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THE BOTTOM LINE

Through new technologies and business models, off-grid power markets promise to bring electricity access to more rural communities at a faster pace than is possible with grid extension alone. Apart from regulatory support and access to international finance, this incipient market sector depends critically on accurate and timely data. New approaches to data are gaining momentum in developing countries and have the potential to transform the rural electrification agenda.

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Data as an Enabler in the Off-Grid Sector: Focus on Tanzania

Why are we talking about off-grid electricity?

More than a billion people lack access to electricity, and many of them live far from the grid

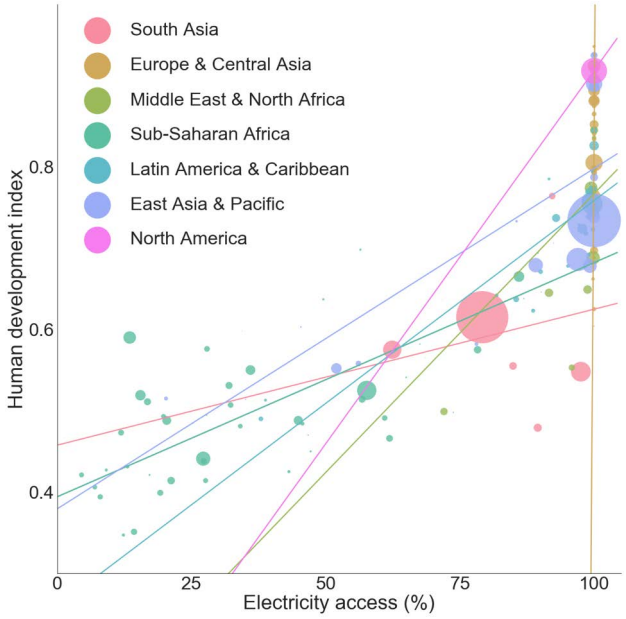
Reliable access to electricity brings change across the board, driving business growth and productivity and enabling students to learn more as they find themselves able to complete homework after dark and even gain personal access to the Internet. Conversely, the lack of electricity makes it difficult to improve living conditions, a likely factor in the relationship between electricity access and the United Nations' Human Development Index (figure 1).

Today around the globe, about a billion people have little or no access to electricity. The Sustainable Development Goals aim to replace that deficit with affordable and clean energy for all by 2030.[1] Despite localized success stories, however, electricity access in Africa is not keeping pace with population growth (World Bank 2017b). Electricity access stood at around 38 percent in the region in 2014 (GTF 2017).

In response, the traditional approach of top-down master plans and grid extensions is being challenged by bottom-up approaches and new technological solutions, such as mini-grids based on a variety of technologies that can bring access to entire towns. Within the World Bank's Multi-Tier Framework, mini-grids serve as an intermediate step between solar-powered systems that energize individual homes and connection to the national grid (figure 2). Mini-grids can bring electricity access to areas that would otherwise wait many years to be connected to the grid.

These mini-grid solutions are being pursued largely by private firms. Their growing success has been powered by advances in geospatial data, mobile phones, and big data analysis. Along with technical solutions, innovative approaches to financing and payment are opening the market to communities that were previously

Figure 1. The relationship between electricity access and human development is clear



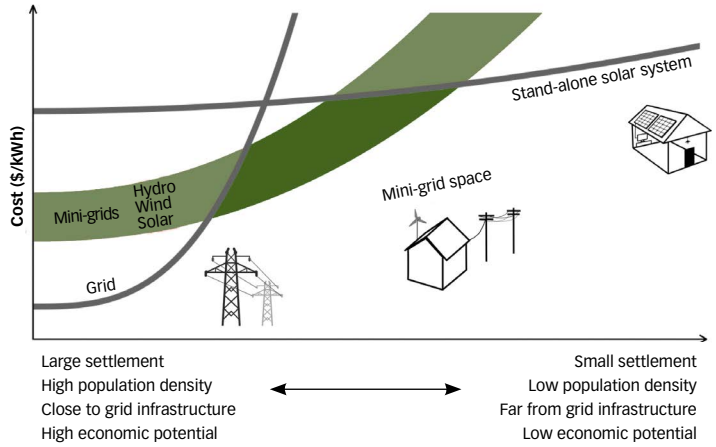
Source: World Bank (2017a) and UNDP (2017).

Note: Each point represents a country, scaled by population. The lines are linear regressions for each region.

1 http://www.undp.org/content/undp/en/home/sustainable-development-goals.html.

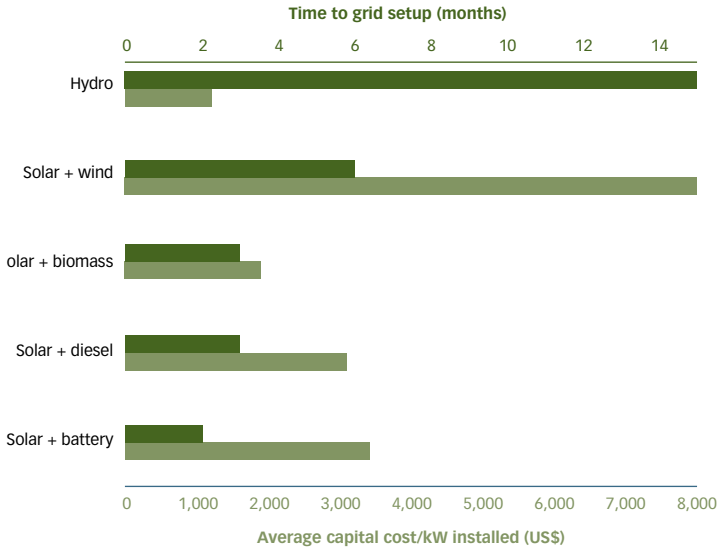
Despite localized success stories, electricity access in Africa is not keeping pace with population growth. Electricity access stood at round 38 percent in the region in 2014.

Figure 2. Comparison of electricity access alternatives



Source: Adapted from Franz et al. (2014).

Figure 3. Average time to setup, and capital costs of mini-grid systems, by technology



Source: Bardouille and Shepherd (2017).

considered "unbankable." These approaches rely on external finance for mini-grid installations, allowing users and communities to pay a monthly or usage-based fee and avoid high upfront costs.

What are the obstacles to market analysis in this field?

A lack of technical data, along with outdated institutional systems, can hinder progress

These new technologies and approaches are creating possibilities that did not exist before, but they are capital intensive (figure 3) and have a long payback time in a sector where capital is still relatively limited. Careful market analysis is therefore required to target communities that are in need, can pay, have potential for growth, and are unlikely to be connected to the grid before the off-grid project can pay off. The information required for this analysis is often hard to come by or nonexistent in developing countries, which prevents both the private and public sectors from being able to plan strategically.

Data-based market intelligence is necessary to assess the feasibility and bankability of projects and to unlock and sustain outside investment. Unreliable data are almost worse than none at all—they pose additional risks to investors and tarnish the reputation of the sector as a whole. Private developers can fall back on consultants and international expertise to overcome these issues, but this is an expensive and inefficient path, one that may not be available to smaller, local developers.

To solve some of these problems, the World Bank Group's Open Data and Analytics program has developed cutting-edge tools. The initiative was launched in 2016 with a twin goal:

- To push adoption of open data and modern analytics tools within the World Bank Group, as well as an "open by default" attitude to data. As one of the top global spenders on development-related data, the World Bank has a responsibility to ensure that data are more widely accessible and used.
- Provide a global public good to countries, academia, private groups, and others that can benefit from an open repository containing the most up-to-date data on energy and energy access.

Mini-grids serve as an intermediate step between solar-powered systems that energize individual homes and connection to the national grid. They can bring electricity access to areas that would otherwise wait many years to be connected to the grid. But because they are capital-intensive, careful market analysis is required to target communities that are in need, can pay, have potential for growth, and are unlikely to be connected to the grid before the off-grid project can pay off.

To date, the program has published nearly 100 previously inaccessible World Bank datasets and supported World Bank lending operations and technical assistance programs related to geographic information systems (GIS), energy access, and renewable energy.

It is common for national utilities to cling to a monopoly on energy sector development and thus control the data that other players need to develop. Without transparency on national infrastructure plans, it is extremely difficult for developers to be confident that their identified markets are not targeted for grid extensions, and that their business models will have support into the future. Public sector support is therefore essential to the successful development of mini-grid technologies.

Can geospatial information systems and open data help?

Yes, provided they are generated and used in a sustainable way that has institutional support

Geographic information systems (GIS), together with advances in satellite imagery, data storage, and processing power, have revolutionized infrastructure planning, as well as disaster response and other facets of development. GIS data are the cornerstone of any effort to find suitable markets for off-grid electricity solutions; with advances in GIS, answers to previously unanswerable questions are coming to light. However, GIS analysis is only as valuable as the data it is based on.

When data are openly and freely available, modelers and analysts around the world can use them to create important insights by combining data and algorithms in new and exciting ways. Some examples are online tools such as the Global Solar Atlas (http://www.globalsolaratlas.info/) produced by the Energy Sector Management Program (ESMAP) at the World Bank and Electrification Pathways (http://electrification.energydata.info) from ESMAP and KTH.

The Open Data and Analytics program surveyed a range of experts to understand the key drivers, barriers, and potential of using GIS for energy planning (Berndtsson 2016). The research included interviews with 49 private off-grid developers, governmental planners, academics, and development specialists. The questionnaire and interviews asked respondents for input on the following themes:

- What types of GIS data are primarily used, and what is their relative importance?
- What spatial and temporal resolution is needed for different types of data?
- What current data sources are used, and what value is placed on open data?

Responses to the survey questions showed a clear focus on two primary questions: (i) locating concentrations of people without electricity, and (ii) determining their ability to pay for electricity. Gaps in data on grid infrastructure and population centers were the problems most often cited by respondents, ahead of data on energy spending, roads, social indicators, land use, climate, and so on.

In many developing countries, distribution-level grid data are scarce, as are updated, realistic expansion plans. When these exist, they are often outdated and inaccurate. Projects like the World Bank's Africa Infrastructure Country Diagnostic (Foster 2008) have sought to remedy this, but sustained solutions have proven elusive.

Many governments have electrification master plans and strategies, but they are updated only every few years. The fine details that emerge in the interim often reflect political necessity or local demands. The bottom line is that it is hard to get up-to-date information not only on where the grid will be extended, but also on its current status and reach.

In addition to these data gaps, respondents indicated the importance of open data, with more than 90 percent using open data sources as a core part of their value chain. Data from local authorities and governments are often free but not easily accessible, making them much less valuable. About 70 percent of respondents indicated that data more than a year old are no longer very useful, suggesting the need for sustained and supported data-gathering efforts.

Mini-grid developers in Tanzania have a more specific goal of finding markets that fit their business model (box 1). To overcome problems of data scarcity, some have come up with innovative ways of generating new data, as well as new ways of using existing data.

A recent World Bank Group discussion with five private mini-grid developers in Tanzania offered insight into the major barriers and constraints encountered in trying to identify suitable markets and plan projects. Three overarching issues emerged:

The bottom line is that it is hard to get up-to-date information not only on where the grid will be extended, but also on its current status and reach.

Box 1. The mini-grid sector in Tanzania

Tanzania has seen a surge in private sector interest in mini-grid development in recent years. International and local companies have built more than 109 mini-grid systems based on solar, wind, diesel, hydro, and hybrid technologies (World Resources Institute 2017). The level of private sector interest suggests the potential for more such systems.

With support from the International Finance Corporation, Tanzania is creating mini-grid wiring standards to ensure compatibility with the national grid. If the national grid arrives in a village served by a mini-grid, the mini-grid can be connected and the owner can recoup its investment through one of three options:

- Selling assets to the national utility
- Reselling electricity from the national utility to the mini-grid's existing customers
- Generating electricity and selling all or part of it to the national utility

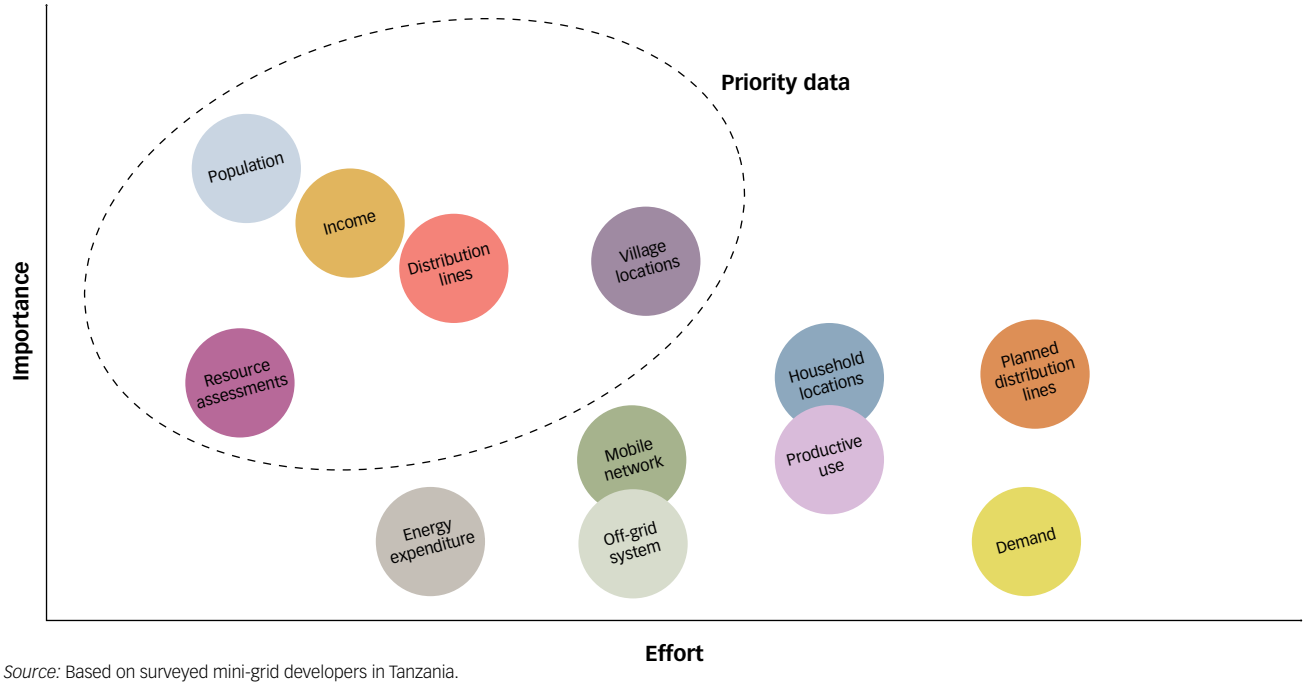
These options are all likely to affect profitability, so it remains important for mini-grid developers to be able to target villages that will generate income for at least a few years before being connected to the grid. Tanzania's Rural Energy Agency has an official electrification prospectus, which identifies around 200 additional villages that will not be connected by the country's grid extension program.

- **Data openness.** If data are available only in a printed format that is difficult to digitize, or only in a visualization, they cannot be imported into developers' planning tools and used effectively. Bureaucratic processes can pose further barriers to accessing important data.
- **Data quality.** Institutional data often come with little description of their accuracy or limitations (in contrast to academic practice). This makes it difficult for developers to assess reliability, often requiring site visits that negate much of the benefit of the data. Developers report travelling to villages listed on national census data, only to find that the village is 10 kilometers away or has half the listed population.
- **Data timeliness.** Many developing countries are experiencing rapid development, and if data are even a year or two out of date, their value may be eroded. As countries grow and change, data-gathering efforts should keep pace.

All five developers are using modern data techniques to overcome these issues. One is using freely available imagery and a process of manually "pinning" each household. By combining this with additional information on house size, roof type, household size statistics, and census data on each village, they can create accurate and current predictions about the number of potential customers and, at the same time, select sites and make initial plans for the mini-grid layout. The consultation with private developers resulted in the prioritization of datasets as illustrated in figure 4.

Projects like the World Bank's Africa Electricity Grids Explorer (http://africagrid.energydata.info/) have shown the potential of crowd-sourcing and modern data analytics to furnish better infra-structure data at a lower cost. At least one developer in East Africa has begun using drones to replace unreliable data. Drones allow the developer to create highly detailed estimates and plans on a per-village basis, but on-site work and a significant investment of time and money are still required.

Figure 4. Effort vs. importance of datasets for developers in Tanzania



Source: Based on surveyed mini-grid developers in Tanzania.

The World Bank's Africa Electricity Grids Explorer has shown the potential of crowd-sourcing and modern data analytics to furnish better infrastructure data at a lower cost.

What progress has been made to fill the data gap?

Powerful new technologies can provide better market analysis—given sufficient commitment and capacity

Advances in satellite imagery, both in terms of spatial resolution and frequency of updates, are making it possible to remotely track all corners of the earth and dynamically assess changes in infrastructure, population, and the natural environment (Popkin 2016). Advances in machine learning and processing power are keeping pace, and it is now possible to monitor agriculture cycles, land-use, infrastructure, and even individual houses and roads.

Some of these developments are expected to shake up the field of energy planning. Machine learning has already proved its potential in mapping settlements and population density in extremely high resolution (Gros and Tiecke 2016), and is now starting to be applied directly to energy problems. At the same time, the ubiquity of mobile phones with global positioning systems is creating the potential for new and innovative solutions, such as communities tracking their own infrastructure or using drones to map transmission systems and detect problems (Smith 2015). On the other end of the spectrum, tools such as ESMAP's Regulatory Indicators for Sustainable Development (RISE, http://rise.esmap.org/) allow policy makers,

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Live Wire 2014/16. "Tracking Access to Electricity," by Sudeshna Ghosh Banerjee and Elisa Portale.

Live Wire 2014/33. "Tracking Progress Toward Providing Sustainable Energy for All in Sub-Saharan Africa," by Elisa Portale and Joeri de Wit.

Live Wire 2014/34. "Scaling Up Access to Electricity: Pay-as-You-Go Plans in Off-Grid Energy Services," by Alejandro Moreno and Asta Bareisaite.

Live Wire 2014/35. "Planning for Electricity Access," by Debabrata Chattopadhyay, Rahul Kitchlu, and Rhonda L. Jordan.

Live Wire 2015/51. "Scaling Up Access to Electricity: Emerging Best Practices for Mini-Grid Regulation," by Chris Greacen, Stephanie Nsom, and Dana Rysankova.

Live Wire 2015/52. "Private Sector Participation in Transmission Systems: Making It Work," by Pedro E. Sanchez and Samuel Oguah.

Table 1. Open-data initiatives in developing countries

Country	URL	Launched	Datasets	Notes
Tanzania	opendata.go.tz	2017	755	Managed by the National Bureau of Statistics and now receiving data contributions from most ministries.
India	data.gov.in	2012	4,157	Hosts data from 81 federal and 24 state departments, and boasts over 11 million views.
Ghana	data.gov.gh	2012	133	Complemented by Code for Ghana, which produces open tools and visualizations on a project basis.
Bolivia	geo.gob.bo	2013	2012	Primarily geospatial data, with features for extracting data based on regional boundaries.

developers, and investors to explore regulatory frameworks and pertinent issues on a country-by-country basis.

One of the most exciting developments is the growing community of contributors to OpenStreetMap, a free online mapping system that anyone can use and contribute to. OpenStreetMap is gaining traction across sectors and being widely used in disaster-response projects. The World Bank–supported Dar Ramani Huria in Tanzania is using OpenStreetMap to improve flood resilience in Dar es Salaam, while the Red Cross's Missing Maps projects is putting volunteers to work helping the world's most vulnerable communities. With the right input, these tools and approaches could completely change the rural energy sector's ability to perform market analysis.

More broadly, the open data agenda is gaining acceptance in private and public sectors on a global scale. The U.S. Data Act (U.S. Congress 2014) is opening up all U.S. federal spending, complementing existing and highly successful programs like the World Bank's Open Data initiative. Similar initiatives are taking off elsewhere in the world (table 1), as the old paradigm of closed-until-needed is being replaced by an appreciation of the value that data can provide to different stakeholders.

However, these technological developments alone will not bring mini-grids to the billion people who still lack access to electricity. For that to happen, governments need to be committed to open data as an enabler of development and to the off-grid sector as a driver of increased electricity access and development. Also needed in ministries are enhanced technical capacity for engineering, GIS, and energy planning.

What has been learned?

Five key lessons and recommendations emerge from efforts to date

Recommendation 1. The market for off-grid development is there and can be an important driver of increased access in areas that are far from the grid. Even when countries have ambitious goals of connecting the entire country, off-grid solutions can be a stopgap to quicken the pace of electrification, while also increasing generating capacity—a particularly valuable factor in situations where system capacity is insufficient to supply newly extended grid lines.

Recommendation 2. GIS is already being used around the world to target areas that are both in need (far from the grid and not likely to be connected soon) and offering a promising market (densely populated and already spending on other fuels, while also offering the potential for development of non-household uses of electricity). GIS capabilities have allowed the sector to expand and attract international finance and interest, but governments and development partners must support these approaches to bring transformational change that will add benefit throughout the sector.

Recommendation 3. Many developing countries still suffer from a lack of accessible and transparent data, which discourages private sector investments at a larger scale. The problem lies not only in the actual lack of data, but also in making what data there are available for use. Attitudes are slowly changing, with many countries embracing the benefits created by open-data policies—a promising trend that should be encouraged.

MAKE FURTHER CONNECTIONS

Live Wire 2016/67. "Managing the Grids of the Future in Developing Countries: Recent World Bank Support for SCADA/EMS and SCADA/DMS Systems," by Varun Nangia, Samuel Oguah, and Kwawu Gaba.

Live Wire 2017/73. "Forecasting Electricity Demand: An Aid for Practitioners," by Jevgenijs Steinbuks, Joeri de Wit, Arthur Kochnakyan, and Vivien Foster.

Live Wire 2017/76. "Increasing the Potential of Concessions to Expand Rural Electrification in Sub-Saharan Africa," by Richard Hosier, Morgan Bazilian, and Tatia Lemondzhava.

Recommendation 4. Many of the technical advances achieved to date require highly specialized capacity and resources, which has kept many players from achieving higher efficiency. With open data and focused efforts in certain areas where data can be transformational as a public good, it is possible to create a more level playing field and reduce the barriers to entering the market. Modern analytics are showing promise by transforming data into insights and information that can be used to make decisions.

Recommendation 5. All the discoveries from the activities reported here have shown that support from the public sector is needed to foster interdepartmental and multistakeholder cooperation. Without alignment of goals between public and private institutions, private developers will constantly be on the defensive. They depend on government data for planning, and on government regulation and policy for continued profitability. Government planners should recognize that private developers offer a powerful force for improving access to electricity and the development benefits it brings.

References

Bardouille, P., and D. Shepherd. 2017. "Operational and Financial Performance of Mini-Grid DESCOs: Findings and Insights from Pioneer Benchmarking of this Emerging Sector." International Finance Corporation, Washington, DC. January.

Berndtsson, C. 2016. "Open Geospatial Data for Energy Planning." Master's Thesis, KTH Royal Institute of Technology. http://urn.kb.se/resolve?urn=urn%3Anbn%3Ase%3Akth%3Adiva-186392.

Foster, V. 2008. "Africa Infrastructure Country Diagnostic: Overhauling the Engine of Growth: Infrastructure in Africa," September. http://siteresources.worldbank.org/INTAFRICA/Resources/AICD_exec_summ_9-30-08a.pdf.

"Franz, M., Peterschmidt, N., Rohrer, M., and Kondev, B. 2014. "Mini-grid Policy Toolkit: Policy and Business Frameworks for Successful Mini-grid Roll-outs" RECP, EUEI PDF, ARE, REN21.

Gros, A., and T. Tiecke. 2016. "Connecting the World with Better Maps," *Facebook Code*. February 21. https://code.facebook.com/posts/1676452492623525/connecting-the-world-with-better-maps/.

GTF. 2017. "Global Tracking Framework>Time>Access to Electricity," *GTF*. http://gtf.esmap.org/time.

Popkin, G. 2016. "Satellite Alerts Track Deforestation in Real Time." February 23. https://www.nature.com/news/satellite-alerts-track-deforestation-in-real-time-1.19427.

Smith, R. 2015. "Utilities Turn to Drones to Inspect Power Lines and Pipelines." *Wall Street Journal*. May 5. https://www.wsj.com/articles/utilities-turn-to-drones-to-inspect-power-lines-and-pipelines-1430881491.

UNDP. 2017. "Human Development Data (1990-2015)," *UNDP Human Development Reports*. [Online]. http://hdr.undp.org/en/data.

U.S. Congress. 2014. *Digital Accountability and Transparency Act of 2014*. https://www.gpo.gov/fdsys/pkg/PLAW-113publ101/html/PLAW-113publ101.htm.

World Bank. 2017a. "Access to Electricity (% of population), 1990–2014," *World Bank Open Data*. http://data.worldbank.org/indicator/EG.ELC.ACCS.ZS.

World Bank. 2017b. *State of Electricity Access Report 2017*. http://documents.worldbank.org/curated/en/364571494517675149/full-report.

World Resources Institute. 2017. "Tanzania—Mini-Grid Locations (2017)," March. https://energydata.info/dataset/mini-grid-locations-in-tanzania.

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