Demand remained low among new customers, however, and many Kenyans were reluctant to pay for a connection even at highly subsidized rates (Lee, Miguel, and Wolfram 2020).

Sustained urbanization is driving permanent changes in the way people and economies are spatially distributed. Policy makers and practitioners need to begin engaging in critical discussions about how assumptions about rural/urban affect their work.

Figure 7. Reasons Kenyan survey respondents cite for not being connected to the grid



Note: Categories in panel b are based on the URCA framework.

More work needs to be done to understand the drivers of electricity uptake in these under-grid, peri-urban communities (Blimpo, Postepska, and Xu 2020). Using spatial techniques to isolate the responses of specific communities within larger datasets would be a helpful starting point.

How can policy makers operationalize the new spatial frameworks?

More disaggregated spatial frameworks can immediately be integrated into survey design, modeling, and governance

More sophisticated spatial frameworks and data inputs can be immediately integrated into electrification planning and policy making in several ways.

First, governments should review the jurisdictions of the national and municipal institutions responsible for electric service provision. Certain populations, such as people in informal settlements, rapidly growing rural towns, or areas in the peri-urban periphery, do not fall cleanly between rural/urban distinctions and may not be adequately targeted by existing institutions. This analysis might point to the need for new institutions (such as a Weak Grid Electrification Agency), new initiatives or task forces within existing institutions, or increased coordination between national agencies and municipal governments. Such a review should seek to examine the rural-urban definitions used by different institutions and to understand how outdated or poor-quality underlying data may influence these definitions and their application in policy and legal processes.

Second, energy access surveys should not rely exclusively on government-level rural/urban designations for their sampling strategies; disaggregated spatial frameworks should complement them. Although the URCA dataset is an important step forward in efforts to deconstruct the rural-urban binary, adaptations are required to make it accessible and useful for energy access policy makers. Future iterations should integrate energy-specific indicators such as the proximity of existing grid infrastructure, using geospatial data. They should also seek ways to disaggregate peri-urban communities still further, as the less than one hour commute time used in the URCA framework is too coarse. Spatial frameworks should also be adapted to account for differences in how populations are distributed within and across cities and towns of various size categories, across relevant local, national, or regional scales.

Third, geospatial least-cost electrification models should be adapted to avoid defining parameters and constraints based on a binary rural/urban distinction. Demand estimation, for example, is an important modeling assumption that is often based (explicitly or implicitly) on rural or urban status. This assumption can have particularly counterproductive impacts on electrification planning, as higher-density, urban-proximate areas with strong access to productive appliance supply chains and financing that are designated as having "rural" levels of demand may not receive systems of appropriate capacity to support their economic activity. Demand estimation techniques should incorporate frameworks such as the URCA and continue to integrate emerging high-resolution, spatialized socioeconomic and demographic data inputs. It is also important to incorporate urban-rural dynamics and patterns in the development of the least-cost planning model.

Awareness is important to driving change in the tools, discourse, and frameworks used to guide efforts to achieve SDG 7. Practitioners and policy makers must recognize that sustained urbanization is driving permanent changes in the way people and economies are spatially distributed—in ways that are consequential for electrification efforts—and begin engaging in critical discussions about how rural/urban assumptions affect their own work.

The authors are grateful to Samuel Miles of the University of California, Berkeley, for his help in developing the concepts reported in this brief.

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